Interview of John Bingham

Interviewed by:
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James Pelkey: If you could help me first with, I know that you were with Vadic early on, and that you were at GTE Lenkurt before Vadic, but that's about all I know of your background.

John Bingham: Oh, I've been all over Silicon Valley. I was at GTE Lenkurt from '59 through -- with a couple of other interim periods that don't matter very much -- from '59 through '68, '68 or '69. In the early part of '70, I was at Fairchild. We went off to try to develop some modems at Fairchild; then from mid '70 to mid '72, I was at Memorex, where I also working on modems. The Fairchild thing didn't work out because they just pulled the rug out totally from under all of the financing. The Memorex thing just began to look like a dead end. At one time they had committed themselves to developing all their own modems and so on, but after a couple of years it became apparent that they weren't really very enthusiastic about it. By that time, I had developed a few interesting ideas on multiplexing, and I did indeed propose these to Memorex and got absolutely nowhere, so it was then that I went and approached Vadic. I knew the guy who was chief engineer at Vadic at that time. He had been with me in the venture at Fairchild, and had gone straight from Fairchild to Vadic, so when Memorex wasn't working out, I went to see Dennis Anderson and proposed some ideas to him. He said: "Well, come along and talk to Ken and Ted Saunders," and that was how it got started.

Pelkey: And what year was this when you joined them?

Bingham: This was '72.

Pelkey: Did you work on modems at GTE Lenkurt?

Bingham: At the end of my time with Lenkurt, yes. I was initially, in fact I really got started in my whole technical career, as a filter designer, and this became quite important in the early development of the full duplex modems, and I think we can talk about that in a little while. In the last two or three years at Lenkurt, I was in their data transmission department, and I was working with Adam Lender on a lot of the adaptive equalizer schemes and things like that.

Pelkey: And that was for -- they were interested in that for modem technology or central office type switching?

Bingham: For leased-line modems? They had developed a 208, and Adam had his own partial response scheme that Lenkurt had built into their own modem, which wasn't selling particularly well because it didn't conform to an AT&T standard.

Pelkey: In those days, the leased-line business, outside of some military, government and NASA applications, it was AT&T where the modem business was, in leased-line, and there was no dial-up business, correct?

Bingham: Yes.

Pelkey: So at Memorex you did some work as well on modem, but it never really got into a product?

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Bingham: They put it onto a card, and after I left, I talked to a few people, and they did build a couple of hundred of them, but Memorex in those days was such an ephemeral organization, you never knew for certain whether, each morning when you went in, if the place was still going to be there, and they had so many changes in management, just about the time I left, it looked as though they were going to dump the whole modem business, and I think they did, essentially. They decided to buy them outside.

Pelkey: Were they leased-line modems you were working on?

Bingham: Leased-line modems, yes.

Pelkey: So you never worked on any dial modems until you got to Vadic?

Bingham: Well, the effort at Fairchild was to build a very -- well, I guess, basically, for that time, which was a fairly ambitious undertaking, was to build a one chip 103.

Pelkey: That was ambitious.

Bingham: It was, at that time, yes, but they didn't really have the expertise. It would have been a very big chip, and I think they began to realize that this was impractical.

Pelkey: Where there any other people at Fairchild who were associated with that activity that became important in the communications industry today?

Bingham: Not in the communications industry as you think of it, thought actually in LANs –

Pelkey: Ralph Ungermann was there. Was Ungermann at Fairchild?

Bingham: You mean Ungermann of Ungermann -Bass? No. There was one guy who went on to try to form his own company to do some local area networks, his name is Milt something. Maybe it'll come to me later on, but I don't know that he'd be able to give you very much of a handle on the history.

Pelkey: What were the ideas that you got to Dennis Anderson?

Bingham: The primary one was -- the funny thing was that the one that I brought turned out, in the long run, to be impractical. The idea was to do all of the filtering in the baseband, and then be able to just chose a carrier frequency, modulate into the passband, and then, in the receiver, demodulate down into the baseband, using one of any number of different carriers, and do all of the recovery in the baseband. I had, by that time, perfected some, what were at the time, fairly innovative methods of carrier recovery and ways of doing coherent detection, which was known, but not much publicized at that stage. I thought that I had invented it. It turned out, subsequently, that Lindsey and Simon had thought of it before me, not much before but somewhat before, but as far as I was concerned I had invented it because I didn't know of Lindsey and Simon's work. So it was the idea of being able to modulate and demodulate with

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any number of different carriers, and then be able to do the carrier recovery in the baseband in the receiver in order to do coherent detection. At that time, QAM, quadra-triamplitude modulation, was nearly always affected in the receiver using something they called differential detection. Coherent detection was certainly understood by the better theorists, but was not much implemented, I gathered.

