Global Market Insight
for Information
Technology Companies

# 1995 RESEARCH PROGRAMS

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**Dataquest**

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**Boston Area**
550 Cochituate Road
Framingham, MA 01701-9324
United States
Phone: (1) 508-370-5555
Fax: (1) 508-370-6262

**London Area**
Holmers Farm Way
High Wycombe, Buckinghamshire
HP12 4XH
United Kingdom
Phone: (44) 1494-422722
Fax: (44) 1494-422742

**Tokyo**
Shinkawa Sanko Building
6th Floor
1-3-17, Shinkawa
Chuo-ku, Tokyo 104
Japan
Phone: (81) 3-5566-0411
Fax: (81) 3-5566-0425

**Taiwan**
3/F, No. 87 Sung Chiang Road
Taipei
Taiwan, R.O.C.
Phone: (886) 2-509-5390
Fax: (886) 2-509-5660

**Corporate Headquarters**
1290 Ridder Park Drive
San Jose, CA 95131-2398
United States
Phone: (1) 408-437-8000
Fax: (1) 408-437-0292

**Paris**
Tour Franklin, Cedex 11
94042 La Défense, Paris
France
Phone: (33) 1-41-25-18-00
Fax: (33) 1-41-25-18-18

**Munich**
Kronstadter Strasse 9
81677 Munich 80
Germany
Phone: (49) 89-930-9090
Fax: (49) 89-930-3277

**Asia/Pacific**
1/fl China Hong Kong Tower
8-12 Hennessy Road
Hong Kong
Phone: (852) 527-7881
Fax: (852) 520-0079

**Korea**
Trade Tower, Suite 3806
159 Samsung-dong
Kangnam-gu, Seoul 135-729
Korea
Phone: (82) 2-551-1331
Fax: (82) 2-551-1330





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**Dataquest**

a company of
The Dun & Bradstreet Corporation

251 River Oaks Parkway, San Jose, CA 95134-1913
(408) 468-8000 Fax (408) 954-1780

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# Errata

On page 15 of *PC Graphics Controllers: A Focused Analysis* (PSAM-WW-FR-9502), Figure 4-3 was mistitled. The correct title is "Bus Interface Forecast for Desktop Graphics Controllers." The figure is also titled incorrectly in the List of Figures. Dataquest regrets the error and apologizes for any inconvenience. Please insert this page into the inside front pocket of your PC Semiconductor Applications binder.

For further information, contact Industry Analyst Geoff Ballew at (408) 468-8676 or at gballew@dataquest.com.

**COMMUNICATION SEMICONDUCTORS**
**AND APPLICATIONS WORLDWIDE 1995**
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Dataquest

Perspective

Communications Semiconductors and Applications Worldwide

## Dataquest Predicts

# The Future of ADSL

**Abstract:** *No one disagrees that the local loop must evolve to support higher-speed data and video services. As regional Bell operating companies (RBOCs) and other local network providers face the daunting task of migrating from narrowband, twisted-pair local loop to a fiber/coax-based infrastructure, asymmetric digital subscriber line (ADSL) will be used to provide data and some video services. This document forecasts ADSL usage based on an analysis of worldwide local loop penetration combined with semiconductor and market timing issues.*
*By Eileen Healy and Greg Sheppard*

## Competition from Cable TV Will Drive ADSL in the United States

In the United States, cable TV companies already offer some data services using cable modems. Recent announcements indicate that they will aggressively market these services beginning in 1996. As they become more sophisticated with two-way interactive and switched services, the threat to telephone companies will increase. This near-term threat will force the telcos to respond quickly. Broadband loop deployment, for example, Hybrid Fiber-Coax (HFC), Switched Digital Video (SDV), and Fiber to the Curb (FTTC), will, in most cases, take too long to deploy to meet this threat. Even multipoint, multichannel distribution system (MMDS)—wireless cable services that can be deployed relatively quickly—will need to be augmented with high-speed data services. Asymmetric digital subscriber line (ADSL), which provides bandwidth as high as 52 Mbps over twisted pair, fills the gap.

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## Dataquest Predicts

Dataquest predicts that ADSL will be deployed more widely in the United States than public network providers' forecasts and plans indicate. This will be attributed to the overwhelming undertaking of migrating to broadband local loops combined with intense market pressure to respond to higher-bandwidth services enabled by cable modems. Dataquest predicts that the worldwide volumes necessary to drive down ADSL chipset prices to acceptable levels will be reached by 1998.

## Applications That Will Use ADSL Transceivers and Cable Modems

The bandwidth that ADSL delivers and the service demand are both important in determining which applications are most likely to drive ADSL deployment. In the past, ADSL was touted as the answer to cable TV entertainment video services. These days, most agree that ADSL is not competitive for video except in niche markets. High-speed data services that can complement other technologies such as MMDS are much more competitive. The applications that are likely to drive ADSL deployment include:

- Telecommuting
- News on demand
- TV listings
- Videoconferencing
- Transaction services (home shopping, banking, and so on)
- Internet access
- Security and home management

ADSL can provide the control channel for the CATV, broadcast, and video-on-demand services. It can also be used for videoconferencing at 384 Kbps.

Limited cable data services are being offered in the United States using cable modems. Typically, the cable modems are leased as part of a service to minimize the out-of-pocket expenses for the customer. For example, individual stock market investors can only access the U.S. stock market via cable modems. There are currently about 10,000 users of these services, each paying approximately $80 per month to lease the cable modems and access Wall Street financial data.

TCI, the largest U.S. cable provider, has created a new company called "@Home" to offer cable data services. The plan is to offer data services at up to 512 Kbps at prices similar to telco ISDN services ($30 per month) that only deliver 144 Kbps. Telcos, which stand to lose their plain old telephones (POTS) services to CATV as well, must respond quickly in threatened territories. In some cases where telcos are being aggressive with HFC and other broadband deployment, ADSL may not be needed. However, Dataquest predicts that in many cases, such broadband loops will not be ready.

## Technology Alternatives

ADSL and its higher-speed version, very high speed digital subscriber line (VDSL), provide up to 52 Mbps of data to the home over existing copper twisted pair. Table 1 shows the bandwidth and distance limits. POTS can also be delivered over the same twisted pair as ADSL/VDSL, eliminating the POTS powering issues associated with fiber-based broadband deployment.

**Table 1**
**ADSL Bandwidth/Distance Trade-Offs**

| | Bandwidth (Mbps) | Theoretical Distance (KFt) | Curent Practical Distance (KFt) |
|---|---|---|---|
| ADSL | 1.5 | 18 | 12 |
| ADSL | 6.0 | 12 | 9 |
| VDSL | 52.0 | 3 | 0.5 |

Note: Distance assumes 24 gauge copper twisted pair.
Source: Dataquest (November 1995)

### Broadband Deployment

Local telephone companies now understand that in information-rich countries such as the United States, low-speed digital services like ISDN are not sufficient for the future. All telcos are now planning to deploy fiber closer to the customer. Various architectures are available, with fiber either going directly to the customer or coaxial cable going from a neighborhood fiber node to the customer. Eventually, this transition from twisted pair to broadband access will be complete, but Dataquest believes the implementation will spread over several decades. Table 2 shows the estimated equipment cost to telcos to migrate their networks to broadband. In addition to cost, there are other barriers to broadband deployment. The biggest barrier today is the delays in dealing with the public, both government or community organizations and individual citizens. People once sat back unquestioningly as public utilities did their work. Now many protest when their streets are dug up, and an ugly box is installed in their view. ADSL eliminates some of the deployment barriers.

**Table 2**
**Telco Broadband Equipment Costs (Millions of Dollars)**

| | Equipment Cost to Modernize to Broadband |
|---|---|
| Ameritech | 8,079 |
| Bell Atlantic | 8,669 |
| BellSouth | 8,719 |
| NYNEX | 7,429 |
| Pacific Telesis | 6,866 |
| SBC Communications | 6,221 |
| U S WEST | 6,414 |

Source: Dataquest (November 1995)

Three different technologies are currently considered viable for residential broadband deployment, HFC, SDV, and MMDS. Different architectures are possible to provide interactive video and data services. ADSL is being considered as a complement not only to HFC and SDV, but also to MMDS.

## ADSL

Over 15 different vendors are developing ADSL chipsets and/or transceivers. This level of interest, combined with the potential number of transceivers needed (over 1 million), results in a market that can drive down the cost of ADSL to levels needed for widespread deployment.

There are two different modulation techniques being developed for ADSL. Modulation techniques for VDSL are even less settled. Carrierless amplitude/phase (CAP) modulation and discrete multitone (DMT) modulation will both exist for a period of time. CAP, while available earlier, is not the accepted industry standard; DMT is. CAP is currently licensed by AT&T to several different chipmakers. Table 3 shows the announced players in the ADSL market.

**Table 3**
**ADSL Vendors**

| Company | Building Chips | Building Systems | Focus of Development | Partners |
|---|---|---|---|---|
| Advanced Video Access | | X | CAP | |
| Alcatel | X | X | DMT | |
| Amati Communications | | X | DMT | Motorola |
| Analog Devices | X | | DMT | Aware Inc. |
| AT&T Paradyne | X | | DMT | |
| Aware Inc. | | X | DMT | |
| ECI Telecom | | X | DMT | |
| Ericsson Schrack AG | X | X | DMT | |
| Hyundai | | X | CAP | |
| LGIC (Goldstar) | | X | CAP | |
| IJTE (Il-Jin Telecom Electronics Co.) | | X | CAP | |
| Motorola | X | | DMT | Amati |
| NEC Australia | | X | CAP and DMT | |
| Orckit Communications | X | X | DMT | |
| PairGain Technologies | X | X | DMT | |
| Performance Telecom | | X | CAP | |
| Westell Inc. | | X | CAP and DMT | |

Source: ADSL Forum, Dataquest (October 1995)

## Costs and the Semiconductor Industry Role

### Partnerships Create Solutions

For the most part, silicon solutions for ADSL have been born from the partnerships of DSP-oriented chip companies and companies possessing algorithm technology. Clearly, these are win-win proposals as chip companies are given a chance to participate in the value-add chain early, and the algorithm houses stand a chance to collect royalties from the sale of millions of chips. These next-generation solutions generally entail taking elements of off-the-shelf DSP cores, data conversion, and analog elements and customizing them for executing the various ADSL algorithms. In addition, some of algorithms will be stored on flash memory-based (or similar) firmware for execution on the DSP processor. Figure 1 shows a block diagram of a generic ADSL modem highlighting silicon opportunities. Figure 2 shows the associated network architecture.

### Forecast Scenarios and Silicon Costs

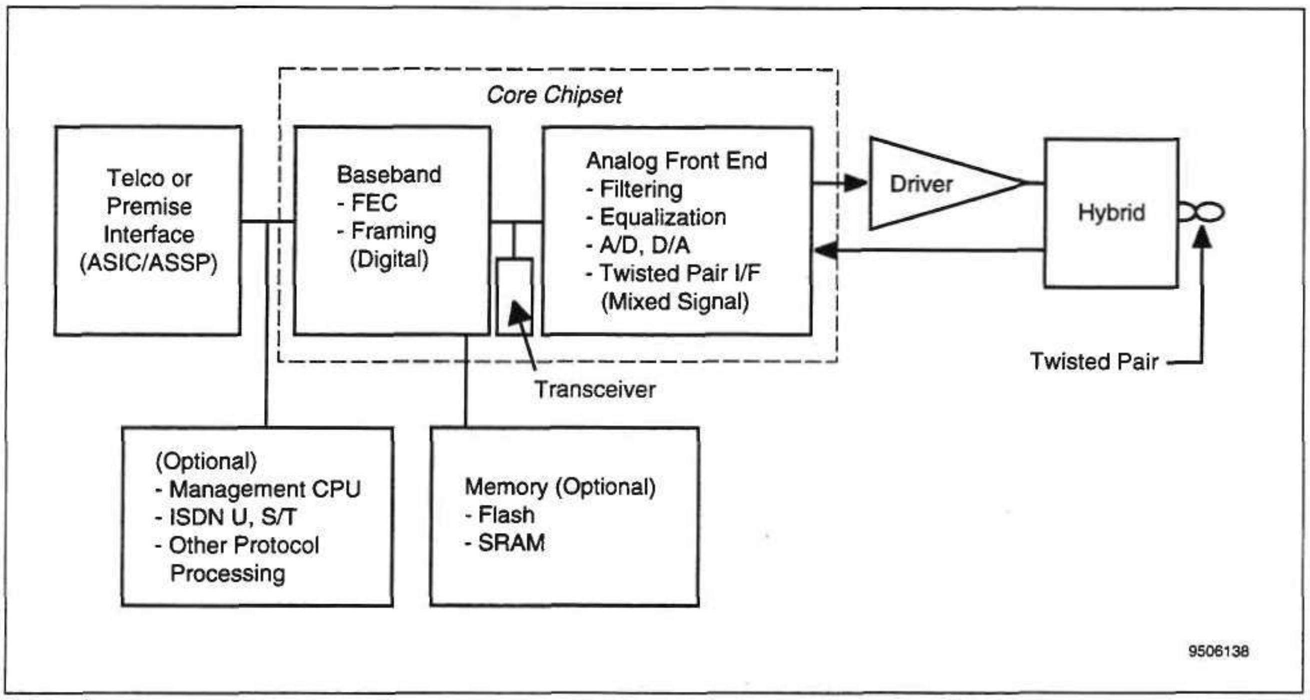
Table 4 shows worldwide PSTN line in service around the world. Typical growth and rehabilitation rates for telcos are both about 3 percent per year. New access lines grow at 3 percent, and about 3 percent of the existing lines need to be rehabilitated in any given year because of age or damage. Table 5 shows the potential penetration of ADSL of the worldwide access lines. One scenario assumes a pessimistic outlook of 0.5 percent penetration where prices remain high, implementations remain proprietary, other broadband alternatives thrive, and consumer demand falters. The 2 percent scenario assumes that prices come down rapidly, and implementations go smoothly serving strong demand. Some countries such as Japan insist that they will never use ADSL. Developing regions such as Africa will have little use for ADSL.We think the most likely outcome is 1 percent penetration primarily into affluent demographic areas of world, especially where telcos are responding to a competitive threat. Dataquest's forecast for ADSL equipment shipments into the United States is shown in Figure 3. This forecast includes all speeds of ADSL, including what is known as VDSL at 52 Mbps. It is revised for the June 1995 Dataquest forecast.

Table 6 shows the ADSL modem semiconductor demand that can be derived from a 1 percent penetration scenario with a chipset on either end of the line. By late 1997, the silicon cost should drop to about $160 per line based on announced plans. There is no reason why the modem chipset cost couldn't drop to $70 a line once the first few million units are shipped and third-generation silicon is available. On the subscriber side, this chipset could be integrated into a set-top box with further integration economies recognized.

ADSL is beginning to receive greater semiconductor industry support with several vendors accelerating their development efforts in recent months. ADSL system builders can expect highly integrated, standard, second-generation silicon designs to hit the market in 1996 and 1997. By early 1997, the semiconductor content of an ADSL modem should cost under $100 for basic functionality. This should enable central office (CO) line cards and subscriber modems that could cost $400 or less, thus helping tip the scale toward ADSL rollout.

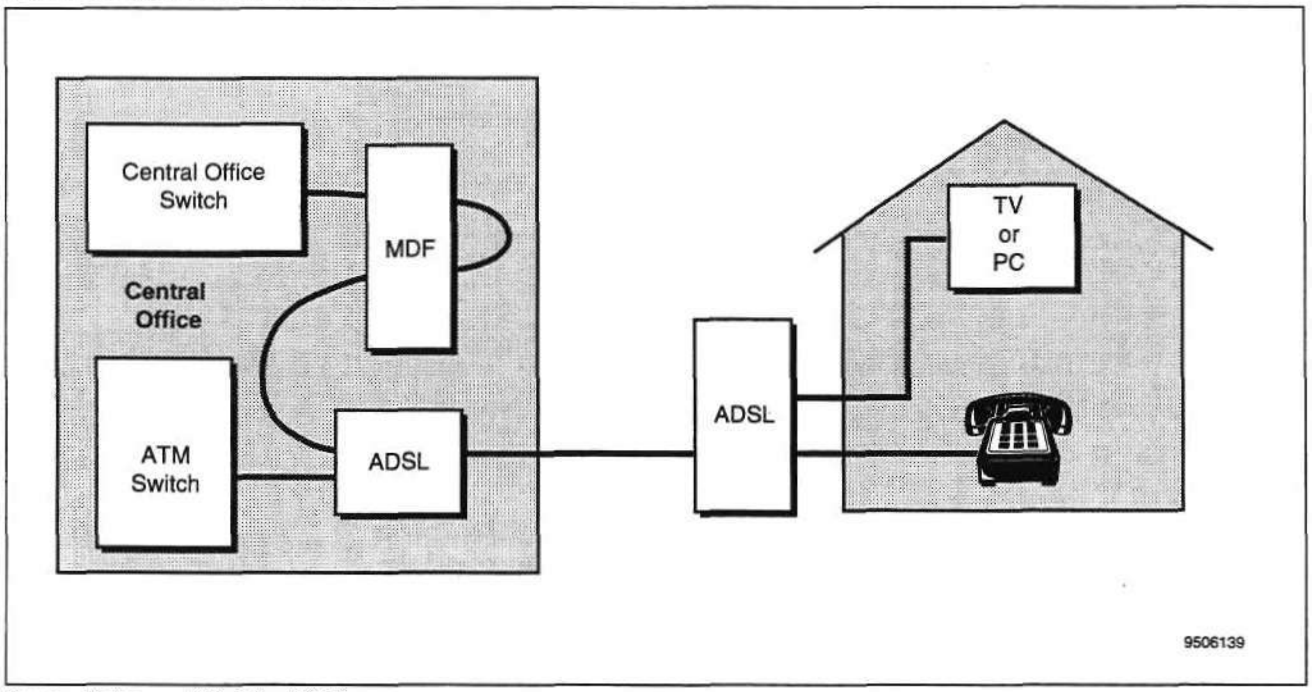
  

**Figure 1**
**Next-Generation Generic ADSL Modem**




Source: Dataquest (October 1995)

**Figure 2**
**ADSL Network Architecture**




Source: Dataquest (October 1995)

**Table 4**
**PSTN Forecast by Country (Millions of Access Lines)**

| | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|
| Country | | | | | |
| Austria | 3.8 | 3.9 | 4.0 | 4.1 | 4.3 |
| Belgium | 4.7 | 4.9 | 5.0 | 5.2 | 5.5 |
| Canada | 17.4 | 17.7 | 17.9 | 18.1 | 18.5 |
| China | 30.0 | 37.0 | 45.0 | 54.0 | 75.0 |
| Denmark | 3.1 | 3.2 | 3.2 | 3.2 | 3.3 |
| Finland | 2.9 | 2.9 | 3.0 | 3.1 | 3.2 |
| France | 32.4 | 33.2 | 33.9 | 34.6 | 36.0 |
| Germany | 40.7 | 42.5 | 44.3 | 46.0 | 49.0 |
| Greece | 5.5 | 5.7 | 6.0 | 6.2 | 6.6 |
| Hong Kong | 3.3 | 3.5 | 3.6 | 3.8 | 4.1 |
| Ireland | 1.1 | 1.2 | 1.2 | 1.2 | 1.3 |
| Italy | 25.5 | 26.0 | 26.5 | 27.0 | 28.0 |
| Japan | 61.4 | 62.6 | 63.8 | 64.7 | 66.7 |
| Mexico | 9.5 | 10.6 | 11.8 | 13.2 | 16.2 |
| Netherlands | 7.9 | 8.1 | 8.2 | 8.4 | 8.7 |
| Norway | 2.4 | 2.4 | 2.5 | 2.6 | 2.7 |
| Portugal | 3.7 | 3.9 | 4.2 | 4.3 | 4.7 |
| South Korea | 18.9 | 20.0 | 21.0 | 22.0 | 24.0 |
| Singapore | 1.4 | 1.4 | 1.5 | 1.6 | 1.8 |
| Spain | 15.1 | 15.8 | 16.6 | 17.3 | 18.8 |
| Sweden | 6.1 | 6.1 | 6.1 | 6.2 | 6.3 |
| Switzerland | 4.5 | 4.6 | 4.7 | 4.8 | 5.0 |
| Taiwan | 8.7 | 9.3 | 9.7 | 10.3 | 11.5 |
| Turkey | 13.4 | 14.7 | 16.1 | 17.5 | 20.5 |
| United States | 158.3 | 163.1 | 167.0 | 171.0 | 178.0 |
| United Kingdom | 28.9 | 29.7 | 30.4 | 31.1 | 32.3 |
| Region | | | | | |
| Africa | 13.5 | 14.9 | 16.6 | 18.6 | 22.8 |
| Latin America | 41.1 | 45.6 | 50.4 | 55.5 | 67.4 |
| Australasia | 10.9 | 11.2 | 11.4 | 11.7 | 12.2 |
| Central and Eastern Europe | 67.7 | 72.3 | 77.7 | 84.0 | 98.0 |
| Others | 44.0 | 51.6 | 60.0 | 69.3 | 90.7 |
| Total | 687.7 | 729.5 | 773.4 | 820.4 | 922.8 |

Source: Dataquest (October 1995)

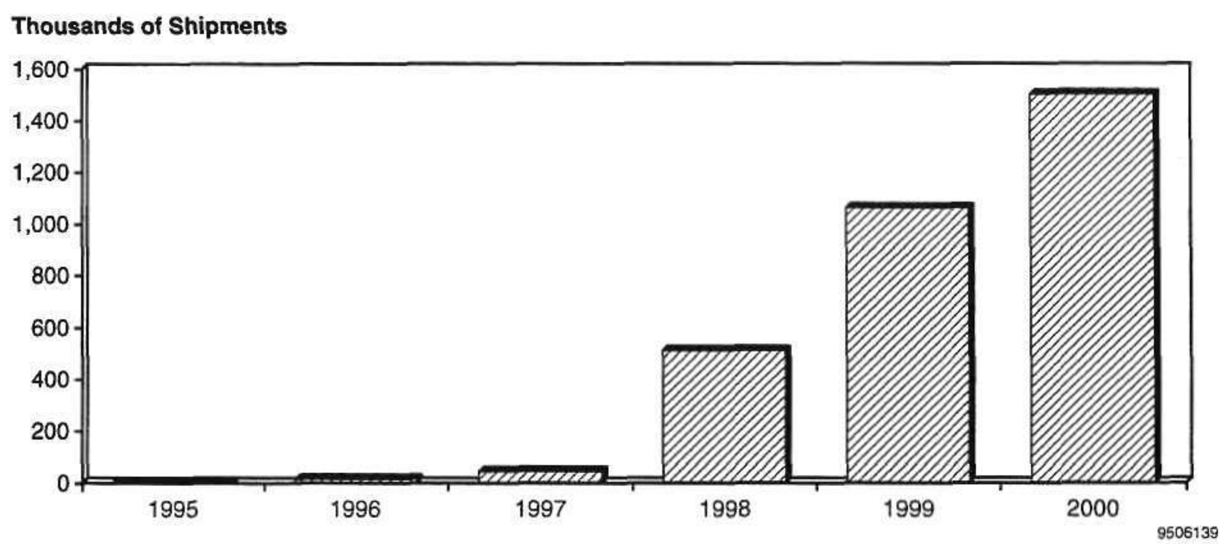
  

## Table 5
## Potential ADSL Access Lines in Service (Millions)

| | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|
| United States | | | | | |
| 0.5% Penetration | 0.01 | 0.07 | 0.26 | 0.53 | 0.92 |
| 1% Penetration | 0.01 | 0.13 | 0.51 | 1.06 | 1.82 |
| 2% Penetration | 0.02 | 0.33 | 1.03 | 2.14 | 3.68 |
| Rest of World | | | | | |
| 0.5% Penetration | 0.04 | 0.24 | 0.97 | 2.24 | 4.11 |
| 1% Penetration | 0.04 | 0.45 | 1.93 | 4.43 | 8.13 |
| 2% Penetration | 0.09 | 1.21 | 3.89 | 8.94 | 16.42 |
| Worldwide Total | | | | | |
| 0.5% Penetration | 0.05 | 0.31 | 1.23 | 2.77 | 5.03 |
| 1% Penetration | 0.05 | 0.58 | 2.44 | 5.48 | 9.95 |
| 2% Penetration | 0.10 | 1.55 | 4.92 | 11.08 | 20.10 |

Source: Dataquest (November 1995)

## Figure 3
## Shipments of ADSL Equipment to the United States




Source: Dataquest (October 1995)

## Table 6
## ADSL Modem Chipset Forecast (1 Percent Scenario)

| | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|
| Units (M) | 0.1 | 0.7 | 2.0 | 3.4 | 7.4 |
| ASP ($) | 140.0 | 80.0 | 61.0 | 45.0 | 34.0 |
| Revenue ($M) | 14.0 | 52.9 | 123.6 | 152.4 | 253.1 |

Source: Dataquest (November 1995)

## Now Comes the Real Silicon

The first round of silicon was targeted at implementing ADSL modems (or transceivers) for various field trials in the United States, Europe, Israel, and Asia. All three modulation approaches—DMT, CAP, and QAM (quadrature amplitude modulation)—were supported to various degrees. Although AT&T continues to push CAP, all of the participating semiconductor companies are now focusing on driving the costs down in their DMT approaches.

The initial silicon solutions included data converters (12/16 bit), multiple DSP processors and ASICs, and a variety of standard analog and discrete components. Next-generation silicon, which will begin hitting the market in 1996, is boiling down to either one or two chips. Analog Devices is working on a 3-chip solution and Alcatel Mietec are working on two-chip solution: a DSP-based baseband section and the analog front end. Motorola is working on an aggressive single-chip design integrating the baseband and analog front end.

One of the stimulants of resurged interest in ADSL from the silicon vendors is attributed to the fact that open standards are stabilizing and tend to reduce development risk. Next-generation solutions are targeted at implementing recently approved standards for North America and Europe set jointly by the ANSI T1E1 body and the European Telecommunications Standards Institute (ESTI).

## Analog Devices/Aware

This team is bringing a solution to the market using Aware's DMT technology and Analog Devices' silicon expertise. The current chipset includes the ADSP-21061 SHARC DSP, a digital interface controller, a specialized digital filter, an analog front end, and two devices comprising the hybrid telephone line interface. The current generation chipset is priced at $170 in OEM quantities. The DSP runs firmware developed in part by Aware for executing the DMT algorithms. A more integrated chipset is in the works for mid-1996. So far, Westell, Newbridge, and NEC Australia are using this team's technology.

The 1996 version will boil down the solution to a baseband chip and an analog front-end chip. Analog Devices claims the solution is capable of the complete ADSL category 2 implementation (8-Mbps downstream and 640-Kbps interactively for distances up to 12,000 feet or 3.7km, and a POTS line). So far this team claims to be the leader in supplying advanced silicon for DMT-based prototype products.

## Motorola/Amati

These companies are acting in a similar manner as the pair mentioned earlier with Amati supplying the DMT expertise and Motorola the silicon. Motorola is discussing its next-generation single chip, a mixed-signal solution that would ship in volume in the first quarter of 1997. Apparently key to Motorola's approach is integration of numerous analog functions including high-precision data converters. The chip will support the category 2 specifications plus certain other unannounced features.

Motorola has the only announced single-chip version at this point. Because of the challenges of integrating precision data converters and a desirable feature set, this team is taking a degree of risk, but it does have a chance of hitting a home run with a very low cost solution.

### Some Challenges and Speculation on the Future

From an enabling technology perspective, the greatest risk aside from market take-up lies in creating standards-compatible or interoperable chipsets. The question to be asked is, "Will, for example, Motorola/Amati's solution work with Analog Devices/Aware's approach?" The vendors say it will, but will the "proprietariness" built into their solutions get in the way?

Because ADSL can minimally support 6.144-Mbps simplex (one MPEG 2 movie), 640-Kbps duplex (videoconferencing and ISDN), and a POTS telephone call at the same time, there are plenty of silicon integration possibilities. Possibilities include videoconferencing functions, ISDN protocol ICs, and ATM SAR functions (Alcatel Mietec supports ATM). The TV set can be used as a low-cost videoconferencing display unit (the most expensive part of a video phone). Likewise, the ISDN bit stream can be directed to the PC from the ADSL terminal for World Wide Web surfing and remote office access for work at home. It's also conceivable that ATM could use ADSL as its physical layer, creating a seamless link to ATM capability that the carriers are already evaluating.

## Conclusions

Demand for high-speed data services will grow as cable modems become affordable, and as applications such as Internet access demand more bandwidth. Telcos will be forced to revisit ADSL as a viable, low-cost response to cable modems. A conservative analysis of worldwide demand for ADSL has shown that prices will fall and that ADSL will be deployed more aggressively than today's telco plans would indicate.

**For More Information...**

Greg Sheppard, Director/Chief Analyst ................................. (408) 468-8261
Internet address ...................................................gsheppard@dataquest.com
Via fax ........................................................................................ (408) 954-1780



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Perspective

Communications Semiconductors and Applications Worldwide

# Conference Summary

# Value-Add Opportunities for Chips: A Report from Networld + Interop


**Abstract:** *Driven by the need to accelerate clogged networks and to provide remote access to Internet and office networks, the Networld + Interop fall show served as a springboard for a variety of technology markets for semiconductor suppliers. New chip opportunities are abundant in 100-Mbps adapters and hubs, LAN switches, ISDN adapters and other remote access devices, frame relay and T/E carrier systems, and ATM LAN and WAN systems.*
*By Greg Sheppard*


## Introduction

The fall trade show Networld + Interop was full of network equipment vendors describing their plans for the near term and the more distant future, and Dataquest was there with its antennae up for opportunities for chip vendors. Figure 1 outlines the big picture. Performance upgrades of clogged networks, access for remote and home offices, Internet access, and the rapidly emerging Japan-Asia/Pacific markets are driving demand in the new technology markets.

## Hot Technologies Ripe for New Chips

In terms of technology, the areas with the greatest R&D activity include: 100-Mbps local area networks (LAN)—Fast Ethernet and 100 VG-AnyLAN; LAN switches; integrated services digital network (ISDN); wide area network (WAN) access and switching; and asynchronous transfer mode (ATM). Table 1 presents a synopsis of important thrusts presented at the show and the implication for semiconductor vendors.


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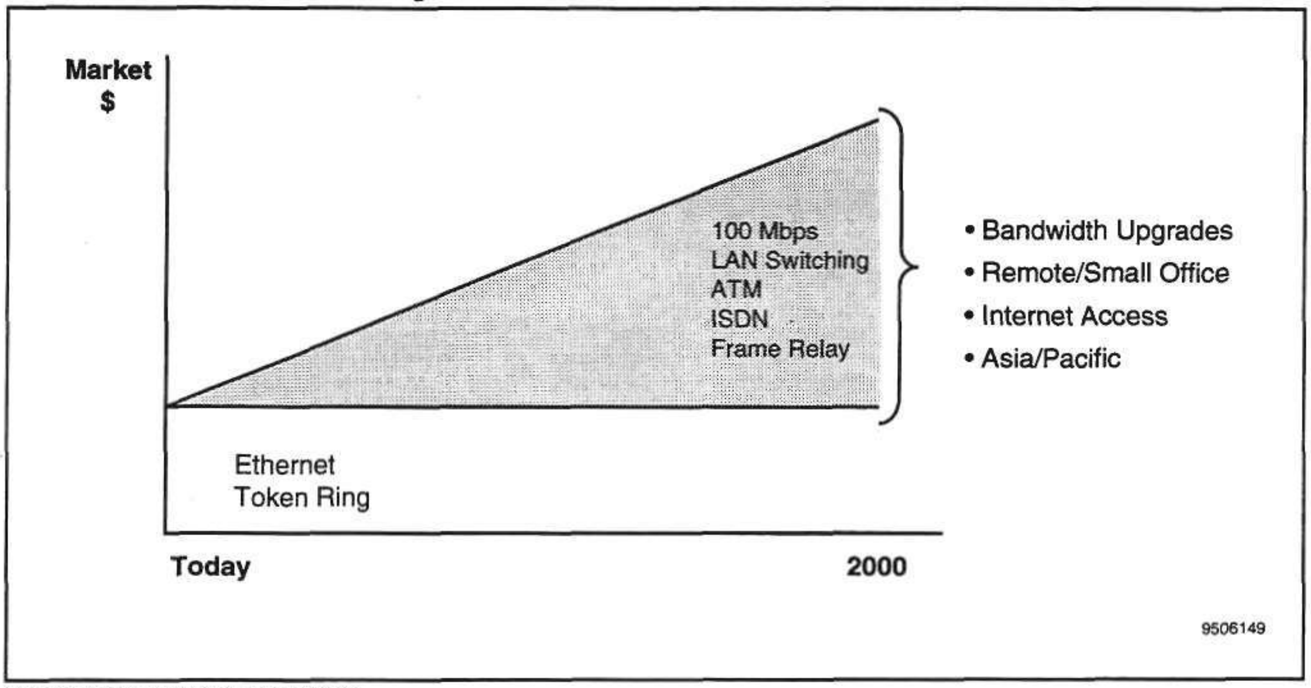
**Figure 1**
**Drivers of the Network Chip Market**




Source: Dataquest (November 1995)

## 100 Mbps (Fast Ethernet, 100 VG-AnyLAN)

The 100-Mbps area is kicking into high gear as shipments of Fast Ethernet and 100 VG-AnyLAN adapters and ports accelerate during the third quarter. There were numerous announcements by networking vendors of 10/100-Mbps adapter cards with only 50 percent price premiums over comparable 10-Mbps or 16-Mbps cards. Prices for 100-Base-TX adapters were $149 (PCI, quantities of 20), 100-Base-T4 for $239 (PCI), and unmanaged hub ports for $150 a port. Dozens of hubs and switches were announced that could support 100-Mbps modules or, in some cases, were entirely 100 Mbps. It appears that 100-Mbps TX (two twisted pairs) is poised to give fiber-distributed data interface (FDDI) a run for its money as an inexpensive backbone technology. There were several companies throwing their support to the more technologically robust 100-Base-T4 (four pairs) as well, but TX remained in the lead in terms of introductions. From a semiconductor perspective, the TX-Fast Ethernet interface uses a physical layer technology similar to that of FDDI, therefore FDDI semiconductor vendors stand to benefit no matter which way the market goes.

### 100-Mbps Product Announcement Overview

Some key announcements for 100 VG-AnyLAN included the following:

- Adapters: Interphase, Ragula (using TI ThunderLAN—$239), PureData
- Bridges: Anritsu, MultiMedia LANs, Ragula
- Hubs/Switches: Anritsu, Compex, Plaintree, PureData, Ragula
- Routers: Hewlett-Packard

**Table 1**
**Emerging Networking Semiconductor Opportunities**

| Technology | Time to Volume (500,000 Ports/ Units) | Chip Requirements | Next-Generation Evolution | Key OEMs |
|---|---|---|---|---|
| 100 Mbps | | | | |
| Fast Ethernet Adapters | 1995 | MAC, PMD (TX, T4, FX) | MAC + PHY | 3Com, Intel |
| 100 VG-AnyLAN Adapters | 1995/First half of 1996 | MAC, PMD | MAC + PHY | Hewlett-Packard |
| Fast Ethernet Hub | 1995/First half of 1996 | Repeater, PMD | Switch | Grand Junction, Bay Networks |
| 100 VG-AnyLAN Hub | 1995/First half of 1996 | Repeater, PMD | Switch | Hewlett-Packard |
| LAN Switches | | | | |
| Ethernet—10 Mbps | 1995 | Switch (ASSP/ASIC), PMD, 32-bit MPU, SRAM | 100 Mbps | Cisco, Atlantec |
| Token Ring | 1996 | Switch (ASSP/ASIC), PMD, 32-bit MPU, SRAM | 100 VG-AnyLAN, ATM 25 | IBM, Madge |
| ISDN | | | | |
| BRI-PC Adapters | 1995/First half of 1996 | U transceivers, programmable controllers | ISDN + modem | Motorola, Ascend |
| WAN Access | | | | |
| PCMCIA 10-Base-T/V.34 Modem | 1995/First half of 1996 | LAN controller, V.34 chipset or 32-bit controller | 100 Mbps + ISDN | Megahertz |
| Inverse Multiplexer | 1998 | LAN controller, programmable 32-bit controller, T/E-carrier ICs (2 Mbps and less) | ATM, Multiplexer ICs | Digital Link |
| Access Server/Router | 1996/1997 | LAN controller, V.34 chipset or 32-bit controller, T/E-carrier ICs (2 Mbps and less) | 100 Mbps + ISDN | Cisco |
| Frame Relay Access Device | 1998 | LAN controller, programmable 32-bit controller, T/E-carrier ICs | ISDN, SMDS, ATM support | Motorola |
| Enterprise/Edge Switch | 1997 | LAN controller, ASIC, ATM, and T/E carrier ICs | T3/E3, ATM 622 Mbps | Stratacom, Cascade |
| ATM | | | | |
| Adapter Cards | 1998 | SAR, PHY (25, 155 Mbps) | Ethernet + ATM | Fore |
| Switches | 1998 | SAR, PHY (25, 155 Mbps, 622 Mbps), switch (ASIC/ASSP), SRAM | Ethernet + Token Ring + ATM | Fore, Newbridge |

Source: Dataquest (November 1995)

Key announcements for Fast Ethernet included the following:

- 3Com highlighted its complete solution to Fast Ethernet with new adapter cards, hubs, switches, and routers.
- Asante broadened its Fast Ethernet presence with 100-Base-TX management units, 10/100-Mbps bridges, and expansion of its already extensive line of adapters and hubs.
- D-Link announced a $150-a-port 100-Base-T4 12-port hub (unmanaged) and a $239 PCI 100-Base-T4 adapter.
- Intel announced the Express Pro 10/100 Fast Ethernet TX (PCI) adapter card, $149 (quantities of 20).
- Microdyne announced a 10/100 Fast Ethernet card, $185 (industry standard architecture—ISA), $199 (PCI).

## Here Come the 100-Mbps Chips

A major opportunity for chip vendors is for Fast Ethernet and 100 VG-AnyLAN medium access control (MAC) devices (for ISA and PCI buses) that support 10-Mbps Ethernet traffic as well. The other opportunity is for TX and T4 transceivers and clock recovery. In the future, expect the transceivers to be integrated on the MAC chip. Design-wins are occurring this year for TX and T4 repeater controller ICs for hubs.

Some semiconductor announcements around show time included the following:

### Fast Ethernet

- Digital Semiconductor introduced the 21140A, the upgrade to the popular 21140 PCI-bus 10/100 Mbps Ethernet controller. The new chip features boot ROM capability, compatibility with PCI bus specification 2.1, and power management features. Production of the chip will begin in January 1996, and the price is $23 for quantities of 5,000.
- Mitel Semiconductor announced that it has joined the incAlliance promoting isochronous networking using IEEE 802.9. It is complementing National Semiconductor's node chips with its MT90840 Distributed HyperChannel switch chip for backbone switches.
- Taiwan-based Macronix has introduced its MX98741, a Fast Ethernet (100 Mbps) hub repeater controller capable of supporting up to 16 TX/FX ports. TX is a twisted pair interface, and FX is a fiber-optic line interface. The chip, when combined with the appropriate physical layer devices (clock recovery) and management functions, makes a complete hub solution. Samples are already available, and the parts are priced at $65 in quantities of 100.

### 100 VG-AnyLAN

Although both had already announced these products in August, Motorola discussed its 100 VG-AnyLAN controllers and Pericom its 100 VG-AnyLAN programmable multilevel logic device/transceiver. Motorola's MC68852 (PCI version) and xx853 (ISA version) will be available in November and will cost $22 and $10, respectively. The Pericom 100-Mbps T4 PMD/transceiver (PI2C5001) for four pairs of Category 3 or 5 wiring is priced at $25 (quantities of 1,000) for February 1996 production. These companies will add significant support to the AnyLAN standard in its battle with Fast Ethernet, joining AT&T and Texas Instruments as important merchant suppliers to this market.

## LAN Switches

LAN switching is shifting into high gear. Practically every major networking company was either introducing a product or rounding out an existing switch line. Most of the switches introduced appeared to be using ASIC approaches, as opposed to using 32-bit MPUs. Switches based on the cut-through switch technique, which starts forward frames as soon as the destination address is read, were the most popular. Some product introductions included the following:

- Amber Wave announced its 10-Base-T AmberSwitch workgroup switch for $175 per port.
- Cabletron announced ASIC-based Smart Module technology (10-Base-T and FDDI) based on LSI Logic's CoreWare library.
- LanOptics, Madge/LANNET, and Proteon announced Token Ring switches.
- Plaintree added Fast Ethernet and 100 VG-AnyLAN upgrades to its Wave switch family (ASIC-based).
- Proteon claimed to have an industry first with its 10-Base-T LAN switch for under $100 per port.
- SMC announced a Fast Ethernet module for its EliteSwitch multitechnology switch family.

## WAN

Internet, online access, and remote access are hot markets, and a number of technologies are positioning for volume. ISDN is perhaps the most-targeted technology, with frame relay not far behind. Inverse multiplexers that break 10-Mbps LAN traffic into T1 (or sub-T1) channels for WAN use are also ramping in volume.

After a long gestation, ISDN is blooming in the United States, which joins Europe and Japan as significant markets. So-called ISDN "digital modems" (terminal adapters) are being bundled with under-$30 service offers for the residential and small office markets. Most of the new offerings for the U.S. market include the U interface. Frame relay is finding success as a cost-effective solution for connecting distributed branch offices. Enterprise and carrier edge switches from companies like Stratacom and Cascade are in high demand to support mixed-service requirements, including frame relay, T1/E1, and switched multimegabit data service (SMDS), and ATM support is emerging. Frame relay access devices (FRADs), sometimes called frame relay assemblers and disassemblers, work in conjunction with the switches to terminate the layer-2 protocol requirements of frame relay.

Specific chip opportunities for these WAN systems include ISDN U and S/T transceivers, fixed-function and programmable protocol controllers, and T/E carrier transceivers, multiplexers, and framers. Controllers that link the LAN MAC and ISDN protocol functions have great potential in remote LAN access servers and routers. Expect frame relay protocol processing and switching to become fertile ground for ASIC libraries and ASSPs.

## ISDN

Some ISDN-related announcements included the following:

- 3Com jumped in with both feet by announcing a whole range of ISDN products, from adapters to internetworking. The Aperture II integrates terminal adapter, bridge/router, and analog modem functionality (including up to 10 primary rate interfaces—PRIs—using an i960 as its main CPU).
- Motorola Information Systems introduced the BitSurfer Pro ISDN "digital modem" for basic rate interface (BRI) use for home/remote office users ($495). The original BitSurfer is being bundled for under $300 with services like those of U.S. regional Bell operating company Pacific Bell and sold through retail superstores.
- Remote access servers/routers were introduced by Micom, Motorola, ITV, Adtran (high-bit-rate digital subscriber line—HDSL—available also), Farallon (router), PairGain (HDSL), PCSI (with compressed voice based on LD-CELP and Enhanced-CELP), Shiva (ISDN), and U.S. Robotics (ISDN, BRI, PRI).

## Frame Relay and Others

Other announcements of interest included the following:

- Xylogics (to be acquired by Bay Networks) is rounding out its universal remote access family with its Remote Annex 6100, which replaces a remote access server, a T1 data service unit/channel service unit, a T1 multiplexer, and 24 V.34 modems. The system runs on a 486 MPU and up to 8MB of DRAM. The company also announced an Ethernet-ISDN access device that extends its Nautica family. The access device uses the Motorola 68302 and 68360 MPUs along with up to 4MB of DRAM and 1MB of flash memory.
- FastComm, one the leaders in FRADs, just introduced a new version with embedded flash memory to support field software updates.
- Digital Link introduced the PremisWay ATM multiplexer for T3/E3 WAN lines. The company also introduced a new rack-mount inverse multiplexer that can break LAN traffic down into multiple T1 lines (thus avoiding the need for expensive T3 lines).
- Hypercom and Motorola have added voice-over frame relay to their router/FRAD families.
- Hughes Network Systems introduced the S8000-5, a midrange backbone access switch to handle frame relay and other WAN traffic.

## Asynchronous Transfer Mode

Many companies introduced products recently approved or nearing approval by the ATM Forum. Two of those standards are LAN Emulation, a method of smoothly interfacing ATM with traditional LAN technology, and

Network Node Interface (NNI), a method of linking public network nodes. Frame relay with ATM via permanent virtual circuits was worked out in August, helping to expand both technologies with guaranteed interoperability. The issue of traffic flow (for supporting data, voice, and multimedia, among others) is still keeping companies from issuing finalized hardware. In particular, management of available bit rate (ABR) mode is subject to continuing debate.

Because of the fluidity of ATM standards, many segment assembly-reassembly (SAR) functions are remaining in ASIC or software form, running on 32-bit processors like the i960 or MIPS varieties. Most vendors are using ASIC-based ATM switch fabrics. As the flow control issue is worked out in the ATM forum, expect the market for ASSP SARs (AAL 4/5 and AAL 1) and switch fabric to emerge rapidly.

## ATM Products Hit the Street

Some notable ATM announcements included the following:

- CrossComm announced that it is using ATM shared memory switch technology from the chip company MMC Networks. The four-chip set consists of a memory access buffer, a port interface, and two switch controllers. Known as ViX, MMC technology is scalable to 20 Gbps of throughput.
- Cascade's 500 ATM Switch, scalable from 2.5 Gbps to 10 Gbps, has four parallel switching planes to support the four ATM Forum-defined classes of service (flow control): Constant Bit Rate (CBR), Variable Bit Rate-Real Time (VBR-RT), Variable Bit Rate-Nonreal Time (VBR-NRT), and Available Bit Rate/Unspecified Bit Rate.
- Atlantec introduced a LAN-ATM edge router for use in its standard hub products, allowing ATM backbone hookup.
- Fore Systems introduced an ATM-ready Ethernet switch to accelerate migrate legacy traffic to ATM backbones.
- Xyplex introduced a family of stackable ATM switches (7000 Series) and an Ethernet-to-ATM edge router module that inserts into its hubs. The ATM supports 25 Mbps, 100 Mbps (TAXI-based), and 155 Mbps (fiber and UTP). Fore Systems, the leader in ATM switching, is taking the opposite tack as it moves its switch family toward interfacing legacy LAN traffic.
- Madge/LANNET introduced a 25-Mbps ATM switch.
- Bay Networks unveiled the System 5000 backbone switch, which is based on ATM technology but can support legacy LAN use.
- Newbridge announced additional capability, such as high-speed frame relay, to its Mainstreet ATM switch. The company claims an installed base of 900 of these switches used for ATM access.
- Although it is primarily an enabling technology provider, Scorpio Communications introduced an ATM switching platform with scalable speeds up to 10 Gbps. The system can be used to jump-start uninitiated system vendors while using Scorpio matrix switch chip silicon. The company's technology (when coupled with driver software) addresses most of the management and signaling. Scorpio's silicon partner is LSI Logic.

On the semiconductor side of ATM, PMC-Sierra introduced two new products targeted at the public interface as it attempts to leverage its position in the LAN ATM physical interface. As standards firm up in this area, PMC-Sierra has a good chance of leading here, as well.

- The S/UNI-155-PLUS is the first physical interface solution that addresses the NNI requirements for 155-Mbps public ATM networks. The chip is available now and is priced at $105 in high volumes.
- Another chip targeted at the enterprise and edge switch vendors is the PM3744-RI S/UNI-MPH, which handles four T1/E1 interfaces (framers, among others) and one ATM Utopia interface. The chip is available now and is priced at $125 in high volumes.

## Chip Vendors to Add RMON

Starting with Advanced Micro Devices earlier this year, several network controller houses signed up for support of this remote monitoring technology (RMON). Texas Instruments and Level One Communications announced that their implementations will work with RMON driver software from Epilogue. RMON allows system managers to monitor network statistics and health from remote sites. The chip vendors indicated that future silicon spins will involve building some of the management statistic features necessary to speed up RMON activities. Support of RMON at the silicon level helps avoid the use of higher-performance, more expensive MPUs to carry out the function.

## Dataquest Perspective

There is no doubt that opportunities for chip companies abound in the systems described here. From 100-Mbps LANs, LAN switches, ISDN, frame relay, inverse multiplexers, and ATM, the opportunities flow. As usual, the devil is in the details, and companies must remain flexible regarding future LAN and WAN directions if they are to be successful. Market timing, standards take-up, de facto implementations, and function integration are still very fluid in most of these areas. Issues like programmability (trading off software for hardware) and time to market are key concerns for network equipment vendors. Programmability is benefiting processor vendors, while time to market is benefiting the ASIC/FPGA and physical layer interface companies. It was also clear at this trade show that the controller chip vendors need to focus on having driver/firmware-level software available for their chips just to stay competitive.

**For More Information...**

Greg Sheppard, Director and Principal Analyst ..................... (408) 468-8261
Internet address ..................................................... gsheppard@dataquest.com
Via fax ..................................................................................... (408) 954-1780

Dataquest

Perspective

Communications Semiconductors and Applications Worldwide

# Market Analysis

# Pagers: To the Future and Beyond

**Abstract:** *The paging industry experienced significant developments during 1995 that moved it to the brink of providing true personal communications services. This document provides a brief summary of the evolution of paging technology and describes important protocols that will play a fundamental role in the development of paging services and technologies. Finally, new semiconductor opportunities created by advanced paging devices are analyzed along with descriptions of selected new chips that have found applications in pagers.*
*By Dale Ford*

## This Is NOT Your Father's Pager

The paging industry witnessed a flurry of developments during 1995 that set the paging world on a new path to an exciting future. With the introduction of new services, the opening of new markets, and the application of new technologies and standards, the pager has begun a metamorphosis into a true personal communications device. The evolution of paging devices from simple beepers or vibrators into robust devices that will provide services from wireless e-mail to mobile answering machines is shown in Figure 1. New paths of communication have been opened that will make the pager a valuable access point to a network that includes portable and desktop computers, fax machines, telephones, corporate LANs, the Internet, and other pagers and cellular phones.

**Dataquest**

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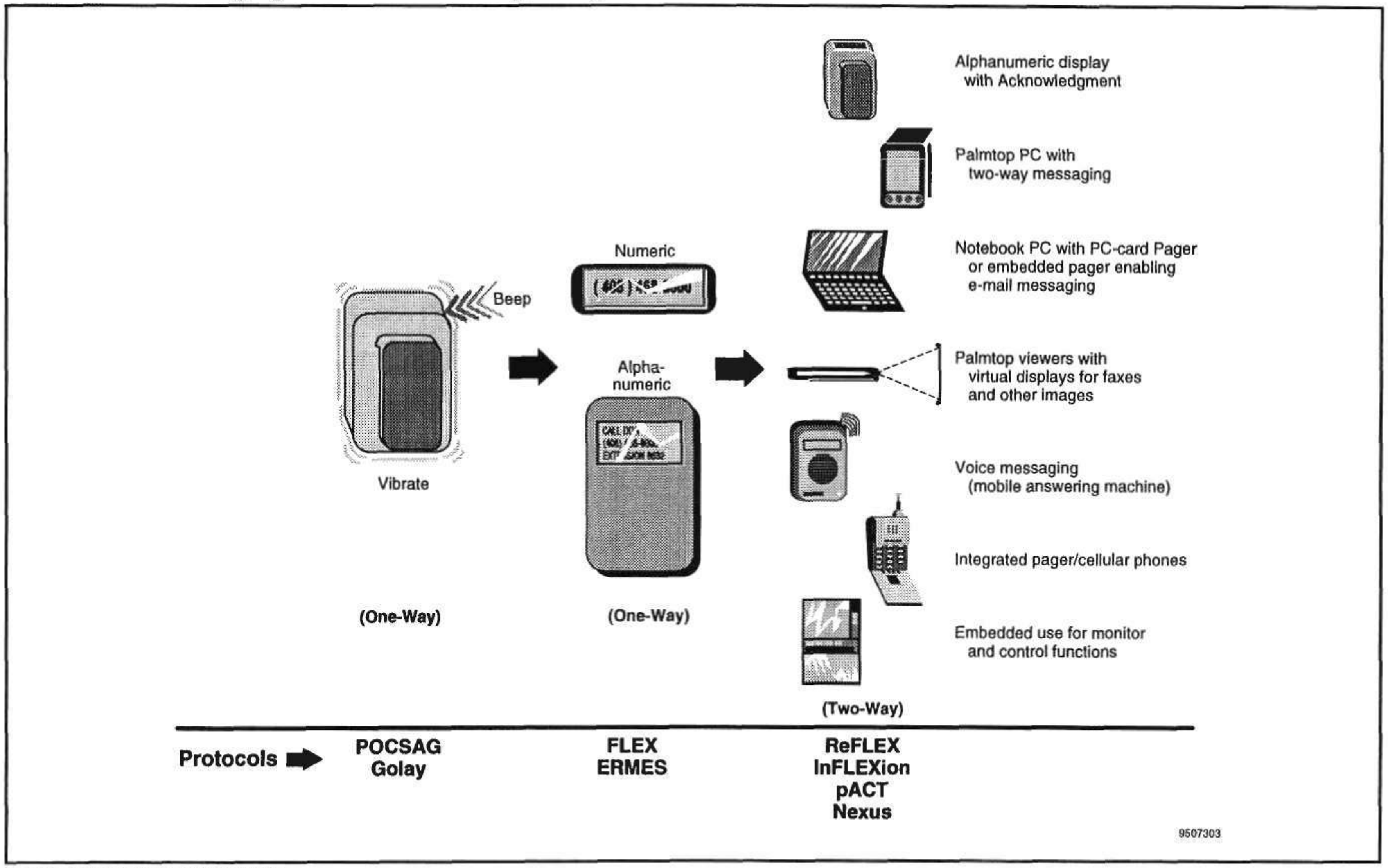
**Figure 1**
**The Evolution of Paging Terminals: Yesterday, Today, and Tomorrow**




Source: Dataquest (December 1995)

Some of the highlights of 1995 were the introduction of the first two-way paging services by SkyTel on September 18, the continued growth of the paging market to almost 100 million subscribers worldwide, and the introduction and development of new standards and protocols that will provide the foundation for future paging devices and services. It could be said that many of the announcements from pager manufacturers in recent years have been more about flash and style than substance as manufacturers worked to expand the consumer market with pagers in new colors and in form factors such as pens and watches. (However, the miniaturization that has been accomplished in pagers is no small feat.) The major announcements in 1995 revolved around fundamental developments that will take pager functionality to new levels with higher data rates, longer battery life, two-way messaging, and enhanced services. These announcements have significance for chip manufacturers interested in microcontroller, memory, analog, and even DSP semiconductor application opportunities.

## New Protocols, New Pagers

For the past 15 years, the de facto protocol for pager communications has been Post Office Code Standardization Advisory Group (POCSAG). When it was introduced in 1981, it was considered a high-speed protocol. POCSAG operates at 512, 1,200, and 2,400 bits per second (bps) and can handle up to 2 million addresses per carrier. Almost all of the tone-only, numeric, and alphanumeric pagers have operated on the POCSAG protocol. Beginning with the introduction of longer messaging and alphanumeric pagers, POCSAG started to exhibit significant limitations. Even at its highest operating speed, it will not meet the needs of service providers in the future. Many paging service operators provided little marketing and sales support for the introduction of alphanumeric pagers because of critical resource limitations in their systems.

Although Motorola introduced the Golay protocol in 1983 to address some of the POCSAG limitations, this standard has not been widely utilized. The need for increased capacity, improved reliability, higher data rates, longer battery life, and roaming capability led to the introduction of the European Radio Message System (ERMES) protocol and Motorola's FLEX protocol. Now, with the introduction of two-way messaging services and devices, Motorola has begun an aggressive promotion of two new standards, ReFLEX and InFLEXion, that build on its FLEX technology. AT&T Wireless recently announced a competitive two-way messaging standard called personal Air Communications Technology (pACT). Also, Nexus, an Israeli company, has begun promotion of a low-cost two-way system that could most accurately be described as an extension of the POCSAG standard.

### The FLEX Family

Motorola is promoting the FLEX family of protocols as the platform that will move the paging industry into the 21st century. It has moved aggressively, investing $100 million to accomplish its desire to establish FLEX as a worldwide de facto standard for pagers. The establishment of FLEX as a high-tech brand was very successful in 1995, as the term FLEX became almost synonymous with next-generation paging technology. The FLEX brand is becoming to pagers what "Pentium" is to the PC industry. In addition to its use as a brand in the one-way protocol, the term has been extended into the two-way standards with ReFLEX and InFLEXion. A late entrant, the pACT standard of AT&T Wireless is the only major challenger to the FLEX family, and this is only in two-way applications.

### FLEX

The FLEX one-way messaging protocol was introduced by Motorola in June 1993. Motorola describes the major benefits of this new protocol as follows:

- **Capacity/speed:** FLEX operates at speeds of 1,600, 3,200, and 6,400 bps. Compared with a POCSAG 2,400-bps system, the FLEX 6,400 bps provides twice the capacity. A FLEX system can support up to 1 billion individual addresses and up to 600,000 numeric pagers per channel. FLEX pagers are designed to operate at any of the three speeds, eliminating the need for stocking multiple versions and allowing system operators to upgrade their system infrastructures without making subscriber units obsolete.
- **Battery life:** The use of a "synchronous" time slot protocol allows the pager to search for messages at specific times and conserve battery power. A FLEX pager can extend battery life to more than five times that of typical POCSAG pagers.
- **Flexibility:** The FLEX system is designed to coexist with a POCSAG or Golay system so an operator can operate a channel with two protocols prior to dedicating an entire channel to FLEX.
- **Data integrity:** Accurate message delivery is enabled by improving protection from signal fading and implementing checksum validations, message numbering, and positive end-of-message control. FLEX is able to withstand 10ms fade at all speeds and still decode information accurately.

Motorola will also support the Telocator Data Protocol (TDP) suite, which was completed by the Personal Communications Industry Association in 1995. This protocol provides a method of transmitting data such as spreadsheets and word processor files over a paging transmission system. A rival to this protocol, called Limited Size Messaging (LSM), is being backed by AT&T in its pACT protocol.

The FLEX protocol has been adopted by 70 percent of the world's largest paging markets. FLEX technology adopters include 16 of the top 20 U.S. service providers; 21 major carriers in China; and top operators in Indonesia, Singapore, Malaysia, Thailand, Latin America, Canada, and Japan. The FLEX protocol has been licensed to 23 subscriber device and infrastructure manufacturers. Some of the major licensees are NEC, Uniden, Maxon, and Wireless Access for subscriber units and Glenayre and Ericsson for infrastructure equipment.

In an important strategic move, Motorola began licensing the FLEX technology to selected semiconductor companies. The first licensing agreement, with Texas Instruments, was announced in September 1995. Both Texas Instruments and Motorola plan volume production of ICs in the second half of 1996. Motorola has announced that it will enter into additional licensing agreements with other companies in the future and that it will also license the ReFLEX and InFLEXion technologies.

The licensing of the technology to chip manufacturers brings some important benefits to Motorola. First, this will allow it to enlist chip companies on its team to expand the paging market and promote the FLEX high-speed protocol beyond what Motorola could do alone. Ideally, manufacturers of a wide variety of electronics, from pagers to palmtop PCs to home alarm systems, could purchase a FLEX chip and combine it with an off-the-shelf RF receiver to add paging functionality to their products. As the global paging market expands and the U.S. share of the market decreases, promotion of FLEX as an international standard will become more important and more costly. Teaming with the key semiconductor companies will enhance Motorola's global efforts while keeping costs from skyrocketing.

Motorola will also benefit through leveraging the core strengths of semiconductor licensees in improving the technology and reducing costs. From the perspective of the bottom line, the model of licensing chip companies and earning royalties through that channel could be more profitable. Significant costs of marketing and manufacturing can be shared with a team of players or off-loaded to other manufacturers to reduce Motorola's direct costs in the long run. Finally, in a world where the concept of "open standards" has become a critical marketing issue, Motorola will be able to deflect some of the criticism drawn by its creation of a proprietary standard by opening up the technology to semiconductor licenses.

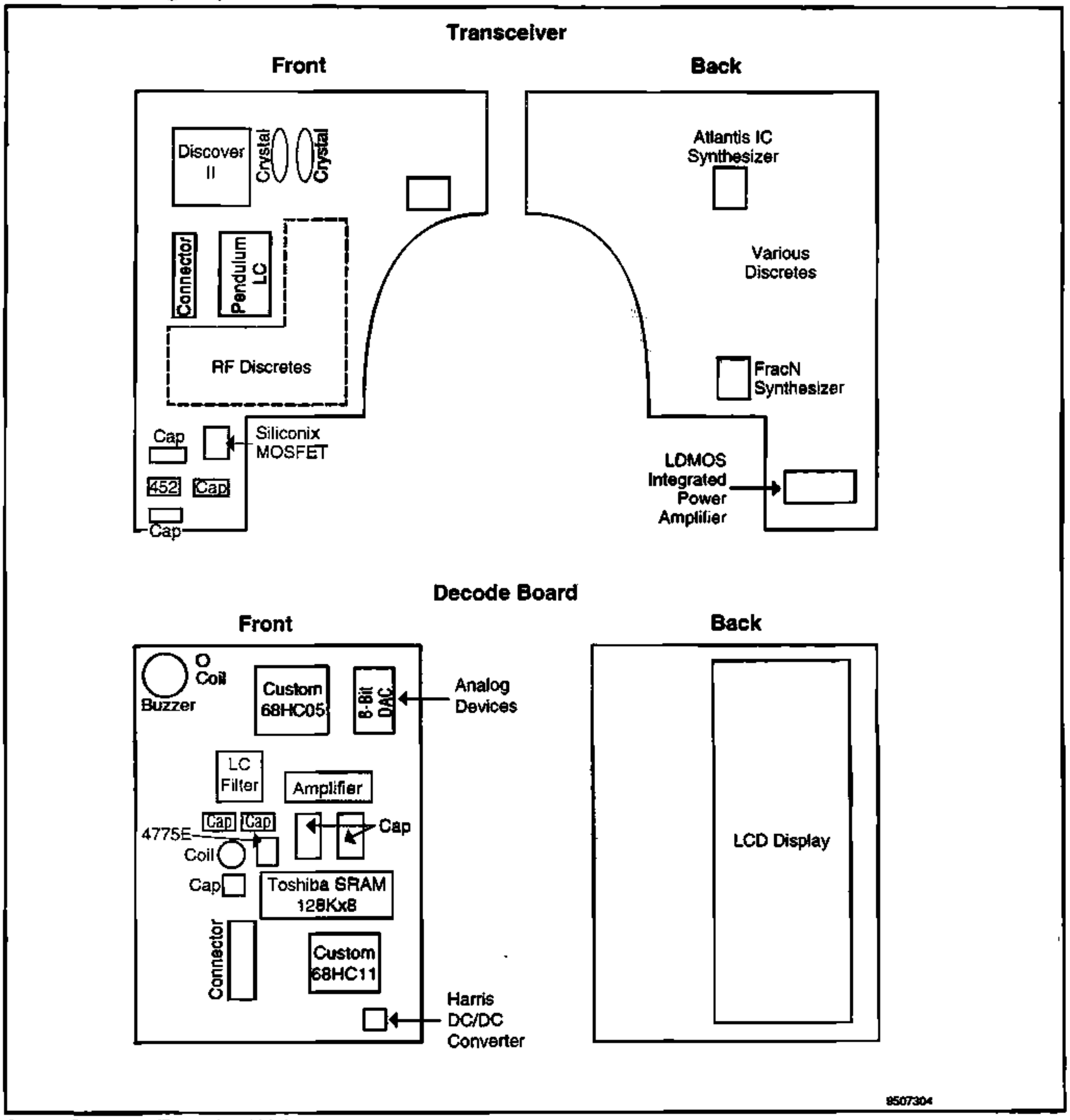
**ReFLEX and InFLEXion**

Anticipating the creation of a new market for two-way paging through the U.S. narrowband PCS auctions, Motorola began working on two-way technologies with potential service providers in the earliest stages. The result of this work was the first set of two-way paging protocols, ReFLEX 25 and ReFLEX 50. The ReFLEX protocol builds on the FLEX technology by adding a response channel to the paging system for all message acknowledgment, customized response, and subscriber-initiated messaging. The first two-way narrowband PCS service in the United States was launched in September 1995 by SkyTel using the ReFLEX 25 protocol. Motorola's infrastructure equipment and Tango pager provided the hardware for the system launch. Figure 2 shows the system cards used in the Motorola Tango.

The InFLEXion protocol is the most advanced two-way paging protocol in the FLEX family. There are both voice and data versions of this protocol. The voice application uses a proprietary compression scheme to store four minutes of voice messages in 4Mb of memory on a subscriber device. It also allows for messages to be stored for later recall in the infrastructure in a memory bank called the Wireless Messaging Gateway if memory needs to be cleared on the subscriber device. InFLEXion also features system registration capability, which will provide increased system capacity by providing regional and local frequency reuse. PageNet will use InFLEXion in its system when it introduces its VoiceNow service in 1996. PageMart will also use InFLEXion and ReFLEX technology in its system. Motorola will supply its Tenor pager for use in these systems. Figure 3 provides a diagram of a two-way messaging system using ReFLEX or InFLEXion technology.

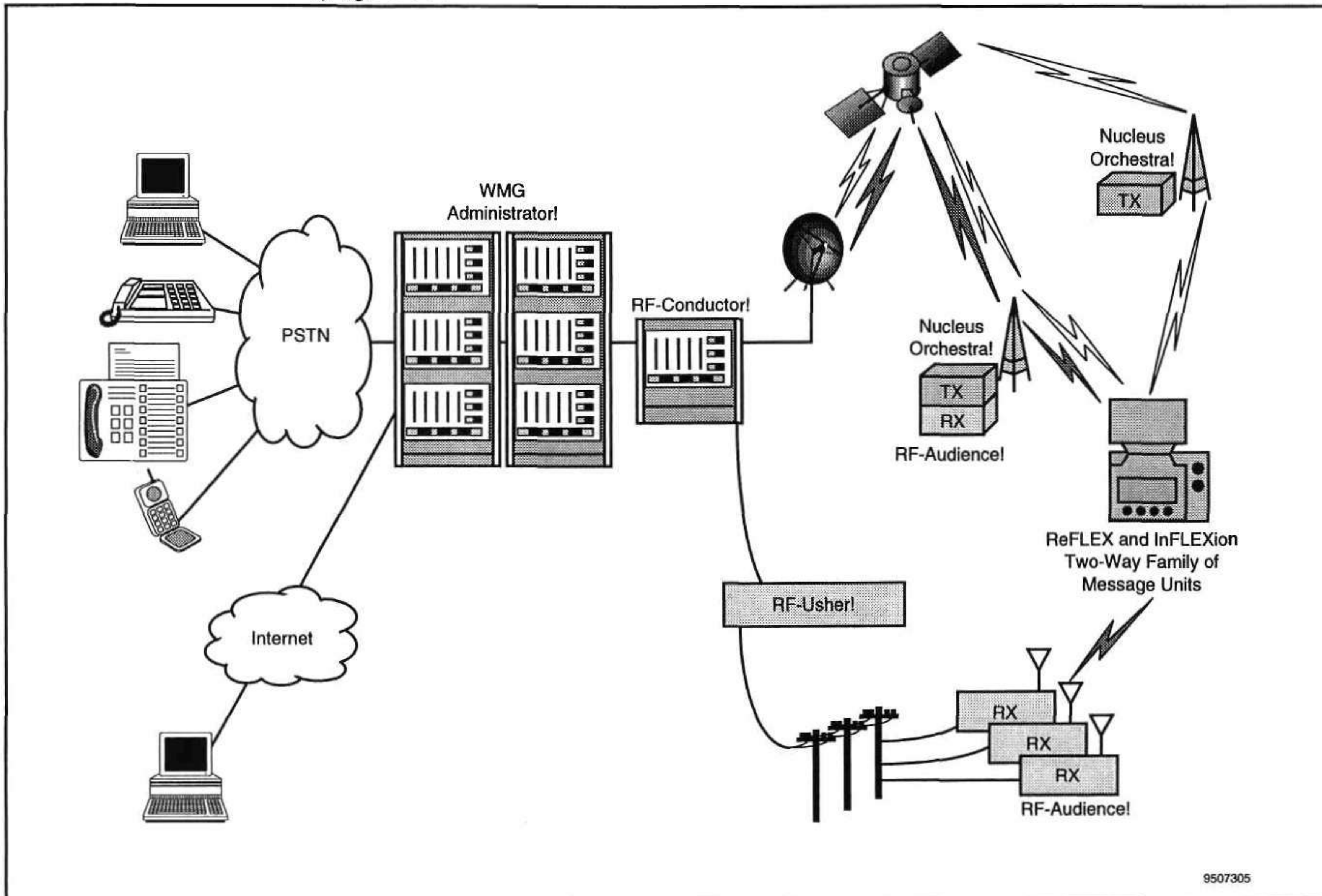
Glenayre Technologies has been licensed by Motorola to design and manufacture infrastructure equipment incorporating InFLEXion and ReFLEX for narrowband PCS. Wireless Access has been licensed to produce pagers using the ReFLEX technology. As mentioned, Motorola will also enter into ReFLEX and InFLEXion licensing agreements with selected semiconductor companies.

**Figure 2**
**Motorola Tango System Cards**




Source: Dataquest (December 1995)

**Figure 3**
**Motorola's Advanced Messaging Solution**




Source: Motorola

## pACT

After winning a national license in the U.S. narrowband PCS auctions, AT&T Wireless announced that it would develop its own two-way technology for paging. In October 1995, AT&T Wireless unveiled pACT. It will deploy this technology in its own network and plans to compete with the FLEX technologies in the market. The pACT protocol is rooted in Cellular Digital Packet Data (CDPD) technology, and, because of its extensive use of Internet Protocol (IP), it should be easily integrated with other networks. AT&T Wireless claims that by using intelligent base stations with automatic registration and network mobility management it will be able to provide superior network efficiencies. As mentioned before, the pACT standard also supports the LSM protocol for transmitting binary data. Other features of this system as described by AT&T Wireless are as follows:

- Use of a cellular-like network design that will enable carriers to add capacity easily and that allows frequency reuse
- Ability to locate subscriber devices within the network
- Full data encryption and authorization
- Symmetrical message-transfer capability within the narrowband PCS spectrum

Early support agreements for the pACT system have been announced with Pacific Communication Sciences Inc. (PCSI) and Retix. PCSI announced a multimillion-dollar contract from AT&T Wireless Services to develop and supply base station equipment. It is ideally positioned for this contract because of its earlier development efforts with CDPD. PCSI is also developing a highly integrated pACT chipset for use in paging devices. Its chipset solution consists of two baseband chips and an IF device designed to minimize cost, power consumption, and size of implementation. The baseband device includes an embedded microcontroller, a pACT protocol communication processor, and an array of peripheral functions. The modem chip performs the channel modulation/demodulation functions and the third chip, the IF device, integrates a significant portion of the IF functions.

Retix was chosen as the sole supplier of the pACT Data Intermediate System (PD-IS), software that will route packet data and handle mobility management. NEC and Ericsson are also expected to develop products for the pACT protocol but have not yet announced specific plans. AT&T Wireless is promoting pACT as an open standard because hardware and software developers can design pACT-based subscriber units without paying licensing fees. The company expects to have a network ready for commercial services in the second half of 1996.

## Nexus

The Nexus two-way paging system is different from the Motorola and AT&T Wireless systems because it does not operate in the new narrowband PCS spectrum. Instead, it uses a carrier's existing paging infrastructure to send messages to a two-way pager; the pagers use 2 MHz in the unlicensed 902-to-928-MHz band (also used by cordless phones and wireless speakers) to transmit replies. To avoid interference with cordless phones and other wireless devices, the pagers use frequency-hopping spread-spectrum technology. In this system, subscribers send responses and initiate messages to other subscriber units, public and private e-mail networks, or a recipient's telephone. When a message is sent to a telephone, it is converted from text to speech for delivery. Nexus is targeting its system as a lower-performance solution that offers the advantage of low cost for service providers. It is avoiding head-to-head competition with Motorola and AT&T Wireless.

Samsung has agreed to manufacture the Two-Way Acknowledgment Group (TAG) pager for Nexus. Glenayre Technologies has signed an agreement to cooperate in the integration of Glenayre's paging infrastructure products and Nexus' reverse channel receivers and two-way applications platform. To bring its service to market, Nexus has formed an alliance with American Paging to form American Messaging Services and plans to roll out services in mid-1996, beginning in Minneapolis; Chicago; and Orlando, Florida. American Paging also won five regional narrowband PCS licenses.

### ERMES

The ERMES concept began in the late 1980s with several European paging operators seeking to create a common protocol for European countries. In 1990, the ERMES memorandum of understanding was approved by 23 signatories, and, by 1993, trials of the system were started in various European countries. The first ERMES service was launched in France, followed by Hungary and Germany. The major goals of the ERMES protocol are to increase subscriber capacity for all types of service, improve messaging performance, and improve battery life. ERMES is a one-way messaging protocol and offers a signaling speed of 6,250 bps. Although operators in Malaysia and the United Arab Emirates have also added their signatures to the memorandum of understanding, the ERMES protocol has not yet become a major influence beyond Europe. It is unlikely that a pattern similar to that of the Groupe Speciale Mobile (GSM) cellular handset will be repeated with the ERMES protocol.

### Other Protocols

In addition to the major standards described, other protocols and systems being developed include the following:

- MobileComm's voice-messaging service, dubbed ReadyTalk, uses spare capacity in existing cellular networks to transmit voice messages from a landline phone to a ReadyTalk transceiver capable of storing up to 30 30-second messages. A subscriber can respond with a 30-second voice message. Following beta tests, MobileComm plans to launch its service in the fourth quarter of 1996 in cellular markets operated by sister company BellSouth Cellular.
- Philips Telecom's Advanced Paging Operators Code (APOC) paging format, is designed to provide a simple migration path from POCSAG-based systems to a system that can operate at 6,400 bps. The company has licensed Glenayre to provide infrastructure equipment for this system.

## Protocol Comparisons and Selections

Table 1 presents a comparison of the major paging protocols, and Table 2 shows the protocol technology selections of the winners of narrowband PCS licenses in the first two rounds of auctions.

## Table 1
## Comparison of Major Paging Protocols

| Protocol | Applications | Operating Frequency | Infrastructure Requirements | Roaming Capability | Outbound Channel | Outbound Signaling Speed | Inbound Channel | Inbound Channel Signaling Speed |
|---|---|---|---|---|---|---|---|---|
| **POCSAG** | | | | | | | | |
| Low-speed, one-way worldwide prevailing technology | One-way numeric and alpha (4-bit/7-bit) | Any available paging frequency | Existing infrastructure | Not supported | 25 KHz | 512, 1,200 or 2,400 bps | NA | NA |
| **ERMES** | | | | | | | | |
| European one-way protocol | One-way numeric and alpha (4-bit/7-bit binary) | 169.425 KHz to 169.8 MHz | Mostly new infrastructure | Yes, between ERMES systems | 25 KHz | 6,250 bps | NA | NA |
| **FLEX** | | | | | | | | |
| High-speed, one-way standard | One-way numeric and alpha (4-bit/7-bit binary symbolic characters) | Any available paging frequency | Modest upgrade (typically) | Supported | 25 KHz | 1,600, 3,200, or 6,400 bps | NA | NA |
| **ReFLEX 25** | | | | | | | | |
| Two-way messaging and data protocol (can also put two channels in 50 KHz) | Two-way short messages (4-bit/7 bit, binary) | Out: 929-932 MHz and 940-941 MHz In: 901-921 MHz | Modest transmit upgrade or new transmit plus new receive infrastructure | Yes | 25 KHz or 50 KHz | 1,600, 3,200, or 6,400 bps per 25 KHz channel | 12.5 KHz in 901-902 MHz | 800, 1,600, 6,400, or 9,600 bps |
| **ReFLEX 50** | | | | | | | | |
| Two-way messaging and data protocol | Two-way short messages (4-bit/7-bit binary) | Out: 929-932 MHz and 940-941 MHz In: 901-902 MHz | Modest transmit upgrade or new transmit plus new receive infrastructure | Yes | 50 KHz | Up to 25.6 Kbps | 12.5 KHz in 901-902 MHz | 9,600 bps |
| **InFLEXion Voice** | | | | | | | | |
| Advanced voice messaging protocol (supports up to seven subchannels) | Voice paging (with acknowledgement) | Out: 930-931 MHz and 940-941 MHz In: 901-902 MHz | Modest upgrade to new ReFLEX infrastructure | Yes | 50 KHz | Digitally processed compression | 12.5 KHz in 901-902 MHz | 800, 1,600, 6,400, or 9,600 bps |

(Continued)

## Table 1 (Continued)
## Comparison of Major Paging Protocols

| Protocol | Applications | Operating Frequency | Infrastructure Requirements | Roaming Capability | Outbound Channel | Outbound Signaling Speed | Inbound Channel | Inbound Channel Signaling Speed |
|---|---|---|---|---|---|---|---|---|
| **InFLEXion Data** | | | | | | | | |
| High speed, two-way data protocol (supports up to seven subchannels, each up to 16 Kbps; 50-KHz channels capacity to 112 Kbps) | Two-way data (4-bit/7 bit, binary) | Out: 930-931 MHz and 940-941 MHz In: 901-902 MHz | Modest upgrade to InFLEXion Voice infrastructure | Yes | 50 KHz | 4,000, 8,000, 12 Kbps or 16 Kbps per subchannels | 12.5 KHz in 901-902 MHz | 800, 1,600, 6,400, or 9,600 bps |
| **pACT** | | | | | | | | |
| Two-way messaging and data protocol | Two way short messages and data | Out: 930-931 MHz and 940-941 MHz In: 901-902 MHz | New transmit plus new receive infrastructure | Yes | 50 KHz | 8,000 bps | 50 KHz or 12.5 KHz | 8,000 bps |
| **Nexus** | | | | | | | | |
| Two way messaging and data systems | Two way short messages | Out: 800-1,000 MHz In: VHF, UHF, or 902-928 MHz | Minor update to POCSAG infrastructure plus new receive infrastructure | Yes | 7.5 KHz | 512, 1,200, or 2,400 bps (POCSAG) | 12.5 KHz, 25 KHz or 50 KHz | 200 bps |

NA = Not applicable
Source: Motorola, AT&T, and Nexus

**Table 2**
**Technology Selections of Narrowband PCS Winners**

| Service Provider | License | Technology Selection |
|---|---|---|
| PageNet | National | InFLEXion Voice; considering ReFLEX 25 |
| AT&T Wireless | National | pACT |
| SkyTel (MTel) | National | ReFLEX 50 |
| AirTouch Paging | National and three regions | ReFLEX 25 |
| BellSouth Wireless | National | Leaning toward ReFLEX 25 |
| PageMart II | National and five regions | ReFLEX 25 and InFLEXion Voice |
| PCS Development | Five regions | InFLEXion Voice |
| MobileMedia PCS | Five regions | ReFLEX 25; evaluating InFLEXion and pACT |
| American Paging | Five regions | ReFLEX 25; possible addition of InFLEXion (Also deploying Nexus) |
| Adelphia Communications | Three regions | No information |
| Benbow PCS Ventures | Two regions | Evaluating ReFLEX 25, InFLEXion, and pACT |
| Ameritech Mobile Services | One region | Evaluating ReFLEX 25 |
| Insta-Check Systems | One region | Evaluating ReFLEX 25 and InFLEXion |

Source: Dataquest (December 1995)

## North American Pager Manufacturers

Although North America has been a significant importer of pagers, there is a growing trend to locate manufacturing in the region of consumption. For example, Uniden claims it has experienced major increases in pager sales in North America, and it is shifting design activities to Fort Worth, Texas, and establishing manufacturing in Mexico. Dataquest predicts that production of one-way pagers will decline in North America. However, the growth in production of two-way pagers will result in a 6 percent compound annual growth rate in total North American pager production from 1994 to 1999. Table 3 presents a summary of pager design and manufacturing activity in North America.

## Technologies and Chips Pushing the Envelope

The paging products that were introduced in 1995 are impressive, but exciting new technologies that will form the foundation for the next generation of pagers are already in the advanced stages of development. Introduction of even more advanced paging products will both enable new market opportunities for service providers and present new applications opportunities for semiconductor manufacturers. While pagers present a high-volume opportunity for microcontrollers such as Motorola's 68HC05 and 68HC11, there are other chip opportunities emerging in pager products.

### Low-Power Chips

Pagers are leading the charge down the low-voltage, low-power curve. Although many other products are at 3V implementations, some pager chips have been developed for 1V operation.

**Table 3**
**North American Pager Manufacturing and Design Locations**

| Company | Design Location | Manufacturing Location |
|---|---|---|
| Motorola | One-way: Boynton Beach, Florida | One-way: Boynton Beach, Florida; Chihuahua, Mexico; and Puerto Rico |
| | Two-way: Fort Worth, Texas | Two-way: Forth Worth, Texas |
| NEC | - | Guadalajara, Mexico |
| Uniden | Forth Worth, Texas | Mexico (planned) |
| Panasonic/Matsushita | Alpharetta, Georgia | Peachtree, Georgia (mainly numeric) |
| AT&T | - | Mexico |
| Samsung | - | Deerfield Beach, Florida (final assembly only) |

Source: Dataquest (December 1995)

### Memory

Pagers present an ideal opportunity for low-power memory products. While lower power is obviously desirable from the perspective of extending battery life, low-power memory will have even more importance in the new voice pagers. The current memory being used in two-way voice pager designs pose a problem for RF signal quality because of the noise created during the refresh cycle. One possible solution for this problem comes from Nexcom Technology. It has developed NexFLASH, which it claims has the advantages of both EEPROM and EPROM-flash without their limitations. Nexcom's new serial flash memory operates on low power and has been demonstrated to store 10 minutes to 15 minutes of voice on one 8Mb chip. This type of product has exciting potential in voice pager applications. Motorola has also done materials research that has led to breakthroughs in nonvolatile memory. Its ferroelectric nonvolatile memory provides the advantage of low-voltage, low-energy switching, which is also ideal for wireless applications.

### Power Amplifiers

In another important development related to low-power technology, Motorola has developed a scalable, low-cost RF power amplifier. Its Lateral DMOS (LDMOS) power amplifier is used in the Tango Pager shown in Figure 2.

## DSPs

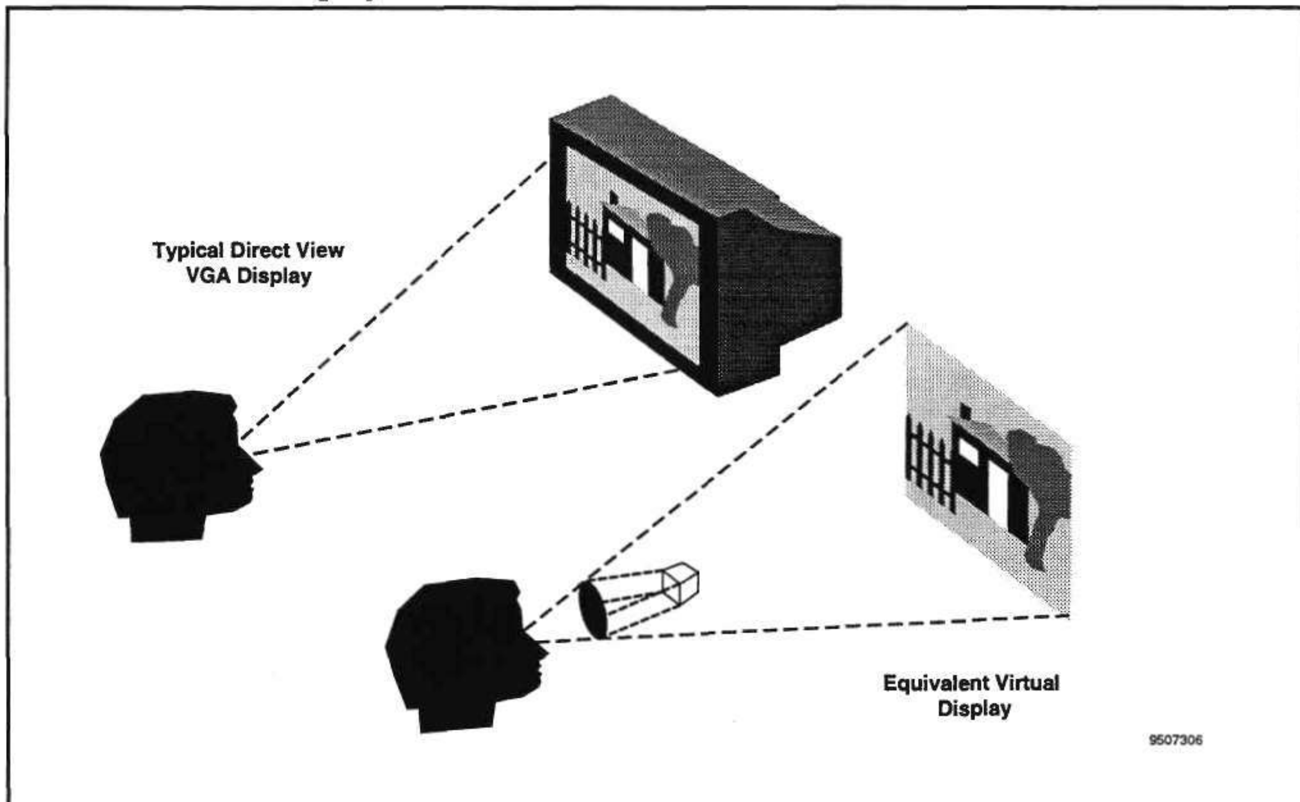
The new high-speed protocols and products that implement voice (and, in the future, image) compression will present a new application for DSPs that can deliver tailored, cost-effective processing power. AT&T Microelectronics has already begun promoting its Peace of Mind Processor (POMP) for pager solutions and has design-wins in Motorola products. It would also appear that Motorola is seeking to leverage Texas Instruments' DSP technology through its "strategic" licensing agreement.

## Virtual Display

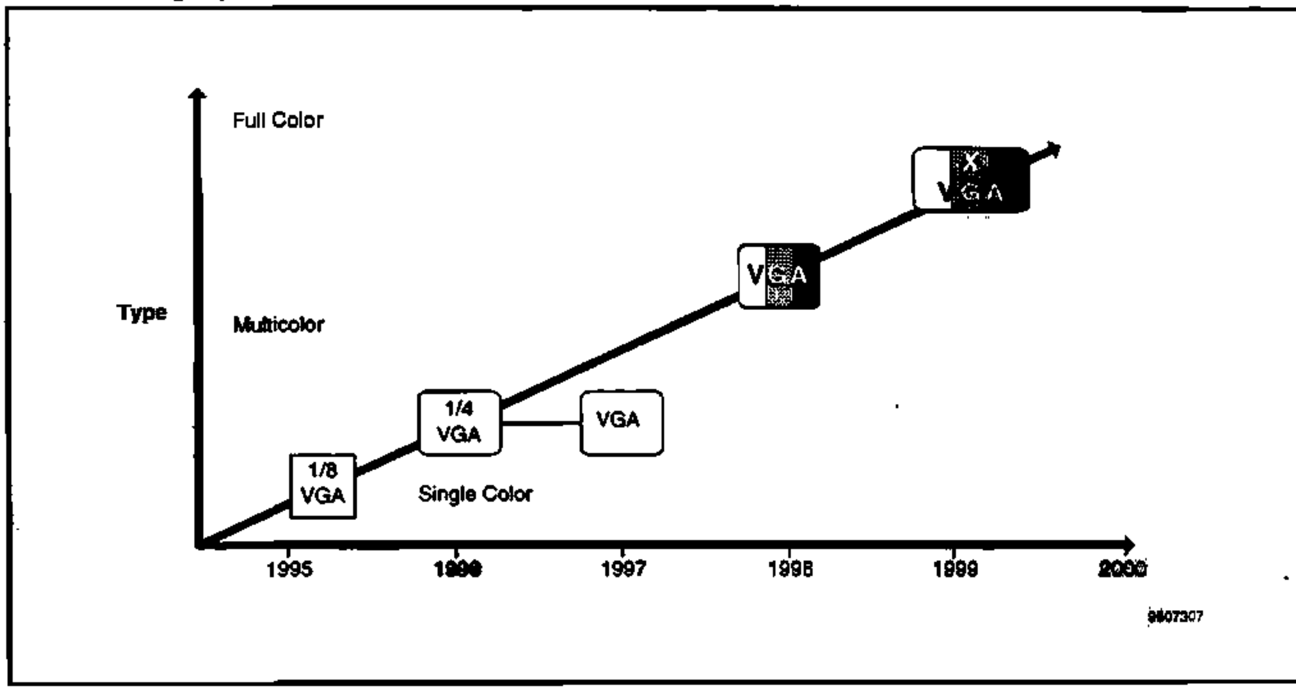
At its 1995 Horizons conference, Motorola unveiled its development of virtual display technology for mobile applications. As shown in Figure 4, this type of display would eventually allow a pager that fits in the palm of the hand to present a full VGA image. A lens that measures 1 cubic inch could present a full VGA image of 36 x 21 inches. Development of this display was started about two years ago and is already in its second redesign, with major improvements in power and size. By early 1995, a device had been developed that could display a monochrome one-eighth VGA image, or 14 lines of 40 characters with less than 70mW power drain. It was expected that the company would achieve a 16-level gray-scale image by the end of 1995. Figure 5 shows the development path that Motorola plans to follow. By the end of 1996, it expects power consumption to be reduced to 30mW to 40mW. The company is working with several customers and expects to have actual product designs using the device by the end of 1996. Although there are myriad applications for such a device, the most obvious application is in paging technology.

**Figure 4**
**What is a Virtual Display?**




Source: Motorola

**Figure 5**
**Virtual Displays of the Future**




Source: Motorola

Low-cost optics is one of the key elements in this display. Motorola has accessed patented technology that has led to the development of a plastic, refractive, defractive, single-fold lens. Other technologies developed by Motorola for this product are as follows:

- Advanced gallium arsenide processing technology for low-power emissive image source
- Aggressive, ultrafine geometry interconnect technology for reduced weight and size
- Integrated CMOS driver electronics for reliability and ease of use

Reflection Technology has also developed a virtual display used in a product called FaxView, a mobile cellular data messaging device. The FaxView uses Scanned Linear Array display technology, the same technology featured in Nintendo's 3-D immersion game system, Virtual Boy. The FaxView is able to store 20 fax pages and presents an image equivalent to a 12-inch screen with 864 x 256 pixel resolution. However, the main drawback to this product for pager applications is the power consumption levels.

## Summary

A review of the new paging products and technologies that came to the market in 1995 offers a glimpse of the exciting potential this market holds. While cellular data products continue on a slow development path, paging solutions for voice, data, and image communications have hit an aggressive curve. With current and forecast capabilities, pagers could capture a major share of the wireless data communications market before effective cellular data solutions are widely available. Although Short Messaging Service (SMS) is available through cellular services, it comes up short on many aspects, such as in-building penetration, battery life, and cost of the subscriber unit when compared with pagers. On the other hand, pager products will soon be available that provide solutions to the majority of the data communications needs of a mobile environment, from e-mail messaging to fax capability.

Semiconductor manufacturers will be key players on the development teams pursuing the next-generation technologies. With the use of pagers in imaging and voice applications, the development of efficient compression technology for mobile applications should capture increasing interest. As chip companies seek new opportunities for their microcontrollers, DSPs, memory, power amplifiers, and RF devices, they will be presented with familiar challenges. As always, mobile products are pushing chip suppliers to provide solutions that offer higher integration and higher performance with lower power consumption and lower cost.

CSAM-WW-MA-9504 Qty: 1
Ms. Maria Valenzuela
Dataquest Incorporated
1-1100

--INTERNAL DIST.--

**For More Information...**

Dale Ford, Senior Industry Analyst .......... (408) 468-8311
Internet address .......... dford@dataquest.com
Via fax .......... (408) 954-1780

Perspective

Communications Semiconductors and Applications Worldwide

# Dataquest Predicts

# The Future of ADSL


**Abstract:** *No one disagrees that the local loop must evolve to support higher-speed data and video services. As regional Bell operating companies (RBOCs) and other local network providers face the daunting task of migrating from narrowband, twisted-pair local loop to a fiber/coax-based infrastructure, asymmetric digital subscriber line (ADSL) will be used to provide data and some video services. This document forecasts ADSL usage based on an analysis of worldwide local loop penetration combined with semiconductor and market timing issues.*


*By Eileen Healy and Greg Sheppard*


## Competition from Cable TV Will Drive ADSL in the United States

In the United States, cable TV companies already offer some data services using cable modems. Recent announcements indicate that they will aggressively market these services beginning in 1996. As they become more sophisticated with two-way interactive and switched services, the threat to telephone companies will increase. This near-term threat will force the telcos to respond quickly. Broadband loop deployment, for example, Hybrid Fiber-Coax (HFC), Switched Digital Video (SDV), and Fiber to the Curb (FTTC), will, in most cases, take too long to deploy to meet this threat. Even multipoint, multichannel distribution system (MMDS)—wireless cable services that can be deployed relatively quickly—will need to be augmented with high-speed data services. Asymmetric digital subscriber line (ADSL), which provides bandwidth as high as 52 Mbps over twisted pair, fills the gap.


**Dataquest**

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## Dataquest Predicts

Dataquest predicts that ADSL will be deployed more widely in the United States than public network providers' forecasts and plans indicate. This will be attributed to the overwhelming undertaking of migrating to broadband local loops combined with intense market pressure to respond to higher-bandwidth services enabled by cable modems. Dataquest predicts that the worldwide volumes necessary to drive down ADSL chipset prices to acceptable levels will be reached by 1998.

## Applications That Will Use ADSL Transceivers and Cable Modems

The bandwidth that ADSL delivers and the service demand are both important in determining which applications are most likely to drive ADSL deployment. In the past, ADSL was touted as the answer to cable TV entertainment video services. These days, most agree that ADSL is not competitive for video except in niche markets. High-speed data services that can complement other technologies such as MMDS are much more competitive. The applications that are likely to drive ADSL deployment include:

- Telecommuting
- News on demand
- TV listings
- Videoconferencing
- Transaction services (home shopping, banking, and so on)
- Internet access
- Security and home management

ADSL can provide the control channel for the CATV, broadcast, and video-on-demand services. It can also be used for videoconferencing at 384 Kbps.

Limited cable data services are being offered in the United States using cable modems. Typically, the cable modems are leased as part of a service to minimize the out-of-pocket expenses for the customer. For example, individual stock market investors can only access the U.S. stock market via cable modems. There are currently about 10,000 users of these services, each paying approximately $80 per month to lease the cable modems and access Wall Street financial data.

TCI, the largest U.S. cable provider, has created a new company called "@Home" to offer cable data services. The plan is to offer data services at up to 512 Kbps at prices similar to telco ISDN services ($30 per month) that only deliver 144 Kbps. Telcos, which stand to lose their plain old telephones (POTS) services to CATV as well, must respond quickly in threatened territories. In some cases where telcos are being aggressive with HFC and other broadband deployment, ADSL may not be needed. However, Dataquest predicts that in many cases, such broadband loops will not be ready.

## Technology Alternatives

ADSL and its higher-speed version, very high speed digital subscriber line (VDSL), provide up to 52 Mbps of data to the home over existing copper twisted pair. Table 1 shows the bandwidth and distance limits. POTS can also be delivered over the same twisted pair as ADSL/VDSL, eliminating the POTS powering issues associated with fiber-based broadband deployment.

**Table 1**
**ADSL Bandwidth/Distance Trade-Offs**

| | Bandwidth (Mbps) | Theoretical Distance (KFt) | Curent Practical Distance (KFt) |
|---|---|---|---|
| ADSL | 1.5 | 18 | 12 |
| ADSL | 6.0 | 12 | 9 |
| VDSL | 52.0 | 3 | 0.5 |

Note: Distance assumes 24 gauge copper twisted pair.
Source: Dataquest (November 1995)

### Broadband Deployment

Local telephone companies now understand that in information-rich countries such as the United States, low-speed digital services like ISDN are not sufficient for the future. All telcos are now planning to deploy fiber closer to the customer. Various architectures are available, with fiber either going directly to the customer or coaxial cable going from a neighborhood fiber node to the customer. Eventually, this transition from twisted pair to broadband access will be complete, but Dataquest believes the implementation will spread over several decades. Table 2 shows the estimated equipment cost to telcos to migrate their networks to broadband. In addition to cost, there are other barriers to broadband deployment. The biggest barrier today is the delays in dealing with the public, both government or community organizations and individual citizens. People once sat back unquestioningly as public utilities did their work. Now many protest when their streets are dug up, and an ugly box is installed in their view. ADSL eliminates some of the deployment barriers.

**Table 2**
**Telco Broadband Equipment Costs (Millions of Dollars)**

| | Equipment Cost to Modernize to Broadband |
|---|---|
| Ameritech | 8,079 |
| Bell Atlantic | 8,669 |
| BellSouth | 8,719 |
| NYNEX | 7,429 |
| Pacific Telesis | 6,866 |
| SBC Communications | 6,221 |
| U S WEST | 6,414 |

Source: Dataquest (November 1995)

Three different technologies are currently considered viable for residential broadband deployment, HFC, SDV, and MMDS. Different architectures are possible to provide interactive video and data services. ADSL is being considered as a complement not only to HFC and SDV, but also to MMDS.

## ADSL

Over 15 different vendors are developing ADSL chipsets and/or transceivers. This level of interest, combined with the potential number of transceivers needed (over 1 million), results in a market that can drive down the cost of ADSL to levels needed for widespread deployment.

There are two different modulation techniques being developed for ADSL. Modulation techniques for VDSL are even less settled. Carrierless amplitude/phase (CAP) modulation and discrete multitone (DMT) modulation will both exist for a period of time. CAP, while available earlier, is not the accepted industry standard; DMT is. CAP is currently licensed by AT&T to several different chipmakers. Table 3 shows the announced players in the ADSL market.

**Table 3**
**ADSL Vendors**

| Company | Building Chips | Building Systems | Focus of Development | Partners |
|---|---|---|---|---|
| Advanced Video Access | | X | CAP | |
| Alcatel | X | X | DMT | |
| Amati Communications | | X | DMT | Motorola |
| Analog Devices | X | | DMT | Aware Inc. |
| AT&T Paradyne | X | | DMT | |
| Aware Inc. | | X | DMT | |
| ECI Telecom | | X | DMT | |
| Ericsson Schrack AG | X | X | DMT | |
| Hyundai | | X | CAP | |
| LGIC (Goldstar) | | X | CAP | |
| IJTE (Il-Jin Telecom Electronics Co.) | | X | CAP | |
| Motorola | X | | DMT | Amati |
| NEC Australia | | X | CAP and DMT | |
| Orckit Communications | X | X | DMT | |
| PairGain Technologies | X | X | DMT | |
| Performance Telecom | | X | CAP | |
| Westell Inc. | | X | CAP and DMT | |

Source: ADSL Forum, Dataquest (October 1995)

## Costs and the Semiconductor Industry Role

### Partnerships Create Solutions

For the most part, silicon solutions for ADSL have been born from the partnerships of DSP-oriented chip companies and companies possessing algorithm technology. Clearly, these are win-win proposals as chip companies are given a chance to participate in the value-add chain early, and the algorithm houses stand a chance to collect royalties from the sale of millions of chips. These next-generation solutions generally entail taking elements of off-the-shelf DSP cores, data conversion, and analog elements and customizing them for executing the various ADSL algorithms. In addition, some of algorithms will be stored on flash memory-based (or similar) firmware for execution on the DSP processor. Figure 1 shows a block diagram of a generic ADSL modem highlighting silicon opportunities. Figure 2 shows the associated network architecture.

