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LAS VEGAS, NEVADA

HDTV WORLD '91 CONFERENCE & EXHIBITION

National Association of NAB® BROADCASTERS

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HDTV WORLD '91 CONFERENCE & EXHIBITION

April 1991

Dear HDTV Enthusiast:

On behalf of NAB and the 1991 HDTV World Conference Committee, NAB is pleased to present the premier issue of the *HDTV World Conference Proceedings.*

NAB is proud of the success of the first HDTV World Conference, devoted exclusively to the fast-changing, high tech, high stakes arena of high definition and advanced television technologies.

Broadcasters, program producers, researchers, and manufacturers provide papers on advanced television, covering everything from transmission standards to international implications, from post production to programming, to system and equipment descriptions and technical papers on state-of-the-art advanced television technologies.

The pace of HDTV technology development seems to accelerate every year. We hope the *HDTV World Proceedings* will add to the sense of history and base of knowledge held by all HDTV World attendees.

Best regards,

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Senior Vice President
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Chairman
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Suite 300
Washington, D.C. 20006

Mr. Wendell Bailey
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1724 Massachusetts Avenue, N.W.
Washington, D.C. 20036

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New York, NY 10023

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Director General, Broadcast Systems
Research Communications Research Centre
3701 Carling Avenue
P.O. Box 11490
Station H
Ottawa, Ontario, Canada K2H 8S2

Mr. William Connolly
President
Sony Advanced Systems
3 Paragon Drive
M.D. 2N70
Montvale, NJ 07645-1735

Mr. Dale Cripps
HDTV Newsletter
P.O. Box 5247
901 SW King Street, #402
Portland, OR 97208-5247

Mr. Greg DePriest
Toshiba America
Consumer Products
82 Totowa Road
Wayne, NJ 07470

Mr. Joseph Flaherty
Senior Vice President, Technology
CBS, Inc.
51 W. 52nd Street
New York, NY 10019

Dr. Richard Green
President and CEO
Cable Television Laboratories, Inc
1050 Walnut Street, Suite 500
Boulder, CO 80302

Dr. Leonard Golding
Hughes Network Systems
11717 Exploration Lane
Germantown, MD 20874

Mr. Howard Miller
Senior Vice President, Broadcast Operations
& Engineering
Public Broadcasting Service
1320 Braddock Place
Alexandria, VA 22314

Mr. Barry Rebo
President
Rebo HD Studio, Inc.
530 West 25th Street
New York, NY 10001

Mr. Michael Sherlock
President, Operations & Technical Services
NBC, Inc.
30 Rockefeller Plaza
New York, NY 10112

Dr. Masao Sugimoto
Director General
NHK Laboratories
1-10-11 Kinuta, Setagaya-ku
Tokyo 157, Japan

Mr. George T. Waters
Director
Technical Department
European Broadcasting Union
Ancienne Route 17A/Case postale 67
CH-1218 Grand-Sacconex
Geneva, Switzerland

Ms. Margita White
President
Association for Maximum Service Television
1400—16th Street, N.W.
Washington, D.C. 20036

Mr. Dan Wells
Vice President, Business Development
Comsat Video Enterprises
22300 Comsat Drive
Clarksburg, MD 20871

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THE EVOLUTION OF HIGH DEFINITION TELEVISION

Corey Carbonara, Ph.D.
Baylor University
Waco, Texas

ABSTRACT

From the development of early mechanical television systems, spurred by the efforts of key inventors, to the development of higher definition electronic forms of television subsidized by large corporations and consortia, standardization and commercialization of television technologies have become increasingly complex processes. And these processes have involved a series of historical trajectories.

This paper examines the evolution of high definition television by examining a series of historical stages that illustrate the relationship between a variety of interinstitutional forces--technological, economic, regulatory, and social--which have inexorably impacted the development and management of television technologies. By tracing the evolution of high definition television this paper provides a template for helping us understand current issues that affect the future of high definition worldwide. Three significant watersheds in television technology--namely monochrome, color and high definition TV (HDTV)--are briefly examined and related to the management and diffusion of advanced television today.

INTRODUCTION

The global television industry is facing the most crucial and dynamic stage in its evolution. New television technologies are literally changing the stakes of each facet of the industry, both domestically and worldwide. Newer distribution technologies, such as cable, DBS, VCR and fiber optics are literally in heavy competition with over-the-air broadcasting for the audiences of over 600 million television receivers worldwide. Currently, HDTV has been defined as a television system that has approximately five times the visual information detail of pure NTSC, about ten times the color information, more than two times the horizontal and vertical resolution, the potential for a great improvement in picture brightness, a wider aspect ratio and sound quality that is equal to compact disc.

Throughout the evolution of the television technology, the standardization and subsequent commercialization of each significant development has necessarily addressed issues of compatibility, cost and convenience. The development and diffusion of high definition television actually involved a series of historical trajectories. For example, no fewer than four electronic broadcast standards for black and white television were adopted, and four for color. Presently, there are three major incompatible systems remaining as color standards in the world today--PAL, SECAM, and NTSC.

The standardization and commercialization of new television technologies affect culture through a series of contextual factors--social, political, economic, institutional, industrial, and aesthetic--that results in shifts in the strategies and policies of both industry and government. Technological developments in television have resulted in implementation and diffusion of new products and processes that have changed the economic, political, social, and cultural stakes for manufacturers, broadcasters, and regulatory agencies around the world.

An examination of each major stage in the evolution of television technology yields insight into the process. One of the goals of this paper is to examine the evolutionary process of new television technologies within a historical framework. This type of research offers both descriptive and prescriptive possibilities. Historical analysis can offer the opportunity to discern patterns in a longitudinal fashion, enabling the generation of hypotheses about both linear and cyclical patterns in the standardization and diffusion process.

The Scope of HDTV

Although the term "high definition television" (HDTV) is now applied to a current technological advances in television's technology, in actuality the term "high definition" has been widely used to define a number of earlier advances in television's picture quality. RCA first used the term in its 1934 Annual Report, identifying the role HDTV would play in the commercialization of television. Also in 1934, Vladimir Zworykin, a leading pioneer in the development of electronic television, defined the parameters for HDTV "regarding 240 scanning lines as a minimum."[1] Overseas, a British engineering report from the Royal Television Committee in London offered a similar technical definition for HDTV.

But while "definition" is an issue throughout this paper, our emphasis actually will be on the technological development of television leading to current HDTV systems. In analyzing the technical data, it is clear that the technological development can be divided into six major stages. Obviously, there will be overlap of the stages because new developments did not end laboratory efforts on earlier systems that were already under consideration. Technical developments of television systems overlapped in a temporal fashion. However, for the purposes of this paper, the technological development of television had been placed in perspective by positioning it within major temporal stages or periods:

- Stage I(1884-1930): Development of Low Definition Mechanical Scanning Systems
- Stage II (1924-1934): Search for Higher Definition Monochrome
- Stage III (1934-1940): Development of Monochrome
- Stage IV (1937-1947): Standardization of Monochrome
- Stage V (1910-1966): The History of Color Television Systems
- Stage VI (1966-1991): Development of Current HDTV Systems

This paper will examine the relationship between technology and management by retracing its history, offering the lessons and examples of the past as a template for the present in order to facilitate a greater understanding of the current standardization and commercialization process for high definition television.

MONOCHROME TELEVISION

Stage I (1884-1930): Development of Low Definition Mechanical Scanning Systems

At the turn of the century, television hardware consisted of a mechanical device yielding about 24 scan lines. Any significant improvement in television resolution was considered high definition television. The earliest development of television--low definition TV defines a period where the first mechanical picture representation and distribution systems were developed. Included here are the mosaic facsimile devices and the evolution of sequentially scanned rotating mechanical systems.

There is about 100 years of history behind the evolution of high definition television, beginning with Nipkow in 1884. But since Nipkow and his early efforts, other corporations such as RCA would soon get involved in television, with the goal of increasing definition. As early as 1929, we see a major increase in resolution to 80 lines. At that point major corporations saw that there was a tremendous stake in television and began to set the agenda for improved electronic systems that became prominent during Stage II.

Stage II (1924-1934): Search for Higher Definition Monochrome

In Stage II, between 1924 and 1934, we have the refinement of these mechanical systems and the introduction of electronic scanning in television. 1931 is a key year for experimentation in higher definition television and Orrin Dunlap, who was manager of RCA's department of information, outlined these tremendous advances in 1931--TV transmission across the Atlantic, color television experiments and increased picture definition.

By the end of Stage II, television had moved from the low-definition efforts of the independent sole inventor, to the electronic high-definition accomplishments of corporate programs--such as RCA, Philco and individuals like Philo T. Farnsworth, who combined with the major corporate programs to initiate major efforts--with large capital budgets dedicated to the development of an all-electronic HDTV. Remember, at that point in television's history, HDTV is defined as 240 lines or greater.

Television innovations also resulted in the formation of early corporate strategic alliances. For example, in 1929 when RCA joined in its efforts with both GE, Westinghouse and Bell Labs to form a research facility at the Victor plant in Camden, New Jersey, this action signified the tremendous effort launched by a number of the key organizations in the battle for TV's full commercialization. Progress continued not only in the U.S., but the other side of the Atlantic as well. It is shortly after this period that we also begin to see the development of electronic systems.

Stage III (1934-1940): Development of Monochrome

During Stage III, from 1934 to 1940, RCA moved forward with a spectacular research and development surge in high definition television of 240 lines and greater. The period also characterizes the struggle between large corporations to satisfy the demands of both the public and the government--especially represented by the FCC--to allow the standardization and commercialization of monochrome television to take place. If we move ahead, we see that the key questions about commercialization have a historical significance echoed today by questions about our current Advanced Television issues:--will these be enough sets to warrant advertising?...Enough stations for adequate coverage?...And when will the FCC authorize commercial licenses?

By the end of Stage III, television had moved predominantly to the electronic forms of monochrome television capable of far more resolution than the 240 lines. The standards adopted during this time included the EMI Marconi 405-line system and the Radio Manufacturers Association standard of 441 lines, indicating the desire to push for the subsequent commercialization of television.

Stage IV (1937-1947): Standardization of Monochrome

The period between 1937 and 1947--Stage IV--signified the arrival of the standardization and commercialization of high-definition electronic systems throughout the world. However, before standards were implemented in this country, the FCC would establish a national coordinating committee called the NTSC that would help resolve industry differences and coordinate and develop television standards.

NTSC, the National Television Systems Committee, was comprised mainly of industry officials and professional engineers forming a self-regulatory body to augment the regulation that was taking place in the FCC. The first meeting was in July of 1940 and addressed these major issues--quality of picture definition, method of synchronization, number of lines of resolution and the number of frames per second. These echo the concerns that we have currently heard expressed by the ATSC and the FCC Advisory Committee on an Advanced Television Service.

Stage IV demonstrated the necessity of standardization before full commercialization. It also emphasized the role of non-broadcast applications in terms of the development of monochrome television. Standardization of broadcast television in the United States could not have occurred without direct government intervention in terms of the FCC forming the NTSC and the NTSC providing the necessary intra-industrial cooperation to establish and negotiate a single unanimous American standard of 525 lines with 30 frames per second and 60 fields per second, adopted by the FCC in 1941. In addition, consumer acceptance and programming supply were all necessary ingredients to establish not only American black and white standards in the 1940's but, also the color standards of the 1950's.

But, equally significant was the role played by non-residential applications in the development of television technology. For example, as early as 1925, television was being utilized by the U.S. Navy to transmit weather maps to naval ships at sea. And in WWII, two airborne television systems code named "block" and "ring" were responsible for major improvements in the post-war technical quality of television, including the development of the "image orthicon" camera tube.

COLOR TELEVISION

Stage V (1910-1966): The History of Color Television Systems

Development of Early Color Television Systems: From 1910 to the late 1940's. The history of color television represents Stage V and illustrates once again that there can be more than one way to develop a technology. The idea of color television actually predated the first technology developed by either of these firms, with experimentation by sole inventors recorded in technical journals as early as 1910.

From its earliest beginnings color TV could be categorized into two basic scanning categories, simultaneous or sequential. Simultaneous systems allowed for the additive simultaneity of images scanned in three primary colors of red, green, and blue (RGB). Sequential systems were either mechanically or electronically based and used a variety of interlacing methods to produce the "fused" information as continuous images for the eye, based on the concept of "visual persistence". The competition between simultaneous and sequential systems became the basis of the color battle between RCA and CBS.

Management support for these systems intensified as both companies recognized the enormous economic stakes of color TV. Color television would become a $3 billion business for RCA by 1965. Early work in the U.S. on color television began with the efforts of Bell Laboratories in 1929. Competitive efforts that sparked the initial interest in color television at CBS began as early as 1936. CBS' strategy with color television was to leapfrog monochrome television and push the industry--and the FCC--immediately into color. Some competitors, including RCA, viewed the early involvement in color by CBS as a way to delay the growth of monochrome television in order to gain time in strengthening its competitive position; others believed that CBS correctly saw color television as the next major innovation and pushed for its adoption based on belief on the quality of its system. RCA began its initial color television efforts in the late 1930's. By the early 1940's, the RCA research effort took on a sense of urgency when CBS petitioned the FCC to adopt its field sequential system.

In 1941, the Federal Communication Commission authorized monochrome television standards but denied color authorization, maintaining it was premature to consider spectrum allocations for color television at that time. After World War II, the investigation of the CBS field sequential color television proposal and RCA's proposal of its dot sequential matrix color system resumed. In 1947, the FCC rejected the CBS proposal on the grounds that consumers would need to purchase new television sets in order to receive the color signal. By 1948, questions about interference--due to the rapid licensing of 108 television stations--and the continued development of color systems by CBS and RCA led the FCC to issue a "freeze" on the expansion of television station allocations which lasted four years.

First Domestic Battle for Color Television Standards: The Late 1940's to 1950. By the end of the 1940's, technical advancements had progressed to the point where a color decision by the FCC was imminent. The players in the standardization process included the U.S. Senate which advocated the immediate adoption of a color system. The complexity of the RCA system made it less desirable, while the CBS system had the inconvenience of incompatibility. The philosophy guiding the FCC's actions involved the major issues of cost and quality; compatibility was applicable only to the extent that it affected the initial acceptance by the American public. Considering the rapid rate of diffusion for black and white TV and the development of an improved color compatible system by RCA, much of the press and the industry felt that the 1950 FCC ruling approving the CBS field sequential color system was a premature one. At issue was the concern for the rapid growth of monochrome set sales during the "freeze"--over 6 million receivers in 1950 alone--that made the timing of the initial diffusion of color crucial.

The Second National Television Systems Committee and the Battle for Color Compatibility: The 1950's. By the early 1950's, galvanized by the enormous economic stakes in color television and the motivation and challenge to prove the superiority of an all-electronic compatible color television system, the industry united around a second self regulatory National Television Systems Committee (NTSC). Similar to the first NTSC that recommended monochrome standards in 1941, the second NTSC provided a forum for the critical examination of color proposals to find one color system that could serve the public interest for compatibility and also satisfy the FCC.

In 1953, the FCC reversed its earlier decision and standardized the NTSC recommendations for compatible color television, predominantly based on the RCA system and its compatibility with the 24 million black and white TV sets in America. The technical victory of the second NTSC served as a major victory for RCA/NBC, who contributed the most technology to the NTSC for the all-electronic compatible color system. The victory also illustrates the necessity of balancing the technical requirements of the FCC with the practical economic limitations of the industry. However, another decade would be necessary for the actual diffusion of color television in the U.S.

Standardization, Commercialization and Adoption -- The Growth of a Domestic Color Television Industry: The Early 1960's. In the early 1960's, color television began to emerge as a successful commodity in consumer home entertainment for the United States, but only after it had overcome obstacles of high prices, patent disputes and the need for programming to stimulate color sales. The diffusion of color television constituted a variety of contextual factors: the saturation mark of monochrome sets offering higher potential profit margins with color television; the use of ratings research to encourage networks and advertisers to increase color programming, which subsequently, stimulated the sale of color receivers; and the role of program producers and local stations in increasing awareness and feasibility of color TV as an innovation, through the production of additional programming. Equally important was consumer interest in supporting the adoption of color TV, further allowing other stakeholders to invest more capital resources in the medium.

Attempts for the International Standardization of Color Television: The Mid-1960's. By the middle of the 1960's, the diffusion of color had become an international issue, and again a whole range of contextual factors--industrial, technical, political, and economic--figured into the regulatory standardization process. The French example of SECAM illustrated how important cooperation and collaboration are between governments and institutions. The French move to color also demonstrated how standards could be utilized as a non-tariff barrier to trade, building an indigenous industry for color television, while at the same time protecting it from outside competition. The strategic alliances developed between nations generates political support for technology, while also creating foreign markets.

However, foreign markets are quite fragmented and--as indicated in the U.S., where standardization resulted in maximum commercialization--revenues would be higher if Europe had adopted a single color standard. The adoption process involved both cooperative alliances and competitive conflict, depending on the political ties associated between countries. The international standardization process also identified the need for well planned policies--by both industry and government--to facilitate the use of technology as a trade incentive rather than a barrier.

In addition, the color example shows the importance of competition in promoting creativity and innovation in industry. RCA as a result of the color battle innovated patent pools, promotional campaigns, a service company, new forms of audience measurement based on qualitative as well as quantitative demographics, and new programming and selling strategies with the intent of stimulating both the television industry and consumers to adopt color television. CBS would give up on its idea to manufacture color sets and hold out on moving its network to color until it became apparent that advertisers were demanding that service and would underwrite conversion costs.

HIGH DEFINITION TELEVISION

Stage VI (1966-1991):Development of Current HDTV Systems

Introduction: The 1960's. During the mid-1960's Japan began its long-range planning on the requirements for an advanced television system that could meet the high definition demands of the 21st century. The introduction of television in Japan took place over 30 years ago. In 1968, within ten years of the introduction of television in Japan and only two years after Japan adopted NTSC as its color standard, Nippon Hoso Kyokai (NHK, or Japan Broadcasting Corporation) began research on a new HDTV system that would use projected 35mm film as a technical benchmark. Led by HDTV pioneer Dr. Takashi Fujio at NHK, the research team examined the psychophysical attributes of human vision as well as the technical foundation for such a system. Dr. Fujio concluded that HDTV--called "Hi Vision" by NHK--needed a resolution of 1000 or more scan lines. NHK established 1125 lines for Hi Vision based on mathematical correlations to both the 525-line (US/Japan) and 625-line (Europe) color standards in use by those countries today.[2] Much of this early work resulted in significant contributions to studies of visual and aural acuity as well as specific research on the movement and characteristic of color and the eye, psychological effects of the visual field, motion adaptive qualities of the human eye and the effect of collateral sound effects to the presentation of visual material.[3]

However, it should be stated that a variety of early efforts also took place by both American and European firms to develop HDTV. A number of companies had developed early systems beyond 1000 lines during this period, even reaching 10,000 lines, primarily for non-broadcast applications.[4]

Decade of Development: The 1970's. In 1972, NHK drafted a program of study for HDTV to the CCIR. Based upon the parameters of the NHK system that included 1125 lines, a 60Hz field rate and a 5:3 aspect ratio, the CCIR set up an internal committee in 1974 to study the possible standardization of HDTV.[5] It was also in the early 1970's (around the same time period that RCA entered the satellite business) that RCA began to study a new satellite distribution technology that beamed powerful signals directly to very small receiving dishes at the home. This new distribution service is called Direct Broadcast Satellites (DBS).