Pelkey: Where did you come up with those ideas and what prompted you to think about those ideas that led to you solve coherent detection?

Bingham: There was a problem that we were presented with at Memorex. We were trying to build a 201, which is a 2400 bit per second half duplex modem, and I just wanted to make a better receiver, that was all, and I can't for the life of me remember how it was that I came at that.

Pelkey: Was it something you did on your own or do you go off and do reading?

Bingham: There wasn't much to read, no, because -- don't remember any references at that stage. I subsequently found a whole sequence of them by Lindsey and Simon, which probably were published around about that time, but Vadic didn't have much in the way of a library.

Pelkey: Where were Lindsey and Simon?

Bingham: They were at UCLA. One of them was at UCLA, the other was as Linkabit. I think Lindsey is at Linkabit and Simon is at UCLA, but it might be the other way around.

Pelkey: So you went to Vadic and you presented these ideas, in terms of filter design, and coherent detection, and they said: "Let's have a try at that."

Bingham: Well, it was more complicated than that. The original idea I had was to build a -- 8 x 300 was my original suggestion. Yeah, that sounds right, because in my work at Lenkurt, with the leased-line stuff, there were quite a few of what they call telemetering modems, where they would take many low data rate channels and analog multiplex them onto a series of carriers, which would then be combined an passed over one phone line, and when I began to get these ideas at Memorex about these simple ways of doing multiplexing and then the de-multiplexing using QAM, I thought this was a natural for a telemetering type modem, so what I proposed to Vadic was an 8 x 300, and I explained how I was going to do it. Ken thought that 8 x 300 was interesting, but from his knowledge of the dial-up market, 2 x 12 would be much more interesting, and could I do a 2 x 12. So I went away and thought about it for a few days and said: "Yes, I certainly could." So I provided the technical idea --the theoretical idea -- Ken came up with the product, defined the product that we ought to design, so then we got together. Sometimes we like to say that Ken was the father of it and I was the mother of it, or vice versa, but we don't want to carry that analogy too far.

Pelkey: Was it early '72 when you joined Vadic?

Bingham: June of '72.

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Pelkey: And then you began to work on this product. You said how it came out was little bit different than where you started out?

Bingham: As it turned out -- to start with, the most important thing, I think, was my expertise in filter design, because that was the first of what later became a whole series of modems, but that was the first one where there was a fair amount of quite heavy filtering that had to be done in order to separate the very high level reflected transmit signal from the low level receive signal. In a dial-up situation, you may have very high losses on the line. On the other hand, you may have an extremely poor match of your own output impedance to the input impedance of the line, so you got a lot of your own transmitted signal reflected back, and you finish up having to do something like 60 or 65 dB of filtering to extract the little tiny receive signal from the very large reflected transmit signal. This, I think, since it was a full duplex modem, it was probably the first time that this problem had ever really been seriously tackled, so the filter design became very important. There was a guy by the name of Ted Saunders at Vadic in those days who had some good circuits for designing active RC filters, and his ideas and mine, that I had accumulated at Lenkurt, between us, managed to put together some very good filters, and in actual fact, they were -- the filters that were in the 3400 were better than anything that was in the 212 or any of the other full duplex modems that have come out subsequently. They're more economical. They're designed in a better way. They're not designed in a 'bull in a china shop' approach. So the filter design business is what gave me the edge, but the original way that I had thought about, which was doing all the filtering in the baseband in the transmitter, modulating, de-modulating, and then doing all the filtering in the baseband in the receiver, turned out not to be practical because of the enormous amount of delay through the filter -- I'm getting awfully technical now -- the enormous amount of delay through the low-pass filter in the receiver. What you have to do is look at the output of this filter in order to decide what to do with the phase of the de-modulating carrier, so it turns out that the delay through this rather large filter is inside the loop that you are using to control the de-modulating carrier, and indeed the carrier recovery loop, the idea that I had thought of previously, which worked very nicely in a half-duplex modem where you didn't have this large amount of filter, but where you have this enormous amount of filtering in the baseband, the carrier recovery loop didn't work worth a damn. It was incredibly slow, and sometimes it broke into oscillation, so we had to scrap that idea, and we went to a much more conventional idea of using band-pass filters rather than low-pass filters, but Ted had some interesting ideas about how to switch band-pass filters, which he had used in the 103, switched the pass-band of them, and so that was how the product eventually turned out. We finished up with two band-pass filters rather than low-pass filters.

Pelkey: When did you complete the 3400?

