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Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of	
Rules for High Definition Television Broadcasting (Digital TV)	MM Docket No. 87-268 FCC 96-207

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Comment

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Interest

I have an interest in the present proceeding from three viewpoints:

First, as a consumer and a prospective viewer of programs broadcast using the proposed standards;

Second, as an owner of a computer system with a high-resolution display on which I would like to view HDTV programs, rather than buying expensive new equipment;

Third, as an active licensee in the Amateur Radio service.

Summary

I generally favor the proposed rule-making actions described in the Federal Register (May 20, 1996 pages 26864-26872).

My one point of concern with the ATSC standard is that any provision for a pixel shape other than square should be a self-liquidating temporary measure, provided only for backward compatibility at the lower performance levels. This appears to be the case.

I support additional inquiries and standards-making activities along the lines discussed in the notice, but as follow-on activities and not as vital matters that should further delay a Report and Order. Although the reasons for the glacial pace of this proceeding have been largely beyond the Commission's control, the wrangling has gone on far too long. It's more than time to release a standard and get on with real-world implementation.

Finally, I suggest broadening the agenda to consider orderly relocation of the TV broadcast service to higher bands during the replacement of the nation's inventory of transmitting and receiving equipment.

Definitions

I define the following terms for convenience in discussion:

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Receiving set: a DTV receiving installation, complete except for antenna and feedline
Receiver: a radio receiver for the DTV signal, whose output is the raw data stream from one RF channel
Data converter: a unit that converts the data stream from a receiver into an electrical signal compatible with some device, such as an NTSC TV set, a high-resolution computer monitor, or a high-fidelity sound system
Display unit: any unit that converts a decoded, isochronous electrical signal into a human-perceptible image or sound
Receiver-converter: a unit combining a receiver and a data converter, but no display

Issues and discussion

Pixel shape

Newspaper accounts at the time of the release of the NPRM implied that the new standard would be based on an unequal-sided pixel. A reading of the the condensed version in the Federal Register implies that oblong pixels would be used only in the 704×480 format, which appears to be some sort of ad-hoc hybrid for displaying old footage on NTSC sets.

This issue is important. An HDTV standard based on any pixel shape other than square would probably be doomed in the marketplace. The time is past when the broadcasting industry could go off on its own with an incompatible imaging standard and confidently expect consumers to buy it. While the HDTV proponents spent years preventing the adoption of each others' technology, the personal computer industry gained a decisive lead. Early in this period, they tried and abandoned odd-shaped pixels. They were unmanageable; software-generated images were distorted or ragged or both, and application programs had to include multiple drivers for different displays. Today, the installed base of high-resolution monitors is large and growing rapidly, and it all uses square pixels.

Broadcast TV is no longer the consumer's only source of electronic images, nor is it in a position to either dominate or evade de facto standards. Images move over the Internet and via all sorts of machine-readable media, and these *have* to be square-pixel images, because they display in windows on monitors that simultaneously display graphics and other computer-generated images. HDTV will encounter the twin realities of high prices for monitors of adequate resolution and image quality, meaning that a single monitor must be time-shared between computer and entertainment uses, and the strong likelihood that many viewers will want to display broadcast images in a window on the monitor *while simultaneously* displaying unrelated computer-generated information elsewhere on the same screen.

While some consumers may buy a complete DTV receiving set, many others will be budget-limited to a receiver-converter, which will be expected to smoothly patch the

broadcast image window into the video signal coming from the computer.

Aspect ratio

Aspect ratio probably isn't as vital an issue as it appears at first glance. Again, the reason is windowing. As long as the pixels remain square, the image can be shrunk to be fully in view on less than the full area of the display unit, or it can be magnified so that the most interesting parts of the image fill the screen. Given that the data converter and/or the display unit are implemented with today's technology, the user will be able to vary window dimensions and cropping at will.

