The FCC Digital Television Standards Decision*

WILLIAM F. SCHREIBER

ABSTRACT *The FCC's DTV standards decision of December 1996 is criticized on the grounds that it is likely to hinder rather than to help the development of a viable broadcasting service. The standard-setting process began in 1987, resulting in a proposal to the FCC in 1995. The so-called Grand Alliance proposal was not perfect, as it had too many scanning formats, it used interlace, and had no provision for inexpensive receivers or easy upgrading, but it was a complete system. Because of a dispute between the computer and TV industries, a private advisory committee was formed at FCC urging. It met secretly without public participation, in apparent violation of the Federal Advisory Committee Act. The committee agreed to eliminate the table of scanning formats, and the FCC adopted this radical proposal within a month. Rather than correcting the drawbacks of the GA proposal, the FCC made it worse by introducing uncertainty as to which formats would be for broadcasting and which formats receivers would accept. In so doing, the FCC ignored the views of other government agencies, public-interest groups, and disinterested individuals, but apparently accepted the often erroneous and self-serving statements of the commercial entities involved.*

Keywords: digital television, DTV, FCC, HDTV, television broadcasting standards, television.

Introduction

The FCC Inquiry began in 1987 as a study to determine the effect of the development of high-definition television on the existing broadcasting service. The Inquiry was requested by the TV industry, in part to halt the reassignment of certain unused UHF channels to non-TV applications. A common belief at the time was that the over-the-air broadcasters would need more spectrum to compete with HDTV provided by alternative media. The Inquiry soon devolved into a program to develop a domestic HDTV standard for terrestrial broadcasting, although exactly how that transition took place remains a mystery. Later on HDTV became Advanced Television (ATV) and ultimately Digital Television (DTV), again without formalities.

Although the Inquiry has been conducted for the most part in compliance with the Federal Advisory Committee Act (FACA), the complex initial organization of the Advisory Committee (ACATS) was conducted in secret. The appointment to key positions in the Inquiry of a number of individuals who had been pushing the Japanese 1125-line interlaced system (the NHK system) led some, such as myself, to believe that

*This article, which was originally written in January 1997 and slightly revised in January 1998, represents the opinion of the author only, who is not in the pay of any company that has a financial interest in the DTV standard. Since his retirement in 1990, the author has had no part in the MIT Advanced Television Research Program.

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ACATS would be the vehicle by which this system would become the US standard. SMPTE made itself into a standardization agency accredited by ANSI, and 'documented' (actually made some improvements in) the system. ANSI first accepted the NHK system, redubbed SMPTE 240 M, but then rejected it on appeal by ABC as not being in common use. In spite of the great pressure that was applied to adopt the NHK system as the production standard, the effort appeared to have failed.

The MUSE bandwidth-reduced transmission system was developed to permit sending NHK signals by satellite. This technique is now being used in Japan, although the system has not become a commercial success. In connection with MUSE broadcasting, Japanese companies developed a complete line of production equipment. Narrow MUSE, a version that enabled terrestrial transmission of a modified NHK signal in a 6 MHz analog channel, was one of the systems tested by ATTC for the US standard, but turned out to be the poorest-performing system of all. It appeared that the NHK system was dead, at least in the US. Ironically, however, the latest action by the Federal Communications Commission in setting the domestic digital transmission standard will result in the NHK system becoming the *de facto* HDTV production standard.

It would take too much space to recount, in this article, the complete history of the Inquiry, so what follows is very brief, covering only the points that are essential to understand the full import of the latest FCC decision.

While many entities would have accepted the NHK system as a production standard, virtually the entire industry believed that the HDTV broadcasting format should be backward-compatible with NTSC. Proposals by MIT and others for developing an entirely new system and to use simulcasting to serve existing receivers were ridiculed. However, it eventually was realized that compatible HDTV was impossible within a single 6 MHz channel. The 1989 Zenith proposal for a hybrid analog/digital simulcast system, the general ideas of which was accepted by the FCC, was the first step in the opinion turnabout. The General Instrument all-digital proposal in 1990 finished the job. It became clear that the HDTV system would be all-digital, and that simulcasting would be used during a transition period lasting 10 to 15 years. The Commission developed a plan to lend a second channel to existing licensees for digital transmission, and to reclaim the existing NTSC channels at the end of the period. It was assumed that enough viewers would have purchased digital receivers by that time to make the shut-down of analog broadcasting politically acceptable. The existence of more than 200 million NTSC receivers and more than 60 million NTSC VCRs gives some idea of the magnitude of that task.

The first round of tests at the ATTC resulted in the withdrawal of the two analog systems, but there was insufficient difference in performance among the digital systems to pick a winner.[1] The remaining system proponents reluctantly combined forces under pressure. The result was the Grand Alliance system, documented by ATSC[2] and submitted to the Commission by ACATS in 1995. A notable characteristic of the GA system was a total of 14 different scanning formats (no proponent gave up any of his formats) including many using interlace.[3] This was widely objected to by the computer industry, which had given up interlace long before for good reasons. A portion of the computer industry formed the Computer Industry Committee on Advanced Television Service (CICATS) and launched a highly visible campaign against adoption of the GA system.

After the FCC asked for comments on the proposed adoption of the GA system, the impasse between the TV industry and the computer industry evidently caused the Commissioners to believe that it would be unwise to set a standard under these conditions, even though there is no doubt that they had full authority to do so on their

own. There was even talk in the newspapers of locking the two groups in a room until they came to an agreement. In October, Commissioner Susan Ness wrote to a number of individuals in the various contending groups, urging them to meet privately, iron out their differences, and present the Commission with a plan that could be implemented immediately.