Bingham: We shipped the first ones in May of 1973, but it was arguable that they were not really completed until long after that, that that first year or so resulted in an enormous number of changes. It was an agonizing time as we went out on field trips and found out why this one didn't work and that one didn't work. We learned an enormous amount about the actual environment of telephone modems, the modem on the telephone line.

Pelkey: And when did it finally get robust?

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Bingham: The sales were quite low for about a year and a half. Probably the second version of it, the redesigned one that didn't have yellow wires all over it, came out in '75. So it was about '75 that it began to -- there was that period from '75 through '76 where, before AT&T announced theirs, was probably the best time as far as the 3400 was concerned. It was the only thing on the market and it was pretty well -- it was not totally debugged, but it was certainly doing pretty well by that time.

Pelkey: When did AT&T introduce the 212?

Bingham: The date I've got in mind is September of '76, but that was the date that was written on their compatibility specs. Whether the modem came out a few months before or after that I don't remember.

Pelkey: So from '75 until the Bell 212 was introduced, you were the only game in town?

Bingham: As far as 1200 full duplex, yes.

Pelkey: There were 1200 half duplex modems? Who was supplying those?

Bingham: Vadic made them. It was called a 203 or a -- the numbers, I always forget them. It was a CCITT V23 -- 202, sorry, 202. Yes, of course. The problem is that the CCITT numbers and the Bell numbers don't match up, and you tend to thing that the last digit is matching between the two, and they don't. It was either a Bell 202 or a V23 modem. Lot's of people were making those. There probably a dozen manufacturers in those days.

Pelkey: What was Vadic's business during this period of time, until you got this 3400 straightened out? Vadic started in, what, '69?

Bingham: That sounds right, late '69 or so.

Pelkey: Late '69. What was the company selling?

Bingham: Mainly 103s, I think. There biggest single customer was GE, or was it -- certainly they were building 103s for GE, and they had one other customer that they built a little 103 on a small card for, I can't remember who it was. That was probably their biggest seller.

Pelkey: That's a 300 –

Bingham: 300 bit per second full duplex, yes.

Pelkey: Why did Vadic beat AT&T to the market with the 2400 full duplex?

Bingham: I've often wondered about that.

Pelkey: They were the repository of all modem technology. Not all, but most of the modem technology that existed at the time existed at AT&T.

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Bingham: I don't know. I'd like to think it was just because I was smarter.

Pelkey: It turns out your design was a better design than their's. When they introduced their design, you must have gotten some satisfaction.

Bingham: Well, yes and no. They made some wise decisions, like building in Bell103-compatibility that Ken Krechmer will tell you about at great length. Also because they came out somewhat later, they made some decisions about what else they'd put in there simply because the ICs were available, which they weren't when we designed it; in particular, the idea of putting in a scrambler, which we regretted to the end of the 3400 time that we had not done, but we just couldn't because there weren't any chips available that wouldn't get awfully hot. The modem, as we built it in those days, would burn an enormous amount of power and get tremendously hot anyway, so we couldn't have put any more circuitry in there.

Pelkey: What's a scrambler?

Bingham: A scrambler is a device that randomizes the customers' data, in order to make sure that certain critical circuits, generally in the receiver, don't get hung up on certain steady, repeated patterns. If, in a typical full duplex modem, for example, if the customer isn't typing, then the modem just transmits what is called a steady mark; in other words, continuous ones. If you didn't use a scrambler, this comes out as just a very simple, repetitive signal. You can design your modem such that the receiver will be very robust to this one particular repetitive signal, but then it turns out that there are some other patterns which can sometimes be sent, such that the signal that's on the line becomes, again, a very simple, repetitive signal, and after a while, you begin to run out of ideas as to how to make the receiver robust to all of these. The steady space is the next most common one. Then there's -- people who were testing modems in those days developed all sorts of fiendish test patterns. If you type continuous 'U's on the keyboard, this sends alternating zeros and ones forever, and so they would test the modem with the so-called U pattern. You would fill up a whole screen with 'U's and then dump it, and the 3400 didn't like those. The carrier recovery loop in the receiver was very good for all steady marks, pretty good for steady space, and really poor for zero/one repeated, because there just wasn't any way that you could defend yourself against these. AT&T put a scrambler, which essentially takes the input signal and feeds some of the -- anyway, basically it randomizes the input data, and then de-randomizes it in the receiver, by using some shift registers and some exclusive/or's and things like that. The penalty is that it increases the error rate by a factor of three, because for every primary error in the receiver, this signal gets fed back and multiplies, reproduces two more errors in addition to the primary one, so you got a three to one error rate repair increase, which isn't all that serious, but it does make for much more robust carrier recovery and this sort of thing, so we definitely regretted that we didn't have the opportunity to put it in there.