By the late-1970's, HDTV research began to be transferred from Japan through many of the technical journals and conferences held by the International Electrical and Electronics Engineers (IEEE) and the Society of Motion Picture and Television Engineers (SMPTE). In 1977, SMPTE formed its first study group on HDTV, under the leadership of Donald Fink. In 1978, the BBC entered into discussions on high definition by publishing a report on a system of satellite broadcasting for HDTV. That same year, reports on HDTV began to appear in various technical journals with more frequency. The following year, NHK began its first satellite transmission experiments in HDTV. Once again, it should be pointed out that during these periods, experimentation in HDTV continued by both American and European firms.

Searching for Standards: The 1980's. In February 1981, NHK demonstrated HDTV in North America for the first time at a SMPTE winter conference. As a result of these demonstrations in San Francisco, CBS began a more directed effort in HDTV. That same year, CBS petitioned the FCC for allocation of the 12GHz DBS spectrum for an HDTV system. By March 1982, CBS initiated its first 12 GHz terrestrial broadcast experiments.[6] In addition, 1982 marks the year that the Advanced Television Systems Committee (ATSC) was formed. The ATSC is based on the same NTSC that initiated standards for monochrome and color.[7]

In 1983, RCA began work on Improved Definition Television (IDTV). For RCA, IDTV research primarily involved merging RCA's vast knowledge of digital technology with its existing knowledge of color television. That same year, the International Radio Consultative Committee (CCIR) of the International Telecommunications Union (ITU) set up an Interim Working Party with the charter to produce a recommendation for a single worldwide standard for HDTV studio production and international program exchange.

The international focus on HDTV from the CCIR and SMPTE organizations drew attention from many companies. It was at this time that RCA began to focus on the utilization of HDTV as a studio production tool. After reviewing the initial findings of the SMPTE Study Group on HDTV from the late 1970's, Dr. Powers, through his role as Chairman of the SMPTE Technology Group, set up a SMPTE Working Group on High Definition Electronic Production (WGHDEP) in 1983. Led by its chairman, Richard Stumpf, Vice President of Technology at MCA/Universal, this group of motion-picture cinematographers and technicians and television engineers has been responsible for the establishment of HDTV production standards that are currently in use today. The major focus of this group has been to develop standard parameters for the development of an HDTV as an electronic production tool in both original production and post-production.[8] Unlike the development of monochrome and color television, HDTV--with its equivalency to motion-picture quality--was getting participation from technical leaders in the motion-picture industry.

In 1984, the Japanese government and industry, through the NHK, agreed on a 1125/60 Hz emission standard called Multiple Sub-Nyquist Encoding (MUSE). MUSE is a bandwidth compression technique used for direct broadcasting via satellite transmission. Japan had already made the decision that DBS would be one of the first distribution media for HDTV in that country. Given the long-term commitment of Japan toward HDTV and the development of both transmission and production equipment, RCA began to increase its efforts in HDTV. And by 1984 RCA had developed a 750-line progressive scan 60Hz system that was in competition with the 1125-line, 60Hz system of NHK.

In January 1985, the principal parameters of the NHK 1125/60 system had been adopted at the ITU Interim Working Party meeting held in Tokyo. And in February 1985, the SMPTE WGHDEP had recommended to the Advanced Television Systems Committee (ATSC) and the U.S. Department of State HDTV production system parameters based upon the 1125/60 approach. Despite the recommendations of the SMPTE and ATSC, RCA shifted their emphasis from HDTV production to IDTV and EDTV approaches for consumer reception. However, when RCA believed that improvements to the television signal--including the appeal of wider screens--had marketing potential, RCA combined its different technological approaches to IDTV and EDTV in its ACTV approach. Advanced Compatible Television (ACTV) was created as an alternative method of transmitting ATV signals. ACTV research began at the David Sarnoff Research Center in 1985.[9]

By the mid-1980's, CBS acquired a full 1125/60 HDTV system from Sony. CBS began to conduct numerous demonstrations of HDTV, some that compared the effectiveness of the NHK Multiple Sub-Nyquist Encoding (MUSE) bandwidth compression technique with the full bandwidth of the Sony HD system.[10] Around this same time period, CBS began its efforts in creating an HDTV transmission system to be utilized exclusively for DBS. CBS Laboratories executive Ren McMann devised a two-channel approach in which one channel was NTSC compatible, while the other channel was high definition. The HDTV display in the home would output 1050-line/59.94Hz interlace signals.[11]

Other companies also began to investigate HDTV in the 1980's. For example, in Germany, Bosch began a project on HDTV under the direction of Dr. Ulrich Reimers. One of the earliest projects at the Bosch Laboratories was to measure the resolution capability of both television imaging pick-up tubes and display cathode ray tubes (CRT). In May of 1986, the proposed 1125/60 HDTV production standard was submitted for adoption at the CCIR Plenary Meeting in Dubrovnik, Yugoslavia. By March 1986, the European Community (EC) organized enough support to have the process of standardization delayed at Dubrovnik for at least two years. Despite the lobbying efforts and free royalty considerations for HDTV equipment sold in parts of Europe to certain European consumer electronics companies--if they successfully lobbied for support from their country for 1125/60--the proposal was rejected at the CCIR meeting in May 1986.[12] The impact of the 1986 CCIR Plenary Assembly in Dubrovnik was the postponement of the CCIR decision on the worldwide standardization of HDTV for studio production and program exchange, until its next CCIR cycle in May 1990.

The experience in Dubrovnik illustrated the politicalization of the standards process--a lesson that had been learned once before with the development of the French SECAM standard as a non-tariff barrier to trade and the development of an indigenous industry for France. European countries felt that they had an opportunity to prevent what it considered to be a "technology gap" in HDTV technology because of Japan's development of a working system. Just as SECAM was a method of building an indigenous industry for France, in a similar way, Europe hoped it could compete in HDTV on a global scale. However, a major difference between the example with SECAM and the situation with HDTV was that Europe realized that, unlike the development of color standards, no one country had the resources to develop the needed technology for an entire HDTV system.

Considering the lesson of incompatible color standards that divided Europe, a strategic alliance was formed that would allow many Western European countries to compete in HDTV on a global scale. In response to the outcome at Dubrovnik, in October 1986, many countries in Western Europe joined a Pan-European international strategic alliance called EUREKA, that included a project dedicated to the evolution of a European High Definition system that could complement the Western European based MAC System.[13] The specific goals of EUREKA were to develop alternative standards for HDTV production that could be acceptable to both 60Hz (Japan, USA, Canada) and 50Hz (Europe, Australia, Africa) countries and create an HD MAC system that could compete with the Japanese HD MUSE system.

In North America, the first announcement of the Sarnoff ACTV system was made at the Ottawa HDTV Conference in 1987. Also in 1987, the National Association of Broadcasters (NAB) and Association of Maximum Service Telecasters (AMST) petitioned the FCC to examine spectrum issues relating to HDTV and voiced concern over the possible reallocation of UHF spectrum to land mobile services (i.e. fire, police, industrial, CB two-way radio communications). As a direct result of the NAB/AMST petition, the FCC issued a Notice of Inquiry (NOI) regarding Advanced Television Systems (ATV) and also took the following actions:

- An FCC freeze on applications for new UHF stations in 30 of the top 40 markets
- A freeze on the "UHF sharing" proceedings
- Issuance of an order setting up a joint FCC-Industry Advisory Committee on ATV to generate information and produce policy recommendations as a bases for future FCC rulemaking with a deadline of September 1989 in completion of its final report to the FCC

This FCC Advisory Committee represented a departure from its previous method of issuing hearings and demonstrations. The impact of deregulation of the Reagan Administration on the FCC was that with HDTV, the commission would become dependent on the private sector to assist the FCC in its decision by framing the issues, planning and implementing testing procedures, and offering recommendations on standards to the FCC. The framework of the Advisory Committee established three subcommittees that are subsequently comprised of Working Parties. The subcommittees listed were placed into three categories consisting of planning, systems and implementation. These subcommittees coordinated their activities with other organizations such as the ATSC, Advanced Television Test Center (ATTC), Center for Advanced Television (CATS) and the National Cable Television Association-Cable Labs (NCTA).

In addition, by 1987 efforts were under way in the United States to standardize the 1125/60 system as an American HDTV studio production standard. Work by the US Advanced Television Systems Committee (ATSC) and the SMPTE WGHDEP culminated in a passed resolution on 1125/60 signal parameters, first by the SMPTE in 1987, and secondly, by the ATSC in 1988. However, two major broadcast organizations--the National Association of Broadcasters (NAB) and The Association of Maximum Service Telecasters (AMST)--voted against the 1125/60 proposal on the grounds that it diverted local broadcasters from the opportunity to participate in the full range of possible advanced television systems.[14]

In 1988, the FCC Advisory Committee on Advanced Television Service (ACATS) presented its interim report to the FCC. At that time, almost 20 proponent ATV systems had been under consideration by the FCC, which was considerably more systems than were presented to the FCC at any time in the standardization of either monochrome or color. However, on September 1, 1988, the FCC narrowed the field significantly by its tentative decision setting guidelines for establishing a standard for the terrestrial broadcast transmission of HDTV.[15] In its "Tentative Decision and Further Notice of Inquiry" the FCC announced fundamental policies and defined the boundaries for the development of Advanced Television: HDTV must be compatible with existing NTSC service; it would have no additional spectrum allocations outside of the VHF and UHF bands; and it would begin an inquiry on the relative advantage of a variety of allocation schemes for HDTV transmission including one 6MHz channel, one additional 3MHz augmentation channel (not necessarily contiguous) to the main channel, one additional 6MHz channel (not necessarily contiguous) as either an augmentation channel or a simulcast channel for HDTV during a transition period.[16]

Through the tentative decisions, the FCC eliminated transmission systems from consideration for standardization that were incompatible with existing NTSC. This effectively ruled out the possibility of a terrestrial broadcast system based on the Japanese HDTV Multiple Sub-Nyquist Encoding technique called "MUSE-E".[17] In addition, the FCC decision ruled out the consideration of utilizing the spectrum band above 1GHz as augmentation channels.[18]

By the fall of 1988, HDTV-related activities had greatly intensified in the U.S. In October 1988, the Secretary of Commerce, William Verity, appointed an Advisory Committee on Advanced Television to study the potential impact of HDTV on U.S. industries. That same month, the American National Standards Institute (ANSI) accepted SMPTE 240M (the HDTV 1125/60 production standard approved by SMPTE) as an American national standard for studio production. In December 1988, the U.S. government would once again play an active role in the technological development of television. That month, the Defense Advanced Research Projects Agency (DARPA) announced its availability of grants totalling $30 million for two HDTV projects. One project involved the development of HDTV display devices. The other project involved the development of HDTV video signal/computer processors.

In March 1989, North American countries would establish a strategy that appeared to be similar to that taken by the Europeans at Dubrovnik in 1986. The North American National Broadcasters Association recommended that the CCIR not adopt a worldwide HDTV studio standard at the conclusion of its present study period in 1990. NANBA also recommended to encourage the identification of a "common image format" and the continuation of testing terrestrial formats, in order to establish potential relationships between emission standards and studio standards.[19] Also in March 1989, The Sixth World Conference of Broadcasting Unions recommended studies based on two different approaches towards the achievement of a worldwide production standard. These two approaches involved systems with a common data rate and systems with a common image structure.[20] On a similar note, in April 1989, an ANSI Appeals Board rescinded its earlier approval of the SMPTE 240M after a second appeal by Capital Cites/ABC. The 1125/60 system once given enormous support by the U.S. was becoming increasingly challenged by some of the broadcasting and cable industry groups.

A variety of U.S. government and industry proposals were introduced in the first half of 1989. Secretary of Commerce Robert Mosbacher outlined a plan that would relax antitrust laws and change the capital gains tax to cultivate HDTV manufacturing efforts by American firms. By May 1989, eight Congressional bills were introduced on the topic of HDTV (six House bills, two Senate bills) advocating some form of government aid for strategic alliances, antitrust relaxation, and national cooperative research.

Other interinstitutional players began to become more involved as the HDTV issues broadened to included other industries such as the computer and semiconductor industries. By mid-1989, industry groups such as the American Electronics Association (AEA) introduced an HDTV business plan to the U.S. Congress. The AEA plan calls for Congress to provide $1.3 billion in grants, loans and credits for the development of a consortium providing a strategic alliance between government and American institutions to research, develop and manufacture HDTV products.[21]

In June, 1989, DARPA awarded its first round of HDTV display technology development bids to Newco, Inc., Raychem Corporation, Texas Instruments, Inc., Projectavision. Photonoics Technology, Inc. was awarded a DARPA contract on flat screen display technology.[22] According to DARPA, more announcements regarding HDTV image processor awards were forthcoming. And an additional $50 million for DARPA's HDTV research project was recommended by a Congressional subcommittee working on the 1990 Defense Budget.[23]

In August 1989, a new hearing was set for a third appeal on the ANSI HDTV issue, this time validating the SMPTE 240M 1125/60 HDTV production standard. The ANSI/SMPTE standard stamp is important to the manufacturers and users of HDTV production equipment because of the need for common signal parameters for different pieces of the production process. Cameras need to be able to match with HD Video Tape Recorders, Switchers and other signal processors. If standards do not exist, the risk of technical obsolescence or incompatibility becomes even more acute.[24]

Standardization and Commercialization: The 1990's.

In March 1990, FCC Chairman Alfred Sikes stated the exact goals for the FCC in the implementation of a HDTV transmission standard. The FCC's intent is to select a simulcast HDTV standard that would be compatible with the current 6 MHz channelization plan but utilizing design principles that would not be limited to the constraints of existing NTSC technology and would be independent of NTSC. The target for the standardization selection by the FCC is the second quarter of 1993. With the intention of the FCC to standardize a simulcast system, the possibility of approving an augmentation system was eliminated. Augmentation systems represent substantial spectrum availability and utilization problems.[25] The FCC formalized what the marketplace was leaning towards in the development of simulcast approaches to HDTV terrestrial broadcast. Developers of simulcast approaches are Zenith, the David Sarnoff Research Center/North American Philips consortium and the Japan Broadcasting Corporation (NHK).[26]

The "augmentation" approach to terrestrial broadcasting of HDTV allowed for existing television channels to continue to broadcast NTSC signals on their 6 MHz allocations. However, an additional 3 MHz or 6 MHz would be assigned to each station for the transmission of additional information that served to augment the picture resolution of the main NTSC transmission. In addition, side-panel information could also be transmitted in the augmentation channel providing a 16:9 aspect ratio. Existing sets would continue to receive NTSC, while new HDTV sets would combine the NTSC channel with the augmentation channel to receive the full HDTV transmission.

The "simulcast" approach also allows existing television channels to keep their existing channel allocations. However, each station would also be given an additional 6 MHz channel to transmit a bandwidth compressed HDTV signal. Existing NTSC receivers would take the

NTSC signal, while new HDTV sets would pick up the HDTV signal. Simulcast is deemed superior to augmentation by some experts due to the fact that simulcast makes more efficient utilization of RF spectrum. In addition, simulcast systems are not constrained by the limitations of various NTSC artifacts. However, if the testing of simulcast systems indicates that such a system is not feasible for broadcast, then the commission may still select an augmented version of an extended-definition system. One important concern of a HDTV service is making sure that existing NTSC channels are not interfered with.[27]

The Commission also stated that it would not make a decision on extended-definition television (EDTV) until it reached its primary goal of standardizing a HDTV standard based on a simulcast system approach. Therefore, the FCC decision did not stifle the continued development of EDTV systems. Proponents of EDTV systems are Sarnoff/Philips, NHK, Faroudja Laboratories, Production Services, and the Massachusetts Institute of Technology (MIT).

Regarding the distinction between HDTV, EDTV and improved-definition television (IDTV), the FCC defined each technology in accordance with industry-wide accepted definitions of these terms that were developed by the U.S. Advanced Television Systems Committee (ATSC) in 1989. As stated earlier, HDTV represents a signal that provides at least double the horizontal and vertical resolution of existing 525 NTSC on a 16:9 aspect ratio, increased color fidelity and CD equivalent sound quality. EDTV represents a signal that would provide enhanced pictures to the home, including wide-screen to special EDTV receivers, while at the same time providing a picture that could be decoded by existing NTSC receivers. IDTV represents a signal that improves NTSC without changing the transmitted NTSC signal. This includes improvements such as line-doubling and ghost-cancellation. According to FCC Chairman Sikes, IDTV is an area that does not require action to be taken by the commission in order to implement improvements to NTSC.[28]

In June of 1990, General Instrument Corporation--an American based electronics company--became a contender for the simulcast HDTV FCC standard by its announcement of its DigiCipher system. DigiCipher utilizes a proprietary compression algorithm that forms the basis of the all-digital 6 MHz simulcast transmission technique. The inclusion of the General Instrument DigiCipher system brought the total number of systems to be tested to six.[29] In November, the Advanced Television Research Consortium--consisting of NBC, David Sarnoff Research Center, Philips Consumer Electronic Co., and Thomson Consumer Electronics Inc.--had converted to a digital approach by announcing its plans for the joint development of an advanced digital television system. Also in November of 1990, a new test schedule was released by the FCC indicating the laboratory testing of all proposed systems that will take place at the Advanced Television Test Center in Alexandria, Virginia. Field testing to begin after the completion of the laboratory tests.[30]

By the end of 1990, another proponent had also switched to an all-digital HD approach. Zenith Electronics Corp., who in joint agreement with AT&T, developed its own digital version of Zenith's "Spectrum Compatible " simulcast system incorporating techniques from AT&T in digital video compression and advanced semiconductor technology. Both of these conversions to digital had to be pre-certified by the FCC Advisory Committee and Systems Subcommittee Working Party 1 before the end of February 1990.[31]

The FCC Advisory Committee on Advanced Television Service will be testing the proponents during the 1991-1992 time period, with the final FCC decision on a HDTV broadcast standard in 1993. The following table serves as a list of the test sequence and calendar for the transmissions systems by the Advanced Television Test Center and the Cable Television Laboratories:

- 4/12/91-6/12/91 ACTV (ACTV/DSRC)
- 6/19/91-8/12/91 Narrow MUSE (NHK)
- 9/3/91-10/24/91 DigiCipher (General Instrument)
- 10/31/91-12/27/91 HDTV (Zenith)
- 1/8/92-3/3/92 Simulcast HDTV (Philips)
- 3/10/92-4/30/92 Channel Compatible (MIT)

SUMMARY

As should now be readily apparent, the evolution of high definition television, was comprised of a series of technological stages that offer valuable insights as to the management of this technology. Beginning with the evolution of mechanically based low definition television systems, developed for the most part by sole inventors, television evolved into an electronic medium capable of true high definition, defined as resolution 240 scan lines or greater. Even though the development of an all-electronic monochrome television system was confined to a small number of firms that were able to compete within the industry, intra-industry competition delayed the authorization of a broadcast television standard in the United States. However, standardization was greatly assisted by regulatory intervention and the establishment of the NTSC, which coordinated the efforts of the entire television industry.[32]

In addition, the nagging problem of early television's "vicious triangle"--i.e., multiple, conflicting demands for advertising support, consumer acceptance, and programming supply--appeared to be solved by the late

1940's, as monochrome television burst upon the American scene at a time when Americans had a enormous appetite for consumer products. It was also during this period that the American television industry had established the infrastructure to foster the commercialization of this new medium. Indeed, the concerted effort to commercialize television necessarily affected TV receiver set sales, which would triple in one year (from 1947 to 1948). And in that same year, business entrepreneurs clamored for broadcast television station licenses from the FCC.

