6 - CSPP /
ATV

202 - 429 - 7011

Computer Systems Policy Project

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James A. Unruh   Unisys

November 8, 1995

Richard E. Wiley, Esquire
Wiley, Rein, and Fielding
1776 K Street, NW
Washington, D.C. 20006

Dear Mr. Wiley:

As the Advisory Committee on Advanced Television Service (ACATS) prepares to submit its recommendations for Advanced Television (ATV) standards to the FCC, the Computer Systems Policy Project (CSPP) urges ACATS to ensure that the system promotes interoperability with computers. A computer-interoperable ATV standard will enable new applications for the National Information Infrastructure (NII), promote further economic growth in the world-leading U.S. computer industry, and bring increased benefits and enjoyment to consumers. When CSPP described its vision for the NII in its 1993 report, *Perspectives on the National Information Infrastructure*, we noted that interoperability of applications and technologies across sectors is key to the successful implementation of the NII.

CSPP appreciates the hard work of the ACATS and commends the progress that has been made. We are pleased that the digital ATV standard under consideration includes progressive scan, square pixel grids, and ATM and MPEG-2 standard compatibility, all of which are important factors for computer interoperability. We believe that the proposed ATV standard is a large step towards a greatly enhanced entertainment television system that aims to be part of the National Information Infrastructure.

CSPP endorses the ATV standard as currently proposed, with one exception, and urges ACATS to incorporate the following position in its recommendation to the FCC:

> Progressive Scan vs. Interlace: CSPP strongly supports all of the proposed Advanced Television formats that include progressive scan, since these formats provide for reasonable interoperability with computer systems. The computer industry remains firmly convinced that progressive scan is the technology for the future and that Advanced Television, particularly in HDTV, should evolve towards exclusively progressive scan formats over time. We feel strongly that as soon as progressive technologies are available, the HDTV interlace formats should be sunsetted. We urge the ACATS to develop an implementation plan for achieving this goal.
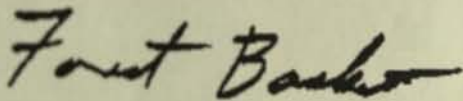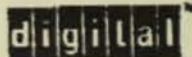
ATV Receivers: In addition, CSPP believes that every advanced television receiver should be able to receive, decode and display all the proposed ATV signals. We understand that this position has been extensively discussed by the Grand Alliance and we strongly support it. We believe that adopting this recommendation will facilitate the transition to progressive scan Advanced Television formats. We urge the Advisory Committee on Advanced Television Service to include such a requirement when it makes its recommendation to the FCC.

In summary, CSPP supports the ACATS process, and hope that you incorporate our concerns into your final recommendation.

Sincerely,

Forest Baskett
Senior Vice President of R&D, Silicon Graphics Inc.
Chairman, CSPP Chief Technologists

d i g i t a l

Digital Equipment Corporation
Government Relations and International Trade Law
1401 H Street, N.W.
Washington, D.C. 20005

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To   SAM FULLER & TOM GANNON

Fax		Phone

Total pages including cover   Date   11/16/95

From   Grace L. Hinchman

              Manager, Public Affairs

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Internet address   grace.hinchman@dec.mts.dec.com

Subject   Sam & Tom: Attached is a copy of the Microsoft

submission to Dick Wiley which actually reflects Apple's

position. Also attached is a memo Paul Misner (A partner of Dick

Wiley's) sent to Microsoft to try and explain the issues outlined

in the Microsoft memo. Apparently, Craig Monday of Microsoft is

going to try and call Sam to try and discuss these issues prior to

the November 28th meeting. Please give a call if you have any

any questions.   Grace.

If you have any problems receiving this fax, please call

Phone   Sherri Thomas   Phone (202) 383-5631 (DTN 427)

Despite the importance of the interoperability of the FCC terrestrial broadcasting
standard with computers, it must be kept in perspective. In some instances, interoperability

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Finally, in a networked computing environment, the computer industry's own lack of interoperability across vendor-specific operating systems, file formats, and display formats constitutes a *far* more fundamental interoperability barrier than any broadcast ATV issue. Most corporate users of computers continue to be frustrated by the inability of Windows-based PCS, Apple Macintoshes, and various workstations running different flavors of UNIX to share application software and to seamlessly interoperate with text, graphics, sound, and video.

So much for Apple's basic philosophy on ATV. In addition, however, many of Apple's specific objections to the ATV system that are flatly untrue, technically inaccurate, or they concern issues that are not relevant to a transmission standard and, thus, are not within the regulatory scope of the FCC or its Advisory Committee.

III. Specific Apple Allegations

A.   Interlace Scanning

Apple's objects to the use of interlace in some standard definition ATV formats. Progressive scan, square pixel formats that are VGA compatible (640 x 480) are provided for the SDTV applications of ATV that benefit from their use. Interlace is just another form of compression, which has its place in a multiple format system wherein — within the constraints allowed by the bit rate that can be transmitted in 6 MHZ -- program producers can choose the format and frame rate that provides the combination of spatial resolution, temporal resolution, and transmission bit rate that is best suited for their application. Each of these parameters has its own associated artifacts, which have different levels of visibility on different kinds of picture content and which must be balanced in a compressed video system.

Indeed, reducing spatial resolution results in fuzzy, unclear pictures that are unacceptable in many applications. Reducing frame rate results in jerky motion. Reducing bit rate results in blockiness and noisy pictures. The use of interlace is a compromise between spatial and temporal resolution that simultaneously provides smooth motion rendition and full vertical resolution on still pictures. This approach has served television quite well for the last 50 years, and cannot be hastily precluded as one of the format options in an ATV system. Apple's attempt to limit the scope of format choices available to content producers is inconsistent with the flexibility in its own Quicktime product and, more fundamentally, it ignores scientific principles and good engineering practices which enable moving images to be represented in the format that represents their content with the least objectionable degradation.

Apple claims that perfect de-interlacing is theoretically impossible. Although it is true that certain pathological cases can be identified where de-interlacing algorithms will not properly remove interlace artifacts, these pathological cases are of little practical consequence.

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The kinds of pictures, text, and graphics that are commonly used in both television and computers can be de-interlaced extremely well. The television industry has been developing de-interlacing techniques for well over 10 years and the performance of de-interlacers will be a source of competition among manufacturers. Furthermore, contrary to Apple's assertion, a de-interlacer is not a large expense. Relative to the complexity of High Level MPEG-2 decoders and the other functionality required in an ATV receiver, a very good de-interlacer can be provided in receivers at small incremental cost. The level of IC technology used to produce a cost-effective ATV receiver (or a high performance microprocessor) allows a de-interlacer to occupy a small portion of a single IC. The consensus opinion of the five consumer electronics and/or IC manufacturers in the Grand Alliance (Thomson, Philips, Zenith, GI and AT&T) who are committed to produce ATV receivers with de-interlacing circuitry credibly rebuts Apple's unsubstantiated assertions.

B.   60 Hz Scanning Rate

First and foremost, Apple's arguments relate to display issues that have nothing to do with a transmission standard. The notion that a transmission frame rate is tied to display frame rates is an obsolete technical concept. The ATV system allows transmission at 23.98, 24, 29.97, 30, 59.94 and 60 Hz. These rates are adequate to represent a wide range of camera panning and motion rendition. Of course, motion picture films successfully continue to use a 24 Hz frame rate despite the fact that higher frame rates are technically possible. Double or triple shuttering is used to reduce display flicker in theaters, with 48 Hz being the most common display frame rate for film. In computers, where there is no standard for display format or frame rate, it is the responsibility of software to determine the method of conversion between source and display frame rates. Some software alters the speed of the video clip to match the display frame rate, while other software occasionally repeats (and/or deletes) frames. A similar approach has been successfully used for showing 24 Hz films on 59.94 Hz television for over 40 years. Apple's own Quicktime product is an example of such video display software, which is capable of showing 59.94 Hz video on either 66 Hz or 75 Hz Apple computer screens.

As for Apple's assertion that 70+ Hz is required for displays, it is notable that many computer screens (including most of Apple's) run at 66 Hz. It seems rather strange that while Apple is such a staunch advocate of 72 Hz, it makes 66 Hz and 75 Hz displays for its Macintosh computers, but no 72 Hz display. (If it's such a good idea - why not?) Computer displays are also available at 60 Hz and a wide variety of other rates. The real technical need is to achieve a display rate that is adequate to eliminate human perception of large area flicker. Perceptibility of flicker is a function of display brightness and viewing distance (flicker is actually more perceptible in peripheral vision than in foveal vision). Flicker perceptibility is a rather smooth function of display rate that has no sharp threshold. Thus, it is not surprising that a wide variety of computer display rates have proliferated. Also, the requirements of

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entertainment displays are different than computer displays, which are scrutinized at very close
viewing distances. Entertainment television display has been sufficient at 60 Hz, and no need
for higher display rates is accepted by the consumer electronics industry, particularly since a
higher display rate increases cost. Receiver manufacturers are free to provide any display rate
or rates that they desire, and accomplish this with either multi-scan displays or electronic
frame rate conversion.

The MPEG-2 standard used in ATV identifies its frame rates in a header/descriptor,
but despite extensive participation by computer companies, no explicit provision was made for
a 72 Hz frame rate in the MPEG-2 header. Many representatives of the computer industry
participated in the MPEG-2 process (indeed, as you may know, the Information Technologies
Industry Council ("ITI") is the secretariat for the U.S. MPEG group), and Apple's assertion
that 72 Hz transmission represents computer industry interests is unsubstantiated by the facts.

The observation that 24 Hz movie transmission (provided by the ATV system) would
look very good on a 72 Hz display is quite correct. But the display frame rate (or rates) used
by ATV receiver or computer manufacturers is outside the domain of a transmission standard
and the regulatory authority of the FCC. Further, it is a product decision that is best left to the
competitive marketplace. Any HDTV manufacturer can provide 72 Hz display capability as a
competitive feature. As for handling 60 Hz transmissions on a 72 Hz display, this requires the
very same ratio conversion as the 50 to 60 Hz conversion that is routinely performed when
European television is aired in the US.

C.   Lack of Data or Code Capability

Apple's assertion that the ATV system has no data or code capability is totally
unfounded. The Grand Alliance prototype hardware has been subjected to extensive bit error
rate measurements in both Laboratory and Field testing. These measurements document the bit
error rate performance of the system as a function of carrier-to-noise ratio (CNR). In any
wireless transmission system, the CNR at a given receiving location is a function of
transmitter power, RF propagation, and receiver antenna gain.

Of course, viewable picture and acceptable audio tests at error rates in the 10^{-4} to 10^{-6}
range are being tested - this is what determine the limits of television service broadcast in the
extremely difficult VHF/UHF over-the-air environment. The fact that picture and sound can
tolerate higher error rates than pure data is a fundamental characteristic of their nature. Since
the ATV channel will be allocated to broadcasters for the primary use of providing television
service to the public, it is entirely appropriate to establish planning factors that reflect the
requirements for this application. Other frequency allocations for data PCS and wireless LANs
(such as proposed by Apple) would undoubtedly consider different requirements for their
primary use.

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Of course, error free data transmission is not guaranteed by any transmission system (particularly not by telephone modems used extensively for computer communications). In fact, communications theory tells us that there is a fundamental tradeoff between channel capacity and BER - raising the bit rate on a given medium inevitably increases the BER. Except near the limits of ATV coverage, a BER in excess of 10^{-9} is easily achieved and is more than adequate for most data applications. Further, near the limits of ATV coverage, BER improves by about one order of magnitude for a 0.25 dB improvement in CNR, meaning that consumers requiring better error rates for data applications can simply purchase a better antenna to improve their data reception reliability. In computer communications, it is up to the end-to-end application to ensure that usable data has been reliably received. Protocols like FTP apply error detection codes to assure the correct receipt of data - similar software approaches can be applied to data broadcast in the ATV channel by those applications that require it.

D.   Non-Square Pixels

Apple's arguments for square pixel formats center on applications that require overlay of geometrically accurate circles. Although this is certainly a virtue of the Grand Alliance HDTV and 640 x 480 SDTV formats, it must be recognized that not every application has such a requirement.[1] Apple's position on this issue is philosophically similar to their position on interlace. Despite the inclusion of the 640 x 480 (compatible with VGA computer displays) square pixel format in ATV, Apple wishes to deny other users of ATV the flexibility to choose formats with rectangular (non-square) pixels. The non-square pixel standard definition formats (704 x 480 in both 4:3 and 16:9 aspect ratios) are included in ATV to provide interoperability with the large archive of content and the installed base of production facilities of broadcasters. The 704 x 480 format corresponds to an international standard, ITU-R BT.601, that has been the basis for most digital television equipment purchases over the last 10 years, resulting in a substantial archive of programming content in this format. Apple's move to deny the existence of the 704 x 480 non-square pixel formats is odd, particularly because video capture boards that utilize this format in its interlaced form are available for virtually every brand of computer.

E.   Lack of Overlay Planes

Apple's perspective assumes that all applications are computer-based and require such capabilities. Overlay planes simply are not required for simple television viewing. The definition of such extensions to basic television service need not be (and should not be) defined as part of an FCC transmission standard. If necessary, they could be subsequently defined

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[1]   Apple's viewgraphs incorrectly state that a 640 x 480, 16:9 aspect ratio format is included in the Grand Alliance system. It is not.

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without delaying the introduction of service. Note that there is no unified computer industry
standard for cursor control, text and graphics definitions, standardized color lookup tables, 3-
D graphics or window controls, &tc. Microsoft and Apple products are completely different
on these issues. They even differ on window controls, and the mouse. Until a single computer
industry standard emerges for overlay, any voluntary or FCC-based standards are premature.

F.   Requirement to Decode All Formats

        Apple's position on this issue is irresponsible - it would let the public buy receivers
that will unexpectedly and unexplainably (to them) not function when certain formats are
transmitted. The advocated solution of layered compression is impractical. Extensive work in
layered coding has shown that it is not as efficient as single layer compression. While such
approaches are intellectually appealing and suitable for applications where limited bit rate is
not a constraint, this is not a practical approach to providing high quality HDTV pictures in a
6 MHZ channel. Apple's approach is "viewgraph engineering" - it remains totally
unsubstantiated. Apple has not demonstrated for the Advisory Committee so much as a single
video simulation of the approaches they advocate.

G.   Lack of Digital Interface Specification

        Apple's allegations on his issue are unwarranted and incorrect. Digital interfaces for
consumer television equipment have no place in the discussion of transmission standards. They
are totally outside the scope and purview of the FCC and its Advisory Committee process. Of
course, the consumer electronics industry recognizes the need to develop such standards. The
EIA is the appropriate standards body, and work on developing appropriate interface standards
is in progress.

H.   Poorly Conceived Aspect Ratios

        There are many different film formats - if there were one film standard, HDTV would
have used it. The 16:9 aspect ratio is a compromise -- developed by the Hollywood community
-- that minimizes the cropping required for pan and scan in the most commonly used film
formats; it likewise minimizes the loss of resolution when the original aspect ratio is
maintained. Broad national and international consensus on 16:9 goes back to the mid 1980s,
when the issue was actively discussed, particularly in a SMPTE standards committee chaired
by Universal Studios. It has been used in an HDTV production standard since the SMPTE
240M standard and the ITU-R (formerly CCIR) 50 Hz and 60 Hz production standards were
established in the late 1980s.

        The "any aspect ratio" approach advocated by Apple is unnecessarily complex. The
concern voiced by Apple over interpolation required to transform non-square pixel formats to

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square pixel ones is simple by comparison to the interpolation needed to handle the variety of
aspect ratios that they advocate. The simple solution that Apple totally misses is that by simply
performing the letterboxing at the broadcast source, any aspect ratio picture can be transmitted
within the 16:9 transmission format. With this approach, ATV does not need any rules and the
presentation of picture content in different film formats can be decided on a case by case basis
by the program provider, using good artistic judgment.

I.   Overscan Not Defined

The discussion of overscan is a receiver issue that has no place in a transmission
standard. Although overscan is commonly used in computer monitors, it is not defined or
required by any standard. Why should TV be different? Apple's idea of a rigidly defined menu
bar is outdated. It's own Macintosh software established the precedent of "tear-off" menus that
can be separated from the main menu bar. Software should define "menu items" and leave the
presentation details (where the menu is placed and how it looks) to the receiver.

J.   Limited TV Colors

Film, printers and TV have different color because they are different physical
processes. Nothing about the ATV definition can change that.

Apple's assertions about computer color are misleading - most computers have a very
limited color gamut (8-bit color is still quite common). There is no standard for color
reproduction in computer monitors, and extremely inconsistent color matching among the
many monitors that can be used with a given computer. A problem that Apple fails to
acknowledge is that computer graphics are usually rendered in linear space rather than gamma
corrected space, resulting in color errors on computer monitors.

The constant luminance principle suggested by Apple was well-understood and rejected
by the proponents of all four digital HDTV systems and again subsequently dismissed by the
Grand Alliance. Constant luminance has never been used in an imaging system (television or
computer). The theoretical advantage of this approach is that transmission errors result in
slightly less perceptible visual errors. Even in error-prone analog transmission systems,
however, this approach has never had enough practical value to be used in a deployed system.
In digital systems that exhibit perfect transmission over a wide range of impairments and then
sudden catastrophic failure, constant luminance is of no practical value. It would be interesting
to know whether Apple plans to support constant luminance representations in its Quicktime
software.

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K.   Must Deploy Now

Apple's criticism of the Advisory Committee testing methodology is totally
unwarranted and irrelevant to the ATV standard. Apple claims that software testing was never
done. To the contrary, extensive software testing was done by the Grand Alliance and
reviewed by the Advisory Committee during system development. As every video engineer
knows, such simulations are a valuable step in developing a viable system design. But every
experienced video engineer also has experienced techniques that appear to work well in
simulation and exhibit unacceptable performance when implemented in real hardware.
Accordingly, and by early agreement of the Advisory Committee, simulations are not
sufficiently rigorous for establishing a national transmission standard.

Advisory Committee testing is far more rigorous and spans more material than software
simulations. For example, software simulations do not usually adequately test rate control
dynamics that involve performance over periods of picture material that fill the buffer and
require rate control intervention. This was not of particular concern in developing the generic
MPEG-2 standard, which left such details to subsequent competition. It would have been
irresponsible for the FCC Advisory Committee to accept that adequate picture quality could be
produced at a particular bit rate without hardware verification. It should further be noted that
in addition to hardware testing, software verification of certain system aspects HAS been done
in Advisory Committee laboratory testing (e.g., MPEG syntax compliance and bit stream
splicing). It also should be noted that, in its years of participation in the Advisory Committee,
Apple has not presented simulation results for the ideas that it advocates.

L.   Migration Strategy

Apple's allegations about migration strategy are way off base. The whole multi-format
approach of ATV provides different formats so that each application can use the format most
suitable for its particular characteristics. Forcing computer values onto entertainment television
makes no more sense than attempting to force every computer display to be 60 Hz and use
HDTV colorimetry in order to be TV-compatible. Apple just doesn't accept the fact that other
companies PREFER to use formats that Apple doesn't like. (Maybe the FCC should outlaw
Microsoft DOS file format, too!)

The approach of ensuring that ATV receivers can decode all formats is a responsible
approach that protects the public and content creators from obsolescence. Contrary to Apple's
assertion, no one advocates that interlaced content should suddenly become unwatchable on
ATV. On the contrary, responsible parties involved in ATV standardization observe that if
progressive formats indeed demonstrate their claimed advantages to the public, interlaced
formats will gradually fade in popularity; the inclusion of multiple formats allows the

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marketplace to determine which formats are most widely used and accepted. Apple's approach
is both restrictive and presumptuous.

IV. Concluding Remarks

Apple's continuing confusion between transmission standards and receiver related
issues is doing a disservice to the broadcast, consumer electronics, and computer industries.
Attempts to regulate ATV receiver performance can only be rationalized if the same rules are
applied to computers. The result would be a harmful restriction of diversity and a distortion of
marketplace preferences.

The Advisory Committee has sought to develop an *inclusive* standard which addresses
the needs of terrestrial broadcasting -- for which this ATV transmission standard is primarily
intended -- and all other affected industries. Apple, a company not known for its open systems
standards, takes the opposite approach. Having failed to achieve consensus standards in its
own industry, it seeks to *exclude* the needs of other industries in the standardization of ATV.

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Advanced Television (ATV) Position Paper

November 15, 1995

Overview

The computer industry as a whole has not used the national television standard[1] for computer displays for many years now, finding it inadequate for clear, crisp presentation of modern computer applications. The bifurcation of the display technology business into disjointed computer and television branches made sense so long as television broadcast was analog and computer displays were, of course, driven digitally. It did not matter when the number of personal computers was small relative the number of home televisions.

The massively influential digital revolution, now in full flower, has changed the logic. Television broadcast is to be completely digital, and home computer sales approach or exceed those of home television sets. Digital technology is now sufficiently developed to actually implement the "digital convergence" between video and computers.

We believe that the current ACATS proposal to the FCC for a new digital television broadcast standard does not adequately support the digital convergence now possible between television and computing.

The ACATS proposal[2] does include some accommodation for computer industry concerns. We believe, however, that the approach advocated will cause compliant displays to be so expensive that market pressures will force vendors to subvert the proposed standard, honoring only convenient subsets of the proposal. This would lead directly to a continuation of today's bifurcation into two unconverged markets. Those parts of the proposal that the broadcast industry found useful would be honored by one subset of vendors, those parts compatible with computer industry needs by another. Neither branch would fully honor the standard as proposed – the "standard" would fail to standardize.

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[1] NTSC in the U.S. A similar statement holds for PAL and SECAM in other countries.

[2] Essentially that of the Grand Alliance.

v1.02

MICROSOFT

FAX

To: Paul Misener

COMPANY: Wiley, Rein & Felding

Fax: 202/429-7207

From: Jack Krumholtz   (202) 895-2169

Fax: 202/364-8853

Date: November 15, 1995

No. of Pages (including this page) 6

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Please contact Shirley King 202/895-2170, if there is a problem with the transmission.

● Comments:

Paul - Per my voicemail message. Please call to discuss.

                                              Jack

The Issues

The following specific issues are addressed subsequently in some detail:

- No data capability (a digital data channel without specification)
- Interlaced scanning (as opposed to progressive)
- Requirement of multiple unrelated display formats (as opposed to a single base level plus optional layered improvements)
- 60 Hz transmission rate (as opposed to, say 72 Hz)
- Non-square pixel spacing for lower resolution formats
- Awkward aspect ratios (most popular film aspect ratio not honored)
- Overscan not defined
- Limited colorimetry
- Must deploy now

Data Capability

A general way to look at a digital broadcast channel is as a stream of bits, not necessarily carrying video information, to each consumer. The MPEG-2 digital compression standard, upon which the ACATS proposal is built, permits transmission of arbitrary data. The ACATS proposal, however, does not provide for standardization of this general and powerful data capability which could be of immense importance in the transmission of, for example, text, graphics, alternative audio, computer programs, and overlay planes.

We believe that the FCC should standardize the use of its channels for general data transmission as well as video — for applications other than just broadcast television. Particularly important would be error correction mechanisms and transmission protocols.

Interlace v Progressive

We believe that interlaced scanning should no longer be supported. If video were being created for the first time today, interlace would not be suggested by anyone in our industry as a new standard.

Almost no modern computer displays use interlacing because of the difficulty reading text and line graphics on interlaced displays. Horizontal lines, in both text and graphics, flicker in a most unpleasant manner.

Integration of digital video with text and line graphics is happening now in the multimedia component of the computer industry, a very expansive consumer market.

Although it is possible to up-convert interlaced to non-interlaced (progressive) scan by circuitry in a display or receiver, we believe the cost per unit to do a conversion of adequate high quality to be prohibitive for the consumer market. Quality should match or exceed today's common standard in the computer industry.

We believe that it is possible to compress high resolution formats with progressive scan into the allowed channels.

Multiple Formats

The ACATS proposal offers 14 different display formats, 11 if interlaced ones are disallowed.[3] A television receiver, to be compliant, would have to honor all of them. We believe the cost of this, per set, would be so high as to make the proposal unrealistic.

Although the collection of 14 formats is described as a "layered" system, it is not a layered system as that term is used in the computer industry. A layered system would have a base layer that all displays honor. Then each higher resolution or wider format layer, from a logical *family* of formats, would be combined in or over the base layer if the receiver honored it. There is no required, or base, format in the current proposal (since presumably all formats are honored). The 14 formats do not form a logical, interrelated family; they are simply listed.

Refresh Rate

A 60 Hz refresh rate (or slower) is insufficient for the computer display market, in particular for text display of the quality currently expected by users of computer applications. Even with progressive scan, a 60 Hz progressive display of black text on a white page background — quite common in word processing — very noticeably flashes, an unpleasant and tiring phenomenon. The computer industry has settled on displays with refresh rates of 70 Hz or higher.

It is possible to up-convert from 60 Hz to 70 or more, but as with interlace-to-progressive scan conversion, the circuitry to do so per unit at a satisfactory quality level (at or exceeding current computer industry standards) we believe to be unrealistically expensive.

A rate of 72 Hz is compelling, being an exact multiple of the 24 Hz rate used in the film industry. Since film is used to produce a high percentage of television content, we believe a rate easily converted from the standard film rate and slightly greater than the 70 Hz required by the computer industry is attractive.

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[3] Actually 18 and 14, respectively, if different aspect ratios are counted as different formats too.

Square Pixel Spacing

The ACATS proposal supports square pixel spacing[4] for "most" of the 14 formats. However, three of the lower resolution formats have non-square pixel spacing: 704x480 on a 4:3 screen, 704x480 on a 16:9 screen, and 640x480 on a 16:9 screen.

Although it is possible to compensate for non-square pixel spacing with special circuitry, this again adds expense to the display. Furthermore, the vast majority of computer operating systems and applications programs assume square pixel spacing. Image file formats would have to be changed to include fields indicating the pixel spacing ratio (the ratio between horizontal spacing and vertical spacing).

We believe it makes more sense to simply disallow formats with non-square pixel spacing. A logical layering scheme would honor this rule.

Aspect Ratios

The ACATS proposal supports two aspect ratio: 16:9 and 4:3. The lower ratio 4:3 (about 1.333:1) is that of the current national television standard. We do not oppose this standard being continued for low resolution formats.

We believe, however, that the higher ratio 16:9 (about 1.777:1) is a curious one that may satisfy viewers looking for a broader format, but does so in isolation from the rest of the communications world. In particular, the film industry — again, the source of much television content and soon multimedia content for the computer industry — uses two aspect ratios commonly. One very common format is 1.85:1. The other, wide-screen (Cinemascope, or Panavision) format is 2.4:1.

We believe that an aspect ratio of 1.85:1 makes more sense than 1.777:1. The 2.4:1 format is probably too expensive to realize in cathode-ray technology to be feasible. A truly layered system of interrelated formats could provide a 4:3 base layer with higher layers at 1.85:1 (or larger) aspect ratio.

We also believe that the television and film industries should preserve film properties during the digitization process applied to film and only convert them to some other format at a last step, if necessary, in a receiver or display. Thus cropping and letterboxing standards for digitized film displayed on FCC formats should also be established. The MPEG-2 compression standard could be used in this regard, using its "pan-and-scan" capability.

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[4] Pixels are points, not squares. It is the spacing of these points that is the issue. "Square pixel spacing" means that the pixels are equally spaced horizontally and vertically and is the preferred wording.

Overscan

Computer applications commonly use the edges of the displayed image for user interface controls, such as menus, buttons, and sliders. Therefore overscan is not used in the computer industry. We believe that the need for overscan is arguable in the digital world and that it compromises the artistic intent of frames created full frame.

If overscan is allowed then it should be precisely defined, rather than undefined as in the ACATS proposal. A precise definition would specify exactly the area of a frame visible on all displays.

Colorimetry

An increasingly serious problem with computer displays is color constancy. An image on one display often looks very different when seen on a different display, even from the same manufacturer. This problem is becoming more and more important as color applications, such as multimedia and graphic arts, become prevalent.

We believe that the ACATS proposal does not adequately address this complex issue.

Must Deploy Now

The ACATS has urged the FCC to act promptly on deployment of a new digital television standard. We believe that the rapid development of digital computer technology has changed the nation's needs during the eight years that the advanced television issues have been studied (not counting the even longer periods in other countries). Some of these needs are sketched above.

We believe these issues are too important to be overlooked in a rush to deployment. The current standard has been with us for many decades. We can assume that any new standard will generate an equally inertial infrastructure. We suggest that the issues above are serious and require reasoned deliberation.

Conclusion

We believe, for the reasons outlined above, that the ACATS proposal currently before the FCC is inadequate and will not be honored. We believe that this is a once-in-a-lifetime opportunity for infrastructure redesign and that, therefore, revisions are required.

To: Sam

do there anything
I should do
on this? Tom

CC: Sam After
return
(cover only)

✓ Sam has
his copy

fax

digital

Digital Equipment Corporation
Government Relations and International Trade Law
1401 H Street, N.W.
Washington, D.C. 20005

To   SAM FULLER & TOM GANNON

Fax   **Phone**

Total pages including cover   **Date**   11/16/95

From   Grace L. Hinchman

                Manager, Public Affairs

Fax   (202) 383-5030   **DTN fax** 427-5030

Phone   (202) 383-5003   **DTN** 427-5003

Internet address   grace.hinchman@dcc.mts.dec.com

Subject   Sam & Tom: Attached is a copy of the Microsoft

submission to Dick Wiley which actually reflects Apple's

position. Also attached is a memo Paul Misner (A partner of Dick

Wiley's) sent to Microsoft to try and explain the issues outlined

in the Microsoft memo. Apparently, Craig Monday of Microsoft is

going to try and call Sam to try and discuss these issues prior to

the November 28th meeting. Please give a call if you have any

any questions.   Grace.

If you have any problems receiving this fax, please call

Phone   Sherri Thomas   **Phone** (202) 383-5631 (DTN 427)

Federal Communications Commission
Mass Media Bureau
1919 M Street, NW
Washington DC, 20554
Tel: 202-418-2000
Fax: 202-418-2828
sshapiro@fcc.gov

Date: October 10, 1995
To: Dr. Samuel Fuller   508-486-2957
From: Saul T. Shapiro
Subject: ACATS Membership
Pages: 20 including this one

cc: R. Hundt
R. Dancey
J. Genachowski
(letter only)

On behalf of Chairman Reed Hundt, I would like to extend an invitation to you to join the FCC's Advisory Committee on Advanced Television Services (ACATS)   This Committee was originally chartered in September, 1987 to advise the Commission on creating a standard for High Definition Television (HDTV). The process has since evolved considerably, taking on the form suggested by the accompanying materials.

Following you will find a letter from the Committee's Chairman, former FCC Chairman Richard Wiley, announcing the next (and very likely final) ACATS meeting, as well as a complete listing of current members. In addition, I am sending a variety of recent articles describing some of the key issues before the Committee, as well as the very contentious issue currently being debated on Capitol Hill regarding auctioning of spectrum the FCC earlier set aside for the transition to digital television.

There are currently two openings on the Committee.   The Chairman is very interested in inviting your participation in the hopes of introducing a new voice and perspective to a process which stands to reshape the broadcast and communications industry for the coming digital era. Far more than just "pretty pictures," the standard adopted for digital broadcast will create new distribution channels for software, newspapers and music in addition to video. New services and applications will emerge of which today we can only dream.

While the current membership is heavily tilted in favor of broadcast television and movie production, with these two open positions the Chairman is hoping to lend some balance to the deliberations over the next two months. As an active member, you will be expected to review and comment upon final reports drafted by Mr. Wiley, as well as attend the final meeting here in Washington on November 28.
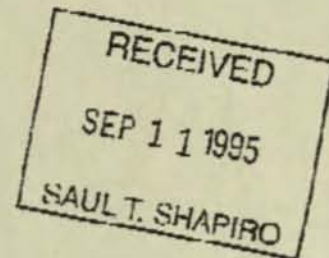
Thank you so much for your serious consideration of the Chairman's invitation. Should you have any questions, please feel free to call me at the number shown above.

P5100202.sts

WILEY, REIN & FIELDING

1776 K STREET, N. W.
WASHINGTON, D. C. 20006
(202) 429-7000

RICHARD E. WILEY
(202) 429-7010

FACSIMILE
(202) 429-7049

September 7, 1995

Dear Advisory Committee Members:

The purpose of this letter is to advise you that our next, and hopefully final, meeting will be held on Tuesday, November 28 at 2:00 p.m., in the Federal Communications Commission Conference room (8th Floor, 1919 M Street, Washington, D.C.). At that time, you will be asked to recommend to the FCC a new broadcast transmission standard for our country. The existing "NTSC" standard was adopted back in 1941.

As you know, for eight years, our all-industry Committee has worked diligently to discharge the assignment given to us by the FCC in 1987. Well over one thousand industry volunteers -- drawn from the broadcast, cable, telephone, DBS, computer, and program production industries -- have participated in the Committee's efforts. Along the way, our work has witnessed some memorable developments: the introduction of digital transmission, the formation of the Grand Alliance and the construction of its world-leading technology system, and the testing of that system (and its predecessors) by three futuristic laboratories -- the Advanced Television Test Center, the CableLabs, and the Advanced Television Evaluation Laboratory in Ottawa, Canada.

Our rigorous laboratory testing program is virtually complete, and we are in the midst of a series of "field" evaluations (i.e., actual over-the-air and cable tests) in Charlotte, North Carolina. Based on early reports from our technical experts, I am confident that the Grand Alliance system will prove to be worthy of the Committee's recommendation to the Commission. Its tremendously flexible architecture will permit the delivery -- on a dynamic basis -- of High Definition Television ("HDTV"), multi-program Standard Definition Television ("SDTV") (essentially, the digital equivalent of NTSC), and also data services related or unrelated to the program offering.

If our Committee decides to recommend this system as the basis of a new broadcast transmission standard, and if the FCC ultimately adopts the recommendation, the Grand Alliance system should provide a new era in video service for the United States -- an era that

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will include larger and wider screens, photographic quality
pictures, and CD quality sound -- what has been called "the theater
of the home." It will also introduce, for the first time, a
digital bitstream into the American home that will enable our
citizens to realize new services envisioned by the so-called
National Information Infrastructure. And the Grand Alliance
system, at the insistence of the Advisory Committee, will be
compatible with the so-called MPEG-2 international standards which
should promote compatibility between our advanced video standard
and others established throughout the world. All told, it
represents a very exciting technological development.

Through the years, the Committee has attempted to maintain a
spirit of cooperation and harmony between the different industries
involved in our efforts. Given their divergent interests, this has
not always been easy. We have succeeded by following certain
principles: open involvement, public meetings, peer review
(especially, effective, I found, among technical experts),
decisions by consensus, and always working for the best available
technology.

However, it is in the nature of an industry advisory committee
that no industry or individual company can get everything that it
might want. And now, as our finish line is in sight, some
individual efforts are being made to alter the extremely broad-
based consensus that we have achieved. For example:

a.   Some broadcasters, once the Grand Alliance system's
      flexibility became evident, began to focus exclusively on
      SDTV and its multi-program capability to the exclusion of
      the quality improvements inherent in HDTV (when, as
      indicated, the system does not require such an either/or
      decision):

b.   Conversely, when over-the-air multi-channel programming
      became a possibility, some in the cable industry objected
      to the FCC's plan to allow broadcasters flexible use of
      digital television.

c.   Similarly, some in the DBS industry have asserted that
      broadcasters do not need to provide HDTV when it can be
      offered by cable and DBS. 4 x 2.15

d.   Recently, some in Hollywood belatedly have argued that
      the television screen dimensions contemplated in the
      Grand Alliance system (16 x 9, as compared to the current
      4 x 3), which were long ago agreed to by our Committee
      with the leadership of the Hollywood community, is not
      adequate.

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e.   And some in the computer industry have objected to the
      fact that the Grand Alliance system encompasses both
      progressive and interlaced scanning formats and, instead,
      have insisted that an all-progressive scan system is
      preferable.[1]

Perhaps a little background on this final point might be
helpful. The fundamental decision to include both formats (which
we found could be done at a minimal cost penalty) was considered
and decided by the Advisory Committee, again on a consensus basis,
nearly two years ago. This determination was made in order to
strike a balance between different industries. An interlaced
format permits over 1,000 scanning lines to be compressed into a 6
MHz channel and, thus, provides a better, clearer video picture (of
great importance, obviously, to the broadcast and cable television
industries). On the other hand, a progressive format allows only
about 700 scanning lines at this time but is preferable for
interoperability with other imaging formats, including computers.
By enabling initial use of both progressive and interlace
techniques, the requirements of all relevant industries can be met.

Despite these individual and fragmentary objections, the
Advisory Committee has continued to "stay the course" and to
maintain our very broad consensus among all of the affected
industries. Indeed, to the extent economically feasible, we have
strived to create an inclusive standard.

Consistent with the FCC's desire, we intend to make our
recommendation to the Commission this year. It is this
recommendation that you will be asked to consider on November 28.
It will include a standard with both HDTV and SDTV formats, and
also a White Paper showing how the Grand Alliance system can shift
dynamically, in different day parts, between the two.

I hope and trust that all of you will make every effort to
attend this final, and historic, meeting. However, if it proves
impossible for you to do so, we will accept attendance and
participation by your representatives. FCC Chairman Hundt plans to
address our session and has invited all Committee members to attend
an informal reception in his office at the conclusion of our
meeting (perhaps around 4:30 p.m. or so).

_____

[1]   However, the Grand Alliance system has been endorsed by
various computer interests working within our Advisory Committee
and by the NIST/ARPA Workshop conducted by the Clinton
Administration.

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      It continues to be my privilege to serve as your Chairman. I
want to thank you for all of your support, participation and
encouragement over the last eight years. I very much look forward
to seeing you on November 28.

      Best regards.

                                    Sincerely yours,

                                    Dick

                                    Richard E. Wiley

M = member (22) + Wiley =23   NO. 582   D26
E = ex officio (12)   6/9
I = for information (3)

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The Fight for Digital TV's Future

By EDMUND L. ANDREWS and JOEL BRINKLEY

WASHINGTON

IT was billed as a demonstration of high-definition television, a chance for Government officials to glimpse a nearly completed system designed to broadcast panoramic pictures at least as crisp and sharp as movies in a theater.

After eight years of struggle, a consortium of seven corporate and research powerhouses from the United States and Europe — including AT&T, M.I.T. and Philips, and known as "the Grand Alliance" — finally seemed close to finishing a system that would usher in a new generation of television.

And so the invited guests came last December, senior officials from the Federal Communications Commission, Commerce Department and Congress, trudging through the pre-Christmas chill into a pair of windowless rooms at AT&T's Washington offices.

They did indeed see stunningly realistic images of mountain vistas, springtime flowers and sun-sparkled lakes. But the demonstration also showed that the technology behind high-definition television could do far more than generate state-of-the-art pictures and sound.

Today's HDTV technology could be used to transmit huge amounts of data to the home — Internet computer files, paging messages, electronic mail and much more — just as easily as it could be used to send "Gone with the Wind," "ER" or "Monday Night Football" to living-room television screens.

It was exhilarating. But the very wizardry of the technology has set off a nasty, high-stakes battle in Washington. One reason is that the system being perfected now is a far cry from what corporate executives, politicians and policy makers had in mind back when HDTV captured the nation's attention in the late 1980's. Then, the four-letter acronym seemed another symbol of the decline of American technology and the apparently relentless rise of Japan. The Japanese had been quietly working on HDTV — defined roughly as pictures twice as wide and twice as sharp as conventional TV — since the 1960's and seemed on their way to controlling the first new TV transmission standard in 50 years.

Alarmed by prospect of losing technological leadership, and perhaps thousands of jobs as well, Washington did two things. First, the F.C.C. set up a race of sorts to establish an HDTV standard for America. And a few years later, the commission promised to set aside new channel space — extremely valuable "real estate" in the broadcast spectrum — for HDTV.

When the race began, with Washington acting as a referee, it was assumed that HDTV would use the analog technology that makes possible the TV and radio broadcasts in use now. But the Grand Alliance developers were able to make the jump to digital technology, employing the 1's and 0's that form the high-speed instructions which control the operation of computers, CD players and telephone switches. Digital code is the lingua franca of today's information age and the much-discussed information highway of tomorrow.

By mastering digital HDTV, the Grand Alliance group leaped ahead of the Japanese. But digital technology has also drastically changed the commercial opportunities and the policy debate surrounding HDTV in 1995.

"The term HDTV was coined to describe the possibility of getting pretty pictures," said Reed E. Hundt, chairman of the Federal Communications Commission. "But what's clear to everyone now is that advanced television is not about pretty pictures anymore. It's about the digitization of television and a huge range of new services — a true watershed moment for the broadcast world."

But therein lies the political battle. Like any such fight, this one is about money, and it entails endless efforts to manipulate public policy for private gain. In this case, the struggle is largely over a prized parcel of the nation's airwaves — the television licenses earmarked for HDTV, estimated to be worth at least $1 billion if they were auctioned on the open market.

But it also raises policy questions that could ultimately affect virtually every home in America. What is "high-definition television" really supposed to be?

The biggest open question is this: should television broadcasters, who were each promised access to a second channel in order to make a "transition" to

Fear of Japan got HDTV going. But now, the race is for money and airwaves. The referee? The F.C.C.

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HDTV, still get that channel even if they have no interest in transmitting high-resolution pictures?

And 1995 is the year Mr. Hundt and the F.C.C. are scheduled to answer those questions.

In one corner is the National Association of Broadcasters, the industry's powerful lobbying group, whose members include the major television networks and hundreds of other owners of local television stations. It was one of the association's chief lobbyists, John Abel, who first suggested pleading with regulators and Congress eight years ago that advanced TV was crucial to the future of his industry.

But today, he and many other broadcasters say they don't want HDTV at all — at least if it is defined the old way, as better pictures and sound. They argue that it offers them few opportunities to make additional money, even after they must spend millions to install new transmitters and production equipment. Most of them adamantly oppose any specific requirement to carry HDTV programming, even just two or three hours a day. At the same time, however, they very much want their second channel and argue they should be free to do almost anything with it.

"**D**IGITAL does not mean higher quality," said Mr. Abel, now the industry's most outspoken critic of HDTV, in an interview last week. "Digital means flexibility. I ask you, what is the public policy rationale of having the same content on two channels?"

But supporters of HDTV — led by companies in the Grand Alliance who developed the technology at the Federal Government's urging — say the broadcasters would stunt the adoption of a critical new technology if they get their way, and block the introduction of a potentially popular new product that could create tens of thousands of jobs. They also argue that the broadcasters are making a veiled attempt to grab a valuable chunk of the airwaves for free — precisely at a time when the Government has begun auctioning other licenses for billions of dollars.

"The broadcasters are saying, 'Gimme, gimme, gimme, and don't tell us how to use it,' " argued Robert Rast, a vice president of the General Instrument Corporation, the company that first invented an entirely digital transmission technology for HDTV and which is now part of the Grand Alliance.

FOR months, this brawl has been fought largely out of the public's view. But now that HDTV development is almost complete, the disputes are rapidly rising to the top of the agenda for the Federal Communications Commission. A Government advisory group plans to start testing the new system in March, and the F.C.C. hopes to adopt the system as a new nationwide standard for television late this year. By that schedule, the first HDTV's could go on sale in less than two years.

It was startlingly pretty pictures on a new Japanese television that started the HDTV saga eight years ago. The National Association of Broadcasters, trying to salvage a lobbying battle that appeared lost, invited NHK, Japan's public television network, to demonstrate their HDTV system, called MUSE, at the Capitol in January 1987.

Another industry group was trying to take over some of the vacant channels that were theoretically reserved for conventional TV broadcasting. But as a last, desperate lobbying strategy the broadcasters, at Mr. Abel's suggestion, tried an innovative ploy: Let's say we need those vacant channels for HDTV.

Even though some F.C.C. commissioners questioned the broadcasters' sincerity, the strategy worked. Members of Congress who attended the demonstration of MUSE saw another commercial threat from Japan, perhaps the gravest ever. And that spawned a frenzy of official concern. Even Mr. Hundt found himself caught up in it. As he helped his friend, Al Gore, run for President in 1988, Mr. Hundt recalled, "We wanted to make HDTV a campaign issue — American industry trailed behind the Japanese, and it seemed that it would have a significant impact on jobs and the future of technology."

In response to these concerns, the F.C.C. set up the Advisory Committee on Advanced Television Service, headed by Richard E. Wiley, a former F.C.C. chairman. Its mission was to advise the F.C.C. on choosing an HDTV standard for America.

With the F.C.C.'s blessing, the Advisory Committee opened a competition. Anyone in the world could enter, and 23 HDTV proposals came forward. The best system would be selected as the new television standard for the United States, meaning the winner could reap billions of dollars.

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From the beginning, most people believed the Japanese would win. Nothing else in the world was as advanced as MUSE, which had been under development since the late 1960's. But then in May of 1991, the VideoCipher division of General Instrument, a little known research lab in San Diego that made satellite television equipment, turned the race on its head by offering a fully digital system — something broadcast engineers had considered virtually impossible.

All of the other contestants, including NHK, were offering analog systems. But General Instrument's device transmitted the TV signal just the way computers do, and that suddenly gave television a degree of flexibility it had never had before.

Every one of the other contestants in the race, save the Japanese, quickly switched to fully digital systems. And in 1991 the F.C.C., under its then chairman, Alfred Sikes, ruled that every TV station in the country would be loaned a second channel for the transition to HDTV.

In 1993, the Japanese dropped out of the race, and the remaining contestants joined forces to form what came to be known as "the Grand Alliance." Its members are AT&T, General Instrument, the Massachusetts Institute of Technology, the David Sarnoff Research Center, Thomson Consumer Electronics, Philips Consumer Electronics and the Zenith Corporation. For the last 18 months they have been combining elements of their own prototypes to build the consortium's system.

BY all accounts, the HDTV system now nearing completion offers far more possibilities than anybody imagined eight years ago. Instead of offering just one channel of "true" high-definition programming, it can provide as many as six programs of conventional-resolution TV simultaneously in the space one TV channel occupies today. Or it is possible to reduce the digital bit rate of the high-definition signal when the images are relatively simple — such as an anchorperson reading the news — and pack in millions of bits for other uses.

Broadcasters, led by Mr. Abel, don't want to spend several million dollars on new, digital equipment just to send high-resolution pictures. But they would dearly love to use the second channel for other possibilities: two-way paging systems or high-speed wireless links for computers, for example. Some broadcasters, particularly Rupert Murdoch's Fox Broadcasting Company, propose using digital technology on the second channel to squeeze more conventional television programs into the frequencies that are normally reserved for just one.

But there lies the problem. A single television license can be worth hundreds of millions of dollars, because it gives a company exclusive rights to what the broadcasters' association likes to call "prime beach front property" on the broadcast spectrum. TV broadcasters would be getting these licenses for a second channel at precisely the time when cellular telephone and paging companies are being forced to bid for their own licenses in multibillion-dollar open auctions.

In the interview, Mr. Hundt suggested that if broadcasters intend to offer cable-television-style subscription services on the second channels, the Government could choose to auction them instead. And the broadcasters' opponents call their ambitions "a flagrant spectrum grab."

F.C.C. officials must reconcile these competing interests, and much is at stake. Television equipment manufacturers adamantly want to build a critical mass market for HDTV, and the companies building the Grand Alliance prototype say they do not believe many people are going to buy expensive new televisions — the earliest models are expected to sell for about $3,500, though that price is almost certain to fall — just because they can double as two-way pagers or provide additional programming similar to what most people already get on cable.

"Services of high complexity don't appeal to most people," said Joseph Donahue, a senior officer with Thomson Consumer Electronics.

"They're intimidated. Surveys and test projects show that most people, more than half, want to use the device to watch TV, watch movies. In simple terms, we must capitalize on the huge interest in TV."

F.C.C. officials have their own ideas. Mr. Hundt often talks about a bargain in which broadcasters would get their second channel in exchange for new commitments to carry educational television, nonprofit services or even free advertising for political candidates.

"Maybe we would obligate broadcasters to dedicate part of their spectrum for some public purpose," he said. At the same time, though, Mr. Hundt does not seem particularly enthused about high-definition pictures. And that leaves some Grand Alliance members to feel they have been betrayed. They spent hundreds of millions of dollars at the Government's request, they say, to create the most advanced HDTV system in the world. Now that they are nearly finished, some in Government and industry are saying they don't want it — at least for its original purpose.

But Mr. Hundt says: "The technology has caused the policy to change."

IN the end, HDTV proponents argue that their system can do it all — provide stunning high-definition pictures while also offering the capability to provide additional services. "It's not an either-or situation," Mr. Wiley says. "You can have high quality and everything else, too."

But Mr. Rast cautions: "The fuzzier that HDTV becomes, the harder it is to present to consumers."

As early as 1989, just two years after Mr. Abel helped place high-definition television on the national agenda, he was complaining that HDTV would be "a huge expense for broadcasters." And using one tactic after another, he and others in the industry have been trying to evade any responsibility for broadcasting HDTV ever since.

TODAY, broadcasters argue that there's no public demand for HDTV, so why even bother offering it? At an industry conference last year, Mr. Abel told a group of broadcasters: "You don't want HDTV. And consumers say they don't want it, either."

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In a remarkable display of lobbying prowess, the broadcasters almost persuaded lawmakers in the House and Senate last year to give them their way. The issue arose as Congress was trying to pass a sweeping overhaul of telecommunications law that would have let telephone and cable television companies enter each other's markets.

The National Association of Broadcasters drafted an amendment that would have allowed broadcasters to offer "ancillary" data services over the second channel. But it would also have permitted broadcasters to offer little if any high-definition programming, as long as they were offering some sort of "advanced television" — a term open to varying interpretations. In exchange, Edward Fritts, the association's president, offered to pay a five-percent royalty on revenues from nonbroadcast services.

The idea had never been discussed in a public hearing, but Mr. Fritts persuaded a friendly lawmaker to propose it at the last minute, as the House Energy and Commerce subcommittee was voting on the broader bill. Not everybody liked it. "We're being played for Uncle Sucker," exclaimed Representative Michael L. Synar, an Oklahoma Democrat on the subcommittee. After a short but heated debate, supporters of the bill withdrew the proposal.

But the broadcasters hardly gave up. When the full Energy and Commerce Committee voted on the legislation, it slipped the provision back in. A similar provision made its way into a bill being drafted by the Senate Commerce Committee.

Members of the Grand Alliance loudly protested, charging in a letter to Senate lawmakers that the broadcaster proposal would "threaten to undermine the implementation of HDTV in the United States."

Mr. Fritts fired back. "The Alliance has spent millions of dollars developing a technology that no one has any idea consumers will want to buy," he wrote. "Mandating their technology would ultimately force consumers to buy their product, whether they want it or not."

The provision remained part of the bill, but the legislation was derailed by unrelated disputes.

To the broadcasters' assertion that nobody wants HDTV, Mr. Donahue repeatedly points out that "there's never been a demand for a new product before it was introduced." The chicken-and-egg truism, he adds, applies to most of the communications and entertainment services Americans take for granted today. The public was not calling for radio services in 1918, television in the 1930's or color TV in the 1950's.

More recently, they point out, there was no public clamor for a means to tape record television shows before video-cassette recorders were introduced. The same was true for compact disks, personal computers and cellular phones.

