COMPARISON OF PROPOSED ATV SYSTEMS

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Abstract

The Federal Communications Commission appointed an Advisory Committee on Advanced Television Service in 1987 to determine if an ATV system should be recommended for adoption as the United States standard. The Committee has developed requirements and laboratory tested the proposed systems to select the best system for the United States.

In February 1993, after reviewing the results of the tests and analysis, plus proposals for improvements, the Committee determined that none of the systems could be selected. It further determined that the four proposed digital transmission systems should have their proposed improvements incorporated and then be retested. The results of the lab tests and their impact on the cable industry are outlined in this paper.

BACKGROUND

In 1987 the Federal Communications Commission (FCC) impaneled the Advisory Committee on Advanced Television Service (ACATS) to develop information that would assist the FCC in establishing an advanced television (ATV) standard for the United States. The committee, through its various sub-committees and working parties, has developed a list of desired attributes for the ATV service, produced the procedures to determine the ability of proposed systems to meet the desired attributes, reviewed proposed systems to determine if they should be tested and tested those systems which appeared to be capable of providing ATV quality pictures and capable of meeting the required transmission characteristics.

Of more than 20 systems or subsystems originally proposed, only six made it to the development point where they could be tested. One of the systems, an enhanced NTSC system, was withdrawn from consideration by its developer shortly after its laboratory tests were completed. The five remaining systems were tested and analyzed to determine if any were acceptable for recommendation as a standard. Four of the systems used a digital transmission format and the fifth system used an analog transmission format.

The five systems that were tested and analyzed, in the order in which they were tested, are:[1]

1) The Narrow-MUSE system, proposed by NHK which developed the original 1125-line high definition studio production system. This system utilized a 6 MHz analog transmission technique. The video format was 1125 lines, 2:1 interlaced, with a 60 Hz field rate.
2) The American Television Alliance (General Instrument and Massachusetts Institute of Technology) DigiCipher system used a 32 QAM carrier to transport a 1050-line, 2:1 interlaced, 59.94 Hz field rate signal.
3) The Zenith/AT&T Digital Spectrum Compatible-HDTV (DSC-HDTV) system used a digital 2/4 VSB modulation technique to transport a 787/788 line, 1:1 progressively scanned 59.94 frame rate signal.
4) The Advanced Television Research Consortium (David Sarnoff Research Center, Thomson Consumer Electronics, North American Philips, NBC, and Compression Labs) - Advanced Digital - HDTV (AD-HDTV) system used two separate 32 QAM

channels (within 6 MHz) to transport a 1050-line, 2:1 interlaced 59.94 Hz frame rate signal.

5) The second American Television Alliance system Channel Compatible DigiCipher (CCDC), used a 32 QAM carrier to transport a 787/788 line, 1:1 progressively scanned 59.94 Hz frame rate signal.

The aspect ratio of all systems was 16:9.

The laboratory tests began on July 12, 1991, with the Advanced Television Research Consortium's Advanced Compatible TV system and continued at about two-month intervals by the other systems. The Advanced Compatible TV system was withdrawn from consideration after its tests were completed and it will not be considered here. The test results of major interest to the cable television industry are the impairment levels at which a specified impairment just becomes visible in the picture (the threshold of visibility). These carrier-to-impairment levels will be cited in this paper. After the threshold of visibility, the signal quality degradation of the digital transmission systems is very rapid, while the analog transmission system has a more gradual degradation after the threshold.

The five ATV system results were compared by the Advisory Committee to determine if one system could be recommended for adoption as a standard.

TEST RESULTS

Carrier-to-Noise Ratio

The carrier-to-noise ratio is one of the major design limitations for a cable television system. As the number of amplifiers in cascade increases, the carrier-to-noise degrades. Television viewers are becoming increasingly critical in their acceptance of pictures with noise present. The 1958 TASO tests determined that a 30 dB signal-to-noise was considered "somewhat objectionable;" a similar test in 1983 determined that a 40 dB S/N produced the same rating while a 1992 CableLabs' study[2] determined that current viewers consider a 45 dB S/N to be "slightly annoying." Many cable operators are designing systems to deliver an end-of-system S/N ratio in the mid 40s to meet the demands of their customers. The ATV signal delivered to the subscriber's home must be at least as noise tolerant as NTSC signals to avoid having to rebuild the cable system.

The noise bandwidth of the various ATV systems are greater than the 4 MHz bandwidth used for NTSC systems. In order to compare the various systems most easily, the noise bandwidth has been normalized to 1 Hz. The 45 dB C/N for NTSC in 4 MHz becomes a C/N_O of 111 dB in 1 Hz.