My own opinion is that the views of the two groups were irreconcilable, and that a decision should have been made by the Commission.[4] I assume that there was tremendous pressure on the participants to agree on something, which they ultimately did, in secret and with no public representation. The resulting Agreement, which was incorporated immediately into the Fourth Report and Order, seems to me to be considerably worse than the original proposals of either side. It seems likely that this 'compromise', in which the standard is not fully delineated (the table of scanning formats was eliminated, so the use of any number of scan lines and any aspect ratio, interlaced or not, is legal), will slow down the acceptance of digital broadcasting, perhaps making the eventual shutdown of NTSC impossible. Unless analog broadcasting can eventually be turned off and the spectrum so released be put to other uses, there will have been no substantial reason for making this expensive change in broadcasting standards. For all its defects, NTSC has been the foundation of a very popular and profitable industry.

It should be borne in mind that the terrestrial broadcasters have always looked on HDTV as more a threat rather than an opportunity. What would have motivated them to make the considerable investment required to move heavily into HDTV broadcasting would have been HDTV provided by their competitors—cable and satellite. The latter, however, have opted for multiplexing a number of standard-definition programs in each channel, which means that terrestrial broadcasters will probably do the same.[5] Provision for this kind of service is included in the GA system standard.

The Fourth Order will be implemented by a number of rules. Obviously, how much free (advertiser-supported) service is to be provided in the new channels is one such rule that is likely to be set. Without it, the new channels could be used for any purpose, even purposes other than television. Whether a requirement for a certain minimum amount of high-definition programming will be imposed or whether some children's educational programming will become mandatory remains to be seen. It is also possible that the Commission will have further thoughts on ensuring that early receivers will be able to function as the system evolves over time—a long-standing FCC desideratum—or that a transition to all-progressive transmission, to which everybody is paying lip service, will actually take place.

One purpose of this article is to show what is worrisome about the FCC decision and to make suggestions about using rules to ward off some of the damage to the public interest that seems to be in the offing. It is even possible that Congress, which can direct the FCC if it wants to, may be interested in some of these matters. In the last session of Congress, a great deal of interest was shown in the FCC plan to make the second channel available to broadcasters without charge during the transition period, a step regarded by some members as a giant giveaway.

Compared to other problems facing our country, the decision about TV standards seems to be very simple, especially as many of the disputes about what to do concern facts rather than opinions. The conversion to a new system will cost about $100–200 billion—a lot of money but not enough to bankrupt the country should it fail. With unusual foresight, the nation has established machinery that ought to have been capable of making a sound decision. In my view, the machinery has failed, in spite of the expenditure of considerable time, effort, and money. If we cannot solve rather simple problems of this kind, how are we ever to solve much more difficult and more important

problems, such as presented by the budget, by welfare, by health care, and by learning to live in the global economy? Therefore, the second purpose of this article is to tell this story clearly, so that lessons may be learned for the future.

Drawbacks of the Grand Alliance Proposal

Although much good work was done by the digital system proponents, there are some deficiencies in the GA standard. These include the absence of a migration path to higher quality, the use of interlace, the lack of provision for inexpensive receivers or set-top converters, less than the maximum possible spectrum efficiency, and limited aspect ratio and interoperability. The use of 14 different scanning formats, which is bound to raise the cost of receivers, is probably due to the shotgun wedding forced on the system proponents by the FCC.[6] No proponent was willing to give up his own format, so all were included. If the Commission itself had taken the four systems and chosen the two or three really necessary formats, a much better result could have been obtained, but such a procedure is evidently impermissible in today's political climate.

No Migration Path

Although all parties to the Inquiry agree that progressive scan provides better quality, and that eventual resolution improvements would be desirable, there is no provision in the standard for making any such changes in a manner that permits the early receivers and other equipment to continue to be used. The single known way this might be done within the GA standard would be to use more accurate motion estimation at the encoder. This would raise the compression ratio and so would free up some channel capacity without requiring any receiver modification. However, there is no such improved motion estimator in sight, and even if perfect motion estimation were possible, the amount of improvement would be small.

It has been suggested that the use of packet transmission and packet identifiers (PIDs) would permit new packets for enhancement data to be ignored by early receivers. That is true. However, to make packets available for this service, the original image quality would have to be obtained with fewer packets in a manner that would be compatible with early receivers. Again, no such system has even been mentioned to date.

The CICATS proposal called for a 'layered' system in which the base layer would be standard definition (SD). Since the cost of the MPEG decoder, which will be a significant part of the cost of a minimum receiver, depends primarily on its processing speed and the amount of memory, and because a standard-definition system requires only one fourth the speed and memory of an HDTV system, this difference is important. In the CICATS scheme, packets are available for enhancement since the SD base layer does not consume all the channel capacity. However, at least part of the base receiver circuitry must operate at the higher speed, and the total channel capacity available for enhanced receivers is just the 19.3 Mb/s provided in the GA system.

In my submission of 5 December 1996, I suggested an alternate migration method that would surely work for receivers having a signal-to-noise ratio (SNR) higher than threshold.[7] This situation will exist in most of the reception area of each station when the usual scheme of a single centralized transmitter is used, and could also be achieved at almost any location by the use of a special antenna and/or a special low-noise amplifier. When the SNR is above the threshold of reception, additional channel capacity is available that goes unused in the GA system. Enhancement signal(s) can be transmitted within this extra capacity, and they can be added to the base signal to provide higher

picture quality. Such extra data appears to be random noise to early receivers, which, as a result, do not have to be designed with enhancement in mind. Details of the enhancement scheme can be established after early receivers are in place without fear of making them obsolete. Enhanced receivers can extract this extra data from the signal to produce better pictures. The total data rate available to such receivers could be much higher than that of the GA system without the use of extra spectrum.

Too Many Formats, No Cheap Receivers

Since no system proponent was willing to give up any scanning format, a large number are included in the GA standard.[8] All receivers, even the smallest and cheapest, must be able to decode all formats and convert them to the receiver display format. While there is some disagreement about exactly how much this will raise the cost of receivers, there is no doubt at all that the cost will be higher. In particular, the need for a full HDTV decoder will certainly raise the cost of the cheapest receivers and set-top converters significantly, particularly as compared with a layered scheme such as that of CICATS or as I have suggested above.