Pelkey: Did you put it in afterwards?

Bingham: No we couldn't because, you see, there's always the rule that you've got to be compatible with your product that's in the field. You can't start building new modems and say:

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"Sorry guys, everything you've got out there won't be able to talk to this, because now we've got a scrambler," so that was one of the things that ham-strung us all the way through, but it is rule number one of this, and so many businesses. You've got to be compatible with your established base.

Pelkey: Now, during this earlier period, when you were dealing with the 3400 -- the concept of circuit design, did you have people who had worked at Bell Labs on the team at Vadic who knew something about circuit design?

Bingham: Which sort of circuits?

Pelkey: My understanding is there weren't a lot of people in those days that knew much about designing modem type circuits. I don't know what's unique about them, but it was not a well-known art form at that time, and people with applied mathematics skills were critical. Does that make any sense?

Bingham: Not much. I can't see that it was a particularly special sort of field. I had working with me -- well I had worked with him at Memorex and he came with me to Vadic -- a guy by the name of Chester Tumer, but he was extremely good. He was a designer as well, really, even though he worked as a tech, and he had some great ideas. I had always been extremely theoretical up until then. At Lenkurt I didn't do much actual product design at all. I was in the research and the development department, but I learned logic design and the nitty-gritty of actually building active IC filters and so on pretty fast. I did most of that while I was at Memorex. I don't think it was that special.

Pelkey: Ken expressed to me the view that a low cost operational amplifier was critical to reducing the cost of modems.

Bingham: Yeah, we had something like 20 dual op amps in that modem package. That was very vital, and the price of op amps was coming down at a tremendous rate in the early '70s.

Pelkey: Who was the vendor of those, Fairchild?

Bingham: National was the biggest, I think. Fairchild -- I don't know who else was, but I think National was by far the biggest.

Pelkey: Going back to this concept of the knowledge of how to design and build modems, it was obviously in doing filter designs. These were complicated circuits, particularly dealing with the telephone line that was very unpredictable. Where did people develop the skills? Was it trial and error, or were there places where people developed some skills and then came in contact with other people? There wasn't a lot written..

Bingham: I hardly ever had recourse to textbooks. 90% of the stuff that I got from other people I got from the IEEE transactions. First of all, it was the transactions on circuit theory and then, in the more recent years, it's been the transactions on communications. The filter stuff, which was quite important, sort of came from a synthesis that I made of some papers that I remember

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reading back in the middle '60s, and I developed some special circuits when I was at Lenkurt, circuits which were particularly appropriate for doing very sharp filters, using resistors, capacitors and op amps. Then when I got to Vadic, I should these to Ted Saunders, and he said: "Hum, yeah, that sounds great. Why don't we mix it with this," and this sort of things, and the combination of the two skills produced what amounted to a very good pair of filters.

Pelkey: And Ted's background was?

Bingham: Ted had come from AT&T. He was a project leader at Bell way back in the mid '60s.

Pelkey: Working in the modem area?

Bingham: I don't think so. I don't remember, if I ever knew, that is.

Pelkey: So then you finally got all the yellow wires off, and in '75, the 3400 was finally a robust 1200 bit full duplex modem. Then AT&T announced the 212, and there was some scrambling on your part, what to do and how to respond to the 212? Do you have any recollections of that period of time, in terms of the pressure in engineering, or the issues of how to resolve it?

Bingham: Well, the big problem was to make an 'all-things to-all-people modem,' because we decided to come out with the triple modem, which would be -- no, I guess we did a dual first of all. We built a 3400/212, and then -- well that, by definition would have to be a triple, because a 212 has a 103 in it anyway. So that was really a pain, because it now meant that we had to have the ability to switch the filters, because the 212 and the 3400 don't use quite the same frequency bands for their transmit and receive signals, so not only did we have to switch the filters between the high and the low bands, but we had to switch them between the Bell high band and the Vadic high band, and the Bell low band and the Vadic low band. So the filtering problem became quite horrendous. The first triple modem was messy. It bolstered Vadic's sales quite enormously, because by that time, there was a large established base of 3400s out there and customers didn't want to give up on it. Then, in subsequent years, of course, as people replaced them, they tended to replace them with 212s, and the 212 took over. We spent a lot of time in those days doing comparative testing, and there -- it's such a nebulous area, but the general conclusion was that a well-designed and built 3400 was quite a bit superior to a well-designed 212. Well, that's not fair, because obviously we didn't have access to what Bell thought of their 212s'. If we took a 212 that we just bought, and compared it to a well tweaked up 3400, the 3400 would be much better. A standard off the shelf 3400 would still be somewhat better than an off the shelf 212, even without the scrambler.

