Development of HDTV Emission Systems in North America

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1. Introduction

Television engineers in the United States and Canada are immersed in a study which could lead to the development of high definition television (HDTV) emission standards for North America in the next three years. The primary force, to date, has been the terrestrial broadcasting industry which has made clear its intent to compete with other forms of the media -- cable, broadcast satellite, video cassette, video disk -- for television viewers of the future. Organizations have been formed in the United States and Canada to address the issues.

Other regions only plan to use satellite broadcasting for HDTV. The North American approach will be more easily understood if the broadcasting structure and the relationship between the different forms of the media are understood. This article will explain first these structures and then the processes which are being used to define the appropriate technical systems for HDTV broadcasting. Technical proposals which have been made will then be summarized.

2. The broadcasting structure in North America

Compared to other regions, the structure of broadcasting in the United States and Canada is unique, being a complex interconnected web of over-the-air, cable, and satellite delivery media programmed by numerous competing sources, many independent of the delivery mechanism. North American viewers are well served, most having access to 10 or 12 channels and many with access to 30 or more. Over fifty percent of the viewers in the United States, and even more in Canada, receive their television on cable. Over fifty percent of viewers in both countries use video cassette recorders (VCR) for viewing rented and time-shifted programs. About two million homes in the United States and a similar percentage in Canada directly receive satellite signals used to distribute programs to broadcast terrestrial stations and cable head ends. In the United States the Federal Communications Commission (FCC) has granted construction permits for high power direct broadcast satellites (DBS) but systems are not yet operational. The introduction of the medium power satellite ANIK-E in 1990 will add a number of new television services by satellite for the Canadian viewers.

The introduction of HDTV into North American broadcasting will be subject to many forces -- technical, economic, and political. The technical standards must take these forces into account and, at the same time, enable the introduction of consumer products -- receivers, VCRs, disks, etc. -- that are economical and capable of displaying both current and HDTV services.

In the North American television industry, three clear motives can be seen in the introduction of HDTV services:

1. Enhance current services Existing terrestrial broadcasters, many of which are relatively small and independent, may take this approach to improve market share or to enhance business viability in the face of new competing services. Constraints of spectrum, investment, and market may lead to HDTV systems compatible with current NTSC receivers even if there is loss of potential quality.

2. Provide new services New service providers, especially those with access to cable or satellite delivery, may press to establish HDTV services at a higher quality level with a lower level of NTSC compatibility. Tape and disk distribution may be significant.

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3. Launch new distribution technologies High-power DBS and the broadband integrated services digital network (B-ISDN) are examples of this approach. The new wideband technology will create new competitors for the viewers' screen. Standards affecting the viewers' terminals are an important consideration.

In the United States, television broadcasting is regulated on a media basis by the FCC which regulates, among other things, the technical aspects of broadcasting, including the use of spectrum. FCC regulation is most pronounced for terrestrial broadcasting and less so for cable and satellite broadcasting. States and local jurisdictions are also involved in the regulation of cable and common carriers (potential B-ISDN suppliers). The FCC is currently concentrating on spectrum matters related to terrestrial broadcasting of advanced television (ATV)[1].

In Canada, television broadcasting is regulated on a service basis, essentially neutral to delivery media, by the Department of Communications (DOC) and the Canadian Radio and Telecommunications Commission (CRTC). Interest in HDTV is thus broadly based, taking account of all potential delivery media.

Both the United States and Canada have considerable sharing and overlapping of television services and thus the question of HDTV services and standards has an international aspect to it. Practical considerations dictate similar standards throughout North America. It will take time to resolve this complex issue in a way that is acceptable to the many diverse participants in the discussion.

3. The search for HDTV broadcasting systems

Several organizations are now in place in North America and involved in the search for the most appropriate HDTV emission systems. Many different factors are being investigated in this search. This section will review events of the past several years which are seen as elements leading to the present situation.

The Society of Motion Picture and Television Engineers (SMPTE) established a Study Group on High Definition Television in 1977. The Study Group held seven meetings and issued its report in the February and March issues of the SMPTE Journal in 1980. The principal findings of the Study Group were that the appropriate line rate for HDTV is approximately 1100 lines per frame, that the frame rate should be 30 frames per second interlaced, that aspect ratio should be not less than 5:3, that luminance and chrominance should be kept separate, and that the luminance bandwidth should be about 25 MHz.

In 1982 the United States Advanced Television Systems Committee (ATSC) was formed by the United States television industry (broadcasters, cable industry, satellite operators, consumer electronics manufacturers, professional equipment manufacturers, motion picture industry) to coordinate and develop standards for advanced television systems. Its founders[2] established the ATSC in the belief that the prompt, efficient and effective development of a coordinated set of national standards (and of a single national position in the development of international standards) for advanced television was essential to the United States' ability to foster a new generation of domestic television service.

The work of the ATSC in HDTV initially was in the area of production. In 1986 a group was formed to coordinate and develop standards for the distribution of HDTV programs to the public. This group initiated a testing program in 1987 to determine propagation characteristics in the UHF and other bands for two channel systems (some proposed systems would broadcast NTSC in one channel and an augmentation signal in a second non-contiguous channel) and for wide-band systems.