If the base layer is progressive scan, its picture quality can still be much higher than that of NTSC, even though the channel capacity actually used is much less than needed by the existing analog signal. This is due, in part, to MPEG data compression; it is also due to the lack of interlace artifacts and to the 60 frame/sec rate of the progressive system compared with the 30 frame/sec rate of NTSC. GA advocates often state that interlace is better for sports, but, in fact, the reverse is true. Particularly in the case of fast camera motion, often used in football and basketball, much better motion rendition will be provided by progressive scan.

The NHK System as the Production Standard

One of the great ironies of the entire HDTV Inquiry is that the 1125/60 interlaced system developed by NHK and the major Japanese electronics companies, which had once seemed invincible but was struck down by ANSI and the ATTC tests, has triumphed in the end. Unless the FCC decision is somehow modified, it is highly likely that no studio equipment for progressive-scan HDTV will ever be developed and no such material will ever be broadcast in the US. What is so troubling about this is that the arguments advanced during the Inquiry to permit the use of interlace in HDTV digital broadcasting are all demonstrably false, without exception. The only benefit from interlace is to certain foreign manufacturers who unwisely made investments in this obsolete technology and who will now have a chance to foist it off on the US. Everyone else will be adversely affected. Image quality for a given spectrum allocation will be lower, interoperability with other imaging media will be reduced, interlace artifacts will not be eliminated, and transcoding will be more expensive and will cause greater loss in quality.

The arguments that were used to permit the use of interlace in standard-definition broadcasting are somewhat different but equally specious. Interlace is not better for sports and does not necessarily make for more sensitive cameras. It is true that a small additional expense is required to convert archival NTSC interlaced material to progressive scan for transmission, but this cost—$10,000 per station maximum—is totally insignificant compared to the cost of doing any digital broadcasting at all.[9]

A clear illustration of the falsity of the pro-interlace arguments is shown by the statement often made in the Inquiry that most interlace (I) problems can be cured by

using a progressive (P) display (this is not entirely true), and that an I-to-P converter can be used in the receiver rather than at the encoder. One principle followed in TV system design since the earliest times is that when there is a choice between putting a processing step at the transmitter or the receiver, it should preferably be at the small number of transmitters rather than the large number of receivers, for reasons of total cost. If the I-to-P converter is so simple, what can possibly be wrong with putting it at the encoder?

Drawbacks of the FCC Order

The DTV decision is the first major overhaul of TV broadcasting standards in 46 years. The Commission had the rare opportunity to authorize a system with much higher technical quality and much more efficient use of very scarce spectrum. The process to accomplish these goals has been underway since 1987. Evidently in the interest of getting started without further delay and without major objections from the interested industries, the FCC has compromised both these goals to the extent that the move to digital broadcasting may well fail for lack of a market. Even if it 'succeeds', there is a strong likelihood that it will prove impossible to improve the system over time, for example by eventually moving to progressive scan.

The main difficulties with the FCC decision is that it did not correct any of the deficiencies in the GA system pointed out above. Instead, it compounded the problem of moving to an entirely new broadcasting system by eliminating the table of formats from the ATSC standard. This action clearly reduced the certainty of compatibility that is essential to public acceptance. In addition, the Commission did not define the conditions under which the second channels can be used or impose any public-interest obligations on the broadcasters. This group of issues may, perhaps, be fixed by further rules, but the correction of the basic difficulties with the standard itself call for some modification of the decision.

Finally, the Commission did not seem to keep in mind that shutting down NTSC after the transition period, a chancy prospect at best, requires the cheapest possible receivers. The shut-down is essential in order to reduce the amount of spectrum required for TV so that it can be used for other purposes. This will be politically impossible unless a very large number of digital receivers are in use.

An endemic problem in the broadcasting industry is the paucity of efforts to understand the future of broadcasting. The number of people in all the networks and in the television manufacturers located in the US who are paid primarily to think about the future is nearly zero. This accounts for the persistence within the industry of a number of long-held ideas that were eventually found to be fallacious, including the idea that HDTV would take more than 6 MHz, that HDTV had to be compatible with NTSC, and that digital transmission was a 'pipedream'.[10] I think that is the basic reason why some of the false ideas of the GA proponents are still circulating. These false ideas include the alleged advantages of interlace, the alleged superiority of 1080 I to 720 P, the impracticality of using progressive transmission exclusively, and the ideas that the GA system has headroom for improvements and has a high level of interoperability. It is quite understandable that some of these ideas have been put forth by persons and companies that thought such ideas were in their own financial interest. However, it is disappointing that they should not have been shot down by the Commission, which *does* have a knowledgeable staff whose members are paid to think about the future.

The Agreement

It is fairly easy to understand the attitude of the TV industry going into the negotiations that led to the Agreement. After spending a good deal of money, time, and effort, a system was produced and those who bore the expense wanted to start getting their money back. CICATS, on the other hand, for good reasons, wanted progressive scan and square pixels. It is hard to see how no standard (which they said was their preferred outcome) would have helped in this unless they thought that the FCC had intended to impose a requirement that computers should accept all the formats if they accepted any. Given the Commission's extreme reluctance to regulate receivers, it was never likely that this was a realistic fear. On the other hand, CICATS' second choice—a single standard-definition progressive format with upgrading by the use of enhancement signals—would have been good for both industries, in that it would have increased certainty and reduced costs for everyone while providing higher spectrum efficiency.

There never was a way to compromise these two views. Therefore the Agreement does not lie between the two points of view. It is orthogonal to both, making it possible to have even more formats than in the GA proposal (bad for the computer industry) and making it even harder to guarantee that all receivers will be capable of handling all formats that will be used (bad for the TV industry).