From the analysis of the history of color television in the United States one learns that, as with monochrome television, here too there were a variety of internal and external factors that significantly affected the technological evolution and commercialization. The diffusion of color television involved an adoption process that was spurred on by intra-industrial competition that accelerated the growth of color systems before standardization but delayed the diffusion process because of inter-media competition with monochrome.

The early stages of development for color television systems established the factors necessary for its success, particularly compatibility, bandwidth restrictions, and a direct view receiver. But a premature adoption by the FCC and subsequent economic threats from CBS actually inspired the innovation of compatible systems. The efforts of the second NTSC illustrated industrial cooperation and collaboration in developing compatible color standards.

Standardization was essential for the commercialization of color television. Both manufacturers and the public need the assurances that come from standards as prerequisite for the social context of diffusion and the promise of revenues based on intra-industrial technical standardization. The FCC decision approving the CBS field sequential system in 1950 and subsequent reversal of that decision in 1953 facilitates the need for innovations to be able to demonstrate their commercial readiness prior to approval by the FCC. In addition, the protection of existing innovations that have readily diffused constitutes a public-interest issue--very important to the FCC with its mandate to operate in the public interest.[33]

The development of a domestic color television industry signifies a variety of management decisions that take into account the interinstitutional forces of regulation and competition resulting in the creation of new international alliances, selling strategies, promotional campaigns, service supports, patent pools, quality vs. quantity demographics, and new programming strategies that served as catalysts for diffusion. The adoption of color television was dependent on programming as an incentive not only for advertisers, but for retailers as well.

The "take off" point on the diffusion curve for color television began in 1959 when color TV first demonstrated its profitability. Monochrome had reached its saturation in 1959 and color promised a higher profit margin for dealers. Color television's commercialization was greatly enhanced by networks and advertisers when ratings research revealed the quality demographics of the color TV audience.

In the international arena, the standardization process for color television signifies how national standards can serve as a non-tariff device for protecting and promoting an indigenous industry. Governments, as signifying practices cultivated the diffusion of color television, as demonstrated through the adoption of SECAM, PAL, NTSC around different parts of the world. In addition, the international standardization process constitutes the politics of technological innovation and creates the necessity for the establishment of national policies that reflect the competitive positioning of a country in relation to creating export opportunities for the diffusion of new video technological innovations.

The evolution of high definition television and advanced television systems and the potential diffusion of these systems constitutes economic and policy considerations that will have a direct impact upon the major stakeholders of the technology and a larger macroeconomic impact upon the U.S. economy and world trade by the year 2000. Past failures in achieving a worldwide standard for AM stereo, color and monochrome television, and 1/2" VCR formats have resulted in costly transformations of standards, diminishing the potential return of investment on media productions and distribution. Cost sharing based on programming exchange and international strategic alliances benefit from the potential for a worldwide HDTV standard. The lack of a worldwide standard for HDTV production results in higher costs and expensive international distribution strategies as economic consequences.

Spectrum allocation constitutes the primary policy concern affecting the distribution and transmission of HDTV/ATV systems. For terrestrial broadcast of HDTV, simulcast becomes a way to address the issue of compatibility. And the move toward digital approaches to HDTV affect cost and convenience considerations for both broadcasters and consumers.

The macroeconomic impacts of HDTV will undoubtedly affect the U.S. economy and international trade. International Strategic Alliances such as the European Eureka project reflect the dynamic changes acting upon global competitiveness in both hardware and software areas that are needed for the complete commercialization of HDTV. The success of foreign collaborative efforts indicate the need for similar efforts by firms not only on the institutional level, but also on the industrial and national levels.

Signs of the potential creation of an American HDTV industry stimulation are apparent at the government level by the recent actions of DARPA. Demand for HDTV products could also come from computer industry displays and industrial and commercial applications. Aggressive pursuit of these early-demand areas would help gain early footholds in applied niche-markets.

Given the history of the standardization of both monochrome and color television, the adoption and diffusion of HDTV for terrestrial use will be dependent on the development of standards set by the FCC. Historically, the potential for commercialization in the American television industry has been most realized after the presence of technological standards in the marketplace. If one considers the plethora of newer distribution technologies for HDTV on the horizon beyond broadcasting; the continued efforts of harmonization by international standards groups such as the CCIR; and the versatility of HDTV for a variety of business and industrial applications; the future for HDTV can appear promising indeed.

Using the lessons from the past, these groups outlining the events leading to the development, standardization and diffusion of television systems may be able to help us understand the evolutionary process of how new technologies become adopted by a society as they gain public acceptance and mass utilization. One example of this was the agenda of technical, economic, and societal issues before the NTSC and FCC in 1941 that can essentially serve as a template for current agendas of the various subcommittees and working parties of the FCC Advisory Committee on Advanced Television Service:

- Improved picture definition being adequate enough for the public
- Identification of specific synchronization signals
- Choice of a fixed or flexible number of scanning lines
- Number of channels necessary to broadcast HDTV
- Comparison with projected 35mm motion picture film as a measurement of resolution
- Utilization in other markets beyond broadcast
- Impact on other existing media
- Compatibility with existing systems
- Affordability of technology by average citizens
- Ability for technical improvements without the risk of obsolescence.

Endnotes

[1] Vladimir Zworykin, "Television," *Journal of the Franklin Institute* 217 (1934) [Rpt. as G. Shiers, ed., *Technical Development of Television* (New York: Arno Press, 1973) 3.

[2] For more information on the early NHK research efforts see T. Fujio, "A Study of the High-Definition TV System in the Future," *IEEE Transactions on Broadcasting* BC-24.4 (Dec. 1978): 92-100.

[3] See Kenneth Donow, *HDTV: Planning for Action* (Washington D.C.: NAB, April, 1988) 18.

[4] Corey Carbonara, "A Historical Perspective of Management, Technology, and Innovation in the American Television Industry," diss., University of Texas at Austin, 1989 9.

[5] The original NHK HDTV system consists of the following parameters: 1125 lines, 60Hz field rate, 2:1 interlace, and 5:3 aspect ratio.

[6] This is the bandwidth where direct broadcast satellite transmission are located.

[7] The charter members of the ATSC are the National Association of Broadcasters (NAB, Electronic Industries Association (EIA), the Institute of Electrical and Electronic Engineers (IEEE), the National Cable Television Association (NCTA) and the Society of Motion Picture and Television Engineers (SMPTE). The Chairman of the ATSC is Mr. James McKinney. The Executive Director is Dr. Robert Hopkins.

[8] This author has actively participated as a member in this SMPTE Working Group since 1984.

[9] One of the key new developments associated with the ACTV system that distinguished it from all other previous work was the method of using the "Fukinuki Hole" to separate both high and low frequency components of the signal in the edges or "wings" of the image. For more information on the "Fukinuki Hole" see also Mark Schubin, *High Definition Glossary* (New York: HDTV Group/Videography, 1988).

[10] MUSE was originally a term to describe NHK's DBS transmission scheme. Currently, MUSE refers to a family of ATV transmission proposals. The Sub-Nyquist portion of the name refers to the fact that MUSE is a sub-sampling system and as such, has been subject to motion artifacts.

[11] The CBS HDTV DBS system utilized frame conversions that were initiated prior to the uplink from the source transmission.

[12] Adam Watson Brown, "The Campaign for High Definition Television: A Case Study in Triad Power," *Euro-Asia Business Review* 6.2 (April 1987); "NHK Offers Deal on HDTV," *Broadcast* 30 Aug. 1985.

[13] MAC signals are a family of television signal formats that separate color and luminance (monochrome) signals into component channels which are time compressed so that active line time remains constant. Most MAC signals contain digital audio and data channels. MAC has achieved the majority of its popularity as a satellite transmission system for Europe.

[14] See E. Feldman, "Advanced Television Update," *Via Satellite* (March 1988); Donow, *HDTV: Planning for Action.*

[15] "FCC Writes a First Draft for HDTV," *Broadcasting* 115.10 (5 Sept. 1988): 32-34.

[16] Federal Communications Commission, MM Docket 87-268, 88-288, 37462. As quoted in Federal Communications Commission, *Economic Factors and Market Penetration: The Working Party 5 Report to the FCC Planning Subcommittee on Advanced Television Service* (Washington, D.C.: FCC, 9 May 1988). This document was supplied to me as a member of the FCC Advisory Group on Advanced Television Service.

[17] MUSE-E stands for a MUSE system optimized for broadcasting rather than satellite transmission. It is a non-compatible proposal that occupies 8.1 MHZ base bandwidth, requiring four fields to build up a full resolution picture. The system requires motion compensation for display.

[18] "High Definition TV," *Broadcasting* 115. 13 (26 Sept. 1988): 20.

[19] The NANBA members are ABC, CBS, CNN, NBC, PBS (all American); CBC and CTV (both Canadian); and Televisa (Mexican). See David Hack, "High Definition Television," Congressional Research Service, CRS Issue Brief (Washington, D.C.: U.S. Library of Congress, 5 June 1989).

[20] The World Conference is made up of nine international regional broadcasting unions.

[21] John Gatski, "Capitol Hill's HDTV Plans Draw Positive Reactions," *TV Technology* 7.7 (June 1989): 1.

[22] For more information on the DARPA HDTV initiative see "DARPA Allocates Money for HDTV," *TV Technology* 7.9 (Aug. 1989):.3.

[23] Chip Cavanagh, "ATV Funding May Increase; DARPA selects 1st Companies," *Television Broadcast* (July 1989): 1, 23.

[24] For more information on this twist of events in the ANSI standards battle for SMPTE 240M see Alan Carter, "ANSI Sets Third Hearing Date for SMPTE 240M," *TV Technology* 7.9 (Aug. 1989): 1.

[25]"FCC to Take Simulcast Route to HDTV," *Broadcasting* (26 Mar. 1990): 38-40.

[26]Alan Carter, "FCC: Broadcasters Will Simulcast HDTV," *TV Technology* 8.4 (April, 1990): 6.

[27]David Hughes, "FCC Decides to Push for 'Pure' HDTV, " Television Broadcast 13.4 (April, 1990): 1, 55.

[28]"FCC to Take Simulcast Route to HDTV," *Broadcasting* (26 Mar. 1990): 38-40.

[29]The six systems are ACTV (Advanced Compatible Television/DSRC), Narrow MUSE (NHK), DigiCipher (General Instrument), SC-HDTV (Zenith), Simulcast HDTV (Philips), Channel Compatible HDTV (MIT).

[30]Ronald Jurgen, "Consumer Electronics: Digital HDTV," *IEEE Spectrum* 28.1 (Jan.1991): 65-68.

[31]Lex Felker, "Digital HD Proposals Anticipated," *TV Technology* 9:1 (January 1991): 12.

[32] For more information on the ways that the intra-industrial competition occurred see F. C. Waldrop and J. Borkin, *Television: A Struggle for Power* (1938; New York: Arno Press, 1971) 131.

[33] Section 303 of the Communications Act of 1934 first established its famous PICON rule that specified the powers of the FCC to act "as public convenience, interest, or necessity requires.."

EUROPE'S DEMANDS ON ENHANCED TELEVISION

Dr. Albrecht Ziemer
German Television ZDF
Mainz, Germany

ABSTRACT

In order to describe the European situation regarding the demands on enhanced television I would like to make 3 statements at first and give the conclusion arising from these statements later on.

FIRST STATEMENT

Today's situation in European broadcasting

There are private and public broadcasters:

- Private broadcasters are financed exclusively by advertising
  - Public broadcasters are financed by fees as well as by advertising

Both, public and private broadcasters, use simultaneously and often all transmission systems, which are terrestrial, cable and DTH satellites.

Consequence:

The demand for enhanced television systems in Europe is not caused by competition between different broadcasting sytems but by the technical competition between the various transmission systems which are all reaching the same receivers. The demand is arising as a result of better transportation capacities of cable and satellites compared to terrestrial transmission.

SECOND STATEMENT

In future TV broadcasting will have to compete more and more with TV narrowcasting. In other words: The same TV set shows pictures delivered by means of broadcasting as well as pictures coming from VTR's. Recent developments in consumer VTR's, such as S-VHS and High 8 mm, will strengthen this competition.

TV broadcasters will have to be careful not to get in the same position as sound broadcasters are already facing it today: In most existing sound sets the quality coming from the source "audio broadcasting" is the down-end compared to other sources, such as tape, disc and compact disc.

It could be expected that the manufacturers of TV sets themselves will react as a result to better sources coming along with TV narrowcasting. TV broadcasters will risk their business if they offer an inferior quality on this new generation of TV sets compared to other sources.

THIRD STATEMENT

HDTV (High Definition Television) will be large screen television which will cause a new technology for TV sets not yet available today. Furthermore it will bring new programmes with new dramaturgic tools. The large screen television in the HDTV future cannot be compared with today's programmes and the current programme production for small screen television. There is no chance of a smooth transition from today's television to HDTV and no possibility for any evolution.

Consequence:

There will be a co-existence of today's television and HDTV for a long time. This co-existence will be supported by a comparatively more brilliant picture in the 625 line PAL/SECAM world in contrast to the 525 line NTSC world.

CONCLUSION

The above given three statements will create the following environment for enhanced television systems in Europe:

More space regarding the transmission capacity via satellite and cable as well as higher quality in narrowcasting will bring about new generations of small screen tube-based receivers which will offer better resolution, flicker-free pictures and a minimum of cross interference. These receivers will also allow to reproduce the dual mode aspect ratio 4:3 as well as 16:9.

For reasons of competition it will be vital for all broadcasters to serve these new receivers with suitable and equivalent signals. This is especially of importance regarding terrestrial broadcasting which is the backbone of business for most broadcasters. Therefore it is obvious that there is a demand for an enhancement of the traditional TV standards NTSC as well as PAL and SECAM in Europe. This enhancement has to be realized in a downward compatible manner in order to avoid a loss of audience and business. The schedule for the market penetration of the a.m. new 16:9 receivers sets the start of their market introduction in Europe for 1991, which makes it necessary to have enhanced standards in operation at least by the mid nineties. This enhancement has to be regarded separately/independently from an upcoming HDTV due to the fact that HDTV will not replace our present small screen televsion for a long time to come.

PROGRESS IN HIGH DEFINITION TELEVISION

P. Bögels
Eureka HDTV Project EU 95 Directorate
The Netherlands

Today I would like to bring you up to date on the European Eureka HDTV project's progress and plans. I will also discuss the situation regarding HDTV worldwide.

First to recap on the project's background. The Eureka HDTV project EU95 was set up in 1986. It took account of the fact that 70 % of the world has a 50 Hs infrastructure and currently uses PAL or SECAM television technology.

The Eureka project's basic philosophy was that the system must guarantee an evolutionary, compatible route to HDTV. We are convinced that for an HDTV system to succeed it must offer benefits to everyone all along the TV chain: viewers, broadcasters, satellite and cable operators, and local electronic industries.

So, right from the start we opted for a totally open, non-proprietary system that could support a wide range of hardware. We also took a total systems approach from programme making to replay. And we based our whole scenario on the gradual introduction of HDTV. This will be in three compatible steps to ensure that no part of the audience is cut off from their basic programmes and no broadcaster is cut off from his audience.

Phase one of this introduction is the transition phase from PAL to the MAC transmission system initially developed for direct broadcasting via satellite. Even on existing sets, MAC gives a considerable improvement in picture quality. The MAC digital data structure allows up to eight sound channels to be transmitted simultaneously with each programme. So at the touch of a button viewers can select the language, or dialect, they prefer. And because MAC signals are far more robust than PAL, coverage in remote areas will be far better.

Phase two is the introduction of wide-screen 16:9 MAC transmissions - starting now in Europe. Viewers can, for the first time enjoy movies as the makers intended - in their own homes. 16:9 MAC TV sets are now in the shops and I don't think it will be very long before the number of sets in use in the home is in six figures.

When phase 3 - HDTV transmission - starts in Europe in the middle of the decade, there will already be a large pool of MAC viewers who will be able not only to continue to watch their MAC programmes but also to watch those using the HD-MAC transmission system. Movies are already European viewers' number one choice of viewing, even though they cannot yet be enjoyed on 16:9 wide screen TV's. The introduction of 16:9 viewing will make them more popular than ever.

So, who are the participants in the Eureka HDTV project? The initial project proposal came from Bosch, Philips, Thomson and Thorn EMI. Thorn later became a part of Thomson. And last year NOKIA - the third largest European manufacturer of TV sets - also joined the Directorate. The latest member of the Directorate is a consortium representing participants in Italy.

Today, as well as the five members of the directorate, there are a number of so-called 'B participant' companies and organisation involved in the project. The number is constantly growing as new members are joining almost daily. Which is why my slide is always out of date. What I can tell you is that today there at least 40 from 11 countries.

The project's total research activity, covering the entire TV chain, was divided over 10 Project Groups. These groups met for the first time in January 1987. By the end of 1989 a total of more than 2,000 man years had gone into the project. And the work is far from over. Projections for the years 1990 to 1992 indicate that phase 2 of the project will involve a further 3,150 man years. It's a lot of effort, and investment, but we are convinced the MAC/HD-MAC route to HDTV will work; technically, economically, socially.

One of the project's prime goals was to set the system standards. For the origination and production areas we propose a Single World Production Standard of 1250 lines/50 Hz/1:1 progressive scanning. This takes account of the worldwide digital standard of recommendation 601, provides an optimum interface to the 24/25 frames per second standard of 35 mm film - the only truly world standard in operation, provides enough headroom for conversion into the world's transmission standards and interfaces readily to the HD-MAC transmission standard.

We chose the HD-MAC transmission system to ensure compatibility with the existing MAC/PAL/SECAM standards. The HD-MAC transmission system effectively transmits its 1250 HDTV lines in a MAC compatible 625 line format together with digital information for reconstructing the 1250 line picture. Existing 625 line sets can receive the signals and display them in normal MAC quality. HDTV receivers receive and display the full 1250 lines.

We also had to take into account the increasing application of subscription TV and the increased use of TV for professional broadcasting to closed groups of authorised viewers. This created a demand for a conditional access standard which can answer two major needs. It must offer programme providers a practical system for obtaining payment, protecting copyright and meeting legal requirements by enabling them to restrict access to certain programmes to paying subscribers. And it must provide the security needed to ensure that only authorised viewers can receive programmes broadcast for closed user groups. This led to development of the Eurocrypt system. Finally, we had to set the two standard necessary for the home environment: a display standard for TV receivers and a replay standard for VCRs and Laser Disks.

But setting the standards has been only one of our achievements.
So, to keep everyone up-to-date with our progress, we have regularly participated in international exhibitions. In Berlin, in the Summer of 1987, we demonstrated cameras, telecine and monitors all to the working European HDTV standard and displaying the results on prototype receivers. In 1988 in Brighton we put together and demonstrated a complete working chain from production through to satellite transmission, reception and replay.

In 1989 in Montreux we were able to show more complete productions shot in the 1250 line/50Hz HDTV standard as well as fully equipped outside broadcast vans complete with editing, recording, paintbox, telecine and mixing facilities, etc. And at the IFA in Berlin where we not only demonstrated our complete, up-dated system but built a complete, working HDTV studio which was used by several broadcasters to make programmes - they gained valuable experience and we gained additional programmes for the HDTV stockpile. The signals from Berlin were transmitted via TV-SAT 2, KOPERNIKUS and TDF-1. In 1989 we also gave demonstrations and presentations in several countries in the Far East - Australia, Singapore and China.