Even with new equipment, the aspect ratio of the display unit won't necessarily be the same as the aspect ratio of the TV picture, especially if the display unit isn't dedicated to TV. Structural considerations make it easier to build a CRT with a relatively low aspect ratio. This might lead to use of the upper part of the display for high-aspect ratio images, while the bottom of the tube displays closed captions and operator interface windows.

All this suggests an additional use for the control packets in the data stream. The standard protocol could provide codes for cropping recommendations. Within the window space allocated by the user, the data converter could size the image to fit the window either horizontally or vertically, or crop asymmetrically when recommended. Data converters will have to deal in a rational manner with differences between the resolution of the received image and the resolution of the display unit anyway, because of the multiple formats permitted by the standard.

Interlaced vs. progressive scanning

This also is rapidly turning into a non-issue. In 1987 it would have been a big sticking point. But memory prices are now so low that the hardware cost of storing one frame worth of data is trivial. So it doesn't matter whether the data stream is interlaced or progressive; the data converter can output either one without regard to the order the pixels were received.

Frame rates

This is more of a problem.

A data converter with enough memory to store a frame can double or triple the frame rate to reduce flicker. Multiscan monitors can accomodate unusual in-between frame rates, up to a point. However, there are limits to what buffering can accomplish in the way of frame rate manipulation. If the rate from the data converter doesn't match the rate coming from the computer, it wouldn't be very easy for them both to drive the same display unit at the same time.

The computer industry has been pushing frame rates above 70Hz in recent years to reduce flicker and operator fatigue. Obviously, this isn't so good for bandwidth-limited

broadcasting, which would prefer to synchronize to the 60Hz power line. It's probably easier for computers to fall back to 60Hz than for broadcast signals to speed up. Also, the fatigue factor is probably a lot less for watching broadcast images, since the user's eyes don't scan back and forth as they do when reading text on the screen. It seems likely that future versions of computer video boards will find it necessary to incorporate a provision to drop back to a 60Hz frame rate when sharing a display unit with an isochronous TV feed.

In the meantime, not all that many of today's computer-generated images are isochronous. So a high-end DTV data converter might cope with windowing by buffering the computer's video signal and periodically discarding a frame.

The right degree of regulation

The Commission is quite right to be concerned that mandatory technical standards may stifle future technical advances. On the other hand, complete lack of regulation would have an even more stifling effect; DTV would have little chance of a successful launch without a common set of initial standards.

It's not a matter of choosing the lesser of two evils, though. There is a continuous range of options between no regulation and complete rigidity; the optimum will be found somewhere in the middle.

The proposed technical standard's greatest virtue is that it serves as a clear starting point. It can serve as a minimum common set of protocols to be supported by all receiving systems, without setting limits on what may be added in the future.

One attractive possibility the proposal mentions is allowing the use of additional, non-regulated technical standards after some particular date. This would have the virtue of getting DTV up and running quickly with common signal formats, while sparing the Commission and the public a future years-long wrangle like the one just concluded.

The trick is to protect the public's prospective investment in DTV receiving equipment against the threat of artificial obsolescence. Here, I have some suggestions.

First of all, any plan to phase in new standards later should recognize that one of the most striking trends in electronics today is the rapidly increasing speed and declining cost of small digital signal processor ICs (DSPs). We should expect that DTV receivers will soon turn to DSPs for demodulation if they don't start out that way, and data converters will probably be implemented with DSPs from the beginning of commercial availability. This means that everything after the IF bandpass filter will soon be programmable.

To take advantage of this, it would beneficial if the Commission and the Grand Alliance were to collaborate on some further standards-making activities, after the release of the proposed DTV technical standard.

The first follow-on standard could add protocols for over-the-air downloading of

machine instructions to receivers and data converters. This would add packet identifiers for either machine language or source code for receiving and displaying the images about to be transmitted.

However, it may also turn out that a significant number of receivers and receiving sets have their demodulation and data conversion algorithms hard-wired in custom integrated circuits. This implementation is a little more difficult to protect against obsolescence, but not impossible. The key is to design in modularity at the beginning — and do it without running up the initial cost.