In 1987 the Canadian Advanced Broadcast Systems Committee (CABSC) was formed by the Canadian government, Canadian Broadcasting Corporation (CBC) and other broadcasters, cable television operators, and industry to provide a national forum for the development of standards and introduction strategies for HDTV broadcasting. Two subcommittees were formed, the Strategy Subcommittee which is to identify the best schemes for coherent implementation of advanced broadcast systems and the Technical Subcommittee which is to investigate technical issues related to advanced broadcast systems and make recommendations on inputs to other national and international organizations. Current activities are directed toward the establishment of introduction strategies

appropriate for the Canadian situation and the definition of HDTV emission systems suitable for the terrestrial, cable, and satellite facilities. As a part of the effort to arrive at a common solution, a high level of cooperation and collaboration exists with the FCC and testing laboratories in the United States. Canadian work has concentrated on the characterization and simulation of the delivery channel to the consumer and this will form the basis of testing in both countries. Future work will test the performance of candidate systems, both in simulation and in practical tests, as part of the screening process. The current Canadian view is that it will be difficult to find a single system that meets the diverse needs of the delivery mechanisms currently in use. Consequently, a related family of systems may be chosen that results in a common receiver design and fully exploits the capability of the various delivery mechanisms.

In January 1987 the Association of Maximum Service Telecasters (MST) and the National Association of Broadcasters jointly demonstrated the feasibility of HDTV terrestrial broadcasting in Washington, DC using UHF channels 58 and 59 as a single channel.

Also in early 1987, the FCC was considering a request from non-television interests to re-allocate some spectrum in the UHF television band to non-broadcast applications. MST coordinated the efforts of more than 50 broadcasters to petition the FCC to first consider the impact of HDTV on the terrestrial broadcasters. It was asserted that the broadcasters may need additional spectrum to broadcast HDTV. Further, it was claimed that the other forms of the media would be able to deliver HDTV programs to the public and the terrestrial broadcasters would have a competitive disadvantage if they could not deliver HDTV to their viewers.

In July 1987 the FCC adopted a "Notice of Inquiry" to consider the technical and public policy issues surrounding the use of ATV technologies by terrestrial broadcast licensees. The primary focus of the proceeding is the initiation of terrestrial broadcast ATV service.

In November 1987 the FCC formed an Advisory Committee on Advanced Television Service to advise the FCC "on the facts and circumstances regarding ATV systems for Commission consideration of the technical and public policy