### Forecast Scenarios and Silicon Costs

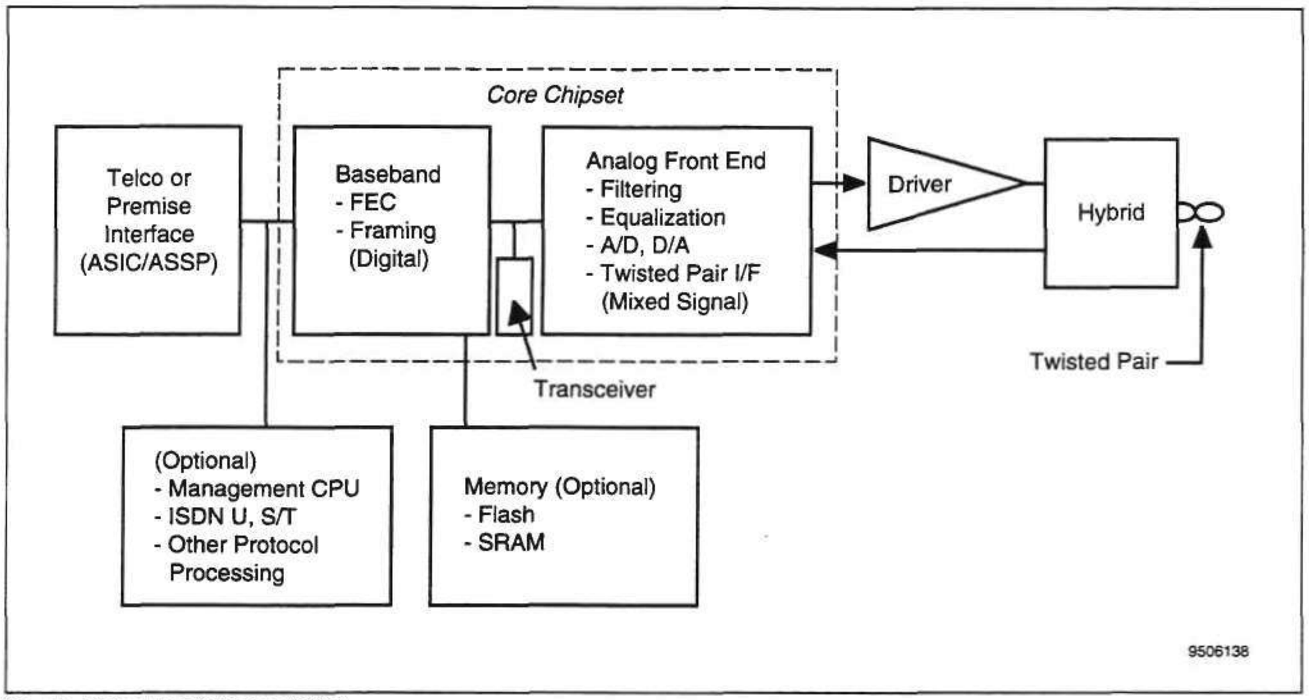
Table 4 shows worldwide PSTN line in service around the world. Typical growth and rehabilitation rates for telcos are both about 3 percent per year. New access lines grow at 3 percent, and about 3 percent of the existing lines need to be rehabilitated in any given year because of age or damage. Table 5 shows the potential penetration of ADSL of the worldwide access lines. One scenario assumes a pessimistic outlook of 0.5 percent penetration where prices remain high, implementations remain proprietary, other broadband alternatives thrive, and consumer demand falters. The 2 percent scenario assumes that prices come down rapidly, and implementations go smoothly serving strong demand. Some countries such as Japan insist that they will never use ADSL. Developing regions such as Africa will have little use for ADSL.We think the most likely outcome is 1 percent penetration primarily into affluent demographic areas of world, especially where telcos are responding to a competitive threat. Dataquest's forecast for ADSL equipment shipments into the United States is shown in Figure 3. This forecast includes all speeds of ADSL, including what is known as VDSL at 52 Mbps. It is revised for the June 1995 Dataquest forecast.

Table 6 shows the ADSL modem semiconductor demand that can be derived from a 1 percent penetration scenario with a chipset on either end of the line. By late 1997, the silicon cost should drop to about $160 per line based on announced plans. There is no reason why the modem chipset cost couldn't drop to $70 a line once the first few million units are shipped and third-generation silicon is available. On the subscriber side, this chipset could be integrated into a set-top box with further integration economies recognized.

ADSL is beginning to receive greater semiconductor industry support with several vendors accelerating their development efforts in recent months. ADSL system builders can expect highly integrated, standard, second-generation silicon designs to hit the market in 1996 and 1997. By early 1997, the semiconductor content of an ADSL modem should cost under $100 for basic functionality. This should enable central office (CO) line cards and subscriber modems that could cost $400 or less, thus helping tip the scale toward ADSL rollout.

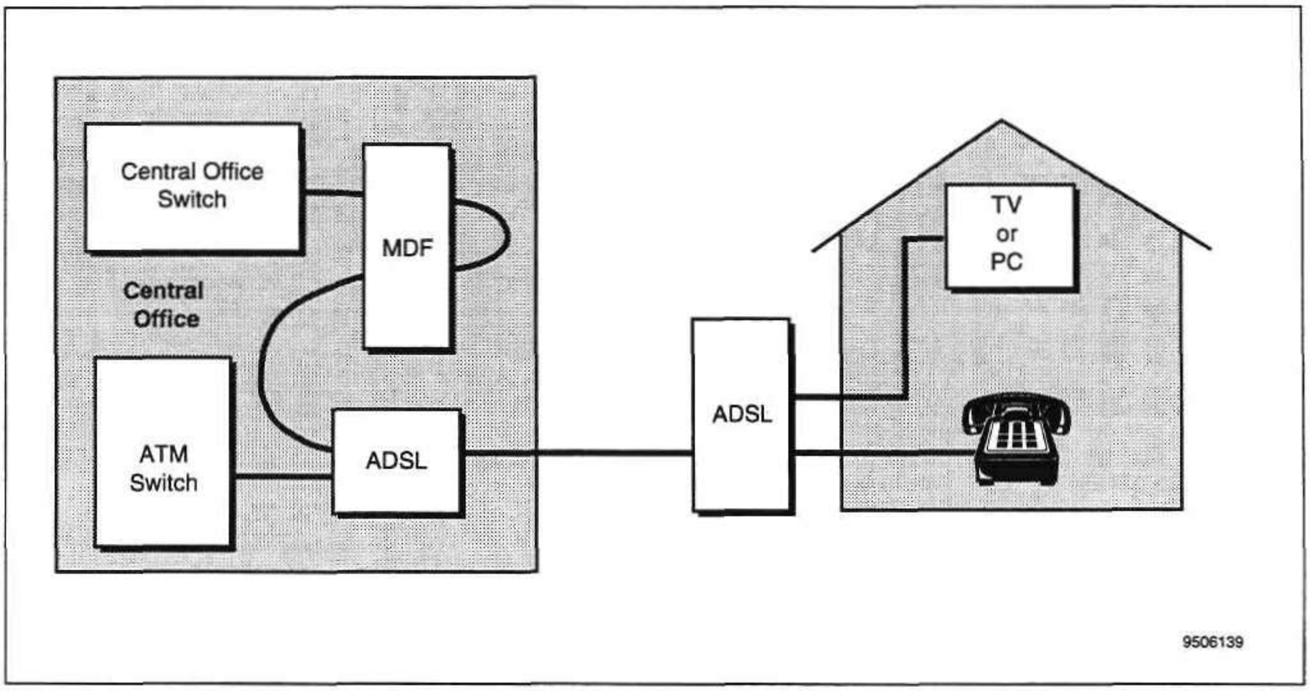
  

**Figure 1**
**Next-Generation Generic ADSL Modem**




Source: Dataquest (October 1995)

**Figure 2**
**ADSL Network Architecture**




Source: Dataquest (October 1995)

**Table 4**
**PSTN Forecast by Country (Millions of Access Lines)**

| | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|
| Country | | | | | |
| Austria | 3.8 | 3.9 | 4.0 | 4.1 | 4.3 |
| Belgium | 4.7 | 4.9 | 5.0 | 5.2 | 5.5 |
| Canada | 17.4 | 17.7 | 17.9 | 18.1 | 18.5 |
| China | 30.0 | 37.0 | 45.0 | 54.0 | 75.0 |
| Denmark | 3.1 | 3.2 | 3.2 | 3.2 | 3.3 |
| Finland | 2.9 | 2.9 | 3.0 | 3.1 | 3.2 |
| France | 32.4 | 33.2 | 33.9 | 34.6 | 36.0 |
| Germany | 40.7 | 42.5 | 44.3 | 46.0 | 49.0 |
| Greece | 5.5 | 5.7 | 6.0 | 6.2 | 6.6 |
| Hong Kong | 3.3 | 3.5 | 3.6 | 3.8 | 4.1 |
| Ireland | 1.1 | 1.2 | 1.2 | 1.2 | 1.3 |
| Italy | 25.5 | 26.0 | 26.5 | 27.0 | 28.0 |
| Japan | 61.4 | 62.6 | 63.8 | 64.7 | 66.7 |
| Mexico | 9.5 | 10.6 | 11.8 | 13.2 | 16.2 |
| Netherlands | 7.9 | 8.1 | 8.2 | 8.4 | 8.7 |
| Norway | 2.4 | 2.4 | 2.5 | 2.6 | 2.7 |
| Portugal | 3.7 | 3.9 | 4.2 | 4.3 | 4.7 |
| South Korea | 18.9 | 20.0 | 21.0 | 22.0 | 24.0 |
| Singapore | 1.4 | 1.4 | 1.5 | 1.6 | 1.8 |
| Spain | 15.1 | 15.8 | 16.6 | 17.3 | 18.8 |
| Sweden | 6.1 | 6.1 | 6.1 | 6.2 | 6.3 |
| Switzerland | 4.5 | 4.6 | 4.7 | 4.8 | 5.0 |
| Taiwan | 8.7 | 9.3 | 9.7 | 10.3 | 11.5 |
| Turkey | 13.4 | 14.7 | 16.1 | 17.5 | 20.5 |
| United States | 158.3 | 163.1 | 167.0 | 171.0 | 178.0 |
| United Kingdom | 28.9 | 29.7 | 30.4 | 31.1 | 32.3 |
| Region | | | | | |
| Africa | 13.5 | 14.9 | 16.6 | 18.6 | 22.8 |
| Latin America | 41.1 | 45.6 | 50.4 | 55.5 | 67.4 |
| Australasia | 10.9 | 11.2 | 11.4 | 11.7 | 12.2 |
| Central and Eastern Europe | 67.7 | 72.3 | 77.7 | 84.0 | 98.0 |
| Others | 44.0 | 51.6 | 60.0 | 69.3 | 90.7 |
| Total | 687.7 | 729.5 | 773.4 | 820.4 | 922.8 |

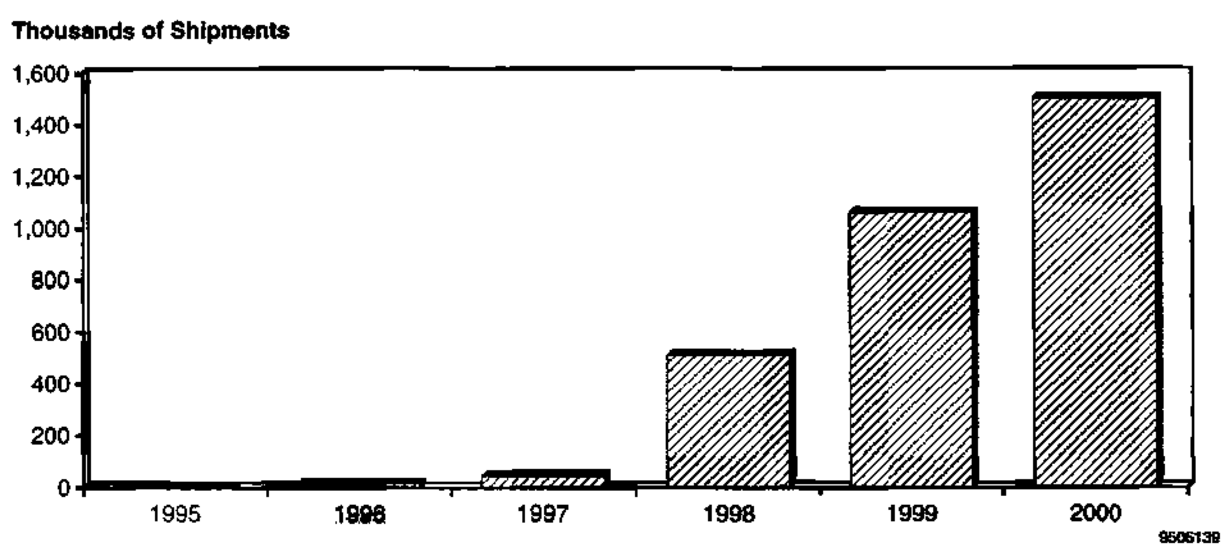
Source: Dataquest (October 1995)

**Table 5**
**Potential ADSL Access Lines in Service (Millions)**

| | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|
| United States | | | | | |
| 0.5% Penetration | 0.01 | 0.07 | 0.26 | 0.53 | 0.92 |
| 1% Penetration | 0.01 | 0.13 | 0.51 | 1.06 | 1.82 |
| 2% Penetration | 0.02 | 0.33 | 1.03 | 2.14 | 3.68 |
| Rest of World | | | | | |
| 0.5% Penetration | 0.04 | 0.24 | 0.97 | 2.24 | 4.11 |
| 1% Penetration | 0.04 | 0.45 | 1.93 | 4.43 | 8.13 |
| 2% Penetration | 0.09 | 1.21 | 3.89 | 8.94 | 16.42 |
| Worldwide Total | | | | | |
| 0.5% Penetration | 0.05 | 0.31 | 1.23 | 2.77 | 5.03 |
| 1% Penetration | 0.05 | 0.58 | 2.44 | 5.48 | 9.95 |
| 2% Penetration | 0.10 | 1.55 | 4.92 | 11.08 | 20.10 |

Source: Dataquest (November 1995)

**Figure 3**
**Shipments of ADSL Equipment to the United States**




Source: Dataquest (October 1995)

**Table 6**
**ADSL Modem Chipset Forecast (1 Percent Scenario)**

| | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|
| Units (M) | 0.1 | 0.7 | 2.0 | 3.4 | 7.4 |
| ASP ($) | 140.0 | 80.0 | 61.0 | 45.0 | 34.0 |
| Revenue ($M) | 14.0 | 52.9 | 123.6 | 152.4 | 253.1 |

Source: Dataquest (November 1995)

## Now Comes the Real Silicon

The first round of silicon was targeted at implementing ADSL modems (or transceivers) for various field trials in the United States, Europe, Israel, and Asia. All three modulation approaches—DMT, CAP, and QAM (quadrature amplitude modulation)—were supported to various degrees. Although AT&T continues to push CAP, all of the participating semiconductor companies are now focusing on driving the costs down in their DMT approaches.

The initial silicon solutions included data converters (12/16 bit), multiple DSP processors and ASICs, and a variety of standard analog and discrete components. Next-generation silicon, which will begin hitting the market in 1996, is boiling down to either one or two chips. Analog Devices is working on a 3-chip solution and Alcatel Mietec are working on two-chip solution: a DSP-based baseband section and the analog front end. Motorola is working on an aggressive single-chip design integrating the baseband and analog front end.

One of the stimulants of resurged interest in ADSL from the silicon vendors is attributed to the fact that open standards are stabilizing and tend to reduce development risk. Next-generation solutions are targeted at implementing recently approved standards for North America and Europe set jointly by the ANSI T1E1 body and the European Telecommunications Standards Institute (ESTI).

## Analog Devices/Aware

This team is bringing a solution to the market using Aware's DMT technology and Analog Devices' silicon expertise. The current chipset includes the ADSP-21061 SHARC DSP, a digital interface controller, a specialized digital filter, an analog front end, and two devices comprising the hybrid telephone line interface. The current generation chipset is priced at $170 in OEM quantities. The DSP runs firmware developed in part by Aware for executing the DMT algorithms. A more integrated chipset is in the works for mid-1996. So far, Westell, Newbridge, and NEC Australia are using this team's technology.

The 1996 version will boil down the solution to a baseband chip and an analog front-end chip. Analog Devices claims the solution is capable of the complete ADSL category 2 implementation (8-Mbps downstream and 640-Kbps interactively for distances up to 12,000 feet or 3.7km, and a POTS line). So far this team claims to be the leader in supplying advanced silicon for DMT-based prototype products.

## Motorola/Amati

These companies are acting in a similar manner as the pair mentioned earlier with Amati supplying the DMT expertise and Motorola the silicon. Motorola is discussing its next-generation single chip, a mixed-signal solution that would ship in volume in the first quarter of 1997. Apparently key to Motorola's approach is integration of numerous analog functions including high-precision data converters. The chip will support the category 2 specifications plus certain other unannounced features.

Motorola has the only announced single-chip version at this point. Because of the challenges of integrating precision data converters and a desirable feature set, this team is taking a degree of risk, but it does have a chance of hitting a home run with a very low cost solution.

### Some Challenges and Speculation on the Future

From an enabling technology perspective, the greatest risk aside from market take-up lies in creating standards-compatible or interoperable chipsets. The question to be asked is, "Will, for example, Motorola/Amati's solution work with Analog Devices/Aware's approach?" The vendors say it will, but will the "proprietariness" built into their solutions get in the way?

Because ADSL can minimally support 6.144-Mbps simplex (one MPEG 2 movie), 640-Kbps duplex (videoconferencing and ISDN), and a POTS telephone call at the same time, there are plenty of silicon integration possibilities. Possibilities include videoconferencing functions, ISDN protocol ICs, and ATM SAR functions (Alcatel Mietec supports ATM). The TV set can be used as a low-cost videoconferencing display unit (the most expensive part of a video phone). Likewise, the ISDN bit stream can be directed to the PC from the ADSL terminal for World Wide Web surfing and remote office access for work at home. It's also conceivable that ATM could use ADSL as its physical layer, creating a seamless link to ATM capability that the carriers are already evaluating.

## Conclusions

Demand for high-speed data services will grow as cable modems become affordable, and as applications such as Internet access demand more bandwidth. Telcos will be forced to revisit ADSL as a viable, low-cost response to cable modems. A conservative analysis of worldwide demand for ADSL has shown that prices will fall and that ADSL will be deployed more aggressively than today's telco plans would indicate.

CSAM-WW-PD-9501 Qty: 1
Ms. Maria Valenzuela
Dataquest Incorporated
1-1100

--INTERNAL DIST.--

### For More Information...

Greg Sheppard, Director/Chief Analyst ............ (408) 468-8261
Internet address ............ gsheppard@dataquest.com
Via fax ............ (408) 954-1780

Market Analysis

Communications Semiconductors and Applications Worldwide

# Market Analysis

# New High-Speed LAN IC Opportunities Hit the Ground Running


**Abstract:** *Dataquest predicts that Fast Ethernet will rise to be the predominant 100-Mbps Ethernet IC standard. 100VG-AnyLAN also will prove an attractive volume alternative. 25-Mbps ATM ICs will start shipping this year as the standard rushes to implementation.*
*By Greg Sheppard*


## 100 Megabits, Mega-Hit

100-Mbps LAN technology is off to a strong start in 1995, much stronger than most had predicted. LAN network interface cards (NICs) and intelligent hub ports capable of dual operation at both 10 Mbps and 100 Mbps (known as 10/100) are finding good acceptance in the marketplace.

Dataquest expects a billion-dollar 10/100-Mbps Ethernet IC market (controllers, hub functions, and transceivers) to develop by 1999 (see Figure 1 and Table 1). Helping kick-start this market are a projected 2 million hub ports and 1 million 10/100-Mbps NICs expected to ship in 1995. Of the two standards, Fast Ethernet (or 100-base-T) is expected to command the majority of the market versus 100VG-AnyLAN.


Dataquest

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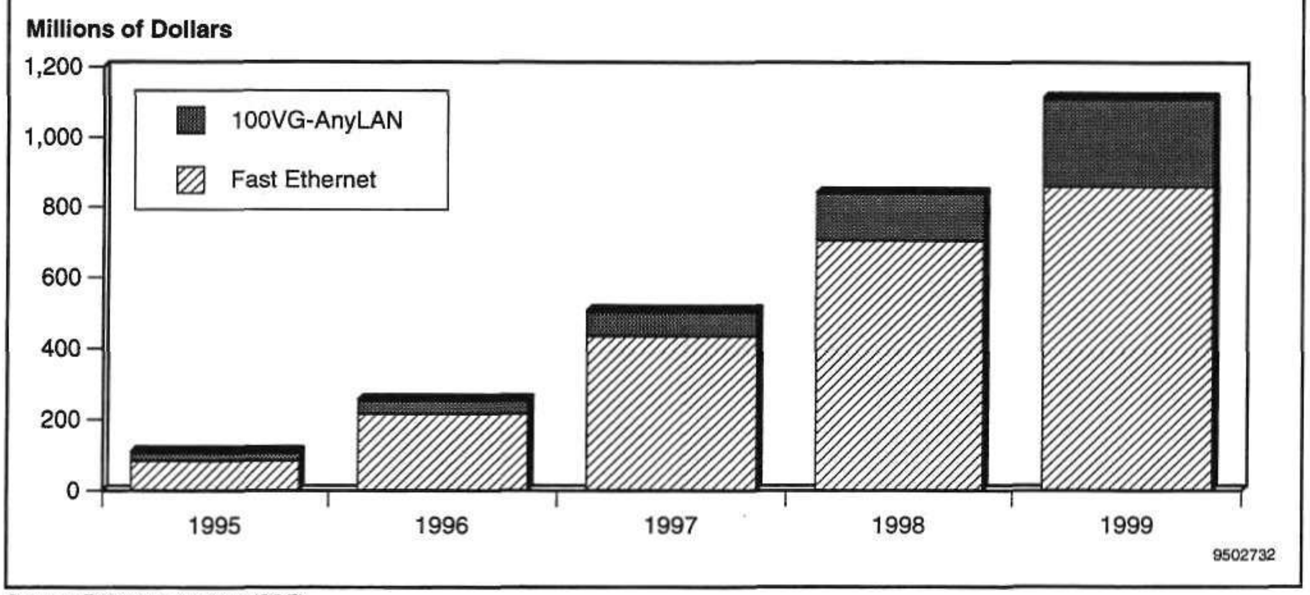
**Publication Date:** June 5, 1995
**Filing:** Market Analysis

**Figure 1**
**Fast Ethernet and AnyLAN ASSP/ASIC Market, Worldwide, 1994-1999**




Source: Dataquest (June 1995)

**Table 1**
**Fast Ethernet LAN and 100VG-AnyLAN ASSP/ASIC Market, Worldwide**

| | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|
| Fast Ethernet LAN ASSP/ASIC | | | | | |
| LAN Nodes | 2,385 | 7,071 | 16,994 | 32,111 | 43,525 |
| Node ASSP/ASIC Dollar Content | 35.4 | 30.6 | 25.7 | 22.0 | 19.8 |
| ASSP/ASIC Revenue ($M) | 84.4 | 216.5 | 436.1 | 706.7 | 861.1 |
| 100VG-AnyLAN | | | | | |
| LAN Nodes | 681 | 1,238 | 2,737 | 6,177 | 12,635 |
| Adapter/MB Nodes (K Units) | 35.9 | 30.2 | 25.7 | 21.8 | 19.8 |
| ASSP/ASIC Revenue ($M) | 24.4 | 37.4 | 70.2 | 134.9 | 250.4 |

Source: Dataquest (June 1995)

Several key factors are accelerating the overall move to 10/100-Mbps solutions:

- There is broadening availability of debugged, NIC, and hub offerings from big market players such as Hewlett-Packard, 3Com, and SMC.
- Prices on 10/100-Mbps NICs and hub ports are rapidly declining (both about $200; sub-$150 seen as possible by the fourth quarter of 1995).
- Because of the aforementioned two factors, users are able to invest in 10/100-Mbps LAN elements piecemeal and operate at 10 Mbps in the meantime.
- The media independent interface (MII) makes solutions easy for fiber, shielded twisted pair (STP), and Category 3, 4, and 5 unshielded twisted pair (UTP) and its 2-pair and 4-pair varieties.

## Which 100Mb Standard?

Dataquest is predicting that Fast Ethernet 100-base-T (based on IEEE 802.3u) will capture some 80 percent of the 100Mb LAN IC market, based on the relative strength and composition of the powerful alliance behind Fast Ethernet. Although considered by many to be technologically superior, 100VG-AnyLAN (based on 802.12) has not garnered enough marketing muscle to establish clear superiority.

To detail the technical pros and cons of each standard would be near folly because of the "specsmanship" that has been going on. It is generally acknowledged that 100VG-AnyLAN superiority is in supporting both Ethernet and token-ring frames and in its ability to serve more easily the bandwidth needs of multimedia.

As of the March InterOp trade show, the Fast Ethernet Alliance had about 75 members, whereas the 100VG-AnyLAN Alliance had 25 listing some sort of product plans. In our view, however, AnyLAN was dealt a blow by the recent preference IBM appears to be giving 25Mb Asynchronous Transfer Mode (ATM) as an alternative migration path for Token Ring users.

## 25-Mbps ATM to Arrive in 1995

This lower-speed alternative of ATM appears ready to begin penetrating the networking market. The ATM Forum, the de facto ATM industry standards body, recently recognized 25-Mbps ATM as a viable option. One of the near-term markets for 25-Mbps ATM is as an alternative for token-ring users in that the specification is based mostly on a version token-ring with overhead processing striped away. We believe IBM's effectiveness at promoting this standard will severely impact its success.

Table 2 presents our forecast for the specialized protocol/transceiver IC opportunity presented by the 25-Mbps ATM marketplace. We believe that a near-$100 million IC market is feasible by 1999. The Desktop ATM25 Alliance is leading the charge to make 25-Mbps ATM product available and interoperable.

**Table 2**
**25-Mbps ATM ASSP/ASIC Market, Worldwide**

| | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|
| LAN Nodes (K Units) | 82 | 176 | 792 | 1,512 | 2,495 |
| ASSP/ASIC Dollar Content | 55.0 | 48.4 | 43.6 | 40.1 | 36.9 |
| ASSP/ASIC Revenue ($M) | 4.5 | 8.5 | 34.5 | 60.6 | 92.0 |

NA = Not applicable
Source: Dataquest (June 1995)

## Dataquest Perspective

This article has only touched on some of the emerging opportunities for chips in high-speed networks. Although FDDI is very important, we did not mention it as the entrenched 100-Mbps leader. Dataquest expects FDDI to continue being a major backbone technology because of its stable embodiment into hub-server and internetworking ports.

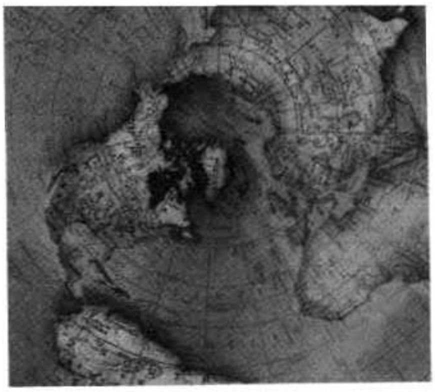
Another high-speed alternative is switched 10-Mbps technology as it is washed in on a wave of switched hub systems from at least 20 networking vendors. Because it preserves investment in wiring plant and NICs, switched Ethernet and now token-ring will get a good market run over the next two to three years as a bridge to 100-Mbps alternatives. Also expect full-duplex Ethernet, capable of simultaneous two-way transmission, to address the needs of many bandwidth-limited networks.

Dataquest continues to believe that ATM (155-Mbps and above) will become the predominant networking technology in the four- to five-year time horizon. But in the meantime there will be plenty of cost-effective, slower-speed alternatives to keep a dozen chip companies quite happy on margin-laden products.



**For More Information...**

Greg Sheppard, Director/Principal Analyst ............ (408) 437-8261
Internet address ............ gsheppard@dataquest.com
Via fax ............ (408) 437-0292



Dataquest

# Communications Application Markets—Telephones and Mobile Communication

Market Trends

**Program:** Communications Semiconductors and Applications Worldwide
**Product Code:** CSAM-WW-MT-9503
**Publication Date:** December 4, 1995
**Filing:** Market Analysis

# Communications Application Markets—Telephones and Mobile Communication

## Market Trends

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# Chapter 1
# Introduction and Methodology

This document is the fifth in a series of six that provide reference information and analysis about the principal system application markets for semiconductors. The six areas are data processing, wireline communications, wireless communications and fixed terminals, consumer electronics, automotive electronics, and a combined document on industrial and military and civil aerospace electronics. Each document brings forth basic information about the opportunity offered by particular systems:

- System market size (in production terms) in revenue, units, and average selling price
- System market and product feature trends
- Hardware architecture trends and semiconductor device opportunities
- Semiconductor content and market forecast
- A listing of key OEMs

The information in this report is gathered from both primary and secondary sources. Primary sources include surveys and interviews of industry vendors and customers, as well as analyst knowledge and opinion. Some of the primary sources include Dataquest's own services. Secondary sources include various governmental and trade sources on sales, production, trade, and public spending. Semiconductor content assumptions are based on both surveys of producing OEMs and physical teardown evaluations by Dataquest analysts of representative systems.

The brand share information presented in this book comes from The Scout Report® of The Polk Company. The Scout Report® has been designed to accurately measure the retail purchase activity of U.S. households. Based on a widely accepted survey methodology, the sample is drawn quarterly from a nationally representative group of 50,000 respondents, and response rates average 70 percent. Brand shares reported in The Scout Report® are point estimates of the actual brand shares and have a small margin of error. Brand shares are based on a representation of retail sales to end-use consumers in the United States and may not correspond directly to other commonly reported measures of product movement such as production or wholesale shipments.

The forecast methodology is based on various methods and assumptions, depending upon the area. To form a solid basis for projecting system demand, capital, government, and consumer spending, assumptions are made for various regions of the world. For specific markets, saturation and displacement dynamics are considered as well. Key exogenous factors such as new software introductions, exchange rates changes, and government policies also are considered. Semiconductor content forecasts are based upon interviews of system marketers and designers (including makers of enabling semiconductor technology) along with an analysis of historical trends.

*Project Analyst: Dale Ford*

## Chapter 2
# Terminal Devices and Mobile Applications

## Overview

Telephone handsets have traditionally been classified in the communications application sector, but all the three telephone types, corded, cordless and cellular, are rapidly becoming consumer-oriented products. The consumer market has given new life to pager sales as they have even reached "fashion accessory" status. World demand for telephones and pagers continues to rise, driven by the following:

- Demand for more than one telephone per household
- The rapid introduction of telephone capacity in the developing regions of the world, especially Asia and Central and Eastern Europe
- The growing demand for mobile communications for both data and voice

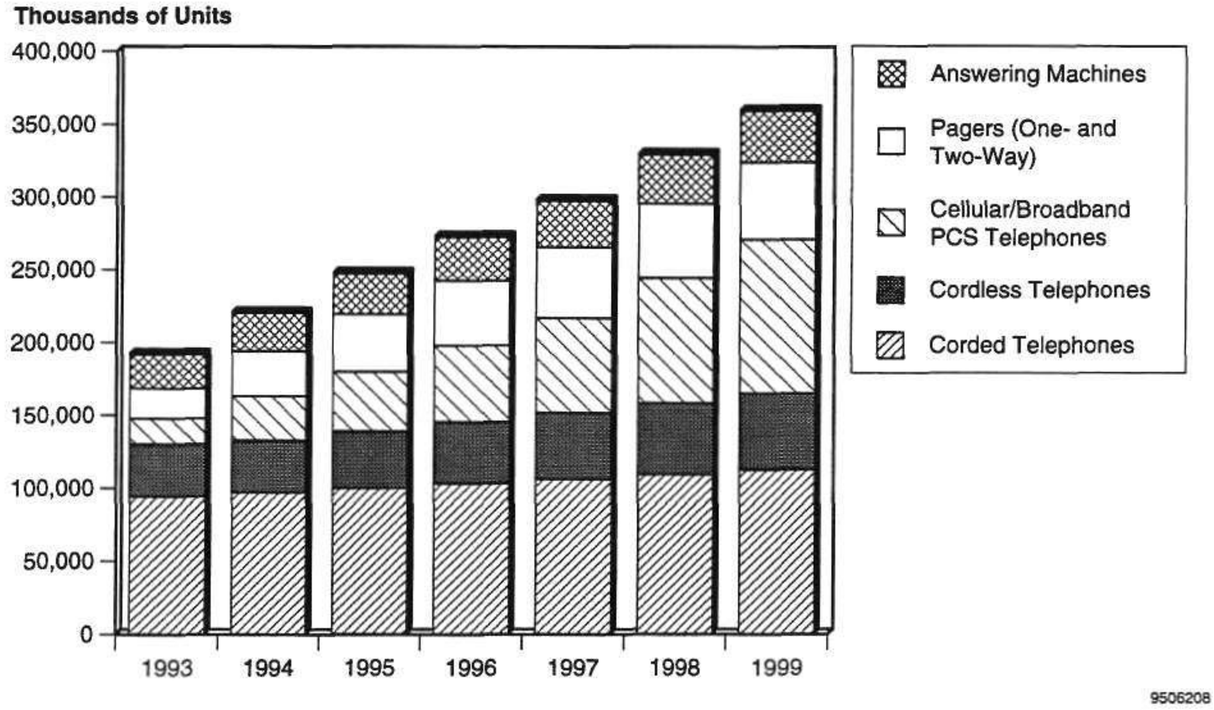
Despite the demand for standard corded telephones for both residential and business users, there is a groundswell of demand for wireless telephony products, either cordless or cellular. The global direction is to embrace the benefits of wireless connectivity. The demand is in all four major regions of the world, Asia/Pacific, Japan, Europe, and North America.

The future of wireless communications is already taking its next logical step, with the concept of a personal communications network (PCN in Europe) and personal communications service (PCS in the United States). The idea is that the same telephone can be used in the home, at work, and out in public places. This is one step away from the ultimate concept of a person with a single telephone number (so calls are placed to a person not a place) and one single telephone that can be used anywhere in the world.

Worldwide production of telephone handsets, pagers, and answering machines is forecast to grow at 10.3 percent compound annual growth rate (CAGR) for the next five years, led by cellular/PCS telephone and pager production expanding at 28.2 percent and 11.3 percent CAGR, respectively. Table 2-1 and Figure 2-1 show the worldwide production forecast summary for telephone handsets, pagers, and answering machines.

Overall, as a producer of telephone handsets and other communications terminals, North America produces less than half of what the region consumes. Although sales are dominated by brand names such as AT&T, General Electric, Motorola, and the regional Bell operating companies (RBOCs), production and design of commodity corded and cordless products are predominantly contracted to Pacific Rim suppliers or offshore captive operations. However, for the fast-growing cellular and emerging PCS areas, a majority of market needs is expected to continue to be designed and built locally. This trend can be attributed to time-to-market needs, diminishing labor content in the final product, and the desire to mitigate trade friction by the large Japanese OEMs. Table 2-2 and Figure 2-2 show the forecast for North American production of communications terminals. Table 2-3 lists companies with telephone handset manufacturing facilities in North America.

**Figure 2-1**
**Worldwide Terminal Device Production**




Source: Dataquest (November 1995)

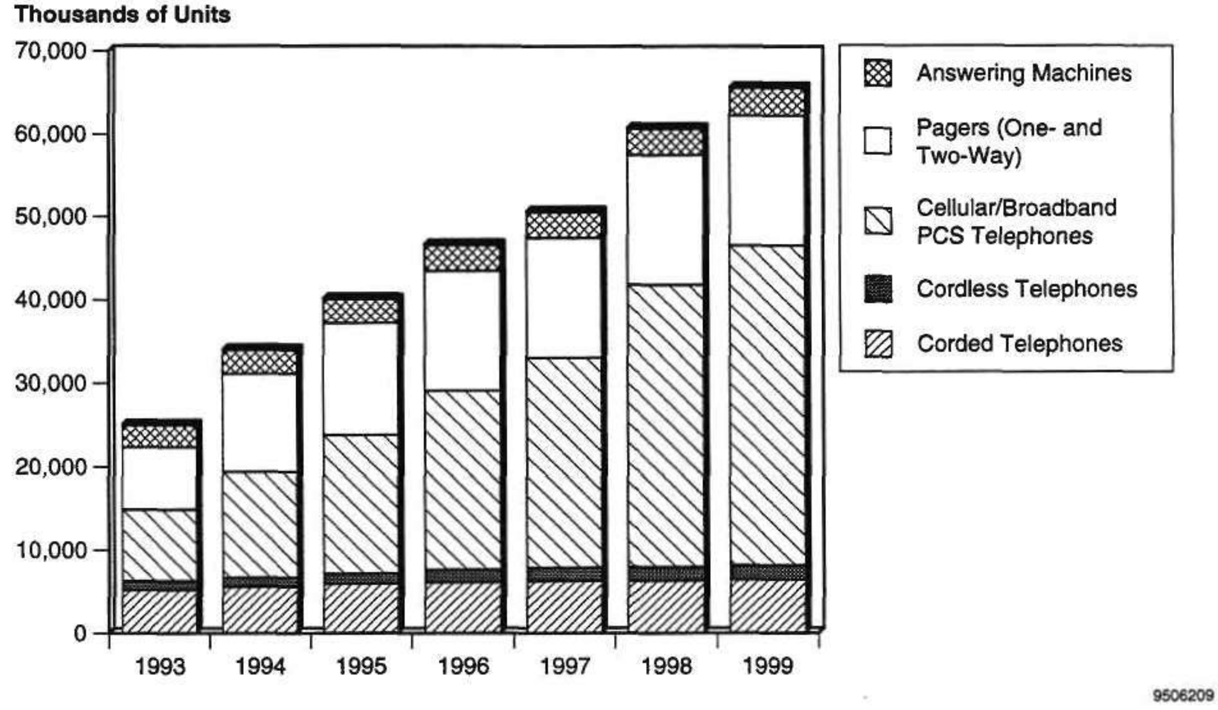
**Table 2-1**
**Worldwide Terminal Device Productions (Thousands of Units)**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|
| Corded Telephones | 94,762 | 97,257 | 100,174 | 103,180 | 106,275 | 109,463 | 112,747 | 3.0 |
| Cordless Telephones | 35,405 | 35,685 | 39,134 | 42,668 | 45,764 | 49,173 | 52,744 | 8.1 |
| Cellular/Broadband PCS Telephones | 17,848 | 30,534 | 40,779 | 52,382 | 64,818 | 85,900 | 105,939 | 28.2 |
| Pagers (One- and Two-Way) | 20,672 | 30,919 | 39,336 | 44,564 | 48,989 | 51,287 | 52,768 | 11.3 |
| Answering Machines | 23,470 | 26,273 | 28,194 | 30,099 | 31,901 | 33,655 | 35,431 | 6.2 |
| Total | 192,156 | 220,668 | 247,618 | 272,893 | 297,748 | 329,479 | 359,629 | 10.3 |

Source: Dataquest (November 1995)

**Figure 2-2**
**North American Terminal Device Production**




Source: Dataquest (November 1995)

**Table 2-2**
**North American Terminal Device Production (Thousands of Units)**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|
| Corded Telephones | 5,264 | 5,584 | 5,980 | 6,180 | 6,297 | 6,333 | 6,460 | 3.0 |
| Cordless Telephones | 1,080 | 1,134 | 1,215 | 1,516 | 1,596 | 1,652 | 1,735 | 8.9 |
| Cellular/Broadband PCS Telephones | 8,515 | 12,697 | 16,636 | 21,433 | 25,180 | 33,906 | 38,402 | 24.8 |
| Pagers (One- and Two-Way) | 7,517 | 11,723 | 13,405 | 14,415 | 14,418 | 15,657 | 15,712 | 6.0 |
| Answering Machines | 2,608 | 2,803 | 2,887 | 3,078 | 3,099 | 3,145 | 3,302 | 3.3 |
| Total | 24,984 | 33,940 | 40,123 | 46,621 | 50,589 | 60,693 | 65,610 | 14.1 |

Source: Dataquest (November 1995)

**Table 2-3**
**Companies Manufacturing Telephones in North America**

| Company | Location | Corded | Cordless | TAM* | Cellular |
|---|---|---|---|---|---|
| Alpine | Greenwood, Indiana | | | | 3 |
| AT&T | Guadalajara, Mexico | | | ✓ | |
| | Little Rock, Arkansas | | | | ✓ |
| Ericsson–GE | Lynchburg, Virginia | | | | ✓ |
| Fujitsu | Richardson, Texas | | | | ✓ |
| Hughes Network Systems | San Diego, California | | | | ✓ |
| JRC International | Alberta, Canada | | | | ✓ |
| Mitel | Ontario, Canada | ✓ | | | |
| Mitsubishi | Atlanta, Georgia | | | | ✓ |
| Motorola | Schaumburg, Illinois | | ✓ | | |
| | Libertyville, Illinois | | | | ✓ |
| | Grayslake, Illinois | | | | ✓ |
| NEC | Irving, Texas | | | | ✓ |
| | Hillsborough, Oregon | | | | ✓ |
| Nokia | Fort Worth, Texas | | | | ✓ |
| | (Second site planned) | | | | ✓ |
| Northern Telecom | Canada | ✓ | | | |
| | Mexico | | ✓ | | |
| Intek/Acquired from NovAtel | Lethbridge, Alberta, Canada | | | | ✓ |
| Oki | Suwanee, Georgia | | | | ✓ |
| Panasonic | Peachtree City, Georgia | | | | ✓ |
| Qualcomm | San Diego, California | | | | ✓ |
| Siemens/ROLM | Austin, Texas | ✓ | | | |
| Sony Wireless Telecomm | San Diego, California | | | | ✓ |
| Tandy | Texas | ✓ | ✓ | ✓ | ✓ |
| Uniden | Fort Worth, Texas | | | | ✓ |

*TAM = Telephone answering machine
Source: Dataquest (November 1995)

The worldwide semiconductor market for telephones, pagers, and answering machines will grow at an amazing 29.5 percent CAGR from 1993 to 1998, led by cellular/PCS handsets and the rapidly expanding wireless market. Table 2-4 and Figure 2-3 show a summary of this forecast. Table 2-5 and Figure 2-4 show the North American semiconductor market forecast for communications terminals.

North America remains an active region both as a market and as a producer of telephone handsets, pagers, and answering machines. Cordless or wireless telephone terminals and pagers, in particular, are finding tremendous acceptance in the home market.

The penetration of U.S. households by the various types of communications terminal equipment is shown in Table 2-6. As implied in the list, there remains substantial room for further penetration by cordless and cellular telephones. Digital versions of these are expected to rapidly replace their analog predecessors as well. The other looming opportunity

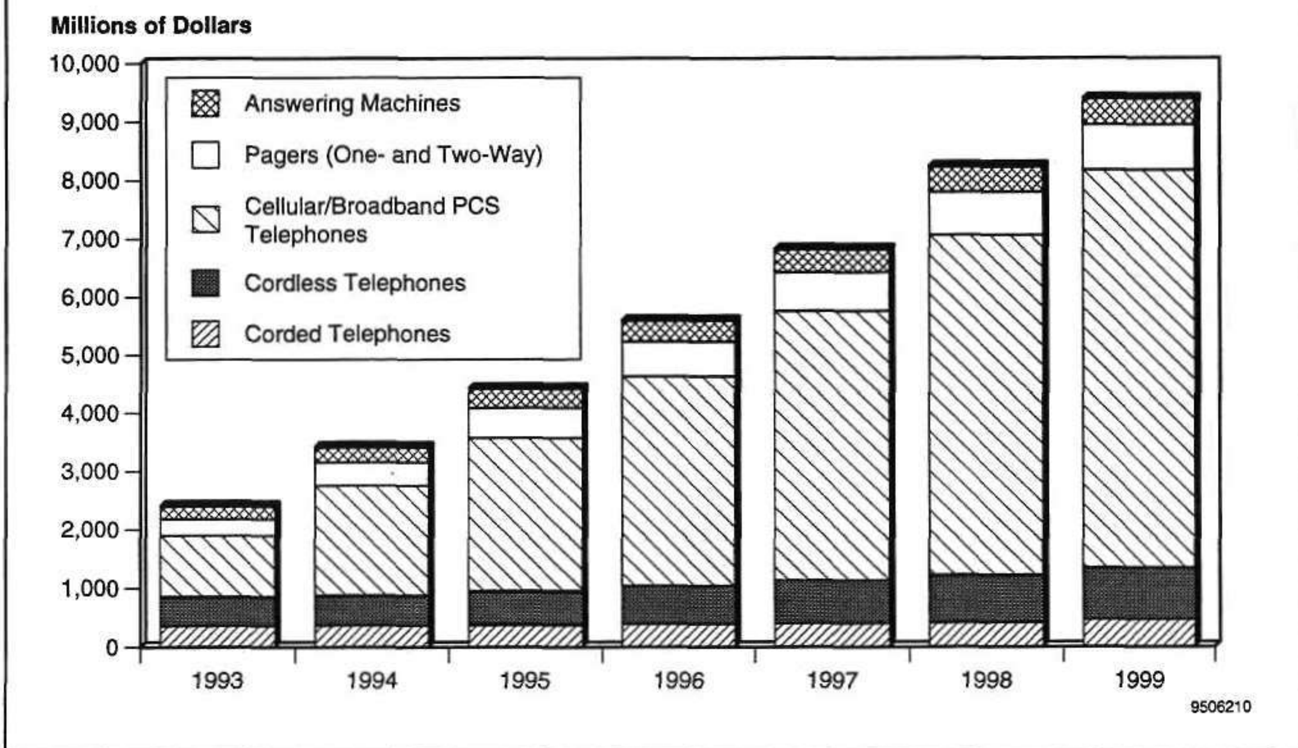
  

## Table 2-4
## Worldwide Semiconductor Market for Terminal Devices (Millions of Dollars)

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|
| Corded Telephones | 365 | 374 | 378 | 393 | 405 | 415 | 471 | 4.7 |
| Cordless Telephones | 498 | 508 | 581 | 649 | 725 | 807 | 873 | 11.4 |
| Cellular/Broadband PCS Telephones | 1,038 | 1,874 | 2,619 | 3,591 | 4,620 | 5,838 | 6,827 | 29.5 |
| Pagers (One- and Two-Way) | 285 | 404 | 515 | 593 | 665 | 738 | 774 | 13.9 |
| Answering Machines | 213 | 252 | 324 | 358 | 393 | 427 | 442 | 11.9 |
| Total | 2,398 | 3,412 | 4,418 | 5,584 | 6,807 | 8,226 | 9,387 | 22.4 |

Source: Dataquest (November 1995)

## Figure 2-3
## Worldwide Semiconductor Market for Terminal Devices




Source: Dataquest (November 1995)

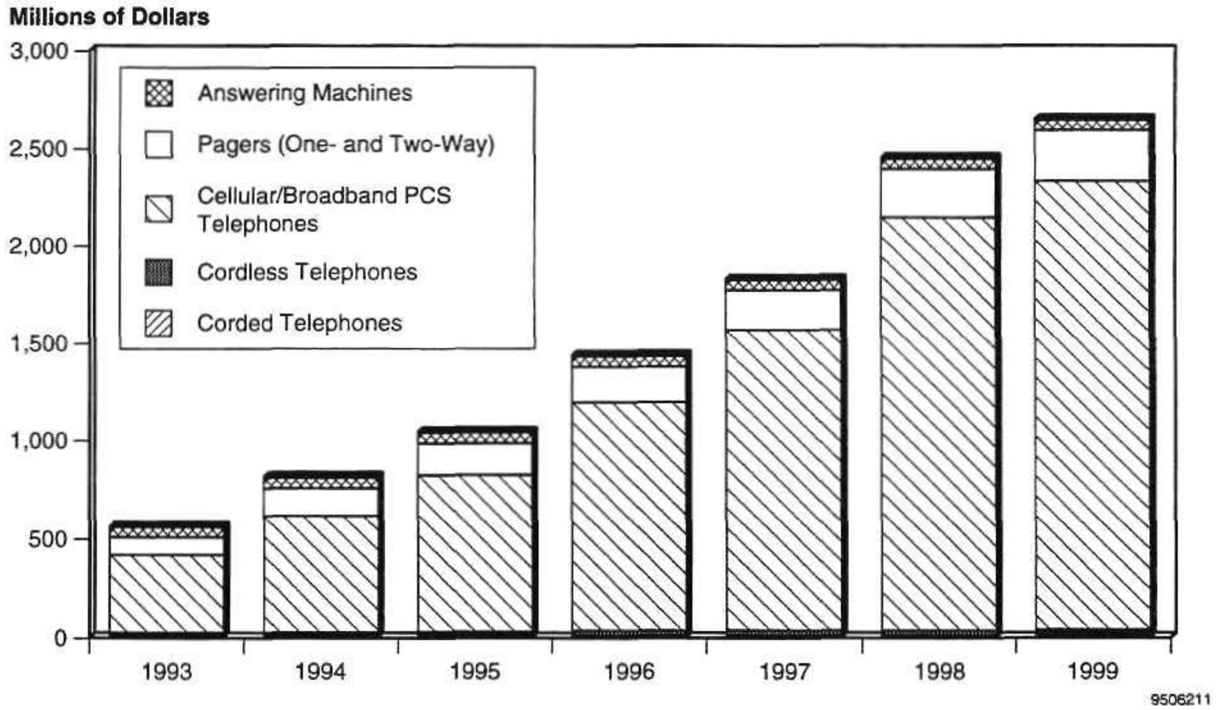
  

**Table 2-5**
**North American Semiconductor Market for Terminal Devices (Millions of Dollars)**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|
| Corded Telephones | 13 | 14 | 15 | 16 | 16 | 16 | 19 | 6.6 |
| Cordless Telephones | 14 | 15 | 17 | 21 | 22 | 21 | 23 | 8.9 |
| Cellular/Broadband PCS Telephones | 393 | 587 | 793 | 1,159 | 1,528 | 2,108 | 2,289 | 31.3 |
| Pagers (One- and Two-Way) | 90 | 141 | 161 | 182 | 204 | 250 | 261 | 13.2 |
| Answering Machines | 50 | 55 | 54 | 55 | 52 | 50 | 50 | -2.2 |
| Total | 560 | 812 | 1,041 | 1,433 | 1,823 | 2,446 | 2,642 | 26.6 |

Source: Dataquest (November 1995)

**Figure 2-4**
**North American Semiconductor Market for Terminal Devices**




Source: Dataquest (November 1995)

**Table 2-6**
**U.S. Household Penetration of Communications Devices, January 1995 (Percent)**

| Category | Percentage |
|---|---|
| All Telephones | 96 |
| Telephone Answering Devices | 54 |
| Cordless Telephones | 52 |
| Cellular Telephones | 20 |
| Pagers | 12 |
| Caller ID Units | 6 |

Source: EIA/CEG

in the United States is PCS handsets now that the Federal Communications Commission (FCC) has completed the initial rounds to auction off the required spectrum. Figure 2-5 shows a time line of the rollout of PCS services in the United States. Canada is also moving ahead with PCS trials and plans to award licenses soon. The fast-growing economy of Mexico, along with its newly privatized phone system, is creating many fertile opportunities. New PCS services targeted at two-way pagers will add significantly to the growth of this market, beginning in 1997. Caller ID boxes have penetrated the U.S. market. With new FCC regulations that will expand caller ID services into California, growth in this market is expected to remain strong.

The North American market shipments and revenue for all types of communications terminals are shown in Table 2-7. The largest category by far remains corded telephones. However, cellular/PCS shipments will rival corded phone shipments toward the end of the decade. Cordless telephones are penetrating the market rapidly as they become the replacement phone of choice. Answering machines continue their home penetration as sociological fears have been replaced by the messaging needs of two-income homes. Cellular phones continue to penetrate the so-called business consumer market, but recent surveys suggest that non-business use is becoming even more important. Pager sales are increasingly driven by the consumer market. Figure 2-6 illustrates the cost/benefit relationship between various devices.

The strong growth of wireless communications markets will drive a robust wireless infrastructure equipment market. Table 2-8 presents a preliminary forecast for worldwide wireless infrastructure production.

## Definitions

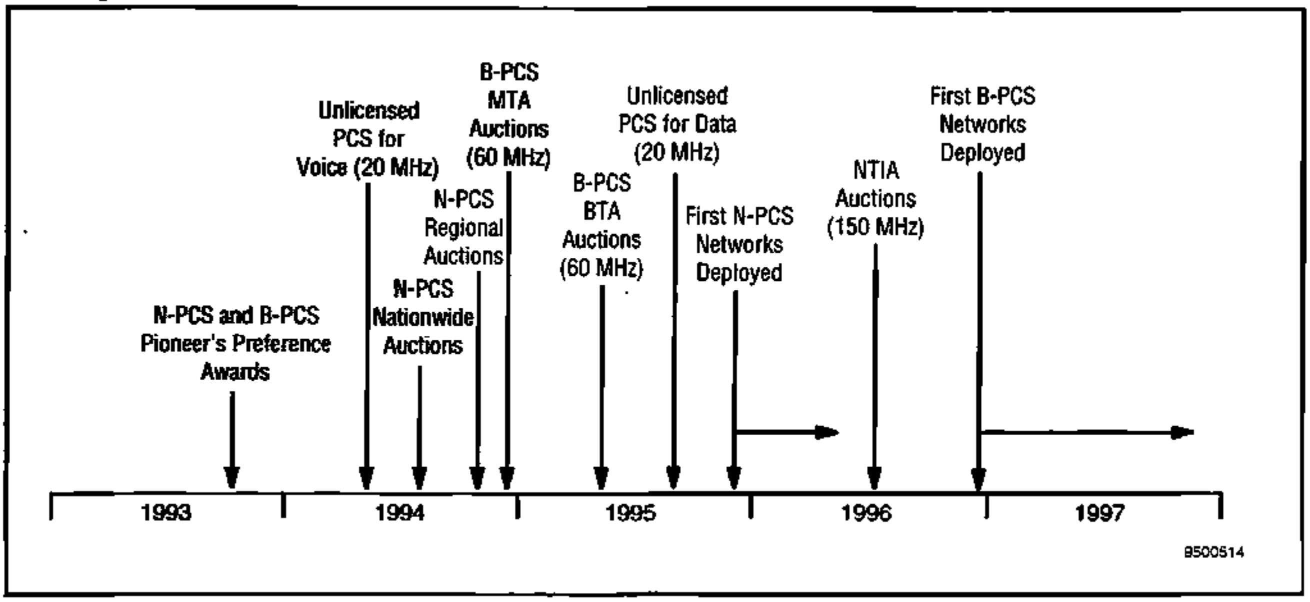
### Corded

Standard: This includes all one- and two-piece telephones that connect via a cord directly to the public switched telephone network (PSTN) or a PBX. These telephones have a limited range of additional capabilities; as a maximum it would include a "last-number redial" facility and a limited number of telephone number memories (maximum 10 memories).

Feature: This definition typically includes those telephones that include, as a minimum, a liquid crystal display (LCD), last-number redial, and 10 or more telephone number memories. This type would usually also include on-hook dialing or a speakerphone capability.

**Figure 2-5**
**PCS Spectrum Time Line**



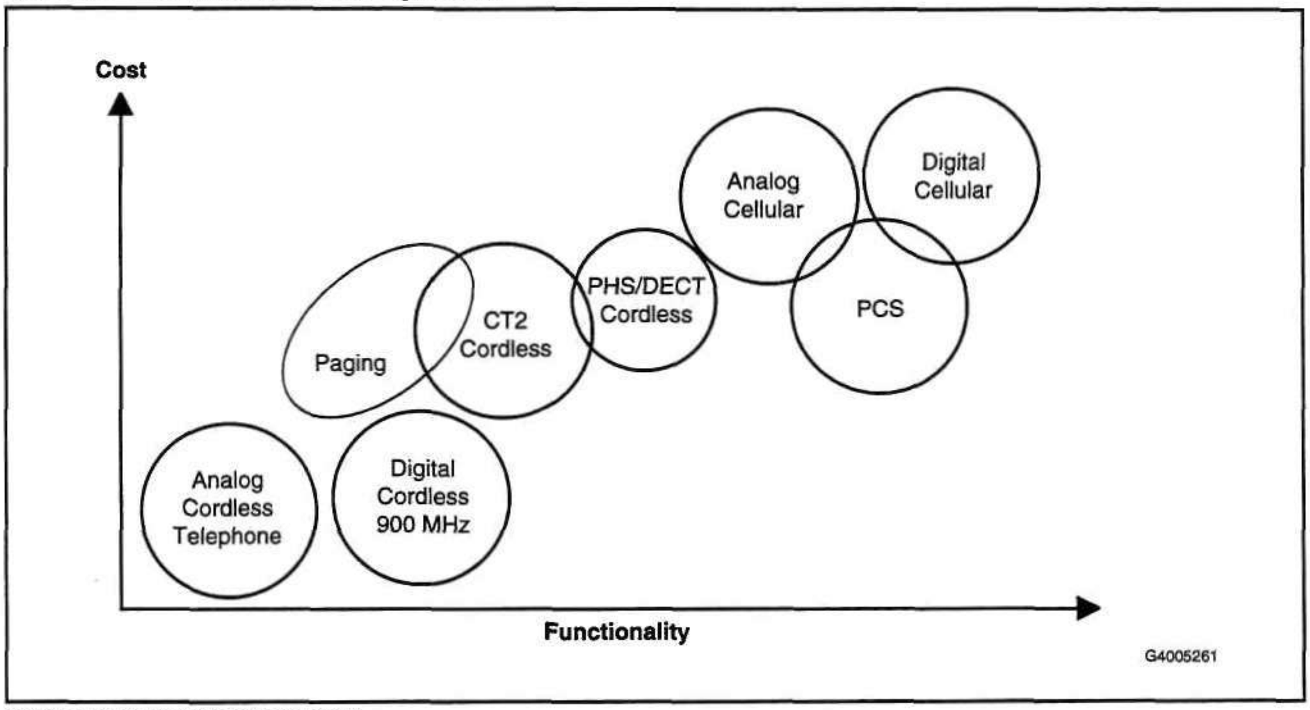

Source: Dataquest (November 1995)

**Table 2-7**
**North American Communications Terminal Market**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|
| **Shipments (K)** | | | | | | | | |
| Corded Telephones | 42,019 | 39,954 | 39,339 | 39,059 | 38,831 | 38,874 | 38,963 | -1.5 |
| Cordless Telephones | 17,801 | 19,030 | 20,625 | 21,533 | 22,609 | 23,740 | 24,927 | 5.9 |
| Cellular/Broadband PCS Telephones | 9,001 | 13,478 | 17,186 | 21,367 | 24,285 | 32,031 | 36,223 | 21.9 |
| Pagers (One- and Two-Way) | 7,069 | 11,548 | 13,291 | 14,430 | 14,277 | 15,687 | 15,393 | 5.9 |
| Answering Machines | 17,930 | 19,360 | 18,590 | 19,140 | 19,523 | 19,913 | 20,312 | 1.0 |
| Total (K) | 93,820 | 103,370 | 109,031 | 115,529 | 119,525 | 130,244 | 135,816 | 5.6 |
| **Revenue ($M)** | | | | | | | | |
| Corded Telephones | 1,279 | 1,268 | 1,237 | 1,214 | 1,206 | 1,207 | 1,207 | -1.1 |
| Cordless Telephones | 1,282 | 1,294 | 1,279 | 1,184 | 1,130 | 1,092 | 1,047 | -3.2 |
| Cellular/Broadband PCS Telephones | 4,084 | 5,703 | 6,178 | 6,997 | 7,144 | 8,476 | 8,983 | 9.5 |
| Pagers (One- and Two-Way) | 557 | 866 | 988 | 1,072 | 1,228 | 1,589 | 1,576 | 12.7 |
| Answering Machines | 1,091 | 1,085 | 977 | 951 | 920 | 898 | 897 | -3.7 |
| Total | 8,292 | 10,216 | 10,658 | 11,418 | 11,628 | 13,262 | 13,710 | 6.1 |

Source: Dataquest (November 1995)

**Figure 2-6**
**Mobile Communications Systems**




Source: Dataquest (November 1995)

**Table 2-8**
**Worldwide Wireless Infrastructure Equipment Production Forecast* (Preliminary) (Millions of Dollars)**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|
| Revenue | 9,680 | 10,907 | 12,991 | 15,534 | 18,011 | 20,817 | 23,124 | 16.2 |
| Semiconductor Market | 484 | 563 | 692 | 854 | 1,019 | 1,214 | 1,387 | 19.8 |

*Includes base station and microcell equipment for PCS, cellular, paging, and other wireless radio communications.
Note: These numbers are preliminary estimates. More detailed information will be available from Dataquest's Personal Communications North America program in early 1996.
Source: Dataquest (November 1995)

## Cordless

This definition includes all telephones with a handset that has no wired connection to the PSTN or PBX. The base station usually includes the line interface to the PSTN or PBX. This category includes both analog and digital cordless telephones. It also includes digital cordless telephones for telepoint-type systems. The major differentiator for cordless telephones from cellular telephones is the lack of capability to roam from one base station to another or the ability to roam only at pedestrian speeds.

## Cellular/Broadband PCS

This definition includes all handsets (hand-portable, transportable, and mobile) that have a radio link to a cellular or microcellular base station. The cellular system maintains a control link with each handset whether stationary or moving at speed, and controls an automatic seamless handover from one cell base station to the next adjacent cell as the handset user moves.

### Pagers

This definition includes all tone-only, tone-and-voice, digital (numeric), and alphanumeric paging devices. It also incudes paging devices developed for use in narrow-band PCS service. These pagers have limited two-way messaging capability and can also serve as "mobile answering machines."

### Answering Machines

Integrated Telephone Answering Machine (TAM): This equipment category includes devices that can play an outgoing message and record an incoming message, and, most important, also include a telephone. The answering function may be solid-state or tape-based.

Standalone Answering Machine (AM): This equipment category includes devices that can play an outgoing message and record an incoming message. The answering function may be solid-state or tape-based. This product is a standalone device that does not include a telephone handset. Normally it would be used in conjunction with an existing telephone.

## Chapter 3
# Corded Telephones

## Market and Production Trends

Until recently, the implementation of voice telephony had been entrenched in the standard corded telephone, which had functionally changed very little in the last 50 years. Business users were the drivers to take the corded telephone to the next level of functionality. They drove the demand for feature telephones, with capabilities to recall stored numbers, provide hands-free dialing, and enable speakerphone conversations. The cost of such telephones dropped substantially with the development of low-cost 8- and 4-bit microcontrollers.

The demand for corded telephones remains high; however, the growth rate for standard corded telephones is falling in all world regions except Asia. The demand is now from both business and residential users for more feature-rich telephones, which are exhibiting positive growth rates. Tables 3-1 through 3-3 and Figures 3-1 and 3-2 present the worldwide corded telephone production forecast and the North American corded telephone production and market forecast.

**Table 3-1**
**Worldwide Corded Telephone Handset Production**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|
| Units (K) | 94,762 | 97,257 | 100,174 | 103,180 | 106,275 | 109,463 | 112,747 | 3.0 |
| Standard | 72,733 | 71,877 | 72,878 | 73,786 | 74,668 | 75,301 | 75,918 | 1.1 |
| Feature/Multiline | 22,029 | 25,380 | 27,297 | 29,393 | 31,607 | 34,163 | 36,829 | 7.7 |
| Factory ASP ($) | 30 | 29 | 29 | 28 | 27 | 27 | 27 | -1.7 |
| Factory Revenue ($M) | 2,807 | 2,815 | 2,878 | 2,912 | 2,917 | 2,967 | 2,989 | 1.2 |
| Semiconductor Content ($) | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 1.7 |
| Semiconductor Market ($M) | 365 | 374 | 378 | 393 | 405 | 415 | 471 | 4.7 |

Source: Dataquest (November 1995)

**Table 3-2**
**North American Corded Telephone Handset Production**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|
| Units (K) | 5,264 | 5,584 | 5,980 | 6,180 | 6,297 | 6,333 | 6,460 | 3.0 |
| Factory ASP ($) | 35 | 33 | 31 | 29 | 28 | 27 | 26 | -4.7 |
| Factory Revenue ($M) | 184 | 184 | 185 | 179 | 176 | 171 | 168 | -1.8 |
| Semiconductor Content ($) | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3.5 |
| Semiconductor Market ($M) | 13 | 14 | 15 | 16 | 16 | 16 | 19 | 6.6 |

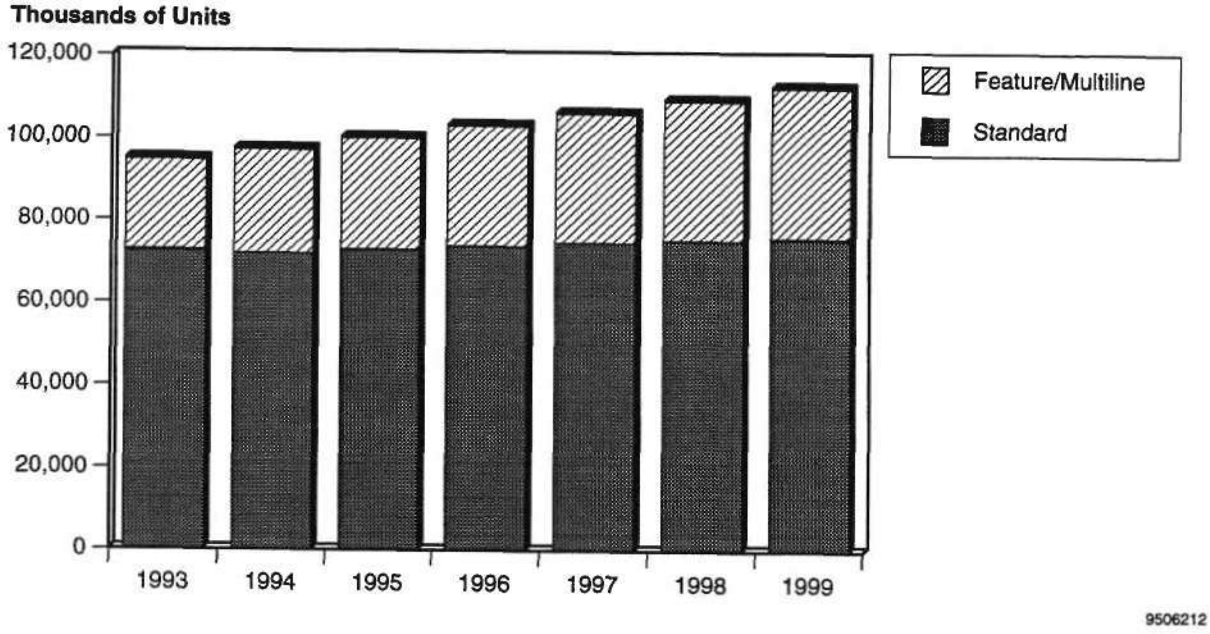
Source: Dataquest (November 1995)

## Table 3-3
## North American Corded Telephone Market

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|
| Market Revenue ($M) | 1,279 | 1,268 | 1,237 | 1,214 | 1,206 | 1,207 | 1,207 | -1.1 |
| Factory ASP Overall ($) | 30 | 32 | 31 | 31 | 31 | 31 | 31 | 0.4 |
| Factory ASP Standard ($) | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 0.0 |
| Factory ASP Feature/ Multiline ($) | 67 | 65 | 62 | 59 | 57 | 55 | 53 | -3.9 |
| Units (K) | 42,019 | 39,954 | 39,339 | 39,059 | 38,831 | 38,874 | 38,963 | -1.5 |
| Standard | 28,995 | 26,052 | 25,046 | 24,223 | 23,433 | 22,697 | 21,993 | -4.8 |
| Feature/Multiline | 13,024 | 13,901 | 14,293 | 14,836 | 15,398 | 16,176 | 16,970 | 4.4 |

Source: Dataquest (November 1995)

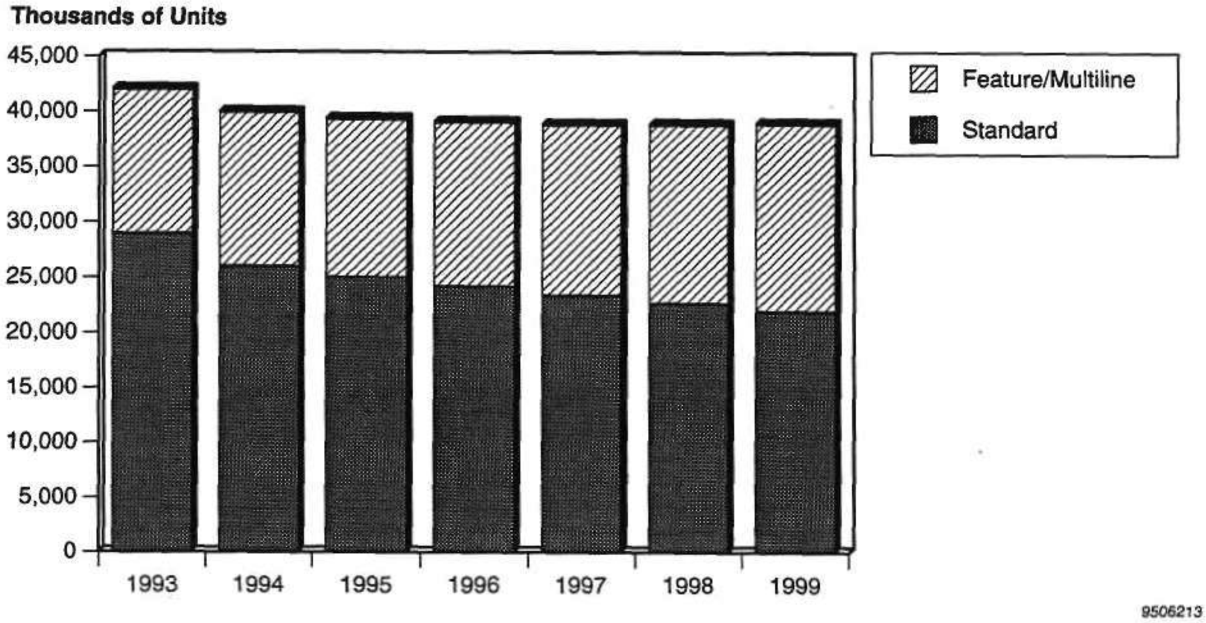
## Figure 3-1
## Worldwide Corded Telephone Handset Production




Source: Dataquest (November 1995)

**Figure 3-2**
**North American Corded Telephone Handset Market**




Source: Dataquest (November 1995)

## Brand Share Leaders

Tables 3-4 and 3-5 list the unit and revenue brand share leaders in corded telephones in the U.S. market for 1994 and for the third quarter of 1994 through the second quarter of 1995, respectively.

**Table 3-4**
**U.S. Corded Telephone Brand Share Leaders, First Quarter 1994 through Fourth Quarter 1994 (Percent)**

| Brand | Unit Market Share | Revenue Market Share |
|---|---|---|
| AT&T | 31.4 | 37.9 |
| General Electric | 15.4 | 15.8 |
| Conair | 11.8 | 6.7 |
| BellSouth | 7.3 | 6.0 |
| Sony | 5.1 | 6.8 |
| Radio Shack | 4.6 | 5.9 |
| Unisonic | 4.0 | 1.8 |
| Lenoxx | 3.5 | 1.7 |
| Southwestern Bell | 2.1 | 2.0 |
| Panasonic | 1.5 | 2.5 |
| Others | 13.3 | 12.9 |
| Total | 100.0 | 100.0 |

Source: The Scout Report®/The Polk Company

**Table 3-5**
**U.S. Corded Telephone Brand Leaders, Third Quarter 1994 through Second Quarter 1995 (Percent)**

| Brand | Unit Market Share | Revenue Market Share |
|---|---|---|
| AT&T | 30.9 | 38.5 |
| General Electric | 14.7 | 14.7 |
| Conair | 11.6 | 6.7 |
| BellSouth | 5.7 | 4.8 |
| Radio Shack | 5.4 | 6.3 |
| Lenoxx | 4.9 | 2.5 |
| Sony | 4.4 | 5.7 |
| Unisonic | 3.6 | 1.8 |
| Southwestern Bell | 3.3 | 3.6 |
| Panasonic | 1.6 | 3.0 |
| Others | 13.9 | 12.4 |
| Total | 100.0 | 100.0 |

Source: The Scout Report®/The Polk Company

## Feature and Technology Trends

In recent years, with the advent of the featurephone, the market mix of corded telephones began to change dramatically as phones with speakerphones, LCDs or touch screens, and caller ID energized product lines. Brief descriptions of some of these functions are as follows:

- Caller ID: The incorporation of the caller ID function in phones is probably the fastest-growing advanced feature. Caller ID entails the display of the telephone number of an inbound phone call. The benefit the marketers are promoting is the reduction of unwanted solicitation or harassment calls. It has become quite controversial in some states as privacy advocates have effectively blocked its incorporation in California, Texas, and Pennsylvania. Approximately 45 states have adopted caller ID capability. Telephones and special adjunct units are shipping in most states. New FCC regulations will open up the remaining states, including California, in the second half of 1995. Dataquest places the caller ID-featured phone and adjunct market at 3.3 million units in 1994, growing to 8 million in 1995. This includes caller ID features in both corded and cordless handsets.
- LCDs and touch screens: In general, LCDs are showing up on an ever-increasing number of phones. Used mostly for displaying the dialed number, they will eventually evolve into a caller ID role as well.
- ISDN: Even though Bellcore (the common research group of the RBOCs) claims that as many as half the access lines are ISDN ready, very few ISDN-capable telephones have shipped to the U.S. market. However, in the meantime, the SS7 signaling protocol (to create what is known as ISDN-1) has evolved to allow disparate ISDN systems to communicate with each other. This, along with a new tariff structure and new services, is making it feasible for ISDN to roll out in the United States, and shipments are beginning to accelerate. The promise of ISDN is that it

brings the advantages of being digital (transmission quality, compressibility). It also enables the PTO to grow services by offering integrated data and videophone services to a single terminal.

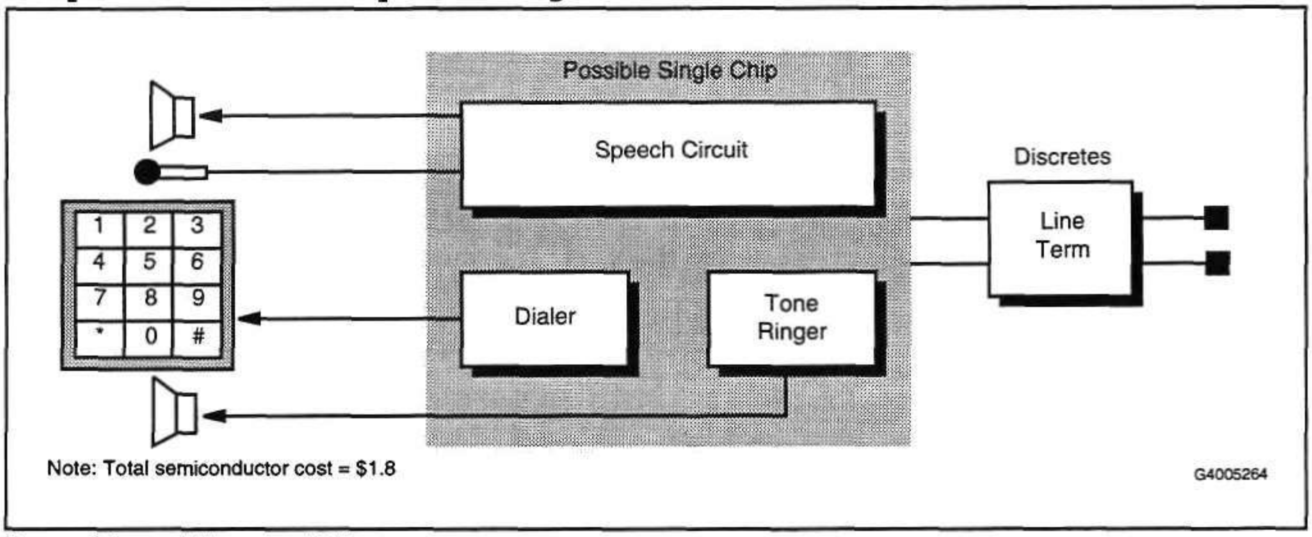
- Videophones: Videophone technology is beginning to emerge as a real opportunity as standards firm and costs come down. The decreasing of costs is due to several chip vendors hard at work on chipsets for CODECs, compression, protocols, and so on.

## Standard Telephones

The standard telephone has evolved over the years from electromechanical equipment to the present full electronic design. Figure 3-3 shows a configuration for a standard telephone. Each of the three key devices currently in a telephone can be traced to individual key improvements in telephone handset design. The three key devices are as follows:

- Dual-tone multifrequency (DTMF) dialer: The DTMF dialer/keypad interface function was developed when DTMF dialing began to replace pulse dialing as digital exchange switching was introduced in the 1970s and 1980s. Also at this time the rotary dialer was replaced with a numeric keypad.
- Tone ringer: The tone ringer was developed as a replacement for the telephone electromechanical bell call ringer. This device detects the ring voltage on the telephone line and generates from an internal source a tone that will drive a loudspeaker or piezoelectric buzzer.
- Speech circuit: The speech circuit has traditionally been implemented in bipolar technology, and the dialer and tone ringer in CMOS. These technology splits have complicated the development of cost-effective, true single-chip telephones.

**Figure 3-3**
**Simplified Standard Telephone Design**




Source: Dataquest (November 1995)

Another complication for telephone handset manufacturers, especially those building for export markets, is the different country variations of line characteristics. To address this challenge Philips Components has taken integration one step further with the recent development of the programmable single-chip telephone. This allows handset manufacturers to program (using on-chip, one-time-programmable memory) after assembly of the telephone "line and load" characteristics to suit individual country markets.

### Feature Telephones

The original feature telephones were developed to support PBX/key telephone systems (KTS). These features originally included memory facilities and displays. A feature telephone today may have the following additional capabilities besides the standard telephone features:

- Multinumber store (usually more than 10)
- Alphanumeric display
- Hands-free dialing
- Speakerphone facility
- Mute (secrecy) capability
- Timer/clock function
- Caller identification

Figure 3-4 shows a configuration of a feature telephone, showing the following key devices:

- Speech circuit
- Microcontroller/DTMF dialer
- Tone ringer
- Speakerphone IC
- LCD

The major difference between a feature telephone and a standard telephone is the addition of a microcontroller/DTMF dialer and a speakerphone IC. The 4- or 8-bit microcontroller usually includes a DTMF dialer and provides all the memory storage capability, timer/clock functions, and interface/drive for the LCD. The speakerphone IC allows the user to have a conversation while the handset is still on the hook.

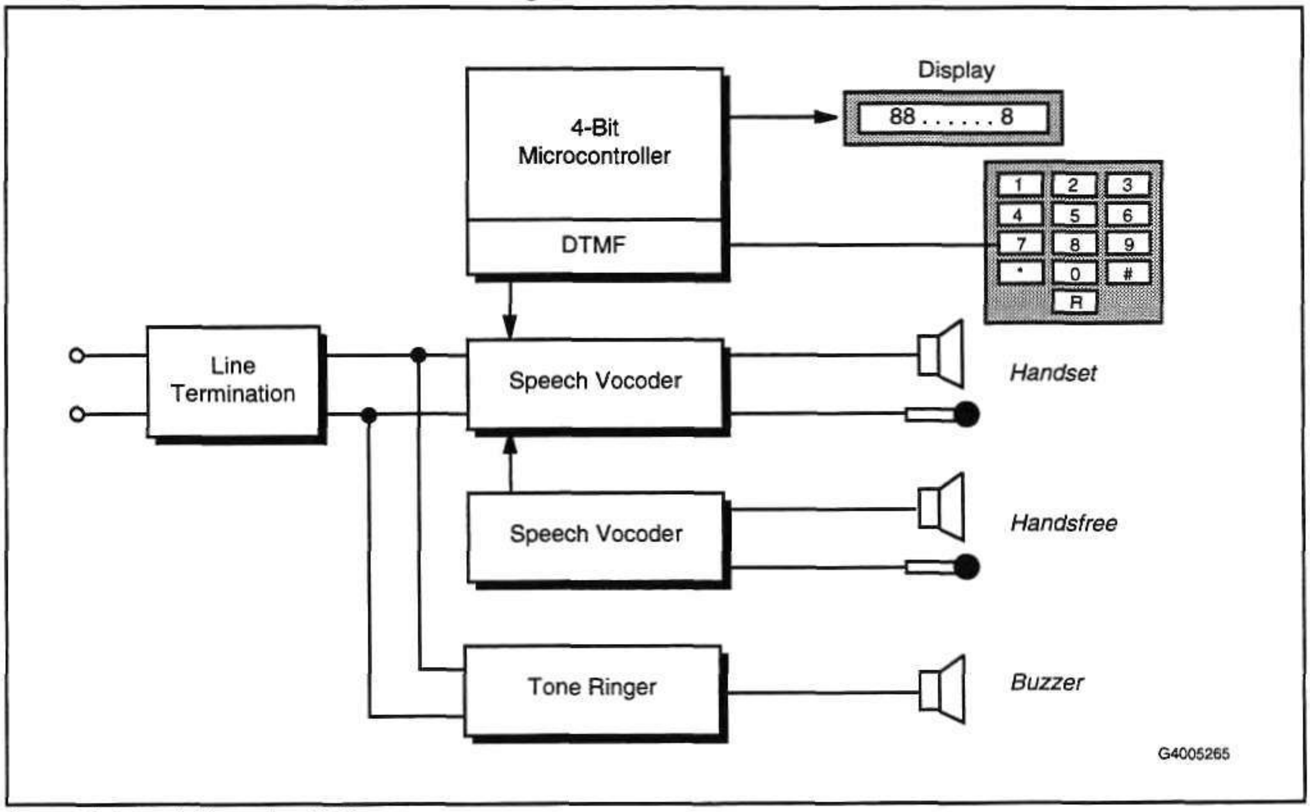
## Semiconductor Opportunities

IC opportunities within advanced corded feature telephones include the following:

- Integrated speech, dialer, and speakerphone functions
- Caller ID (decode and LCD driver)
- Touch-screen interface
- Integrated versions of these with a 4- or 8-bit MCU
- ISDN (CODECs, S/T/U interface, and LAP-D controller)

**Figure 3-4**
**Simplified Feature Telephone Design**




Source: Dataquest (November 1995)

# Chapter 4
# Cordless Telephones

## Market and Production Trends

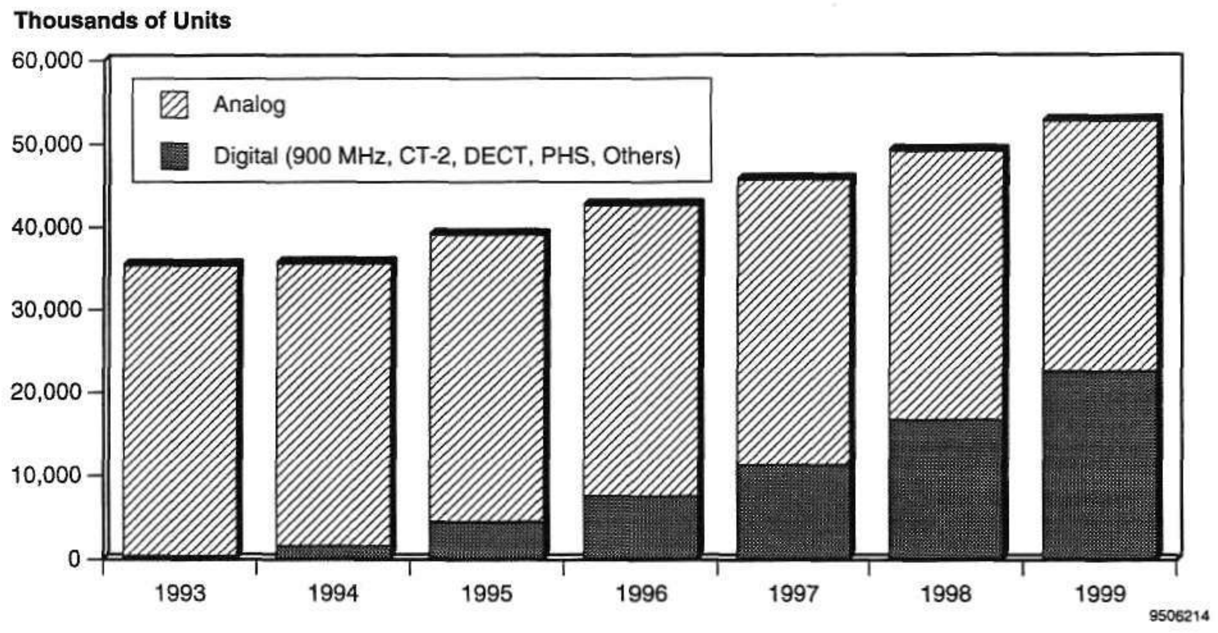
Worldwide production of cordless telephone handsets is forecast to grow at a strong 8.1 percent CAGR during the next five years, as shown in Figure 4-1 and Table 4-1. Digital handset production will grow at 69.5 percent CAGR during this time frame and account for more than 40 percent of all shipments by 1999. Table 4-2 shows that, although North American production will grow at a faster pace than the worldwide rate, it represents less than 4 percent of worldwide production.

The primary market driver of cordless telephones in North America has been the residential market. The residential cordless phone market continues to advance as the convenience and continuing price/performance improvements of cordless telephones keep attracting new users. With a 52 percent household penetration rate in the United States, there is nothing to prevent cordless phones from being in every home. Figure 4-2 and Table 4-3 present a market forecast for all of North America. Substantial growth opportunities exist in penetration of Mexican homes.

## Brand Share Leaders

Tables 4-4 and 4-5 list the unit and revenue brand share leaders in cordless telephones in the U.S. market for 1994 and for the third quarter of 1994 through the second quarter of 1995, respectively.

**Figure 4-1**
**Worldwide Cordless Telephone Handset Production**




Source: Dataquest (November 1995)

## Table 4-1
## Worldwide Cordless Telephone Handset Production

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|
| Units (K) | 35,405 | 35,685 | 39,134 | 42,668 | 45,764 | 49,173 | 52,744 | 8.1 |
| Digital (900 MHz, CT-2, DECT, PHS, Others) | 414 | 1,614 | 4,532 | 7,638 | 11,360 | 16,718 | 22,599 | 69.5 |
| Analog | 34,991 | 34,071 | 34,602 | 35,030 | 34,403 | 32,456 | 30,146 | -2.4 |
| Factory ASP ($) | 82 | 77 | 74 | 73 | 72 | 72 | 71 | -1.6 |
| Factory Revenue ($M) | 2,907 | 2,747 | 2,914 | 3,120 | 3,297 | 3,523 | 3,741 | 6.4 |
| Semiconductor Content ($) | 14 | 14 | 15 | 15 | 16 | 16 | 17 | 3.1 |
| Semiconductor Market ($M) | 498 | 508 | 581 | 649 | 725 | 807 | 873 | 11.4 |

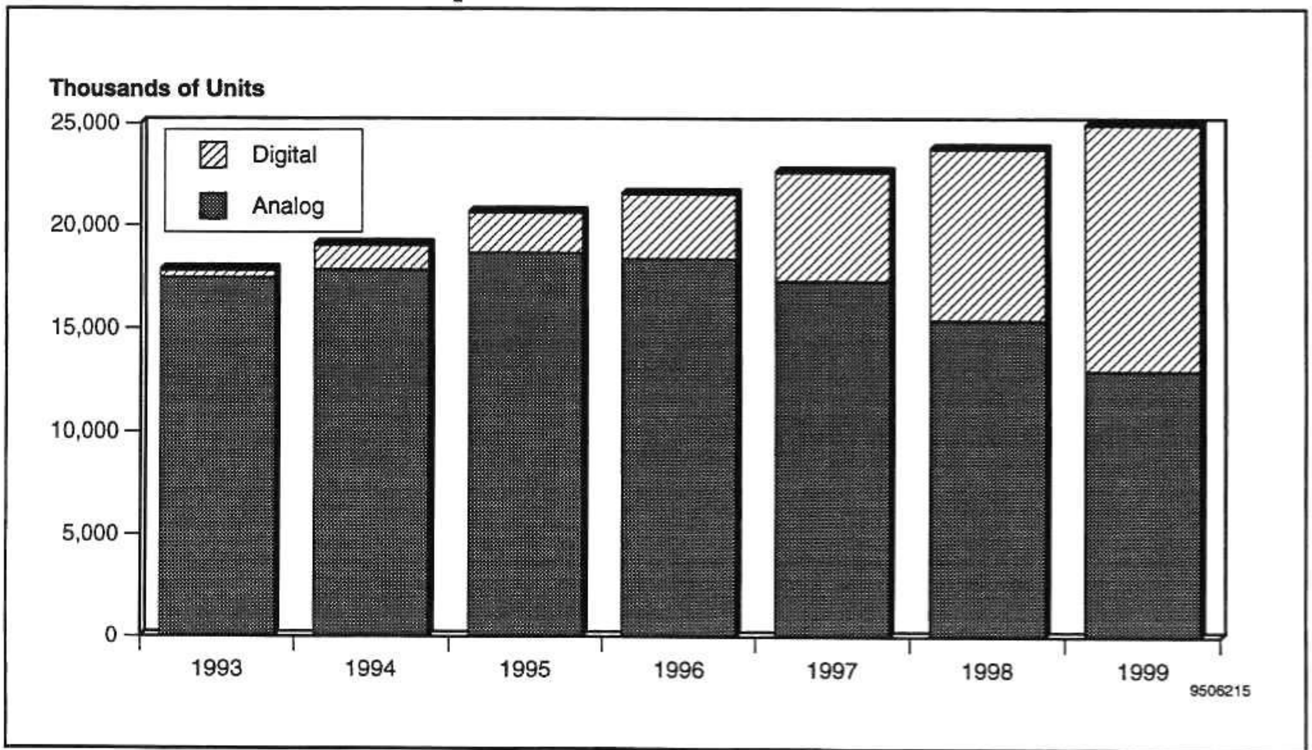
Source: Dataquest (November 1995)

## Table 4-2
## North American Cordless Telephone Handset Production

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|
| Units (K) | 1,080 | 1,134 | 1,215 | 1,516 | 1,596 | 1,652 | 1,735 | 8.9 |
| Factory ASP ($) | 74 | 72 | 68 | 64 | 60 | 56 | 52 | -6.4 |
| Factory Revenue ($M) | 80 | 82 | 83 | 97 | 96 | 93 | 90 | 1.9 |
| Semiconductor Content ($) | 13 | 13 | 14 | 14 | 14 | 13 | 13 | 0.0 |
| Semiconductor Market ($M) | 14 | 15 | 17 | 21 | 22 | 21 | 23 | 8.9 |

Source: Dataquest (November 1995)

## Figure 4-2
## North American Cordless Telephone Handset Production




Source: Dataquest (November 1995)

**Table 4-3**
**North American Cordless Telephone Market**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|
| Market Revenue ($M) | 1,282 | 1,294 | 1,279 | 1,184 | 1,130 | 1,092 | 1,047 | -3.2 |
| Factory ASP Overall ($) | 74 | 73 | 68 | 61 | 58 | 55 | 51 | -5.8 |
| Factory ASP Analog ($) | 72 | 68 | 62 | 55 | 50 | 46 | 42 | -8.6 |
| Factory ASP Digital ($) | 183 | 155 | 124 | 99 | 84 | 72 | 61 | -17.0 |
| Units (K) | 17,801 | 19,030 | 20,625 | 21,533 | 22,609 | 23,740 | 24,927 | 5.9 |
| Analog | 17,463 | 17,850 | 18,666 | 18,389 | 17,296 | 15,431 | 12,962 | -2.4 |
| Digital | 338 | 1,180 | 1,959 | 3,144 | 5,313 | 8,309 | 11,965 | 89.7 |

Source: Dataquest (November 1995)

**Table 4-4**
**U.S. Cordless Telephone Brand Share Leaders, First Quarter 1994 through Fourth Quarter 1994 (Percent)**

| Brand | Unit Market Share | Revenue Market Share |
|---|---|---|
| AT&T | 27.3 | 31.1 |
| General Electric | 13.1 | 10.4 |
| Sony | 12.3 | 13.7 |
| Panasonic | 10.2 | 11.8 |
| BellSouth | 9.7 | 7.9 |
| Uniden | 8.8 | 6.8 |
| Southwestern Bell | 4.0 | 3.3 |
| Cobra | 3.3 | 3.5 |
| Radio Shack | 3.2 | 3.3 |
| Toshiba | 2.0 | 2.1 |
| Others | 6.1 | 6.1 |
| Total | 100.0 | 100.0 |

Source: The Scout Report®/The Polk Company

**Table 4-5**
**U.S. Cordless Telephone Brand Share Leaders, Third Quarter 1994 through Second Quarter 1994 (Percent)**

| Brand | Unit Market Share | Revenue Market Share |
|---|---|---|
| AT&T | 27.2 | 31.3 |
| General Electric | 14.0 | 11.2 |
| Sony | 12.0 | 12.5 |
| Uniden | 9.8 | 7.6 |
| Panasonic | 9.8 | 12.1 |
| BellSouth | 9.1 | 7.3 |
| Southwestern Bell | 4.4 | 3.7 |
| Radio Shack | 3.2 | 3.5 |
| Cobra | 3.0 | 3.4 |
| Toshiba | 1.9 | 1.9 |
| Others | 5.6 | 5.5 |
| Total | 100.0 | 100.0 |

Source: The Scout Report®/The Polk Company

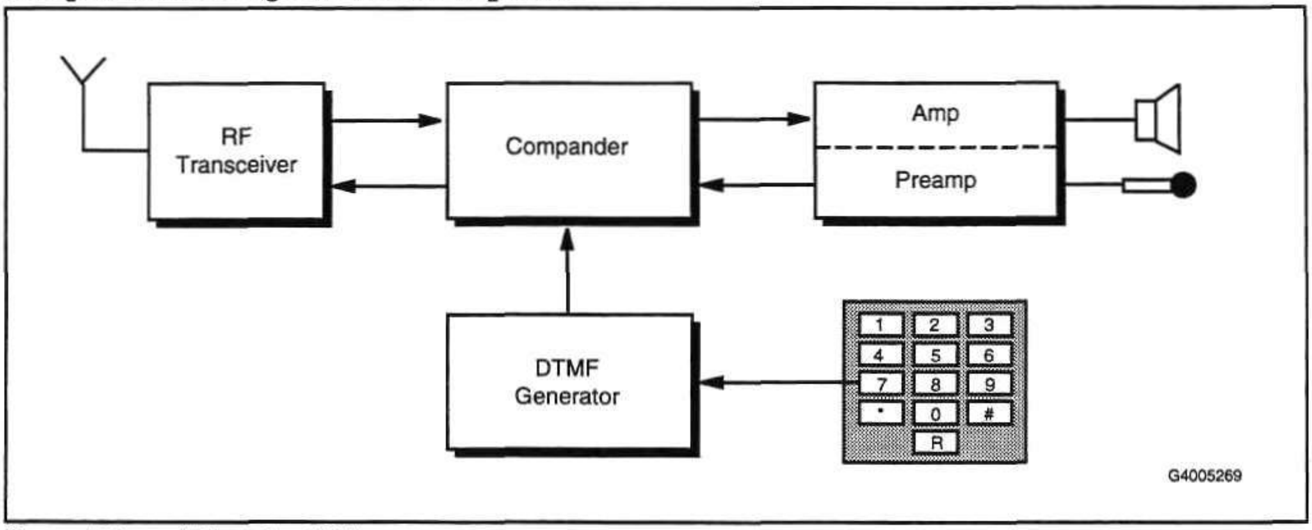
## Feature and Technology Trends

There is a great deal of overlap in technologies and markets among cellular, cordless, and personal communications services. The 900-MHz digital cordless technology (DCT) is meant to be used within 100m of a base station. The personal handyphone system (PHS), CT2, CT2+, and DECT handsets can be used as basic cordless phones in the home/office or as a low-mobility PCS system outside the home. The PHS and DECT technologies have a chance of being employed as PCS or PCN communicators in the United States.

Despite the problems of analog cordless telephones such as poor speech quality, channel interference, and lack of privacy, there are some new technical and device performance improvements that will prolong the analog cordless life cycle. New 25-channel cordless phones have found strong market acceptance in the United States and could push out growth of digital handsets.

Figure 4-3 is a simplified diagram of a typical analog cordless telephone; a significant portion of the semiconductor cost is in the radio section. Opportunities still exist for greater levels of integration and improved performance and noise reduction. One advantage that digital cordless telephones will have over analog cordless telephones is that they will be smaller in size. To help sustain the market for analog cordless, many OEMs are demanding that semiconductor vendors supply 3V operation devices. This reduces battery requirements, which are the most significant contributors to weight and volume of bulky analog cordless telephones.

**Figure 4-3**
**Simplified Analog Cordless Telephone**




Source: Dataquest (November 1995)

## Digital Cordless

DCT will eventually supersede analog cordless. (Digital cordless has a number of regional and proprietary supporting standards.) The essential objectives in the development of digital telephones is to improve the following areas of performance over analog cordless:

- Superior speech quality
- Better range and propagation capabilities
- Secure speech/secure base station access
- Much greater user densities

To achieve these objectives, digital standards employ some of the following techniques:

- Speech compression—all current DCT use 32-Kbps, adaptive differential pulse-code modulation (ADPCM)
- Access methods such as time-division multiple access (TDMA) and time-division duplex (TDD)
- Higher frequencies (some at 1.8 to 1.9 GHz) for better propagation
- New frequency allocation, with more bandwidth

These capabilities have opened up additional opportunities for cordless from the present domination by residential users to business users (wireless PBX/key systems) and telepoint.

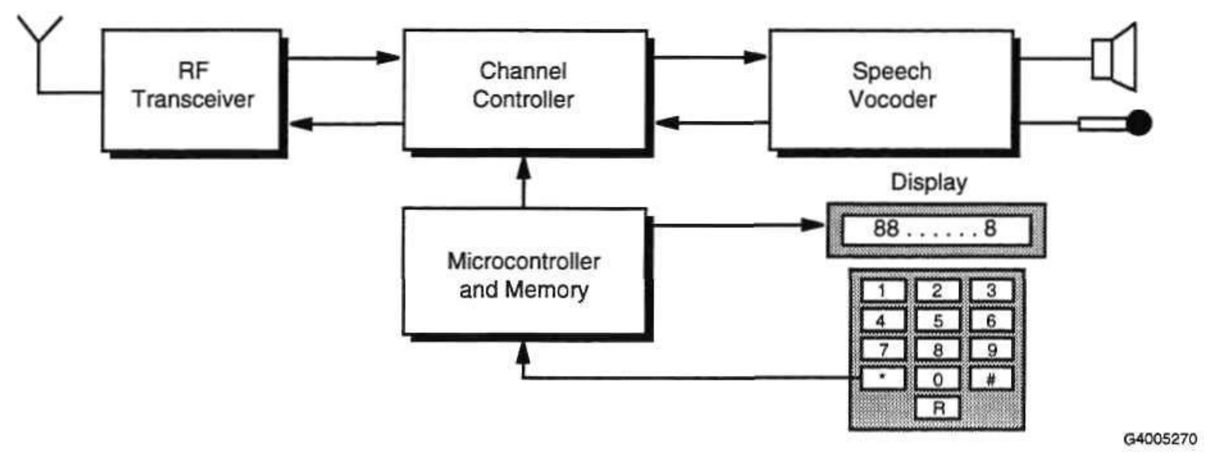
The current lineup of digital cordless systems/standards includes 900-MHz DCT (AT&T for the U.S. residential market), CT2 (and variants), DECT, and PHS for Japan. The last two have been designed from scratch to support very high user densities. The standards have also addressed the additional opportunities of public access (telepoint) and business users where this will be a major advantage. These standards also support roaming (at pedestrian speeds), which of course is mandatory in an office environment, as users move throughout a building from one base station area to another. This roaming capability has driven a strong market for PHS as a low-mobility system in Japan. The PHS system provides the foundation for the low-mobility PACS standard in the United States. DECT technology drives the proposed wireless communications premise equipment (WCPE) standard.

Figure 4-4 is a simplified diagram of a digital cordless telephone, showing the key elements:

- Speech vocoder
- Channel controller
- Microcontroller/memory
- RF transceiver

**Figure 4-4**
**Simplified Digital Cordless Telephone**




Source: Dataquest (November 1995)

State-of-the-art semiconductor solutions have now integrated all baseband (non-RF) functions into a single chip with the exception of memory. These single-chip DCT devices include the following:

- Voice PCM CODEC/compression, decompression
- Channel processor—TDMA controller and signaling protocol processor
- 8-bit microcontroller with keyboard, display interface, and DTMF dialer

Some of these highly integrated devices are already available with 3V operation, with volume prices in the range of $10 to $15.