What's important is protecting the display unit against premature retirement, since that's where most of the cost is. Today, a 17" 1280×1024 color monitor with well-defined boundaries between neighboring pixels costs the consumer about $800. At 19" the price jumps to about $1800, and it climbs rapidly from there. Try to shortchange the CRT price, and the pixels start blurring into each other, and all of a sudden it isn't high-definition any more.

Receivers and decoding logic, on the other hand, are a lot less expensive, and have much more potential for further cost reduction.

So if there's a well-defined and accepted set of standard interfaces between the receiver, the data converter, and the display unit, accessible to the equipment owner, it becomes possible to retrofit an existing receiving system with a new receiver or converter at modest cost. Of course, every receiver and receiving set will have a 75Ω coaxial input connector, because that's what the TV industry uses for the antenna input. So a family of interface standards could be built upon that 75Ω connector, which would open up the receiving set to external add-on boxes. This approach would yield total flexibility, without incurring any penalty in hardware that might never be used, such as module sockets, reserve power supply capacity, or extra internal space. We'd end up with something analogous to a component hi-fi system.

The first of these interface standards would define a physical layer for the demodulated DTV data stream in serial form; this would specify logic levels, bit rates, etc. When the user selects this form of input to the coax connector, the receiver would be bypassed. Switching to the data-stream input mode could be as simple as selecting "Channel 0".

A second, similar standard could define a serial format for the decompressed image, leaving out the details of windowing or the exact electrical interface to a particular display unit. This would bypass most of the data converter, presenting an add-on data converter with a single target format by which it could be sure of driving any existing display through the rear end of the old converter.

Yet another alternate use for the 75Ω connector would be an input to the receiver IF, probably after the bandpass filter. (IFs in any radio service tend to become standardized quickly, without any special effort.) The IF input would allow retrofitting a receiving system with an external RF front end, to allow receiving new bands, revised or non-

standard channel widths, and even non-US signals.

I would also suggest that the 75Ω connector standards be made compatible with the transmission of a small amount of DC power from the receiver to the source of either RF or data; this would simplify the installation of antenna-mounted preamps and other low-power devices.

Once these standards are published, their implementation in a piece of consumer equpment becomes a selling point, or perhaps an option which the customer can decide whether to buy. I don't believe their promotion requires a legal mandate to include them in consumer receivers, but it would probably require some forceful action by the Commission to get them written and published in time to do any good.

Assuming that the prerequisites for equipment longevity are accomplished, the accompanying rules might go something like:

> Beginning five years after the release of these rules, a DTV station may use any modulation type, image coding, data format, aspect ratio, resolution, number of multiplexed image channels, or other technical standards, provided that:
>
> The licensed bandwidth and signal strength are not exceeded;
>
> The pixel is square;
>
> At least every 5 seconds a data packet is transmitted that identifies all of the technical standards and parameters in use;
>
> Before each program or hour-long program segment using a technical standard not specified in these rules, the station transmits either the executable machine language required to receive the signal or the source code from which the machine language can be compiled.

Obviously, downloading isn't the only way to reprogram a receiver and converter, or even necessarily the best way. Equipment makers might provide various other methods. It makes a pretty good last-ditch protection against forced obsolescense, though, and should give the consumer considerable peace of mind.

Differences in technical standards between broadcast and cable DTV

As the proposal recognizes, there are all sorts of reasons why technical standards for DTV delivery by cable may diverge from those for transmission by radio. For example, cable isn't bothered by multipath fading, so cable operators might opt for QAM or even something like 64-PSK instead of VSB. There is no reason to expect that cable systems using frequency division would adopt the same band plan as over-the-air broadcasting. Indeed, the day may not be far off when some cable companies abandon copper cable entirely, and run a fiber optic line all the way to the set-top box.