The European satellite programme has also progressed well. By the end of 1990, 13 satellites offering more than 100 channels were in orbit over Europe. With all these channels we need a lot of programmes. To date we have produced more than 50 HDTV programmes for our stockpile but we need a lot more and we are working hard to produce more. Events such as the 1992 Winter and Summer Olympic games and the 1992 Sevilla World Expo offer an ideal opportunity. I'll tell you a little more about some of the plans for new HDTV programmes and for the start of large-scale experimental broadcasting in Europe in a moment.

Today there is a renewed interest in satellite TV both in Europe and elsewhere in the world. One reason is that, after delays for technical reasons, MAC products are now flowing from the production lines in quantity. Today the European industry has a production capacity of two million MAC satellite TV receivers per year. Once consumers begin to appreciate the superior sound and picture quality of MAC, as well as its 16:9 movie-screen format, then we can expect to see an exponential growth in the numbers of viewers of MAC satellite programmes. This will provide the basis for the introduction of HDTV - using the HD-MAC transmission system - from 1995 onwards.

But we are not ready to sit back on our laurels yet. Phase 1 of the EU 95 project gave us standards; phase 2 must give us systems. We must make sure that the infrastructure for large-scale experimental broadcasting is in place in time for the 1992 Olympics and we must further the evolutionary introduction of HDTV into the home.
To this end, our activities include:

- design and realisation of components,
- definition and development of more prototype equipment including studio equipment, receivers, VCRs and Laser Disc players,
- stimulation of software production,
- further detailing of system specifications,

- preparation of scenarios for the introduction of HDTV into the studio world,
- support to other organisations for the introduction of HD-MAC on a national basis and
- contact with the EBU, CCIR and the other European projects and studies concerning HDTV.

For phase two, two new project groups have been formed. One concentrates on sound and is developing proposals for (surround) sound systems and prototype hardware. The other is studying the non-broadcast uses of HDTV.

One of the busiest project groups during phase 2 is Transmission. Their work load includes studies and hardware development related to the transmission of HD-MAC on AM cable networks and optical fibre. They are also developing a common filter standard for cable and satellite and produce prototype hardware. A key new area of study and testing is the terrestrial transmission of HD-MAC. First trials in France for MAC terrestrial transmission have now been successfully completed.

As I've said, Europe has an acute shortage of terrestrial frequencies and has thus opted for a comprehensive satellite programme. But this is not the situation everywhere- in some parts of the world countries have spare terrestrial frequencies and have no intention of going to satellites. Should this cut them off from HDTV? We do not think so - and thus an important part of our work in phase 2 will be to prove the use of the HD-MAC system in terrestrial applications.

This is a good point at which to compare the Japanese, US and European approaches to HDTV and see how far they are down the road. I'll start with Japan, where the impetus for change began. In the terrestrial area, they plan to improve their NTSC terrestrial transmissions by going first to a system of Enhanced Definition Television (EDTV) and then perhaps following the USA. There will be a parallel satellite NTSC scenario with digital sound.

They do have some problems with their approach to true HDTV.
For this they have a totally separate programme and a system - MUSE - that is incompatible with NTSC in the production and transmission areas as well as in the display and replay areas. This means that the millions of Japanese viewers who have bought NTSC satellite tuners will have to buy an expensive MUSE to NTSC converter. They'll need another when EDTV-1 comes along and yet another for EDTV-2. Would you do that? I wouldn't and I don't thing the Japanese will either - at least not in the millions needed for commercial success.

I'm not alone in that view. Although in the beginning the USA looked favourably towards the Japanese system, when they realised the implications of a production and transmission system incompatible with both NTSC and movie film, they backed-off hastily. The FCC is now considering two, parallel scenarios in the transmission area; a Simulcast system where NTSC-compatible (59.94 Hz) programmes and HDTV programmes will be transmitted simultaneously, and a programme of NTSV improvements known as EDTV 16:9.

Recommendations for the systems will be presented to the Federal Communications Commission in the Fall of 1992 and a decision is expected by the Fall of 1993. Currently, there are five serious proposals for each of the possible systems.

Now Europe where, starting in the terrestrial area, today's PAL system will remain for a number of years during the transition period to MAC. Some broadcasters are, however, looking to extend the life of PAL and see a future in 16:9 PALplus. This would give a 'letter-box' picture when transmitting wide-screen programmes and whether or not this will be acceptable to viewers at home has yet to be investigated.
However, to ensure wide-screen viewing on terrestrial broadcasts, PALplus is proceeding with a target date of 1996.

The MAC transmission system is Europe's route towards HDTV - it works, and it is available now with the D2-MAC system. And don't forget, MAC and HD-MAC provide compatibility with existing PAL/SECAM TV sets - through a satellite tuner and also through a cable tuner on cable networks using the hyperband - and they give an enhanced viewing and listening experience with no limitations.

So let's move on to see how Europe is preparing itself for the implementation of HDTV public broadcasting. I mentioned earlier the need for a stockpile of programmes to be ready for the launch of HDTV. We also need a fully trained and experienced pool of engineers and creative people who know and understand the techniques of HDTV programme making. To make sure this all happens, there have been several initiatives including the formation of the European Economic Interest Grouping (EEIG) now called 'Vision 1250'.

Vision 1250, which is sponsored by national EC governments and the CEC, will coordinate the activities of industry, the EBU, broadcasters, programme providers and transmission organisations to ensure HDTV gets off to a flying start.
One of Vision 1250's key activities is to make fully-equipped HDTV Outside Broadcast vans available for use by programme makers. At the moment we have several in full operation which, thanks to the work of the IHD, a French initiative that was Vision 1250's predecessor, are already heavily booked. incidentally, by mid year, when HD-MAC encoders and decoders are available in quantity, the OB vans will also be available to cable operators for transmission tests to check the use of the MAC/HD-MAC system on their cable networks. By the time of the 1992 Olympic Games, the current fleet of seven OB vans will have grown to 10 vans, all fully equipped with editing facilities.

Another major initiative is concerned with ensuring the implementation of HDTV on a per-country basis. To this end, National Governments are setting up National HDTV platforms. The individual National Platforms are concerned with the financing, production of programmes, telecommunications infrastructure and planning the actual introduction of public HDTV broadcasts in their respective countries. Discussions with other participating countries ensures Europe-wide stimulation and coordination of HDTV activities.

There are already active National Platforms in The Netherlands, France and Germany and others are being put in place in other countries. One important task for them will be to learn from each other and share expertise, programme material and facilities. I said earlier that our stockpile of HDTV programmes is growing quite rapidly. One organisation with a very active and interesting stockpiling agenda is the BBC in the UK. They already have 14 productions 'in the can' - a total of 21 and a half hours of programming - and are forging ahead with many more.

A major event last year was coverage of the Wimbledon tennis championships. This is especially appropriate as Wimbledon tends to be the trail-blazer other sporting organisers follow. For example, the first public colour transmissions in the UK were from Wimbledon in 1967. Last year the BBC had HDTV cameras covering the Centre Court for the whole fortnight. Four HDTV displays enabled spectators to see ball-by-ball play. There were displays in the Royal Box Guest Area, the Players lounge, the Press Rest Room and the public pavilion. This gave more than 400,000 visitors the chance of seeing our HDTV system in action.

Among other events on the BBC's 1990 programme were ballet and opera from Covent Garden, the Royal Ascot race meeting, Promenade Concerts from the Albert Hall, the Welsh Agricultural Show and the Edinburgh Tattoo. But the age of spectacular HDTV has, in fact already begun. It started with the HDTV coverage of the 1990 World Cup Soccer final tournament in Italy last Summer.

National teams from 150 countries entered the competition. The 22 winners from the qualifying rounds plus Italy as host country and Argentina as the cup holders played at 12 different locations throughout Italy. there was live HDTV coverage of all six matches played in Rome which included the final. The signals from the stadium were transmitted via a two km 140 Mbit/s optical fibre link to the RAI production centre in Rome for uplinking to the Olympus satellite. From Olympus they were transmitted to two downlinks: in France and uplinked again to the TDF-1 satellite. Reception sites equipped to display the signals from any of the three satellites were located in Milan, Frankfurt, Paris, Eindhoven and London as well as Rome itself.

For HDTV, the big exhibition event of 1990 was the IBC in Brighton in September. What made the Brighton event so - shall I say 'interesting' - is rather than being contained in just one building, it involved the Brighton Centre, the Metropole Hotel and the Esplanade on the sea front. This, as you can imagine, does rather complicate matters but it was a very interesting exercise. And we put on a very interesting demonstration.

We had OB vans on the promenade fully equipped with cameras for local HDTV coverage as well as editing facilities. The OB vans 'collected' signals from the cameras and from satellites and fed them, via a fibre optic link, to the HDTV theatre in the Brighton Centre from where they were distributed to participants' stands in the Brighton Centre and the Metropole Hotel.

This year, the big exhibition event will again be the IFA in Berlin. As I mentioned earlier, our 1,400 square meter stand at the 1989 IFA included a complete working HDTV studio. We also installed a complete fibre optics network on which we transmitted HD-MAC and HDTV pictures to other stands which enabled us to prove the practical compatibility between D2-MAC 4:3, D2-MAC 16:9 and HD-MAC and demonstrate fibre optics as a part of the transmission system. Now, although we have not yet finalised our plans for this year's show, you can be sure it will once again show just how far we are on the road to HDTV.

The sporting highlights of 1992 will, without doubt, be the Winter Olympic Games in France and the Summer Olympic Games in Spain. The games will also be HDTV highlights. The Winter Olympics will be centred on Albertville in France where the ceremonial part of the games plus the skating events will be held at two different locations. The other events will be held in Courchevel and Meribel, both of which are about 60 km away from Albertville.

We will be providing live HDTV coverage of the opening and closing ceremonies as well as several events taking place at the different locations. The different venues will be covered by two OB vans. Signals will be transmitted via a microwave link to the HDTV Broadcast Centre in Albertville where final editing and post production facilities will be available and from where the signals will be uplinked to several satellites.

The HDTV signals will be displayed on up to 100 HDTV receivers sited in reception centres throughout Europe. HDTV coverage of the Summer Olympic Games in Barcelona will follow a similar pattern but on a much larger scale. We will have a number of fully equipped OB vans available to cover events at the Olympic Stadium and the Saint Jordi Palace. And ONE THOUSAND HD-MAC sets will be installed at strategic sites, most of which will be open to the general public, throughout Europe. We will be finalising the details of our Summer Olympics coverage with our EUREKA colleagues in Spain.

The first 1000 HD-MAC sets will be supplied by a number of participant companies from different European countries. The sets will be a mixture of front projection sets, direct vision sets and back-projection sets. But 1992 won't be all sport, Expo'92 will be held in Sevilla, Spain throughout the summer. It's likely that there will be an HDTV centre in the EC pavilion with distribution of HDTV signals to the stands of the member countries.

Already, many European Governments are planning special HDTV displays and demonstrations on their stands. Things are still very much in the planning phase, of course, but ideas include a complete 'HDTV studio of the future' from the BBC. When I tell you that this features a 40 Gbit a second optical fibre link, you get some idea of the technology jump represented by HDTV.

Another interesting idea, which has been taken up by the participating countries, is that from different locations in their own countries and via different satellites and channels, they will transmit live HDTV pictures directly to Sevilla for reception on the various participant's stands. A good way to show HDTV and life throughout Europe at the same time. We will ensure that all these pictures, plus of course those from the Olympic Games, will also be seen live throughout Europe on HD-MAC displays sited at strategic points.

But we must not forget that in the future TV, or should I say HDTV, will increasingly offer a new age of communications in the professional arena and will form the core of many applications public and private, broadcasting and non-broadcasting.

In Europe, even before HDTV is introduced for public broadcasting on a large scale, it will be used for data and vision broadcasting, to groups of professionals for example, as well as in the fields of publicity and archiving. In fact this has already begun with the Distance Learning experiments that are taking place on the Olympus satellite. More than 300 organisations are taking part - which shows just how much interest and potential there is in such new ideas.

We are taking active measures to stimulate the introduction of such HDTV services. Such as setting up a new project group in phase 2 specifically to study the non-broadcasting aspects of HDTV.

To sum up, we're on the road to the new world of HDTV television. It's a world that is full of challenges. But it is also full of opportunities. Opportunities to develop expertise in HDTV programme making and distribution. Opportunities for hands-on experience of professional HDTV equipment. Opportunities to offer new services and facilities. Opportunities for everyone in the broadcasting world.
Thank you.

THE TRANSITION TO HDTV:
Changing the World

Monday, April 15, 1991

Moderator:
Michael Sherlock, NBC, New York, New York

THE TRANSITION TO ATV—IS IT REAL? WILL BROADCAST TELEVISION SURVIVE IT?

Howard N. Miller
Public Broadcasting Service
Alexandria, Virginia

Many commercial as well as public broadcast stations have questioned whether HDTV will ever become a reality. Some have even questioned if HDTV will spell the end of broadcast television. The PBS answers to our stations have been yes to the first question and no to the second. Let me share our reasoning.

There are three conditions which must exist if HDTV is to evolve in the United States.

First, there must be programming. There may have been earlier questions about the willingness of major production companies to invest in the HDTV programming or conversion of films to HDTV. These questions were most certainly answered by the Sony and Matsushita purchase of American Production Studios along with their film libraries. The only question now remaining is what production format will be needed to accommodate the simulcast broadcast distribution format. In the interim, public broadcasting has and will continue to invest in selected HDTV programming produced under the SMPTE 240M production standard and down converted to NTSC. We continue to produce selected programs in order to gain more experience with this new medium.

Second, there must be a distribution system. Setting broadcast transmission issues aside for the moment, it appears that several major DBS players are incorporating HDTV into their plans. If this does occur, much of the cable industry will have little choice but to move ahead with their own HDTV distribution plans. Even without DBS competition, some cable operators in selected demographic areas are almost certain to begin distribution of a limited amount of HDTV programming. HDTV growth rate in cable beyond this limited distribution will depend upon the subscriber growth rates in these initial markets.

A number of cable operators have also expressed interest in EDTV services as a way of offering some form of ATV while avoiding or delaying the need to increase channel capacity.

The latest FCC ruling on advanced television indicates that the Commission will not consider modifications to the existing rules covering NTSC broadcasting to accommodate some aspects of EDTV until after all the simulcast systems tests have been completed. This ruling was clearly intended to pave the way for the broadcast industry to have access to a long term competitive HDTV service. The conditions under which the Commission will revisit EDTV have not been fully explained in the ruling. Under existing FCC rules, wide screen would not be allowed as part of an EDTV broadcast format but other elements of ACTV or the Farudja Laboratories EDTV system would be allowed.

Public Broadcasting supports the Commission's position and also urges that final simulcast channel allocations be completed at the same time as a system is selected. It is likely that HDTV, and perhaps some form of EDTV, will be offered to the public regardless of what actions are taken by the commission or the broadcasters. HDTV satellite distribution of special events has already occurred in closed circuit form. An HDTV based movie distribution service is planned for Florida. Farudja Laboratories now offers EDTV products to both broadcast and cable markets. Such applications are bound to expand if any degree of success is achieved.

The third condition is public acceptance. This condition is clearly the most difficult to predict since there is no directly comparable television experience to draw upon. We do know that there has been a recent receiver market shift to larger screen sizes as well as increased sales of projection sets. This shift clearly signals significant public interest in larger sets and improved picture quality. Such improvements are only now becoming possible because of better NTSC receiver circuitry and displays. Simple extrapolation of this trend would suggest a likely move of the high end consumer market to some form of advanced television.

Conversely, the entire television industry recognizes that receiver price sensitivity will be a major factor in determining the growth rate of any new advanced television system in the U.S. The initial $18,000 price announced in Japan for MUSE type HDTV receivers was therefore quite discouraging. On the other hand, Zenith has indicated that it will introduce its' advanced television receivers for prices approximately $500 above comparable sized NTSC receiver prices. Thompson, like the Japanese, has indicated that initial HDTV receivers are likely to be quite expensive but that its wide screen EDTV receivers could be introduced at prices well below those of HDTV receivers. The main point is that all major receiver manufacturers are poised to introduce some form of EDTV or HDTV. We just don't know the introductory prices.

Several receiver manufacturers have indicated that over time, the cost of ATV circuitry costs will decline. Larger high resolution displays will eventually account for a major percentage of the premium costs for such receivers. One can therefore conclude that, if both EDTV and HDTV sets are introduced, eventually there should be relatively small price differences between EDTV and HDTV receivers of comparable size.

This suggests that in the long term, consumer preferences between EDTV and HDTV sets may rest more upon available program offerings than on differences in set prices. HDTV should evolve as a clear winner with this kind of comparison. It offers not only the possibility of more program sources and superior video quality, but it also incorporates similar receiver based improvements to any NTSC programming as those offered by EDTV.

With this background information we can now return to the question of whether broadcast television can survive, and if so, how. It is certainly no secret that broadcast television is no longer considered a growth industry. Most broadcast networks as well as some stations are struggling just to maintain their current market shares. It is no wonder, therefore, that many stations approach high definition with great reluctance.

This is the type of situation assessment by which the business philosophies of the eighties would have indicated a cutback in investments. It describes a "cash cow" which should be fed as little as possible and be milked until it dies or is divested. Business philosophies of the eighties advised that resulting cash be diverted to higher growth business segment such as cable or DBS "stars" or to other industries.

It is not surprising that some broadcast organizations advocate doing nothing, delaying the selection process, or urging that the broadcast industry focus on alternative schemes requiring minimal investments. Certainly the actions of these broadcasters suggest a continuation of the eighties financial retrenchment strategy. Such actions seem to dismiss the value of very strong local presence and the continued popularity enjoyed by many local television stations. This popularity continues regardless of whether the programs of these stations are delivered to the home by broadcast signals or by cable.

Fortunately there are many others in the industry who are not so quick to relinquish the strong market position which many local stations continue to hold. The NAB and MSTV were largely responsible for the successful efforts in preventing further re-allocation of broadcast spectrum to other non-broadcast uses by the Commission. The Commission has indicated that, until the advanced television proceedings have been completed, no further broadcast spectrum will be allocated. A number of organizations are continuing to develop plans and strategies aimed at retaining the long term competitive viability of the broadcast business rather than to give in to a short term quick cash mentality. Most of these organizations look upon EDTV merely as an insurance policy against high introductory costs of simulcast receivers or extended delays of the channel allocation process. The outcome of this short term versus long term struggle within the broadcast industry is by no means resolved. It may mean the eventual shake out of some stations unwilling to commit to long term broadcast investments. More importantly, if a substantial number of broadcasters express an unwillingness to move ahead with a simulcast service, our currently unused channels and spectrum could be in jeopardy.

The position of public broadcasting in this regard is very clear. We do not accept the concept that terrestrial broadcasting will eventually become the A.M. radio equivalent of television or that it will be wiped out by cable, DBS or fiber. We have no intention of weakening or abandoning our commitment to our local broadcast stations. We intend to be a leader in simulcast over the air broadcasting. We will continue to rely upon local station produced and acquired programming as integral elements of our services to the public. We expect the local stations to capture a significant share of cable viewers in the future with HDTV just as they have in the past with NTSC.

We look upon any possible near term actions such as upgrades to EDTV merely as possible steps toward achieving these long term objectives.

The mission of public broadcasting is to serve all of the American public. Thus, we will urge local stations to continue to expand their services to the public whether this be by broadcast, on cable or through video cassettes, etc. This means that we will not abandon terrestrial broadcasting. We will continue to deliver our programming to the entire public, including those segments who choose not to or are unable to acquire cable or satellite delivered services.

It is clear that for the foreseeable future at least, there will be a substantial part of the public that will continue to depend solely on over the air broadcasting for its programming. It is for these reasons that public broadcasting has consistently been a strong advocate for a fully competitive HDTV terrestrial broadcast service for the United States.