The RF section represents the most significant opportunity for integration and cost reduction. A single radio subsystem interface (RSSI) specification has been agreed upon that will define the interface between the RF section and the baseband section. This will do the following:

- Enable different chipset vendors to provide functional compatibility with others
- Give OEMs more choice and involve less design effort for integration of RF and baseband sections
- Present an opportunity for semiconductor vendors to work toward complementary or second-source chipsets

Digital cordless and digital cellular exhibit certain similarities. Table 4-6 shows that there are some key differences that will always keep a significant price differential between the opposing types of telephone.

The European digital cordless market has two competing solutions: CT-2 and DECT standards. Table 4-7 outlines the comparisons between these two systems. The potentially lower-cost RF solutions and the high level of support from semiconductor vendors will make DECT the ultimate winner in the DCT battle. The overall component costs (this includes all semiconductors and other components such as filters) for DECT were lower than CT-2 in 1995. Figure 4-5 shows a second-generation DECT product

### Table 4-6
### Differences between Digital Cordless and Digital Cellular Telephones

| Feature | Cordless | Cellular |
|---|---|---|
| Speech Compression | ADPCM<br>32 Kbps<br>G.722 CODEC | VSELP/RPE-LTP<br>7.25/13 Kbps<br>DSP |
| Equalizer | No | Yes |
| Encryption | Not usual | Usual |
| Power Output | Usually fixed <250mW | Usually variable >250mW |
| Cell/Base Station Handover | Not usual (where possible under handset control) | Mandatory (under base station control) |

ADPCM = Adaptive differential pulse-code modulation
VSELP = Vector sum excited linear predictive coding
RPE-LTP = Regular pulse excitation, long-term prediction
Source: Dataquest (November 1995)

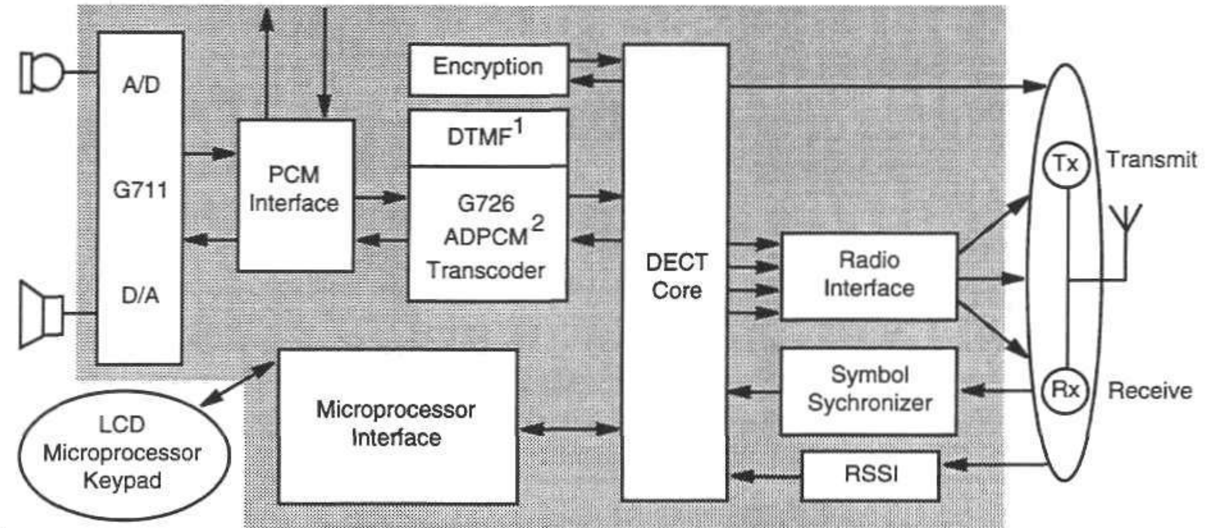
### Table 4-7
### DECT and CT2 Specification Comparison

| | CT2 | DECT |
|---|---|---|
| Radio Frequency Band (MHz) | 864-868 | 1880-1900 |
| Bandwidth (MHz) | 4 | 20 |
| Channelization | FDMA | TDMA/FDMA |
| Channel Spacing | 100 KHz | 1.728 MHz |
| Number of Frequency Channels | 40 | 10 |
| Voice Channels per Frequency Channel | 1 | 12 |
| Duplex Method | TDD | TDD |
| Total Duplex Channels | 10 | 120 |
| Speech Coder | ADPCM | ADPCM |
| Bit Rate (Kbps) | 32 | 32 |
| Channel Bit Rate (Kbps) | 72 | 1,152 |
| Modulation Technique | GFSK | GMSK |
| Voice and Data | No | Yes |
| Frame Time (ms) | 2 | 10 |
| Peak Transmit Power (mW) | 10 | 250 |
| Average Transmit Power (mW) | 5 | 10 |

Source: Dataquest (November 1995)

Figure 4-5
DECT Handset Block Diagram




1 Dual-tone multifrequency
2 Adaptive differential pulse-code modulation

Source: VLSI Technology Inc.

that will incorporate highly integrated solutions for both the RF and voice/channel CODEC/controller. The latest semiconductor solutions suggest that these second-generation telephones will have about seven devices for a complete solution, as shown in Table 4-8.

## Semiconductor Opportunities

The worldwide semiconductor market for cordless telephones was $508 million in 1994. The majority of this market was for analog handsets. With the overlap between cellular and cordless telephone technologies, many of the semiconductor market opportunities are the same for both products. Chapter 5 provides a detailed listing of these opportunities.

Table 4-8
DECT Semiconductor Solution—Second-Generation

| Function | No. of Devices | Semiconductor |
|---|---|---|
| Integrated Power Amplifier | 1 | GaAs linear* |
| RF Front End | 4 | RF linear |
| Voice CODEC/Channel Controller | 1 | MOS logic (ASIC) |
| Microcontroller (ROM/RAM/EEPROM) | 1 | MOS micro |

*GaAs = Gallium arsenide
Source: Dataquest (November 1995)

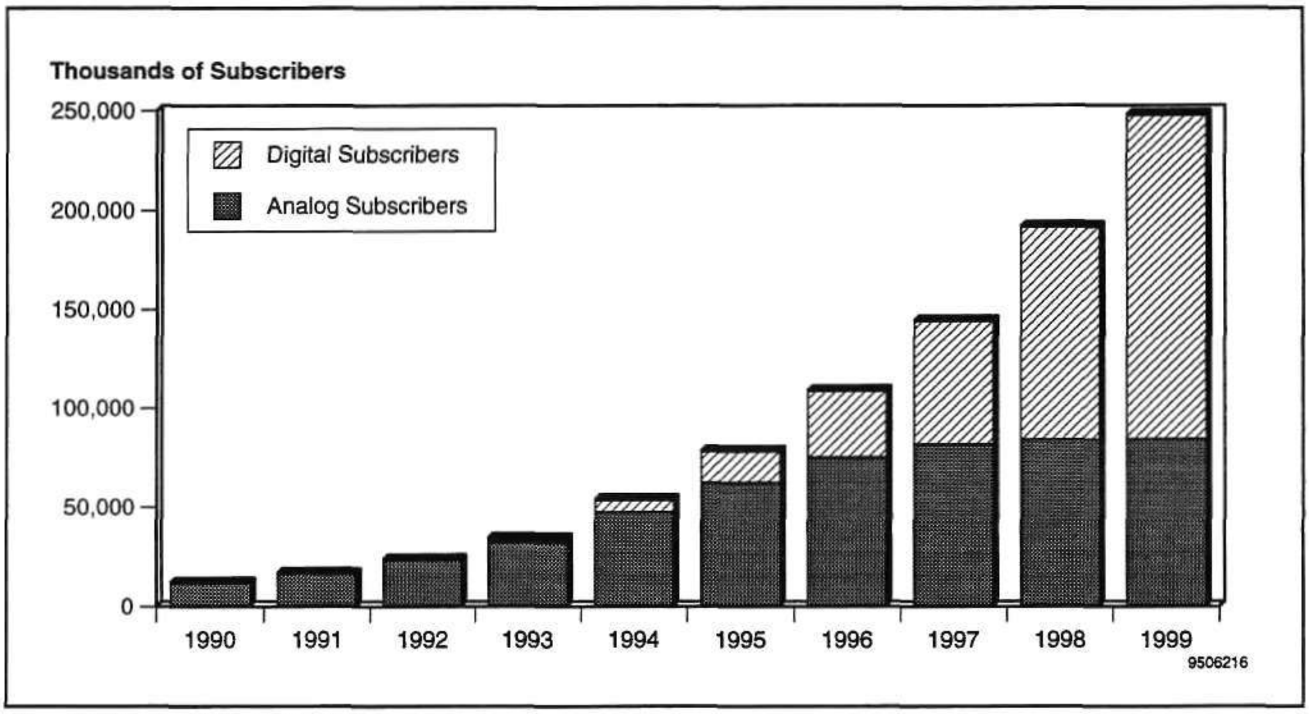
  

# Chapter 5
# Cellular and Broadband PCS Telephones

## Market and Production Trends

More than 53 million people were subscribing to cellular services worldwide by the end of 1994, with 49 percent in North America, 26 percent in Western Europe, and 20 percent in the Asia/Pacific and Japan region. North America's share of subscribers will decrease to 34 percent by 1999, while the Asia/Pacific and Japan subscribers will grow to 33 percent of the worldwide cellular population (see Figure 5-1). Table 5-1 provides a brief description of the cellular services in countries with the largest cellular subscriber populations. The highest levels of cellular telephone population penetration are found in the Scandinavian countries. The penetration of cellular telephones in the United States reached 9.1 percent of the population by the end of 1994. This translates into about a 20 percent U.S. household penetration.

**Figure 5-1**
**Worldwide Cellular and Broadband PCS Subscribers**




Source: Dataquest (November 1995)

**Table 5-1**
**Major International Cellular/PCS Markets**

| Country | Number of Subscribers* (Thousands) | Type of System | Cellular Carriers |
|---|---|---|---|
| United States | 23,630 | AMPS—CDMA/TDMA/ PCS (Multiple) | Two operators per market in 306 metropolitan statistical areas and 428 rural service areas |
| Japan | 3,800 | NTT/J—TACS/PDC | Nippon Telegraph & Telephone |
| | | | Nippon Idou Tsushin |
| | | | Daini Denden |
| United Kingdom | 3,402 | TACS/GSM/DCS-1800 | Cellnet |
| | | | Vodafone Group |
| Germany | 2,456 | GSM/C-Netz/DCS-1800 | Deutsche Bundespost Telekom |
| | | | Mannesmann Mobilfunk |
| | | | E-Plus Mobilfunk |
| Italy | 2,148 | ETACS/GSM | SIP |
| Canada | 1,768 | AMPS/DAMPS | A national Block A carrier (Rogers Cantel) and 10 Block B provincial carriers |
| China | 1,570 | AMPS/GSM/TACS/ ETDMA | MPT and various regional operators (PTAs) |
| Australia | 1,444 | AMPS | Telecom Australia |
| | | | Optus Communications |
| South Korea | 960 | AMPS/CDMA | Korea Telecommunications Authority |
| Sweden | 843 | NMT/GSM | Comvik AB |
| | | | Swedish Nordic Tel |
| | | | Telia Mobitel |
| Thailand | 810 | AMPS/NMT/GSM/ DCS-1800 | Telephone Organization of Thailand |
| | | | Communications Authority of Thailand |
| | | | Advanced Information Services |
| | | | Total Access Communications |
| Finland | 645 | NMT/GSM | Oy Radiolinja |
| | | | Telecom Finland |
| | | | Alands Mobiltelefon |
| Taiwan | 630 | AMPS/GSM | Directorate General of Telecommunications |
| Malaysia | 568 | NMT/TACS/AMPS/ DAMPS/GSM/DCS-1800 | Telekom Malaysia |

(Continued)

**Table 5-1 (Continued)**
**Major International Cellular/PCS Markets**

| Country | Number of Subscribers* (Thousands) | Type of System | Cellular Carriers |
|---|---|---|---|
| Norway | 554 | NMT/GSM | Norwegian Telecom Mobile |
| | | | Celcom |
| Denmark | 549 | NMT/GSM | Telecom Denmark |
| France | 536 | NMT/GSM/DCS-1800 | France Telecom |
| | | | Ligne SFR |
| Mexico | 500 | AMPS | Nine nonwireline companies and one wireline company |
| Hong Kong | 439 | GSM/AMPS/DAMPS | Pacific Link Communications |
| | | TACS/ETACS | Hutchison Telecom |
| | | | Hong Kong Telecom CSL |
| Brazil | 461 | AMPS | Telebrasilia, Teleri, Regional |

*Number of subscribers as of end of 1994.
Source: Dataquest (November 1995)

As worldwide cellular/PCS subscribers increase from 53.5 million in 1994 to 248 million in 1999, this will drive the handset market from 27.8 million units to 97 million in the same period (see Table 5-2). Worldwide production of cellular telephone handsets is forecast to grow at a strong 28.2 percent CAGR during the next five years. Figure 5-2 and Tables 5-3 and 5-4 show the worldwide forecast for cellular telephone handset production. Although analog handsets represented over 90 percent of the market in 1993, digital handset production will grow to surpass analog handset production by 1997.

Cellular telephones based on GSM technology represent the large majority of digital cellular phones with the adoption of a common standard in Europe. Multiple digital standards are competing for market acceptance in the United States. Digital telephones are expected to experience rapid growth, with dual-mode analog/digital cellular/PCS telephones representing the majority of the North American cellular/PCS handset market by 1998. Table 5-5 and Figure 5-3 show the forecast for the North American cellular/PCS telephone market. Figure 5-4 shows the growing number of U.S. cellular/PCS telephone subscribers, expected to exceed 76 million people by 1999, that are driving the handset market forecast. An increasing number of these subscribers are using their cellular/PCS telephones for personal calls and safety. Surveys have found that almost 60 percent of all cellular use in the United States is for personal calls.

The digital GSM handset market exploded in Europe during the 1990s as the European countries agreed on the unified GSM standard. This market had experienced very low cellular penetration rates before then. With the introduction of the GSM standard, which allowed easier roaming between countries, the market took off and quickly grew to become the largest digital cellular market in the world. Many countries in other regions have also adopted the GSM standard. However, the U.S. market has been much slower than expected in accepting the digital technology. Dataquest predicts that digital (dual-mode) handset shipments will account for a

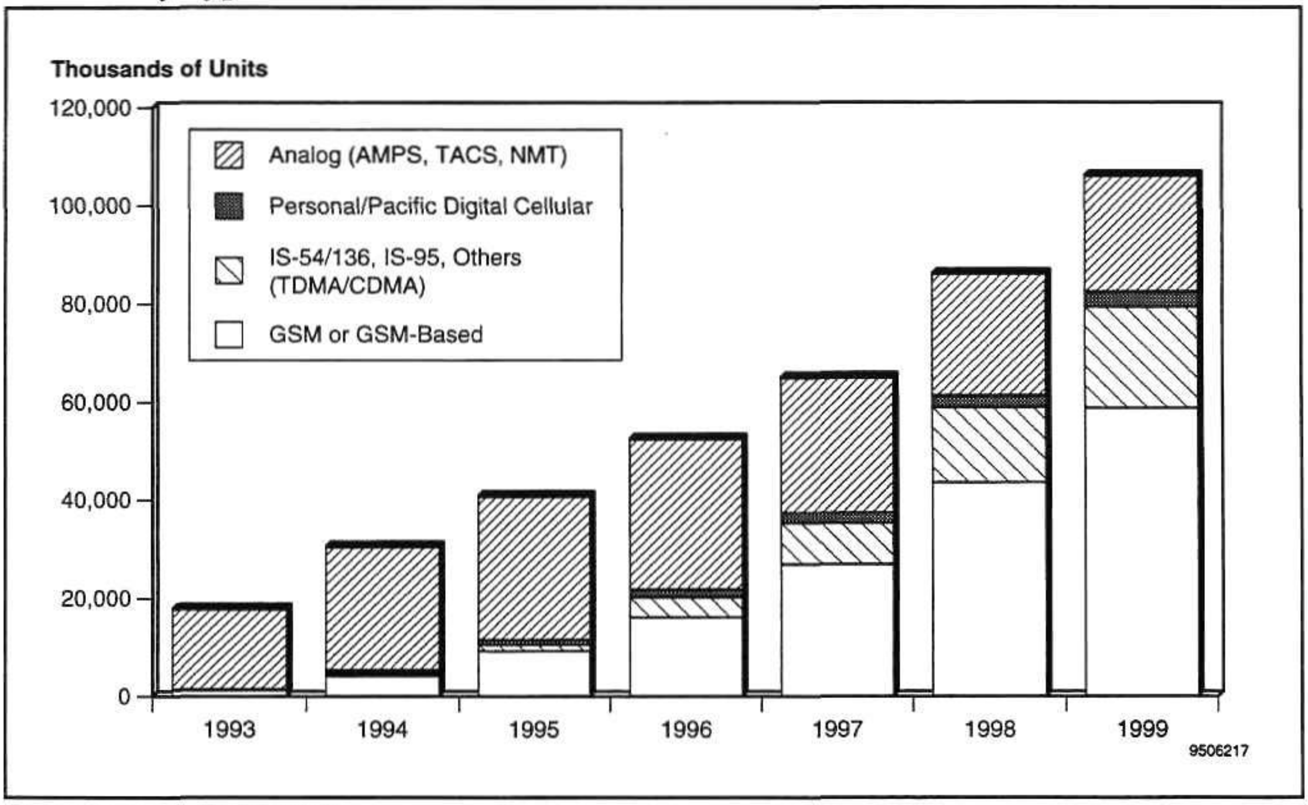
  

**Table 5-2**
**Worldwide Cellular and Broadband PCS Telephone Market**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|
| Subscribers (K) | 34,096 | 53,548 | 78,113 | 108,540 | 144,025 | 191,564 | 248,006 | 35.9 |
| Units (K) | 16,225 | 27,758 | 37,315 | 48,133 | 59,624 | 78,936 | 97,116 | 28.5 |
| Analog Units (K) | 14,796 | 22,779 | 26,748 | 28,188 | 25,622 | 23,241 | 22,225 | -0.5 |
| Digital Units (K) | 1,429 | 4,979 | 10,567 | 19,945 | 34,002 | 55,696 | 74,891 | 72.0 |
| Factory ASP ($) | 472 | 426 | 375 | 340 | 306 | 269 | 249 | -10.2 |
| Factory Revenue ($M) | 7,663 | 11,830 | 13,992 | 16,366 | 18,243 | 21,200 | 24,172 | 15.4 |

Source: Dataquest (November 1995)

**Figure 5-2**
**Worldwide Cellular and Broadband PCS Telephone Handset Production Estimate by Type**




Source: Dataquest (November 1995)

**Table 5-3**
**Worldwide Cellular and Broadband PCS Telephone Handset Production**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|
| **Analog Production** | | | | | | | | |
| Units (K) | 16,275 | 25,057 | 29,155 | 30,443 | 27,416 | 24,635 | 23,559 | -1.2 |
| Factory ASP ($) | 458 | 414 | 357 | 322 | 280 | 265 | 280 | -7.5 |
| Factory Revenue ($M) | 7,454 | 10,374 | 10,408 | 9,803 | 7,676 | 6,528 | 6,596 | -8.7 |
| Semiconductor Content ($) | 43 | 42 | 42 | 43 | 43 | 43 | 45 | 1.4 |
| Semiconductor Market ($M) | 700 | 1,052 | 1,225 | 1,309 | 1,179 | 1,059 | 1,060 | 0.1 |
| **Digital Production** | | | | | | | | |
| Units (K) | 1,572 | 5,477 | 11,624 | 21,939 | 37,403 | 61,265 | 82,380 | 72.0 |
| Factory ASP ($) | 620 | 482 | 420 | 365 | 325 | 270 | 240 | -13.0 |
| Factory Revenue ($M) | 975 | 2,640 | 4,882 | 8,008 | 12,156 | 16,542 | 19,771 | 49.6 |
| Semiconductor Content ($) | 215 | 150 | 120 | 104 | 92 | 78 | 70 | -14.1 |
| Semiconductor Market ($M) | 338 | 822 | 1,395 | 2,282 | 3,441 | 4,779 | 5,767 | 47.7 |
| **Total Production** | | | | | | | | |
| Units (K) | 17,848 | 30,534 | 40,779 | 52,382 | 64,818 | 85,900 | 105,939 | 28.2 |
| Factory ASP ($) | 472 | 426 | 375 | 340 | 306 | 269 | 249 | -10.2 |
| Factory Revenue ($M) | 8,429 | 13,014 | 15,291 | 17,810 | 19,832 | 23,070 | 26,368 | 15.2 |
| Semiconductor Content ($) | 58 | 61 | 64 | 69 | 71 | 68 | 64 | 1.0 |
| Semiconductor Market ($M) | 1,038 | 1,874 | 2,619 | 3,591 | 4,620 | 5,838 | 6,827 | 29.5 |

Source: Dataquest (November 1995)

**Table 5-4**
**Worldwide Cellular and Broadband PCS Telephone Handset Production Estimate by Type (Thousands of Units)**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|
| Digital/Dual-Mode (All Types) | | | | | | | | |
| GSM or GSM-Based | 1,416 | 4,271 | 9,331 | 16,228 | 27,008 | 43,560 | 58,671 | 68.9 |
| IS-54/136, IS-95, Others (TDMA/CDMA) | 156 | 579 | 1,350 | 4,063 | 8,320 | 15,200 | 20,600 | 104.3 |
| Personal/Pacific Digital Cellular | 0 | 627 | 943 | 1,648 | 2,075 | 2,505 | 3,109 | 37.7 |
| Analog (AMPS, TACS, NMT) | 16,275 | 25,057 | 29,155 | 30,443 | 27,416 | 24,635 | 23,559 | -1.2 |
| Total | 17,848 | 30,534 | 40,779 | 52,382 | 64,818 | 85,900 | 105,939 | 28.2 |

Source: Dataquest (November 1995)

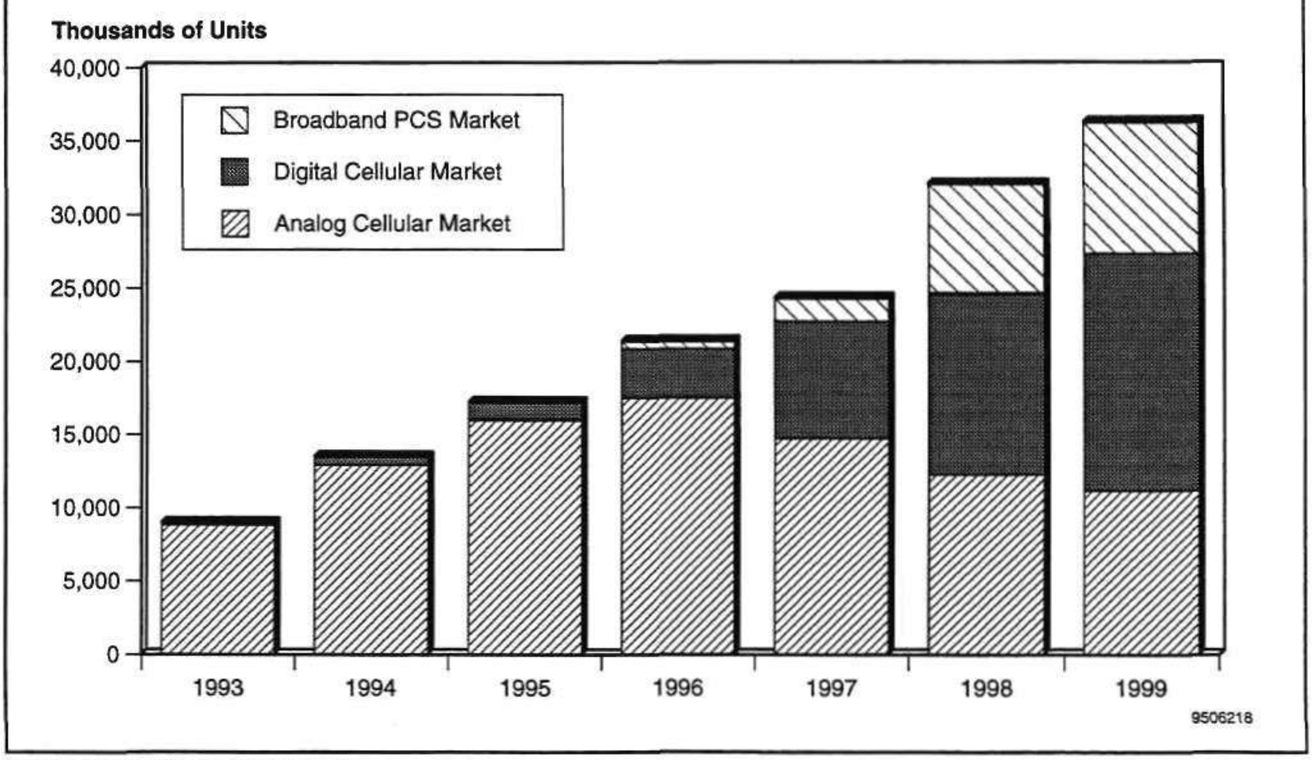
  

**Table 5-5**
**North American Cellular and Broadband PCS Telephone Market**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|
| **Cellular Market** | | | | | | | | |
| Units (K) | 9,001 | 13,478 | 17,186 | 20,867 | 22,715 | 24,651 | 27,313 | 15.2 |
| Analog Units (K) | 8,859 | 12,951 | 16,007 | 17,509 | 14,758 | 12,287 | 11,189 | -2.9 |
| Digital Units (K) | 142 | 527 | 1,179 | 3,358 | 7,957 | 12,364 | 16,124 | 98.2 |
| Factory ASP ($) | 454 | 423 | 359 | 326 | 294 | 267 | 255 | -9.6 |
| Factory Revenue ($M) | 4,084 | 5,703 | 6,178 | 6,812 | 6,673 | 6,594 | 6,978 | 4.1 |
| **Broadband PCS Market** | | | | | | | | |
| Units (K) | - | - | - | 500 | 1,570 | 7,380 | 8,910 | NM |
| Factory ASP ($) | - | - | - | 370 | 300 | 255 | 225 | NM |
| Factory Revenue ($M) | - | - | - | 185 | 471 | 1,882 | 2,005 | NM |
| **Total Market** | | | | | | | | |
| Units (K) | 9,001 | 13,478 | 17,186 | 21,367 | 24,285 | 32,031 | 36,223 | 21.9 |
| Factory ASP ($) | 454 | 423 | 359 | 327 | 294 | 265 | 248 | -10.1 |
| Factory Revenue ($M) | 4,084 | 5,703 | 6,178 | 6,997 | 7,144 | 8,476 | 8,983 | 9.5 |

Source: Dataquest (November 1995)

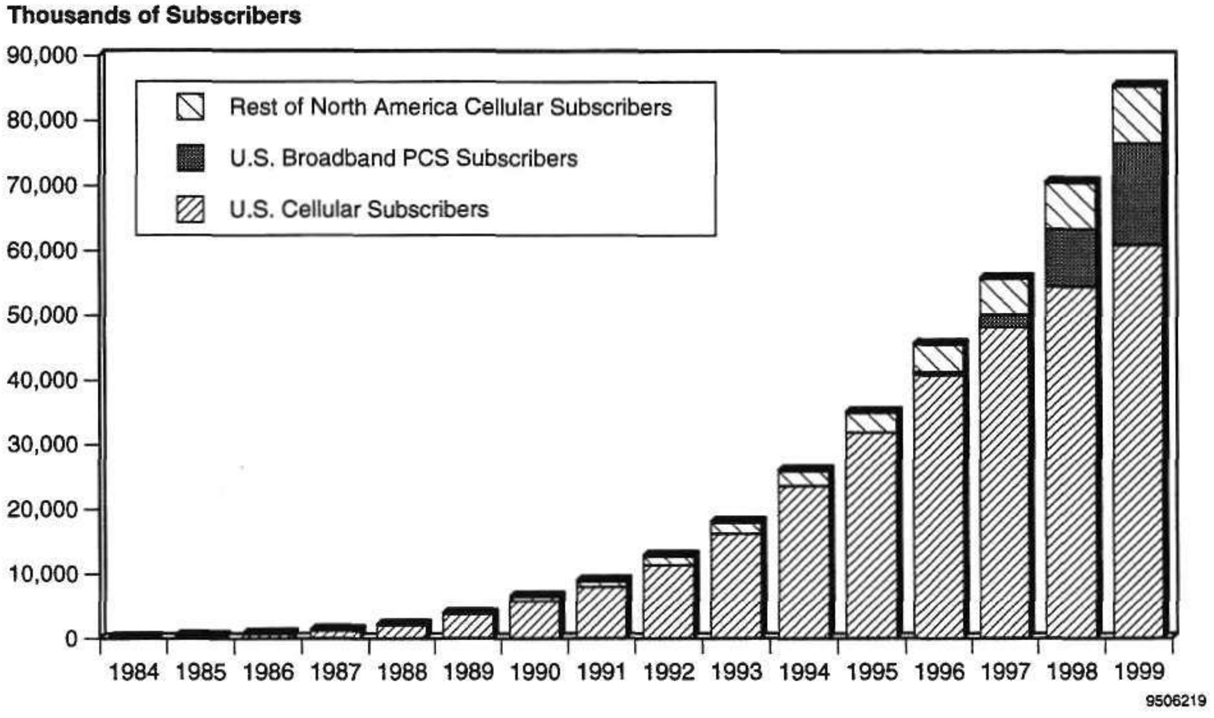
**Figure 5-3**
**North American Cellular and Broadband PCS Telephone Market**




Source: Dataquest (November 1995)

**Figure 5-4**
**North American and U.S. Cellular and Broadband PCS Subscribers**




Source: Dataquest (November 1995)

little less than 7 percent of total North American handset shipments in 1995. This slower acceptance of digital handsets in the U.S. market in particular is because of a number of factors:

- The higher price of digital phones, compared with analog. Low-priced analog handsets have been very popular items as many consumers seek an economical entry into the market. Cellular providers have been pushing handset manufacturers for increased shipments of analog AMPS handsets as they seek to expand the consumer market. Also, the promotion of digital services and handsets by the service providers has not been as aggressive.
- The voice quality of early digital handsets, widely criticized by experienced cellular subscribers, who find it inferior to the voice quality offered by analog handsets. It is expected that newer speech technologies will improve the voice quality in the digital handsets.
- Limited consumer awareness of meaningful digital benefits. These include increased talk time and privacy enabled by encryption.
- The availability of digital service in relatively few markets.

The North American production of cellular/PCS handsets shown in Table 5-6 reflects this lower penetration of digital handsets into the market.

The rollout of digital cellular and PCS services will require additional investment in infrastructure equipment. An estimate of the worldwide cellular infrastructure market for the GSM standard and the semiconductor

**Table 5-6**
**North American Cellular and Broadband PCS Telephone Production**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|
| **Analog Production** | | | | | | | | |
| Total Shipments (k) | 8,359 | 12,117 | 15,339 | 17,194 | 14,734 | 12,431 | 11,256 | -1.5 |
| Factory ASP ($) | 448 | 420 | 355 | 320 | 285 | 270 | 285 | -7.5 |
| Handset Factory Revenue ($M) | 3,745 | 5,089 | 5,445 | 5,502 | 4,199 | 3,356 | 3,208 | -8.8 |
| Semiconductor Content ($) | 43 | 42 | 42 | 43 | 43 | 43 | 45 | 1.4 |
| Semiconductor Market ($M) | 359 | 509 | 644 | 739 | 634 | 535 | 507 | -0.1 |
| **Digital Production** | | | | | | | | |
| Total Digital Shipments (K) | 156 | 579 | 1,297 | 4,239 | 10,445 | 21,474 | 27,146 | 115.9 |
| Digital Factory ASP ($) | 810 | 500 | 420 | 361 | 308 | 261 | 232 | -14.3 |
| Handset Factory Revenue ($M) | 126 | 290 | 545 | 1,531 | 3,221 | 5,612 | 6,285 | 85.0 |
| Total Semiconductor Content ($) | 215 | 135 | 115 | 99 | 86 | 73 | 66 | -13.4 |
| Baseband Content ($) | 110 | 66 | 55 | 50 | 43 | 37 | 33 | -12.8 |
| RF/IF Content ($) | 74 | 49 | 42 | 34 | 30 | 26 | 23 | -14.0 |
| Other Content ($) | 32 | 21 | 18 | 15 | 13 | 11 | 10 | -14.0 |
| Semiconductor Market ($M) | 33 | 78 | 149 | 420 | 895 | 1,573 | 1,782 | 86.9 |
| Baseband Market ($M) | 17 | 38 | 72 | 214 | 451 | 786 | 896 | 88.2 |
| RF/IF Market ($M) | 11 | 28 | 54 | 144 | 311 | 551 | 620 | 85.6 |
| Other Markets ($M) | 5 | 12 | 23 | 62 | 133 | 236 | 266 | 85.6 |
| **Total Production** | | | | | | | | |
| Shipments (K) | 8,515 | 12,697 | 16,636 | 21,433 | 25,180 | 33,906 | 38,402 | 24.8 |
| Factory ASP ($) | 455 | 424 | 360 | 328 | 295 | 265 | 247 | -10.2 |
| Handset Factory Revenue ($M) | 3,871 | 5,379 | 5,990 | 7,033 | 7,420 | 8,968 | 9,493 | 12.0 |
| Semiconductor Content ($) | 46 | 46 | 48 | 54 | 61 | 62 | 60 | 5.2 |
| Semiconductor Market ($M) | 393 | 587 | 793 | 1,159 | 1,528 | 2,108 | 2,289 | 31.3 |

Source: Dataquest (November 1995)

opportunity it drives is shown in Table 5-7. Table 5-8 provides an estimate of the market revenue generated by investments in the U.S. cellular infrastructure. This table does not include additional investment that will be made for the new PCS infrastructure.

### Table 5-7
### Worldwide GSM Infrastructure Equipment Market Forecast (Millions of Dollars)

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|
| Revenue | 1,742 | 3,100 | 5,253 | 7,068 | 9,567 | 12,718 | 12,360 | 31.9 |
| Semiconductor Market | 87 | 160 | 280 | 389 | 541 | 742 | 741 | 35.9 |

Source: Dataquest (November 1995)

### Table 5-8
### U.S. Cellular Infrastructure Equipment Market Forecast*

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|
| Base Stations | | | | | | | | |
| Shipments (K) | 3,884 | 6,623 | 7,661 | 9,148 | 11,404 | 13,215 | 15,581 | 18.7 |
| Factory ASP ($K) | 350 | 350 | 343 | 336 | 321 | 315 | 308 | -2.5 |
| Factory Revenue ($M) | 1,359 | 2,318 | 2,628 | 3,075 | 3,661 | 4,157 | 4,803 | 15.7 |
| Semiconductor Content ($K) | 17.5 | 18.1 | 18.3 | 18.5 | 18.2 | 18.4 | 18.5 | 0.5 |
| Semiconductor Market ($M) | 68 | 120 | 140 | 169 | 207 | 243 | 288 | 19.2 |
| Microcells | | | | | | | | |
| Shipments (K) | 254 | 277 | 2,910 | 2,591 | 3,877 | 5,368 | 4,240 | 72.6 |
| Factory ASP ($K) | 100 | 100 | 130 | 150 | 150 | 150 | 150 | 8.4 |
| Factory Revenue ($M) | 25 | 28 | 378 | 389 | 582 | 805 | 636 | 87.2 |
| Semiconductor Content ($K) | 6 | 6.2 | 8.2 | 9.8 | 10 | 10.2 | 10.5 | 11.3 |
| Semiconductor Market ($M) | 2 | 2 | 24 | 25 | 39 | 55 | 45 | 92.0 |

*Does not include equipment for PCS (2 GHz) base stations
Source: Dataquest (November 1995)

## Market and Brand Share Leaders

Table 5-9 presents the worldwide market share for cellular/PCS handsets. Table 5-10 lists the unit and revenue brand share leaders for cellular telephones in the U.S. market for the period of the third quarter of 1994 through the second quarter of 1995.

**Table 5-9**
**Worldwide Cellular Telephone Market Share, 1994**

| Manufacturer | Shipments (K) | Unit Market Share (%) |
|---|---|---|
| Motorola | 8,906.1 | 32.5 |
| Nokia | 5,740.8 | 21.0 |
| Ericsson | 2,980.8 | 10.9 |
| NEC | 2,433.9 | 8.9 |
| Panasonic | 1,476.0 | 5.4 |
| Mitsubishi | 1,201.2 | 4.4 |
| Oki | 889.5 | 3.2 |
| Others | 3,768.4 | 13.8 |
| Total | 27,396.6 | 100.0 |

Source: Dataquest (November 1995)

**Table 5-10**
**U.S. Cellular Telephone Brand Share Leaders, Third Quarter 1994 through Second Quarter 1995 (Percent)**

| Brand | Unit Market Share | Revenue Market Share |
|---|---|---|
| Motorola | 53.4 | 57.0 |
| AT&T | 7.4 | 7.3 |
| Nokia-Mobira | 5.6 | 4.5 |
| Cellular One | 4.4 | 4.3 |
| NEC | 3.8 | 3.5 |
| Radio Shack | 3.3 | 3.0 |
| Audiovox | 2.6 | 2.7 |
| Uniden | 1.8 | 1.4 |
| GE/Ericsson | 1.7 | 1.9 |
| Panasonic | 1.6 | 1.4 |
| Others* | 14.4 | 13.0 |
| Total | 100.0 | 100.0 |

*Others include Blaupunkt, Hughes, JVC, Mitsubishi, Muratec, Novatel, Omni, Pioneer, Qualcomm, Technophone, and Toshiba
Source: The Scout Report®/The Polk Company

## Feature and Technology Trends

Since the commercial launch of cellular systems in the early 1980s there have been a number of different regional analog cellular systems, and these are reviewed in Table 5-11. Some of the technical differences between the digital cellular and cordless standards are highlighted in Table 5-12.

**Table 5-11**
**Analog Cellular Network Standards**

| | AMPS | TACS | NMT-450 | NMT-900 |
|---|---|---|---|---|
| Frequency Band (MHz) | | | | |
| Tx | 824-849 | 871-904 | 453-456 | 890-915 |
| Rx | 869-894 | 916-949 | 463-468 | 935-960 |
| Carrier Spacing (kHz) | 30 | 25 | 25 | 12.5 |
| Access Method | FDMA | FDMA | FDMA | FDMA |
| Modulation Scheme | PSK | PSK | FFSK | FFSK |
| Implementation | Australia<br>Canada<br>Hong Kong<br>Japan<br>United States | Greece<br>Italy<br>Spain<br>United Kingdom | Austria<br>Belgium<br>Scandinavia | Netherlands<br>Scandinavia<br>Switzerland |

AMPS = Advanced mobile phone system
FDMA = Frequency-division multiple access
FFSK = Fast frequency shift keying
PSK = Phase shift keying
TACS = Total access communications system
Source: Dataquest (November 1995)

**Table 5-12**
**Digital Cellular and Digital Cordless Standards, Technical Differences**

| | GSM[1] | DCS-1800[2] / PCS-1900 | IS-54/IS-136 | PDC[3] | IS-95 | CT2[4] | DECT[5] | PHS[6] |
|---|---|---|---|---|---|---|---|---|
| Region | Europe<br>Other regions | Europe<br>United States | United States | Japan | United States<br>Asia | United Kingdom (Telepoint)<br>Canada<br>France (Telepoint)<br>Hong Kong<br>Singapore | Europe | Japan<br>Hong Kong |
| Frequency | 935-960 MHz<br>890-915 MHz | 1.7-1.9 GHz<br>1.8-2.0 GHz | 824-849 MHz<br>869-894 MHz<br>1.8-2.0 GHz | 810-826 MHz<br>940-956 MHz<br>1429-1441 MHz<br>1447-1489 MHz<br>1501-1513 MHz | 824-849 MHz<br>869-894 MHz<br>1.8-2.0 GHz | 864-868 MHz | 1.88-1.9 GHz | 1.9 GHz |
| Access Method | TDMA[7] | TDMA | TDMA | TDMA | CDMA | TDMA | TDD/TDMA | TDD/TDMA |
| Modulation | GMSK[8] | GMSK | π/4 DQPSK[9] | π/4 DQPSK | QPSK[10]<br>DQPSK | Two-level GFSK | GMSK | π/4 DQPSK |
| Speech CODEC | RPE-LTP[11]<br>8/13 Kbps | RPE-LTP<br>8/13 Kbps | VSELP[12]<br>7.25/13 Kbps | VSELP/PSI-CELP<br>11.2/5.6 Kbps | ADPCM[13]<br>8.55/13 Kbps | ADPCM<br>32 Kbps | ADPCM<br>32 Kbps | ADPCM<br>32 Kbps |
| Output Power | 20mW to 20W | 2.5mW to 1W | 2.2mW to 6W | Up to 2W | 0.2W to 6.3W | 1mW to 10mW | 250mW | 10mW (Indoor)<br>500mW (Outdoor) |
| Channel Spacing | 200 kHz | 200 kHz | 30 kHz | 25 kHz | 1.23 MHz | 100 kHz | 1.728 MHz | 300 kHz |
| Number of Frequencies | 124 | 374 | 832 | 1,600 | 10 | 40 | 10 | 40 |
| Time Slots | 8 | 8 | 3 | 3 | NA | 2 (TDMA)<br>40 (FDMA)[14] | 24 (2 x12) | 8 (2 x4) |

NA = Not applicable
[1]Global system mobile
[2](PCN) digital cellular
[3]Personal/Pacific digital cellular
[4]Digital cordless telephone
[5]Digital European cordless
[6]Japanese digital cordless Personal Handyphone System
[7]Time-division multiple access
[8]Gaussian mean shift keying
[9]Differential quadrature phase shift keying
[10]Quadrature phase shift keying
[11]Regular pulse excitation, long-term prediction
[12]Vector sum excited linear predictive coding
[13]Adaptive differential pulse-code modulation
[14]Frequency-division multiple access
Source: Dataquest (November 1995)

Countries that use AMPS cellular systems, according to *Cellular Business,* are as follows:

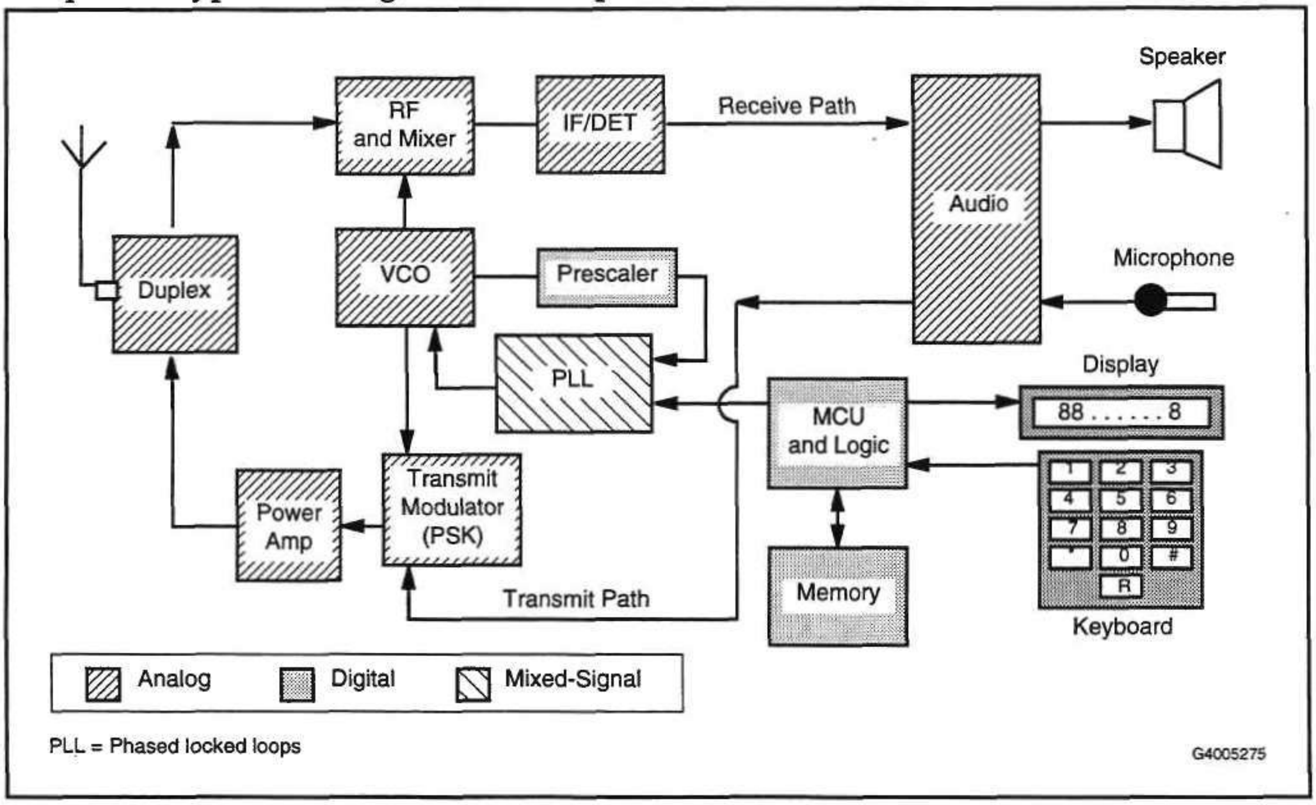
- Anguilla
- Antigua
- Argentina
- Aruba
- Australia
- Bahamas
- Bangladesh
- Barbados
- Barbuda
- Belize
- Bermuda
- Bolivia
- Brazil
- Brunei
- Cambodia
- Canada
- Cayman Islands
- Chile
- China
- Colombia
- Costa Rica
- Cote d'Ivoire
- Cuba
- Curacao
- Dominican Republic
- Ecuador
- El Salvador
- Fiji
- Gabon
- Ghana
- Grenada
- Guadeloupe
- Guam
- Guatemala
- Guyana
- Hong Kong
- Indonesia
- Israel
- Jamaica
- Kazakhstan
- Korea
- Laos
- Lebanon
- Malaysia
- Mexico
- Montserrat
- Myanmar
- Netherlands Antilles
- New Zealand
- Nicaragua
- Pakistan
- Paraguay
- Peru
- Philippines
- Russia
- Samoa (American)
- Singapore
- St. Kitts/Nevis
- St. Lucia/St. Vincent/Grenadines
- St. Martin/Bartholemy
- Suriname
- Taiwan
- Thailand
- Trinidad & Tobago
- Turks/Caicos
- United States
- Uruguay
- Venezuela
- Vietnam
- Virgin Islands
- Zaire

Figures 5-5 and 5-6 show an AMPS (analog) cellular and a dual-mode (digital) phone (based on TDMA or CDMA access). A digital or dual-mode phone can be separated into two major sections, the baseband and the RF or access arrangement. New designs of these phones will reduce the chip count to 4 or 5 chips, from earlier designs that use 8 to 12 ICs and dozens of discrete components and passive filters. In digital cellular and PCS, the baseband and transmission/reception section of the phone deal primarily with digitized bit streams. There are six major functions in the baseband section and each one could be an individual DSP-based IC, as follows:

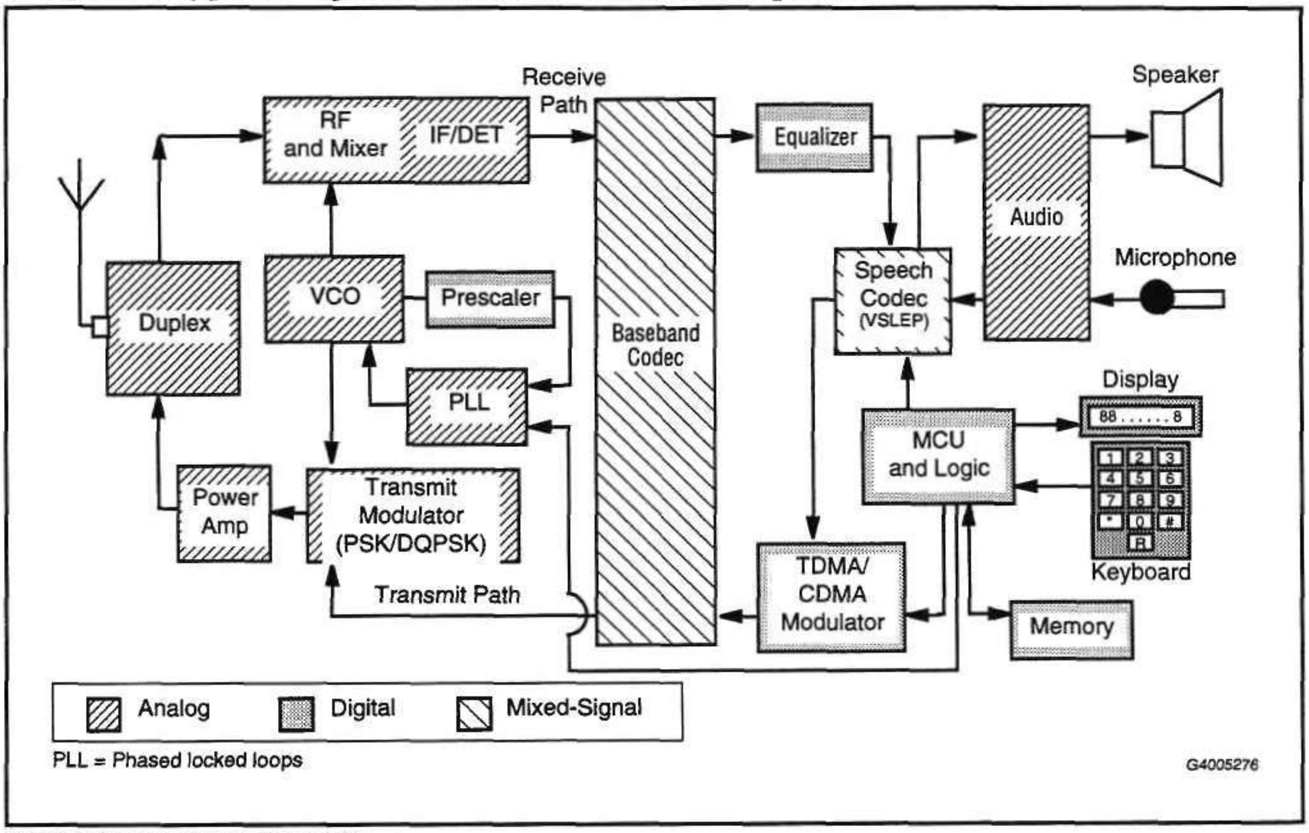
- Audio interface/CODEC—manages amplification, signal conditioning, A/D, and D/A to the handset speaker and microphone. This functionality can also include the full duplex speakerphone circuit and voice recognition circuits.
- Vocoder—encodes and compresses the digitized voice according to specification, such as vector sum excited linear predictive coding (VSELP) for the IS-54.
- Baseband CODEC—takes the compressed voice bit stream (or data stream) and prepares it for the transmission by putting it into the right time slot for TDMA or several channels according to CDMA. Dual-mode and AMPS phones also use FDMA channelization.
- Modem—optional for accepting computer bit streams and converts them for transmission over voice channel. It can include "packetizing" for the new data standards like cellular digital packet data (CDPD at 108 bytes per packet) or Mobitex.

**Figure 5-5**
**Simplified Typical Analog Cellular Telephone**




Source: Dataquest (November 1995)

**Figure 5-6**
**Simplified Typical Digital/Dual-Mode Cellular Telephone**




Source: Dataquest (November 1995)

- Microcontroller—8-bit or 16-bit for handling dialer, ringer, and LCD control and interface.
- Memory—either a 64K EEPROM/flash for user presets; SRAM (32K×8) for the same purpose or for a scratch pad.

The RF or access arrangement section has two major functions, transmission and reception, and involves at least six ICs and numerous discrete transistors and diodes (including gallium arsenide [GaAs] versions), passive filters, and oscillators. There are three major functions in the RF section:

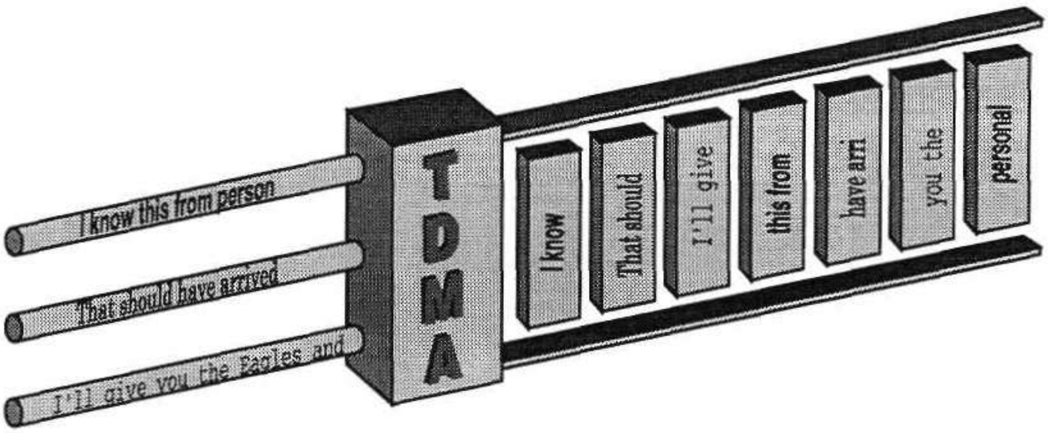
- Differential quadrature phase shift keying (DQPSK) transmitter and receiver, which handle many of the transceiver modulation functions. Dual-mode and AMPS phones use phase shift keying for modulation as well.
- Phase locked loops (at least two), prescalers, and a voltage-controlled oscillator (VCO) for generating necessary frequency signals.
- Power amplifier for transmission and a low-noise amplifier for reception.

The principal contenders for digital encoding are TDMA, extended-TDMA (E-TDMA), and CDMA. Figure 5-7 provides an illustration of how these technologies work. In converting to digital encoding it is necessary that both the base station equipment at the service provider and the subscriber handsets have the same standard. It has been decided that a new

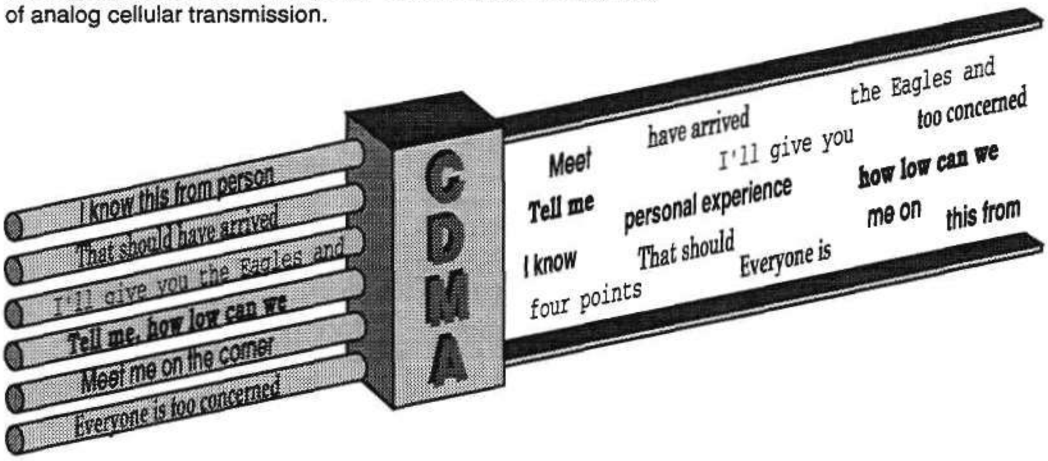
  

## Figure 5-7
## TDMA and CDMA Digital Transmission Technologies

Two emerging forms of digital transmission can save spectrum space in both cellular phones and the PCS of the future. Time division multiple access (TDMA) chops calls into pieces of data that are identified on the receiving end by the time slots to which they are assigned. TDMA enables one wireless channel to handle several calls.




The second technology, code division multiple access (CDMA), spreads its pieces of calls across a wide swath of communications frequencies. The fragments carry a code identifying their phone of origin, and the receiving station uses the code to identify and reconstitute the original signal. CDMA may offer 10 to 20 times the capacity of analog cellular transmission.




Source: Eric Zimits, Volpe, Welty & Co.

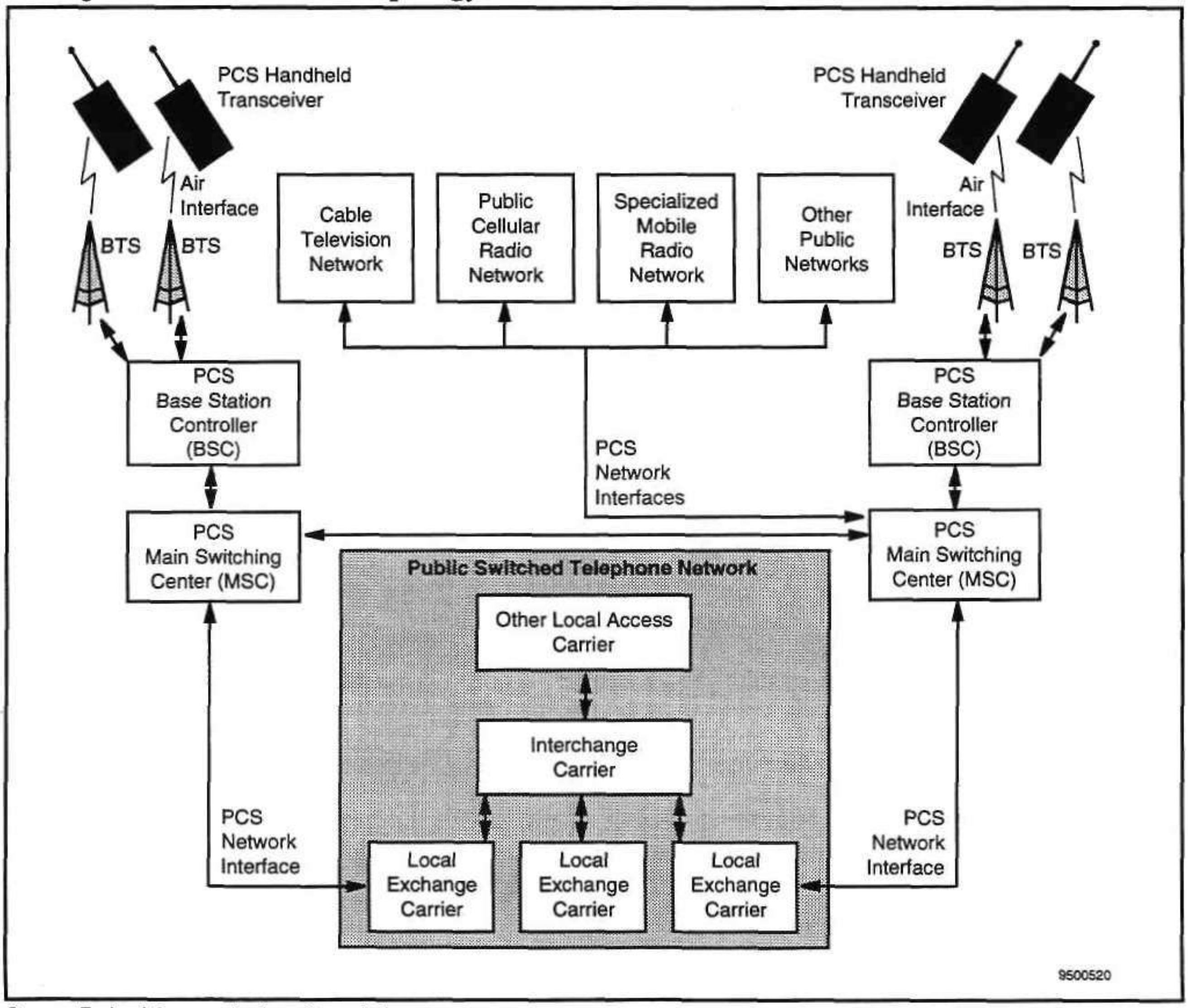
9500515

Source: Eric Zimits, Volpe, Welty & Co.

digital system will be backwardly compatible with AMPS. This is forcing the carriers to use dual-mode technology capable of AMPS and either TDMA or CDMA, the leading digital contenders. Figure 5-8 shows an example of a PCS network topology.

The CTIA has endorsed the use of dual-mode technology based on TDMA. This combination is also known as standard IS-54. A new enhanced standard based on IS-54 was introduced this year. This standard, called IS-136, provides improved voice quality and power savings. TDMA, as the name implies, provides time slots for various users and can achieve a threefold improvement in time capacity over AMPS. The major equipment backers of TDMA include AT&T, Ericsson-GE (joint venture), and Motorola-Nortel (joint venture for base stations). Some of the basic patents for TDMA are controlled by InterDigital Communications (King of Prussia, Pennsylvania).

**Figure 5-8**
**Example of PCS Network Topology**



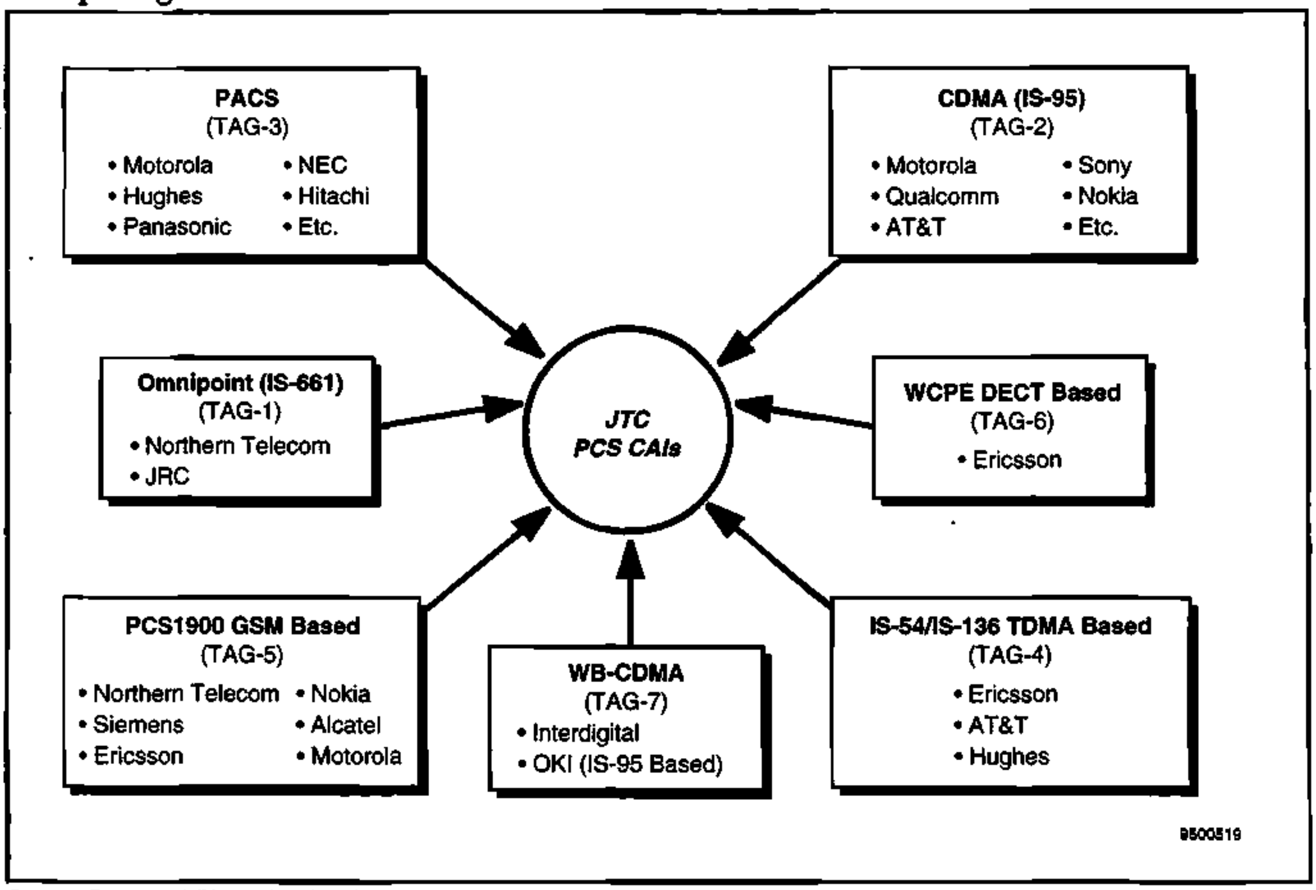

Source: Federal Communications Commission

CDMA technology has also been endorsed as a standard and has been labeled IS-95. CDMA employs spread-spectrum techniques. According to a key patent holder and licenser, Qualcomm of San Diego, California, CDMA has the capability of improving channel capacity 10 or 20 times over AMPS. CDMA backers include AT&T, Ericsson-GE, Motorola, and Qualcomm.

In addition to the IS-54/IS-136 and IS-95 standards, there are a number of other standards competing for the PCS market in the United States. The most recent standard to receive interim status approval is the Omnipoint standard, which employs a combination of TDMA, CDMA, and frequency division (FDMA) technologies. This standard has been labeled IS-661. The PCS-1900 technology is based on the GSM standard and uses TDMA technology. The PACS and WCPE standards are also gaining some momentum for use in low-mobility applications. Figure 5-9 illustrates the competing U.S. standards and some of their principal supporters. Table 5-13 lists the digital technology endorsements by major U.S. mobile carriers and winners of the first broadband PCS auction.

Dataquest believes that both TDMA and CDMA dual-mode cellular telephone systems will coexist. CDMA apparently has superior capacity and power performance, and recent test results indicate that TDMA is subject to warbling or distortion. Many of the service providers admit that CDMA is superior but that time-to-market pressures have forced them to adopt TDMA.

**Figure 5-9**
**Competing PCS Standards**




Source: Dataquest (November 1995)

**Table 5-13**
**Major Cellular/PCS Players and Their Technology Selections**

| Service Provider | North American TDMA | CDMA | PCS-1900 (GSM) |
|---|---|---|---|
| **Cellular** | | | |
| AirTouch Cellular | | X | |
| Ameritech Cellular | | X | |
| Bell Atlantic Mobile | | X | |
| BellSouth Cellular | X | | |
| GTE Mobilnet | | X | |
| McCaw Cellular | X | | |
| NYNEX Mobile | | X | |
| Southwestern Bell Mobile | X | | |
| Sprint Cellular | | X* | |
| **PCS** | | | |
| APC | | | X |
| AT&T Wireless | X | | |
| BellSouth | | | X |
| GTE Macro | | X | |
| PCS PrimeCo | | X | |
| Pacific Telesis | | | X |
| Sprint Telecom Venture (WirelessCo) | | X* | |
| Western Wireless | | | X |

*Negotiating with CDMA vendors
Source: Dataquest (November 1995)

As stated previously, digital cellular handsets based on GSM technology represent the large majority of digital cellular telephones. The unified European standard has enabled strong growth in this market. Some of the countries that operate or plan to operate GSM systems are as follows:

- Australia
- Austria
- Bahrain
- Belgium
- Cameroon
- China
- Cyprus
- Denmark
- Egypt
- Finland
- France
- Germany
- Greece
- Hong Kong
- Hungary
- India
- Indonesia
- Iran
- Ireland
- Italy
- Kuwait
- Laos
- Lebanon
- Luxembourg
- Malaysia
- Morocco
- Netherlands
- New Zealand
- Norway
- Oman
- Pakistan
- Philippines
- Portugal
- Qatar
- Russia
- Saudi Arabia
- Singapore
- South Africa
- Spain
- Sweden
- Switzerland
- Syria
- Taiwan
- Thailand
- Turkey
- United Arab Emirates
- United Kingdom
- Vietnam

There is much activity to reduce component count in these systems. Table 5-14 shows the semiconductor technology solutions for second-generation handsets. Figure 5-10 is a block diagram of a second-generation GSM telephone that supports voice and data services. Figure 5-11 shows a block diagram for a CDMA handset.

Figures 5-12 and 5-13 present the radio frequency allocation for the new broadband PCS services and the overall wireless spectrum allocation for various wireless applications in the United States.

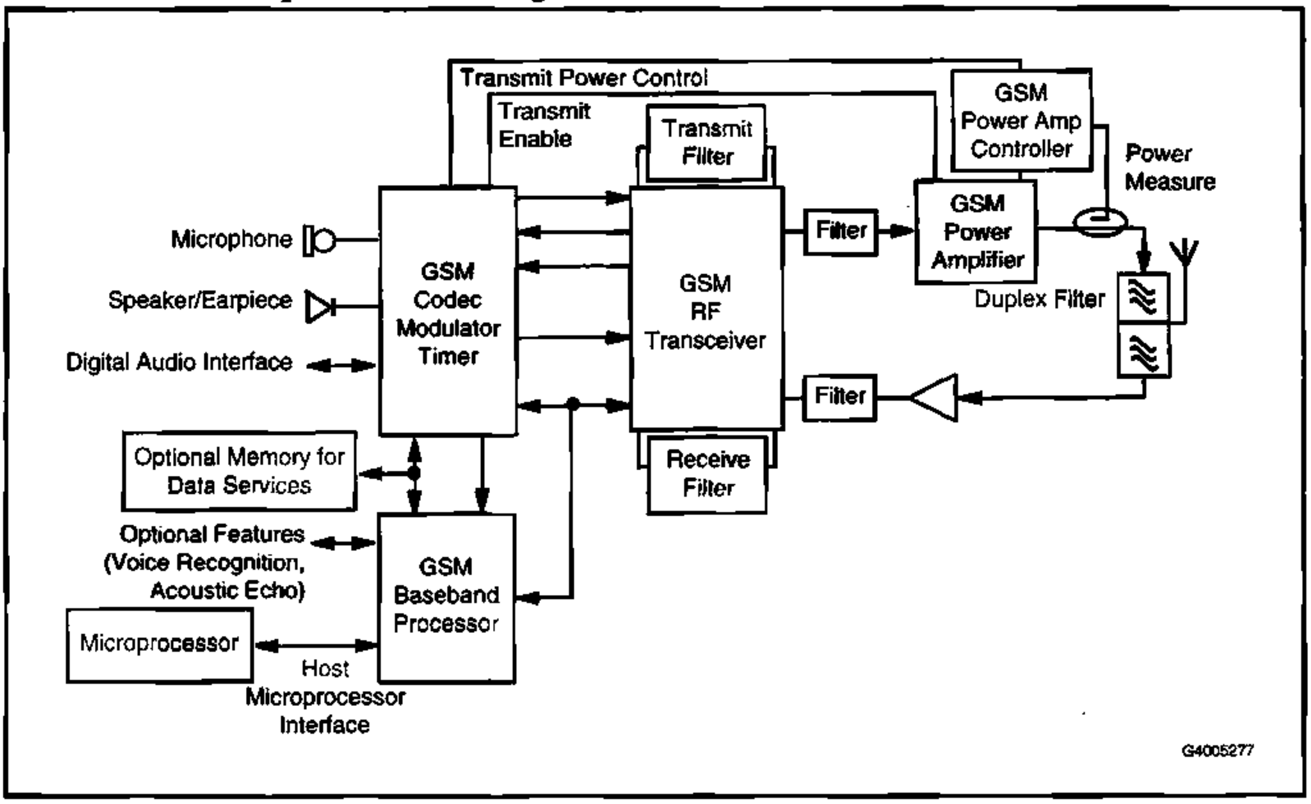
  

**Table 5-14**
**GSM Telephone Handset Semiconductor Devices**

| Function | No. of Devices | Semiconductor |
|---|---|---|
| Integrated Power Amplifier | 1 | Analog (GaAs) |
| RF Front End | 1 | RF linear |
| Baseband Processor | 1 | Mixed-signal (ASIC) |
| Channel Controller | 1 | MOS logic (ASIC) |
| Voice Processor | 1 | DSP |
| Audio I/O | 2 | Linear |
| Microcontroller/Microprocessor | 1 | MOS microcomponent |
| Flash EPROM (4Mb) | 2 | MOS memory |

Source: Dataquest (November 1995)

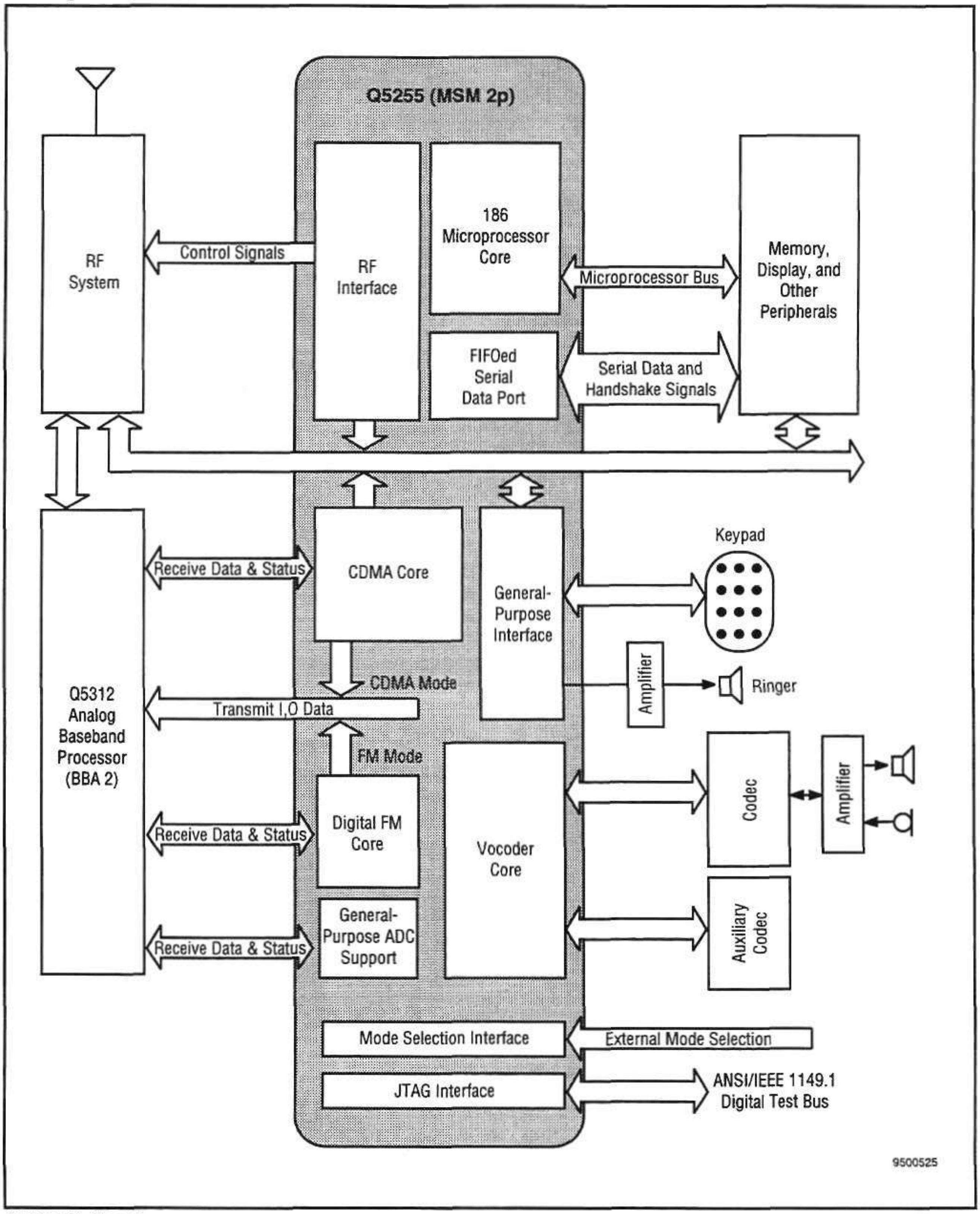
**Figure 5-10**
**GSM Cellular Telephone Block Diagram**




Source: AT&T Microelectronics

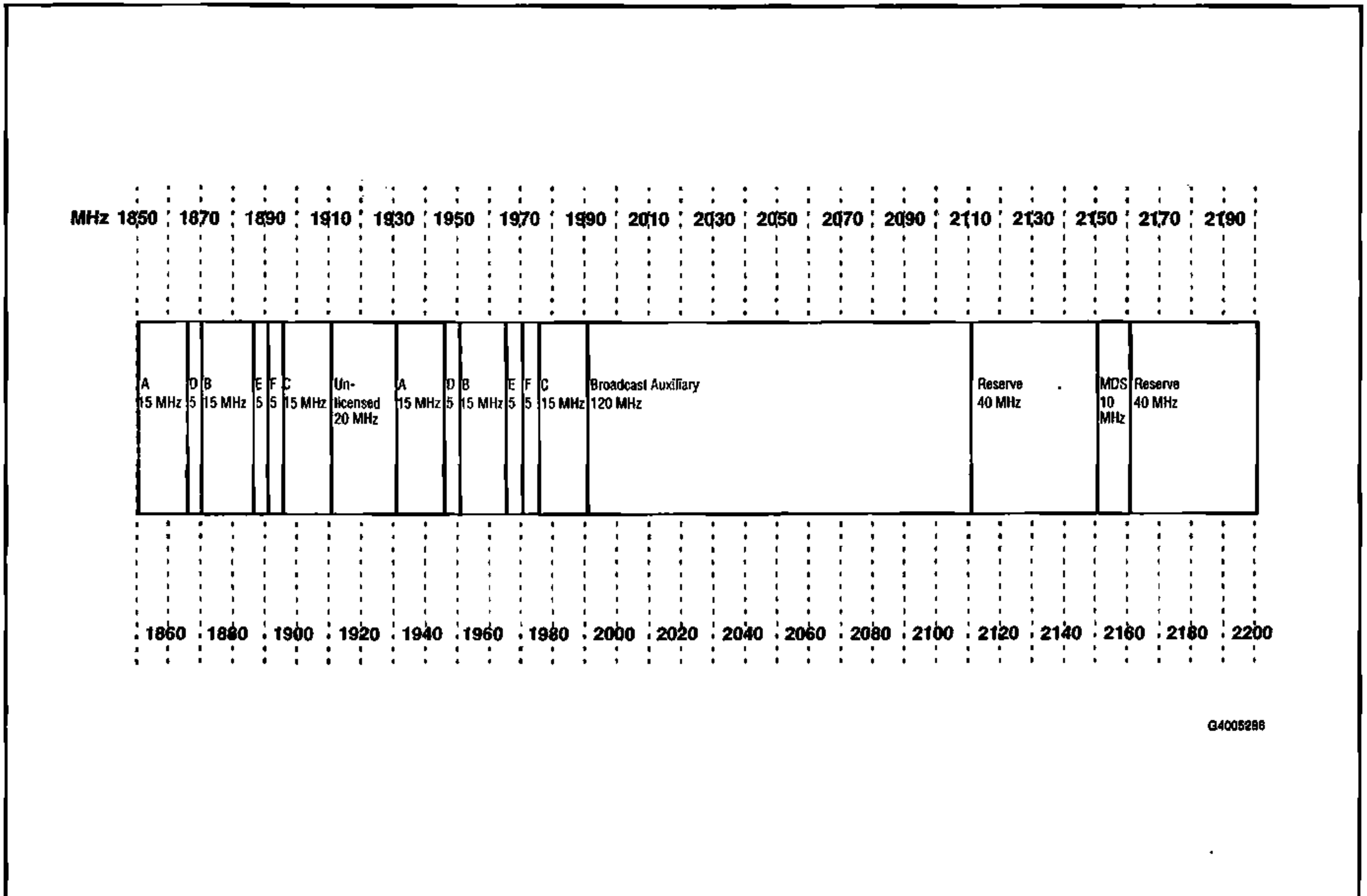
**Figure 5-11**
**Example of a CDMA Handset**




Source: Qualcomm

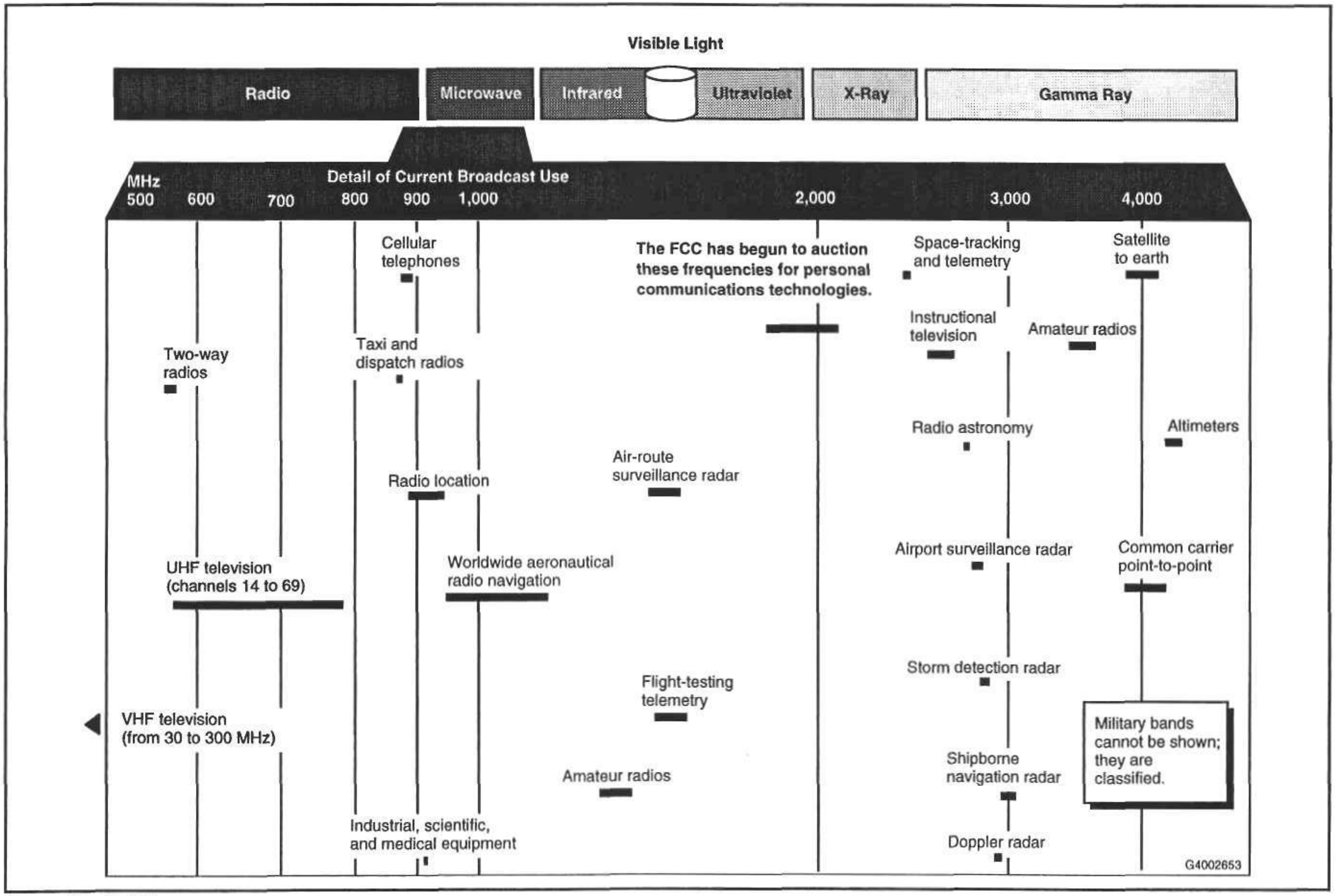
  

**Figure 5-12**
**Broadband PCS Spectrum Plan**




Source: Federal Communications Commission

**Figure 5-13**
**The Wireless Spectrum**



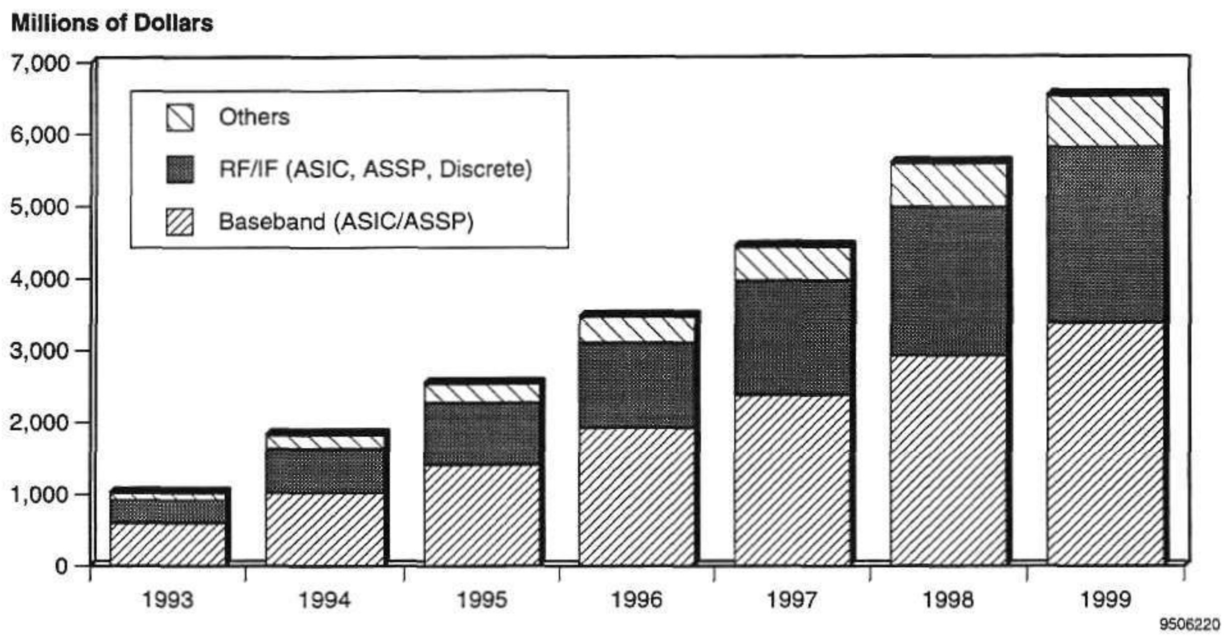

Source: *New York Times*

## Semiconductor Opportunities

Figure 5-14 and Table 5-15 show the worldwide cellular/PCS telephone handset semiconductor market forecast. Specific IC opportunities for digital cordless, cellular, and PCS telephones include:

- 3V versions of all activities
- Thin QFP packages for PCMCIA cards for PDAs
- Speech and baseband CODECs
- Speakerphone circuits
- TDMA/CDMA modulators
- CDPD/Mobitex modem/packetizer (for data communications)
- Phase locked loops/prescalers
- RF power/low-noise amps (902 to 928 MHz, 1.8 to 1.9 GHz)
- IF IC and discretes (oscillators, amps, frequency detection, and filters)
- 12-/24-bit MCU (with LCD driver)
- Voice recognizer (DSP based)
- Memory (EEPROM-serial, SRAM-optional, Flash)
- Various integrations of these

**Figure 5-14**
**Worldwide Cellular and Broadband PCS Telephone Handset Semiconductor Market**




Source: Dataquest (November 1995)

**Table 5-15**
**Worldwide Cellular and Broadband PCS Handset Semiconductor Market**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|
| **Analog** | | | | | | | | |
| Semiconductor Content ($) | 43 | 42 | 42 | 43 | 43 | 43 | 45 | 1.4 |
| Semiconductor Market ($M) | 700 | 1,052 | 1,225 | 1,309 | 1,179 | 1,059 | 1,060 | 0.1 |
| Baseband (ASIC/ASSP) ($M) | 431 | 664 | 773 | 822 | 768 | 690 | 660 | -0.1 |
| RF/IF (ASIC, ASSP, Discrete) ($M) | 201 | 291 | 339 | 365 | 308 | 277 | 300 | 0.6 |
| Others ($M) | 67 | 97 | 113 | 122 | 103 | 92 | 100 | 0.6 |
| **Digital/Dual-Mode** | | | | | | | | |
| Semiconductor Content ($) | 215 | 150 | 120 | 104 | 92 | 78 | 70 | -14.1 |
| Semiconductor Market ($M) | 338 | 822 | 1,395 | 2,282 | 3,441 | 4,779 | 5,767 | 47.7 |
| Baseband (ASIC/ASSP) ($M) | 173 | 359 | 642 | 1,106 | 1,616 | 2,242 | 2,719 | 49.9 |
| RF/IF (ASIC, ASSP, Discrete) ($M) | 116 | 324 | 527 | 823 | 1,278 | 1,775 | 2,134 | 45.8 |
| Others ($M) | 50 | 139 | 226 | 353 | 548 | 761 | 914 | 45.8 |
| **Total Cellular** | | | | | | | | |
| Semiconductor Content ($) | 58 | 61 | 64 | 69 | 71 | 68 | 64 | 1.0 |
| Semiconductor Market ($M) | 1,038 | 1,874 | 2,619 | 3,591 | 4,620 | 5,838 | 6,827 | 29.5 |
| Baseband (ASIC/ASSP) ($M) | 604 | 1,023 | 1,414 | 1,928 | 2,383 | 2,932 | 3,378 | 27.0 |
| RF/IF (ASIC, ASSP, Discrete) ($M) | 317 | 615 | 866 | 1,188 | 1,586 | 2,053 | 2,434 | 31.7 |
| Others ($M) | 100 | 190 | 264 | 357 | 468 | 600 | 710 | 30.2 |

Source: Dataquest (November 1995)

## Chapter 6

# Pagers (One- and Two-Way)

## Market and Production Trends

New technologies and services have revitalized the pager market, with pager subscriptions growing at a record pace as shown in Table 6-1 and Figure 6-1. Worldwide pager production is forecast to grow by 11.3 percent CAGR during the next five years (see Table 6-2 and Figure 6-2). Table 6-3 shows the North American pager production forecast. Pagers have moved from serving as simple "beepers" to playing a role in future PCS markets delivering text messages, providing limited two-way messaging, and offering nationwide coverage. There were more than 70 million pager users worldwide by the end of 1994. The number of pager subscribers worldwide is growing at a strong pace, with soaring subscriber populations in the Asia/Pacific region. U.S. subscriptions to one-way pager services grew by a record-breaking 7.5 million in 1994 and are expected to grow another 7.5 million in 1995 (see Figure 6-3). Shipments of one-way alphanumeric pagers in North America are forecast to grow by 37.2 percent CAGR through 1999 as pager subscribers take advantage of new services.

Most traditional paging services cover only local or regional areas. The 10 largest paging service providers controlled almost 45 percent of the U.S. market in 1993. National paging service providers are making significant gains, with about 5 percent of pager subscribers using nationwide services. The big three of the nationwide paging networks are SkyTel, MobileComm, and PageNet.

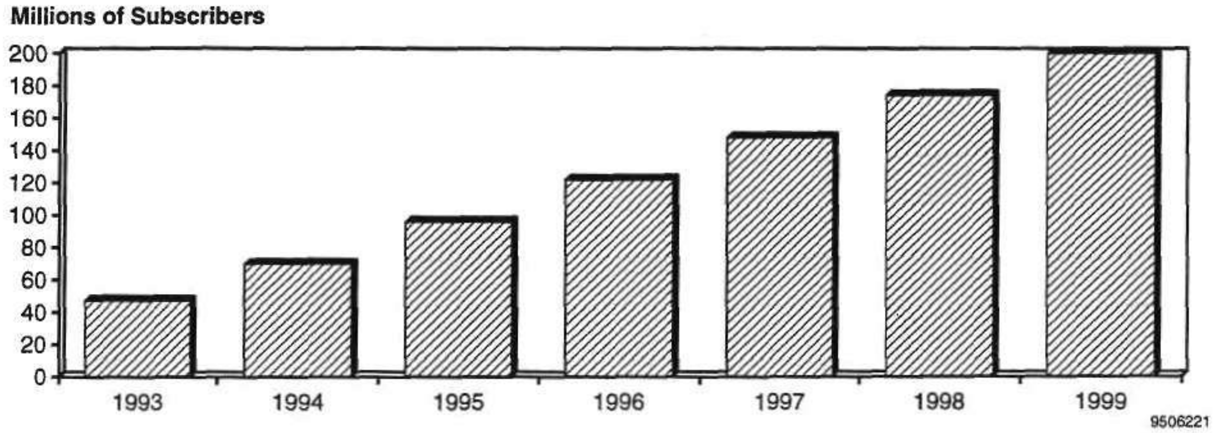
Perfectly timed to build on the rising swell of subscribers in the paging market, two rounds of auctions for narrowband PCS licenses in the United States were completed during 1994. The winners of these auctions are shown in Table 6-4. By September 18, SkyTel had announced the availability of the first nationwide two-way paging service. Several new competitors are expected to enter the market during 1996. The new services that will be enabled by narrowband PCS technology include two-way messaging, acknowledgment paging, enhanced voice messaging (mobile answering machine), facsimile transmission, and e-mail communications. Figure 6-4 provides an illustration of how new advanced messaging networks will operate. While traditional paging services are predicted to reach 50 million subscribers by 1999, demand for narrowband PCS services will add another 11 million subscribers to the overall pager market by then. Also, Canada is already proceeding with plans for similar services. American Paging and Upper Canada Communications have entered into an agreement to coordinate development of narrowband PCS services. This alliance has gained approval from the FCC and Industry Canada to construct and operate transmitters that will allow it to develop a North American network using matching frequencies. Table 6-5 and Figure 6-5 show the forecast for the North American paging market.

## Table 6-1
## Worldwide Pager Market (One-Way and Two-Way)

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|
| Subscribers (M) | 47 | 70 | 96 | 122 | 148 | 174 | 200 | 23.4 |
| Units (K) | 19,630 | 30,043 | 38,806 | 44,099 | 48,750 | 51,141 | 52,603 | 11.9 |
| Factory ASP ($) | 76 | 74 | 71 | 70 | 73 | 76 | 76 | 0.6 |
| Factory Revenue ($M) | 1,489 | 2,210 | 2,766 | 3,103 | 3,540 | 3,883 | 3,982 | 12.5 |

Source: Dataquest (November 1995)

## Figure 6-1
## Worldwide Pager Market (One-Way and Two-Way)




Source: Dataquest (November 1995)

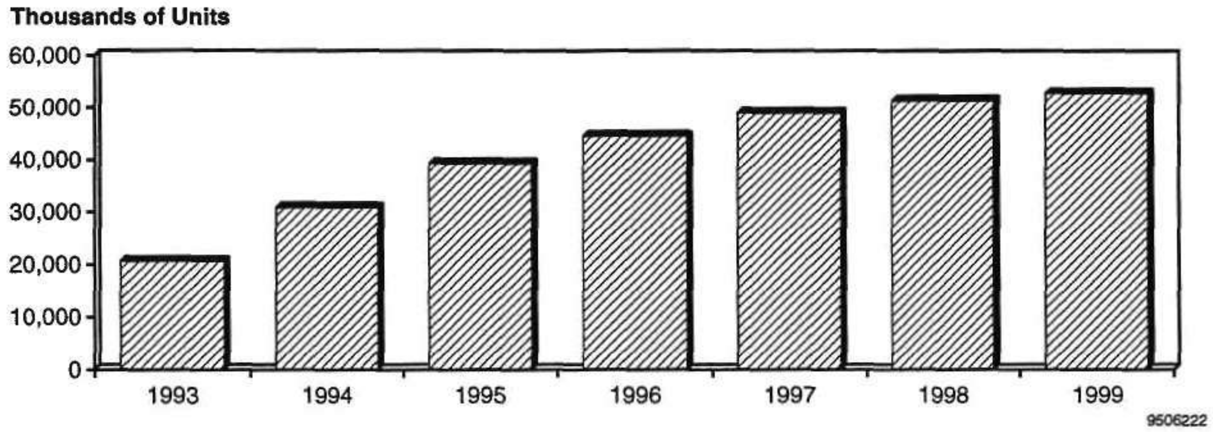
## Table 6-2
## Worldwide Pager Production

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|
| Units (K) | 20,672 | 30,919 | 39,336 | 44,564 | 48,989 | 51,287 | 52,768 | 11.3 |
| Factory ASP ($) | 76 | 74 | 71 | 70 | 73 | 76 | 76 | 0.6 |
| Factory Revenue ($M) | 1,568 | 2,275 | 2,804 | 3,135 | 3,558 | 3,894 | 3,994 | 11.9 |
| Semiconductor Content ($) | 14 | 13 | 13 | 13 | 14 | 14 | 15 | 2.3 |
| Semiconductor Market ($M) | 285 | 404 | 515 | 593 | 665 | 738 | 774 | 13.9 |

Source: Dataquest (November 1995)

**Figure 6-2**
**Worldwide Pager Production**




Source: Dataquest (November 1995)

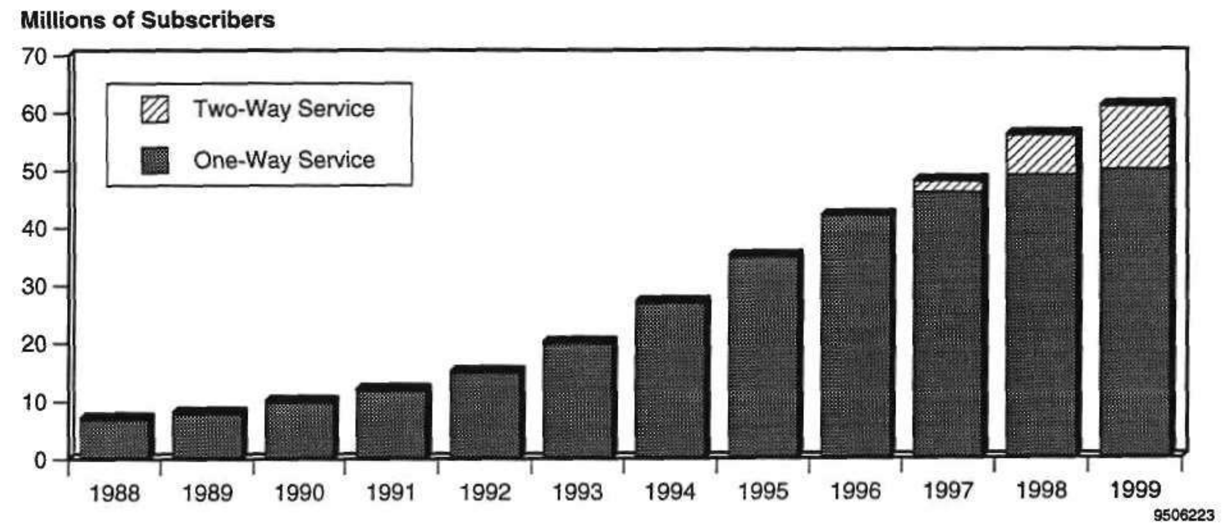
**Table 6-3**
**North American Production of One-Way and Two-Way Pagers**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|
| **One Way Pagers** | | | | | | | | |
| Units (K) | 7,517 | 11,720 | 13,363 | 14,088 | 12,295 | 10,780 | 10,665 | -1.9 |
| Factory ASP ($) | 78 | 75 | 74 | 73 | 74 | 77 | 81 | 1.5 |
| Factory Revenue ($M) | 588 | 878 | 989 | 1,029 | 910 | 833 | 860 | -0.4 |
| Semiconductor Content ($) | 12 | 12 | 12 | 13 | 13 | 14 | 14 | 3.1 |
| Semiconductor Market ($M) | 90 | 141 | 160 | 176 | 160 | 146 | 149 | 1.2 |
| **Two-Way Pagers/ Narrowband PCS** | | | | | | | | |
| Units (K) | - | 3 | 41 | 327 | 2,122 | 4,878 | 5,046 | 347.9 |
| Factory ASP ($) | - | 193 | 192 | 179 | 167 | 155 | 151 | -4.8 |
| Factory Revenue ($M) | - | 1 | 8 | 59 | 354 | 755 | 761 | 326.3 |
| Semiconductor Content ($) | - | 18 | 18 | 20 | 21 | 22 | 22 | 4.3 |
| Semiconductor Market ($M) | - | 0 | 1 | 6 | 44 | 105 | 112 | 367.1 |
| **Total Pagers** | | | | | | | | |
| Units (K) | 7,517 | 11,723 | 13,405 | 14,415 | 14,418 | 15,657 | 15,712 | 6.0 |
| Factory ASP ($) | 78 | 75 | 74 | 75 | 88 | 101 | 103 | 6.6 |
| Factory Revenue ($M) | 588 | 878 | 996 | 1,087 | 1,265 | 1,588 | 1,620 | 13.0 |
| Semiconductor Content ($) | 12 | 12 | 12 | 13 | 14 | 16 | 17 | 6.7 |
| Semiconductor Market ($M) | 90 | 141 | 161 | 182 | 204 | 250 | 261 | 13.2 |

Source: Dataquest (November 1995)

**Figure 6-3**
**U.S. Pager Subscribers**



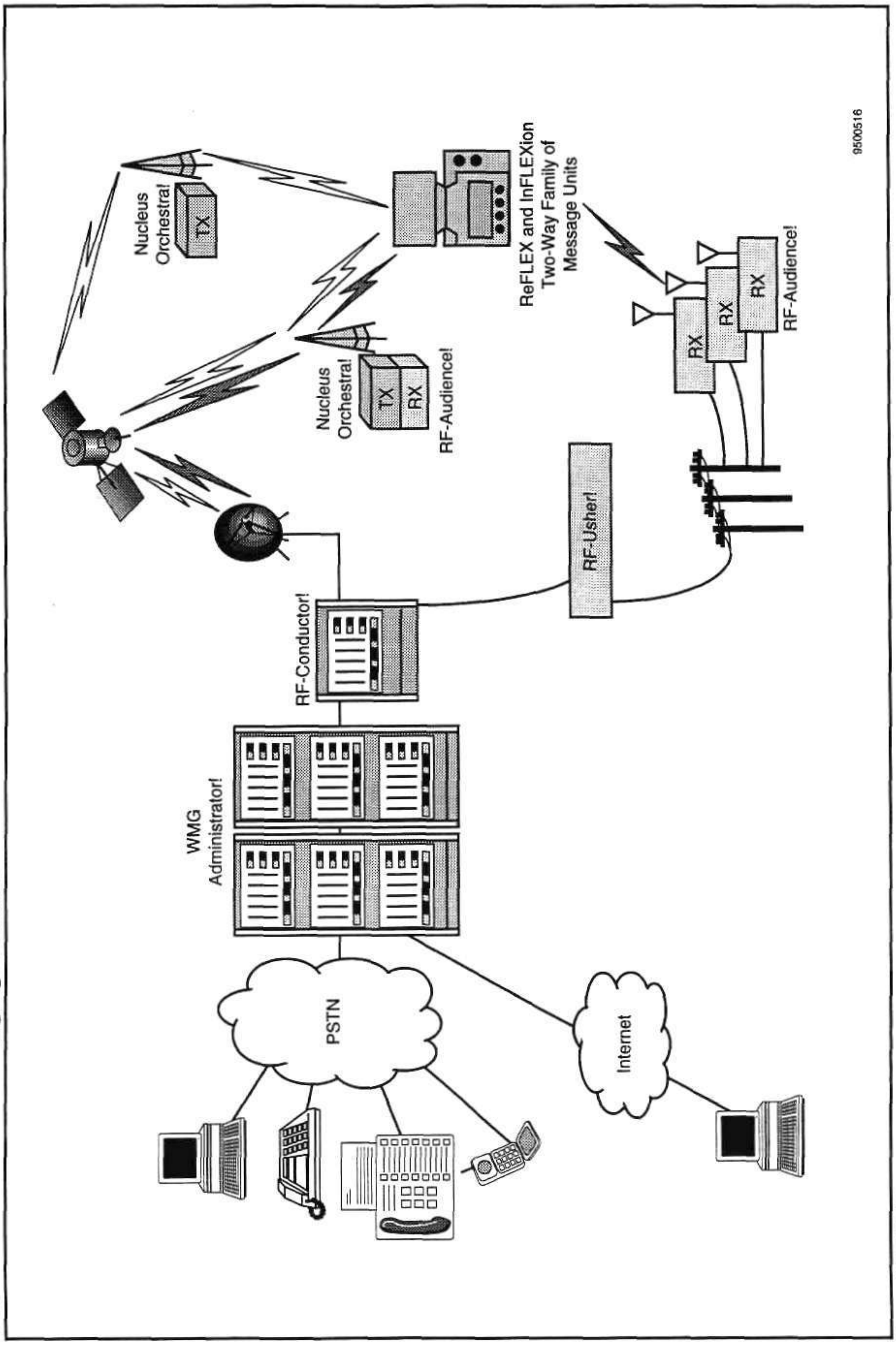

Source: Dataquest (November 1995)

**Table 6-4**
**U.S. Narrowband PCS Auction Winners**

| National Licenses | Regional Licenses |
|---|---|
| PageNet | PageMart II (All Five Regions) |
| AT&T Wireless | PCS Development (All Five Regions) |
| SkyTel (MTel) | MobileMedia PCS (All Five Regions) |
| AirTouch Paging | American Paging (All Five Regions) |
| BellSouth Wireless | AirTouch Paging (Three Regions) |
| PageMart II | Adelphia Communications (Lisa-Gaye Shearing) (Three Regions) |
| | Benbow PCS Ventures (Two Regions) |
| | Ameritech Mobile Services (One Region) |
| | Insta-Check Systems (One Region) |

Source: Dataquest (November 1995)

**Figure 6-4**
**Motorola's Advanced Messaging Solution**




Source: Motorola Inc.