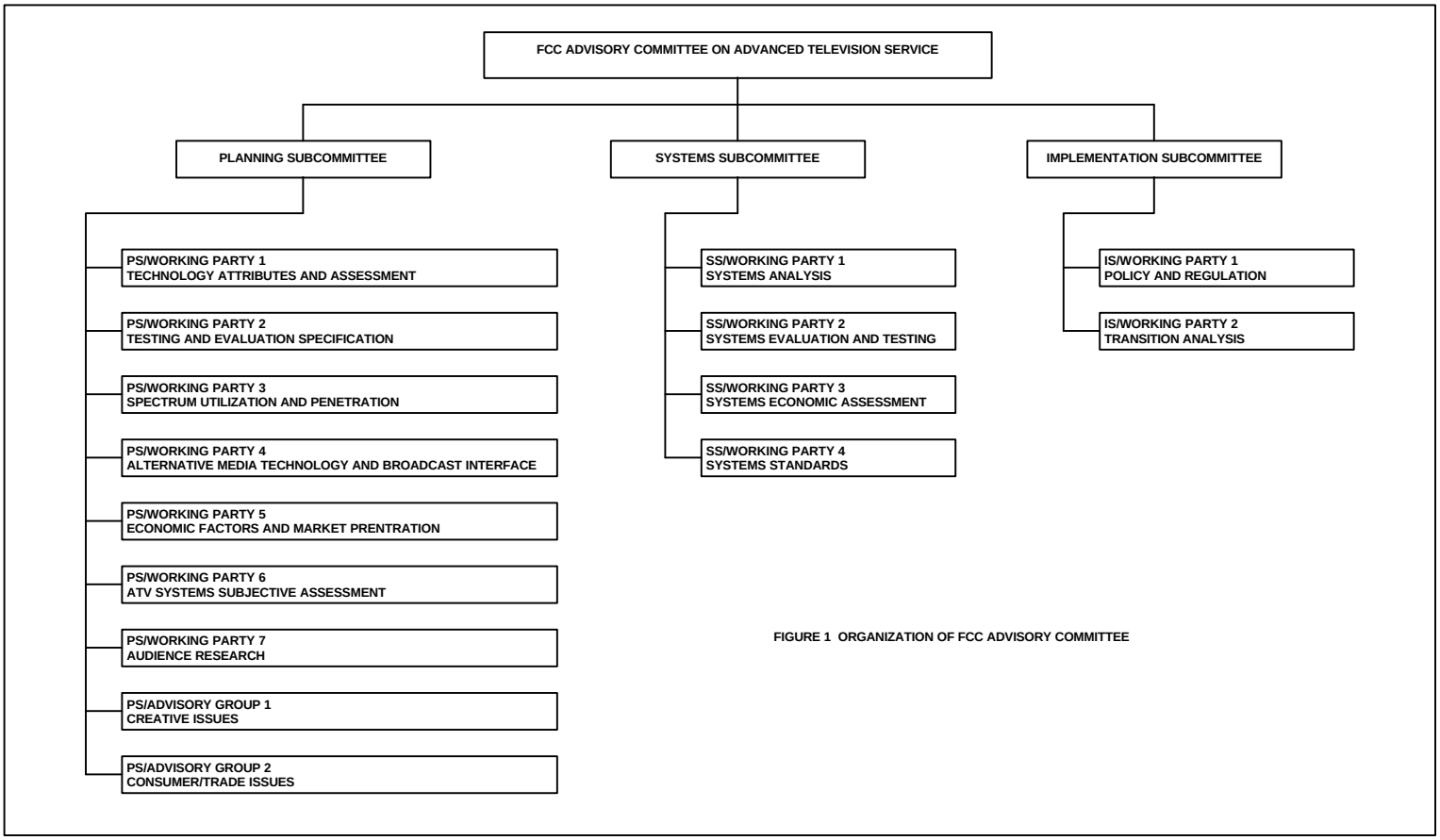

FIGURE 1 ORGANIZATION OF FCC ADVISORY COMMITTEE

issues." The scope of activity is to "develop recommendations regarding the introduction of terrestrial ATV service" and includes "technical, economic, legal and regulatory issues." The Advisory Committee is composed of a panel of industry leaders representing diverse viewpoints. Three subcommittees report to the Advisory Committee. A total of 15 sub-groups report to the three subcommittees. The organization of the Advisory Committee is shown in Figure 1. Since the studies of the Advisory Committee are quite broad, a summary of the studies of each group is given in Annex I. The Advisory Committee forwarded its first report to the FCC in June 1988. Its second report is scheduled for April 1989.

On September 1, 1988 the FCC adopted a "Tentative Decision and Further Notice of Inquiry." Several tentative findings were made. They were as follows:

1. Providing for terrestrial broadcast use of ATV techniques would benefit the public.

2. The benefits of ATV technology can be realized most quickly if existing terrestrial broadcasters are permitted to implement ATV.

3. Any spectrum capacity needed for terrestrial broadcasting of ATV must be obtained from the spectrum now allocated to terrestrial broadcast television (VHF and UHF).

4. Existing terrestrial broadcast service to viewers using NTSC receivers must be continued at least during a transition period either by broadcasting ATV signals that can be received directly by NTSC receivers or by simulcasting NTSC and ATV signals on separate channels.

5. The need for NTSC compatibility and the scarcity of spectrum lead to the conclusion that systems requiring more than 6 MHz to broadcast a signal non-compatible with NTSC receivers will not be authorized for terrestrial broadcast service.

6. It is in the public interest not to retard the independent introduction of ATV in other services or on non-broadcast media, although sensitivity is expressed to the benefits of compatibility between equipment associated with the various video delivery methods.

The FCC set forth four alternative methods for accommodating ATV in the terrestrial broadcasting service. Each terrestrial broadcaster would:

A. Provide an NTSC compatible[3] ATV service within the current 6 MHz assignment.

B. Be provided an additional 3 MHz for an augmentation signal.

C. Be provided an additional 6 MHz for an augmentation signal.

D. Be provided an additional 6 MHz for a simulcast[4] non-compatible ATV signal.

The FCC is seeking comments on its tentative decisions, on the options for accommodating ATV service, on ATV systems being designed for terrestrial broadcast service, on how technical standards should be established for ATV, and on possible scenarios for distributing supplemental spectrum if it is decided to do so.

Many other organizations have formed task groups to study HDTV from different perspectives. Several terrestrial broadcasters formed the Advanced Television Test Center (ATTC). The ATTC plans to test the systems proposed for broadcasting ATV and submit its test results to the different organizations involved. The cable industry formed the Cable Television Laboratories to conduct research on HDTV relevant to the cable industry. Congressional committees have held inquiries to examine the possibility of increasing the competitiveness of American industry in manufacturing HDTV consumer electronics.

4. Techniques under consideration

Several organizations have proposed ATV systems for terrestrial, cable, and/or satellite broadcasting in North America. Some of the organizations have proposed more than one system. Figure 2 lists the systems proposed to the