"The public hasn't seen HDTV," Mr. Wiley told an industry conference last fall. "My view is that the public has to be given a chance to see HDTV and choose whether they want it." ■

7

TECHNICAL SUBGROUP MEMBERSHIP

10/20

Co-Chairs

1. Irwin Dorros
2. Joseph Flaherty (CBS)

Members

3. Lynn Claudy (NAB)
4. Birney Dayton (NVision)
5. Alex Felker (Time Warner Telecommunications)
6. Branko Gerovac (MIT)
7. Michael Haley (IBM)
8. John Henderson (Hitachi)
9. Robert Hopkins (ATSC)
10. Renville McMann (Consultant)
11. Mark Richer (PBS)
12. Robert Sanderson (Eastman Kodak)
13. Craig Tanner (CableLabs)
14. Victor Tawil (MSTV)
15. George Vradenburg (Latham & Watkins)

Ex-Officio Members

1. Metin Akgun (CRC)
2. Robert Bromery (FCC)
3. Peter Fannon (ATTC)
4. James Gaspar (Panasonic)
5. Reggie Gilliam
6. George Hanover (EIA)
7. Brian James (CableLabs)
8. Robert Niles (Capital Cities/ABC)
9. Richard Prodan (CableLabs)
10. Charles Rhodes (ATTC)
11. Peter Smith (NBC)
12. Laurence Thorpe (Sony)

Observers

1. Brian Olsen (Advanced Broadcasting Systems of Canada)
2. Kenneth Davies (SMPTE/CBC)
3. Midhat Gazale (Association for Television of the Future)
4. Ji Fusheng (State Science & Technology Commission/PRC)
5. Keiichi Kubota (NHK)
6. Howard Miller (PBS)
7. Victor Rojas (Televisa)
8. George Waters (EBU)
9. Yan Honggi (Ministry of Radio, Film & Television/PRC)

July 18, 1995

(5/20)

Commissioners diverge on digital

ATV proposal raises issues of flexibility, public interest

By Chris McConnell

The actual decisions may be a long way off, but FCC commissioners last week voiced differing views on how the advanced TV regulatory picture ultimately will look.

Issuing the first in a three-part series of advanced TV proceedings, commissioners offered diverging comments on how the rules should treat the issues of public interest obligations and spectrum flexibility.

The proposal issued last week raised questions about both subjects and invited comments on whether there should be minimum HDTV broadcasting requirements; how the transition to digital broadcasting should be defined; how the analog spectrum should be recovered; whether mandatory receiver standards are needed; the impact of digital TV on must-carry and other laws, and whether there should be special considerations for small-market broadcasters.

The commission's notice tentatively concluded that existing broadcasters should get the first crack at obtaining a digital license and that they should have freedom to offer a mix of high-definition, standard-definition "and perhaps other services."

But the extent of that flexibility drew different responses from commissioners. Commissioner Andrew Barrett worried that broadcasters will not provide HDTV without a requirement to do so and said he will consider reversing his support for granting broadcasters a second channel if there is no minimum HDTV rule.

Chairman Reed Hundt contended that such a requirement might be more meddling than the prime time access rule (PTAR) killed by commissioners at the same meeting, although he also said commissioners should keep an open mind until comments come in this fall. Hundt, who said he would prefer that Congress—rather than the FCC—tackle the ATV issues, speculated that mandating one channel of HDTV would preclude multiple channels of standard-definition programing. "It would be a prohibition on speech," he said.

Hundt also cited children's educational TV as an area where government intervention could be warranted. "It is our kids who stand to gain the most, and to lose the most, from our decisions in this proceeding," Hundt said in a statement on the rulemaking.

Commissioner James Quello, however, voiced concern about "the specter of social contracts," in which the government would extract program requirements from broadcasters in exchange for digital broadcasting rights.

Hundt has suggested that broadcasters might provide children's educational TV or other types of programing as "in-kind compensation" for flexibility in the second channels. Last week he also suggested that broadcasters implement contracts in each market stipulating plans for educational programing (see story, page 11).

While Quello and Barrett cited the preservation of free, over-the-air TV as an overriding concern, Hundt also maintained that the FCC previously has not needed to take any action to achieve such a result. He asked whether there will be any need for the FCC to "meddle" in the digital age to achieve such a result.

Commissioners were more in agreement on the issue of heading off any broadcast efforts to keep both channels. In addition to preserving free TV and fostering the transition to digital TV, the FCC proposal states as one of its goals the recovery of spectrum "in contiguous blocks for new, as-yet-undefined services."

"There isn't any person here who hasn't heard, 'We'll never give it back,'" Hundt said. Commissioner Rachelle Chong questioned FCC General Counsel Bill Kennard on the likelihood of winning in court if broadcasters refuse to give the analog channel back. Kennard predicted a win.

Later this fall, the FCC will launch two more rulemaking proceedings covering the allotment and assignment of channels for digital TV and the adoption of a digital transmission standard. ∎

2nd channel: To free or not to free?

Senator Pressler

Awarding broadcasters a free second channel to make the transition to digital television is "outrageous," Henry Geller told the Senate Commerce Committee last week.

Broadcasters "are not entitled to 12 mhz," said Geller, former FCC general counsel and National Telecommunications and Information Administration chief. If broadcasters are awarded a second channel, it should be returned to the government on a "date certain," he said.

Geller made the statements during a hearing on spectrum reform held by Senate Commerce Committee Chairman Larry Pressler (R-S.D.). The hearing kicked off Pressler's search last week for the $14 billion in spectrum revenue called for in the Senate budget proposal.

Geller also suggested that the government could raise revenue by ending public interest regulation of the broadcasting industry. In return, broadcasters could be charged a "3% fee" on their gross revenue, with the revenues from the fees used to finance public television.

Panelists said it will be difficult to repeat the success of the first broadband PCS auctions, which raised $7.7 billion for the U.S. Treasury. That sale was driven by scarcity, but as more spectrum goes to market, they said, prices naturally will fall.

Panelists at the hearing included Stanley S. Hubbard, president, Hubbard Broadcasting; Wayne Perry, vice chairman, McCaw Cellular and AT&T Wireless Services, and Peter Pitsch, Progress & Freedom Institute.

Although Pressler did not single out any particular slice of spectrum for the auction block, he asked if broadcasters should be charged for their digital spectrum. —CSS

Quest for Sharper TV Likely To Bring More TV Instead

Technology Allows Expansion of Programs

By EDMUND L. ANDREWS

WASHINGTON, July 9 — High-definition television, which became the rallying cry for the revival of the American electronics industry in the 1980's, now seems to be a wonder whose time may never come.

Just as the vision of HDTV, with its promise of dazzlingly sharp pictures, is on the verge of becoming reality, broadcasters and regulators increasingly agree that what the American public will want is more television, not better television.

For broadcasters, the hot new buzz words are "standard definition" television, or SDTV. Using the same technology created to make high-definition television possible, "standard definition" television allows a broadcaster to pack four or five programs of ordinary quality onto a single channel. Picture quality could actually be worse for some new services, depending on how a television station uses the newly available technology.

"With digital, you can make the picture as bad as you want," said Peter Fannon, head of the Advanced Television Testing Center in Fairfax, Va. Weaker pictures require less data, making it possible to send more programs over one band of radio frequencies.

The new possibilities leave broadcasters and regulators confronting a basic transformation in the television industry. The Federal Communications Commission is preparing to overhaul its policies this month in response. That process, in turn, is creating a huge political battle over the control of both old and new broadcast frequencies. The fight centers on who should pay for the frequencies, who can profit from them and how the public should share in the benefits.

Television broadcasters, who had been promised new channels to introduce high-definition television, want the freedom to do as they please with those channels. In Congress, however, Republicans are hungrily eyeing this new broadcast real estate as a source of income to help reduce the deficit. They want to make broadcasters pay for the channels, one way or another.

Meanwhile, Reed E. Hundt, the chairman of the F.C.C., would like to force broadcasters to provide more public services like educational programming for children.

The broadcasters are hardly of one mind about how to proceed. Many are uneasy about all the available options. Companies that own local stations fear that having four or five channels will cannibalize their existing business, forcing them to pay for more programming without being able to attract more advertising.

But companies that own stations and produce large quantities of programming — like Rupert Murdoch's Fox Broadcasting and some major networks — see a big opportunity to market their material in new ways.

Mr. Murdoch, whose News Corporation owns Fox, has floated the idea of creating a new all-news channel, among other things, that would be carried as part of a digital package by Fox affiliates. In place of one channel broadcasting Fox programming, there would be a package of four channels including an all-news channel, an all-children's channel and a sports channel in addition to the channel carrying existing Fox programming.

Other broadcasters see opportunities to offer paging or specialized information services that may have nothing to do with television.

Oddly enough for the consumer, the end result of an eight-year quest to provide reliably higher-quality pictures may in fact be lower-quality pictures, depending on how a television station uses the new technology.

"I predict that television broadcasters will have a knob they can dial, and the knob will basically say 'great pictures' at one end and 'lousy pictures' at the other," said Robert Hopkins, executive director of the Advanced Television Systems Committee, an industry group of broadcasters and equipment manufacturers that has proposed new formats for "standard definition" television.

Industry executives and regulators are now circulating more than a dozen new formats for digital television, all of which use the same technology as HDTV but stretch or smush the pictures to use less data for each picture. As envisioned, television stations would be able to beam several pay-television programs, like all-movie channels or an all-news channel, and leave room for one "free" channel.

Supporters of this standard digital television say the pictures will be better than those today, even if they are not as sharp, because they will

be freer of interference. "The quality is going to look a lot better," said John Abel, head of technology for the National Association of Broadcasters.

Whatever the quality of the pictures, Congressional Republicans see in the new digital universe a new source of Federal revenue. The budget resolution recently passed by Congress calls for raising $14 billion over the next seven years by auctioning radio frequencies.

Broadcasters are now increasingly alarmed about an informal proposal circulating in the House that would require them to give back their original television licenses in 10 years, at which point they would switch to digital transmission. The Government would begin auctioning the licenses three years earlier, in the year 2002.

The newest twists about high-definition television dramatize the unpredictable impact of Government-prodded industrial policy. Congress and the F.C.C. both seized on the issue in the 1980's as a symbol for restoring American prowess in consumer electronics. At the time, Japanese companies appeared to be far ahead in the field and well poised to repeat their victories in videocassette recorders and cameras.

The new American system, developed by a consortium of companies, is now in the final stages of testing and the F.C.C. hopes to approve it as a national standard by the year's end.

But most broadcasters doubt there is much demand for high-definition television. Most proposed formats for "standard definition" television that a broadcaster could choose from would provide roughly the same sharpness as today's television, as measured by the number of pixels or color dots on a screen.

A few formats would offer wider pictures, like those on a movie screen, by stretching the space between each pixel and thus thinning the resolution. One option would provide blurrier pictures than at present. Mr. Hopkins said that option was created for tasks like offering a picture within the main picture.

The biggest challenge for standard-digital television is likely to be live sports, which entails fast-changing images that require large amounts of data. If images are sent at relatively low data rates, viewers could see pictures lock up briefly as the television receiver struggles to capture the data it needs.

NEW YORK TIMES

JUL 10 1995

The new system could be a boon for old-movie channels, because movies are filmed with less than half as many frames a second as video and therefore can be transmitted with less data. Broadcasters wanting to squeeze more out of their channel might be able to pack in four separate movie services and still have room to offer an unrelated wireless service like paging.

Mr. Hundt of the F.C.C., said the market should probably determine picture quality. "Fundamentally, the logic of flexibility is that broadcasters should be free to regulate the quality of their pictures as well as their content, according to market demand," he said last week.

The big question is what, if anything, broadcasters should provide in exchange for being lent a second channel for converting to the digital age. As part of its proceeding, the F.C.C. will ask whether broadcasters should be automatically entitled to a second channel at all or whether broadcasters should be required to provide other public services, like expanded children's programming.

"The public should get something in return," said Gigi Sohn, deputy director of the Media Access Project, a nonprofit group in Washington. "There are all kinds of different possibilities — children's television, free air time for political candidates."

One thing the public will eventually have to swallow will be the requirement that they replace or supplement their current televisions and VCR's with receivers that can pull in digital signals.

An advisory committee is expected to complete testing on the new transmission system by the fall, and F.C.C. officials hope to tackle most of the policy issues by year-end. That might mean that the first digital TV sets reach the market by 1997 — if anyone wants to buy them.

2 TV Stations Bought by Fox

LOS ANGELES, July 9 (AP) — The Fox Television Stations have purchased stations in Colorado and Tennessee for $150 million.

Fox, a unit of Rupert Murdoch's News Corporation, bought WHBQ-TV in Memphis on Wednesday from Comcorp of Tennessee Inc. for $80 million, a Fox spokeswoman, Jill Tsukamoto, said. The station was an ABC affiliate.

On Monday, Fox bought KDVR-TV in Denver from the Renaissance Communications Corporation for $70 million. KFCT, KDVR's satellite station in Fort Collins, Colo., was included in the transaction.

Fox also sold Renaissance KDAF-TV in Dallas for $100 million.

FCC says TV licenses worth $35 billion

Airwave auctions could reduce deficit

By Michael Arndt
TRIBUNE STAFF WRITER

The federal government could pocket $35 billion by auctioning off licenses that will serve as entry tickets for TV broadcasting in the 21st Century, according to an analysis by the Federal Communications Commission.

That sum is high even for an industry that in this month alone has seen Walt Disney Co. offer $19 billion to acquire Capital Cities/ABC Inc. and Westinghouse Electric Corp. raise nearly $11 billion to acquire and run CBS Inc.

At $35 billion, the auction would raise as much as the government will spend this year on four full departments—Justice, Interior, State and Commerce—plus the Environmental Protection Agency.

Both the Clinton administration and the Republican leadership in Congress have come out in favor of requiring the FCC to sell off more airwave licenses to help plug the federal deficit and bring the budget into balance.

Under the budget guidelines that Congress has passed, the agency would be responsible for raising $14 billion in fiscal 1996, which starts Oct. 1, through auctions.

As Congress considered a separate measure overhauling the telecommunications industry, the FCC was asked how much money it could raise by selling off the hundreds of TV licenses for the now digital spectrum it expects to issue over the next decade or so.

FCC Chairman Reed Hundt, who was in Chicago Friday, said that the agency came up with the $35 billion estimate based on the sale this month of an unaffiliated UHF station in New York for $207 million to Dow Jones Co. and the $8.9 billion the FCC has raised in four previous telecommunications auctions.

But while more auctions could be an easy source of money, Congress so far has not specified which licenses should be sold.

And some analysts say the television industry—historically one of the most potent lobbying groups in Washington—may be able to persuade Congress to permit the FCC to continue giving away TV licenses, as it has since the first days of broadcasting.

Indeed, neither the Senate nor House bill rewriting the nation's bedrock 61-year-old communications act says anything about selling licenses, though lawmakers are expected to try to insert such an amendment in a final budget measure next month.

Arguing against an auction, the National Association of Broadcasters has said current TV-license holders should be given licenses for a new portion of the radio spectrum to enable them to begin beaming digital signals.

The association makes that point because for as long as 15 years, TV stations may be required to continue using their existing licenses to transmit analog signals as the nation switches over to the new, clearer digital technology.

But free-market advocates and proponents of a balanced budget counter that taxpayers should no longer give away something that the industry could well afford to buy.

"It would be a blatant giveaway of taxpayers' dollars" not to sell these licenses to the highest bidders, contended Adam Thierer, an economics fellow at the conservative Heritage Foundation in Washington.

2

From: NAME: Grace Hinchman @DCC
           FUNC: Government Relations
           TEL: 427-5003 (Fax 5030)   <HINCHMAN.GRACE@COPSS2A1@SOAREA@AL
F>
To: Sam Fuller@LJO
CC: Tom Gannon@LJO,
           Robert Bismuth@LJO

     Sam, I just got off the phone with Tom Gannon and he is unsure who
is going to be attending the Advisory Committee on Advanced Television
Service (ACATS) meeting in Washington D.C. The meeting is next week and I
believe it very important that Digital be present for a couple of reasons:

     1) Since Digital has been involved in the ACATS process for several
years and, indeed, responsible for several of the ACATS compromises, Digital
can best register the position of the computer industry as reflected by CSPP
and ITI.

     2) At the specific request of Chairman Reed Hundt, Microsoft was named
as the second "computer industry" representative to the ACATS. I learned
today that Microsoft will vote against the proposed recommendations of the
Committee as outlined in the memo I faxed to you. Craig Mundy (sp.?) is
attending the meeting for Microsoft.

     3) Our participation can only enhance our alliance relationship with
Microsoft by having Microsoft observe Digital in this industry-leader role
during such a high visibility meeting with FCC Chairman Reed Hundt.

     Could you please let me know if you, Tom Gannon or someone else from
ATG will be attending on behalf of Digital because I would like to accompany
you/him/her to the meeting. (Should be an interesting meeting!)

Regards, Grace

MICROSOFT PARTNERSHIP

FEDERAL COMMUNICATIONS COMMISSION
WASHINGTON

OFFICE OF
THE CHAIRMAN

October 23, 1995

Dr. Samuel Fuller
Digital Equipment Corporation
30 Porter Road
Littleton, MA 04160

FEDERAL COMMUNICATIONS COMMISSION
WASHINGTON, D. C. 20554

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

Dear Dr. Fuller:

Thank you for accepting my invitation to join the Commission's Advisory Committee for Advanced Television Service. Your participation will help to insure that the process begun in 1987 will soon be brought to a successful conclusion. The introduction of digital broadcast promises to bring great benefits to our economy through the creation of new products and services for the American people.

Enclosed you will find a letter sent today to all current members of the Advisory Committee. In addition to introducing you and the other new members, I have outlined my hopes and expectations for the few remaining activities of the Committee. I want to make clear that I am confident that there are still contributions to be made and your participation will be welcomed and valued.

As an active member, you will be expected to review and comment upon final reports drafted by Committee Chair Richard Wiley, as well as attend the final meeting here in Washington on November 28. I have asked Mr. Wiley to contact you in the near future to outline the specific actions required. I look forward to seeing you here in Washington next month.

Again, thank you for volunteering your valuable time to this very important endeavor. In years hence I am confident you will look back at this effort as richly rewarding to your industry, the economy at large and most importantly the American people.

Very truly yours,

Reed Hundt
Chairman

cc: R. Wiley, Chairman, ACATS

October 23, 1995

Dr. Samuel Fuller
Digital Equipment Corporation
30 Porter Road
Littleton, MA 04160

Dear Dr. Fuller:

Since the Advisory Committee on Advanced Television Service was chartered eight years ago on September 30, 1987, literally thousands of hours and millions of dollars have been invested by industry participants in defining and testing what promises to be the leading digital broadcast technology in the world. At long last, the end is in sight. You have been asked to join me here in Washington on November 28, 1995 to cast the final vote on a recommendation for a digital broadcast standard for the United States. This will truly be an historic moment, marking the beginning of the end of analog broadcast and a significant milestone in the creation of this nation's information superhighway.

I want to thank you for the tremendous contributions each of you has made to this process over these many years the standard has been developed, defined, redefined and tested. Assuming that the Commission adopts the standard, it will very likely shape the broadcast industry for the next fifty years, just as the NTSC standard has for the past fifty. Given that this standard will have a tremendous impact on the future of not only the broadcast television industry but also on all emerging multimedia interests, I felt that it was important for me to take this time to impress upon you, as a member of this rather select and august Committee, the importance I place on your continued, direct participation. It is, in my view, essential that members participate fully and completely in the culmination of this standards process. Committee members have been chosen because of their personal experience, expertise or leadership positions in the broadcast and communications industries. I am asking that you make every effort to participate personally in this final review, recommendation and meeting, relying on your appointed representative only as a last resort.

As the Committee has been in existence for some eight years, changes have been made from time to time to reflect the evolution of the technology and the details of the process. As we enter the last phase of its activities, I thought it would be appropriate to update the structure and procedures of the Committee. To that end, I would like to reaffirm a decision made by Chairman Sikes in 1992 which stated that members who are or were associated with the development of the system refrain from voting on the recommendation to avoid even the appearance of a conflict of interest and to ensure a fair, balanced and objective report.
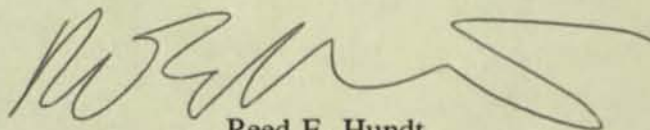
I am also announcing the appointment of several new members to the Committee to bring it up to its full amount as permitted by Charter. I am sure you will join me in welcoming these new members and will help, if necessary, in bringing them up to date on the many difficult issues faced by the Committee as it undertakes what we all hope is its final obligation to the Commission.

These new members are Ervin Duggan, President and Chief Executive Officer, PBS; Samuel Fuller, Vice President of Research, Digital Equipment Corporation and Craig Mundie, Senior Vice President, Microsoft Corporation.

In addition to these new voting members, I am inviting Peter Bingham, President, Philips Laboratories to join in the final deliberations as an *ex officio* member. *Ex officio* members are entitled to participate in the deliberations of the Advisory Committee and may express their views, enter into debate on issues and offer suggestions as to any position the Committee should adopt. They may not, unfortunately, participate in any vote and the Parent Committee is not obligated to embody their views in the final report. Nevertheless, I feel it is essential that we welcome their expert advice and opinions to help ensure the standard recommended is the best possible to serve the needs of all sectors of the information and entertainment economy.

Please accept my heartfelt thanks on behalf of the American people for your contribution to this difficult task. The challenges have been formidable, but the rewards promise to be great. You can all be proud of this effort. I look forward to seeing you here in Washington on November 28, and hope that you will join me in my office for a reception immediately following the Advisory Committee's meeting.

Best regards,

Reed E. Hundt
Chairman

FEDERAL COMMUNICATIONS COMMISSION
WASHINGTON

OFFICE OF
THE CHAIRMAN

October 23, 1995

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Very truly yours,

Reed Hundt
Chairman

11/27-28

ATG Woods

cc: R. Wiley, Chairman, ACATS

October 23, 1995

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Digital Equipment Corporation
30 Porter Road
Littleton, MA 04160

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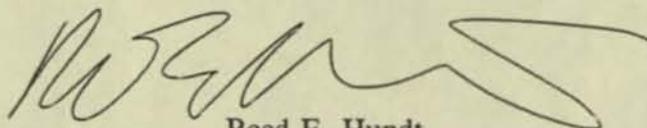
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Best regards,

Reed E. Hundt
Chairman

WILEY, REIN & FIELDING

RECEIVED

NOV 02 1995

SAM FULLER

November 1, 1995

Re: FCC Advisory Committee on Advanced Television Service

Dear Members:

As you previously have been advised, our Committee will meet for the final time on <u>Tuesday, November 28</u> (at 2:00 p.m., in the Federal Communications Commission Conference room, 8th Floor, 1919 M Street, Washington, D.C.). At that time, we hopefully will agree on a "Final Report and Recommendation" to the FCC.

Enclosed for your review and comment is a draft of this document. I request that you submit any comments or suggested changes by <u>November 15</u>. Thereafter, I will prepare a revised draft for presentation and, hopefully, adoption at our November 28 meeting.

Thank you for your consideration and best regards.

Sincerely yours,

Dich

Richard E. Wiley
Advisory Committee Chairman

REW:lcg
Enclosure
cc: FCC Chairman/Hundt

ADVISORY COMMITTEE
FINAL REPORT AND RECOMMENDATION

FEDERAL COMMUNICATIONS COMMISSION

ADVISORY COMMITTEE ON ADVANCED TELEVISION SERVICE

November 28, 1995

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I.   INTRODUCTION

This is the final report and recommendation of the FCC's Advisory Committee on Advanced Television Service. It was adopted by the Advisory Committee at its ninth and final meeting, held in Washington, DC, on November 28, 1995.

This year is the 100th anniversary of radio broadcasting. Television is only half as old; it was introduced in 1941 when the FCC adopted the current NTSC standard.[1] Subsequently, TV was improved in 1953 when the Commission approved the NTSC color standard. Only a few minor improvements (most notably, the addition of stereo audio in 1986) have been made in the ensuing four decades. This report heralds the greatest advance in broadcast television technology since its inception over fifty years ago. The possibilities for the future include dazzling pictures, CD-quality sound, the flexibility for multiple programs and data streams, and interoperability with alternative media and systems including computers.

In 1987, the FCC and Advisory Committee began to study the potentially great technical improvements that might be possible with advanced television ("ATV").[2] At the time, new transmission systems were being developed for direct broadcasting satellite and other media. It was not certain, however, whether a complete ATV system could work in 6 MHz over-the-air

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[1]   The NTSC standard, which is named after the National Television Systems Committee which developed and modified it, is embodied in Part 73 of the Commission's Rules, *See* 47 C.F.R. § 73.682 (1994).

[2]   The FCC defines ATV to "include any system that results in improved television audio and video quality . . .." *Tentative Decision and Further Notice of Inquiry* in MM Docket No. 87-268, 3 F.C.C. Rcd 6520, 6521 note 1 (1988). High definition television ("HDTV"), a subset of ATV, generally refers to systems that provide quality approaching that of 35 mm film. *Id.* HDTV "has a resolution of approximately twice that of conventional television in both the horizontal (H) and vertical (V) dimensions and a picture aspect ratio (HxV) of 16:9." ATSC Digital Television Standard at 5.

channels. Now, eight years later, after countless public meetings involving hundreds of industry volunteers and a rigorous program of testing and analysis conducted on seven prototype ATV systems at three futuristic laboratories, the Advisory Committee on Advanced Television Service herein recommends that the Federal Communications Commission adopt the "ATSC Digital Television Standard" as the U.S. standard for ATV broadcasting.

This standard represents truly world-leading technology. It will allow American television broadcasters and viewers to participate in the digital age and is equally available for cable TV providers and subscribers. In addition, more than any other ATV system in the world, the technology is interoperable with other imaging media and systems.

The present document has two principal sections. First, the Advisory Committee reports on its history, progress and results, including the final tests on a prototype advanced television system from a consortium of companies known as the Digital HDTV Grand Alliance. Second, the Committee sets forth the details of its recommendation.

II.   REPORT OF THE ADVISORY COMMITTEE

A.   Purpose of the Committee

In early 1987, the Federal Communications Commission ("FCC" or "Commission") initiated a rule making proceeding on advanced television ("ATV") service "to consider the technical and public policy issues surrounding the use of advanced television technologies by television broadcast licensees."[3] Later that year, and in order to assist the FCC "in gathering and

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3   *Notice of Inquiry* in MM Docket No. 87-268, 2 F.C.C. Rcd 5125, 5126 (1987).

processing much of the necessary information" on ATV,[4] the Commission established the

Advisory Committee on Advanced Television Service ("Advisory Committee" or "ACATS").[5]

In its Charter, the Advisory Committee was given the broad mandate to "advise the

Federal Communications Commission on the facts and circumstances regarding advanced

television systems for Commission consideration of the technical and public policy issue[s]."[6]

The Committee's Charter also directed that

> In the event that the Commission decides that adoption of some
> form of advanced broadcast television is in the public interest the
> Committee would also recommend policies, standards and
> regulations that would facilitate the orderly and timely introduction
> of advanced television services in the United States.[7]

The Advisory Committee's work became more specifically directed on advising the FCC on a

technical standard for ATV broadcasting when, in late 1990, it entered a Memorandum of

Understanding ("MOU") with the Commission and two ATV test laboratories.[8] This narrowed

focus was articulated by the Committee a few months later: "Ultimately, it is the Advisory

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4   *Id.*

5   *Formation of Advisory Committee on Advanced Television Service and
Announcement of First Meeting*, 52 Fed. Reg. 38523 (October 16, 1987). ACATS was formally
established under the provisions of the Federal Advisory Committee Act ("FACA"), *codified at* 5
U.S.C. App. II (1988). The Committee has operated in accordance with the provisions of the
FACA and GSA's Federal Property Management Regulations. 41 C.F.R. § 101-6.10 (1994).

6   *Id.* at p. 38523. The Advisory Committee Charter is attached at Appendix A.

7   *Id.*

8   A copy of the MOU is attached at Appendix B. In accordance with the Charter,
the Committee on occasion also has received direction from the Chairman of the FCC.

Committee's goal to agree on an ATV technical description that can be recommended to the FCC for consideration as the next generation television transmission standard."[9]

B.   Committee Structure and Participants

The FCC appointed the twenty five members of the Advisory Committee and selected Richard E. Wiley to be its Chairman. Described in the Charter as the "Parent Committee," the membership of this private-sector body was selected to achieve balanced representation from among the broadcasting, cable, consumer electronics, satellite broadcasting, program production, film, and telephone industries. At the time, these were the major industries thought to be involved in advanced television. Due largely to the state of technology in 1987, the FCC did not then perceive the computer industry as being significantly affected by ATV broadcasting. However, subsequent technological advances, particularly the introduction of digital transmission technology that enhances interoperability with computers and other media and systems, generated significant interest within that industry. Thereafter, computer company officials participated actively and effectively in ACATS activities. Additionally, the Chairman of the FCC recently appointed two industry members to the Parent Committee to replace other members who had resigned.[10]

This Parent Committee has met roughly once per year since its inception and, as enumerated below, has presented several interim reports to the Commission. The work of the

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[9]   Fourth Interim Report of the Advisory Committee on Advanced Television Service ("ACATS Fourth Interim Report") at pp. 18-19 (April 1, 1991). Obviously, the Commission, not the Advisory Committee has the authority to establish a broadcasting standard. *See* 47 U.S.C. § 303 (e), (f) (1988).

[10]   A current membership list of the Parent Committee is attached at Appendix C.

Advisory Committee, however, was achieved primarily by volunteers organized in various

groups under the Parent Committee. Part of this staff organization was described in the Charter,

which listed the Planning, Systems, and Implementation Subcommittees. The Advisory

Committee also formed a "Special Panel" in early 1992,[11] and a "Technical Subgroup" later that

year.[12] Both of these bodies were comprised of leading technical experts and were structured

with constituent subgroups.[13] As with all Advisory Committee bodies, the leadership of these

groups was selected to balance the interests of the various affected industries.

By some estimates, over 1000 individuals have participated in the Advisory Committee's

work during its eight year history. Participants have come from the broadcasting, cable,

consumer electronics, computer, program production, film, telephone, and other industries --

many of them recognized experts in their fields. Representatives of labor, academia, and public

interest groups also have taken part. Moreover, because all Committee meetings have been open

to the public, interested citizens and the press also have attended meetings of the Parent

Committee and its many subgroups.

To the great benefit of the Advisory Committee, members of the FCC's staff often have

observed and participated in Committee meetings. The Commission's guidance, expressed

formally in rule making proceedings and informally in myriad interactions with Advisory

Committee officials, has been invaluable to our work. However, the Committee has received no

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11   Minutes, Advisory Committee Meeting p. 3 (March 24, 1992).

12   Letter, Richard E. Wiley to ATV System Proponents (August 21, 1992).

13   A list of the Advisory Committee staff structure is attached at Appendix D.

funding from the Commission or other government bodies. Its operating costs (*e.g.*, postage, photocopying, and telephone) have been underwritten solely by small donations from Committee members.[14]

C.   Relationship with Other Bodies

Several organizations not directly part of the Advisory Committee were critical to its mission and success. Key among these were the three laboratories that tested ATV hardware from several system proponents including the Digital HDTV Grand Alliance. The largest of the three was the Advanced Television Test Center ("ATTC"), a private, non-profit organization established in 1988 and developed by American broadcasting and other organizations. Using over $15 million in contributions from its sponsors, and $7.5 million in fees from system proponents, the ATTC -- under the expert leadership of its President, Peter Fannon -- constructed a state of the art radio frequency testing facility in Alexandria, Virginia, and conducted the broadcasting laboratory-based tests for the Advisory Committee. Collocated with the ATTC was the ATV facility of the Cable Laboratories, Inc. ("CableLabs"), a research and development consortium of American cable television system operators. CableLabs carried out the cable portions of the Committee's lab and field testing programs. Finally, the Advanced Television Evaluation Laboratory ("ATEL"), an Ottawa-based facility of Canada's Department of

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[14]   *See* Letter, Richard E. Wiley to Advisory Committee Members (May 4, 1993). Early in the Advisory Committee's history, nineteen members contributed $5,000 each, for a sum of $95,000 and, in the summer of 1993, thirteen members contributed $3,000 each, for a grand total of $134,000. Parent Committee members from small organizations or providing special services were not asked to contribute to this operating fund. A small balance remains.

Communications managed by the Canadian Communications Research Centre, conducted subjective tests using non-expert viewers from both Canada and the United States.[15]

Another organization which made highly valuable contributions to the Advisory Committee's report was the Advanced Television Systems Committee ("ATSC"), an ANSI-accredited standards organization formed in 1984 by the Joint Committee on Intersociety Cooperation ("JCIC").[16] With the approval of the FCC, the ATSC has done vital work in documenting the ATV broadcasting standard recommended herein.[17] The ATSC is ably chaired by James C. McKinney, a member of the Advisory Committee.

D. Advisory Committee Accomplishments

Over its eight year history, and in the course of making numerous decisions, the Advisory Committee produced thousands of public documents, among which are five Interim Reports to the FCC, and ATV System Recommendation dated February 24, 1993, and a report to Congress in 1989.

Given its primary mandate to advise the FCC on a standard for ATV broadcasting, one of the most critical early determinations was that the Committee would evaluate and recommend a

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[15] In addition, the Association of Maximum Service Television ("MSTV") and the Public Broadcasting Service ("PBS") played key roles in the Advisory Committee's field testing process in Charlotte, North Carolina.

[16] The JCIC itself was formed by the Electronics Industries Association, the Institute of Electrical and Electronic Engineers, the National Association of Broadcasters, the National Cable Television Association, and the Society of Motion Picture and Television Engineers.

[17] *Memorandum Opinion and Order / Third Further Notice of Proposed Rule Making* in MM 87-268, 7 FCC Rcd 6924, 6982-6983 (1992).

system to the Commission only if it had been tested in hardware form.[18] Thereafter, work was focused on preparing for, conducting, and analyzing ATV hardware tests.

Initially, some 23 different concepts for an ATV broadcasting system were submitted to the Committee. All of them employed analog video transmission techniques. Some proposals were for enhanced definition television ("EDTV") systems, which would augment, either within the existing channel or with additional spectrum, the quality of NTSC broadcasts. Other entities proposed so-called "simulcast" HDTV systems, which would operate on different channels and in a manner unrelated to NTSC broadcasts. Through proponent mergers and attrition, the 23 proposals soon were reduced to a handful.

In 1990, the FCC made a key decision to "select a 'simulcast' high definition television (HDTV) system -- that is, a system that employs design principles independent of the existing NTSC technology for ATV service."[19] That same year, one of the remaining system proponents, General Instrument Corporation, modified its proposal to incorporate all-digital transmission. Three of the other four remaining HDTV systems thereafter adopted this technological advance; only NHK retained its original analog transmission design. Although the introduction of digital eventually resulted in at least two years' delay in the Advisory Committee schedule, the advance was well worth the wait. Indeed, after much more time and money spent with analog ATV proposals, both Japan and Europe now are pursuing digital solutions.

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[18]   *See Operating Procedures* of the Committee's Systems Subcommittee (approved April 29, 1988): "[o]nly candidate ATV systems which have been reduced to hardware will be evaluated and tested by [Systems Subcommittee] Working Party 2."

[19]   *Report and Order* in MM Docket No. 87-268, 5 F.C.C. Rcd 5627 (adopted August 24, 1990).

From mid-1991 through the end of 1992, the one remaining EDTV system and all five

HDTV systems were subjected to an exacting program of laboratory tests at the ATTC,

CableLabs, and ATEL.[20] As described above, these laboratories are designed to emulate the

broadcast and cable transmission environments, as well as the home viewing environment. The

test procedures were exhaustively developed by the Advisory Committee, with the objective of

determining which of the competing systems should be recommended to the FCC as the basis for

a new transmission standard. For a variety of reasons, not the least of which was the limited

availability of test equipment and space, the systems were tested serially rather than in head-to-

head comparisons, and video subjective testing was conducted by comparing pictures produced

by each system to a single studio reference picture rather than to each other.

There were innumerable tasks and countless meetings involved in preparing for and

conducting the test program. For example, detailed test plans, sometimes specific to the

particular system under test, had to be developed. Then, after testing procedures for the analog

systems had been developed, the Committee was required to redesign many of them with the

advent of digital transmission systems. Moreover, new pieces of hardware had to be constructed

solely for use in testing, and great care and precision was required to create video and audio test

sequences in order to make certain that the systems were completely tested.

All of these efforts took time. On some occasions, implementation errors in the proposed

ATV systems caused additional delays in testing. Further, considerable effort was invested in

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20   At the request of its proponents, the Advisory Committee did not report or
consider the test results on the EDTV system. Letter, James E. Carnes to Richard E. Wiley
(March 2, 1992); Letter Richard E. Wiley to James E. Carnes (March 5, 1992).

fashioning evaluation methods and criteria to allow the Advisory Committee to assess all of the

test results. These criteria included video/audio quality, interoperability, spectrum issues, and

cost issues.[21]

Chaired by Dr. Robert Hopkins, the Special Panel convened for four days in early 1993 to

consider the test results. Under the rigorous technical criteria established by the Committee, the

four digital HDTV systems proved superior to the analog proposal which, accordingly, was

eliminated from further consideration. Although the Panel explicitly found that "digital HDTV

is achievable for the United States,"[22] it also concluded that each of the digital entries had

shortcomings that required further technical refinements. Indeed, in presentations at a November

1992 meeting of the Technical Subgroup formed for this purpose,[23] the remaining proponents had

suggested a number of significant improvements to their respective systems.

In February 1993, and based on the Special Panel Report, the Advisory Committee

offered the proponents two options: either undergo a second, expensive and time-consuming

testing process or, alternatively, combine their efforts into a single "best of the best" (or so-called

"grand alliance") system[24]. There were three key advantages to the latter option: first, because

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[21]   Letter, Richard E. Wiley to FCC Chairman Alfred C. Sikes (January 10, 1992).
This letter forwarded to the Commission the Advisory Committee's proposed ATV System
Recommendation Process.

[22]   ATV System Recommendation at p. 1-1 (February 24, 1993).

[23]   Letters, Richard E. Wiley to Advisory Committee Members and ATV System
Proponents (August 21, 1992). The Technical Subgroup was co-chaired by Joseph A. Flaherty
of CBS and Irwin Dorros, formerly of Bellcore.

[24]   Press Release, FCC Advisory Committee on Advanced Television Service
(February 24, 1993). The Committee already was aware that such an alliance might be formed.
See Letter, Richard E. Wiley to Advisory Committee Members (January 18, 1993).

the systems were becoming more alike as their proponents learned from each other's technical advances, the Advisory Committee's eventual task of selecting between them was becoming more problematic; second, the retesting process was certain to be expensive and time-consuming for all concerned; and third, and most importantly, a single system -- encompassing the best features of various proposals -- might lead to the development of a truly superior technology. This option of combining the systems had been discussed by the Committee two years earlier.[25]

After many months of arduous business and technical negotiations, the proponents chose the latter course. In late May, 1993, a consortium called the Digital HDTV Grand Alliance was formed with a number of major American and European entities: AT&T, the David Sarnoff Research Center, General Instrument, the Massachusetts Institute of Technology, North American Philips, Thomson Consumer Electronics, and Zenith Electronics.[26]

At the time, the Advisory Committee made clear to the Grand Alliance members that they should not present the Committee with an inflexible, technical *fait accompli*; the Committee's work had been, and must remain, a public process.[27] Accordingly, the Committee directed the Technical Subgroup to work with the Alliance, optimize its proposal, and generate agreement on specifications for a prototype system.[28] Thereafter, the Subgroup would supervise construction

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[25] *See* ACATS Fourth Interim Report at p. 19 (April 1, 1991): "[I]n the unlikely event that each system proves to be inadequate, a new design could be composed of elements drawn from the different systems. If so, the Advisory Committee would encourage the establishment of voluntary agreements among proponents to synthesize their designs."

[26] ACATS Press Release (May 24, 1993). Attached at Appendix E.

[27] Letter, Richard E. Wiley to ATV System Proponents (May 11, 1993).

[28] Letter, Richard E. Wiley to Advisory Committee Members (May 24, 1993).

and testing of the system and, if all went well, the Advisory Committee would recommend it to the Commission.

Six so-called "Expert Groups" were formed within the Technical Subgroup, each to focus on selected aspects of the Grand Alliance proposal. After detailed discussions between these Groups and the Alliance extending over many months, a modified and considerably enhanced system proposal was developed. In October 1993 and February 1994, the Advisory Committee approved for prototype construction all the elements of this proposal.[29]

The Grand Alliance system was tested at the ATTC, CableLabs, and ATEL facilities from March through August, 1995. The complete Alliance system also was evaluated in the field, by PBS, MSTV, and CableLabs, at the Advisory Committee broadcasting facilities in Charlotte, in July and August 1995.[30] Detailed test reports were prepared by each organization.[31] Based on these reports, the Technical Subgroup prepared the Committee's Final Technical Report.[32]

In early 1995, the Chairman of the FCC asked the Advisory Committee to investigate specific scanning formats for so-called standard definition television ("SDTV").[33] Several

[29]   Press Releases, Advisory Committee on Advanced Television Service (October 21, 1993, and February 24, 1994).

[30]   Field tests on the Grand Alliance VSB modem alone already had shown it to perform "significantly better" than NTSC. Press Release, Advisory Committee on Advanced Television Service (September 19, 1994).

[31]   The test reports are attached at Annexes 1-5.

[32]   Attached at Appendix F.

[33]   This term is used to signify a digital television system in which the quality is approximately equivalent to that of NTSC. ATSC Digital Television Standard at 8.

months earlier, the Technical Subgroup had prepared a "White Paper,"[34] which described how

the Grand Alliance system could carry multiple streams of data that, for example, could each be

an SDTV program. The Technical Subgroup considered the merits of various proposed SDTV

scanning formats and, on July 19, 1995, based on the recommendation of its Expert Group,

adopted two such formats for inclusion in the ATV standard.[35]

E. Description of the Grand Alliance System

As indicated above, the Advisory Committee approved system specifications premised

on the ATV proposal from the Digital HDTV Grand Alliance. From these specifications,

which were also used by the Alliance to construct its prototype system, the ATSC Digital

Television Standard was derived. In essence, the ATSC standard describes five subsystems:

scanning, video and audio compression, transport, and transmission.

For scanning, the standard includes two HDTV formats: a 720 lines x 1280 pixels per

line format at 24, 30, and 60 frames per second progressively scanned, and a 1080 lines x

1920 pixels per line format at 24 and 30 frames per second progressively scanned and 60 fields

per second interlaced scanned. Two SDTV formats also are described: 480 lines by 704

pixels per line in both 4:3 and 16:9 aspect ratios, and 408 lines by 640 pixels per line in 4:3

aspect ratio. Each SDTV format offers progressive scanning modes.

This balance of scanning formats -- designed to accommodate the interests of various

industries operating within the Advisory Committee -- was reached only after considerable

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34   Attached at Appendix G.

35   *See* Report on SDTV Video Formats, Expert Group on Scanning Formats /
Compression at p. 1 (July 19, 1995). Attached at Appendix H.

deliberation in the Advisory Committee's subgroups. Proponents of various formats argued vigorously for their respective positions but, ultimately, agreed on one point: that an over 1000-line 60 Hz progressive scanning format would be preferable. Unfortunately, this format is not possible with current state-of-the-art compression technology. The Committee foresees, however, that improvements in compression will allow the ATV standard to "migrate" to incorporate it in the coming years.[36] The Committee also believes that including the interlace scanned 1080-line, 60 Hz format will provide such a migration path.

For digital video compression, the Alliance system incorporates MPEG-2 parameters, including "B-frames." Audio compression employs 5.1-channel Dolby AC-3 techniques. The packetized data transport system incorporates features and services of MPEG-2 that are applicable to ATV and provided for in the MPEG-2 transport layer. Finally, the transmission subsystem is based on 8- and 16-VSB technology for broadcasting and cable, respectively.

F.   Interoperability with Alternative Media and Systems

Since its inception, the Advisory Committee has emphasized the need for U.S. ATV broadcasting technology to be interoperable with alternative media, particularly cable television systems. The Committee believes interoperability also takes on critical importance given the future needs for high resolution digital imagery in American homes and the development of a National Information Infrastructure ("NII"). Indeed, entertainment-based HDTV receivers will introduce digital video transmissions into many residences.

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[36]   The Information Technology Industry Council, an association of information technology product and service providers, has endorsed this rapid migration approach in order to "best achieve the maximum benefits to consumers." Letter, Rhett Dawson, ITI President, to Richard E. Wiley (October 31, 1995).

As noted above, interoperability was one of the selection criteria adopted by the Committee. Over four years ago, the working party tasked to study interoperability was asked to reexamine this issue following introduction of the digital HDTV systems. It developed recommendations that led to agreement on so-called "headers and descriptors." This method of data identification, combined with advanced data packetization techniques, acts as a kind of translator to tell all digital devices what type of data is being transmitted.

The working party and an "interoperability review panel" also adopted a list of eleven characteristics critical to interoperability.[37] The Advisory Committee believes the Grand Alliance system adequately addresses all of these factors. For example, compliance with the MPEG-2 standard was emphasized by the Technical Subgroup and adopted by the Grand Alliance to increase international compatibility and, more importantly, interoperability among a variety of digital devices.

A critical aspect of the scanning format scheme, unanimously recommended by the Technical Subgroup, is the availability of progressive scanning and square pixels. These attributes are preferable for some -- particularly computer -- applications. However, interlaced scanning also is important: it is a video data compression technique in which although only half the amount of data is transmitted, the bulk of the video picture remains. In particular, the test results on the Grand Alliance system demonstrate that there are advantages to both higher line

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37   The list of characteristics is attached at Appendix I. These "were based on the needs and desires exhibited by alternative media advocates, not only for the delivery of terrestrial broadcast programming, but also for other delivery approaches and applications relating to computing, communications, motion pictures, and imaging." ATV System Recommendation at pp. 4-4, 4-5 (February 24, 1993).

number interlaced, and lower line number progressive scanning formats, and that there is no

evidence in the Advisory Committee's record that would justify dropping either format at this

time.

In all, the Advisory Committee believes that the Grand Alliance plan strikes the best

balance between various technical considerations and needs of different industries. It is a

balance that has been endorsed by, among others, a subgroup of the Federal Government's

Information Infrastructure Task Force, the 1994 NIST/ARPA Workshop on Advanced Digital

Video, and the Information Technology Industry Council. In this regard, it is noteworthy that all

other ATV broadcasting systems being developed in the world do not include *any* progressive

scanning format. The U.S. approach wisely incorporates the best of *both* scanning techniques.

G.   Other Technologies

As required by the 1990 MOU with the FCC and test laboratories, the Advisory

Committee has reviewed

> new technical advancements in the state of the art, not already
> provided by the ATV systems pre-certified by the Advisory
> Committee, that appear to offer important benefits to the public
> and are sufficiently concrete so as to be tested contemporaneously
> with the pre-certified systems.[38]

In early 1992, the Advisory Committee found, based on a review of current technology,

that there were no new concepts "sufficiently concrete so as to be tested contemporaneously with

the pre-certified systems," and that the five HDTV proponent systems then under consideration

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[38]   MOU at p. 3. *See* Appendix B.

represented the state of available technology.[39] Later that year, another meeting concluded that a few recently-proposed systems were not sufficiently developed to be considered further by the Advisory Committee. This assessment that was ratified by the Special Panel.[40]

In 1994-95, at the request of an industry consortium eventually known as the COFDM-Limited Liability Corporation ("COFDM-LLC"), the Committee reviewed a proposal for an ATV modem that would operate using coded orthogonal frequency division multiplexing ("COFDM") techniques.[41] The Technical Subgroup established an Certification Experts Group, and tasked it to review the COFDM-LLC proposal which, if it were shown to be "demonstrably superior" to the VSB-based modem already approved as part of the Grand Alliance system, would be recommended for further evaluation and testing by the Advisory Committee. The Experts Group found, however, "based on the claimed benefits of COFDM techniques and, specifically, of the COFDM modem proposed by the COFDM-LLC, as well as the shortcomings discussed [in the report]", that "[t]he modem presented by the COFDM-LLC is not ready for test at this time," and "[t]he COFDM-LLC did not demonstrate the superiority of COFDM over VSB for the majority of markets."[42]

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39   Fifth Interim Report of the Advisory Committee on Advanced Television Service (March 24, 1992).

40   Special Panel Document No. SP-019 (February 8, 1993).

41   Letters, Richard E. Wiley to Advisory Committee Members (February 18, 1994), and to Michael J. Sherlock (April 21, 1994, and September 15, 1994).

42   Report of the Certification Experts Group at p. 4 (August 8, 1995). Attached at Appendix J.

H.   Final Technical Report

As noted above, the Advisory Committee's Technical Subgroup adopted a Final

Technical Report for the Advisory Committee on October 31, 1995.[43] Based on Advisory

Committee-approved specifications and thorough laboratory and field testing of the prototype

ATV system as designed and constructed by the Digital HDTV Grand Alliance, the Technical

Subgroup found that: (1) the Grand Alliance system meets the Committee's performance

objectives and is better than any of the four original digital ATV systems; (2) the Grand Alliance

system is superior to any known alternative system; and (3) the ATSC Digital Television

Standard,[44] based on the Advisory Committee design specifications and Grand Alliance system,

fulfills the requirements for the U.S. ATV broadcasting standard. Thus, the Subgroup

recommended that the ATSC standard be adopted as the U.S. ATV broadcasting standard.

III.   RECOMMENDATIONS OF THE ADVISORY COMMITTEE

The Advisory Committee hereby adopts the findings of the Technical Subgroup.

Specifically, the Grand Alliance system meets the Committee's performance objectives and is

better than any of the four original digital ATV systems; the Grand Alliance system is superior to

any known alternative system; and the ATSC Digital Television Standard, based on the Advisory

Committee design specifications and Grand Alliance system, fulfills the requirements for the

U.S. ATV broadcasting standard.

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43   Attached at Appendix F.

44   Attached at Appendix K.

Accordingly, *the Advisory Committee on Advanced Television Service recommends that the Federal Communications Commission adopt the ATSC Digital Television Standard as the U.S. standard for ATV broadcasting.*

Although this standard, in accordance with the limited mandate of the Advisory Committee, is recommended for terrestrial ATV broadcasting, the Committee believes that it is suitably interoperable with other video delivery media and imaging systems, including cable television, direct broadcast satellite, and computer systems. The extent to which various features and applications of the standard are allowed or required to be applied to alternative media must be left to the discretion of the FCC as part of its deliberations in the ongoing rulemaking proceeding.

In addition, other ATV regulatory issues, including some previously addressed by the Advisory Committee (*e.g.*, broadcasting allotment and assignment planning), are also being addressed directly by the FCC. For example, the Committee worked at length on broadcasting allotment and assignment planning issues but, more recently, the FCC requested that the Committee discontinue its efforts in deference to the rule making proceeding. Additionally, the Technical Subgroup has recommended that the Commission require that receivers (and set-top boxes designed to receive ATV broadcasts for display on NTSC sets) be able to receive adequately all ATV formats. This issue now is being addressed in the FCC's rule making.[45]

The Advisory Committee initially was chartered by the FCC for a two-year period. Since then, the Charter has been extended every two years. As a final administrative matter, upon

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[45]   *Fourth Further Notice of Proposed Rule Making and Third Notice of Inquiry* in MM Docket No. 87-268, 10 FCC Rcd [___ , ___] (1995).

acceptance of this Final Report and Recommendation, the Committee recommends that the FCC disband the Advisory Committee on Advanced Television Service on December 31, 1995.