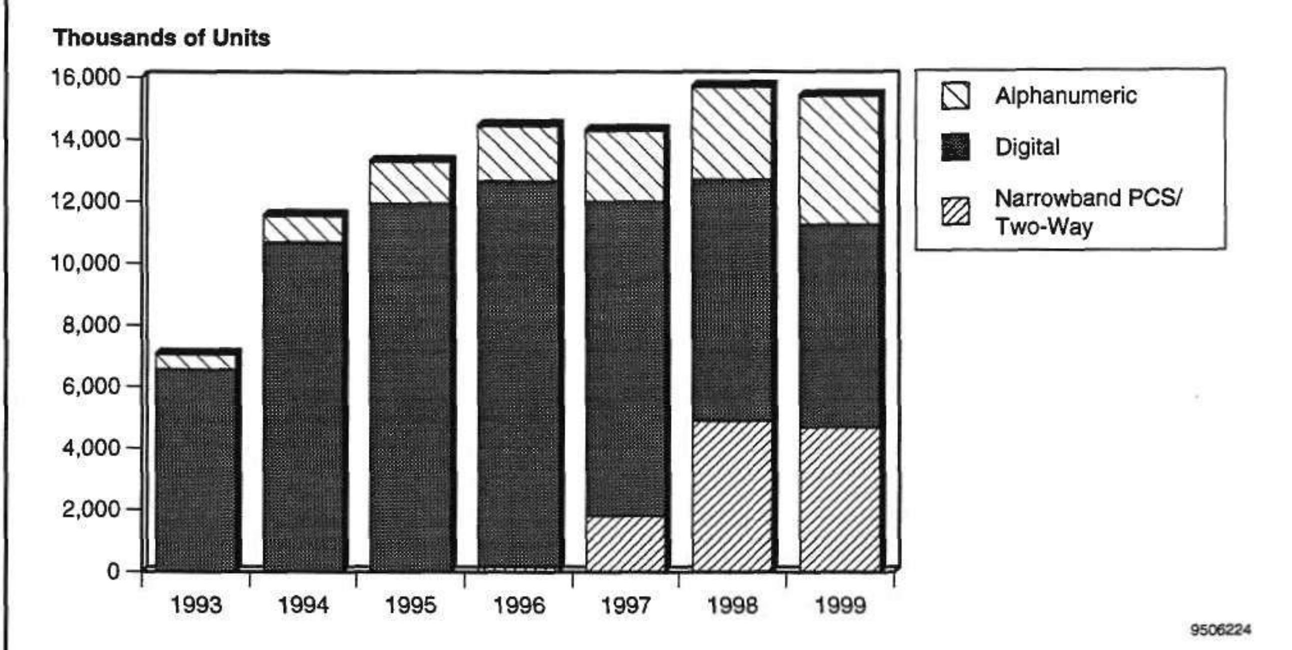
  

## Table 6-5
## North American Pager and Narrowband PCS Market

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|
| Market Revenue ($M) | 557 | 866 | 988 | 1,072 | 1,228 | 1,589 | 1,576 | 12.7 |
| Factory ASP ($) | 79 | 75 | 74 | 74 | 86 | 101 | 102 | 6.4 |
| Total Shipments (K) | 7,069 | 11,548 | 13,291 | 14,430 | 14,277 | 15,687 | 15,393 | 5.9 |
| Narrowband PCS/ Two-Way (K) | 0 | 0 | 28 | 162 | 1,814 | 4,900 | 4,676 | NM |
| Digital Shipments (K) | 6,554 | 10,683 | 11,914 | 12,503 | 10,186 | 7,799 | 6,583 | -9.2 |
| Alphanumeric Shipments (K) | 480 | 851 | 1,340 | 1,766 | 2,277 | 2,988 | 4,134 | 37.2 |
| Tone-Only Shipments (K) | 16 | 6 | 3 | 0 | 0 | 0 | 0 | -100.0 |
| Tone and Voice Shipments (K) | 19 | 8 | 6 | 0 | 0 | 0 | 0 | -100.0 |

NA = Not meaningful
Source: Dataquest (November 1995)

## Figure 6-5
## North American Pager and Narrowband PCS Market




Source: Dataquest (November 1995)

Motorola is the dominant supplier of pagers to the North American market, with more than 60 percent market share. Most pagers sold in North America are produced in the North American region. In addition to Motorola, other major OEMs in the worldwide market include NEC, Uniden, Panasonic/Matsushita, Samsung, Hyundai, Goldstar, and Philips.

Motorola also developed some of the first two-way paging devices. The Tango pager, which will enable two-way messaging, is being used by SkyTel in its narrowband PCS service. Motorola's Tenor will provide enhanced voice messaging and act as a mobile answering machine. These pagers employ new protocols based on the FLEX technology developed by Motorola. The Tango uses ReFLEX technology and the Tenor is based on InFLEXion technology. Motorola has started to develop semiconductor partners to promote this technology and announced its first licensing agreement with Texas Instruments for the FLEX high-speed, one-way paging technology. Additional licensing agreements are expected in the future. Motorola is seeking to establish the FLEX family as a de facto protocol for pagers. However, AT&T, AT&T Wireless, and Ericsson have announced their decision to develop a competing technology. AT&T claims that details of its competing technology will be announced soon. AT&T would use this technology in the services it would provide with its nationwide license. Another alternative technology comes from Nexus Telecommunications Systems of Israel. The Nexus pagers would offer a lower-cost, lower-performance solution with its NexNet network. Nexus has already entered into agreements with American Paging to develop a service in the United States. Samsung has signed a nonexclusive licensing agreement to manufacture the two-way TAG-pager for Nexus.

At this point, Motorola has the advantage with strong momentum from 15 major U.S. paging companies adopting the FLEX protocol. FLEX has also been adopted by Bell Mobility and numerous service providers in Japan and Asia/Pacific, where much of the growth in the worldwide paging market will take place. Also AirTouch, MobileComm, Mtel, and PageMart have adopted the ReFLEX protocol, and PageNet has selected the InFLEXion protocol.

## Feature and Technology Trends

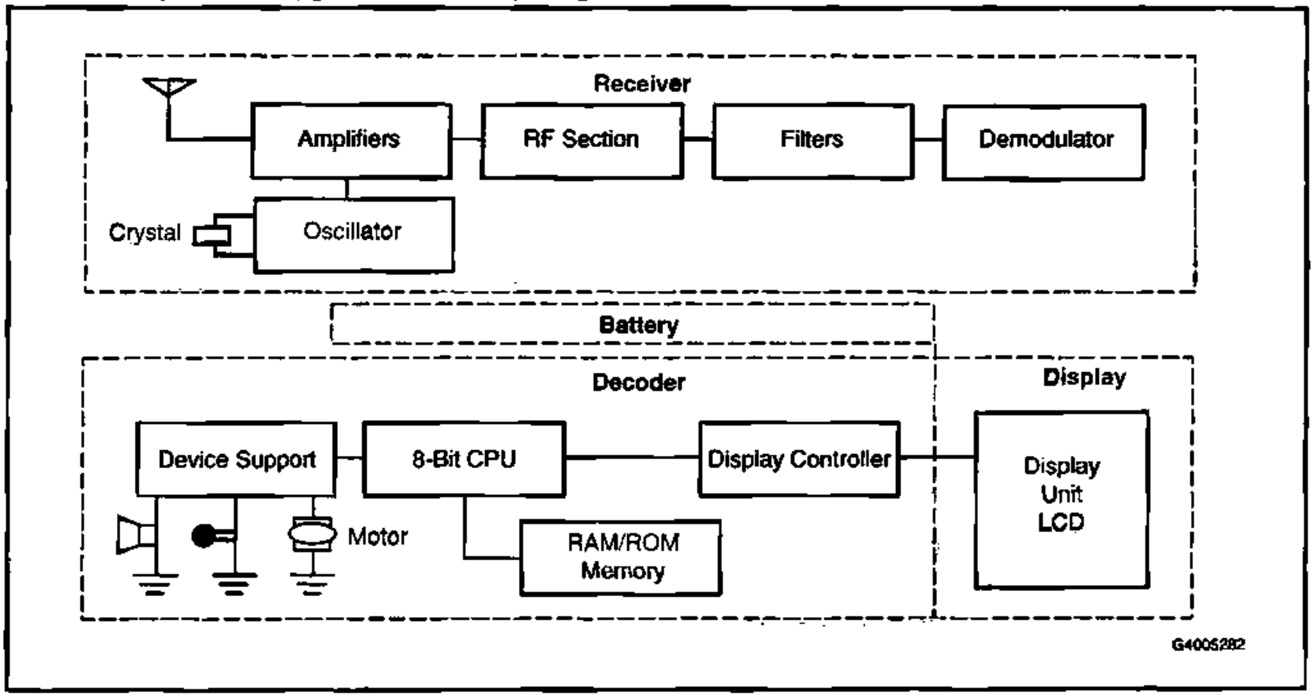
Pagers have changed dramatically in the past decade, taking advantage of microminiaturization, microprocessor advances, and extended battery life. Perhaps the most important feature of the new pagers is their small size. Credit card-size pagers are now available, and wristwatch pagers manufactured by Motorola and Swatch have also debuted. Figure 6-6 shows a block diagram of a one-way pager, which consists of the following modules:

- Receiver: includes the antenna, amplifier, and filter sections for amplifying and filtering the incoming RF paging signal
- Decoder: includes microprocessor and memory to decode, manage, and store messages
- Display: displays messages and other information
- Battery: provides power

Controls allow users to set parameters and access information.

**Figure 6-6**
**Block Diagram of Typical One-Way Pager**




Source: Mtel Technologies

Some of the features offered by one-way pagers are:

- Numeric and alphanumeric paging
- Retaining and playing back received messages
- Vibration alert or buzzer alert
- Scrolling LCD display
- 24-hour built-in clock
- Time stamp
- Low-voltage alarm
- Canned messages

The new generation of two-way pagers will present new semiconductor opportunities for DSP products in the high-end devices and expand the consumption of memory and RF devices in this area.

## Chapter 7

# Answering Machines

## Market, Feature, and Production Trends

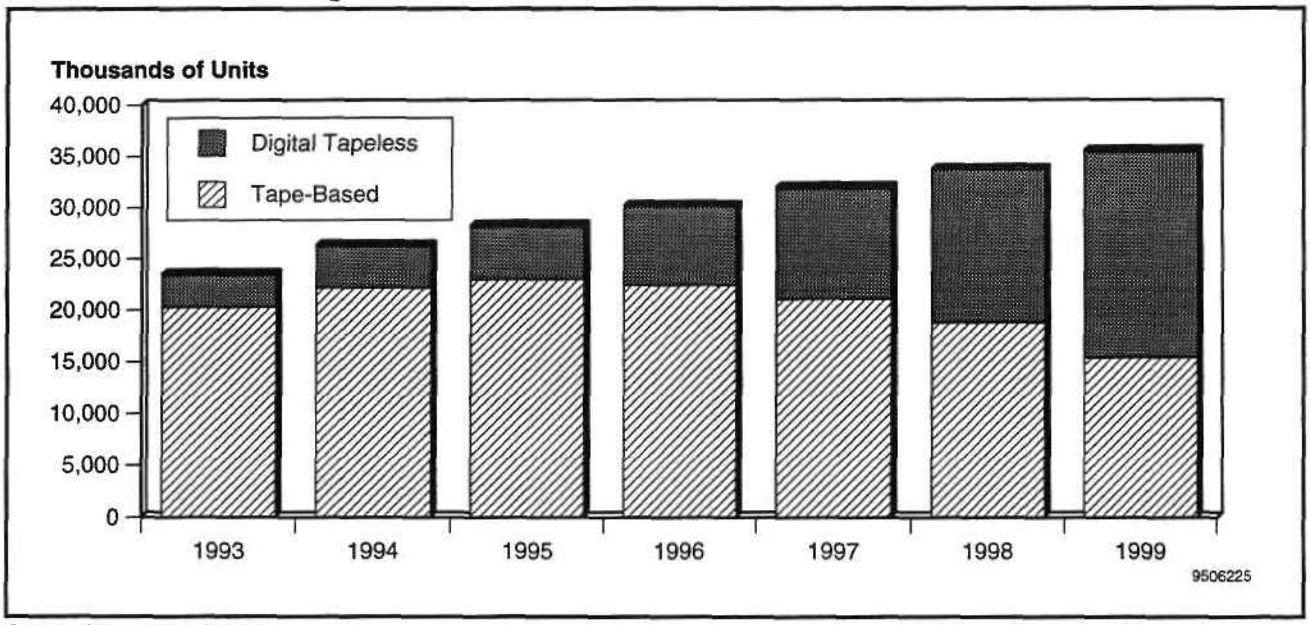
Worldwide answering machine production is expected to continue healthy growth during the forecast period, exceeding 35 million units by 1999 (see Table 7-1 and Figure 7-1). Less than 10 percent of the worldwide production of answering machines takes place in North America (see Table 7-2).

**Table 7-1**
**Worldwide Answering Machines Production**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|
| Units (K) | 23,470 | 26,273 | 28,194 | 30,099 | 31,901 | 33,655 | 35,431 | 6.2 |
| Tape-Based | 20,302 | 22,201 | 22,978 | 22,424 | 21,055 | 18,746 | 15,413 | -7.0 |
| Digital Tapeless | 3,168 | 4,072 | 5,216 | 7,675 | 10,846 | 14,909 | 20,019 | 37.5 |
| Factory ASP ($) | 46 | 42 | 42 | 41 | 39 | 37 | 37 | -2.9 |
| Factory Revenue ($M) | 1,074 | 1,115 | 1,197 | 1,230 | 1,247 | 1,254 | 1,295 | 3.0 |
| Semiconductor Content ($) | 9 | 10 | 11 | 12 | 12 | 13 | 12 | 5.4 |
| Semiconductor Market ($M) | 213 | 252 | 324 | 358 | 393 | 427 | 442 | 11.9 |

Source: Dataquest (November 1995)

**Figure 7-1**
**Worldwide Answering Machine Production**




Source: Mtel Technologies

**Table 7-2**
**North American Answering Machine Production**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|
| Units (K) | 2,608 | 2,803 | 2,887 | 3,078 | 3,099 | 3,145 | 3,302 | 3.3 |
| Factory ASP ($) | 63 | 59 | 58 | 57 | 56 | 55 | 54 | -1.7 |
| Factory Revenue ($M) | 164 | 166 | 168 | 176 | 172 | 173 | 180 | 1.6 |
| Semiconductor Content ($) | 19 | 20 | 19 | 18 | 17 | 16 | 15 | -5.3 |
| Semiconductor Market ($M) | 50 | 55 | 54 | 55 | 52 | 50 | 50 | -2.2 |

Source: Dataquest (November 1995)

Answering machines have become extremely popular in North America, as indicated by a penetration rate of 54 percent in the United States. The outlook for answering machines is for continued penetration, as implied in Table 7-3 and Figure 7-2. An estimated 52 percent of the answering machines are standalone, without a handset, and the balance is integrated with the handset. There is a strong trend toward removing the microcassette tapes, which are failure-prone and cannot be accessed randomly (for voice mailboxes). Digital answerphones took 17 percent of the market in 1994 and are predicted to take nearly 57 percent by 1999. The cassettes are being replaced by audio-RAM (ARAM) with CODECs and DSP-based chips for compression and filtering.

Another important trend with digital is that it is apparently replacing the phone company messaging service (which costs about $10 per month) with further features that the consumer desires, like mailboxes and reliability.

Another strong trend is toward cordless answerphones (analog transmission at 46 to 49 MHz). By most estimates they account for 24 percent of the market. Although currently at a price premium, cordless is expected to account for 50 percent of the market by 1997. By this time a substantial percentage of answerphones will be cordless and feature digital recording. We expect added features like LCDs and caller ID to penetrate answerphones at a similar rate as regular telephones. Besides Centrex-based services, the only other competition for answering machines comes from home computer-based fax/modem cards and standalone units capable of storing voice mail on a PC's hard disk. Microsoft recently proposed a standard software interface to help further catalyze interoperability of office equipment including telephone equipment.

## Brand Share Leaders

Tables 7-4 through 7-9 show the unit and revenue brand share leaders for standalone, integrated corded telephone, and integrated cordless telephone answering machines in the U.S. market, respectively. Brand shares are provided for 1994 and for the third quarter of 1994 through the second quarter of 1995.

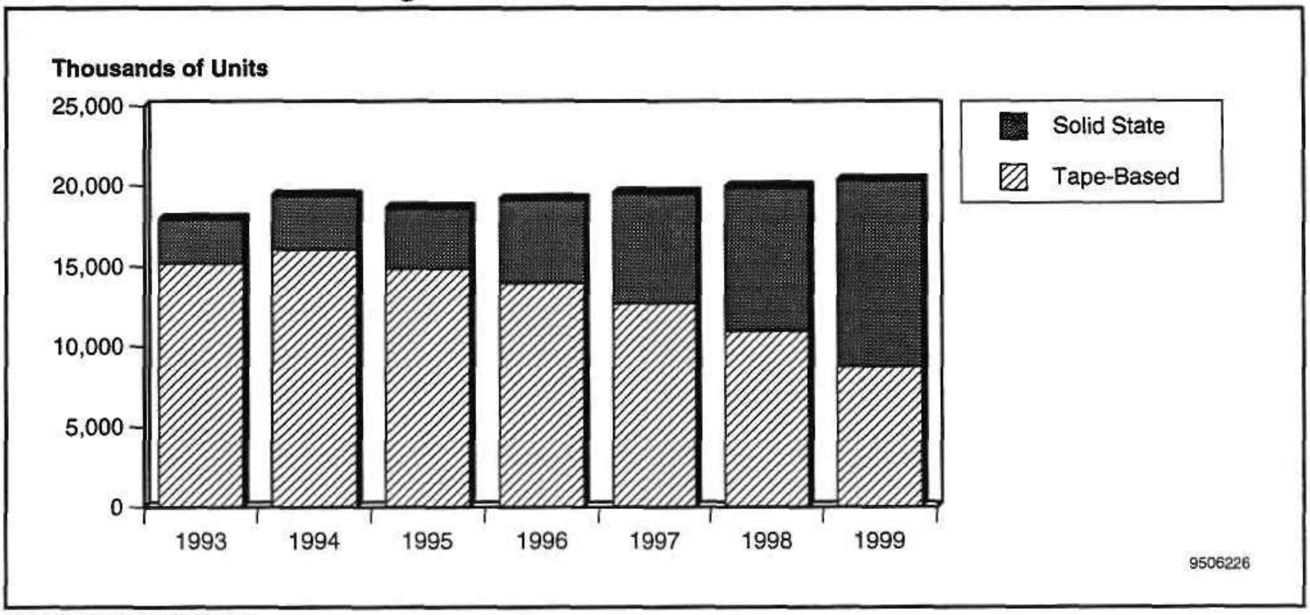
  

## Table 7-3
## North American Answering Machine Market

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|
| Market Revenue ($M) | 1,091 | 1,085 | 977 | 951 | 920 | 898 | 897 | -3.7 |
| Factory ASP Overall ($) | 61 | 56 | 53 | 50 | 47 | 45 | 44 | -4.7 |
| Factory ASP Tape-Based ($) | 58 | 54 | 50 | 46 | 42 | 38 | 35 | -8.3 |
| Factory ASP Solid State ($) | 77 | 66 | 63 | 60 | 57 | 54 | 51 | -5.0 |
| Total Units (K) | 17,930 | 19,360 | 18,590 | 19,140 | 19,523 | 19,913 | 20,312 | 1.0 |
| Tape-Based | 15,241 | 16,069 | 14,872 | 13,972 | 12,690 | 10,952 | 8,734 | -11.5 |
| Solid State | 2,690 | 3,291 | 3,718 | 5,168 | 6,833 | 8,961 | 11,578 | 28.6 |

Source: Dataquest (November 1995)

## Figure 7-2
## North American Answering Machine Market




Source: Mtel Technologies

**Table 7-4**
**U.S. Standalone Answering Machine Brand Share Leaders, First Quarter 1994 through Fourth Quarter 1994 (Percent)**

| Brand | Unit Market Share | Revenue Market Share |
|---|---|---|
| AT&T | 32.4 | 38.6 |
| GE | 17.7 | 15.2 |
| PhoneMate | 13.0 | 11.7 |
| BellSouth | 7.2 | 5.7 |
| Panasonic | 5.8 | 7.9 |
| Conair | 4.5 | 3.3 |
| Unisonic | 4.4 | 2.7 |
| Radio Shack | 4.1 | 4.8 |
| Southwestern Bell | 2.6 | 2.4 |
| Spectra | 2.1 | 1.4 |
| Others | 6.2 | 6.3 |
| Total | 100.0 | 100.0 |

Source: The Scout Report®/The Polk Company

**Table 7-5**
**U.S. Standalone Answering Machine Brand Share Leaders, Third Quarter 1994 through Second Quarter 1995 (Percent)**

| Brand | Unit Market Share | Revenue Market Share |
|---|---|---|
| AT&T | 35.3 | 40.4 |
| GE | 16.5 | 14.4 |
| PhoneMate | 11.8 | 10.7 |
| BellSouth | 7.9 | 6.7 |
| Conair | 4.9 | 3.8 |
| Panasonic | 4.7 | 6.5 |
| Radio Shack | 4.0 | 4.9 |
| Unisonic | 3.6 | 2.2 |
| Southwestern Bell | 3.5 | 3.2 |
| Sony | 1.9 | 2.6 |
| Others | 5.9 | 4.6 |
| Total | 100.0 | 100.0 |

Source: The Scout Report®/The Polk Company

**Table 7-6**
**U.S. Answering Machine Integrated with Corded Phone Brand Share Leaders, First Quarter 1994 through Fourth Quarter 1994 (Percent)**

| Brand | Unit Market Share | Revenue Market Share |
|---|---|---|
| AT&T | 28.8 | 32.9 |
| GE | 23.9 | 21.5 |
| BellSouth | 13.1 | 9.7 |
| PhoneMate | 11.0 | 11.1 |
| Panasonic | 6.5 | 8.5 |
| Sony | 4.1 | 5.0 |
| Conair | 2.4 | 1.3 |
| Radio Shack | 2.0 | 2.7 |
| Southwestern Bell | 1.7 | 1.9 |
| Unisonic | 1.1 | 0.7 |
| Others | 5.4 | 4.7 |
| Total | 100.0 | 100.0 |

Source: The Scout Report®/The Polk Company

**Table 7-7**
**U.S. Answering Machine Integrated with Corded Phone Brand Share Leaders, Third Quarter 1994 through Second Quarter 1995**

| Brand | Unit Market Share | Revenue Market Share |
|---|---|---|
| AT&T | 31.8 | 34.7 |
| GE | 23.7 | 21.7 |
| PhoneMate | 11.1 | 11.3 |
| BellSouth | 10.2 | 7.4 |
| Panasonic | 6.1 | 9.2 |
| Sony | 5.0 | 5.3 |
| Conair | 2.9 | 1.7 |
| Southwestern Bell | 2.7 | 2.7 |
| Radio Shack | 1.7 | 2.1 |
| Unisonic | 0.9 | 0.5 |
| Others | 3.9 | 3.4 |
| Total | 100.0 | 100.0 |

Source: The Scout Report®/The Polk Company

**Table 7-8**
**U.S. Answering Machine Integrated with Cordless Phone Brand Share Leaders, First Quarter 1994 through Fourth Quarter 1994 (Percent)**

| Brand | Unit Market Share | Revenue Market Share |
|---|---|---|
| AT&T | 23.2 | 24.6 |
| Panasonic | 22.5 | 25.1 |
| Sony | 12.0 | 13.3 |
| BellSouth | 12.5 | 10.1 |
| PhoneMate | 10.2 | 8.5 |
| GE | 7.1 | 6.3 |
| Southwestern Bell | 5.5 | 4.9 |
| Sanyo | 3.0 | 3.4 |
| Cobra | 1.0 | 0.7 |
| Radio Shack | 0.8 | 1.1 |
| Others | 2.2 | 2.0 |
| Total | 100.0 | 100.0 |

Source: The Scout Report®/The Polk Company

**Table 7-9**
**U.S. Answering Machine Integrated with Cordless Phone Brand Share Leaders, Third Quarter 1994 through Second Quarter 1995**

| Brand | Unit Market Share | Revenue Market Share |
|---|---|---|
| AT&T | 24.3 | 26.4 |
| Panasonic | 19.1 | 21.6 |
| Sony | 13.3 | 14.6 |
| PhoneMate | 12.3 | 10.4 |
| BellSouth | 10.5 | 8.4 |
| GE | 7.4 | 6.5 |
| Southwestern Bell | 6.4 | 5.6 |
| Sanyo | 2.4 | 2.4 |
| Radio Shack | 1.2 | 1.5 |
| Cobra | 0.8 | 0.7 |
| Others | 2.3 | 1.9 |
| Total | 100.0 | 100.0 |

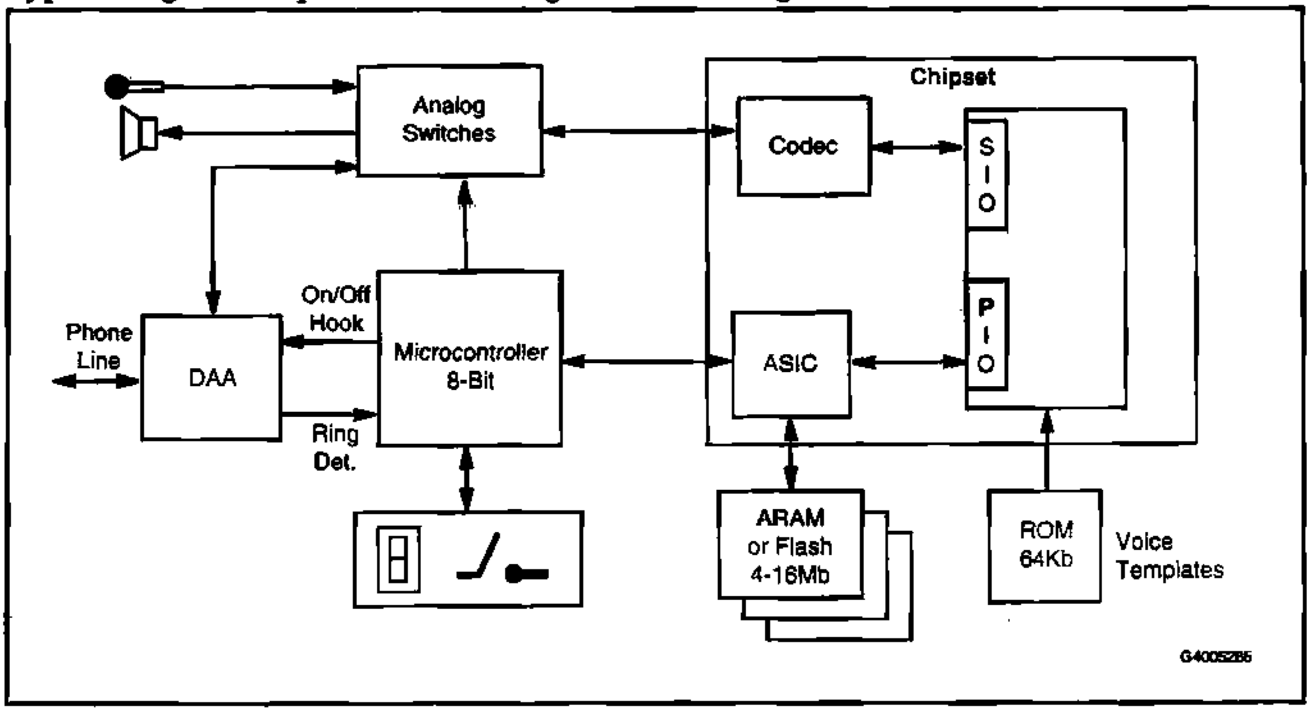
Source: The Scout Report®/The Polk Company

## Technology Trends and Semiconductor Opportunities

Cassettes in new answering machines are being replaced by ARAM, with CODECs and DSP-based chips for compression and filtering (see Figure 7-3). However, the volatile supply and pricing of ARAM has been frustrating to manufacturers and slowed market growth. Flash memory is now hitting price points at which it is beginning to be designed into answering machines instead of ARAM. Record times are typically being offered from 4 to 20 minutes. The length of recording time is dependent on the amount of ARAM used and the audio compression algorithm employed. Almost all answering machines are now using digitized outgoing messages of a few seconds stored on ARAMs. As described, answering machine semiconductor opportunities exist for:

- 12-bit CODEC (ADPCM or TrueSpeech)
- ARAM 4Mb to 16 Mb
- Tape transport control
- DSP-based combination of these

**Figure 7-3**
**Typical Digital Telephone Answering Machine Design**




Source: Dataquest (November 1995)

## Chapter 8
# Satellite-Based Services and Specialized Mobile Radio

## Satellite-Based Services

Satellite-based services (L2) would essentially be a cellular voice and data communications system using low-earth-orbit (LEO) satellites, which are 400 to 700 miles above the earth, medium-earth-orbit (MEO) satellites, which are 5,000 to 10,000 miles above the earth, or geostationary (or "fixed") satellites. More than twelve proposals are in various stages of obtaining approval and licensing from the FCC and from international bodies. Recently, two systems launched their first satellites into orbit and three other systems received FCC licenses. American Mobile Satellite Corporation launched its first geostationary satellite above North America and Orbital Communications launched the first two satellites of its planned system of 24 satellites. Motorola's Iridium, Loral and Qualcomm's Globalstar, and TRW's Odyssey all received FCC licenses for their systems. Constellation Communications and Mobile Communications with its Ellipso system are both actively pursuing licenses. Perhaps the most ambitious project that has been announced is the Teledesic system backed by AT&T (24 percent ownership), Bill Gates (30 percent ownership), and Craig McCaw (30 percent ownership). The system would deploy 840 satellites to ring the earth, with service planned to begin in 2001. Table 8-1 presents a summary of eleven proposed satellite systems.

While all of these systems have the use of satellites as a switching and transmission system in common, they can vary significantly in the types of service they plan to offer. For example, the Teledesic system would provide communications for videoconferencing, computer networking, and other services as part of the spectrum called the Ka-band. The system would not compete with the global pocket telephone satellite systems being built by Motorola, TRW, and Loral. Figure 8-1 presents a depiction of Motorola's proposed Iridium system. Motorola's Iridium and Loral's Globalstar would also target slightly different markets. The Iridium would seek deep-pocketed business travelers while the Globalstar system is targeting a general worldwide market. They also differ significantly in the architecture of their systems. The Iridium system would pass signals between its more complicated satellites while the Globalstar system would relay communications using ground stations, which are easier to maintain and modify. The TDMA and CDMA technologies are also competing in the satellite communications arena. The Globalstar and Odyssey systems use CDMA as the air interface, and the Iridium system will use TDMA technology.

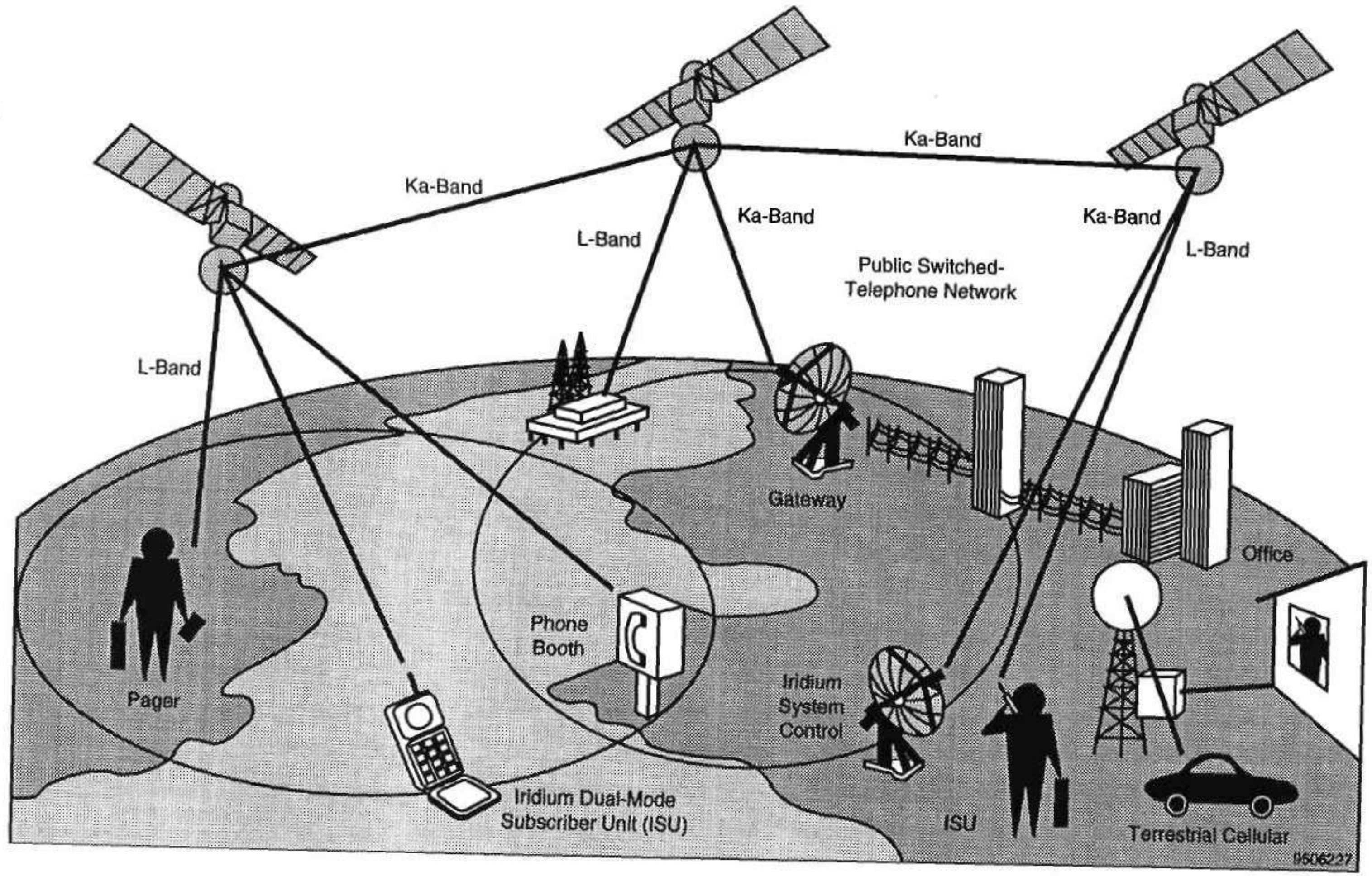
American Mobile Satellite Corporation (AMSC), which is co-owned by Hughes, AT&T, and Singapore Telecom, launched its first satellite in the spring of 1995 to a geostationary orbit 23,000 miles above Lubbock, Texas. This system presents a good example of the type of service and hardware offered in a satellite-based system. AMSC plans to provide mobile voice and data applications for a variety of users including land mobile, maritime, aeronautical, and fixed-site markets. The satellite can support hundreds of thousands of subscribers and would provide dual-band satellite/

**Table 8-1**
**Proposal for Sattellite-Based Services**

| Company | Number of Satellites | Target Service* | Satellite/System Type | Comments |
|---|---|---|---|---|
| Orbital Communications | 26 - 48 | 1995 | Little LEO | Holds FCC license; two satellites in place and functioning |
| American Mobile Satellite Corporation | - | 1995 | Geostationary | Holds FCC license; one satellite in place and functioning |
| Motorola (Iridium) | 66 | 1998 | Big LEO | Received FCC approval |
| Loral, Qualcomm (Globalstar) | 48 | 1998 | Big LEO | Received FCC approval |
| TRW (Odyssey) | 12 | 1998-99 | MEO | Received FCC approval |
| Teledesic | 840 | 2001 | LEO | Working with FCC licensing and regulations; backed by AT&T, McCaw, and Gates |
| Constellation Communications | 46 | 1996 | - | Seeking FCC approval but denied initially for financing |
| Mobile Communications (Ellipso) | 16 | - | Little LEO | Seeking FCC approval but denied initially for financing |
| ICO Global Space Communications (Inmarsat-P) | 12 | 2000 | MEO | Offshoot of Inmarsat |
| VITA and CTA (GEMnet-VITAsat) | 40 | 1995 | - | Holds two satellites under Pioneer's Preference; Seeking 38 more licenses |
| Starsys (Starsys Global Positioning) | 24 | 1997 | | |

*Indicates start of initial service. Full-constellation deployment and full service would follow over four to five years, typically.
Source: Dataquest (November 1995)

**Figure 8-1**
**Motorola's Iridum: A Low-Earth-Orbit (LEO) Satellite Network**




Source: Motorola Inc.

cellular service for seamless coverage. AMSC's Skycell Satellite Roaming Service has agreements with 156 cellular carriers across the United States to be authorized service providers. Westinghouse Electronic Corporation's Series 1000 dual-band phones, expected to cost about $2,000, are available as units to be mounted in vehicles or in briefcases equipped with satellite dishes. Talk time will average $1.50 per minute, and customers will pay a $25-per-month access fee. The company plans to begin offering services in December 1995 to North American truck, ship, aircraft, and vehicle fleets. By 1997, it expects to offer services to cellular-phone users after a $600 million expansion. End-user terminals for cellular/satellite systems are expected to cost between $600 to $750 at introduction. This price would decline as the market begins to support volume shipments.

Some projections have placed the market for satellite-based services at $160 billion over the next decade, and this has lured more than $23 billion in combined proposals for satellite networks. There has been a race for financial backing. However, these systems are viewed as high-risk investments by the financial community because of fears that not all of the systems can be successful. Constellation Communications and Mobile Communications were denied licenses by the FCC because of concerns over financing. A recent $300 million bond offering from Iridium was pulled from the market when investors demanded a return that Iridium considered too high. Iridium has decided to pursue bank financing, which it believes it can obtain for around 14 percent instead of the effective 25 percent return that bond investors were seeking. In addition to technological hurdles, significant financial hurdles still stand in the way of the development of satellite communications.

## SMR

Specialized mobile radio (SMR) frequencies are in both the 220-MHz and the 800-MHz ranges, compared with cellular frequencies, which are higher in the same 800- to 900-MHz band. Voice SMR services originally had been designated for private radio dispatch and fleet management; a lifting of FCC restrictions would allow reuse of the spectrum for cellularlike service. Leading the movement for the use of SMR for nationwide digital communication is Nextel Communications. Motorola has a 20 percent stake in Nextel, which it acquired in exchange for SMR licenses. Nextel, in return, is using Motorola equipment to deploy the network. Nextel's strategy is to acquire as many 800-MHz SMR licenses as possible, and in its efforts to do so, Nextel has allied with critical partners to gain access to technology and licenses nationwide. Nextel is converting the networks it has acquired from analog to digital TDMA systems. In 1995, Craig McCaw invested $1.1 billion in Nextel and received control over operations and corporate strategy. McCaw has already announced his plan to shift Nextel's focus from providing cellular/PCS services to a "focus on wireless work groups in the business segment." In one of his first moves, McCaw obtained a promise from Motorola to improve the Motorola Integrated Radio System technology, which has been renamed Integrated Dispatch Enhanced Network.

**For More Information...**

Dale Ford, Senior Industry Analyst .......... (408) 468-8311
Internet address .......... dford@dataquest.com
Via fax .......... (408) 954-1780



Dataquest
a company of
The Dun & Bradstreet Corporation

# DATAQUEST WORLDWIDE OFFICES


## NORTH AMERICA

**Worldwide Headquarters**
Dataquest Incorporated
251 River Oaks Parkway
San Jose, California 95134-1913
United States
Phone: 1-408-468-8000
Facsimile: 1-408-954-1780

**Dataquest Incorporated**
Nine Technology Drive
P.O. Box 5093
Westborough, Massachusetts 01581-5093
United States
Phone: 1-508-871-5555
Facsimile: 1-508-871-6262

**Dataquest Global Events**
3990 Westerly Place, Suite 100
Newport Beach, California 92660
United States
Phone: 1-714-476-9117
Facsimile: 1-714-476-9969

Sales Offices:
- Washington, DC (Federal)
- New York, NY (Financial)
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## LATIN AMERICA

Research Affiliates and Sales Offices:
- Buenos Aires, Argentina
- Sao Paulo, Brazil
- Santiago, Chile
- Mexico City, Mexico

## EUROPE

**European Headquarters**
Dataquest Europe Limited
Holmers Farm Way
High Wycombe, Bucks HP12 4XH
United Kingdom
Phone: +44 1494 422 722
Facsimile: +44 1494 422 742

**Dataquest Europe SA**
Immeuble Défense Bergères
345, avenue Georges Clémenceau
TSA 40002
92882 - Nanterre CTC Cedex 9
France
Phone: +33 1 41 35 13 00
Facsimile: +33 1 41 35 13 13

**Dataquest GmbH**
Kronstadter Strasse 9
81677 München
Germany
Phone: +49 89 93 09 09 0
Facsimile: +49 89 93 03 27 7

Sales Offices:
- Brussels, Belgium
- Kfar Saba, Israel
- Milan, Italy
- Randburg, South Africa
- Madrid, Spain

## JAPAN

**Japan Headquarters**
Dataquest Japan K.K.
Shinkawa Sanko Building
6th Floor
1-3-17, Shinkawa
Chuo-ku, Tokyo 104
Japan
Phone: 81-3-5566-0411
Facsimile: 81-3-5566-0425

## ASIA/PACIFIC

**Asia/Pacific Headquarters**
7/F China Underwriters Centre
88 Gloucester Road
Wan Chai
Hong Kong
Phone: 852-2824-6168
Facsimile: 852-2824-6138

**Dataquest Korea**
Suite 2407, Trade Tower
159 Samsung-dong, Kangnam-gu
Seoul 135-729
Korea
Phone: 822-551-1331
Facsimile: 822-551-1330

**Dataquest Taiwan**
11F-2, No. 188, Section 5
Nan King East Road
Taipei
Taiwan, R.O.C.
Phone: 8862-756-0389
Facsimile: 8862-756-2663

**Dataquest Singapore**
105 Cecil Street
#06-01/02 The Octagon
Singapore 0106
Phone: 65-227-1213
Facsimile: 65-227-4607

**Dataquest Thailand**
12/F, Vanissa Building
29 Soi Chidlom
Ploenchit Road
Patumwan, Bangkok 10330
Thailand
Phone: 662-655-0577
Facsimile: 662-655-0576

Research Affiliates and Sales Offices:
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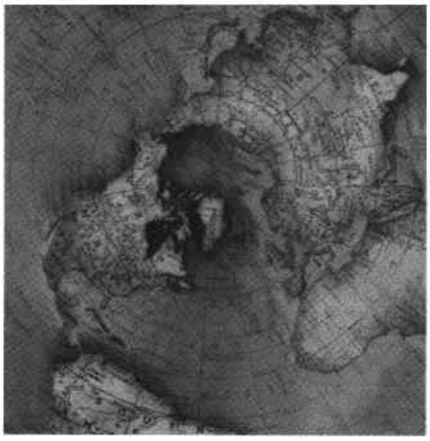

Dataquest

# LAN, WAN, Voice, and Broadband Communications Semiconductor Device Forecast

## Market Trends

**Program:** Communications Semiconductors and Applications Worldwide
**Product Code:** CSAM-WW-MT-9502
**Publication Date:** December 11, 1995
**Filing:** Market Analysis

# LAN, WAN, Voice, and Broadband Communications Semiconductor Device Forecast

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## Chapter 1
# Introduction and Methodology

This document presents Dataquest's view of the market opportunity for semiconductors used in wireline communications system applications. These applications include local area network (LAN) systems, wide area network (WAN) systems, premises voice-based systems, and public transmission and switching systems. Devices covered include communications system-specific devices that embody some dedicated standard or functionality. Communications semiconductor competitive analysis and market shares are covered in a separate Communications Semiconductor and Applications Worldwide document (CSAM-WW-CT-9501, July 13, 1995). System market trends are covered in another Communications Semiconductor and Applications Worldwide document (CSAM-WW-MT-9501, October 30, 1995).

The 1994 market sizing is based on primary research surveys of semiconductor companies' shipments of dedicated communications functions.

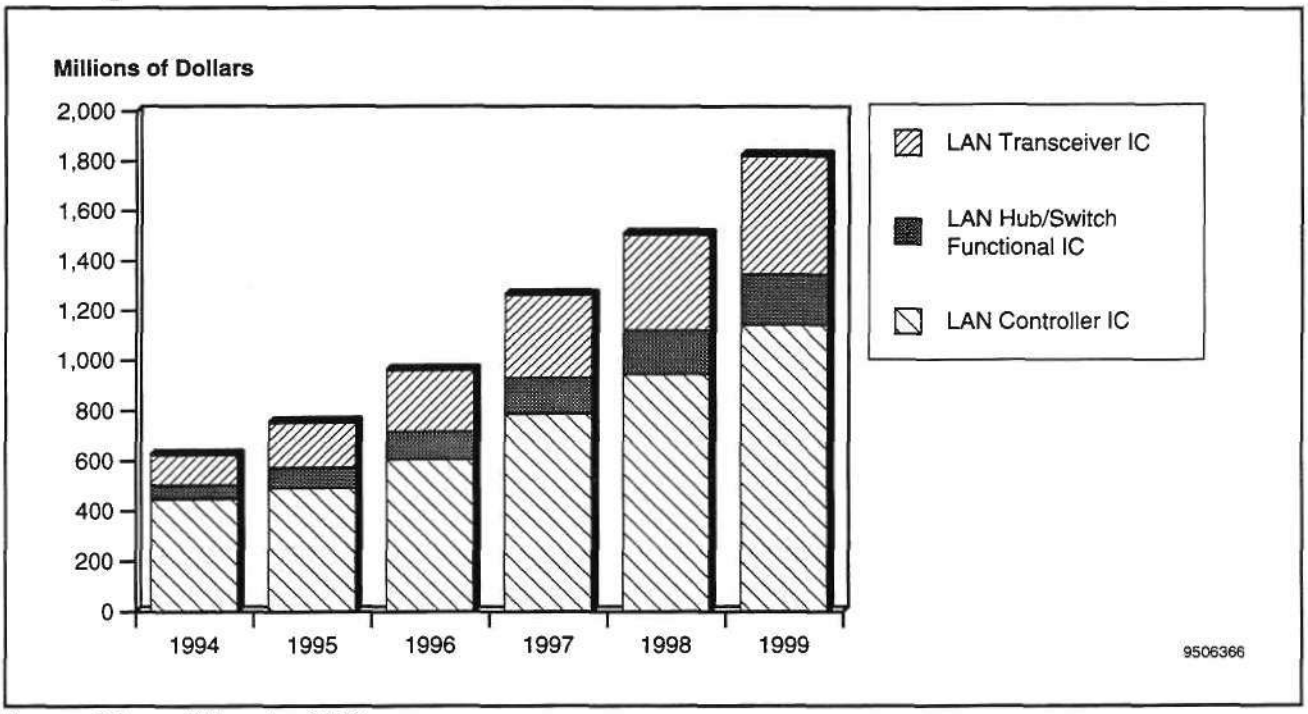
Future-year forecasts are based in part on projections made by Dataquest's Telecommunications services analysts, who have also measured 1994 on a vendor-market-share basis. Further insight is added by converting system forecasts into a nodal model necessary for building a base unit forecast. Average selling price (ASP) projections are based in part on vendor surveys, system semiconductor content modeling over time, and an analysis of valued-added and competitive pressures that could raise or lower prices.

## Chapter 2
# The LAN IC Market

The worldwide forecast for LAN ICs is presented in Figures 2-1 and 2-2 and Tables 2-1 through 2-3. Key trends and assumptions about this market include the following:

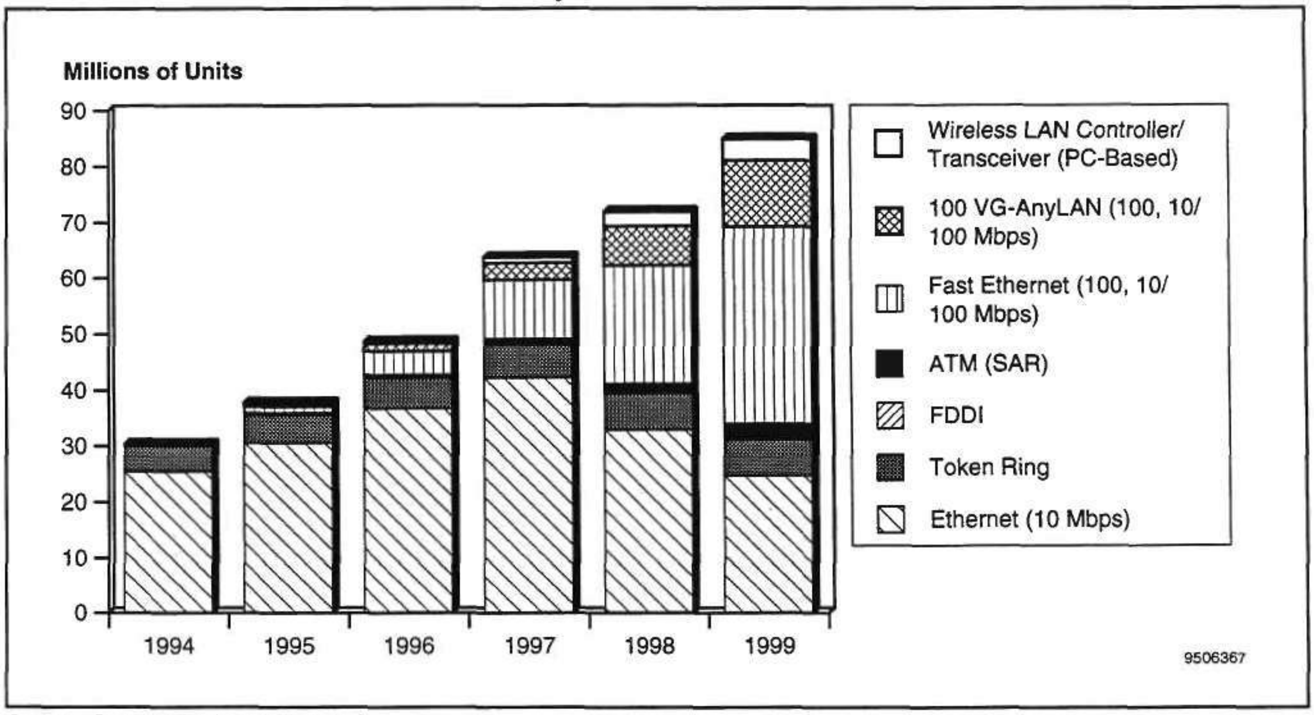
- Network connectivity will continue to rise as new markets develop in the small office/home office, Europe, Japan, Asia/Pacific, and Latin America.
- There will be an ever-increasing need for performance improvement as networks grow larger and new traffic types such as Internet access, fax transmission, groupware, and, eventually, multimedia demand more bandwidth.
- 10-Base-T will retain the majority of the desktop controller/medium access control (MAC) market until the 1997-to-1998 period, when the 10/100-Mbps technologies will rival it in popularity because of narrowed price premiums and added flexibility. Asynchronous transfer mode (ATM) will not hit the desktop market significantly until the end of the decade—the lower-cost 10/100-Mbps technologies will hold it off until then. Opportunities exist for full-duplex Ethernet, motherboard-mounted controllers, and controllers that support sleep modes.
- Of the two competing 100-Mbps technologies, Fast Ethernet is expected to attain greater market acceptance, primarily because of the breadth and strength of its backers. We expect 100 VG-AnyLAN to achieve the attractive 12-million-node-shipment level by 1999. Expect MAC, transceiver, and hub repeater and switch chips for both of these standards to present significant opportunities.
- Expect the 100-Mbps MAC and transceiver functions to be integrated by late 1996 or early 1997 for NIC applications. Likewise, expect more sophisticated hub repeater functions that incorporate physical-medium-dependent features. TX transceivers will be the most popular Fast Ethernet transceivers initially, with T4 rising in importance during 1996.
- FDDI will remain the most popular "fat pipe" and backbone technology at the department level for the next two years as 100-Mbps Fast Ethernet and VG-AnyLAN move into the workgroup level. ATM will become very important in enterprise switches, eventually moving toward workgroup hub/switch by the end of the decade.
- Switched Ethernet and Token Ring will prove to be viable interim technology for small workgroups needing near-term improvement in bandwidth. This technology would allow dedicated 10-Mbps Ethernet or 16-Mbps Token Ring support to the desktop, effectively doubling performance in many cases. Expect both ASIC and eventually ASSP switch chipsets to offer significant opportunities.

## Figure 2-1
## LAN-Specific IC Market Forecast, Worldwide




Source: Dataquest (November 1995)

## Figure 2-2
## LAN Controller IC Market Forecast by Standard, Worldwide




Source: Dataquest (November 1995)

**Table 2-1**
**LAN Controller IC Market Forecast, Worldwide**

| | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|
| Ethernet (10 Mbps) | | | | | | | |
| Units (M) | 25.50 | 30.60 | 36.72 | 42.23 | 32.94 | 24.70 | -1 |
| ASP ($) | 11.99 | 10.07 | 9.27 | 9.08 | 8.90 | 8.72 | -6 |
| Revenue ($M) | 305.8 | 308.2 | 340.3 | 383.5 | 293.2 | 215.5 | -7 |
| PCI I/F Units (M) | 0.77 | 3.37 | 6.24 | 11.82 | 14.82 | 15.32 | 82 |
| Motherboard Units (M) | 2.04 | 4.13 | 5.88 | 8.45 | 9.88 | 8.15 | 32 |
| Token Ring | | | | | | | |
| Units (M) | 4.47 | 5.10 | 5.61 | 6.00 | 6.42 | 6.35 | 7 |
| ASP ($) | 26.75 | 24.61 | 23.38 | 22.91 | 22.68 | 22.46 | -3 |
| Revenue ($M) | 119.6 | 125.4 | 131.1 | 137.5 | 145.6 | 142.7 | 4 |
| FDDI | | | | | | | |
| Units (M) | 0.16 | 0.21 | 0.27 | 0.32 | 0.35 | 0.36 | 17 |
| ASP ($) | 51.25 | 45.10 | 39.69 | 35.72 | 33.93 | 33.25 | -8 |
| Revenue ($M) | 8.2 | 9.2 | 10.6 | 11.4 | 11.9 | 11.8 | 8 |
| ATM (SAR) | | | | | | | |
| Units (M) | 0.03 | 0.07 | 0.23 | 0.63 | 1.50 | 2.55 | 142 |
| ASP ($) | 120.00 | 71.63 | 57.18 | 44.93 | 36.67 | 32.86 | -24 |
| Revenue ($M) | 3.9 | 5.3 | 12.9 | 28.4 | 55.1 | 83.8 | 84 |
| Fast Ethernet (100, 10/ 100 Mbps) | | | | | | | |
| Units (M) | 0.03 | 1.04 | 4.10 | 10.40 | 21.00 | 35.20 | 326 |
| ASP ($) | 53.00 | 22.00 | 17.60 | 14.08 | 12.67 | 12.04 | -26 |
| Revenue ($M) | 1.3 | 22.9 | 72.2 | 146.4 | 266.1 | 423.8 | 217 |
| PCI I/F Units (M) | 0.02 | 0.73 | 3.28 | 8.84 | 18.90 | 33.44 | 367 |
| 100 VG-AnyLAN (100, 10/ 100 Mbps) | | | | | | | |
| Units (M) | 0.05 | 0.59 | 1.35 | 3.10 | 7.05 | 11.80 | 198 |
| ASP ($) | 55.00 | 24.00 | 19.20 | 15.36 | 13.82 | 13.13 | -25 |
| Revenue ($M) | 2.8 | 14.2 | 25.9 | 47.6 | 97.5 | 155.0 | 124 |
| PCI I/F Units (M) | 0.03 | 0.41 | 1.08 | 2.64 | 6.35 | 11.21 | 227 |

(Continued)

**Table 2-1 (Continued)**
**LAN Controller IC Market Forecast, Worldwide**

| | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|
| Wireless LAN Controller/ Transceiver (PC-Based) | | | | | | | |
| Units (M) | 0.09 | 0.13 | 0.33 | 0.98 | 2.54 | 3.82 | 113 |
| ASP ($) | 68.00 | 54.40 | 43.52 | 34.82 | 31.33 | 29.77 | -15 |
| Revenue ($M) | 5.9 | 6.8 | 14.2 | 34.1 | 79.7 | 113.6 | 80 |
| Total LAN Controllers | | | | | | | |
| Units (M) | 30.33 | 37.74 | 48.60 | 63.66 | 71.74 | 84.91 | 23 |
| ASP ($) | 14.76 | 13.06 | 12.49 | 12.39 | 13.18 | 13.49 | -2 |
| Revenue ($M) | 447.5 | 493.0 | 607.0 | 788.5 | 945.6 | 1,145.8 | 21 |
| Regional Demand (%) | | | | | | | |
| North America | 55 | 53 | 51 | 49 | 47 | 45 | |
| Europe | 17 | 17 | 16 | 16 | 16 | 16 | |
| Japan | 6 | 6 | 6 | 6 | 5 | 5 | |
| Asia/Pacific | 22 | 24 | 27 | 29 | 32 | 34 | |

Source: Dataquest (November 1995)

**Table 2-2**
**LAN Hub/Switch IC Market Forecast, Worldwide**

| | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|
| Ethernet Repeater (10/20 Mbps) | | | | | | | |
| Units (M) | 2.70 | 3.98 | 4.88 | 5.23 | 5.32 | 5.13 | 14 |
| ASP ($) | 17.00 | 14.26 | 13.55 | 12.87 | 12.87 | 12.87 | -5 |
| Revenue ($M) | 45.9 | 56.8 | 66.1 | 67.4 | 68.5 | 66.0 | 10 |
| Percentage ASSP | 85 | 88 | 91 | 97 | 100 | 100 | |
| Percentage ASIC | 15 | 12 | 9 | 3 | 0 | 0 | |
| Ethernet Switch Chipset (10/20 Mbps) | | | | | | | |
| Units (M) | 0.01 | 0.19 | 0.48 | 1.27 | 1.87 | 2.31 | 182 |
| ASP ($) | 21.50 | 19.78 | 18.20 | 17.29 | 16.42 | 15.60 | -6 |
| Revenue ($M) | 0.3 | 3.8 | 8.8 | 21.9 | 30.8 | 36.1 | 165 |
| Percentage ASSP | 2 | 5 | 45 | 65 | 80 | 85 | |
| Percentage ASIC | 98 | 95 | 55 | 35 | 20 | 15 | |
| Token Ring Hub/Switch Chipset (4/16 Mbps) | | | | | | | |
| Units (M) | 0.44 | 0.48 | 0.50 | 0.52 | 0.52 | 0.52 | 3 |
| ASP ($) | 32.00 | 29.44 | 27.08 | 24.92 | 22.92 | 21.09 | -8 |
| Revenue ($M) | 14.2 | 14.0 | 13.5 | 12.9 | 12.0 | 10.9 | -5 |
| Percentage ASSP | 0 | 0 | 0 | 0 | 0 | 0 | |
| Percentage ASIC | 100 | 100 | 100 | 100 | 100 | 100 | |
| Fast Ethernet Repeater/Switch Chipset (100, 10/100) | | | | | | | |
| Units (M) | 0 | 0.10 | 0.41 | 1.04 | 2.10 | 3.52 | 326 |
| ASP ($) | 85.00 | 70.00 | 52.50 | 39.38 | 31.50 | 25.20 | -22 |
| Revenue ($M) | 0.2 | 7.3 | 21.5 | 41.0 | 66.2 | 88.7 | 234 |
| Percentage ASSP | 2 | 20 | 60 | 80 | 90 | 90 | |
| Percentage ASIC | 98 | 80 | 40 | 20 | 10 | 10 | |
| 100 VG-AnyLAN Repeater/Switch Chipset (100, 10/100) | | | | | | | |
| Units (M) | 0.01 | 0.05 | 0.14 | 0.31 | 0.71 | 1.18 | 198 |
| ASP ($) | 85.00 | 72.00 | 54.00 | 40.50 | 32.40 | 25.92 | -21 |
| Revenue ($M) | 0.4 | 3.4 | 7.3 | 12.6 | 22.8 | 30.6 | 135 |
| Percentage ASSP | 90 | 85 | 85 | 80 | 85 | 85 | |
| Percentage ASIC | 10 | 15 | 15 | 20 | 15 | 15 | |

(Continued)

**Table 2-2 (Continued)**
**LAN Hub/Switch IC Market Forecast, Worldwide**

| | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|
| Total LAN Hub/Switch Functional IC Market, Worldwide | | | | | | | |
| Units (M) | 3.16 | 4.75 | 6.27 | 8.06 | 9.82 | 11.48 | 29 |
| ASP ($) | 19.19 | 17.22 | 17.53 | 17.76 | 18.07 | 17.57 | 0 |
| Revenue ($M) | 60.6 | 81.9 | 109.9 | 143.1 | 177.4 | 201.8 | 29 |
| Regional Demand (%) | | | | | | | |
| North America | 65 | 64 | 63 | 62 | 61 | 60 | |
| Europe | 18 | 18 | 18 | 18 | 18 | 18 | |
| Japan | 4 | 4 | 4 | 4 | 4 | 4 | |
| Asia/Pacific | 13 | 14 | 15 | 16 | 17 | 18 | |

Source: Dataquest (November 1995)

**Table 2-3**
**LAN Transceiver IC Market Forecast, Worldwide**

| | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|
| Ethernet (10/20 Mbps) | | | | | | | |
| Units (M) | 21.44 | 23.58 | 22.40 | 20.16 | 18.15 | 16.33 | -5 |
| ASP ($) | 4.00 | 3.20 | 2.88 | 2.74 | 2.74 | 2.74 | -7 |
| Revenue ($M) | 85.8 | 75.5 | 64.5 | 55.2 | 49.7 | 44.7 | -12 |
| Token Ring | | | | | | | |
| Units (M) | 3.10 | 3.88 | 4.65 | 5.35 | 5.88 | 6.18 | 15 |
| ASP ($) | 8.00 | 7.76 | 7.37 | 7.00 | 7.00 | 7.00 | -3 |
| Revenue ($M) | 24.8 | 30.1 | 34.3 | 37.5 | 41.2 | 43.3 | 12 |
| Fast Ethernet (TX/ CDDI, T4) | | | | | | | |
| Units (M) | 0.12 | 2.08 | 6.56 | 15.60 | 26.25 | 38.72 | 218 |
| ASP ($) | 35.00 | 22.00 | 16.50 | 11.55 | 8.09 | 7.28 | -27 |
| Revenue ($M) | 4.2 | 45.8 | 108.2 | 180.2 | 212.2 | 281.7 | 132 |
| 100 VG-AnyLAN | | | | | | | |
| Units (M) | 0.12 | 1.18 | 2.16 | 4.65 | 8.81 | 12.98 | 155 |
| ASP ($) | 35.00 | 23.00 | 17.25 | 12.94 | 9.06 | 8.15 | -25 |
| Revenue ($M) | 4.2 | 27.1 | 37.3 | 60.2 | 79.8 | 105.8 | 91 |
| Total LAN Transceivers | | | | | | | |
| Units (M) | 24.78 | 30.72 | 35.77 | 45.76 | 59.09 | 74.21 | 25 |
| ASP ($) | 4.80 | 5.81 | 6.83 | 7.28 | 6.48 | 6.41 | 6 |
| Revenue ($M) | 119.0 | 178.4 | 244.3 | 333.0 | 382.9 | 475.5 | 32 |
| Regional Demand (%) | | | | | | | |
| North America | 58 | 56 | 54 | 52 | 50 | 48 | |
| Europe | 16 | 16 | 16 | 15 | 15 | 15 | |
| Japan | 6 | 6 | 6 | 6 | 5 | 5 | |
| Asia/Pacific | 20 | 22 | 24 | 27 | 30 | 32 | |

Source: Dataquest (November 1995)

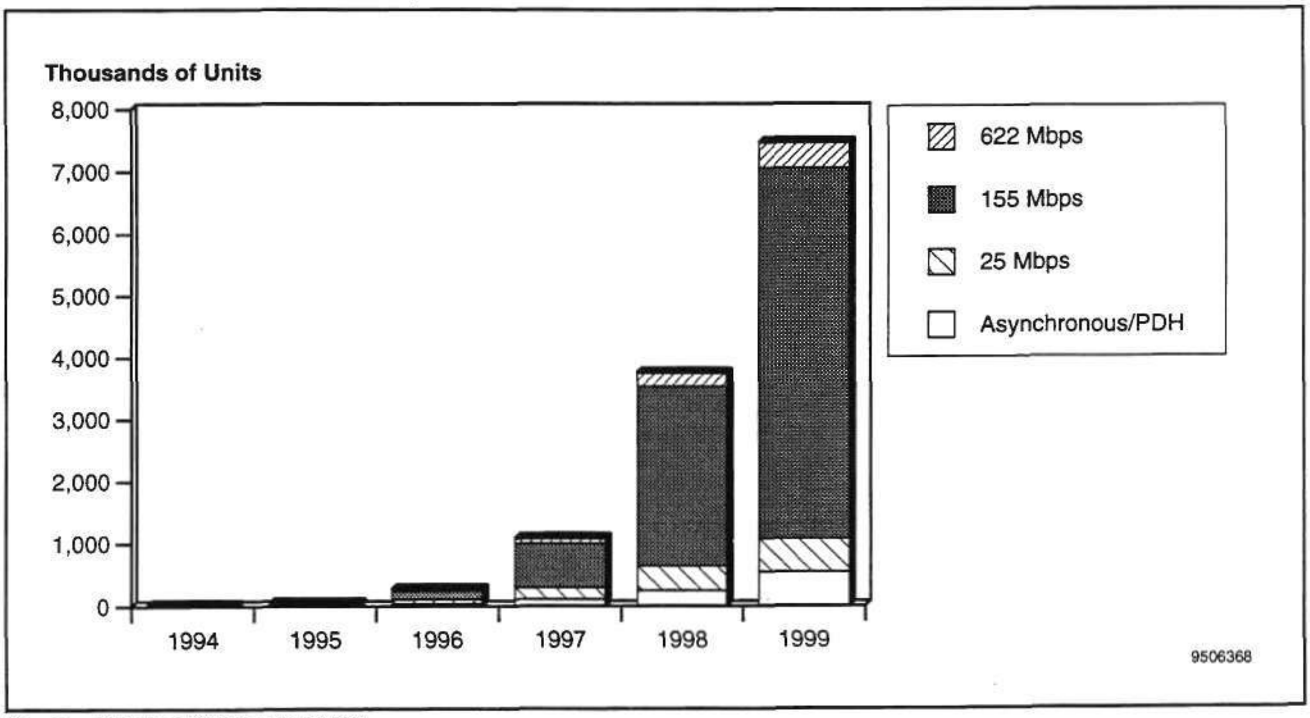
## Chapter 3
# The Asynchronous Transfer Mode IC Market

The worldwide forecast for asynchronous transfer mode-specific ICs is presented in Figures 3-1 through 3-3 and Tables 3-1 and 3-2. Note the asynchronous transfer mode ICs used in LAN, WAN, and public applications are also included in the market numbers. Key trends and assumptions about this market include the following:

- By mid-1996, most standards that affect the deployment of ATM in all aspects of LAN, WAN, and public infrastructure are expected to be stable. Key standards include LAN emulation (so that ATM can be seamlessly integrated with legacy LANs); flow control, or how different traffic is handled (for example, constant bit rate—CBR—for isochronous traffic like voice and live video); and public networks (via the network node interface standard—NNI).
- Initial broad deployment is occurring in LAN backbone applications, particularly in backbone and enterprise switches. The primary speed is expected to be 155 Mbps (SONET/SDH), with 622 Mbps emerging for campus backbone use. Desktop penetration with ATM adapter cards is expected to present a significant niche opportunity by the end of the decade. Switched Ethernet and Token Ring and their 10/100-Mbps follow-up should control the majority of desktop links for some time to come. The 25-Mbps speed will constitute a significant part of the ATM desktop mix.
- PBXs are expected to incorporate ATM as a high-speed pipe to the Public Switched Telephone Network (PSTN), replacing traditional time-division multiplexing.
- Carrier systems such as edge and core switches will incorporate ATM interfaces increasingly toward the end of decade. Initial use will support T/E-carrier as the physical layer on the local loop, migrating to synchronous SONET/SDH later this decade.
- The 155-Mbps physical interfaces implementing the UNI specification from the ATM Forum currently offer the greatest standard ATM chip opportunity. The segment assembly-reassembly (SAR) function is mostly implemented with 32/64 MPUs and ASICs now. This will show a trend toward a mix of ASSP versions as standards stabilize and volumes develop, thus warranting ASSP treatment by chip vendors.
- The 155-Mbps SAR and PHY functions are separate now, but an integrated solution will hit the market in late 1995. Economy and time-to-market advantages should compel designers to use increasing numbers of these integrated chips, causing them to become the largest opportunity in the ATM market, along with switches.
- 622-Mbps SARs and PHYs (two to three separate chips) will ramp in volume as that speed grade becomes increasingly popular by the end of the decade.
- ATM-specific switch ICs that support all the speeds will become the largest single ATM chip category by 1999. Currently, this market is largely ASIC-based. However, by 1999, a large ASSP market will develop. Included in this category are several management functions designed to support manageability and throughput.
- Chipsets that support the 25-Mbps and the T/E carrier (also known as asynchronous or plesiochronous digital hierarchy—PDH) speeds (especially T1/E1) will grow to be significant niche opportunities by 1999.

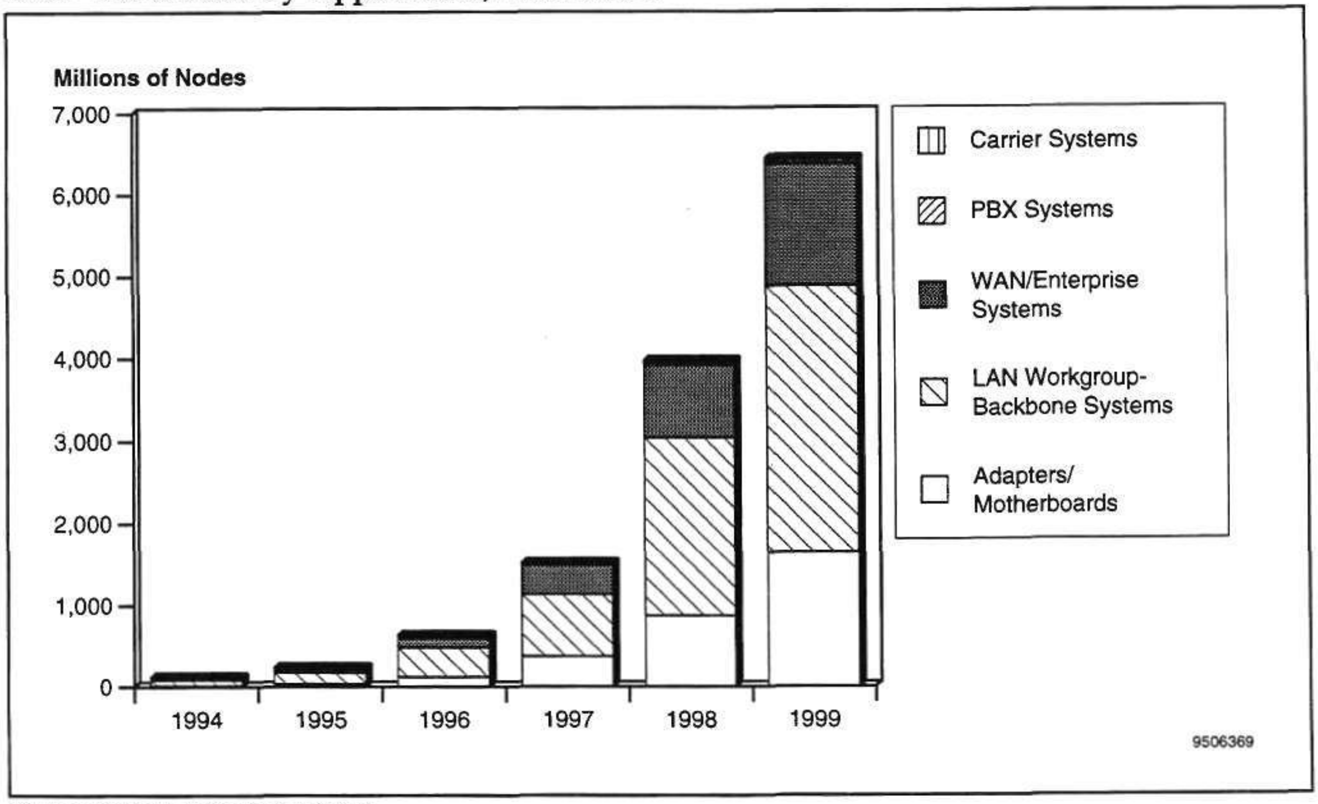
  

### Figure 3-1
### ATM Node Market Forecast, Worldwide



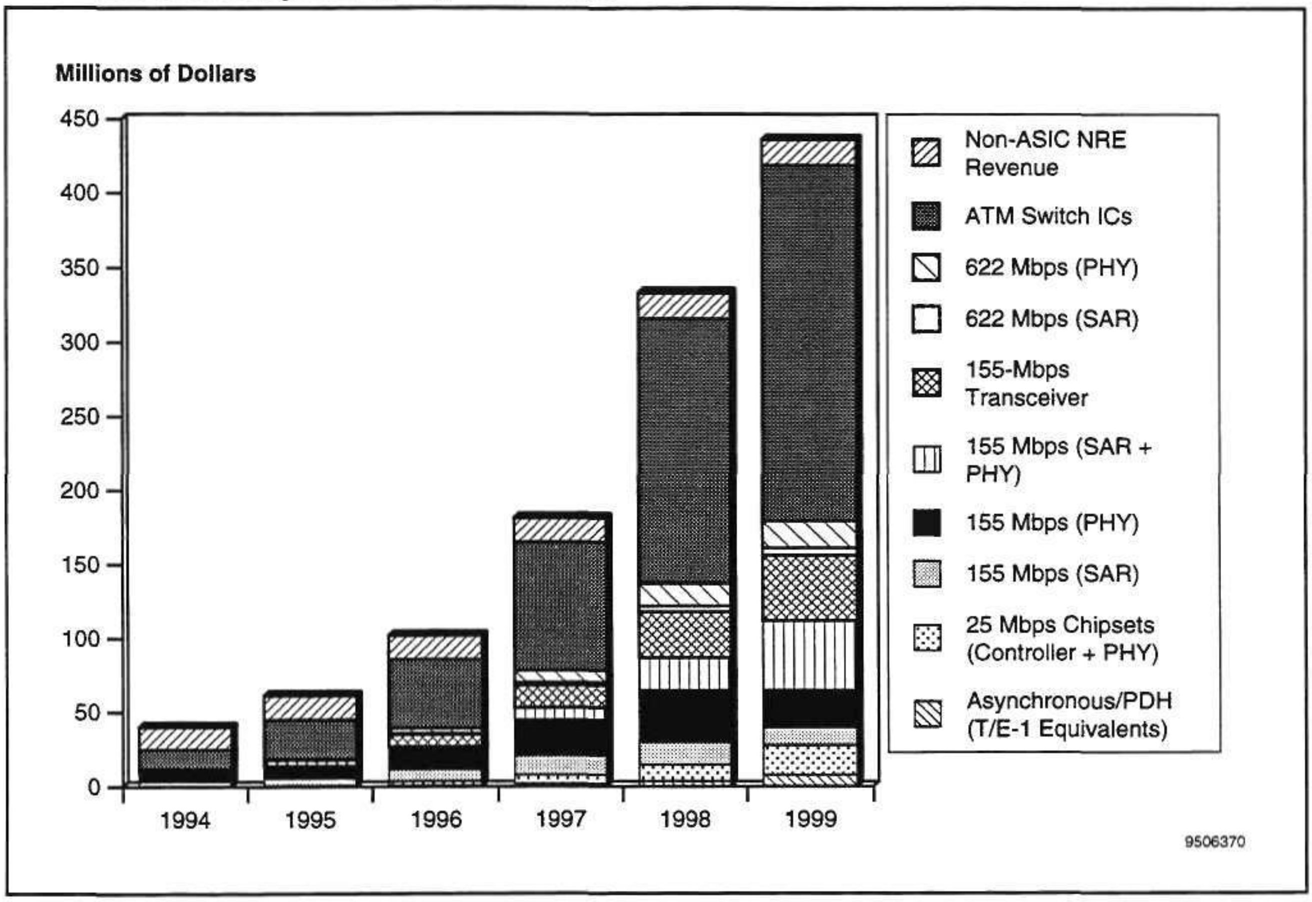

Source: Dataquest (November 1995)

### Figure 3-2
### ATM IC Forecast by Application, Worldwide




Source: Dataquest (November 1995)

**Figure 3-3**
**ATM IC Forecast by Revenue, Worldwide**




Source: Dataquest (November 1995)

**Table 3-1**
**ATM IC Market Forecast by Application, Worldwide**

| | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1995-1999 |
|---|---|---|---|---|---|---|---|
| Adapters/Motherboard (K Units) | 20 | 43 | 127 | 381 | 878 | 1,653 | 107 |
| 25 Mbps | 0 | 5 | 25 | 75 | 173 | 242 | 117 |
| 51-155 Mbps | 20 | 38 | 102 | 305 | 702 | 1,403 | 106 |
| 622 Mbps | 0 | 0 | 0.2 | 1 | 3.5 | 8 | NM |
| LAN Workgroup-Backbone Systems (K Ports) | 74 | 136 | 359 | 758 | 2,164 | 3,222 | 88 |
| 25 Mbps | 0 | 8 | 38 | 113 | 224 | 290 | 105 |
| 51-155 Mbps | 74 | 127 | 318 | 635 | 1,905 | 2,858 | 86 |
| 622 Mbps | 0 | 1 | 4 | 10 | 35 | 75 | 172 |
| WAN/Edge/Enterprise Systems (K Ports) | 14 | 44 | 122 | 354 | 878 | 1,495 | 103 |
| Asynchronous/PDH (T/E-1 Equivalents) | 4 | 15 | 45 | 113 | 248 | 545 | 105 |
| 51-155 Mbps | 10 | 28 | 67 | 202 | 504 | 731 | 92 |
| 622 Mbps | 0 | 1 | 10 | 40 | 126 | 219 | 238 |
| PBX Systems (K Ports) | 0 | 0 | 2 | 4 | 9 | 14 | NM |
| Asynchronous/PDH (T/E-1 Equivalents) | 0 | 0 | 1 | 2 | 5 | 7 | NM |
| 51-155 Mbps | 0 | 0 | 1 | 2 | 4 | 6 | NM |
| 622 Mbps | 0 | 0 | 0 | 0 | 0 | 1 | NM |
| Carrier Systems (K Ports) | 4 | 7 | 12 | 20 | 29 | 40 | 44 |
| 51-155 Mbps | 4 | 6 | 9 | 13 | 18 | 25 | 33 |
| 622 Mbps | 0 | 1 | 3 | 7 | 11 | 15 | 97 |
| Total ATM (K Units/Ports) | 112 | 229 | 622 | 1,517 | 3,957 | 6,423 | 95 |
| Asynchronous/PDH (T/E-1 Equivalents) | 4 | 15 | 46 | 115 | 253 | 552 | 106 |
| 25 Mbps | 0 | 13 | 63 | 188 | 397 | 531 | 110 |
| 155 Mbps | 108 | 199 | 497 | 1,157 | 3,133 | 5,022 | 91 |
| 622 Mbps | 0 | 2 | 17 | 58 | 176 | 318 | 192 |

NM = Not meaningful
Source: Dataquest (November 1995)

**Table 3-2**
**ATM IC Market Forecast by Function and Speed, Worldwide**

| | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1995-1999 |
|---|---|---|---|---|---|---|---|
| Asynchronous/ PDH-Based (PHY) | | | | | | | |
| T/E Carrier Units (K) | 4.0 | 15.0 | 46.0 | 114.5 | 252.5 | 551.5 | 106 |
| ASP ($) | 110.5 | 60.8 | 42.6 | 34.0 | 27.2 | 24.5 | -17 |
| Revenue ($M) | 0.4 | 0.9 | 2.0 | 3.9 | 6.9 | 13.5 | 71 |
| 25 Mbps Chipsets (Controller + PHY) | | | | | | | |
| Units (K) | 0 | 13.0 | 62.5 | 187.5 | 396.8 | 531.3 | 110 |
| ASP ($) | 0 | 55.0 | 44.0 | 30.8 | 24.6 | 22.7 | -16 |
| Revenue ($M) | 0 | 0.7 | 2.8 | 5.8 | 9.8 | 12.0 | 76 |
| 155 Mbps (SAR) | | | | | | | |
| Units (K) | 32.6 | 61.3 | 143.7 | 301.3 | 531.4 | 485.3 | 51 |
| ASP ($) | 120.0 | 75.0 | 56.3 | 42.2 | 31.6 | 26.9 | -19 |
| Revenue ($M) | 3.9 | 4.6 | 8.1 | 12.7 | 16.8 | 13.1 | 23 |
| Percentage ASIC | 42.0 | 31.0 | 28.0 | 28.0 | 28.0 | 27.0 | |
| Percentage ASSP | 8.0 | 12.0 | 42.0 | 52.0 | 62.0 | 68.0 | |
| Percentage MPU | 50.0 | 57.0 | 30.0 | 20.0 | 10.0 | 5.0 | |
| 155 Mbps (PHY) | | | | | | | |
| Units (K) | 108.0 | 199.0 | 471.9 | 983.1 | 1,879.5 | 1,506.7 | 50 |
| ASP ($) | 69.6 | 45.6 | 34.2 | 25.7 | 19.5 | 17.5 | -17 |
| Revenue ($M) | 7.5 | 9.1 | 16.1 | 25.2 | 36.6 | 26.4 | 24 |
| 155 Mbps (SAR + PHY) | | | | | | | |
| Units (K) | 0 | 0 | 16.0 | 129.1 | 531.4 | 1,455.9 | NM |
| ASP ($) | 0 | 0 | 85.0 | 61.2 | 44.7 | 35.7 | NM |
| Revenue ($M) | 0 | 0 | 1.4 | 7.9 | 23.7 | 52.0 | NM |
| Percentage ASIC | 0 | 0 | 10 | 10 | 10 | 10 | |
| Percentage ASSP | 0 | 0 | 90 | 90 | 90 | 90 | |
| 155-Mbps Transceiver (Copper) | | | | | | | |
| Units (K) | 10.8 | 19.9 | 124.2 | 578.3 | 2,349.4 | 4,520.1 | 196 |
| ASP ($) | 22.0 | 21.0 | 15.8 | 12.6 | 10.1 | 9.1 | -15 |
| Revenue ($M) | 0.2 | 0.4 | 2.0 | 7.3 | 23.7 | 41.0 | 150 |

(Continued)

**Table 3-2 (Continued)**
**ATM IC Market Forecast by Function and Speed, Worldwide**

| | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1995-1999 |
|---|---|---|---|---|---|---|---|
| 622 Mbps (SAR) | | | | | | | |
| Units (K) | 0 | 0.1 | 3.7 | 13.6 | 43.8 | 81.6 | 339 |
| ASP ($) | 0 | 260.0 | 195.0 | 146.3 | 109.7 | 82.3 | -21 |
| Revenue ($M) | 0 | 0 | 0.7 | 2.0 | 4.8 | 6.7 | 249 |
| Percentage ASIC | 0 | 100 | 90 | 70 | 55 | 45 | |
| Percentage ASSP | 0 | 0 | 10 | 30 | 45 | 55 | |
| 622 Mbps (PHY) | | | | | | | |
| Units (K) | 0 | 1.5 | 17.3 | 58.3 | 175.5 | 317.7 | 192 |
| ASP ($) | 0 | 384.8 | 230.9 | 150.1 | 105 | 73.5 | -28 |
| Revenue ($M) | 0 | 0.6 | 4.0 | 8.8 | 18.4 | 23.4 | 110 |
| ATM Switch and Support ICs | | | | | | | |
| Ports (K) | 112.0 | 228.5 | 622.5 | 1,516.9 | 3,957.3 | 6,422.8 | 95 |
| ASP per Port ($) | 115.0 | 110.0 | 77.0 | 57.8 | 46.2 | 37.0 | -20 |
| Revenue ($M) | 12.9 | 25.1 | 47.9 | 87.6 | 182.8 | 237.4 | 57 |
| Percentage ASIC | 100 | 99 | 90 | 65 | 55 | 50 | |
| Percentage ASSP | 0 | 1 | 10 | 35 | 45 | 50 | |
| Non-ASIC NRE Revenue ($M) | 15.0 | 16.0 | 16.0 | 16.0 | 17.0 | 17.0 | 1 |
| Total Revenue ($M) | 40.0 | 57.4 | 100.9 | 177.1 | 340.6 | 442.6 | 50 |
| Regional Demand | | | | | | | |
| North America | 85 | 83 | 77 | 72 | 66 | 61 | |
| Europe | 10 | 10 | 15 | 18 | 22 | 26 | |
| Japan | 4 | 6 | 7 | 8 | 9 | 10 | |
| Asia/Pacific | 1 | 1 | 1 | 2 | 3 | 3 | |

NM = Not meaningful
Source: Dataquest (November 1995)

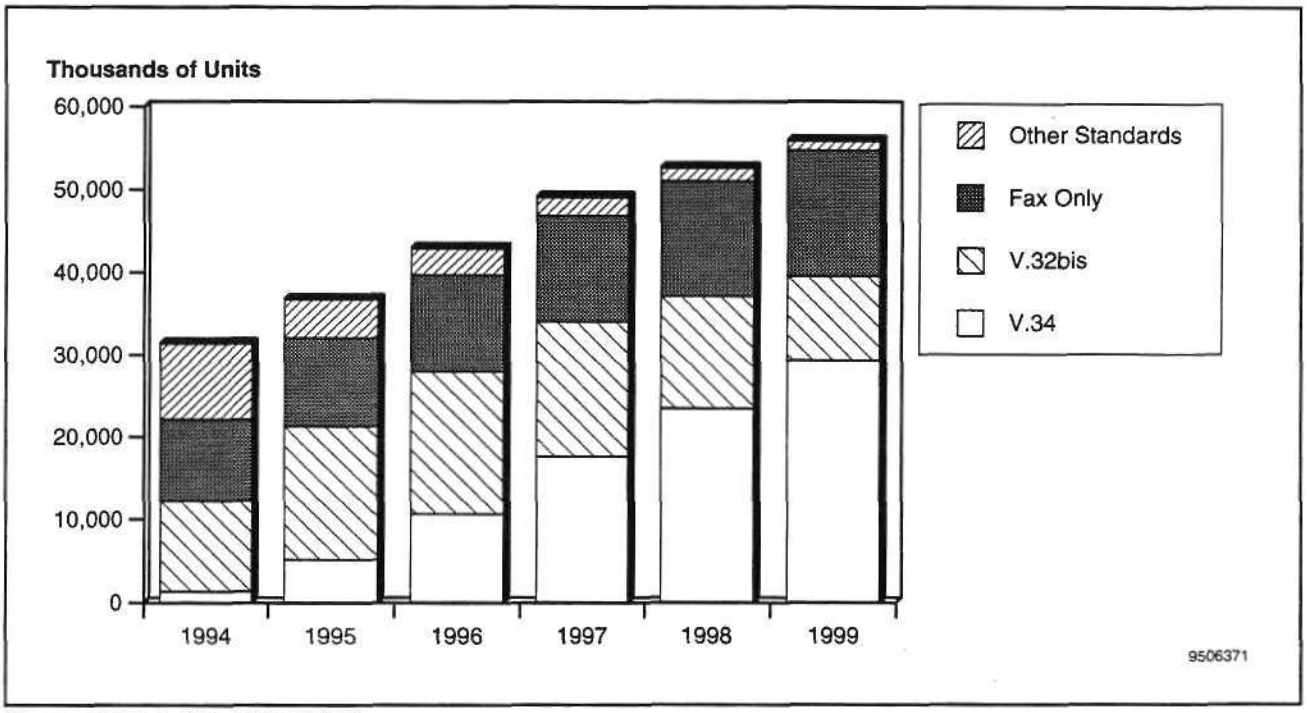
## Chapter 4

# The Modem IC Market

The worldwide forecast for modem ICs is presented in Figure 4-1 and Table 4-1. Key trends and assumptions about this market include the following:

- The overall modem IC market continues to expand rapidly as several new demand drivers absorb more chipsets. Some of those key drivers include the following:
  - Internet access
  - Online service access (America Online, CompuServe, and others)
  - PC OEM bundling for home systems and notebooks
  - Remote LAN access from homes and branch offices, or mobile access
  - Embedded modems in credit verification systems, vending machines, and others
- The V.34 standard (28.8 Kbps) is ramping quickly as most of the global modem system vendors now have several models available on the market. The only thing preventing a rapid market rollover to V.34 is relatively higher pricing as modem IC vendors seek to maximize profits with the higher speed and full feature sets. Because of this, V.34 is not expected to cross over V.32bis (14.4 Kbps) in unit volume until late 1997 or 1998.
- V.32bis modem ICs that support V.29 (9.6 Kbps) faxing are now the high-volume product. Product lines have recently broadened to incorporate speakerphone, caller ID, and answering phone capability. One or more of these features can add 25 percent to 100 percent to the price shown in Table 4-1.
- The same trend is evident in V.34 modems with advanced features commanding a premium. The latest high-value-added feature appearing in modem chipsets is digital simultaneous voice and data (DSVD), for which there is an ITU standards effort under way. DSVD employs voice compression techniques to combine a phone conversation with data transmission to support conferencing sessions over the same line.
- ISDN-basic rate is becoming widely regarded as the next modem standard after V.34. ISDN-basic rate uses a digital transmission technique and is capable of speeds up to 128 Kbps in one direction.
- Standard fax chips that support on V.29 or V.17 Class 1 or 2 faxing are also a substantial and growing market. These are used in standalone fax machines and fax-only PC cards.
- There are several other standards, such as V.32 (9.6 Kbps) and V.22bis (2.4 Kbps), that continue to serve many applications and areas of the world adequately. Because the new standards are backwardly compatible, we predict that many of the older standards will be phased out gradually over the next five years.
- Modems for use in transferring data and multimedia content on a CATV coax are being introduced. Broad deployment is not expected until 1997.

**Figure 4-1**
**Modem IC Market Forecast, Worldwide**




Source: Dataquest (November 1995)

**Table 4-1**
**Modem Chipset Market Forecast, Worldwide**

| | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|
| V.34 | | | | | | | |
| Units (K) | 1,410 | 5,217 | 10,695 | 17,647 | 23,470 | 29,337 | 84 |
| ASP ($) | 60.5 | 42.0 | 28.5 | 24.2 | 23.0 | 21.8 | -18 |
| Revenue ($M) | 85 | 219 | 304 | 427 | 540 | 641 | 50 |
| V.32 bis | | | | | | | |
| Units (K) | 10,891 | 16,119 | 17,295 | 16,431 | 13,637 | 10,228 | -1 |
| ASP ($) | 29.0 | 17.8 | 16.4 | 14.7 | 14.0 | 13.0 | -15 |
| Revenue ($M) | 316 | 287 | 283 | 242 | 191 | 133 | -16 |
| Fax Only | | | | | | | |
| Units (K) | 9,875 | 10,764 | 11,732 | 12,788 | 13,939 | 15,194 | 9 |
| ASP ($) | 8.8 | 8.3 | 8.2 | 8.1 | 8.1 | 8.0 | -2 |
| Revenue ($M) | 87 | 89 | 96 | 104 | 112 | 121 | 7 |
| Other Standards | | | | | | | |
| Units (K) | 9,230 | 4,615 | 3,231 | 2,261 | 1,583 | 1,108 | -35 |
| ASP ($) | 12.4 | 11.7 | 11.1 | 10.6 | 10.1 | 9.6 | -5 |
| Revenue ($M) | 114 | 54 | 36 | 24 | 16 | 11 | -38 |
| Total | | | | | | | |
| Units (K) | 31,406 | 36,714 | 42,953 | 49,127 | 52,630 | 55,867 | 12 |
| ASP ($) | 19.2 | 17.7 | 16.8 | 16.2 | 16.3 | 16.2 | -3 |
| Revenue ($M) | 602 | 650 | 720 | 797 | 859 | 906 | 9 |
| Regional Demand (%) | | | | | | | |
| North America | 30 | 28 | 26 | 24 | 22 | 22 | |
| Europe | 10 | 11 | 11 | 12 | 13 | 13 | |
| Japan | 21 | 19 | 18 | 17 | 16 | 16 | |
| Asia/Pacific | 39 | 42 | 45 | 47 | 49 | 49 | |

Source: Dataquest (November 1995)

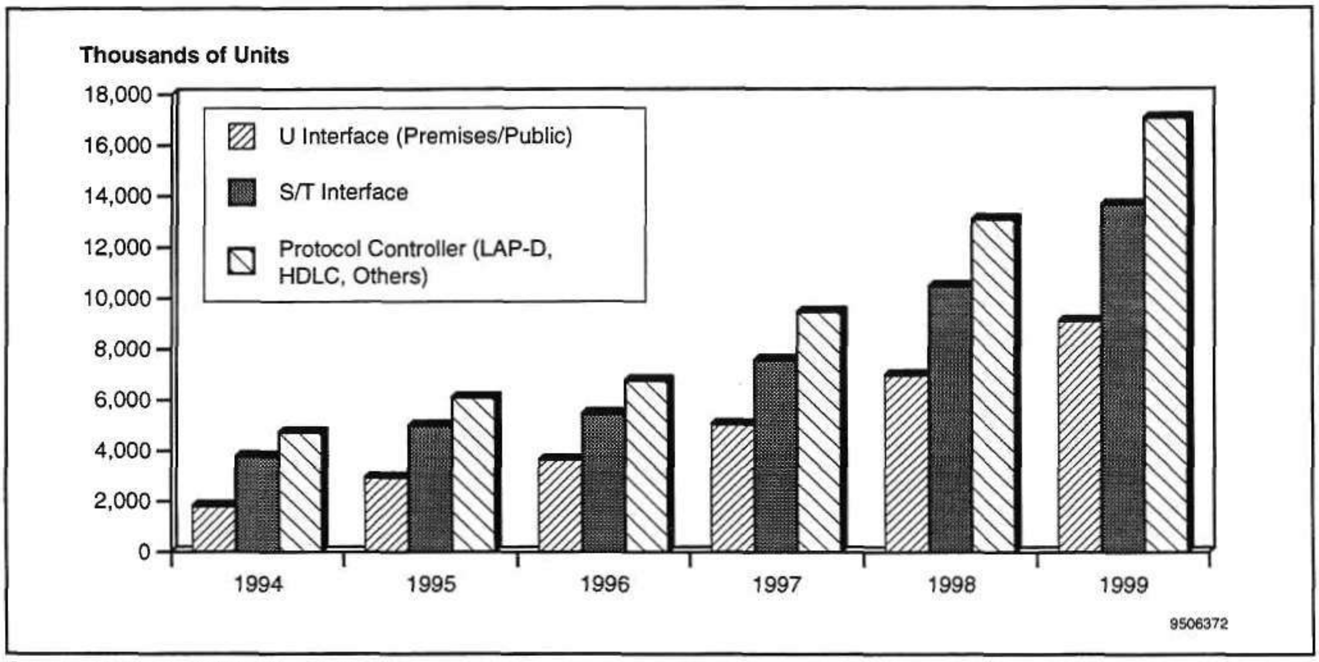
  

## Chapter 5
# The ISDN IC Market

The worldwide forecast for ISDN ICs is presented in Figure 5-1 and Table 5-1. Key trends and assumptions about this market include the following:

- After languishing for nearly a decade, ISDN is finally kicking into high gear, aided by supply and demand factors. On the supply side, Deutsche Telecom in Germany and U.S. carriers like Pacific Bell have cut their basic-rate (two 56-Kbps channels) service fees dramatically. Pacific Bell service can be acquired for under $30 per month plus $0.01 minute for off-peak residential use. Dataquest is projecting that 11 million basic rate lines will be in use worldwide by the end of the decade, up from 1.5 million currently.
- Key applications of ISDN chips include central office and PBX line cards, PC and workstation adapters (or "digital modems"), routers, remote access servers, WAN systems, telephones, and Group 4 fax machines.
- Key ICs used in the market include transceivers to the two-wire public twisted pair known as the U interface, an intrapremises transceiver standard known as S/T, and protocol controllers.
- Single-chip U and S/T transceivers are becoming standard and shipping in ever-increasing volumes.
- There are opportunities for protocol chips that implement the LAP-D function for controlling the data channel (D channel), the HDLC protocol for the bearer channels (B channels), and functions for controlling the bonding of two bearer channels for asymmetrical uses such as downloading multimedia-rich Internet/World Wide Web files.