It is instructive to try to imagine what would have been the reaction of the two groups if the Commission had made a decision on its own, based on protecting the public interest. For example, if the FCC had decided to adopt the GA proposal *in toto*, the computer industry would certainly not have abandoned its plan to put TV on computer screens. The industry clearly believes that this is essential to its future profitability. On the other hand, if the FCC had decided to authorize a single standard with upgrading only by sending enhancement signals, the TV industry would not have abandoned digital TV. Receiver manufacturers are clearly anxious to start selling digital receivers and broadcasters are salivating over the profit possibilities of a second channel. There may well have been some public protest, appeals to Congress, and even lawsuits, but the Commission is used to all of this. It could have made a principled defense of its position, based on protecting the public interest while making a great deal of spectrum available for new businesses.

Elimination of the Table of Formats

The only way to guarantee that all receivers will accept all of the GA formats is for the FCC to require it. The Grand Alliance does not have the power to enforce this requirement even on its own members, not to mention other manufacturers. Since the Commission is clearly reluctant to do any receiver regulation at all, a second possible action would have been to require broadcasters to use only these formats, with the industry using a labelling scheme so that consumers could at least know the capabilities of the receivers that they buy. This is especially important when receivers first go on the market and when only some of the formats will be in use. Without any of these steps, it will not be surprising that some receivers will be sold that do not work with all formats, since this would give a competitive advantage. The very first newspaper article about incompatibility between receivers and broadcast formats will greatly diminish the public's enthusiasm for digital TV, and place the shut-down of NTSC in peril.

A key element in the Commission's strategy has been to turn off analog (NTSC) broadcasting after 10 or 15 years. The purpose of this laudable idea was to provide more viewer choice than is now available using less spectrum, and to use the eventually

released spectrum for new services. The assumption was that there would be a rapid proliferation of digital receivers. This would have been difficult enough to achieve with the high receiver costs under the Grand Alliance proposal due to its many different scanning formats and to the need for a full HDTV decoder in every receiver, even the cheapest. Rapid proliferation will now be even more difficult to achieve with the uncertainty introduced into the standard by failure to specify which scanning formats will be used.

In a similar situation, the Commission previously declined to set standards for satellite broadcasting, as a result of which there are now at least three mutually incompatible systems in use. Although these are all MPEG systems, hardware bought for one service cannot be used on the other services, and none will be usable with any version of the DTV standard just issued. There is nothing in the FCC decision that will prevent a similar situation from developing in over-the-air broadcasting, either with respect to transmission standards or to receiver capabilities.

No Correction of Problems in the GA Proposal

As pointed out above, the GA system has no migration path to higher quality, too many formats, no provision for inexpensive receivers, and uses interlace. The arguments presented by the Grand Alliance and member companies in support of these highly disadvantageous characteristics are for the most part false and in all other cases, at least misleading. By quoting some of these statements in the Fourth Order, evidently with approval, the Commission appears to have accepted these specious claims.

The record in the Inquiry provided all the information the Commission needed to set a standard that would have had none of these difficulties, and it could have appointed a disinterested expert committee to help, if that had been felt necessary. It could have eliminated interlace, have reduced the number of formats, and could have chosen upgrading by enhancement. These steps would have reduced the cost of the cheapest receivers and would have provided a practical migration path. At the same time, they would have eliminated all uncertainty about receiver performance, guaranteeing that the early receivers would continue to work as the system is changed and upgraded over time. These steps would have provided the best incentive for the public to buy a large enough number of digital receivers so that NTSC could be turned off after a reasonable transition period. Instead, the Commission has set up a situation quite similar to that now existing in satellite broadcasting, where three incompatible standards are in use.

Questionable Statements in the Fourth Report and Order

The origin of the Commission's decisions can be found in the discussion in the Order. In marked contrast to previous papers from the Commission in this docket, all of which have been thoughtful, accurate, and well written, to a large extent the Fourth Order accepts uncritically the claims of the Grand Alliance and of companies expecting to make profits based on the GA system, while disregarding the statements made by opponents and public-interest groups. Here are some inaccuracies and questionable conclusions:

> *Para. 1.* The signatories to the agreement do not have the power to ensure that receivers will be operable with all the formats. It is highly likely that only 480 I and 1080 I will be commonly used at first. Since there is a competitive advantage to omitting some receiver formats, we may well see sets on the market having only these two formats, thus preventing 720 P from ever being broadcast.

Para. 2. While it is conceivable that the Agreement will 'satisfy' the signatories, it is not in the interest of the public, which will pay the entire cost of a new TV system.

Para. 3. How could it possibly be in the public interest to eliminate the table of formats, thus decreasing the certainty that early receivers will continue to be operable as the system changes over time? The Agreement will certainly not increase the speed of adoption of digital television. The very best that can be hoped for is that it does not slow it down.

Para. 5. Interactivity of any kind requires a reverse channel, which is not provided for in the GA system; thus no interactivity is possible. There is likewise no path to nondisruptive improvement over time, a long-standing FCC desideratum, nor is any characteristic of the GA system relevant to the issue of continued free (advertiser-supported) broadcasting.

Para. 7. This paragraph fails to note that the group in question was appointed by Commissioner Ness and met in private without any representation of the public interest. Since 'data broadcasting' means anything other than video or audio, licensees could, in principle, use the new channels for any purpose whatsoever. The Commission must still set the rules for usage of the new channels to ensure that the public interest is maintained.

The quotation from the ATSC document alleges more effectiveness to the packet-identification numbers (PIDs) than is warranted. It is true that, in the absence of a high-definition data stream, some packets could be used for other services. However, unless someone learns how to do HDTV in less than the capacity of the full channel in a manner that is compatible with the early receivers, it will never be possible to improve the quality of an HDTV signal, e.g., by moving from 1080 I to 1080 P, using this method.

Para. 8–10. These paragraphs are couched in market-development jargon, but fail to make the essential distinction between the broadcasting market and many other markets. The broadcasters use a publicly owned facility—the broadcast spectrum—which is in limited supply. (This is quite different from the oft-mentioned VHS–Beta battle, which did not involve spectrum and was properly left to the companies involved.) It is in the public interest that the most efficient possible use be made of this spectrum; that is what calls for fully delineated standards. To believe that the market will come up with the most efficient solution is to believe in magic. What is quite believable is that, in the absence of a fully defined standard, the transition to all-digital broadcasting will fail. One may compare this situation with AM stereo audio, which failed without a standard, and TV stereo, which succeeded with a standard.