It seems less than optimum to force such systems to recreate a UHF signal and a complex modulation format merely to interface with the customer.

The interface standards discussed in the previous section would be a good way to

cope with all these issues.

The demodulated data stream standard would be a particularly attractive general-purpose electrical interface to DTV receiving systems, not only for input from cable services, but also for non-broadcast sources such as digital video recorders and closed-circuit cameras.

It would probably *not* be economically feasible for cable systems to bypass the data converter and drive the display unit directly from the cable box. There are too many electrical interface standards among high-resolution monitors for the cable box to support them all; thus, it would be more practical to either use data formats directly supported by the broadcast-standard data converter, or download executable DSP code into it. I don't know that it's necessary for the Commission to make these formats mandatory for non-broadcast services; incompatible formats would most likely fail in the marketplace for lack of compatible display equipment. Similarly, a cable company that failed to support all broadcast DTV standards (that is, convert them to its internal transmission standards and back again at the customer's site) would probably find itself strangled by lack of program material.

A minor point...

Since the data stream is packetized, it would be possible for the receiver/converter to pass some data back to the set-top box during unused time slots. This may result in convenience features or added capabilities.

Out-of-channel emissions

The proposal's emission mask appears to be narrowly optimized to minimize interference between DTV signals and co-located adjacent-channel NTSC sources. This isn't the only consideration. Eventually, mutually distant DTV stations are likely to be packed in on adjacent channels. It seems more appropriate to set limits on the total amount of power (spectral density, actually) a station may radiate outside its authorized channel, rather than the ratio of out-of-channel power to its own authorized signal. That would protect the service areas of stations on other channels.

Receiver performance

The proposal talks of a 10db noise figure for typical consumer-grade receivers. I disagree. We're not living in the days of vacuum tubes and Mad Man Muntz any more. With state-of-the art receiver components available today at rock-bottom prices, and with the sophisticated filters that are routinely built into TV sets for reasons of cost-effectiveness, there is no reason to tolerate bad receiver design for an instant — especially in a service that gobbles up spectrum the way TV does. Signal strengths need not be planned for stone-deaf receivers.

More to the point, next-generation receivers should be subject to appropriate performance specifications for EMI immunity. From the earliest days of broadcast television,

the services that operate transmitters in residential neighborhood have been plagued by badly designed TV receivers. Hams experienced these problems first. There are a lot more of these services now — CB, GMRS, cordless phones in at least three bands, cellular phones, remote-controlled toys, PCS, FRS, and passing vehicles with commercial land mobile transmitters all up and down the spectrum. Years ago, the ham community lobbied Congress to give the FCC authority to mandate interference immunity requirements for broadcast receivers. This authority should be used. The public is hardly in a position to evaluate the EMI immunity of a receiver that appears to work correctly in the store. And the victim of manufacturer corner-cutting whose set exhibits no problems until the day three years after the warranty expires, when the hospital a block away puts up a paging transmitter, is flat out of luck.

A good starting point would be IEC 801-3 level 2 and IEC 801-6 level 2, with a limit of one uncorrectable packet per minute. These standards pretty well describe the residential RF environment: medium power transmitters at distances of 10 meters or so. This isn't difficult to deal with. I routinely design commercial instruments to make high-precision electrical measurements in a level 3 environment; that is, one meter away from a hand-held transmitter. It doesn't take much in the way of parts and manufacturing labor, just attention to detail during design and prototype test.

Spectrum allocation

One issue the NPRM doesn't even touch on is spectrum allocation. This, however, is extremely timely when several industries and the Commission are collaborating on standards changes so fundamental that they will eventually cause the total replacement of the nation's inventory of TV equipment.