IV.   CONCLUDING REMARKS

The Advisory Committee is indebted to the hundreds of companies, entities, and individuals which have been involved in this entire project. Their cooperative and productive efforts have made a great contribution to the advancement of the video medium in this country and the rest of the world. The Committee also is grateful for the continuous oversight, guidance and support provided by the FCC, particularly the four Chairmen with which the Committee has been honored to work, and the staffs of the Mass Media Bureau, Office of Engineering and Technology, and Office of Plans and Policies.

Respectfully submitted,

FCC ADVISORY COMMITTEE ON
ADVANCED TELEVISION SERVICE

By: _____
       Richard E. Wiley, Chairman

November 28, 1995

APPENDICES

Appendix A.

Charter of the
Advisory Committee on Advanced Television Service

FEDERAL COMMUNICATIONS COMMISSION

Formation of Advisory Committee on Advanced Television Service and Announcement of First Meeting

The Federal Communications Commission has established an advisory committee to assist the Commission in considering the issues surrounding the introduction of advanced television service in the United States. The committee is expected to advise the Commission on the facts and circumstances regarding advanced television systems and to recommend policies, standards, and regulations that could accommodate the orderly and timely introduction of advanced television service. The charter for the committee is attached.

The first meeting of the Advisory Committee on Advanced Television Service will be held on November 17, 1987, in the Commision Meeting Room, Room 856, 1919 M Street, N.W., Washington, D.C. The meeting will start at 2:00 P.M. All interested parties are invited to attend.

The agenda for the first meeting will consist of:

1. FCC Chairman's Remarks;
2. Administrative Matters;
3. Committee Charter;
4. Committee Work Plan—
   Proposed Schedule
   Discussion and Approval;
5. Designation of Subsequent Meetings;
6. Concluding Remarks.

Any questions regarding this meeting should be directed to Mr. William Hassinger at (202) 632-6460 or Mr. Victor Tawil at (202) 653-8162.

Charter for Advisory Committee on Advanced Television Service

A. The Committee's Official Designation

Advisory Committee on Advanced Television Service

The Advisory Committee will have no more than twenty-five members and will function as a Parent Committee. These members will be chosen by the Commission so as to obtain diverse and representative viewpoints. The Advisory committee Chairman will direct the activities of the Committee and Subcommittees and will receive guidance, advice and instructions from the Chairman of the Federal Communications Commission.

B. Name of Subcommittee(s)

Three Subcommittees: Planning Subcommittee, Systems Subcommittee, Implementation Subcommittee.

Membership of Subcommittees will be open to all interested parties.

C. Committee's Objectives and Scope of its Activity

Parent Committee

Objective: The Committee will advise the Federal communications Commission on the facts and circumstances regarding advanced televsion systems for Commission consideration of the technical and public policy issue. In the event that the Commission decides that adoption of some form of advanced broadcast television is in the public interest, the Committee would also recommend policies, standards and regulations that would facilitate the orderly and timely introduction of advanced television services in the United States.

Scope of activity: All steps necessary to assemble information, analyze information, deliberate upon appropriate policies and actions, and develop recommendations regarding the introduction of terrestrial advanced television service. Includes technical, economic, legal and regulatory issues.

Planning Subcommittee

Objective: To plan the attributes of advanced television service in the United States.

Scope of Activity: All steps necessary to provide advice on desired features of terrestrial advanced television service.

(a) Define the desirable characteristics of advanced television service; for example, in terms such as picture quality, population served, costs to broadcaster/consumer/ manufacturers, relationship to existing broadcast service, relationship to non-broadcast services.

(b) Review the technical planning factors for the existing television service and recommend planning factors for advanced television service, including consideration of factors such as coverage area, quality of service, frequency reuse criteria, receiver quality, spectrum allocations.

Systems Subcommittee

Objective: To specify the transmission/reception facilities appropriate for providing advanced television service in the United States.

Scope of Activity: All steps necessary to provide advice on the parameters of systems to provide terrestrial advanced television service.

(a) Evaluate, on technical and economic bases, advanced television systems now under development for the purpose of determining feasibility for implementation in the United States.

(b) Recommend advanced television system(s) now under development as candidate(s) for implementation, or specify the design of an appropriate system.

(c) Advise on the appropriate transmission/reception technical standards and spectrum requirements for the recommended system(s).

Implementation Subcommittee

Objective: To establish a scheme for implementation of advanced television servi. in the United States.

Scope of Activity: All steps necessary to provide advice on policies, regulations and standards for implementation of terrestrial advanced television service.

(a) Develop a transition scheme for implementation of advanced television service in the United States.

(b) Recommend appropriate FCC policies and regulations to oversee implementation of advanced television service and develop guidelines for industry activities.

D. Period of Time Necessary for the Committee To Carry out its Purposes

An initial written report containing recommendations of the Committee on fundamental parameters and spectrum requirements must be submitted by 6 months from the date of the first meeting.

E. Official to Whom the Committee Reports

The Chairman of the Federal Communication Commission.

F. Agency Responsible for Providing Necessary Support for the Committee

The Federal Communications Commission will furnish necessary administrative support, including facilities needed for conducting meetings of the Committee.

G. Description of Duties for Which the Committee is Responsible

The duties of the Committee and its Subcommittees will be to assemble information, to conduct deliberations and to prepare and submit recommendations appropriate to the attainment of the objectives listed under (C) above.

H. Estimated Annual Operating Costs in Dollars and Person Years

The estimated operating costs are $10,000 for the FCC. Estimated person-years are 3.0 for the FCC and 25.0 for non-government participants.

I. Estimated Number and Frequency of Committee Meetings

The Committee will meet three times per year or at such intervals as the Committee decides. Subcommittees are expected to meet on a monthly basis until completion of their tasks.

J. Committee's Termination Date

The Committee will terminate September 30, 1989.

Appendix B.

Memorandum of Understanding

MEMORANDUM OF UNDERSTANDING

The Federal Communications Commission ("FCC"), the Advisory
Committee on Advanced Television Service ("Advisory Committee"),
and the ATV testing laboratories [the Advanced Television Test
Center, Inc. ("ATTC"), Cable Television Laboratories, Inc.
("CableLabs") and the Canadian Communications Research Centre
("CRC")[1]] are engaged in a collaborative effort to bring about the
implementation of advanced television ("ATV") service for the
American public.

Three years ago, the FCC in conjunction with industry,
launched a comprehensive plan to establish advanced television
service. The Commission's primary goal in the ATV proceeding is to
ensure the development of a technically excellent ATV service that
will most efficiently meet the needs of terrestrial broadcasters,
receiver manufacturers, cable television operators and, most
important, consumers. As the Advisory Committee enters the active
testing phase of its program for evaluating ATV transmission
systems, we observe that substantial progress has already been made
toward making the selection of a standard for advanced television
service. The efforts of the Advisory Committee, the testing

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1   In this particular effort, CRC is joined by the
Canadian Broadcasting Corporation, the Canadian Department of
Communications, Leitch Video International and Telesat Canada.

laboratories, and other industry parties have significantly advanced the Commission's ability to assess the merits of ATV technical designs. In addition, system designers have made advancements in developing new technical schemes for transmitting ATV service.

The Commission has stated that it intends to complete action on this project as promptly as possible. This objective is a considerable undertaking that poses a number of formidable challenges. The FCC's stated intention is to select an ATV standard by the second quarter of 1993. The successful, on-time accomplishment of all of the tasks of the ATV project will require hard work, dedication, and cooperation on the part of all of those involved. To this end, the undersigned parties agree to resolve any disagreements or contingencies that may arise in a prompt and cooperative manner.

In order to meet these challenges and accomplish our goals, the Commission, the Advisory Committee, and the testing laboratories will continue to work together to complete, in a timely manner, the major tasks undertaken by each. This memorandum of understanding describes the role and activities of each of these parties in this process.

FCC

The FCC, consistent with its policy-making and other responsibilities, will continue to review the Advisory Committee's testing plans and procedures, including the plans and procedures for field testing. The FCC will assist the Advisory Committee and

testing laboratories in the testing process. This will include on-site observers and participants and participation on the "expert viewer panel." The FCC will contribute, as feasible, staff and mobile monitoring facilities for field testing. The FCC will also take all necessary steps, including the development of analytic tools, to prepare an allotment table and/or assignment plan for ATV channels. This will ensure that channels are available for ATV service in a timely manner.

Advisory Committee

The Advisory Committee will continue to refine the testing plans and procedures, including finalizing the data reporting formats and developing the plans and procedures for field testing. Through its oversight and direction, the Advisory Committee will continue to work with ATTC, CableLabs, and CRC to seek to carry out the established procedures within the established deadlines. The Advisory Committee will also continue to work with ATV system proponents to ensure the timely delivery of systems for testing. The Advisory Committee will continue to maintain close coordination with the Commission through regular contacts with key staff members and periodic meetings with the FCC Chairman.

The Advisory Committee will develop a plan for reviewing new technical advancements in the state of the art, not already provided by the ATV systems pre-certified by the Advisory Committee, that appear to offer important benefits to the public and are sufficiently concrete so as to be tested contemporaneously with the pre-certified systems. Accordingly, it will prepare a

report and recommendation to the Commission by early 1992, on whether any of these new developments should be tested and the impact such additional testing would have on the test schedule.

Subject to the provisions of this memorandum of understanding, the Advisory Committee will complete all of its work and submit its final report to the Commission by September 30, 1992.

Testing Laboratories

ATTC and CableLabs will make all reasonable efforts to carry out their laboratory testing activities (which do not include field testing) consistent with the plans and procedures established by the Advisory Committee and will coordinate with the CRC to seek to ensure the continuity and integrity of the ATV testing program. ATTC and CableLabs, in cooperation with the Advisory Committee Chairman, will maintain regular c -tact with the Commission and its staff. Results of tests performed by ATTC and CableLabs will be provided to the Commission on a prompt and regular basis.
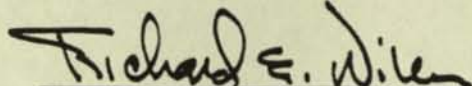
Consistent with the above, ATTC and CableLabs will seek to ensure that testing of proponents' systems certified for testing by the Advisory Committee begins in a timely manner and is completed so as to permit the Advisory Committee to deliver its final report to the FCC on time.

In summary, the essential intent of this agreement is to ensure that the research and work necessary for introducing ATV service to the American public is developed in a cooperative and efficient manner, and is not intended to create any obligations to
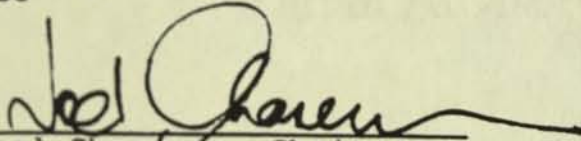
non-signatories or to alter in any way the obligations between ATTC and CableLabs.
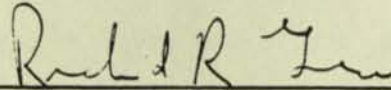
Alfred C. Sikes, Chairman
FCC

Richard E. Wiley, Chairman
FCC Advisory Committee

Joel Chaseman, Chairman
Advanced Television Test
  Center, Inc.

Richard R. Green, President
Cable Television
  Laboratories, Inc.

Date: November 14, 1990

Appendix C.

Parent Advisory Committee

Advisory Committee on Advanced Television Service

Chairman
Richard E. Wiley, Wiley, Rein & Fielding

Members
Frank Biondi, Viacom International, Inc.
Joel Chaseman, Chaseman Enterprises International
Joseph Collins, American T.V. & Comm. Corp.
William Connolly
Martin Davis, Wellspring Associates, Inc.
Irwin Dorros
James C. Dowdle, Tribune Broadcasting Co.
Ervin S. Duggan, PBS
Joseph Flaherty, CBS, Inc.
Samuel Fuller, Digital Equipment Corporation
Stanley S. Hubbard, Hubbard Broadcasting
James Kennedy, Cox Enterprises
James C. McKinney, Advanced Television Systems Committee
Craig Mundie, Microsoft Corporation
Thomas S. Murphy, Capital Cities/ABC Inc.
Rupert Murdoch, Fox, Inc.
Jerry K. Pearlman, Zenith Electronics Corporation
F. Jack Pluckhan, Quasar
Ward Quaal, The Ward L. Quaal Company
Richard D. Roberts, TeleCable Corporation
Burton Staniar, The Knoll Group
James Tietjen, SRI International
Laurence Tisch, CBS, Inc.
Robert Wright, NBC

Ex officio (non-voting) Members
Peter Bingham, Philips Laboratories
Wendell Bailey, National Cable Television Association
Henry L. Baumann, National Association of Broadcasters
Joseph Donahue, Thomson Consumer Electronics, Inc.
Brenda L. Fox, Dow, Lohnes & Albertson
Richard Friedland, General Instrument Corporation
Robert Graves, R.K. Graves Associates
Larry Irving, U.S. Department of Commerce, NTIA
Keiichi Kubota, NHK Science & Technical Research Labs
Jae Lim, Massachusetts Institute of Technology
Vonya B. McCann, U.S. Department of State
George Vradenburg III, Latham & Watkins
Margita White, MSTV

Appendix D.

Advisory Committee Staff Structure

Advisory Committee Staff Structure

Parent Committee

Planning Subcommittee

PS/WP-1	Technology Attributes and Assessment
PS/WP-2	Testing and Evaluation Specifications
PS/WP-3	Spectrum Utilization and Alternatives
PS/WP-4	Alternative Media Technology and Broadcast Interface
PS/WP-5	Economic Factors and Market Penetration
PS/WP-6	Systems Subjective Assessment
PS/WP-7	Audience Research
PS/AG-1	Creative Issues
PS/AG-2	Consumer/Trade Issues

Systems Subcommittee

SS/WP-1	Systems Analysis
SS/WP-2	System Evaluation and Testing
SS/WP-3	Economic Assessment
SS/WP-4	System Standards

Implementation Subcommittee

IS/WP-1	Policy and Regulation
IS/WP-2	Transition Scenarios

Field Test Technical Oversight Committee

Special Panel

Technical Subgroup

Experts Group on Scanning Formats / Compression
Experts Group on Audio
Experts Group on Transport
Joint Experts Group on Interoperability
Experts Group on Transmission
Experts Group on Cost Factors

Experts Group on Certification

Appendix E.

ACATS Press Release (May 24, 1993)

Advisory Committee
on Advanced Television Service

FOR IMMEDIATE RELEASE: May 24, 1993

HDTV "Grand Alliance" Proposal
Will Be Considered by FCC Advisory Committee

Washington, D.C. The Federal Communications Commission's Advisory Committee on

Advanced Television Service (established by the Commission in 1987) will review a single

digital high definition television (HDTV) system proposed today by a "Grand Alliance" of

entities that, until now, had sponsored the four remaining competitive HDTV systems.

These entities (AT&T, the David Sarnoff Research Center, General Instrument,

Massachusetts Institute of Technology (MIT), North American Philips, Thomson Consumer

Electronics, and Zenith Electronics) today reached a business and technical agreement and

submitted to the Committee a merged system proposal.

The proposed system, if recommended by the Advisory Committee and adopted by

the FCC, could place the U.S. in the forefront of high definition video technology. An all-

digital standard, which would facilitate interoperability among broadcasting, cable,

computer, and telecommunications technologies, has worldwide potential.

Advisory Committee Chairman Richard E. Wiley, who had encouraged the complex

negotiations leading to the agreement, said "I believe the Grand Alliance proposal, subject

to Advisory Committee and ultimate FCC approval, will help to conclude a process that has

fostered the development of highly advanced digital HDTV technology. The members of

the Alliance should be commended for their accomplishments." Wiley added that the

benefits of the Grand Alliance include development of a digital system incorporating the

best elements of the four systems and acceleration of HDTV service implementation. The FCC's Advisory Committee endorsed the Alliance concept at a meeting in February.

Important aspects of the Grand Alliance technical proposal submitted today include the employment of progressive scan transmission (where entire picture frames are transmitted sequentially) and the use of so-called "square pixels" (where the dots on a television screen are arranged in equally spaced rows and columns). Both of these design aspects are important for the interoperability of HDTV with computers, telecommunications, and other media and applications. Interlaced scan transmission (as deployed in today's TV systems) would also be accommodated in the initial deployment.[1]

Specifically, the proponents agree that all large-screen HDTV receivers (34 inches in diagonal and above) will incorporate a 60 frame per second 787.5 line or higher progressive scan display mode. Progressive display would be optional initially for smaller screen receivers. The proponents also concur that all transmission of film material will be in a progressive scan format beginning immediately upon the commencement of HDTV service. Finally, the Grand Alliance proponents unanimously endorse the objective of migrating the standard to a high line number (i.e. thousand-line plus) progressive scan transmission, as soon as feasible, and will work together to eliminate interlaced scanning format from the transmission path in the future.

To support multiple transmission formats, the merged system will feature source adaptive processing. Moreover, to promote system flexibility and extensibility, the merged system also will feature a prioritized, packetized data transport structure. Additionally, the

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[1] MIT believes that a digital video broadcast standard that exclusively utilizes progressive scan transmission, from the beginning, is in the best interests of the United States.

Grand Alliance entities agree to support the Alliance's proposed HDTV compression system in the International Standards Organization as the MPEG-2 HDTV profile.

Over the next few weeks, Advisory Committee participants will review the technical merits of the Grand Alliance proposal, which includes procedures for deciding on a few remaining component designs based on the results of specific tests. Various subgroups of the Advisory Committee will work with the Grand Alliance members as their merged system concept is finalized and, eventually, will oversee the testing of the completed system. Based on the results of those tests, the Committee may recommend the system to the FCC as the basis for a high definition television standard for our country. The FCC, of course, has the ultimate authority to adopt transmission standards.

Appendix F.

Final Technical Report

FINAL TECHNICAL REPORT

Federal Communications Commission

Advisory Committee on Advanced Television Service

October 31, 1995

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FINAL TECHNICAL REPORT

Table of Contents

List of Figures

List of Tables

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FINAL TECHNICAL REPORT

1.   INTRODUCTION

This is the final technical report of the Advisory Committee on Advanced Television Service. It was prepared by the Advisory Committee's Technical Subgroup, and is presented as the primary appendix to the Advisory Committee's November 1995 final report to the Federal Communications Commission.

This final technical report is primarily a report and analysis of extensive tests conducted by the Advisory Committee on the ATV system proposed by the Digital HDTV Grand Alliance. It also contains comparisons of the Grand Alliance system with the four original digital systems previously tested by the Advisory Committee. Organized in accordance with the four principal subsystems of the Grand Alliance system, this report addresses scanning formats, compression (video and audio), transport, and transmission (spectrum utilization and transmission robustness). Finally, and based on the information in this report, the conclusions of the Technical Subgroup are presented for the Advisory Committee's consideration.

2.   SCANNING FORMATS

Scanning formats supported by the ATV system are shown in Table 2.1. In the table, 60I means 60 Hz interlaced scanning, 60P means 60 Hz progressive scanning, 30P means 30 Hz progressive scanning, and 24P means 24 Hz progressive scanning. These rates can be the stated integer value, or 1000/1001 times the integer value (e.g., 59.94 Hz). The Digital HDTV Grand Alliance System prototype was designed before the 480-line formats were included in the ATV system specification, and supports only the high definition ATV formats, i.e., the 1080 x 1920 and 720 x 1280 formats.

Table 2.1 ATV system scanning formats.

Vertical Lines	Horizontal Pixels	Aspect Ratio		Picture Rate			
1080	1920	16:9		60I		30P	24P
720	1280	16:9			60P	30P	24P
480	704	16:9	4:3	60I	60P	30P	24P
480	640		4:3	60I	60P	30P	24P

2.1.   RESOLUTION

During testing, measurements were made to determine how the resolution of the Digital HDTV Grand Alliance System compared with the target specifications. Had data been available from the four original digital systems, target specifications would have been derived as the "Best of the Best." Data from the previous systems were not given in the Advisory Committee's report "ATV System Recommendation," however, because of apparent irregularities in the data. Therefore, the Scanning Formats / Compression Expert Group, in order to establish target specifications for resolution, assumed that an interlaced scanning system should deliver limiting vertical resolution equal to 65 % of the number of active scanning lines, and that a progressive

scan system should deliver 90 %. The Expert Group assumed that horizontal resolution would be limited to about 80 % of the number of active samples because of filtering, and that the diagonal resolution would be the vector sum of the horizontal and vertical resolution. Dynamic resolution was assumed to be about 80 % of the static resolution. In the case of an interlaced scanning system, for vertical resolution under motion, the picture will take on the characteristics of a progressively scanned system with half the number of scanning lines (i.e., vertical resolution of 1080I becomes 540P under motion). The chrominance resolution of the Grand Alliance System, because it is based on the MPEG-2 Main Profile, should be half the luminance resolution in both the horizontal and vertical directions. These assumptions give rise to the target specifications shown in Table 2.2. Note that all values are expressed as cycles per active picture height. It should be further noted that these target specifications were generated on the assumption that the video compression is transparent (i.e., the target specifications estimate the resolution of the input to the system and assume that there will be no measurable loss due to video compression).

Table 2.2 Target specifications for resolution.

	1080 x 1920			720 x 1280		
	Horizontal	**Vertical**	**Diagonal**	**Horizontal**	**Vertical**	**Diagonal**
Static Luma (c/aph)	430	350	550	290	325	435
Static Chroma (c/aph)	215	175	275	145	160	215
Dynamic Luma (c/aph)	345	195*	395*	230	260	345
Dynamic Chroma (c/aph)	170	95*	195*	115	130	170

* Because of error calculating dynamic vertical resolution with interlaced scanning, the following values have been replaced: 195 replaced 280, 395 replaced 440, 95 replaced 140, and 195 replaced 220.

Static resolution was measured using an electronic circular zone plate. Dynamic resolution was measured using an electronic radial resolution pattern that was held stationary and rotated at 0.5, 1.5, and 5.0 revolutions per minute.

Table 2.3 gives a summary of the measurements and the target specifications. Dynamic resolution is shown only at the maximum rotation rate, 5.0 rpm. In all cases, the lowest dynamic resolution was measured at this rotation rate. At lower rotation rates, the system met, or exceeded, most target specifications.

2.1.1.   Static Luminance Resolution

For the 1080I format, static luminance resolution exceeded the target specification for both horizontal and vertical resolution, but missed the target for diagonal resolution by 2 %.

For the 720P format, static luminance resolution exceeded the target specification for horizontal resolution, but missed by 15 % for vertical resolution and 8 % for diagonal resolution.

2.1.2.   Static Chrominance Resolution

For the 1080I format, static chrominance resolution exceeded the target specification for horizontal resolution, but missed the target by 20 % for vertical resolution and 5 % for diagonal resolution.

For the 720P format, static chrominance resolution exceeded the target for horizontal, vertical, and diagonal resolution.

Table 2.3 Resolution of the Digital HDTV Grand Alliance system.

1080 x 1920	Target Specification			Measured Value			Comments
	H	V	D	H	V	D	
Static Resolution, Luma (c/aph)	430	350	550	460	400	540	See Note 1
Static Resolution , Chroma (c/aph)	215	175	275	250	140	260	See Note 2
Dynamic Resolution, 5.0 rpm, Luma (c/aph)	345	195	395	500	200	540	
Dynamic Resolution, 5.0 rpm, Chroma (c/aph)	170	95	195	135	100	135	See Note 3

720 x 1280	Target Specification			Measured Value			Comments
	H	V	D	H	V	D	
Static Resolution, Luma (c/aph)	290	325	435	320	275	400	See Note 4
Static Resolution , Chroma (c/aph)	145	160	215	180	180	230	
Dynamic Resolution, 5.0 rpm, Luma (c/aph)	230	260	345	300	210	360	See Note 5
Dynamic Resolution, 5.0 rpm, Chroma (c/aph)	115	130	170	170	160	183	

Note 1: The difference between the target specification and the measured value for diagonal resolution is within the range of measurement error likely in the test procedure.

Note 2: To avoid smearing in horizontal motion, the Grand Alliance prototype employed field-based, rather than frame-based, vertical chroma decimation. Target specifications for vertical and diagonal do not account for this.

Note 3: To process material rotating at 5.0 rpm, coarse coefficient quantization is necessary, particularly in chroma. Performance of horizontal resolution is better than specification at lower rotational velocities.

Note 4: The target specification for vertical resolution assumes a limiting vertical resolution of 90 % of the number of scanning lines. This may be too optimistic an assumption. The specification for diagonal resolution is partially derived from the vertical resolution.

Note 5: The target specification for vertical resolution is derived from that for static luminance resolution, which may be too optimistic (see also Note 3).

2.1.3. Dynamic Luminance Resolution

For the 1080I format, the dynamic horizontal and diagonal luminance resolution, at all rotation speeds, exceeded the target and did not vary. The vertical resolution exceeded the target at all rotation speeds, although it did decrease at 5.0 rpm.

For the 720P format, the dynamic horizontal and diagonal resolutions, at all rotation speeds, exceeded the target and did not vary. The vertical resolution exceeded the target at 0.5 rpm, but missed by 8 % at 1.5 rpm and by 19 % at 5.0 rpm.

2.1.4. Dynamic Chrominance Resolution

For the 1080I format, the dynamic vertical chrominance resolution exceeded the target at all rotation speeds. The horizontal resolution exceeded the target at all rotation speeds except 5.0 rpm where it missed by 21 %. The diagonal resolution missed at all speeds by 18 % except for 5.0 rpm where it missed by 31 %.

For the 720 format, dynamic chrominance resolution exceeded the target at all rotation speeds.

2.2.   FORMAT CONVERSION

Tests were run at ATEL to determine the quality loss when a 1080I signal is transmitted, but displayed on a 720P monitor rather than a 1080I monitor; and the quality loss when a 720P signal is transmitted, but displayed on a 1080I monitor rather than a 720P monitor. The sequences that were selected for assessment were ones in which the expert observers were able to see differences. Furthermore, on two of the motion sequences, a more critical portion of the sequence was used for assessment than was used in the Quality, Basic Material test.

In the case of transmitted 1080I signals, tests were run using two still pictures and four moving sequences. Of these six sequences, two are considered "basic material," two are considered "graphics," and two are considered "noise and cuts." A weighted average of the target specification for this combination of sequences, when not using format conversion, is -0.77 grade. The target specification with format conversion is -1.0 grade. The average measured value without format conversion (i.e., 1080I was transmitted and displayed as 1080I) was -0.54 grade. The average measured value with format conversion (i.e., 1080I was transmitted and scan converted in the receiver for display as 720P) was -0.58 grade. The average difference in quality was 0.04 grade (i.e., scan converting for the 720P display showed a loss of quality of 0.04 grade compared with the 1080I display).

In the case of transmitted 720P signals, tests were run using one still and six moving sequences. Of these seven sequences, four are considered "basic material," one is considered "graphics", and two are considered "noise and cuts." A weighted average of the target specification for this combination of sequences, when not using format conversion, is -0.6 grade. The target specification with format conversion is -1.0 grade. The average measured value without format conversion (i.e., 720P was transmitted and displayed as 720P) was -0.51 grade. The average measured value with format conversion (i.e., 720P was transmitted and scan converted in the receiver for display as 1080I) was -0.69 grade. The average difference in quality was 0.18 grade (i.e., scan converting for the 1080I display showed a loss of quality of 0.18 grade compared with the 720P display).

In both cases, the target specification of less than 1.0 grade was met. The target specification can be viewed in another way. For "basic material," the target specification allowed for video compression (without scan conversion) is 0.3 grade. The target specification for video compression plus scan conversion is 1.0 grade. This means that 0.7 grade is allowed for quality loss due to scan conversion. In the case of 720P transmission and scan conversion to 1080I, the average loss was 0.04 grade. In the case of 1080I transmission and scan conversion to 720P, the average loss was 0.18 grade. In both cases, again, the target specification was met. The difference seen by the non-expert viewers was very small, much less than had been anticipated. Table 2.4 gives a summary of the measurements and the target specification. The expert observers characterized the conversions as slightly poorer than when presented in the original format. They said the quality loss was manifested as a slight loss in resolution and a slight increase in noise.

Table 2.4 Scan conversion quality of the Digital HDTV Grand Alliance system.

	Target Specification	Measured Value	Comments
Quality, Receiver Conversion, 720-lines transmission, 1080-lines display	≤ 0.7 Grade below non-conversion	-0.18 Grade	
Quality, Receiver Conversion, 1080-lines transmission, 720-lines display	≤ 0.7 Grade below non-conversion	-0.04 Grade	

Note: Grade is the average over all sequences tested in each category, not the maximum

3.   COMPRESSION

3.1.   VIDEO

Video compression in the Digital HDTV Grand Alliance System is based on the MPEG-2 Main Profile. To determine the quality after video compression, twenty-six different sequences were used to test the system. Table 3.1 is a summary of the results. All test categories were well within the target specification. Recognizing that the target specifications were based on the "Best of the Best" of the four original digital systems, the Grand Alliance System is clearly the superior system in both the 1080I mode and the 720P mode.

Table 3.1 Quality of the Digital HDTV Grand Alliance system measured by non-expert viewers.

	Target Specification	Measured Value		Comments
		1080 x 1920	720 x 1280	
Quality, Basic Material	≤ 0.3 Grade below reference	-0.12 Grade	-0.11 Grade	
Quality, Noise & Cuts	≤ 1.0 Grade below reference	-0.40 Grade	-0.50 Grade	
Quality, Graphics & NII	≤ 1.0 Grade below reference	-0.06 Grade	-0.04 Grade	
Quality, 24 fps Film	≤ 0.25 Grade below reference	-0.04 Grade	-0.01 Grade	

Note: Grade is the average over all sequences tested in each category, not the maximum

In the first round of testing, the DigiCipher system, across all sequences, was found to be 0.3 grade lower in quality than the reference (0.3 for stills and 0.3 for motion sequences), DSC-HDTV was 0.9 grade lower in quality than the reference (0.5 for stills and 1.2 for motion sequences), AD-HDTV was 0.3 grade lower in quality than the reference (0.3 for stills and 0.3 for motion sequences), and CCDC was 1.0 grade lower in quality than the reference (0.5 for stills and 1.3 for motion sequences).

In the second round of testing, the Grand Alliance System, across all sequences, was 0.15 grade lower in quality than the reference in both the 1080I mode (0.0 for stills and 0.2 for motion sequences) and the 720P mode (0.1 for stills and 0.2 for motion sequences). It should be noted that in the second round of testing, 10 image sequences were retained from the first round and 16 new sequences were selected, many of which are more critical than those in the first round. The

Grand Alliance System performed better than the systems from the first round, despite the inclusion of the more critical sequences.

In detail, in the 1080I mode, nineteen of the twenty-six sequences were statistically indistinguishable from the reference. For the seven sequences that were statistically significant, the average quality loss was 0.4 grade. One sequence, M49 (Picnic with Ants), which consists of a central still image with noise encroaching from the sides, is known to be particularly stressful for image compression algorithms. For that sequence, the quality loss was 0.75 grade. In the 720P mode, twenty-one of the twenty-six sequences were statistically indistinguishable from the reference. For the five sequences that were statistically significant, the average quality loss was 0.5 grade. Sequence M49 showed a quality loss of 1.3 grades.

Figure 3.1 shows the quality scores for the four original digital systems, and for the Grand Alliance System in the 720P mode and in the 1080I mode. Only the sequences that were common in the two rounds of testing are included in the figure. A list of all sequences, with a brief statement giving the attributes of each sequence, can be found in the subjective assessment portion of the laboratory test report.

Figure 3.1 Quality of the Digital HDTV Grand Alliance system and the four original digital systems compared with the 1125-line studio quality reference.

Figure 3.2 shows the quality scores for the Grand Alliance System on all sequences used in the second round of testing. The figure shows that both modes performed close to reference, and that the relative performance of the two modes varied from test sequence to test sequence.

The 1080I mode shows improvement over the interlaced scanning systems in the first round of testing; the 720P mode shows substantial improvement. The improvement in the 720P mode has been attributed to two factors: 1) good performance of the Grand Alliance System in the 720P mode, and 2) the use of less noisy source material for the six core camera originated motion sequences.

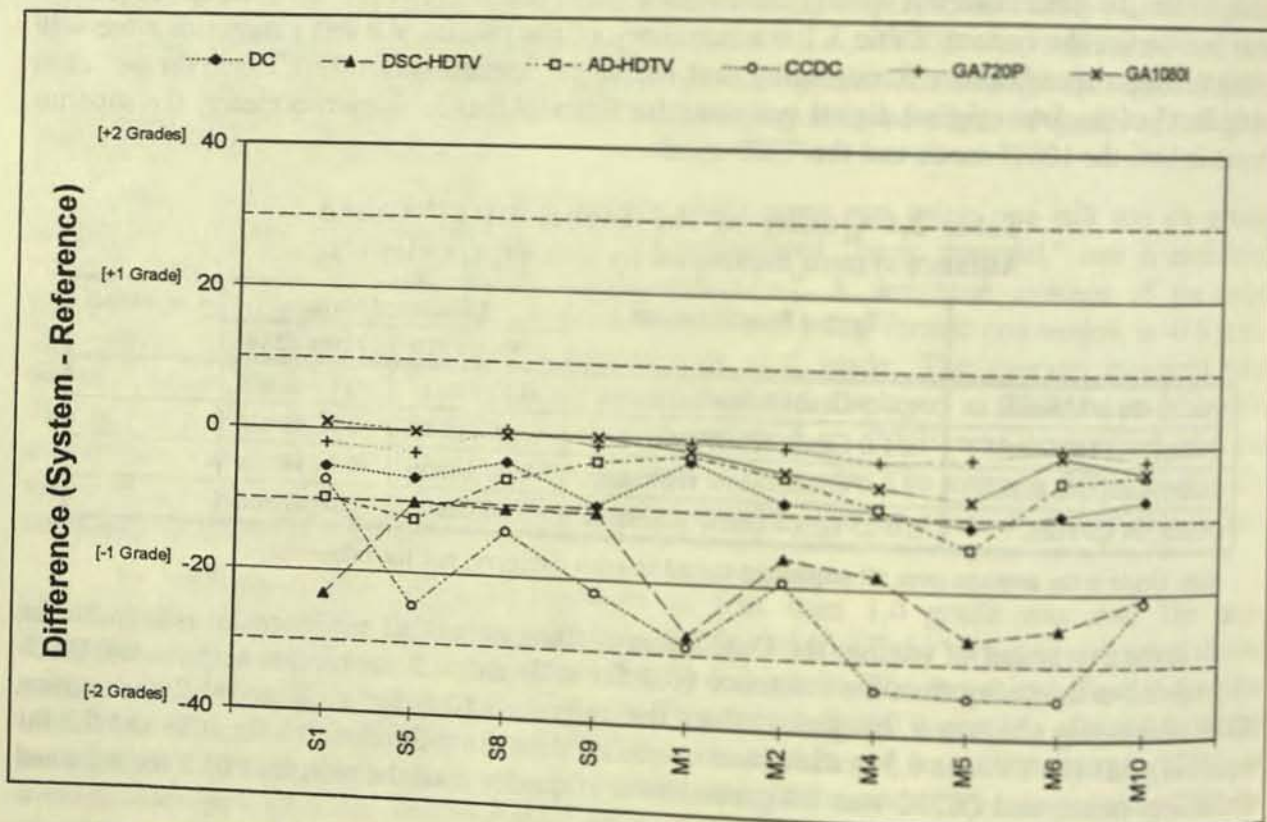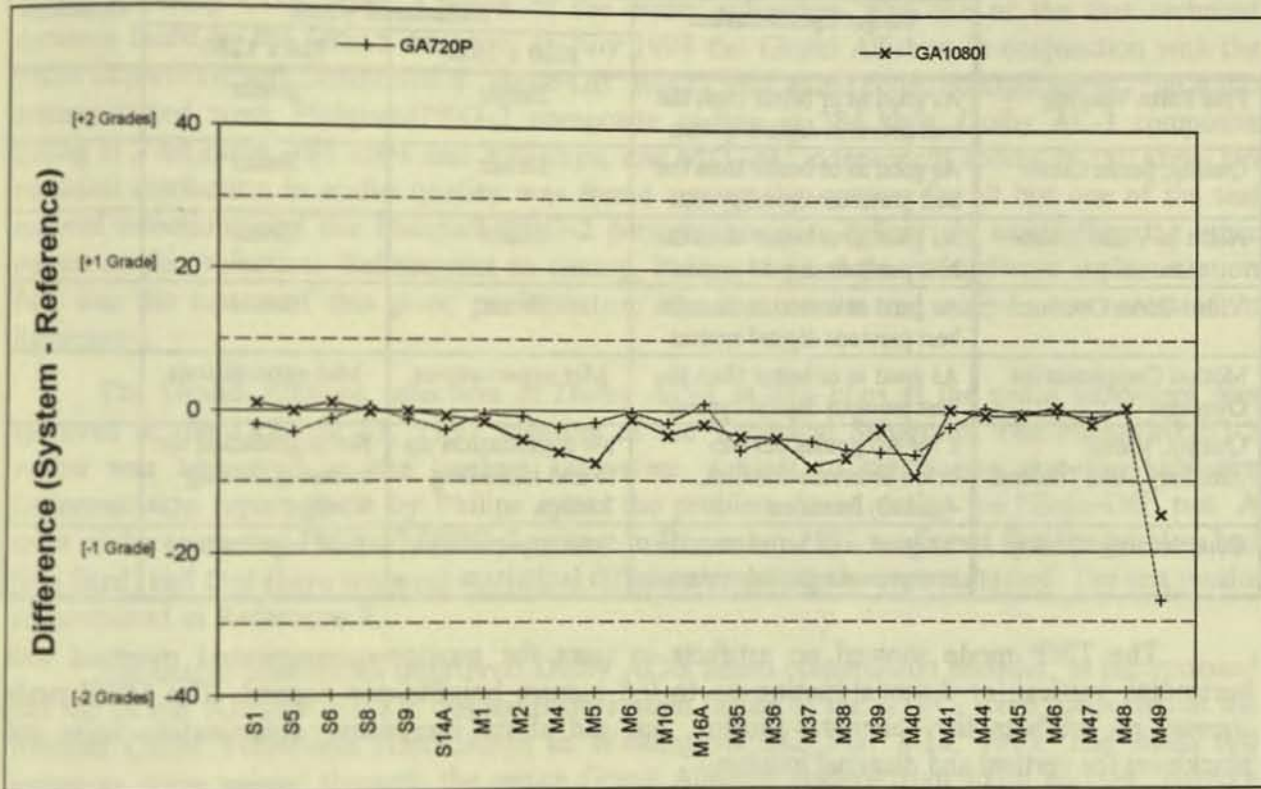**Figure 3.2 Quality of the Digital HDTV Grand Alliance system across all sequences compared with the 1125-line studio quality reference.**

A number of tests were conducted by the expert observers. A summary is shown with the target specifications in Table 3.2. The expert observers found that the video quality of the Digital HDTV Grand Alliance System was clearly superior to that of any of the previous proponent systems, and they said that applies to all types of video tested — still images, motion sequences, computer graphics, and film. They did observe some compression artifacts, but only on the most difficult images. The level of compression artifacts, they said, was significantly lower than for any previous system. The expert observers, like the non-expert viewers, found the quality of the Grand Alliance System, in both modes, to be excellent and superior to any of the previous systems. They noted that scene cut performance was much improved over the previous systems.

When noise was introduced into the 1080I source, no enhancement of the noise was found at low noise levels. At the highest level of added noise, an increase in blockiness was seen, but the image exhibited much better quality than was observed at POU. When noise was introduced into the 720P source, a slight increase in image artifacts was found. At high levels, there was an

increase in the blockiness of the image, but the image exhibited much better quality than was observed at POU.

Table 3.2 Quality of the Digital HDTV Grand Alliance system measured by expert observers.

	Target Specification	Measured Value		Comments
		1080 x 1920	720 x 1280	
Free Form Viewing	As good as or better than the best previous digital system	Better	Better	
Quality, Scene Cuts	As good as or better than the best previous digital system	Better	Better	
Noise in Video Source	As good as or better than the best previous digital system	Better	Better	
Video Coder Overload	As good as or better than the best previous digital system	Better	Better	
Motion Compensation Overload	As good as or better than the best previous digital system	Met expectations	Met expectations	
Quality, Video/ Auxiliary Data Tradeoff	2 (of 10) grades per Mb below reference for film, 4 (of 10) for video	No degradation up to and including 3 Mbps	No degradation up to and including 3 Mbps	
Concatenation Quality	As good as or better than the best previous digital system	Met expectations	Met expectations	

The 720P mode showed no artifacts in tests for motion-compensated overload with horizontal, vertical, or diagonal motion up to 0.8 picture heights per second. The 1080I mode showed no artifacts for horizontal motion, but did show increasing quantization noise and blockiness for vertical and diagonal motion.

The Grand Alliance has commented that two factors may have contributed to this difference in performance. First, the frame rate for 720P is greater than that for 1080I (60 frames per second rather than an effective 30 frames per second) and, in consequence, the time range over which the search operates is greater for 720P. And, second, the spatial range of the search is a fixed number of pixels for both formats and, because pixel spacing is greater in 720P, the effective search range also is greater.

The expert observers conducted tests to see how image quality deteriorated as channel capacity was reduced by transmitting auxiliary data. They found little or no increase in artifacts as the auxiliary data rate was increased to 3 Mbps. At 4 Mbps, the sequence M40 (Dream Team) showed a clear increase in the visibility of artifacts. The expert observers concluded that care must be exercised in combining an auxiliary channel with a high data rate together with video scenes with high peak complex motion; subjective degradation of the video may increase rapidly as channel capacity is diverted from video to auxiliary data.

When video material was passed through the system twice, somewhat more noise was seen on the second pass in the 1080I mode. For the 720P mode, more blockiness and noise were visible. The effects were worse with 720P than 1080I.

3.2. AUDIO

3.2.1. Audio and Long Form Entertainment Tests

Following the formation of the Grand Alliance in May 1993 it became necessary to select specific subsystems to be incorporated into the complete HDTV transmission system to be tested by the Advisory Committee. Choice of the audio subsystem was one of the first technical decisions faced by the Grand Alliance. In July 1993 the Grand Alliance, in conjunction with the Audio Experts Group, conducted a "Bake-Off" test of four audio codec configurations. The audio systems tested were Philips/MPEG-2 composite coding at 384 kbps, Dolby AC-3 composite coding at 2 bit rates, 384 kbps and 320 kbps, and MIT-AC independent coding at 580 kbps. No statistical distinction in audio quality was found among the systems for all but one of the test material selections and the Philips/MPEG-2 performance was definitively worse than the other codecs on this selection. Subsequent to testing, Philips claimed that a hardware implementation flaw was the cause of this poor performance. The test results and analysis are contained in Reference 1.

The Grand Alliance selection of Dolby AC-3 at 384 kbps as the audio subsystem was approved at the October 21, 1993 meeting of the Technical Subgroup. The Philips/MPEG-2 system was approved as the backup subsystem, subject to verification that the hardware implementation repair made by Philips cured the problem found during the "Bake-Off" test. A retest of the corrected Philips/MPEG-2 system in December 1993 confirmed that the problem had been fixed, and that there were no statistical differences among the systems tested. The test results are contained in Reference 2.

Subjective tests of an improved Dolby AC-3 audio compression encoder, as incorporated into the Grand Alliance HDTV transmission system tested at the ATTC, were conducted at the National Cable Television Association in Washington DC, May 8-18, 1995. The audio test sequences were passed through the entire Grand Alliance system, from audio encoder, through system multiplexing and transmission modulation, demodulation and demultiplexing, and finally audio decoding. The primary goal of these tests was to verify that the audio coder used in the Grand Alliance system was as good as or better than the coder tested in 1993.

The full report of the FCC ACATS SS/WP2 Audio Task Force is contained in Reference 3 but, in summary, it was concluded that:

1. The audio quality of the fully integrated Grand Alliance coder is better than that of the coder tested in 1993.

2. The audio quality of the Grand Alliance coder in the multi-channel mode was indistinguishable from that of the source.

3. The audio quality of the Grand Alliance coder in the 5.1 mode with 2 channel reproduction, while it can be detected by some expert listeners on some audio test material, is very nearly transparent (better than grade 4.5 on the 5 point impairment scale).

4. The audio quality of the Grand Alliance coder in the 2 channel mode is very nearly transparent (better than grade 4.7 on the 5 point impairment scale).

The Long Form Entertainment Tests were originally proposed by PS/WP6 (Subjective Assessment) to verify that the system could successfully handle program length audio and video HDTV test materials. The test materials consist of two reels. The first reel is 50 minutes in length and contains a wide variety of video segments with associated stereo and mono audio. The second reel contains several segments from the film "Hunt for Red October" with 6 channel surround-sound audio and is 23 minutes in length. The Long Form Entertainment Tests were conducted in October 1995 and the results are contained in Reference 5.

Table 3.3 contains the results of the Audio and Long Form Entertainment Tests.

Table 3.3 ATV subjective audio and long form entertainment tests.

	Target Specification	Measured Value	Comments
ATV Multi-channel Audio	Subjectively as good as or better than the Grand Alliance/ Audio Experts Group tests	Better	
Long Form Entertainment Program	EO&C, no noticeable impairments	Met expectations	

3.2.2. Dual Stream Audio

On February 3, 1992 the ATSC Executive Committee approved the release of document T3/186 that offered guidance to industry on desirable features for digital audio and data services associated with an Advanced Television service. Conformance with this document was subsequently incorporated into the FCC ACATS selection criteria for the audio subsystem of the proposed Grand Alliance HDTV system. One of the attributes recommended in T3/186 was the capability to decode two audio bit streams simultaneously to allow visually impaired services, voice-overs, multiple languages and other services to be combined with a main audio service in a receiver. This dual stream audio capability requires two audio decoders in the receiver or at least the ability of a single decoder to handle two independent bit streams simultaneously. The need for all receivers to have dual stream audio capability was challenged and the Audio and Transport Experts Groups were requested to make a recommendation to the Technical Subgroup on the subject.

On May 16, 1995 a joint open meeting of the Audio and Transport Experts Groups was held to discuss and analyze the dual stream audio issue and a recommendation resulting from that meeting, that dual stream audio should be optional, was made to the Technical Subgroup on May 18, 1995. The Technical Subgroup was unable to approve the recommendation at that meeting and the Experts Groups were requested to produce a white paper on dual stream audio that also explained the rationale behind the recommendation.

The paper was completed as a joint effort by members of the two Experts Groups and presented to the Technical Subgroup by Jim Gaspar, Chair of the Audio Experts Group, at the July 19, 1995 meeting. The paper and the recommendation for optional dual stream audio decoding were approved unanimously at the meeting. The impact of making dual stream audio optional is that it requires at least one complete main audio service to be included in the audio service mix provided by the broadcaster. The dual stream white paper is contained in Reference 4.

3.2.3. References

1. "Analysis of Grand Alliance Audio Tests July 28, 29, 30," August 28, 1993.

2. "Analysis of Grand Alliance Audio Tests December 7 and 8," December 15, 1993.

3. "Report on Multichannel and Stereo Listening Tests," July, 1995.

4. "An Explanation of Dual Stream Audio Decoding," July 14, 1995.

5. "Report on the Long Form Viewing Tests," October, 1995.

4. TRANSPORT

A number of tests were performed to examine the Grand Alliance prototype's ability to perform the transport layer functions prescribed by the ATSC Digital Television Standard. The target specifications list four tests as demonstrations, as shown in Table 4.1.

Table 4.1 Interoperability and Packetization Target Specifications.

	Target Specification
Header/Descriptor Robustness	Demonstration only
Switching between Compressed Data Streams	Demonstration only
Simulation of ATM Network Transmission	Demonstration only
Transport Interoperability with Computer Networks	Demonstration only

4.1. SWITCHING BETWEEN COMPRESSED DATA STREAMS

The Grand Alliance conducted a laboratory demonstration indicating the practicality of decoding video from a bit stream created by concatenating various video elementary streams. Within the range of test material prescribed for this demonstration, the test showed the feasibility of switching between compressed data streams.

4.2. HEADER/DESCRIPTOR ROBUSTNESS

The Grand Alliance demonstrated that the prototype ATV receiver recovers from loss of certain header information, as expected, with visible artifacts in the reconstructed video. For this demonstration, slice headers and picture headers for I, P, and B-frames were deliberately delivered in error. It was observed that for errors on I-frame headers, the visible artifacts could affect the entire group of pictures (GOP). For loss of a B-frame header, the subjective impact is limited to that B-frame only. When a P-frame header is lost, the duration of visible artifacts lies between the duration for loss of an I-frame header and a B-frame header.

4.3. COMPRESSION AND TRANSPORT LAYER INTEROPERABILITY

4.3.1. Syntactic and Semantic Compliance of the ATV Bit Stream

A bit stream recorded at the output of the Grand Alliance encoding system was analyzed through the use of software specially developed to check for MPEG-2 and ATSC syntactic and semantic compliance. Note that although a great number of bit stream elements were checked, practical considerations prevented the tests from being absolutely exhaustive. As a result, these

tests did not verify that the Grand Alliance encoder would be completely compliant under all coding conditions. For instance, coded bit streams were not tested for video formats other than 720P at 59.94 Hz frame rate, and 1080I at 29.97 Hz frame rate.

A list of the specific bit stream elements tested is beyond the scope of this summary report; however, for perspective, the following is a summary of the quantities of syntactic and semantic elements tested:

- 66 elements of the MPEG-2 Systems Standard (ISO/IEC 13818-1)

- 14 elements of the ATSC Digital Television Standard, Annex C, "Service Multiplex and Transport Systems Characteristics" (ATSC A/53)

- 34 elements of the MPEG-2 Video Standard (ISO/IEC 13818-2)

- 3 elements of the ATSC Digital Television Standard, Annex A, "Video Systems Characteristics" (ATSC A/53)

Compliance violations were detected in the Program Association Table, the Program Map Table, the Program Paradigm, in Descriptors, in PES Headers, and in Video Syntax Start Codes. All were considered minor syntactic or semantic violations, and correction of these violations should be straightforward. These corrections, however, may be critical to receivers' ability to decode correctly ATV programs. The detected violations do not represent any impairment in picture quality or transmission coverage, and thus did not affect any test results in these areas.

Any commercial encoding systems produced for the marketplace must be produced in full compliance with the overall ATSC Standard.

4.3.2.   Interoperability with ATM Networks

The goal of this series of tests was to demonstrate that a 19 Mbps ATV transport bit stream can be interfaced to, and transported by, an Asynchronous Transfer Mode (ATM) network. The tests were conducted at the Charlotte, North Carolina field test site utilizing fiber-based ATM transport facilities provided by Bell South.

Using equipment provided by the Grand Alliance, ATV transport data stream packets were split into ATM-sized payloads and then formed into ATM cells with appropriate ATM headers and syntax. These were then transmitted via the ATM network, through a single ATM switch, and returned to the field test site. Here they were converted back into ATV transport packets. The ATM channel was selected for constant bit rate, which provides minimum timing errors, or "jitter."