Para. 11. The quoted statement of the GA and ATSC is wrong in at least two respects. The system does not 'emphasize' progressive scan, even if more than half of the formats are P. It is clear that 480 I and 1080 I (perhaps even 1035 I) will be the principal formats at first. It even remains to be seen whether 24 P will be used for film. As for 'unmatched interoperability', only the exclusive use of progressive scan and square pixels could have accomplished that.

Para. 14. The Commission notes that public-interest groups generally favor a single mandated standard, but evidently these views were not persuasive. It is absolutely indisputable that a layered system with a standard-definition base layer would

provide the cheapest digital receivers and the cheapest set-top converters for enabling NTSC receivers to be used with digital broadcasts.

Para. 16. This paragraph repeats the specious claims of advocates of the GA system about its alleged 'flexibility, extendibility, interoperability, and headroom for growth'. The use of a packet transmission system does allow the later introduction of packets for other purposes, that would be ignored by early receivers. (See above comments on para. 7.) However, a prerequisite is the development of a system, not yet visible on the horizon, that permits the transmission of an HDTV signal in less than 20 to 25 Mb/s in a manner that will operate correctly on these early receivers. There is no 'headroom' in the GA system for further extensions without such a development. Of course, if HDTV is abandoned and only standard-definition signals are transmitted, then there will be room for new services.

The benefit to broadcasters from including the 480 I formats so that NTSC video can be used without transcoding will prove to be insignificant. The cost of such transcoding at the transmitting station is entirely negligible as compared with the cost of transmitting any digital video at all. As for electronic news gathering (ENG), the T3/T6 ATSC subcommittee, at a meeting that I attended on 14 March 1996, voted down a proposed 360×640 P format that would have been of higher quality than NTSC and would have made for excellent low-cost cameras with superior motion rendition and sensitivity at least as high as that of 480 I cameras. For the same picture resolution, interlace is not more sensitive or otherwise superior to progressive scan. The Commission should have realized that this was simply one more specious argument for continuing with an outmoded technology.

Para. 17. Here the Commission again notes that public-interest groups generally oppose the GA standard.

Para. 18. Here the Commission repeats, uncritically, the false statement that 1080 I is justified because current technology does not permit the transmission of more than 1000 lines P. The point is that 1080 I is not superior to 720 P in any way, as clearly shown in the ATTC tests. The record in this docket is perfectly clear on this issue.

The Commission also repeats, uncritically, the statement that some computer systems already accept interlaced video, 'proving that interlaced scanning is compatible with computers'. Any person not entirely ignorant of television technology knows that any format can be converted into any other format. Whether this is good or bad depends on the cost and quality of the conversion. Again, the record is perfectly clear, but the Commission has ignored it.

Para. 21. Here the Commission notes, but ignores, the fact that the NTIA urges a definite plan to move to progressive scan. One would think that, at least, the Commission might give some reason for ignoring what seems to be an excellent suggestion coming from the president's principal advisor within the government on telecommunication matters.

Paras 30–42. This section gives a cogent argument for requiring a standard, but concludes that omitting the table of permissible formats does not vitiate the argument. Para. 39 goes so far as to state that this omission will allow consumers to choose 'which formats are most important to them'. Unless the consumer can see two different formats side by side and can choose one or the other independent of the other aspects of the service (such as program availability), the consumer will not be able to make the choice. The nature of television systems, which require an

immense infrastructure as well as a large number of receivers in order to operate at all, precludes 'design by the market'.

Paras 40–41. This section repeats the incorrect notion that PIDs provide headroom and guarantee that consumer equipment will continue to operate properly as the system is altered over time. As discussed above, the full capacity of the terrestrial transmission channel is required to transmit a single HDTV program in the GA system. In order to use some of the packets for improvements or for different services, it must be possible to transmit HDTV with fewer packets, and in a manner that is compatible with the early receivers. Such compatibility is not guaranteed in any way by the GA or DTV standards. The situation is not at all comparable to adding color to monochrome NTSC, since it is just this kind of compatibility that was at the heart of the NTSC color conversion.

Para. 42. Here the Commission attempts to justify its conclusion that it is not practical to eliminate interlace from the standard at the outset, and that the migration to progressive scanning is best left to the market. I believe that in my earlier submissions, I have clearly demonstrated that the use of interlace is of no advantage whatsoever to any domestic interest, and is likely to make the transition to progressive scanning, admitted by everyone to be superior, at least difficult and perhaps impossible. The continued use of interlace reduces the spectrum efficiency by reducing the image quality that can be achieved within a give spectrum allocation. The failure of the Commission to see this point is regrettable.

Para. 46. Here the Commission contends that it is not relying solely on the Agreement to reach its conclusion that the elimination of the table of formats will not delay the implementation of digital television. However, a careful reading of the Fourth Order shows that this is not the case. No other reason is, in fact, put forth. Full reliance is being placed on the Agreement to support the conclusion that the required degree of certainty is maintained in spite of the deletion of a key element of the standard. (Before Commissioner Ness's letter, no one ever claimed this to be true.) Furthermore, the Commission appears to have the opinion that it is the contentions of the 'major industries affected by this decision', that is most compelling, rather than the views of the public, which will bear the entire cost of a new TV system, and of independent commentators.

In addition to disregarding the views of public-interest groups, the NTIA, and the Department of Defense, the Commission has also disregarded a number of points that I think that I proved beyond doubt in my own submissions. While it is true that I have only logic on my side, and not economic power, my arguments have been sufficiently persuasive that they were often quoted by other parties and some attempt was made to refute them by GA supporters. These points include the following:

(a) A progressive-scan signal having the same frame rate as an interlaced signal and the same number of lines per frame, and therefore having twice the analog bandwidth, when coded by MPEG, uses exactly the same digital data rate for transmission. Extensive studies in Europe have proved this point beyond doubt. Interlace does not increase the compressibility of either standard-definition or high-definition video.
(b) The 1080-line interlaced format does not have higher actual vertical resolution than the 720-line progressive format or is superior to it in any way, as clearly demonstrated by ATTC tests, both objective and subjective. This disposes of the false idea that interlace is required because it is necessary to have more than 1000 lines for true high definition.