It may have been reasonable to locate TV down in the VHF and lower UHF regions 50 years ago, when there were few other uses for these bands. Today, the situation is far different. The TV broadcast service is tying up more than 1/3 of all spectrum space below 1GHz. This is prime land-mobile spectrum; its propagation characteristics are ideal for communication between low-powered stations close to the ground and for many non-communication uses as well. Because of the many innovations in mobile and hand-held operations in the last decade, this part of the spectrum is in great demand. Every time someone thinks up a new use for short-to-medium range radio signals, the pressure on the existing radio services grows more intense.

The Amateur service is usually first to be targeted when someone wants a slice of VHF/UHF spectrum. The struggle for survival grows more difficult every year. We have already lost every mode of operation in the 220MHz band except FM repeaters, and now our two principal local mobile bands are under attack by an especially inappropriate proposal.

The present NPRM appears to lead to some easing of the spectrum crunch in the

VHF and lower UHF regions, but it could go much further.

The concept of interleaving DTV channels with co-located existing NTSC transmitters isn't bad, as far as it goes. The cost benefits are obvious: simulcasting can be done with existing antennas and linear amplifiers, while the installed base of receiving antennas can be used for the new DTV signals. The obvious implication is that when NTSC finally phases out, the unused spaces between the surviving DTV channels could be eliminated in a general reassignment of channels, freeing at least half of the UHF TV band for other services. It appears likely that VHF TV would disappear altogether when NTSC shuts down, since the cut-up nature of the three VHF TV bands makes adjacent-channel simulcasting a dubious proposition to begin with.

But the fact is, while TV broadcasting needs two or three hundred megahertz of spectrum, it doesn't need that space to be where it is now. If PCS is able to operate successfully in the 2GHz region, it's difficult to believe that TV broadcasting stations, with their 1500-foot towers and hundred-kilowatt ERPs, couldn't do it better. Specialized TV services already operate in S-band. There, or in X-band, these high-elevation stations can reach over trees and terrain, penetrate windows and reinforced concrete walls, and bounce around inside buildings. Moving all TV broadcasting above 1GHz when NTSC terminates would release as much as 366MHz for services better fitted to the lower frequencies.

Obviously, the first step is to find a new home for TV broadcasting. I don't mean to brush that aside as trivial, but I must admit to less familiarity with spectrum loading in the lower microwave region than in the bands below 1.3GHz. The 2.5 to 2.69GHz region is a strong possibility, since that's basically a TV band now. 190 MHz is enough for 31 channels, which ought be enough for any metropolitan area, since DTV stations won't need to be separated by empty channels (at least, not if we insist that DTV receivers have modern IF filters). Also, antennas of any significant aperture size are quite directive in this band, so point-to-point links should be able to coexist in channels that are also used for broadcasting, as long as the broadcast coverage zones and narrow-beam paths are properly coordinated.. It's also possible that the radar bands in the 5 to 5.6GHz region may not be loaded to the limit, and some rearranging might allow TV channels to be worked in there.

Assuming that suitable microwave spectrum can be found, the key points in a transition plan would be:

Announcement of the new band and channel plan at the earliest possible date, so that receiver manufacturers could support it in their designs;

Allocation of a channel in the new band to each existing station intending to continue operation after NTSC phase-out;

New construction permits and licenses to be issued only for the new

band;

Operation of existing VHF and UHF transmitters and antennas to be permitted long enough for reasonable recovery of investment, or until replacement is necessary for other reasons, but probably not more than a few years after the end of NTSC broadcasting;

Band planning for re-allocation of present TV broadcasting bands; reallocation of present TV channels on a spot basis as they become vacant, starting with those neither occupied not pre-allocated to simulcasting.

One objection likely to be raised to putting TV in the microwave region is the cost of low-loss microwave feedline. Actually, that isn't a factor for receivers. The obvious receiving system design is to incorporate a low-noise preamp and down-converter into the antenna assembly itself, and power and control it through the cable as a remote front end. This means that existing runs of RG-6 or RG-11 would be adequate. A down-converter would also typically include an RF switch, so that RF from existing TV antennas could be passed straight-through to the feedline during the simulcast era.

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June 29, 1996