The first of the three tests was designed to verify the basic connection to the ATM network. A D-3 VTR provided 19 Mbps source data, in ATV transport stream format, but consisting of pseudo-random data sequences. These were successfully passed through the ATM channel with no bit errors detected.

The second of the tests utilized a D-3 VTR to feed into the ATM network a transport stream consisting of compressed HDTV pictures and sound. The returned ATM signal was reconverted to an ATV transport stream and fed to the Grand Alliance 8 VSB modulator, and then broadcast via the channel 53 transmitter, and also transmitted via cable television plant (in the 16 VSB mode). Error-free reception was achieved at both broadcast and cable receive sites.

The third test involved increasing the length of the ATM path to a total distance of approximately 450 miles, and increasing the number of ATM switches in the circuit to six. While generally successful, at times ATM packet jitter exceeded the buffer capacity of the ATM receiver, resulting in errors in the decoded picture that were different in appearance from those caused by typical over-the-air impairments.

In summary, all three tests proved the feasibility of carrying the ATV transport stream over a public carrier's fiber-based ATM network, but indicated that commercial equipment will need to be designed to cope with packet jitter that arises in more complex ATM network configurations.

4.3.3.   Multiple Ancillary Data Services

In order to demonstrate, in a limited fashion, the ability of the Grand Alliance prototype system to deliver multiple independent programs within a single 6 MHz RF channel, the system was configured for this test to transmit simultaneously four data channels at bit rates as follows: 4.738 Mbps, 5.744 Mbps, 3.747 Mbps, and 4.717 Mbps. The transmission channel was unimpaired, and a strong level signal (-28 dBm) was presented to the receiver. Each of the "sub-channels" was selected, in turn, for output at the decoder, and each was received error-free.

4.4.   AUDIO/VIDEO/CAPTIONING LATENCY

Because the signal processing in a digital television system has the potential to introduce varying delays between the audio, video and closed-captioning data signals, tests were performed on the Grand Alliance prototype system to measure these absolute and relative delays.

4.4.1.   Absolute Latency

For the 1080I format, the absolute delay for video was 846 ms. For the 720P mode, the absolute delay for video was 813 ms. These latencies may be of interest to future designers of interactive television systems utilizing the Grand Alliance system, because these delays set the lower bound for responsiveness of the system to a user request for a high definition video sequence.

4.4.2.   Relative Latencies

For the 1080I format, audio was found to lag the video by 9 - 13 ms, with variations over this range depending upon the channel examined in the 5.1-channel audio configuration. Such a lag is not considered to be perceptible to viewers, except in cases of concatenated processing through a series of ATV encoding systems, through which the audio lag would accumulate. The Grand Alliance is encouraged to investigate whether this relative delay in audio content can be reduced through encoding system design changes.

For the 720P format, audio was found to lead the video by 36 - 40 ms, varying by channel in the 5.1-channel audio configuration. Such a lead in audio timing is nearing the perceptible threshold, but can be expected to be corrected via a relatively inexpensive delay in the audio signal at the appropriate point in the ATV encoding system.

As to captioning, for the 1080I format, captioning was found to lead the video by 17 - 33 ms (that is, by one or two fields), depending upon whether the captioning was presented

to the encoder on Field One or Field Two. Correction of this lead can be expected to be a relatively simple matter for future encoder designs.

For the 720P format, captioning latency essentially matched the video latency, leading the video by only 1 ms.

Target specifications and measured values for relative latencies are given in Table 4.2.

Table 4.2 Relative latencies of the Digital HDTV Grand Alliance system.

	Target Specification	Measured Value		Comments
		1080 x 1920	720 x 1280	
Video-Audio Relative Latency	< 15 ms	10.3 ms	38.4 ms	See Note 1
Video-Captioning Relative Latency	< 100 ms	33 ms	1 ms	

Note 1: Relative timing of video and audio is fully programmable. In the prototype system, timing was not optimized for the 720P mode.

5.   TRANSMISSION

5.1.   SPECTRUM UTILIZATION

5.1.1.   Introduction

The Advisory Committee on Advanced Television Service considered two criteria for spectrum utilization — accommodation percentage and service area. "Accommodation percentage" specifies the fraction of existing NTSC television stations that could be assigned an ATV channel. "Service area" refers to the interference-limited coverage area of new ATV stations. The methodology for calculating the results of the analyses of these criteria was described in Chapter 8 of the "ATV System Recommendation" adopted by the Advisory Committee on February 24, 1993.

5.1.2.   Accommodation Percentage

Allotment studies were undertaken based on the results of laboratory testing of the Grand Alliance prototype ATV system. For terrestrial broadcasting, an allotment/assignment plan that provides a second channel for each television licensee, construction permit holder, and construction permit applicant was developed. In the plan, an attempt was made to match the new ATV coverage with the existing coverage of the companion NTSC station. Approximate realization of that objective was achieved through reducing ATV coverage of some stations and allowing new interference to the coverage areas of some NTSC stations. The effect of the interference tradeoffs is detailed in the following section.

5.1.3.   Service Area

Table 5.1 shows the planning factors employed in the devising of the allotment/assignment table and in the analyses of service and interference. Shown also in Table 5.1 are the target specifications which are based on the "Best of the Best" values from the four original digital systems. The carrier-to-noise, co-channel, and adjacent-channel interference data were derived

from laboratory testing of the Grand Alliance prototype. Of particular note is the matter of interference to NTSC from an upper adjacent-channel ATV operation.

Table 5.1 System-specific planning factors for Grand Alliance prototype (D/U in dB).

	Target Specification	Measured Value	Comments
Carrier-To-Noise	< 15.6 dB	+15.19 dB	

Co-Channel	Target Specification	Measured Value	Comments
ATV-into-NTSC	< 36.5 dB	+34.44 dB	
NTSC-into-ATV	< 3.5 dB	+1.81 dB	
ATV-into-ATV	< 16.6 dB	+15.27 dB	

Adjacent-Channel	Target Specification	Measured Value	Comments
Lower ATV-into-NTSC	< -14.5 dB	-17.43 dB	
Upper ATV-into-NTSC	< -12.5 dB	-11.95 dB	See Note 1
Lower NTSC-into-ATV	< -41.5 dB	-47.73 dB	
Upper NTSC-into-ATV	< -43.0 dB	-48.71 dB	
Lower ATV-into-ATV	< -37.5 dB	-41.98 dB	
Upper ATV-into-ATV	< -37.5 dB	-43.17 dB	

Note 1: Target specification is based on video interference which was met during testing (-17.00 dB). During testing, it was discovered that audio interference occurs before video interference; the measured value shown in this table is based on audio interference.

In the 1993 testing of the original systems, and in the 1994 comparative testing of the 8 VSB and 32 QAM transmission subsystems (called the bake-off), consideration was given only to video interference. In the 1995 testing of the Grand Alliance prototype, interference from ATV into BTSC stereo and the second audio program (SAP) channel were tested also. In a substantial number of the twenty-four NTSC receivers used in the ATTC testing program, audio was found to degrade before video when the interfering signal was ATV in the upper adjacent-channel. The threshold for video performance degradation to CCIR Grade 3 was found to be at a desired-to-undesired (D/U) ratio of -17.00 dB for the median receiver. The threshold for audio performance degradation to CCIR Grade 3 for the median receiver was found to be at a D/U ratio of -11.95 dB.[1] Since the D/U ratio for audio is greater than the D/U ratio for video (i.e., audio degraded before video), in the instance of upper adjacent-channel ATV-into-NTSC interference, the audio ratio was used in service and interference determinations. In all other interference considerations, video degraded before audio, therefore video D/U ratios were used.

5.1.3.1.   Service Area Evaluation

Nationwide coverage area and population analyses are summarized in Table 5.2 and Table 5.3. In this analysis, the data base is the same as that used for the bake-off analysis. The

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[1] The threshold for audio performance degradation to CCIR Grade 3 was found to be at a D/U ratio of -7.95 dB for twenty percent of the receivers, and at -10.95 dB for thirty percent of the receivers. For further information, see the coverage analysis report of the Transmission Expert Group.

VHF/UHF scenario is assumed, and co-channel, adjacent-channel, and taboo constraints are used. ATV performance, based on the prototype testing, was essentially equivalent[2] to the performance predicted on the basis of the bake-off test results, and substantially better than the four original digital systems. Areas and populations served are greater and interference is less.

Table 5.2 Aggregate population statistics for Grand Alliance prototype (VHF/UHF scenario, co-channel, adjacent-channel, and taboo constraints).

Aggregate Population Statistics	Based on Median Video	Based on Median Audio
Total population for ATV and NTSC coverage areas	2,912.03 M	2,912.03 M
NTSC population lost due to NTSC interference	301.30 M	301.30 M
NTSC population lost due to ATV interference	93.2 M	118.36 M
ATV population lost due to NTSC and ATV interference	73.07 M	73.07 M
ATV population lost due to ATV-only interference	38.45 M	38.45 M

Table 5.3 NTSC population statistics for Grand Alliance prototype (VHF/UHF scenario, co-channel, adjacent-channel, and taboo constraints).

Population loss relative to population in coverage area	NTSC stations with added population loss due to ATV	
	Based on Median Video	Based on Median Audio
No Interference	60.9 %	57.6 %
0 - 5 %	24.7 %	24.4 %
5 - 10 %	5.1 %	6.1 %
10 - 15 %	2.8 %	3.6 %
15 - 20 %	1.8 %	2.1 %
20 - 25 %	1.3 %	1.5 %
25 - 30 %	0.5 %	1.5 %
30 - 35 %	0.7 %	0.3 %
> 35 %	2.2 %	2.9 %

Interference to NTSC audio from the upper adjacent-channel ATV had to be present during the bake-off testing, but audio effects were not tested; concentration was on video. A reasonable assumption is that, had audio effects been considered in the bake-off tests, coverage analysis based on upper adjacent audio would have yielded similar results to those shown in Table 5.2.

Table 5.2 compares the effects of NTSC and ATV interference on the viewing population. The numbers entered in the table for "population" are the product of the number of viewers and the number of stations they potentially receive. This accounts for a total "population" of almost 3 billion. The table shows that the biggest "lost" population is potential NTSC viewership already lost because of NTSC interference; this population statistic describes the situation as it exists today and forms a baseline. Compared with this number, the effects on existing NTSC of adding a new ATV service are small. The ruggedness of the new ATV service is apparent also because its

[2] Based on upper adjacent video.

"lost" population is smaller than the present "lost" population with NTSC. These results indicate that the loss of population coverage due to interference will be significantly decreased after the transition to ATV is completed.

5.1.3.2. Comparison with Four Original Digital Systems

Figure 5.1 and Table 5.4 have been provided to allow comparisons to the 1993 testing of the four original digital systems. Results of the previous tests are included in the "ATV System Recommendation." The computer input for this analysis is based on the 1993 data base, assumes the VHF/UHF scenario, considers only co-channel and adjacent-channel interfering sources, and uses the upper adjacent-channel ATV-into-NTSC D/U ratio of -17.00 dB, which is the video threshold.
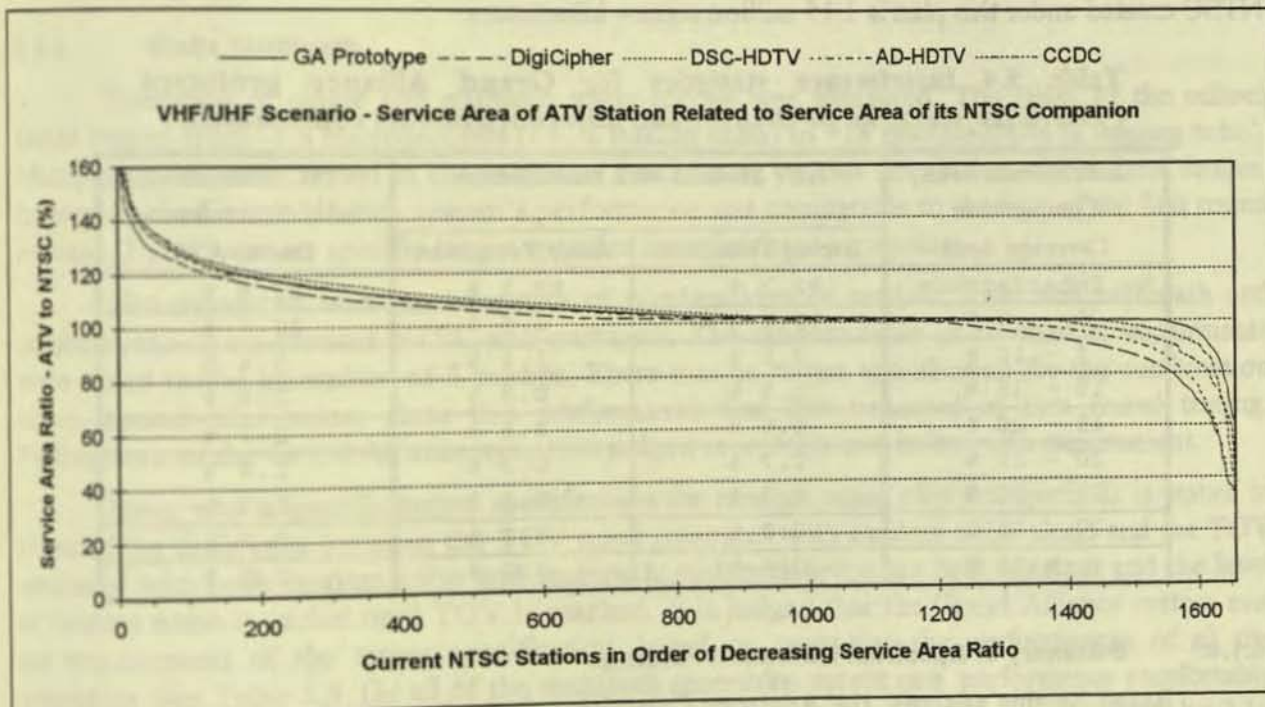

Figure 5.1 Interference-limited service area of each ATV station relative to the interference-limited service area of its companion NTSC station (VHF/UHF scenario, co-channel and adjacent-channel constraints).

Figure 5.1 depicts the interference-limited service area of each ATV station, during the transition period, relative to the interference-limited service area of its companion NTSC station under the VHF/UHF scenario, taking into account co-channel and adjacent-channel constraints. The graph shows the Grand Alliance prototype, as a solid line, along with the four original digital systems. In the graph, the 1,657 current NTSC stations are placed in order of decreasing ATV to NTSC service area ratio. Examination of the graph for the Grand Alliance prototype reveals that 11 % (183) of the ATV stations under this scenario would have an ATV service area at least 20 % larger than their companion NTSC service area, and 98.85 % (1,638) would have an ATV service area at least 80 % of their companion NTSC service area. The total ATV interference-limited service area for all 1,657 stations is 39.7 million square kilometers. It is clear from this

graph that the performance of the Digital HDTV Grand Alliance System exceeds that of any of the four original digital systems.

Table 5.4 shows the interference statistics for the VHF/UHF scenario, taking into account co-channel and adjacent-channel constraints. During the transition period, 82.3 % of ATV stations would receive no interference. This would rise to 89.1 % after the transition period ends. Also during the transition period, 0.4 % of the ATV stations would receive interference in more than 35 % of their noise-limited coverage area. This would decrease to 0.2 % after the transition period ends. The total interference area created within the ATV noise-limited coverage area during the transition period is 0.41 million square kilometers. Of the existing NTSC stations, 63.8 % would not receive any new interference because of the ATV service, while 2.2 % would receive new interference in more than 35 % of their Grade B area. The total new interference into NTSC created under this plan is 1.15 million square kilometers.

Table 5.4 Interference statistics for Grand Alliance prototype (VHF/UHF scenario, co-channel and adjacent-channel constraints).

Interference Area Compared to Coverage Area	ATV Stations with Interference		NTSC Stations with Added Interference Due to ATV
	During Transition	**After Transition**	**Due to ATV**
No Interference	82.3 %	89.1 %	63.8 %
0 - 5 %	10.1 %	6.6 %	20.7 %
5 - 10 %	3.5 %	1.8 %	5.4 %
10 - 15 %	1.5 %	0.9 %	2.8 %
15 - 20 %	0.6 %	0.5 %	2.2 %
20 - 25 %	0.7 %	0.3 %	1.4 %
25 - 30 %	0.3 %	0.3 %	1.0 %
30 - 35 %	0.3 %	0.3 %	0.5 %
> 35 %	0.4 %	0.2 %	2.2 %

5.1.4.   Summary of Spectrum Utilization Findings

Based on this analysis, the Advisory Committee finds that the Grand Alliance system is superior to all of the previously analyzed proponent systems in utilization of spectrum.

5.2.   TRANSMISSION ROBUSTNESS

This section identifies the various tests of transmission performance. For each test, the purpose and importance of the test and the test methodology is summarized. A brief statement of the results is given also for each test, with emphasis on comparison of performance of this Grand Alliance system with the previous proponent systems.

5.2.1.   Random RF Noise Performance

Random noise was added at RF to the desired digital signal. As expected for the Grand Alliance system's modulation and error correction, random RF noise has no effect on the recovered video and audio data until the level of noise is raised to a point very close to a "threshold" value. The value of carrier-to-noise ratio (C/N) where the effects of noise begin to be visible is called the Threshold of Visibility (TOV).

For the Grand Alliance system, the C/N at TOV was 15.19 dB.

As expected and designed into the system, the threshold is very sharp. Visible image impairments change from just barely visible to destructive of the picture within ~ 1 dB of worsening of the C/N.

A similar measure can be made on the recovered audio data (Threshold of Audibility). For the Grand Alliance system, the C/N at TOA was 14.92 dB.

As expected, the video and audio fail approximately together, with audio measuring as slightly more robust against RF noise. Audio does not fail before video.

Performance in the presence of RF noise impairment is superior to the first round systems and meets target specifications. See Table 5.5.

5.2.2.   Static Multipath

Tolerance of single and multiple static echoes was measured. The delay of the echoes tested ranged from -1.8 microseconds (i.e., a leading echo) to +18 microseconds (a lagging echo). Multiple echoes were tested in ensembles of 5 echoes at various amplitudes within these ranges. In general, the Grand Alliance system's performance was comparable to the best of the first round systems. There were no specific target specifications for these parameters.

Also measured was the tolerance of combinations of random noise and multipath and combinations of co-channel NTSC and multipath. The random noise or co-channel impairments were added to the ensembles of 5 echoes. There was no target specification for the combination of co-channel plus noise, since this performance was not measured in first round testing. Performance of the Grand Alliance system is judged acceptable and in line with expectations.

There was a specific target specification for random noise plus multipath. It is stated in terms of the difference between the TOV point measured with random noise alone and the TOV measured with both random noise and multipath; multipath levels are held constant and the level of random noise is varied until TOV is reached. It is judged that the Grand Alliance system met the requirements of the target specification, based on averaging the performances of all the ensembles. See Table 5.5. (In all of the multipath ensembles except one, performance comfortably surpassed the requirements of the specification; the one exception was worse than target by 0.14 dB.)

Table 5.5 Random RF noise performance of Grand Alliance prototype.

	Target Specification	Measured Value	Comments
Threshold Characteristics for Random Noise - Video	< 15.6 dB	15.19 dB	
Threshold Characteristics for Random Noise - Audio	< 15.6 dB	14.92 dB	
Threshold Characteristics for Random Noise (Audio + Video)	Audio usable at or beyond video POU	Audio did not fail before video	
Random Noise in Presence of Multipath	< 3.5 dB	2.42 (±1.22) dB	

5.2.3.   Flutter

Flutter is time-varying or dynamic multipath. This performance attribute was tested with both ensembles of ghosts and with single ghosts at various rates of "motion" from 0.05 Hz to 5 Hz. This testing was more extensive than in the first round. Where comparable data exist, the Grand Alliance system shows improved performance.

5.2.4.   Impulse Noise (Burst Error)

Both over the air and cable reception suffer interference from bursts or impulses of noise. The ability to deliver corrected data in the presence of bursts of interference is important.

The 8 VSB Grand Alliance system performed better than the target specification by withstanding a 169 μs burst at a repetition rate of 10 Hz. The second part of the test specified a time duration for the pulse as a percentage of the threshold pulse width, and not the width specified in the target values, so a comparison with the target value is not possible. See Table 5.9.

The 16 VSB Grand Alliance system was able to withstand a 120 μs burst at a repetition rate of 10 Hz which almost met the target value of 129 μs at 10 Hz. See Table 5.10.

5.2.5.   Discrete Frequency Interference

The intent of this test is to probe for sensitivity of the digital signal to particular interfering frequencies, such as could be encountered from RF signals other than broadcast television. Discrete frequency interference tolerance was tested both from tones within the desired ATV channel and from tones in adjacent channels.

The Grand Alliance system performed better than the target specifications. See Table 5.6.

Table 5.6 Discrete frequency interference performance of the Grand Alliance prototype.

	Target Specification	Measured Value	Comments
Discrete Frequencies (25)	< -39.5 dB adj. ch.	-48.5 (±3.5) dB	
	< 12.75 dB in band	11.1 (±2.0) dB	

5.2.6.   Co-channel Interference into ATV

Tests measured both ATV-into-ATV and NTSC-into-ATV co-channel interference, at both moderate and weak power levels. The Grand Alliance system performed better than target specifications on all of these tests. See Table 5.1.

5.2.7.   Co-channel Interference into NTSC

The test measured ATV-into-NTSC co-channel interference at moderate and weak power levels. The Grand Alliance system performed better than target specifications on all of these tests. See Table 5.1.

5.2.8.   Adjacent-Channel Interference

Upper and lower adjacent-channel interference were both tested, and tests were performed in both directions, i.e., ATV-into-NTSC and NTSC-into-ATV. Tests were performed at strong, moderate, and weak power levels.

With regard to ATV-into-ATV tests, the threshold of visibility at weak and moderate desired power exceeded performance in the first round tests. At strong desired power, the threshold of visibility exceeded that level of interference expected to occur under real-world conditions.

The Grand Alliance system performed better than target specifications on all NTSC-into-ATV tests and on lower adjacent-channel ATV-into-NTSC. With regard to upper adjacent-channel video interference ATV-into-NTSC, the tests found a "color stripe" artifact in the NTSC video at all NTSC power levels. Analysis shows that it is caused by the ATV pilot carrier frequency "beating" with the NTSC color subcarrier. Analysis also suggests that another "luminance beat," hidden during the testing by the color beat, would be present, caused by the ATV pilot carrier beating with the NTSC visual carrier. Finally, during these tests, some NTSC receivers showed loss of color and other picture artifacts.

The analysis shows that use of precision carrier offset between the ATV pilot and the NTSC color subcarrier will eliminate visibility of both artifacts. The loss of color and other artifacts, however, would not be affected by carrier offset.

Given the above, also examined carefully were the effects of upper adjacent-channel ATV-into-NTSC interference on the BTSC stereo signal and on the SAP channel. Results show that the stereo and SAP signals are more sensitive to upper adjacent-channel interference than is the video. Assuming the use of offset to eliminate the video beat artifacts, coverage was computed based on the interference levels measured for the stereo and SAP channels. Nevertheless, the system met target specifications, because those targets were based on video performance. See Table 5.1.

5.2.9.   Taboo Interference

Tests were performed at all the significant traditional UHF taboo channels. The Grand Alliance system performed better than target specifications an all taboos except N+2, ATV-into-NTSC. It missed that target by about 0.6 dB. The taboo performance of the Grand Alliance system is judged acceptable. See Table 5.7.

5.2.10.   Peak-to-Average Power

The ratio of peak-to-average power, with 99.9% probability was measured as 5.9 dB, which was lower (i.e., better) than target specification. See Table 5.8.

5.2.11.   Threshold Characteristics

Thresholds against impairments are generally sharp for digital systems with error correction. The Grand Alliance system exhibited the expected sharp thresholds, as discussed above in individual test summaries.

5.2.12.   Cable Transmission

5.2.12.1.   Composite Second Order

Composite second order (CSO) impairment arises from the distortion characteristics of active elements in a cable television system. System performance in the presence of CSO impairment is a function of the spectral characteristics of the modulation scheme and the receiver front end design. The ability to withstand high levels of CSO is desirable.

Table 5.7 Taboo interference performance of Grand Alliance prototype.

	Target Specification	Measured Value	Comments
N-2 Taboo A/N	< -23.5 dB	-23.73 dB	
N+2 Taboo A/N	< -28.5 dB	-27.93 dB	See Note 1
N+4 Taboo A/N	< -22.5 dB	-24.96 dB	
N+14 Taboo A/N	< -32.5 dB	-33.38 dB	
N+15 Taboo A/N	< -22.5 dB	-30.58 dB	
N-8 Taboo A/N	< -25.5 dB	-31.62 dB	
N+8 Taboo A/N	< -36.5 dB	-43.22 dB	
N-2 Taboo N/A	< -53 dB	-62.45 dB	
N-2 Taboo A/A	< -53 dB	-60.52 dB	
N+2 Taboo N/A	< -53 dB	-59.86 dB	
N+2 Taboo A/A	< -53 dB	-59.13 dB	
N-3 Taboo N/A	< -53 dB	< -61.79 dB	
N-3 Taboo A/A	< -53 dB	< -60.61 dB	
N+3 Taboo N/A	< -53 dB	< -62.49 dB	
N+3 Taboo A/A	< -53 dB	< -61.53 dB	

Note 1: Target specification missed by less than 0.6 dB. This is judged acceptable.

Table 5.8 Peak-to-average power for the Grand Alliance prototype.

	Target Specification	Measured Value	Comments
Peak/Average Power (99.9% probability)	< 6.95 dB	5.9 dB	

The 8 VSB Grand Alliance system had a measured carrier-to-interference level of 27 dB which is slightly poorer than the target value of < 25 dB, however, as NTSC pictures start exhibiting interference in the 50 dB range, it is unlikely the 8 VSB system would have to operate in a mid-20's carrier-to-interference environment. See Table 5.9.

The 16 VSB Grand Alliance system had a measured carrier-to-interference level of 35 dB which meets the target value of < 38 dB. See Table 5.10.

5.2.12.2. Composite Triple Beat

Composite triple beat (CTB) impairment also arises from the distortion characteristics of active elements in a cable television system. Along with random noise, it is one of the primary limiting characteristics in cable system transmission performance. System performance in the presence of CTB impairment is a function of the spectral characteristics of the modulation scheme and the receiver front-end design. The ability to withstand high levels of CTB is desirable.

The 8 VSB Grand Alliance system had a measured carrier-to-interference level of 39 dB which is slightly poorer than the target specification of < 37 dB; however, as NTSC pictures start exhibiting this interference in the 50 dB range, it is unlikely the 8 VSB system would have to operate in a high-30's carrier-to-interference environment. See Table 5.9.

The 16 VSB Grand Alliance system had a measured carrier-to-interference level of 47 dB which meets the target specification of < 49 dB. See Table 5.10.

5.2.12.3.   Phase Noise

Phase noise is a function of the stability of oscillators used in the transmission chain to generate or translate the frequency of the transmitted signal. The ability to withstand high levels of phase noise is desirable.

The 8 VSB Grand Alliance system had a measured carrier-to-phase noise ratio of 78 dB which was better than the target specification of < 81 dB. See Table 5.9.

The 16 VSB Grand Alliance system had a measured carrier-to-phase noise ratio of 82 dB which was better than the target specification of < 87 dB. See Table 5.10.

5.2.12.4.   Residual FM

Residual frequency modulation is another form of deviation in oscillators used in frequency conversion equipment. The ability to withstand high levels of residual FM is desirable.

The 8 VSB Grand Alliance system had a threshold residual FM of 9 kHz which was better than the target specification of > 6.5 kHz. See Table 5.9.

The 16 VSB Grand Alliance system had a threshold residual FM of 7 kHz which was better than the target specification of > 4 kHz. See Table 5.10.

5.2.12.5.   Fiber Optics

Cable systems are increasingly introducing amplitude modulated fiber optic links to reduce amplifier cascades and improve system reliability. The lasers will clip if over-modulated resulting in distortion in the channels.

The 8 VSB Grand Alliance system reached threshold BER with a laser modulation level of 7.8 % which was better than the target value of 4.5 %; however, the number of carriers available to modulate the laser was lower than the number used to set the target and a direct comparison is not possible. See Table 5.9.

The 16 VSB Grand Alliance system reached threshold BER with a laser modulation level of 7.3 % which was better than the target value of 4 %; however, the number of carriers available to modulate the laser was lower than the number used to set the target and a direct comparison is not possible. See Table 5.10.

5.2.12.6.   Channel Change and Channel Acquisition

Current television viewers are accustomed to rapid channel change capability, and an ATV service must emulate this feature closely if consumer frustration is to be avoided. Channel change time is a function of two processes: carrier acquisition and bit stream synchronization; and bit stream decompression through recognizable picture display and presentation of audio.

The 8 VSB Grand Alliance system exhibited an average channel acquisition time of 0.7 seconds which just met the target value for acquisition. See Table 5.9.

The 16 VSB Grand Alliance system, with an average acquisition time of 1.1 seconds, was slower than the target value of 0.7 seconds. See Table 5.10.

5.2.12.7. *Multiple Impairment — Second Order vs. Noise*

The ability of digital systems to handle a specific impairment is normally reduced if a second impairment is present. Noise and second order distortion trade-off was determined by decreasing the amount of noise necessary to reach threshold when the amount of second order distortion was decreased a specified amount.

The level of second order interference was reduced 6 dB before the noise-only threshold was reached on the 8 VSB Grand Alliance system. With the second order distortion 3 dB below the threshold value, the amount of noise necessary to reach threshold was within 0.5 dB of the noise threshold. The system was better than the random noise target value of < 15.6 dB. See Table 5.9.

The 16 VSB Grand Alliance system traded-off between noise and distortion until the distortion was reduced 15 dB below its threshold value. With the second order distortion 3 dB below its threshold value, noise was 3 dB from its threshold value. The system was slightly below the random noise threshold target value of 28.85 dB with a threshold of 29.1 dB. This was due to the lower tuner input level compared to the previous tests. See Table 5.10.

5.2.12.8. *Multiple Impairment — Third Order vs. Noise*

The trade-off between noise and composite third order distortion was determined by reducing the level of the third order distortion in specified steps and determining the noise necessary to reach threshold.

The noise-only threshold was reached on the 8 VSB Grand Alliance system when the third order distortion was reduced 3 dB.

The 16 VSB Grand Alliance system reached the noise threshold level when the third order distortion was reduced 6 dB below its threshold value. With the third order distortion 3 dB below its threshold value, noise was 0.4 dB from its threshold value.

5.2.12.9. *Multiple Impairment — Phase Noise vs. Noise*

The relationship between phase noise and random noise was determined by reducing the phase noise below its threshold level in specified steps and determining the level of random noise necessary to reach threshold at those levels.

The 8 VSB Grand Alliance system reached the noise threshold when the phase noise was reduced 15 dB below its threshold level. The system was within 2 dB of its noise threshold with the phase noise reduced 3 dB below threshold.

The 16 VSB system reached the noise threshold when the phase noise was reduced 9 dB below its threshold and was within 1 dB of threshold with the phase noise reduced 3 dB below threshold.

Table 5.9 Cable television tests performed on the Grand Alliance prototype.

	Target Specification	Measured Value	Comments
Composite Second Order Distortion	< 25 dB	27.1 dB	See Note 1
Composite Triple Beat Distortion	< 37 dB	39.1 dB	See Note 1
Phase Noise	< 81 dB	78.3 dB	
Residual FM	> 6.5 kHz	9.2 kHz	
Fiber Optic Tests	> 4.5 %	7.8 %	
Channel Change / Channel Acquisition	< 0.7 s	0.7 s	
Threshold Characteristics for Random Noise - Data	< 15.6 dB	15.0 dB	
Local Oscillator Instability	> ±89 kHz	> ±100 kHz	
Dynamic Multipath - Acquisition Time in the Presence of Multipath and Noise	< 0.75 s	0.9 s	See Note 2
Burst Error Correction	> 169 μs @ 10 Hz	180 μs @ 10 Hz	
	> 1.05 kHz @ 20 μs	240 Hz @ 118 μs	See Note 3

Note 1: The measured value missed the target specification by 2 dB, but there is more than 20 dB margin with typical operating conditions. This is judged acceptable.

Note 2: Test included more severe multipath conditions than anticipated when target specification was set.

Note 3: The test was different from the target specification.

Table 5.10 High data rate cable television tests performed on the Grand Alliance prototype.

	Target Specification	Measured Value	Comments
Composite Second Order Distortion	< 38 dB	35.4 dB	
Composite Triple Beat Distortion	< 49 dB	47.2 dB	
Phase Noise	< 87 dB	81.8 dB	
Residual FM	> 4.0 kHz	7.0 kHz	
Fiber Optic Tests	> 4.0 %	7.3 %	
Channel Change / Channel Acquisition	< 0.7 s	1.1 s	See Note 1
Threshold Characteristics for Random Noise - Data	< 28.85 dB	29.1 dB	See Note 2
Local Oscillator Instability	> ±89 kHz	> ±100 kHz	
Dynamic Multipath - Acquisition Time in the Presence of Multipath and Noise	< 0.75 s	1.2 s	See Note 3
Burst Error Correction	> 129 μs @ 10 Hz	120 μs @ 10 Hz	See Note 4
	> 1.45 kHz @ 20 μs	480 Hz @ 68 μs	See Note 5

Note 1: Measured value reflects prototype hardware anomaly, not a system characteristic. Intended design was for identical acquisition performance in both 8 VSB and 16 VSB modes.

Note 2: Measured value missed target specification by 0.25 dB. This is judged acceptable.

Note 3: Test included more severe multipath conditions than anticipated when target specification was set.

Note 4: Measured value missed target specification by 7.5 %. This is judged acceptable.

Note 5: The test was different from the target specification.

5.2.12.10. Multiple Impairment — Residual FM vs. Noise

The residual FM vs. random noise relationship was determined by reducing the residual FM in specified steps and determining the amount of noise necessary to reach threshold at those FM levels.

The 8 VSB Grand Alliance system did not reach the noise threshold when the residual FM was reduced to 25 % (2.2 kHz) of its threshold level.

The 16 VSB Grand Alliance system reached the noise threshold when the residual FM was reduced to 25 % (1.5 kHz) of its threshold value. At 75 % of the FM threshold value, the noise was within 0.4 dB of the threshold value for noise only. (16 VSB performed better than 8 VSB in this regard.)

5.2.12.11. Local Oscillator Instability

Variations in received frequencies are of concern to both broadcasters and cable operators. A consumer receiver must be able to identify and acquire signals that are offset from the nominal frequency assignment.

Both the 8 VSB and 16 VSB Grand Alliance systems were better than the target value pull-in range of > ±89 kHz. See Table 5.9 and Table 5.10.

5.2.12.12. Minimum Isolation between Receivers

Changing channels on one TV set connected to the same splitter as a second TV set may change the frequency response of the signal fed to the second set. The equalizer in the second set must respond quickly to minimize errors. The minimum isolation was defined as the highest level of ghost that could be switched in and out without causing errors in the data.

The 8 VSB Grand Alliance system was able to tolerate a 17 dB down ghost without producing any errors. There is no target value.

The 16 VSB Grand Alliance system was able to tolerate a 28 dB down ghost without producing any errors. There is no target value.

5.2.12.13. Effect of High Level Sweep

Summation sweep systems used on cable systems to determine frequency response come in two general types, a high level sweep and a lower level "bursty" system.

The 8 VSB Grand Alliance system exhibited periodic data errors with the high level sweep and no errors with the "bursty" type system.

The 16 VSB Grand Alliance system exhibited periodic data errors with the high level sweep and no errors with the lower level "bursty" sweep system.

There is no target specification for sweep systems. The high level sweep system causes interference in NTSC pictures.

5.2.12.14. Hum Modulation

Faulty amplifier power supplies can amplitude modulate RF signals at power line frequencies.

The 8 VSB Grand Alliance system reached threshold with 6.7 % hum modulation while the 16 VSB system reached threshold at 6 % modulation. There is no target value for hum modulation, but these values are well above the modulation level that would result in visible hum on an NTSC picture.

5.2.13.   Summary of Transmission Robustness Findings

The performance of the Grand Alliance system in laboratory testing has met the expectations defined by the target specifications. In the few instances where individual test results did not meet the target values stated for that particular test, the deviations were minor and do not have any significant effect on image quality or spectrum utilization.

5.3.   FIELD TEST

Field testing was performed under both terrestrial broadcasting and cable conditions.

For terrestrial broadcasting, the complete system was tested at a set of sites selected for their difficult reception conditions, as measured in an earlier field test of the modem subsystem (documented in SS/WP2-1354). In those earlier modem-only tests, a bit error rate (BER) of $3x10^{-6}$ was selected as the criterion for the threshold of visibility (TOV) of video impairments. Full system testing, including subjective observation of pictures and sound, verified the reliability of that value of BER. Because the locations for full system testing were a selected and difficult sub-set of the complete group of test locations, they are not a representative sample. The full system testing, however, verified the utility of the data taken on the full set of locations. The sites for full system testing included 10 sites in homes where tests were performed both within the residence using a set-top antenna, and outdoors, adjacent to the residence, using a mast-mounted antenna.

Complete system field testing began on July 25, 1995 and was completed on August 23. The tests were conducted using the same facilities near Charlotte, North Carolina, as employed in modem-only tests. As before, the NTSC transmitted peak visual effective radiated powers (ERP) on channels 6 and 53 were one-tenth of the maximum allowed by FCC rules, and the average ATV ERP was approximately one-sixteenth (12 dB below) of the NTSC peak visual ERP.

Tests of the complete system showed, as also indicated by the earlier modem subsystem testing, that satisfactory digital HDTV reception is available more widely than satisfactory analog NTSC reception. Even where objective measurements of BER indicate the probability of momentary impairment of the signal, subjective observation of picture and sound fails to detect impairment.

An objective measurement that should permit reliable prediction of satisfactory HDTV service at UHF is field strength; subjective assessment of video and audio correlated very well with field strength in channel 53 tests. That correlation did not hold at channel 6 because sample size and impulse interference effects prevented a proper channel 6 analysis. At only two of the seven sites, with signal strength at or below that which laboratory testing had indicated to be the limit of HDTV service, was subjectively satisfactory service observed. On the other hand, every site except one (out of a total of 15) where the signal strength was weak, but above the threshold, had subjectively satisfactory HDTV service. The 28 sites with moderate or strong signal strength all had subjectively satisfactory HDTV service.

In brief, terrestrial transmission testing of the complete system supports the conclusion that HDTV service will be available where NTSC service is presently available, and in many instances where NTSC service is unacceptable.

The complete system, with both 8 VSB and 16 VSB modulation, was tested also in cable environments in Charlotte, including existing cable systems and fiber optic links. Tests of 16 VSB were the more stringent. The 16 VSB receiver worked at all locations where the delivered signal met FCC specifications, and at many sites where it did not. Some systems were tested at frequencies beyond their maximum design frequency, resulting in less than FCC-specification conditions. Also, strong in-band beats were observed on some systems that affected both the NTSC and HDTV signals. The 16 VSB receiver continued to operate in these situations until the carrier-to-noise threshold was reached.

6.   CONCLUSIONS

Based on Advisory Committee approved specifications, and thorough laboratory and field testing of the prototype ATV system as designed and constructed by the Digital HDTV Grand Alliance, the Technical Subgroup finds the following:

1. the Grand Alliance system meets the Committee's performance objectives and is better than any of the four original digital ATV systems;

2. the Grand Alliance system is superior to any known alternative system; and

3. the ATSC Digital Television Standard, based on the Advisory Committee design specifications and Grand Alliance system, fulfills the requirements for the U.S. ATV broadcasting standard.

Accordingly, the Technical Subgroup recommends that the ATSC Standard be adopted as the U.S. ATV broadcasting standard.

Appendix G.

White Paper
on
Multiple Service Transmission
Via the Grand Alliance System

Multiple Service Transmission via the Grand Alliance System

May 1995

The purpose of this paper is to 1) provide an overview of the capabilities and flexibility of the Grand Alliance system, 2) assess the capability of the Grand Alliance system for the multiple service concept, and 3) provide examples of service models that might be considered for multiple service transmission.

Executive Summary

The FCC Advisory Committee on Advanced Television Service (ACATS) Technical Subgroup has approved the specifications for the Grand Alliance Advanced Television System. While the efforts of ACATS have been centered on high definition television (wide screen, high resolution), the television industry recognizes other potential benefits inherent in a flexible digital broadcast television system.

The Grand Alliance system utilizes a layered digital system architecture. This approach coupled with a flexible, packetized transport and a standardized approach to video compression provide the ability to support transmission of multiple services.

The transport layer provides the ability to multiplex and demulitiplex multiple program and data services.

The utilization of MPEG-2 for video compression provides the features required to support additional program formats such as wide screen and 4x3 aspect ratio at various resolutions. These features include the ability to specify sampling structure, picture aspect ratio, input format and information to support pan and scan. MPEG-2 also provides the ability to dynamically allocate the number of bits per service which is essential for multiple service transmission.

Utilization of the Grand Alliance System for multiple service transmission can be supported by a variety of consumer products including digital HDTV, wide screen and standard definition receivers. Set-top adapters are also possible.

1. Introduction

The efforts of the FCC Advisory Committee on Advanced Television Service (ACATS) have been centered around high definition television (HDTV). HDTV will provide wide screen, high resolution images coupled with high quality sound. Many organizations and individuals now recognize the potential power inherent in a digital broadcast television system and there is significant interest in the use of the Grand Alliance system for distribution of a variety of services in addition to HDTV. This might include such things as transmission of multiple 4x3 aspect ratio or wide screen programs with resolution equivalent or better than the current analog NTSC system. Utilization of the GA system for transmission of data and other services has also been contemplated.

This paper will describe the flexibility of the Grand Alliance System to provide multiple services and provide some examples of how these services could be implemented. It will also describe some of the consumer devices likely to be needed to implement these new services.

2. Overview of the Grand Alliance system

The Grand Alliance system utilizes a layered digital system architecture with headers/descriptors to provide flexible operating characteristics. The layers of the GA system are: picture, sound, compression, transport and transmission.

The picture layer consists of raw pixel data, organized as pixels, scan lines and frames. The GA system supports multiple formats and frame rates.

The compression layer transforms the raw video and audio samples into a coded bit stream that can be executed by the receiver to recreate the picture and sound. The video compression syntax conforms to the ISO-MPEG MPEG-2 video standard, at a nominal data rate of approximately 18.9 Mbps. The Dolby AC-3 audio compression is used in the GA system to provide 5.1 channel surround-sound at a nominal rate of 384 kbps.

The GA transport layer provides the means for dynamic allocation of video, audio and auxiliary data.

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The transmission layer modulates a serial bit stream into a signal that can be transmitted ov.r a 6 MHz television channel. The transmission system is based on a trellis-coded 8 vestigial sideband (VSB) modulation technique for terrestrial broadcasting. 16 VSB can be used for cable television applications.

3. System capable of multiple services

The GA system design is based on the ISO layer architecture which inherently provides flexibility and interoperability. The following sections of this paper will describe the capability of the GA system for transmission of multiple services.

3.1 Video compression system

Multiple service transmission will not impose any significant technical difficulty on the GA video compression system. The assumption here is that the information generated by each individual service will not exceed the specification of the GA system. The specific specifications for multiple service transmission is examined against the GA and MPEG-2 specifications.

Input source

The GA system supports two main format variations, with different numbers of lines per frame. These two formats have 720 active lines and 1080 active lines per frame. For multiple service transmission, the input sources could be the composite (SMPTE 170M) and component (SMPTE 253) analog NTSC signals, digital parallel and serial NTSC signals. MPEG-2 specification provide the mechanism to indicate the video format by use of a three-bit integer indicating the representation of the picture prior to coding. The eight video formats specified are component (000), PAL (001), NTSC (010), SECAM (011), MAC (100), unspecified video format (101), reserved (110 & 111).

Sampling structure

In the MPEG-2 specification the sampling size is specified in the sequence header as horizontal/vertical_size_value and horizontal/vertical-size. The horizontal/vertical_size_value is the width/height of the displayable part of the luminance component of pictures in samples and forms the 12 least significant bits of horizontal/vertical_size. The

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horizontal/vertical_size is a 14-bit unsigned integer, the 12 least significant bits are defined in horizontal/vertical_size_value, the 2 most significant bits are defined in horizontal/vertical_size_extension. For multiple service the sampling structure can be specified based on the standards mentioned in the section of input source.

Colorimetry

The SMPTE 274M is one of the input formats specified by the GA system. The SMPTE 274M which underlies the HDTV 1920 x 1080 format allows for the use of SMPTE 240M colorimetry as an interim measure while specifying ultimate use of ITU-R Recommendation 709. It is desirable for multiple service to have identical colorimetry as specified in the GA system. In the MPEG-2 specification a flag called color_description can be set to "1" to indicate the presence of color_primaries, transfer_characteristics and matrix_coefficients in the bitstream. Both SMPTE 240M and ITU-R Recommendation 709 colormetry parameters can be specified by the color_primaries, transfer_characteristics and matrix_coefficients.

Picture aspect ratio

In MPEG-2, the picture aspect ratio information is defined by a four-bit integer. The aspect ratio information is provided by means of aspect_ratio_information in the sequence header and (optional) display_horizontal/vertical_size in the sequence_display_extension. The aspect_ratio_information either specifies the "sample aspect ratio" (SAR) of the reconstructed frame or alternatively it gives the "display aspect ratio" (DAR). If sequence_diaplay_extension is not present the sample aspect ratio may be calculated as follows:

$$SAR = DAR \times \frac{horizontal\_size}{vertical\_size}$$

In this case horizontal_size and vertical_size are constrained by the SAR of the source and the DAR selected.

If sequence_display_extension is present, the sample aspect ratio may be calculated as follows:

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$$SAR = DAR \times \frac{display\_horizontal\_size}{display\_vertical\_size}$$

Examples of appropriate values for signals sampled in accordance with ITU-R Rec. 601 for 525-line format are 704 (display_horizontal_size) and 480 (display_vertical_size).

For multiple service transmission both 16x9 and 4x3 aspect ratios can be used. The GA system, since it is based on the MPEG-2 specification, is capable of supporting both aspect ratios.

Pan and scan

Since the aspect ratio of the input source may differ from that of the display, pan and scan is an essential feature. Pan and scan information is supported within the GA video syntax. This information is transmitted as an extension within the picture layer syntax. The MPEG-2 video syntax does communicate certain display parameters for use in reconstructing the video. A display window within the encoded raster may be defined as a window on a large area display device. In the case of pan and scan position of the window representing the displayed region of a large picture can be specified on a field-by-field basis. It is specified in the picture display extension. A typical use of the pan-scan window is to describe the 4:3 aspect ratio rectangle within a 16x9 video sequence.

Transparent coding of composite video

Decoding NTSC before transmission and recording to NTSC after transmission of composite source signals in contribution and distribution requires a precise reconstruction of the carrier amplitude and phase reference signal. The MPEG-2 specification provides the capability that the input format can be indicated in the sequence header using the video_format bits. Reconstruction of the carrier signal is possible by using the carrier parameters such as field_sequence, sub_carrier, burst_amplitude and sub_carrier phase that are enabled by setting the composite_display_flag in the picture header.

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Picture quality

Within the total data stream supported by the GA compression system the picture quality depends on the number of services multiplexed. Picture quality is defined by the bit rate used. Provision for high picture quality is made by high bit rate limits relating to a certain level in a particular profile. The level specifies the spatial resolution and determines the maximum data rate it can support. For multiple service applications, high, main and low levels defined by the MPEG-2 can be used to provide services with different picture quality. The profile defines the picture quality in terms of coding latency, resolution and scalability. The levels that can be used to support multiple services are simple profile, main profile and scalable profile.

In the GA system specification chrominance band quality is specified as 4:2:0 (half as many samples in the horizontal and vertical directions). Selectable color primaries are specified by the MPEG-2. The chrominance can be sampled in one of three formats: the 4:2:0 , 4:2:2 (half as many samples in the horizontal direction only) and 4:4:4 (identical samples as luminance signal). However, the 4:4:4 chrominance is currently not supported in any profile.

Data rate control

It is essential that the number of transmitted bits per service can be dynamically allocated. Certain program services may contain more information and demand more bits to be allocated for required quality while others may need less. The data rate control can be implemented in two ways, which are both supported by the MPEG-2 specification. A bit_rate description is transmitted with the Sequence Header Code.

For constant bit rate (CBR) coding, the number of transmitted bits per service is constant on the channel. Since the encoder output rate generally varies depending on the picture content, the constant rate is regulated by buffering. In this mode, picture quality may vary depending on its content.

The other mode is known as variable bit rate (VBR) coding, in which case the number of transmitted bits per service may vary on the channel under some constriction. VBR is meant to provide constant quality coding. VBR can be used in conjunction with statistical multiplexing for multiple service to achieve coding efficiency.

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Low delay mode

A low coding delay may be desirable for some services, such as live interview and call-in programs. Low coding delay mode can be obtained by setting the low_delay flag in the Sequence Header code.

The total encoding and decoding delay can be kept low by not using B-pictures. This eliminates frame reordering delay. A low buffer occupancy for both encoder and decoder is needed for low delay. By using intra update (progressive refresh) on the basis of one or more slices per frame instead of intra frames this can be accommodated.

Examples of video compression models for multiple service

Based on the MPEG-2 specification two video compression models are discussed in this section. They are MPEG-2 MP@ML and SP@ML.

In the MPEG-2 specification, profiles and levels provide a means of defining the syntax and semantics. A profile is a defined sub-set of the entire bit stream syntax. The profile can be defined by the profile identification. A level is a defined set of constraints imposed on parameters in the bit stream. For a given profile, the same syntax set is supported regardless of level. Decoders defined for a specified compliance point (profile and level) shall be capable of accommodating images encoded at lower-order compliance points.

The MP@ML stands for a main profile at main level. The specification for this model includes: I, P and B-frames, 4:2:0 chrominance sampling, frame rate of 30/29.9 Hz, maximum active horizontal pixels of 720 and vertical lines of 480 with maximum data rate of 15 Mbps. It is believed that this model is sufficient to provide high picture quality for multiple service. GA decoders are capable of decoding a MP@ML bit stream.

The second model, SP@ML, is a simple profile with main level. The difference between SP@ML and MP@ML is that SP@ML provides lower coding delay than that of MP@ML. By not using B-frames in SP@ML frame reordering delay can be reduced (0 frame delay for the field-based, 1 frame delay for the frame-based).

3.2 Audio compression system

The audio compression system in the GA system is the Dolby AC-3 multiple-channel audio compression system. It can support up to six audio channels for every video channel. The AC-3 syntax support bit rates ranging from 32 kbps to 640 kbps per individual AC-3 elementary stream. An AC-3 elementary stream may convey many types of audio services. The major service types are main service and associated service. Under the GA system specification receivers shall support the decoding of main audio services at bit rates up to and including 384 kbps, and support the decoding of the combination of a main service and a single associated service with a combined maximum bit rate of 512 kbps.

For multiple services, the total number of audio channels can be determined by the number of video services and the number of audio channels associated with each video service. The total audio data rate in a multiple service data stream is determined by not only the total number of audio channels, but also the audio quality associated with each service.