	AVE	BTA	DSCR		DEL	FAR	HRS	NHK				MIT		NYIT	NAP		OCS	PS	QTV	SA	ZEN
			ACTV 1	ACTV II				MUSE	MUSE 6	MUSE 9	NARRROW MUSE	RC	CC		HD MAC	HD NTSC					
SPECTRUM CATEGORY	A	A	A	C	A	A	A	*	A	B	D	A	D	B/C	*	B	C	A	A	*	D
RF BANDWIDTH (MHZ)	6	6	6	12	6	6	6	*	6	9	12	6	12	9/12	*	9	12	6	6	*	12
H-RESOLUTION (TVL/PH)	660	NTSC	400	600	660	330	NTSC	574	422	422	568	300	675	750	495	495	?	?	NTSC	534	612
V-RESOLUTION (TVL/PH)	660	NTSC	480	800	660	400	NTSC	?	690	690	650	600	762	900	480	480	?	?	NTSC	480	720
FULL DIAGONAL RESOLUTION	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	YES	NO	?	?	NO	NO	NO
FULL TEMPORAL RESOLUTION	NO	YES	NO	NO	NO	YES	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	?	YES	YES	NO
WIDE SCREEN	YES	NO	YES	YES	YES	NO	NO	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	NO	YES	YES
INTEGRATED SIDE PANELS	NO	N/A	NO	NO	YES	N/A	N/A	YES	YES	YES	YES	YES	YES	YES	YES	NO	N/A	YES	N/A	YES	YES
SEPARATE COLOR	NO	NO	NO	NO	NO	NO	NO	YES	NO	NO	YES	NO	YES	NO	YES	NO	NO	?	NO	YES	YES
FIELD STORE REQUIRED	YES	NO	YES	YES	YES	YES	NO	YES	YES	YES	YES	YES	YES	YES	OPT	OPT	YES	?	NO	YES	YES

N/A - NOT APPLICABLE ? - NOT SPECIFIED

ORGANIZATIONS PROPOSING SYSTEMS

AVE	AVELEX	NYIT	NEW YORK INSTITUTE OF TECHNOLOGY
BTA	BROADCASTING TECHNOLOGY ASSOCIATION	NAP	NORTH AMERICAN PHILIPS CORPORATION
DSRC	DAVID SARNOFF RESEARCH CENTER	OCS	OSBORNE ASSOCIATES
DEL	DEL REY GROUP	PS	PRODUCTION SERVICES
FAR	FAROUDJA LABORATORIES	QTV	QUANTICON
HRS	HIGH RESOLUTION SCIENCES	SA	SCIENTIFIC ATLANTA
NHK	JAPAN BROADCASTING CORPORATION	ZEN	ZENITH ELECTRONICS CORPORATION
MIT	MASSACHUSETTS INSTITUTE OF TECHNOLOGY		

SPECTRUM CATEGORY OF PROPOSED SYSTEMS

A = 6 MHZ COMPATIBLE
B = 6 MHZ NTSC + 3 MHZ AUGMENTATION SIGNAL
C = 6 MHZ NTSC + 6 MHZ AUGMENTATION SIGNAL
D = SIMULCAST (6 MHZ NTSC IN ONE CHANNEL, 6 MHZ NON-COMPATIBLE SELF-CONTAINED ATV SIGNAL IN SECOND CHANNEL)
* = SATELLITE DESIGN, REQUIRES ONE TRANSPONDER

FIGURE 2 SUMMARY OF SYSTEMS PROPOSED TO FCC ADVISORY COMMITTEE

Advisory Committee along with some of the video parameters. A summary of the technical characteristics of each system is given in Annex II. In addition to these proposals, two organizations, Digideck and Dolby Laboratories, have proposed audio systems which could be incorporated in the systems listed in Figure 2. All of these organizations have submitted detailed information to the Advisory Committee, information which is available to the public.[5]

The first two rows in Figure 2 give spectrum related information for the proposed systems. The first row shows the spectrum category of each system in terms of the FCC's four alternative methods listed above. The second row shows the bandwidth of the RF channel required for terrestrial broadcasting. An asterisk (*) in these rows indicates that the system is designed for satellite broadcasting and requires one transponder.

Rows three through six in Figure 2 give information about the resolution of the proposed systems. Rows three and four show the horizontal and vertical resolution for still pictures expressed in TV lines per picture height. Some of the proposed systems have the same resolution as the NTSC system; in these cases the resolution is shown as "NTSC." The fifth row is marked "YES" if the diagonal resolution is comparable to the horizontal and vertical resolution. Note that NTSC does not have full diagonal resolution because of the presence of the color subcarrier. The sixth row is marked "YES" if the dynamic resolution is equal to the static resolution.

The last four rows of Figure 2 give general information about the proposed systems. The seventh row is marked "YES" if the proposed system is wide screen and, if so, row eight shows whether the side panels are treated as an integral part of the picture or if they are treated as a separate signal. The ninth row is marked "YES" if the color information is carried separate from the luminance signal. The last row is marked "YES" if the receiver requires a field store ("OPT" means optional).

5. Conclusions

In contrast with other regions, there is great interest in North America in terrestrial broadcasting of HDTV. Several systems have been proposed for terrestrial, cable, and satellite broadcasting. Organizations are in place and are proceeding to examine the proposed systems and define the technical standards. The introductory date of HDTV services in North America is difficult to predict. At the present time, many questions exist concerning the business, economic, and technical aspects. In addition there is no consensus on the level of quality required for the services to be viable.