Pelkey: So the other elements of transmission, you handled much better than AT&T.

Bingham: Yes, well, the most important thing was the filtering and the signal-to-noise performance in the high band. Vadic chose to use . . .

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Bingham: . . . easy carrier frequency, just for the sake of ease of implementation, for ease of digital generation of carrier frequencies and this sort of thing, and as a result, came up with numbers which were too high. Vadic used somewhat more antiquated techniques, using a lot more discrete circuitry, which was more appropriate in 1972, but as a result were able to optimize the frequencies a little bit better.

Pelkey: So when you came out with you triple modem, you had to have a scrambler in order to be 212 compatible. When did you introduce the triple modem, do you recall?

Bingham: '78, something of that order. I don't remember for sure.

Pelkey: The 212 was introduced in September of '76. How long before the decision was made to come up with the triple modem?

Bingham: Well, there was a lot going on during that time. There was possibilities of suits against AT&T and also against UDS, and we were examining everybody else's modems. Probably it was about a year after the Bell modem came out and it became apparent that it was going to be well received and well established. I would think it was at least a year before the decision was made to build a triple. It might have been longer than that.

Pelkey: So, essentially, after you made a decision to do it, you came up with the triple modem in about a year then?

Bingham: No, don't quote me on that. I'm not sure. That would be my recollection of it, but you'd have to go back to Ken or somebody.

Pelkey: Was that a priority in the organization, once you decided to do it?

Bingham: It was a fairly important product, yes.

Pelkey: How many people in engineering were working on it at this point?

Bingham: Probably no more than four.

Pelkey: Were you the project leader?

Bingham: No. I can't remember who was. I was sort of technical guru and adviser by that time. I'm not particularly good on practical matters. I tend to make mistakes and lose drawings and things like that, so I think they decided that I was better of as a technical advisor, rather than having complete responsibility for a product.

Pelkey: Do you recall when UDS responded with a 1200 full duplex?

Bingham: They were pretty damn fast. Let's see, when did they -- it must have been '77 or at the very latest early '78.

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Pelkey: There was a suit?

Bingham: Well, that was when we first saw the UDS modem. The important part of the Vadic patent was a combination of coherent detection with filters to achieve a full duplex modem, and that we claimed was the new aspect of it. Although we said in the patent, in the preamble, that coherent detection was somewhat understood, we couldn't really claim, even though we said the way we did it was novel and probably better than it had been done before, we couldn't really claim that the idea was patentable, and similarly full duplex transmission had been known since the 103, but the idea of doing a synchronous modem using coherent detection, a synchronous full duplex modem using coherent detection, had not been done, and that's what we patented. In the course of a lot of conversations with Bell, probably in '77, we established that Bell did not violate the patent, because they were not using coherent detection in the receiver, but we got hold of a UDS modem and we did, not reverse engineering, but a very careful study of it, and we probed it here, there and everywhere, and looked at every single signal we could possibly find, and came to the conclusion that they did use coherent detection, even though they didn't know that they did. Well, the guy that designed the UDS modem, a guy by the name of Leon Pearce, was very much a 'design by the seat of your pants' type of character. He'd put a few circuits together and look at a few patterns or waveforms on an oscilloscope, and so: "Oh, yes, I need two more 'ands' there and three more 'ors' there," and the circuit, as a result, sort of grew, and the schematic was almost impenetrable. It wasn't totally, because obviously we eventually did penetrate it, but it was a God-awful mess, and the -- some of the signals that they produced at different places were quite bizarre. It finally took me, I guess, at least a month of scratching my head over every little line, and finally figured out what it was they were doing, and when we came to the trial, I made a presentation on what it was they had done, and Leon sort of sat there and went: "Oh!" He basically didn't know what he had done, I mean, he didn't realize the implications of it. He had, in actual fact, I think had probably never read a technical book or technical article on coherent detection in his life, but had sort of instinctively come up with this de-modulation technique which was equivalent to coherent detection, and the judge agreed with us, it was.

Pelkey: And when was the trial?