We recognize that from a short term cost perspective it would be far easier for stations to stay with NTSC or to offer only an EDTV service rather than to implement simulcast HDTV. This would be especially true if a new tower and new antenna were required for a simulcast channel. In the long term, however, such a strategy would risk both the loss of simulcast channel allocations and the carriage of our HDTV services on cable. Our services would thus become inferior to those which could be offered on cable and the

"A.M." characterization would come true. We want to be very clear that any public television interest in EDTV will be guided by consumer demand or substantial channel allocation delays rather than what we know to be manageable differences in start-up costs.

Gloom and doom at the station level seems to focus on the simulcast HDTV implementation costs. While these costs are not insignificant, they will enable us to continue to reach non-cabled homes as well as assuring continued cable coverage.

Our previously reported studies on this subject have clearly shown that it is within the financial reach of most public broadcasting stations to offer at least a pass through simulcast HDTV service.

Experimental HDTV production activities have convinced us that some programs produced in high definition will be of special interest to HDTV viewers and capture a different share of these viewers than they would of NTSC viewers. It would seem to us that such a situation would be well suited to targeted advertising on the simulcast channel by commercial broadcasters. We have also demonstrated that NTSC close-ups can be extracted from the panoramic HDTV shots. Therefore, programming can be customized for each channel even under simulcast broadcast restrictions envisioned by the FCC. It is not even certain that the FCC will require 100% of the programs to be the same on the two channels. Even limited differentiation of the two channels offers us the opportunity to expand our viewership.

We have also reported that the differential costs between implementation of an EDTV service and a start up simulcast service are nowhere near as great as some have concluded. Some broadcasters have commented that the better pictues provided by HDTV do not offer any financial returns. We have demonstrated that locally produced or acquired NTSC programming can continue to remain a valuable element of a simulcast television service simply by up conversion.

Quite simply we look upon simulcast HDTV much more as a growth opportunity for broadcast television than as a threat.

We urge that those commercial stations who share our commitment to the long term viability of our locally oriented broadcast television services join with us to advocate the development of practical and affordable transition plans which will lead to fully competitive broadcast originated HDTV services.

TRANSITION TO HDTV—A BROADCASTER'S SCENARIO

Joseph Flaherty
CBS Inc.
New York, New York

High Definition Television promises a major technical advance over the present NTSC broadcast system, having twice the resolution, improved color rendition, a wide screen display, and stereo sound of compact disc quality.

While competing distribution media (cable, satellite, and home video) can provide HDTV service without regulatory action, terrestrial broadcasting faces special challenges due to broadcasting spectrum constraints.

To address these issues, the FCC's Advisory Committee on Advanced Television Service is evaluating proposed terrestrial broadcast systems, looking towards selection of a standard by the FCC in 1993.

The FCC has decided on a simulcast system, one in which TV stations will broadcast both the current NTSC signal and a HDTV signal.

Of particular concern to broadcasters is the capital investment required to implement simulcast HDTV terrestrial broadcast service. This report presents the interim results of an ongoing CBS study to define scenarios for the transition to simulcast HDTV service, and to project the costs of such a transition.

Important contributions were made by CBS affiliates in providing a data base for the study. From these, the following working premises have been employed:

(i) TV stations will most likely make the transition to simulcast HDTV service in a number of phases, each of which will provide an incremental capability. The first phase would allow a network HDTV signal to be passed through the station and broadcast, while in later phases, the station would be able to originate HDTV programs in the studio.

(ii) Individual TV stations must be able to implement the successive phases of the transition one at a time and at a pace appropriate to their economic and marketplace considerations.

(iii) The first stations to make the transition will most likely be those in the largest markets, while those in smaller markets will start the transition in later years.

Financial assumptions made in developing the transition scenarios include the following:

(i) The transmitter power for HDTV broadcast will be much less than for a NTSC transmitter, and the transmitting antenna will thus be smaller and can be mounted on the existing tower.

(ii) Economies of scale will lead to a 10 percent reduction in the cost of units of equipment for each doubling of the number of units manufactured.

(iii) The cost of labor to install the equipment will be 20 percent of the cost of the capital equipment.

Based on these conclusions and assumptions, it is projected that the capital investment required to provide full simulcast HDTV service will range from $11.6 million for the first larger-market stations to convert, to $6.9 million for later stations in smaller markets.

Taking account of the historic capital investment in maintaining current NTSC equipment (an investment that will decline during the transition), the incremental capital investment over historic NTSC capital investment required for the transition to simulcast HDTV may range from $9 million for stations in the largest markets to $6 million for stations in the smallest markets.

CBS is releasing this "work-in-progress" in order to stimulate further dialogue in the industry about the issues involved in what promises to be the complex and costly process of adopting HDTV technology to terrestrial broadcasting.

While much lower than previous published costs, the projected capital investment to convert to HDTV represents multiples of existing capital spending levels and promises to be a significant burden on many stations. Thus, the broadcast industry has much work to do in order to refine its approach to HDTV conversion and to reduce HDTV conversion costs as part of the industry's large need to develop the capability to react flexibly, efficiently, and economically to competitive and marketplace HDTV developments as and when they occur.

HDTV: HIGH DEFINITION VIDEO—LOW DEFINITION AUDIO?

Emil L. Torick
Consultant
Darien, Connecticut

ABSTRACT

A curious thing has happened along the way to HDTV: Hardly anyone seems to have recognized that improved standards of audio performance should be an essential component of this new entertainment medium. Despite occasional vague references by video-system proponents and others to such descriptions as "stereo," "digital" or "CD-Quality," no unified industry effort is underway to determine what the all-important audio parameters should be. It is not a trivial matter; both the number of audio channels and the method for encoding and transmission are inextricably entwined with the considerations of bandwidth limitations for the entire audio-video system. The determination of the audio parameters is much too important a task to be left entirely to video design engineers or computer scientists. The time has come to involve both the audio engineering and creative programming communities in this task.

INTRODUCTION

As the HDTV industry rushes towards the finalization of advanced television (ATV) standards in order to meet various deadlines of the FCC, CCIR and WARC, we are at serious risk that the development of appropriate audio standards for this new ATV service is being neglected or ignored. On one hand, this sorry state of affairs may be understandable. ATV industry activities are being managed primarily by video engineers who are largely unaware of the large body of psychoacoustic knowledge that has been accumulating for generations. Instead of encouraging active participation by the audio engineering community, ATV industry study groups seem unwilling to address the very real and difficult technical audio issues at hand. Furthermore, none have yet dared to risk the relative tranquillity of study group meetings by inviting participation by the ultimate users of ATV systems, the members of the creative production community, who will have to deal with the various (and there will be many) idiosyncracies of the new service. Finally, to short change audio now risks the future support of consumers, who in the past seem to have been relatively unconcerned about quality in shopping for television sets, but often have been almost fanatical in the search for high quality audio systems. If ATV is going to succeed in this consumer marketplace, it must incorporate the finest audio performance possible.

What are the major audio issues which must be addressed? There are basically only two: the number and functional assignment of the audio channels, and the encoding/modulation techniques which will determine the high fidelity performance parameters, interference immunity and degradation characteristics. We often hear the term "CD-Quality" used to describe the desired audio performance in ATV service. This is perhaps the most overused and meaningless word in our industry. What is "CD-Quality" in the ATV context? Does it mean simply digital? Does it mean 20-kHz audio bandwidth? Does it refer to the 4.3218 Mbit/s data rate of the Compact Disc? (Hardly, considering the difficulty of compressing both audio and video into a 6-MHz transmission channel.) Does "CD-Quality" mean a signal-to-noise ratio in excess of 90 dB in steady-state laboratory bench tests, but perhaps something far less in real world operation? Does it mean single-tone total harmonic distortion less than 0.001%, but significant dynamic distortion and fluttering acoustic images when the program material gets busy? (We may find out too late unless an appropriate test plan is devised.) Finally, does it really mean only two audio channels to accompany the video program? . . . I certainly hope not.

Unfortunately, the adequate coverage of all pertinent ATV audio topics within a single brief paper like this is an impossible task. Instead, this paper deals largely with the multichannel problem, for one reason because it is possibly the most difficult and certainly because it is the most neglected one.

THE PROPONENT SYSTEMS

As a starting point, it may be useful to examine what the ATV proponents have declared so far about their audio systems. The following table is derived from data submitted prior to the end of 1990 to the FCC Advisory Committee on ATV. It is clear that various data compression schemes are being considered by the proponents. It is not clear yet which is the most robust and capable of providing the superior audio quality.

Table 1: ATV Proponent Systems

Proponent	Number of Channels	Bit rate (kbit/s) before error correction	Bit rate (kbit/s) including error correction
ATRC	2 + 2	512	- - -
General Inst.	4	1760	2087
M.I.T.	4	500	598
N.H.K.	4	1350	- - -
Sarnoff	2	235	341
Zenith	2 + 1	330	377

TWO CHANNELS ARE NOT ENOUGH

If there is one parameter on which most audio engineers agree, it is the need for a separate audio channel to accompany on-screen images, especially talkers and solo instruments. While this is only a minimum number, it is important to understand the basic requirement, because there may still be many who believe, erroneously, that the two-channel stereo of home music systems is all that is necessary for ATV. The problem which must be addressed concerns the instability of conventional stereo acoustic images which have been encoded to appear in the space between a pair of loudspeakers. The traditional encoding technique is simple enough: the center signal is divided with half its power (i.e. -3 dB) added to left signal and half to the right signal. Thus:

Left (total) = Left + 0.7 Center, and
Right (total) = Right + 0.7 Center.

A listener positioned along the line of symmetry between the loudspeakers will hear the center audio as a phantom or virtual image at the center of the stereo stage. Under such conditions, speech sounds, for example, will be spatially coincident with the on-screen video image of the talker. Unfortunately, this desireable coincidence of the audio and video images is lost if the listener is not positioned properly.

There is a large body of scientific knowledge on how humans localize sound. Most of the research has been conducted with earphone listening to monophonic signals to study what is termed "lateralization". The more difficult case of "localization" in stereophonic listening with loudspeakers is less well understood, but the influence of two factors is dominant - - interaural amplitude differences and interaural time delay. Of these two, time delay is by far the more influential factor in localization. Over intervals related to the time it takes for a sound wave to travel around the head from one ear to the other, interaural time clues determine where a listener will perceive the location of sounds. Interaural amplitude differences have a somewhat lesser influence on localization, as the baffle effect of the head causes the amplitude of sounds at the near side of the head to be greater than at the ear on the opposite side. An amplitude effect is simulated in stereo music systems by the action of the stereo balance control which adjusts the relative gain of the left and right channels. It is possible also to implement stereo balance controls based on time delays, but the required circuitry would be more complex. In any case, however, adjustments of the stereo balance control usually can satisfy only one listener at a time.

THE HAT-SIZE FORMULA

What happens when the listener is not positioned on the line of symmetry between the loudspeakers? In response to just a rather small shift in position, the center sound will appear to be coming entirely from the loudspeaker which is closer to the listener rather than from the intended location at the video display. The physical dimensions which predict such a shift in image can be derived from several physiological and geometric factors. For those who prefer to deal in mathematical equations, the following formula, based on a hyperbolic function, may be used as a guide to determine the distance of the listener off the center line where the acoustic center image will shift entirely to one loudspeaker. The formula is an approximation, with enough simplifying assumptions to cause discomfort to physiologists and mathematicians alike; nevertheless, it is a useful one:

$$X = \sqrt{(0.45\, h\, \pi)^2 \;\; (1/4 + y^2/s^2)}$$

where X = the distance off-axis for a complete shift of the center image
h = the listener's hat size
y = the distance of the listener from a line connecting the loudspeakers
s = the separation between loudspeakers

The use of the hat size is not facetious. When modified by the 0.45 factor, which represents the ratio of the posterior arc to the circumference of the head in the above equation, it is a convenient way to describe the shortest acoustic path length around the head. For most listeners, who wear approximately a size-7 hat (i.e. 7-inch diameter), the above formula can be further simplified:

$$X = \sqrt{(25 + 100y^2 / s^2)}$$

Anyone can easily verify this shifted-image effect using just a home stereo music system. Set the controls so that monophonic program is being fed at balanced levels to both loudspeakers. If you sit or stand anywhere on the center line, you should hear the program appearing midway between the loudspeakers. Let's assume that the loudspeakers are spaced 8 feet

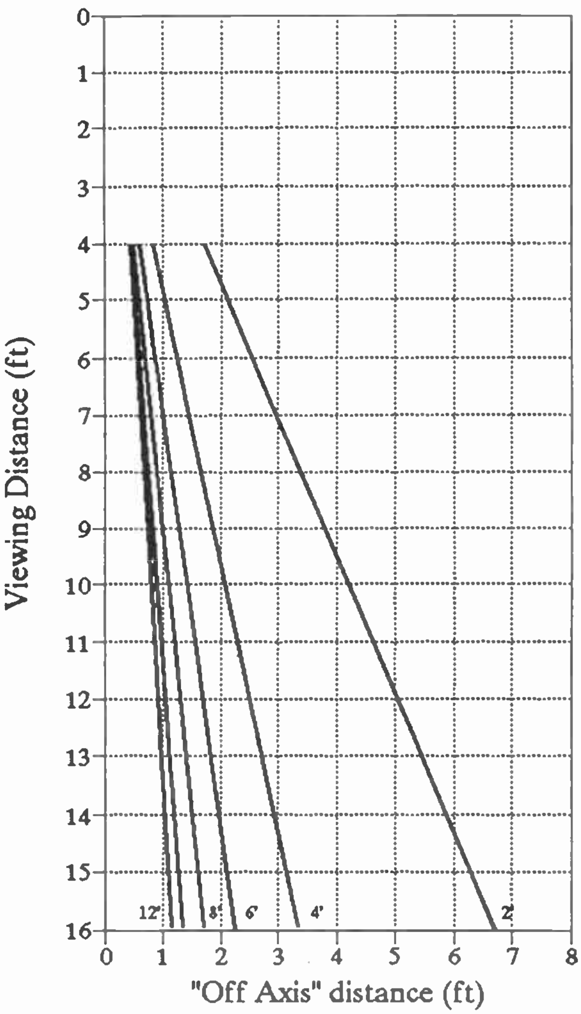

Figure 1: Distances at which complete shift of center image occurs, for several values of loudspeaker separation (i.e., 12, 10, 8, 6, 4 and 2 feet).

(96 inches) apart, and you are located back 10 feet (120 inches). If you change your position to either side by 11 inches, the sound will jump to the closer loudspeaker. If you are back only 6 feet, you need to move only 9 inches off the center axis. If you are back 16 feet, the complete shift of image will occur when you are about 22 inches off center, although this latter distance may be more difficult to determine due to the confusion caused by room reverberation. All of these values will be different, of course, for other dimensions of loudspeaker separation, as illustrated by the family of curves shown in Figure 1. Listener position is most critical when loudspeakers are widely spaced, and less critical when they are closely spaced as, for example, when attached to a video monitor. In the limit, the least ambiguity occurs when there is only a single loudspeaker at the monitor.

From experimental data and the plots above, it is possible to establish a generalized rule regarding the center acoustic image in two-loudspeaker stereo:

WHEN A SIGNAL IS FED COHERENTLY TO BOTH LOUDSPEAKERS OF A STEREO PAIR, THE SOUND WILL APPEAR TO EMANATE DIRECTLY FROM A SINGLE LOUDSPEAKER IF ITS DISTANCE TO THE LISTENER IS LESS THAN THE DISTANCE OF THE OTHER LOUDSPEAKER BY 10 INCHES OR MORE.

Clearly, one solution to the problem of the center acoustic image is to position the loudspeakers as close to the edge of the picture as possible. However, with small video monitors, to do so defeats the purpose of stereo sound; with large screen displays, the acceptable viewing area becomes severely limited. The real solution is quite simple: ATV requires, at a minimum, a third audio channel dedicated exclusively to the transmission of center signals for reproduction by a center loudspeaker positioned at the video display.

THE 4-2-4 SURROUND-SOUND MATRIX

There is at the present time a specialty market for surround-sound decoders to be used for playback of video tapes which have an appropriately encoded stereo sound track. The best of these products provide decoded audio output signals to left, center, right and surround loudspeakers. The most recent edition of the Audio magazine Annual Equipment Directory lists 14 brands of surround-sound decoders, ranging in price from $500 to $1900. The average price is about $900. Such high prices represent a distortion of the principle which usually guides the electronic entertainment industry, namely, placing the burden of complexity at the head end of the system in order to minimize costs to the consumer. In this example, it would be far less costly if the consumer were provided with multiple discrete sound tracks, but present standards do not support such capability.

The technology for surround-sound devices originated in the mid 1970s when the recorded music industry attempted to develop consumer formats for quadraphonic sound recording and broadcasting. The business rapidly developed into a competition between so-called "discrete" and "matrix" formats. The former utilized high-frequency subcarriers on vinyl disc records, and the latter combined four audio channels into two for recording or transmission. At least three matrix systems achieved some degree of commercial exploitation. They shared a common trait: all-pass phase shift networks were used for encoding and decoding in an attempt to reconstitute an aurally acceptable version of the original four channels. There have been numerous reasons suggested for the failure of all quadraphonic music systems. On a technical level, two are particularly significant: 1) On discrete recordings, the mechanically delicate high-frequency subcarriers on vinyl discs could survive only a few passes by the playback stylus before becoming degraded, and 2) the 4-2-4 matrix systems were discredited in comparison with the discrete mode in tests conducted by the National Quadraphonic Radio Committee. The NQRC conducted extensive psychoacoustic tests utilizing "golden ear" expert listeners from the recording industry.

In the 1980s, the 4-2-4 matrix technology was revived by Dolby Laboratories as a means for providing center and surround sound in movie theaters. For most cinematic productions the audio is usually mixed down to four or six sound tracks. Although further editing to the 4-2-4 matrix format imposes numerous artistic constraints and significant additional costs, it nevertheless is used frequently as a means for providing center-front and surround-sound capability within the limitations of the two optical sound tracks of cinematic film. Recently, the same encoded sound tracks have been appearing in video recordings for home playback.

In addition to audio companding for noise reduction in playback, the encoding parameters of the cinema matrix are as follows:

$$L(total) = L + 0.707C - j\,0.707S$$
$$R(total) = R + 0.707C + j\,0.707S$$

where the "j" coefficient denotes an idealized frequency-independent 90° phase shift. It is quite apparent from the above equations what the major defects of this matrix are. For one, the 180° phase relationship between the two j terms causes the surround signal to be completely cancelled in a monophonic summation. Furthermore, the summation for the derivation of a center channel has left and right signal crosstalk only 3 dB down from the center signal - - hardly a value of stereo separation that could be considered "CD-Quality." There are techniques in use which alleviate some of these defects. For example, differential time delays are applied to the surround signals, to provide acoustic precedence of the center sounds and comb filtering rather than complete cancellation of the surround signal. To improve separation, decoders employ various gain-riding and signal cancellation techniques. The intent of such decoder operation is to momentarily reduce the level of competing signals while the listener's attention is focused on the most important signal, usually the center channel dialogue. These so-called "logic" decoders operate with rapid time constants and often produce satisfying effects. However, there is no denying that, in the presence of dominant center sounds, matrix logic decoders cause a temporary collapse of stereo effects to a monophonic mode. Such action might be considered analogous to a video compression scheme with motion detection which causes the picture background to go to black while motion is being portrayed on the screen. If for no other reason, this lack of interdependent portrayal of a center acoustic image is why no 4-2-4 matrix system is adequate for a truly high-definition ATV service.