Footnotes

1. ATV has been defined by the FCC to include all advances in television ranging from simple improvements in the NTSC system to full high definition television, generally regarded as meaning twice the horizontal and vertical resolution of current systems, a wide aspect ratio, improved color rendition, and high quality multiple channel sound.

2. The founders and Charter Members of the ATSC are the Electronic Industries Association (EIA), the Institute of Electrical and Electronics Engineers (IEEE), the National Association of Broadcasters (NAB), the National Cable Television Association (NCTA), and the Society of Motion Picture and Television Engineers (SMPTE).

3. In this article, "NTSC compatible" means the broadcast signal can be received and displayed with normal quality on a conventional NTSC receiver without any converters.

4. In this article, "simulcast" means that programs are broadcast simultaneously in the NTSC format in one 6 MHz channel and in a "non-NTSC compatible" ATV (or HDTV) format in a second 6 MHz channel.

5. Advisory Committee documents may be obtained through International Transcription Services, Inc. in Washington, DC.

Annex I

The FCC Advisory Committee on Advanced Television Service

The Advisory Committee on Advanced Television Service was established by the Federal Communications Commission (FCC) to advise the FCC on the facts and circumstances regarding advanced television systems for Commission consideration of the technical and public policy issues. In the event the Commission decides that adoption of some form of advanced broadcast television is in the public interest, the Committee would also recommend policies, standards and regulations that would facilitate the orderly and timely introduction of advanced television services in the United States.[1]

The scope of activity includes all steps necessary to assemble and analyze information, deliberate upon appropriate policies and actions, and develop recommendations regarding the introduction of terrestrial advanced television service.

The Advisory Committee reports to the Chairman of the FCC and is composed of about twenty-five television industry leaders selected to represent diverse viewpoints. Three subcommittees report to the Advisory Committee.

1.0 Planning Subcommittee The objective of the Planning Subcommittee is to plan the attributes, or desired features, of terrestrial advanced television service (picture quality, population served, costs to broadcasters, consumers, and manufacturers, relationship to existing broadcast service, relationship to non-broadcast services) and recommend planning factors for advanced television service (coverage area, quality of service, frequency reuse criteria, receiver quality, spectrum allocations).

Seven working parties and two advisory groups report to the Planning Subcommittee.

1.1 Working Party on Technology Attributes and Assessments Define and list the desirable attributes of terrestrial transmission systems for ATV. The list of basic issues of interest will be used by other working parties as a guideline for gathering data and describing and evaluating various systems under consideration.

1.2 Working Party on Testing and Evaluation Specifications Develop specifications for the testing and evaluation of proposed ATV systems and develop a draft schedule for

testing and evaluation to be performed by the Systems Subcommittee. The specifications shall include measurements related to the attributes developed by the Working Party on Technology Attributes and Assessments.

1.3 Working Party on Spectrum Utilization and Alternatives Carry out studies on the availability of spectrum to support various ATV schemes for terrestrial broadcasting using modeling techniques in connection with a number of spectrum utilization scenarios. Scenarios will be based on a series of assumptions including coverage, bandwidth, allocations, other radio service considerations, taboos, international agreements, and projection ratios.

1.4 Working Party on Alternative Media Technology and Broadcast Interface Establish a point of reference or baseline for designers of broadcast ATV systems so that a user friendly interface is achieved whenever broadcast signals interface with alternative media. Be a focal point for other working parties to obtain information on the operational, technical and environmental aspects of alternative media. Alternative distribution technologies include satellite, fiber optics, cable television, microwave, VCR, and video disk. Develop tests required to determine the suitability of proposed ATV systems for transmission through and between the alternative media.

1.5 Working Party on Economic Factors and Market Penetration Identify the economic factors which will influence the development and penetration of ATV services and the impact on program providers, program distributors, and consumer equipment manufacturers. Provide a methodology for economic evaluation. Define the economic issues. Identify the factors involved in consumer acceptance of ATV in terms of time and cost. Special attention will be given to the probable incremental cost to consumers.

1.6 Working Party on ATV Systems Subjective Assessment Identify system characteristics in need of subjective assessment and recommend test methods for the subjective assessment of picture and sound quality of proposed ATV distribution systems. Topics in need of specification may include viewing conditions, test methods, data analysis, and subject populations. Propose guidelines for the production of subjective test material with static and moving scenes. In accordance with CCIR Recommendation 500, the test material "shall be critical, but not unduly so."

1.7 Working Party on Audience Research Define, plan, and execute audience research which will lead to an understanding of viewer preference in the field of HDTV programs viewed in the home. Investigate the types of programs most appreciated in HDTV, the types of viewers who most appreciate HDTV programs, the willingness of viewers to pay a premium for HDTV display, and the willingness of viewers to pay a premium for HDTV service in the home.

1.8 Advisory Group on Creative Issues Assess the views of the creative community in relationship to the development and implementation of a terrestrial ATV transmission system in the United States.

1.9 Advisory Group on Consumer/Trade Issues Identify the consumer and trade issues that must be resolved before a set of recommendations can be forwarded to the FCC.