Examples of audio compression model for multiple service

To estimate the audio data rate needed for multiple services a potential model is presented: Assume that a total of four video channels are transmitted in the GA data stream and four audio channels are associated with each video service. For each video channel four audio channels are further defined as main service and associated service with 2-channel each. The main service could be a stereo pair. The associated service could be a second audio program (SAP) and a descriptive video service (DVS). In this example both the maximum data rate and minimum data rate constrained by the AC-3 specification are used for each category. With these assumptions the total audio data rate can be calculated as follows:

- Maximum data rate case:

Total audio data rate = 4 x (2 x 256 + 2 x 192) = 3.584 Mbps

- Minimum data rate case:

Total audio data rate = 4 x (2 x 128 + 2 x 96) = 1.792 Mbps

3.3 Transport system

The GA transport system is based on the MPEG-2 transport system specification. MPEG-2 transport system compatibility implies that a GA transport bit stream may handle other MPEG-2 applications. The GA transport system provides three major functions: packetization, multiplexing and synchronization.

Fixed length transport stream

In the GA transport system the MPEG-2 transport stream approach is utilized. Transport streams have advantages for environments where errors and data loss events are likely. Furthermore, the transport stream combines one or more programs with one or more independent time bases into a single stream. In the GA transport stream each packet is transmitted in a fixed length with transport header preceded. The fixed length packetization offers a great deal of flexibility when attempting to multiplex multiple service data on a single bit stream.

Dynamic capacity allocation

By using fixed length packets complete flexibility to allocate channel capacity for multiple video, audio and auxiliary data services can be obtained. The use of a packet id (PID) in the packet header as a means of bit stream identification makes it possible to have a mix of multiple video, audio and auxiliary data services. The entire channel capacity could also be used in bursts for data delivery.

Packet identification

Packet identification (PID) is essential for multiple service transmission in the GA transport system. It provides the mechanism for multiplexing and demultiplexing bit streams by enabling identification of packets belonging to a particular elementary or control bit stream.

Program specific information (PSI)

The MPEG-2 transport system is designed to multiplex a set of programs into a single data stream. These programs, along with their associated elementary video, audio and data streams, are identified by the program specific information (PSI) tables. These tables

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provide the structure for the management of the programs within the transport stream, thus enabling a decoder to extract, re-assemble, and display individual programs selected by users. All specific information in the tables is treated as private data and left for broadcasters and other service providers to sort out among themselves.

Multiplexing

The GA multiplexing approach can be defined as a combination of multiplexing at two different layers. In the first layer a program transport stream is formed by multiplexing one or more elementary bit streams such as video, audio and data. In the second layer the program transport streams are combined (using asynchronous packet multiplexing) to form the overall system. The second layer is called the system multiplex which is the key for the transmission of multiple services. Multiplexing of multiple services within a single bit stream is achieved before the modulator in the transmitter. Demultiplexing takes place after the demodulator in the receiver.

Single program transport multiplex

In this layer a transport stream is formed by multiplexing individual packetized elementary bit streams sharing a common time-base and a control bit stream that describes the program. Elementary PID defines a coded video, coded audio or other coded bit stream by indicating the type of data stored in the packet payload. Individual programs in a multiple service transmission data stream can be extracted by identifying assigned PIDs. Elementary PID is stored in the link header. The program_map_table which is one of the tables defined by the PSI in the transport stream provides the mappings between program numbers and the elementary streams that comprise them.

The transport syntax allows a program to be comprised of a large number of elementary bit streams, with no restriction on the types of applications required within a program. A program transport stream does not need to contain compressed video or audio bit streams, or for example, it could contain multiple audio bit streams for a given video bit stream.

System multiplex

In the GA transport system, multiple services can be achieved by use of the system multiplex. In addition to the transport bit streams (with the corresponding PIDs) that define

the individual programs, a system level control bit stream with PID = 0 is defined. This bit stream carries the program_association_table that maps program identities to their program transport streams. The program_association_table enables demultiplexing of programs by decoders. The program identity is represented by a number in the program_association_table. The map indicates the program_map_PID of the bit stream containing the program_map_table for a program. As a table specified by the PSI layer, the program_association_table is transmitted as the payload of the bit stream.

The process of identifying a program and its contents takes place in two stages. In the first stage the PID of the bit stream carrying the program_map_table for the program is identified by using the program_association_table in the PID = 0 bit stream. In the second stage the PIDs of the elementary bit streams that make up the program from the appropriate program_map_table are obtained. Once the process is completed the filters at a demultiplexer can be set to receive the transport bit streams that correspond to the program of interest.

Statistical multiplexing

Statistical multiplexing is an efficient mechanism to provide higher quality and more consistent video relative to a fixed bandwidth system when bits can be dynamically allocated among the video streams. The benefit of statistical multiplexing depends on the number of video programs sharing the bit stream and the picture content associated with each individual programs. The benefit of statistical multiplexing increases as the number of multiplexed programs are increased.

The data rate control mechanism in the video compression layer makes the implementation of statistical multiplexing possible. Various configurations can be implemented for different applications. For example, by using limited statistical multiplexing the bit rate of any designated program video stream cannot fall below a programmable threshold and the rest of the bit rate budget can be shared with other video streams.

Synchronization

Synchronization among multiple elementary streams is accomplished with Presentation Time Stamps (PTS) in the Transport streams. Decoding of N elementary streams is synchronized by adjusting the decoding of streams to a common master time base rather

than by adjusting the decoding of one stream to match that of another. The master time base may be one of the N decoders' clocks, the data source's clock, or it may be some external clock.

Synchronization of a decoding system with a channel is achieved through the use of the Program Clock Reference (PCR) in the Transport Stream. Since each program may have its own time base, there are separate PCR fields for each program in a transport stream containing multiple programs.

Access control

Implementation of a conditional access system is supported by the transport syntax with bits defined in the packet header. In the MPEG-2 specification conditional access is defined by conditional_access_table as part of the PSI. The conditional_access_table provides the association between one or more conditional access systems, their entitlement management message (EMM) streams and any special parameters associated with them. The functionality is flexible and complete in the sense of supporting all transmission aspects of applicable key encryption and descrambling approaches that may be used. Conditional access can be exercised on a elementary stream by stream basis, including the ability to selectively scramble bit streams in a program if desired.

Examples of transport models for multiple service

In this section two examples are studied to examine the capability of the GA transport system for multiple service transmission.

1. 4-channel service example

This model is configured with 4 independent NTSC like program channels. Each video program has four audio channels. The following block diagram illustrates the multiplexing and demultiplexing of transport bit streams. It should be noted that the layered approach to define the multiplexing function does not necessarily imply that program and system multiplexing must be implemented in separate stages. Program and system level multiplexing can be implemented within a single multiplexer stage.

For this example the video data rate for each service can be estimated based on the total information data rate supported by the GA system. Assumed that the total information data rate supported by the GA system is 19 Mbps. As discussed earlier with the example in the audio compression, the total audio data rate ranges between 3.584 to 1.792 Mbps. The higher rate provides better audio quality. Therefore, the video data rate for each program is about 4 Mbps.

Elementary stream 1 (video) — PID 1
Elementary stream 2 (audio-1) — PID 2
Elementary stream 3 (audio-2) — PID 3
Elementary stream 4 (audio-3) — PID 4
Elementary stream 5 (audio-4) — PID 5
Elementary stream map — PID 6
(program_map_table)

Transport multiplexer

Transport bitstream 1 (muxed program-1)
Transport bitstream 2 (muxed program-2)
Transport bitstream 3 (muxed program-3)
Transport bitstream 4 (muxed program-4)
Program stream map PID=0 (program_association_table)

System multiplexer

System bitstream

4-channel multiplex model

4-channel demultiplexing model

2. 2-wide screen + data service model

This example illustrates a service which provides two wide-screen NTSC programs with 4 audio channels per video program. In addition, a high speed synchronous data channel which is independent of video program service is provided for each video service. The potential applications of data service could be graphics, data and text.

Assume that the data rate of the high speed data channel is 1.5 Mbps (T1 rate) and total audio data rate is between 1.792 to 0.896 Mbps (same assumption made as the example in the section of audio compression), the video data rate for each wide-screen NTSC channel is about 7 Mbps. *It should be noted that at this video data rate the subjective picture quality of wide-screen NTSC has not been evaluated by the authors of this paper.*
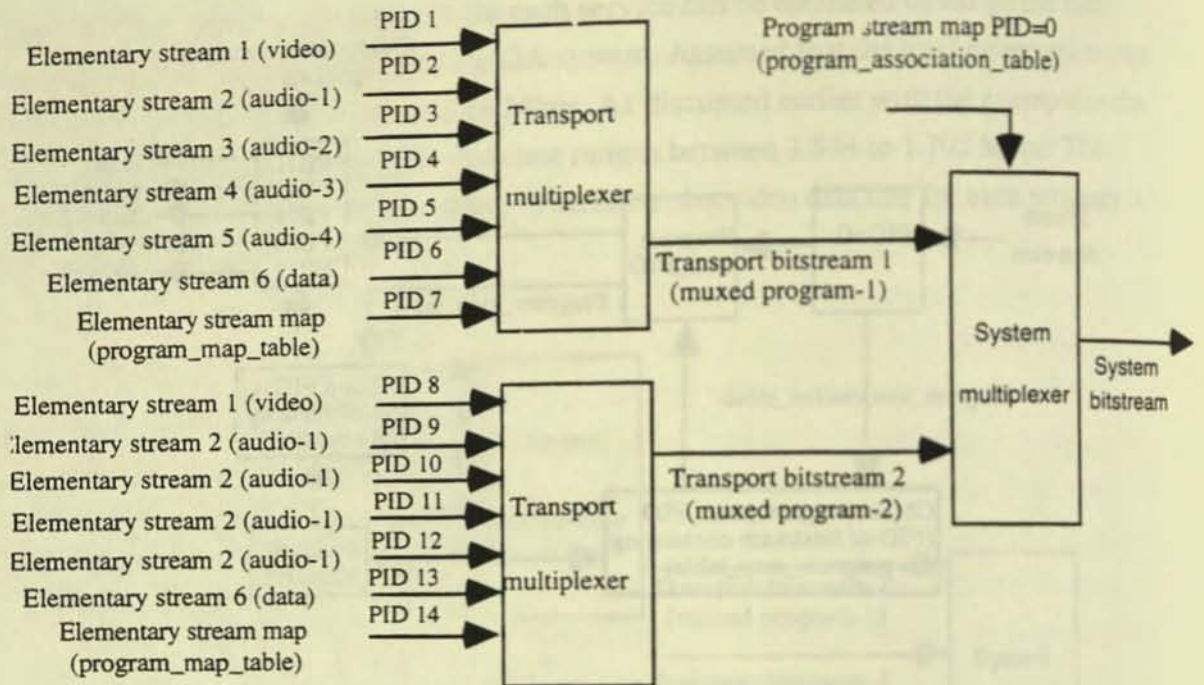
2-wide-screen-channel multiplex model
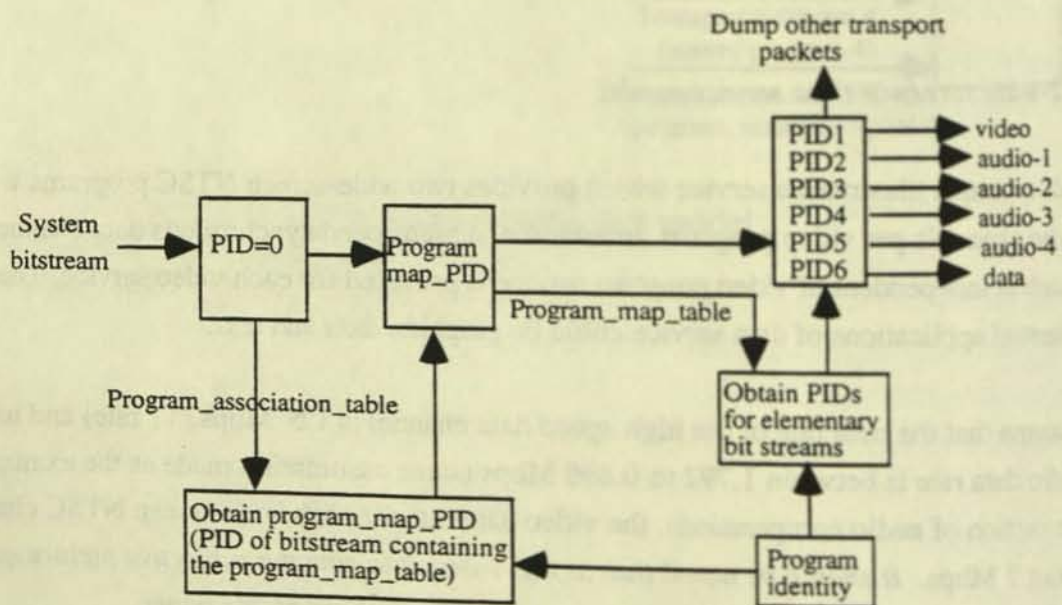
2-wide-screen-channel demultiplexing model

3.4 Transmission system

Since the multiplexed multiple service data stream will be constrained within the GA total data rate, it is believed that multiple service transmission will not impact the GA transmission system. However, the threshold of visibility (TOV) for multiple service transmission might in fact be improved from that of a single HDTV service. For instance, transmission errors might hit one of the programs and not be seen on others. Also, in a multiplexed multiple service data stream, errors will be spread into different program packets and the subjective impact on each program might be less severe than in a single HDTV service. However, this possible improvement is not likely to be significant enough to effect any spectrum planning issues.

3.5 Consumer receiver issues

The transmission of multiple services will require the development of a variety of consumer devices. With the MPEG-2 transport architecture new elementary bit streams could be handled at the transport layer without hardware modifications, by assigning new packet IDs at the transmitter and filtering out these new PIDs in the bit stream at the receiver. The functionality of receiving multiple service could be either implemented with receivers or set-top adaptors.

Data demultiplexer and decoder

The receiver designed for multiple service transmission should be capable of extracting the selected video stream along with associated audio and data streams. The use of packet ID (PID) in the header as a means of bit stream identification makes the extraction possible. The control bit stream contains the program_map_table that describes the elementary stream map.

Receiver functionality

Some receiver functions should be considered so as to ensure that programs transmitted via the GA system can be correctly processed and presented. A receiver can be defined as either a HDTV receiver or a digital receiver with conventional display. The following are some issues to be considered for consumer receivers.

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- Aspect ratio

As mentioned earlier, programs with 4:3 and 16:9 aspect ratios may be co-existent. Receivers should be capable of detecting aspect ratio by reading the extension of the picture layer header.

- Pan and scan

For different program and display aspect ratios, the pan and scan function should be executed automatically or selected manually based on user's choices. Receivers should perform the conversion to allow a 4:3 monitor to give a full-screen display of a selected portion of a 16:9 coded picture with correct aspect ratio.

- Colorimetry

By detecting the sequence display extension such as color_primaries, transfer_characteristics and matrix_coefficients, receivers should be capable of converting/processing colorimetry for proper display.

- Display

By detecting the sequence header, receivers should be capable of reconstructing the video format, field/frame rate, color field identification, colorimetry and etc. A HDTV receiver should be able to decode the GA HDTV signal as well as any lower MPEG-2 profile/level. A digital receiver with conventional display should be able to receive and process any MPEG-2 compliant service. This receiver should decode and downconvert HDTV data streams for display.

- Closed captioning

Receivers should be capable of detecting and displaying high speed HDTV closed captioning data. For set-top adaptors the high speed data should be converted so that it can be displayed as on screen display (OSD) or inserted on line 21 for display.

- Graphics and data

The receiver function of handling graphics and displaying data and text should be considered for data or graphic related services. Interface with other devices such as

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computers can be provided by receivers so that data could be transmitted, displayed, stored and manipulated. Separate ATV modem cards for computers could also be developed.

- Digital and analog VCR recording

Along with the development of digital consumer VCRs a baseband serial digital interface for digital recording is necessary. The interface may exchange transport streams (packets) with a digital VCR. To provide conventional analog VCR recording, an interface is needed so that an analog baseband signal can be connected to a conventional VCR.

```
 GA HDTV ──┐
 (8-VSB)   │                              ──► Video
Digital NTSC──┐  ┌──────────┐
 (8-VSB)      ├──┤  HDTV    │──►           ──► Digital bit stream for recording
  NTSC ───────┤  │          │
              │  │ receiver │──►           ──► Digital data
 GA HDTV ─────┘  │          │
 (16-VSB)        └──────────┘              ──► Multi-channel audio

                                           ──► Analog baseband video for recording
```
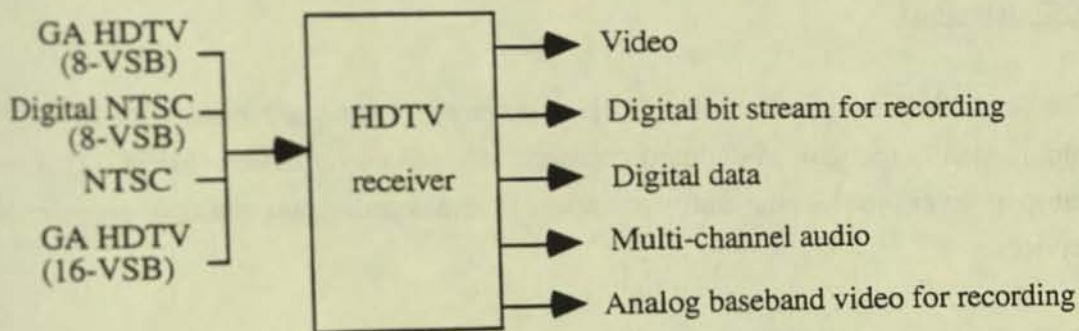
Functional Diagram of HDTV Receiver

Set-top adaptors

The large existing NTSC TV set population provides a consumer market for set-top adaptors. A set-top adaptor should perform the functions of demodulation, demultiplex, program data streams extraction and display format conversion. The output of the adaptor should interface with existing NTSC TV sets.

```
GA HDTV
(8-VSB)
Digital NTSC ──┐          ┌─────────┐           ──► NTSC
(8-VSB)        │          │ Digital │
               ├──────►   │ receiver│           ──► Digital bit stream for recording
NTSC ──────────┘          │   or    │
GA HDTV                   │ Set-top │           ──► Digital data
(16-VSB)                  │ adaptor │
                          └─────────┘
```
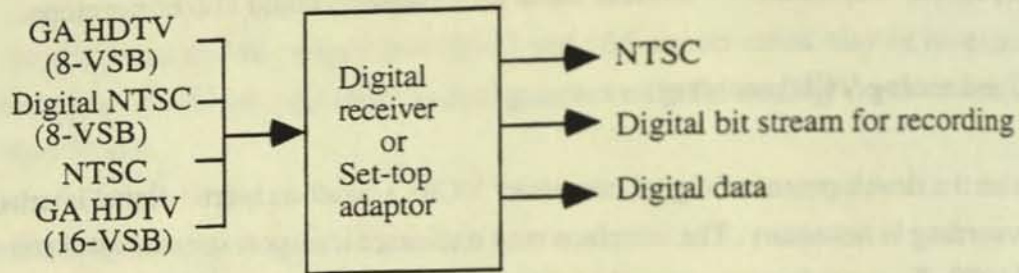
Functional Diagram of Digital Receiver/Set-top Adaptor

4. Conclusions

The Grand Alliance system utilizes a flexible transport structure along with an internationally recognized standard approach to video compression (MPEG-2). The transport layer provides the ability to multiplex and demulitiplex multiple program and data services.

The utilization of MPEG-2 for video compression provides the features required to support additional program formats such as wide screen and 4x3 aspect ratio at various resolutions. These features include the ability to specify sampling structure, picture aspect ratio, input format and information to support pan and scan. MPEG-2 also provides the ability to dynamically allocate the number of bits per service which is essential for multiple service transmission.

These attributes in conjunction with the inherent benefits of digital transmission can provide some new benefits and opportunities for broadcasters and viewers.

References

1. "Grand Alliance HDTV system specification," Version1.0, April 14, 1994.

2. Draft International Standard, "Generic coding of moving pictures and associated audio-Recommendation H.222.0," ISO/IEC 13818-1, 10 June, 1994.

3. Draft International Standard, "Generic coding of moving pictures and associated audio information: video-Recommendation H.262.0," ISO/IEC 13818-2, 10 June, 1994.

Appendix H.

Report on SDTV Video Formats

Expert Group on Scanning Formats / Compression
Report on SDTV Video Formats

SUMMARY

In a meeting conducted by the Expert Group on Scanning Formats / Compression and attended by more than fifty persons, a consensus was reached by the participants that the Advisory Committee should recommend the following SDTV formats to the FCC to accompany the HDTV formats in the ATV standard:

Recommended SDTV Video Formats

Active Lines	Horizontal Pixels	Picture Aspect Ratio		Picture Rate			
480	704	4:3	16:9	60I	60P	30P	24P
480	640	4:3		60I	60P	30P	24P

BACKGROUND

At the Technical Subgroup meeting on May 18, 1995 ATSC was asked to document the following SDTV video formats:

Active Lines	Horizontal Pixels	Picture Aspect Ratio	Picture Rate
480	704	4:3 & 16:9	60I, 30P, 24P
480	640	4:3	60I, 30P, 24P
360	480 / 640	4:3 / 16:9	60P, 30P, 24P
240	320	4:3	30P, 24P

ATSC began its documentation of the formats, but found that a number of people were concerned that sufficient discussion had not been conducted on the issue. Subsequently, Advisory Committee Chairman Wiley asked the Expert Group on Scanning Formats / Compression to conduct a full and open discussion on the SDTV formats that the Advisory Committee should recommend to the FCC to accompany the HDTV formats in the ATV standard. A review was scheduled for July 13 (and, if necessary, July 14) and widely advertised.

Over 50 persons attended the meeting. Twelve persons made formal presentations. A variety of positions were evident from the presentations. In summary, the combination of the positions stated were that:

1. The two 480-line formats should be combined into one format.
2. A picture rate of 60P should be added to the two 480-line formats.
3. The picture rate of 60I should be deleted from the two 480-line formats.
4. The picture rate of 60I should be retained in the two 480-line formats.

5. The 480-line format with 16:9 aspect ratio should have square pixels.

6. The 360-line format should be deleted.

7. The 360-line format should be retained.

8. The 240-line format should be deleted.

9. The 240-line format should be retained.

10. The pixel formats should be stated as ranges, not fixed numbers.

11. The picture aspect ratio of 2:1 should be added.

12. The picture rates of 36P and 72P should be added, or should replace 30P, 60P, and 60I.

A discussion was conducted on the various points, examining each point to determine where consensus could be reached. The participants did reach consensus on points 2 (a picture rate of 60P should be added to the two 480-line formats), 6 (the 360-line format should be deleted) and 8 (the 240-line format should be deleted). Four persons indicated that they did not agree with the consensus.

Appendix I.

Interoperability Characteristics

Interoperability Characteristics

PS/WP4 identified a number of characteristics that contribute significantly to Interoperability, Scope of Services and Features, and Extensibility. These were based on needs and desires exhibited by alternative media advocates, not only for the delivery of terrestrial broadcast television programming, but also for other delivery approaches and applications relating to computing, communications, motion pictures, and imaging. In relative order of importance, these characteristics are:

An all-digital implementation based on a layered architecture model;

The use of universal headers and descriptors (as agreed by an industry standards group, for example, SMPTE);

Transmission of the signal in progressive scan format;

Use of a flexible, packet data transport structure;

Viewer transparent channel re-allocation (limited picture and sound while most of the channel capacity is devoted to data transmission for conditional access addressing or other purposes);

Ability to implement lower-performance, low-cost ATV receivers (comparable price/performance options to current NTSC receivers);

Ability to implement a low-cost ATV consumer VCR;

System architecture and implementation that will allow improvements and extensions to be incorporated as technology advances while maintaining backward compatibility;

Square pixels, or at least the option to select square pixel presentation;

Compatibility with relevant international standards, or commitments to this objective; and

Easily-implementable and user-accessible "still/motion multi-window transmission."

Appendix J.

Report of the Experts Group on Certification

Certification Experts Group

July 20, 1995 Meeting

Chairman's Report

Submitted to:

The Hon Richard Wiley
Chairman
ACATS

Submitted by:

Birney Dayton
Chairman
Certification Experts Group

August 8, 1995

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The Certification Experts Group (CEG) met on July 20, 1995 to review the presentation of the COFDM-6 proposal by the COFDM-LLC (COFDM-Limited Liability Corporation). The CEG had been formed by the Chairman of the Advisory Committee as part of an effort to determine whether the proposed system was "demonstrably superior" to the Grand Alliance 8-VSB modem already under test.

The proposed modem had been described in an earlier mailing to the CEG, and the CEG had responded with an extensive list of questions 10 days prior to the meeting. The majority of questions had focused on several key areas of concern. Those were the following:

1. Receiver oscillator (and system) phase noise sensitivity.
2. Peak-to-average power ratio.
3. Channel linearity requirements (transmitter linearity and receiver A/D converter bit requirement).
4. Dynamic ghost rejection.
5. ATV to NTSC interference concerns related to the deployment of single frequency networks (SFNs).

The COFDM-LLC's response to some of the simpler questions for clarification of the system definition were relatively clear and concise. Unfortunately, the response to most of the five critical questions above was either not available or the system proposed for test had critical problems in the particular area. A brief summary follows.

1. The original document submitted proposed a -105 dBc (@10 kHz) spec on oscillator stability. The proposal did not clarify whether this was a specification of the receiver oscillator or the entire system. If the requirement was for the receiver only, it would represent a requirement for a 30 to 40 dB improvement over the tuners planned for VSB. If the requirement represented a system specification, then the phase jitter that could be allotted to the receiver would be even less. When questioned about this issue, the COFDM-LLC did not have a direct answer. Eventually, they allowed that in test at the CRC, the system failed at -85 dBc with a high C/N ratio. The CEG panel concluded that the original -105 dBc spec was a reasonable system spec for threshold C/N, since less than 20 dB of margin in phase noise would represent a compromise of the data eye at 64 QAM. The COFDM-LLC pointed to a recent paper by Thomson that proposed a technique to achieve phase noise performance in this region. The system proposed for test, however, achieved the requisite performance by inclusion of a laboratory type HP frequency synthesizer for the local oscillator. It was noted that such oscillators had been included in earlier proposals certified by SS/WP1 for test. It was also noted that the Grand Alliance VSB system does not require such an oscillator.

2. In response to questions about peak-to-average power ratio, the COFDM-LLC indicated that the expected ratio was 2 or 3 dB higher than VSB, and also that the C/N threshold measured in very preliminary testing by CRC was between .5 and 1 dB poorer than the Current VSB system. In the view of the CEG, this

translated to a potential coverage impact for a single transmitter installation of 2 to 4 dB depending on the actual back-off requirements of a real transmitter relative to the peak-to-average ratio.

3. A number of questions were asked regarding the requirements for both transmitter linearity, and receiver dynamic range (focused on the number of bits required in the A/D). The most useful response was that the prototype system used a 12 bit A/D. A chart was presented showing curves for an undefined COFDM system with a "large number of carriers" Whether the chart was generated for a 4 PSK, 16 QAM, or 64 QAM system was not clear. The COFDM-LLC had no quantitative data related directly to the COFDM-6 proposal to show the tradeoff between the number of effective bits in the receiver A/D and the C/N threshold. The CEG concluded that with the data presented, a minimum of 10 useful bits would be required to avoid a performance impact. The typical accuracy reduction of 2+ bits at high signal frequencies for off-the-shelf video A/D converters was pointed out, and the COFDM-LLC was asked to explain how the required A/D could be built cost-effectively. The response pointed to the above mentioned chart with the possibility that 8 effective bits might be enough. No quantitative connection to COFDM-6 or direct answer to the A/D cost issue was offered.

4. During the course of questioning, it was learned that the COFDM-6 prototype had an 8 to 10 second acquisition time, and 6 dB reduction in d/u ratio for even slowly moving ghosts (.05 Hz). After some intense questioning, the COFDM-LLC explained the nature of the acquisition and tracking system in the prototype. It was pointed out that for the system to meet the COFDM claim (and SFN requirement) of 0 dB d/u ratio, in a practical sense, it would have to achieve 0 dB for at least reasonably moving ghosts. It was further pointed out that the reason for this requirement is that, in the real world, the vast majority of ghosts are dynamic virtually all the time. The CEG concluded that to expect test results for the system that would indicate successful SFN deployment in a real world of non-static ghosts, signal acquisition would need to be several times faster, and signal tracking would need to be approximately 2 orders of magnitude faster.

5. In the questions prior to the meeting, the CEG's concern with ATV to NTSC interference was highlighted with a request for examples of COFDM and SFN deployment in several diverse markets. The COFDM-LLC presented a reasonably extensive example of coverage improvement for a single station in the Los Angeles market using one or two regional transmitters in addition to the main Mt. Wilson transmitter. Unfortunately, the presentation did not address several key issues that were highlighted in the advance questions.

    a. The presentation was made with no reference to any of the other many stations and services originating on Mt. Wilson, and the primary concern with SFN deployment is the opportunity for ATV to NTSC interference by the remote ATV transmitters.

b. In the example given, the remote transmitters were fed by microwave. In practice, microwave spectrum would likely not be available for all the stations in the LA market. The cost of fiber optic feeds was not analyzed.

c. The example given did not address how the allocation plan would be affected by the deployment of multiple synchronous transmitters, since the example involved the use of a second transmitter to cover the Mojave desert, where the next potentially interfering channel allocations are in Las Vegas. The CEG had specifically proposed the example of New York City, where many of the expected problems with SFN deployment would surface. Some of those unaddressed issues were as follows:

Lack of tower site availability for peripheral transmitters.
Allocation impact in an already short-spaced area.
Increased ATV to NTSC interference from peripheral transmitters
Potential inadequacy of 64 μs guard interval in flat terrain with multiple transmitters

The members of the CEG had expected that after a year of investigation, the COFDM-LLC would provide much more depth of explanation as to the details of deployment of both COFDM and SFNs, since most of the potential difficulties had been identified in the Technical Subgroup by early 1994.

At the end of the meeting, based on the claimed benefits of COFDM techniques and, specifically, of the COFDM modem proposed by the COFDM-LLC, as well as the shortcomings discussed above, the members of the CEG unanimously agreed on the two following statements:

"The modem presented by the COFDM-LLC is not ready for test at this time"

"The COFDM-LLC did not demonstrate the superiority of COFDM over VSB for the majority of markets."

Subsequent to the above unanimous conclusions, the COFDM-LLC requested a further hearing approximately one week later. The members of the CEG were individually polled to determine their sense of whether sufficient change could take place in a week to affect the outcome. The responses varied from "Very little likelihood that a week will make any difference" to "The same problems that were identified a year and a half ago are still here". None of the CEG members felt that a second review in the near future would change the CEG's conclusion. Accordingly, the CEG unanimously decided to not certify for test the COFDM-6 system proposed by the COFDM-LLC.

Appendix K.

ATSC Digital Television Standard

ATSC DIGITAL TELEVISION STANDARD

ADVANCED TELEVISION SYSTEMS COMMITTEE
James C. McKinney, Chairman
Dr. Robert Hopkins, Executive Director

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ATSC DIGITAL TELEVISION STANDARD

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ATSC DIGITAL TELEVISION STANDARD

FOREWORD

This Standard was prepared by the Advanced Television Systems Committee (ATSC) Technology Group on Distribution (T3). The document was approved by the members of T3 on February 23, 1995 for submission by letter ballot to the membership of the full ATSC as an ATSC Standard. The document was approved by the Members of the ATSC on April 12, 1995. Changes to Annex A, to include standard definition video formats, were approved by the members of T3 on August 4, 1995 and by the Members of the ATSC on September 15, 1995.

This Standard consists of a cover document which provides background information and an overview of the digital television system defined by the Standard. The system consists of various subsystems that are described in the annexes.

1. SCOPE & DOCUMENTATION STRUCTURE

1.1 Scope

The Digital Television Standard describes the system characteristics of the U. S. advanced television (ATV) system. The document and its normative annexes provide detailed specification of the parameters of the system including the video encoder input scanning formats and the pre-processing and compression parameters of the video encoder, the audio encoder input signal format and the pre-processing and compression parameters of the audio encoder, the service multiplex and transport layer characteristics and normative specifications, and the VSB RF/Transmission subsystem.

1.2 Documentation structure

The documentation of the Digital Television Standard consists of this document which provides a general system overview, a list of reference documents, and sections relating to the system as a whole. The system is modular in concept and the specifications for each of the modules are provided in the appropriate annex.

2. REFERENCES

Normative references may be found in each normative Annex. The Digital Television Standard is based on the ISO/IEC MPEG-2 Video Standard, the Digital Audio Compression (AC-3) Standard, and the ISO/IEC MPEG-2 Systems Standard. Those references are listed

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NOTE: The user's attention is called to the possibility that compliance with this standard may require use of an invention covered by patent rights. By publication of this standard, no position is taken with respect to the validity of this claim, or of any patent rights in connection therewith. The patent holder has, however, filed a statement of willingness to grant a license under these rights on reasonable and nondiscriminatory terms and conditions to applicants desiring to obtain such a license. Details may be obtained from the publisher.

here for the convenience of the reader. In addition, a guide to the use of the Digital Television Standard is listed.

ATSC Standard A/52 (1995), *Digital Audio Compression (AC-3)*.

ATSC Document A/54 (1995), *Guide to the Use of the ATSC Digital Television Standard.*

ISO/IEC IS 13818-1, International Standard (1994), *MPEG-2 Systems.*

ISO/IEC IS 13818-2, International Standard (1994), *MPEG-2 Video.*

3. DEFINITIONS

3.1 Definitions

With respect to definition of terms, abbreviations and units, the practice of the Institute of Electrical and Electronics Engineers (IEEE) as outlined in the Institute's published standards shall be used. Where an abbreviation is not covered by IEEE practice, or industry practice differs from IEEE practice, then the abbreviation in question will be described in Section 3.4 of this document. Many of the definitions included therein are derived from definitions adopted by MPEG.

3.2 Compliance notation

As used in this document, *"shall"* or *"will"* denotes a mandatory provision of the standard. *"Should"* denotes a provision that is recommended but not mandatory. *"May"* denotes a feature whose presence does not preclude compliance, that may or may not be present at the option of the implementor.

3.3 Treatment of syntactic elements

This document contains symbolic references to syntactic elements used in the audio, video, and transport coding subsystems. These references are typographically distinguished by the use of a different font (e.g., restricted), may contain the underscore character (e.g., sequence_end_code) and may consist of character strings that are not English words (e.g., dynrng).

3.4 Terms employed

For the purposes of the Digital Television Standard, the following definition of terms apply:

ACATS: Advisory Committee on Advanced Television Service.

access unit: A coded representation of a presentation unit. In the case of audio, an access unit is the coded representation of an audio frame. In the case of video, an access unit includes all the coded data for a picture, and any stuffing that follows it, up to but not including the start of the next access unit. If a picture is not preceded by a group_start_code or a sequence_header_code, the access unit begins with a the picture start code. If a picture is preceded by a group_start_code and/or a sequence_header_code, the access unit begins with

the first byte of the first of these start codes. If it is the last picture preceding a sequence_end_code in the bit stream all bytes between the last byte of the coded picture and the sequence_end_code (including the sequence_end_code) belong to the access unit.

A/D: Analog to digital converter.

AES: Audio Engineering Society.

anchor frame: A video frame that is used for prediction. I-frames and P-frames are generally used as anchor frames, but B-frames are never anchor frames.

ANSI: American National Standards Institute.

Asynchronous Transfer Mode (ATM): A digital signal protocol for efficient transport of both constant-rate and bursty information in broadband digital networks. The ATM digital stream consists of fixed-length packets called "cells," each containing 53 8-bit bytes—a 5-byte header and a 48-byte information payload.

ATEL: Advanced Television Evaluation Laboratory.

ATM: See asynchronous transfer mode.

ATTC: Advanced Television Test Center.

ATV: The U. S. advanced television system.

bidirectional pictures or **B-pictures** or **B-frames:** Pictures that use both future and past pictures as a reference. This technique is termed *bidirectional prediction*. B-pictures provide the most compression. B-pictures do not propagate coding errors as they are never used as a reference.

bit rate: The rate at which the compressed bit stream is delivered from the channel to the input of a decoder.

block: A block is an 8-by-8 array of pel values or DCT coefficients representing luminance or chrominance information.

bps: Bits per second.

byte-aligned: A bit in a coded bit stream is byte-aligned if its position is a multiple of 8-bits from the first bit in the stream.

CDTV: See conventional definition television.

channel: A digital medium that stores or transports a digital television stream.

coded representation: A data element as represented in its encoded form.

compression: Reduction in the number of bits used to represent an item of data.

constant bit rate: Operation where the bit rate is constant from start to finish of the compressed bit stream.

conventional definition television (CDTV): This term is used to signify the *analog* NTSC television system as defined in ITU-R Recommendation 470. See also *standard definition television* and ITU-R Recommendation 1125.

CRC: The cyclic redundancy check to verify the correctness of the data.

D-frame: Frame coded according to an MPEG-1 mode which uses DC coefficients only.

data element: An item of data as represented before encoding and after decoding.

DCT: See discrete cosine transform.

decoded stream: The decoded reconstruction of a compressed bit stream.

decoder: An embodiment of a decoding process.

decoding (process): The process defined in the Digital Television Standard that reads an input coded bit stream and outputs decoded pictures or audio samples.

decoding time-stamp (DTS): A field that may be present in a PES packet header that indicates the time that an access unit is decoded in the system target decoder.

digital storage media (DSM): A digital storage or transmission device or system.

discrete cosine transform: A mathematical transform that can be perfectly undone and which is useful in image compression.

DSM-CC: Digital storage media command and control.

DSM: Digital storage media.

DTS: See decoding time-stamp.

DVCR: Digital video cassette recorder

ECM: See entitlement control message.

editing: A process by which one or more compressed bit streams are manipulated to produce a new compressed bit stream. Conforming edited bit streams are understood to meet the requirements defined in the Digital Television Standard.

elementary stream (ES): A generic term for one of the coded video, coded audio or other coded bit streams. One elementary stream is carried in a sequence of PES packets with one and only one stream_id.

elementary stream clock reference (ESCR): A time stamp in the PES Stream from which decoders of PES streams may derive timing.

EMM: See entitlement management message.

encoder: An embodiment of an encoding process.

encoding (process): A process that reads a stream of input pictures or audio samples and produces a valid coded bit stream as defined in the Digital Television Standard.

entitlement control message (ECM): Entitlement control messages are private conditional access information which specify control words and possibly other stream-specific, scrambling, and/or control parameters.

entitlement management message (EMM): Entitlement management messages are private conditional access information which specify the authorization level or the services of specific decoders. They may be addressed to single decoders or groups of decoders.

entropy coding: Variable length lossless coding of the digital representation of a signal to reduce redundancy.

entry point: Refers to a point in a coded bit stream after which a decoder can become properly initialized and commence syntactically correct decoding. The first transmitted picture after an entry point is either an I-picture or a P-picture. If the first transmitted picture is not an I-picture, the decoder may produce one or more pictures during acquisition.

ES: See elementary stream.

ESCR: See elementary stream clock reference.

event: An event is defined as a collection of elementary streams with a common time base, an associated start time, and an associated end time.

field: For an interlaced video signal, a "field" is the assembly of alternate lines of a frame. Therefore, an interlaced frame is composed of two fields, a top field and a bottom field.

forbidden: This term, when used in clauses defining the coded bit stream, indicates that the value shall never be used. This is usually to avoid emulation of start codes.

FPLL: Frequency and phase locked loop.

frame: A frame contains lines of spatial information of a video signal. For progressive video, these lines contain samples starting from one time instant and continuing through successive lines to the bottom of the frame. For interlaced video a frame consists of two fields, a top field and a bottom field. One of these fields will commence one field later than the other.

GOP: See group of pictures.

Group of pictures (GOP): A group of pictures consists of one or more pictures in sequence.

HDTV: See high definition television.

high definition television (HDTV): High definition television has a resolution of approximately twice that of conventional television in both the horizontal (H) and vertical (V) dimensions and a picture aspect ratio (HxV) of 16:9. ITU-R Recommendation 1125 further defines "HDTV quality" as the delivery of a television picture which is subjectively identical with the interlaced HDTV studio standard.

high level: A range of allowed picture parameters defined by the MPEG-2 video coding specification which corresponds to high definition television.

Huffman coding: A type of source coding that uses codes of different lengths to represent symbols which have unequal likelihood of occurrence.

IEC: International Electrotechnical Commission.

intra-coded pictures or **I-pictures** or **I-frames:** Pictures that are coded using information present only in the picture itself and not depending on information from other pictures. I-pictures provide a mechanism for random access into the compressed video data. I-pictures employ transform coding of the pel blocks and provide only moderate compression.

ISO: International Organization for Standardization.

ITU: International Telecommunication Union.

JEC: Joint Engineering Committee of EIA and NCTA.

layer: One of the levels in the data hierarchy of the video and system specification.

level: A range of allowed picture parameters and combinations of picture parameters.

macroblock: In the advanced television system a macroblock consists of four blocks of luminance and one each Cr and Cb block.

main level: A range of allowed picture parameters defined by the MPEG-2 video coding specification with maximum resolution equivalent to ITU-R Recommendation 601.

main profile: A subset of the syntax of the MPEG-2 video coding specification that is expected to be supported over a large range of applications.

Mbps: 1,000,000 bits per second.

motion vector: A pair of numbers which represent the vertical and horizontal displacement of a region of a reference picture for prediction.

MP@HL: Main profile at high level.

MP@ML: Main profile at main level.

MPEG: Refers to standards developed by the ISO/IEC JTC1/SC29 WG11, *Moving Picture Experts Group*. MPEG may also refer to the Group.

MPEG-1: Refers to ISO/IEC standards 11172-1 (Systems), 11172-2 (Video), 11172-3 (Audio), 11172-4 (Compliance Testing), and 11172-5 (Technical Report).

MPEG-2: Refers to ISO/IEC standards 13818-1 (Systems), 13818-2 (Video), 13818-3 (Audio), 13818-4 (Compliance).

pack: A pack consists of a pack header followed by zero or more packets. It is a layer in the system coding syntax.

packet data: Contiguous bytes of data from an elementary data stream present in the packet.

packet identifier (PID): A unique integer value used to associate elementary streams of a program in a single or multi-program transport stream.

packet: A packet consists of a header followed by a number of contiguous bytes from an elementary data stream. It is a layer in the system coding syntax.

padding: A method to adjust the average length of an audio frame in time to the duration of the corresponding PCM samples, by continuously adding a slot to the audio frame.

payload: Payload refers to the bytes which follow the header byte in a packet. For example, the payload of a transport stream packet includes the PES_packet_header and its PES_packet_data_bytes or pointer_field and PSI sections, or private data. A PES_packet_payload, however, consists only of PES_packet_data_bytes. The transport stream packet header and adaptation fields are not payload.

PCR: See program clock reference.

pel: See pixel.

PES packet header: The leading fields in a PES packet up to but not including the PES_packet_data_byte fields where the stream is not a padding stream. In the case of a padding stream, the PES packet header is defined as the leading fields in a PES packet up to but not including the padding_byte fields.

PES packet: The data structure used to carry elementary stream data. It consists of a packet header followed by PES packet payload.

PES Stream: A PES stream consists of PES packets, all of whose payloads consist of data from a single elementary stream, and all of which have the same stream_id.

PES: An abbreviation for packetized elementary stream.

picture: Source, coded or reconstructed image data. A source or reconstructed picture consists of three rectangular matrices representing the luminance and two chrominance signals.

PID: See packet identifier.

pixel: "Picture element" or "pel." A pixel is a digital sample of the color intensity values of a picture at a single point.

predicted pictures or **P-pictures** or **P-frames:** Pictures that are coded with respect to the nearest *previous* I or P-picture. This technique is termed *forward prediction*. P-pictures provide more compression than I-pictures and serve as a reference for future P-pictures or B-pictures. P-pictures can propagate coding errors when P-pictures (or B-pictures) are predicted from prior P-pictures where the prediction is flawed.

presentation time-stamp (PTS): A field that may be present in a PES packet header that indicates the time that a presentation unit is presented in the system target decoder.

presentation unit (PU): A decoded audio access unit or a decoded picture.

profile: A defined subset of the syntax specified in the MPEG-2 video coding specification

program clock reference (PCR): A time stamp in the transport stream from which decoder timing is derived.

program element: A generic term for one of the elementary streams or other data streams that may be included in the program.

program specific information (PSI): PSI consists of normative data which is necessary for the demultiplexing of transport streams and the successful regeneration of programs.

program: A program is a collection of program elements. Program elements may be elementary streams. Program elements need not have any defined time base; those that do have a common time base and are intended for synchronized presentation.

PSI: See program specific information.

PTS: See presentation time-stamp.

PU: See presentation unit.

quantizer: A processing step which intentionally reduces the precision of DCT coefficients

random access: The process of beginning to read and decode the coded bit stream at an arbitrary point.

reserved: This term, when used in clauses defining the coded bit stream, indicates that the value may be used in the future for Digital Television Standard extensions. Unless otherwise specified within this Standard, all reserved bits shall be set to "1".

SCR: See system clock reference.

scrambling: The alteration of the characteristics of a video, audio or coded data stream in order to prevent unauthorized reception of the information in a clear form. This alteration is a specified process under the control of a conditional access system.

SDTV: See standard definition television.

slice: A series of consecutive macroblocks.

SMPTE: Society of Motion Picture and Television Engineers.

source stream: A single, non-multiplexed stream of samples before compression coding.

splicing: The concatenation performed on the system level or two different elementary streams. It is understood that the resulting stream must conform totally to the Digital Television Standard.

standard definition television (SDTV): This term is used to signify a *digital* television system in which the quality is approximately equivalent to that of NTSC. This equivalent quality may be achieved from pictures sourced at the 4:2:2 level of ITU-R Recommendation 601 and subjected to processing as part of the bit rate compression. The results should be such that when judged across a representative sample of program material, subjective equivalence with NTSC is achieved. Also called standard digital television. See also *conventional definition television* and ITU-R Recommendation 1125.

start codes: 32-bit codes embedded in the coded bit stream that are unique. They are used for several purposes including identifying some of the layers in the coding syntax. Start codes consist of a 24 bit prefix (0x000001) and an 8 bit stream_id.

STD input buffer: A first-in, first-out buffer at the input of a system target decoder for storage of compressed data from elementary streams before decoding.

STD: See system target decoder.

still picture: A coded still picture consists of a video sequence containing exactly one coded picture which is intra-coded. This picture has an associated PTS and the presentation time of succeeding pictures, if any, is later than that of the still picture by at least two picture periods.

system clock reference (SCR): A time stamp in the program stream from which decoder timing is derived.

system header: The system header is a data structure that carries information summarizing the system characteristics of the Digital Television Standard multiplexed bit stream.

system target decoder (STD): A hypothetical reference model of a decoding process used to describe the semantics of the Digital Television Standard multiplexed bit stream.

time-stamp: A term that indicates the time of a specific action such as the arrival of a byte or the presentation of a presentation unit.

TOV: Threshold of visibility.

Transport Stream packet header: The leading fields in a Transport Stream packet up to and including the continuity_counter field.

variable bit rate: Operation where the bit rate varies with time during the decoding of a compressed bit stream.

VBV: See video buffering verifier.

Video buffering verifier (VBV): A hypothetical decoder that is conceptually connected to the output of an encoder. Its purpose is to provide a constraint on the variability of the data rate that an encoder can produce.

video sequence: A video sequence is represented by a sequence header, one or more groups of pictures, and an end_of_sequence code in the data stream.

8 VSB: Vestigial sideband modulation with 8 discrete amplitude levels.

16 VSB: Vestigial sideband modulation with 16 discrete amplitude levels.

3.5 Symbols, abbreviations, and mathematical operators

3.5.1 Introduction

The symbols, abbreviations, and mathematical operators used to describe the Digital Television Standard are those adopted for use in describing MPEG-2 and are similar to those used in the "C" programming language. However, integer division with truncation and rounding are specifically defined. The bitwise operators are defined

assuming two's-complement representation of integers. Numbering and counting loops generally begin from 0.

3.5.2 Arithmetic operators

+	Addition.
-	Subtraction (as a binary operator) or negation (as a unary operator).
++	Increment.
- -	Decrement.
* or ×	Multiplication.
^	Power.
/	Integer division with truncation of the result toward 0. For example, 7/4 and -7/-4 are truncated to 1 and -7/4 and 7/-4 are truncated to -1.
//	Integer division with rounding to the nearest integer. Half-integer values are rounded away from 0 unless otherwise specified. For example 3//2 is rounded to 2, and -3//2 is rounded to -2.
DIV	Integer division with truncation of the result towards -∞.
%	Modulus operator. Defined only for positive numbers.

Sign( ) $Sign(x) = 1 \quad x > 0$

$\qquad\qquad\qquad 0 \quad x = 0$

$\qquad\qquad\qquad -1 \quad x < 0$

NINT ( )	Nearest integer operator. Returns the nearest integer value to the real-valued argument. Half-integer values are rounded away from 0.
sin	Sine.
cos	Cosine.
exp	Exponential.
√	Square root.
$\log_{10}$	Logarithm to base ten.
$\log_e$	Logarithm to base e.

3.5.3 Logical operators

||	Logical OR.
&&	Logical AND.
!	Logical NOT.

3.5.4 Relational operators

>	Greater than.

\>   Greater than.

≥   Greater than or equal to.

<   Less than.

≤   Less than or equal to.

=   Equal to.

!=   Not equal to.

max [,...,]   The maximum value in the argument list.

min [,...,]   The minimum value in the argument list.

3.5.5 Bitwise operators

&   AND.

| OR.

\>>   Shift right with sign extension.

<<   Shift left with 0 fill.

3.5.6 Assignment

=   Assignment operator.

3.5.7 Mnemonics

The following mnemonics are defined to describe the different data types used in the coded bit stream.

bslbf   Bit string, left bit first, where "left" is the order in which bit strings are written in the Standard. Bit strings are written as a string of 1s and 0s within single quote marks, e.g. '1000 0001'. Blanks within a bit string are for ease of reading and have no significance.

uimsbf   Unsigned integer, most significant bit first.

The byte order of multi-byte words is most significant byte first.

3.5.8 Constants

π   3.14159265359...

e   2.71828182845...

3.5.9 Method of describing bit stream syntax

Each data item in the coded bit stream described below is in bold type. It is described by its name, its length in bits, and a mnemonic for its type and order of transmission.

The action caused by a decoded data element in a bit stream depends on the value of that data element and on data elements previously decoded. The decoding of the data elements and definition of the state variables used in their decoding are described in the clauses containing the semantic description of the syntax. The following constructs are used to express the conditions when data elements are present, and are in normal type.

Note this syntax uses the "C" code convention that a variable or expression evaluating to a non-zero value is equivalent to a condition that is true.

while (condition) {
    data_element
    . . .
}
	If the condition is true, then the group of data elements occurs next in the data stream. This repeats until the condition is not true.

do {
    data_element
    . . . }
while (condition)
	The data element always occurs at least once. The data element is repeated until the condition is not true.

if (condition) {
    data_element
    . . .
}
	If the condition is true, then the first group of data elements occurs next in the data stream.

else {
    data_element
    . . .
}
	If the condition is not true, then the second group of data elements occurs next in the data stream.

for (i = 0;i<n;i++) {
    data_element
    . . .
}
	The group of data elements occurs n times. Conditional constructs within the group of data elements may depend on the value of the loop control variable i, which is set to zero for the first occurrence, incremented to 1 for the second occurrence, and so forth.