**Figure 5-1**
**ISDN IC Market Forecast, Worldwide**




Source: Dataquest (November 1995)

**Table 5-1**
**ISDN BRI IC Market Forecast, Worldwide**

| | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|
| U Interface (Premises/ Public) | | | | | | | |
| Units (K) | 1,799 | 2,935 | 3,641 | 5,046 | 6,974 | 9,095 | 38.3 |
| ASP ($) | 19.0 | 16.2 | 14.5 | 13.8 | 13.5 | 13.3 | -6.9 |
| Revenue ($M) | 34.2 | 47.4 | 52.9 | 69.7 | 94.4 | 120.6 | 28.7 |
| S/T Interface | | | | | | | |
| Units (K) | 3,778 | 4,989 | 5,461 | 7,569 | 10,460 | 13,642 | 29.3 |
| ASP ($) | 4.9 | 4.7 | 4.4 | 4.2 | 4.0 | 3.8 | -5.0 |
| Revenue ($M) | 18.5 | 23.2 | 24.2 | 31.8 | 41.7 | 51.7 | 22.8 |
| Protocol Controller (LAP-D, HDLC, Others) | | | | | | | |
| Units (K) | 4,722 | 6,087 | 6,772 | 9,461 | 13,076 | 17,053 | 29.3 |
| ASP ($) | 12.0 | 10.8 | 9.7 | 9.2 | 8.8 | 8.3 | -7.0 |
| Revenue ($M) | 56.7 | 65.7 | 65.8 | 87.4 | 114.7 | 142.1 | 20.2 |
| Total ISDN | | | | | | | |
| Units (K) | 10,298 | 14,011 | 15,874 | 22,077 | 30,510 | 39,790 | 31.0 |
| ASP ($) | 10.6 | 9.7 | 9.0 | 8.6 | 8.2 | 7.9 | -5.7 |
| Revenue ($M) | 109.4 | 136.4 | 142.9 | 188.8 | 250.8 | 314.4 | 23.5 |
| Regional Shipment Split (%) | | | | | | | |
| North America | 10 | 15 | 20 | 23 | 25 | 27 | |
| Europe | 45 | 43 | 41 | 39 | 37 | 35 | |
| Japan | 20 | 19 | 18 | 17 | 16 | 15 | |
| Asia/Pacific-ROW | 25 | 23 | 21 | 21 | 22 | 23 | |

Source: Dataquest (November 1995)

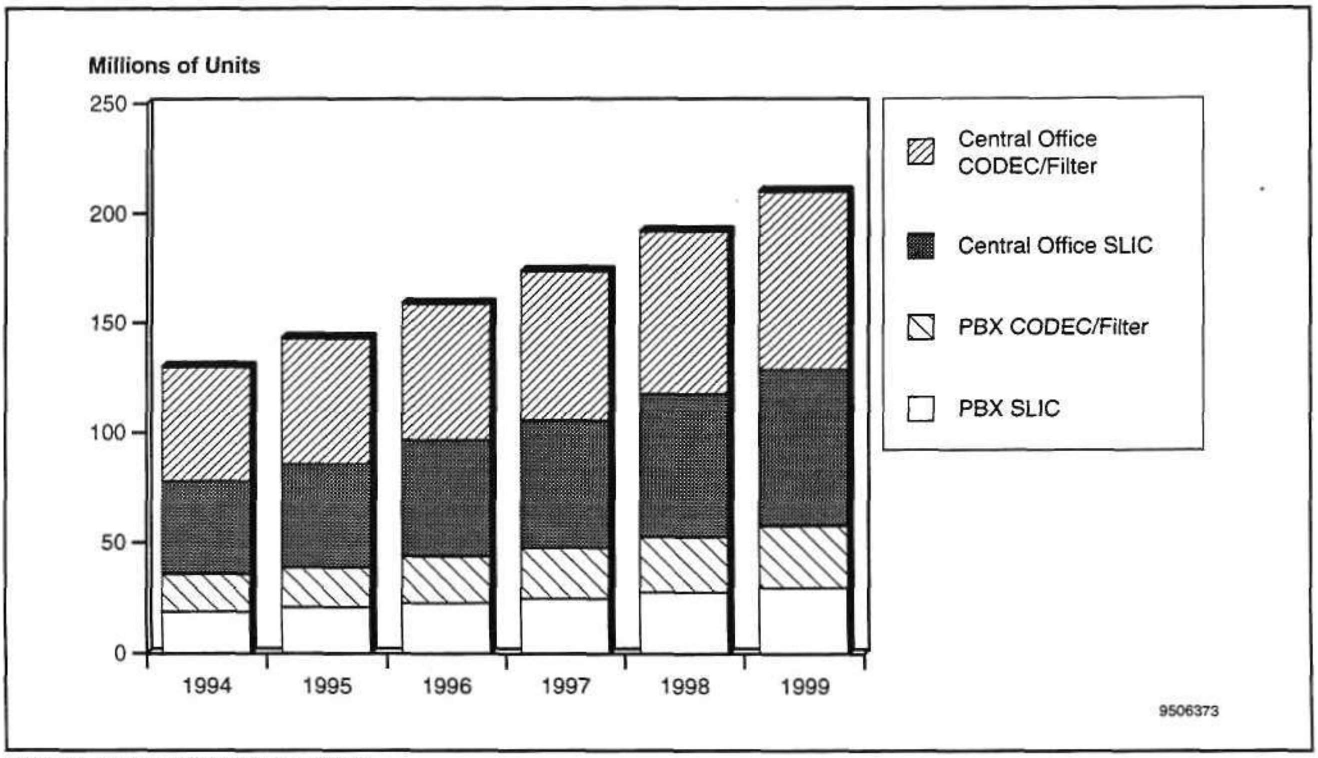
  

# Chapter 6
# The Line Card, T/E Carrier, and SONET/SDH Markets

The worldwide forecast for line card ICs is presented in Figure 6-1 and Table 6-1. Key trends and assumptions about this market include the following:

- Primary applications for these devices include central office (CO) line cards and PBX systems.
- The two major types of line card ICs (analog) are subscriber line interface circuits (SLICs) and CODEC/filters (also known as combos). Digital line cards employ ISDN functions primarily. Externally oriented CO line cards generally require more sophisticated SLICs and combos.
- Although the SLIC market is fairly mature, there are numerous developments helping to lower the cost of line cards and add value to SLICs. Opportunities exist for SLICs that support more than one channel (duals, among others) and for new versions that eliminate the need for separate mechanical relays to direct the ring voltage. Advanced high-voltage isolating bipolar technology is helpful for this market.
- CODEC/filters convert voice signals to and from digital PCM format (u-Law or A-Law) for routing through the backplane switch fabric. PCM is required as modern CO and PBX switches are, in effect, software-programmable computers with the switch fabric implemented in CMOS and bipolar ASIC technology. Key opportunities for CODEC/filters include those tailored for certain vendors' switches (backplane mux), dual and quad channel, DSP (for voice quality and compression), and certain microprocessor interfaces.

**Figure 6-1**
**Line Card IC Market Forecast, Worldwide**




Source: Dataquest (November 1995)

**Table 6-1**
**Line Card IC Market Forecast, Worldwide (Per-Channel Basis)**

| | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|
| PBX | | | | | | | |
| Total Revenue ($M) | 95.7 | 101.6 | 107.8 | 113.8 | 120.5 | 127.7 | 5.9 |
| SLIC | | | | | | | |
| Units (M) | 18.5 | 20.5 | 22.8 | 25.1 | 27.6 | 30.3 | 10.4 |
| ASP ($) | 3.6 | 3.4 | 3.2 | 3.1 | 3.0 | 2.8 | -4.6 |
| Revenue ($M) | 66.6 | 70.2 | 74.1 | 77.4 | 81.7 | 86.3 | 5.3 |
| CODEC/Filter | | | | | | | |
| Units (M) | 16.7 | 18.5 | 20.5 | 22.8 | 25.0 | 27.6 | 10.6 |
| ASP ($) | 1.8 | 1.7 | 1.6 | 1.6 | 1.5 | 1.5 | -3.0 |
| Revenue ($M) | 29.1 | 31.4 | 33.8 | 36.4 | 38.8 | 41.4 | 7.3 |
| Central Office | | | | | | | |
| Total Revenue ($M) | 420.2 | 441.3 | 463.5 | 484.4 | 506.0 | 525.8 | 4.6 |
| SLIC | | | | | | | |
| Units (M) | 41.9 | 47.0 | 52.6 | 58.4 | 64.8 | 71.3 | 11.2 |
| ASP ($) | 5.9 | 5.5 | 5.2 | 4.9 | 4.6 | 4.3 | -6.0 |
| Revenue ($M) | 247.3 | 260.4 | 274.1 | 286.3 | 298.7 | 308.9 | 4.5 |
| CODEC/Filter | | | | | | | |
| Units (M) | 52.4 | 57.1 | 62.3 | 67.9 | 74.0 | 80.6 | 9.0 |
| ASP ($) | 3.3 | 3.2 | 3.0 | 2.9 | 2.8 | 2.7 | -4.0 |
| Revenue ($M) | 172.9 | 180.9 | 189.3 | 198.1 | 207.3 | 216.9 | 4.6 |
| Total Line Card ICs | | | | | | | |
| Total Revenue ($M) | 516.0 | 542.9 | 571.3 | 598.2 | 626.6 | 653.5 | 4.8 |
| SLIC | | | | | | | |
| Units (M) | 60.4 | 67.5 | 75.4 | 83.5 | 92.4 | 101.7 | 11.0 |
| ASP ($) | 5.2 | 4.9 | 4.6 | 4.4 | 4.1 | 3.9 | -5.6 |
| Revenue ($M) | 313.9 | 330.6 | 348.2 | 363.7 | 380.4 | 395.2 | 4.7 |
| CODEC/Filter | | | | | | | |
| Units (M) | 69.1 | 75.6 | 82.8 | 90.6 | 99.0 | 108.2 | 9.4 |
| ASP ($) | 2.9 | 2.8 | 2.7 | 2.6 | 2.5 | 2.4 | -4.0 |
| Revenue ($M) | 202.1 | 212.3 | 223.1 | 234.5 | 246.1 | 258.3 | 5.0 |
| Regional Demand (%) | | | | | | | |
| North America | 35 | 35 | 34 | 33 | 32 | 31 | |
| Europe | 52 | 51 | 51 | 50 | 49 | 48 | |
| Japan | 6 | 6 | 5 | 5 | 4 | 4 | |
| Asia/Pacific | 7 | 8 | 10 | 12 | 15 | 17 | |

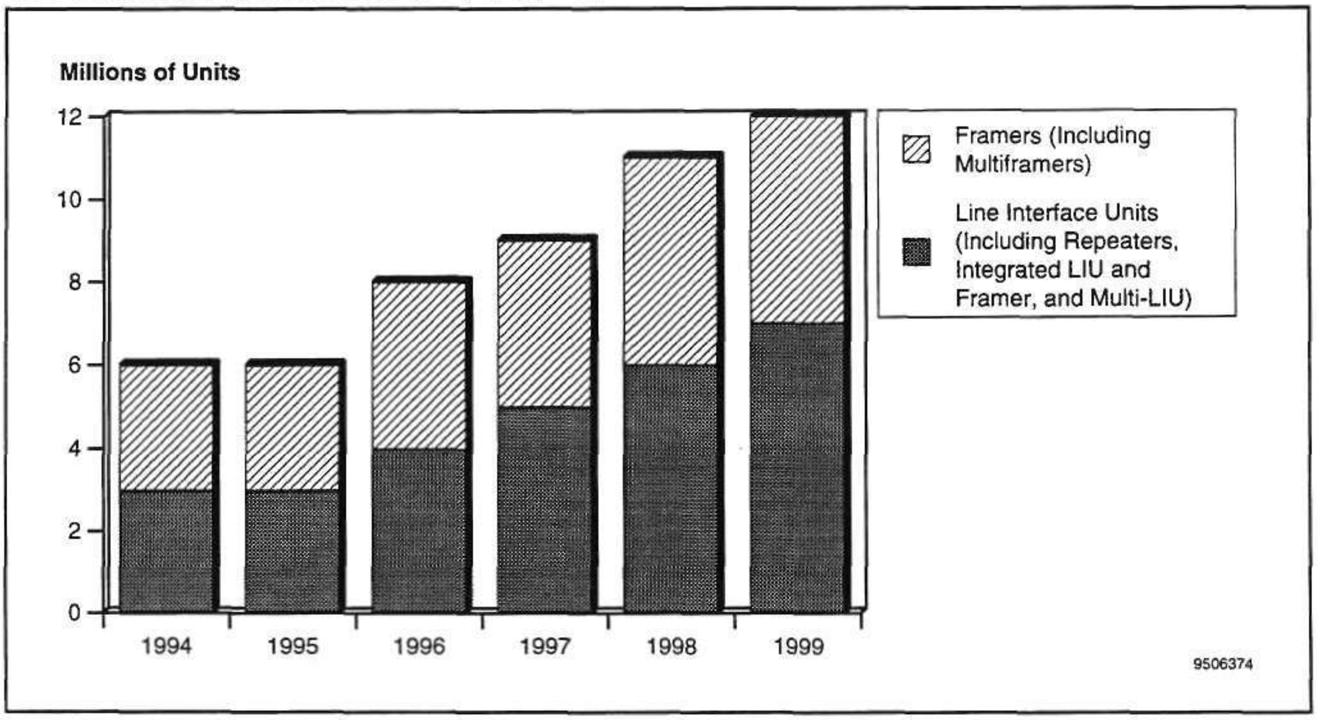
Source: Dataquest (November 1995)

The worldwide forecast for T/E carrier ICs (also known as plesiochronous digital hierarchy—PDH) is presented in Figure 6-2 and Table 6-2. Key trends and assumptions about this market include the following:

- HDSL (high-speed digital subscriber loop) technology is replacing T/E-1 deployments in some areas. Its primary advantage is the elimination of costly repeaters.
- T/E carrier ICs are used to implement a digital plesiochronous telecom circuit between the carrier and customer premises equipment. Also known as T (United States) or E (Europe) carriers, these circuits are generally leased from the local carrier for carrying multiplexed data and voice traffic to and from PBXs, LAN, WAN, and videoconferencing systems. The most common speeds are T1/E1 (1.5/2.0 Mbps), T3/E3 (45 Mbps/34 Mbps), and fractional T1 (a common speed is 384 Kbps).
- Key applications include DSU/CSUs, cross-connects, channel banks, multiplexers, inverse multiplexers, PBX and CO line cards, and routers.
- T/E carrier line shipments are on the upswing, driven by the need to transfer more data, faster, between facilities. Services like frame relay and switched multimegabit data service (SMDS) are becoming vary popular now because they can employ T/E carrier circuits as the physical layer.
- T/E carrier ICs include transceivers, framers, and specialized clock and elastic store functions. Opportunities include combining the transceiver and framer in a single IC, quad transceivers and framers (for inverse multiplexers), multiplexers on a chip, T/E carrier-ATM functions, and more highly integrated T3/E3 transceivers.

**Figure 6-2**
**T/E Carrier IC Market Forecast, Worldwide**




Source: Dataquest (November 1995)

**Table 6-2**
**T/E Carrier IC Market Forecast, Worldwide**

| | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|
| Line Interface Units(Including Repeaters, Integrated LIU and Framer, and Multi-LIU) | | | | | | | |
| T1/E1 Mbps | | | | | | | |
| Units (M) | 2.5 | 3.1 | 3.9 | 4.7 | 5.6 | 6.4 | 20.9 |
| ASP ($) | 11.5 | 12.0 | 12.6 | 13.2 | 13.8 | 14.5 | 4.8 |
| Revenue ($M) | 28.5 | 37.1 | 48.7 | 61.3 | 77.3 | 93.3 | 26.7 |
| ≥T3/E3 | | | | | | | |
| Units (M) | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 39.5 |
| ASP ($) | 45.0 | 44.1 | 43.2 | 42.4 | 41.5 | 40.7 | -2.0 |
| Revenue ($M) | 5.4 | 7.9 | 11.7 | 17.2 | 21.0 | 25.7 | 36.7 |
| Total | | | | | | | |
| Units (M) | 2.6 | 3.3 | 4.1 | 5.1 | 6.1 | 7.0 | 22.1 |
| ASP ($) | 13.0 | 13.7 | 14.6 | 15.5 | 16.1 | 16.9 | 5.3 |
| Revenue ($M) | 33.9 | 45.0 | 60.3 | 78.5 | 98.3 | 119.0 | 28.5 |
| Framers (Including Multiframers) | | | | | | | |
| T1/E1 Mbps | | | | | | | |
| Units (M) | 2.5 | 3.0 | 3.4 | 3.8 | 4.2 | 4.6 | 12.9 |
| ASP ($) | 20.0 | 20.8 | 21.6 | 22.5 | 23.4 | 24.3 | 4.0 |
| Revenue ($M) | 49.6 | 61.9 | 74.0 | 86.2 | 98.7 | 110.8 | 17.4 |
| ≥T3/E3 | | | | | | | |
| Units (M) | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 39.5 |
| ASP ($) | 65.0 | 64.4 | 61.1 | 58.1 | 55.2 | 52.4 | -4.2 |
| Revenue ($M) | 7.8 | 11.6 | 16.5 | 23.5 | 27.9 | 33.2 | 33.6 |
| Total | | | | | | | |
| Units (M) | 2.6 | 3.2 | 3.7 | 4.2 | 4.7 | 5.2 | 14.8 |
| ASP ($) | 22.1 | 23.3 | 24.5 | 25.9 | 26.8 | 27.8 | 4.7 |
| Revenue ($M) | 57.4 | 73.5 | 90.5 | 109.8 | 126.6 | 144.0 | 20.2 |
| Clock/Elastic Store/ Multiplexer/Mapper | | | | | | | |
| Revenue ($M) | 18.3 | 24.9 | 31.7 | 39.5 | 47.2 | 55.2 | 24.8 |
| HDSL Function Sets | | | | | | | |
| Units (M) | 0 | 0.1 | 0.1 | 0.2 | 0.2 | 0.3 | 41.3 |
| ASP ($) | 78.0 | 77.2 | 73.4 | 69.7 | 66.2 | 62.9 | -4.2 |
| Revenue ($M) | 3.5 | 5.9 | 9.0 | 12.8 | 14.6 | 15.9 | 35.3 |

(Continued)

**Table 6-2 (Continued)**
**T/E Carrier IC Market Forecast, Worldwide**

| | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|
| Total T/E Carrier | | | | | | | |
| Units (M) | 5.2 | 6.5 | 8.0 | 9.5 | 11.0 | 12.5 | 18.9 |
| ASP ($) | 21.6 | 22.9 | 24.1 | 25.4 | 26.0 | 26.8 | 4.4 |
| Revenue ($M) | 113.1 | 149.3 | 191.5 | 240.5 | 286.7 | 334.2 | 24.2 |
| Regional Demand (%) | | | | | | | |
| North America | 61 | 60 | 59 | 58 | 57 | 56 | |
| Europe | 40 | 40 | 40 | 39 | 38 | 37 | |
| Japan | 5 | 5 | 5 | 5 | 5 | 5 | |
| Asia/Pacific | 4 | 4 | 4 | 4 | 4 | 5 | |

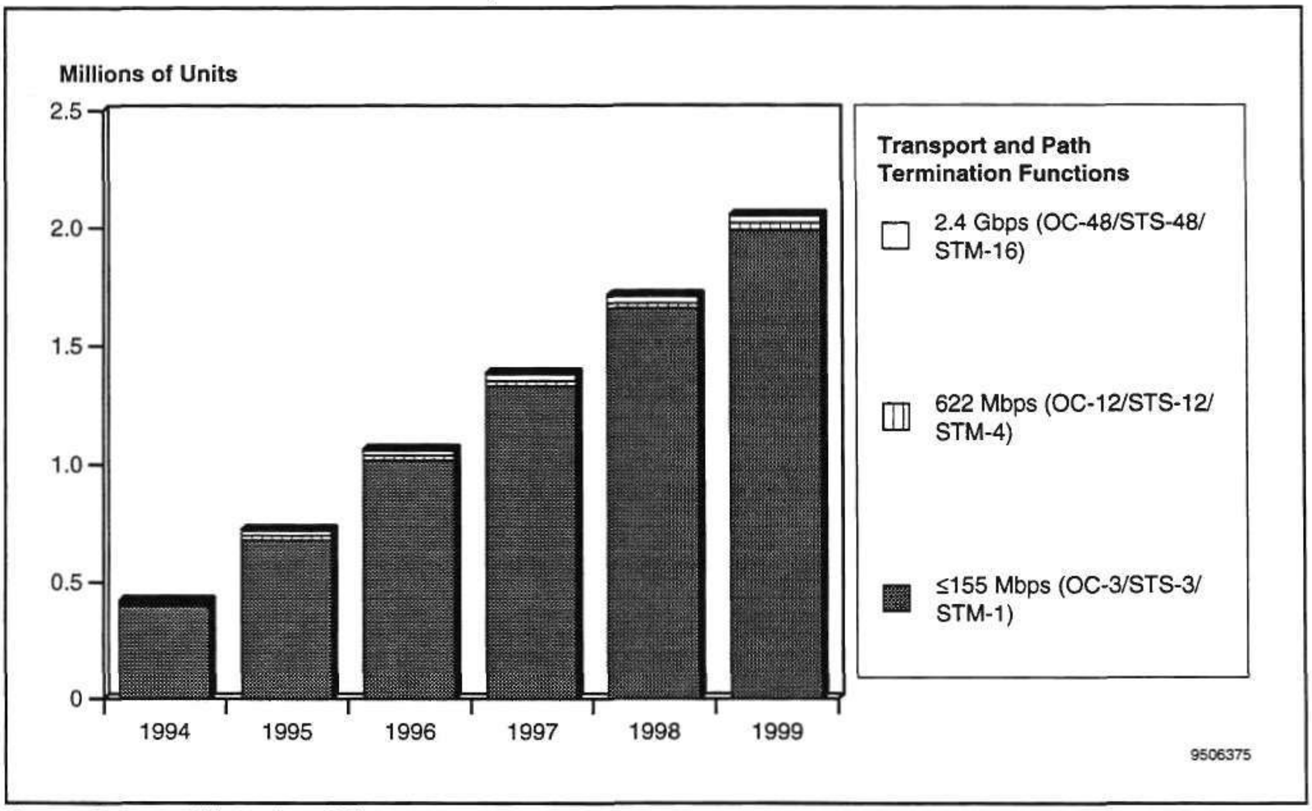
Source: Dataquest (November 1995)

The worldwide forecast for SONET/SDH ICs is presented in Figure 6-3 and Table 6-3. Key trends and assumptions about this market include the following:

- SONET/SDH ICs are used primarily in synchronous fiber-optic communications equipment used by telephone carriers, cable TV companies, and some private networks. SONET/SDH physical layer functions are also being employed in ATM technology (these are included in the ATM category).
- Key applications include a variety of different multiplexers (add-drop and inverse, among others), cross-connects, and terminals that concentrate voice, data, and multimedia traffic. This technology can range from 51 Mbps to several gigabits per second. The most common speeds are 155, 622, and 2048 Mbps.
- Key SONET/SDH functions include transceivers and framers. Transceivers can vary from a single chip (155 Mbps or less) working over copper wiring to three or four chips (clock recovery, and serialization, among others) for fiber optics at the higher speeds (excluding fiber transceiver module, which converts electrical signals to and from optical signals). The higher speeds most often involve bipolar-ECL and GaAs technologies.
- Other functions include ICs that implement multiplexing and connect tributary circuits.

**Figure 6-3**
**SONET/SDH IC Market Forecast, Worldwide**




Source: Dataquest (November 1995)

**Table 6-3**
**SONET/SDH IC Market Foercast, Worldwide**

| | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|
| Transport and Path Termination Functions | | | | | | | |
| ≤155 Mbps (OC-3/ STS-3/STM-1) | | | | | | | |
| Units (M) | 0.40 | 0.68 | 1.02 | 1.33 | 1.66 | 1.99 | 37.8 |
| ASP ($) | 142.0 | 120.7 | 102.6 | 92.3 | 83.1 | 74.8 | -12.0 |
| Revenue ($M) | 56.8 | 82.1 | 104.6 | 122.4 | 137.7 | 148.8 | 21.2 |
| 622 Mbps (OC-12/ STS-12/STM-4) | | | | | | | |
| Units (M) | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 | 0.03 | 22.1 |
| ASP ($) | 370.0 | 314.5 | 267.3 | 240.6 | 216.5 | 194.9 | -12.0 |
| Revenue ($M) | 3.7 | 4.9 | 4.8 | 4.9 | 5.1 | 5.3 | 7.4 |
| 2.4 Gbps (OC-48/ STS-48/STM-16) | | | | | | | |
| Units (M) | 0.01 | 0.02 | 0.02 | 0.03 | 0.03 | 0.03 | 28.5 |
| ASP ($) | 565.0 | 536.8 | 509.9 | 484.4 | 460.2 | 437.2 | -5.0 |
| Revenue ($M) | 5.7 | 10.7 | 11.7 | 12.8 | 14.0 | 15.3 | 22.0 |
| Total | | | | | | | |
| Units (M) | 0.42 | 0.72 | 1.06 | 1.37 | 1.71 | 2.05 | 37.3 |
| ASP ($) | 157.5 | 136.5 | 114.2 | 102.1 | 91.6 | 82.6 | -12.1 |
| Revenue ($M) | 66.2 | 97.7 | 121.1 | 140.2 | 156.8 | 169.3 | 20.7 |
| Regional Demand (%) | | | | | | | |
| North America | 58 | 58 | 57 | 57 | 56 | 56 | |
| Europe | 35 | 35 | 35 | 35 | 35 | 35 | |
| Japan | 5 | 5 | 5 | 5 | 6 | 6 | |
| Asia/Pacific | 2 | 2 | 3 | 3 | 3 | 3 | |

Source: Dataquest (November 1995)

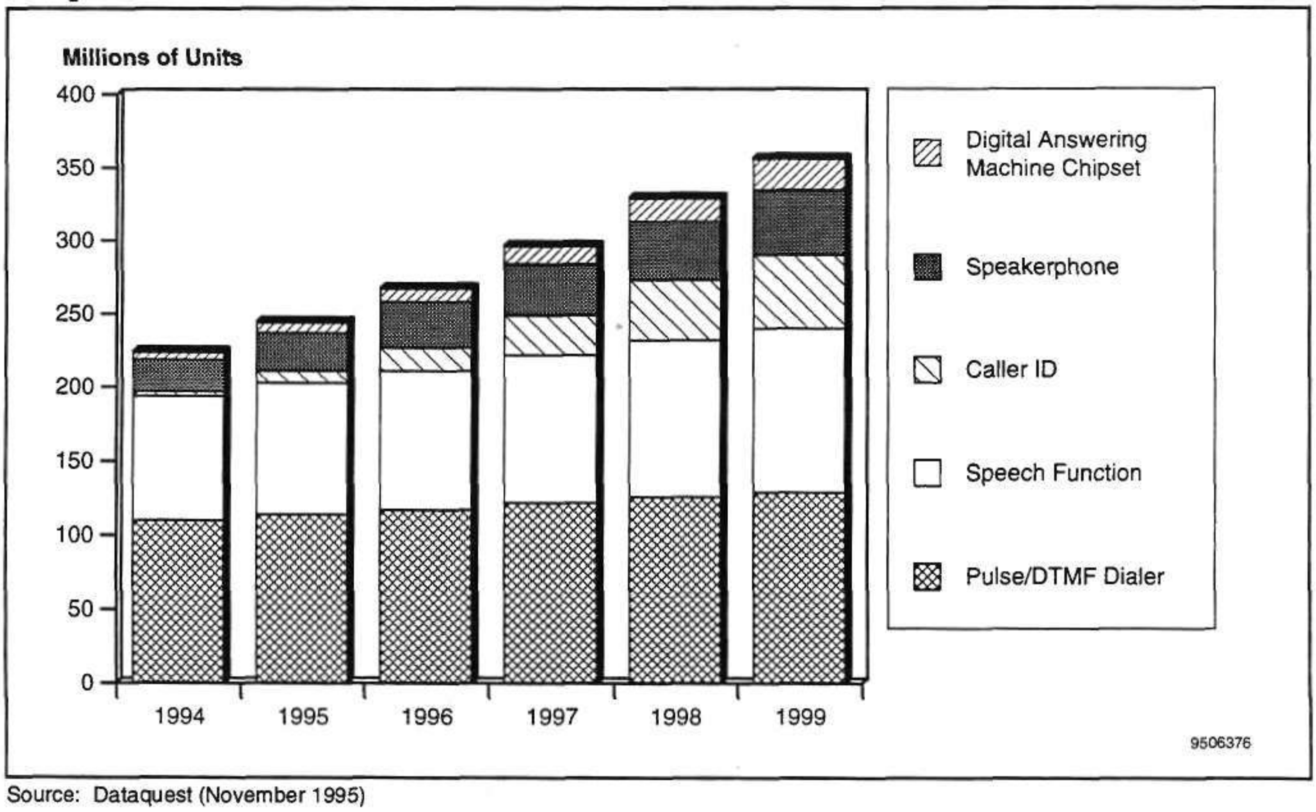
  

# Chapter 7
# The Wired Telephone IC Market

The worldwide forecast for wired telephone ICs is presented in Figure 7-1 and Table 7-1. Key trends and assumptions about this market include the following:

- The world corded-telephone market is projected to grow at a rate of 3 percent on a unit basis through the rest of the decade. Growth is driven by new access line and PBX line shipments, but is being clipped somewhat by the strength of cordless and limited-mobility cellular phones like Digital European Cordless Telecommunications (DECT) and Personal Handy Phone System (PHS). Feature/multiline phones are growing at about twice the rate of the overall market.
- Vast quantities of simple single-line phones requiring basic dialers and speech functionality still account for a large part of this market.
- New features like caller ID and speakerphone continue to penetrate the market rapidly. Caller ID has received clearance by the U.S. Federal Communications Commission, and the United States is being joined by Canada, several European countries, and Japan for rollout of this feature. Initial volume caller ID shipments are for so-called adjunct units that attach to phones and present the calling party's number on an LCD.
- Tapeless or digital answering machines are penetrating the market rapidly as their prices come down and quality improves. The core chipset features a codec for converting voice into digital samples for storage on a DRAM (audio-RAM).

**Figure 7-1**
**Telephone and Answerer IC Market Forecast, Worldwide**




Source: Dataquest (November 1995)

**Table 7-1**
**Corded Telephone/Answerer (Non-ISDN) IC Forecast, Worldwide**

| | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|
| Pulse/DTMF Dialer | | | | | | | |
| Units (M) | 110.4 | 113.7 | 117.5 | 121.6 | 125.6 | 128.9 | 3.2 |
| ASP ($) | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 0 |
| Revenue ($M) | 82.8 | 85.3 | 88.1 | 91.2 | 94.2 | 96.7 | 3.2 |
| Speech Function | | | | | | | |
| Units (M) | 83.9 | 88.7 | 94.0 | 99.7 | 105.5 | 110.9 | 5.7 |
| ASP ($) | 0.65 | 0.65 | 0.65 | 0.65 | 0.65 | 0.65 | 0 |
| Revenue ($M) | 54.5 | 57.6 | 61.1 | 64.8 | 68.6 | 72.1 | 5.7 |
| Caller ID | | | | | | | |
| Units (M) | 3.3 | 8.0 | 16.4 | 26.8 | 41.5 | 50.3 | 72.3 |
| ASP ($) | 1.45 | 1.16 | 1.07 | 1.01 | 0.99 | 0.97 | -7.7 |
| Revenue ($M) | 4.8 | 9.2 | 17.6 | 27.1 | 41.2 | 49.0 | 59.1 |
| Speakerphone | | | | | | | |
| Units (M) | 22.1 | 26.1 | 30.5 | 35.3 | 40.2 | 45.1 | 15.4 |
| ASP ($) | 1.10 | 1.01 | 0.96 | 0.91 | 0.87 | 0.82 | -5.6 |
| Revenue ($M) | 24.3 | 26.5 | 29.4 | 32.2 | 34.9 | 37.2 | 8.9 |
| Digital Answering Machine Chipset | | | | | | | |
| Units (M) | 4.8 | 6.7 | 9.4 | 12.2 | 15.9 | 21.5 | 34.9 |
| ASP ($) | 16.50 | 14.52 | 13.07 | 11.76 | 11.17 | 10.61 | -8.4 |
| Revenue ($M) | 79.2 | 97.6 | 122.9 | 143.8 | 177.6 | 227.8 | 23.5 |
| Total Revenue ($M) | 245.6 | 276.2 | 319.1 | 359.2 | 416.5 | 482.7 | 14.5 |
| Regional Demand (%) | | | | | | | |
| North America | 28 | 28 | 27 | 27 | 26 | 26 | |
| Europe | 35 | 35 | 34 | 34 | 33 | 33 | |
| Japan | 11 | 11 | 10 | 10 | 9 | 9 | |
| Asia/Pacific | 26 | 26 | 29 | 29 | 32 | 32 | |

Source: Dataquest (November 1995)

## Appendix A
# Definitions of Terms and Technology

**ATM:** Asynchronous transfer mode is an emerging network technology that provides bandwidth on demand by using 53-byte cells that can transfer voice, data, and multimedia traffic at speeds up to 2 Gbps.

**Category 3, 4, 5 UTP cabling:** Unshielded twisted pair LAN cabling. Category 3 is known as voice grade, Category 4 is data grade, and Category 5 is the highest form of data grade.

**Ethernet:** A LAN technique that embodies IEEE standard 802.3 for transferring data up to 20 Mbps (full duplex) using carrier sense multiple access/collision detect (CSMA/DC). A variant, 10-Base-T, uses Category 3, 4, 5 twisted-pair wiring.

**Fast Ethernet:** An extension of the IEEE 802.3 standard (802.3u) that supports 100-Mbps data rates. Variants include 100-Base-TX (two twisted pairs of Category 5 or shielded twisted-pair wiring), 100-Base-T4 (four twisted pairs of Category 3, 4, 5 wiring), and 100 Base-FX (one pair of fiber-optic cabling, 52.5/125 microns).

**FDDI/CDDI:** Fiber distributed data interface is a ANSI-sponsored 100-Mbps LAN technique that uses token passing as an access method. CDDI is the copper wire-based version of FDDI.

**Frame relay:** An emerging switched (lease or dial-up) WAN technology that transfers data in frames (groups) at speeds up to T1/E1 (1.5/2.0 Mbps).

**Integrated Services Digital Network (ISDN):** An emerging tariffed WAN service and technology employing digital transmission with capability for basic rate interface (BRI—128 Kbps dividable into two bearer and one data channel) and primary rate interface (PRI—1.5 or 2.0 Mbps).

**Line card:** A plug-in telephone line interface card for central office (telephone company) and PBX switches. Can be analog or digital based.

**Physical layer (or PHY):** Pertaining to the lowest layer of data communications protocol where electrical, mechanical, and physical media-dependent features such as serialization and encoding are specified.

**SONET/SDH:** Synchronous optical network/synchronous digital hierarchy are the U.S. and European standards, respectively, that define a physical layer of voice, data, and multimedia communications. They are scalable above 2 Gbps and can be used as the physical layer for layer-2 protocols (frame relay, ATM).

**T/E carrier:** Refers to the time-multiplexed digital transmission technique that is scalable from 56 Kbps to over 45 Kbps. Lines are typically leased from the telephone carrier.

**Token Ring:** The popular mainstream LAN technique defined by IEEE standard 802.5 uses a collisionless token-passing access method to transmit data at speeds of either 4 Mbps or 16 Mbps.

**100 VG-AnyLAN:** A 100-Mbps LAN technology defined by IEEE standard 802.12 that employs a demand priority scheme and is capable of supporting Token Ring as well. Works over Category 3, 4, 5, and shielded twisted-pair cabling.

**For More Information...**

Greg Sheppard, Director and Chief Analyst ............................ (408) 468-8261
Internet address ..................................................... gsheppard@dataquest.com
Via fax ..................................................................................... (408) 954-1780



Dataquest
a company of
The Dun & Bradstreet Corporation

## DATAQUEST WORLDWIDE OFFICES


**NORTH AMERICA**
**Worldwide Headquarters**
Dataquest Incorporated
251 River Oaks Parkway
San Jose, California 95134-1913
United States
Phone: 1-408-468-8000
Facsimile: 1-408-954-1780

**Dataquest Incorporated**
Nine Technology Drive
P.O. Box 5093
Westborough, Massachusetts 01581-5093
United States
Phone: 1-508-871-5555
Facsimile: 1-508-871-6262

**Dataquest Global Events**
3990 Westerly Place, Suite 100
Newport Beach, California 92660
United States
Phone: 1-714-476-9117
Facsimile: 1-714-476-9969

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Sao Paulo, Brazil
Santiago, Chile
Mexico City, Mexico

**EUROPE**
**European Headquarters**
Dataquest Europe Limited
Holmers Farm Way
High Wycombe, Bucks HP12 4XH
United Kingdom
Phone: +44 1494 422 722
Facsimile: +44 1494 422 742

**Dataquest Europe SA**
Immeuble Défense Bergères
345, avenue Georges Clémenceau
TSA 40002
92882 - Nanterre CTC Cedex 9
France
Phone: +33 1 41 35 13 00
Facsimile: +33 1 41 35 13 13

**Dataquest GmbH**
Kronstadter Strasse 9
81677 München
Germany
Phone: +49 89 93 09 09 0
Facsimile: +49 89 93 03 27 7

Sales Offices:
Brussels, Belgium
Kfar Saba, Israel
Milan, Italy
Randburg, South Africa
Madrid, Spain

**JAPAN**
**Japan Headquarters**
Dataquest Japan K.K.
Shinkawa Sanko Building
6th Floor
1-3-17, Shinkawa
Chuo-ku, Tokyo 104
Japan
Phone: 81-3-5566-0411
Facsimile: 81-3-5566-0425

**ASIA/PACIFIC**
**Asia/Pacific Headquarters**
7/F China Underwriters Centre
88 Gloucester Road
Wan Chai
Hong Kong
Phone: 852-2824-6168
Facsimile: 852-2824-6138

**Dataquest Korea**
Suite 2407, Trade Tower
159 Samsung-dong, Kangnam-gu
Seoul 135-729
Korea
Phone: 822-551-1331
Facsimile: 822-551-1330

**Dataquest Taiwan**
11F-2, No. 188, Section 5
Nan King East Road
Taipei
Taiwan, R.O.C.
Phone: 8862-756-0389
Facsimile: 8862-756-2663

**Dataquest Singapore**
105 Cecil Street
#06-01/02 The Octagon
Singapore 0106
Phone: 65-227-1213
Facsimile: 65-227-4607

**Dataquest Thailand**
12/F, Vanissa Building
29 Soi Chidlom
Ploenchit Road
Patumwan, Bangkok 10330
Thailand
Phone: 662-655-0577
Facsimile: 662-655-0576

Research Affiliates and Sales Offices:
Melbourne, Australia
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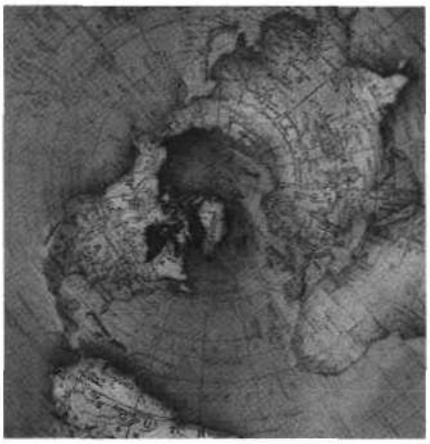

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# Communications Application Markets—LAN, WAN, Voice and Public

Market Trends

**Program:** Communications Semiconductors and Applications Worldwide
**Product Code:** CSAM-WW-MT-9501
**Publication Date:** October 30, 1995
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# Chapter 1
# Introduction and Methodology

This document brings forth basic information about the opportunity offered by LAN, WAN, voice, and public telecom switching and transmission systems:

- System market size (in production terms) in revenue, units, and average selling price
- System market and product feature trends
- Hardware architecture trends and semiconductor device opportunities
- Semiconductor content and market forecast
- A listing of key OEMs

The information in this report is gathered from both primary and secondary sources. Primary sources include surveys and interviews of industry vendors and customers, as well as analyst knowledge and opinion. Some of the primary sources include Dataquest's own industry services. Secondary sources include various governmental and trade sources on sales, production, trade, and public spending. Semiconductor content assumptions are based on both surveys of producing OEMs and physical teardown evaluations by Dataquest analysts of representative systems.

The forecast methodology is based on various methods and assumptions, depending upon the area. To form a solid basis for projecting system demand, capital, government, and consumer spending assumptions are made for various regions of the world. For specific markets, saturation and displacement dynamics are considered as well. Key exogenous factors such as new software introductions, exchange rates changes, and government policies also are considered. Semiconductor content forecasts are based upon interviews of system marketers and designers (including makers of enabling semiconductor technology) along with an analysis of historical trends.

*Project Analyst: Gregory Sheppard*

# Chapter 2
# Local Area Networks (Cards, Hubs, and Internetworking Systems)

## Market and Feature Trends

Tables 2-1 through 2-3 present market forecasts and accompanying semiconductor demand for LAN network interface cards (NICs), intelligent hubs, routers, bridges, asynchronous transfer mode (ATM) nodes, 100-Mbps and FDDI technologies, and wireless LAN nodes. Following are the primary trends:

- Large/medium-size office LAN desktop connectivity will continue to rise, reaching near 100 percent saturation in the United States and Europe by the end of the decade. Developing countries, small offices and business, and home offices will provide much of the new connectivity growth.
- LAN bandwidth demands will be driven by a variety of trends including increased use of applications servers, networking faxing, groupware (such as Lotus Notes), and multimedia-rich file transfer messaging (store and forward or conferencing).
- IS managers are under pressure to upgrade as they consider a variety of speed enhancing technologies for desktop connectivity and the backbone (see Figures 2-1 and 2-2), including:
    - Full duplex Ethernet (20 Mbps)
    - Iso-Ethernet (16 Mbps)
    - Switched Ethernet (10 Mbps)
    - Switched token ring (16 Mbps)
    - Fast Ethernet (100 Mbps)
    - 100 VG AnyLAN (100 Mbps)
    - FDDI/CDDI (100 Mbps)
    - ATM (25 Mbps to 622 Mbps)
- Ethernet will remain the dominant networking technology for the next two years although token ring will also experience substantial growth. The evolution of shared media hubs to the switches capable of dedicating full bandwidth to each desktop is giving both Ethernet and token ring extended market lives. 20-Mbps full-duplex Ethernet technology is also appearing in NICs, hubs, and switches.
- New high-speed technologies like 100-Mbps Fast Ethernet, 100 VG AnyLAN, and ATM are beginning to find use in premise network backbones. The market is expected to move rapidly to technology known as 10/100, which uses networking systems capable of both 10 Mbps and 100 Mbps. This allows a gradual integration to higher speeds to take place within the bound legacy installations.

- FDDI is the most popular backbone technology today. Most hubs, LAN switches, and routers offer an FDDI "fat pipe" for high-speed transfer. FDDI will be challenged as a backbone technology in the future by both the 100-Mbps technologies and ATM. ATM is already finding early success in the so-called enterprise backbones switches.
- Isochronous or real-time networking demands for videoconferencing or voice over data are slowly emerging. ATM has the best prospects for long-term success for serving this kind of need. Iso-Ethernet does have some potential for addressing this need in the interim, allowing users to exploit existing cabling.
- PCI bus NICs are being designed in prolific numbers and should become mainstream within two to three years. 10-base-T will remain the predominant Ethernet variety. The trend is toward installing category 5 twisted-pair of fiber in most upgrades and new installations. Category 3 twisted-pair wire is the most common currently. PCMCIA card versions are enabling notebook computer connectivity and are expected to grow rapidly.
- PCs targeted at large businesses, like most workstations today, will have embedded LAN controllers designed onto the motherboard at an increasing rate.
- Intelligent shared media hubs are being replaced by LAN switches capable of dedicating full bandwidth (such as 10, 16, or 100 Mbps) to the desktop. In many cases, these LAN hubs or switches support one of the 100-Mbps FDDI, upgradable with routers and ATM functionality. Stackable hubs are gaining strong market acceptance as well.
- Two 100-Mbps technologies are doing battle for that market. Fast Ethernet (IEEE 802.3u) is backed by the Fast Ethernet alliance, whose members include 3Com, Cabletron, David Systems, Grand Junction, Intel, LAN Media, Lannet, National Semiconductor, SMC, Sun Microsystems, and Bay Networks. Fast Ethernet, or 100-base-T, as it's called, supports the traditional CSMA/CD protocol of Ethernet but requires different encoding schemes, depending upon the cabling used. The other technology is known as 100 VG-AnyLAN (803.12), and its constituency includes AT&T Microelectronics, Acctron, Alantec, Asante, Banyan, Bytec/NSC, Compex, D-Link, David Systems, Hewlett-Packard, IB, Katron, Microsoft, Novell, Optical Data Systems, Proteon, SMC, Ungermann-Bass, Wellfleet, and Zynx. Both of these standards are being implemented in a form allowing backward compatibility with 10-Mbps rates and token ring in AnyLAN's case.
- ATM is based in part on synchronous optical network (SONET)/ synchronous digital hierarchy (SDH) technology will emerge throughout 1995 and 1996. This technology employs 53-byte fixed-length cells that can operate from speeds as low as 25 Mbps to 155 Mbps and up to 2 Gbps in backbone and public transmission applications. Adopted initially by the hub/switch vendors, adapter cards for workstations and servers are also hitting the market. The main standards body is the ATM Forum, which works with interested players to ensure that local area networking (LAN), wide area networking (WAN), and public equipment will work with each other. ATM is viewed as the overarching technology network managers desire to have. So far, ATM is starting in the backbone of premise and public networks.

- The remote LAN access market (via routers, modems, ISDN adapters, and so on) is proving to be very popular. Access to files at work, e-mail, and remote offices are the drivers.
- Radio-frequency (RF) versions employing spread spectrum technology operating in the ISM bands are expected to be the most popular, although infrared (IR) will find many point-to-point uses. Worldwide the 2.4-GHz band should become the most popular, with 902-MHz the most popular in existing vertical applications in the United States. Early market build will come from the rollover of users from proprietary solutions in the handheld data terminal market. Work on the IEEE 802.11 standard, which would govern wireless LAN interoperability, would have a flexible MAC layer (up to 20 Mbps) and three PHY layers, two spread spectrum, and an IR. Ratification of IEEE 302.11 is expected in mid-1996.

**Table 2-1**
**Worldwide LAN Network Interface Card (NIC) Application Market**

| | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|---|
| Units (K) | 11,276 | 15,965 | 26,479 | 33,018 | 43,727 | 53,914 | 60,865 | 68,057 | 20.8 |
| Ethernet | 8,099 | 12,641 | 22,733 | 27,072 | 33,440 | 38,000 | 29,700 | 21,349 | -1.2 |
| Token Ring | 2,281 | 2,685 | 3,161 | 4,300 | 5,200 | 5,800 | 6,000 | 5,900 | 13.3 |
| 10/100 Mbps (Fast Ethernet/AnyLAN) | 0 | 0 | 27 | 1,128 | 4,560 | 9,500 | 24,300 | 39,650 | 329.9 |
| FDDI | 24 | 55 | 108 | 155 | 195 | 220 | 225 | 210 | 14.2 |
| ATM (All Speeds) | 0 | 0 | 8 | 35 | 105 | 250 | 520 | 850 | 154.3 |
| Other (Arcnet, etc.) | 872 | 584 | 442 | 328 | 227 | 144 | 120 | 98 | -26.0 |
| Factory ASP ($) | 243 | 191 | 133 | 120 | 103 | 97 | 95 | 93 | -6.9 |
| Factory Revenue ($M) | 2,745 | 3,050 | 3,516 | 3,962 | 4,504 | 5,230 | 5,782 | 6,329 | 12.5 |
| Semiconductor Content ($) | 55 | 43 | 29 | 28 | 25 | 24 | 25 | 25 | -3.0 |
| Semiconductor Market ($M) | 618 | 686 | 774 | 911 | 1,081 | 1,307 | 1,503 | 1,709 | 17.2 |
| ASIC/ASSP ($M) | 531 | 590 | 667 | 786 | 933 | 1,130 | 1,299 | 1,476 | 17.2 |
| Volatile Memory ($M) | 37 | 41 | 46 | 55 | 65 | 78 | 90 | 103 | 17.2 |
| Nonvolatile Memory ($M) | 15 | 17 | 19 | 22 | 25 | 30 | 35 | 39 | 16.2 |
| Others* ($M) | 34 | 38 | 42 | 49 | 57 | 69 | 80 | 91 | 16.7 |
| North America | | | | | | | | | |
| Unit Production (K) | 3,744 | 4,765 | 6,767 | 8,883 | 9,462 | 10,761 | 11,110 | 11,911 | 12.0 |
| Production Revenue ($M) | 1,217 | 1,430 | 1,529 | 1,643 | 1,438 | 1,399 | 1,300 | 1,254 | -3.9 |
| Semiconductor Market ($M) | 286 | 343 | 398 | 411 | 374 | 364 | 351 | 350 | -2.5 |

*Others include standard logic, linear, discrete, and optoelectronic.
Source: Dataquest (October 1995)

**Table 2-2**
**Worldwide Hub (Shared Media and Switched) Application Market)**

| | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|---|
| Ports (K) | 9,552 | 20,090 | 31,521 | 47,069 | 61,272 | 78,260 | 94,846 | 106,888 | 27.7 |
| Ethernet | 7,420 | 16,087 | 27,100 | 41,569 | 53,208 | 63,850 | 70,235 | 72,342 | 21.7 |
| Percent Switched | 0 | 0 | 0.4 | 4.4 | 9.0 | 22.0 | 32.0 | 41.0 | |
| Token Ring | 2,074 | 3,856 | 4,120 | 4,411 | 4,609 | 4,794 | 4,842 | 4,793 | 3.1 |
| Percent Switched | 0 | 0 | 0 | 0.3 | 1.6 | 5.2 | 10.0 | 19.7 | |
| 10/100 Mbps (Fast Ethernet/AnyLAN) | 0 | 0 | 105 | 729 | 2,770 | 8,117 | 17,095 | 25,908 | 200.9 |
| FDDI | 58 | 147 | 178 | 267 | 312 | 308 | 293 | 273 | 8.9 |
| ATM (All Speeds) | 0 | 0 | 18 | 93 | 372 | 1,190 | 2,381 | 3,571 | 188.1 |
| Port Factory ASP ($) | 170 | 122 | 116 | 103 | 100 | 97 | 94 | 91 | -4.7 |
| Factory Revenue ($M) | 1,626 | 2,461 | 3,656 | 4,848 | 6,127 | 7,591 | 8,915 | 9,727 | 21.6 |
| Semiconductor Content ($) | 34 | 25 | 24 | 22 | 21 | 21 | 20 | 20 | -3.5 |
| Semiconductor Market ($M) | 325 | 500 | 753 | 1,013 | 1,299 | 1,632 | 1,944 | 2,140 | 23.2 |
| ASIC/ASSP ($M) | 216 | 332 | 502 | 671 | 856 | 1,062 | 1,265 | 1,393 | 22.7 |
| MPU/MCU ($M) | 29 | 45 | 68 | 91 | 117 | 147 | 175 | 193 | 23.2 |
| Volatile Memory ($M) | 59 | 90 | 136 | 188 | 248 | 326 | 393 | 432 | 26.0 |
| Nonvolatile Memory ($M) | 7 | 10 | 14 | 19 | 23 | 29 | 33 | 36 | 20.5 |
| Others* ($M) | 15 | 22 | 33 | 44 | 55 | 67 | 78 | 86 | 20.9 |
| North America | | | | | | | | | |
| Unit Production (K) | 7,737 | 15,469 | 23,010 | 32,478 | 39,827 | 47,738 | 54,062 | 56,651 | 19.7 |
| Production Revenue ($M) | 1,317 | 1,895 | 2,669 | 3,345 | 3,983 | 4,631 | 5,082 | 5,155 | 14.1 |
| Semiconductor Market ($M) | 263 | 385 | 550 | 699 | 844 | 996 | 1,108 | 1,134 | 15.6 |

* Others include standard logic, linear, discrete, and optoelectronic.
*Source: Dataquest (October 1995)*

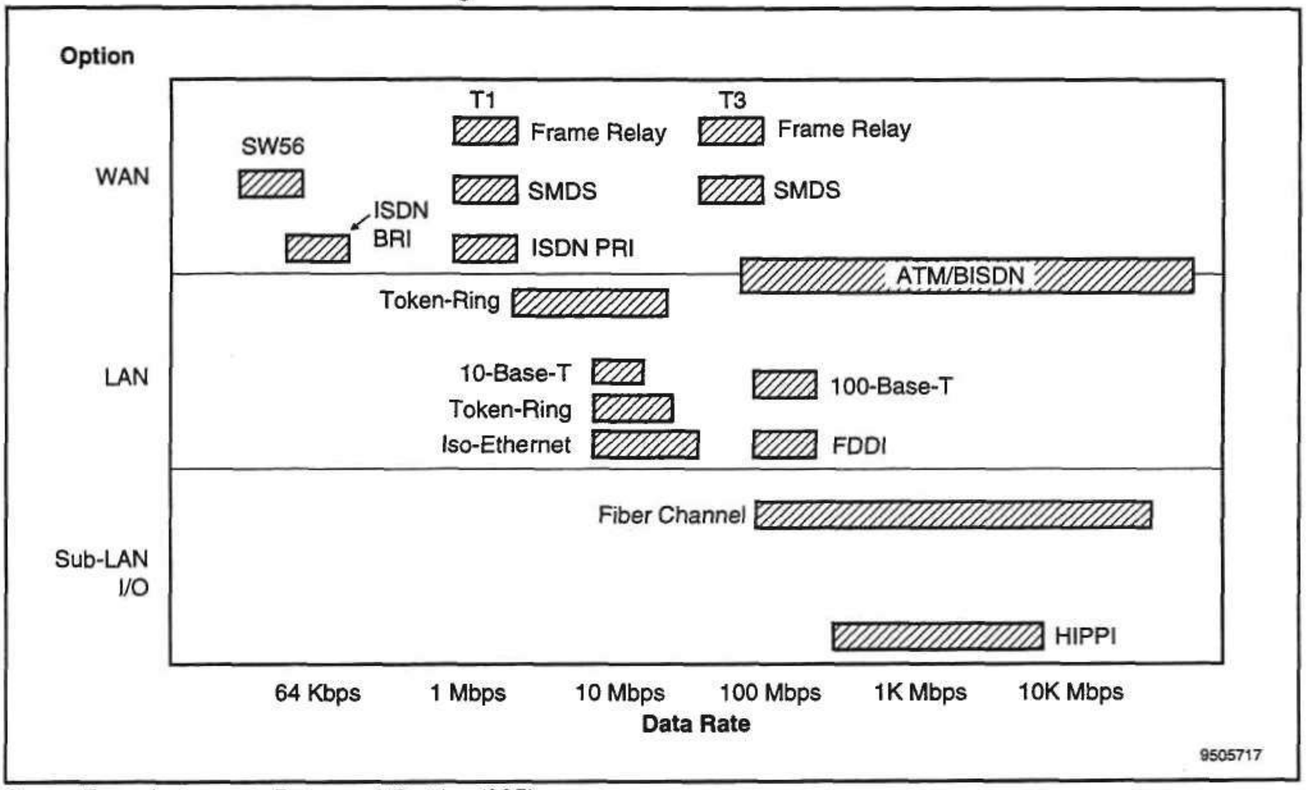
**Table 2-3**
**Worldwide Internetworking Application Market (Routers, Bridges)**

| | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|---|
| Units (K) | 171 | 243 | 421 | 691 | 1,078 | 1,522 | 2,107 | 2,587 | 43.8% |
| Routers | 73 | 140 | 296 | 549 | 921 | 1,359 | 1,955 | 2,449 | 52.6% |
| Bridges | 98 | 103 | 125 | 143 | 157 | 163 | 152 | 138 | 1.9% |
| Factory ASP Internetworking ($K) | 9.6 | 7.7 | 7.2 | 6.3 | 5.3 | 4.7 | 4.1 | 3.9 | -11.4% |
| Factory Revenue Internetworking ($M) | 1,642 | 1,883 | 3,046 | 4,333 | 5,746 | 7,126 | 8,655 | 10,198 | 27.3% |
| Semiconductor Content ($) | 1,348 | 1,100 | 1,042 | 940 | 853 | 796 | 739 | 749 | -6.4% |
| Semiconductor Market ($M) | 230 | 267 | 439 | 650 | 919 | 1,211 | 1,558 | 1,938 | 34.6% |
| ASIC/ASSP ($M) | 146 | 164 | 255 | 359 | 489 | 618 | 763 | 930 | 29.5% |
| MPU/MCU ($M) | 28 | 32 | 53 | 80 | 113 | 149 | 192 | 238 | 35.3% |
| Volatile Memory ($M) | 30 | 40 | 79 | 130 | 202 | 291 | 405 | 523 | 46.0% |
| Nonvolatile Memory ($M) | 16 | 19 | 33 | 52 | 75 | 102 | 131 | 163 | 37.7% |
| Others* ($M) | 10 | 12 | 19 | 29 | 40 | 52 | 67 | 83 | 34.0% |
| North America | | | | | | | | | |
| Unit Production (K) | 138 | 190 | 316 | 498 | 744 | 1,005 | 1,328 | 1,578 | 38.0% |
| Production Revenue ($M) | 1,330 | 1,468 | 2,285 | 3,119 | 3,965 | 4,703 | 5,453 | 6,221 | 22.2% |
| Semiconductor Market ($M) | 186 | 209 | 329 | 468 | 634 | 800 | 981 | 1,182 | 29.1% |

* Others include standard logic, linear, discrete, and optoelectronic.
Source: Dataquest (October 1995)

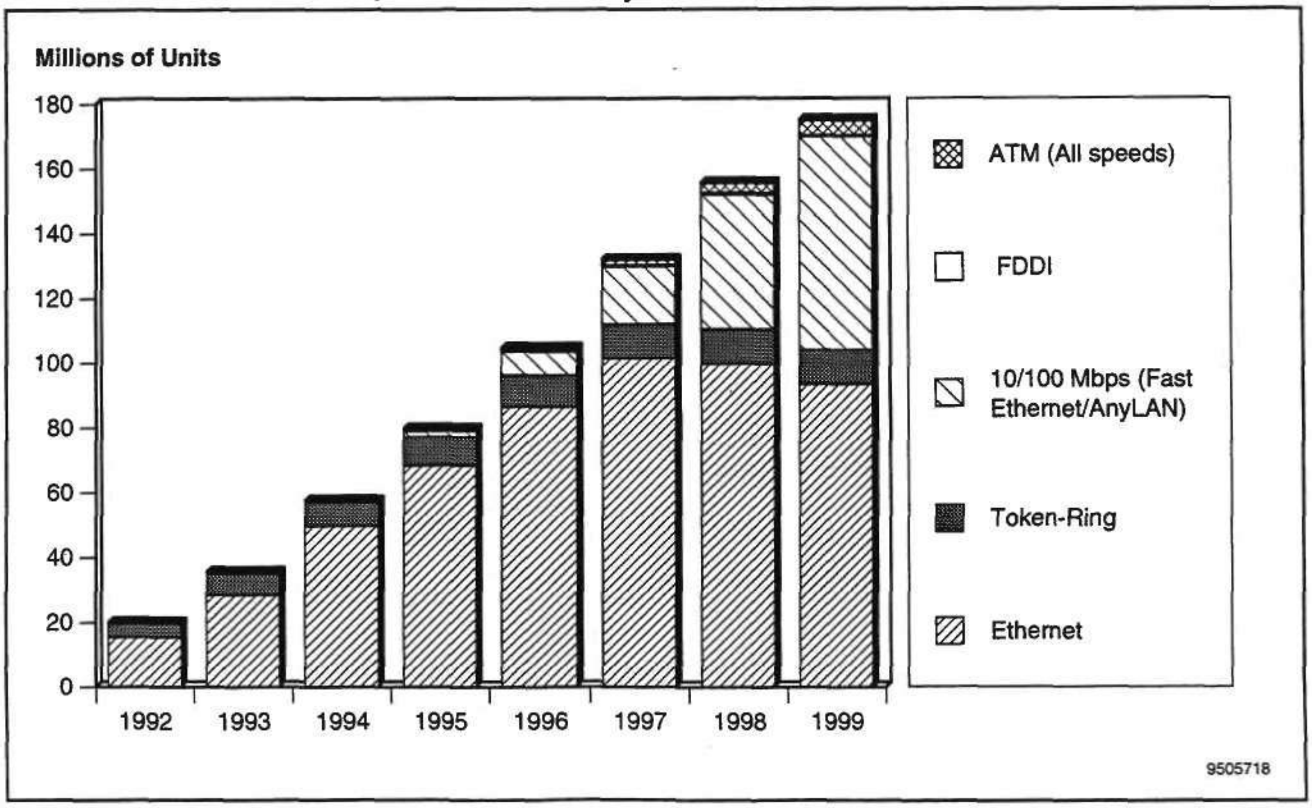
  

**Figure 2-1**
**Alternative Network Technologies**




Source: Texas Instruments, Dataquest (October 1995)

**Figure 2-2**
**Worldwide NIC and Hub/Switch Nodes by Standard**




Source: Dataquest (October 1995)

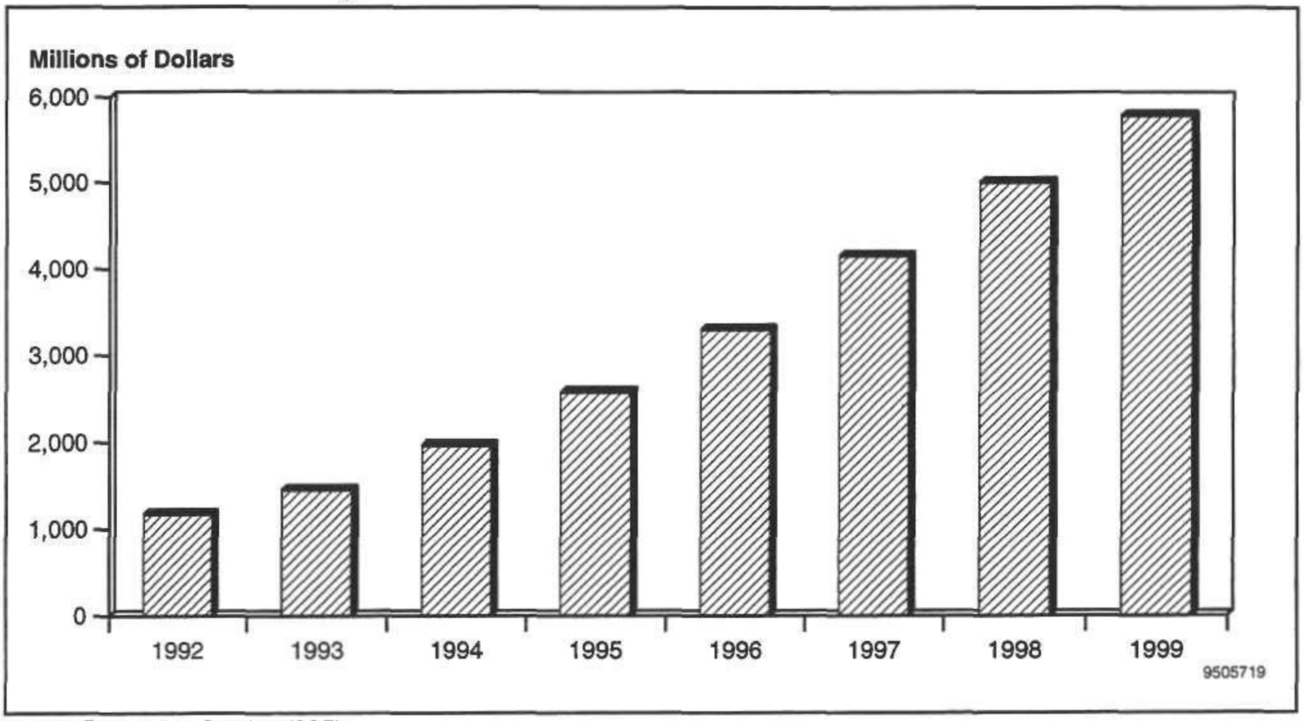
## Semiconductor Opportunities

Refer to Tables 2-1 through 2-3 for the semiconductor application forecast in LANs. Figure 2-3 presents a forecast of overall networking semiconductor demand. Market growth is sustained by the increasing network connectivity, higher-speed upgrades, and the semiconductor-rich intelligence of hubs, switches, and routers. Key semiconductor opportunities are as follows:

- The standard LAN NIC architectures are rapidly heading toward one or two ICs that comprise the transceiver (coax, shielded twisted-pair, unshielded twisted-pair), the physical layer processing (encoding, among others), and MAC functions (for example, CSMA/CD features). Full duplex Ethernet at 20 Mbps is rolling out quickly. 3V varieties of 10-base-T controllers are needed for PCMCIA applications as well.
- Controllers and transceivers for both the Fast Ethernet and 100 VG AnyLAN are commencing market introduction.
- Figure 2-4 shows a block diagram for a typical, managed, intelligent hub (or switch). In this case the core architecture is based on 32-bit MPUs (i960, 68XXX MIPS, 29K. . .) along with 4MB of DRAM for processing management software. The I/O processor is a medium-performance, 32-bit MPU that off-loads the main MPU of that functionality. The ASIC (or ASSP in the future) performs the switching function for a switched hub version). The shared memory is 2 to 8MB of SRAM used to buffer the data. There is also as much as 4 to 6MB of flash/ EPROM used for code storage. Routers have a similar architecture.
- More advanced standard NICs are incorporating features such as combining Ethernet and token-ring protocol processing, combining with SCSI host adaptation functions, with super I/O functions (serial/ parallel, FDD, and IDE), and even with WAN functions such as modems or ISDN.
- Higher-performance NICs are using 1Mx16 DRAMs for buffering, and all NICs require some EPROM/flash/ICs for card hardware ID and plug-and-play compatibility.
- FDDI chipsets are further integrating to two to three chips. Both copper (CDDI) and low-cost fiber (LED) versions are gaining in popularity.
- ATM NICs are requiring both ASICs and standard parts. Key elements are transceivers (fiber and copper), physical layer processing (PHY), and the AAL/SAR layer-processing elements. The ATM Forum has defined the UNI and UTOPIA standards for the physical and bus interfaces, respectively.
- RF ICs and discretes covering the ISM bands will be needed, along with IEEE 802.11 controllers.

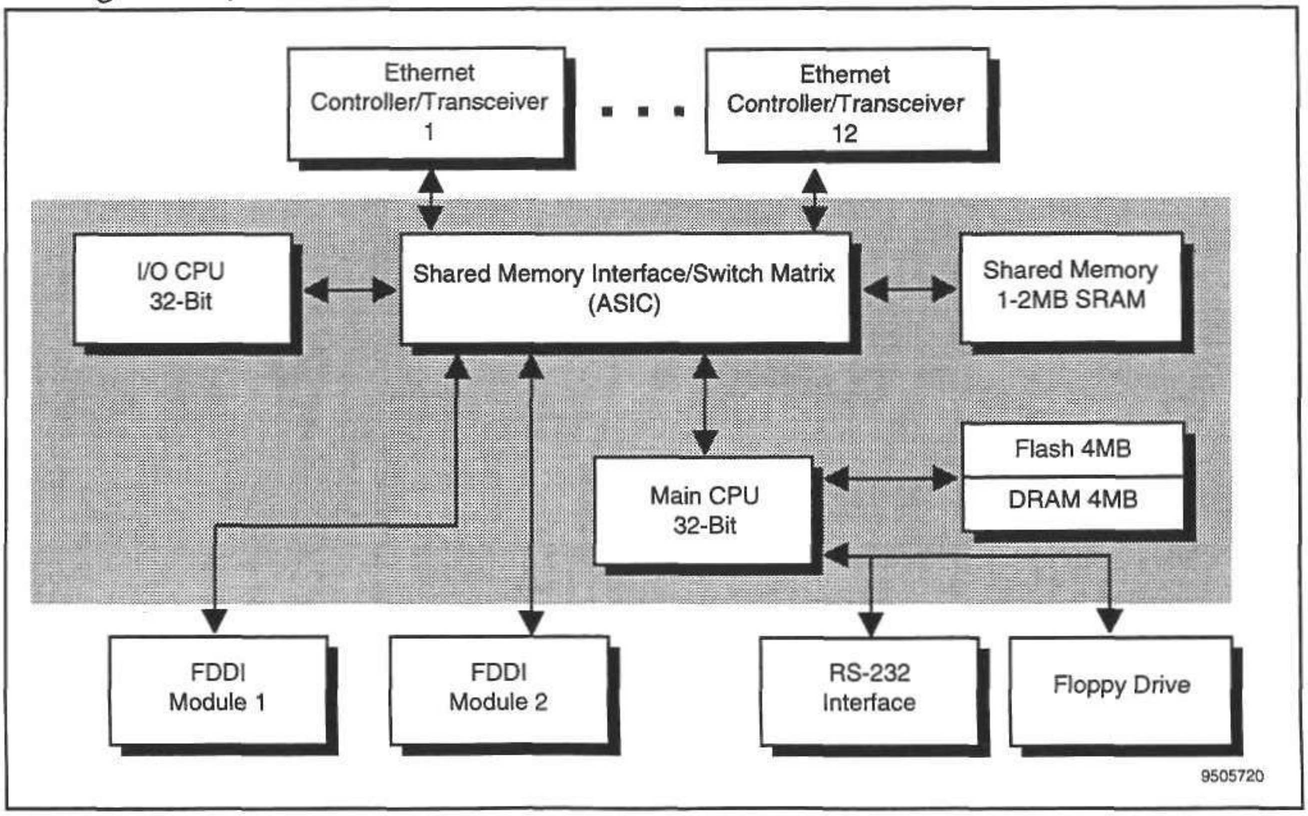
  

**Figure 2-3**
**Worldwide Networking Semiconductor Demand**




Source: Dataquest (October 1995)

**Figure 2-4**
**Intelligent Hub/Switch Architecture**




Source: Dataquest (October 1995)

## OEMs

The following bullets present the key OEMs supplying LAN card, hub, and internetworking hardware.

Leading LAN card OEMs in rank order are as follows:

- 3Com
- Intel
- Standard Microsystems
- D-Link
- IBM
- Microdyne
- Compex
- Madge Networks
- CNET Technology
- Digital Equipment

Leading intelligent hub OEMs in rank order are as follows:

- Bay Networks
- Cabletron Systems
- Chipcom
- 3Com
- Hewlett-Packard
- UB Networks
- Digital Equipment
- IBM
- Optical Data Systems
- Networth

Leading Intranetworking (router) OEMs in rank order are as follows:

- Cisco Systems
- Bay Networks
- Shiva
- Digital Equipment
- 3Com
- CrossComm
- Cabletron Systems
- Gandolf Systems
- Ascom Timeplex
- Advanced Computer Communications

Leading bridge OEMs in rank order are as follows:

- Gandolf Systems
- Cabletron Systems
- Combinet
- Develcom
- Digital Equipment
- Micom Communications

# Chapter 3
# Wide Area Network (WAN) Systems, Modem, Fax, and Videoconferencing

## Modems and Facsimile

### Market and Feature Trends

The following captures the important market trend information concerning modems and fax machines:

- Modems
  - Table 3-1 and Figure 3-1 present the estimate for worldwide modem shipments in standalone versions, PC add-in card, and PCMCIA card versions. The data includes modem cards capable of fax and other advanced features such as voice mail, speaker phone, and simultaneous voice and data.
  - Near-term shipment growth is being driven heavily by a ramp-up in home modem use in the United States. Home use is for so-called home offices, remote access for work-at-home use, and the rapid rise in popularity of online services such as the Internet, America Online, and CompuServe.
  - PCMCIA card versions are gaining in popularity as notebook computer users desire gaining access to e-mail and databases while not in the office.
  - Growth in many European and other regions continues to be limited by government-controlled public telephone and telegraph (PTT) agencies, which dampen modem ownership. The United Kingdom is an example where privatization of the British Telecom and less restrictive premise equipment ownership is spurring modem sales. The relatively higher availability of basic-rate ISDN lines (and other digital connections) in Europe and Japan is also limiting the growth of modems that operate on analog lines.
  - V.22bis (2400-bps, two-wire, and full duplex) was the most popular standard worldwide in 1993. During 1994, it was surpassed by V.32bis modems (14.4-Kbps and lower, two-wire, and full duplex) in 1994 as prices come down. V.32bis should remain the dominant standard until after 1997, when V.34 (28.8-Kbps) becomes dominant.
  - V.34 (also known as V.Fast) was ratified as a standard and has become an International Telecommunications Union (ITU) standard. The demand for transferring larger, multimedia-rich files is causing users to upgrade to the higher throughput rates. Remote access to office LANs is also driving demand.
  - Most modems now support error correction (MNP 2-4 and V.42) as well as data compression (MNP 5 and V.42bis). There is also a strong trend to add plug-and-play functionality to PC modem cards so they can be installed without concern for the system configuration. Other evolving features include call discrimination, which can distinguish the types on incoming calls, caller ID support, answering machine emulation, business audio I/O, MNP 10 for more robust cellular communication, and universal "worldwide" standards support for call progress and handshaking, among others.

- An industry group comprising Intel, U.S. Robotics, Rockwell, Creative Labs, and Hayes is creating a standard known as digital simultaneous voice data (DSVD). This protocol, vying for ITU standard status, allows the simultaneous use of a phone line for both voice and data transmission.
- The trend is toward most modems supporting V.17 faxing (14.4-Kbps) in addition to V.29 (9.6-Kbps) and other fax speeds. There also is a trend toward supporting the EIA/TIA-578 Class 1 standard, which extends the "AT" command set allowing the PC application software control over advanced fax functions.
- Telephony (data and fax modem) functions could become more standardized as Microsoft Windows Telephony API (TAPI) feature is issued as a standard feature in Windows 95. This would not only support the plug-and-play rollout but would simplify application developers' jobs by creating a standard software interface capable of using a multitude of modem features.
- Cable modems that can push data at speeds approaching 1 Gbps are being developed by companies such as General Instrument (with Intel), Scientific-Atlanta, and Motorola. Cable modems will help enable the push by cable companies into the telephone/data transmission services area.
- ISDN basic rate (BRI) (56/64-Kbps full duplex plus a data channel, 2B+D) has been rolling out in Europe and Japan for many years. There is renewed interest in the United States recently because Pacific Bell has introduced a residential ISDN service for $22 a month. This was done in conjunction with large online service providers that want to deliver multimedia-rich services to the home. Because of digital and speed advantages, the number of ISDN lines installed is expected to grow to over 10 million worldwide by 1999.
- Intel is soliciting industry interest in its native signal processing (NSP) approach. This would entail using software algorithms to displace many of the digital functions found in a modem system or chipset.

- Fax machines
  - Table 3-2 presents the fax machine forecast. Unit growth is slowing as market saturation nears in most of the developed countries. Developing countries and home offices in countries such as the United States are the main growth opportunities for fax machines.
  - The trend toward plain paper machines continues as they lower in price relative to direct thermal transfer. Plain paper should be the majority of shipments by 1996.
  - Laser/LED marking engines for plain paper machines are ramping quickly as a percentage of the market. The combination of good printing performance and cost-effectiveness will propel ink jet technology promoted by HP, and Canon should become the volume leader by 1998.
  - Network faxing is becoming a reality with client/server fax software that allows users to send and receive documents directly from their PCs as an adjunct to e-mail or perhaps in its absence. The same is true with home PCs. These latter trends are serving to limit the growth of standalone machines capable of scanning.

- Numerous efforts are under way to push integrated faxing, printing, scanning, and copying technology. Several integrated systems are on the market, targeted at small office/home office users.
- Group 4- or ISDN-based faxing continues to be relegated to a small fraction of the market as line availability, cost, and lack of user interest limit demand. Color fax remains a very small consideration.

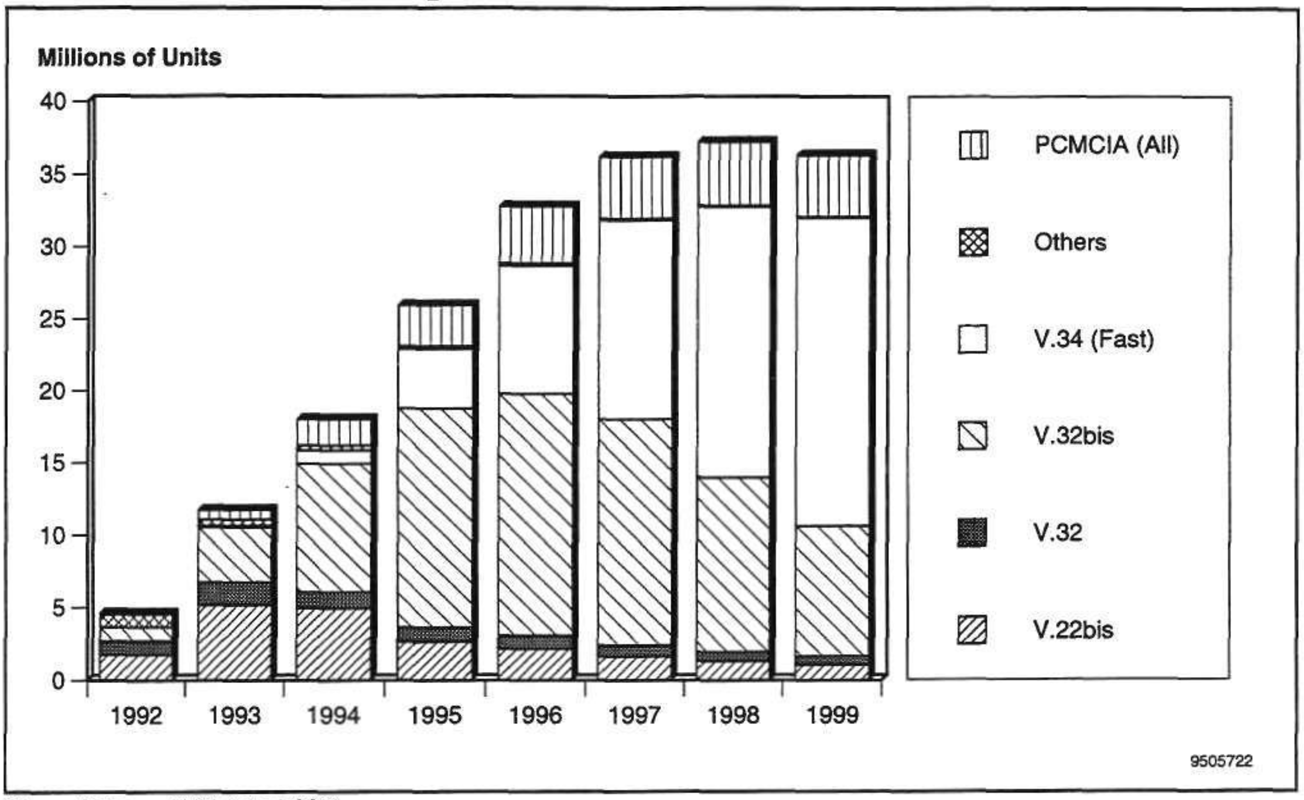
**Table 3-1**
**Worldwide Modem* Application Market Estimates**

| | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|---|
| Units (K) | 4,556 | 11,722 | 17,972 | 25,897 | 32,752 | 36,171 | 37,192 | 36,291 | 15.1 |
| V.22bis | 1,779 | 5,186 | 4,960 | 2,657 | 2,167 | 1,652 | 1,330 | 1,085 | -26.2 |
| V.32 | 944 | 1,563 | 1,103 | 989 | 937 | 776 | 630 | 585 | -11.9 |
| V.32bis | 943 | 3,798 | 8,873 | 15,136 | 16,695 | 15,615 | 12,056 | 8,985 | 0.3 |
| V.34 (Fast) | 16 | 104 | 913 | 4,136 | 8,873 | 13,790 | 18,758 | 21,354 | 87.9 |
| Other | 874 | 455 | 363 | 211 | 163 | 126 | 92 | 92 | -24.1 |
| PCMCIA (All) | 0 | 616 | 1,761 | 2,768 | 3,918 | 4,213 | 4,327 | 4,190 | 18.9 |
| Factory ASP ($) | 307 | 152 | 132 | 128 | 118 | 111 | 105 | 101 | -5.2 |
| Factory Revenue ($M) | 1,399 | 1,782 | 2,372 | 3,315 | 3,865 | 4,015 | 3,905 | 3,665 | 9.1 |
| Semiconductor Content ($) | 63 | 42 | 40 | 36 | 34 | 33 | 32 | 31 | -5.0 |
| Semiconductor Market ($M) | 286 | 492 | 719 | 932 | 1,114 | 1,194 | 1,190 | 1,125 | 9.4 |
| North America | | | | | | | | | |
| Unit Production (K) | 1,595 | 3,868 | 5,571 | 7,510 | 8,843 | 9,043 | 9,298 | 9,073 | 10.2 |
| Production Revenue ($M) | 490 | 588 | 735 | 961 | 1,043 | 1,004 | 976 | 916 | 4.5 |
| Semiconductor Market ($M) | 100 | 162 | 223 | 270 | 301 | 298 | 298 | 281 | 4.8 |

*Includes all types plus those with fax capability
Source: Dataquest (October 1995)

**Figure 3-1**
**Worldwide Modem Unit Shipments**




Source: Dataquest (October 1995)

**Table 3-2**
**Worldwide Fax Machine Application Market Estimates**

| | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|---|
| Units (K) | 5,692 | 7,208 | 8,723 | 9,879 | 10,604 | 11,161 | 11,476 | 12,070 | 6.7 |
| Factory ASP ($) | 641 | 626 | 571 | 519 | 477 | 457 | 464 | 459 | -4.3 |
| Factory Revenue ($M) | 3,646 | 4,513 | 4,977 | 5,128 | 5,062 | 5,095 | 5,321 | 5,536 | 2.2 |
| Semiconductor Content ($) | 79 | 88 | 87 | 82 | 79 | 79 | 83 | 83 | -0.9 |
| Semiconductor Market ($M) | 452 | 634 | 759 | 810 | 838 | 882 | 953 | 1,002 | 5.7 |
| MPU/MCU ($M) | 41 | 57 | 68 | 73 | 75 | 79 | 86 | 90 | 5.7 |
| Volatile Memory ($M) | 32 | 44 | 61 | 65 | 71 | 75 | 86 | 90 | 8.2 |
| Nonvolatile Memory ($M) | 14 | 19 | 19 | 20 | 21 | 22 | 24 | 25 | 5.7 |
| Modem ($M) | 72 | 101 | 118 | 126 | 126 | 132 | 138 | 145 | 4.3 |
| ASIC/ASSP ($M) | 99 | 146 | 182 | 203 | 218 | 238 | 267 | 281 | 9.0 |
| Logic/Analog/ Discrete ($M) | 167 | 228 | 266 | 275 | 276 | 282 | 295 | 311 | 3.2 |
| Optoelectronics ($M) | 27 | 38 | 46 | 49 | 50 | 53 | 57 | 60 | 5.7 |
| North America | | | | | | | | | |
| Unit Production (K) | 211 | 258 | 328 | 384 | 423 | 441 | 420 | 439 | 6.0 |
| Production Revenue ($M) | 200 | 199 | 226 | 252 | 270 | 272 | 267 | 261 | 2.9 |
| Semiconductor Market ($M) | 17 | 21 | 27 | 31 | 34 | 35 | 34 | 35 | 5.3 |

Source: Dataquest (October 1995)

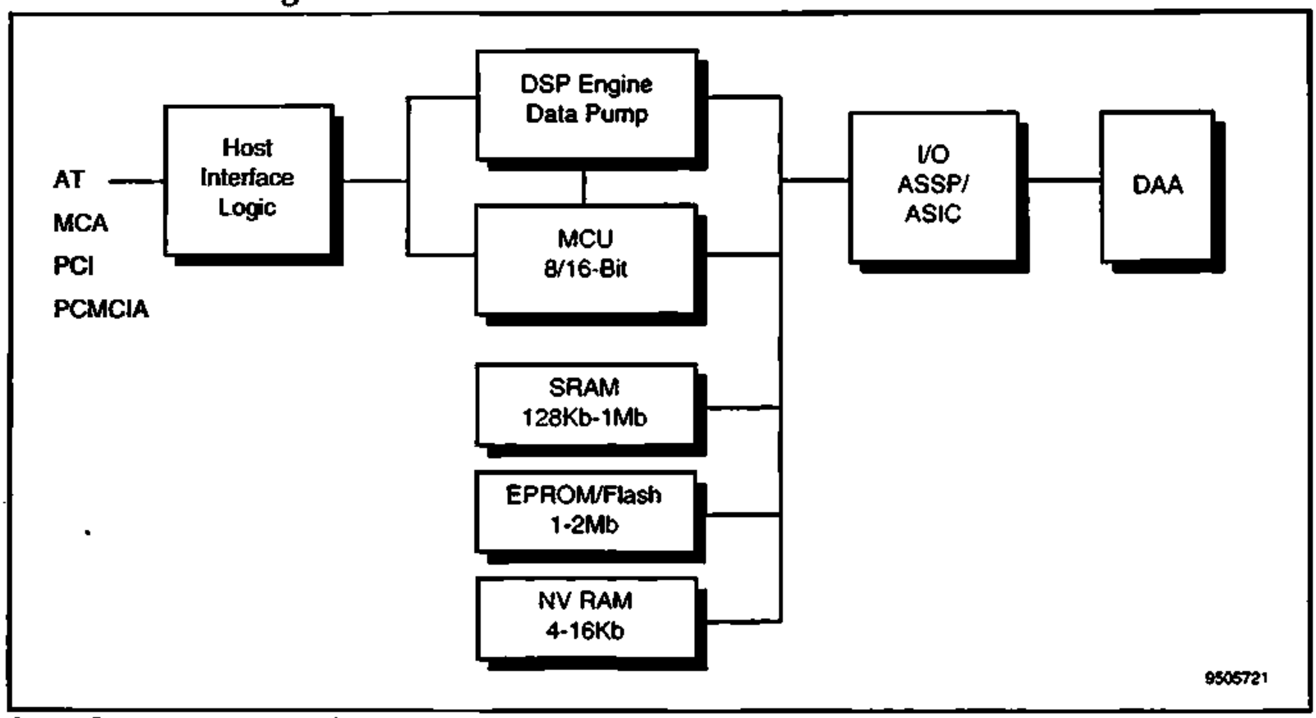
## Semiconductor Opportunities

### Modems (Data/Fax and Standalone/Card)

Figure 3-2 presents a block diagram of a typical modem capable of data, fax, and voice handling. Key chip opportunities in this application include:

- CMOS DSP-based chipsets (ASSP, ASIC, or pDSP) for implementing the various standards, with V.34/V.17 being the eminent opportunity. These chipsets would need to support many of the feature trends noted earlier. Ultimately, predominantly 3V versions will be needed. Mbps versions will be required for emerging cable (coax) versions.
- For PC card/PCMCIA versions there will be a migration toward PCI and PCMCIA bus interfaces that support plug-and-play Microsoft versions.
- There will be 128Kb to 1Mb of SRAM (trend toward 35ns or faster) for V.42 compression, among others.
- There will be 1 to 2Mb of flash or EPROM for control code storage.
- There will be 4 to 16Kb of EEPROM or NVRAM for power-down configuration storage.
- There will be RS-232 drivers and receivers, and optoisolators. Future interface alternatives include Geoport (Apple) support.

**Figure 3-2**
**Modem Block Diagram**




Source: Dataquest (October 1995)

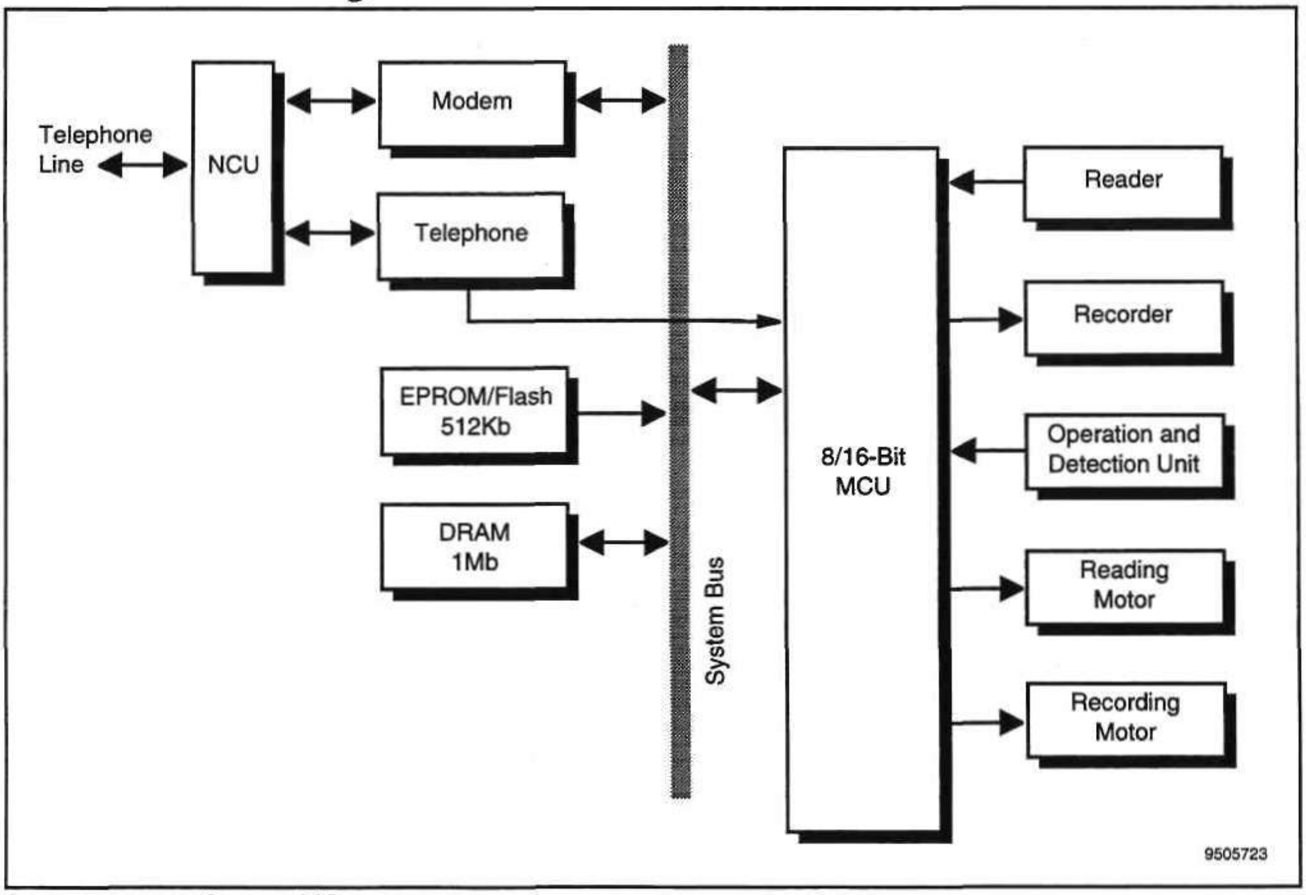
  

### Fax Machines

The trend toward more digital controls continues. Figure 3-3 shows a generic block diagram. Highlights in this segment are as follows:

- New fax modem chips supporting V.17 and earlier specifications—standard telephony functions including dialer and tape answering machine controls; ISDN versions require an S-interface controller, an LAP-D controller, and a rate adapter
- Memory requirements for DRAM page buffer 1Mb (predominantly) to 4Mb and flash/EPROM code storage for 0.5 to 1Mb
- 8-bit MCU (predominantly) through to 16- or 32-bit MPU to support advanced processing features, plus standard telephony/motor/sensor/front panel control
- Motor drivers, linear CCD (8 pixels/mm or greater), and CCD support circuitry

**Figure 3-3**
**Fax Machine Block Diagram**




Source: Dataquest (October 1995)

### OEMs

The following bullets list the leading brand names in modems in fax machines. The modem market tends to be dominated by U.S. companies, whereas the fax machine market is dominated by Japanese companies. It should be noted that ASCII of Japan and GVC of Taiwan are cited as large modem OEMs producing for several of the leading brands.

Leading modem marketers in rank order are as follows:

- GVC Technologies
- U.S. Robotics
- Hayes Microcomputer
- Zoom Telephonics
- Practical Peripherals
- Boca Research
- Megahertz
- Motorola
- AT&T Paradyne
- Multitech Systems

Leading fax machine marketers in rank order are as follows:

- Sharp
- Panasonic/Matsushita
- Canon
- Muratec
- Toshiba
- Brother
- Hewlett-Packard
- Funai
- Samsung
- Ricoh

## Digital WAN Equipment (T/E-Carrier, Cell/Frame Relay, ATM, and ISDN)

### Market and Feature Trends

The following highlights some of the market trends in WAN equipment:

- Digital WAN equipment is increasingly being used to extend campus LANs across wide geographic areas. Newer WAN technology can support server and real-time video traffic in addition to voice and data. New technologies include a group of fast packet switching approaches including frame relay, switched multimega digital services (SMDS), and ATM. Figure 3-4 details some of the differences among these technologies.

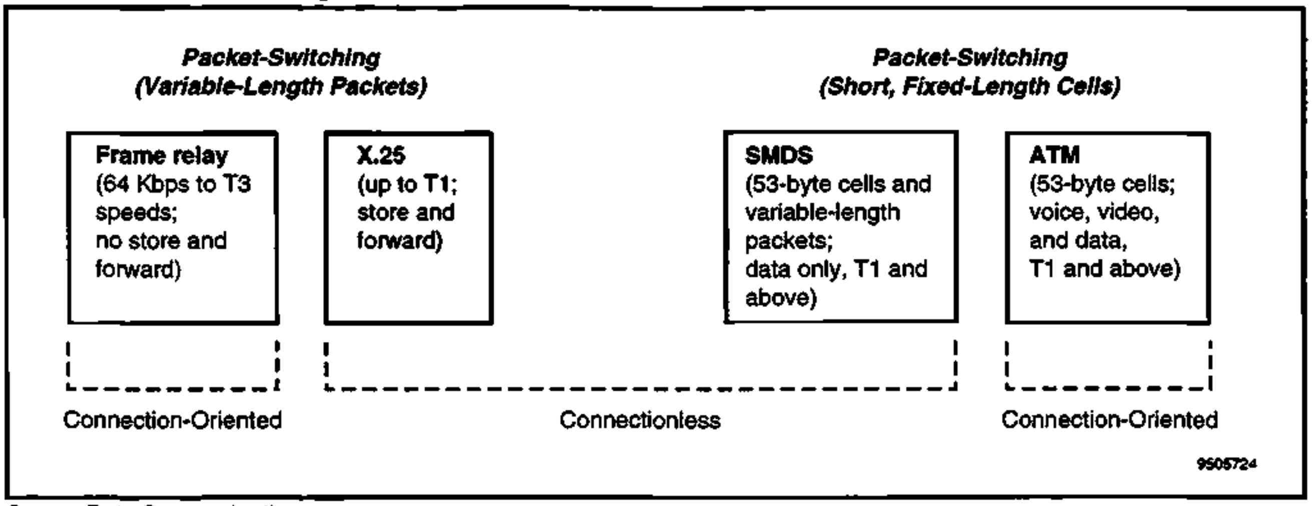
- Key digital WAN equipment includes T/E-1&3 carrier multiplexers, fractional and sub-T1 multiplexers, cell switches (ATM and SMDS), frame relay switches and access devices (Frame Relay), X.25 PADs and switches, and ISDN terminal adapters.
- Table 3-3 presents the outlook for digital WAN systems and derived semiconductor demand. The fastest-growing segments are ISDN adapters, T3 multiplexers, and fast cell/frame relay switches.
- Although technically not a new WAN technology, ISDN is expanding rapidly in Europe and Japan and is beginning to grow in the United States. Demand for basic rate (128Kb full-duplex) for the desktop or home and primary rate (1.5-Mbps) for business and institutions is being served initially by adapter units and computer add-in cards. LAN internetworking equipment such as routers are also starting to support ISDN interfaces. ISDN basic rate service is available for under $30 per month in the United States. The availability of ISDN-capable lines, reasonably priced services, and adapters rapidly heading to less than $300 in price is stimulating demand. The most pervasive use of ISDN to date appears to be the displacement of switched 56- to 64-Kbps services to support desktop videoconferencing, Internet and remote access.
- Frame relay is rapidly becoming the dominant WAN Service in the United States and Europe. Its cost-effectiveness is converting users from other services like Switched 56, X.25, and even T1 leased lines.
- As files get longer and the traffic richer with multimedia content and the need for isochronous connections (real time) for videoconferencing expanding, the demand for speed is expected to increase. The ATM/SDH rate of 155 Mbps is positioned to be a popular speed to serve the WAN market. T3/E3 is gaining some ground as an intermediate speed feature.
- Another alternative known as SMDS is based on the IEEE 802.6 MAN standard. This technology has not proved attractive to end users as ATM is perceived as a better long-term solution.
- Overall it appears as though narrow band ISDN (128-Kbps) and ATM could become the principal digital WAN technologies in operation by the year 2000. X.25 should slowly fade away and Frame Relay and SMDS will find some "large" niche use in the meantime as offered by certain service providers.

