BROADCASTING HIGH DEFINITION TELEVISION

Ben Crutchfield
Director of Special Engineering Projects

Department of Science and Technology
National Association of Broadcasters

ABSTRACT

High definition television has been broadcast over the air in both the UHF TV and 13 GHz bands. This first demonstration broadcast, sponsored by the National Association of Broadcasters and the Association of Maximum Service Telecasters, used the 1125 line, 60 field/sec. system developed by NHK. For transmission, the wideband video signal was compressed to 8.1 MHz using the MUSE system, also developed by NHK. This signal was transmitted by vestigial sideband AM in the UHF band and FM at 13 GHz.

Receiving points include the NAB, the FCC, and Congress. Programming includes a variety of materials produced on high definition video tape and other materials produced on 35mm film and transferred to tape.

The purposes of this project are to: promote development of a system for terrestrial broadcast of HDTV; assess the performance of proposed systems, and; demonstrate to the FCC and Congress the need for adequate spectrum to allow terrestrial broadcast of HDTV.

This paper describes the demonstration setup and results and discusses the plans for future activities.

INTRODUCTION

On January 7, 1987, experimental television station WWHD-TV signed on in Washington, DC. The operation of this station demonstrated that high definition television programs could be delivered to viewers by means that many had dismissed:

- Terrestrial (not satellite) broadcast,
- In the UHF television band,
- Using conventional, spectrum-efficient vestigial sideband amplitude modulation (VSB-AM).

This historic broadcast was commemorated in a ceremony at the Federal Communications Commission where broadcast HDTV programs were received and displayed on direct view and rear projection equipment. There were also operating versions of a 1/2 inch video cassette recorder-player and a video disc player.

After more than three weeks of daily operations, WWHD-TV signed off at the end of January, completing the first in a planned series of demonstration broadcasts by the National Association of Broadcasters and the Association of Maximum Service Telecasters.

OBJECTIVE

The objective of this project is to demonstrate to the broadcast industry, its regulators, and the public that significant advances in the technical improvement of television have reached the point where they may be delivered, at least on an experimental basis, via terrestrial broadcast methods.

At present, HDTV is being used to produce program materials ranging from commercials to feature length "films." Results have been good, both aesthetically and technically, and producers report significant savings of money and time compared with the use of 35mm film. HDTV combines the image quality of 35mm film with the speed and flexibility of electronic production and post production.

While these productions must, at present, be converted to standard television or film for distribution, we expect to see consumer HDTV equipment appear on the market in the U.S. in about five years. Prototypes of video cassette and disc players have been demonstrated; work is now beginning on the design for VLSI chips needed for mass production of affordable units. Chip development will take about three years and product design, another two years.

For broadcasters, it is particularly important to begin working on a system for HDTV delivery immediately. Any system will take time to develop, but more urgently, it is essential to determine the spectrum requirements and then secure the necessary spectrum. Other services are pressing for more spectrum, including spectrum already allocated to television broadcast. Without spectrum, broadcasters will probably be at a competitive disadvantage with respect to other media. We are acutely aware of what happened to AM radio when FM "caught on." In a decade, a major shift occurred as audiences turned to "high definition radio." We have also seen the sudden shift from vinyl audio disc to CD, abated only by anticipation of the arrival of digital audio tape (DAT) recorders. The common thread is consumer demand for higher quality.

ADVANCED TELEVISION SYSTEMS

Production

There is a wide range of improved television systems. Scientists and engineers in the U.S., Japan and Europe are studying or actually testing various approaches. At one end of the technological spectrum are improvements to the existing NTSC (or PAL or SECAM) standard. These apply to one or more phases of the imaging, encoding, processing and display systems and are generally compatible with existing equipment.

Because of compatibility, these improvements may be tested with existing broadcast facilities. No special test setup or authorization is required. Furthermore, much of the work being done is in the area of receiver improvement and appears on the market in the form of the latest model receiver.

The next big step in improvement of picture quality, however, is expected to come in the form of a system incorporating some of the following features:

- Increased number of scanning lines (possibly double or more) for higher vertical resolution,
- Wider bandwidth for higher horizontal resolution,
- Higher frame rate to reduce flicker,
- Progressive scanning,
- Wider aspect ratio,
- Separation of luminance and color signals

Probably the most important factor, from the point of view of the broadcaster, is the increase in bandwidth of the final output signal. It now appears that making a major improvement in picture quality means, inescapably, transmitting more information per unit time, which means more bandwidth. The HDTV production system used in the demonstration has a bandwidth over 20 MHz.