As noted, the group of data elements may contain nested conditional constructs. For compactness, the {} are omitted when only one data element follows.

data_element [ ]	data_element [ ] is an array of data. The number of data elements is indicated by the context.
data_element [n]	data_element [n] is the n+1th element of an array of data.
data_element [m][n]	data_element [m][n] is the m+1,n+1 th element of a two-dimensional array of data.
data_element [l][m][n]	data_element [l][m][n] is the l+1,m+1,n+1 th element of a three-dimensional array of data.
data_element [m..n]	data_element [m..n] is the inclusive range of bits between bit m and bit n in the data_element.

Decoders must include a means to look for start codes and sync bytes (transport stream) in order to begin decoding correctly, and to identify errors, erasures or insertions

while decoding. The methods to identify these situations, and the actions to be taken, are not standardized.

3.5.9.1 Definition of bytealigned function

The function bytealigned( ) returns 1 if the current position is on a byte boundary; that is, the next bit in the bit stream is the first bit in a byte. Otherwise it returns 0.

3.5.9.2 Definition of nextbits function

The function nextbits( ) permits comparison of a bit string with the next bits to be decoded in the bit stream.

3.5.9.3 Definition of next_start_code function

The next_start_code( ) function removes any zero bit and zero byte stuffing and locates the next start code.

This function checks whether the current position is byte-aligned. If it is not, 0 stuffing bits are present. After that any number of 0 bytes may be present before the start-code. Therefore start-codes are always byte-aligned and may be preceded by any number of 0 stuffing bits.

Table 3.1 Next Start Code

Syntax	No. of bits	Mnemonic

next_start_code( ) {
    while (!bytealigned( ))
        zero_bit
    while (nextbits( )!='0000 0000 0000 0000 0000 0001')
        zero_byte
}
	1
	
	8
		'0'
		
		'00000000'

4. BACKGROUND

4.1 Advanced Television Systems Committee (ATSC)

The Advanced Television Systems Committee, chaired by James C. McKinney, was formed by the member organizations of the Joint Committee on InterSociety Coordination (JCIC)[1] for the purpose of exploring the need for and, where appropriate, to coordinate development of the documentation of Advanced Television Systems. Documentation is understood to include voluntary technical standards, recommended practices, and engineering guidelines.

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[1] The JCIC is presently composed of: the Electronic Industries Association (EIA), the Institute of Electrical and Electronics Engineers (IEEE), the National Association of Broadcasters (NAB), the National Cable Television Association (NCTA), and the Society of Motion Picture and Television Engineers (SMPTE).

Proposed documentation may be developed by the ATSC, by member organizations of the JCIC, or by existing standards committees. The ATSC was established recognizing that the prompt, efficient and effective development of a coordinated set of national standards is essential to the future development of domestic television services.

On June 5, 1992 ATSC provided information to the Federal Communications Commission (FCC) outlining proposed industry actions to fully document the advanced television system standard. The FCC has recognized the importance of prompt disclosure of the system technical specifications to the mass production of advanced television system professional and consumer equipment in a timely fashion. The FCC has further noted its appreciation of the diligence with which the ATSC and the other groups participating in the standardization are pursuing these matters.[2]

Supporting this activity, the ATSC Executive Committee requested that the T3/S1 Specialist Group on Macro Systems Approach meet and suggest which portions of an advanced television system broadcasting standard might require action by the FCC and which portions should be voluntary.

Subsequently, T3/S1 held meetings and developed recommendations in two areas:

1. Principles upon which documentation of the advanced television system should be based; and

2. A list of characteristics of an advanced television system that should be documented.

The list tentatively identified the industry group(s) that would provide the documentation information and the document where the information would likely appear.

The recommendations developed by the T3/S1 Specialist Group were modified by T3 to accommodate information and knowledge about advanced television systems developed in the period since June 1992. Some of the modifications to the recommendations ensued from the formation of the Grand Alliance. The modified guidelines were approved at the March 31, 1994 meeting of the T3 Technology Group on Distribution and are described in Section 4.5.

4.2 Advisory Committee on Advanced Television Service (ACATS)

A "Petition for Notice of Inquiry" was filed with the FCC on February 21, 1987 by 58 broadcasting organizations and companies requesting that the Commission initiate a proceeding to explore the issues arising from the introduction of advanced television technologies and their possible impact on the television broadcasting service. At that time, it was generally believed that High Definition Television (HDTV) could not be broadcast using 6 MHz terrestrial broadcasting channels. The broadcasting organizations were concerned that the alternative media would be able to deliver HDTV to the viewing public placing terrestrial broadcasting at a severe disadvantage.

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[2] FCC 92-438, MM Docket No. 87-268, "Memorandum Opinion and Order/Third Report and Order/Third Further Notice of Proposed Rule Making," Adopted: September 17, 1992, pp. 59-60.

The FCC agreed that this was a subject of utmost importance and initiated a proceeding (MM Docket No. 87-268) to consider the technical and public policy issues of advanced television systems. The Advisory Committee on Advanced Television Service was empaneled by the Federal Communications Commission in 1987 with Richard E. Wiley as chairman to develop information that would assist the FCC in establishing an advanced television standard for the United States. The objective given to the Advisory Committee in its Charter by the FCC was:

"The Committee will advise the Federal Communications Commission on the facts and circumstances regarding advanced television systems for Commission consideration of technical and public policy issues. In the event that the Commission decides that adoption of some form of advanced broadcast television is in the public interest, the Committee would also recommend policies, standards and regulations that would facilitate the orderly and timely introduction of advanced television services in the United States."

The Advisory Committee established a series of subgroups to study the various issues concerning services, technical parameters, and testing mechanisms required to establish an Advanced television system standard. The Advisory Committee also established a system evaluation, test and analysis process that began with over twenty proposed systems, reducing them to four final systems for consideration.

4.3 Digital HDTV Grand Alliance (Grand Alliance)

On May 24, 1993 the three groups that had developed the four final digital systems agreed to produce a single, best-of-the best system to propose as the standard. The three groups (AT&T and Zenith Electronics Corporation; General Instrument Corporation and the Massachusetts Institute of Technology; and Philips Consumer Electronics, Thomson Consumer Electronics, and the David Sarnoff Research Center) have been working together as the "Digital HDTV Grand Alliance." The system described in this Standard is based on the Digital HDTV Grand Alliance proposal to the Advisory Committee.

4.4 Organization for documenting the Digital Television Standard

The ATSC Executive Committee assigned the work of documenting the advanced television system standards to T3 specialist groups dividing the work into five areas of interest: **Video** (including input signal format and source coding), **Audio** (including input signal format and source coding), **Transport** (including data multiplex and channel coding), **RF/Transmission,** (including the modulation subsystem) and **Receiver** characteristics. A steering committee consisting of the chairs of the five specialist groups, the chair and vice-chairs of T3, and liaison among the ATSC, the FCC, and ACATS was established to coordinate the development of the documents. The members of the steering committee and areas of interest were as follows:

Stanley Baron	T3 chair
Jules Cohen	T3 vice-chair
Brian James	T3 vice-chair

Larry Pearlstein	T3/S6 (Video systems characteristics), chair
Graham S. Stubbs	T3/S7 (Audio systems characteristics), chair
Bernard J. Lechner	T3/S8 (Service multiplex and transport systems characteristics), chair
Lynn D. Claudy	T3/S9 (RF/Transmission systems characteristics), chair
Werner F. Wedam	T3/S10 (Receiver characteristics), chair
Robert M. Rast	Grand Alliance facilitator
Robert Hopkins	ATSC
Robert M. Bromery	FCC Office of Engineering and Technology
Gordon Godfrey	FCC Mass Media Bureau
Paul E. Misener	ACATS

4.5 Principles for documenting the Digital Television Standard

T3 adopted the following principles for documenting the advanced television system standard:

1. The Grand Alliance was recognized as the principal supplier of information for documenting the advanced television system, supported by the ATSC and others. Other organizations seen as suppliers of information: EIA, FCC, IEEE, MPEG, NCTA, and SMPTE.

2. The Grand Alliance was encouraged to begin drafting the essential elements of system details as soon as possible to avoid delays in producing the advanced television system documentation.

3. FCC requirements for the advanced television system standard were to be obtained as soon as possible.

4. Complete functional system details (permitting those skilled in the art to construct a working system) were to be made publicly available.

5. Protection of any intellectual property made public must be by patent or copyright as appropriate.

6. The advanced television system documentation shall include the necessary system information such that audio and video encoders may be manufactured to deliver the system's full demonstrated performance quality.

7. The advanced television system documentation shall point to existing standards, recommended practices or guideline documents. These documents shall be referenced in one of two ways as deemed appropriate for the application. In the first instance, a specific revision shall be specified where review of changes to the referenced document is required before changes might be incorporated into the advanced television system document. The second instance references the document without specificity to revision and allows any changes to the referenced documents to be automatically incorporated.

8. System specifications shall explain how future, compatible improvements may be achieved.

9. As ongoing improvements take place in the advanced television system, manufacturers of encoders and decoders should coordinate their efforts to insure compatibility.

10. The advanced television system standard must support backward compatibility of future improvements with all generations of advanced television system receivers and inherently support production of low cost receivers (not withstanding that cost reduction through reduced performance quality may also be used to achieve inexpensive products).

11. The advanced television system standard should not foreclose flexibility in implementing advanced television system receivers at different price and performance levels.

12. The advanced television system standard should not foreclose flexibility in implementing program services or in data stream modification or insertion of data packets by down-stream (local) service providers.

13. The advanced television system documentation shall address interoperability with non-broadcast delivery systems including cable.

14. The advanced television system standard shall identify critical system parameters and shall provide information as to the range of acceptable values, the method of measurement, and the location in the system where measurement takes place.

5. SYSTEM OVERVIEW

5.1 Objectives

The Digital Television Standard describes a system designed to transmit high quality video and audio and ancillary data over a single 6 MHz channel. The system can deliver reliably about 19 Mbps of throughput in a 6 MHz terrestrial broadcasting channel and about 38 Mbps of throughput in a 6 MHz cable television channel. This means that encoding a video source whose resolution can be as high as five times that of conventional television (NTSC) resolution requires a bit rate reduction by a factor of 50 or higher. To achieve this bit rate reduction, the system is designed to be efficient in utilizing available channel capacity by exploiting complex video and audio compression technology.

The objective is to maximize the information passed through the data channel by minimizing the amount of data required to represent the video image sequence and its associated audio. The objective is to represent the video, audio, and data sources with as few bits as possible while preserving the level of quality required for the given application.

Although the RF/Transmission subsystems described in this Standard are designed specifically for terrestrial and cable applications, the objective is that the video, audio, and service multiplex/transport subsystems be useful in other applications.

5.2 System block diagram

A basic block diagram representation of the system is shown in Figure 5.1. This representation is based on one adopted by the International Telecommunication Union, Radiocommunication Sector (ITU-R), Task Group 11/3 (Digital Terrestrial Television Broadcasting). According to this model, the digital television system can be seen to consist of three subsystems.[3]

1. Source coding and compression,
2. Service multiplex and transport, and
3. RF/Transmission.
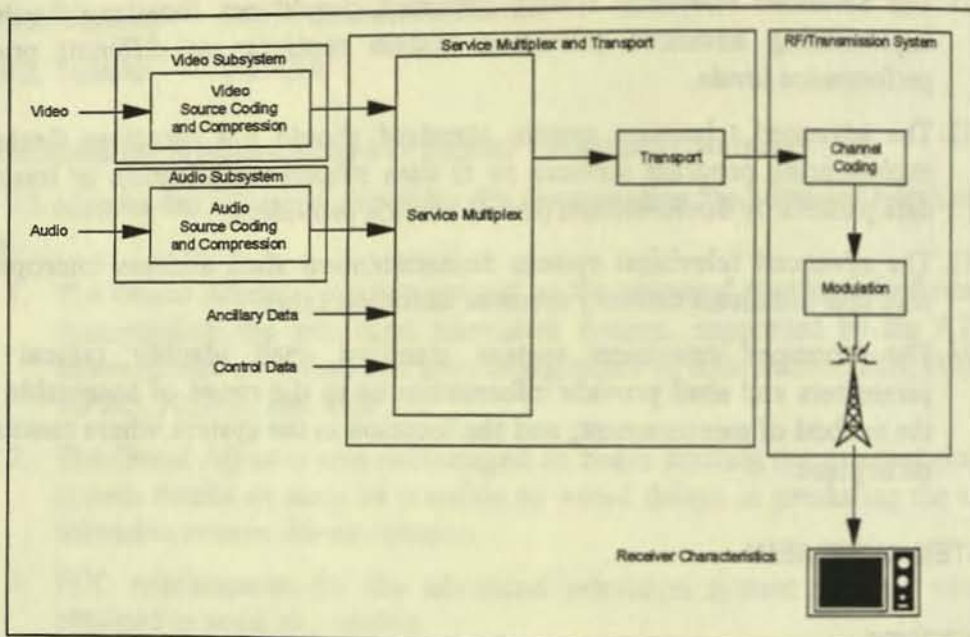
Figure 5.1. ITU-R digital terrestrial television broadcasting model.

"Source coding and compression" refers to the bit rate reduction methods, also known as data compression, appropriate for application to the video, audio, and ancillary digital data streams. The term "ancillary data" includes control data, conditional access control data, and data associated with the program audio and video services, such as closed captioning. "Ancillary data" can also refer to independent program services. The purpose of the coder is to minimize the number of bits needed to represent the audio and video information. The digital television system employs the MPEG-2 video stream syntax for the coding of video and the Digital Audio Compression (AC-3) Standard for the coding of audio.

"Service multiplex and transport" refers to the means of dividing the digital data stream into "packets" of information, the means of uniquely identifying each packet or packet type,

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[3] ITU-R Document TG11/3-2, "Outline of Work for Task Group 11/3, Digital Terrestrial Television Broadcasting," June 30, 1992.

and the appropriate methods of multiplexing video data stream packets, audio data stream packets, and ancillary data stream packets into a single data stream. In developing the transport mechanism, interoperability among digital media, such as terrestrial broadcasting, cable distribution, satellite distribution, recording media, and computer interfaces, was a prime consideration. The digital television system employs the MPEG-2 transport stream syntax for the packetization and multiplexing of video, audio, and data signals for digital broadcasting systems.[4] The MPEG-2 transport stream syntax was developed for applications where channel bandwidth or recording media capacity is limited and the requirement for an efficient transport mechanism is paramount. It was designed also to facilitate interoperability with the ATM transport mechanism.

"RF/Transmission" refers to channel coding and modulation. The channel coder takes the data bit stream and adds additional information that can be used by the receiver to reconstruct the data from the received signal which, due to transmission impairments, may not accurately represent the transmitted signal. The modulation (or physical layer) uses the digital data stream information to modulate the transmitted signal. The modulation subsystem offers two modes: a terrestrial broadcast mode (8 VSB), and a high data rate mode (16 VSB).

Figure 5.2 illustrates a high level view of encoding equipment. This view is not intended to be complete, but is used to illustrate the relationship of various clock frequencies within the encoder. There are two domains within the encoder where a set of frequencies are related, the source coding domain and the channel coding domain.
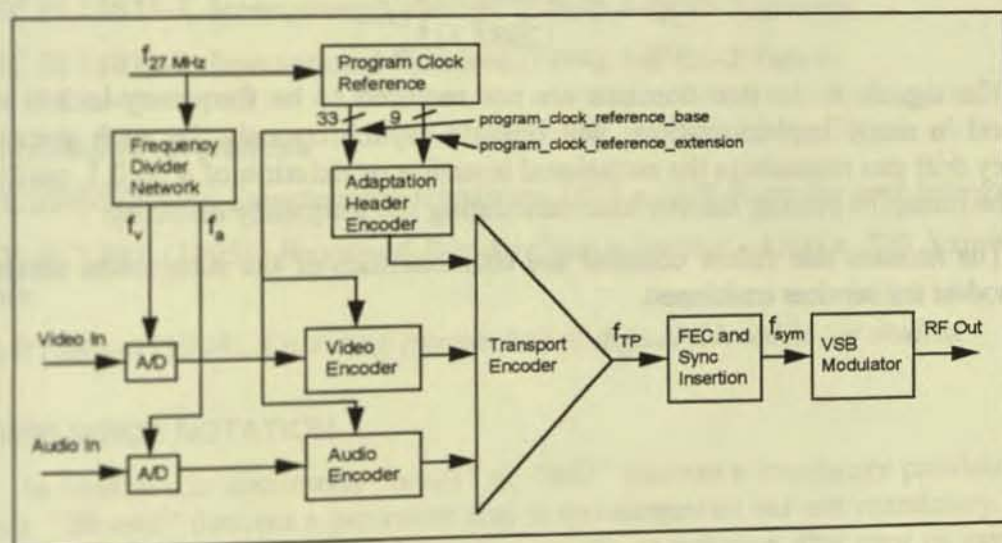
Figure 5.2. High level view of encoding equipment.

The source coding domain, represented schematically by the video, audio and transport encoders, uses a family of frequencies which are based on a 27 MHz clock (f_{27MHz}). This clock is used to generate a 42-bit sample of the frequency which is

[4] Chairman, ITU-R Task Group 11/3, "Report of the Second Meeting of ITU-R Task Group 11/3, Geneva, October 13-19, 1993," January 5, 1994, p. 40.

partitioned into two parts defined by the MPEG-2 specification. These are the 33-bit program_clock_reference_base and the 9-bit program_clock_reference_extension. The former is equivalent to a sample of a 90 kHz clock which is locked in frequency to the 27 MHz clock, and is used by the audio and video source encoders when encoding the presentation time stamp (PTS) and the decode time stamp (DTS). The audio and video sampling clocks, f_a and f_v respectively, must be frequency-locked to the 27 MHz clock. This can be expressed as the requirement that there exist two pairs of integers, (n_a, m_a) and (n_v, m_v), such that:

$$f_a = \left(\frac{n_a}{m_a}\right) \times 27 MHz$$

and

$$f_v = \left(\frac{n_v}{m_v}\right) \times 27 MHz$$

The channel coding domain is represented by the FEC/Sync Insertion subsystem and the VSB modulator. The relevant frequencies in this domain are the VSB symbol frequency (f_{sym})and the frequency of the transport stream (f_{TP}) which is the frequency of transmission of the encoded transport stream. These two frequencies must be locked, having the relation:

$$f_{TP} = 2 \times \left(\frac{188}{208}\right)\left(\frac{312}{313}\right) f_{sym}$$

The signals in the two domains are not required to be frequency-locked to each other, and in many implementations will operate asynchronously. In such systems, the frequency drift can necessitate the occasional insertion or deletion of a NULL packet from within the transport stream, thereby accommodating the frequency disparity.

The annexes that follow consider the characteristics of the subsystems necessary to accommodate the services envisioned.

ANNEX A

(Normative)

VIDEO SYSTEMS CHARACTERISTICS

1. SCOPE

This Annex describes the characteristics of the video subsystem of the Digital Television Standard. The input formats and bit stream characteristics are described in separate sections.

2. REFERENCES

2.1 *Normative references*

The following documents contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreement based on this standard are encouraged to investigate the possibility of applying the most recent editions of the documents listed below.

ISO/IEC IS 13818-1, International Standard (1994), *MPEG-2 Systems*.

ISO/IEC IS 13818-2, International Standard (1994), *MPEG-2 Video*.

2.2 *Informative references*

SMPTE 274M (1995), *Standard for television, 1920 x 1080 Scanning and Interface*.

SMPTE S17.392 (1995), *Proposed Standard for television, 1280 x 720 Scanning and Interface*.

ITU-R BT.601-4 (1994), *Encoding parameters of digital television for studios*.

3. COMPLIANCE NOTATION

As used in this document, *"shall"* or *"will"* denotes a mandatory provision of the standard. *"Should"* denotes a provision that is recommended but not mandatory. *"May"* denotes a feature whose presence does not preclude compliance, that may or may not be present at the option of the implementor.

4. POSSIBLE VIDEO INPUTS

While not required by this standard, there are certain television production standards, shown in Table 1, that define video formats that relate to compression formats specified by this standard.

Table 1 Standardized Video Input Formats

Video standard	Active lines	Active samples/ line
SMPTE 274M	1080	1920
SMPTE S17.392	720	1280
ITU-R BT.601-4	483	720

The compression formats may be derived from one or more appropriate video input formats. It may be anticipated that additional video production standards will be developed in the future that extend the number of possible input formats.

5. SOURCE CODING SPECIFICATION

The ATV video compression algorithm shall conform to the Main Profile syntax of ISO/IEC 13818-2. The allowable parameters shall be bounded by the upper limits specified for the Main Profile at High Level.[1] Additionally, ATV bit streams shall meet the constraints and specifications described in Sections 5.1 and 5.2.

5.1 Constraints with respect to ISO/IEC 13818-2 Main Profile

The following tables list the allowed values for each of the ISO/IEC 13818-2 syntactic elements which are restricted beyond the limits imposed by MP@HL.

In these tables conventional numbers denote decimal values, numbers preceded by **0x** are to be interpreted as hexadecimal values and numbers within single quotes (e.g., '10010100') are to be interpreted as a string of binary digits.

5.1.1 Sequence header constraints

Table 2 identifies parameters in the sequence header of a bit stream that shall be constrained by the video subsystem and lists the allowed values for each.

Table 2 Sequence Header Constraints

Sequence header syntactic element	Allowed value
horizontal_size_value	see Table 3
vertical_size_value	see Table 3
aspect_ratio_information	see Table 3
frame_rate_code	see Table 3
bit_rate_value (≤ 19.4 Mbps)	≤ 48500
bit_rate_value (≤ 38.8 Mbps)	≤ 97000
vbv_buffer_size_value	≤ 488

The allowable values for the field bit_rate_value are application dependent. In the primary application of terrestrial broadcast, this field shall correspond to a bit rate which is less than or equal to 19.4 Mbps. In the high data rate mode, the corresponding bit rate is less than or equal to 38.8 Mbps.

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[1] See ISO/IEC 13818-2, Section 8 for more information regarding profiles and levels.

5.1.2 Compression format constraints

Table 3 lists the allowed compression formats.

Table 3 Compression Format Constraints

vertical_size_value	horizontal_size_value	aspect_ratio_information	frame_rate_code	progressive_sequence
1080[2]	1920	1,3	1,2,4,5	1
			4,5	0
720	1280	1,3	1,2,4,5,7,8	1
480	704	2,3	1,2,4,5,7,8	1
			4,5	0
	640	1,2	1,2,4,5,7,8	1
			4,5	0

Legend for MPEG-2 coded values in Table 3
aspect_ratio_information   1 = square samples   2 = 4:3 display aspect ratio   3 = 16:9 display aspect ratio
frame_rate_code   1 = 23.976 Hz   2 = 24 Hz   4 = 29.97 Hz   5 = 30 Hz   7 = 59.94 Hz   8 = 60 Hz
progressive_sequence   0 = interlaced scan   1 = progressive scan

5.1.3 Sequence extension constraints

Table 4 identifies parameters in the sequence extension part of a bit stream that shall be constrained by the video subsystem and lists the allowed values for each. A sequence_extension structure is required to be present after every sequence_header structure.

Table 4 Sequence Extension Constraints

Sequence extension syntactic element	Allowed values
progressive_sequence	see Table 3
profile_and_level_indication	see Note
chroma_format	'01'
horizontal_size_extension	'00'
vertical_size_extension	'00'
bit_rate_extension	'0000 0000 0000'
vbv_buffer_size_extension	'0000 0000'
frame_rate_extension_n	'00'
frame_rate_extension_d	'0000 0'

Note: The profile_and_level_indication field shall indicate the lowest profile and level defined in ISO/IEC 13818-2, Section 8, that is consistent with the parameters of the video elementary stream.

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[2] Note that 1088 lines are actually coded in order to satisfy the MPEG-2 requirement that the coded vertical size be a multiple of 16 (progressive scan) or 32 (interlaced scan).

5.1.4 Sequence display extension constraints

Table 5 identifies parameters in the sequence display extension part of a bit stream that shall be constrained by the video subsystem and lists the allowed values for each.

Table 5 Sequence Display Extension Constraints

Sequence display extension syntactic element	Allowed values
video_format	'000'

The preferred and default values for color_primaries, transfer_characteristics, and matrix_coefficients are defined to be SMPTE 274M[3] (value 0x01 in all three cases). While all values described by MPEG-2 are allowed in the transmitted bit stream, it is noted that SMPTE 170M values (0x06 in all three cases) will be the most likely alternate in common use.

5.1.5 Picture header constraints

In all cases other than when vbv_delay has the value 0xFFFF, the value of vbv_delay shall be constrained as follows:

$$vbv\_delay \leq 45000$$

5.2 Bit stream specifications beyond MPEG-2

This section covers the extension and user data part of the video syntax. These data are inserted at the sequence, GOP, and picture level. The syntax used for the insertion of closed captioning in picture user data is described.[4]

5.2.1 Picture extension and user data syntax

Table 6 describes the syntax used for picture extension and user data.

Table 6 Picture Extension and User Data Syntax

	No. of bits	Mnemonic
extension_and_user_data(2) {		
while ((nextbits( ) == extension_start_code) || (nextbits() == user_data_start_code)) {		
if (nextbits()== extension_start_code)		
extension_data(2)		
if (nextbits() == user_data_start_code)		
user_data(2)		
}		
}		

---

[3] At some point in the future, the color gamut may be extended by allowing negative values of RGB and defining the transfer characteristics for negative RGB values.

[4] In order to decode the user data, the decoder should properly recognize the 32-bit ATSC registration identifier at the PSI stream level (see ISO/IEC 13818-1).

5.2.2 Picture user data syntax

Table 7 describes the picture user data syntax.

Table 7 Picture User Data Syntax[5]

	No. of bits	Mnemonic
user_data( ) {		
user_data_start_code	32	bslbf
ATSC_identifier	32	bslbf
user_data_type_code	8	uimsbf
if (user_data_type_code == '0x03') {		
process_em_data_flag	1	bslbf
process_cc_data_flag	1	bslbf
additional_data_flag	1	bslbf
cc_count	5	uimsbf
em_data	8	bslbf
for (i=0 ; i < cc_count ; i++) {		
marker_bits	5	'1111 1'
cc_valid	1	bslbf
cc_type	2	bslbf
cc_data_1	8	bslbf
cc_data_2	8	bslbf
}		
marker_bits	8	'1111 1111'
if (additional_data_flag) {		
while(nextbits() != '0000 0000 0000 0000 0000 0001') {		
additional_user_data	8	
}		
}		
}		
next_start_code()		
}		

5.2.3 Picture user data semantics

user_data_start_code — This is set to 0x0000 01B2.

ATSC_identifier — This is a 32 bit code that indicates that the video user data conforms to this specification. The value ATSC_identifier shall be 0x4741 3934.

user_data_type_code — The 8-bit code is set to 0x03.

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[5] Shaded cells in this table indicate syntactic and semantic additions to the ISO/IEC 13818-2 standard.

process_em_data_flag — This flag is set to indicate whether it is necessary to process the em_data. If it is set to 1, the em_data has to be parsed and its meaning has to be processed. When it is set to 0, the em_data can be discarded.

process_cc_data_flag — This flag is set to indicate whether it is necessary to process the cc_data. If it is set to 1, the cc_data has to be parsed and its meaning has to be processed. When it is set to 0, the cc_data can be discarded.

additional_data_flag — This flag is set to 1 to indicate the presence of additional user data.

cc_count — This 5-bit integer indicates the number of closed caption constructs following this field. It can have values 0 through 31. The value of cc_count shall be set according to the frame rate and coded picture structure (field or frame) such that a fixed bandwidth of 9600 bits per second is maintained for the closed caption payload data. Sixteen (16) bits of closed caption payload data are carried in each pair of the fields cc_data_1 and cc_data_2.

em_data — Eight bits for representing emergency message.[6]

cc_valid — This flag is set to '1' to indicate that the two closed caption data bytes that follow are valid. If set to '0' the two data bytes are invalid.

cc_type — Denotes the type of the two closed caption data bytes that follow.[7]

cc_data_1 — The first byte of a closed caption data pair.

cc_data_2 — The second byte of a closed caption data pair.

additional_user_data — Any further demand for picture user data could be met by defining this part of the bit stream.

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[6] Syntax and semantics to be specified by EIA.

[7] EIA, *Recommended Practice for Advanced Television Closed Captioning*, draft, July 1, 1994.

ANNEX B

(Normative)

AUDIO SYSTEMS CHARACTERISTICS

1. SCOPE

This Annex describes the audio system characteristics and normative specifications of the Digital Television Standard.

2. NORMATIVE REFERENCES

The following documents contain provisions which in whole or part, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and amendment, and parties to agreement based on this standard are encouraged to investigate the possibility of applying the most recent editions of the documents listed below.

ATSC Standard A/52 (1995), *Digital Audio Compression (AC-3)*.

AES 3-1992 (ANSI S4.40-1992), *AES Recommended Practice for digital audio engineering — Serial transmission format for two-channel linearly represented digital audio data.*

ANSI S1.4-1983, *Specification for Sound Level Meters.*

IEC 651 (1979), *Sound Level Meters.*

IEC 804 (1985), Amendment 1 (1989) *Integrating/Averaging Sound Level Meters.*

3. COMPLIANCE NOTATION

As used in this document, *"shall"* or *"will"* denotes a mandatory provision of the standard. *"Should"* denotes a provision that is recommended but not mandatory. *"May"* denotes a feature whose presence does not preclude compliance, that may or may not be present at the option of the implementor.

4. SYSTEM OVERVIEW

As illustrated in Figure 1, the audio subsystem comprises the audio encoding/decoding function and resides between the audio inputs/outputs and the transport subsystem. The audio encoder(s) is (are) responsible for generating the audio elementary stream(s) which are encoded representations of the baseband audio input signals. At the receiver, the audio subsystem is responsible for decoding the audio elementary stream(s) back into baseband audio.
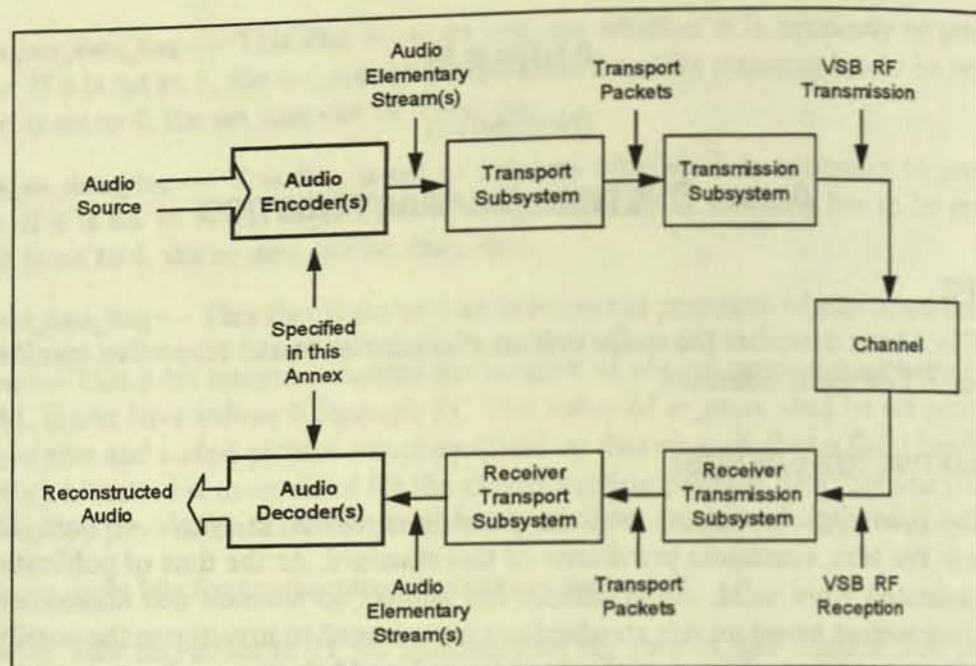
Figure 1. Audio subsystem in the digital television system.

5. SPECIFICATION

This Section forms the normative specification of the audio system. The audio compression system conforms with the Digital Audio Compression (AC-3) Standard, subject to the constraints outlined in this Section.

5.1 Constraints with respect to ATSC Standard A/52

The digital television audio coding system is based on the Digital Audio Compression (AC-3) Standard specified in the body of ATSC Doc. A/52 (the annexes are not included). Constraints on the system are shown in Table 1 which shows permitted values of certain syntactical elements. These constraints are described in Sections 5.2 - 5.4.

Table 1 Audio Constraints

AC-3 syntactical element	Comment	Allowed value
fscod	Indicates sampling rate	'00' (indicates 48 kHz)
frmsizecod	Main audio service or associated audio service containing all necessary program elements	≤ '011100' (indicates ≤ 384 kbps)
frmsizecod	Single channel associated service containing a single program element	≤ '010000' (indicates ≤ 128 kbps)
frmsizecod	Two channel dialogue associated service	≤ '010100' (indicates ≤ 192 kbps)
(frmsizecod)	Combined bit rate of a main and an associated service intended to be simultaneously decoded	(total ≤ 512 kbps)
acmod	Indicates number of channels	≥ '001'

5.2 Sampling frequency

The system conveys digital audio sampled at a frequency of 48 kHz, locked to the 27 MHz system clock. The 48 kHz audio sampling clock is defined as:

(1)   48 kHz audio sample rate = (2 ÷1125) × (27 MHz system clock)

If analog signal inputs are employed, the A/D converters should sample at 48 kHz. If digital inputs are employed, the input sampling rate shall be 48 kHz, or the audio encoder shall contain sampling rate converters which convert the sampling rate to 48 kHz.

5.3 Bit rate

A main audio service, or an associated audio service which is a complete service (containing all necessary program elements) shall be encoded at a bit rate less than or equal to 384 kbps. A single channel associated service containing a single program element shall be encoded at a bit rate less than or equal to 128 kbps. A two channel associated service containing only dialogue shall be encoded at a bit rate less than or equal to 192 kbps. The combined bit rate of a main service and an associated service which are intended to be decoded simultaneously shall be less than or equal to 512 kbps.

5.4 Audio coding modes

Audio services shall be encoded using any of the audio coding modes specified in A/52, with the exception of the 1+1 mode. The value of acmod in the AC-3 bit stream shall have a value in the range of 1-7, with the value 0 prohibited.

5.5 Dialogue level

The value of the dialnorm parameter in the AC-3 elementary bit stream shall indicate the level of average spoken dialogue within the encoded audio program. Dialogue level may be measured by means of an "A" weighted integrated measurement (LAeq). (Receivers use the value of dialnorm to adjust the reproduced audio level so as to normalize the dialogue level.)

5.6 Dynamic range compression

Each encoded audio block may contain a dynamic range control word (dynrng) which is used by decoders (by default) to alter the level of the reproduced audio. The control words allow the decoded signal level to be increased or decreased by up to 24 dB. In general, elementary streams may have dynamic range control words inserted or modified without affecting the encoded audio. When it is necessary to alter the dynamic range of audio programs which are broadcast, the dynamic range control word should be used.

6. MAIN AND ASSOCIATED SERVICES

6.1 Overview

An AC-3 elementary stream contains the encoded representation of a single audio service. Multiple audio services are provided by multiple elementary streams. Each elementary stream is conveyed by the transport multiplex with a unique PID. There are a number of audio service types which may (individually) be coded into each elementary stream. Each AC-3 elementary stream is tagged as to its service type using the bsmod bit field. There are two types of *main service* and six types of *associated service*. Each associated service may be tagged (in the AC-3 audio descriptor in the transport PSI data) as being associated with one or more main audio services. Each AC-3 elementary stream may also be tagged with a language code.

Associated services may contain complete program mixes, or may contain only a single program element. Associated services which are complete mixes may be decoded and used as is. They are identified by the full_svc bit in the AC-3 descriptor (see A/52, Annex A). Associated services which contain only a single program element are intended to be combined with the program elements from a main audio service.

This Section specifies the meaning and use of each type of service. In general, a complete audio program (what is presented to the listener over the set of loudspeakers) may consist of a main audio service, an associated audio service which is a complete mix, or a main audio service combined with an associated audio service. The capability to simultaneously decode one main service and one associated service is required in order to form a complete audio program in certain service combinations described in this Section. This capability may not exist in some receivers.

6.2 Summary of service types

The audio service types are listed in Table 2.

Table 2 Audio Service Types

bsmod	Type of service
000 (0)	Main audio service: complete main (CM)
001 (1)	Main audio service: music and effects (ME)
010 (2)	Associated service: visually impaired (VI)
011 (3)	Associated service: hearing impaired (HI)
100 (4)	Associated service: dialogue (D)
101 (5)	Associated service: commentary (C)
110 (6)	Associated service: emergency (E)
111 (7)	Associated service: voice-over (VO)

6.3 Complete main audio service (CM)

The CM type of main audio service contains a complete audio program (complete with dialogue, music, and effects). This is the type of audio service normally provided.

The CM service may contain from 1 to 5.1 audio channels. The CM service may be further enhanced by means of the VI, HI, C, E, or VO associated services described below. Audio in multiple languages may be provided by supplying multiple CM services, each in a different language.

6.4 Main audio service, music and effects (ME)

The ME type of main audio service contains the music and effects of an audio program, but not the dialogue for the program. The ME service may contain from 1 to 5.1 audio channels. The primary program dialogue is missing and (if any exists) is supplied by simultaneously encoding a D associated service. Multiple D associated services in different languages may be associated with a single ME service.

6.5 Visually impaired (VI)

The VI associated service typically contains a narrative description of the visual program content. In this case, the VI service shall be a single audio channel. The simultaneous reproduction of both the VI associated service and the CM main audio service allows the visually impaired user to enjoy the main multi-channel audio program, as well as to follow (by ear) the on-screen activity.

The dynamic range control signal in this type of VI service is intended to be used by the audio decoder to modify the level of the main audio program. Thus the level of the main audio service will be under the control of the VI service provider, and the provider may signal the decoder (by altering the dynamic range control words embedded in the VI audio elementary stream) to reduce the level of the main audio service by up to 24 dB in order to assure that the narrative description is intelligible.

Besides providing the VI service as a single narrative channel, the VI service may be provided as a complete program mix containing music, effects, dialogue, and the narration. In this case, the service may be coded using any number of channels (up to 5.1), and the dynamic range control signal applies only to this service. The fact that the service is a complete mix shall be indicated in the AC-3 descriptor (see A/52, Annex A).

6.6 Hearing impaired (HI)

The HI associated service typically contains only dialogue which is intended to be reproduced simultaneously with the CM service. In this case, the HI service shall be a single audio channel. This dialogue may have been processed for improved intelligibility by hearing impaired listeners. Simultaneous reproduction of both the CM and HI services allows the hearing impaired listener to hear a mix of the CM and HI services in order to emphasize the dialogue while still providing some music and effects.

Besides providing the HI service as a single dialogue channel, the HI service may be provided as a complete program mix containing music, effects, and dialogue with enhanced intelligibility. In this case, the service may be coded using any number of channels (up to 5.1). The fact that the service is a complete mix shall be indicated in the AC-3 descriptor (see A/52, Annex A).

6.7 Dialogue (D)

The D associated service contains program dialogue intended for use with an ME main audio service. The language of the D service is indicated in the AC-3 bit stream, and in the audio descriptor. A complete audio program is formed by simultaneously decoding the D service and the ME service and mixing the D service into the center channel of the ME main service (with which it is associated).

If the ME main audio service contains more than two audio channels, the D service shall be monophonic (1/0 mode). If the main audio service contains two channels, the D service may also contain two channels (2/0 mode). In this case, a complete audio program is formed by simultaneously decoding the D service and the ME service, mixing the left channel of the ME service with the left channel of the D service, and mixing the right channel of the ME service with the right channel of the D service. The result will be a two channel stereo signal containing music, effects, and dialogue.

Audio in multiple languages may be provided by supplying multiple D services (each in a different language) along with a single ME service. This is more efficient than providing multiple CM services, but, in the case of more than two audio channels in the ME service, requires that dialogue be restricted to the center channel.

Some receivers may not have the capability to simultaneously decode an ME and a D service.

6.8 Commentary (C)

The commentary associated service is similar to the D service, except that instead of conveying essential program dialogue, the C service conveys optional program commentary. The C service may be a single audio channel containing only the commentary content. In this case, simultaneous reproduction of a C service and a CM service will allow the listener to hear the added program commentary.

The dynamic range control signal in the single channel C service is intended to be used by the audio decoder to modify the level of the main audio program. Thus the level of the main audio service will be under the control of the C service provider, and the provider may signal the decoder (by altering the dynamic range control words embedded in the C audio elementary stream) to reduce the level of the main audio service by up to 24 dB in order to assure that the commentary is intelligible.

Besides providing the C service as a single commentary channel, the C service may be provided as a complete program mix containing music, effects, dialogue, and the commentary. In this case the service may be provided using any number of channels (up to 5.1). The fact that the service is a complete mix shall be indicated in the AC-3 descriptor (see A/52, Annex A).

6.9 Emergency (E)

The E associated service is intended to allow the insertion of emergency or high priority announcements. The E service is always a single audio channel. An E service is given priority in transport and in audio decoding. Whenever the E service is present, it will

be delivered to the audio decoder. Whenever the audio decoder receives an E type associated service, it will stop reproducing any main service being received and only reproduce the E service out of the center channel (or left and right channels if a center loudspeaker does not exits). The E service may also be used for non-emergency applications. It may be used whenever the broadcaster wishes to force all decoders to quit reproducing the main audio program and reproduce a higher priority single audio channel.

6.10 Voice-over (VO)

The VO associated service is a single channel service intended to be reproduced along with the main audio service in the receiver. It allows typical voice-overs to be added to an already encoded audio elementary stream without requiring the audio to be decoded back to baseband and then re-encoded. It is always a single audio channel. It has second priority (only the E service has higher priority). It is intended to be simultaneously decoded and mixed into the center channel of the main audio service. The dynamic range control signal in the VO service is intended to be used by the audio decoder to modify the level of the main audio program. Thus the level of the main audio service may be controlled by the broadcaster, and the broadcaster may signal the decoder (by altering the dynamic range control words embedded in the VO audio elementary stream) to reduce the level of the main audio service by up to 24 dB during the voice-over.

Some receivers may not have the capability to simultaneously decode and reproduce a voice-over service along with a program audio service.

7. AUDIO ENCODER INTERFACES

7.1 Audio encoder input characteristics

Audio signals which are input to the digital television system may be in analog or digital form. Audio signals should have any DC offset removed before being encoded. If the audio encoder does not include a DC blocking high pass filter, the audio signals should be high pass filtered before being applied to the encoder. In general, input signals should be quantized to at least 16-bit resolution. The audio compression system can convey audio signals with up to 24-bit resolution. Physical interfaces for the audio inputs to the encoder may be defined as voluntary industry standards by the AES, SMPTE, or other standards organizations.

7.2 Audio encoder output characteristics

Conceptually, the output of the audio encoder is an elementary stream which is formed into PES packets within the transport subsystem. It is possible that systems will be implemented wherein the formation of audio PES packets takes place within the audio encoder. In this case, the output(s) of the audio encoder(s) would be PES packets. Physical interfaces for these outputs (elementary streams and/or PES packets) may be defined as voluntary industry standards by SMPTE or other standards organizations.

ANNEX C

(Normative)

SERVICE MULTIPLEX AND TRANSPORT SYSTEMS CHARACTERISTICS

1. SCOPE

This Annex describes the transport layer characteristics and normative specifications of the Digital Television Standard.

2. NORMATIVE REFERENCES

The following documents contain provisions which in whole or in part, through reference in this text, constitute provisions of this Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and amendment, and parties to agreements based on this Standard are encouraged to investigate the possibility of applying the most recent editions of the documents listed below.

ATSC Standard A/52 (1995), *Digital Audio Compression (AC-3)*.

ISO/IEC IS 13818-1, International Standard (1994), *MPEG-2 Systems*.

ISO/IEC IS 13818-2, International Standard (1994), *MPEG-2 Video*.

ISO/IEC CD 13818-4, MPEG Committee Draft (1994), *MPEG-2 Compliance*.

The normative reference for the Program Guide will be the standard developed from ATSC document T3/S8-050, "Program Guide for Digital Television".

The normative reference for System Information will be the standard developed from ATSC document T3/S8-079, "System Information for Digital Television".

3. COMPLIANCE NOTATION

As used in this document, *"shall"* or *"will"* denotes a mandatory provision of the standard. *"Should"* denotes a provision that is recommended but not mandatory. *"May"* denotes a feature whose presence does not preclude compliance, that may or may not be present at the option of the implementor.

4. SYSTEM OVERVIEW

The transport format and protocol for the Digital Television Standard is a compatible subset of the MPEG-2 Systems specification defined in ISO/IEC 13818-1. It is based on a fixed-length packet transport stream approach which has been defined and optimized for digital television delivery applications.

As illustrated in Figure 1, the transport function resides between the application (e.g., audio or video) encoding and decoding functions and the transmission subsystem. The encoder's transport subsystem is responsible for formatting the coded elementary

streams and multiplexing the different components of the program for transmission. At the receiver, it is responsible for recovering the elementary streams for the individual application decoders and for the corresponding error signaling. The transport subsystem also incorporates other higher protocol layer functionality related to synchronization of the receiver.
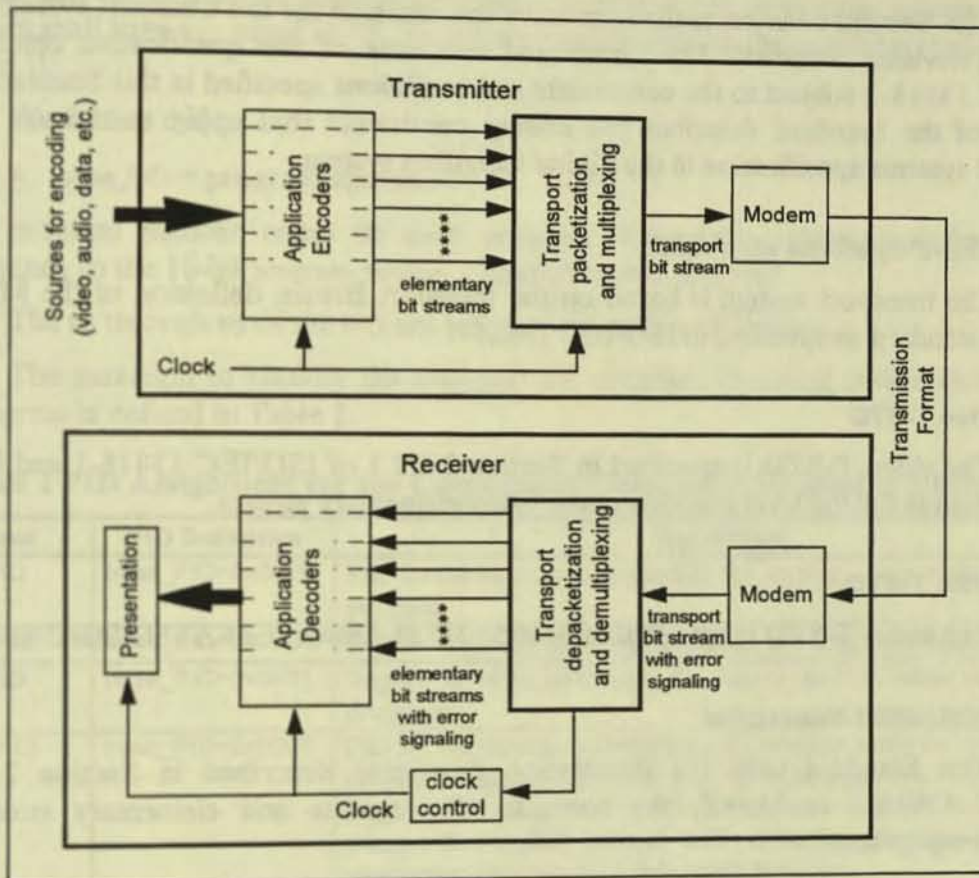
Figure 1. Sample organization of functionality in a transmitter-receiver pair for a single program.

The overall system multiplexing approach can be thought of as a combination of multiplexing at two different layers. In the first layer, single program transport bit streams are formed by multiplexing transport packets from one or more Packetized Elementary Stream (PES) sources. In the second layer, many single program transport bit streams are combined to form a system of programs. The Program Specific Information (PSI) streams contain the information relating to the identification of programs and the components of each program.

Not shown explicitly in Figure 1, but essential to the practical implementation of this Standard, is a control system that manages the transfer and processing of the elementary streams from the application encoders. The rules followed by this control system are not a part of this Standard but must be established as recommended practices by the users of the Standard. The control system implementation shall adhere to the

requirements of the MPEG-2 transport system as specified in ISO/IEC 13818-1 with the additional constraints specified in this Standard. These constraints may go beyond the constraints imposed by the application encoders.

5. SPECIFICATION

This Section constitutes the normative specification for the transport system of the Digital Television Standard. The syntax and semantics of the specification conform to ISO/IEC 13818-1 subject to the constraints and conditions specified in this Standard. This Section of the Standard describes the coding constraints that apply to the use of the MPEG-2 systems specification in the digital television system.

5.1 MPEG-2 Systems standard

The transport system is based on the transport stream definition of the MPEG-2 Systems standard as specified in ISO/IEC 13818-1.

5.1.1 Video T-STD

The video T-STD is specified in Section 2.4.2.3 of ISO/IEC 13818-1 and follows the constraints for the level encoded in the video elementary stream.

5.1.2 Audio T-STD

The audio T-STD is specified in Section 3.6 of Annex A of ATSC Standard A/52.

5.2 Registration descriptor

This Standard uses the registration descriptor described in Section 2.6.8 of ISO/IEC 13818-1 to identify the contents of programs and elementary streams to decoding equipment.

5.2.1 Program identifier

Programs which conform to this specification will be identified by the 32-bit identifier in the section of the Program Map Table (PMT) detailed in Section 2.4.4.8 of ISO/IEC 13818-1. The identifier will be coded according to Section 2.6.8, and shall have a value of 0x4741 3934.

5.2.2 Audio elementary stream identifier

Audio elementary streams which conform to this specification will be identified by the 32-bit identifier in the section of the Program Map Table (PMT) detailed in Section 2.4.4.8 of ISO/IEC 13818-1. The identifier will be coded according to Section 2.6.8, and shall have a value of 0x4143 2D33.

5.3 The program paradigm

The program paradigm specifies the method that shall be used for allocating the values of the Packet Identifier (PID) field of the transport packet header in a systematic manner. Within one transport multiplex, television programs that follow the program paradigm are assigned a program number ranging from 1 to 255. The binary value of the program number is used to form b_{11} through b_4 of the PID. Programs adhering to the paradigm shall have b_{12} equal to '0'. Programs not adhering to the paradigm shall have b_{12} equal to '1'.

We further define:

- base_PID = program number << 4

where program number refers to each program within one transport multiplex and corresponds to the 16-bit program_number identified in PAT and PMT.

The b_0 through b_3 of the PID are assigned according to Table 1.

The paradigm to identify the transport bit streams containing certain elements of the program is defined in Table 1.