Bingham: Oh, it was about '80, I suppose, something like that. Again, Ken would be an authority on that. So we basically put on a fairly good show, I thought, and we proved to the judge's satisfaction that A, what we had done was novel and B, we had indeed disclosed everything we needed to disclose, we had full disclosure, therefore it was, from the technical point of view, it was patentable, and the judge took time out, in non- legal terms, because he said the only point that had not been resolved was whether in actual fact we had failed as far as the 'on sale' clause was concerned, that is, whether we had started to market this product more than a year before we had filed, or vice versa, whether we had filed more than a year after we had essentially started to market it. He took this one under advisement, and we had to go back four or five months later to hear arguments on the on-sale issue, and we lost on that, because he decided that we had, indeed, really known that we had a product, because we were advertising it furiously. What we -- at that time, Ken understood the patent law to mean that you had to file for a patent within one year of shipping your first product, but UDS argued, and I think rightly, that shipment is -- you can't say that shipment is the day that you have a final product. If you've been

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announcing and giving seminars to your customers and testing in house for two or three months before that, then you know damn well that you've got a product several months before that time, and you can't say an exact day when the clock starts, but in this case, they argued that the clock started quite a bit before we actually shipped, and I think they were absolutely right. It was a goof on our part. Vadic was very strapped for money in those days, and we were delaying having to pay the filing fees as long as we possibly could. As it turned out, it was a terrible costly mistake, because the combination of full duplex with coherent detection, even though Bell didn't use that technique in their Bell 212, they certainly used it in the V22- BIS, that is in the full duplex 2400. You have to use coherent detection for that, and if Vadic had had a patent on coherent detection with full duplex modems, it would have been tremendously valuable, subsequently, as a way of barring other people, or at least controlling, other people's access to the full duplex 2400 bit per second market.

Pelkey: And to swap that for other people's intellectual properties.

Bingham: Yes, right. Even at the time, it didn't seem all that important. Bell didn't use the 212, and UDS was a somewhat inconsequential factor in the business anyway, but Ken argued that we had to defend the patent, and in retrospect, I can see he was right.

Pelkey: Why didn't you come up with a 2400? Why was Concord the one that introduced 2400?

Bingham: Why did they beat us to it?

Pelkey: Vadic never really became a factor in 2400. They finally introduced a product, but Concord really –

Bingham: Well, we didn't have anybody who was really good on digital design -- digital signal processing for the receiver. I knew a lot about the theory of it. I knew I could certainly design the block diagram of an adaptive equalizer, but at the time, the off the shelf microprocessors weren't fast enough to do it, so the first full duplex 2400s came out with custom designed digital signal processing chips in the receiver, and we didn't have anybody who was particularly good on those, so we would not have been able to build a very good adaptive equalizer for the receiver.

Pelkey: Were you trying or was it a response to seeing it in the marketplace?

Bingham: As I remember, I think the first one we did was using an 8051, and that didn't come out until quite a bit later. That was, as I remember, that was sort of a funny stagnant period in Vadic's history. The initial surge had somehow or other lost its power. We should have worked on that a lot earlier than we did, but I can't remember exactly why we didn't. One was certainly the lack of expertise in the DSP receiver –

Pelkey: Were you constrained for a lack of funds in engineering?

Bingham: No not at that time, Vadic probably would have been a $30 million a year company by that time, and they were extremely profitable.

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Pelkey: What was the company working on?

Bingham: Well, by that time they were building more and more of these combinations of triple modems, with more and more complex auto-answer systems and this sort of thing, and were getting quite deeply involved in the use of microprocessors for doing the hand shaking and this sort of thing, and that, I would say, was occupying most of the engineering efforts.

Pelkey: Why did you and UDS miss the opportunity of the PC market?

Bingham: I don't know. I think it's simply because Ken misread it. I think at the time people said to themselves that the PC is just a fad. All sorts of jokes were made about 1 million PCs were sold, and 990,000 of them are sitting in people's closets after they played a few games. I don't think anybody at that time believed that it was going to be a big market.

Pelkey: Even the engineers felt this way? You weren't saying: "Wait a minute, this is something that -- "

Bingham: I didn't know enough about that side of it at all to say anything much one way or the other, but I think the thing was we just didn't recognize how big it was going to be. I'm still surprised, I must admit, I'm still very surprised that it's such a big market. I would have thought that most PCs would be very happy to be stand-alone PCs. I don't know why people need all this data transmission capability, but –

Pelkey: Why did Vadic and UDS not get into leased-line modems? Why did leased-line modem guys not get into dial-ups?

Bingham: I don't really know.

Pelkey: What would you hypothesize?

Bingham: Well, I would think that the leased-line modem -- you become very dependent on certain special customers. You get an in with these customers and you supply into this particular system, and Vadic had made a definite effort to get out of that in the early '70s, and it was probably hard to get back into it. The full duplex 1200 was very obviously aimed at the switched network, because most leased lines are four-wire anyway, so you don't need a full duplex modem. I mean, you get full duplex modem, but you can do it without all of the filtering to separate the channel. So the 1200 full duplex was very definitely a switched networks - - and the switched network business was growing much faster than the leased-line was in those days, and I suppose it just didn't make sense to bring the leased-line along with them at the same time. We felt that the business really lay in the switched network.