The most noise-tolerant ATV system was the Channel Compatible DigiCipher system with a C/N_O of 83 dB at the threshold of visibility. The DigiCipher and DSC-HDTV systems were next at 84 dB followed by the AD-HDTV systems at 86 dB. The N-MUSE system was determined to be "slightly annoying" with a C/N_O of 100 dB. (The ATV digital transmission systems normally show no indication of impairments until a certain level of impairment is reached. As the impairment is increased beyond that threshold point, the picture quickly becomes unusable for normal viewing. The analog transmission systems exhibit a more gradual degradation in quality as the impairment level is increased. The values above give the threshold point for the digital systems and the "slightly annoying" value for the analog N-MUSE system.)

Composite Triple Beat

A second major design consideration for cable television systems is the composite triple beat (CTB) ratio. This impairment limits the number of amplifiers in cascade and is used in determining the output levels of the amplifiers. The NCTA Recommended Practices, Second Edition, suggests a performance objective of 53 dB for NTSC signals. Some of the ATV systems have been designed to operate in the presence of NTSC signals by incorporating notches in the receiver, splitting the channel around the NTSC visual carrier, etc., and are expected to have good CTB performance because the CTB products generally fall on or near the NTSC visual carrier.

The best performance in the presence of CTB was the DSC-HDTV system with a threshold at a C/I of 11 dB. The next best performance was obtained with the AD-HDTV system at a C/I of 16 dB, followed by N-MUSE with a C/I of 27 dB, DigiCipher with a C/I of 31 dB, and CCDC with a C/I of 33 dB.

All of the tested ATV systems performed significantly better than NTSC in the presence of CTB. When the CTB improvement and the C/N improvements are considered, it is expected to be possible to operate these signals at lower levels than the NTSC signals and still provide high quality pictures to the subscribers.

Composite Second Order

Composite second order (CSO) distortion products have had a reduced impact on system design consideration since the introduction of push-pull amplifiers. This impact has increased with the introduction of AM fiber optic links which typically have a degraded second order performance. The beat product typically falls about 1.25 MHz above the NTSC visual carrier and the ATV signals do not normally protect that area from unwanted energy. Most rejection of the beat product would be due to the action of the equalizer in the receiver.

The best performance was exhibited by the CCDC system with a threshold C/I of 12 dB followed by the DigiCipher system with a C/I of 16 dB. The DSC-HDTV system was next with a threshold C/I of 20 dB, the AD-HDTV systems with a C/I of 21 dB and the N-MUSE system with a threshold C/I of 38 dB.

As with the CTB results, the ATV systems were significantly more tolerant of the CSO distortion than NTSC and this impairment should not pose a significant problem when introduced into the cable system.

Hum Modulation

The power supplies in cable amplifiers do not normally contribute significant hum modulation to the amplified signal. However, in instances when the voltage feeding the power supply drops sufficiently low, the unit may go out of regulation and begin to create significant hum modulation. NTSC television sets are fairly immune to the effect of hum modulation and will not display the effect until the modulation reaches about 3%.

The four digital transmission systems were very tolerant of hum modulation and did not display any effect until the modulation was above 10%. The N-MUSE signal reached threshold at only 1% hum modulation.

The digital ATV transmission systems will not have any problems operating on cable systems designed to provide hum-free NTSC signals. The N-MUSE system is more susceptible to hum interference than NTSC and may have a problem on marginal cable television systems if the level of hum modulation is just below the NTSC threshold of visibility.

High Level Sweep

Most cable television operations utilize some form of high level sweep to maintain the frequency response of their systems. The original sweep systems made use of a signal about 10 dB above the visual carrier which was quickly swept across the band of interest and the detected result displayed on an oscilloscope. The visual effect in the picture was a small number of lines on the screen turning white. If the sweep signal were only turned on for brief periods, the subscribers might not notice and few would complain.

The N-MUSE system reacted in a similar manner to NTSC with a few lines being blanked. The four digital systems were more severely impacted as they lost sync and froze the picture or displayed errors in the video.

Cable operators would have a significant problem if the high level sweep signal were used on systems with a digital ATV transmission system. The N-MUSE would have problems comparable to the NTSC signals.

Phase Noise

Phase noise is generated in synthesized oscillators and imparted to signals during the heterodyne process. NTSC receivers are fairly immune to the effects of phase noise and no specifications have been set for phase noise contribution by processing equipment. Digital transmissions are generally more susceptible to phase noise interference. It may be necessary to set minimum specifications for frequency conversion equipment to ensure the total phase noise in the cable systems and customer's equipment does not exceed the capability of the receiver to handle the distortion.