(c) Interlace is not 'better for sports'. On the contrary, motion rendition at 60 fps progressive is superior to that obtained at 30 fps interlaced, and no reduction in resolution or frame rate is required for progressive scan, when MPEG coding is used.
(d) One of the arguments advanced by interlace advocates was that there was no 720 P progressive camera available, and such a camera was probably a decade away. In 1996, with DARPA funding, precisely such a camera was developed by Polaroid.
(e) There is no advantage, economic or otherwise, to any domestic stakeholder from using interlace for digital terrestrial broadcasting. There is only a temporary advantage to some foreign-owned companies that made unwise investments in this obsolete technology and are now trying to foist the resulting products on the US.

Considerations Related to the Federal Advisory Committee Act

The Federal Advisory Committee Act (FACA) provides that any committee advising a federal agency shall represent all interested parties and shall conduct all of its meetings in public. The law applies if the committee is either 'appointed' or it findings 'utilized'. The FCC acknowledged that ACATS was subject to this law. All meetings of the Advisory Committee and its very numerous subcommittees, as far as I know, were held in public with a Commission representative present. The organization of ACATS and the appointment of key personnel, however, were done in private, with the result that the public, in my opinion, was never properly represented. Women, minorities, and labor were also inadequately represented. A number of complaints were filed, but nothing was ever done about them.

In the case of the committee, in effect appointed by Commissioner Ness in her letter of 24 October 1996, meetings were held in secret and the public, which surely is an 'interested party', was not represented. When the 'Agreement' was reached, its principles were incorporated into the Fourth Order without change, in spite of the fact that they differed considerably from the previously announced positions of the Commissioners. While clever lawyers may well be able to get around the requirements of the law as stated therein in plain English, it is clear that the intent of the law was evaded.

FACA is not a mere technicality. The idea behind it is that public policy made in secret is likely to be bad policy. In this case, the deletion of the table of formats adds additional uncertainty as to whether the initial receivers will continue to be usable as the system evolves over time. Sufficient uncertainty may well slow down the adoption of digital TV by broadcasters and viewers enough to put in doubt the plan to shut down NTSC after a transition period. This plan depends on rapid proliferation of digital receivers, which, in turn, requires both certainty as to usability and the lowest possible cost. For exactly this reason, the Commission had wisely made nondisruptive improvement over time a preferred characteristic of the system to be selected. It is relevant that most of the commenting organizations that represent the public interest in some way had called for a single mandated standard. This would have provided the needed certainty and minimized the cost of the least expensive receivers.

An earlier case in which the intent of FACA was flouted was the 1993 effort to formulate a much-needed plan for healthcare. Much of the work was carried out in secret, with inadequate public representation. As a result, no national consensus was reached and all the work went for nothing. Although these procedures were eventually found not to have violated the letter of the law, the disregard by the task force for the wisdom incorporated in the Act set back the hope for an improved system for many years. This should be apparent to everyone, regardless of one's views on the healthcare problem.

There is no question at all that it is among the Commission's responsibilities in cases such as this to represent the public interest. There is also no question but that the public interest is not the primary concern of the parties to the Agreement. Under our economic and legal system, they are in business to make money for their shareholders. Delegating to this group the authority to set a key element of the standard at least has placed the public interest in danger. If digital television fails, or if NTSC cannot be turned off after 10 or 15 years, or if the most efficient use of the broadcast spectrum cannot be achieved, this danger will have materialized. Too much time and effort has gone into the Inquiry to put its success in jeopardy in this manner. A more detailed discussion of the FACA issue is contained in my submission of 5 December 1996.

Repairing the Damage

The FCC, after careful study, had decided that digital television was in the public interest and had made a reasonable plan for its implementation—namely, loaning a second channel to current licensees for a transition period. After the transition period, the analog channels would be reclaimed. More TV service would be provided than at present within a smaller spectrum allocation. The spectrum thus released would be available for new services from which the public would benefit. This is the heart of the plan, and is the part most placed in jeopardy by the terms of the Fourth Order, mainly because the standard is not fully delineated, giving rise to uncertainty on the part of potential investors and purchasers. Other goals not realized by the Fourth Order are nondisruptive improvement over time, the achievement of the most efficient use of spectrum, and the abandonment of interlace.

The question now is what further action can be taken by the Commission, through rules of implementation or otherwise, that may serve to achieve its original goals in spite of the drawbacks of the Fourth Order. Of course, if any steps are taken to avoid these drawbacks, it is conceivable that some of the parties to the Agreement will no longer feel bound by it. In that case, they may attempt to interfere with the Commission's plan in Congress, in the courts, or in public opinion. My hope is, that on further reflection, the Commissioners will come to understand that they do not have much to fear from such actions except for the possibility that Congress, in its budget-balancing zeal, may order auctions of the spectrum for the second channel, rather than letting it go free to current licensees. A way to deal with this problem is discussed below.

Paying for the Second Channel

Since auctioning the second channel is the biggest threat to the implementation plan, it might be wise for the Commission to adopt a proactive stance. I have long thought that all entities that profit from the use of the public airwaves ought to pay for the privilege, perhaps by a fraction of the profits. This idea might be applied to all spectrum assignments made after the passage of a new law or the exercise of the FCC's existing authority to levy fees, and to existing assignments after, say, 5 years. The law might provide for time-limited exemptions on the Commission's finding that a particular exemption is in the public interest. Such a finding might be based, in the DTV case, on the extraordinary expense involved in shifting to digital transmission and the public benefit that would eventually accrue from shutting down NTSC.