This 1125 line system was developed by NHK. Design criteria were based on the performance of 35mm film, including the wider aspect ratio, 5.3:3. An important overall design objective, however, was relative picture size for the viewer. It has been found that people tend to view NTSC pictures from a distance of six to seven times the picture height. For a 19-inch (diagonal) picture, the height is about 12 inches and the average viewing distance is about six to seven feet. For 35mm film, people tend to select a seat at a distance of three to four times picture height. Since the relative distance is half, the picture covers twice the visual angle for the viewer or four times the area for a picture of same aspect ratio. Most 35mm film uses an aspect ratio on the order of 5:3 so a 35mm picture actually covers closer to five times the visual area of a conventional television picture.

The design objective was, then, not to produce simply a clearer picture but to produce a picture clear enough that viewers would sit closer and experience a greater sense of reality. It is not coincidence that making a picture with five times the relative area requires around five times the bandwidth: over 20 MHz instead of 4.2 MHz.

Transmission

Delivering to the consumer a signal as wide as four or five conventional television channels is not practical for today's media. Those that could, such as CATV or multichannel multipoint distribution services (MMDS), would probably find that one channel of HDTV programming would not generate enough revenue to warrant the trade-off of the four or five conventional channels. Tape is not a likely medium in the foreseeable future, either, since 20 MHz is well beyond the capacity of professional one inch video tape recorders currently used in studios.

For terrestrial broadcasters, the possibility of finding enough spectrum to accommodate such wide signals is practically nil.

Fortunately, the technology that gave us laptop computers gives us a way to process picture information as data. It is no longer necessary that the television system be the same from studio camera to home receiver, as it is now. High speed processors and cheap memory provide the means to convert picture information to digital data and perform sophisticated processing on that data. After the program production and post production are completed, using full bandwidth recordings, the finished product can be transmitted by a system which transmits only enough information to satisfy the eye.

Researchers working with video have known for a long time that much of the information in a video signal is redundant. Unless there is much rapid action or a sharp transition between scenes, it is often hard to distinguish one frame from the next. Nonetheless, current television systems, including NTSC, update every part of the picture every time a frame is scanned, and this is true from camera to receiver.

Another relevant fact which has been known for some time is that the human visual system is less sensitive to detail in a scene or part of a scene which is moving. If, for example, the eye (or camera) is fixed on a scene and a car drives through, the eye will distinguish more detail in the unmoving scenery and less detail in the car.

This means that it is possible to build a television transmission system which updates visual information on moving parts of a scene more frequently but with less detail and updates static parts less frequently but with more detail. While there are ways to do this, the net result is a reduction in the amount of information which must be transmitted in a given period of time, and that, of course, means a reduction in bandwidth.

The most highly developed of these systems is MUSE, developed in Japan by NHK. MUSE stands for MUltiple Subnyquist sampling and Encoding. The encoder at the transmitter takes the wideband video signal and reduces it to 8.1 MHz, baseband. At the receiving end, the decoder reconstitutes the signal for display on an HDTV monitor. Sampling and processing are done digitally, but the transmitted signal is analog for further spectrum efficiency. See Table 1 for characteristics of MUSE.

The MUSE Demonstration

In the first demonstration, we used the MUSE system, developed by NHK for satellite, cassette and tape delivery of HDTV. An important, non-technical advantage of MUSE is that it is a working system. It has been tested by NHK in both satellite and terrestrial broadcast applications. The NAB-MST demonstration used vestigial sideband amplitude

Table 1 Characteristics of the MUSE system

System		Motion-compensated multiple subsampling system (Multiplexing of Y and C signal is by TCI format.)
Scanning		1125/60 2:1
Bandwidth of transmission baseband signal		8.1 MHz (-6 dB)
Resampling clock rate		16.2 MHz
Horizontal bandwidth	(Y)	20-22 MHz (for stationary portion of the picture) 12.5 MHz (for moving portion of the picture)*
	(C)	7.0 MHz (for stationary portion of the picture) 3.1 (for moving portion of the picture)*
Synchronization		Positive digital sync
* Values for a prototype receiver: these values should be 16 MHz and 4 MHz, if a perfect digital two-dimensional filter could be used.		

modulation (VSB-AM) for the UHF channel and frequency modulation (FM) for a 13 GHz channel. The latter was operated as a backup and as to demonstrate the possibility of using the SHF band where UHF may not be available.