## Semiconductor Opportunities

Principal digital WAN chip opportunities include:

- T-Carrier ICs and ASIC library elements (transceivers, framers, and mux, among others)
- S/T and U interface, LAP-D, rate conversion controllers for ISDN adapter cards
- HDSL line controllers
- ATM standard ICs and ASIC elements: transceivers (copper/fiber), physical interface (UNI, Saturn, and Utopia), AAL (5/1) and SAR, switching elements, and content addressable memory
- Volatile and nonvolatile memory: 4- to 64MB per switch

**Figure 3-4**
**Fast Packet Switching**




Source: Data Communications

**Table 3-3**
**Worldwide Digital WAN Equipment Application Market Estimates**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|
| Units (K) | 850 | 1,120 | 1,442 | 1,891 | 2,373 | 2,888 | 3,566 | 26.1 |
| Time Division Multiplexers | 185 | 204 | 209 | 216 | 223 | 233 | 243 | 3.6 |
| 64 Kbps and Below | 87 | 67 | 62 | 57 | 52 | 48 | 44 | -8.0 |
| T-1/E-1 and Below Muliplexers | 69 | 108 | 117 | 126 | 136 | 147 | 159 | 8.0 |
| Backbone Multiplexers | 29 | 29 | 30 | 33 | 35 | 37 | 40 | 7.0 |
| Inverse Multiplexers | 9 | 19 | 27 | 43 | 61 | 79 | 86 | 35.3 |
| DSU/CSUs | 472 | 532 | 585 | 644 | 689 | 723 | 759 | 7.4 |
| ISDN Adapters (Standalone, Cards) | 122 | 238 | 456 | 776 | 1,125 | 1,512 | 2,075 | 54.2 |
| X.25 PADS | 62 | 66 | 68 | 70 | 70 | 69 | 65 | -0.2 |
| Cell/Frame Relay Access/Switches | 0 | 61 | 97 | 143 | 205 | 273 | 338 | 40.8 |
| Factory ASP ($) | 2,618 | 2,582 | 2,467 | 2,294 | 2,194 | 2,073 | 1,931 | -5.6 |
| Factory Revenue ($M) | 2,224 | 2,891 | 3,556 | 4,339 | 5,206 | 5,987 | 6,886 | 19.0 |
| Semiconductor Content ($) | 275 | 284 | 296 | 298 | 307 | 311 | 309 | 1.7 |
| Semiconductor Market ($M) | 234 | 318 | 427 | 564 | 729 | 898 | 1,102 | 28.2 |
| North America | | | | | | | | |
| Unit Production (K) | 680 | 885 | 1,125 | 1,456 | 1,780 | 2,137 | 2,603 | 24.1 |
| Production Revenue ($M) | 1,779 | 2,284 | 2,774 | 3,341 | 3,905 | 4,431 | 5,026 | 17.1 |
| Semiconductor Market ($M) | 187 | 251 | 333 | 434 | 547 | 665 | 804 | 26.2 |

Source: Dataquest (October 1995)

### OEMs

Principal OEMs supplying digital WAN equipment in rank order are as follows:

- Newbridge Networks
- Ascom Timeplex
- NET
- Micom
- Tellabs
- Telco
- Cray Communications
- Stratacom
- Motorola
- AT&T
- Cascade

## Videoconferencing

### Market and Feature Trends

Videoconferencing comprises room systems fixed in place, roll-about systems based on movable carts, desktops based primarily on PCs, or workstation-based enhancements with add-in cards and a camera/ microphone input. Video telephones are primarily consumer-targeted items with lesser capability. The following comprises some of the principal market and product feature trends:

- In general this market continues to gain notoriety as efficient, downsized companies turn to videoconferencing as a means of improving internal productivity and customer communications. This technology is finding great use in vertical markets such as telemedicine, teletraining, and tele-education, where limited professional personnel can be more effectively used.
- Room systems have served much of the need until recently when roll-about systems became popular. In general these systems are integrated with the main elements: the video/audio compression/decompression (codec), displays, cameras, speakers, microphones, computer interfaces (for presentation, graphics, and scanned images), remote control units, and multipoint control units for three-way or more conferences. Perhaps the most defining element is the software, which manages user interface, the computer interface, and the telephone network.
- Room/roll-about systems are feature-rich and typically allow 640 x 480-pixel resolutions at 30 frames per second (depending upon the type of line leased). Most of the recent entries by the established videoconferencing players support the ITU H.320 standard, which is an open standard specifying various protocol, formatting, and compression features. The established videoconferencing vendors continue to sell proprietary approaches, while also supporting the interoperable H.320 standard. H.320 uses the H.261 real-time, compression standard, whereas Compression Labs, for example, uses its proprietary CDV algorithm.

- Key to establishing a videoconferencing link is that various telephone lines can be used. Most high-performance setups use a T1/E1 (1.5- to 2-Mbps) or fractional T1 (384-Kbps) link to transfer the video, audio, and support data and control signals. Because these lines are expensive to lease, lower-performance conferencing systems operate over switched 56-Kbps or ISDN basic rate lines (128-Kbps).
- The latest incarnation of videoconferencing is the enhancement of the PC or workstation into a personal conferencing system. This system today generally requires two add-in boards (including an ISDN or modem connection), a camera, a speaker, and a microphone. Systems capable of 320 x 240 video at 15 frames per second can cost $2,500. Prices should drop to less than $1,000 per seat as volumes develop (or vice versa).
- Desktop videoconferencing should be aided by an initiative established by Intel and Microsoft that brings a standard telecommunications applications interface to Windows/Chicago (Windows 95), known as TAPI. This, along with the display control interface (DCI) capability that supports multiple software and hardware codecs, should aid in the ease of software development and interoperability. H.320 is clearly heading toward being the most heavily supported desktop videoconferencing standard.
- Video phones continue to offer the consumer marginal frame rate performance relative to the price. Higher-performance versions operating at V.34 and ISDN basic data rates will improve their performance and appeal dramatically before the end of the decade. H.324 is a proposed ITU standard using the V.34 interface.
- Table 3-4 presents a forecast of videoconferencing systems and the accompanying semiconductor demand. The basic underlying assumptions include continued growth in the high-performance systems as user needs continue to expand. Desktop systems are expected to take two to three years to develop into significant volume as user familiarity, the price per seat, performance, interoperability, and software applications issues are worked out. Another large issue concerns the bandwidth of a telephone line. However, competitive ISDN service for less than $30 per month plus declining prices on the traditional WAN services (T1 and fractional T1) will help lower acquisition barriers.

## Semiconductor Opportunities

Figure 3-5 presents a block diagram of typical videoconferencing system. Key semiconductor opportunities are noted as follows:

- Real-time, symmetrical, codec ICs; key standards include H.261, Indeo, and various other proprietary algorithms
- ITU G.711 and 772 (ADPCM) audio codecs; the TrueSpeech speech compression licensed by the DSP Group and supported by Microsoft could become popular for videoconferencing as well
- Digital video and audio ICs (data conversion, color space, scaling, mixing, amplification, filtering, and A/V synchronization)
- 1 to 8MB of DRAM (plus EDO and synchronous varieties) or VRAM for buffer
- V.34 modems, ISDN (S/T and LAP-D), T1/E1 or fractional T1 functions, and LAN controller
- ASIC integration variations of those listed using CMOS and some BiCMOS or bipolar technology

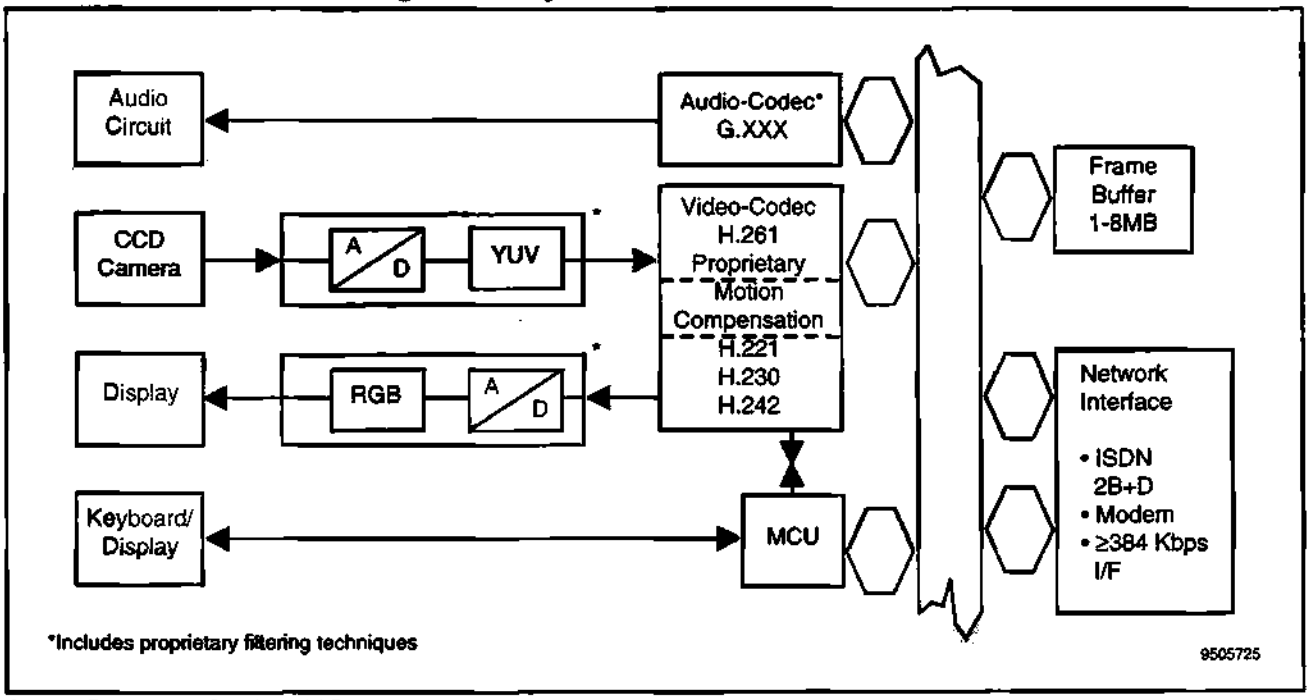
**Table 3-4**
**Worldwide Videoconferencing/Phones Application Market**

| | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|---|
| Conferencing | | | | | | | | | |
| Units (K) | 12 | 36 | 87 | 133 | 197 | 411 | 891 | 1,905 | 85.3 |
| Room/Roll-About | 6 | 8 | 13 | 17 | 21 | 24 | 25 | 24 | 12.0 |
| Desktop | 6 | 28 | 74 | 115 | 176 | 387 | 867 | 1,881 | 91.2 |
| Factory ASP ($K) | 27 | 13 | 6 | 6 | 4 | 3 | 2 | 1 | -26.0 |
| Factory ASP Room/ Roll-About ($K) | 49 | 42 | 32 | 27 | 23 | 21 | 19 | 17 | -11.8 |
| Factory ASP Desktop ($K) | 5.1 | 4.8 | 1.7 | 2.4 | 1.9 | 1.5 | 1.2 | 1.2 | -6.5 |
| Factory Revenue ($M) | 331 | 467 | 548 | 738 | 818 | 1,077 | 1,508 | 2,657 | 37.1 |
| Factory Revenue Room/ Roll-About ($M) | 299 | 331 | 424 | 462 | 483 | 497 | 468 | 400 | -1.2 |
| Factory Revenue Desktop ($M) | 32 | 136 | 124 | 276 | 335 | 580 | 1,040 | 2,257 | 78.7 |
| Phones | | | | | | | | | |
| Units (K) | 53 | 83 | 97 | 157 | 271 | 429 | 914 | 1,827 | 79.9 |
| Factory ASP ($) | 1.10 | 0.90 | 0.65 | 0.54 | 0.48 | 0.44 | 0.37 | 0.30 | -14.3 |
| Factory Revenue ($M) | 56 | 75 | 63 | 85 | 130 | 189 | 338 | 548 | 54.2 |
| Semiconductor Content ($) | 592 | 455 | 365 | 341 | 264 | 211 | 153 | 137 | -17.8 |
| Semiconductor Market ($M) | 39 | 54 | 67 | 99 | 123 | 177 | 277 | 513 | 50.1 |
| MPU/MCU ($M) | 3 | 4 | 5 | 7 | 9 | 12 | 19 | 36 | 50.1 |
| Memory ($M) | 5 | 6 | 7 | 11 | 14 | 19 | 30 | 56 | 50.1 |
| ASIC/ASSP ($M) | 27 | 38 | 48 | 71 | 88 | 127 | 198 | 367 | 50.4 |
| Logic/Analog/ Discrete ($M) | 4 | 5 | 7 | 10 | 12 | 17 | 27 | 50 | 49.8 |
| Optoelectronics ($M) | 0 | 1 | 1 | 1 | 1 | 2 | 3 | 5 | 50.1 |
| North America | | | | | | | | | |
| Unit Production (K) | 52 | 93 | 129 | 188 | 281 | 462 | 939 | 1,940 | 72.0 |
| Production Revenue ($M) | 310 | 422 | 428 | 535 | 569 | 696 | 960 | 1,603 | 30.2 |
| Semiconductor Market ($M) | 31 | 42 | 47 | 64 | 74 | 97 | 144 | 267 | 41.5 |

Source: Dataquest (October 1995)

**Figure 3-5**
**Generic Videoconferencing/Phone System**




Source: Dataquest (October 1995)

## OEMs

Leading videoconferencing/phone OEMs in rank order are as follows:

- Picturetel
- Compression Labs
- GPT
- VTEL
- Intel
- IBM
- AT&T
- Creative Labs (Share Vision)
- Hitachi
- NEC

# Chapter 4
# Premise Switching and Call Processing Systems

## Market and Feature Trends

Principal trends with voice communications equipment such as PBXs, key telephone systems (KTS), voice messaging (VM) systems, interactive voice response (IVR), and automatic call distribution (ACD) systems include:

- PBXs and KTSs will remain the central premise equipment in nonresidential voice communications. The other voice systems are typically used as adjuncts to PBXs. The main market attraction of these systems is for productivity purposes and thus they are very sensitive to capital spending cycles. They are enjoying a general upswing in the developed countries and new penetration in places such as eastern Europe, Latin America, and Asia.
- KTS phone systems are principally used by smaller companies with two or more lines. They typically do not require an access code, as PBXs do, but do provide various features such as holding (plus music) and intercom. In general KTSs are turning to digital processing as new models emerge. There are about as many KTS lines shipped as PBX lines. This market is very mature and is expected to remain flat over the forecast time frame.
- PBXs continue to add value by incorporating many new features, including:
  - Wireless options, with offerings emerging from many including Ericsson (CT-3), Spectralink, and Northern Telecom. DECT wireless technology is mentioned often as a solution for wireless offices.
  - Computer telephony integration (CTI) describes a general trend toward PBXs being modified to support LAN and WAN environments. Today many PBXs can connect to servers or intelligent hubs, with Novell's NetWare being the most popular network operating system. Microsoft and Intel are evangelizing the TAPI technology as a means of standardizing the software interface to telecom premise equipment.
  - Most PBXs can now optionally offer T1/E1 and ISDN primary and basic rate trunk line interfaces. Future other WAN features such as ATM, T3, routers, and modems are not out of the question as the PBX vendors attempt to do battle with the networking vendors.
  - PBXs will also trend to offer support for fax and audio/video store-and-forward as well as real-time support for videoconferencing.
- Voice message system unit growth will continue robustly into small businesses that do not have these systems yet but can afford them. These systems continue to offer more features including larger message capacity, thanks to lower disk drive prices. Some of the market continues to be absorbed by PBX systems integrating this functionality.
- IVR, as a newer technology, continues to emerge as it moves away from the United States into other markets. These systems continue to find good interest from almost any organization (banks and pension funds,

among others) with customer or public support requirements for information that can easily be accessed with key telephone button strokes. Planned improvements include speech recognition.

- ACDs distribute phone calls to waiting agents (airlines, among others). They will continue to push into smaller operations willing to stay competitive. This function is also being absorbed by PBXs equipped with ACD software, but separate functionality remains a robust market.

Tables 4-1 through 4-4 present the worldwide market for these voice systems and their accompanying semiconductor demand.

**Table 4-1**
**Worldwide PBX/KTS Application Market Estimates**

| | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|---|
| System Units (K) | 1,477 | 1,400 | 1,452 | 1,532 | 1,631 | 1,738 | 1,853 | 2,004 | 6.7 |
| Lines/Stations (K) | 23,009 | 24,204 | 26,134 | 27,670 | 29,525 | 31,511 | 33,849 | 36,420 | 6.9 |
| Factory ASP ($K) | 6 | 7 | 7 | 7 | 7 | 7 | 8 | 8 | 0.8 |
| Factory Revenue ($M) | 9,428 | 9,546 | 10,535 | 11,229 | 12,024 | 12,881 | 13,929 | 15,113 | 7.5 |
| Semiconductor Content ($) | 581 | 641 | 697 | 711 | 723 | 741 | 774 | 792 | 2.6 |
| Semiconductor Market ($M) | 858 | 897 | 1,011 | 1,089 | 1,178 | 1,288 | 1,435 | 1,587 | 9.4 |
| ASIC/ASSP | 515 | 538 | 605 | 654 | 704 | 769 | 848 | 938 | 9.2 |
| Memory | 120 | 135 | 162 | 180 | 200 | 219 | 251 | 278 | 11.4 |
| MPU/MCU | 77 | 82 | 93 | 100 | 110 | 120 | 135 | 149 | 9.9 |
| Others | 146 | 144 | 152 | 156 | 165 | 180 | 201 | 222 | 7.9 |
| North America | | | | | | | | | |
| Unit Production (K) | 443 | 406 | 407 | 414 | 424 | 434 | 445 | 481 | 3.4 |
| Production Revenue ($M) | 2,828 | 2,768 | 2,950 | 3,032 | 3,126 | 3,220 | 3,343 | 3,627 | 4.2 |
| Semiconductor Market ($M) | 257 | 260 | 283 | 294 | 306 | 322 | 344 | 381 | 6.1 |

Source: Dataquest (October 1995)

**Table 4-2**
**Worldwide Interactive Voice Response System Application Market Estimates**

| | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|---|
| Units (K) | 8 | 12 | 20 | 26 | 34 | 44 | 56 | 72 | 29.4 |
| Factory ASP ($K) | 71 | 59 | 44 | 45 | 46 | 47 | 49 | 49 | 2.4 |
| Factory Revenue ($M) | 569 | 675 | 873 | 1,180 | 1,566 | 2,079 | 2,739 | 3,566 | 32.5 |
| Semiconductor Content ($) | 2,488 | 2,054 | 1,552 | 1,610 | 1,667 | 1,706 | 1,774 | 1,798 | 3.0 |
| Semiconductor Market ($M) | 20 | 24 | 31 | 42 | 56 | 75 | 100 | 130 | 33.2 |
| North America | | | | | | | | | |
| Unit Production (K) | 7 | 11 | 18 | 23 | 30 | 39 | 49 | 62 | 27.9 |
| Production Revenue ($M) | 529 | 621 | 795 | 1,062 | 1,393 | 1,829 | 2,383 | 3,067 | 31.0 |
| Semiconductor Market ($M) | 19 | 22 | 28 | 38 | 50 | 66 | 87 | 112 | 31.7 |

Source: Dataquest (October 1995)

**Table 4-3**
**Worldwide Voice Messaging Application Market Estimates**

| | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|---|
| Units (K) | 39 | 62 | 84 | 109 | 142 | 175 | 213 | 256 | 25.0 |
| Factory ASP ($K) | 28 | 22 | 21 | 22 | 24 | 24 | 24 | 23 | 2.4 |
| Factory Revenue ($M) | 1,101 | 1,337 | 1,735 | 2,422 | 3,349 | 4,226 | 5,147 | 5,979 | 28.1 |
| Semiconductor Content ($) | 1,819 | 1,429 | 1,431 | 1,552 | 1,676 | 1,737 | 1,764 | 1,730 | 3.9 |
| Semiconductor Market ($M) | 72 | 88 | 120 | 170 | 238 | 304 | 376 | 442 | 29.9 |
| North America | | | | | | | | | |
| Unit Production (K) | 37 | 56 | 74 | 95 | 121 | 145 | 174 | 205 | 22.4 |
| Production Revenue ($M) | 1,024 | 1,217 | 1,544 | 2,107 | 2,846 | 3,507 | 4,195 | 4,783 | 25.4 |
| Semiconductor Market ($M) | 67 | 80 | 107 | 148 | 202 | 253 | 306 | 354 | 27.1 |

Source: Dataquest (October 1995)

**Table 4-4**
**Worldwide Automatic Call Distributor Application Market Estimates**

| | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|---|
| Units (K) | 7 | 10 | 13 | 16 | 19 | 22 | 26 | 31 | 19.9 |
| Factory ASP ($K) | 88 | 74 | 71 | 75 | 75 | 77 | 76 | 73 | 0.6 |
| Factory Revenue ($M) | 644 | 727 | 884 | 1,167 | 1,421 | 1,705 | 1,959 | 2,261 | 20.7 |
| Semiconductor Content ($) | 2,647 | 2,226 | 2,192 | 2,334 | 2,406 | 2,458 | 2,515 | 2,407 | 1.9 |
| Semiconductor Market ($M) | 19 | 22 | 27 | 36 | 45 | 55 | 65 | 75 | 22.2 |
| North America | | | | | | | | | |
| Unit Production (K) | 5 | 7 | 9 | 10 | 12 | 14 | 16 | 20 | 18.1 |
| Production Revenue ($M) | 451 | 502 | 601 | 782 | 938 | 1,108 | 1,254 | 1,424 | 18.8 |
| Semiconductor Market ($M) | 14 | 15 | 19 | 24 | 30 | 35 | 41 | 47 | 20.3 |

Source: Dataquest (October 1995)

## Semiconductor Opportunities

Semiconductor opportunities are as follows:

- Architecturally, PBXs are now bus-oriented (VME, among others), modular systems that allow for the easy upgrade of various voice, LAN, and WAN options.
- In general the trend is toward more memory as more processing and CTI features are added. PBXs today have 2 to 16MB of DRAM, which could double during the next five years. VM, IVR, and ACD systems have 2 to 10MB typically. All of these systems employ 1 to 4MB of EPROM/flash for control code and to support various power-down and backup modes. These systems also tend to be large users of FIFOs and other specialty memory.

- 32-bit MPUs are used in PBXs, ACDs, IVRs, and VMs. Often multiple (two to four) processors are employed, divvying up various host and I/O functions. x386 appears to be the most popular, but 80960, 68K, and RISC CPUs such as the R3000 are making it into some designs. To manage individual or groups of line cards, 8-bit MCUs are often employed.
- Perhaps the largest opportunity is for line card circuits (for all the voice systems) and switch matrixes that manage either analog POTS phones, the digital phones (either ISDN or PCM), and PSTN interfaces for POTS, ISDN (BRI/PRI), and T1. Although many of these functions are standard ASSPs, many OEMs choose to use ASIC approaches. Many of these functions are appearing in CMOS or BiCMOS form, depending upon specific use. Specific functions and library functions include:
  - Slice Codecs/filters (uLaw, aLaw, PCM— 9.6 Kbps through 64 Kbps)
  - ISDN functions (S/T, U, LAP-D, and echo cancelers)
  - T1/E1 transceivers and framers
  - Cross-point switches
  - Various integrations of those listed, plus other features

## OEMs

Leading PBX/KTS OEMs in rank order are as follows:

- AT&T
- ROLM/Siemens
- NEC
- Alcatel
- Bosch
- Philips
- Ericsson
- Toshiba
- Mitel
- Fujitsu

Leading interactive voice response systems OEMs in rank order are as follows:

- AT&T
- InterVoice
- Periphonics
- IBM
- Syntellect
- Brite Voice
- Stylus

- Computer Communications ETC
- Voicetek

Leading interactive voice messaging system OEMs in rank order are as follows:

- Octel
- Northern Telecom
- AT&T
- Active Voice Technology
- ROLM/Siemens
- Applied Voice Technology
- Centigram
- Unisys

Leading automatic call distributor OEMs in rank order are as follows:

- AT&T
- Northern Telecom
- ROLM/Siemens
- Aspect Telecommunications
- Ericsson
- Rockwell
- EXECUTONE
- Philips
- Alcatel

# Chapter 5
# Public Switching and Transmission Systems

## Market and Feature Trends

Key equipment involved in the public switching and transmission markets are central office switches and fiber-optic and nonfiber-optic transmission systems consisting of primarily digital cross-connects, multiplexers, and repeaters. Transmission systems comprise the local telephone line (local loop), the trunk lines (conduits between switches), and the long distance lines. In the United States, there are separate, privately owned local (regional Bell operating companies—RBOCs—or Baby Bells) and long distance (AT&T and MCI, among others) telephone service companies that invest in this equipment. In most of the rest of the world, there is generally a single state-controlled PTT of telephone and data transmission services. There is a trend toward privatizing many of these, however, and Japan (NTT), the United Kingdom (British Telecom), and Mexico (Telephonos de Mexico) have sold majority stakes of their PTTs to investor interests.

The following describes key trends in the public switching and transmission markets.

- Principal new line shipments will occur in eastern Europe, China and the rest of Asia, and Latin America. Line shipments in the United States will decline throughout forecast period as the conversion to digital is completed and replacement economics takes over. Western Europe is also expected to slow growth in line shipments, while Japan has delayed much of its planned national fiber-optic rollout until the next decade. Tables 5-1 and 5-2 show a market forecast of public switching and transmission equipment and accompanying semiconductor demand.
- The traditional PTTs are under attack, however, especially in the United States. Companies known as competitive access providers (CAPs) are being allowed to compete for services. The most visible CAP contenders are the cable TV companies, which have plenty of bandwidth on their fiber/coax systems and can provide a host of traditional telecommunications services including data transmission for corporate users and videoconferencing. Pending deregulation legislation in the U.S. Congress could have the impact of sparing investment in local phone access and long distance services.
- The other major battle is for interactive, TV-based services to the home. The combatants are the telephone companies, cable TV companies, and a wave of new companies exploiting wireless links. At stake is a potential annual market worth $25 billion (in the United States alone) or more in interactively delivered services. Interactive services would include pay-per-view movies delivered individually to each home at any time, directories, extension education programs, and home banking and shopping. From a switching and transmission standpoint, these services will demand a new generation of high-bandwidth, two-way-capable delivery systems.

- The major technical trend in public equipment is the conversion to digital techniques for transmission and switching and the increasing use of high-speed fiber-optics for transmission.
- There continues to be a significant increase in the number of ISDN lines in the United States, joining progress in Europe and Japan, as a new set of standards known as ISDN-1, -2, and -3 allow equipment from different manufacturers to be interoperable. Several U.S. RBOCs have recently started monthly basic-rate (128-Kbps full-duplex) ISDN services for less than $30 per month. These services support such features as videoconferencing and more sophisticated audio, video, and graphical interaction with the Internet, America Online, and other online services.
- Fiber-optic rollout is moving from the trunk lines between central office switches or cable TV headend equipment to being inserted in the local loop to the subscribers. This trend is known as fiber-in-the-loop or FITL. The most popular fiber transmission standard is known globally as SDH and in the United States as SONET. It is scalable from 155 Mbps, known as STS-12, to 2 Gbps or more.
- To support video-on-demand (VOD) and other high-bandwidth services, a technology that uses fiber optics to the last few hundred homes and then coax cables to the home itself is being developed. It is known as Hybrid Fiber-Coax (HFC). Figure 5-1 illustrates such a system.
- Key equipment used in fiber-optic transmission includes various types of multiplexers (add-drop, among others), repeaters inserted every few thousand feet to refresh the optical signal, optical line terminals that terminate optical signals at the switch, and optical network units (ONUs). Next-generation digital loop carrier (NGDLC) systems bring the fiber to the neighborhood and convert the optical signal to electrical for use on coax or twisted-pair. NGDLCs form the backbone of the hybrid fiber/coax systems being installed by the phone and cable TV companies.
- ATM and asymmetrical digital subscriber loop (ADSL) technologies are also scrambling to be chosen in next-generation broadband systems. ATM is a scalable, bandwidth-on-demand switching technology that employs a standard 53 bytes cells to move multimedia traffic. It is being tested by the service companies around the world, with large-scale rollout not expected to begin until 1996 at the earliest. ADSL is a DSP-based technology that stretches the bandwidth of traditional local loop twisted-pair technology to handle MPEG-2 (6-Mbps) bit streams delivering movies to the home. Developed by Bellcore, this technology is being evaluated as an alternative or bridge to fiber/coax delivery by companies in the United States and Europe. There is a possibility of several million ADSL nodes being shipped by the end of the century.
- Radio-in-the-loop (RITL) is also emerging as an alternative service providers for minimizing expensive infrastructure investment. This technique has been used by the cable TV community for years but is now also being used by the telephone companies in rural areas. Several of these systems operate in the microwave frequencies above 10 GHz. It is possible that radio could be used in as many as 5 million local loop lines by the end of decade.

## Table 5-1
## Worldwide Central Office Switch Application Market

| | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|---|
| Lines (K) | 42,237 | 48,054 | 49,609 | 51,823 | 53,651 | 55,841 | 58,512 | 61,438 | 4.4 |
| Factory ASP ($) | 363 | 327 | 325 | 324 | 328 | 324 | 325 | 325 | 0.1 |
| Factory Revenue ($M) | 15,316 | 15,711 | 16,100 | 16,798 | 17,606 | 18,120 | 19,040 | 19,992 | 4.4 |
| Semiconductor Content ($) | 26 | 24 | 24 | 25 | 25 | 25 | 26 | 26 | 1.4 |
| Semiconductor Market ($M) | 1,118 | 1,163 | 1,207 | 1,277 | 1,356 | 1,413 | 1,504 | 1,599 | 5.8 |
| North America | | | | | | | | | |
| Unit Production (K) | 13,630 | 14,929 | 15,005 | 14,418 | 13,897 | 13,604 | 13,495 | 13,521 | -2.1 |
| Production Revenue ($M) | 2,777 | 3,005 | 2,955 | 2,811 | 2,640 | 2,557 | 2,496 | 2,501 | -3.3 |
| Semiconductor Market ($M) | 284 | 311 | 313 | 303 | 291 | 287 | 286 | 290 | -1.5 |

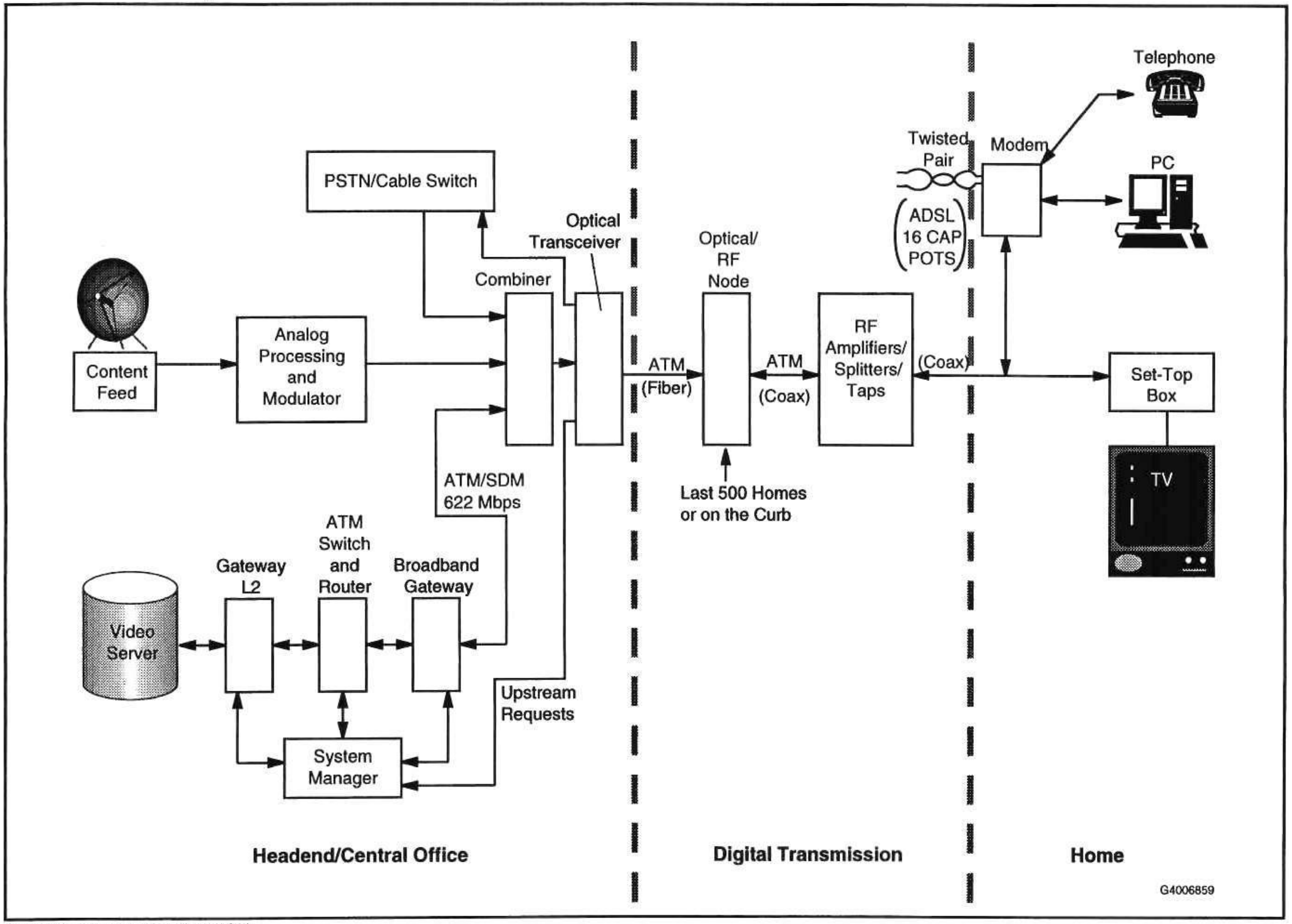
Source: Dataquest (October 1995)

## Table 5-2
## Worldwide Public Transmission Equipment Application Market

| | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|---|
| Factory Revenue ($M) | 14,989 | 17,124 | 19,542 | 21,345 | 23,619 | 25,901 | 27,864 | 34,921 | 12.3 |
| SONET/SDH Multiplexers | 448 | 1,108 | 1,802 | 2,203 | 2,624 | 2,972 | 3,349 | 3,800 | 16.1 |
| Non-SONET/SDH Multiplexers | 2,551 | 2,192 | 1,933 | 1,418 | 1,005 | 759 | 528 | 286 | -31.8 |
| Digital Cross Connects | 1,176 | 1,296 | 1,617 | 1,926 | 2,169 | 2,358 | 2,599 | 2,904 | 12.4 |
| Local Loop | 10,814 | 12,528 | 14,190 | 15,797 | 17,820 | 19,811 | 21,388 | 27,930 | 14.5 |
| Semiconductor Market ($M) | 1,109 | 1,284 | 1,485 | 1,644 | 1,842 | 2,046 | 2,229 | 2,794 | 13.5 |
| North America | | | | | | | | | |
| Production Revenue ($M) | 3,046 | 3,588 | 5,215 | 5,643 | 6,754 | 7,632 | 8,643 | 11,505 | 17.1 |
| Semiconductor Market ($M) | 225 | 269 | 396 | 435 | 527 | 603 | 691 | 920 | 18.4 |

Source: Dataquest (October 1995)

**Figure 5-1**
**Overall Cable/Telephone Multimedia Delivery**




Source: Dataquest (October 1995)

## Semiconductor Opportunities

Tables 5-1 and 5-2 present a forecast of the semiconductor market from public switching and transmission applications. Key opportunities include:

- Standard line card circuits (see the PBX discussion)
- New line card circuits such as ISDN U interface and ADSL functions
- CMOS and BiCMOS ASIC libraries to support the building of switch matrixes, digital cross-connects, multiplexers, and optical network units; new technologies such as SDH and ATM need to be supported with framing, clock, multiplexing, protocol/adaptation processing, and switching macros
- High-speed SRAM, FIFO, and DRAM (for switch software)
- Standard transceiver and physical interface functions such as T/E courier SONET; laser-based optoelectronic transceiver modules will be needed in increasing quantities, as well as copper coax terminations
- 16- to 32-bit MPU, MCU for management and housekeeping

## OEMs

Leading central office switch OEMs in rank order are as follows:

- Alcatel
- AT&T
- Siemens
- Ericsson
- Northern Telecom
- NEC
- AG Communications
- GPT

Leading transmission equipment OEMs in rank order are as follows:

- Alcatel
- AT&T
- Siemens
- NEC
- Ericsson
- Fujitsu
- Philips
- DSC
- Bosch
- Tellabs

**For More Information...**

Gregory Sheppard, Chief Analyst ............................................ (408) 468-8261
Internet address ....................................................gsheppard@dataquest.com
Via fax ............................................................................................ (408) 954-1780



Dataquest
a company of The Dun & Bradstreet Corporation

# DATAQUEST WORLDWIDE OFFICES

## NORTH AMERICA

**Worldwide Headquarters**
Dataquest Incorporated
251 River Oaks Parkway
San Jose, California 95134-1913
United States
Phone: 1-408-468-8000
Facsimile: 1-408-954-1780

**Dataquest Incorporated**
Nine Technology Drive
P.O. Box 5093
Westborough, Massachusetts 01581-5093
United States
Phone: 1-508-871-5555
Facsimile: 1-508-871-6262

**Dataquest Global Events**
3990 Westerly Place, Suite 100
Newport Beach, California 92660
United States
Phone: 1-714-476-9117
Facsimile: 1-714-476-9969

Sales Offices:
- Washington, DC (Federal)
- New York, NY (Financial)
- Dallas, TX

## LATIN AMERICA

Research Affiliates and Sales Offices:
- Buenos Aires, Argentina
- Sao Paulo, Brazil
- Santiago, Chile
- Mexico City, Mexico

## EUROPE

**European Headquarters**
Dataquest Europe Limited
Holmers Farm Way
High Wycombe, Bucks HP12 4XH
United Kingdom
Phone: +44 1494 422 722
Facsimile: +44 1494 422 742

**Dataquest Europe SA**
Immeuble Défense Bergères
345, avenue Georges Clémenceau
TSA 40002
92882 - Nanterre CTC Cedex 9
France
Phone: +33 1 41 35 13 00
Facsimile: +33 1 41 35 13 13

**Dataquest GmbH**
Kronstadter Strasse 9
81677 München
Germany
Phone: +49 89 93 09 09 0
Facsimile: +49 89 93 03 27 7

Sales Offices:
- Brussels, Belgium
- Kfar Saba, Israel
- Milan, Italy
- Randburg, South Africa
- Madrid, Spain

## JAPAN

**Japan Headquarters**
Dataquest Japan K.K.
Shinkawa Sanko Building
6th Floor
1-3-17, Shinkawa
Chuo-ku, Tokyo 104
Japan
Phone: 81-3-5566-0411
Facsimile: 81-3-5566-0425

## ASIA/PACIFIC

**Asia/Pacific Headquarters**
7/F China Underwriters Centre
88 Gloucester Road
Wan Chai
Hong Kong
Phone: 852-2824-6168
Facsimile: 852-2824-6138

**Dataquest Korea**
Suite 2407, Trade Tower
159 Samsung-dong, Kangnam-gu
Seoul 135-729
Korea
Phone: 822-551-1331
Facsimile: 822-551-1330

**Dataquest Taiwan**
11F-2, No. 188, Section 5
Nan King East Road
Taipei
Taiwan, R.O.C.
Phone: 8862-756-0389
Facsimile: 8862-756-2663

**Dataquest Singapore**
105 Cecil Street
#06-01/02 The Octagon
Singapore 0106
Phone: 65-227-1213
Facsimile: 65-227-4607

**Dataquest Thailand**
12/F, Vanissa Building
29 Soi Chidlom
Ploenchit Road
Patumwan, Bangkok 10330
Thailand
Phone: 662-655-0577
Facsimile: 662-655-0576

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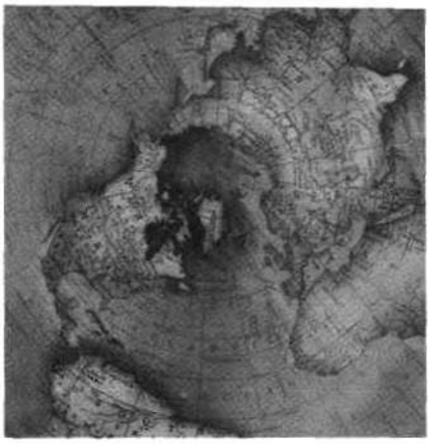

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# Communications Semiconductor Industry: Big Players, but Fragmented Too

Competitive Trends

**Program:** Communications Semiconductors and Applications Worldwide
**Product Code:** CSAM-WW-CT-9501
**Publication Date:** June 26, 1995
**Filing:** Competitive Dynamics

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# Chapter 1
# Overall Industry View

This report examines the competitive landscape of the wired and wireless communications chip markets. Market share and supplier matrices are presented for LAN (by standard), modem (by standard), line card, T/E carrier, SONET/SDH, ISDN, telephone, wireless baseband (cellular, cordless-analog, and digital), and wireless RF/IF dedicated functions.

The communications semiconductor industry has a long history of very steady growth based on ever-evolving waves of applications. Starting with telephones about 100 years ago, hundreds of classes of communications systems have emerged that manage voice, data, video, and multimedia traffic. In fact, the first use of a solid-state transistor, as developed by Bell Labs, was for voice telecommunications systems. Most of the early use of chip technology in communications systems was the employment of basic building blocks such as transistors, op amps, and catalog logic. That has since evolved to where chips implementing certain standards can require hundreds of thousands of gates and analog elements.

The outgrowth of that first simple application has resulted in more than 80 semiconductor companies now producing communications-specific chips or functions. Many of these companies have evolved into being technology enablers for the OEM community with substantial investment in intellectual property in both ASSP and ASIC forms.

## Overall Suppliers

Table 1-1 lists the leading overall suppliers of semiconductors for communications system applications. Revenue of all semiconductor products is included, whether communications-specific or not. For example, this includes sales to communications applications of broadly applied products such as memories, MCUs, and discretes. A communications application can be anything from LAN and WAN systems to telephone and voice systems with associated switching and transmission infrastructure, to mobile communications such as cellular and pager systems.

Fed by a tremendous global surge in wireless applications, Motorola was the largest overall supplier for communications system use in 1994. Seven of the top 10 suppliers also appear among Dataquest's overall top 10 in semiconductor market share. This is a testament to the breadth of product lines many of these companies maintain.

AT&T Microelectronics, Siemens, and SGS-Thomson are not in the overall top 10 list, but they share a common theme: they have a major focus on the communications market.

## Communications-Specific Suppliers

Table 1-2 ranks the top suppliers of semiconductors tailored for use in a voice, data, or multimedia communications function. These semiconductors are primarily logic, analog, and mixed-signal ICs that embody some form of protocol and/or transceiver functionality. We have broken the market into several major categories that are covered in more detail in later tables: LAN, modem, ATM, transmission (WAN, line card, and SONET/SDH), telephone, wireless, and other dedicated communications ICs.

**Table 1-1**
**Top 10 Vendors of Semiconductors for Communications System Use, Worldwide Revenue (Millions of Dollars)**

| Company | 1994 Revenue | Market Share (Percentage of Revenue) |
|---|---|---|
| Total Market | 18,583.0 | 100.0 |
| Motorola | 2,464.0 | 13.8 |
| NEC | 1,503.6 | 8.4 |
| AT&T | 1,144.0 | 6.4 |
| Fujitsu | 991.8 | 5.5 |
| Toshiba | 975.9 | 5.5 |
| Texas Instruments | 835.6 | 4.7 |
| Hitachi | 788.4 | 4.4 |
| SGS-Thomson | 696.0 | 3.9 |
| Intel | 637.4 | 3.6 |
| Siemens | 586.0 | 3.3 |
| Other Companies | 7,960.3 | 42.8 |

Source: Dataquest (June 1995)

The leading company in terms of revenue is Motorola, which is driven by its strength in wireless communications. Rockwell claims the second spot, riding the modem wave of home connectivity.The next two are a duo of European companies—SGS-Thomson and Philips Semiconductor—which are thriving off supplying a communications-centric European market. NEC rounds out the top five with its strength in the wireless area, participating in both baseband and RF/IF technologies.

## Motorola

Motorola excels at supplying chips for its internal use with its mobile communications systems groups. The company is very strong with specialized DSP-based processors used in cellular and pager handsets and accompanying base station equipment. Another strength is a broad RF/IF catalog, including a strategic position in GaAs MMICs and discretes. Motorola is also a big player in MPUs and protocol controllers used in LAN backbones and ISDN, as well as general-purpose microcontrollers. It also is benefiting by investment in FDDI and ISDN technology.

## Rockwell

Rockwell is the undisputed king of the modem market. It dominates both the data/fax modem business and the fax-only market. It also is the early leader in the new V.34 (28.8 Kbps) market. In a move to diversify, the company has invested in CDPD wireless data technology and has a presence in the SONET/SDH broadband market.

## SGS-Thomson

SGS-Thomson's success in this market is because of its position in mixed-signal technology as applied to telecommunications applications. It is dominant in line card and telephone ICs, where its mixed-signal technology is highly valued. It also is a significant player in the budding ATM market, with both ASIC and ASSP offerings.

  

Table 1-2
**Top 10 Vendors of Communications-Specific ICs, Worldwide Revenue (Millions of Dollars)**

| Company | Communications-Specific ICs | LAN ICs | Modem ICs | ATM ICs | Transmission and Switching ICs | Telephone Answering Machine ICs | Wireless ICs | Other Dedicated ICs |
|---|---|---|---|---|---|---|---|---|
| Total Market | 5,791.8 | 637.4 | 780.4 | 40.1 | 1,477.0 | 567.0 | 2,089.1 | 200.8 |
| Motorola | 749.1 | 9.4 | 7.3 | 0 | 49.5 | 30.0 | 624.9 | 28.0 |
| Rockwell | 496.0 | 0 | 494.0 | 0 | 2.0 | 0 | 0 | 0 |
| SGS-Thomson | 431.4 | 7.0 | 30.0 | 2.0 | 232.0 | 89.0 | 31.4 | 40.0 |
| Philips | 356.3 | 5.0 | 2.0 | 1.0 | 20.0 | 30.0 | 253.3 | 45.0 |
| NEC | 347.8 | 0 | 20.0 | 0 | 86.0 | 25.0 | 211.8 | 5.0 |
| AT&T | 342.8 | 2.0 | 35.0 | 0.5 | 167.0 | 85.0 | 46.3 | 7.0 |
| Siemens | 326.5 | 5.0 | 5.0 | 2.0 | 197.0 | 40.0 | 57.5 | 20.0 |
| Advanced Micro Devices | 299.2 | 182.2 | 0 | 0 | 102.0 | 0 | 5.0 | 10.0 |
| Texas Instruments | 285.1 | 71.9 | 51.4 | 2.2 | 70.0 | 12.0 | 77.6 | 0 |
| Fujitsu | 217.3 | 22.0 | 0.6 | 4.0 | 17.0 | 15.0 | 158.7 | 0 |
| Other Companies | 1,940.3 | 332.9 | 135.1 | 28.4 | 534.5 | 241.0 | 622.6 | 45.8 |

Source: Dataquest (June 1995)

### Philips Semiconductor

Philips has twin strengths in the transmission and wireless areas. Philips maintains a solid presence in line card, T/E carrier, and SONET/SDH technologies. One of the world's leading RF/IF houses, Philips has become a large player in both analog cellular and cordless markets, and is an emerging player in digital cellular chips.

  

# Chapter 2
# LAN IC Suppliers

The local area network (LAN) IC marketplace is fairly concentrated and has about 25 participants. The technology is complicated and requires mixed-signal designs. The market is fairly concentrated, with the top five players accounting for more than 60 percent of shipments. New entrants and product extensions are concentrating on such new technologies as 10/100-Mbps (Fast Ethernet and VG AnyLAN) controllers and transceivers.

## Market Position

Table 2-1 lists the market leading suppliers in LAN ICs. These products include standard ICs that process certain LAN standards including Ethernet, token-ring, FDDI, and other LAN protocols. Protocol (MAC), hub, and transceiver ICs are included.

**Table 2-1**
**Top 10 Vendors of LAN ICs*, Worldwide Revenue (Millions of Dollars)**

| Company | 1994 Revenue | Market Share (Percentage of Revenue) |
|---|---|---|
| Total Market | 637.4 | 100 |
| Advanced Micro Devices | 182.2 | 28.6 |
| National Semiconductor | 136.1 | 21.3 |
| Texas Instruments | 71.9 | 11.3 |
| IBM Microelectronics | 58.5 | 9.2 |
| Standard Microsystems | 37.5 | 5.9 |
| Fujitsu | 22.0 | 3.5 |
| Intel | 17.5 | 2.7 |
| Micro Linear | 17.0 | 2.7 |
| SEEQ Technology | 15.1 | 2.4 |
| Digital Semiconductor | 12.5 | 2.0 |
| Other Companies | 67.1 | 10.5 |

*Including controller, transceiver, hub ICs
Source: Dataquest (June 1995)

Advanced Micro Devices (AMD) was the market leader overall and for the Ethernet controller category (see Table 2-2). Its success is attributable to an aggressive rollout of a broad 10-base-T offering for both adapter card and motherboard use. National Semiconductor remained strong, with a broad offering now also targeted at captive adapter card offerings.

Table 2-3 notes the leading token-ring controller suppliers. Texas Instruments tops the list in this market, edging out IBM in total revenue for controllers.

  

**Table 2-2**
**Top 10 Vendors of LAN Ethernet Controller Chipset ICs, Worldwide Shipments (Thousands of Units) and Revenue (Millions of Dollars)**

| Company | 1994 Shipments | 1994 Revenue | Market Share (Percentage of Revenue) |
|---|---|---|---|
| Total Market | 20,656 | 277.6 | 100.0 |
| Advanced Micro Devices | 9,750 | 106.0 | 38.2 |
| National Semiconductor | 5,400 | 72.5 | 26.1 |
| Standard Microsystems | 2,000 | 36.0 | 13.0 |
| Fujitsu | 1,200 | 18.0 | 6.5 |
| Intel | 900 | 17.5 | 6.3 |
| Digital Semiconductor | 500 | 12.5 | 4.5 |
| Symbios Logic | 490 | 10.0 | 3.6 |
| SEEQ Technology | 230 | 2.2 | 0.8 |
| Silicon Systems | 90 | 1.2 | 0.4 |
| VLSI Technology | 31 | 0.6 | 0.2 |
| Other Companies | 65 | 1.2 | 0.4 |

Source: Dataquest (June 1995)

**Table 2-3**
**Top Three Vendors of LAN Token-Ring Controller Chipset ICs, Worldwide Shipments (Thousands of Units) and Revenue (Millions of Dollars)**

| Company | 1994 Shipments | 1994 Revenue | Market Share (Percentage of Revenue) |
|---|---|---|---|
| Total Market | 4,471 | 119.6 | 100.0 |
| Texas Instruments | 2,100 | 54.3 | 45.4 |
| IBM Microelectronics | 1,850 | 51.8 | 43.3 |
| National Semiconductor | 490 | 12.9 | 10.8 |
| Other Companies | 31 | 0.6 | 0.5 |

Source: Dataquest (June 1995)

AMD's patient presence is starting to pay off. It remained atop a fast-growing FDDI chipset market in 1994 (see Table 2-4). National Semiconductor and Motorola round out the rest of the FDDI market.

National Semiconductor was the leading vendor of LAN transceiver ICs, including those for twisted-pair, coax, and fiber interfaces (see Table 2-5). Micro Linear made a strong move into this area recently, with a broad offering covering everything from Ethernet to FDDI, and 10/100-Mbps Fast Ethernet to ATM 155 Mbps.

  

**Table 2-4**
**Top Three Vendors of LAN FDDI Controller Chipset ICs, Worldwide Shipments (Thousands of Units) and Revenue (Millions of Dollars)**

| Company | 1994 Shipments | 1994 Revenue | Market Share (Percentage of Revenue) |
|---|---|---|---|
| Total Market | 2,450 | 40.9 | 100.0 |
| Advanced Micro Devices | 1,300 | 21.0 | 51.3 |
| National Semiconductor | 700 | 10.5 | 25.7 |
| Motorola | 450 | 9.4 | 23.0 |

Source: Dataquest (June 1995)

**Table 2-5**
**Top 10 Vendors of LAN Transceiver ICs, Worldwide Shipments (Thousands of Units) and Revenue (Millions of Dollars)**

| Company | 1994 Shipments | 1994 Revenue | Market Share (Percentage of Revenue) |
|---|---|---|---|
| Total Market | 23,535 | 130.6 | 100.0 |
| National Semiconductor | 7,020 | 32.3 | 24.7 |
| Texas Instruments | 2,200 | 17.6 | 13.5 |
| Micro Linear | 2,800 | 17.0 | 13.0 |
| Advanced Micro Devices | 2,900 | 15.2 | 11.6 |
| SEEQ Technology | 2,540 | 12.7 | 9.7 |
| Level One Communications | 1,600 | 8.0 | 6.1 |
| IBM Microelectronics | 800 | 6.4 | 4.9 |
| Silicon Systems | 1,655 | 4.2 | 3.2 |
| Fujitsu | 600 | 4.0 | 3.1 |
| SGS-Thomson | 510 | 3.5 | 2.7 |
| Other Companies | 910 | 9.7 | 7.4 |

Source: Dataquest (June 1995)

## Supplier Matrix

Table 2-6 shows the supplier matrix for LAN ICs. Ethernet controllers and transceivers are the areas most broadly supplied.

  

**Table 2-6**
**Communications Semiconductor Supplier Matrix—LAN**

| | LAN (ASSP/ASICs) Suppliers | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Company | Ethernet | Token-Ring | Fast Ethernet | AnyLAN | FDDI | Fiber Channel | Hub | Other LAN |
| Advanced Micro Devices | C, T | C | | | | | X | SCSI combo, full duplex |
| Applied Micro Circuits Corporation | | | | T | T | | | |
| AT&T | C | | | C, T | | T | X | |
| Broadcom | T | | T | | | | X | |
| Crystal | C, T | | | | | | | |
| Cypress Semiconductor | | | T | | | | | |
| Digital Semiconductor | C | | C | | | | | |
| Fujitsu | C, T | | | | | | | |
| Hewlett-Packard | | | | | T | C, T | X | |
| IBM Microelectronics | | C, T | | | | | | |
| ICS | | | T | | | | | |
| Intel | C, T | | | | | | | |
| Level One Communications | T | | | | | | X | |
| LSI Logic | C | | | | | | X | |
| MicroLinear | T | | T | | T | | | |
| Mitel | | | | | C, T | | | |
| Motorola | | | | C, T | | | | |
| National Semiconductor | C, T | C, T | C, T | | C, T | | X | Super I/O combo |
| Pericom | T | T | | T | | | | |
| Philips | T | | | | | | | |
| S MOS | | | | | | | | |
| SEEQ Technology | C | | C | | | | X | |
| Silicon Systems | C, T | | | | | | | |
| Standard Micro | C, T | | C | | | | | Arcnet |
| Symbios Logic | C, T | | | | | | | ARCNET |

(Continued)

**Table 2-6 (Continued)**
**Communications Semiconductor Supplier Matrix—LAN**

| | LAN (ASSP/ASICs) Suppliers | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Company | Ethernet | Token-Ring | Fast Ethernet | AnyLAN | FDDI | Fiber Channel | Hub | Other LAN |
| Texas Instruments | | C, T | C | C | | | | Combo EN/TR |
| United Microelectronics | C | | | | | | | |
| Vitesse | | | | | | C | | |
| Winbond | C | | | | | | | |

Notes:
C = Controller
T = Transceiver
X = Hub repeater/controller
Source: Dataquest (June 1995)

# Chapter 3
# Modem IC Suppliers

The modem IC market has been dominated by Rockwell for almost a decade now. This a difficult business to obtain profits in because price competition on common standards and features remains fierce. New suppliers have been few and far between, starting with the V.32bis generation of products. So far those targeting the V.34 market generally are the same cast of characters.

## Market Position

Rockwell remains the leader in the modem IC marketplace, capturing nearly 60 percent of total market revenue (see Tables 3-1 through 3-4). It continues to reinvest and reinvent cost-competitive integrated chipsets with each new standards cycle, as shown by its position in the V.32bis (14.4 Kbps) and the newly ratified V.34 (28.8 Kbps) markets. Its recent investment in an 8-inch fab and with Chartered Semiconductor is helping provide extra capacity to boost its shipments.

**Table 3-1**
**Top 10 Vendors of Modem ICs*, Worldwide Revenue (Millions of Dollars)**

| Company | 1994 Revenue | Market Share (Percentage of Revenue) |
|---|---|---|
| Total Market | 780.4 | 100.0 |
| Rockwell | 494.0 | 63.3 |
| Texas Instruments | 51.4 | 6.6 |
| Sierra Semiconductor | 41.5 | 5.3 |
| Cirrus Logic | 40.0 | 5.1 |
| AT&T | 35.0 | 4.5 |
| SGS-Thomson | 30.0 | 3.8 |
| NEC | 20.0 | 2.6 |
| Silicon Systems | 14.2 | 1.8 |
| Toshiba | 12.0 | 1.5 |
| Analog Devices | 8.9 | 1.1 |
| Other Companies | 33.4 | 4.3 |

*Including chipsets, standalone functions, DSPs for modem use; includes fax-only modem ICs
Source: Dataquest (June 1995)

**Table 3-2**
**Top 10 Vendors of Modem Chipset ICs*, Worldwide Shipments (Thousands of Units) and Revenue (Millions of Dollars)**

| Company | 1994 Shipments | 1994 Revenue | Market Share (Percentage of Revenue) |
|---|---|---|---|
| Total Market | 31,406 | 674.9 | 100.0 |
| Rockwell | 17,250 | 452.0 | 67.0 |
| Texas Instruments | 1,620 | 41.4 | 6.1 |
| Cirrus Logic | 1,700 | 40.0 | 5.9 |
| Sierra Semiconductor | 2,560 | 36.5 | 5.4 |
| AT&T | 1,320 | 33.0 | 4.9 |
| SGS-Thomson | 1,995 | 30.0 | 4.4 |
| Silicon Systems | 1,974 | 12.9 | 1.9 |
| Analog Devices | 210 | 7.7 | 1.1 |
| Exar | 500 | 5.0 | 0.7 |
| Yamaha | 355 | 3.8 | 0.6 |
| Other Companies | 1,922 | 12.6 | 1.9 |

*Including controller, data pump, analog front-end, and various integrated versions; includes fax only
Source: Dataquest (June 1995)

**Table 3-3**
**Top Three Vendors of V.34 Modem Chipset ICs*, Worldwide Shipments (Thousands of Units) and Revenue (Millions of Dollars)**

| Company | 1994 Shipments | 1994 Revenue | Market Share (Percentage of Revenue) |
|---|---|---|---|
| Total Market | 1,410 | 92.8 | 100.0 |
| Rockwell | 1,200 | 78.0 | 84.1 |
| AT&T | 120 | 8.0 | 8.6 |
| Texas Instruments | 45 | 3.8 | 4.1 |
| Other Companies | 45 | 3.0 | 3.2 |

*Including controller, data pump, and analog front-end, and various integrated versions
Source: Dataquest (June 1995)

TI is ranked second; it maintains a broad position in modem DSP and analog front-end technology. Sierra and AT&T are leveraging their DSP business very effectively to capture OEMs interested in flexibility. Cirrus Logic has risen dramatically to become the No. 4 player. It was one of the first to add answering machine capability into a standard offering.

New areas for adding value for many of these companies include voice over data (or digital simultaneous voice and data, DSVD), speaker phone, answering machine, and caller ID.

  

**Table 3-4**
**Top Six Vendors of V.32bis Modem Chipset ICs*, Worldwide Shipments (Thousands of Units) and Revenue (Millions of Dollars)**

| Company | 1994 Shipments | 1994 Revenue | Market Share (Percentage of Revenue) |
|---|---|---|---|
| Total Market | 10,891 | 359.6 | 100.0 |
| Rockwell | 7,000 | 245.0 | 68.1 |
| Texas Instruments | 1,050 | 30.0 | 8.4 |
| Cirrus Logic | 1,200 | 30.0 | 8.3 |
| Sierra Semiconductor | 660 | 25.0 | 7.0 |
| AT&T | 600 | 17.0 | 4.7 |
| Analog Devices | 200 | 7.0 | 1.9 |
| Other Companies | 181 | 5.6 | 1.6 |

*Including controller, data pump, and analog front-end, and various integrated versions
Source: Dataquest (June 1995)

## Supplier Matrix

Table 3-5 lists suppliers in various markets. Intense price competition in recent years has limited the number of entrants into the new standards.

  

**Table 3-5**
**Communications Semiconductor Supplier Matrix—Modems**

| | Modem (ASSP, ASICs, pDSPs) Suppliers | | | | | | |
|---|---|---|---|---|---|---|---|
| Company | V.34 | V.32terbo | V.32bis | V.32 | V.22bis | Fax Only | Other |
| Advanced Micro Devices | | | | | | | Previous standards |
| Analog Devices | X | | X | X | X | | AFE, DSP |
| AT&T | X | X | X | | | | |
| Cirrus Logic | | | X | X | | | |
| Exar | | | | | | | AFE |
| Fujitsu | | | | | | | AFE, previous standards |
| GEC Plessey | | | | | | | AFE |
| Mitel | | | X | | | | |
| Motorola | | | | | | | Previous standards |
| National Semiconductor | | | | | | | AFE, previous standards |
| NEC | | | | | | X | |
| OKI | | | | | | | Previous standards |
| Philips | | | | | | | AFE |
| Rockwell | X | | X | X | X | X | Previous standards |
| S MOS | | | | | | | Previous standards |
| Sanyo | | | | | | X | |
| SGS-Thomson | | | | X | X | | AFE |
| Sierra Semiconductor | | | X | X | X | X | Previous standards |
| Silicon Systems | | | | | X | | Previous standards |
| Texas Instruments | X | | X | X | X | | AFE, DSP |
| Toshiba | | | | | | | AFE |
| Yamaha | | | | | X | X | |

Source: Dataquest (June 1995)

## Chapter 4
# Transmission IC Suppliers

The transmission IC category covers those companies involved in marketing specialized silicon oriented for wide area networking (WAN), line cards for public and premise use, and SONET/SDH synchronous broadband transmission. Table 4-1 shows overall market rankings. SGS-Thomson, Siemens, and AT&T top the list. This area continues to be an ongoing strength for European suppliers as they help enable strong European telecommunications equipment houses such as Alcatel, Ericsson, and Siemens.

**Table 4-1**
**Top 10 Vendors of WAN, Line Card, SONET/SDH ICs, Worldwide Revenue (Millions of Dollars)**

| Company | 1994 Revenue | Market Share (Percentage of Revenue) |
|---|---|---|
| Total Market | 1,477.0 | 100.0 |
| SGS-Thomson | 232.0 | 15.7 |
| Siemens | 197.0 | 13.3 |
| AT&T | 167.0 | 11.3 |
| Advanced Micro Devices | 102.0 | 6.9 |
| NEC | 86.0 | 5.8 |
| Alcatel Mietec | 70.0 | 4.7 |
| Texas Instruments | 70.0 | 4.7 |
| Ericsson | 62.0 | 4.2 |
| Harris | 50.0 | 3.4 |
| Motorola | 49.5 | 3.4 |
| Other Companies | 391.5 | 26.5 |

Source: Dataquest (June 1995)

## Line Card IC Suppliers

Table 4-2 presents the leading suppliers of line card ICs. Line cards are used to terminate the local loop line from the central office or internal lines from the PBX or key system. This category includes both analog and digital components and includes such items as SLICs, SLACs, filter, codecs, and various combinations of the aforementioned. ISDN ICs are measured separately. SGS-Thomson, AMD, and AT&T account for about 40 percent of the worldwide market. This is a traditional focus area for merchant players such as SGS-Thomson, AMD, and Harris. AT&T, Siemens, and NEC are driven for the most part by captive supply relationships.

## T/E Carrier IC Suppliers

Table 4-3 presents the leading suppliers of T/E carrier ICs, which are used to transmit information digitally over a wide area, generally point-to-point. These ICs are used in variety of multiplexing, PBX, DSU/CSU, and cross-connect systems that handle or terminate T/E carrier data streams.

**Table 4-2**
**Top 10 Vendors of Line Card ICs*, Worldwide Revenue (Millions of Dollars)**

| Company | 1994 Revenue | Market Share (Percentage of Revenue) |
|---|---|---|
| Total Market | 749.0 | 100.0 |
| SGS-Thomson | 125.0 | 16.7 |
| Advanced Micro Devices | 95.0 | 12.7 |
| AT&T | 90.0 | 12.0 |
| NEC | 72.0 | 9.6 |
| Siemens | 70.0 | 9.3 |
| Texas Instruments | 54.0 | 7.2 |
| Harris | 45.0 | 6.0 |
| Motorola | 40.0 | 5.3 |
| Ericsson | 25.0 | 3.3 |
| GEC Plessey | 25.0 | 3.3 |
| Other Companies | 108.0 | 14.4 |

*SLICs, SLACs, filters, among others
Source: Dataquest (June 1995)

This category includes transceiver, other physical, and higher-layer ICs ranging from T1/E1 (1.5/2 Mbps) through T3/E3 and above (≥45 Mbps). SGS-Thomson and Siemens have been successful in this area, leveraging off their strength in ISDN primary rate technology. Level One has grown briskly by specializing in T/E carrier transceivers.

**Table 4-3**
**Top 10 Vendors of T/E Carrier ICs, Worldwide Revenue (Millions of Dollars)**

| Company | 1994 Revenue | Market Share (Percentage of Revenue) |
|---|---|---|
| Total Market | 280.1 | 100.0 |
| SGS-Thomson | 40.0 | 14.3 |
| Siemens | 35.0 | 12.5 |
| Level One Communications | 35.0 | 12.5 |
| AT&T | 28.0 | 10.0 |
| Mitel | 25.0 | 8.9 |
| Brooktree | 21.0 | 7.5 |
| Alcatel Mietec | 15.0 | 5.4 |
| Ericsson | 10.0 | 3.6 |
| Philips | 10.0 | 3.6 |
| Austria Mikro Systeme | 10.0 | 3.6 |
| Other Companies | 51.1 | 18.2 |

Source: Dataquest (June 1995)

  

## SONET/SDH IC Suppliers

SONET/SDH is a synchronous technology used primarily in public telecommunications networks and cable TV distribution. Today it is used principally in various types of multiplexing systems that combine lower-speed data streams into faster synchronous data streams over fiber-optic media. Elements of this technology also are used in ATM networking as measured separately.

SONET/SDH ICs include various specialized physical layer and transceiver functions along with various higher-layer functions for network management. The leading suppliers in this market are AT&T, Siemens, and SGS-Thomson (see Table 4-4). TranSwitch is the largest noncaptive player in this market. GaAs companies such as Vitesse and Anadigics have active supplying physical layers functions such as clock recovery.

**Table 4-4**
**Top 10 Vendors of SONET/SDH ICs, Worldwide Revenue (Millions of Dollars)**

| Company | 1994 Revenue | Market Share (Percentage of Revenue) |
|---|---|---|
| Total Market | 115.7 | 100.0 |
| AT&T | 25.0 | 21.6 |
| Siemens | 12.0 | 10.4 |
| SGS-Thomson | 10.0 | 8.6 |
| Vitesse Semiconductor | 9.0 | 7.8 |
| TranSwitch | 7.5 | 6.5 |
| Anadigics | 6.0 | 5.2 |
| Ericsson | 5.0 | 4.3 |
| Alcatel Mietec | 5.0 | 4.3 |
| NEC | 5.0 | 4.3 |
| Texas Instruments | 5.0 | 4.3 |
| Other Companies | 26.2 | 22.7 |

Source: Dataquest (June 1995)

## ISDN IC Suppliers

Table 4-5 lists the leading suppliers of ISDN functions. ISDN ICs are used in both basic rate (128-Kbps) and primary rate (1.5/2-Mbps) applications, including digital modems/terminal adapters, videoconferencing systems, fax machines, line cards, and telephone terminals. This area includes transceivers and higher-layer protocol processing. European suppliers Siemens, SGS-Thomson, and Alcatel Mietec have about 70 percent of the specialized ISDN chip market, because of the stronger early acceptance of ISDN services in Europe.

**Table 4-5**
**Top Eight Vendors of ISDN ICs, Worldwide Revenue (Millions of Dollars)**

| Company | 1994 Revenue | Market Share (Percentage of Revenue) |
|---|---|---|
| Total Market | 113.7 | 100.0 |
| Siemens | 40.0 | 35.2 |
| SGS-Thomson | 25.0 | 22.0 |
| Alcatel Mietec | 15.0 | 13.2 |
| Advanced Micro Devices | 7.0 | 6.2 |
| NEC | 5.0 | 4.4 |
| Mitel | 5.0 | 4.4 |
| Motorola | 3.5 | 3.1 |
| Fujitsu | 3.0 | 2.6 |
| Other Companies | 10.2 | 9.0 |

Source: Dataquest (June 1995)

## Supplier Matrix

Table 4-6 lists suppliers of WAN, line card, and SONET/SDH suppliers.

**Table 4-6**
**Communications Semiconductor Supplier Matrix—WAN, Line Card, SONET/SDH**

| Company | SLIC, SLAC, Filter, CODEC | T/E Carrier | ISDN | SONET/ SDH | Switch | Other |
|---|---|---|---|---|---|---|
| Advanced Micro Devices | X | | X | | | |
| Alcatel Mietec | X | X | X | X | X | |
| Anadigics | | | | X | | |
| Analog Devices | X | | | X | | ADSL |
| Applied Micro Circuits Corporation | | | | X | | |
| Aptek | X | | | | | |
| AT&T | X | X | | X | X | |
| Broadband | | | | | | QAM |
| Brooktree | | X | | | | HDSL |
| Dallas Semiconductor | | X | | | X | |
| Ericsson | X | X | X | X | X | |
| Fujitsu | | | X | | X | |
| GEC Plessey | X | | | | X | |
| Gould AMI | X | | X | | | |
| Harris | X | | | | X | |
| Integrated Telecom | | X | | X | | |
| Intel | X | | | | | |
| Level One Communications | | X | X | | | SW 56 |
| LSI Logic | | X | | | | |

(Continued)

  

**Table 4-6 (Continued)**
**Communications Semiconductor Supplier Matrix—WAN, Line Card, SONET/SDH**

| Company | SLIC, SLAC, Filter, CODEC | T/E Carrier | ISDN | SONET/ SDH | Switch | Other |
|---|---|---|---|---|---|---|
| Maxim | | | | | X | |
| Mitel | X | X | X | | X | |
| Mitsubishi | | | | | X | |
| Motorola | X | X | X | | X | ADSL |
| National Semiconductor | X | X | X | | | |
| NEC | X | | X | | X | |
| OKI | X | | | | | |
| Parigain | | | | | | HDSL |
| PMC-Sierra | | X | | X | | |
| Raytheon | | | | | X | |
| Samsung | X | | | | X | |
| SGS-Thomson | X | | X | | X | |
| Siemens | X | X | X | | | |
| Sierra Semiconductor | | | | | X | |
| Silicon Systems | X | X | | | X | |
| TEMIC | X | X | X | | | |
| Texas Instruments | X | | | | | |
| TranSwitch | | X | | X | | |
| TriQuint Semiconductor | | | | X | | |
| Vitesse | | | | X | | |
| VLSI Technology | | X | | | | |

Source: Dataquest (June 1995)

# Chapter 5
# ATM IC Suppliers

So far semiconductor shipments to the asynchronous transfer mode (ATM) market have been little better than sample quantities. As the standards firm and deployment begins in earnest over the next few years ATM will become a very lucrative market. ATM systems include various LAN, WAN, and carrier switches, LAN backbone ports, and adapter cards.

## Market Position

Although the ATM IC market is small, initial strong presence could position a supplier well as the market begins its expansion. ATM-specific ICs include transceivers (copper and fiber), clock recovery, cell segmentation and reassembly (SAR), ATM adaptation layers (AALs), and other specialized switches and memories.

There are dozens of suppliers. However, Sierra Semiconductor subsidiary PMC-Sierra was the largest supplier to the ATM market with its SUNI physical layer chips (see Table 5-1).

**Table 5-1**
**Top 10 Vendors of ATM ICs, Worldwide Revenue (Millions of Dollars)**

| Company | 1994 Revenue | Market Share (Percentage of Revenue) |
|---|---|---|
| Total Market | 40.1 | 100.0 |
| PMC-Sierra | 9.5 | 23.7 |
| LSI Logic | 5.0 | 12.5 |
| Fujitsu | 4.0 | 10.0 |
| TranSwitch | 4.0 | 10.0 |
| VLSI Technology | 3.9 | 9.7 |
| Texas Instruments | 2.2 | 5.5 |
| SGS-Thomson | 2.0 | 5.0 |
| Siemens | 2.0 | 5.0 |
| Integrated Telecom | 1.5 | 3.7 |
| National Semiconductor | 1.5 | 3.7 |
| Other Companies | 4.5 | 11.3 |

Source: Dataquest (June 1995)

## Supplier Matrix

Table 5-2 lists ATM IC suppliers.

**Table 5-2**
**Communications Semiconductor Supplier Matrix—ATM**

| Company | SAR/AAL | Switch | Physical Transceiver |
|---|---|---|---|
| Analog Devices | | | X |
| Applied Micro Circuits Corporation | X | X | X |
| AT&T | X | X | X |
| Brooktree | X | X | X |
| Cypress Semiconductor | | | X |
| Fujitsu | X | X | X |
| Hewlett-Packard | | | X |
| Hitachi | | X | |
| IBM Microelectronics | X | X | X |
| IDT | X | | |
| Integrated Telecom | X | | X |
| LSI Logic | X | | X |
| Micro Linear | | | X |
| Mitel | | | X |
| Motorola | X | X | |
| National Semiconductor | X | | X |
| NEC | | X | |
| PMC-Sierra | X | | X |
| Raytheon | | X | X |
| Scorpio Communications | | X | |
| Sumitomo | | | X |
| Texas Instruments | X | X | X |
| TranSwitch | X | | X |
| TriQuint Semiconductor | | | X |
| Vitesse Semiconductor | | X | X |
| VLSI Technology | X | | X |
| SGS-Thomson | X | X | X |
| Siemens | X | X | X |

Source: Dataquest (June 1995)

  

# Chapter 6
# Telephone IC Suppliers

There is no lack of suppliers of telephone ICs—more than 100 million terminals are produced each year in every part of the globe. The barrier to entry for basic telephone functions is fairly low, except that volume efficiencies are required to be a large supplier. New areas of value-added include single-chip "telephones," tapeless answering machine functions, and feature/smart phone functions.

## Market Position

Telephone ICs include dialers, DTMF generators, codecs, speech circuits, speaker phone functions, and various combinations of all these. ISDN ICs are tracked separately. The largest suppliers of telephone ICs are noted in Table 6-1. SGS-Thomson and AT&T top the list in a fairly fragmented market.

**Table 6-1**
**Top 10 Vendors of Telephones and Answering Machines ICs, Worldwide Shipments (Thousands of Units) and Revenue (Millions of Dollars)**

| Company | 1994 Shipments | 1994 Revenue | Market Share (Percentage of Revenue) |
|---|---|---|---|
| Total Market | 232,736 | 567.0 | 100.0 |
| SGS-Thomson | 41,525 | 89.0 | 15.7 |
| AT&T | 36,000 | 85.0 | 15.0 |
| Siemens | 16,100 | 40.0 | 7.1 |
| Matsushita | 14,000 | 35.0 | 6.2 |
| Philips | 12,950 | 30.0 | 5.3 |
| Motorola | 10,000 | 30.0 | 5.3 |
| NEC | 10,600 | 25.0 | 4.4 |
| Mitel | 10,000 | 25.0 | 4.4 |
| Sanyo | 8,000 | 20.0 | 3.5 |
| DSP Semiconductor | 2,250 | 18.0 | 3.2 |
| Other Companies | 71,311 | 170.0 | 30.0 |

Source: Dataquest (June 1995)

## Supplier Matrix

Table 6-2 lists telephone ICs suppliers.

**Table 6-2**
**Communications Semiconductor Supplier Matrix—Telephone**

| | Telephone IC Suppliers | |
|---|---|---|
| Company | Voice and Signaling | Answering Machine |
| Aptek | X | |
| AT&T | X | X |
| California Micro Devices | X | |
| Cherry Semiconductor | X | |
| Dallas Semiconductor | | X |
| DSP Semiconductor | | X |
| Exar | X | |
| Fujitsu | X | |
| GEC Plessey | X | |
| Goldstar | X | |
| Harris | X | |
| Hualon Microelectronics | X | |
| Matsushita/Panasonic | X | X |
| Mitel | X | |
| Motorola | X | |
| National Semiconductor | X | |
| NEC | | X |
| OKI | X | |
| Philips | X | |
| S MOS | X | |
| Samsung | X | |
| Sanyo | X | |
| Seiko Epson | X | |
| SGS-Thomson | X | |
| Siemens | X | |
| Sierra Semiconductor | X | |
| Silicon Systems | X | |
| Sony | X | X |
| Teltone | X | |
| Texas Instruments | X | |
| Zilog | | X |

Source: Dataquest (June 1995)

  

## Chapter 7
# Wireless Communications IC Suppliers

Supplying the strong internal demand from its mobile communications systems groups, Motorola holds a commanding market share in the wireless communications semiconductor markets, including both the RF/IF and baseband categories (see Table 7-1). A new generation of digital technologies is opening the door for a reshuffling of market share in the cordless and cellular baseband semiconductor markets. Vendors with strong DSP and ASIC/ASSP products have been very aggressive in capturing significant business opportunities in the early stages of these markets. As growth continues to accelerate in the digital product segments, the competition among chip suppliers will heat up as they attempt to capture business with both tier-one handset manufacturers and tier-two players that will be seeking effective, low-cost solutions in this high-growth market. Suppliers of RF/IF products also will be challenged to hold their market share as new wireless products are developed for higher ranges in the frequency spectrum such as the 2-GHz "personal communications" markets. As part of the competition, the debate over the relative merits of silicon versus gallium arsenide solutions will be advanced by companies with technology strengths in each area.

**Table 7-1**
**Top 10 Vendors of Wireless ICs*, Worldwide Revenue (Millions of Dollars)**

| Company | 1994 Revenue | Market Share (Percentage of Revenue) |
|---|---|---|
| Total Market | 2,089.1 | 100.0 |
| Motorola | 624.9 | 29.9 |
| Philips | 253.3 | 12.1 |
| NEC | 211.8 | 10.1 |
| Fujitsu | 158.7 | 7.6 |
| Hitachi | 116.2 | 5.6 |
| GEC Plessey | 94.1 | 4.5 |
| Texas Instruments | 77.6 | 3.7 |
| Mitsubishi | 71.2 | 3.4 |
| VLSI Technology | 60.1 | 2.9 |
| Siemens | 57.5 | 2.8 |
| Other Companies | 363.7 | 17.4 |

*Analog cordless, digital cordless, analog cellular, digital cellular/PCS, wireless LAN, wireless modem; also pager—RF/IF only
Source: Dataquest (June 1995)

## Market Position

Table 7-2 lists the market shares for suppliers of RF/IF chips in the analog cordless, digital cordless, analog cellular, digital cellular/PCS, wireless LAN, wireless modem, and pager markets. As stated, Motorola has been able to capitalize on the leading position of its systems products in almost every wireless market segment to fuel a strong semiconductor demand in the RF/IF area. This same factor is shown in the market share for baseband products (see Table 7-3). Table 7-3 summarizes revenue for baseband products in the same application segments as Table 7-2, with the exception of pagers.

### Table 7-2
### Top 10 Vendors of Wireless RF/IF ICs*, Worldwide Revenue (Millions of Dollars)

| Company | 1994 Revenue | Market Share (Percentage of Revenue) |
|---|---|---|
| Total Market | 1,085.5 | 100.0 |
| Motorola | 353.0 | 32.5 |
| Philips | 155.4 | 14.3 |
| Fujitsu | 137.7 | 12.7 |
| NEC | 84.3 | 7.8 |
| GEC Plessey | 80.4 | 7.4 |
| Matsushita | 50.5 | 4.7 |
| Mitsubishi | 49.1 | 4.5 |
| Siemens | 40.4 | 3.7 |
| Hitachi | 34.0 | 3.1 |
| Sony | 21.8 | 2.0 |
| Other Companies | 78.9 | 7.3 |

*Analog cordless, digital cordless, analog cellular, digital cellular/PCS, wireless LAN, wireless modem; also pager—RF/IF only
Source: Dataquest (June 1995)

### Table 7-3
### Top 10 Vendors of Wireless Baseband ICs*, Worldwide Revenue (Millions of Dollars)

| Company | 1994 Revenue | Market Share (Percentage of Revenue) |
|---|---|---|
| Total Market | 1,003.6 | 100.0 |
| Motorola | 271.9 | 27.1 |
| NEC | 127.5 | 12.7 |
| Philips | 97.9 | 9.8 |
| Hitachi | 82.2 | 8.2 |
| Texas Instruments | 71.8 | 7.2 |
| VLSI Technology | 60.1 | 6.0 |
| AT&T | 40.6 | 4.0 |
| SGS-Thomson | 31.4 | 3.1 |
| Austria Mikro Systeme | 27.7 | 2.8 |
| Toshiba | 25.2 | 2.5 |
| Other Companies | 167.3 | 16.7 |

*Analog cordless, digital cordless, analog cellular, digital cellular/PCS, wireless LAN, wireless modem
Source: Dataquest (June 1995)

  

Table 7-4 shows the major role of Japanese companies in the analog cordless telephone market; they represent two-thirds of the revenue from baseband chips. A comparison of Tables 7-5 and 7-6 illustrates the changing order shaping up in the cellular communications world of baseband semiconductors as digital technologies push toward center stage. Table 7-7 shows the dominant role of the GSM market in driving market shares for digital cellular baseband products. It is quickly noted that the nine leading suppliers of GSM baseband products also occupy the top nine positions in the overall digital cellular markets in about the same order.

### Table 7-4
### Top 10 Vendors of Analog Cordless ICs, Worldwide Revenue (Millions of Dollars)

| Company | 1994 Revenue | Market Share (Percentage of Revenue) |
|---|---|---|
| Total Market | 172.0 | 100.0 |
| NEC | 37.4 | 21.7 |
| Philips | 25.0 | 14.5 |
| Hitachi | 23.8 | 13.8 |
| Motorola | 21.0 | 12.2 |
| Toshiba | 19.3 | 11.2 |
| Fujitsu | 15.4 | 9.0 |
| Mitsubishi | 8.5 | 4.9 |
| GEC Plessey | 8.0 | 4.7 |
| Matsushita | 4.3 | 2.5 |
| OKI | 4.1 | 2.4 |
| Other Companies | 5.2 | 3.0 |

Source: Dataquest (June 1995)

### Table 7-5
### Top 10 Vendors of Analog Cellular Baseband ICs, Worldwide Revenue (Millions of Dollars)

| Company | 1994 Revenue | Market Share (Percentage of Revenue) |
|---|---|---|
| Total Market | 469.1 | 100.0 |
| Motorola | 149.0 | 31.8 |
| Philips | 68.0 | 14.5 |
| Hitachi | 56.4 | 12.0 |
| NEC | 40.0 | 8.5 |
| VLSI Technology | 26.0 | 5.5 |
| SGS-Thomson | 25.0 | 5.3 |
| Austria Mikro Systeme | 22 | 4.7 |
| Texas Instruments | 21.0 | 4.5 |
| TEMIC | 15.0 | 3.2 |
| Mitsubishi | 13.6 | 2.9 |
| Other Companies | 33.1 | 7.1 |

Source: Dataquest (June 1995)

  

**Table 7-6**
**Top 10 Vendors of Digital Cellular Baseband ICs, Worldwide Revenue (Millions of Dollars)**

| Company | 1994 Revenue | Market Share (Percentage of Revenue) |
|---|---|---|
| Total Market | 321.5 | 100.0 |
| Motorola | 80.4 | 25.0 |
| Texas Instruments | 49.8 | 15.5 |
| NEC | 47.1 | 14.7 |
| AT&T | 40.6 | 12.6 |
| VLSI Technology | 29.1 | 9.1 |
| Siemens | 17.1 | 5.3 |
| Analog Devices | 17.1 | 5.3 |
| TEMIC | 7.5 | 2.3 |
| SGS-Thomson | 6.4 | 2.0 |
| Cirrus Logic | 6.0 | 1.9 |
| Other Companies | 20.4 | 6.3 |

Source: Dataquest (June 1995)

**Table 7-7**
**Top 10 Vendors of Digital Cellular Baseband ICs for GSM, Worldwide Revenue (Millions of Dollars)**

| Company | 1994 Revenue | Market Share (Percentage of Revenue) |
|---|---|---|
| Total Market | 235.5 | 100.0 |
| Motorola | 65.4 | 27.8 |
| NEC | 33.2 | 14.1 |
| Texas Instruments | 33.2 | 14.1 |
| AT&T | 27.9 | 11.8 |
| VLSI Technology | 23.0 | 9.8 |
| Siemens | 17.1 | 7.3 |
| Analog Devices | 12.5 | 5.3 |
| TEMIC | 7.5 | 3.2 |
| SGS-Thomson | 6.4 | 2.7 |
| Philips | 2.8 | 1.2 |
| Other Companies | 6.5 | 2.8 |

Source: Dataquest (June 1995)

## Supplier Matrix

Table 7-8 lists suppliers in the different wireless communications market segments.

  

**Table 7-8**
**Communications Semiconductor Supplier Matrix—Wireless**

| Company | RF/IF | Analog Cordless Baseband | Analog Cellular Baseband | Digital Cordless Baseband | Digital Cellular Baseband | GSM Baseband |
|---|---|---|---|---|---|---|
| Advanced Micro Devices | | | | X | | |
| Alcatel Mietec | | | | | X | X |
| Anadigics | X | | | | | |
| Analog Devices | | | | | X | X |
| AT&T | X | | | | X | X |
| Austrian Mikro Systems | | X | X | | X | X |
| Cherry Semiconductor | | | X | | | |
| Cirrus Logic (PCSI) | | | | | X | |
| Exar | X | | | | | |
| Fujitsu | X | X | X | | | |
| GEC Plessey | X | X | | | X | X |
| Harris Semiconductor | X | | | | X | |
| Hewlett-Packard | X | | | | | |
| Hitachi | X | X | X | | X | |
| IMI | X | | X | | X | |
| M/A Comm | X | | | | | |
| Matsushita/Panasonic | X | X | X | | | |
| Mitel | | | X | | | |
| Mitsubishi | X | X | X | | | |
| Motorola | X | X | X | X | X | X |
| National Semiconductor | X | | | X | | |
| NEC | X | X | X | X | X | X |
| NJRC | X | | | | | |
| OKI | X | X | X | | | |
| Philips | X | X | X | | X | X |
| Qualcomm | | | | | X | |
| SGS-Thomson | | | X | | X | X |
| Sharp | | X | | | | |
| Siemens | X | | | | X | X |
| Silicon Systems | X | | X | | | |
| Sony | X | | | | | |
| TEMIC | | | X | | X | X |
| Texas Instruments | X | | X | X | X | X |
| Toshiba | X | X | X | | | |
| TriQuint | X | | | | | |
| VLSI Technology | | | X | X | X | X |

Source: Dataquest (June 1995)

  

# Chapter 8
# Communications ASIC Suppliers

## Market Position

ASICs are very popular with communications systems designers. Time-to-market and differentiation are very important to this market, and the customization offered by ASICs fits perfectly. Many ASIC vendors are investing in macrocell libraries that implement large building blocks of protocol, switching, and management functionality.

Table 8-1 shows the largest suppliers of ASICs for use in communications applications. This is a very fragmented market, but the largest four companies—AT&T, NEC, Fujitsu, and Motorola—are all heavily supplying captive needs. The largest merchant vendor of ASICs is LSI Logic, whose investments in communications-rich macro libraries like in LAN hubs and ATM functions are paying off.

**Table 8-1**
**Top 10 Vendors of ASICs for Communications Applications, Worldwide Revenue (Millions of Dollars)**

| Company | 1994 Revenue | Market Share (Percentage of Revenue) |
|---|---|---|
| Total Market | 3,639.3 | 100.0 |
| AT&T | 564.0 | 15.5 |
| NEC | 384.1 | 10.6 |
| Fujitsu | 275.9 | 7.6 |
| Motorola | 270.0 | 7.4 |
| LSI Logic | 207.0 | 5.7 |
| Toshiba | 157.1 | 4.3 |
| GEC Plessey | 133.0 | 3.7 |
| Hitachi | 115.5 | 3.2 |
| VLSI Technology | 112.4 | 3.1 |
| Texas Instruments | 111.7 | 3.1 |
| Other Companies | 1,308.6 | 36.0 |

Source: Dataquest (June 1995)

**For More Information...**
Greg Sheppard, Director/Principal Analyst .......................... (408) 437-8261
Internet address ..................................................gsheppard@dataquest.com
Via fax ............................................................................... (408) 437-0292



Dataquest
a company of The Dun & Bradstreet Corporation

# Dataquest

a company of
The Dun & Bradstreet Corporation

Corporate Headquarters
Dataquest Incorporated
1290 Ridder Park Drive
San Jose, California 95131-2398
United States
Phone: 1-408-437-8000
Facsimile: 1-408-437-0292

Dataquest Incorporated
Nine Technology Drive
P.O. Box 5093
Westborough, Massachusetts 01581-5093
United States
Phone: 1-508-871-5555
Facsimile: 1-508-871-6180

Dataquest Global Events
3990 Westerly Place, Suite 100
Newport Beach, California 92660
United States
Phone: 1-714-476-9117
Facsimile: 1-714-476-9969

European Headquarters
Dataquest Europe Limited
Holmers Farm Way
High Wycombe, Buckinghamshire
HP12 4XH
United Kingdom
Phone: 44-1494-422722
Facsimile: 44-1494-422742

Dataquest GmbH
Kronstadter Strasse 9
81677 München
Germany
Phone: 49-89-930-9090
Facsimile: 49-89-930-3277

Dataquest Europe SA
Immeuble Défense Bergères
345, avenue Georges Clémenceau
TSA 40002
92882 - Nanterre CTC Cedex 9
France
Phone: 33-1-41-35-13-00
Facsimile: 33-1-41-35-13-13

Japan Headquarters
Dataquest Japan K.K.
Shinkawa Sanko Building, 6th Floor
1-3-17, Shinkawa, Chuo-ku
Tokyo 104
Japan
Phone: 81-3-5566-0411
Facsimile: 81-3-5566-0425

Asia/Pacific Headquarters
7/F China Underwriters Centre
88 Gloucester Road
Wan Chai
Hong Kong
Phone: 852-2824-6168
Facsimile: 852-2824-6138

Dataquest Korea
Suite 2407, Trade Tower
159 Samsung-dong, Kangnam-gu
Seoul 135-729
Korea
Phone: 822-551-1331
Facsimile: 822-551-1330

Dataquest Taiwan
11F-2, No. 188, Section 5
Nan King East Road
Taipei, 105
Taiwan, R.O.C.
Phone: 8862-756-0389
Facsimile: 8862-756-2663

Other research offices in Beijing, Singapore, and Thailand

Sales agents in Australia, Belgium, Germany (Kronberg), Israel, Italy, South Africa, and Spain

Dataquest

a company of
The Dun & Bradstreet Corporation

251 River Oaks Parkway, San Jose, CA 95134-1913
(408) 468-8000 Fax (408) 954-1780

November 2, 1995

Dear Client,

Due to a delay in the publication of the market trends book titled "Communications Application Markets- Telephones and Mobile Communications" I have decided to fax you the key statistics and forecasts that will be published in this book. This document has been completed and submitted to our document production group. However, understanding the importance of this information, I have decided to send you this information immediately. The following pages contain the major tables with data for: corded telephones, cordless telephones, cellular and PCS handsets, one- and two-way pagers, answering machines, and satellite communications. While I apologize for the delay in publication of this document, I hope that the information in this fax will be helpful in meeting your research needs. The complete document should be shipped to you before the end of November. I would also note that the remaining publications for your service are on schedule and should be shipped to you by the original planned date.

I look forward to working with you as we continue our research in the area of semiconductors and communications. Thank you.

Sincerely,

Dale Ford
Senior Industry Analyst
Semiconductor Application Markets

# COMMUNICATIONS APPLICATION MARKETS
# TELEPHONES AND MOBILE COMMUNICATIONS

**Worldwide Terminal Device Production (Thousands of Units)**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR 1994-99 |
|---|---|---|---|---|---|---|---|---|
| Corded Telephones | 94,762 | 97,257 | 100,174 | 103,180 | 106,275 | 109,463 | 112,747 | 3.0% |
| Cordless Telephones | 35,405 | 35,685 | 39,134 | 42,668 | 45,764 | 49,173 | 52,744 | 8.1% |
| Cellular/Broadband PCS Telephones | 17,848 | 30,534 | 40,779 | 52,382 | 64,818 | 85,900 | 105,939 | 28.2% |
| Pagers (One- and Two-Way) | 20,672 | 30,919 | 39,336 | 44,564 | 48,989 | 51,287 | 52,768 | 11.3% |
| Answering Machines | 23,470 | 26,273 | 28,194 | 30,099 | 31,901 | 33,655 | 35,431 | 6.2% |
| TOTAL | 192,156 | 220,668 | 247,618 | 272,893 | 297,748 | 329,479 | 359,629 | 10.3% |

Source: Dataquest (November 1995)

**North American Terminal Device Production (Thousands of Units)**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR 1994-99 |
|---|---|---|---|---|---|---|---|---|
| Corded Telephones | 5,264 | 5,584 | 5,980 | 6,180 | 6,297 | 6,333 | 6,460 | 3.0% |
| Cordless Telephones | 1,080 | 1,134 | 1,215 | 1,516 | 1,596 | 1,652 | 1,735 | 8.9% |
| Cellular/Broadband PCS Telephones | 8,515 | 12,697 | 16,636 | 21,433 | 25,180 | 33,906 | 38,402 | 24.8% |
| Pagers (One- and Two-Way) | 7,517 | 11,723 | 13,405 | 14,415 | 14,418 | 15,657 | 15,712 | 6.0% |
| Answering Machines | 2,608 | 2,803 | 2,887 | 3,078 | 3,099 | 3,145 | 3,302 | 3.3% |
| TOTAL | 24,984 | 33,940 | 40,123 | 46,621 | 50,589 | 60,693 | 65,610 | 14.1% |

Source: Dataquest (November 1995)

**Worldwide Semiconductor Market for Terminal Devices (Millions of Dollars)**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR 1994-99 |
|---|---|---|---|---|---|---|---|---|
| Corded Telephones | 365 | 374 | 378 | 393 | 405 | 415 | 471 | 4.7% |
| Cordless Telephones | 498 | 508 | 581 | 649 | 725 | 807 | 873 | 11.4% |
| Cellular/Broadband PCS Telephones | 1,038 | 1,874 | 2,619 | 3,591 | 4,620 | 5,838 | 6,827 | 29.5% |
| Pagers (One- and Two-Way) | 285 | 404 | 515 | 593 | 665 | 738 | 774 | 13.9% |
| Answering Machines | 213 | 252 | 324 | 358 | 393 | 427 | 442 | 11.9% |
| TOTAL | 2,398 | 3,412 | 4,418 | 5,584 | 6,807 | 8,226 | 9,387 | 22.4% |

Source: Dataquest (November 1995)

**North American Semiconductor Market for Terminal Devices (Millions of Dollars)**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR 1994-99 |
|---|---|---|---|---|---|---|---|---|
| Corded Telephones | 13 | 14 | 15 | 16 | 16 | 16 | 19 | 6.6% |
| Cordless Telephones | 14 | 15 | 17 | 21 | 22 | 21 | 23 | 8.9% |
| Cellular/Broadband PCS Telephones | 393 | 587 | 793 | 1,159 | 1,528 | 2,108 | 2,289 | 31.3% |
| Pagers (One- and Two-Way) | 90 | 141 | 161 | 182 | 204 | 250 | 261 | 13.2% |
| Answering Machines | 50 | 55 | 54 | 55 | 52 | 50 | 50 | -2.2% |
| TOTAL | 560 | 812 | 1,041 | 1,433 | 1,823 | 2,446 | 2,642 | 26.6% |

Source: Dataquest (November 1995)

**U.S. Household Penetration of Communications Devices, January 1995**

| Category | Percent |
|---|---|
| All Telephones | 96% |
| Telephone Answering Devices | 54% |
| Cordless Telephones | 52% |
| Cellular Telephones | 20% |
| Pagers | 12% |
| Caller ID Units | 6% |

Source: EIA/CEG

# COMMUNICATIONS APPLICATION MARKETS
# TELEPHONES AND MOBILE COMMUNICATIONS

**North American Communications Terminal Market**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR 1994-99 |
|---|---|---|---|---|---|---|---|---|
| SHIPMENTS | | | | | | | | |
| Corded Telephones (K) | 42,019 | 39,954 | 39,339 | 39,059 | 38,831 | 38,874 | 38,963 | -1.5% |
| Cordless Telephones (K) | 17,801 | 19,030 | 20,625 | 21,533 | 22,609 | 23,740 | 24,927 | 5.9% |
| Cellular/Broadband PCS Telephones | 9,001 | 13,478 | 17,186 | 21,367 | 24,285 | 32,031 | 36,223 | 21.9% |
| Pagers (One- and Two-Way) (K) | 7,069 | 11,548 | 13,291 | 14,430 | 14,277 | 15,687 | 15,393 | 5.9% |
| Answering Machines (K) | 17,930 | 19,360 | 18,590 | 19,140 | 19,523 | 19,913 | 20,312 | 1.0% |
| TOTAL (K) | 93,820 | 103,370 | 109,031 | 115,529 | 119,525 | 130,244 | 135,816 | 5.6% |
| REVENUE | | | | | | | | |
| Corded Telephones ($M) | 1,279 | 1,268 | 1,237 | 1,214 | 1,206 | 1,207 | 1,207 | -1.1% |
| Cordless Telephones ($M) | 1,282 | 1,294 | 1,279 | 1,184 | 1,130 | 1,092 | 1,047 | -3.2% |
| Cellular/Broadband PCS Telephones | 4,084 | 5,703 | 6,178 | 6,997 | 7,144 | 8,476 | 8,983 | 9.5% |
| Pagers (One- and Two-Way) ($M) | 557 | 866 | 988 | 1,072 | 1,228 | 1,589 | 1,576 | 12.7% |
| Answering Machines ($M) | 1,091 | 1,085 | 977 | 951 | 920 | 898 | 897 | -3.7% |
| TOTAL ($M) | 8,292 | 10,216 | 10,658 | 11,418 | 11,628 | 13,262 | 13,710 | 6.1% |

Source: Dataquest (November 1995)

**Worldwide Wireless Infrastructure Equipment Production Forecast* (Preliminary)****

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR 1994-99 |
|---|---|---|---|---|---|---|---|---|
| Revenue ($M) | 9,680 | 10,907 | 12,991 | 15,534 | 18,011 | 20,817 | 23,124 | 16.2% |
| Semiconductor Market ($M) | 484 | 563 | 692 | 854 | 1,019 | 1,214 | 1,387 | 19.8% |

* *Includes basestation and microcell equipment for PCS, cellular, paging, and other wireless radio communications.*

**These numbers are preliminary estimates. More detailed information will be available through Dataquest's Personal Communications service in early 1996.