Table 1 PID Assignment for the Constituent Elementary Streams of a Program

Name	PID Definition	Description
PMT_PID	base_PID+0x0000	PID for the bit stream containing the program_map_table for the program.
Video_PID	base_PID+0x0001	PID for the bit stream containing the video for the program.
PCR_PID	base_PID+0x0001	Implies the video bit stream also carries the PCR values for the program
Audio_PID	base_PID+0x0004	PID for the bit stream containing the primary audio for the program. The primary audio shall be a complete main audio service (CM) as defined by ATSC Standard A/52 and shall contain the complete primary audio of the program including all required voice-overs and emergency messages.
Data_PID	base_PID+0x000A	PID for the bit stream containing the data for the program.

The program_map_table must be decoded to obtain the PIDs for services not defined by the paradigm but included within the program (such as a second data channel). According to the program paradigm, every 16th PID is a PMT_PID and may be assigned to a program. If a PMT_PID is assigned to a program by the program paradigm, the next 15 PIDs after that PMT_PID are reserved for elements of that program and shall not be otherwise assigned.

5.4 Constraints on PSI

The program constituents for all programs, including television programs that follow the program paradigm and other programs or services that do not follow the program paradigm, are described in the PSI. There are the following constraints on the PSI information:

- Only one program is described in a PSI transport bit stream corresponding to a particular PMT_PID value. A transport bit stream containing a program_map_table shall not be used to transmit any other kind of PSI table (identified by a different table_id).

- The maximum spacing between occurrences of a program_map_table containing television program information shall be 400 ms.

- The program numbers are associated with the corresponding PMT_PIDs in the PID0 Program Association Table. The maximum spacing between occurrences of section 0 of the program_association_table is 100 ms.

- The video elementary stream section shall contain the Data stream alignment descriptor described in Section 2.6.10 of ISO/IEC 13818-1. The alignment_type field shown in Table 2-47 of ISO/IEC 13818-1 shall be 0x02.

- Adaptation headers shall not occur in transport packets of the PMT_PID for purposes other than for signaling with the discontinuity_indictor that the version_number (Section 2.4.4.5 of ISO/IEC 13818-1) may be discontinuous.

- Adaptation headers shall not occur in transport packets of the PAT_PID for purposes other than for signaling with the discontinuity_indicator that the version_number (Section 2.4.4.5 of ISO/IEC 13818-1) may be discontinuous.

5.5 PES constraints

Packetized Elementary Stream syntax and semantics shall be used to encapsulate the audio and video elementary stream information. The Packetized Elementary Stream syntax is used to convey the Presentation Time-Stamp (PTS) and Decoding Time-Stamp (DTS) information required for decoding audio and video information with synchronism. This Section describes the coding constraints for this system layer.

Within the PES packet header, the following restrictions apply:

- PES_scrambling_control shall be coded as '00'.

- ESCR_flag shall be coded as '0'.

- ES_rate_flag shall be coded as '0'.

- PES_CRC_flag shall be coded as '0'.

Within the PES packet extension, the following restrictions apply.

- PES_private_data_flag shall be coded as '0'.

- pack_header_field_flag shall be coded as '0'.

- program_packet_sequence_counter_flag shall be coded as '0'.

- P-STD_buffer_flag shall be coded as '0'.

5.5.1 Video PES constraints

Each PES packet shall begin with a video access unit, as defined in Section 2.1.1 of ISO/IEC 13818-1, which is aligned with the PES packet header. The first byte of a PES packet payload shall be the first byte of a video access unit. Each PES header shall contain a PTS. Additionally, it shall contain a DTS as appropriate. For terrestrial broadcast, the PES packet shall not contain more than one coded video frame, and shall be void of video picture data only when transmitted in conjunction with the discontinuity_indicator to signal that the continuity_counter may be discontinuous.

Within the PES packet header, the following restrictions apply:

- The PES_packet_length shall be coded as '0x0000'.

- data_alignment_indicator shall be coded as '1'.

5.5.2 Audio PES constraints

The audio decoder may be capable of simultaneously decoding more than one elementary stream containing different program elements, and then combining the program elements into a complete program. In this case, the audio decoder may sequentially decode audio frames (or audio blocks) from each elementary stream and do the combining (mixing together) on a frame or (block) basis. In order to have the audio from the two elementary streams reproduced in exact sample synchronism, it is necessary for the original audio elementary stream encoders to have encoded the two audio program elements frame synchronously; i.e., if audio program 1 has sample 0 of frame n at time t0, then audio program 2 should also have frame n beginning with its sample 0 at the identical time t0. If the encoding is done frame synchronously, then matching audio frames should have identical values of PTS.

If PES packets from two audio services that are to be decoded simultaneously contain identical values of PTS then the corresponding encoded audio frames contained in the PES packets should be presented to the audio decoder for simultaneous synchronous decoding. If the PTS values do not match (indicating that the audio encoding was not frame synchronous) then the audio frames which are closest in time may be presented to the audio decoder for simultaneous decoding. In this case the two services may be reproduced out of sync by as much as 1/2 of a frame time (which is often satisfactory, e.g., a voice-over does not require precise timing).

The value of stream_id for AC-3 shall be 1011 1101 (private_stream_1).

5.6 Services and features

5.6.1 Program guide

5.6.1.1 Master program guide PID

At the option of broadcasters, an interactive program guide database may be transmitted in the transport stream. If present, the master program guide data stream shall

be transported in PID 0x1FFD. This PID shall be reserved exclusively for the program guide. The program guide shall be formatted according to the structure and syntax described in the standard developed from ATSC document T3/S8-050, "Program Guide for Digital Television". The program guide database allows a receiver to build an on-screen grid of program information and contains control information to facilitate navigation.

5.6.1.2 Program guide STD model

Each program guide bit stream shall adhere to an STD model that can be described by an MPEG smoothing buffer descriptor (Section 2.6.30 in ISO/IEC 13818-1) with the following constraints:

- sb_leak_rate shall be 250 (indicating a leak rate of 100,000 bps)
- sb_size shall be 1024 (indicating a smoothing buffer size of 1024 bytes)

Note that the smoothing buffer descriptor is referred to here to describe the STD model for the program guide, and does not imply that a smoothing buffer descriptor for the program guide is to be included in the PMT.

5.6.2 System information

5.6.2.1 System information PID

At the option of broadcasters, certain system information may be transmitted in the transport stream. If present, the system information data stream shall be transported in PID 0x1FFC. This PID shall be reserved exclusively for the system information. The system information shall be formatted according to the structure and syntax described in the standard developed from ATSC document T3/S8-079, "System Information for Digital Television". Constraints applying to specific transmission media are given in that standard.

5.6.2.2 System information STD model

The system information bit stream shall adhere to an STD model that can be described by an MPEG smoothing buffer descriptor (Section 2.6.30 in ISO/IEC 13818-1) with the following constraints:

- sb_leak_rate shall be 50 (indicating a leak rate of 20,000 bps)
- sb_size shall be 1024 (indicating a smoothing buffer size of 1024 bytes)

Note that the smoothing buffer descriptor is referred to here to describe the STD model for the system information, and does not imply that a smoothing buffer descriptor for the system information is to be included in the PMT.

5.6.3 Specification of private data services

Private data provides a means to add new ancillary services to the basic digital television service specified in this standard. Private data is supported in two bit stream locations.

1. Private data can be transmitted within the adaptation header of transport packets (Sections 2.4.3.4 and 2.4.3.5 of ISO/IEC 13818-1).

2. Private data can be transmitted as a separate transport stream with its own PID. The contents can be identified as being ATSC private by using the private_data_indicator_descriptor (Section 2.6.29 of ISO/IEC 13818-1) within the PMT.

In either case, it is necessary that the standards which specify the characteristics of such private_streams be consistent with the Digital Television Standard. Standards for private_streams shall precisely specify the semantics of the transmitted syntax as described in Sections 5.6.3.1 and 5.6.3.1.1.

5.6.3.1 Verification model

The standard shall be specified in terms of a verification model by defining the characteristics of the transmitted syntax and an idealized decoder. In ISO/IEC 13818-1 and 13818-2, this is accomplished by using the T-STD and VBV models, respectively. The elements required for specification by this Standard are described in the following Sections.

5.6.3.1.1 Syntax and semantics

The syntax and semantics of the transmitted bit stream that implements the ancillary service shall be completely and unambiguously specified. The decoding process shall also be completely and unambiguously specified.

5.6.3.1.2 Ancillary service target decoder (ASTD)

An idealized decoder model must be precisely defined for the service. Figure 2 introduces a concrete model for pedagogic purposes. It is modeled after the T-STD.

The salient features of the model are the size of the transport demultiplexing buffer (TB), the minimum transfer rate out of the transport demultiplex buffer (R_{leak}), the required System buffering (BS_{sys}), and optionally the partitioning of BS_{sys} between the smoothing portion and the decoder portion. The decoding process, represented as the decoding times T_decode(i), must be completely specified. The behavior of the BS_{sys} buffer must be completely modeled with respect to its input process and its output process. Certain parameters of the service such as bit rate, etc., should also be specified.

5.6.3.2 Stream type and PMT descriptors

A new ancillary service shall be described as a program or elementary stream through documented Program Specific Information.
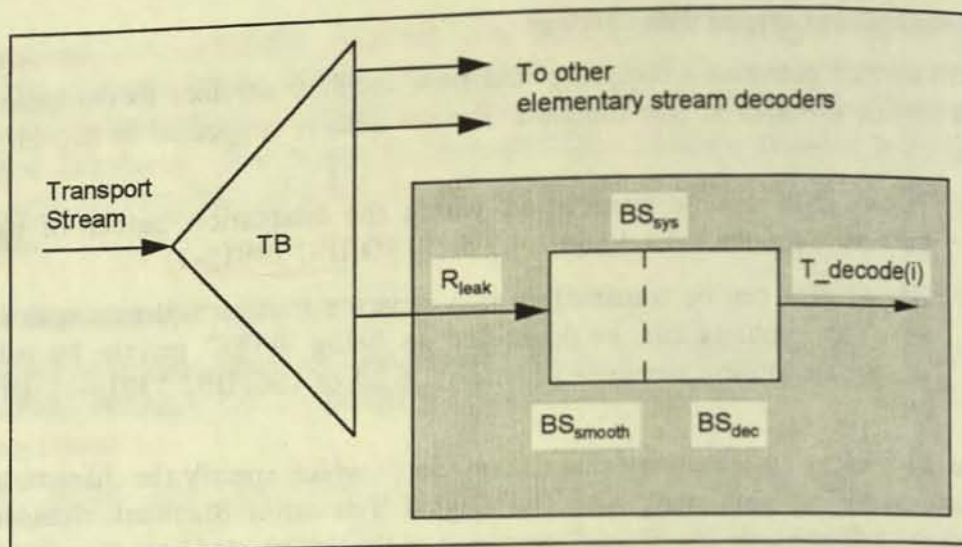
Figure 2. Ancillary service target decoder.

5.6.3.2.1 Stream type

Several identifiers that are part of the transport section of the Digital Television Standard may be used to identify either the signal or constituent parts thereof; however, the fundamental identifier is the User Private stream type. The stream_type codes shall be unambiguously assigned within the range 0x80 to 0xAF. 0x81 has already been assigned within the Digital Television Standard (see Section 5.7.1).

5.6.3.2.2 PMT descriptors

The Ancillary Service specification shall include all pertinent descriptors that are found within the Program Map Table. Specifically, it is recommended that either the private_stream_identifier or the registration_descriptor, or both, be included. Although this is not required for a stream with a unique stream_type code within this Standard, it will enhance interoperability in the case where the stream is stored outside this Standard, or transmitted in some other network that has its own set of stream_type codes.

5.7 Assignment of identifiers

In this Section, those Identifiers and codes which shall have a fixed value are summarized. These include PES Stream IDs and Descriptors. Stream_type codes from 0x80 to 0xAF shall be reserved for assignment as needed within the Digital Television Standard. Descriptor_tag codes from 0x40 to 0xAF shall be reserved for assignment as needed within the Digital Television Standard.

5.7.1 Stream type

The AC-3 audio stream_type shall have the value 0x81.

5.7.2 Descriptors

5.7.2.1 AC-3 audio descriptor

In the digital television system the AC-3 audio descriptor shall be included in the TS_program_map_section. The syntax is given in Table 2 of Annex A of ATSC Standard A/52. There are the following constraints on the AC-3 audio descriptor:

- The value of the descriptor_tag shall be 0x81.

- If textlen exists, it shall have a value of '0x00'.

5.7.2.2 Program smoothing buffer descriptor.

The Program Map Table of each program shall contain a smoothing buffer descriptor pertaining to that program in accordance with Section 2.6.30 of ISO/IEC 13818-1. During the continuous existence of a program, the value of the elements of the smoothing buffer descriptor shall not change.

The fields of the smoothing buffer descriptor shall meet the following constraints:

- The field sb_leak_rate shall be allowed to range up to the maximum transport rates specified in Section 7.2.

- The field sb_size shall have a value less than or equal to 2048. The size of the smoothing buffer is thus ≤ 2048 bytes.

5.8 Extensions to the MPEG-2 Systems specification

This Section covers extensions to the MPEG-2 Systems specification.

5.8.1 Scrambling control

The scrambling control field within the packet header allows all states to exist in the digital television system as defined in Table 2.

Table 2 Transport Scrambling Control Field

transport_ scrambling_ control	Function
00	packet payload not scrambled
01	not scrambled, state may be used as a flag for private use defined by the service provider.
10	packet payload scrambled with "even" key
11	packet payload scrambled with "odd" key

Elementary Streams for which the transport_scrambling_control field does not exclusively have the value of '00' for the duration of the program, must carry a CA_descriptor in accordance with Section 2.6.16 of ISO/IEC 13818-1.

The implementation of a digital television delivery system that employs conditional access will require the specification of additional data streams and system constraints.

6. FEATURES OF 13818-1 NOT SUPPORTED BY THIS STANDARD

The transport definition is based on the MPEG-2 Systems standard, ISO/IEC 13818-1; however, it does not implement all parts of the standard. This Section describes those elements which are omitted from this Standard.

6.1 *Program streams*

This Standard does not include those portions of ISO/IEC 13818-1 and Annex A of ATSC Standard A/52 which pertain exclusively to Program Stream specifications.

6.2 *Still pictures*

This Standard does not include those portions of ISO/IEC 13818-1 Transport Stream specification which pertain to the Still Picture model.

7. TRANSPORT ENCODER INTERFACES AND BIT RATES

7.1 *Transport encoder input characteristics*

The MPEG-2 Systems standard specifies the inputs to the transport system as MPEG-2 elementary streams. It is also possible that systems will be implemented wherein the process of forming PES packets takes place within the video, audio or other data encoders. In such cases, the inputs to the Transport system would be PES packets. Physical interfaces for these inputs (elementary streams and/or PES packets) may be defined as voluntary industry standards by SMPTE or other standardizing organizations.

7.2 *Transport output characteristics*

Conceptually, the output from the transport system is a continuous MPEG-2 transport stream as defined in this Annex at a constant rate of T_r Mbps when transmitted in an 8 VSB system and $2T_r$ when transmitted in a 16 VSB system where:

$$T_r = 2 \ x \left(\frac{188}{208}\right)\left(\frac{312}{313}\right)\left(\frac{684}{286}\right) \ x \ 4.5 = 19.39...Mbps$$

and

$$\left(\frac{684}{286}\right) \ x \ 4.5$$

is the symbol rate S_r in Msymbols per second for the transmission subsystem (see Section 4.1 of Annex D). T_r and S_r shall be locked to each other in frequency.

All transport streams conforming to this Standard shall conform to the ISO/IEC 13818-1 model.

Details of the interface for this output, including its physical characteristics, may be defined as a voluntary industry standard by SMPTE , or other standardizing organizations.

ANNEX D

(Normative)

RF/TRANSMISSION SYSTEMS CHARACTERISTICS

1. SCOPE

This Annex describes the characteristics of the RF/Transmission subsystem, which is referred to as the VSB subsystem, of the Digital Television Standard. The VSB subsystem offers two modes: a terrestrial broadcast mode (8 VSB), and a high data rate mode (16 VSB). These are described in separate sections of this document.

2. NORMATIVE REFERENCES

There are no Normative References.

3. COMPLIANCE NOTATION

As used in this document, *"shall"* or *"will"* denotes a mandatory provision of the standard. *"Should"* denotes a provision that is recommended but not mandatory. *"May"* denotes a feature whose presence does not preclude compliance, that may or may not be present at the option of the implementor.

4. TRANSMISSION CHARACTERISTICS FOR TERRESTRIAL BROADCAST

4.1 Overview

The terrestrial broadcast mode (known as 8 VSB) will support a payload data rate of 19.28... Mbps in a 6 MHz channel. A functional block diagram of a representative 8 VSB terrestrial broadcast transmitter is shown in Figure 1. The input to the transmission subsystem from the transport subsystem is a 19.39... Mbps serial data stream comprised of 188-byte MPEG-compatible data packets (including a sync byte and 187 bytes of data which represent a payload data rate of 19.28... Mbps).

The incoming data is randomized and then processed for forward error correction (FEC) in the form of Reed-Solomon (RS) coding (20 RS parity bytes are added to each packet), 1/6 data field interleaving and 2/3 rate trellis coding. The randomization and FEC processes are not applied to the sync byte of the transport packet, which is represented in transmission by a Data Segment Sync signal as described below. Following randomization and forward error correction processing, the data packets are formatted into Data Frames for transmission and Data Segment Sync and Data Field Sync are added.

Figure 2 shows how the data are organized for transmission. Each Data Frame consists of two Data Fields, each containing 313 Data Segments. The first Data Segment of each Data Field is a unique synchronizing signal (Data Field Sync) and includes the training sequence used by the equalizer in the receiver. The remaining 312 Data Segments each carry the equivalent of

the data from one 188-byte transport packet plus its associated FEC overhead. The actual data in each Data Segment comes from several transport packets because of data interleaving. Each Data Segment consists of 832 symbols. The first 4 symbols are transmitted in binary form and provide segment synchronization. This Data Segment Sync signal also represents the sync byte of the 188-byte MPEG-compatible transport packet. The remaining 828 symbols of each Data Segment carry data equivalent to the remaining 187 bytes of a transport packet and its associated FEC overhead. These 828 symbols are transmitted as 8-level signals and therefore carry three bits per symbol. Thus, 828 x 3 = 2484 bits of data are carried in each Data Segment, which exactly matches the requirement to send a protected transport packet:
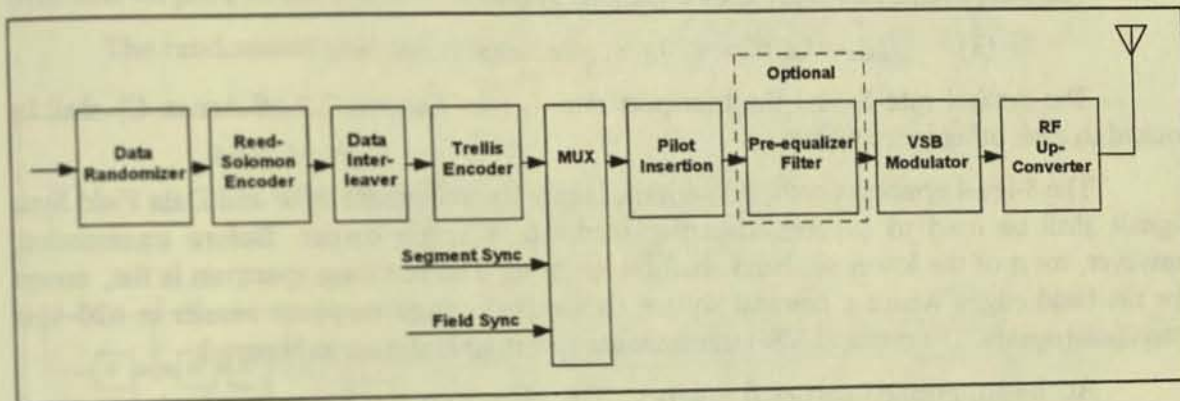
Figure 1. VSB transmitter.
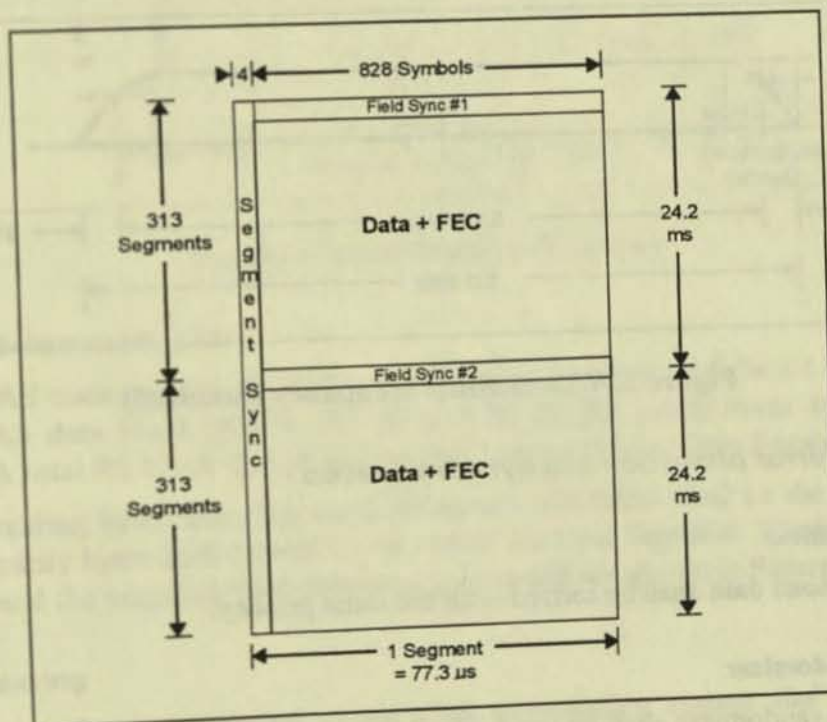
Figure 2. VSB data frame.

187 data bytes + 20 RS parity bytes = 207 bytes

207 bytes x 8 bits/byte = 1656 bits

2/3 rate trellis coding requires 3/2 x 1656 bits = 2484 bits.

The exact symbol rate is given by equation 1 below:

$$(1) \qquad S_r \text{ (MHz)} = 4.5/286 \times 684 = 10.76... \text{ MHz}$$

The frequency of a Data Segment is given in equation 2 below:

$$(2) \qquad f_{seg} = S_r / 832 = 12.94... \times 10^3 \text{ Data Segments/s.}$$

The Data Frame rate is given by equation (3) below:

$$(3) \qquad f_{frame} = f_{seg}/626 = 20.66 ... \text{ frames/s.}$$

The symbol rate S_r and the transport rate T_r (see Section 7.2 of Annex C) shall be locked to each other in frequency.

The 8-level symbols combined with the binary Data Segment Sync and Data Field Sync signals shall be used to suppressed-carrier modulate a single carrier. Before transmission, however, most of the lower sideband shall be removed. The resulting spectrum is flat, except for the band edges where a nominal square root raised cosine response results in 620 kHz transition regions. The nominal VSB transmission spectrum is shown in Figure 3.

At the suppressed-carrier frequency, 310 kHz from the lower band edge, a small pilot shall be added to the signal.
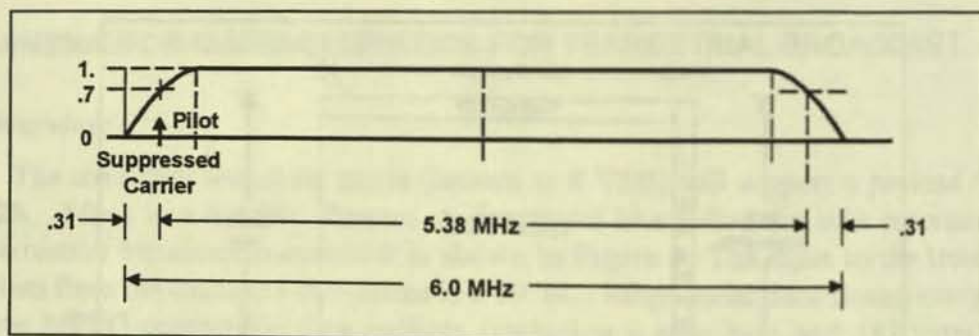
Figure 3. VSB channel occupancy (nominal).

4.2 Channel error protection and synchronization

4.2.1 Prioritization

All payload data shall be carried with the same priority.

4.2.2 Data randomizer

A data randomizer shall be used on all input data to randomize the data payload (not including Data Field Sync or Data Segment Sync, or RS parity bytes). The data randomizer XORs all the incoming data bytes with a 16-bit maximum length pseudo

random binary sequence (PRBS) which is initialized at the beginning of the Data Field. The PRBS is generated in a 16-bit shift register that has 9 feedback taps. Eight of the shift register outputs are selected as the fixed randomizing byte, where each bit from this byte is used to individually XOR the corresponding input data bit. The data bits are XORed MSB to MSB ... LSB to LSB.

The randomizer generator polynomial is as follows:

$$G_{(16)} = X^{16} + X^{13} + X^{12} + X^{11} + X^7 + X^6 + X^3 + X + 1$$

The initialization (pre-load) to F180 hex (load to 1) occurs during the Data Segment Sync interval prior to the first Data Segment.

The randomizer generator polynomial and initialization is shown in Figure 4.
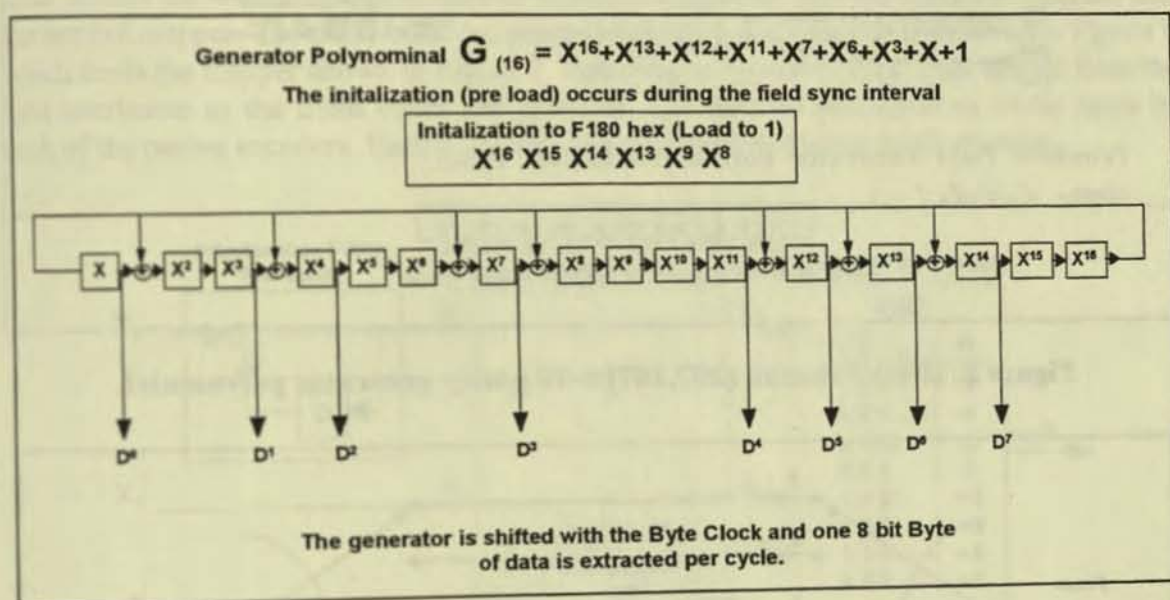
Figure 4. Randomizer polynomial.

4.2.3 Reed-Solomon encoder

The RS code used in the VSB transmission subsystem shall be a t = 10 (207,187) code. The RS data block size is 187 bytes, with 20 RS parity bytes added for error correction. A total RS block size of 207 bytes is transmitted per Data Segment.

In creating bytes from the serial bit stream, the MSB shall be the first serial bit. The 20 RS parity bytes shall be sent at the end of the Data Segment. The parity generator polynomial and the primitive field generator polynomial are shown in Figure 5.

4.2.4 Interleaving

The interleaver employed in the VSB transmission system shall be a 52 data segment (intersegment) convolutional byte interleaver. Interleaving is provided to a depth of about 1/6 of a data field (4 ms deep). Only data bytes shall be interleaved. The

interleaver shall be synchronized to the first data byte of the data field. Intrasegment interleaving is also performed for the benefit of the trellis coding process.

The convolutional interleaver is shown in Figure 6.

$$\prod_{i=0}^{i=2t-1}(X+\alpha^i)$$

Primitive Field Generator Polynomial (Galois Field)

$G(256)= X^8+X^4+X^3+X^2+1$

Each shift of the generator produces a field element
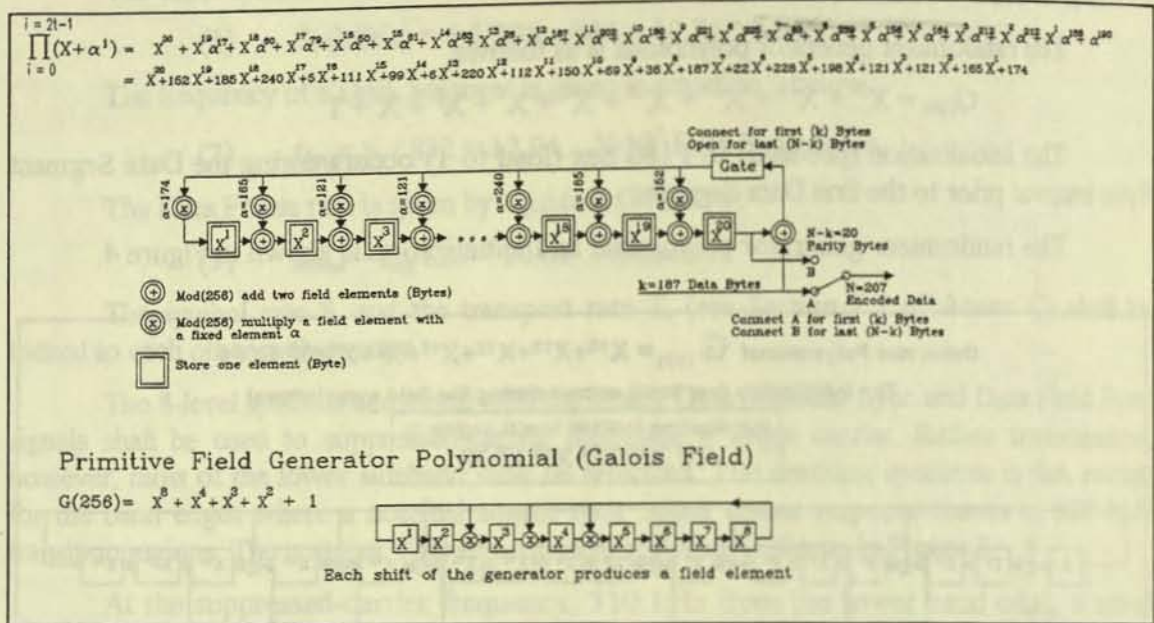
Figure 5. Reed-Solomon (207,187) t=10 parity generator polynomial.

M=4, B=52, N=208, R-S Block =207, BXM=N

Figure 6. Convolutional interleaver (byte shift register illustration).

4.2.5 Trellis coding

The 8 VSB transmission sub-system shall employ a 2/3 rate (R=2/3) trellis code (with one unencoded bit which is precoded). That is, one input bit is encoded into two output bits using a 1/2 rate convolutional code while the other input bit is precoded. The

signaling waveform used with the trellis code is an 8-level (3 bit) one-dimensional constellation. The transmitted signal is referred to as 8 VSB. A 4-state trellis encoder shall be used.

Trellis code intrasegment interleaving shall be used. This uses twelve identical trellis encoders and precoders operating on interleaved data symbols. The code interleaving is accomplished by encoding symbols (0, 12, 24, 36 ...) as one group, symbols (1, 13, 25, 37, ...) as a second group, symbols (2, 14, 26, 38, ...) as a third group, and so on for a total of 12 groups.

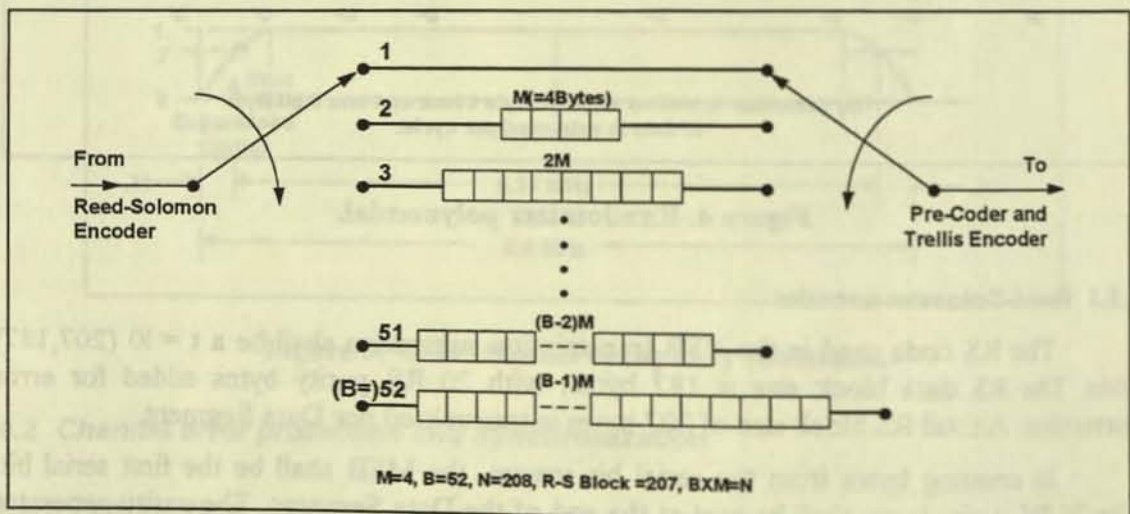In creating serial bits from parallel bytes, the MSB shall be sent out first: (7, 6, 5, 4, 3, 2, 1, 0). The MSB is precoded (7, 5, 3, 1) and the LSB is feedback convolutional encoded (6, 4, 2, 0). Standard 4-state optimal Ungerboeck codes shall be used for the encoding. The trellis code utilizes the 4-state feedback encoder shown in Figure 7. Also shown is the precoder and the symbol mapper. The trellis code and precoder intrasegment interleaver is shown in Figure 8 which feeds the mapper shown in Figure 7. Referring to Figure 8, data bytes are fed from the byte interleaver to the trellis coder and precoder, and they are processed as whole bytes by each of the twelve encoders. Each byte produces four symbols from a single encoder.
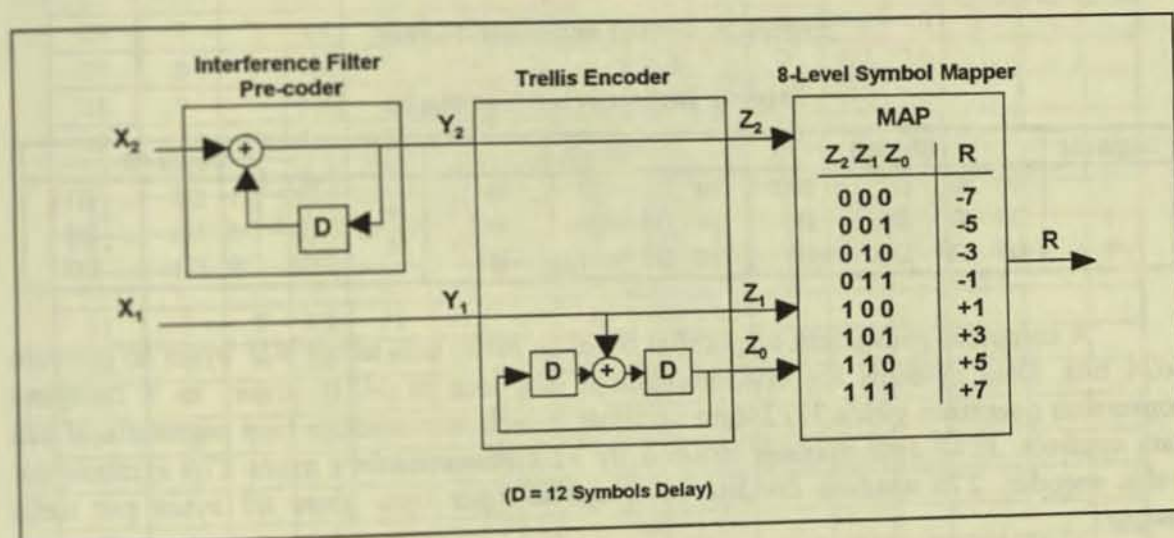
Figure 7. 8 VSB trellis encoder, precoder, and symbol mapper.

The output multiplexer shown in Figure 8 shall advance by four symbols on each segment boundary. However, the state of the trellis encoder shall not be advanced. The data coming out of the multiplexer shall follow normal ordering from encoder 0 through 11 for the first segment of the frame, but on the second segment the order changes and symbols are read from encoders 4 through 11, and then 0 through 3. The third segment reads from encoder 8 through 11 and then 0 through 7. This three-segment pattern shall repeat through the 312 Data Segments of the frame. Table 1 shows the interleaving sequence for the first three Data Segments of the frame.

After the Data Segment Sync is inserted, the ordering of the data symbols is such that symbols from each encoder occur at a spacing of twelve symbols.
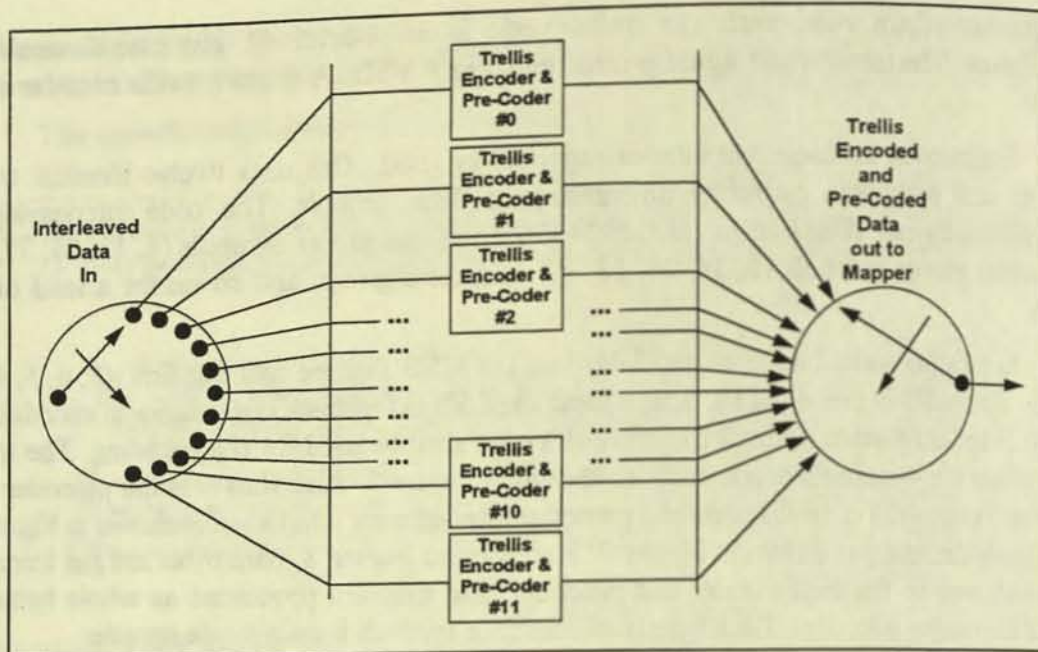
Figure 8. Trellis code interleaver.

Table 1 Interleaving Sequence

Segment	Block 0				Block 1				...	Block 68			
0	D0	D1	D2	... D11	D0	D1	D2	... D11	...	D0	D1	D2	... D11
1	D4	D5	D6	... D3	D4	D5	D6	... D3	...	D4	D5	D6	... D3
2	D8	D9	D10	... D7	D8	D9	D10	... D7	...	D8	D9	D10	... D7

A complete conversion of parallel bytes to serial bits needs 828 bytes to produce 6624 bits. Data symbols are created from 2 bits sent in MSB order, so a complete conversion operation yields 3312 data symbols, which corresponds to 4 segments of 828 data symbols. 3312 data symbols divided by 12 trellis encoders gives 276 symbols per trellis encoder. 276 symbols divided by 4 symbols per byte gives 69 bytes per trellis encoder.

The conversion starts with the first segment of the field and proceeds with groups of 4 segments until the end of the field. 312 segments per field divided by 4 gives 78 conversion operations per field.

During segment sync the input to 4 encoders is skipped and the encoders cycle with no input. The input is held until the next multiplex cycle and then fed to the correct encoder.

Table 2 details the byte to symbol conversion and the associated multiplexing of the trellis encoders. Segment 0 is the first segment of the field. The pattern repeats every 12 segments; segments 5 through 11 are not shown.

Table 2 Byte to Symbol Conversion, Multiplexing of Trellis Encoders

Symbol	Segment 0			Segment 1			Segment 2			Segment 3			Segment 4		
	Trellis	Byte	Bits	Trellis	Byte	Bits	Trellis	Byte	Bits	Trellis	Byte	Bits	Trellis	Byte	Bits
0	0	0	7,6	4	208	5,4	8	412	3,2	0	616	1,0	4	828	7,6
1	1	1	7,6	5	209	5,4	9	413	3,2	1	617	1,0	5	829	7,6
2	2	2	7,6	6	210	5,4	10	414	3,2	2	618	1,0	6	830	7,6
3	3	3	7,6	7	211	5,4	11	415	3,2	3	619	1,0	...	...	...
4	4	4	7,6	8	212	5,4	0	416	3,2	4	620	1,0	...	...	...
5	5	5	7,6	9	213	5,4	1	417	3,2	5	621	1,0	...	...	...
6	6	6	7,6	10	214	5,4	2	418	3,2	6	622	1,0	...	...	...
7	7	7	7,6	11	215	5,4	3	419	3,2	7	623	1,0	...	...	...
8	8	8	7,6	0	204	5,4	4	408	3,2	8	612	1,0	...	...	...
9	9	9	7,6	1	205	5,4	5	409	3,2	9	613	1,0	...	...	...
10	10	10	7,6	2	206	5,4	6	410	3,2	10	614	1,0	...	...	...
11	11	11	7,6	3	207	5,4	7	411	3,2	11	615	1,0	...	...	...
12	0	0	5,4	4	208	3,2	8	412	1,0	0	624	7,6	...	...	...
13	1	1	5,4	5	209	3,2	9	413	1,0	1	625	7,6	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
19	7	7	5,4	11	215	3,2	3	419	1,0	7	631	7,6	...	...	...
20	8	8	5,4	0	204	3,2	4	408	1,0	8	632	7,6	...	...	...
21	9	9	5,4	1	205	3,2	5	409	1,0	9	633	7,6	...	...	...
22	10	10	5,4	2	206	3,2	6	410	1,0	10	634	7,6	...	...	...
23	11	11	5,4	3	207	3,2	7	411	1,0	11	635	7,6	...	...	...
24	0	0	3,2	4	208	1,0	8	420	7,6	0	624	5,4	...	...	...
25	1	1	3,2	5	209	1,0	9	421	7,6	1	625	5,4	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
31	7	7	3,2	11	215	1,0	3	427	7,6	...	...	...	...	...	...
32	8	8	3,2	0	204	1,0	4	428	7,6	...	...	...	...	...	...
33	9	9	3,2	1	205	1,0	5	429	7,6	...	...	...	...	...	...
34	10	10	3,2	2	206	1,0	6	430	7,6	...	...	...	...	...	...
35	11	11	3,2	3	207	1,0	7	431	7,6	...	...	...	...	...	...
36	0	0	1,0	4	216	7,6	8	420	5,4	...	...	...	...	...	...
37	1	1	1,0	5	217	7,6	9	421	5,4	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
47	11	11	1,0	3	227	7,6	...	...	...	...	...	...	...	...	...
48	0	12	7,6	4	216	5,4	...	...	...	...	...	...	...	...	...
49	1	13	7,6	5	217	5,4	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
95	11	23	1,0	...	...	...	...	...	...	...	...	...	...	...	...
96	0	24	7,6	...	...	...	...	...	...	...	...	...	...	...	...
97	1	25	7,6	...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
767	11	191	1,0	...	...	...	...	...	...	...	...	...	...	...	...
768	0	192	7,6	...	...	...	...	...	...	...	...	...	...	...	...
769	1	193	7,6	...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

Symbol	Segment 0			Segment 1			Segment 2			Segment 3			Segment 4		
	Trellis	Byte	Bits	Trellis	Byte	Bits	Trellis	Byte	Bits	Trellis	Byte	Bits	Trellis	Byte	Bits
815	11	203	1,0	3	419	7,6	7	623	5,4	11	827	3,2	...	...	...
816	0	204	7,6	4	408	5,4	8	612	3,2	0	816	1,0	...	...	...
817	1	205	7,6	5	409	5,4	9	613	3,2	1	817	1,0	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
827	11	215	7,6	3	419	5,4	7	623	3,2	11	827	1,0	...	...	...

4.2.6 Data segment sync

The encoded trellis data shall be passed through a multiplexer that inserts the various synchronization signals (Data Segment Sync and Data Field Sync).

A two-level (binary) 4-symbol Data Segment Sync shall be inserted into the 8-level digital data stream at the beginning of each Data Segment. (The MPEG sync byte shall be replaced by Data Segment Sync.) The Data Segment Sync embedded in random data is illustrated in Figure 9.

A complete segment shall consist of 832 symbols: 4 symbols for Data Segment Sync, and 828 data plus parity symbols. The Data Segment Sync is binary (2-level). The same sync pattern occurs regularly at 77.3 µs intervals, and is the only signal repeating at this rate. Unlike the data, the four symbols for Data Segment Sync are not Reed-Solomon or trellis encoded, nor are they interleaved. The Data Segment Sync pattern shall be a 1001 pattern, as shown in Figure 9.
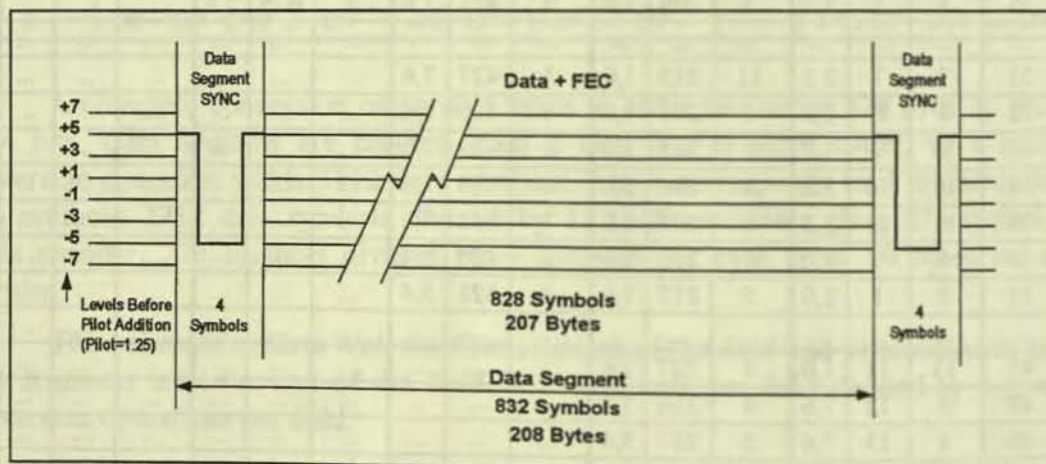

Figure 9. 8 VSB data segment.

4.2.7 Data field sync

The data are not only divided into Data Segments, but also into Data Fields, each consisting of 313 segments. Each Data Field (24.2 ms) shall start with one complete Data Segment of Data Field Sync, as shown in Figure 10. Each symbol represents one bit of data (2-level). The 832 symbols in this segment are defined below. Refer to Figure 10.
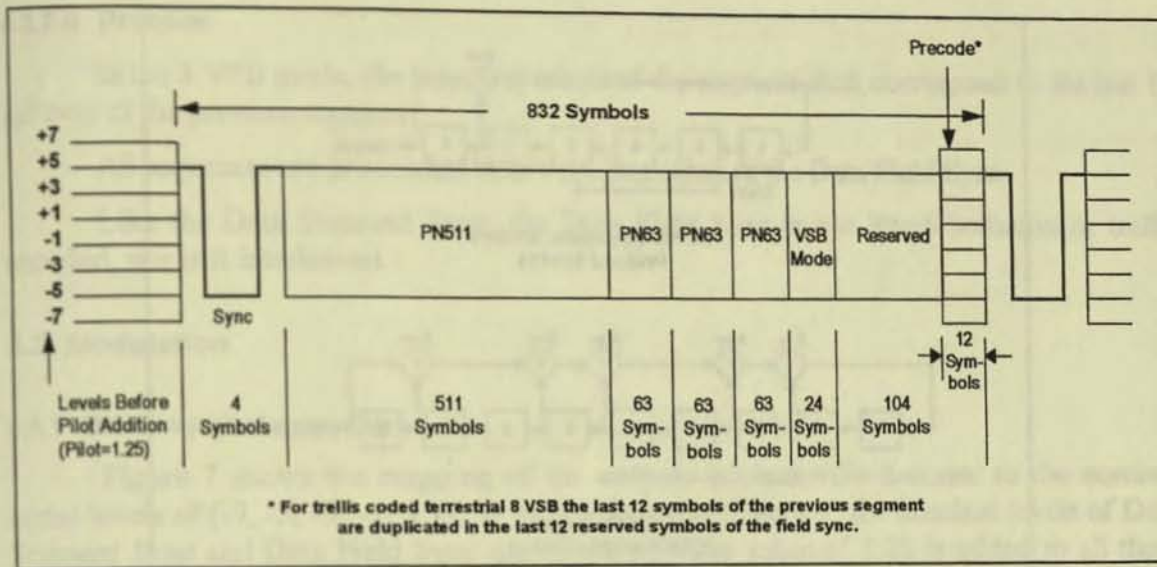
Figure 10. VSB data field sync.

4.2.7.1 Sync

This corresponds to Data Segment Sync and is defined as 1001.