Pelkey: How did you deal with the DAA? Even when you had the completed 3400, the DAA was still a requirement?

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Bingham: I don't remember when it happened -- there was another court finding that allowed us to build our own DAAs, so Vadic built their own DAAs for a few years.

Pelkey: Do you recall when that was?

Bingham: The early 3400s access was by the DAAs supplied by the phone company. When did we start building our own? '79, maybe, or something like that.

Pelkey: By '79 there was also the universal jack.

Bingham: Oh, was there? Did it come along that early?

Pelkey: '77.

Bingham: Oh really? So the DAA was long before that.

Pelkey: Part 68 registration was in '68, and the universal jack came out in late '76 or early '77, but I mean there are still DAAs out there because not everybody had a jack.

Bingham: Oh, ok, then I'm way off in my dates. The Vadic DAA must have been long before that.

Pelkey: Although it could have been after Part 68. They could have said: "Wait a minute, you can build them now because they're not going to be required, but some people aren't going to have jacks out there, so anybody can build them. Here's a spec and just build it." I don't know.

Bingham: Well, the Vadic DAA probably lasted into that period, but it certainly would not have been designed once the -- we wouldn't have started on it once the jack was becoming available, so maybe the Vadic DAA was as early as '74 then or something like that.

Pelkey: Was Carterfone anything that impacted your consciousness during those years?

Bingham: Yeah, well, it was always quoted as the one decision that allowed other companies to get in and compete.

Pelkey: And that was commonly viewed at that point. Did you know that when you went to Vadic?

Bingham: Not when I went to Vadic, but I certainly heard the name frequently in my first few months there.

Pelkey: Was the work of Nyquist important in terms of your work on modems?

Bingham: Yeah. His basic theorems of sampling and data transmission are all due to Nyquist: the Nyquist criteria for transmitting in a limited bandwidth without any coherent(?) interference. I was already familiar with those.

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Pelkey: But you were familiar with those in the '60s when you were at GTE?

Bingham: Yes.

Pelkey: Shannon's work and the stuff that was happening out of MIT, was that of any help to you?

Bingham: That was always held up as a Shangri-La that you might, perhaps, one day, manage to attain. Shannon had proved that theoretical data rates on a noisy channel were something like three times what people were actually able to attain at that time. So people were always saying: "Some day, we'll be able to get these 23,000 kilobits through the phone line," and at that time, 9600 was the limit, but the method by which you would have to achieve that was so complicated, and everybody realized it was so complicated, that it was just generally accepted to be technically impractical. And it still is. People are beginning to approach the Shannon limit, but the techniques that they're using are still quite different from anything that Shannon himself would have thought of.

Pelkey: There's a company called Telebit that has introduced this multi-carrier approach, digital signal processing into dial-up modems. Were you familiar with those concepts of using multi-carrier?

Bingham: Yes. I read Holsinger's original PhD thesis way back in the '60s, I guess. I think he was the one who had the idea first of all, and then probably in the early '80s or late '70s, Ken and I went to talk to a guy by the name of Paul Baran, who was at Packet Data in those days. He was interested in getting a Vadic sponsorship for this modem that he had come up with, and unfortunately, he did such a lousy job of explaining it, that Ken and I came out of that meeting sort of shaking our heads in disbelief. We were both familiar with the multi-channel approach, and I had read quite a few papers by a guy by the name of Salzburg from Bell Labs, and I asked Paul Baran about -- it was Paul Baran and somebody else named Kron (?), something like that -- two of them anyway. I asked Baran about how he had managed to solve this particular problem that Salzburg addressed, and he didn't know, or didn't think he had solved it, or something like that. So I thought: "Oh, my God," then I'd ask him about this other thing and -- Baran was sort of a bit like another Leon Pearce in some ways. He was, as it turned out, an extremely bright engineer, but he did it, again, in a sort of a gut feel way, and he didn't -- I think he genuinely wanted to explain things to us, because he wasn't trying to hid anything, he was trying to get Vadic's backing for this modem, but we came out of it shaking our head in disbelief, which subsequently we regretted very much, because in actual fact, he did have the nucleus of a very good product. He subsequently got a bunch of good engineers around him who were able to realize it in a somewhat more formal -- in a way that would be more understandable by other people who hadn't gone through the original design process. The first product was a good one. It's not as good as Telebit claims it is. It doesn't have -- this multi-carrier approach doesn't have the enormous advantages that everybody had touted for it. In fact, some people have said that it is good per se, and that's just not true. You have to combine it with a lot of other very clever techniques. There's a guy in Japan, Hirosaki, who writes about the multi-carrier modem, and as he describes them, they're, in actual fact, they're worse than the single carrier, because it doesn't -