THE SECOND LANGUAGE ISSUE

In many parts of the world there is a growing and important requirement for simultaneous multilingual capability in television. There are a number of reasons for this. One is a growing desire to maintain local language traditions in the face of increasing homogenization of cultures worldwide. Another is the growing importance of direct satellite broadcasting. For example, whereas at one time terrestrial transmitters served only local needs and languages, satellite transmitters now have a larger area of coverage, overlapping many cultural boundaries. North America also has multilingual needs - - for the Hispanic populations of the south and the English and French populations of the north. There are those who might argue that a single language, namely English, is the dominant language in international commerce, and that is proof that a single sound track is adequate for any program. Such an argument misses the point. There are rich literary and cultural traditions which must be accommodated for the indefinite future. ATV can support such traditions.

In the United States, a decision about multilingual capability in ATV should not be left entirely to engineers. It is basically a sociological question, although one which will require an engineering input for its resolution. The U.S. presently has a fledgling TV dual-language capability. In 1983, when the Broadcast

Television Systems Committee (BTSC) devised a method for the compatible transmission of stereo audio with video, it decided to adapt the encoding principles of FM stereo to the NTSC television service. Consequently, the SCA channel in FM radio became the SAP channel in TV. Like SCA, SAP (Second Audio Program) provides only monophonic, narrow band, noisy audio. Despite the Committee's heroic efforts to improve the channel quality by incorporating a complex noise reduction system, we are still left with a monophonic low-fidelity capability for the second language. It is perhaps indicative of what low esteem broadcasters have for the SAP channel that, more often than not, it is used today for the originally unanticipated purpose of simulcasting the AM radio program of the same licensee.

If there is to be multi- or at least dual-language capability in ATV service in the U.S., the audience for non-English audio deserves something far better than what is offered by the BTSC system. There should be no justification for anything but full-fidelity (CD-Quality?) stereophonic service. Lest this statement alarm those who may be in charge of bandwidth budgeting for their proponent video systems, I would hasten to add that such capability can be readily achieved, as will be shown later.

CURRENT EFFORTS

In the U.S., HDTV matters are being guided by an industry group, the FCC Advisory Committee on Advanced Television Service (ACATS). Let's examine what various groups within the ACATS might be doing to offer guidance to the FCC on multichannel audio matters:

ACATS working parties PS/WP1 and 2 on Technology Attributes and Assessments have had discussions on the issue of the number of audio channels, but have been unable to reach a conclusion, even for a recommended minimum number. SS/WP2 on System Evaluation and Testing has received suggestions to consider the subject but has instead referred it to SS/WP1 for vague consideration as a "system-specific" matter. SS/WP2's Task Force on Audio Test Procedures rejected any responsibility for multichannel issues, deciding instead to perform only single-channel measurements of hi-fi specifications such as frequency response, distortion and hum. PS/WP6 on Subjective Testing is diligently preparing for subjective tests of video parameters but has no plans for multichannel audio evaluation.

In short, the FCC is unlikely to get any useful advice on multichannel audio from its Advisory Committee. Is any additional evidence required to demonstrate that, in the U.S. at least, audio is clearly the poor relative of ATV? The situation is somewhat brighter in other parts of the world, however, and perhaps the important ATV audio decisions will be made elsewhere.

In England, the BBC has been conducting studies on multichannel audio and has reached the tentative conclusion that at least three discrete transmission channels are required. In Japan, NHK has performed a number of studies in support of its preference for four discrete audio channels. In Germany, the IRT, in giving consideration to a high degree of acoustic realism for theatrical as well home video systems, envisions as many as eight channels of audio per program, even before multilingual issues are addressed. The IRT is one of the developers of MUSICAM, a spectrum-efficient source-coding system for digital radio broadcasting. With a data transmission rate of approximately 100 kbit/s per channel, MUSICAM could provide the capability for a large number of audio channels in ATV.

Within the CCIR, several relevant activities are underway, although U.S.- sponsored participation is almost non-existent. CCIR Study Group 10 has two Task Groups working in the area - - TG 10/A, which is studying sound systems for HDTV and EDTV (especially multichannel issues), and the recently chartered TG 10/B for low bit-rate digital audio coding systems. At its meeting in November 1990, Joint Interim Working Party 10-11/6 prepared a Draft New Recommendation on the Subjective Evaluation of Multichannel Sound Systems; this document may eventually provide some much-needed guidance to the U.S. effort in ATV.

A MODEST PROPOSAL

Given the unwillingness or inability of proponents and the video-expert study groups to deal with the multichannel audio issues, let me offer a few suggestions of my own. In fairness to those video system designers who perhaps are still struggling with bandwidth budgeting problems, I prefer to present a proposed hierarchy of audio channel allocations, based on the following premises:

1) A dedicated transmission channel for center sounds is an absolute requirement.

2) If bi-lingual sound capability is provided, listeners to either language should be provided with a full stereo effect, not just monophonic sound as with the BTSC SAP.

3) Given 1) and 2) above, all program dialogue signals should be transmitted in the center channel. For those occasional events when dialogue sounds are intended to originate off-screen, or for added acoustic

realism from multiple center-front loudspeakers, an ancillary steering signal can be transmitted to cause decoders to direct center-channel signals to the appropriate loudspeaker. In this manner, simultaneous full stereo programming can be provided in as many languages as desired, requiring only one transmission channel for each additional language. (The use of such steering signals is not new; studies at EMI in the early days of stereo showed the process to be quite effective, especially with simple program signals.)

4) There may still be a future role for the cinema matrix. Although from the listener's point of view center sound is a necessity, surround sound may be considered a luxury which could be worth the added cost of an expensive decoder. Most of the performance faults of existing surround-sound decoders are associated with the difficulty of reproducing the center signal. With the center signal assigned to its own transmission channel, such decoders could probably deal with the less critical surround signals quite adequately and maintain compatibility with old 4-2-4 encoded programs. Of course, the lowest consumer cost penalty for ATV would be incurred if the surround signal also had a dedicated channel, but this may not be achievable within bandwidth constraints.

Table 2: A Proposed Allocation Hierarchy

Number of Transmission Channels	Primary Allocation	Alternative Allocation
2	(Don't even think about only two.)	
3	L, R, C	4-3-4 (L, R, jS, C)
4	L, R, C1, C2	4-3-4+ (L, R, jS, C1, C2)
5	L, R, C1, C2, S	- - -
6	L, R, C1, C2, S_L, S_R	- - -

As indicated in the table above, the implementation of three discrete transmission channels will provide the minimum acceptable audio performance. If signals are allocated as shown, a surround-sound capability can be provided in three- and four-channel systems by employing the regular 90° phase encoding of the cinema matrix. To do so will permit the allocation of a second language (C2) capability in systems with four or more channels. Finally, a five-channel system can provide a discrete surround signal, and a six-channel system further spatial resolution with separate left and right surround signals.

CONCLUSION

It should be a concern to all involved that important decisions on audio for ATV are being avoided. If the purpose of the ongoing industry studies truly is to provide the world with the best television system possible for service well into the twenty-first century, it is vitally important to set standards for the audio component of ATV now, so that they can be integrated with the video standards before specifications are finalized.

We need to deal especially with the multichannel issues and the question of bilingual capability. The latter is a matter of social policy, and the former is a psychoacoustic consideration. Of the six ATV proponents active in the U.S., only three have proposed using as many as four audio channels, and only one of these has indicated its allocation preferences. Among the others, there is one system with only two channels, another apparently with two stereo channels, and a third with a stereo pair plus a spare. Unfortunately, no one seems to be dealing with the question of what might happen if one of these audio-deficient systems should win the competition for the best video performance. This problem can be avoided by establishing, for the benefit of all ATV proponents, a level playing field with at least a uniform minimum audio specification for any system that is going to compete.

Critical decisions about audio are much too important to be left entirely to video-design engineers or to computer scientists, even those who happen to own home stereo music systems. Some ATV industry leaders only recently have learned to spell the term "psychophysics" and appreciate the value this discipline has in video decision making. It is time to draw on the related body of experience in psychoacoustics which the audio-engineering and creative-programming communities can offer. Audio must no longer be the stepchild of ATV.

PROPOSAL FOR ADVANCED HDTV AUDIO

Thomas B. Keller
Consultant/Cable Television Laboratories, Inc.
Boulder, Colorado

ABSTRACT

The attributes for high definition video have been defined by the FCC Advisory Committee's, Planning Subcommittee, Working Party 1. A channel bandwidth limitation of 6 mHz has been set by the FCC. Working Party 1 has described HDTV audio quality requirements as being CD like. HDTV audio systems testing in Washington are limited to two-channel stereo systems. Papers describing studies that compare two-channel and multi-channel stereophony have been written by CBS in the U.S. [1], NHK in Japan [3], BBC in the United Kingdom [8], and IRT in Germany [7]. All four studies agree that with two-channel stereophony the center signal (phantom or virtual) image is distorted by listening position. The problem is exaggerated as the size of screen is increased. All four organizations recommend that additional channels (speakers) are necessary to produce a stereophony image that can be viewed from a wide angle without distortion. This paper proposes that HDTV audio use a center channel to stabilize the audio image.

Introduction

The purpose of this proposal is to provide a starting point for the ATSC T3/S3 Specialist Group on Digital Services to define the non-video related objectives for HDTV systems. After committee review the document may be sent to proponents, existing video users and providers of ancillary services, and others for comment. This draft defines the program audio, other program-related audio services, audio program control, and ancillary services. The document does not address the ghost canceling training signal. This signal is part of the HDTV video system.

With the imminent introduction of simulcast high definition television, the North American television industries have the opportunity to introduce an advanced digital audio system that will match the viewing experience of the new video service. Recent advances in low bit rate coding techniques make it possible to achieve state of the art quality audio with bit rates as low as 128 kbit/s for each program audio channel. The low bit rate digital audio systems make it possible to transmit the number of discrete audio channels necessary to complement the high definition video.

Proposed Program Audio Attributes

1. The quality of the HDTV program audio will complement the full potential of the new video service.

2. The system will be designed to produce a stable audio image and enhance the ATV visual image.

3. Discrete audio channels should be used. The matrix process is not used in the four channel system. Linear transmission systems will be incorporated, preventing the distortion of the audio image.

4. Viewers will have the option of controlling the dynamic range of the reproduced audio.

5. The four channel simulcast audio system will also accept for transmission: three channel stereophony, two channel stereo, and monophonic programs.

6. The four channel program audio will be convertible to

BTSC stereo for NTSC simulcast.

7. A stereo second language audio program is provided (two channel). Alternately, these channels can be programmed as two separate monophonic channels.

8. A dedicated DVS channel for the visually impaired is provided.

9. The audio system should be more robust than the video to bit errors. Audio should not fail prior to video.

Ancillary Service

1. Teletext service is provided.

2. Conditional access channel is provided.

3. Expandable digital services is provided.

4. Closed Captioning is provided.

5. Program Guide channel is provided.

DESCRIPTION OF SERVICE

Main Program Audio

The main program audio consists of four discrete state of the art digital audio channels. The channels are center, left, right, and rear (surround). The center channel is a discrete channel similar to the center channel used by the film industry. The rear channel, a surround sound channel, is viewer optional. Audio production techniques are the same or similar to those used in the film industry. A programmer-originated control signal will allow the receiver to be switched to a viewer preselected mode of operation. Industry operating standards and recommended operating practices should be developed for the SAP switching nomenclature and logic to prevent the confusion that exists today with BTSC receivers.

Program Audio Expander (Viewer Optional)

To avoid viewer complaints of loudness, program providers have had to limit the dynamic range of the audio signal. A digital expansion channel is provided to allow viewers the ability to expand the audio to its original dynamic range. This channel will control a digital audio expander in the receiver that will restore the original dynamic range to the program channels. Care in implementing this service must be exercised to maintain integrity of the audio image. Twenty kbit/s of data is available per audio channel for the expander control.

Separate Audio Program (SAP)

A two channel full quality stereo service primarily for second language programming is provided. Alternately, the stereo service can be used for two separate monophonic program channels. With user preselection and a programmer-originated control signal, the receiver will switch on command from stereo SAP to one of the preselected monophonic SAP channels.

Descriptive Video Service (DVS)

DVS is a monophonic audio channel that provides program descriptive information to the visually impaired. Because of the growing interest in this service and of possible scheduling conflict with other SAP services, a channel dedicated to DVS is provided.

Teletext

Teletext service of 100 page cycle and 1000 characters per page (8 bits/character) transmitted in 20 seconds requires a bit rate of 40 kbit/s. It should be noted that in some situations teletext may be a program related service.

Other Digital Services

This channel is reserved for the possible interconnection with home digital devices, like computers. The channel could be used for educational or interactive services.

Program Guide

The proposed program guide should be capable of transmitting text accompanied by graphics. For viewer channel scanning, six lines of text identifying the on air show and the next up-coming program are provided. This receiver scanning menu will be refreshed at a one second rate. The data for a complete multi-page program guide is interleaved with the receiver scanning data.

Closed Captioning

Closed captioning is transmitted at a rate of 500 bit/s. To allow for the expansion of this system, a 2 kbit/s channel is provided.

Conditional Access

Because conditional access systems' specifications are usually proprietary for security reasons, detailed specifications on the signal may not be available. The ATSC Specialist Group on Interoperability and Consumer Product Interface T3/S2 is discussing standardization issues relating to scrambling and conditional access.

Capacity Objectives

It is clear that sufficient capacity needs to be allowed in Simulcast ATV systems for advanced audio and data services. When allocating the bit rates for the video, audio and data channels it may be necessary to make tradeoff in channel performance in order to stay within the 6 mHz. Based on information supplied by the ATV proponents, it appears that the 6 Mhz channel has the capacity for transmitting just under 20 Mbit/s of digital data. With overhead, the non-video service should represent less than 9% of the 6 Mhz digital channel's capacity.

The services can be broken down into two categories; program related and program unrelated.

Table 1. Advanced Audio Simulcast HDTV

	Service	DATA RATE kbit/s
PROGRAM RELATED SERVICE	Main Program, Four Channels	512
	SAP Stereo, Two Channels	256
	DVS, One Channel	128
	Expander Control Data	140
	Program Guide	10
	Closed Captioning	2
	Program Mode Control	2
	Conditional Access	400
PROGRAM UNRELATED SERVICES	Teletext Services	
	Other Digital Services	
	Overhead	To be determined by System Proponent
Total	Bits	1450

BACKGROUND ON FOUR CHANNEL SYSTEM SELECTION

Many papers have been written about the problems with two channel stereo television audio [1,2,3,4,5,6]. Papers from the BBC and IRT (FDR) [7&8] all characterize the image distortion experienced with two channel stereo, including recommendations they have submitted to the CCIR. From the data in the IRT paper [4], Figure 1 was drawn illustrating the image distortion that will be experienced when listening to stereo audio with two speakers spaced by 6 1/2' and listening at distances of 2' to 8'. This illustration shows that when listening to the stereo at a distance of 8', while 20" off the center line, the audio image will be shifted by 40%. At the price of separation most BTS receivers have the speakers installed adjacent to the screen to minimize image distortion as illustrated in Figure 2.

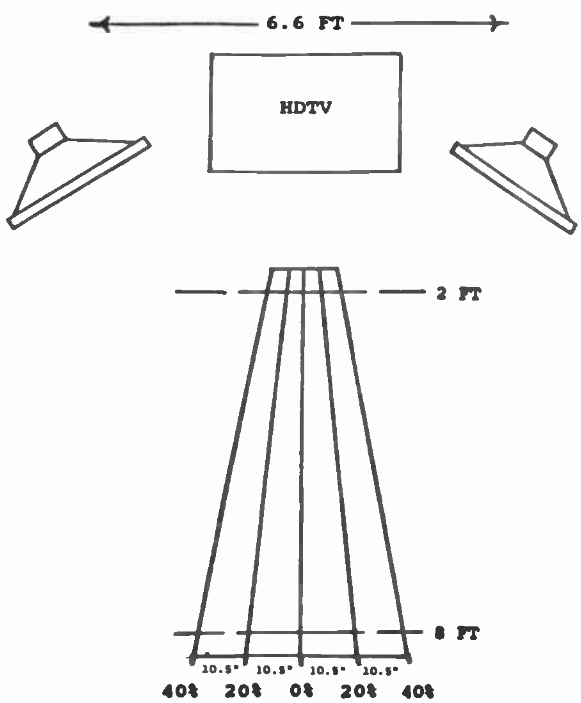

Figure 1. Stereo Image Distortion

The BBC in its recommendation to the CCIR suggested that a three channel system be used as the most practical approach to reduce the image distortion problem [6]. NHK in a study of eight different speaker combinations settled on a four speaker system; left, center, right and surround [2]. IRT in their papers concluded that four front and four surround speakers should be considered [4]. In a paper published by Torick of CBS, a three speaker system was recommended to resolve the image distortion problems [1].

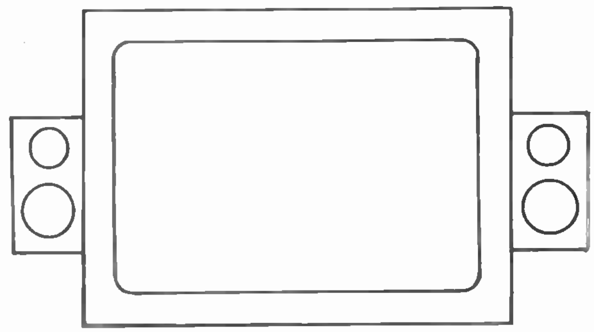

Figure 3. BTSC Stereo

Based on the literature published by the major international broadcasters and the experience of the film industry, a four channel system with a center channel and surround sound is proposed. Figure 3 illustrates the speaker configuration for this system. This proposal is a practical combination for image stabilization, viewing experience enhancement, and transmission channel numbers.

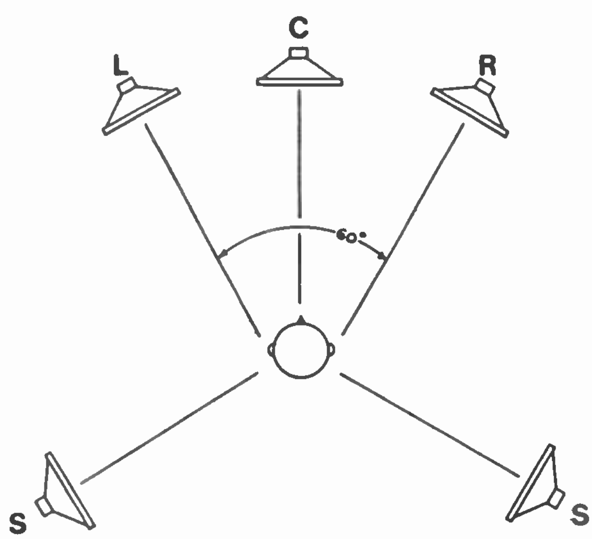

Figure 3. System Speaker Placement

TABLE 2. CHANNEL ACTIVATION WITH TRANSMISSION MODE

TRANSMISSION MODE	CH1	CH2	CH3	CH4	CH5	CH6	CH7
1 4 Channel	on	on	on	on			
2 3 Channel	on	on	on	off			
3 Stereo	off	on	on	off			
4 Monophonic	on	on	on	off			
5 SAP Stereo*					on	on	
6 SAP/1*					on		
7 SAP/2*						on	
8 DVS							on

CHANNEL DESCRIPTION

Ch-1 Center
Ch-2 Left
Ch-3 Right
Ch-4 Rear (Surround)
Ch-5 SAP Left or SAP #1
Ch-6 SAP Right or SAP #2
Ch-7 DVS

TABLE 3. LOUDSPEAKER ACTIVATION BY CHANNEL

TRANSMISSION MODE	CENTER	LEFT	RIGHT	REAR
1 4 Channel	on/ch-1	on/ch-2	on/ch-3	on/ch-4
2 3 Channel	on/ch-1	on/ch-2	on/ch-4	off/ch-4
3 Stereo	off/ch-1	on/ch-2	on/ch-3	off/ch-4
4 Monophonic	on/ch-1	on/ch-1	on/ch-1	off/ch-4
5 SAP	off	on/ch-5	on/ch-6	off
6 SAP/1	on/ch-5	on/ch-5	on/ch-5	off
7 SAP/2	on/ch-6	on/ch-6	on/ch-6	off
8 DVS	on/ch-7	on/ch-7	on/ch-7	off

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CLOSED CAPTIONED TELEVISION: A GLOBAL & HDTV PERSPECTIVE

John E.D. Ball
National Captioning Institute
Falls Church, Virginia

ABSTRACT

Closed captioned television was introduced in the United States in 1980 as a national broadcasting service for deaf television viewers. Today it is provided by U.S. national and local broadcasters, cable TV programmers and home video companies.