2.0 Systems Subcommittee The objective of the Systems Subcommittee is to specify the transmission and reception facilities appropriate for providing advanced television service. The subcommittee is to provide advice on the parameters of systems, and evaluate (technical and economic) and recommend systems under development as candidate for implementation. This subcommittee may specify the design of an appropriate system. It will also advise on the appropriate transmission/reception technical standards and spectrum requirements for the recommended system(s).

Four working parties report to the Systems Subcommittee.

2.1 Working Party on Systems Analysis Analyze the various candidate systems proposed for the distribution of ATV using the attributes developed in the Planning Subcommittee. The transmission media shall include terrestrial broadcast, satellite broadcast, CATV, fiber optic distribution and hybrid systems composed of the above technologies.

2.2 Working Party on Systems Evaluation and Testing Evaluate the transmission performance of various ATV distribution systems based on objectives developed by the Planning Subcommittee. Extensive subjective and objective

performance testing shall be conducted.

2.3 Working Party on Systems Economic Assessment Establish estimates of the costs associated with the distribution of ATV by various systems, with inputs from the Planning and Implementation Subcommittees. An assessment of the technological viability and economic feasibility of each system will be established.

2.4 Working Party on Systems Standard Recommend standards for the transmission of ATV.

3.0 Implementation Subcommittee The objective of the Implementation Subcommittee is to establish a scheme for implementation of advanced television service in the United States. This subcommittee is to provide advice on policies, regulations and standards and develop a transition scheme for implementation of advanced television service. It will also recommend appropriate FCC policies and regulations to oversee implementation of advanced television service and develop guidelines for industry activities.

Two working parties report to the Implementation Subcommittee.

3.1 Working Party on Policy and Regulation Define and address the policies and regulations appropriate to guide the implementation process.

3.2 Working Party on Transition Scenarios Critique the transition process for various generic system concepts in order to evaluate their implementation requirements. Identify generic classes of ATV service. For each class, develop reasonable implementation scenarios and determine requirements for implementation at each stage of the system (production, distribution, transmission, reception, display). Consider impact on terrestrial and alternative media technology. Develop an implementation plan for the selected system.

Footnotes

1. The information in this annex was extracted from documents of the FCC Advisory Committee on Advanced Television Service.

Annex II

Technical Characteristics of Proposed ATV Systems

The organizations listed in this annex have proposed advanced television systems for terrestrial, cable, and/or satellite broadcasting in North America. Following the name of each organization is a summary of the technical characteristics of its proposed system(s).[1]

1.0 Avelex This proposal is a 6 MHz NTSC compatible system. Sub-Nyquist sampling is used with an eight field sequence. Motion compensation is used; the motion vectors are multiplexed with the "I" color-difference signal.

2.0 Broadcasting Technology Association This proposal is the first phase of an improvement of the NTSC system. The aspect ratio remains 4:3. Signals from a high definition studio are converted to 525 lines interlace scan for broadcasting and up-converted to progressive scan in the receiver. New processes in the studio include adaptive pre-emphasis for improved dark area details and quasi constant luminance processing. A reference signal is inserted in the studio and used in the receiver to cancel ghosts. The receiver uses three dimensional luminance and chrominance separation. The second phase, under study, will include wide aspect ratio, higher resolution pictures and a higher fidelity sound system.

3.0 David Sarnoff Research Center This proposal is called ACTV and offers three variations. ACTV-I is a 6 MHz NTSC compatible system with wide aspect ratio and improved resolution. To incorporate the wide aspect ratio, the low frequency components of the side panels are squeezed and hidden in the horizontal overscan area. The high frequency components of the side panels in quadrature with higher horizontal resolution information modulate a new subcarrier hidden in the "Fukinuki hole." Higher vertical resolution information, used to up-convert to progressive scan in the receiver, modulates the picture carrier in quadrature with the

main signal. This last component is not included in the variation called ACTV-E.

The ACTV-II system builds on ACTV-I by adding an augmentation signal in a second channel. The augmentation signal, representing the difference between the HDTV source and the encoded/decoded ACTV-I signal, is compressed to fit a 6 MHz channel. Although decisions have not been made on the format of this signal, one possible technique has been described. The luminance error signal is divided into three frequency bands. Each band is shifted to DC and filtered. The chrominance error signals are low-pass filtered. All of these signals are multiplexed into one 6 MHz signal which is split into alternating lines and expanded in time to produce two 3 MHz signals. These two signals, in quadrature, modulate a carrier in the middle of the channel.

4.0 Del Rey Group This proposal, called HD-NTSC, is a 6 MHz NTSC compatible system. Sub-Nyquist sampling is used with a six field sequence. Motion compensation is used. Wide aspect ratio is accomplished by 1) decreasing horizontal blanking 3 μs, 2) using 2% anamorphic compression, and 3) decreasing the number of active video lines to 414. Digital sound replaces those active video lines.

5.0 Faroudja Laboratories This proposal, called SuperNTSC, is a 6 MHz NTSC compatible system. Signals from a 1050 line source are converted to 525 lines for broadcasting and up-converted to 1050 lines in the receiver. The encoder includes processing of lower level detail and comb filtering. The "Q" bandwidth is raised to 1.3 MHz. The receiver uses complimentary comb filtering and luminance detail processing. Color detail is enhanced whenever there is coincident luminance detail.