Source: Dataquest (November 1995)

**Worldwide Corded Telephone Handset Production**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR 1994-99 |
|---|---|---|---|---|---|---|---|---|
| Units (K) | 94,762 | 97,257 | 100,174 | 103,180 | 106,275 | 109,463 | 112,747 | 3.0% |
| Standard | 72,733 | 71,877 | 72,878 | 73,786 | 74,668 | 75,301 | 75,918 | 1.1% |
| Feature/Multiline | 22,029 | 25,380 | 27,297 | 29,393 | 31,607 | 34,163 | 36,829 | 7.7% |
| Factory ASP ($) | 30 | 29 | 29 | 28 | 27 | 27 | 27 | -1.7% |
| Factory Revenue ($M) | 2,807 | 2,815 | 2,878 | 2,912 | 2,917 | 2,967 | 2,989 | 1.2% |
| Semiconductor Content ($) | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 1.7% |
| Semiconductor Market ($M) | 365 | 374 | 378 | 393 | 405 | 415 | 471 | 4.7% |

Source: Dataquest (November 1995)

**North American Corded Telephone Handset Production**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR 1994-99 |
|---|---|---|---|---|---|---|---|---|
| Units (K) | 5,264 | 5,584 | 5,980 | 6,180 | 6,297 | 6,333 | 6,460 | 3.0% |
| Factory ASP ($) | 35 | 33 | 31 | 29 | 28 | 27 | 26 | -4.7% |
| Factory Revenue ($M) | 184 | 184 | 185 | 179 | 176 | 171 | 168 | -1.8% |
| Semiconductor Content ($) | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3.5% |
| Semiconductor Market ($M) | 13 | 14 | 15 | 16 | 16 | 16 | 19 | 6.6% |

Source: Dataquest (November 1995)

**North American Corded Telephone Market**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR 1994-99 |
|---|---|---|---|---|---|---|---|---|
| Market Revenue ($M) | 1,279 | 1,268 | 1,237 | 1,214 | 1,206 | 1,207 | 1,207 | -1.1% |
| Factory ASP ($) Overall | 30 | 32 | 31 | 31 | 31 | 31 | 31 | 0.4% |
| Factory ASP ($) Standard | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 0.0% |
| Factory ASP ($) Feature/Multiline | 67 | 65 | 62 | 59 | 57 | 55 | 53 | -3.9% |
| Units (K) | 42,019 | 39,954 | 39,339 | 39,059 | 38,831 | 38,874 | 38,963 | -1.5% |
| Standard | 28,995 | 26,052 | 25,046 | 24,223 | 23,433 | 22,697 | 21,993 | -4.8% |
| Feature/Multiline | 13,024 | 13,901 | 14,293 | 14,836 | 15,398 | 16,176 | 16,970 | 4.4% |

Source: Dataquest (November 1995)

# COMMUNICATIONS APPLICATION MARKETS
# TELEPHONES AND MOBILE COMMUNICATIONS

**United States Corded Telephone Brand Share Leaders, Q1 1994 through Q4 1994**

| Brand | % Unit Market Share | % Revenue Market Share |
|---|---|---|
| AT&T | 31.4% | 37.9% |
| General Electric | 15.4% | 15.8% |
| Conair | 11.8% | 6.7% |
| BellSouth | 7.3% | 6.0% |
| Sony | 5.1% | 6.8% |
| Radio Shack | 4.6% | 5.9% |
| Unisonic | 4.0% | 1.8% |
| Lenoxx | 3.5% | 1.7% |
| Southwestern Bell | 2.1% | 2.0% |
| Panasonic | 1.5% | 2.5% |
| Other | 13.3% | 12.9% |
| Total | 100.0% | 100.0% |

Source: The Scout Report / The Polk Company

**United States Corded Telephone Brand Share Leaders, Q3 1994 through Q2 1995**

| Brand | % Unit Market Share | % Revenue Market Share |
|---|---|---|
| AT&T | 30.9% | 38.5% |
| General Electric | 14.7% | 14.7% |
| Conair | 11.6% | 6.7% |
| BellSouth | 5.7% | 4.8% |
| Radio Shack | 5.4% | 6.3% |
| Lenoxx | 4.9% | 2.5% |
| Sony | 4.4% | 5.7% |
| Unisonic | 3.6% | 1.8% |
| Southwestern Bell | 3.3% | 3.6% |
| Panasonic | 1.6% | 3.0% |
| Other | 13.9% | 12.4% |
| Total | 100.0% | 100.0% |

Source: The Scout Report / The Polk Company

**Worldwide Cordless Telephone Handset Production**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR 1994-99 |
|---|---|---|---|---|---|---|---|---|
| Units (K) | 35,405 | 35,685 | 39,134 | 42,668 | 45,764 | 49,173 | 52,744 | 8.1% |
| Digital (900MHz, CT-2, DECT, PHS...) | 414 | 1,614 | 4,532 | 7,638 | 11,360 | 16,718 | 22,599 | 69.5% |
| Analog | 34,991 | 34,071 | 34,602 | 35,030 | 34,403 | 32,456 | 30,146 | -2.4% |
| Factory ASP ($) | 82 | 77 | 74 | 73 | 72 | 72 | 71 | -1.6% |
| Factory Revenue ($M) | 2,907 | 2,747 | 2,914 | 3,120 | 3,297 | 3,523 | 3,741 | 6.4% |
| Semiconductor Content ($) | 14 | 14 | 15 | 15 | 16 | 16 | 17 | 3.1% |
| Semiconductor Market ($M) | 498 | 508 | 581 | 649 | 725 | 807 | 873 | 11.4% |

Source: Dataquest (November 1995)

**North American Cordless Telephone Handset Production**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR 1994-99 |
|---|---|---|---|---|---|---|---|---|
| Units (K) | 1,080 | 1,134 | 1,215 | 1,516 | 1,596 | 1,652 | 1,735 | 8.9% |
| Factory ASP ($) | 74 | 72 | 68 | 64 | 60 | 56 | 52 | -6.4% |
| Factory Revenue ($M) | 80 | 82 | 83 | 97 | 96 | 93 | 90 | 1.9% |
| Semiconductor Content ($) | 13 | 13 | 14 | 14 | 14 | 13 | 13 | 0.0% |
| Semiconductor Market ($M) | 14 | 15 | 17 | 21 | 22 | 21 | 23 | 8.9% |

Source: Dataquest (November 1995)

# COMMUNICATIONS APPLICATION MARKETS
# TELEPHONES AND MOBILE COMMUNICATIONS

**North American Cordless Telephone Market**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR 1994-99 |
|---|---|---|---|---|---|---|---|---|
| Market Revenue ($M) | 1,282 | 1,294 | 1,279 | 1,184 | 1,130 | 1,092 | 1,047 | -3.2% |
| Factory ASP ($) Overall | 74 | 73 | 68 | 61 | 58 | 55 | 51 | -5.8% |
| Factory ASP ($) Analog | 72 | 68 | 62 | 55 | 50 | 46 | 42 | -8.6% |
| Factory ASP ($) Digital | 183 | 155 | 124 | 99 | 84 | 72 | 61 | -17.0% |
| Units (K) | 17,801 | 19,030 | 20,625 | 21,533 | 22,609 | 23,740 | 24,927 | 5.9% |
| Analog | 17,463 | 17,850 | 18,666 | 18,389 | 17,296 | 15,431 | 12,962 | -2.4% |
| Digital | 338 | 1,180 | 1,959 | 3,144 | 5,313 | 8,309 | 11,965 | 89.7% |

Source: Dataquest (November 1995)

**United States Cordless Telephone Brand Share Leaders, Q1 1994 through Q4 1994**

| Brand | % Unit Market Share | % Revenue Market Share |
|---|---|---|
| AT&T | 27.3% | 31.1% |
| General Electric | 13.1% | 10.4% |
| Sony | 12.3% | 13.7% |
| Panasonic | 10.2% | 11.8% |
| BellSouth | 9.7% | 7.9% |
| Uniden | 8.8% | 6.8% |
| Southwestern Bell | 4.0% | 3.3% |
| Cobra | 3.3% | 3.5% |
| Radio Shack | 3.2% | 3.3% |
| Toshiba | 2.0% | 2.1% |
| Other | 6.1% | 6.1% |
| Total | 100.0% | 100.0% |

Source: The Scout Report / The Polk Company

**United States Cordless Telephone Brand Share Leaders, Q3 1994 through Q2 1995**

| Brand | % Unit Market Share | % Revenue Market Share |
|---|---|---|
| AT&T | 27.2% | 31.3% |
| General Electric | 14.0% | 11.2% |
| Sony | 12.0% | 12.5% |
| Uniden | 9.8% | 7.6% |
| Panasonic | 9.8% | 12.1% |
| BellSouth | 9.1% | 7.3% |
| Southwestern Bell | 4.4% | 3.7% |
| Radio Shack | 3.2% | 3.5% |
| Cobra | 3.0% | 3.4% |
| Toshiba | 1.9% | 1.9% |
| Other | 5.6% | 5.5% |
| Total | 100.0% | 100.0% |

Source: The Scout Report / The Polk Company

# COMMUNICATIONS APPLICATION MARKETS
# TELEPHONES AND MOBILE COMMUNICATIONS

**Worldwide Cellular and Broadband PCS Subscribers**

| | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|---|---|
| Number of Analog Subscribers (K) | 23,220 | 32,526 | 47,421 | 62,426 | 75,142 | 81,844 | 84,123 | 84,353 |
| Number of Digital Subscribers (K) | 212 | 1,570 | 6,127 | 15,687 | 33,397 | 62,181 | 107,441 | 163,653 |
| Total Subscribers (K) | 23,432 | 34,096 | 53,548 | 78,113 | 108,540 | 144,025 | 191,564 | 248,006 |

Source: Dataquest (November 1995)

**Worldwide Cellular and Broadband PCS Telephone Market**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR 1994-99 |
|---|---|---|---|---|---|---|---|---|
| Subscribers (K) | 34,096 | 53,548 | 78,113 | 108,540 | 144,025 | 191,564 | 248,006 | 35.9% |
| Units (K) | 16,225 | 27,758 | 37,315 | 48,133 | 59,624 | 78,936 | 97,116 | 28.5% |
| Analog Units (K) | 14,796 | 22,779 | 26,748 | 28,188 | 25,622 | 23,241 | 22,225 | -0.5% |
| Digital Units (K) | 1,429 | 4,979 | 10,567 | 19,945 | 34,002 | 55,696 | 74,891 | 72.0% |
| Factory ASP ($) | 472 | 426 | 375 | 340 | 306 | 269 | 249 | -10.2% |
| Factory Revenue ($M) | 7,663 | 11,830 | 13,992 | 16,366 | 18,243 | 21,200 | 24,172 | 15.4% |

Source: Dataquest (November 1995)

**Worldwide Cellular and Broadband PCS Telephone Handset Production**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR 1994-99 |
|---|---|---|---|---|---|---|---|---|
| **Analog Production** | | | | | | | | |
| Units (K) | 16,275 | 25,057 | 29,155 | 30,443 | 27,416 | 24,635 | 23,559 | -1.2% |
| Factory ASP ($) | 458 | 414 | 357 | 322 | 280 | 265 | 280 | -7.5% |
| Factory Revenue ($M) | 7,454 | 10,374 | 10,408 | 9,803 | 7,676 | 6,528 | 6,596 | -8.7% |
| Semiconductor Content ($) | 43 | 42 | 42 | 43 | 43 | 43 | 45 | 1.4% |
| Semiconductor Market ($M) | 700 | 1,052 | 1,225 | 1,309 | 1,179 | 1,059 | 1,060 | 0.1% |
| **Digital Production** | | | | | | | | |
| Units (K) | 1,572 | 5,477 | 11,624 | 21,939 | 37,403 | 61,265 | 82,380 | 72.0% |
| Factory ASP ($) | 620 | 482 | 420 | 365 | 325 | 270 | 240 | -13.0% |
| Factory Revenue ($M) | 975 | 2,640 | 4,882 | 8,008 | 12,156 | 16,542 | 19,771 | 49.6% |
| Semiconductor Content ($) | 215 | 150 | 120 | 104 | 92 | 78 | 70 | -14.1% |
| Semiconductor Market ($M) | 338 | 822 | 1,395 | 2,282 | 3,441 | 4,779 | 5,767 | 47.7% |
| **Total Production** | | | | | | | | |
| Units (K) | 17,848 | 30,534 | 40,779 | 52,382 | 64,818 | 85,900 | 105,939 | 28.2% |
| Factory ASP ($) | 472 | 426 | 375 | 340 | 306 | 269 | 249 | -10.2% |
| Factory Revenue ($M) | 8,429 | 13,014 | 15,291 | 17,810 | 19,832 | 23,070 | 26,368 | 15.2% |
| Semiconductor Content ($) | 58 | 61 | 64 | 69 | 71 | 68 | 64 | 1.0% |
| Semiconductor Market ($M) | 1,038 | 1,874 | 2,619 | 3,591 | 4,620 | 5,838 | 6,827 | 29.5% |

Source: Dataquest (November 1995)

**Worldwide Cellular and Broadband PCS Telephone Handset Production Estimate by Type**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR 1994-99 |
|---|---|---|---|---|---|---|---|---|
| Digital/Dual-Mode (All Types) (Units K) | | | | | | | | |
| GSM or GSM-based | 1,416 | 4,271 | 9,331 | 16,228 | 27,008 | 43,560 | 58,671 | 68.9% |
| IS-54/136, IS-95,etc. (TDMA/CDMA) | 156 | 579 | 1,350 | 4,063 | 8,320 | 15,200 | 20,600 | 104.3% |
| Personal/Pacific Digital Cellular | 0 | 627 | 943 | 1,648 | 2,075 | 2,505 | 3,109 | 37.7% |
| Analog (AMPS, TACS, NMT) | 16,275 | 25,057 | 29,155 | 30,443 | 27,416 | 24,635 | 23,559 | -1.2% |
| TOTAL | 17,848 | 30,534 | 40,779 | 52,382 | 64,818 | 85,900 | 105,939 | 28.2% |

Source: Dataquest (November 1995)

# COMMUNICATIONS APPLICATION MARKETS
# TELEPHONES AND MOBILE COMMUNICATIONS

**North America and United States Cellular and Broadband PCS Subscribers**

| | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|---|---|
| U.S. Cellular Subscribers (K) | 11,428 | 16,254 | 23,630 | 31,901 | 40,833 | 48,183 | 54,447 | 60,980 |
| U.S. Broadband PCS Subscribers (K) | | | | | 500 | 2,000 | 9,000 | 15,750 |
| Total U.S. Subscribers (K) | 11,428 | 16,254 | 23,630 | 31,901 | 41,333 | 50,183 | 63,447 | 76,730 |
| Rest of North Amer. Cellular Subscribers (K) | 1,305 | 1,680 | 2,273 | 3,049 | 4,179 | 5,527 | 7,112 | 8,769 |
| Total North Amer. Cellular Subscribers (K) | 12,734 | 17,934 | 25,903 | 34,950 | 45,512 | 55,710 | 70,559 | 85,499 |

Source: Dataquest (November 1995)

**North American Cellular and Broadband PCS Telephone Market**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR 1994-99 |
|---|---|---|---|---|---|---|---|---|
| **Cellular Market** | | | | | | | | |
| Units (K) | 9,001 | 13,478 | 17,186 | 20,867 | 22,715 | 24,651 | 27,313 | 15.2% |
| Analog Units (K) | 8,859 | 12,951 | 16,007 | 17,509 | 14,758 | 12,287 | 11,189 | -2.9% |
| Digital Units (K) | 142 | 527 | 1,179 | 3,358 | 7,957 | 12,364 | 16,124 | 98.2% |
| Factory ASP ($) | 454 | 423 | 359 | 326 | 294 | 267 | 255 | -9.6% |
| Factory Revenue ($M) | 4,084 | 5,703 | 6,178 | 6,812 | 6,673 | 6,594 | 6,978 | 4.1% |
| **Broadband PCS Market** | | | | | | | | |
| Units (K) | | | | 500 | 1,570 | 7,380 | 8,910 | NM |
| Factory ASP ($) | | | | 370 | 300 | 255 | 225 | NM |
| Factory Revenue ($M) | | | | 185 | 471 | 1,882 | 2,005 | NM |
| **Total Market** | | | | | | | | |
| Units (K) | 9,001 | 13,478 | 17,186 | 21,367 | 24,285 | 32,031 | 36,223 | 21.9% |
| Factory ASP ($) | 454 | 423 | 359 | 327 | 294 | 265 | 248 | -10.1% |
| Factory Revenue ($M) | 4,084 | 5,703 | 6,178 | 6,997 | 7,144 | 8,476 | 8,983 | 9.5% |

Source: Dataquest (November 1995)

**North American Cellular and Broadband PCS Telephone Production**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR 1994-99 |
|---|---|---|---|---|---|---|---|---|
| **Analog Production** | | | | | | | | |
| Total Shipments (k) | 8,359 | 12,117 | 15,339 | 17,194 | 14,734 | 12,431 | 11,256 | -1.5% |
| Factory ASP ($) | 448 | 420 | 355 | 320 | 285 | 270 | 285 | -7.5% |
| Handset Factory Revenue ($M) | 3,745 | 5,089 | 5,445 | 5,502 | 4,199 | 3,356 | 3,208 | -8.8% |
| Semiconductor Content ($) | 43 | 42 | 42 | 43 | 43 | 43 | 45 | 1.4% |
| Semiconductor Market ($M) | 359 | 509 | 644 | 739 | 634 | 535 | 507 | -0.1% |
| **Digital Production** | | | | | | | | |
| Total Digital Shipments (k) | 156 | 579 | 1,297 | 4,239 | 10,445 | 21,474 | 27,146 | 115.9% |
| Digital Factory ASP ($) | 810 | 500 | 420 | 361 | 308 | 261 | 232 | -14.3% |
| Handset Factory Revenue ($M) | 126 | 290 | 545 | 1,531 | 3,221 | 5,612 | 6,285 | 85.0% |
| Total Semiconductor Content ($) | 215 | 135 | 115 | 99 | 86 | 73 | 66 | -13.4% |
| Semiconductor Market($M) | 33 | 78 | 149 | 420 | 895 | 1,573 | 1,782 | 86.9% |
| **Total Production** | | | | | | | | |
| Shipments (K) | 8,515 | 12,697 | 16,636 | 21,433 | 25,180 | 33,906 | 38,402 | 24.8% |
| Factory ASP ($) | 455 | 424 | 360 | 328 | 295 | 265 | 247 | -10.2% |
| Handset Factory Revenue ($M) | 3,871 | 5,379 | 5,990 | 7,033 | 7,420 | 8,968 | 9,493 | 12.0% |
| Semiconductor Content ($) | 46 | 46 | 48 | 54 | 61 | 62 | 60 | 5.2% |
| Semiconductor Market ($M) | 393 | 587 | 793 | 1,159 | 1,528 | 2,108 | 2,289 | 31.3% |

Source: Dataquest (November 1995)

**Worldwide GSM Infrastructure Equipment Market Forecast**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR 1994-99 |
|---|---|---|---|---|---|---|---|---|
| Revenue ($M) | 1,742 | 3,100 | 5,253 | 7,068 | 9,567 | 12,718 | 12,360 | 31.9% |
| Semiconductor Market ($M) | 87 | 160 | 280 | 389 | 541 | 742 | 741 | 35.9% |

Source: Dataquest (November 1995)

**U.S. Cellular Infrastructure Equipment Market Forecast***

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR 1994-99 |
|---|---|---|---|---|---|---|---|---|
| **Base Stations** | | | | | | | | |
| Shipments (K) | 3,884 | 6,623 | 7,661 | 9,148 | 11,404 | 13,215 | 15,581 | 18.7% |
| Factory ASP ($K) | 350 | 350 | 343 | 336 | 321 | 315 | 308 | -2.5% |
| Factory Revenue ($M) | 1,359 | 2,318 | 2,628 | 3,075 | 3,661 | 4,157 | 4,803 | 15.7% |
| Semiconductor Content ($K) | 17.5 | 18.1 | 18.3 | 18.5 | 18.2 | 18.4 | 18.5 | 0.5% |
| Semiconductor Market ($M) | 68 | 120 | 140 | 169 | 207 | 243 | 288 | 19.2% |
| **Microcells** | | | | | | | | |
| Shipments (K) | 254 | 277 | 2,910 | 2,591 | 3,877 | 5,368 | 4,240 | 72.6% |
| Factory ASP ($K) | 100 | 100 | 130 | 150 | 150 | 150 | 150 | 8.4% |
| Factory Revenue ($M) | 25 | 28 | 378 | 389 | 582 | 805 | 636 | 87.2% |
| Semiconductor Content ($K) | 6.0 | 6.2 | 8.2 | 9.8 | 10.0 | 10.2 | 10.5 | 11.3% |
| Semiconductor Market ($M) | 2 | 2 | 24 | 25 | 39 | 55 | 45 | 92.0% |

*Does not include equipment for PCS (2 GHz) Basestations
Source: Dataquest (November 1995)

**Worldwide Cellular Telephone Market Share, 1994**

| Manufacturer | Shipments (K) | % Unit Market Share |
|---|---|---|
| Motorola | 8,906.1 | 32.5% |
| Nokia | 5,740.8 | 21.0% |
| Ericsson | 2,980.8 | 10.9% |
| NEC | 2,433.9 | 8.9% |
| Panasonic | 1,476.0 | 5.4% |
| Mitsubishi | 1,201.2 | 4.4% |
| Oki | 889.5 | 3.2% |
| Others | 3,768.4 | 13.8% |
| Total | 27,396.6 | 100.0% |

Source: Dataquest (November 1995)

**United States Cellular Telephone Brand Share Leaders, Q3 1994 through Q2 1995**

| Brand | % Unit Market Share | % Revenue Market Share |
|---|---|---|
| Motorola | 53.4% | 57.0% |
| AT&T | 7.4% | 7.3% |
| Nokia - Mobira | 5.6% | 4.5% |
| Cellular One | 4.4% | 4.3% |
| NEC | 3.8% | 3.5% |
| Radio Shack | 3.3% | 3.0% |
| Audiovox | 2.6% | 2.7% |
| Uniden | 1.8% | 1.4% |
| GE / Ericsson | 1.7% | 1.9% |
| Panasonic | 1.6% | 1.4% |
| Other* | 14.4% | 13.0% |
| Total | 100.0% | 100.0% |

Source: The Scout Report / The Polk Company
*Others include: Blaupunkt, Hughes, JVC, Mitsubishi, Muratec, Novatel, Omni, Pioneer, Qualcomm, Technophone, Toshiba

# COMMUNICATIONS APPLICATION MARKETS
# TELEPHONES AND MOBILE COMMUNICATIONS

**Major Cellular/PCS Players and their Technology Selections**

| Service Provider | North American TDMA | CDMA | PCS-1900 (GSM) |
|---|---|---|---|
| Cellular | | | |
| AirTouch Cellular | | X | |
| Ameritech Cellular | | X | |
| Bell Atlantic Mobile | | X | |
| BellSouth Cellular | X | | |
| GTE Mobilnet | | X | |
| McCaw Cellular | X | | |
| NYNEX Mobile | | X | |
| Southwestern Bell Mobile | X | | |
| Sprint Cellular | | X** | |
| PCS | | | |
| APC | | | X |
| AT&T Wireless | X | | |
| BellSouth | | | X |
| GTE Macro | | X | |
| PCS PrimeCo | | X | |
| Pacific Telesis | | | X |
| Sprint Telecomm Venture (WirelessCo) | | X* | |
| Western Wireless | | | X |

* Negotiating with CDMA vendors

Source: Dataquest (November 1995)

**Worldwide Cellular and Broadband PCS Handset Semiconductor Market**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR 1994-99 |
|---|---|---|---|---|---|---|---|---|
| **Analog** | | | | | | | | |
| Semiconductor Content ($) | 43 | 42 | 42 | 43 | 43 | 43 | 45 | 1.4% |
| Semiconductor Market ($M) | 700 | 1,052 | 1,225 | 1,309 | 1,179 | 1,059 | 1,060 | 0.1% |
| **Digital/Dual-Mode** | | | | | | | | |
| Semiconductor Content ($) | 215 | 150 | 120 | 104 | 92 | 78 | 70 | -14.1% |
| Semiconductor Market ($M) | 338 | 822 | 1,395 | 2,282 | 3,441 | 4,779 | 5,767 | 47.7% |
| **Total Cellular** | | | | | | | | |
| Semiconductor Content ($) | 58 | 61 | 64 | 69 | 71 | 68 | 64 | 1.0% |
| Semiconductor Market ($M) | 1,038 | 1,874 | 2,619 | 3,591 | 4,620 | 5,838 | 6,827 | 29.5% |

Source: Dataquest (November 1995)

# COMMUNICATIONS APPLICATION MARKETS
# TELEPHONES AND MOBILE COMMUNICATIONS

**Worldwide Pager Market (One-Way and Two-Way)**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR 1994-99 |
|---|---|---|---|---|---|---|---|---|
| Subscribers (M) | 47.2 | 70 | 96 | 122 | 148 | 174 | 200 | 23.4% |
| Units (K) | 19,630 | 30,043 | 38,806 | 44,099 | 48,750 | 51,141 | 52,603 | 11.9% |
| Factory ASP ($) | 76 | 74 | 71 | 70 | 73 | 76 | 76 | 0.6% |
| Factory Revenue ($M) | 1,489 | 2,210 | 2,766 | 3,103 | 3,540 | 3,883 | 3,982 | 12.5% |

Source: Dataquest (November 1995)

**Worldwide Pager Production**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR 1994-99 |
|---|---|---|---|---|---|---|---|---|
| Units (K) | 20,672 | 30,919 | 39,336 | 44,564 | 48,989 | 51,287 | 52,768 | 11.3% |
| Factory ASP ($) | 76 | 74 | 71 | 70 | 73 | 76 | 76 | 0.6% |
| Factory Revenue ($M) | 1,568 | 2,275 | 2,804 | 3,135 | 3,558 | 3,894 | 3,994 | 11.9% |
| Semiconductor Content ($) | 14 | 13 | 13 | 13 | 14 | 14 | 15 | 2.3% |
| Semiconductor Market ($M) | 285 | 404 | 515 | 593 | 665 | 738 | 774 | 13.9% |

Source: Dataquest (November 1995)

**North American Production of One-Way and Two-Way Pagers**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR 1994-99 |
|---|---|---|---|---|---|---|---|---|
| **One Way Pagers** | | | | | | | | |
| Units (K) | 7,517 | 11,720 | 13,363 | 14,088 | 12,295 | 10,780 | 10,665 | -1.9% |
| Factory ASP ($) | 78 | 75 | 74 | 73 | 74 | 77 | 81 | 1.5% |
| Factory Revenue ($M) | 588 | 878 | 989 | 1,029 | 910 | 833 | 860 | -0.4% |
| Semiconductor Content ($) | 12 | 12 | 12 | 13 | 13 | 14 | 14 | 3.1% |
| Semiconductor Market ($M) | 90 | 141 | 160 | 176 | 160 | 146 | 149 | 1.2% |
| **Two-Way Pagers/Narrowband PCS** | | | | | | | | |
| Units (K) | | 3 | 41 | 327 | 2,122 | 4,878 | 5,046 | 347.9% |
| Factory ASP ($) | | 193 | 192 | 179 | 167 | 155 | 151 | -4.8% |
| Factory Revenue ($M) | | 1 | 8 | 59 | 354 | 755 | 761 | 326.3% |
| Semiconductor Content ($) | | 18 | 18 | 20 | 21 | 22 | 22 | 4.3% |
| Semiconductor Market ($M) | | 0 | 1 | 6 | 44 | 105 | 112 | 367.1% |
| **Total Pagers** | | | | | | | | |
| Units (K) | 7,517 | 11,723 | 13,405 | 14,415 | 14,418 | 15,657 | 15,712 | 6.0% |
| Factory ASP ($) | 78 | 75 | 74 | 75 | 88 | 101 | 103 | 6.6% |
| Factory Revenue ($M) | 588 | 878 | 996 | 1,087 | 1,265 | 1,588 | 1,620 | 13.0% |
| Semiconductor Content ($) | 12 | 12 | 12 | 13 | 14 | 16 | 17 | 6.7% |
| Semiconductor Market ($M) | 90 | 141 | 161 | 182 | 204 | 250 | 261 | 13.2% |

Source: Dataquest (November 1995)

**U.S. Pager Subscribers (Millions)**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|---|
| One-way Service Subscribers | 19.8 | 27.3 | 32.0 | 36.7 | 40.5 | 43.5 | 46.0 |
| Two-way Service Subscribers | 0 | 0 | 0.03 | 0.2 | 2.0 | 6.8 | 11.0 |
| Total Subscribers | 19.8 | 27.3 | 32.0 | 36.9 | 42.5 | 50.3 | 57.0 |

Source: Dataquest (November 1995)

# COMMUNICATIONS APPLICATION MARKETS
# TELEPHONES AND MOBILE COMMUNICATIONS

**North American Pager and Narrowband PCS Market**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR 1994-99 |
|---|---|---|---|---|---|---|---|---|
| Market Revenue ($M) | 557 | 866 | 988 | 1,072 | 1,228 | 1,589 | 1,576 | 12.7% |
| Factory ASP ($) | 79 | 75 | 74 | 74 | 86 | 101 | 102 | 6.4% |
| Total Shipments (K) | 7,069 | 11,548 | 13,291 | 14,430 | 14,277 | 15,687 | 15,393 | 5.9% |
| Narrowband PCS / Two-way (K) | 0 | 0 | 28 | 162 | 1,814 | 4,900 | 4,676 | NM |
| Digital Shipments (K) | 6,554 | 10,683 | 11,914 | 12,503 | 10,186 | 7,799 | 6,583 | -9.2% |
| Alpha Shipments (K) | 480 | 851 | 1,340 | 1,766 | 2,277 | 2,988 | 4,134 | 37.2% |
| Tone Only Shipments (K) | 16 | 6 | 3 | 0 | 0 | 0 | 0 | -100.0% |
| Tone & Voice Shipments (K) | 19 | 8 | 6 | 0 | 0 | 0 | 0 | -100.0% |

Source: Dataquest (November 1995)

**U.S. Narrowband PCS Auction Winners**

| National Licenses | Regional Licenses |
|---|---|
| PageNet | PageMart II (All 5 Regions) |
| AT&T Wireless | PCS Development (All 5 Regions) |
| SkyTel (MTel) | MobileMedia PCS (All 5 Regions) |
| AirTouch Paging | American Paging (All 5 Regions) |
| BellSouth Wireless | AirTouch Paging (3 Regions) |
| PageMart II | Adelphia Communications (Lisa-Gaye Shearing) (3 Regions) |
| | Benbow PCS Ventures (2 Regions) |
| | Ameritech Mobile Services (1 Region) |
| | Insta-Check Systems (1 Region) |

Source: Dataquest (November 1995)

**Worldwide Answering Machine Production**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR 1994-99 |
|---|---|---|---|---|---|---|---|---|
| Units (K) | 23,470 | 26,273 | 28,194 | 30,099 | 31,901 | 33,655 | 35,431 | 6.2% |
| Tape-based | 20,302 | 22,201 | 22,978 | 22,424 | 21,055 | 18,746 | 15,413 | -7.0% |
| Digital tape-less | 3,168 | 4,072 | 5,216 | 7,675 | 10,846 | 14,909 | 20,019 | 37.5% |
| Factory ASP ($) | 46 | 42 | 42 | 41 | 39 | 37 | 37 | -2.9% |
| Factory Revenue ($M) | 1,074 | 1,115 | 1,197 | 1,230 | 1,247 | 1,254 | 1,295 | 3.0% |
| Semiconductor Content ($) | 9 | 10 | 11 | 12 | 12 | 13 | 12 | 5.4% |
| Semiconductor Market ($M) | 213 | 252 | 324 | 358 | 393 | 427 | 442 | 11.9% |

Source: Dataquest (November 1995)

**North American Answering Machine Production**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR 1994-99 |
|---|---|---|---|---|---|---|---|---|
| Units (K) | 2,608 | 2,803 | 2,887 | 3,078 | 3,099 | 3,145 | 3,302 | 3.3% |
| Factory ASP ($) | 63 | 59 | 58 | 57 | 56 | 55 | 54 | -1.7% |
| Factory Revenue ($M) | 164 | 166 | 168 | 176 | 172 | 173 | 180 | 1.6% |
| Semiconductor Content ($) | 19 | 20 | 19 | 18 | 17 | 16 | 15 | -5.3% |
| Semiconductor Market ($M) | 50 | 55 | 54 | 55 | 52 | 50 | 50 | -2.2% |

Source: Dataquest (November 1995)

**North American Answering Machine Market**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR 1994-99 |
|---|---|---|---|---|---|---|---|---|
| Market Revenue ($M) | 1,091 | 1,085 | 977 | 951 | 920 | 898 | 897 | -3.7% |
| Factory ASP ($) Overall | 61 | 56 | 53 | 50 | 47 | 45 | 44 | -4.7% |
| Factory ASP ($) Tape based | 58 | 54 | 50 | 46 | 42 | 38 | 35 | -8.3% |
| Factory ASP ($) Solid state | 77 | 66 | 63 | 60 | 57 | 54 | 51 | -5.0% |
| Units (000) | 17,930 | 19,360 | 18,590 | 19,140 | 19,523 | 19,913 | 20,312 | 1.0% |
| Tape based | 15,241 | 16,069 | 14,872 | 13,972 | 12,690 | 10,952 | 8,734 | -11.5% |
| Solid state | 2,690 | 3,291 | 3,718 | 5,168 | 6,833 | 8,961 | 11,578 | 28.6% |

Source: Dataquest (November 1995)

# COMMUNICATIONS APPLICATION MARKETS
# TELEPHONES AND MOBILE COMMUNICATIONS

**United States Stand-Alone Answering Machine Brand Share Leaders, Q1 1994 through Q4 1994**

| Brand | % Unit Market Share | % Revenue Market Share |
|---|---|---|
| AT&T | 32.4% | 38.6% |
| GE | 17.7% | 15.2% |
| PhoneMate | 13.0% | 11.7% |
| BellSouth | 7.2% | 5.7% |
| Panasonic | 5.8% | 7.9% |
| Conair | 4.5% | 3.3% |
| Unisonic | 4.4% | 2.7% |
| Radio Shack | 4.1% | 4.8% |
| Southwestern Bell | 2.6% | 2.4% |
| Spectra | 2.1% | 1.4% |
| Other | 6.2% | 6.3% |
| Total | 100.0% | 100.0% |

Source: The Scout Report / The Polk Company

**United States Stand-Alone Answering Machine Brand Share Leaders, Q3 1994 through Q2 1995**

| Brand | % Unit Market Share | % Revenue Market Share |
|---|---|---|
| AT&T | 35.3% | 40.4% |
| GE | 16.5% | 14.4% |
| PhoneMate | 11.8% | 10.7% |
| BellSouth | 7.9% | 6.7% |
| Conair | 4.9% | 3.8% |
| Panasonic | 4.7% | 6.5% |
| Radio Shack | 4.0% | 4.9% |
| Unisonic | 3.6% | 2.2% |
| Southwestern Bell | 3.5% | 3.2% |
| Sony | 1.9% | 2.6% |
| Other | 5.9% | 4.6% |
| Total | 100.0% | 100.0% |

Source: The Scout Report / The Polk Company

**United States Answering Machine Integrated with Corded Phone Brand Share Leaders, Q1 1994 through Q4 1994**

| Brand | % Unit Market Share | % Revenue Market Share |
|---|---|---|
| AT&T | 28.8% | 32.9% |
| GE | 23.9% | 21.5% |
| BellSouth | 13.1% | 9.7% |
| PhoneMate | 11.0% | 11.1% |
| Panasonic | 6.5% | 8.5% |
| Sony | 4.1% | 5.0% |
| Conair | 2.4% | 1.3% |
| Radio Shack | 2.0% | 2.7% |
| Southwestern Bell | 1.7% | 1.9% |
| Unisonic | 1.1% | 0.7% |
| Other | 5.4% | 4.7% |
| Total | 100.0% | 100.0% |

Source: The Scout Report / The Polk Company

# COMMUNICATIONS APPLICATION MARKETS
# TELEPHONES AND MOBILE COMMUNICATIONS

**United States Answering Machine Integrated with Corded Phone Brand Share Leaders, Q3 1994 through Q2 1995**

| Brand | % Unit Market Share | % Revenue Market Share |
|---|---|---|
| AT&T | 31.8% | 34.7% |
| GE | 23.7% | 21.7% |
| PhoneMate | 11.1% | 11.3% |
| BellSouth | 10.2% | 7.4% |
| Panasonic | 6.1% | 9.2% |
| Sony | 5.0% | 5.3% |
| Conair | 2.9% | 1.7% |
| Southwestern Bell | 2.7% | 2.7% |
| Radio Shack | 1.7% | 2.1% |
| Unisonic | 0.9% | 0.5% |
| Other | 3.9% | 3.4% |
| Total | 100.0% | 100.0% |

Source: The Scout Report / The Polk Company

**United States Answering Machine Integrated with Cordless Phone Brand Share Leaders, Q1 1994 through Q4 1994**

| Brand | % Unit Market Share | % Revenue Market Share |
|---|---|---|
| AT&T | 23.2% | 24.6% |
| Panasonic | 22.5% | 25.1% |
| Sony | 12.0% | 13.3% |
| BellSouth | 12.5% | 10.1% |
| PhoneMate | 10.2% | 8.5% |
| GE | 7.1% | 6.3% |
| Southwestern Bell | 5.5% | 4.9% |
| Sanyo | 3.0% | 3.4% |
| Cobra | 1.0% | 0.7% |
| Radio Shack | 0.8% | 1.1% |
| Other | 2.2% | 2.0% |
| Total | 100.0% | 100.0% |

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**United States Answering Machine Integrated with Cordless Phone Brand Share Leaders, Q3 1994 through Q2 1995**

| Brand | % Unit Market Share | % Revenue Market Share |
|---|---|---|
| AT&T | 24.3% | 26.4% |
| Panasonic | 19.1% | 21.6% |
| Sony | 13.3% | 14.6% |
| PhoneMate | 12.3% | 10.4% |
| BellSouth | 10.5% | 8.4% |
| GE | 7.4% | 6.5% |
| Southwestern Bell | 6.4% | 5.6% |
| Sanyo | 2.4% | 2.4% |
| Radio Shack | 1.2% | 1.5% |
| Cobra | 0.8% | 0.7% |
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| Total | 100.0% | 100.0% |

Source: The Scout Report / The Polk Company

# COMMUNICATIONS APPLICATION MARKETS
## TELEPHONES AND MOBILE COMMUNICATIONS

**Proposals for Satellite-Based Services**

| Company | Number of Satellites | Target Service* | Satellite/System Type | Comments |
|---|---|---|---|---|
| Orbital Communications (Orbcomm) | 26 - 48 | 1995 | Little LEO | Holds FCC license; Two satellites in place and functioning |
| American Mobile Satellite Corporation | - | 1995 | Geostationary | Holds FCC license; One satellite in place and functioning |
| Motorola (Iridium) | 66 | 1998 | Big LEO | Received FCC approval |
| Loral, Qualcomm (Globalstar) | 48 | 1998 | Big LEO | Received FCC approval |
| TRW (Odyssey) | 12 | 1998-99 | MEO | Received FCC approval |
| Teledisc | 840 | 2001 | LEO | Working with FCC licensing and regulations; Backed by AT&T, McCaw, and Gates |
| Constellation Communications | 46 | 1996 | | Seeking FCC approval but denied initially for financing |
| Mobile Communications (Ellipso) | 16 | | Little LEO | Seeking FCC approval but denied initially for financing |
| ICO Global Space Communications (Inmarsat-P) | 12 | 2000 | MEO | Offshoot of Inmarsat |
| VITA and CTA (GEMnet-VITAsat) | 40 | 1995 | | Holds two satellites under "Pioneer's Preference"; Seeking 38 more licenses |
| Starsys (Starsys Global Positioning) | 24 | 1997 | | |

* Indicates start of initial service. Full constellation deployment and full service would follow over a series of 4 to 5 years typically

Source: Dataquest (November 1995)

Market Analysis

Communications Semiconductors and Applications Worldwide

# Market Analysis

# Communications Chip Market: The Wired and Wireless


**Abstract:** *In this article Dataquest identifies for the first time the market sizes and market shares of the communications-specific chip market and segments. Presented is an overview of the competitive landscape in the wireless, transmission and switching, LAN, modem, and telephone IC markets. A detailed analysis is presented in a Communications Semiconductors and Applications Worldwide Competitive Trends document titled "Communications Semiconductor Industry: Big Players, but Fragmented Too," dated June 26 (CSAM-WW--CT-9501).*


*By Gregory Sheppard*

## The Big Picture

According to our just-completed survey of more than 80 semiconductor vendors, $18.6 billion worth of semiconductors were shipped for use in data, voice, and multimedia communications systems during 1994. These applications accounted for 17 percent of all chip use. Figure 1 indicates how the communications application market break down in terms of multiapplication and communications-specific devices. Multiapplication refers to broadly used products such as memory, standard logic and linear, MPUs and MCUs, and non-RF discretes. The communications-specific category accounts for a third of the total and comprises chips tailored for specific use in networking, transmission, switching, telephone, and wireless communication.

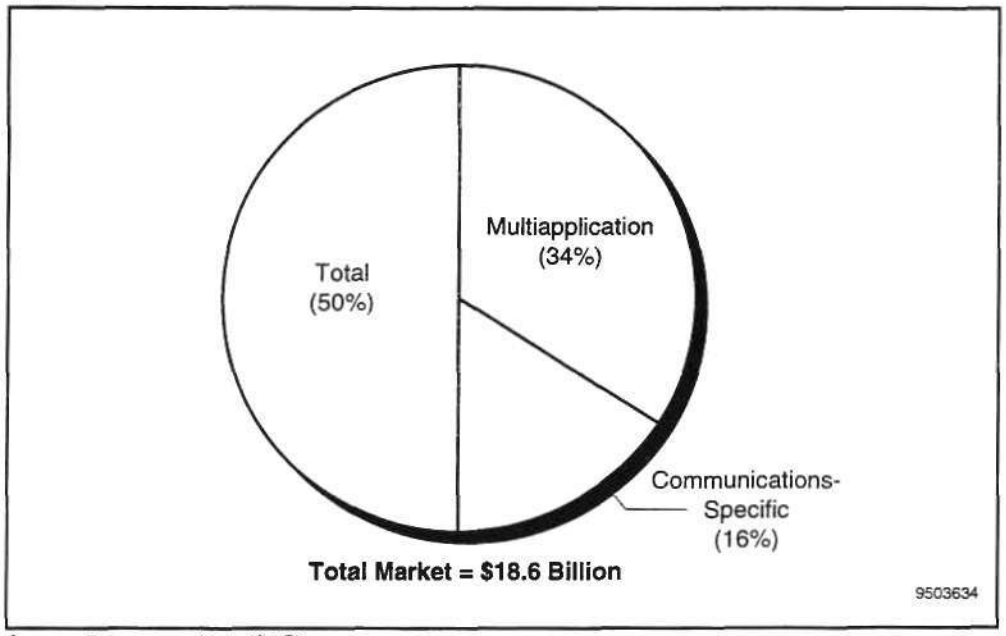
## The Players

Motorola was the largest global supplier of communications-specific ICs (see Figure 2). It benefited greatly from a captive cellular telephone and pager business that surged in volume greatly during the year. Motorola has world-class DSP and RF technology, and its MCU and embedded processor business is also dominant in communications applications.


Dataquest

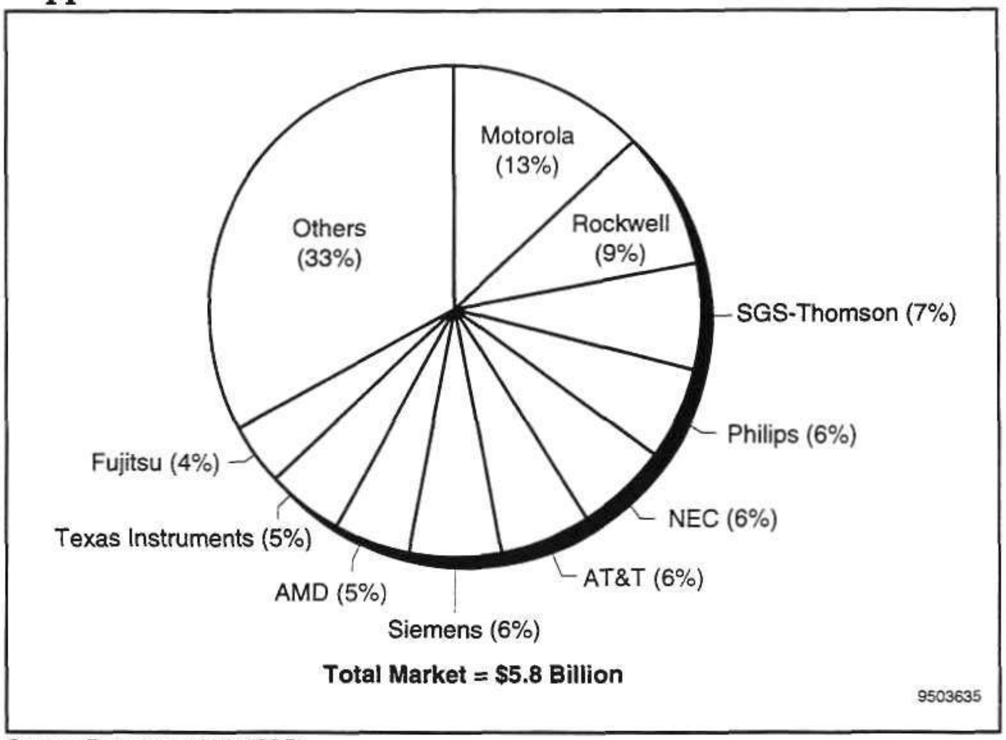
**Program:** Communications Semiconductors and Applications Worldwide
**Product Code:** CSAM-WW-MA-9503
**Publication Date:** July 10, 1995
**Filing:** Market Analysis

**Figure 1**
**1994 Worldwide Communications Semiconductor Application Market**




Source: Dataquest (July 1995)

**Figure 2**
**1994 Worldwide Top 10 Communications-Specific Semiconductor Suppliers**




Source: Dataquest (July 1995)

Rockwell is the undisputed king of the modem chip business and dominates both the data and fax aspects of the business. It is continuing the trend with the new V.34 standard, which operates at 28.8 Kbps for data. SGS-Thomson has been successful targeting its analog and mixed-signal technology at the telephone terminal and public system markets. Philips has benefited from captive demand as well, but it is also a major merchant player in RF/IF devices used in cellular and cordless phones.

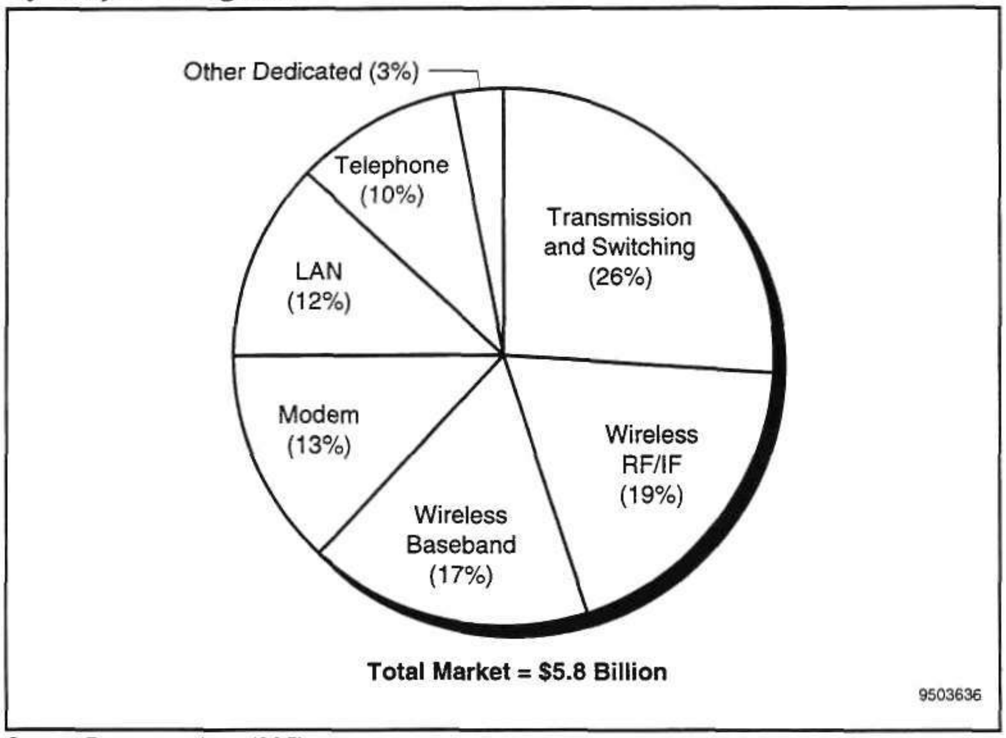
NEC also has strengths in the wireless area and participates in both baseband and RF/IF technologies. AT&T is a largely captive supplier to its network systems group but is making inroads in the merchant modem and wireless chip markets. Siemens is a strong supplier of WAN, transmission, and switching functions and is an emerging wireless player.

AMD is the leader in LAN ICs and a large supplier of line card functions. Texas Instruments is perhaps the most balanced of the top players and maintains a position in the LAN, modem, transmission and switching, and wireless segments. Fujitsu joins NEC as the other major Japanese participant in the communications-specific area, with particular emphasis in wireless technology.

## Communications-Specific Markets

Figure 3 shows a breakdown of the communications-specific semiconductor market. The largest single category was wireless system ICs, which account for 36 percent of the communications-specific category.

**Figure 3**
**1994 Worldwide Communications-Specific Semiconductor Market by Major Categories**




Source: Dataquest (July 1995)

## Wireless

The wireless category includes tailored ICs used in mobile terminals or items such as cellular phones, cordless phones, and pagers. Specific items in this category include DSP-based baseband chipsets for cellular (for example, AMPS and GSM) and cordless phones, pager-specific baseband chips, wireless data protocol chips, and RF/IF ICs and discretes associated with mobile communications use and frequencies. Motorola, Philips, and NEC were the largest suppliers of these types of chips. Top participants in this area enjoy a large degree of captive business. However, independent companies with innovative baseband technology and a proficiency in RF design and power management are gaining business rapidly.

## Transmission and Switching

We include ICs that embody various functions used in the transmission and switching of communications traffic in the WAN and public domain. This category includes items such as line card ICs, T/E carrier functions, SONET/SDH transmission functions, and ISDN ICs. SGS-Thomson, Siemens, and AT&T lead this overall category; at least a dozen others have a significant presence. Key success factors in the business include tight relationships with OEMs, mastery of mixed-signal and optoelectronic transceiver technology, high-speed switching technology, and an insider's view of International Telecommunication Union (ITU) and Post, Telephon und Telegraphenbetriebe (PTT) standards.

## Modem

The modem category is fairly pure in that it includes modem chipsets and supporting functions such as analog front-ends. DSP processors tailored for use in modem applications also are included. Rockwell, TI, and Sierra Semiconductor are the largest participants in this business. This business is extremely competitive, and leading participants have been focusing on adding value by being early participants in new high-speed ITU standards (for example, V.34) and features such as speaker phone, answering machine, and voice over data.

## Networking

Networking ICs include such functions as LAN controllers (for example, Ethernet, token-ring, and FDDI) and transceivers, hub and switch functions, and asynchronous transfer mode (ATM) functions. Advanced Micro Devices, National Semiconductor, and TI are leading participants in this market. Success here is driven in part by the right pricing, but also by OEM relationships and having the right value features (such as bus interfaces, speeds, and integration with other "neighbor" functions, among others).

## Telephone

Telephones are perhaps the most obvious market to the everyday user of telecommunications systems. This category includes ICs that embody the various functions that implement wired telephone terminals (smart and otherwise) and answering machines. Everything from dialers and speech circuits to codecs is included in this category. Leading chip providers include SGS-Thomson, AT&T, and Siemens. Outside of aggressive pricing on the low end of the market, successful vendors become proficient by working closely with large OEMs, by being innovative with integration, by offering new features, and by closely tracking ITU/PTT requirements.

## Dataquest Perspective

As the information in this newsletter makes evident, there is not "a" communications chip market. There are in fact dozens of areas, each requiring its own set of skills for success as a semiconductor supplier.

We noted players such as Motorola, Rockwell, and SGS-Thomson as being leaders in their respective areas in our analysis of the communications-specific chip market. How did they accomplish this? It is difficult to cite generalities, but one trait they share is "focus." Each has a large market share in one or two areas while maintaining core competencies it has been able to leverage into related or displacing markets. An example is Motorola's ability to maintain leadership in digital cellular technology as it begins to displace analog cellular technology.

Although there are many, the two main core competencies include design (IEEE standards, ITU/PTT standards, RF/IF, mixed-signal, and power management, among others) and access to necessary process technologies in required volumes.

**For More Information...**

Greg Sheppard, Director/Principal Analyst ............................ (408) 437-8261
Internet address ..................................................... gsheppard@dataquest.com
Via fax ..................................................................................... (408) 437-0292



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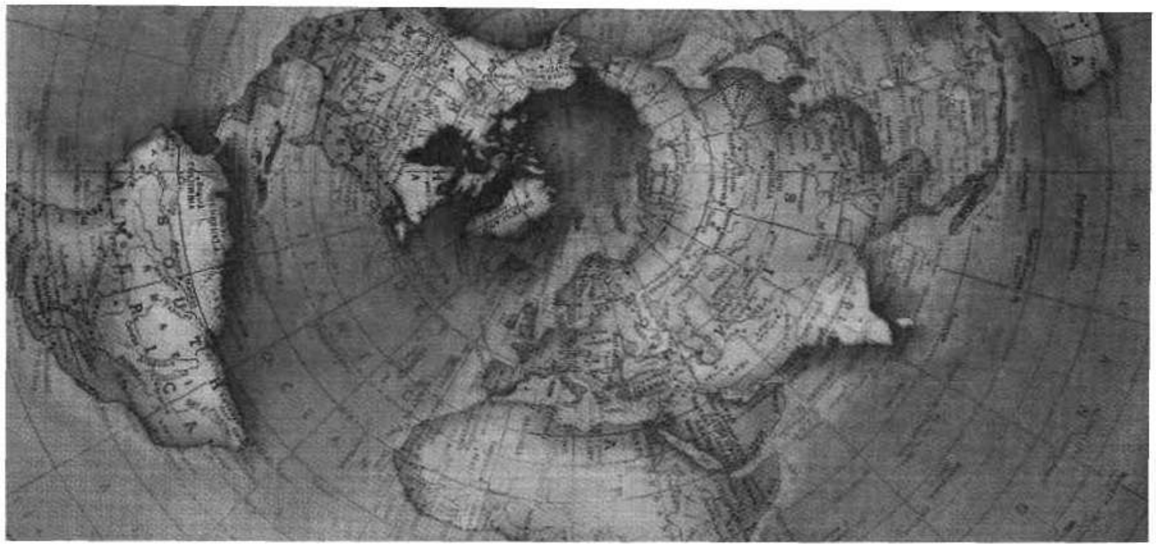
Market Analysis



Communications Semiconductors and Applications Worldwide

# Market Analysis

## New High-Speed LAN IC Opportunities Hit the Ground Running

**Abstract:** *Dataquest predicts that Fast Ethernet will rise to be the predominant 100-Mbps Ethernet IC standard. 100VG-AnyLAN also will prove an attractive volume alternative. 25-Mbps ATM ICs will start shipping this year as the standard rushes to implementation.*
*By Greg Sheppard*

### 100 Megabits, Mega-Hit

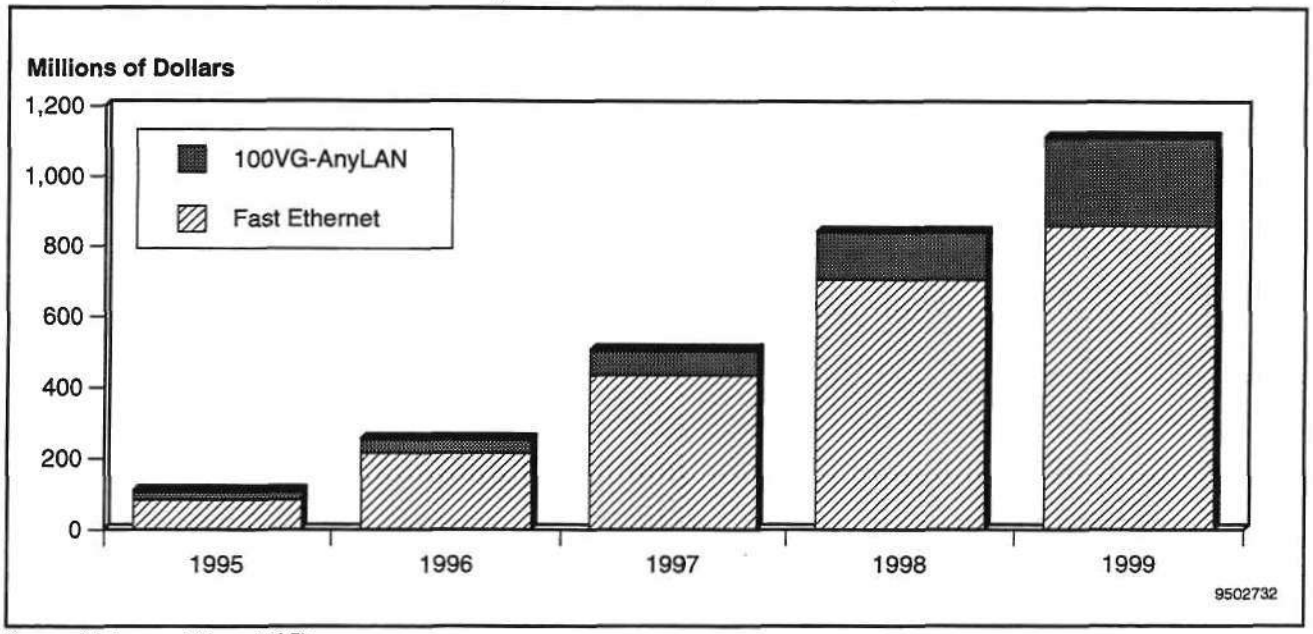
100-Mbps LAN technology is off to a strong start in 1995, much stronger than most had predicted. LAN network interface cards (NICs) and intelligent hub ports capable of dual operation at both 10 Mbps and 100 Mbps (known as 10/100) are finding good acceptance in the marketplace.

Dataquest expects a billion-dollar 10/100-Mbps Ethernet IC market (controllers, hub functions, and transceivers) to develop by 1999 (see Figure 1 and Table 1). Helping kick-start this market are a projected 2 million hub ports and 1 million 10/100-Mbps NICs expected to ship in 1995. Of the two standards, Fast Ethernet (or 100-base-T) is expected to command the majority of the market versus 100VG-AnyLAN.

Dataquest

**Program:** Communications Semiconductors and Applications Worldwide
**Product Code:** CSAM-WW-MA-9502
**Publication Date:** June 5, 1995
**Filing:** Market Analysis

**Figure 1**
**Fast Ethernet and AnyLAN ASSP/ASIC Market, Worldwide, 1994-1999**




Source: Dataquest (June 1995)

**Table 1**
**Fast Ethernet LAN and 100VG-AnyLAN ASSP/ASIC Market, Worldwide**

| | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|
| Fast Ethernet LAN ASSP/ASIC | | | | | |
| LAN Nodes | 2,385 | 7,071 | 16,994 | 32,111 | 43,525 |
| Node ASSP/ASIC Dollar Content | 35.4 | 30.6 | 25.7 | 22.0 | 19.8 |
| ASSP/ASIC Revenue ($M) | 84.4 | 216.5 | 436.1 | 706.7 | 861.1 |
| 100VG-AnyLAN | | | | | |
| LAN Nodes | 681 | 1,238 | 2,737 | 6,177 | 12,635 |
| Adapter/MB Nodes (K Units) | 35.9 | 30.2 | 25.7 | 21.8 | 19.8 |
| ASSP/ASIC Revenue ($M) | 24.4 | 37.4 | 70.2 | 134.9 | 250.4 |

Source: Dataquest (June 1995)

Several key factors are accelerating the overall move to 10/100-Mbps solutions:

- There is broadening availability of debugged, NIC, and hub offerings from big market players such as Hewlett-Packard, 3Com, and SMC.
- Prices on 10/100-Mbps NICs and hub ports are rapidly declining (both about $200; sub-$150 seen as possible by the fourth quarter of 1995).
- Because of the aforementioned two factors, users are able to invest in 10/100-Mbps LAN elements piecemeal and operate at 10 Mbps in the meantime.
- The media independent interface (MII) makes solutions easy for fiber, shielded twisted pair (STP), and Category 3, 4, and 5 unshielded twisted pair (UTP) and its 2-pair and 4-pair varieties.

## Which 100Mb Standard?

Dataquest is predicting that Fast Ethernet 100-base-T (based on IEEE 802.3u) will capture some 80 percent of the 100Mb LAN IC market, based on the relative strength and composition of the powerful alliance behind Fast Ethernet. Although considered by many to be technologically superior, 100VG-AnyLAN (based on 802.12) has not garnered enough marketing muscle to establish clear superiority.

To detail the technical pros and cons of each standard would be near folly because of the "specsmanship" that has been going on. It is generally acknowledged that 100VG-AnyLAN superiority is in supporting both Ethernet and token-ring frames and in its ability to serve more easily the bandwidth needs of multimedia.

As of the March InterOp trade show, the Fast Ethernet Alliance had about 75 members, whereas the 100VG-AnyLAN Alliance had 25 listing some sort of product plans. In our view, however, AnyLAN was dealt a blow by the recent preference IBM appears to be giving 25Mb Asynchronous Transfer Mode (ATM) as an alternative migration path for Token Ring users.

## 25-Mbps ATM to Arrive in 1995

This lower-speed alternative of ATM appears ready to begin penetrating the networking market. The ATM Forum, the de facto ATM industry standards body, recently recognized 25-Mbps ATM as a viable option. One of the near-term markets for 25-Mbps ATM is as an alternative for token-ring users in that the specification is based mostly on a version token-ring with overhead processing striped away. We believe IBM's effectiveness at promoting this standard will severely impact its success.

Table 2 presents our forecast for the specialized protocol/transceiver IC opportunity presented by the 25-Mbps ATM marketplace. We believe that a near-$100 million IC market is feasible by 1999. The Desktop ATM25 Alliance is leading the charge to make 25-Mbps ATM product available and interoperable.

**Table 2**
**25-Mbps ATM ASSP/ASIC Market, Worldwide**

| | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|
| LAN Nodes (K Units) | 82 | 176 | 792 | 1,512 | 2,495 |
| ASSP/ASIC Dollar Content | 55.0 | 48.4 | 43.6 | 40.1 | 36.9 |
| ASSP/ASIC Revenue ($M) | 4.5 | 8.5 | 34.5 | 60.6 | 92.0 |

NA = Not applicable
Source: Dataquest (June 1995)

## Dataquest Perspective

This article has only touched on some of the emerging opportunities for chips in high-speed networks. Although FDDI is very important, we did not mention it as the entrenched 100-Mbps leader. Dataquest expects FDDI to continue being a major backbone technology because of its stable embodiment into hub-server and internetworking ports.

Another high-speed alternative is switched 10-Mbps technology as it is washed in on a wave of switched hub systems from at least 20 networking vendors. Because it preserves investment in wiring plant and NICs, switched Ethernet and now token-ring will get a good market run over the next two to three years as a bridge to 100-Mbps alternatives. Also expect full-duplex Ethernet, capable of simultaneous two-way transmission, to address the needs of many bandwidth-limited networks.

Dataquest continues to believe that ATM (155-Mbps and above) will become the predominant networking technology in the four- to five-year time horizon. But in the meantime there will be plenty of cost-effective, slower-speed alternatives to keep a dozen chip companies quite happy on margin-laden products.

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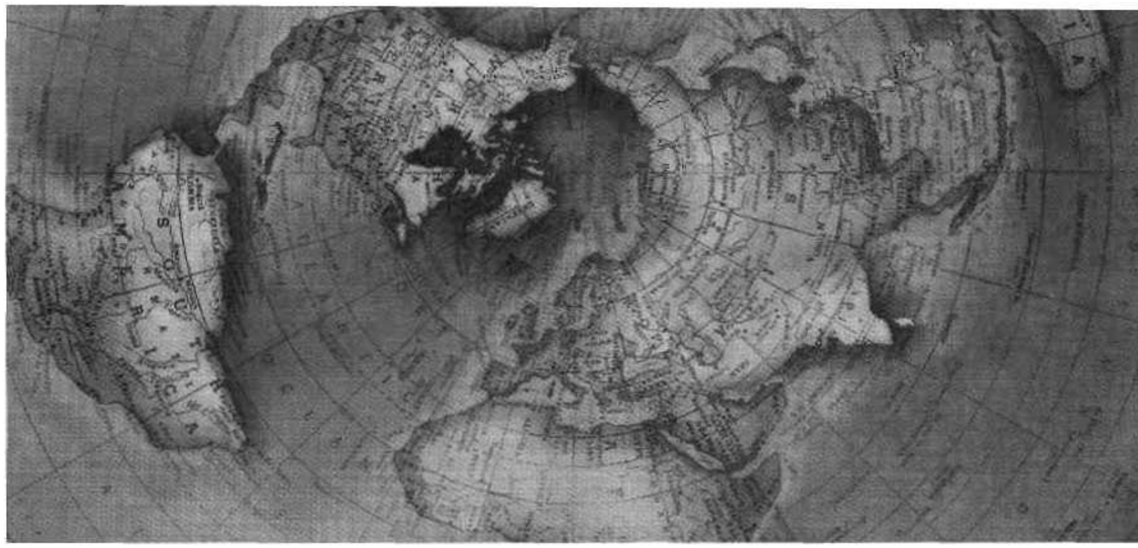
Market
Analysis



Communications Semiconductors and Applications Worldwide

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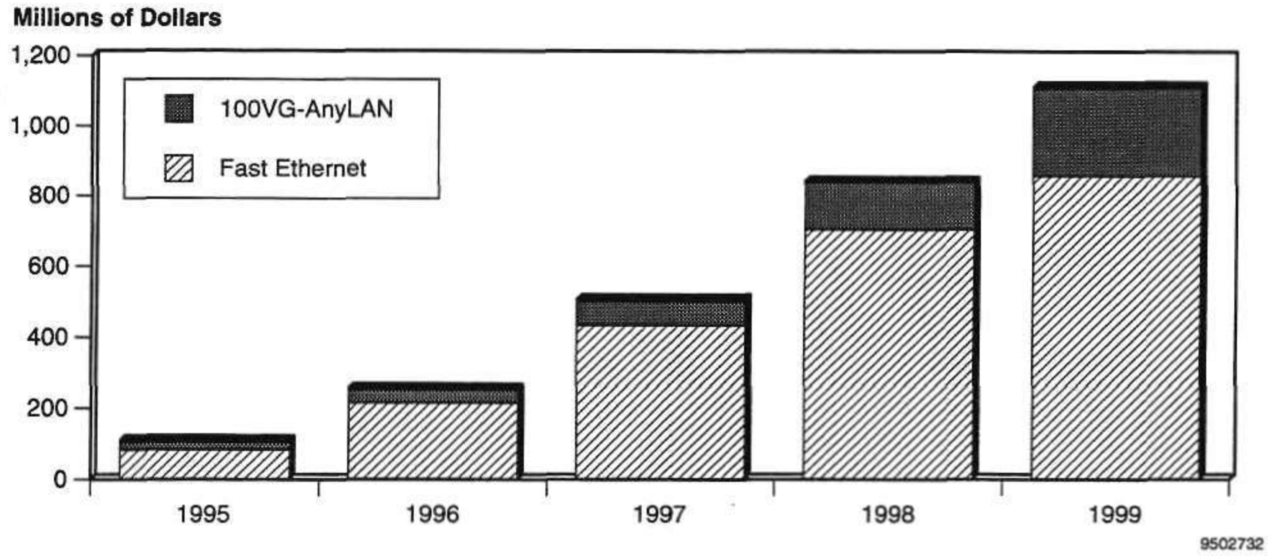


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CSAM-WW-MA-9502 Qty: 1
Ms. Maria Valenzuela
Dataquest Incorporated
1-1100

--INTERNAL DIST.--

**For More Information...**

Greg Sheppard, Director/Principal Analyst .......... (408) 437-8261
Internet address .......... gsheppard@dataquest.com
Via fax .......... (408) 437-0292



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Market Analysis

Communications Semiconductors and Applications Worldwide

# Market Analysis

# For Cellular/PCS Chip Suppliers, Opportunity Calls


**Abstract:** *This report provides details of Dataquest's forecast for the cellular and personal communications (PCS) markets. The number of cellular and PCS subscribers is predicted to grow to 251 million worldwide by 1999. This will drive annual cellular handset production to almost 100 million units by then, which will require $6.2 billion in semiconductors. Details of chipset solutions offered by major suppliers to this market are also provided, along with a summary table of semiconductor product offerings from 19 different semiconductor companies.*


*By Dale Ford*


## Forecast: Cellular and PCS Markets Soar, Driving Major Growth in Wireless Semiconductors

The worldwide growth in cellular and PCS markets in 1994 was explosive. The number of cellular subscribers worldwide grew by 57 percent over 1993, driving the number of cellular handset shipments up 68 percent to 27.4 million units in 1994. In addition to the major growth taking place in Europe and developing regions, the North American market continues its robust growth. The number of cellular subscribers in North America grew by more than 44 percent in 1994, which resulted in cellular handset shipments growing by 50 percent to 13.5 million units. The number of cellular and PCS subscribers in the United States alone is predicted to reach 79 million by 1999. Tables 1 and 2 and Figures 1 through 4 illustrate this growth and Dataquest's forecast through 1999. Dataquest forecasts strong growth in the cellular and PCS markets to continue through 1999 as increased competition, enhanced services, and lower prices drive increased use of wireless services by current users and entrance to the market of new subscribers.


Dataquest

**Program:** Communications Semiconductors and Applications Worldwide
**Product Code:** CSAM-WW-MA-9501
**Publication Date:** May 8, 1995
**Filing:** Market Analysis

**Table 1**
**Worldwide Cellular and Broadband PCS Market**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|
| Subscribers (K) | 34,184 | 53,629 | 77,533 | 107,954 | 144,305 | 193,215 | 251,368 | 36.2 |
| Handset Shipments (K) | 16,300 | 27,397 | 36,230 | 47,687 | 59,869 | 80,146 | 99,836 | 29.5 |
| Average Factory ASP ($) | 478.13 | 435.61 | 389.49 | 349.95 | 314.02 | 281.37 | 252.71 | -10.3 |
| Handset Factory Revenue ($M) | 7,794 | 11,934 | 14,111 | 16,688 | 18,800 | 22,551 | 25,229 | 16.2 |

Source: Dataquest (May 1995)

**Table 2**
**North American Cellular and Broadband PCS Market**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|
| **Cellular Market** | | | | | | | | |
| Subscribers (K) | 17,934 | 25,903 | 34,950 | 45,012 | 53,710 | 61,559 | 69,749 | 21.9 |
| Handset Shipments (K) | 9,008 | 13,491 | 17,225 | 20,938 | 22,715 | 24,555 | 27,313 | 15.2 |
| Average Factory ASP ($) | 451.87 | 423.01 | 377.57 | 339.09 | 301.86 | 268.98 | 243.18 | -10.5 |
| Handset Factory Revenue ($M) | 4,071 | 5,707 | 6,504 | 7,100 | 6,857 | 6,605 | 6,642 | 3.1 |
| **Broadband PCS Market** | | | | | | | | |
| Subscribers (K) | - | - | - | 500 | 2,000 | 9,000 | 15,750 | |
| Handset Shipments (K) | - | - | - | 500 | 1,570 | 7,380 | 8,910 | |
| Average Factory ASP ($) | - | - | - | 370.00 | 300.00 | 255.00 | 225.00 | |
| Handset Factory Revenue ($M) | - | - | - | 185 | 471 | 1,882 | 2,005 | |
| **Total Market** | | | | | | | | |
| Subscribers (K) | 17,934 | 25,903 | 34,950 | 45,512 | 55,710 | 70,559 | 85,499 | 27.0 |
| Handset Shipments (K) | 9,008 | 13,491 | 17,225 | 21,438 | 24,285 | 31,935 | 36,223 | 21.8 |
| Average Factory ASP ($) | 451.87 | 423.01 | 377.57 | 339.81 | 301.74 | 265.75 | 238.71 | -10.8 |
| Handset Factory Revenue ($M) | 4,071 | 5,707 | 6,504 | 7,285 | 7,328 | 8,487 | 8,647 | 8.7 |

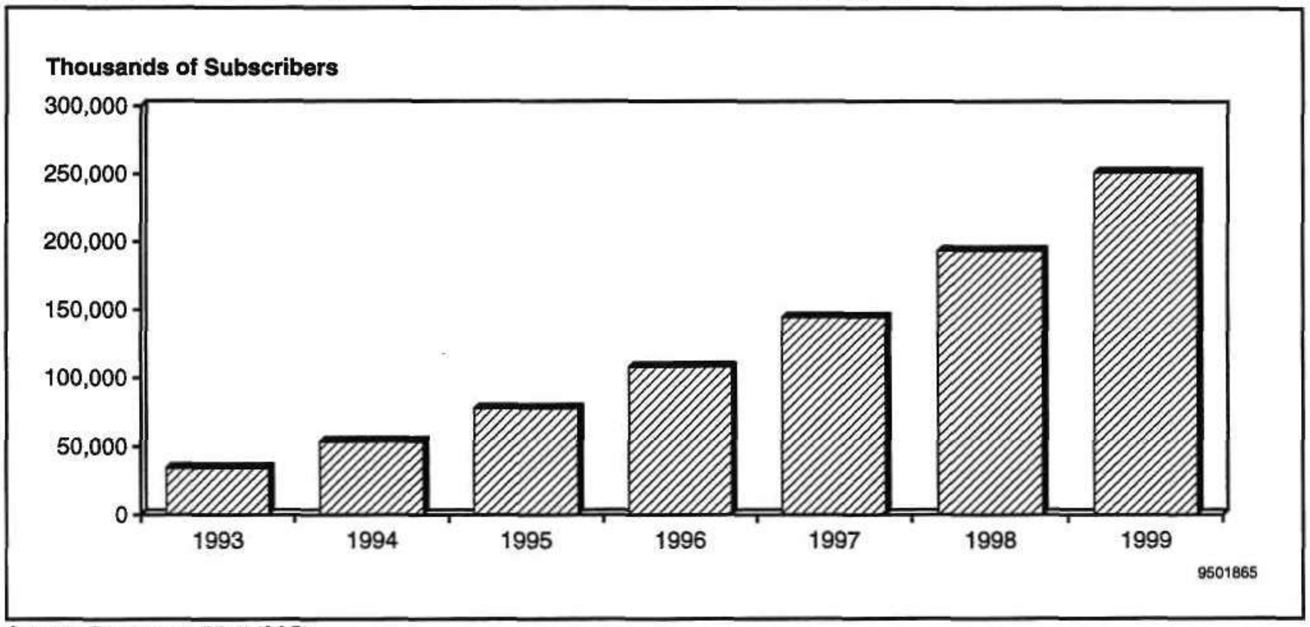
Source: Dataquest (May 1995)

Semiconductor suppliers to the cellular and PCS markets will both enable and benefit from this growth. New digital standards and advances in semiconductor technologies are providing improvements in fundamental areas important to both subscribers and service providers. Advanced semiconductors are extending talk time and stand-by time on cellular handsets, improving voice and transmission quality, and enabling new data services. These new technologies are also making wireless video communications possible. Service providers are benefiting from improved capacity in their networks and the ability to deliver new services to their subscribers.

As the fundamental enabler of these new wireless capabilities, semiconductor manufacturers stand to reap major rewards. Dataquest predicts the worldwide semiconductor market for cellular and PCS handsets to grow from $1.6 billion in 1994 to almost $6.3 billion by 1999, a 31.3 percent compound annual growth rate (CAGR). Semiconductor suppliers for handsets produced for North American markets and standards will also benefit from this growth. The demand for semiconductors in handsets produced in

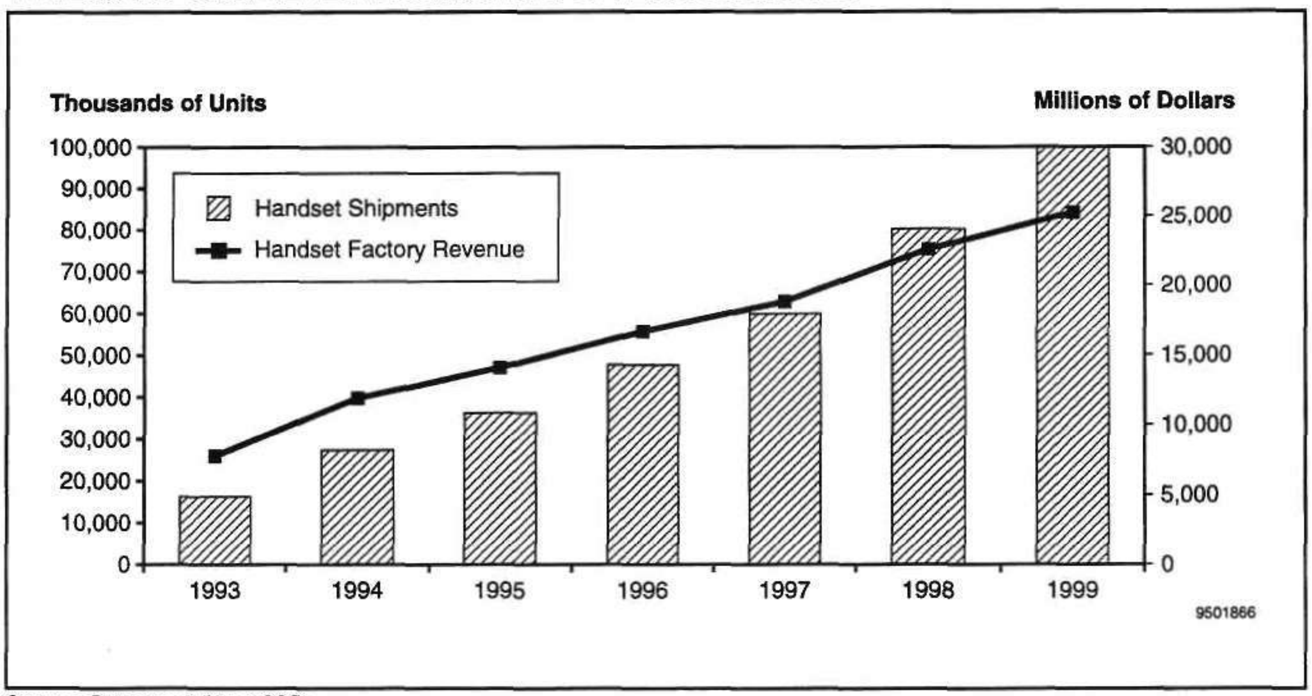
  

**Figure 1**
**Worldwide Cellular and Broadband PCS Subscriber Forecast**




Source: Dataquest (May 1995)

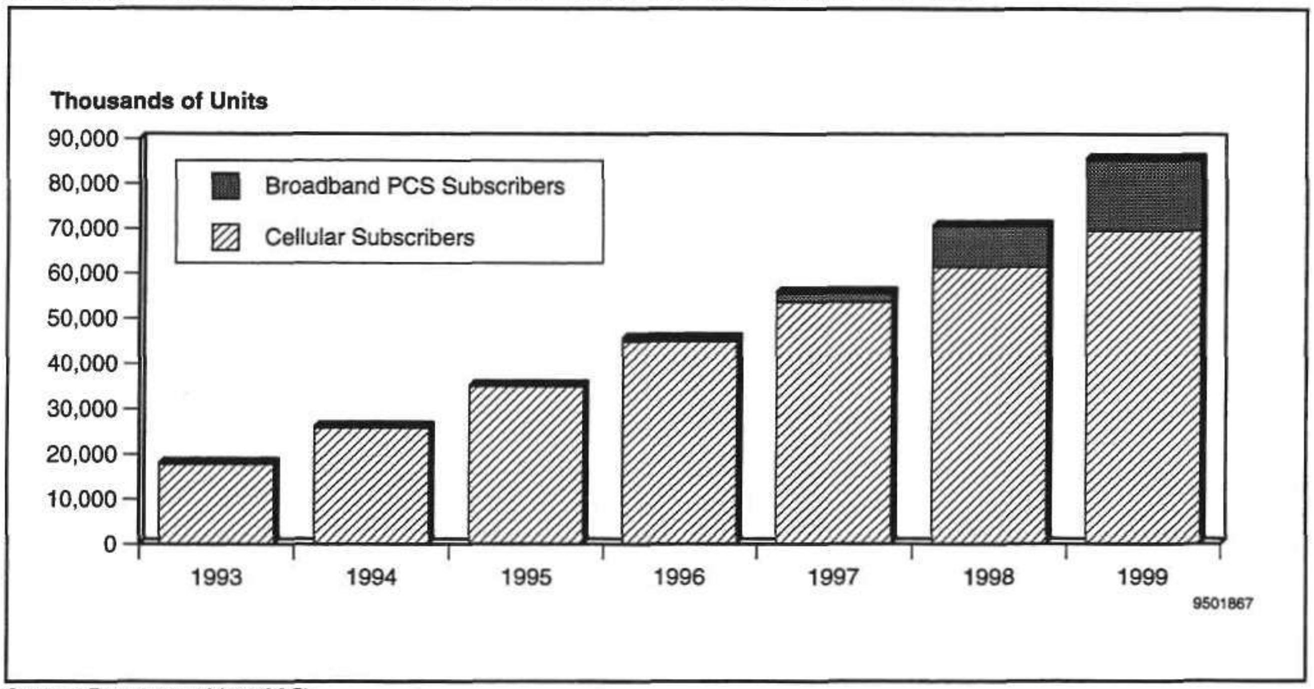
**Figure 2**
**Worldwide Cellular and Broadband PCS Handset Market**




Source: Dataquest (May 1995)

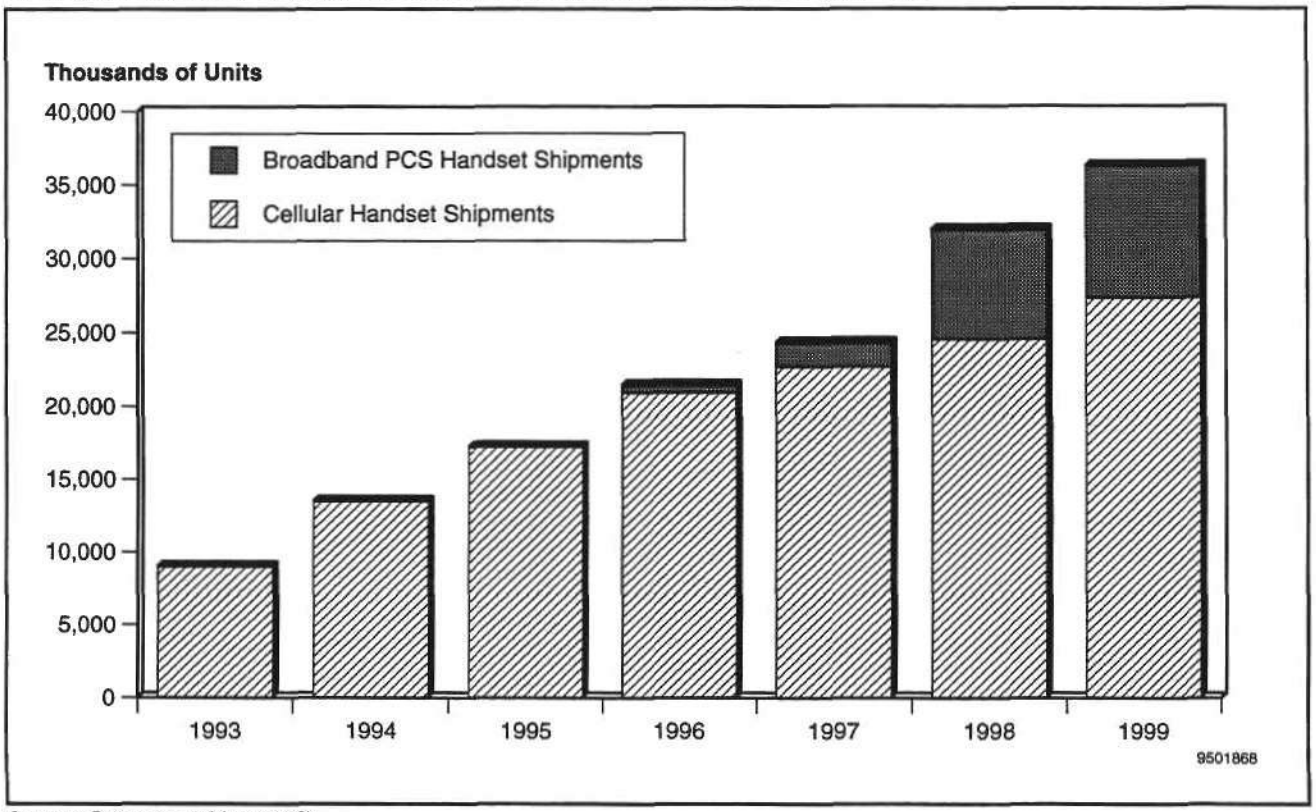
  

**Figure 3**
**North American Cellular and Broadband PCS Subscriber Forecast**




Source: Dataquest (May 1995)

**Figure 4**
**North American Cellular and Broadband PCS Handset Market**




Source: Dataquest (May 1995)

North America is forecast to grow from $526 million in 1994 to more than $2.2 billion in 1999. It is important to note that, although there is a definite distinction between cellular and PCS "dual-mode" handsets in North America now, this distinction will blur as the market moves to "dual-band" handsets approaching 1999. Tables 3 and 4 and Figures 5 through 8 illustrate Dataquest's forecast.

**Table 3**
**Worldwide Cellular and Broadband PCS Production**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|
| **Analog Production** | | | | | | | | |
| Shipments (K) | 14,871 | 22,537 | 24,370 | 24,690 | 23,011 | 20,814 | 15,705 | -7.0 |
| Factory ASP ($) | 448 | 420 | 370 | 330 | 295 | 275 | 285 | -7.5 |
| Handset Factory Revenue ($M) | 6,662 | 9,466 | 9,017 | 8,148 | 6,788 | 5,724 | 4,476 | -13.9 |
| Semiconductor Content ($) | 43 | 42 | 42 | 43 | 43 | 43 | 45 | 1.4 |
| Semiconductor Market ($M) | 639 | 947 | 1,024 | 1,062 | 989 | 895 | 707 | -5.7 |
| **Digital Production** | | | | | | | | |
| Shipments (K) | 1,429 | 4,859 | 11,860 | 22,997 | 36,858 | 59,332 | 84,131 | 76.9 |
| Factory ASP ($) | 810 | 500 | 420 | 360 | 310 | 265 | 235 | -14.0 |
| Handset Factory Revenue ($M) | 1,158 | 2,430 | 4,981 | 8,279 | 11,426 | 15,723 | 19,771 | 52.1 |
| Semiconductor Content ($) | 215 | 135 | 115 | 99 | 86 | 74 | 66 | -13.3 |
| Semiconductor Market ($M) | 307 | 656 | 1,364 | 2,277 | 3,170 | 4,391 | 5,553 | 53.3 |
| **Total Production** | | | | | | | | |
| Shipments (K) | 16,300 | 27,397 | 36,230 | 47,687 | 59,869 | 80,146 | 99,836 | 29.5 |
| Factory ASP ($) | 480 | 434 | 386 | 344 | 304 | 268 | 243 | -11.0 |
| Handset Factory Revenue ($M) | 7,820 | 11,895 | 13,998 | 16,427 | 18,214 | 21,447 | 24,247 | 15.3 |
| Semiconductor Market ($M) | 947 | 1,603 | 2,387 | 3,338 | 4,159 | 5,286 | 6,259 | 31.3 |

Source: Dataquest (May 1995)

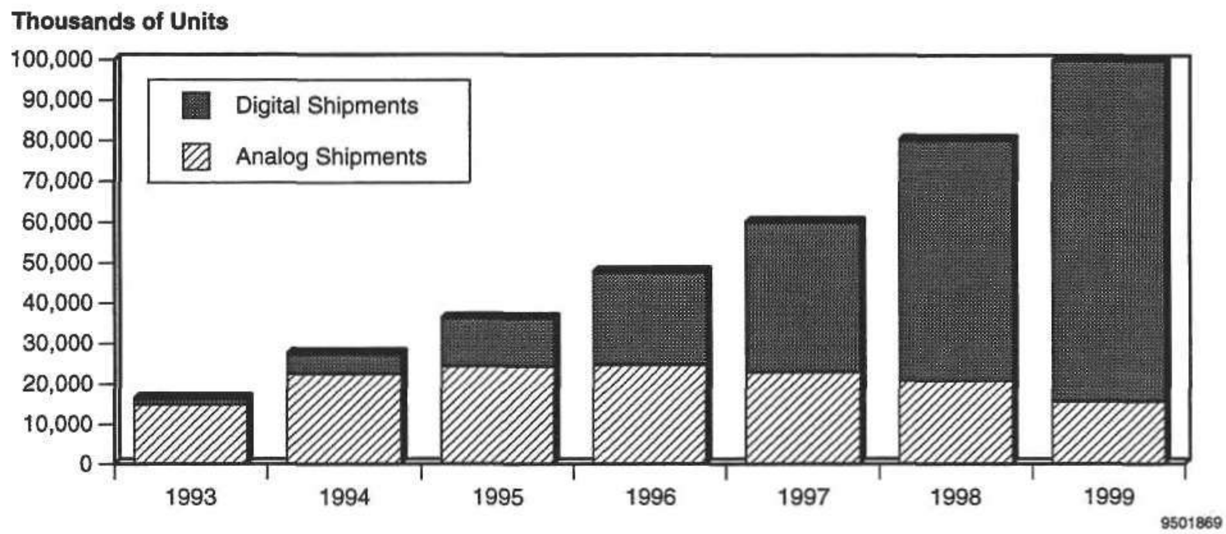
**Table 4**
**North American Cellular and Broadband PCS Production**

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | CAGR (%) 1994-1999 |
|---|---|---|---|---|---|---|---|---|
| **Analog Production** | | | | | | | | |
| Total Shipments (K) | 7,628 | 11,120 | 12,863 | 13,280 | 11,593 | 9,381 | 4,310 | -17.3 |
| Factory ASP ($) | 448 | 420 | 370 | 330 | 295 | 275 | 285 | -7.5 |
| Handset Factory Revenue ($M) | 3,417 | 4,670 | 4,759 | 4,382 | 3,420 | 2,580 | 1,228 | -23.4 |
| Semiconductor Content ($) | 43 | 42 | 42 | 43 | 43 | 43 | 45 | 1.4 |
| Semiconductor Market ($M) | 328 | 467 | 540 | 571 | 498 | 403 | 194 | -16.1 |
| **Digital Production** | | | | | | | | |
| Total Digital Shipments (K) | 119 | 434 | 2,295 | 6,269 | 11,298 | 21,351 | 30,601 | 134.2 |
| Digital Factory ASP ($) | 810 | 500 | 420 | 361 | 309 | 262 | 232 | -14.2 |
| Handset Factory Revenue ($M) | 97 | 217 | 964 | 2,262 | 3,487 | 5,586 | 7,106 | 100.9 |
| Total Semiconductor Content ($) | 215 | 135 | 115 | 99 | 86 | 73 | 66 | -13.4 |
| Baseband Content ($) | 110 | 66 | 55 | 50 | 43 | 37 | 33 | -12.8 |
| RF/IF Content ($) | 74 | 49 | 42 | 34 | 30 | 26 | 23 | -14.0 |
| Other Content ($) | 32 | 21 | 18 | 15 | 13 | 11 | 10 | -14.0 |
| Semiconductor Market ($M) | 26 | 59 | 264 | 621 | 969 | 1,566 | 2,011 | 102.8 |
| Baseband Market ($M) | 13 | 28 | 127 | 316 | 488 | 781 | 1,010 | 104.2 |
| RF/IF Market ($M) | 9 | 21 | 96 | 213 | 336 | 549 | 701 | 101.4 |
| Other Market ($M) | 4 | 9 | 41 | 91 | 144 | 235 | 300 | 101.4 |
| **Total Production** | | | | | | | | |
| Shipments (K) | 7,747 | 11,554 | 15,158 | 19,549 | 22,891 | 30,732 | 34,911 | 24.8 |
| Factory ASP ($) | 454 | 423 | 378 | 340 | 302 | 266 | 239 | -10.8 |
| Handset Factory Revenue ($M) | 3,514 | 4,888 | 5,723 | 6,644 | 6,907 | 8,166 | 8,334 | 11.3 |
| Semiconductor Market ($M) | 354 | 526 | 804 | 1,192 | 1,467 | 1,969 | 2,205 | 33.2 |

Source: Dataquest (May 1995)

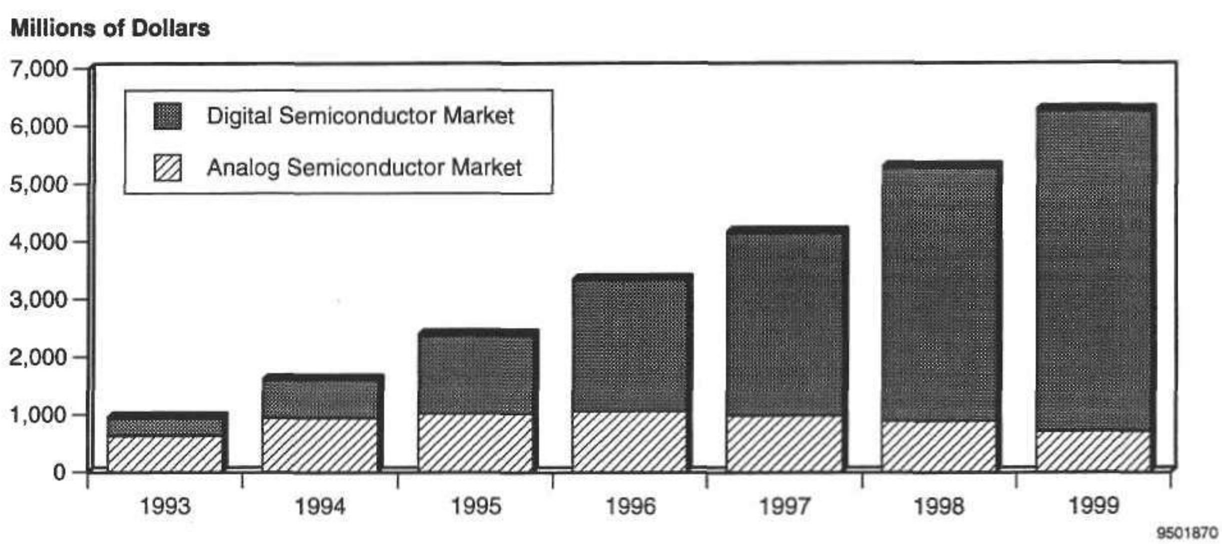
  

**Figure 5**
**Worldwide Cellular and Broadband PCS Handset Production**




Source: Dataquest (May 1995)

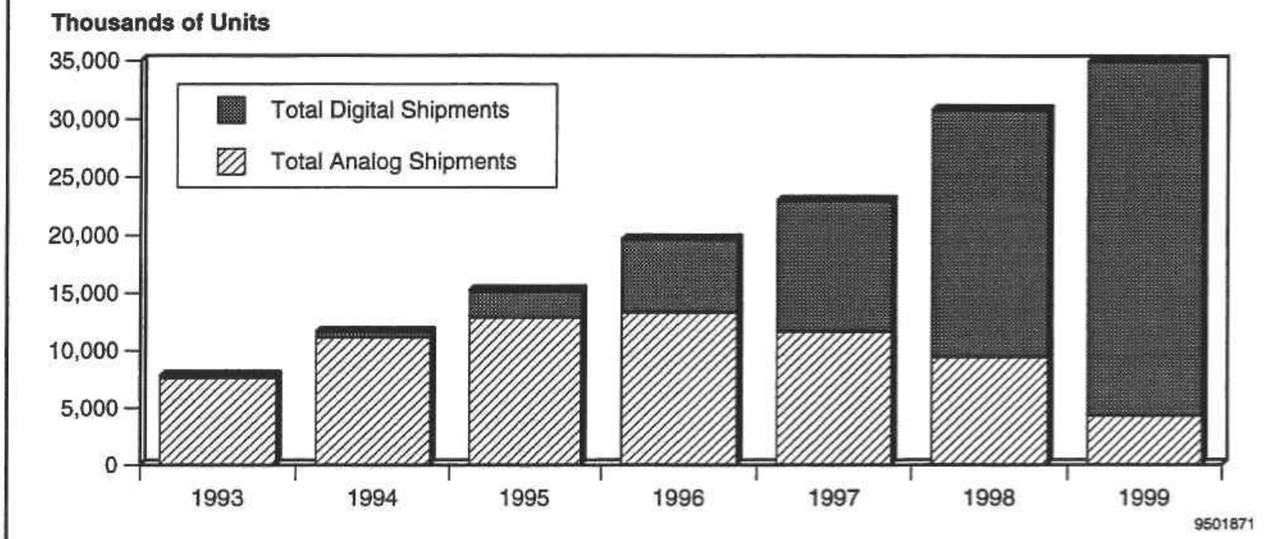
**Figure 6**
**Worldwide Cellular and Broadband PCS Handset Semiconductor Market**




Source: Dataquest (May 1995)

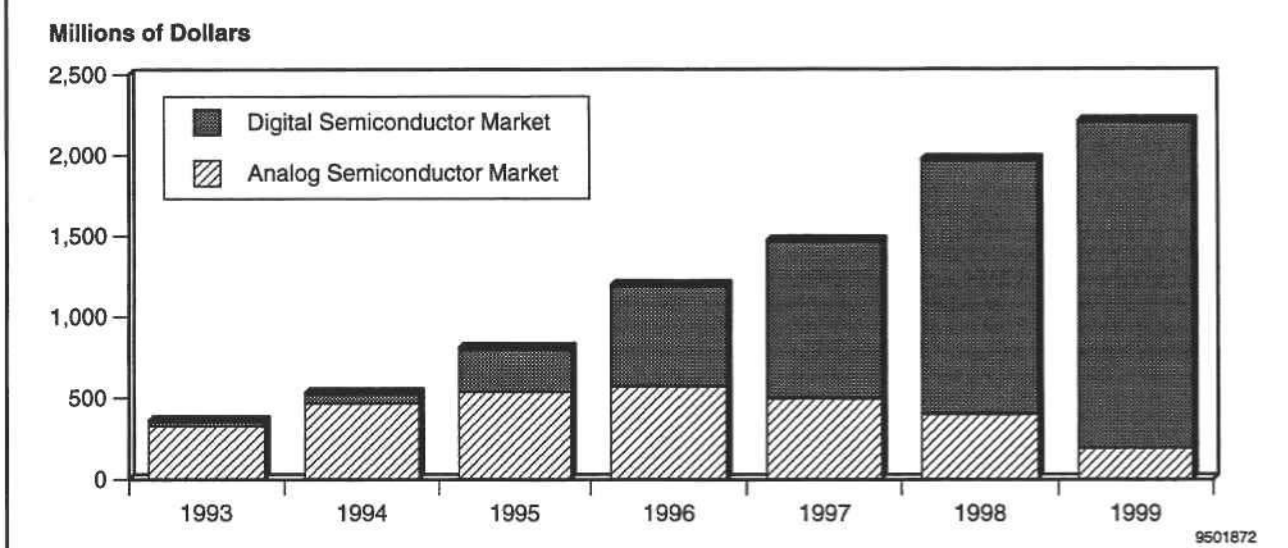
  

**Figure 7**
**North American Cellular and Broadband PCS Production**




Source: Dataquest (May 1995)

**Figure 8**
**North American Cellular and Broadband PCS Semiconductor Market**




Source: Dataquest (May 1995)

## Major Cellular and Broadband PCS Semiconductor Suppliers

Companies including Siemens Semiconductor, Philips Semiconductor, AT&T Microelectronics, and Analog Devices, VLSI Technology, Texas Instruments, and Qualcomm are playing major roles in the merchant semiconductor market for cellular handsets. Some are converting proprietary DSP designs into standard chipset solutions, while others are offering new solutions targeted at offering "tier one" handset manufacturers a low-cost solution and allowing "tier-two" players entry to the market. This section reviews the product offerings from these semiconductor companies.