Shutting Off Interlace

Since all parties agree on the desirability of moving to progressive scan at some point, the suggestion from the NTIA that interlace should be allowed only for a limited time—say 3 years—seems to be quite valid. The only parties that would be put to any considerable expense are the foreign-owned professional equipment manufacturers, who would have to convert their interlaced equipment to progressive scan. The practicality of doing this is shown by Polaroid's development of the 720-line progressive camera. Polaroid developed the camera chip, but the camera itself was converted from an existing Philips 1250-line interlaced camera for a very reasonable cost. In any event, the FCC is not required to take into account the effect of its actions on foreign-owned companies. Furthermore, should a market develop in the US for progressive-scan HDTV studio equipment, we can be sure that all the major overseas manufacturers will be quick to provide what is needed.

It may also be noted that the single step that would best promote interoperability between TV equipment and computers, a goal acknowledged by all parties to be desirable, is the move to an all-progressive system.

Compatibility of Receivers with Broadcast Signals

It is clear that the Grand Alliance does not have the power to require that all broadcasts adhere to one of the listed formats in the ATSC standard, or to require that all receivers be able to receive all of the formats. This compatibility has been made more difficult by the deletion of the list of formats from the Fourth Order. The success of the All-Channel Receiver Law in making UHF TV commercially feasible at no cost to anyone shows, in my opinion, the most direct way to accomplish what everyone admits would be desirable. That is, when a digital receiver is purchased, the purchaser should have absolute assurance that it will work for a reasonable period of time—perhaps 10 years—with any digital broadcast in the US. Given such a law, it is highly likely that broadcasters would use only those formats that all receivers would accept, without further regulation.

If the Commission, for any reason, does not want to regulate receivers in this fashion, then it might promulgate a voluntary standard with the same intent, granting certificates of compliance to manufacturers who abide by the regulation. This might also be done by a private standardization organization such as ANSI, or by a manufacturers' organization.

Nondisruptive Improvement Over Time

My guess is that there will be very little HDTV broadcasting, as the cable and satellite industries have chosen to use compression technology to multiplex a number of standard-definition programs in each channel rather than to transmit a single HDTV program. Without the incentive of HDTV competition from the alternative media, it is hard to see why the terrestrial broadcasters will not do the same thing. If this is the case, then the single-stream 720 P and 1080 I formats can be deleted from the standard, to be replaced by high-definition video based on sending a standard-definition base-layer signal—probably 480 I or 480 P—plus an enhancement signal.[11] Coding of the enhancement signal will be found to be very similar to encoding of P and B frames in MPEG. The enhancement signal can be transmitted as part of the 19.3 MB/s GA data stream, or by use of a nonlinear constellation as I have proposed on p. 158, paragraph 5.

Of course, a standard for the enhancement signal would have to be developed, and that will take some time. However, if it is decided at an early date to use an enhancement

scheme rather than additional scanning formats to achieve high definition with a single data stream, then the design of base-level receivers can proceed in advance of the finalization of details of the enhancement coding. It should be noted that this method of achieving high definition will automatically provide for nondisruptive improvement over time and will also permit the design of the cheapest possible receivers.

Most Efficient Possible Use of Spectrum

Although it is well known that viewers care much more about the desirability of programs than the technical quality of the imagery, the Commission itself makes a judgment about image quality whenever it sets a standard. Higher-quality images need more spectrum. Hence, getting the highest quality for the amount of spectrum allocated is an important aspect of spectrum efficiency. The other element in spectrum efficiency concerns the number of programs of a given bandwidth (or data rate) that are available to each viewer with a given overall allocation of spectrum. NTSC is rather inefficient in this respect, since 67 channels are required to provide only 15 to 20 program choices.

Much higher efficiency is possible with single-frequency networks, where each service area is provided with a cellular network of low-power receivers, all emitting the same signal. With such a network, only 20 channels would have to be allocated to provide 20 different programs to each receiver. However, this possibility has been permanently eliminated the by the choice of the GA modulation scheme, which does not have adequate multipath performance. It is theoretically possible to achieve this performance using highly directional antennas, but it is doubtful that this would be acceptable.

Another method that would improve the spectrum efficiency is to require all transmitting antennas to be co-sited in each city that has too few interference-free channels. While this would cost a considerable amount of money, it would substantially reduce adjacent-channel interference and enable more channels to be made available without requiring more spectrum. It would be needed only in a few cities, and could be phased in over time.

Conclusions

The Federal Communications Commission has taken a most unfortunate step in its desire to get the digital broadcasting age underway as soon as possible. Differences of opinion between the television and computer industries led the Commission to seek a 'compromise' between fundamentally irreconcilable positions. Rather than choosing a system on its own that would protect the public interest, it effectively delegated to a small committee of its choosing, meeting in private, the final decision on a very important aspect of the DTV standard. Aside from the fact that this procedure violates the clear intention of the Federal Advisory Committee Act, which requires open meetings and representation of the public, the deletion of the table of scanning formats from the standard injects a substantial degree of uncertainty as to the future usability of the initial equipment, including receivers.

The proposed Grand Alliance standard had some deficiencies. Nevertheless, it was a complete standard; the resulting system would have succeeded or not according to its perceived merits. The proposed computer-industry standard, in my opinion, was superior in that it would have resulted in cheaper baseline receivers and had a sure path to nondisruptive improvement over time. The FCC standard is worse than either in that it has a considerable degree of uncertainty that may well reduce the rate at which the system proliferates, even to the extent of preventing the shut-down of analog broadcasting after a transition period. Without such a shut-down and the attendant freeing up of spectra for new services, there is no good reason to change our television broadcasting system.

It is still possible that the FCC decision can be amended directly or through the expected promulgation of rules for its implementation. If this can be done, the most important steps would be to set a definite date for the elimination of interlace and take some steps to remove the uncertainty as to formats that is inherent in the Fourth Report and Order. Providing for a definite migration path to higher quality is another step that would be highly desirable.