6.0 High Resolution Sciences This proposal reduces NTSC dot crawl, chroma crawl, and cross color by modifying the relationship between the color subcarrier frequency and the horizontal line frequency from 227.5 cycles per line to 227 cycles per line. An extra half cycle of color subcarrier is inserted at the end of each field so that adjacent fields continue to have opposite phase of color subcarrier.

7.0 Japan Broadcasting Corporation Four different systems have been proposed. The first is the original MUSE system, a wide aspect ratio 8.1 MHz time compressed and multiplexed component signal designed for satellite broadcasting using frequency modulation. Sub-Nyquist sampling is used with a four field sequence. There are 1125 scan lines with 1440 horizontal picture elements.

Three variations of the MUSE system have been proposed for terrestrial broadcasting. MUSE-6 is a 6 MHz NTSC compatible system. Wide aspect ratio is incorporated by masking the top and bottom of the picture, the "letterbox" approach. An 1125 line input signal is converted to 750 lines for broadcasting and up-converted to 1125 lines in the receiver. The lower vertical frequency components of the 750 line signal are carried on 345 active lines of a 525 line signal. The higher vertical frequency components and higher horizontal chrominance components are carried during the top-and-bottom mask portions of the signal. Horizontal luminance resolution is increased in still pictures by folding the spectrum from 3.9 MHz to 5.8 MHz and the spectrum from 5.8 MHz to 7.7 MHz to overlap the 1.9 MHz to 3.9 MHz region.

MUSE-9 builds on MUSE-6 by adding an augmentation signal in a second channel. The augmentation channel, 2.1 MHz of baseband, increases moving resolution from one-half to three-fourths of static resolution. Two channels of digital sound are added as well as an improvement of the first two channels. The augmentation signal is configured as a 525 line signal and broadcast using vestigial sideband amplitude modulation in a 3 MHz channel.

The third variation, Narrow Muse, is a 6 MHz non-compatible system broadcast in the simulcast mode. Narrow Muse is also based on converting 1125 lines to 750 lines for broadcasting and up-converting to 1125 lines in the receiver. There are 1188 horizontal picture elements. The signal format is similar to MUSE. It can be derived from MUSE and converted to MUSE. Baseband bandwidth is 4.86 MHz. The time division multiplex component signal is broadcast using vestigial sideband amplitude modulation.

8.0 Massachusetts Institute of Technology Two systems have been proposed, the MIT-RC system which is receiver compatible and the MIT-CC system which is channel compatible. The MIT-RC system uses the "letterbox" approach to broadcast wide aspect ratio pictures. The top and bottom bars are used to carry luminance enhancement

information. Chrominance horizontal resolution is doubled by reducing the chrominance frame rate to 15 frames per second.

The MIT-CC system is a 6 MHz non-compatible system broadcast in the simulcast mode. Sub-band coding is used. The three dimensional spectrum of the input signal is divided into 45 component blocks. The three lowest resolution blocks are always broadcast, one each for the red, green, and blue signals. The three blocks representing the next highest horizontal, vertical, and temporal frequency blocks are also always broadcast. Three additional blocks are broadcast having been selected according to the degree of motion. The nine selected blocks are then divided into odd and even lines and time-multiplexed into two 3 MHz signals. These two signals are the inputs to a double sideband suppressed carrier quadrature modulator. The carrier is placed in the middle of the channel. Adaptive modulation and scrambling are being considered to further improve picture performance.

9.0 New York Institute of Technology This proposal, called the VISTA system, is a two channel system. The first channel carries an NTSC signal. The second channel carries an augmentation signal. This system was designed to exploit the human visual system by breaking the signal into low spatial, high temporal resolution components (NTSC signal) and high spatial, low temporal resolution components (augmentation signal). Signals from a high definition studio are converted to progressive scan, if they are interlace scan, and processed with temporal filters and diagonal filters. An NTSC signal is extracted for the first channel. The second channel carries 15 frame per second 5.3 MHz data on a single sideband suppressed carrier in a 6 MHz channel or 7.5 frame per second 2.7 MHz data in a 3 MHz channel. The second channel also carries higher resolution (R-Y) information. The augmentation signal is broadcast with NTSC scanning rates. Although the NTSC signal contains 483 active lines, only 443 are used in the HDTV receiver to increase the aspect ratio. Also, horizontal blanking of the NTSC signal is decreased 4 µs for a further increase in the aspect ratio.

10.0 North American Philips This proposed system is called HDS-NA and consists of two formats, the first for satellite transmission and the second for cable and/or terrestrial broadcasting. The satellite signal is a 525 line progressive scan multiplexed analog component signal. Different lines are transmitted with different bandwidth (different compression ratio) to give high spatial and temporal resolution in the vertical and horizontal directions with high spatial low temporal resolution in the diagonal direction. Every second line is sent as a line difference signal and has lowered resolution (compressed 2:1 for transmission). Half of the remaining lines, one of every four, are expanded by the ratio of 16/9 for transmission and have full resolution. The remaining lines, also one of every four, have medium resolution (neither compressed nor expanded in time). This pattern is shifted up one line each field resulting in a four field sequence. Color-difference signals are transmitted only on alternate lines and alternate between the "U" signal and the "V" signal. Also, each color-difference signal alternates between 2:1 compression and 4:1 compression. The signal has wide aspect ratio and four digital sound channels. The baseband bandwidth is 9.5 MHz.