The results were very satisfactory: there were no major difficulties in setting up or operating the system and clear pictures were delivered to all receiving sites. Where ghosts were found, they were removed by antenna positioning and a ghost-cancelling circuit built on the site by NHK engineers. Please see Table 2 for a summary of system data.

There was some concern about the audio signal. In tests where the signal was attenuated, the PCM audio was lost while the picture was still viewable. The sudden cutoff is characteristic of a PCM when the decoder cannot get sufficient data to operate. This would not normally be a problem for satellite use, for which the MUSE system was designed, but further study and work will be necessary to use the MUSE audio for terrestrial broadcast.

In general, MUSE proved to be a very "robust" signal. It looked good at all receiving sites and showed no unusual susceptibility to noise or interference. We were concerned that the motion sensing and compensating circuits might be easily disrupted but there was no evidence that this was the case. We were also concerned that it might take considerable time to set up and adjust the encoder and decoders after a long air and truck trip, particularly since these were developmental rather than production units. That everything worked was a very pleasant surprise, given our tight schedule. In fact, the large and complex encoder, consisting of four tightly-packed racks, was operational within hours of delivery.

CONCLUSIONS AND PLANS

The project described here is to demonstrate the feasibility of terrestrial broadcasting of HDTV. This first phase has successfully demonstrated one possible system and has called the attention of the television industry to the need to be prepared for the arrival of the next generation of television technology.

Several other systems have been proposed for broadcasting HDTV. One which may be available soon is being developed by the New York Institute of Technology. It uses two television signals which may be transmitted on separate channels. This approach involves transmitting a standard NTSC signal on one channel with additional picture information being transmitted on the second channel. Conventional receivers will work with the first channel while high definition receivers will combine the two channels to produce a high definition picture.

To analyze these and other systems, the Advanced Television Systems Committee (ATSC) has established a Technical Specialist Group on HDTV Transmission. ATSC is composed of representatives of the broadcasting and cable industries as well as consumer equipment manufacturers. They are seeking a single standard or family of standards which will serve the needs of all areas of the television industry and, ultimately, the consumer.

This work is considered very important as it will likely set the technical parameters for the development of television well into the next century.

Table 2 WWHD-TV MUSE Demonstration, Washington, DC

Path Description

Transmission Site:	WUSA-TV (Gannet, channel 9, Washington DC), auxilliary tower.
Path Length:	4 to 6 miles.
Receiving Sites:	Federal Communications Commission, 1919 M St. NW.; NAB, 1771 N St. NW; Russell Senate Office Building, 1st & D Sts, NE

UHF System

Encoder:	NHK MUSE II HDTV encoder, analogue video output 8.1 MHz including 2 PCM audio channels.
Transmitter:	ITS Model 20H/257H, vestigial sideband AM, UHF TV channels 59-59, nominal 50 watts (PEP) output, broadbanded for 8.1 MHz baseband input.
Transmission Line:	Cablewave 1 5/8 inch foam, corrugated copper, 350 ft., attenuation approx. 2.5 dB.
Transmitting Antenna:	Micro Communications special design UHF horn, gain 17.8, VSWR across band 1.03:1, ERP approx. 1300 watts.
Preamplifier:	Maspro 30U, broadband, 30 dB gain.*
Receiving Antenna:	Scala PR-450U parabolic reflector, gain 16, VSWR 1.2:1, received signal (typical) -48 dBm free space, -32 dBm into downlead.
Downlead:	Belden 8281 precision coax, 75 ohm.
Receiver:	Nihon Tsushinki precision TV demodulator, special design provided by NHK, output is 8.1 MHz to MUSE II decoder. input adjusted for nominal -37 dBm for design 55 dB S/N.

* Note: Attenuators and filters were used as needed, depending on the location, to prevent overload from high powered UHF-TV signals in the area.

SHF System

Transmission System:	Harris FV13MP 13 GHz portable microwave transmitter and receiver, filters bypassed for broadband operation, nominal 63 mW, 2 ft. dish., approx. -55 dBm to receiver for 56 dB S/N.