Notes and References

1. ACATS assumed, from the outset, that the entire system must come from one vendor, in spite of that fact that no such system existed. The idea that the Commission might do the picking and choosing of system components in order to assemble a system that best served the public interest was never considered.
2. The Advanced Television Systems Committee, although properly initiated by major professional organizations, played a significant role in attempting to make the NHK system the US production standard. It was instrumental in persuading the State Department to support the NHK system in international forums, much to the dismay of our European allies. At one point, its lawyers attempted to 'enjoin' me from publicizing the truth about its activities.
3. The Grand Alliance assumed that all broadcasters would adhere to their table of formats and all receivers would be able to cope with all the formats. I never thought that this would be the case. Only the FCC has the authority to ensure this, and it is doubtful that they would want to.
4. In my submission of 30 September 1996, I proposed some modifications to the GA standard that would have gone far toward satisfying both sides and at the same time would have protected the public interest.
5. It is not clear that this is really in their interests. When I first starting dealing with TV industry executives in 1983, they were all of the opinion that the best thing, from their point of view, was the fewest possible programs with the largest possible viewership for each.
6. It is not easy to count the number of standards. There is provision for 1080×1920, 720×1280, 480×640, and 480×704, interlaced and progressive, at 24, 30, and 60 frames/s. With aspects ratios of 4:3 and 16:9. Not all combinations are allowed, but frame rates 0.01% lower (e.g., 59.94) are also included.
7. This was fully simulated by my students at MIT. This migration method was described in a paper submitted with my filing of 5 December 1996.
8. In spite of including so many formats, an excellent format for a base layer, $360 \times 640 \times 60$ P, was omitted.
9. Actually, much of the NTSC archive that might be used for digital broadcasting originated on film and was converted to NTSC by the 3–2 pulldown method. Such video can easily be reconverted to 24 fps progressive and coded very efficiently. Imedia Corporation, of San Francisco, has demonstrated the transmission of 24 such signals in a single 6 MHz channel.
10. This is an exact quotation from remarks of a leading figure in ACATS, made at an Annenberg Forum that I attended. It was in response to a statement by John Sie that digital transmission might be a good idea for HDTV.
11. There is no doubt that an enhancement technique could be found that would permit an enhanced receiver to display progressive HDTV imagery whether the base layer were 480 I or 480 P. While I do not think that the 480 I standard is necessary, the Commission might feel that including this would be a sufficient concession to TV interests so that they would go along with the scheme.

Appendix

WFS submissions in 1996

(1) *11 March 1996*: Misstatements about interlace in GA submission of 22 January 1996. Several memos are included that rebut all the usual arguments in favor of interlace. FCC is urged to eliminate all the interlaced formats in the GA proposal.

(2) *14 June 1996*: Comments on the 5th NPRM. Interlace. The Polaroid progressive HDTV camera. Coding efficiency of P *vs* I video. References included from US and Europe showing that there is no data-rate penalty from using progressive scan.

(3) *10 July 1996*: Comments on the 5th NPRM, Part II. What kind of DTV standard is needed? Changes that might make the GA standard more attractive. Proposed the appointment of an expert committee. A new very extensive Project RACE reference is included showing that a progressive signal of a given number of lines/frame can be transmitted in the same digital data rate as an interlaced signal with the same number of lines, but having half the bandwidth.

(4) *6 August 1996*: 5th NPRM reply comments: errors in Sony submission. Sony has advanced not a single valid argument in favor of using interlace in broadcasting.

(5) *30 September 1996*: 5th NPRM additional reply comments: errors in NA Philips, ATSC, and GA comments. There are no valid arguments for the use of interlace in broadcasting, although interlace can be used in the cheapest receivers.

(6) *5 November 1996*: Letter to FCC re computer industry objections: a solution to the standards question cannot be found by forcing a compromise between the computer industry and the television industry.

(7) *5 December 1996*: Comments on Agreement between computer and TV representatives.

Glossary

ACATS—The Advisory Committee on Advanced Television Service. The FCC's advisory committee.

Agreement—The agreement of November 1996 between representatives of the TV and computer industries.

ANSI—The American National Standards Institute.

ATSC—The Advanced Television Systems Committee.

ATTC—Advanced Television Testing (Technology) Center, the facility set up by the TV industry to test HDTV systems.

CICATS—Computer Industry Coalition for Advanced Television Systems.

DTV—digital television, the broadcasting system authorized by the FCC.

ENG—Electronic news gathering. The use of TV cameras in the field, often under poor lighting conditions, to gather news for broadcasting.

FACA—Federal Advisory Committee Act.

FCC—Federal Communications Commission.

Fourth Order—Fourth Report and Order, FCC 96-493, issued by the FCC on 27 December 1996, setting forth the digital television broadcasting standard. Available at the FCC Web site.

GA—Grand Alliance, the group of companies in the FCC digital TV competition.

HDTV—High-definition television, generally defined as having twice the resolution horizontally and vertically as NTSC.

I—Interlaced scan. Alternate scan lines are traced out in successive fields.

MIT—Massachusetts Institute of Technology.

MPEG The Motion Picture Experts group. An international group that developed the coding scheme used in the GA system. A P frame is predicted from previous frames, while a B frame is predicted from both previous and subsequent frames.

MUSE—The analog compression system used to transmit NHK video by satellite.

NHK—Japan Broadcasting Corporation, or the 1125-line interlaced system first developed by NHK.

NPRM—Notice of Proposed Rule Making, an FCC document.

NTIA The National Telecommunications and Information Administration. A section within the Commerce Department that formulates telecommunication policy and advises the president on related matters.

NTSC —National Television Systems Committee, the analog TV system now in use in the US and most 60 Hz countries.

P—Progressive scan. All scan lines are traced out in every frame.

PID—Identification of each packet of bits transmitted in a digital coding scheme.

SD—Standard definition. Definition similar to that of NTSC.

SMPTE—Society of Motion Picture and Television Engineers.

UHF—Ultrahigh frequency, channels 14–68.