### Siemens Semiconductor

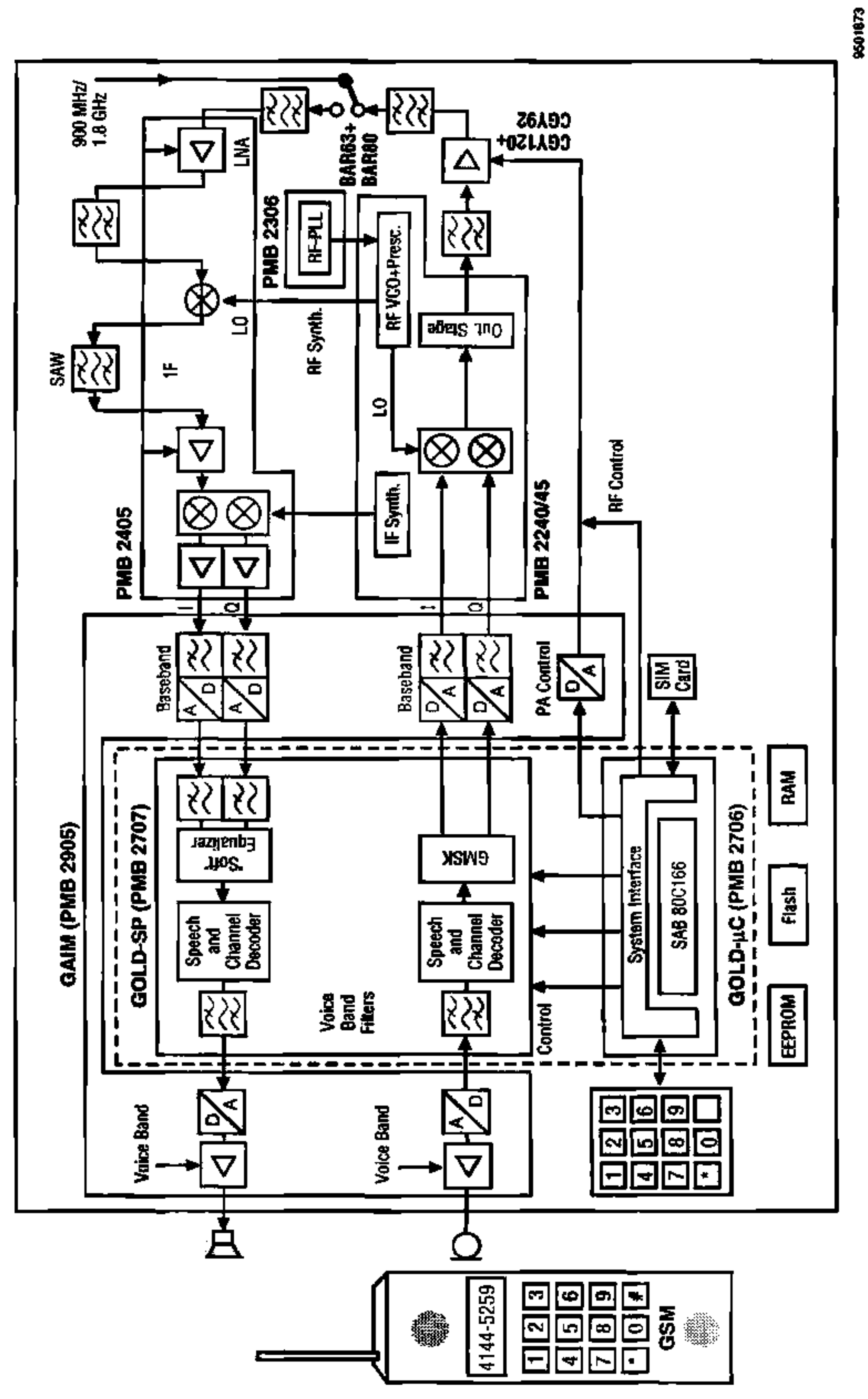
Siemens introduced its GOLD plus (GSM One Chip Logic Device) chipset at Electronica '94 in November. Its new 3V chipset adds a speech codec and voice-band converter to the first-generation GOLD chipset. The A52 encryption algorithm also has been implemented in anticipation of GSM Phase Two. Siemens also introduced a companion GaAs (gallium arsenide) power monolithic microwave integrated circuit (MMIC), the CGY 92, for GSM systems.

As shown in Figure 9, the GOLD plus chipset comprises six chips including three new chips: a signal processor (PMB 2707), a controller chip (PMB 2706), and an analog chip (PMB 2905). Three chips from the previous GOLD chipset are also included: the PMB 2240 transmitter, PMB 2405 receiver, and PMB 2306 phase-locked loop IC. The GOLD Signal Processor (GOLD-SP), PMB 2702, contains two Pine-based parallel DSP cores that deliver total power of more than 50 mips. This chip contains all the algorithms necessary to implement a full-rate speech codec, a channel codec with soft-decision-decoding, and a Viterbi equalizer. It also provides the Gaussian Mean Shift Keying (GMSK) modulation, baseband and voice-band filtering, data services, and encryption. The chip is designed for easy expansion to implement future half-rate vocoding algorithms. The PMB 2706 includes a 16-bit microcontroller and supports low-power operation. The GSM Analog Interface Module, PMB 2905, implements the baseband and voice band A/D and D/A converters. Shipments of the chipset are expected in early 1995 at a price point of $50 each, not including the CGY 92 MMIC. Siemens is following developments in the U.S. wireless markets and has stated that it will adapt its circuits to whatever standards its customers prefer. It has already begun modifications to its current chips to support the DCS-1900 standard.

### Philips Semiconductor

Philips Semiconductor announced a six-chip GSM solution at Electronica '94 that it plans to release in 1995. Its 1995 chipset upgrade will use a customized Philips 16-bit digital signal processor (DSP) for speech and channel coding and equalization. The microcontroller is based on the Motorola 68000. It is also developing a four-chip solution—two baseband chips and two RF/IF chips—targeted for 1996. The 1996 solution probably will merge Philips' proprietary Epics DSP core with a 68000-series core on one chip for the baseband section. This chip also would have a mixed-signal interface. It unveiled its two-chip, 2.7V GSM transceiver at ISSCC in February. One chip is for the RF and the other implements the IF functions. Included in the set are two low-noise amplifiers, fifth-order analog baseband filters, a power-amplifier driver, and an IF synthesizer.

Figure 9
GSM Chipset Example: Siemen's GOLD plus




Source: Siemens

## AT&T Microelectronics

AT&T Microelectronics rolled out its 3V, five-chip GSM solution, Sceptre, in early 1994. Three devices form the physical layer and heart of the solution: the DSP 1618, the CSP1088 conversion signal processor, and the W2020 RF Transceiver with integrated synthesizer. A power amplifier and power control chip round out the design. AT&T is the only supplier not to integrate the microcontroller into its chipset, preferring to give the system designer full reign in the choice of microcontroller for the implementation of layers two and three in the GSM protocol stack. It is assumed that AT&T pursued this design in order to win design-ins with leading manufacturers such as Nokia and Ericsson, which would be reluctant to abandon their existing layer two and three software.

Developed specifically for GSM, the DSP1618 is also sold separately. This chip supplies 26 mips of power at 2.7 mW/mips. The DSP1618 implements MLSE equalization, A5 encryption, convolutional decoding, a speech codec, and a channel codec. The chip also boasts an error correction coprocessor that expedites optimal Viterbi processing for MLSE and convolutional decoding and a bit manipulation unit that speeds burst interleaving and speech vocoding. The CSP1088 performs voice-band and baseband A/D and D/A conversions and GMSK burst modulation with frequency correction. The W2020 was one of the highlights of the ISSCC conference in February. This transceiver is the first fully integrated 3V solution including a transmit modulator, receiver, and frequency synthesizer. This "system chip" is slated to reach volume production in summer 1995. Plans for a GaAs-based power amp and its driver IC, which are supposed to be part of the chipset, have been put on hold as AT&T evaluates its power-amp options.

AT&T also offers products targeted at IS-54 and IS-136 handsets. Its TDMA solution includes: a CSP1027 codec that provides an interface between the speaker and microphone to the DSP; a DSP1617 or DSP1616 baseband processor that implements VSELP and QCELP processing and offers up to 50 mips of power at 5V; a CSP1084 RF/IF interface that contains five digital-to-analog converters and two analog-to-digital converters; a W2010 quadrature modulator that enables direct modulation of RF over 1 GHz; and a W2005 integrated 1-GHz RF/IF mixer.

In addition to its chipset solutions, AT&T is promoting its FlashDSP as a way to cut prototype time for manufacturers developing custom solutions. The FlashDSP chips are not products in themselves. Instead, they are part of a prototyping platform that allows customers that use AT&T DSPs in mass-produced digital consumer products to significantly reduce prototype time. The FlashDSP1618 processor is pin-for-pin compatible with the DSP1618 ROM-encoded counterpart and yields 26 mips at 2.7V. The part costs $1,000 in quantities of 10.

It is also important to note that AT&T has signed licensing agreements with Qualcomm for the critical components in CDMA. However, it has not disclosed any specific plans for products in this area.

## Analog Devices

Analog Devices announced its second-generation GSM solution, the AD20msp410, in February. The package includes a fully compatible Phase 2 software suite and three chips that form the baseband: the AD7015 Baseband Converter, the ADSP-2171 Algorithm Signal Processor (ASP), and the ADSP-TTP01 Physical Layer Processor (PLP). Analog Devices promoted the AD7015 at the ISSCC conference in February as the first fully integrated, baseband/voice-band codec for GSM to combine many of the mixed-signal components required for a GSM handset onto one IC and operate at 3V. The chip includes 11 converters, together with digital filters, modulator, amplifiers, multiplexers, references, and logic to implement a wireless handset codec. In addition to GSM, the chip can be used for DCS-1800 and DCS-1900 handsets. The PLP performs all channel-coding functions and includes a Hitachi H8 16-bit microcontroller. The ASP performs speech coding and soft decision equalization. Analog Devices developed this GSM solution working together with The Technology Partnership of Cambridge, England, a product development and engineering company with expertise in GSM.

ADI expanded its wireless offering in late 1994 when it announced the AD607 and AD608. These parts provide a complete integrated IF solution. The AD607 is versatile enough to be used in GSM, TDMA, and CDMA designs. ADI claims that both parts offer superior performance with very low power consumption operating from a 3V supply. Its RF chip is under development and is expected to be available by mid-1995.

## VLSI Technology

VLSI Technology's Wireless Products Division introduced a new chipset targeted at GSM cellular products at the Cellular Telephone Industry Association's Wireless '95 Show in New Orleans. The GSM solution employs the VP22002 kernel processor and the VP22020 vocoder to perform all the baseband signal processing functions from the speech vocoding to the IF/RF interface. The GSM kernel processor integrates type-approved GSM functional blocks, such as channel coder, equalizer, GMSK modulator, and timing generator, along with VLSI's Functional System Block technology including a 32-bit ARM RISC microcontroller. The ARM processor can deliver a maximum processing power of 13 mips. The GSM Vocoder operates at 13 Kbps and offers fully asynchronous coding and decoding processes, and has two asynchronous data ports and a host microprocessor interface. Pricing for the kernel processor and vocoder is $47 and $18, respectively, in 1,000-piece quantities.

Although these chips are targeted at GSM products, VLSI decided to make its chip announcements in the United States to capture the attention of potential manufacturers of DCS-1900 PCS handsets, which are a derivative of the GSM standard. Moving toward 1996, VLSI plans to introduce a 3V kernel that uses the Oak DSP core, which it licensed from The DSP Group, and a full-rate/half-rate vocoder. It is pushing toward a single-chip solution for GSM by 1997. VLSI is working with Wavecom Inc., a company specializing in RF solutions, to develop an integrated RF design and protocol software. It also plans to introduce a combined GSM/DECT baseband processor in 1997.

CeBIT was the setting for the VLSI Technology and Wavecom introduction of the GTI-2000. This fully integrated GSM system PCB uses the VLSI Technology chipset. In this announcement VLSI began calling these two chips the "TwoC" chipset. The RF module and software for the handset was designed by Wavecom. The developers claim that this 5V product can achieve a talk time of 2.2 to 3.6 hours and stand-by time of 48 hours, depending on the DTX and power control. VLSI expects a future 3V solution to deliver 67 hours of stand-by time. It was announced that the GTI-2000 will be available by mid-1995 and will be marketed to both tier-one and tier-two handset manufacturers.

## Texas Instruments

Texas Instruments announced its new three-chip IS-54B baseband chipset named TCS320IS54B in October 1994. The chipset was designed in a joint effort with Teknekron Communications Systems (TCSI) and includes: the TCM4300 Advanced RF Cellular Telephone Interface Circuit (ARCTIC), a high-performance, mixed-signal device; the TMS320IS54B DSP, a ROM-masked, 16-bit fixed-point DSP capable of 40 mips at 3.3V and tailored to single DSP baseband processing; and the TLV320AC3x Voice Band Audio Processor (VBAP), a high-quality audio codec. Functionally, the ARCTIC combines signal conversion from and to the RF subsystem with wideband data demodulation and other interface timing functions; the DSP handles the voice and channel baseband processing; and the VBAP converts signals to and from the microphone and speaker. TI claims that this chipset cuts power consumption by 60 percent over competing solutions and enables savings up to 30 percent on baseband components. With full production of both 3.3V and 5V devices planned for the first quarter of 1995, pricing for the chipset is less than $60 in quantities greater than 100,000 units.

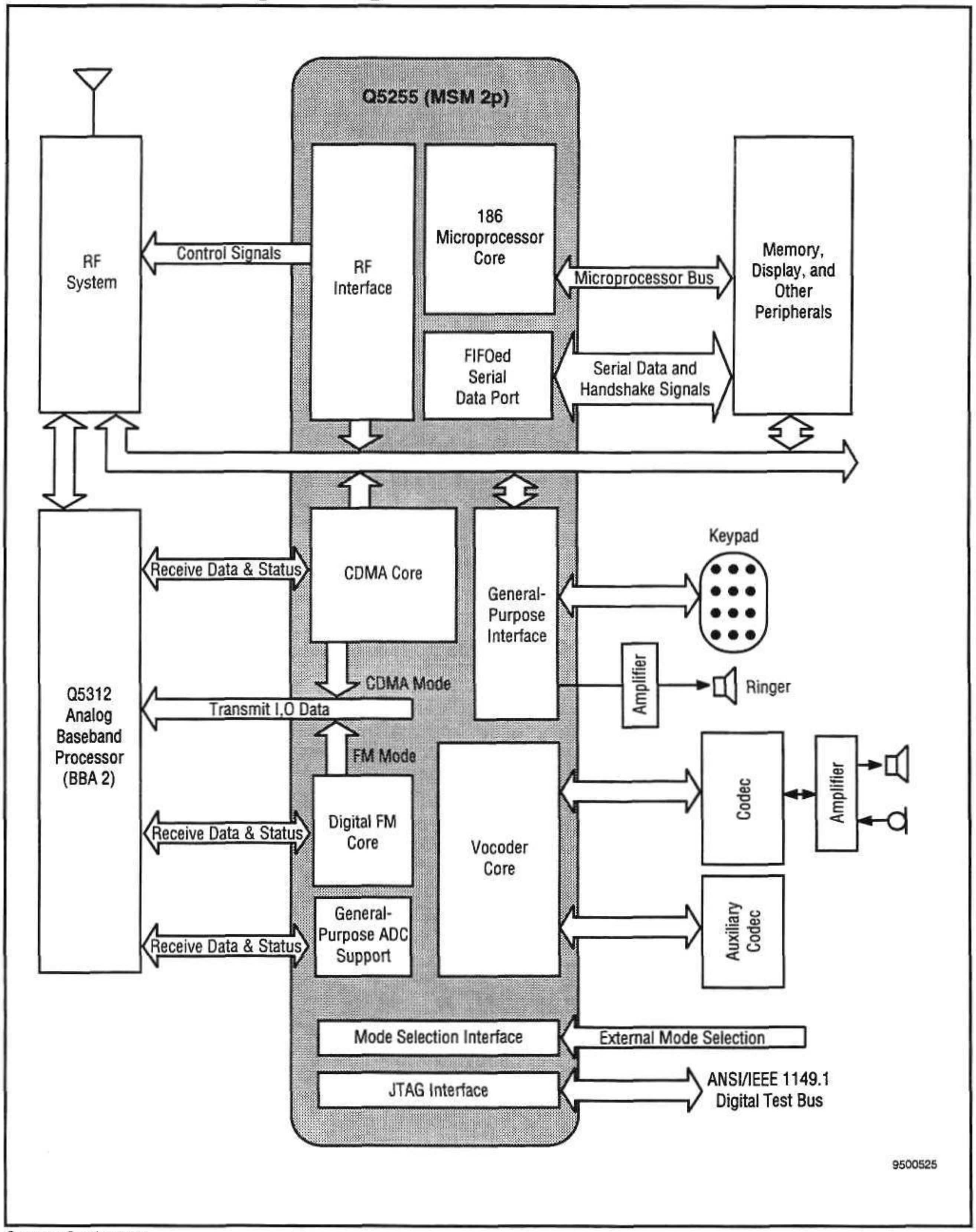
Building on its experience with the IS-54B chipset, TI and TCSI announced plans to develop a new chipset for the IS-136 (IS-54C) standard. This chipset will use the ARCTIC chip, TI's C5X DSP, and a VBAP. Availability for this new baseband product has not been announced yet. TI also has announced plans to produce DSP-based solutions for other standards including GSM, Pacific Digital Cellular in Japan, and eventually CDMA. It also claims to be one of the largest volume suppliers of DSPs for GSM telephones in Europe.

## Qualcomm

Qualcomm has carefully controlled the licensing rights for CDMA chipsets and has been driving the development of the early baseband solutions. Although Qualcomm has licensed many handset and infrastructure companies, the only semiconductor companies known to have licensed key CDMA technologies from Qualcomm are AT&T and Motorola. They are expected to use Qualcomm's chipsets in their first-generation CDMA handsets. In early 1995 Qualcomm announced that it will have a two-ASIC baseband chipset (see Figure 10), to be available beginning in the second half of 1995. The chipset comprises its Baseband Analog Processor (BBA-2) and the Mobile Station Modem (MSM-2). The BBA-2 was developed with a team from Philips Semiconductor.

**Figure 10**
**Qualcomm CDMA Chipset Example**




Source: Qualcomm

## Summary of Major Suppliers of Semiconductor Products

In addition to the companies and products described, a number of other companies are providing semiconductor products for the GSM, DCS-1800, DCS-1900, TDMA, CDMA, Pacific Digital Cellular, and Personal Handy Phone (PHP) markets. Table 5 provides a summary of some top semiconductor companies supplying products for the cellular and PCS markets.

**Table 5**
**Summary of Major Suppliers of Semiconductor Products for Digital Cellular and Broadband PCS**

| Company | Description |
|---|---|
| Siemens Semiconductor | Released a complete 3V chipset in early 1995, called GOLD plus, that provides a six-chip GSM solution using three baseband and three RF/IF chips. |
| Philips Semiconductor | Plans to release a complete chipset in 1995 that provides a six-chip GSM solution. Plans a four-chip solution for 1996. |
| AT&T Microelectronics | Unveiled its 3V, five-chip GSM solution, Sceptre, in early 1994. It offers a chipset solution for the IS-54 and IS-136 handsets. AT&T has signed licensing agreements with Qualcomm for the critical CDMA components. It promotes FlashDSP for manufacturers developing custom solutions with AT&T DSPs. |
| Analog Devices | Introduced its second-generation baseband chipset for GSM, the AD20msp410, in early 1995. It offers an integrated IF chip that can be used in GSM, TDMA, and CDMA designs. |
| VLSI Technology | Announced a two-chip GSM baseband solution, the TwoC chipset, in early 1995. This was followed closely by the announcement of a fully integrated GSM system that employed the chipset called GTI-2000. |
| Texas Instruments | It introduced its TDMA (IS-54B) three-chip baseband solution in late 1994. It also announced development of a baseband chipset for IS-136. It plans to eventually offer GSM, Pacific Digital Cellular (Japan), and CDMA baseband chipsets. |
| NEC | It launched a 3V GSM baseband chipset in early 1994. The chipset required a separate RF front end and communications protocol processor. In late 1994 it announced it is developing a complete GSM chipset that would provide the RF front end, audio, and baseband processing. It is working to implement the baseband in a single chip. Planned availability is mid-1995. |
| Ericsson | It has developed its own proprietary GSM chipset for use in its handsets. In 1994 it was building a new fab to manufacture its own GSM chips. |
| Qualcomm | It has carefully controlled development of the CDMA baseband chipset. In early 1995 it announced a two-chip baseband solution for CDMA handsets. |
| Hitachi | At ISSCC it disclosed details of a four-chipset designed for 1.9 GHz and based entirely on GaAs metal-etch semiconductor field-effect transistors. |

(Continued)

**Table 5 (Continued)**
**Summary of Major Suppliers of Semiconductor Products for Digital Cellular and Broadband PCS**

| Company | Description |
|---|---|
| Toshiba | It is developing a GSM chipset that contains a DSP based on its proprietary TC-8005 DSP core; a Toshiba 16-bit microcontroller; and its bipolar-based RF ICs. Its 30-mips DSP can implement full-rate, 13-Kbps voice compression. It has not disclosed how many chips will be used in its design. Availability is planned for 1996 . Toshiba's Mobile Telephone Division will use the chipset in its GSM handset. |
| Mietec (Alcatel subsidiary) | Alcatel's GSM handset employs a suite of ASICs developed by Mietec. It has a four-chip solution, not including the RF interface. It plans to move to a two-chip baseband solution by 1996. |
| Motorola | It will use its DSP, RF, and microcontroller technologies to field a complete hardware and software solution for the merchant market. It is divulging few details beyond this. It appears that it has licensed CDMA but will probably use Qualcomm's solution for its first generation of CDMA handsets. |
| PCSI (Cirrus Logic subsidiary) | It is developing PHP, PACS, and GSM chipsets. |
| Siliconix (Temic subsidiary) | It plans to have a GSM solution in 1996. Its design will use silicon germanium in the front end. |
| LSI Logic | It unveiled RISC additions to its ASIC-core library, which its customers can use in wireless designs. |
| GEC Plessey Semiconductors | It plans additions to its library of DSP cores built around its strength in RF components. |
| SGS-Thomson Microelectronics | It has developed a new 16-bit, 40-mips DSP core for GSM, the D950, intended for use in ASIC designs. |
| Rockwell | It has begun to talk about its RISC Signal Processor (RSP) architecture. It plans to use the RSP architecture as a foundation for GSM and DECT baseband products it is developing. |
| Hewlett-Packard, Anadigics, Raytheon, Matsushita Electric, M/A Com, Motorola, RF Micro Devices, OKI Semiconductor, Analog Devices, NEC, GEC Plessey, Philips, Texas Instruments, Fujitsu | These companies are suppliers of components for RF and IF solutions. They provide GaAs and/or silicon solutions to the market. |

Source: Dataquest (May 1995)

## Dataquest Perspective and Conclusion

The major growth forecast for semiconductors in the cellular handset market will drive chip companies to develop creative solutions to capture as much of the expanding pie as they can. As standard chipset solutions increase the competition with proprietary solutions developed by tier-one handset manufacturers, chip suppliers to the merchant market will be seeking strategies to compete more effectively.

The teaming of Wavecom and VLSI Technology, Texas Instruments and Teknekron, and Analog Devices and The Technology Partnership for the development of their new wireless products highlights a strategy that is becoming more common for semiconductor manufacturers seeking to supply chips to the wireless arena. These semiconductor companies recognize that they can gain significant advantages by offering complete solutions to the market. To create these products they are developing partnerships with design houses offering expertise in wireless technologies. These partnerships have allowed these companies to move quickly into the market with complete chipset solutions. As the demand for new digital cellular and PCS handsets accelerates, companies that can respond with solid, timely products developed through synergistic partnerships will reap the benefits. Semiconductor companies seeking to enter the wireless markets or expand their presence would be advised to learn from this model of teaming with companies specializing in wireless communications to develop complete solutions for the market.

The products described in this newsletter provide evidence of the progress being made toward more highly integrated, lower-power wireless semiconductors. Table 6 provides a summary of the key semiconductor trends expected over the next five years.

**Table 6**
**TDMA Integration Path**

| | 1992/1993 | 1995/1996 | 1998/1999 |
|---|---|---|---|
| Baseband | Six or seven ICs plus memory chips | Two ICs plus memory chips | One digital IC |
| RF/IF | More than 150 discretes | Three ICs plus discretes | One AFE plus transceiver IC |
| Power | Nonmonolithic PA | Monolithic PA | Monolithic PA plus power control |
| Batteries | Five cells | Three cells | Two cells |

Source: Texas Instruments

**For More Information...**

Dale Ford, Industry Analyst ........................................ (408) 437-8311
Internet address ........................................ dford@dataquest.com
Via fax ........................................ (408) 437-0292



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Perspective

Communications Semiconductors and Applications Worldwide

# Market Analysis

## Pagers: To the Future and Beyond

**Abstract:** *The paging industry experienced significant developments during 1995 that moved it to the brink of providing true personal communications services. This document provides a brief summary of the evolution of paging technology and describes important protocols that will play a fundamental role in the development of paging services and technologies. Finally, new semiconductor opportunities created by advanced paging devices are analyzed along with descriptions of selected new chips that have found applications in pagers.*
*By Dale Ford*

## This Is NOT Your Father's Pager

The paging industry witnessed a flurry of developments during 1995 that set the paging world on a new path to an exciting future. With the introduction of new services, the opening of new markets, and the application of new technologies and standards, the pager has begun a metamorphosis into a true personal communications device. The evolution of paging devices from simple beepers or vibrators into robust devices that will provide services from wireless e-mail to mobile answering machines is shown in Figure 1. New paths of communication have been opened that will make the pager a valuable access point to a network that includes portable and desktop computers, fax machines, telephones, corporate LANs, the Internet, and other pagers and cellular phones.

**Dataquest**

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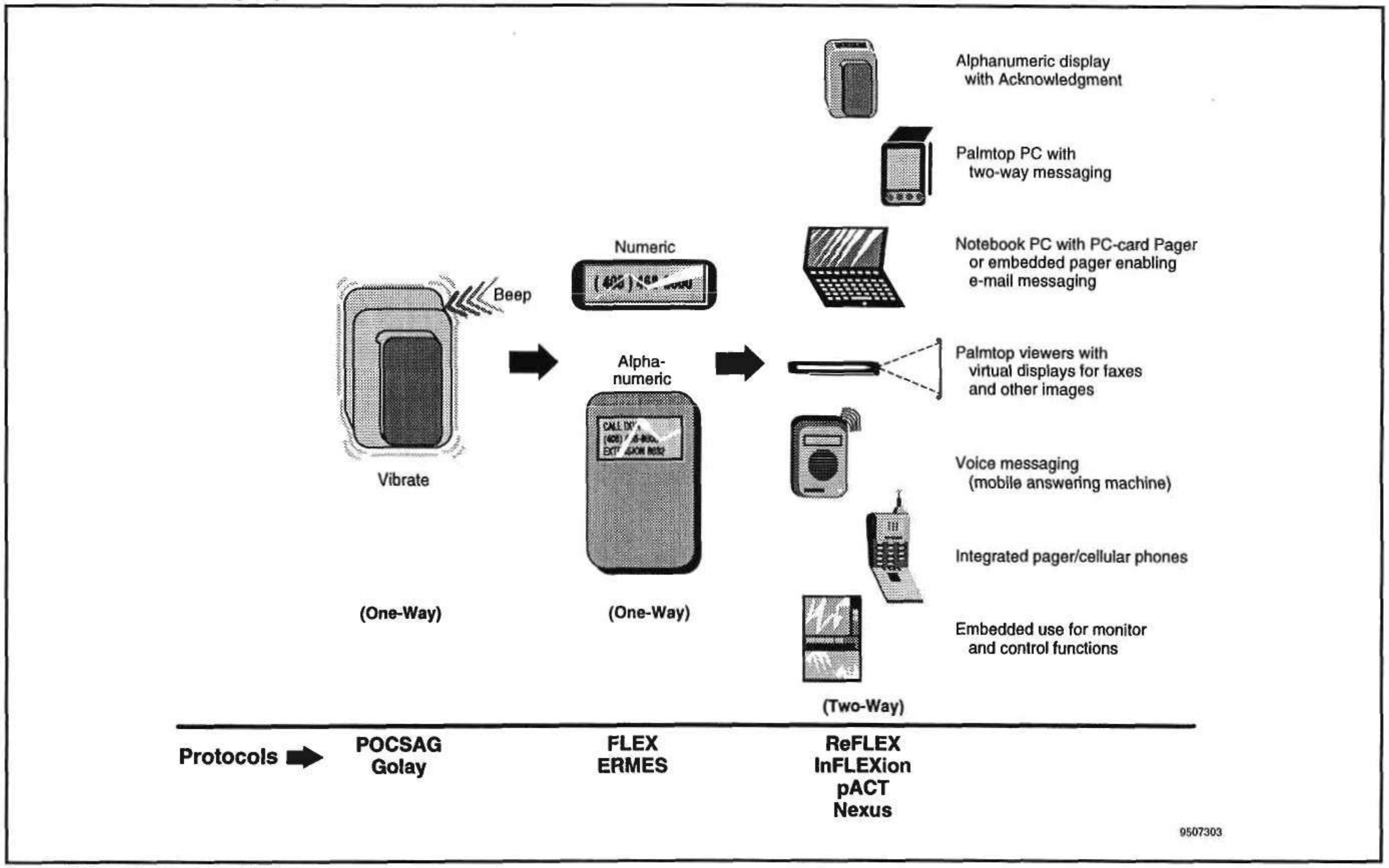
**Filing:** Market Analysis

**Figure 1**
**The Evolution of Paging Terminals: Yesterday, Today, and Tomorrow**




Source: Dataquest (December 1995)

Some of the highlights of 1995 were the introduction of the first two-way paging services by SkyTel on September 18, the continued growth of the paging market to almost 100 million subscribers worldwide, and the introduction and development of new standards and protocols that will provide the foundation for future paging devices and services. It could be said that many of the announcements from pager manufacturers in recent years have been more about flash and style than substance as manufacturers worked to expand the consumer market with pagers in new colors and in form factors such as pens and watches. (However, the miniaturization that has been accomplished in pagers is no small feat.) The major announcements in 1995 revolved around fundamental developments that will take pager functionality to new levels with higher data rates, longer battery life, two-way messaging, and enhanced services. These announcements have significance for chip manufacturers interested in microcontroller, memory, analog, and even DSP semiconductor application opportunities.

## New Protocols, New Pagers

For the past 15 years, the de facto protocol for pager communications has been Post Office Code Standardization Advisory Group (POCSAG). When it was introduced in 1981, it was considered a high-speed protocol. POCSAG operates at 512, 1,200, and 2,400 bits per second (bps) and can handle up to 2 million addresses per carrier. Almost all of the tone-only, numeric, and alphanumeric pagers have operated on the POCSAG protocol. Beginning with the introduction of longer messaging and alphanumeric pagers, POCSAG started to exhibit significant limitations. Even at its highest operating speed, it will not meet the needs of service providers in the future. Many paging service operators provided little marketing and sales support for the introduction of alphanumeric pagers because of critical resource limitations in their systems.

Although Motorola introduced the Golay protocol in 1983 to address some of the POCSAG limitations, this standard has not been widely utilized. The need for increased capacity, improved reliability, higher data rates, longer battery life, and roaming capability led to the introduction of the European Radio Message System (ERMES) protocol and Motorola's FLEX protocol. Now, with the introduction of two-way messaging services and devices, Motorola has begun an aggressive promotion of two new standards, ReFLEX and InFLEXion, that build on its FLEX technology. AT&T Wireless recently announced a competitive two-way messaging standard called personal Air Communications Technology (pACT). Also, Nexus, an Israeli company, has begun promotion of a low-cost two-way system that could most accurately be described as an extension of the POCSAG standard.

### The FLEX Family

Motorola is promoting the FLEX family of protocols as the platform that will move the paging industry into the 21st century. It has moved aggressively, investing $100 million to accomplish its desire to establish FLEX as a worldwide de facto standard for pagers. The establishment of FLEX as a high-tech brand was very successful in 1995, as the term FLEX became almost synonymous with next-generation paging technology. The FLEX brand is becoming to pagers what "Pentium" is to the PC industry. In addition to its use as a brand in the one-way protocol, the term has been extended into the two-way standards with ReFLEX and InFLEXion. A late entrant, the pACT standard of AT&T Wireless is the only major challenger to the FLEX family, and this is only in two-way applications.

### FLEX

The FLEX one-way messaging protocol was introduced by Motorola in June 1993. Motorola describes the major benefits of this new protocol as follows:

- **Capacity/speed:** FLEX operates at speeds of 1,600, 3,200, and 6,400 bps. Compared with a POCSAG 2,400-bps system, the FLEX 6,400 bps provides twice the capacity. A FLEX system can support up to 1 billion individual addresses and up to 600,000 numeric pagers per channel. FLEX pagers are designed to operate at any of the three speeds, eliminating the need for stocking multiple versions and allowing system operators to upgrade their system infrastructures without making subscriber units obsolete.
- **Battery life:** The use of a "synchronous" time slot protocol allows the pager to search for messages at specific times and conserve battery power. A FLEX pager can extend battery life to more than five times that of typical POCSAG pagers.
- **Flexibility:** The FLEX system is designed to coexist with a POCSAG or Golay system so an operator can operate a channel with two protocols prior to dedicating an entire channel to FLEX.
- **Data integrity:** Accurate message delivery is enabled by improving protection from signal fading and implementing checksum validations, message numbering, and positive end-of-message control. FLEX is able to withstand 10ms fade at all speeds and still decode information accurately.

Motorola will also support the Telocator Data Protocol (TDP) suite, which was completed by the Personal Communications Industry Association in 1995. This protocol provides a method of transmitting data such as spreadsheets and word processor files over a paging transmission system. A rival to this protocol, called Limited Size Messaging (LSM), is being backed by AT&T in its pACT protocol.

The FLEX protocol has been adopted by 70 percent of the world's largest paging markets. FLEX technology adopters include 16 of the top 20 U.S. service providers; 21 major carriers in China; and top operators in Indonesia, Singapore, Malaysia, Thailand, Latin America, Canada, and Japan. The FLEX protocol has been licensed to 23 subscriber device and infrastructure manufacturers. Some of the major licensees are NEC, Uniden, Maxon, and Wireless Access for subscriber units and Glenayre and Ericsson for infrastructure equipment.

In an important strategic move, Motorola began licensing the FLEX technology to selected semiconductor companies. The first licensing agreement, with Texas Instruments, was announced in September 1995. Both Texas Instruments and Motorola plan volume production of ICs in the second half of 1996. Motorola has announced that it will enter into additional licensing agreements with other companies in the future and that it will also license the ReFLEX and InFLEXion technologies.

The licensing of the technology to chip manufacturers brings some important benefits to Motorola. First, this will allow it to enlist chip companies on its team to expand the paging market and promote the FLEX high-speed protocol beyond what Motorola could do alone. Ideally, manufacturers of a wide variety of electronics, from pagers to palmtop PCs to home alarm systems, could purchase a FLEX chip and combine it with an off-the-shelf RF receiver to add paging functionality to their products. As the global paging market expands and the U.S. share of the market decreases, promotion of FLEX as an international standard will become more important and more costly. Teaming with the key semiconductor companies will enhance Motorola's global efforts while keeping costs from skyrocketing.

Motorola will also benefit through leveraging the core strengths of semiconductor licensees in improving the technology and reducing costs. From the perspective of the bottom line, the model of licensing chip companies and earning royalties through that channel could be more profitable. Significant costs of marketing and manufacturing can be shared with a team of players or off-loaded to other manufacturers to reduce Motorola's direct costs in the long run. Finally, in a world where the concept of "open standards" has become a critical marketing issue, Motorola will be able to deflect some of the criticism drawn by its creation of a proprietary standard by opening up the technology to semiconductor licenses.

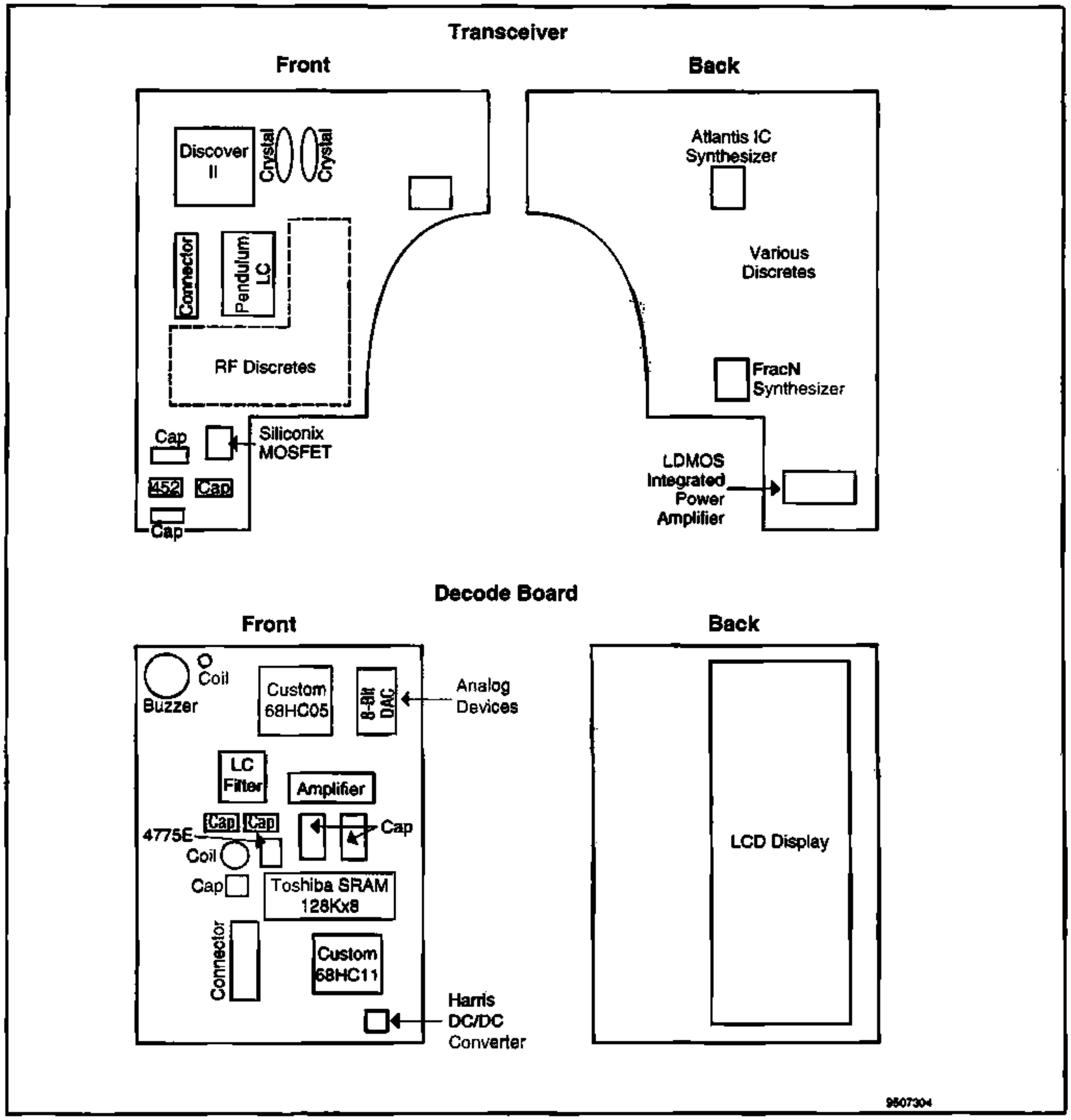
**ReFLEX and InFLEXion**

Anticipating the creation of a new market for two-way paging through the U.S. narrowband PCS auctions, Motorola began working on two-way technologies with potential service providers in the earliest stages. The result of this work was the first set of two-way paging protocols, ReFLEX 25 and ReFLEX 50. The ReFLEX protocol builds on the FLEX technology by adding a response channel to the paging system for all message acknowledgment, customized response, and subscriber-initiated messaging. The first two-way narrowband PCS service in the United States was launched in September 1995 by SkyTel using the ReFLEX 25 protocol. Motorola's infrastructure equipment and Tango pager provided the hardware for the system launch. Figure 2 shows the system cards used in the Motorola Tango.

The InFLEXion protocol is the most advanced two-way paging protocol in the FLEX family. There are both voice and data versions of this protocol. The voice application uses a proprietary compression scheme to store four minutes of voice messages in 4Mb of memory on a subscriber device. It also allows for messages to be stored for later recall in the infrastructure in a memory bank called the Wireless Messaging Gateway if memory needs to be cleared on the subscriber device. InFLEXion also features system registration capability, which will provide increased system capacity by providing regional and local frequency reuse. PageNet will use InFLEXion in its system when it introduces its VoiceNow service in 1996. PageMart will also use InFLEXion and ReFLEX technology in its system. Motorola will supply its Tenor pager for use in these systems. Figure 3 provides a diagram of a two-way messaging system using ReFLEX or InFLEXion technology.

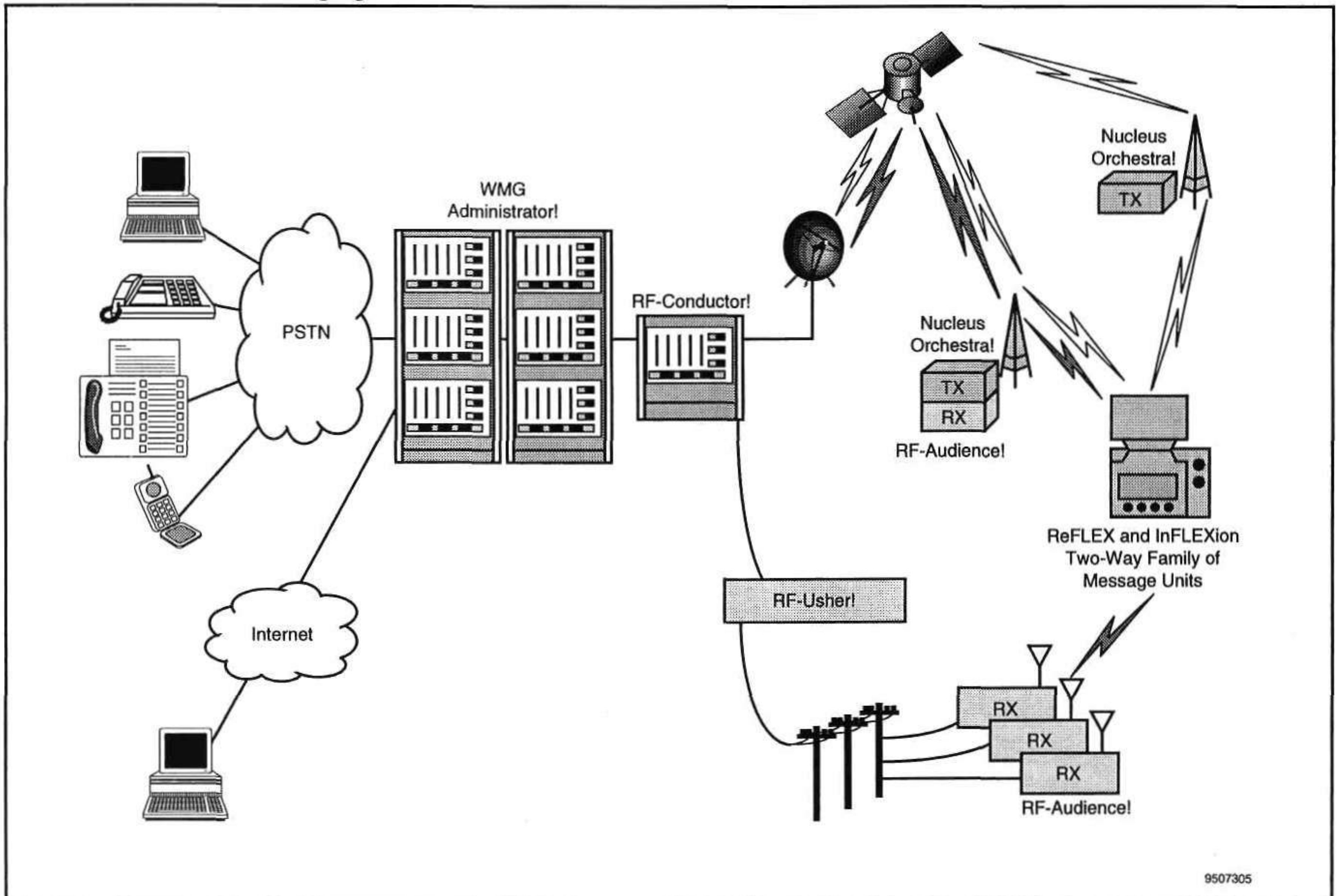
Glenayre Technologies has been licensed by Motorola to design and manufacture infrastructure equipment incorporating InFLEXion and ReFLEX for narrowband PCS. Wireless Access has been licensed to produce pagers using the ReFLEX technology. As mentioned, Motorola will also enter into ReFLEX and InFLEXion licensing agreements with selected semiconductor companies.

**Figure 2**
**Motorola Tango System Cards**




Source: Dataquest (December 1995)

**Figure 3**
**Motorola's Advanced Messaging Solution**




Source: Motorola

## pACT

After winning a national license in the U.S. narrowband PCS auctions, AT&T Wireless announced that it would develop its own two-way technology for paging. In October 1995, AT&T Wireless unveiled pACT. It will deploy this technology in its own network and plans to compete with the FLEX technologies in the market. The pACT protocol is rooted in Cellular Digital Packet Data (CDPD) technology, and, because of its extensive use of Internet Protocol (IP), it should be easily integrated with other networks. AT&T Wireless claims that by using intelligent base stations with automatic registration and network mobility management it will be able to provide superior network efficiencies. As mentioned before, the pACT standard also supports the LSM protocol for transmitting binary data. Other features of this system as described by AT&T Wireless are as follows:

- Use of a cellular-like network design that will enable carriers to add capacity easily and that allows frequency reuse
- Ability to locate subscriber devices within the network
- Full data encryption and authorization
- Symmetrical message-transfer capability within the narrowband PCS spectrum

Early support agreements for the pACT system have been announced with Pacific Communication Sciences Inc. (PCSI) and Retix. PCSI announced a multimillion-dollar contract from AT&T Wireless Services to develop and supply base station equipment. It is ideally positioned for this contract because of its earlier development efforts with CDPD. PCSI is also developing a highly integrated pACT chipset for use in paging devices. Its chipset solution consists of two baseband chips and an IF device designed to minimize cost, power consumption, and size of implementation. The baseband device includes an embedded microcontroller, a pACT protocol communication processor, and an array of peripheral functions. The modem chip performs the channel modulation/demodulation functions and the third chip, the IF device, integrates a significant portion of the IF functions.

Retix was chosen as the sole supplier of the pACT Data Intermediate System (PD-IS), software that will route packet data and handle mobility management. NEC and Ericsson are also expected to develop products for the pACT protocol but have not yet announced specific plans. AT&T Wireless is promoting pACT as an open standard because hardware and software developers can design pACT-based subscriber units without paying licensing fees. The company expects to have a network ready for commercial services in the second half of 1996.

## Nexus

The Nexus two-way paging system is different from the Motorola and AT&T Wireless systems because it does not operate in the new narrowband PCS spectrum. Instead, it uses a carrier's existing paging infrastructure to send messages to a two-way pager; the pagers use 2 MHz in the unlicensed 902-to-928-MHz band (also used by cordless phones and wireless speakers) to transmit replies. To avoid interference with cordless phones and other wireless devices, the pagers use frequency-hopping spread-spectrum technology. In this system, subscribers send responses and initiate messages to other subscriber units, public and private e-mail networks, or a recipient's telephone. When a message is sent to a telephone, it is converted from text to speech for delivery. Nexus is targeting its system as a lower-performance solution that offers the advantage of low cost for service providers. It is avoiding head-to-head competition with Motorola and AT&T Wireless.

Samsung has agreed to manufacture the Two-Way Acknowledgment Group (TAG) pager for Nexus. Glenayre Technologies has signed an agreement to cooperate in the integration of Glenayre's paging infrastructure products and Nexus' reverse channel receivers and two-way applications platform. To bring its service to market, Nexus has formed an alliance with American Paging to form American Messaging Services and plans to roll out services in mid-1996, beginning in Minneapolis; Chicago; and Orlando, Florida. American Paging also won five regional narrowband PCS licenses.

### ERMES

The ERMES concept began in the late 1980s with several European paging operators seeking to create a common protocol for European countries. In 1990, the ERMES memorandum of understanding was approved by 23 signatories, and, by 1993, trials of the system were started in various European countries. The first ERMES service was launched in France, followed by Hungary and Germany. The major goals of the ERMES protocol are to increase subscriber capacity for all types of service, improve messaging performance, and improve battery life. ERMES is a one-way messaging protocol and offers a signaling speed of 6,250 bps. Although operators in Malaysia and the United Arab Emirates have also added their signatures to the memorandum of understanding, the ERMES protocol has not yet become a major influence beyond Europe. It is unlikely that a pattern similar to that of the Groupe Speciale Mobile (GSM) cellular handset will be repeated with the ERMES protocol.

### Other Protocols

In addition to the major standards described, other protocols and systems being developed include the following:

- MobileComm's voice-messaging service, dubbed ReadyTalk, uses spare capacity in existing cellular networks to transmit voice messages from a landline phone to a ReadyTalk transceiver capable of storing up to 30 30-second messages. A subscriber can respond with a 30-second voice message. Following beta tests, MobileComm plans to launch its service in the fourth quarter of 1996 in cellular markets operated by sister company BellSouth Cellular.
- Philips Telecom's Advanced Paging Operators Code (APOC) paging format, is designed to provide a simple migration path from POCSAG-based systems to a system that can operate at 6,400 bps. The company has licensed Glenayre to provide infrastructure equipment for this system.

## Protocol Comparisons and Selections

Table 1 presents a comparison of the major paging protocols, and Table 2 shows the protocol technology selections of the winners of narrowband PCS licenses in the first two rounds of auctions.

## Table 1
## Comparison of Major Paging Protocols

| Protocol | Applications | Operating Frequency | Infrastructure Requirements | Roaming Capability | Outbound Channel | Outbound Signaling Speed | Inbound Channel | Inbound Channel Signaling Speed |
|---|---|---|---|---|---|---|---|---|
| **POCSAG** | | | | | | | | |
| Low-speed, one-way worldwide prevailing technology | One-way numeric and alpha (4-bit/7-bit) | Any available paging frequency | Existing infrastructure | Not supported | 25 KHz | 512, 1,200 or 2,400 bps | NA | NA |
| **ERMES** | | | | | | | | |
| European one-way protocol | One-way numeric and alpha (4-bit/7-bit binary) | 169.425 KHz to 169.8 MHz | Mostly new infrastructure | Yes, between ERMES systems | 25 KHz | 6,250 bps | NA | NA |
| **FLEX** | | | | | | | | |
| High-speed, one-way standard | One-way numeric and alpha (4-bit/7-bit binary symbolic characters) | Any available paging frequency | Modest upgrade (typically) | Supported | 25 KHz | 1,600, 3,200, or 6,400 bps | NA | NA |
| **ReFLEX 25** | | | | | | | | |
| Two-way messaging and data protocol (can also put two channels in 50 KHz) | Two-way short messages (4-bit/7 bit, binary) | Out: 929-932 MHz and 940-941 MHz In: 901-921 MHz | Modest transmit upgrade or new transmit plus new receive infrastructure | Yes | 25 KHz or 50 KHz | 1,600, 3,200, or 6,400 bps per 25 KHz channel | 12.5 KHz in 901-902 MHz | 800, 1,600, 6,400, or 9,600 bps |
| **ReFLEX 50** | | | | | | | | |
| Two-way messaging and data protocol | Two-way short messages (4-bit/7-bit binary) | Out: 929-932 MHz and 940-941 MHz In: 901-902 MHz | Modest transmit upgrade or new transmit plus new receive infrastructure | Yes | 50 KHz | Up to 25.6 Kbps | 12.5 KHz in 901-902 MHz | 9,600 bps |
| **InFLEXion Voice** | | | | | | | | |
| Advanced voice messaging protocol (supports up to seven subchannels) | Voice paging (with acknowledgement) | Out: 930-931 MHz and 940-941 MHz In: 901-902 MHz | Modest upgrade to new ReFLEX infrastructure | Yes | 50 KHz | Digitally processed compression | 12.5 KHz in 901-902 MHz | 800, 1,600, 6,400, or 9,600 bps |

(Continued)

**Table 1 (Continued)**
**Comparison of Major Paging Protocols**

| Protocol | Applications | Operating Frequency | Infrastructure Requirements | Roaming Capability | Outbound Channel | Outbound Signaling Speed | Inbound Channel | Inbound Channel Signaling Speed |
|---|---|---|---|---|---|---|---|---|
| **InFLEXion Data** | | | | | | | | |
| High speed, two-way data protocol (supports up to seven subchannels, each up to 16 Kbps; 50-KHz channels capacity to 112 Kbps) | Two-way data (4-bit/7 bit, binary) | Out: 930-931 MHz and 940-941 MHz In: 901-902 MHz | Modest upgrade to InFLEXion Voice infrastructure | Yes | 50 KHz | 4,000, 8,000, 12 Kbps or 16 Kbps per subchannels | 12.5 KHz in 901-902 MHz | 800, 1,600, 6,400, or 9,600 bps |
| **pACT** | | | | | | | | |
| Two-way messaging and data protocol | Two way short messages and data | Out: 930-931 MHz and 940-941 MHz In: 901-902 MHz | New transmit plus new receive infrastructure | Yes | 50 KHz | 8,000 bps | 50 KHz or 12.5 KHz | 8,000 bps |
| **Nexus** | | | | | | | | |
| Two way messaging and data systems | Two way short messages | Out: 800-1,000 MHz In: VHF, UHF, or 902-928 MHz | Minor update to POCSAG infrastructure plus new receive infrastructure | Yes | 7.5 KHz | 512, 1,200, or 2,400 bps (POCSAG) | 12.5 KHz, 25 KHz or 50 KHz | 200 bps |

NA = Not applicable
Source: Motorola, AT&T, and Nexus

**Table 2**
**Technology Selections of Narrowband PCS Winners**

| Service Provider | License | Technology Selection |
|---|---|---|
| PageNet | National | InFLEXion Voice; considering ReFLEX 25 |
| AT&T Wireless | National | pACT |
| SkyTel (MTel) | National | ReFLEX 50 |
| AirTouch Paging | National and three regions | ReFLEX 25 |
| BellSouth Wireless | National | Leaning toward ReFLEX 25 |
| PageMart II | National and five regions | ReFLEX 25 and InFLEXion Voice |
| PCS Development | Five regions | InFLEXion Voice |
| MobileMedia PCS | Five regions | ReFLEX 25; evaluating InFLEXion and pACT |
| American Paging | Five regions | ReFLEX 25; possible addition of InFLEXion (Also deploying Nexus) |
| Adelphia Communications | Three regions | No information |
| Benbow PCS Ventures | Two regions | Evaluating ReFLEX 25, InFLEXion, and pACT |
| Ameritech Mobile Services | One region | Evaluating ReFLEX 25 |
| Insta-Check Systems | One region | Evaluating ReFLEX 25 and InFLEXion |

Source: Dataquest (December 1995)

## North American Pager Manufacturers

Although North America has been a significant importer of pagers, there is a growing trend to locate manufacturing in the region of consumption. For example, Uniden claims it has experienced major increases in pager sales in North America, and it is shifting design activities to Fort Worth, Texas, and establishing manufacturing in Mexico. Dataquest predicts that production of one-way pagers will decline in North America. However, the growth in production of two-way pagers will result in a 6 percent compound annual growth rate in total North American pager production from 1994 to 1999. Table 3 presents a summary of pager design and manufacturing activity in North America.

## Technologies and Chips Pushing the Envelope

The paging products that were introduced in 1995 are impressive, but exciting new technologies that will form the foundation for the next generation of pagers are already in the advanced stages of development. Introduction of even more advanced paging products will both enable new market opportunities for service providers and present new applications opportunities for semiconductor manufacturers. While pagers present a high-volume opportunity for microcontrollers such as Motorola's 68HC05 and 68HC11, there are other chip opportunities emerging in pager products.

### Low-Power Chips

Pagers are leading the charge down the low-voltage, low-power curve. Although many other products are at 3V implementations, some pager chips have been developed for 1V operation.

**Table 3**
**North American Pager Manufacturing and Design Locations**

| Company | Design Location | Manufacturing Location |
|---|---|---|
| Motorola | One-way: Boynton Beach, Florida | One-way: Boynton Beach, Florida; Chihuahua, Mexico; and Puerto Rico |
| | Two-way: Fort Worth, Texas | Two-way: Forth Worth, Texas |
| NEC | - | Guadalajara, Mexico |
| Uniden | Forth Worth, Texas | Mexico (planned) |
| Panasonic/Matsushita | Alpharetta, Georgia | Peachtree, Georgia (mainly numeric) |
| AT&T | - | Mexico |
| Samsung | - | Deerfield Beach, Florida (final assembly only) |

Source: Dataquest (December 1995)

### Memory

Pagers present an ideal opportunity for low-power memory products. While lower power is obviously desirable from the perspective of extending battery life, low-power memory will have even more importance in the new voice pagers. The current memory being used in two-way voice pager designs pose a problem for RF signal quality because of the noise created during the refresh cycle. One possible solution for this problem comes from Nexcom Technology. It has developed NexFLASH, which it claims has the advantages of both EEPROM and EPROM-flash without their limitations. Nexcom's new serial flash memory operates on low power and has been demonstrated to store 10 minutes to 15 minutes of voice on one 8Mb chip. This type of product has exciting potential in voice pager applications. Motorola has also done materials research that has led to breakthroughs in nonvolatile memory. Its ferroelectric nonvolatile memory provides the advantage of low-voltage, low-energy switching, which is also ideal for wireless applications.

### Power Amplifiers

In another important development related to low-power technology, Motorola has developed a scalable, low-cost RF power amplifier. Its Lateral DMOS (LDMOS) power amplifier is used in the Tango Pager shown in Figure 2.

## DSPs

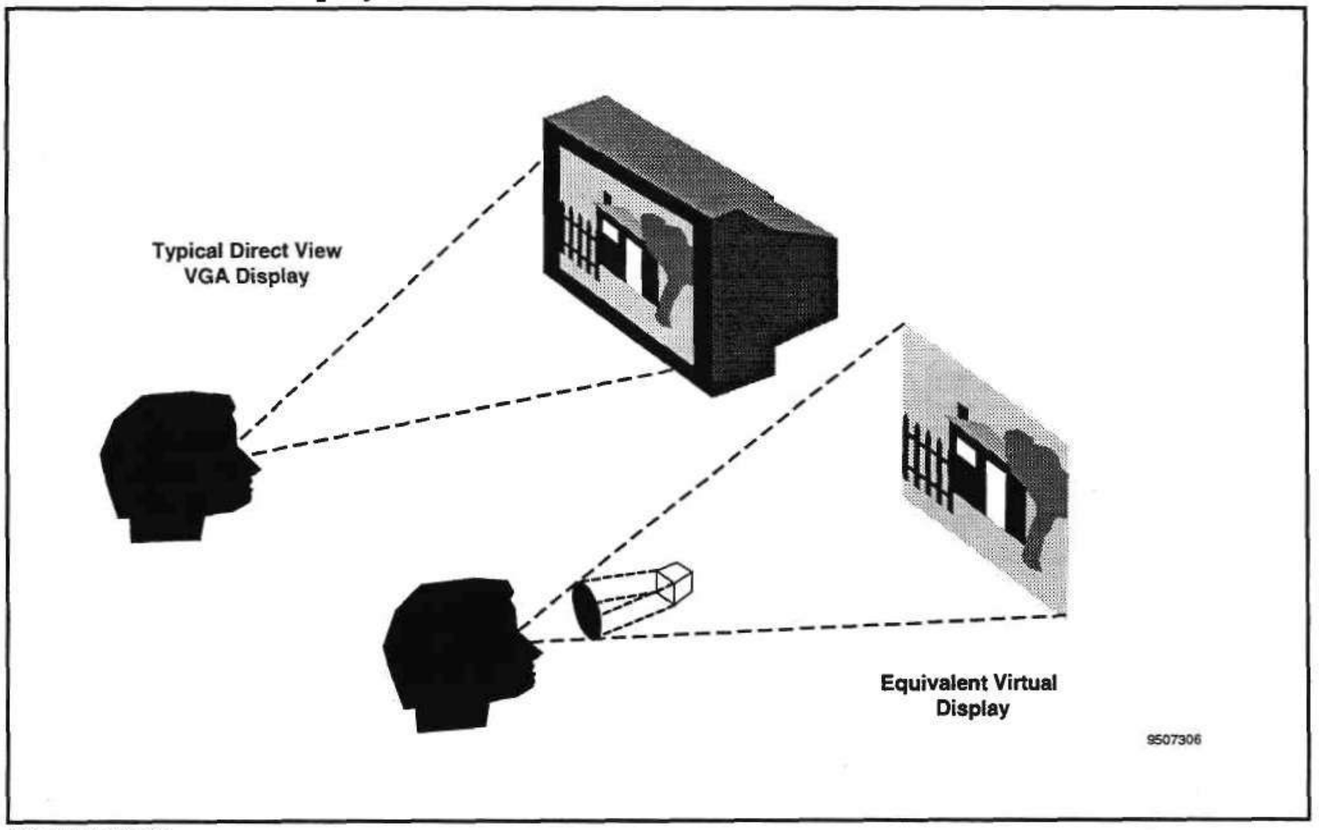
The new high-speed protocols and products that implement voice (and, in the future, image) compression will present a new application for DSPs that can deliver tailored, cost-effective processing power. AT&T Microelectronics has already begun promoting its Peace of Mind Processor (POMP) for pager solutions and has design-wins in Motorola products. It would also appear that Motorola is seeking to leverage Texas Instruments' DSP technology through its "strategic" licensing agreement.

## Virtual Display

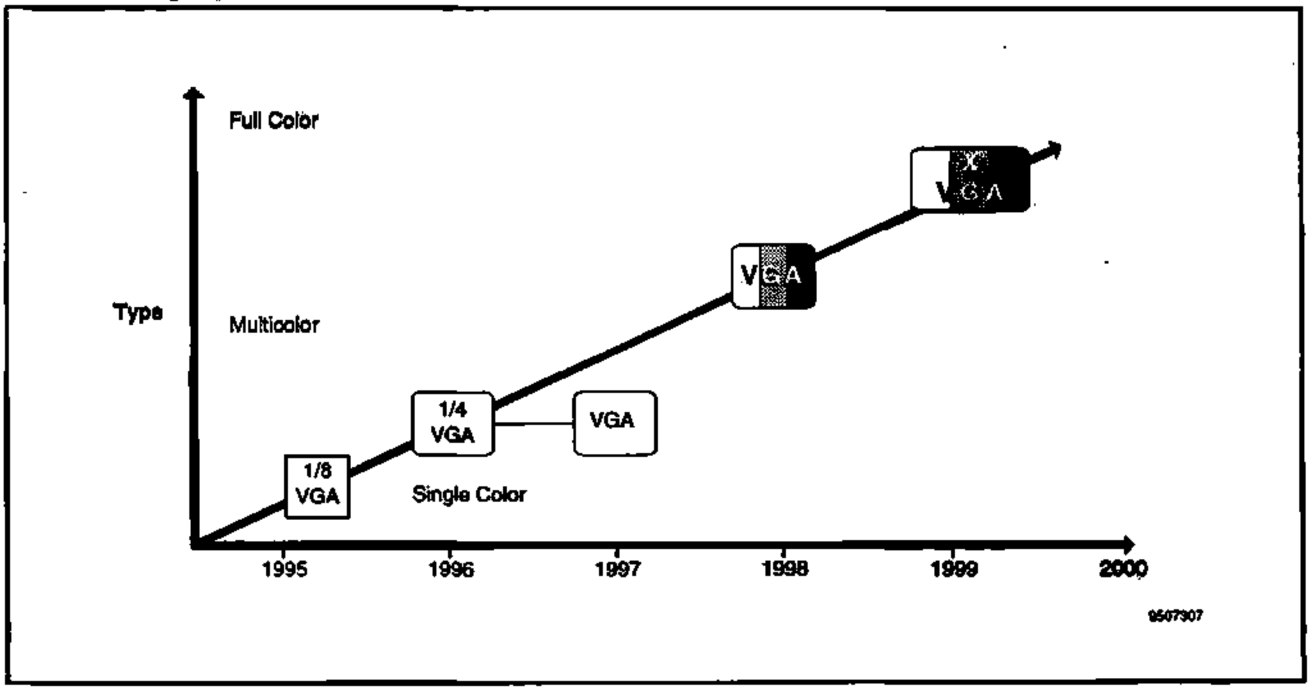
At its 1995 Horizons conference, Motorola unveiled its development of virtual display technology for mobile applications. As shown in Figure 4, this type of display would eventually allow a pager that fits in the palm of the hand to present a full VGA image. A lens that measures 1 cubic inch could present a full VGA image of 36 x 21 inches. Development of this display was started about two years ago and is already in its second redesign, with major improvements in power and size. By early 1995, a device had been developed that could display a monochrome one-eighth VGA image, or 14 lines of 40 characters with less than 70mW power drain. It was expected that the company would achieve a 16-level gray-scale image by the end of 1995. Figure 5 shows the development path that Motorola plans to follow. By the end of 1996, it expects power consumption to be reduced to 30mW to 40mW. The company is working with several customers and expects to have actual product designs using the device by the end of 1996. Although there are myriad applications for such a device, the most obvious application is in paging technology.

**Figure 4**
**What is a Virtual Display?**




Source: Motorola

**Figure 5**
**Virtual Displays of the Future**




Source: Motorola

Low-cost optics is one of the key elements in this display. Motorola has accessed patented technology that has led to the development of a plastic, refractive, defractive, single-fold lens. Other technologies developed by Motorola for this product are as follows:

- Advanced gallium arsenide processing technology for low-power emissive image source
- Aggressive, ultrafine geometry interconnect technology for reduced weight and size
- Integrated CMOS driver electronics for reliability and ease of use

Reflection Technology has also developed a virtual display used in a product called FaxView, a mobile cellular data messaging device. The FaxView uses Scanned Linear Array display technology, the same technology featured in Nintendo's 3-D immersion game system, Virtual Boy. The FaxView is able to store 20 fax pages and presents an image equivalent to a 12-inch screen with 864 x 256 pixel resolution. However, the main drawback to this product for pager applications is the power consumption levels.

## Summary

A review of the new paging products and technologies that came to the market in 1995 offers a glimpse of the exciting potential this market holds. While cellular data products continue on a slow development path, paging solutions for voice, data, and image communications have hit an aggressive curve. With current and forecast capabilities, pagers could capture a major share of the wireless data communications market before effective cellular data solutions are widely available. Although Short Messaging Service (SMS) is available through cellular services, it comes up short on many aspects, such as in-building penetration, battery life, and cost of the subscriber unit when compared with pagers. On the other hand, pager products will soon be available that provide solutions to the majority of the data communications needs of a mobile environment, from e-mail messaging to fax capability.

Semiconductor manufacturers will be key players on the development teams pursuing the next-generation technologies. With the use of pagers in imaging and voice applications, the development of efficient compression technology for mobile applications should capture increasing interest. As chip companies seek new opportunities for their microcontrollers, DSPs, memory, power amplifiers, and RF devices, they will be presented with familiar challenges. As always, mobile products are pushing chip suppliers to provide solutions that offer higher integration and higher performance with lower power consumption and lower cost.

**For More Information...**

Dale Ford, Senior Industry Analyst ........................................ (408) 468-8311
Internet address ..........................................................dford@dataquest.com
Via fax ................................................................................ (408) 954-1780



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Competitive Dynamics

Communications Semiconductors and Applications Worldwide

# Product Analysis

## 100-Mbps LAN Chips—The Race Is On

**Abstract:** *This article summarizes competitive semiconductor offerings in the new 100-Mbps LAN standards of Fast Ethernet and 100VG-AnyLAN. Fast Ethernet has received broader support to date. A majority of companies are targeting margin-laden mixed-signal transceivers.*
*By Greg Sheppard*

### Speed Is the Need

The year 1995 is one of the most dynamic ever in the networking chip business because numerous products are being introduced to support the competing Fast Ethernet and 100VG-AnyLAN 100-Mbps standards.

The point has now been passed as to whether 100-Mbps will be a success because 3 million adapter cards and hubs port are expected to ship this year. The market has been accelerated by products being specified to handle either 10- or 100-Mbps in dealing with Ethernet frames. Network managers are expected to be attracted to this new 10/100 technology, which has only a modest price premium. For further analysis of the market, refer to the Communications Semiconductors and Applications Worldwide Market Analysis newsletter titled "New High-Speed LAN IC Opportunities Hit the Ground Running," published July 5 (CSAM-WW-MA-9502).

### Technology 101

There are two primary competing technologies positioning as the mainstream 100-Mbps upgrade for traditional Ethernet and token-ring networking. The merits of each have been extensively debated, and there is no lack of independent test data demonstrating the superiority of each (in given applications).

**Dataquest**

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## Fast Ethernet

Fast Ethernet is based on IEEE standard 802.3u, which is near full ratification but is already commercially shipping in volume. Fast Ethernet uses the same CSMA/CD access method as 10-Mbps Ethernet but operates at a higher clock rate and uses different transceiver technology and additional signal pairs to minimize radio frequency (RF) and transmission line issues.

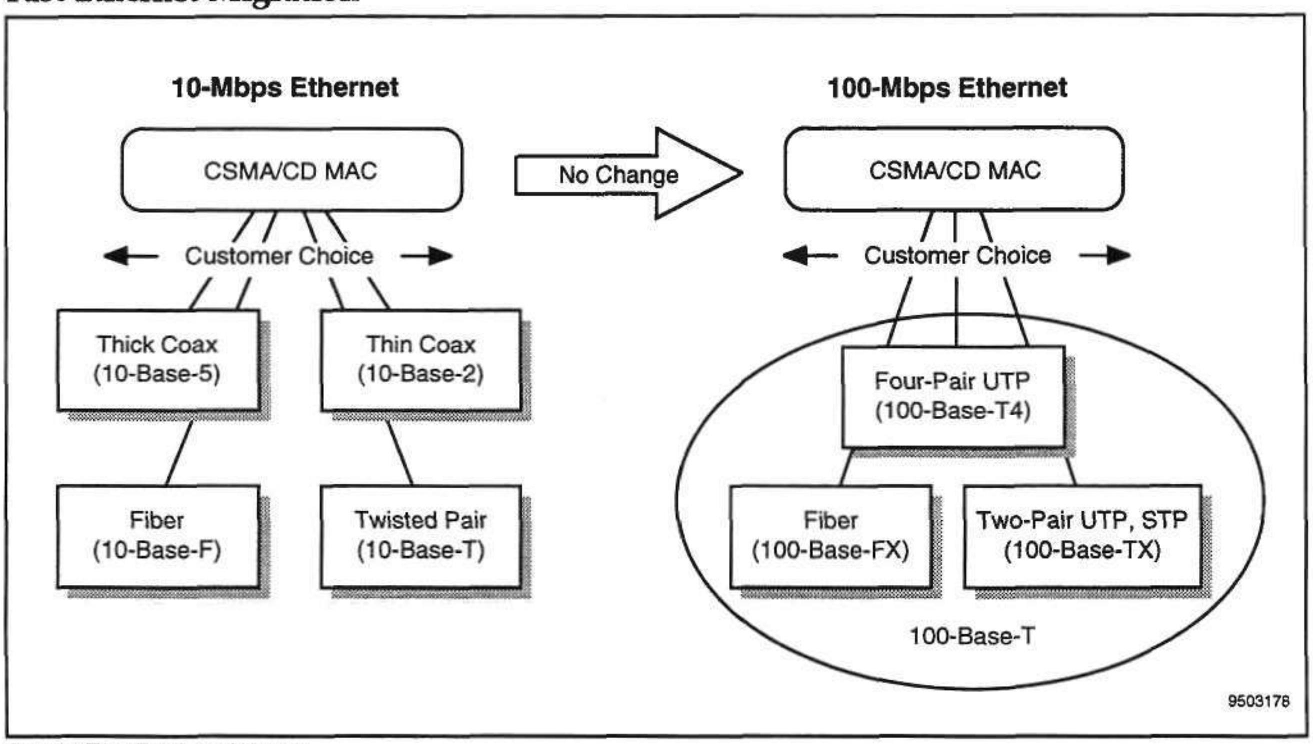
As shown in Figure 1, Fast Ethernet offers a variety of media interfaces, each requiring its own interface silicon. The primary trade-off in interface types is cable run distance for speed. The media-independent interface (MII) acts similarly to the auxiliary transceiver connector (AUI) in current Ethernet, allowing flexibility for different cable/transceiver types. The T4 connection refers to four unshielded twisted pairs (UTPs), TX denotes two UTP or shielding twisted pairs (STPs), and FX refers to fiber.

## 100VG-AnyLAN

The 100VG-AnyLAN approach to fast networking is based on accommodating both Ethernet and token-ring traffic and originally was targeted at just voice grade cabling, hence the "VG" in the name. AnyLAN has its own IEEE standard effort as well, known as 802.12. As with its competing technology, AnyLAN hub ports and adapter cards are shipping in volume.

Instead of CSMA/CD access, AnyLAN employs a demand priority approach where time-sensitive multimedia traffic can be given priority. Figure 2 shows the protocol stack for AnyLAN. The media interface initially offered is with four UTP pairs supported in cable categories 3, 4, and 5. Support is planned for two-pair UTP and STP as well as fiber-optic cabling.

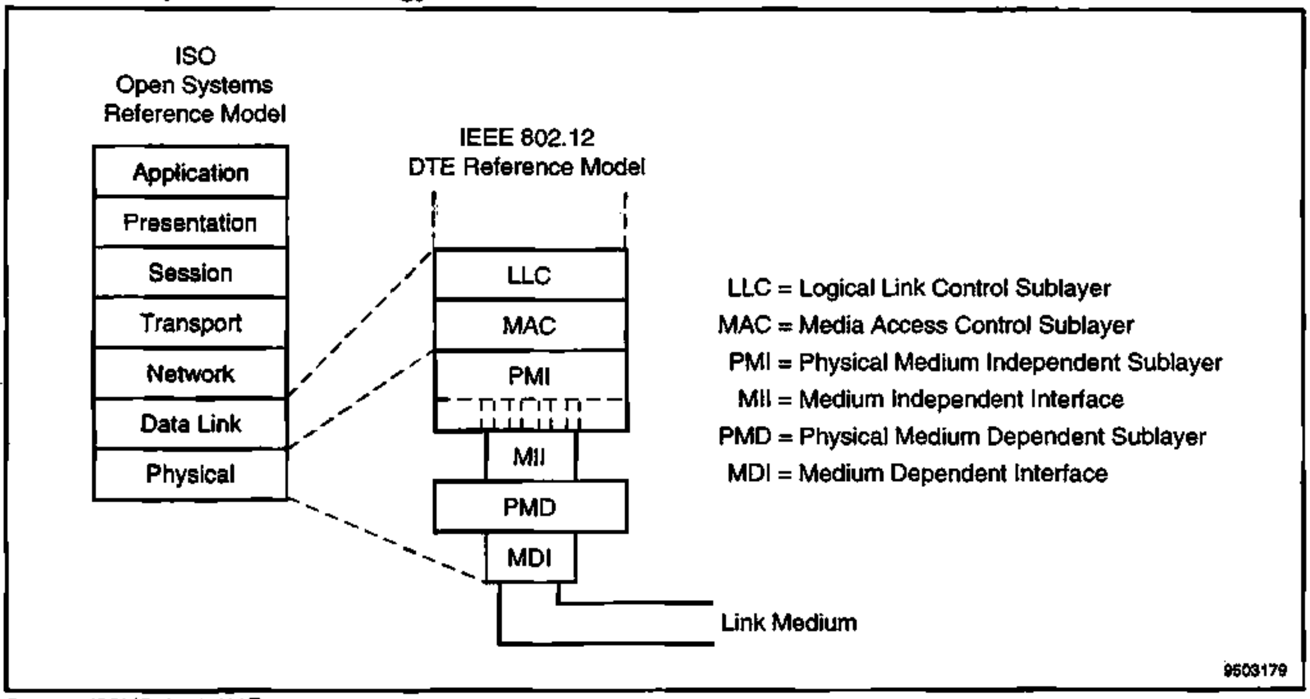
**Figure 1**
**Fast Ethernet Migration**




Source: Fast Ethernet Alliance

**Figure 2**
**100VG-AnyLAN Technology Architecture**




Source: 100VG-AnyLAN Forum

## Competitive Offerings

Table 1 presents the current lineup of silicon vendors offering enabling products such as transceivers, controllers (MAC and physical medium support), and hub functions such as repeaters.

**Table 1**
**Fast Ethernet and VG-AnyLAN Silicon Suppliers**

| Company | Transceiver | Controller/Hub Function |
|---|---|---|
| AMCC | VG (Fiber) | |
| AT&T Microelectronics | VG (UTP) | VG (E/ISA, PCI), Repeater |
| Broadcom | Fast (T4) | Fast Repeater |
| Cypress | Fast (T4) | |
| Digital | | Fast (PCI bus) |
| ICS | Fast (TX) | |
| MicroLinear | Fast (TX) | |
| Motorola | VG planned | VG planned |
| National | Fast | Fast |
| Pericom | VG | |
| SEEQ | | Fast (4 port) |
| SMC | | Fast |
| Texas Instruments | | Fast and VG (Dual) |
| Fast—Fast Ethernet | | |
| VG—100VG-AnyLAN | | |

Source: Dataquest (June 1995)

## AT&T Microelectronics

AT&T Microelectronics is a prime supporter of the 100VG-AnyLAN standard. With its Regatta 100 family, it covers most implementation options from adapter cards to hub/repeaters. The family comprises the ATT2X01 twisted-pair transceiver, ATT2R01 repeater, and two MAC parts ATTMD01 for E/ISA buses and the ATTMD11 for PCI buses. The company claims an adapter card chipset cost of $51.65 and a repeater port cost of $21.15 in 100,000-unit volumes.

## Broadcom

Broadcom is an up-and-coming start-up focused on DSP-based, mixed-signal digital communications products. So far it has done an outstanding job introducing the BCM5000, a Fast Ethernet T4 transceiver ($30 in 1,000-unit quantities). It also has introduced BCM5012, believed to be the industry's first Fast Ethernet repeater controller capable of supporting up to 12 ports ($108 in 1,000-unit quantities).

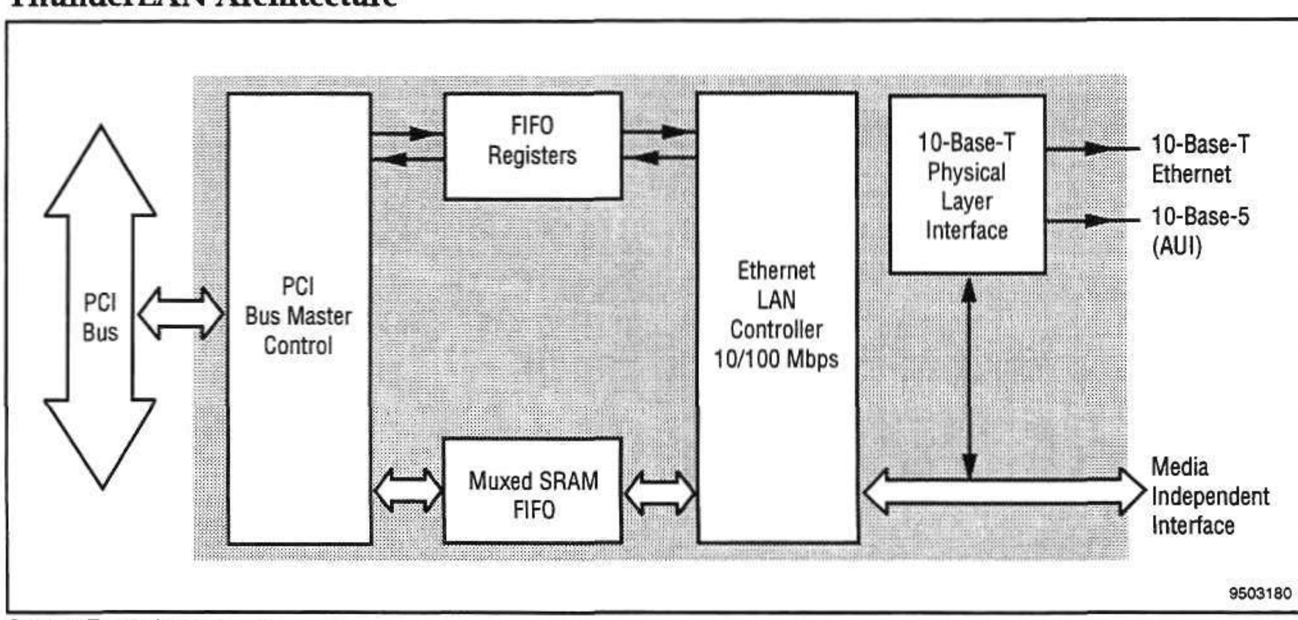
## Digital Semiconductor

Digital has done an outstanding job of getting its 21140 PCI Fast Ethernet controller designed-in at dozens of OEMs. Digital has a strong lead in the PCI area by industry accounts. Digital's success can be attributed to its long history as a developer of PCI technology and its ability to convince industry OEMs that it is a legitimate and nonthreatening merchant vendor.

## Texas Instruments

TI's ThunderLAN controller family is capable of handling both Ethernet or token-ring traffic by simply employing the correct physical layer devices (see Figure 3). At the heart of the chipset is the TNETE100 PCI bus MAC controller ($30 in 10,000-unit quantities) capable of dealing with both standards. TI's approach has been endorsed by Compaq because it allows a great deal of flexibility for a company interested in making things as turnkey as possible for end users.

**Figure 3**
**ThunderLAN Architecture**




Source: Texas Instruments

## Dataquest Perspective

We can expect 10/100-Mbps LAN chips to follow a similar development path as the 10/16-Mbps technology before it. As already noted in the sister newsletter, expect Fast Ethernet to be the larger market of the two because of its broader base of support. However, AnyLAN will grow to be a sizable market as well because of the credible support of Hewlett-Packard and IBM.

From a product innovation standpoint, expect UTP transceivers and accompanying physical layer functions to integrate on to the MAC chips during the next generation. Expect the four-twisted-pair transceiver category to become the preferred media type for most uses. Likewise, the PCI bus interface will overtake ISA/EISA in popularity in the next two years.

The leaders in the 100Mb area now will have to remain nimble and be ready to add value, particularly blending the MAC and physical layer functions when the time arises.

**For More Information...**

Greg Sheppard, Director/Principal Analyst .............................. (408) 437-8261
Internet address ..................................................... gsheppard@dataquest.com
Via fax ........................................................................................ (408) 437-0292



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Competitive Dynamics

Communications Semiconductors and Applications Worldwide

# Product Analysis

# Controllerless Modems: Native Signal Processing Begins

**Abstract:** *The modem market, known for its vicious price competition, forces vendors to continually seek out new methods to reduce costs while improving performance and feature sets. Lower-end modems are the most notorious for providing low profit margins to their makers. As the market for such modems increases, fueled by high demand from price-sensitive home users, vendors are jockeying for position and market share.*
*By Greg Sheppard, Director/Principal Analyst (Semiconductor Application Markets)*
*Lisa Pelgrim, Industry Analyst (Modems North America)*

## AT&T Microelectronics Fires First Salvo

AT&T Microelectronics, one of the top four modem chip suppliers, on October 11, 1994, announced the availability of a new "controllerless" chipset that allows vendors to produce V.32bis (14.4-Kbps) modems at lower prices.

AT&T Microelectronics' new chipset works without the customary controller. This controller function can now be emulated in software running on the host PC. The chipset is targeted at modems destined for use in high-end 386, 486, Pentium, and PowerPC systems. So far, key modem suppliers including Boca Research, ATI Technologies, Cardinal Technologies, and Data Race have adopted this chipset. We estimate that this approach can save an estimated $15 in system cost, translating into more than $30 in savings at the retail level for a V.32bis modem. This is a significant cost savings for modem manufacturers. The key questions now are:

- Will this help the modem chip business make the transition to a lower price point, but with higher volumes?
- Will desktop and mobile PC makers now be motivated to add embedded motherboard modem functionality?

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- As a counterpoint to the second item, will the modem system/board companies see an explosion in opportunity as modems enter the "standard feature" category, as far as OEM bundling is concerned?

### System Requirements

Because the chipset uses the power of the high-speed host CPU, the modems based on the chipset must be used with Intel (or compatible) 386, 486, or Pentium PCs running Windows. The best PC to operate with a controllerless modem is the Pentium. Slower PCs could experience some delays if users are carrying out other operations while operating the modem. Manufacturers report that this delay is somewhat subjective. Many users did not notice any difference during their tests while the modem was transmitting, even when performance had decreased. Only about a 7 percent decrease in performance was reported on a 386-based PC. Almost no decrease was measured on a Pentium. Users of controllerless modem products also will need 4MB RAM minimum, Windows 3.1 or 3.11, a 1.44MB 3.5 inch disk drive, 4MB free hard disk space, and a telephone line. Although the manufacturers list all the requirements on the box, there is no guarantee that buyers will read or comply with this information. Naive retail buyers could purchase this modem without meeting the requirements, which would cause returns. Manufacturers report that this has not been the case. However, fewer than six months of shipping is still too early to measure the effectiveness of the packaging.

## Enabling Events

With the advent of these powerful PCs, extra processing power is becoming available for emulating the modem controller function in software. Windows, the Mac OS, and OS/2 support the boot-time loading of driver-level software that actually provides the emulation of the controller function. AT&T supplies such driver software. Furthermore, Windows 95 will have a built-in universal modem driver functionality as a standard feature. This feature executes, among other tasks, the AT command set used by almost all modems to control their operation.

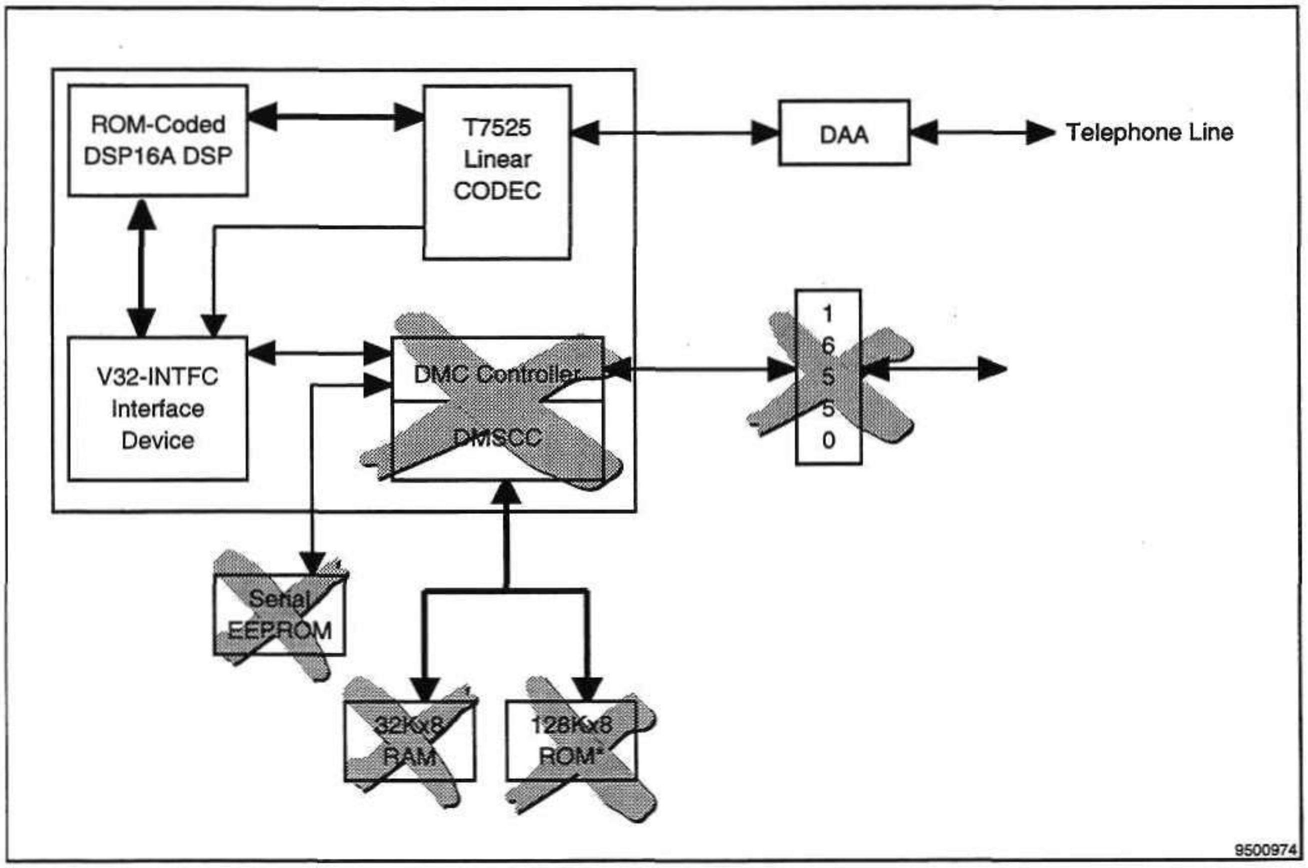
## The Advantages of Controllerless Modems

As noted, we estimate that $15 at the system cost level could easily be saved by using controllerless modems. Figure 1 illustrates a typical modem design and the reduction in part count that can occur by using controllerless modems. The controller is used primarily for processing the AT command set, executing error correction (V.42, MNP), and data compression (V.42bis, MNP). These functions also use an EPROM/flash array and SRAM to store code and scratch pad data. Key advantages of the controllerless approach include the following:

- As the controller functions are emulated by the host software, the need for memory arrays outside of the PC's main memory disappears; therefore, separate nonvolatile and volatile memory is not required
- As error control and compression algorithms improve, software updates can be easily implemented and do not have to be constrained by a lack of processing power and memory.
- There could be an estimated savings of 50 percent in power demand, a crucial feature for PCMCIA cards used in mobile PCs.

**Figure 1**
**The Effect of a Controllerless Modem Chipset on a Modem Design**




Source: AT&T Microelectronics

- There could be a savings of 25 percent in board space, which also is a crucial feature for PCMCIA use and for motherboard implementation. The reduction in space for PCMCIA cards means that multifunctional versions can be constructed combining features such as LAN access and even sound board functionality.

## Modem Vendors

Current products offered by vendors meet the V.32 bis standard but are capable of exceeding the standard and transmitting up to 19.2 Kbps (an unofficial standard called V.32 terbo). Because of the design that eliminates chips from the modem, the most current products are internal cards. External versions eventually will be available. No V.34 products exist in the group. AT&T will team with vendors and work out the technical aspects and implementation of this complex standard. Dataquest expects vendors to continue developing and enhancing the capabilities of modems based on this chip arrangement. Dataquest believes that controllerless modems with voice capability will be introduced to the market in 1995.

The prices of controllerless modems are expected to list at about 20 percent lower than competing modems. Controllerless modems now are being targeted to OEM and retail sales channels. This modem provides a feasible solution for OEM purchasers. PC manufacturers previously were hesitant to include modems in their products for two key reasons:

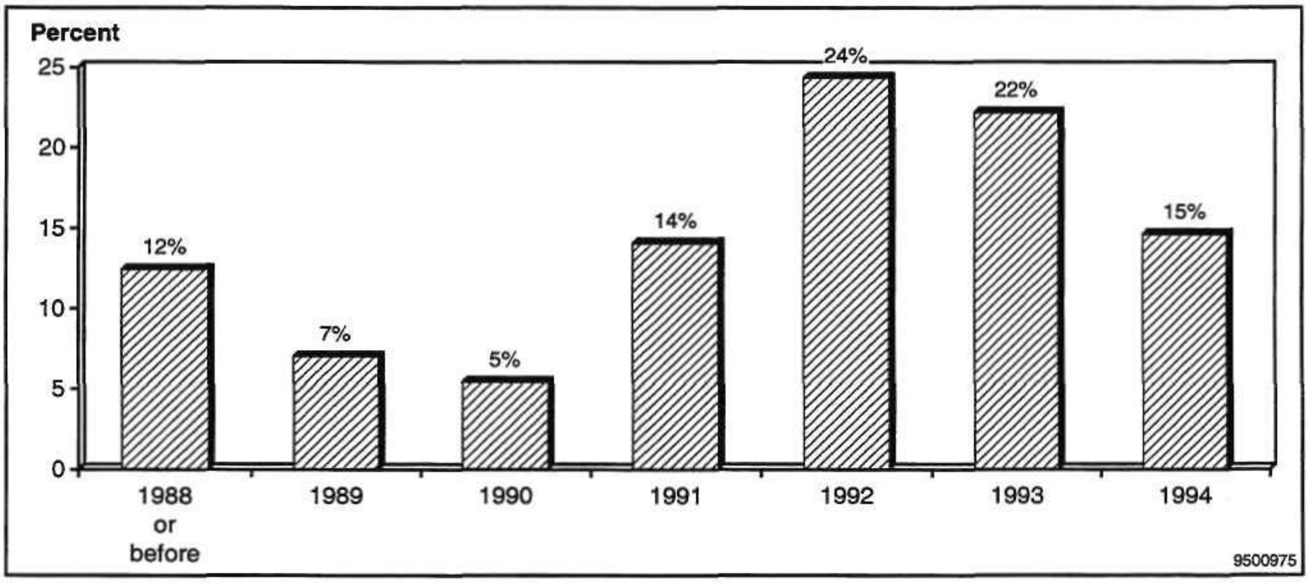
- The PC business is extremely price-competitive. Additional components increase the cost to manufacture and can decrease the already slim profit margin. The addition of a modem, or other nonessential, must allow for a premium price or generate greater market share.
- The standards and speed of the modem have been rapidly increasing over the past several years. This created an environment where obsolescence occurred in the short term, making it less attractive to include a modem in a PC.

Today, the new V.34 (28.8-Kbps) standard is close to the maximum speed capacity on the analog lines. The days of modem speeds doubling are over. The next standard is expected to provide only a slight speed enhancement, pushing throughput to a maximum of 33.6 Kbps. PC manufacturers today can expect modem speeds to be stable, decreasing the threat of modem obsolescence. The controllerless modems meet the V.32bis standard and provide throughput of 14.4 Kbps. They still are considered high-speed modems, although this speed is only half that of the newest standard. For many users, it will be adequate. For PC manufacturers, it will provide a very economical modem, compared with current expensive V.34 modems or higher-priced V.32bis modems. The controllerless version allows even lower costs and makes it an ideal feature on new PCs with a high-speed host CPU.

The low price of the controllerless modem makes it an ideal product for the small-office/home-office (SOHO) modem market. The home market includes users who bring work home, use the home as a business, or conduct home management and hobbyists. Many purchasers in the home market are adding modems to their existing PCs. The installed base of home PCs in North America is very large. Dataquest reported that the installed base of actively used home PCs was 12.5 million in 1994. Home PC users were asked in a recent Dataquest survey about the year of purchase for their most actively used PC. Interestingly, the results reveal that the installed base of active PCs covers a wide range of years (see Figure 2). This indicates that many different types of PCs are in use and that some may be too old to meet the criteria for connection to a controllerless modem. PCs based on the 386 were introduced in 1987, on the 486 in 1989, and on Pentium in 1993. In comparing the purchase years of home PCs and the introduction years of the necessary PC, it is evident that most of the PCs in use are current enough to operate with a controllerless modem.

Only four vendors have announced products that use AT&T's controllerless chipset. All of the modems by these manufacturers are capable of data and fax at 19.2 Kbps and 14.4 Kbps. AT&T was the main supporter of the unofficial standard V.32 terbo with 19.2-Kbps transmission in the pre-V.34 days. As a result, AT&T has maintained the extra speed over other V.32bis (14.4-Kbps) modem chipsets in its offering. This gives modems based on these chips some extra speed without the additional costs. Of course, all the modems are backward-compatible to previous standards.

**Figure 2**
**Year Most Active Home PC Was Purchased**




Source: Dataquest (February 1995)

In addition to the companies described in the following paragraphs, Boca Research is using the controllerless chipsets for an internal modem. However, at this time Boca is unwilling to publicly disclose its market strategy or plans.

ATI Technologies Inc.
33 Commerce Valley Drive East
Thornhill, Ontario
Canada L3T 7N6

ATI introduced its V.32bis controllerless modem to the market on October 31, 1994, and shipped on November 7. In addition to using AT&T's new chipset, the ATI VIGOR fax modem uses software drivers developed by ATI. VIGOR is an internal modem card targeted at both OEM and retail channels. The VIGOR lists at U.S.$89 and Can$119. ATI markets its modem as an energy-saver and is targeting OEM system manufacturers building Energy Star-compliant products. The VIGOR boasts 50 percent less power use over traditional modems. ATI also provides easy upgrades for the VIGOR through a software download at no additional charge. Upgrades for drivers are obtained by connecting to the ATI Bulletin Board or to CompuServe.

Cardinal Technologies
1827 Freedom Road
Lancaster, PA 17601

Cardinal began shipping its controllerless modem, the Cardinal 14.4/ 19.2 Modem for Windows, on October 24, 1994. Cardinal has positioned its product to take advantage of the race to get on the information superhighway. Cardinal's EZ-Install software checks the PC to determine the modem's default settings, shows them on the screen, and automatically installs the included software package. Cardinal includes free trial memberships for online services such as CompuServe, Prodigy, and America Online in the package. List priced at $79 in the United States, the modem is available at PC Connection, Computer City, Ingram-Mirco, Merisel, Tech-Data, and other major distributors and resellers. Retail street prices are as low as $69. Most of these modems are shipped to the United States and Canada and are sold through retail channels. Only about 15 percent ship to OEM customers.

Data Race
11550 IH-10 West #395
San Antonio, TX 78230

Data Race will announce its controllerless modem product on March 6 and begin shipping on March 15. Data Race is the only company to use the chipsets for a PCMCIA application rather than for an internal modem. The new product line, WinMax, will contain three products—a PCMCIA combination modem/Ethernet LAN interface adapter, a PCMCIA modem, and a PCMCIA LAN adapter. Data Race is targeting the WinMax products at the mobile users or road warriors. The target market specifically consists of heavy users of notebook PCs who need to connect to their LAN and use modem applications. WinMax is unique in that it provides concurrent operation between the two features. Users can connect to the LAN and simultaneously use the phone line to make a call or transfer files from the LAN to another location. The WinMax modem/LAN combination is an Ethernet direct connection for 10-Base-T (twisted-pair) LANs. The card is completely self-contained and does not use extra attachment podules. Only the telephone cords to connect the modem to the phone or Ethernet network are needed. A significant benefit of the card is the power-saving feature that results from use of AT&T's chipset. Mobile users are very sensitive to power use, and the WinMax uses half the power of other PCMCIA modems. It uses only 1W during operation, and power use drops to 1mA during sleep mode. The reduced power requirements will greatly impact mobile users who suffer when modems use up batteries quickly. The combination WinMax card has a list price $249, which is very competitive. Market leader Xircom sells a similar product for $649 list. The modem-only WinMax lists at $129 and the Ethernet-only at $99. WinMax will be available directly from Data Race through a toll-free 800 number. This is a new sales tactic for Data Race, which will rely on advertising in publications including *PC Magazine, PC Week, PC Computing,* and *Shoppers Guide* to generate sales calls. Data Race also will license other modem manufacturers interested in this technology and will manufacture private label cards for PC manufacturers.

## What's Next

AT&T Microelectronics initially offered support at the 19.2-Kbps rate (V.32 terbo) for data and V.17 for fax and is now shipping in volume at $29 ($31 for a PCMCIA version). A version that supports voice processing functions is due out in the second quarter of 1995; a V.34 version should follow in the summer. Competitive response from fellow chip vendors is still emerging as AT&T competitors grapple with other value-added directions, including advanced features such as simultaneous voice and data.

## Dataquest Perspective

Initial acceptance of these chips by modem companies suggests that the worldwide market potential for chipsets in 1995 could exceed 5 percent of the market, or 800,000 units, with revenue of $20 million (assuming an average selling price of $25). Dataquest estimates that modem vendors shipped 17,000 modems based on these chips during the two months of availability in 1994. Assuming that end-user performance remains acceptable as the controllerless approach expands into the voice processing and V.34 parts of the market, controllerless modem chips have a chance to enter the mainstream as early as 1996. This approach opens the door to dramatically lowering the cost of most modems (boards, external, and PCMCIA) and positions them as standard items to be bundled or built in by the PC makers. This should help greatly expand the modem chip market as well, even though the average selling prices of the chipsets will shift to a lower level.

We recommend that modem chip vendors pay serious attention to this market area. Those caught off guard or denying that the market exists could miss out on a great opportunity. Likewise, modem manufacturers using this chip can gain a substantial price advantage over competitors. The PCMCIA modems based on this chip have an important competitive advantage—in addition to price—because they offer users reduced power consumption. This solves a major problem for mobile users. Dataquest predicts that controllerless modems will prove to be a very attractive product for retail channels catering to the SOHO market, OEM channels, and mobile users. Modem vendors should pay attention to these new products and their effects on pricing and be ready to take action, or they may see some drastic changes in market share.

**For More Information...**

Greg Sheppard, Director/Principal Analyst ............................ (408) 437-8261
Internet address ........................................................gsheppard@dataquest.com
Via fax ............................................................................................ (408) 437-0292



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