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- the most important part of the multi-carrier is that you have to, in actual fact, do a sounding of the channel, and you have to establish where the channel has high attenuation and where it has low signal-to-noise ratio and so on in order to decide how many bits per symbol you're going to put into each one of these little teeny-weeny channels. If you don't do that and if you just use a simple minded equal loading all the way across, it turns out that the error rate is much worse than it is even on the single channel, single carrier modem. Telebit certainly recognizes this, but they haven't been as explicit in saying this in their presentations. They like to go along with this idea that the multi-channel approach is inherently superior to the single-carrier one, which it isn't, but you can do certain things with it and you can make it adaptive in a way which you cannot make the single carrier system adaptive, and if you do that, under certain circumstance, you can do somewhat better.

Pelkey: Adaptive equalization was required for 2400?

Bingham: Yes. But it would be nice to have it at 1200, because the full duplex 1200, working over really bad lines, it's performance, particularly in the high band, starts to degrade, but you generally can get through moderately good error rates without adaptive equalization. When they came out with the full duplex 2400, and of course the modem has an adaptive equalizer in it, and they use it even when they're running at 1200, and then the performance is considerably enhanced.

Pelkey: Were there other technologies that you saw at Vadic that you passed on, such as the Telebit, that became successful or that you wish you had done?

Bingham: I haven't thought about that one. You mean from other companies?

Pelkey: Just in general, or other companies.

Bingham: There was somebody over in the east bay that claimed to have a very good 144 Kilobit full duplex modem for operation on the unloaded local loops. We went and investigated that, but again, they were a real bunch of garage type engineers. We investigated that, decided that they didn't have anything, and I guess in actual fact, they didn't, so we didn't miss anything.

Pelkey: Why did the modem guys not participate in local area network?

Bingham: Well, it's a very different field. The problems are different. The customers are different.

Pelkey: So it was natural that that didn't happen.

Bingham: Yes. I would say, if the company is big enough and they wanted -- both of them are data transmission, that's true, but that's where the similarity stops. The data rates that you're talking about are much higher. Ken was talking to several people in Racal in England who were seriously –

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Pelkey: The PLANET system?

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Bingham: Right, the PLANET system. I think Milgo would have build it rather than us. I don't think, in actual fact, we ever built it over here.

Pelkey: Why did you sell yourselves to Racal?

Bingham: '77. I think May, or something like that.

Pelkey: Before the triple modem was out?

Bingham: I think so, yes.

Pelkey: Why did you sell to Racal?

Bingham: Just to get some return on the original founders' investment. Let's see, when we were still on Middlefield Road. Several years before, there had been a fairly concerted effort to go public, and we had gone all the way to actually putting together an offering, and we had a stock broker working for us, and I think it was just about the time that the stock was going to be offered that there was a sharp downturn in the market, and we just aborted the whole thing, and it cost Vadic several hundred thousand dollars.

Pelkey: Do you recall who the broker was?

Bingham: The name Dominick something or other comes to mind. It's in the record somewhere or other. So we were somewhat burnt on that, so then there was a period of at least two or three years where they just decided to actually build up profits, get the company as profitable as possible in order to make it look as attractive as possible. We began to realize that going public was not the way to do it. I guess it's favorable again now, but in those days it just wasn't. You couldn't go public without sales considerably higher than what we had at that time, so Ken, and I suppose Dan [Sully], and whoever else was involved in it, were desperately looking around trying to find other people to buy us, just so the original stockholders could get their money back. Racal came through, as it turned out, for the first years, it was apparent that Racal got a fantastic bargain. The price-earnings ratio was ridiculously low.

Pelkey: Particularly after the triple modem took off.

Bingham: Yes. Within a few years, Vadic was the shining star of the whole Racal Corporation. Here we were, probably total sales less than 5% of the total Racal sales, and we were making probably 15% or their profit. So, you know, Jim of Racal would come over once every year and beam and pat us on the head and that sort of thing. It lasted up until about '84, I guess, when I left.

Pelkey: Thank you very much for your time.

Bingham: I don't know what help it's been. I was going to suggest one other person that you ought to talk to. Do you know a guy by the name of Sang Whang. You certainly should talk to

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him. He was originally at Milgo, before it was Racal-Milgo, and was deeply involved in the arguments between Milgo and Codex.

Pelkey: Do you know where I can reach him now?

Bingham: I have a phone number for him, but I don't know how old it is. I'll give it to you . . .

END OF THE INTERVIEW

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