This paper will discuss the current technical status of the service and some of the technical requirements of an HDTV compatible closed captioning standard.

Introduction

The closed captioned television technology was developed to enable deaf people understand what was being said on television. In its earliest form, in 1971, the concept was demonstrated by ABC-TV in cooperation with the then National Bureau of Standards (NBS) as an ancillary service that could be broadcast within the television signal's vertical blanking interval (VBI). The primary service that NBS was interested in was precise time and precise frequency information digitally encoded and injected into the VBI at the network origination point and broadcast nationally. ABC-TV proposed that captions, the visual depiction of a television program's dialogue, should also be created and time diplexed with the time and frequency information before being inserted on Line 1, Field 1, of the television signal. Further study work by a National Association of Broadcasters (NAB) engineering group in 1972, followed by a comprehensive technical development project undertaken by the Public Broadcasting Service (PBS) in 1973-79 led to the launching of the closed captioned television service in 1980. By that time it had been determined that Line 21, Field 1, should be used and that the distribution of time and frequency information on a television network signal was not practical and hence was abandoned.

The caption data signal (see Figure 1) has proved itself to be extremely rugged and recoverable in the presence of high noise and/or significant signal ghosting conditions. This criterion was set by the PBS engineers who were all too familiar with the problems many television viewers experienced with trying to receive public television programs broadcast from UHF-TV transmitters. In essence the criterion was that a television picture deemed "passable" by non-expert viewers, as defined in the TASO studies[1], should be able to deliver caption data in a substantially error free form. That set the instantaneous data rate at a little over 500 kb/s and with just two 8-bit bytes every 1/30th of a second (once per picture period), the effective data transmission rate translated to 480 b/s; believed to be an adequate rate for a captioning service. The decision to adopt such a low data rate was confirmed as the proper one shortly after the service was launched. The introduction of the video cassette recorder (VCR) in the early eighties presented little or no problems to the caption data signal. Similarly, the survivability of the signal proved to be solid even after being subjected to TV signal scrambling/descrambling as used in both satellite distribution and cable TV, and the copy protection video signal processing used in the VCR industry. As a result, the closed captioned television service was able to expand into home video and pay cable TV as well be received satisfactorily in the home from both VHF and UHF transmitters even under marginal reception conditions.

Captioning Technology

The technology that is unique to the captioning of television programs can be separated into three major categories. These are:

1. The caption generation technology; the equipments used to prepare captions and convert them to a suitable digital format.

2. The caption encoding technology; the equipments used to insert captions into the VBI prior to the transmission of a "live" TV program or during the creation (re-recording) of a captioned videotaped program, and

3. The caption decoder technology; the circuitry required in the home to view captions on the television screen (see Figure 2).

These equipments have been refined and improved during the past 10 years, generally exploiting the advances made in the computer, data transmission and television technologies, to reduce costs and improve efficiencies.

The caption generation hardware and software have been substantially reduced in terms of capital and maintenance/ repair costs in recent years. Also, the production output of captioning staff has steadily increased as a direct result of improved equipments and more sophisticated software support systems. In 1980, for example, it took approximately 40 labor hours to caption a pre-recorded one hour television show; today it takes about half that time. In 1983, when real-time (live) captioning was introduced, there were not experienced personnel available and the quality of the service was less than satisfactory. Today, with a growing pool of trained and experienced personnel, the quality is much improved and is continuing to improve. Further progress is anticipated in the future as new technologies emerge, particularly in the optical character reading, word processing and voice recognition disciplines and as the pool of experienced captioning personnel grows. Providing the television industry with a high quality service at an acceptable price is very much dependent on technological advances and on the capacity of caption service providers to exploit them in a timely fashion. This requires an ongoing commitment to fund technical research and development.

Caption encoding equipment is used by the networks, videotape duplicating companies and the other clients of the caption service providers. The process of encoding pre-recorded programs, i.e., creating a captioned dub is expensive and adds significantly to the costs attributable to the provision of the captioning service. The need to reduce if not entirely eliminate this cost element is a subject of continuing study.

The caption decoding technology has consumed much in the way of technical development capabilities and financial capacity during the past five years. These investments however have been very worthwhile. The cost of the set top decoder to the consumer has been reduced from $280 to $180 in just four years and the current unit, TeleCaption 4000, is smaller, lighter and more portable than its three predecessors. Even more significant for the consumer was the passage of the Decoder Circuitry Act of 1990 which will require caption capability to be built into all TV's with a screen size of 13 inches and greater, starting in mid-1993. This will effectively eliminate the cost of receiving the caption service as the technology quickly merges with the on-screen display (OSD) technology and that is already present in over 70% of all TV sets manufactured today. Perhaps the most important point is the fact that integrating the caption circuitry into all television sets will enable many millions of people to benefit from the service who would not otherwise benefit.

Global Implications

The most interesting aspect of the captioning service has been the growing recognition of its value as an educational tool for many different population groups both here in the U.S. and in other parts of the world. For many years, before the introduction of the closed captioned television service, captioned (subtitled) films have been used in the education of deaf children. Captioned television at home now complements the more formal school use and evidence abounds that it has not only benefitted the deaf child but also their siblings. Children with reading problems, having been exposed to captioned television, also show improvements in their reading skills. Furthermore, some 23 million children who live in the U.S. in homes where English is not spoken can also benefit from captioned television. A major study commissioned by the National Captioning Institute

(NCI)[2] recently concluded that these children can "acquire language and literacy incidentally, without formal instruction" when watching captioned television at home. Asian-American and Hispanic-American adults are also turning to captioned television to help them learn English. In 1989, more TeleCaption decoders were sold to those two groups than to deaf people. Decoders are now being purchased in Japan and Korea by people studying English. Captioned American movies, on videocassette, are also being bought on an increasing basis in these countries as educational material. Acquiring solid English skills is regarded as a prerequisite to obtaining a job in international commerce. In Japan, of the over 20 million people who are studying foreign languages, 70% are studying English, according to Naganuma[3]. To predict that Japan, as a nation, will be substantially bi-lingual (English & Japanese) by the year 2000 may not be far off the mark. The Naganuma study also reported a new form of learning English in Japan called "salon English conversation" which is "shattering the image of the conventional English school" where the teachers are not native English speakers. In the "salon" approach the classroom is preferably a "spacious and graceful environment" and the class size is restricted to no more than four students with a native English speaking teacher. This novel approach to teaching English can evidently be reinforced or complemented, according to Naganuma, by having the students also watch captioned American movies and television; a remarkably similar, yet entirely independent conclusion to that reached in the NCI study described above.

In the European Common Market, excluding the United Kingdom and the Republic of Ireland there are some 265 million people. While about 50% of them claim fluency in English, a study conducted by Lintas, an international advertising agency, as reported by Screen Digest[4], found that less than 25% have a knowledge of English. One could maybe conclude from this that there are about 65 million potential English language captioned TV viewers in Europe and another 65 million who could help substantiate their claims of proficiency in English, to some degree, by watching captioned television.

When one looks at the cost of dubbing movies and other TV program material in foreign languages as compared to captioning, dubbing costs are an order of magnitude higher. Also, closed captioning in multiple languages is a very economical way to provide TV programs to a multi-lingual audience via satellite or on videocassette. Clearly there is a role for closed captioning in the global television marketplace.

HDTV & Captioning

The Decoder Circuitry Act of 1990 requires the FCC to include closed captioned television as an integral part of the HDTV standard that the Commission plans to adopt in 1993. This presents a unique opportunity for the HDTV captioning technology to incorporate many features that were not included in the current captioning standard because of technical and/or economical constraints that existed in the late 70's. On the other hand, during the past 10 years, experience has shown that many additional features can and should be added to improve the caption service. However, this must be accomplished without causing incompatibility problems, as the HDTV service will have to co-exist with the current TV service well into the foreseeable future. This will complicate the development of HDTV captioning standards as will in some respects the Commission's choice of system. An all-digital approach seems to be gaining in popularity among the competing proponents, but analog or analog/digital hybrid systems are not being ruled out. As the Commission moves towards its decision, new and improved caption standards need to be developed. The Commission's decision to chose an analog or digital standard will have a significant impact on the design approach used, but many aspects of the captioning standard can be developed now. In the final analysis the HDTV caption standards must facilitate the provision of an improved captioning service by increasing the caption display options for both the service providers and the home viewer. The more difficult challenge though, may lie in the defining of a new captioning standard befitting the superior quality as well as the higher cost of HDTV, while reasonably maintaining the current service's quality, as it will continue to be the prime means of accessing television for many people for a long time to come.

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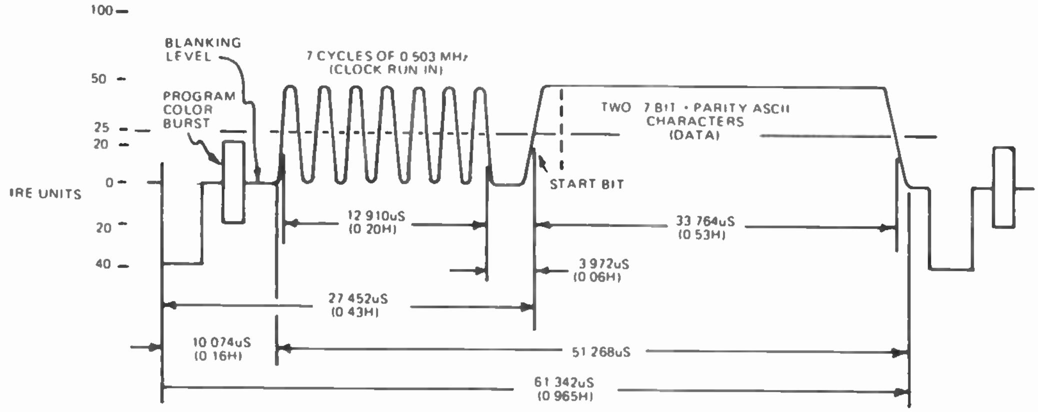


Figure 1

The Line 21 caption data signal

Figure 2

TeleCaption II, NCI's second generation decoder connected to a TV set to show typical caption display.

COST EFFECTIVE APPROACH TO AN HDTV PLAYBACK FACILITY

Paul Heimbach
Viacom International Inc.
New York, New York

ABSTRACT

Some estimates predict costs of between $3 million and $38 million to upgrade studio/playback facilities to HDTV using standard HDTV equipment. Production and playback facilities must be updated with a complete line of HDTV equipment, and transmission facilities must be equipped with the necessary HDTV transmission format encoders. This upgrade is particularly troubling for facilities, like some cable programmers, that originate and distribute multiple, unique, simultaneous channels.

An approach that may allow conversion at significantly reduced costs is to store and playback programming directly in the transmission format. The transmission format, based on the current list of FCC proponents, can make use of existing or modified digital VTRs. HDTV transmission encoders would be used in an off-line operation such as the film to tape transfer process and the coverage of live events.

Due to various interframe coding techniques, real time transitions from one HDTV source to another will require the development of specialized equipment. However, this equipment may prove to be more useful to playback facilities than standard HDTV equipment.

The proposed scenario dictates a hierarchy of HDTV standards, with the highest quality, least processed HDTV format used at the time of production where extensive signal manipulation is used, and the highly processed HDTV format used for program playback directly to the transmission leg.

INTRODUCTION

As the FCC ATV Advisory Committee works toward its goal of defining a US HDTV terrestrial transmission format, cable TV program providers and broadcasters must begin to consider how their plants and facilities can be upgraded to accommodate HDTV program origination and transmission.

Of primary importance is a cost effective and evolutionary upgrade plan. It is safe to say that a duplication of plant facilities to run HDTV programming in parallel with the NTSC product is out of the question for most program providers. Multiple HDTV VTRs costing hundreds of thousands of dollars is also prohibitive.

The HDTV upgrade issue is of particular interest to Viacom International Inc. because of the nature of some of its program channels. Viacom International Inc. is an international, diversified entertainment company involved with TV program creation and production, syndication, TV and radio station ownership and, particularly germane to this paper, ownership of Showtime Networks Inc. and MTV Networks. Showtime Networks Inc. programs and distributes 2 premium channels: Showtime and The Movie Channel. These channels are distributed by satellites to cable, SMATV, hotel and TVRO affiliates. The majority of programming is movies shot on 35mm film produced for theatrical display. By its very nature, this product is high definition and lends itself well as the basis for an HDTV service. This programming is distributed by satellites to the affiliate base for consumption. It is interesting to note that the transmission format (for NTSC or HDTV) is not specified by the FCC. Satellite program providers are free to choose the most effective, efficient formats available. With respect to HDTV, the satellite delivery format may not necessarily be the same as the selected terrestrial format. However, a level of parametric compatibility will exist because the programming will be displayed on consumer HDTV TV sets built to a uniform HDTV standard.

This paper discusses a unique concept developed by Viacom that, if successful, will allow a very cost effective HDTV program origination facility to be built and operated.

BASIC CONCEPT

Without question the HDTV transmission format that will be used by the cable, satellite and terrestrial programming industries will be fully digital.

Some form of bit rate reduction (video compression) will be used to reduce the very high data rates of HDTV to a level that can be easily passed through a satellite transponder, cable channel or terrestrial broadcast channel. Typically, the leading bit rate reduction techniques reduce the bit rate to a value in the neighborhood of 20 megabits per second.

In many program origination cases, conceptually, there is no difference in originating HDTV programming from a full bandwidth HDTV VTR and then compressing it for transmission as compared to compressing the program material offline and recording the 20 megabits per second compressed digital signal for direct playback later. In this case, the digital output of the playback device looks like the output of the compressor and is fed to the transmission chain in the normal manner. Intuitively a 20 megabits per second data recording device should be far less expensive than a full bandwidth analog or digital HDTV VTR.

Admittedly this approach of recording and playing back the compressed signal will impose severe limitations on how the signal is manipulated between the playback device and the transmission chain. Generally all video effects must be done prior to the compression process. Even simple program segment transitions such as wipes or fades will be difficult to accomplish initially but eventually may be possible through signal processing hardware or clever production techniques at the time the compressed program segments are created.

Many video facilities already possess digital recording devices - D1 and D2 format VTRs. In Viacom's specific case 7 Sony LMS systems are used, with the systems using 4 or 5 D2 machines. Clearly, there are major operational, capital and maintenance advantages to be gained if these D2 machines and LMS systems can be used as the HDTV digital storage medium.

The D2 digital VTR is intended to record and playback composite NTSC. The VTR records at rates of about 100 megabits per second and has digital inputs and outputs as well as analog inputs and outputs. The digital ports are intended to interconnect the VTR into digital signal paths that may exist in a production or playback facility.

Conceptually, then, to use the VTR as a compressed video storage device, the 20 megabits per second data stream is delivered to a transcoding device that reformats the data to that expected by the D2 VTR. At this stage, the data now looks like a pseudo digital NTSC signal at the VTR's digital input. Upon playback the digital NTSC formatted data appearing at the VTR's digital output port is presented to another transcoding device that converts the pseudo digital NTSC formatted data back to the 20 Megabits per second compressed format.

The VTR uses sophisticated error concealment and correction techniques to hide bit errors caused by tape dropout, head problems, etc. While these techniques work very well to restore standard NTSC images, they would be disastrous to the recording and playback of a compressed signal. This puts a new requirement on the VTR and tape stock that does not currently exist. Very low Bit Error Rates and very high data integrity must be maintained throughout the process.

Using an unmodified VTR and standard tape stock would be the ideal situation. However, ideal situations rarely exist in the real world. As this application of the D2 machine is further researched, it may be found that a different tape stock is required and electronics changes (eg disabling error concealment) are necessary. It is certainly possible to exploit the excess data capacity of the VTR as compared to the 20 megabits per second data stream. Perhaps this excess data capacity can be used to implement external robust error correction techniques, or to record multiple HDTV programs.

CONCLUSION

This work is just getting under way as this paper is being written. Obviously much work needs to be done. HDTV compression system proponents and broadcast equipment manufacturers have been told of this concept. Their reaction so far has been guarded encouragement along with a desire to further explore this approach.

Clearly there are many advantages to be gained if this approach can be made successful. Facilities that provide primarily playback functions and other program distributors and broadcasters that under more expensive approaches would be prohibited from participating in HDTV could participate.

The reduced investment costs will encourage greater HDTV programming availability and therefore a more rapid rollout of HDTV in the U. S.

A baseline goal is to define those modifications that must be made to the VTR and tape stock by the end of March, 1991. With this information, costs to implement an HDTV program playback facility with offline HDTV compression can be determined. A further but more ambitious goal is to actually implement this approach in a proof of concept system.

DISPLAY TECHNOLOGY: A COMMON MEETING GROUND

Dr. Robert S. Powers
IEEE-USA and MCI Telecommunications Corp.
Richardson, Texas

ABSTRACT

This paper will be a report on joint activities of the Advanced Television Systems Committee, the Committee on Communications and Information Policy of the IEEE-USA, and other interested groups, addressing the potential for major advances in all forms of electronic video displays, based on digital technology.

It is clear that the future of many, if not all, kinds of electronic visualizations will be based on digital technology rather than analog. This gives United States industries -- broadcast, consumer electronics, defense and industrial electronics, and computer manufacturers and users -- an opportunity to guide these new developments to the benefit of all those industries as well as the public around the world. We have the opportunity to create an architecture of standards which will provide for all forms of visual displays, for conversion from one form to another, conversion from one level of resolution to another, backwards compatibility to existing display standards, and forward compatibility to technologies not yet dreamed of.

In November of 1990, the Advanced Television Systems Committee and the IEEE-USA Committee on Communications and Information Policy co-sponsored a Digital Systems Information Exchange meeting to address these potentials. As a result of that meeting, two working groups were formed: One to look ahead to what we might expect the world of visualization to be like 30 years from now, and the other to better define what such an "architecture of standards" for visual displays might be.

Those working groups are meeting between the time of drafting this abstract and introduction and the scheduled time of the NAB HDTV World Conference. Another general meeting is also scheduled for that period of time. The presentation at the Conference will be a summary of those meetings and conclusions.