The terrestrial system uses two channels. The first channel carries an NTSC signal. The second channel carries an augmentation signal. The NTSC channel carries a 4:3 aspect ratio portion of alternate lines of the progressive scan satellite signal. The portion of the picture selected for the 4:3 window is variable to permit pan and scan for NTSC receivers. The resulting side panels, not necessarily equal in width, are broadcast in the augmentation channel. Higher horizontal and vertical resolution and digital sound are also carried in the augmentation channel. Modulation details for the augmentation channel are not decided although digital techniques are being explored as well as various amplitude modulation schemes. Target bandwidth of the augmentation signal is 3 MHz although current work is based on 4.6 MHz.

11.0 Osborne Associates This proposal is called the Osborne Compression System. The HDTV signal can be transmitted in a 45 Mbit data channel, a single 9 MHz channel, or two 6 MHz channels. In the latter case, NTSC is derived from an HDTV source and broadcast in the first channel. An error signal is derived by "up-converting" the NTSC signal to HDTV and subtracting it from the original HDTV signal. The error signal is compressed to fit the second channel.

12.0 Production Services This proposal, called the

GENESYS system, consists of four processes. The first process, analog to digital conversion of the HDTV signal, is described as a modification of delta modulation. The second process is described as a form of waveform modulation which carries the digital HDTV signal by modifying the shape -- not the frequency or amplitude or phase -- of the carrier making it "invisible" to frequency or amplitude or phase demodulators. Both NTSC and HDTV are broadcast in the same channel with the same carrier -- NTSC with vestigial sideband amplitude modulation and HDTV with this waveform modulation. The third process is demodulation of the waveform modulated carrier. The fourth process is digital to analog conversion of the HDTV signal.

13.0 Quanticon This proposed system is called QuanTV. Dither is added to the signal before quantizing to permit the use of a smaller number of bits without contouring.

14.0 Scientific Atlanta This proposal, called HDB-MAC, is an enhancement to the B-MAC satellite delivery system. The input signal, 525 lines progressive scan, is processed with a diagonal filter and sampled in a quincunx pattern. This signal is converted to 525 lines interlace scan by moving up the sample values from every second line into the empty spots in the previous line. The spectrum is folded only above 7 MHz and the resulting signal is compatible with current B-MAC receivers. The bandwidth is increased to 10.7 MHz to increase horizontal resolution. Pan and scan is used to handle both 4:3 and 16:9 aspect ratio pictures. There are six digital sound channels.

15. Zenith Electronics Corporation This proposal is a 6 MHz non-compatible system broadcast in the simulcast mode. It is designed to be broadcast on a taboo channel of its NTSC counterpart and synchronized to that NTSC signal to minimize interference. The input signal is 787.5 lines progressive scan. The low frequency horizontal and vertical detail is sent at a 60 frame per second rate while the higher frequency components are sent at one-fifth this rate. Motion compensation is used. The higher frequency portion of the signal is broken into three blocks -- high frequency vertical detail, high frequency horizontal detail, and middle frequency horizontal and vertical detail. The highest frequency diagonal components are not broadcast. One-fifth of each block is sent every 1/60 of a second and, after 1/12 of a second, the entire signal is sent. A total of 480 "lines" are broadcast every 1/60 of a second (96 lines represent the low frequency detail sent every 1/60 of a second, 144 represent 1/5 of the high frequency vertical detail, 96 represent 1/5 of the middle frequency detail, 48 represent 1/5 of the high frequency horizontal detail, and 96 represent the color-difference signals). The lowest 200 kHz of the signal is digital encoded and placed in the vertical interval -- and thus during the vertical interval of the NTSC signal which is being protected. This multiplexed analog component signal is split into two 3 MHz signals by selecting alternate lines which are each time-expanded a factor of two. Companding is used to raise the level of small amplitude signals and lower the level of high amplitude signals, essentially reducing the data to be only the edges in the picture. Time dispersion is used to spread the power of these edges followed by pre-emphasis of the high frequency components. The two signals are the input to a double sideband suppressed carrier quadrature modulator. The carrier is placed in the middle of the channel. Average broadcast power -- and thus interference -- is much lower than NTSC because of the suppressed carrier and the absence of the low frequency synchronizing signal. This signal provides the same coverage area as NTSC with only 0.2% of the broadcast power. For satellite transmission the two signals are time compressed and multiplexed to form one 6 MHz signal.

Footnotes

1. The information in this annex was extracted from data supplied to the FCC Advisory Committee on Advanced Television Service by the organization proposing the system. The authors do not advocate the selection of any specific system nor do they attest to the accuracy of the claims of the proposing organization.

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