4.2.7.2 PN511

This pseudo-random sequence is defined as $X^9 + X^7 + X^6 + X^4 + X^3 + X + 1$ with a pre-load value of 010000000. The sequence is:

```
0000 0001 0111 1111 1100 1010 1010 1110 0110 0110 1000 1000 1001 1110 0001 1101
0111 1101 0011 0101 0011 1011 0011 1010 0100 0101 1000 1111 0010 0001 0100 0111
1100 1111 0101 0001 0100 1100 0011 0001 0000 0100 0011 1111 0000 0101 0100 0000
1100 1111 1110 1110 1010 1001 0110 0110 0011 0111 0111 1011 0100 1010 0100 1110
0111 0001 0111 0100 0011 0100 1111 1011 0001 0101 1011 1100 1101 1010 1110 1101
1001 0110 1101 1100 1001 0010 1110 0011 1001 0111 1010 0011 0101 1000 0100 1101
1111 0001 0010 1011 1100 0110 0101 0000 1000 1100 0001 1110 1111 1101 0110 1010
1100 1001 1001 0001 1101 1100 0010 1101 0000 0110 1100 0000 1001 0000 0001 110
```

4.2.7.3 PN63

This pseudo-random sequence is repeated three times. It is defined as $X^6 + X + 1$ with a pre-load value of 100111. The middle PN63 is inverted on every other Data Field Sync. The sequence is:

```
1110 0100 1011 0111 0110 0110 1010 1111 1100 0001 0000 1100 0101 0011 1101 000
```

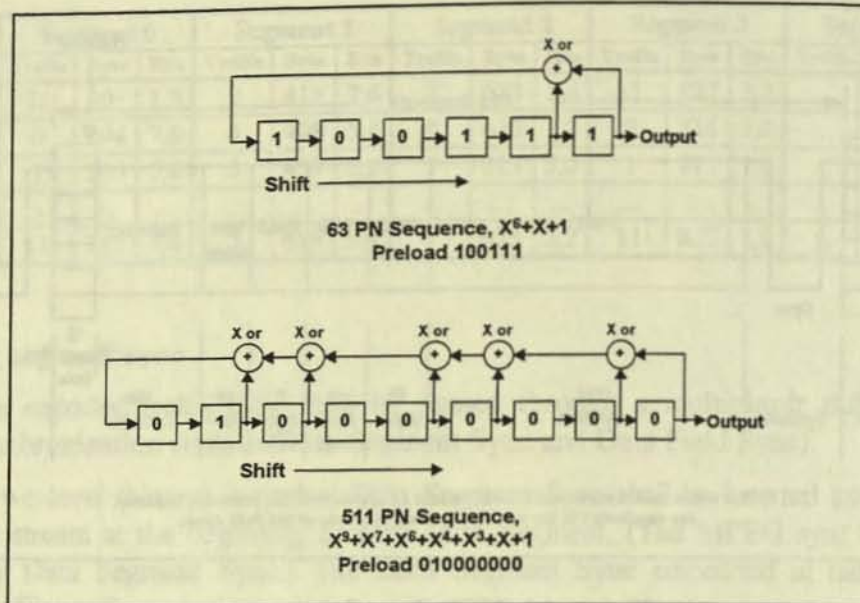The generators for the PN63 and PN511 sequences are shown in Figure 11.

Figure 11. Field sync PN sequence generators.

4.2.7.4 VSB mode

These 24 bits determine the VSB mode for the data in the frame. The first two bytes are reserved. The suggested fill pattern is 0000 1111 0000 1111. The next byte is defined as:

$$\overline{P\ A\ B\ C}P\ A\ B\ C$$

where P is the even parity bit, the MSB of the byte, and A,B, C are the actual mode bits.

P A B C	
0 0 0 0	Reserved
1 0 0 1	Reserved
1 0 1 0	Reserved
0 0 1 1	Reserved
1 1 0 0	16 VSB
0 1 0 1	8 VSB*
0 1 1 0	Reserved
1 1 1 1	Reserved

* In the 8 VSB mode, the preceding bits are defined as :

$$0\ 0\ 0\ 0\ \overline{P\ A\ B\ C}P\ A\ B\ C\ 1\ 1\ 1\ 1$$

4.2.7.5 Reserved

The last 104 bits shall be reserved space. It is suggested that this be filled with a continuation of the PN63 sequence. In the 8 VSB mode, 92 bits are reserved followed by the 12 symbol definition below.

4.2.7.6 Precode

In the 8 VSB mode, the last 12 symbols of the segment shall correspond to the last 12 symbols of the previous segment.

All sequences are pre-loaded before the beginning of the Data Field Sync.

Like the Data Segment Sync, the Data Field Sync is not Reed-Solomon or trellis encoded, nor is it interleaved.

4.3 Modulation

4.3.1 Bit-to-symbol mapping

Figure 7 shows the mapping of the outputs of the trellis decoder to the nominal signal levels of (-7, -5, -3, -1, 1, 3, 5, 7). As shown in Figure 9, the nominal levels of Data Segment Sync and Data Field Sync are -5 and +5. The value of 1.25 is added to all these nominal levels after the bit-to-symbol mapping function for the purpose of creating a small pilot carrier.

4.3.2 Pilot addition

A small in-phase pilot shall be added to the data signal. The frequency of the pilot shall be the same as the suppressed-carrier frequency as shown in Figure 3. This may be generated in the following manner. A small (digital) DC level (1.25) shall be added to every symbol (data and sync) of the digital baseband data plus sync signal (±1, ±3, ±5,±7). The power of the pilot shall be 11.3 dB below the average data signal power.

4.3.3 8 VSB modulation method

The VSB modulator receives the 10.76 Msymbols/s, 8-level trellis encoded composite data signal (pilot and sync added). The ATV system performance is based on a linear phase raised cosine Nyquist filter response in the concatenated transmitter and receiver, as shown in Figure 12. The system filter response is essentially flat across the entire band, except for the transition regions at each end of the band. Nominally, the roll-off in the transmitter shall have the response of a linear phase root raised cosine filter.

5. TRANSMISSION CHARACTERISTICS FOR HIGH DATA RATE MODE

5.1 Overview

The high data rate mode trades off transmission robustness (28.3 dB signal-to-noise threshold) for payload data rate (38.57 Mbps). Most parts of the high data rate mode VSB system are identical or similar to the terrestrial system. A pilot, Data Segment Sync, and Data Field Sync are all used to provide robust operation. The pilot in the high data rate mode also is 11.3 dB below the data signal power. The symbol, segment, and field signals and rates are all the same, allowing either receiver to lock up on the other's transmitted signal. Also, the data frame definitions are identical. The primary difference is

the number of transmitted levels (8 versus 16) and the use of trellis coding and NTSC interference rejection filtering in the terrestrial system.
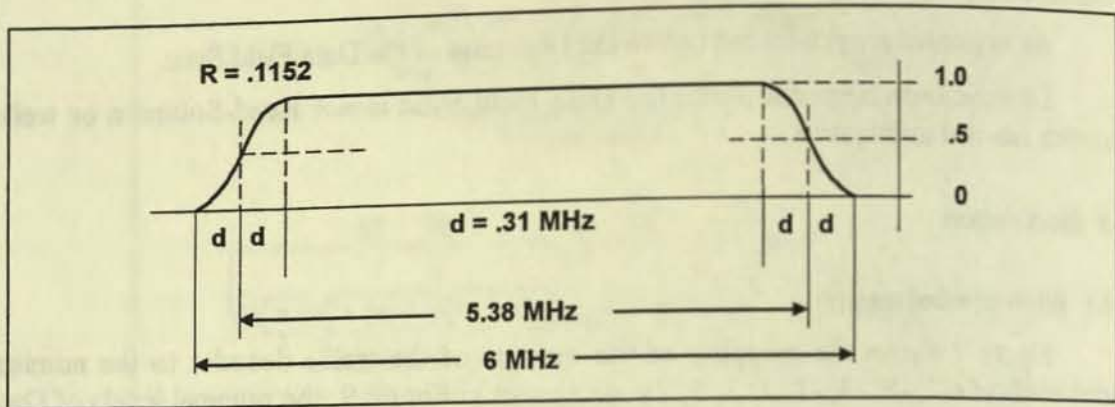

**Figure 12. Nominal VSB system channel response
(linear phase raised cosine Nyquist filter).**

The RF spectrum of the high data rate modem transmitter looks identical to the terrestrial system, as illustrated in Figure 3. Figure 13 illustrates a typical data segment, where the number of data levels is seen to be 16 due to the doubled data rate. Each portion of 828 data symbols represents 187 data bytes and 20 Reed-Solomon bytes followed by a second group of 187 data bytes and 20 Reed-Solomon bytes (before convolutional interleaving).
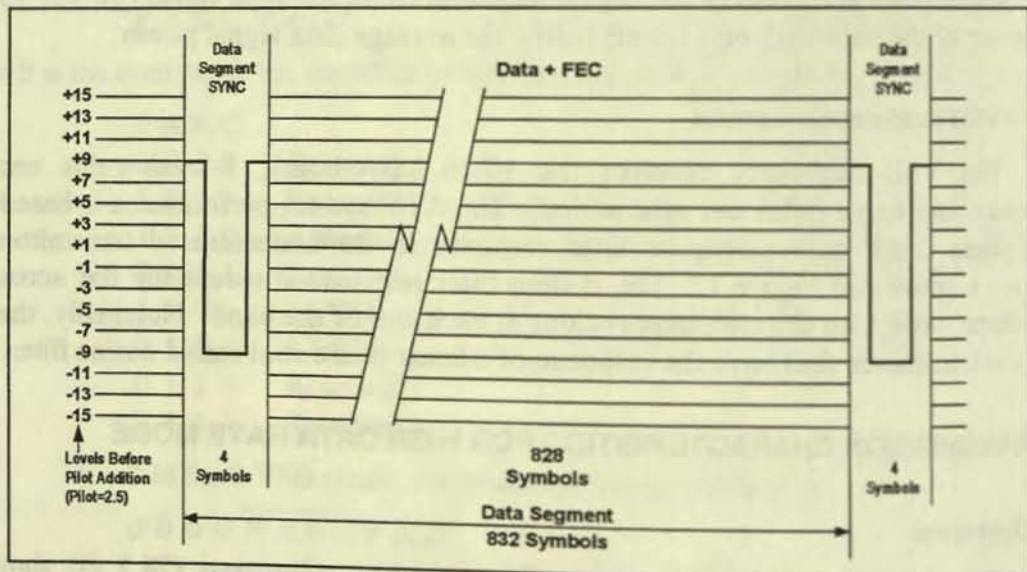

Figure 13. 16 VSB data segment.

Figure 14 shows the block diagram of the transmitter. It is identical to the terrestrial VSB system except the trellis coding shall be replaced with a mapper which converts data to multi-level symbols. See Figure 15.
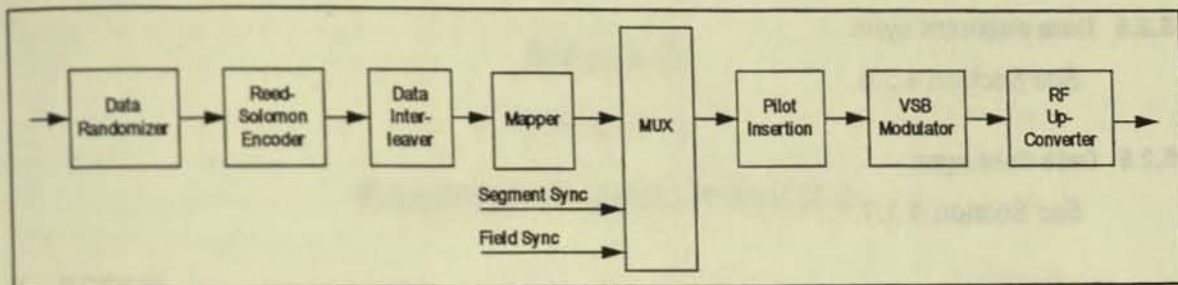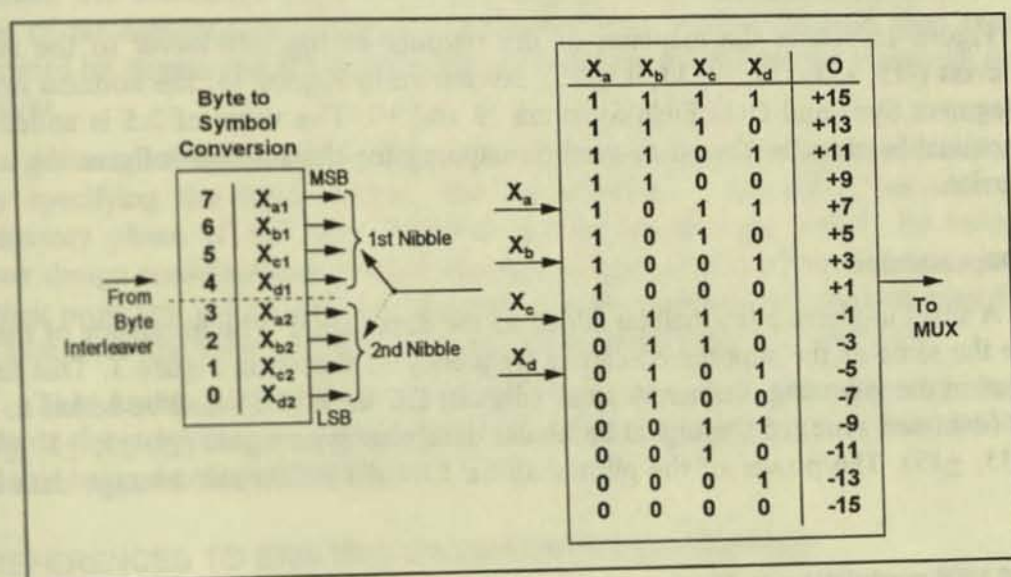
Figure 14. 16 VSB transmitter.

X_a	X_b	X_c	X_d	O
1	1	1	1	+15
1	1	1	0	+13
1	1	0	1	+11
1	1	0	0	+9
1	0	1	1	+7
1	0	1	0	+5
1	0	0	1	+3
1	0	0	0	+1
0	1	1	1	-1
0	1	1	0	-3
0	1	0	1	-5
0	1	0	0	-7
0	0	1	1	-9
0	0	1	0	-11
0	0	0	1	-13
0	0	0	0	-15

Figure 15. 16 VSB mapper.

5.2 Channel error protection and synchronization

5.2.1 Prioritization

See Section 4.2.1.

5.2.2 Data randomizer

See Section 4.2.2.

5.2.3 Reed-Solomon encoder

See Section 4.2.3.

5.2.4 Interleaving

The interleaver shall be a 26 data segment inter-segment convolutional byte interleaver. Interleaving is provided to a depth of about 1/12 of a data field (2 ms deep). Only data bytes shall be interleaved.

5.2.5 Data segment sync

See Section 4.2.6.

5.2.6 Data field sync

See Section 4.2.7.

5.3 Modulation

5.3.1 Bit-to-symbol mapping

Figure 15 shows the mapping of the outputs of the interleaver to the nominal signal levels (-15, -13, -11, ..., 11, 13, 15). As shown in Figure 13, the nominal levels of Data Segment Sync and Data Field Sync are -9 and +9. The value of 2.5 is added to all these nominal levels after the bit-to-symbol mapping for the purpose of creating a small pilot carrier.

5.3.2 Pilot addition

A small in-phase pilot shall be added to the data signal. The frequency of the pilot shall be the same as the suppressed-carrier frequency as shown in Figure 3. This may be generated in the following manner. A small (digital) DC level (2.5) shall be added to every symbol (data and sync) of the digital baseband data plus sync signal (± 1, ± 3, ± 5, ± 7, ± 9, ± 11, ± 13, ± 15). The power of the pilot shall be 11.3 dB below the average data signal power.

5.3.3 16 VSB modulation method

The modulation method shall be identical to that in Section 4, except the number of transmitted levels shall be 16 instead of 8.

ANNEX E

(Informative)

RECEIVER CHARACTERISTICS

1. SCOPE

This informative Annex provides material to help readers understand and implement the normative portions of the Digital Television Standard. The normative clauses of the Standard do not specify the design of a receiver. Instead, they specify the transmitted bit stream and RF signal with a thoroughness sufficient to permit the design of a receiver.

Although the normative portions of the Standard are written in the traditional way — by specifying the signal format, not the receiver — the ATSC believes that the introductory phase of this new Standard can be made more orderly by listing some receiver design considerations in this informative Annex. Service providers need assurance that their programs will be correctly processed in all receivers, and receiver manufacturers need assurance that their receivers will function properly with all broadcasts.

This Annex also contains references to existing (both voluntary and mandatory) standards for television receivers and notes work in progress on voluntary industry standards being developed at this time.

2. REFERENCES TO EXISTING OR EMERGING STANDARDS

47 CFR Part 15, *FCC Rules.*

EIA IS-132, *EIA Interim Standard for Channelization of Cable Television.*

EIA IS-23, *EIA Interim Standard for RF Interface Specification for Television Receiving Devices and Cable Television Systems.*

EIA IS-105, *EIA Interim Standard for a Decoder Interface Specification for Television Receiving Devices and Cable Television Decoders.*

3. COMPLIANCE NOTATION

Compliance with mandatory or voluntary standards and recommended practices for digital television receivers can be inferred only from previous experience with NTSC. Actual standards for digital television receivers have not been developed at this time. As used in this document "appropriate" means that the existing rules for NTSC which are referenced contain most elements of future rules for digital television. Furthermore, the rules may be expanded to cover digital television.

4. STATUS OF RECEIVER STANDARDIZATION ACTIVITIES

4.1 Tuner performance

The FCC Rules under 47 CFR Part 15 which are applicable to conventional television receivers are expected to be appropriate for digital television receivers.

4.1.1 Noise figure

The 10 dB noise figure used as a planning factor has been reviewed considering the needs of digital television reception and has been found appropriate.

4.1.2 Channelization plan for broadcast and cable

The cable channelization plan specified in the FCC Rules under 47 CFR Part 15 which are applicable to conventional television receivers are expected to be appropriate for digital television receivers. Broadcast channelization is specified in the FCC Rules under 47 CFR Part 73.

4.1.3 Direct pickup

The FCC Rules under 47 CFR Part 15 which are applicable to conventional television receivers may be appropriate for digital television receivers, as well. Performance characteristics for reception of digital signals, whether standard or high definition, have not been developed by the industry. It is expected that direct pickup of a given level will have less effect on digital signals than on NTSC.

4.2 Transport

Significant work for identification of multiple programs within a single digital television channel has not taken place in the industry. It is recommended that a digital television receiver provide appropriate features to assist users in the selection of the desired video program service, if multiple video programs within one channel are offered.

4.3 Decoder interface

The FCC Rules which are to be adopted for a decoder interface on NTSC receiver advertised as "cable-ready" or "cable-compatible" are expected to be appropriate for digital television receivers. Much work has been done on this interface standard (IS-105) by the Joint Engineering Committee of EIA and NCTA. Although that interface standard is not intended to apply to digital television receivers, it will almost certainly provide a basis for a decoder interface standard applicable to them.

4.4 Digital data interface

Work on a digital data interface is being performed by the EIA's R-4.1 subcommittee on ATV Receiver Interfaces. R-4.1 intends to define a baseband serial

digital interface so that devices may exchange packetized data, for example, when a digital VCR is connected to a digital television receiver.

It is recommended that manufacturers of digital television receivers wishing to include a digital data interface give consideration to the interface developed by R4.1.

4.5 Conditional access interface

The National Renewable Security System (NRSS) Subcommittee of the Joint Engineering Committee of EIA and NCTA has the responsibility to develop a standard for a plug-in security module. The NRSS standard may be applied in either a standard definition or high definition environment.

It is recommended that manufacturers of digital television receivers wishing to include a conditional access interface give consideration to the NRSS standard developed by the JEC.

4.6 Closed captioning

Closed captioning for television is covered by the FCC Rules under 47 CFR Part 15 which are presently applied to conventional television receivers. These rules are expected to be appropriate for digital television receivers.

Work on defining the technical standard for closed captioning for the digital television system is being performed by the EIA's R-4.3 subcommittee.

5. RECEIVER FUNCTIONALITY

5.1 Video

It is recommended that a digital television receiver be capable of appropriately decoding and displaying the video scanning formats defined in the Digital Television Standard and described in Table 3 "Compression Format Constraints" in Annex A of this Standard.

5.2 Audio

It is recommended that a digital television receiver be capable of selecting and decoding any audio service described in Section 6 of Annex B of this Standard, subject to the bit rate constraints in Section 5.3 of Annex B of this Standard.

It is recommended that a digital television receiver be capable of normalizing audio levels based on the value of the syntactical element dialnorm which is contained in the audio elementary stream.

It is recommended that a digital television receiver be capable of altering reproduced audio levels based on the value of the syntactical element dynrng which is contained in the audio elementary stream.

It is recommended that a digital television receiver provide appropriate features to assist users in the selection of program related audio services.

ANNEXES

{ Not included in this compilation. }

Annex 1.
Test Report of the
Advanced Television Test Center

Annex 2.
Test Report of CableLabs

Annex 3.
Test Report of the
Advanced Television Evaluation Laboratory

Annex 4.
Field Testing Report of MSTV

Annex 5.
Field Testing Report of CableLabs

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F>
To: Sam Fuller@LJO,
         Tom Gannon@LJO
CC: Bruce Holbein@MSO,
         Tom Siekman@MSO,
         Robert Bismuth@LJO

     The ACATS meeting yesterday at the Commission went smoothly. Between
Craig Mundie of Microsoft and myself, the computer industry presented a
unified and coordinated position. In fact, Craig Mundie came-off as being
quite the diplomat! Our conversations with him prior to the meeting seemed
to have paid-off. As a result, his comments were thoughtful focusing on the
rapid evolution of computer technolgies. He never mentioned his laundry list
of objections to the ACATS recommendations, in fact, he never used the words
"progressive scan".

     My remarks centered around the CSPP letter applaudeding the ACATS
process. I also took the opportunity to stress the industry's continuing
concerns that failure to migrate to progressive scan quickly will retard the
convergence of video and computing technologies. After I finished, Jae Lim
from MIT said that he seconds the comments made by Digital Equipment.

     Finally, when the vote was taken to approve the ACATS recommendation,
Dick Wiley was very clever by taking a voice vote and not a roll call vote.
First he asked for those voting in favor of the ACATS recommendations -- a
loud vote of yes, but Craig and I were silent. Then Dick asked for those
voting to oppose the recommendation -- there was silence. Again, Craig and
I were silent. Dick never asked for a vote of present or to abstain!

     All's well that ends well.

Regards, Grace

digital

Digital Equipment Corporation
Government Relations and International Trade Law
1401 H Street, N.W.
Washington, D.C. 20005

fax

To   SAM FULLER & TOM GANNON

Fax   **Phone**

Total pages including cover   **Date**   11/16/95

From   Grace L. Hinchman

                Manager, Public Affairs

Fax   (202) 383-5030   **DTN fax** 427-5030

Phone   (202) 383-5003   **DTN** 427-5003

Internet address   grace.hinchman@dcc.mts.dec.com

Subject   Sam & Tom: Attached is a copy of the Microsoft

submission to Dick Wiley which actually reflects Apple's

position. Also attached is a memo Paul Misner (A partner of Dick

Wiley's) sent to Microsoft to try and explain the issues outlined

in the Microsoft memo. Apparently, Craig Monday of Microsoft is

going to try and call Sam to try and discuss these issues prior to

the November 28th meeting. Please give a call if you have any

any questions.   Grace.

If you have any problems receiving this fax, please call

Phone   Sherri Thomas   **Phone** (202) 383-5631 (DTN 427)

MICROSOFT

FAX

To: Paul Misener

COMPANY: Wiley, Rein & Felding

Fax: 202/429-7207

From: **Jack Krumholtz   (202) 895-2169**

Fax: 202/364-8853

Date: November 15, 1995

No. of Pages (including this page) 6

☐ **Urgent**   ☐ **For Review**   ☐ **Please Comment**   ☐ **Please Reply**   ☐ **Please Recycle**

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Please contact Shirley King 202/895-2170, if there is a problem with the transmission.

● **Comments:**

    Paul - Per my voicemail message. Please call to discuss.

                                                                Jack

M

Advanced Television (ATV) Position Paper

November 15, 1995

Overview

The computer industry as a whole has not used the national television standard[1] for computer displays for many years now, finding it inadequate for clear, crisp presentation of modern computer applications. The bifurcation of the display technology business into disjointed computer and television branches made sense so long as television broadcast was analog and computer displays were, of course, driven digitally. It did not matter when the number of personal computers was small relative the number of home televisions.

The massively influential digital revolution, now in full flower, has changed the logic. Television broadcast is to be completely digital, and home computer sales approach or exceed those of home television sets. Digital technology is now sufficiently developed to actually implement the "digital convergence" between video and computers.

We believe that the current ACATS proposal to the FCC for a new digital television broadcast standard does not adequately support the digital convergence now possible between television and computing.

The ACATS proposal[2] does include some accommodation for computer industry concerns. We believe, however, that the approach advocated will cause compliant displays to be so expensive that market pressures will force vendors to subvert the proposed standard, honoring only convenient subsets of the proposal. This would lead directly to a continuation of today's bifurcation into two unconverged markets. Those parts of the proposal that the broadcast industry found useful would be honored by one subset of vendors, those parts compatible with computer industry needs by another. Neither branch would fully honor the standard as proposed – the "standard" would fail to standardize.

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[1] NTSC in the U.S. A similar statement holds for PAL and SECAM in other countries.

[2] Essentially that of the Grand Alliance.

v1.02

The Issues

The following specific issues are addressed subsequently in some detail:

- No data capability (a digital data channel without specification)
- Interlaced scanning (as opposed to progressive)
- Requirement of multiple unrelated display formats (as opposed to a single base level plus optional layered improvements)
- 60 Hz transmission rate (as opposed to, say 72 Hz)
- Non-square pixel spacing for lower resolution formats
- Awkward aspect ratios (most popular film aspect ratio not honored)
- Overscan not defined
- Limited colorimetry
- Must deploy now

Data Capability

A general way to look at a digital broadcast channel is as a stream of bits, not necessarily carrying video information, to each consumer. The MPEG-2 digital compression standard, upon which the ACATS proposal is built, permits transmission of arbitrary data. The ACATS proposal, however, does not provide for standardization of this general and powerful data capability which could be of immense importance in the transmission of, for example, text, graphics, alternative audio, computer programs, and overlay planes.

We believe that the FCC should standardize the use of its channels for general data transmission as well as video — for applications other than just broadcast television. Particularly important would be error correction mechanisms and transmission protocols.

Interlace v Progressive

We believe that interlaced scanning should no longer be supported. If video were being created for the first time today, interlace would not be suggested by anyone in our industry as a new standard.

Almost no modern computer displays use interlacing because of the difficulty reading text and line graphics on interlaced displays. Horizontal lines, in both text and graphics, flicker in a most unpleasant manner.

Integration of digital video with text and line graphics is happening now in the multimedia component of the computer industry, a very expansive consumer market.

Although it is possible to up-convert interlaced to non-interlaced (progressive) scan by circuitry in a display or receiver, we believe the cost per unit to do a conversion of adequate high quality to be prohibitive for the consumer market. Quality should match or exceed today's common standard in the computer industry.

We believe that it is possible to compress high resolution formats with progressive scan into the allowed channels.

Multiple Formats

The ACATS proposal offers 14 different display formats, 11 if interlaced ones are disallowed.[3] A television receiver, to be compliant, would have to honor all of them. We believe the cost of this, per set, would be so high as to make the proposal unrealistic.

Although the collection of 14 formats is described as a "layered" system, it is not a layered system as that term is used in the computer industry. A layered system would have a base layer that all displays honor. Then each higher resolution or wider format layer, from a logical *family* of formats, would be combined in or over the base layer if the receiver honored it. There is no required, or base, format in the current proposal (since presumably all formats are honored). The 14 formats do not form a logical, interrelated family; they are simply listed.

Refresh Rate

A 60 Hz refresh rate (or slower) is insufficient for the computer display market, in particular for text display of the quality currently expected by users of computer applications. Even with progressive scan, a 60 Hz progressive display of black text on a white page background — quite common in word processing — very noticeably flashes, an unpleasant and tiring phenomenon. The computer industry has settled on displays with refresh rates of 70 Hz or higher.

It is possible to up-convert from 60 Hz to 70 or more, but as with interlace-to-progressive scan conversion, the circuitry to do so per unit at a satisfactory quality level (at or exceeding current computer industry standards) we believe to be unrealistically expensive.

A rate of 72 Hz is compelling, being an exact multiple of the 24 Hz rate used in the film industry. Since film is used to produce a high percentage of television content, we believe a rate easily converted from the standard film rate and slightly greater than the 70 Hz required by the computer industry is attractive.

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[3] Actually 18 and 14, respectively, if different aspect ratios are counted as different formats too.

Square Pixel Spacing

The ACATS proposal supports square pixel spacing[4] for "most" of the 14 formats. However, three of the lower resolution formats have non-square pixel spacing: 704x480 on a 4:3 screen, 704x480 on a 16:9 screen, and 640x480 on a 16:9 screen.

Although it is possible to compensate for non-square pixel spacing with special circuitry, this again adds expense to the display. Furthermore, the vast majority of computer operating systems and applications programs assume square pixel spacing. Image file formats would have to be changed to include fields indicating the pixel spacing ratio (the ratio between horizontal spacing and vertical spacing).

We believe it makes more sense to simply disallow formats with non-square pixel spacing. A logical layering scheme would honor this rule.

Aspect Ratios

The ACATS proposal supports two aspect ratio: 16:9 and 4:3. The lower ratio 4:3 (about 1.333:1) is that of the current national television standard. We do not oppose this standard being continued for low resolution formats.

We believe, however, that the higher ratio 16:9 (about 1.777:1) is a curious one that may satisfy viewers looking for a broader format, but does so in isolation from the rest of the communications world. In particular, the film industry — again, the source of much television content and soon multimedia content for the computer industry — uses two aspect ratios commonly. One very common format is 1.85:1. The other, wide-screen (Cinemascope, or Panavision) format is 2.4:1.

We believe that an aspect ratio of 1.85:1 makes more sense than 1.777:1. The 2.4:1 format is probably too expensive to realize in cathode-ray technology to be feasible. A truly layered system of interrelated formats could provide a 4:3 base layer with higher layers at 1.85:1 (or larger) aspect ratio.

We also believe that the television and film industries should preserve film properties during the digitization process applied to film and only convert them to some other format at a last step, if necessary, in a receiver or display. Thus cropping and letterboxing standards for digitized film displayed on FCC formats should also be established. The MPEG-2 compression standard could be used in this regard, using its "pan-and-scan" capability.

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[4] Pixels are points, not squares. It is the spacing of these points that is the issue. "Square pixel spacing" means that the pixels are equally spaced horizontally and vertically and is the preferred wording.

Overscan

Computer applications commonly use the edges of the displayed image for user interface controls, such as menus, buttons, and sliders. Therefore overscan is not used in the computer industry. We believe that the need for overscan is arguable in the digital world and that it compromises the artistic intent of frames created full frame.

If overscan is allowed then it should be precisely defined, rather than undefined as in the ACATS proposal. A precise definition would specify exactly the area of a frame visible on all displays.

Colorimetry

An increasingly serious problem with computer displays is color constancy. An image on one display often looks very different when seen on a different display, even from the same manufacturer. This problem is becoming more and more important as color applications, such as multimedia and graphic arts, become prevalent.

We believe that the ACATS proposal does not adequately address this complex issue.

Must Deploy Now

The ACATS has urged the FCC to act promptly on deployment of a new digital television standard. We believe that the rapid development of digital computer technology has changed the nation's needs during the eight years that the advanced television issues have been studied (not counting the even longer periods in other countries). Some of these needs are sketched above.

We believe these issues are too important to be overlooked in a rush to deployment. The current standard has been with us for many decades. We can assume that any new standard will generate an equally inertial infrastructure. We suggest that the issues above are serious and require reasoned deliberation.

Conclusion

We believe, for the reasons outlined above, that the ACATS proposal currently before the FCC is inadequate and will not be honored. We believe that this is a once-in-a-lifetime opportunity for infrastructure redesign and that, therefore, revisions are required.

DRAFT

MEMO

To: Jack Krumholtz
From: Paul Misener
Subject: Response to Apple Presentation
Date: November 16, 1995

Pursuant to our telephone conversation yesterday, I prepared this memo based on an informal paper I wrote a few months ago with the help of Advisory Committee technical experts in response to various points made by Apple. I hope this is helpful. I look forward to talking with you some time soon.

I. Introduction

In sum, Apple's objections to the Grand Alliance ATV system under consideration by the Advisory Committee contain technical inaccuracies and/or misunderstandings of the tenets by which the FCC regulates television broadcasting, and a complete lack of consideration of the market economics and operational constraints that face the broadcasting industry. It is fair to say that Apple seeks a computer standard, not an interoperable broadcasting standard.

II. Apple's Basic Assertions

Contrary to Apple's assertion, computer interoperability has not been ignored by the Grand Alliance or in the Advisory Committee process. During the period 1990-1993, when four different digital systems were competing for selection, extensive interoperability reviews were held and a list of recommendations were developed by PS/WP-4. Apple was a key participant in this process. Interoperability criteria were considered and balanced with picture quality, coverage area, and other criteria during the Special Panel meeting in early 1993. Each of the competing systems had different features that provided interoperability advantages, and the Special Panel recommendation to allow improvements or a combination of the proposed systems paved the way for the formation of the Grand Alliance in May 1993. The current Grand Alliance ATV system contains every interoperability feature of all of the predecessor systems and addresses every interoperability consideration developed by PS/WP-4. Further, a digital video workshop co-sponsored by NIST and ARPA, and heavily attended by computer industry companies, endorsed the Grand Alliance system with no dissenting votes. Similarly, a federal Information Infrastructure Task Force committee endorsed rapid adoption of the Grand Alliance system as being critical to the future video rich NII.

Despite the importance of the interoperability of the FCC terrestrial broadcasting standard with computers, it must be kept in perspective. In some instances, interoperability

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comes at the expense of picture quality, coverage area, or excessive cost to broadcasters or consumers and, accordingly, must be balanced against these diverse requirements placed upon a terrestrial broadcasting system. Broad uses and application of a terrestrial broadcasting standard are highly desirable, but should not deter the FCC from its primary objective. In fact, the current ATV proposal carefully considers and balances technical parameters that result in a system that serves both entertainment and computing applications, within the constraints that a 6 MHZ broadcast transmission system allows. Of course, the Advisory Committee also has endeavored to facilitate interoperability with other transmission media and devices, including NTSC broadcasting systems.

Apple's seems to believe that televisions and computers should be forced to merge or, more specifically, that televisions should become computer displays. Most experts take a more balanced view that although the convergence of technologies creates opportunities for such merged products, the initiative to create them is best left to competitive forces and consumer acceptance.

Ironically, Apple would need the single TV-computer device standard to come from the television industry because it seems highly unlikely that a single approach could emerge from the computer industry, particularly because that industry has been unable to standardize a uniform display format and frame rate that works across multiple vendors' computers. One need only to look at a mail-order computer catalog to see the incompatibility and lack of interoperability in the computer display market.

Moreover, today's multimedia computers are capable of handling NTSC video, which is fundamentally far less interoperable with computers than the Grand Alliance system. NTSC is the worst of all worlds from a computer interoperability standpoint: it is analog, interlaced, non-square pixels, 59.94 Hz frame rate, etc. And yet, a wide variety of NTSC video related computer products are available from many different vendors, including Apple (*see*, for instance, their center advertising insert in last week's *Business Week*).

If, as Apple warns, a separate ATV system were to emerge for computers, both computer manufacturers and television receiver manufacturers would be free to produce premium products with the functionality to decode both standards. Such products will be technically and economically feasible using software based decoding on high performance microprocessors that will be used in future PCS. In the era of the Internet, decoding software for many different video compression approaches can be downloaded from an online server. In fact, Apple's own Quicktime video software product for the Macintosh allows different types of video compression to be applied to video files. It seems likely that the broadcast ATV standard will be an important format for video, but possibly not the only one -- if only because the computer industry seems to foster diversity.

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Finally, in a networked computing environment, the computer industry's own lack of interoperability across vendor-specific operating systems, file formats, and display formats constitutes a *far* more fundamental interoperability barrier than any broadcast ATV issue. Most corporate users of computers continue to be frustrated by the inability of Windows-based PCS, Apple Macintoshes, and various workstations running different flavors of UNIX to share application software and to seamlessly interoperate with text, graphics, sound, and video.

So much for Apple's basic philosophy on ATV. In addition, however, many of Apple's specific objections to the ATV system that are flatly untrue, technically inaccurate, or they concern issues that are not relevant to a transmission standard and, thus, are not within the regulatory scope of the FCC or its Advisory Committee.

III. Specific Apple Allegations

A.   Interlace Scanning

Apple's objects to the use of interlace in some standard definition ATV formats. Progressive scan, square pixel formats that are VGA compatible (640 x 480) are provided for the SDTV applications of ATV that benefit from their use. Interlace is just another form of compression, which has its place in a multiple format system wherein — within the constraints allowed by the bit rate that can be transmitted in 6 MHZ — program producers can choose the format and frame rate that provides the combination of spatial resolution, temporal resolution, and transmission bit rate that is best suited for their application. Each of these parameters has its own associated artifacts, which have different levels of visibility on different kinds of picture content and which must be balanced in a compressed video system.

Indeed, reducing spatial resolution results in fuzzy, unclear pictures that are unacceptable in many applications. Reducing frame rate results in jerky motion. Reducing bit rate results in blockiness and noisy pictures. The use of interlace is a compromise between spatial and temporal resolution that simultaneously provides smooth motion rendition and full vertical resolution on still pictures. This approach has served television quite well for the last 50 years, and cannot be hastily precluded as one of the format options in an ATV system. Apple's attempt to limit the scope of format choices available to content producers is inconsistent with the flexibility in its own Quicktime product and, more fundamentally, it ignores scientific principles and good engineering practices which enable moving images to be represented in the format that represents their content with the least objectionable degradation.

Apple claims that perfect de-interlacing is theoretically impossible. Although it is true that certain pathological cases can be identified where de-interlacing algorithms will not properly remove interlace artifacts, these pathological cases are of little practical consequence.

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The kinds of pictures, text, and graphics that are commonly used in both television and
computers can be de-interlaced extremely well. The television industry has been developing
de-interlacing techniques for well over 10 years and the performance of de-interlacers will be a
source of competition among manufacturers. Furthermore, contrary to Apple's assertion, a de-
interlacer is not a large expense. Relative to the complexity of High Level MPEG-2 decoders
and the other functionality required in an ATV receiver, a very good de-interlacer can be
provided in receivers at small incremental cost. The level of IC technology used to produce a
cost-effective ATV receiver (or a high performance microprocessor) allows a de-interlacer to
occupy a small portion of a single IC. The consensus opinion of the five consumer electronics
and/or IC manufacturers in the Grand Alliance (Thomson, Philips, Zenith, GI and AT&T)
who are committed to produce ATV receivers with de-interlacing circuitry credibly rebuts
Apple's unsubstantiated assertions.

B.   60 Hz Scanning Rate

        First and foremost, Apple's arguments relate to display issues that have nothing to do
with a transmission standard. The notion that a transmission frame rate is tied to display frame
rates is an obsolete technical concept. The ATV system allows transmission at 23.98, 24,
29.97, 30, 59.94 and 60 Hz. These rates are adequate to represent a wide range of camera
panning and motion rendition. Of course, motion picture films successfully continue to use a
24 Hz frame rate despite the fact that higher frame rates are technically possible. Double or
triple shuttering is used to reduce display flicker in theaters, with 48 Hz being the most
common display frame rate for film. In computers, where there is no standard for display
format or frame rate, it is the responsibility of software to determine the method of conversion
between source and display frame rates. Some software alters the speed of the video clip to
match the display frame rate, while other software occasionally repeats (and/or deletes)
frames. A similar approach has been successfully used for showing 24 Hz films on 59.94 Hz
television for over 40 years. Apple's own Quicktime product is an example of such video
display software, which is capable of showing 59.94 Hz video on either 66 Hz or 75 Hz Apple
computer screens.

        As for Apple's assertion that 70+ Hz is required for displays, it is notable that many
computer screens (including most of Apple's) run at 66 Hz. It seems rather strange that while
Apple is such a staunch advocate of 72 Hz, it makes 66 Hz and 75 Hz displays for its
Macintosh computers, but no 72 Hz display. (If it's such a good idea - why not?) Computer
displays are also available at 60 Hz and a wide variety of other rates. The real technical need
is to achieve a display rate that is adequate to eliminate human perception of large area flicker.
Perceptibility of flicker is a function of display brightness and viewing distance (flicker is
actually more perceptible in peripheral vision than in foveal vision). Flicker perceptibility is a
rather smooth function of display rate that has no sharp threshold. Thus, it is not surprising
that a wide variety of computer display rates have proliferated. Also, the requirements of

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entertainment displays are different than computer displays, which are scrutinized at very close viewing distances. Entertainment television display has been sufficient at 60 Hz, and no need for higher display rates is accepted by the consumer electronics industry, particularly since a higher display rate increases cost. Receiver manufacturers are free to provide any display rate or rates that they desire, and accomplish this with either multi-scan displays or electronic frame rate conversion.

The MPEG-2 standard used in ATV identifies its frame rates in a header/descriptor, but despite extensive participation by computer companies, no explicit provision was made for a 72 Hz frame rate in the MPEG-2 header. Many representatives of the computer industry participated in the MPEG-2 process (indeed, as you may know, the Information Technologies Industry Council ("ITI") is the secretariat for the U.S. MPEG group), and Apple's assertion that 72 Hz transmission represents computer industry interests is unsubstantiated by the facts.

The observation that 24 Hz movie transmission (provided by the ATV system) would look very good on a 72 Hz display is quite correct. But the display frame rate (or rates) used by ATV receiver or computer manufacturers is outside the domain of a transmission standard and the regulatory authority of the FCC. Further, it is a product decision that is best left to the competitive marketplace. Any HDTV manufacturer can provide 72 Hz display capability as a competitive feature. As for handling 60 Hz transmissions on a 72 Hz display, this requires the very same ratio conversion as the 50 to 60 Hz conversion that is routinely performed when European television is aired in the US.

C.   Lack of Data or Code Capability

Apple's assertion that the ATV system has no data or code capability is totally unfounded. The Grand Alliance prototype hardware has been subjected to extensive bit error rate measurements in both Laboratory and Field testing. These measurements document the bit error rate performance of the system as a function of carrier-to-noise ratio (CNR). In any wireless transmission system, the CNR at a given receiving location is a function of transmitter power, RF propagation, and receiver antenna gain.

Of course, viewable picture and acceptable audio tests at error rates in the 10^{-4} to 10^{-6} range are being tested - this is what determine the limits of television service broadcast in the extremely difficult VHF/UHF over-the-air environment. The fact that picture and sound can tolerate higher error rates than pure data is a fundamental characteristic of their nature. Since the ATV channel will be allocated to broadcasters for the primary use of providing television service to the public, it is entirely appropriate to establish planning factors that reflect the requirements for this application. Other frequency allocations for data PCS and wireless LANs (such as proposed by Apple) would undoubtedly consider different requirements for their primary use.

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Of course, error free data transmission is not guaranteed by any transmission system (particularly not by telephone modems used extensively for computer communications). In fact, communications theory tells us that there is a fundamental tradeoff between channel capacity and BER - raising the bit rate on a given medium inevitably increases the BER. Except near the limits of ATV coverage, a BER in excess of 10^{-9} is easily achieved and is more than adequate for most data applications. Further, near the limits of ATV coverage, BER improves by about one order of magnitude for a 0.25 dB improvement in CNR, meaning that consumers requiring better error rates for data applications can simply purchase a better antenna to improve their data reception reliability. In computer communications, it is up to the end-to-end application to ensure that usable data has been reliably received. Protocols like FTP apply error detection codes to assure the correct receipt of data - similar software approaches can be applied to data broadcast in the ATV channel by those applications that require it.

D.   Non-Square Pixels

Apple's arguments for square pixel formats center on applications that require overlay of geometrically accurate circles. Although this is certainly a virtue of the Grand Alliance HDTV and 640 x 480 SDTV formats, it must be recognized that not every application has such a requirement.[1] Apple's position on this issue is philosophically similar to their position on interlace. Despite the inclusion of the 640 x 480 (compatible with VGA computer displays) square pixel format in ATV, Apple wishes to deny other users of ATV the flexibility to choose formats with rectangular (non-square) pixels. The non-square pixel standard definition formats (704 x 480 in both 4:3 and 16:9 aspect ratios) are included in ATV to provide interoperability with the large archive of content and the installed base of production facilities of broadcasters. The 704 x 480 format corresponds to an international standard, ITU-R BT.601, that has been the basis for most digital television equipment purchases over the last 10 years, resulting in a substantial archive of programming content in this format. Apple's move to deny the existence of the 704 x 480 non-square pixel formats is odd, particularly because video capture boards that utilize this format in its interlaced form are available for virtually every brand of computer.

E.   Lack of Overlay Planes

Apple's perspective assumes that all applications are computer-based and require such capabilities. Overlay planes simply are not required for simple television viewing. The definition of such extensions to basic television service need not be (and should not be) defined as part of an FCC transmission standard. If necessary, they could be subsequently defined

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[1]   Apple's viewgraphs incorrectly state that a 640 x 480, 16:9 aspect ratio format is included in the Grand Alliance system. It is not.

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without delaying the introduction of service. Note that there is no unified computer industry
standard for cursor control, text and graphics definitions, standardized color lookup tables, 3-
D graphics or window controls, &tc. Microsoft and Apple products are completely different
on these issues. They even differ on window controls, and the mouse. Until a single computer
industry standard emerges for overlay, any voluntary or FCC-based standards are premature.

F.   Requirement to Decode All Formats

        Apple's position on this issue is irresponsible - it would let the public buy receivers
that will unexpectedly and unexplainably (to them) not function when certain formats are
transmitted. The advocated solution of layered compression is impractical. Extensive work in
layered coding has shown that it is not as efficient as single layer compression. While such
approaches are intellectually appealing and suitable for applications where limited bit rate is
not a constraint, this is not a practical approach to providing high quality HDTV pictures in a
6 MHZ channel. Apple's approach is "viewgraph engineering" - it remains totally
unsubstantiated. Apple has not demonstrated for the Advisory Committee so much as a single
video simulation of the approaches they advocate.

G.   Lack of Digital Interface Specification

        Apple's allegations on his issue are unwarranted and incorrect. Digital interfaces for
consumer television equipment have no place in the discussion of transmission standards. They
are totally outside the scope and purview of the FCC and its Advisory Committee process. Of
course, the consumer electronics industry recognizes the need to develop such standards. The
EIA is the appropriate standards body, and work on developing appropriate interface standards
is in progress.

H.   Poorly Conceived Aspect Ratios

        There are many different film formats - if there were one film standard, HDTV would
have used it. The 16:9 aspect ratio is a compromise -- developed by the Hollywood community
-- that minimizes the cropping required for pan and scan in the most commonly used film
formats; it likewise minimizes the loss of resolution when the original aspect ratio is
maintained. Broad national and international consensus on 16:9 goes back to the mid 1980s,
when the issue was actively discussed, particularly in a SMPTE standards committee chaired
by Universal Studios. It has been used in an HDTV production standard since the SMPTE
240M standard and the ITU-R (formerly CCIR) 50 Hz and 60 Hz production standards were
established in the late 1980s.

        The "any aspect ratio" approach advocated by Apple is unnecessarily complex. The
concern voiced by Apple over interpolation required to transform non-square pixel formats to

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square pixel ones is simple by comparison to the interpolation needed to handle the variety of aspect ratios that they advocate. The simple solution that Apple totally misses is that by simply performing the letterboxing at the broadcast source, any aspect ratio picture can be transmitted within the 16:9 transmission format. With this approach, ATV does not need any rules and the presentation of picture content in different film formats can be decided on a case by case basis by the program provider, using good artistic judgment.

I.   Overscan Not Defined

The discussion of overscan is a receiver issue that has no place in a transmission standard. Although overscan is commonly used in computer monitors, it is not defined or required by any standard. Why should TV be different? Apple's idea of a rigidly defined menu bar is outdated. It's own Macintosh software established the precedent of "tear-off" menus that can be separated from the main menu bar. Software should define "menu items" and leave the presentation details (where the menu is placed and how it looks) to the receiver.

J.   Limited TV Colors

Film, printers and TV have different color because they are different physical processes. Nothing about the ATV definition can change that.

Apple's assertions about computer color are misleading - most computers have a very limited color gamut (8-bit color is still quite common). There is no standard for color reproduction in computer monitors, and extremely inconsistent color matching among the many monitors that can be used with a given computer. A problem that Apple fails to acknowledge is that computer graphics are usually rendered in linear space rather than gamma corrected space, resulting in color errors on computer monitors.

The constant luminance principle suggested by Apple was well-understood and rejected by the proponents of all four digital HDTV systems and again subsequently dismissed by the Grand Alliance. Constant luminance has never been used in an imaging system (television or computer). The theoretical advantage of this approach is that transmission errors result in slightly less perceptible visual errors. Even in error-prone analog transmission systems, however, this approach has never had enough practical value to be used in a deployed system. In digital systems that exhibit perfect transmission over a wide range of impairments and then sudden catastrophic failure, constant luminance is of no practical value. It would be interesting to know whether Apple plans to support constant luminance representations in its Quicktime software.

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K.   Must Deploy Now

Apple's criticism of the Advisory Committee testing methodology is totally unwarranted and irrelevant to the ATV standard. Apple claims that software testing was never done. To the contrary, extensive software testing was done by the Grand Alliance and reviewed by the Advisory Committee during system development. As every video engineer knows, such simulations are a valuable step in developing a viable system design. But every experienced video engineer also has experienced techniques that appear to work well in simulation and exhibit unacceptable performance when implemented in real hardware. Accordingly, and by early agreement of the Advisory Committee, simulations are not sufficiently rigorous for establishing a national transmission standard.

Advisory Committee testing is far more rigorous and spans more material than software simulations. For example, software simulations do not usually adequately test rate control dynamics that involve performance over periods of picture material that fill the buffer and require rate control intervention. This was not of particular concern in developing the generic MPEG-2 standard, which left such details to subsequent competition. It would have been irresponsible for the FCC Advisory Committee to accept that adequate picture quality could be produced at a particular bit rate without hardware verification. It should further be noted that in addition to hardware testing, software verification of certain system aspects HAS been done in Advisory Committee laboratory testing (e.g., MPEG syntax compliance and bit stream splicing). It also should be noted that, in its years of participation in the Advisory Committee, Apple has not presented simulation results for the ideas that it advocates.

L.   Migration Strategy

Apple's allegations about migration strategy are way off base. The whole multi-format approach of ATV provides different formats so that each application can use the format most suitable for its particular characteristics. Forcing computer values onto entertainment television makes no more sense than attempting to force every computer display to be 60 Hz and use HDTV colorimetry in order to be TV-compatible. Apple just doesn't accept the fact that other companies PREFER to use formats that Apple doesn't like. (Maybe the FCC should outlaw Microsoft DOS file format, too!)

The approach of ensuring that ATV receivers can decode all formats is a responsible approach that protects the public and content creators from obsolescence. Contrary to Apple's assertion, no one advocates that interlaced content should suddenly become unwatchable on ATV. On the contrary, responsible parties involved in ATV standardization observe that if progressive formats indeed demonstrate their claimed advantages to the public, interlaced formats will gradually fade in popularity; the inclusion of multiple formats allows the

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marketplace to determine which formats are most widely used and accepted. Apple's approach is both restrictive and presumptuous.

IV. Concluding Remarks

Apple's continuing confusion between transmission standards and receiver related issues is doing a disservice to the broadcast, consumer electronics, and computer industries. Attempts to regulate ATV receiver performance can only be rationalized if the same rules are applied to computers. The result would be a harmful restriction of diversity and a distortion of marketplace preferences.

The Advisory Committee has sought to develop an *inclusive* standard which addresses the needs of terrestrial broadcasting -- for which this ATV transmission standard is primarily intended -- and all other affected industries. Apple, a company not known for its open systems standards, takes the opposite approach. Having failed to achieve consensus standards in its own industry, it seeks to *exclude* the needs of other industries in the standardization of ATV.