The CCDC, DigiCipher and DSC-HDTV systems all exhibited the effect of phase noise at a C/PN_0 of 82 dB while the AD-HDTV system threshold was 84 dB. The N-MUSE system was extremely sensitive to phase noise and exhibited a threshold of visibility at 106 dB.

The cable industry needs to review design criteria for heterodyne equipment used in the systems to ensure the signal delivered to the subscriber can be used by the ATV receiver to produce quality pictures. It may be necessary to replace poorer performing equipment.

Residual FM

Small amounts of power-supply ripple in synthesized oscillators can result in significant amounts of frequency modulation of the carrier. The NTSC receivers can tolerate a large amount of residual FM before exhibiting any degradation in the picture. The cable industry has not been very concerned about residual FM. However, it is expected that digital transmission systems may have problems with residual FM.

The CCDC and the DigiCipher systems had a threshold of visibility at just under 6 kHz of residual FM. The DSC-HDTV system threshold was at 1.2 kHz, the AD-HDTV system threshold was 0.6 kHz and the N-MUSE system threshold was only 0.1 kHz.

The systems showed significant sensitivity to residual FM and will either have to have significant improvements in their performance or the synthesized oscillators used by the cable industry will have to have very little residual FM.

Channel Change Speed

Cable television subscribers are used to very quickly skimming through the channels to determine which show or shows they wish to watch. When channels are scrambled, the subscriber gets upset if the channel does not unscramble almost immediately upon being tuned. ATV systems must exhibit a similar speed in tuning and producing a picture, if subscribers are to be kept happy.

The CCDC, DigiCipher and DSC-HDTV systems all produced an identifiable picture in under a second, but the time increased when the signal was subjected to significant impairments. The AD-HDTV system required between 2 and 6 seconds to produce an identifiable picture while the N-MUSE system took over 8 seconds to produce an identifiable picture.

The fastest systems, at under 1 second, may be fast enough while the other systems would most likely meet with resistance from the public.

Basic Picture Quality

The picture quality of the proponent systems was compared against an 1125-line studio quality reference picture. Non-expert viewers rated the pictures to determine if there was any significant degradation in picture quality when passed through the compression-decompression process. The test material consisted of a number of still scenes and a computer generated graphic still, video camera motion scenes, transfers from film using a video camera and a computer generated motion scene.

The AD-HDTV and DigiCipher systems performed better than the other systems when processing the video camera-generated motion sequences.[3] When the material transferred from film was observed, the DigiCipher and AD-HDTV performed best, followed by N-MUSE, then CCDC and DSC-HDTV. CCDC and DSC-HDTV performed best with the graphic motion sequence, AD-HDTV and DigiCipher were next best, and N-Muse performed the poorest. The systems performed equally well with the material transferred from stills and with the graphic still. Experts viewing the various scenes commented that, while the systems performed very well, they did not feel that the quality was adequate for acceptance by the general public. It was felt that some characteristics of the compression process, while not noticed during the initial viewing, would become annoying after longer periods of observation.

CONCLUSIONS

The proposed ATV systems are able to operate in the presence of higher levels of impairments of typical concern to the cable industry, i.e., random noise, second and third order distortion and hum modulation. The systems are less tolerant of phase noise, residual FM and high level summation sweep. All of the systems exhibited some artifacts in the basic video quality which are expected to be of concern to the average viewer.

The Advisory Committee, after reviewing the results of the lab tests and entertaining proposals for improvements to the proposed systems, decided that the N-Muse transmission system could not be expected to improve to the capability of the digital transmission systems and it was removed from consideration. The four digital systems are to have the improvements which were proposed and accepted by the Committee implemented so they can be retested. The retests are expected to start in May 1993 and take about six weeks per system after which one system will be recommended for field tests.

The selection process, while requiring a significantly longer time than was originally expected, is working toward the adoption of a very high quality ATV service. It is imperative that the cable industry participate fully in the process along with CableLabs to ensure that the system selected works well on cable as well as over the air.

REFERENCES

1. ATV System Recommendation, Federal Communications Commission, Advisory Committee on Advanced Television Service, February 24, 1993.

2. Subjective Assessment of Cable Impairments on Television Picture Quality, CableLabs, June 22, 1992.

3. Comparative Analysis of Advanced Television Systems, Advanced Television Evaluation Laboratory, January 23, 1993.