PROGRAMMING IN HDTV (I):
A World of Its Own

Monday, April 15, 1991

Moderator:
Rupert Stow, Rupert Stow Associates, East Moriches, New York

COMPILATION FRANCAISE
Daniel Le Conte des Floris
French Motion Picture & TV Network
Paris, France
Program presented: *Compilation Francaise*

CAPTAIN COSMO AND THE LAST FRONTIER*
Francesco Pinto
Radio Televisione Italiana (RAI)
Rome, Italy
Program presented: *Captain Cosmo and the Last Frontier*

HD PRODUCTION, AN ORIGINAL APPROACH: THE TOOLS AND THE RESULTS
Jacques Dumont and Jean-Pierre Lacotte
Thomson Video Equipment
Paris, France
Program presented: Operation possibilities and some results

SPORTS COVERAGE ON HDTV
Francesco Pinto
Radio Televisione Italiana (RAI)
Rome, Italy
Program presented: *Finale*

VERSITILITY OF HDTV TECHNOLOGY IN COMPLEX PROGRAM PRODUCTION*
Michel Oudin
Vision 1250
Brussels, Belgium

AFTER NIGHT MUSIC*
Paul Kafno
Thames Television
London, England
Program presented: *Night Music*

HIGH DEFINITION IN THE PRACTICAL WORLD
David Niles
Captain New York, Inc.
New York, New York
Program presented: *Jackie Mason*

A NEW VISUAL VOCABULARY
Stuart Samuels
Zbig Vision, Ltd.
Hoboken, New Jersey
Program presented: *Manhattan*

*Paper not available at the time of publication.

COMPILATION FRANCAISE

Daniel Le Conte des Floris
French Motion Picture & TV Network
Paris, France

HD production is being used in France to create a broad range of electronic wide screen programming. The program presented is a compilation of three works with specific creative, technical, and market objectives.

For example, one program produced by the CNC required the blending of multiple sources of material (16mm. and 35mm. film, and HDTV), with intricate post-production. The creative objective was to develop an unique style of imaging, a "specificité visuelle" that would retain its special appeal, even when down-converted for broadcast in conventional 625-line formats.

PRODUCER: CNC.
Format: 1250/50.

HD PRODUCTION, AN ORIGINAL APPROACH: THE TOOLS AND THE RESULTS

Jacques Dumont and Jean-Pierre Lacotte
Thomson Video Equipment
Paris, France

The European approach to HD television service is based upon the same principle of compatibility as has been adopted in the U.S. for the introduction of color. This is an efficient protection for the consumer, but it has not helped to lower the large investment required of the production studios.

The European approach to HD is based once more on the concept of compatibility, but takes account of the economic constraints of the professional broadcast market.

The HD-MAC standard is fully compatible with the MAC standard, which perfectly matches the CCIR Rec.601. This is quite easy because the PERITEL connector is an appropriate interface between the transposer-demodulator-decoder-descrambler "black box", and the display.

Thomson Video Equipment has designed and delivered several HD facilities to broadcasters.

PROGRAM:
Producer: Jacques Dumont.
Format: 1250/50.

SPORTS COVERAGE ON HDTV

Francesco Pinto
Radio Televisione Italiana (RAI)
Rome, Italy

"Finale" is a chronicle of the last soccer match of the Italia '90 competition, enriched by flashbacks to the match between Argentina and Germany, played in Mexico City in 1986.

Thus the program is also a journey in time, from one continent to another, and through all the emotions - both joyous and painful - of the 22 players involved.

"Finale" is also a journey from one technology to another, since the flashbacks are on 16mm. film or 525-line television. "Finale" recreates the expressions, the gestures, the tackles, and the shouts which, apart from the game itself, characterized this match.

Accompanying the high definition pictures, the fidelity and impact of Dolby surround sound compete for the viewer's attention "Finale" demonstrates that which was previously impossible: to recreate within the home environment the electrifying atmosphere of the soccer stadium, through the fusion of perfect images and enveloping sound.

The program is a vivid demonstration of how HD technology can help to reproduce the warmth of real life's emotions.

PROGRAM: "Finale".
Producer: Roberto Cecatto.
Director: Anna Cristina Giustianani.
Format: 1250/50.

HIGH DEFINITION IN THE PRACTICAL WORLD

David Niles
Captain New York, Inc.
New York, New York

Captain Paris, a French video production company, was the first to receive HD production equipment, and the first to put it to commercial use in 1986. The first TV commercial for an oil additive involved five layers of Ultimatte with reflections and cast shadows, single frame animation, motion control, miniatures, and post-image manipulation with perspective.

Initially it was concluded that the camera needed to be heavily filtered to reproduce the "film look". However, with continuing exposure to the stunning capacity of HD to reproduce the world around us, clients and directors came to prefer the unfiltered true HD "look".

For the first four years, almost all HD productions were designed to be viewed on a cinema or television screen, leaving little room for exploration of the real potential of HD production.

We are now just beginning to see the true potential of this medium when we experience the HD image viewed in high definition. With images that bring the viewer ever closer to reality, the communication of ideas and the stimulation of emotions are becoming to be seen as the real values of the new medium.

PROGRAM: "Jackie Mason".
Producer: David Niles.
Format: 1125/60

A NEW VISUAL VOCABULARY

Stuart Samuels
Zbig Vision, Ltd.
Hoboken, New Jersey

The latest work by Zbig Vision is a co-production with NHK Enterprises, USA, entitled "Manhattan". The program uses Zbigniew Rubszynski's multi-generational style, layering multiple images within each take.

Up to ten generations of "Ultimatting", combined with pan, tilt, and zoom motion control, produced unique images. Background images of landmark features of Manhattan were shot in motion using special tracks and motion control programming. These backgrounds were next edited to specially composed music.

At Zbig Vision studios, actors and props were matted in multiple passes, using the same motion control computer program designed for the original background shots.

Using this technique the director had complete and precise control of all images, and could, as an electronic painter, create surreal and magical images unattainable in any other medium.

In creating "Manhattan", Rubszynski used an instant editing technique, compositing foreground and background action in real time, and thus avoiding the need for extensive post-production. This technique requires a longer pre-production phase, a more intensive live production phase, but a much shorter post-production operation.

"Manhattan" exemplifies a new visual vocabulary unique to high definition, and a new production technique that will revolutionize special effects operations in both the television and film industries.

PROGRAM: "MANHATTAN".
Producer: Zbig Vision/NHK Enterprises, USA.
Director: Zbigniew Rubszynski.
Format: 1125/60

ENHANCED TELEVISION SYSTEMS: *Toward a Wide Screen World*

Tuesday, April 16, 1991

Moderator:
Julius Barnathan, Capital Cities/ABC, Inc., New York, New York

FULL UTILIZATION OF SIGNALS AND TRANSMISSION SPACES OF NTSC TV SYSTEM
Takahiko Fukinuki
Central Research Laboratory, Hitachi Ltd.
Tokyo, Japan

RECENT DEVELOPMENTS IN SUPERNTSC*
Yves Faroudja
Faroudja Laboratories
Sunnyvale, California

THE IMPLEMENTATION OF WIDE-SCREEN ENHANCED TELEVISION FOR SATELLITE AND TERRESTRIAL BROADCASTING*
Dr. M.D. Windram, W.B. Harding, R.D. Morcom
National Transcommunications Ltd.
United Kingdom

PALplus DEVELOPMENTS
Dr. Albrecht Ziemer
German Television ZDF
Mainz, Germany

A NEW SYSTEM OF NTSC-COMPATIBLE WIDE ASPECT ADVANCED TELEVISION—NEW NTSC MODE 1.5
Shin'ichi Aikoh, Yoshihide Kimata, Masayuki Ishida, Toshiya Ito and Susumu Takayama
Nippon Television Network Corporation
Tokyo, Japan

A RECEIVER-COMPATIBLE WIDER ASPECT RATIO EDTV SYSTEM
A. Takahashi, T. Morita, H. Inoue, H. Nakashima and H. Uratani
Tokyo Broadcasting System Inc.
Tokyo, Japan

K. Kashiigi, T. Tachibama, H. Makita and M. Ashibe
NEC Corporation
Tokyo, Japan

*Paper not available at the time of publication.

FULL UTILIZATION OF SIGNALS AND TRANSMISSION SPACES OF NTSC TV SYSTEM

Takahiko Fukinuki
Central Research Laboratory, Hitachi Ltd.
Tokyo, Japan

ABSTRACT

Fundamental technologies for ATV(Advanced TV) and its future trends will be presented based on our activities.

First, the so-called IDTV(Improved TV), in which picture quality is improved based on the existing standards, is reviewed, and the ways to improve it furhter are proposed.

Then, the EDTV, in which the frequency spectrum is fully utilized, is reviewed. The author proposed an EDTV system, in which resolution is improved both horizontally and vertically by utilizing the "Hole"(an inefficiently used space in the 3D frequency domain) and pro-scan, respectively. Recently the development has included an study of wide-aspect TV.

Additional signals for improvement and the spaces to transmit them are examined and a scheme is recommended. An experimental model based on it is described.

[1] INTRODUCTION

Fundamental technologies for ATV(Advanced TV) and its future direction will be presented, based on the more than 10 years of history/1/, as shown in Table.1.

Recently, television systems with higher picture and audio qualities, such as EDTV-I/II in Japan, ACTV(Advanced Compatible TV) in the U.S., and PALplus in Europe, have gained global interest.

At the beginning of our research, we had the two following fundamental questions on NTSC signals:

1) Is the signal utilized fully and efficiently at receivers?

2) Is the frequency spectrum utilized fully and efficiently?

The first question was solved by developing the so-called IDTV(Improved TV) in 1982/2/, in which two major processings, i.e., motion-adaptive pro-scan conversion and motion-adaptive YC separation were introduced.

For the second question, the author proposed in 1983 an EDTV system fully compatible with the current NTSC standards. In this system, horizontal and vertical resolutions are improved by utilizing the 3D (three-dimensional) frequency space/1,3,4,5/ and the pro-scan conversion, respectively.

Now the development of this system is under way, and recently has included the study of wide-aspect TV.

To date, we have accumulated much knowledge on the requirement for ATV, therefore, it is a good time to review knowledge and consider future trends.

[2] FULL UTILIZATION OF TV SIGNALS

[2.1] Motion-Adaptive 3D Signal Processing

In the mid '70s, we were looking for basic ideas for improving picture quality. Based on the ideas we created, we developed IDTV/2/. Two main processings were developed:

- pro-scan conversion
  (conversion from interlaced scan to progressive scan)
- 3D YC(luma/chroma) separation

The major points in these processings are motion-adaptive processings and their "soft-switched operation". Motion-adaptive processing here implies:

- Inter-field/inter-frame processing in stationary areas
- Intra-field processing in moving areas

"soft switched" implies gradual control according to the degree of movement.

In Japan, these processings were merged into the EDTV-I and were the key technologies of receivers. Currently, IDTV sets appear on the Japanese market as "Clear-vision" receivers.

[2.2] Improvement of Picture Quality

Some people have said, "Picture quality is improved drammatically by IDTV."

Others have said, "The improvement is almost nothing. It is hard to say which area is improved in the picture, unless the area is pointed out."

From the author's experience, both are correct. In other words, the degree of improvement depends mainly on the quality of source signals, and secondarily on the signal processing at IDTV sets, especially that related to movement detection.

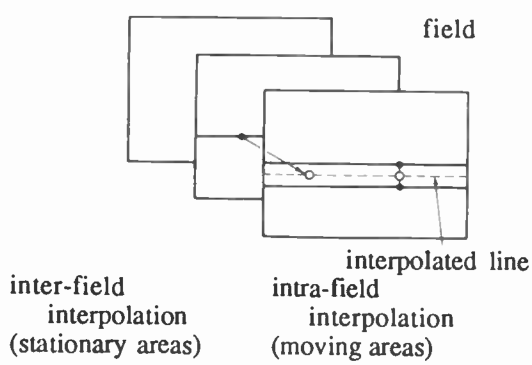
[2.3] Source Signals

If the source quality is not high enough, picture cannot be improved. At present, all studio equipment

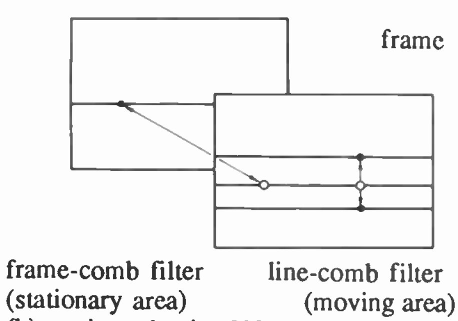
Table 1 R&D of IDTV and EDTV at Central Res. Lab., Hitachi, Ltd.

Year	/IDTV	/EDTV	/Related topics in Japan	/Related Topics in other countries
1975	/Basic Ideas on 3D YC Separation and Pro-Scan Conversion			
1982	/1st version Completed.			
		/Fundamental Idea of EDTV		
1984	/2nd version			
		/1st version Implementation		
		/Opened to Broadcasting Companies		
1985			/TV Picture Improvement Com. founded in MPT.	
			/BTA(Broadcasting Technologies Ass.) founded.	
1986				/Hitachi's Proposal discussed in USA*
1987				/ACTV Proposed through the Use of the "Hole".
			/2-step Introduction(EDTV-I,II) decided by MPT	
1988		/3rd version (YH and QH)		
			/"Hell Week" at FCC ATV WP	
1989			/EDTV-I Broadcasting started.	
			/Study on EDTV-II started at BTA.	
1990		/4th version(Letter-Box, Ver-Tem., YH, etc.)		
				/I-PAL-M, I-PAL-F proposed in Germany.

* at Improved-NTSC Sub-Com., ATSC.
MPT; Ministry of Posts and Telecommunications



(a) motion-adaptive pro-scan conversion



(b) motion-adaptive YC separation

Fig. 1 Two Major Processings in IDTV

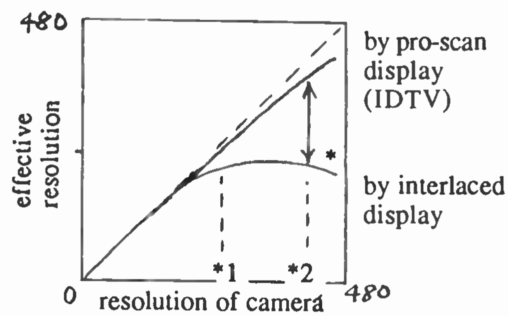


Fig. 2 Effective Vertical Resolution (conceptual)
* reduction of effective resolution due to line flicker
*1 lowest limit of camera resolution
*2 limit where flicker is tolerable

seems to be well adapted to signal decoding of today's TV sets. The characteristics of source signals are determinied by:
- TV cameras, especially vertical resolution
- Signal processing devices such as DVE*
  *(Digital Video Effect)

For example, vertical characteristics of current TV cameras seem to be set at the best condition for today's TV sets, i.e., the lowest limit of camera resolution for obtaining almost the highest effective resolution, as shown in Fig.2.

If cameras are set at the limit where line flicker is tolerable, EDTV picture is improved greatly. One method for obtaining this is down conversion from progressive scan cameras.

As an example of item 2) listed above, 2D comb-filters are adopted in the Y/C separation in DVEs. With luma signals, slant components corresponding to modulated chroma are reduced to chroma.

The distortion caused by 2D separation and re-modulation at DVEs can be observed at IDTV sets. In this sense, IDTV sets can be used as direct-observation testers for the equipment in stations.

[2.4] Processing of Receivers

The design of soft-switched motion-adaptive processings used in IDTV requires "know-how" based on experience. The significant points are in:

- Motion detection
  (measurement of the degree of motion)
- soft-switching operation

For the former, missing detection sometimes degrades more than false detection. Therefore, spatial-temporal filtering of a "motion coefficient" is effective, as is "area filtering".

However, to overcome the theoretical limit in motion detection, a pseudo motion signal was proposed/8/, although it is an EDTV technique.

[2.5] Future Prediction

Generally speaking, IDTV is expected to be used commonly, as large screen displays become more popular. This is because the line structure in large displays is annoying.

A kind of "positive feedback"(a chicken-or-egg question), however, will take place: There will be two future scenerios.

1) Desirable scenerio

Signal sources will be improved by competition between stations and between programs. This will occur in the following sequence.

- Differences between stations and between programs are clear at IDTV sets.
- IDTV set use will become common.
- Signal sources at stations will be improved.
- Station and program differences will become much clearer, and so on.

2) Undesirable scinerio

This is the complete reverse of the desirable scenerio. Namely, differences do not affect general interest, since there are few IDTV sets.

- IDTV sets use will not be common.
- Differences between stations and between programs are not general interest.
- No effort will be made to improve the signal sources.

The author, of course, prefers the first scenerio.

[3] FULL UTILIZATION OF SPACES
-- Brief History --

Some researchers felt that the much more information could be transmitted with existing NTSC satandards, and improved picture quality could be achieved with new standards while maintaining compatibility.

Analysis showed that there is an inefficiently used 3D frequency space in the NTSC system, as will be shown later in Fig.3(a)/1/. The space was named the "Fukinuki Hole" in the USA.

By utilizing this space, the author, in 1983, proposed an fully compatible EDTV system. In this system, horizontal resolution is improved by up to 50%.

The MPT(Ministry of Posts and Telecommunications of Japan) became interested in the proposal, and organizations were founded as shown in Table 1. Study at BTA(Broadcasting Technology Association) started in 1986, and since then, many ideas have proposed.

MPT decided that EDTV would be introduced in two stages, i.e., EDTV-I and EDTV-II. In EDTV-I, little modification was adopted for the NTSC's spectra. Its broadcasting started in 1989.

EDTV-II for high-resolution, wide-aspect, and high-quality audio are now under study at BTA.

In 1986, the Improved NTSC sub-committee of ATSC, USA, studied Hitachi's proposal and related activities in Japan. In Novemver, 1988, a Working Party belonging to the FCC discussed various proposed schemes. The Hole was reported in "Underlying Base of Technologies for ATV" of the Assesment Report.

[4] FIRST VERSION EDTV

[4.1] Original EDTV Concepts

The following are our original EDTV concepts:

(1) Deficiencies inherent in the NTSC system

Deficiencies such as cross-talk and line flicker can be removed or reduced using IDTV techniques.

(2) Vertical luma resolution

This can be improved by adopting pro-scan at TV cameras and pro-scan conversion at receivers.

(3) Horizontal luma resolution

As a result of improved vertical resolution, horizontal resolution should be improved. This can be achieved by inserting higher resolution information, YH(4.2 to 6.3 MHz), into the Hole.

(4) Horizontal resolution of I and Q signals

The I signal can be reproduced up to 1.5 MHz, according to NTSC standards.

Horizontal resolution of a Q signal can be improved, if necessary, by either a technique similar to the insertion of the YH signal/6/, or a technique using the correlation between Y and Q.

(5) Wide-Aspect TV and others

At the beginning, wide-aspect was not considered. This was because we thought it would be achieved by HDTV. However, this is now the main target of EDTV-II.

Other improvements, such as audio, will be described later.

[4.2] The Hole and Other Spaces in Frequency Domain

(1) The Hole

This is in the 1st and 3rd quadrants in the [temporal-vertial] frequency domain(the [f-v] domain). It is symmetrical with modulated chrominance signals, as shown in Fig.3(a). Since the space for color components is essential in NTSC standards, the Hole should be used.

(2) Slant Luma Component Space

The slant luma component, which is now transmitted in NTSC standards, is eliminated for multiplexing enhancement signals, as shown in Fig.3(b)/7/. In addition, the signal is decoded as an annoying stationary luma pattern in IDTV receivers.

Therefore, this space should not be used. If it is, however, it should be limited to narrow bandwidth signals. In this sense, chroma Q details may be suitable/6/.

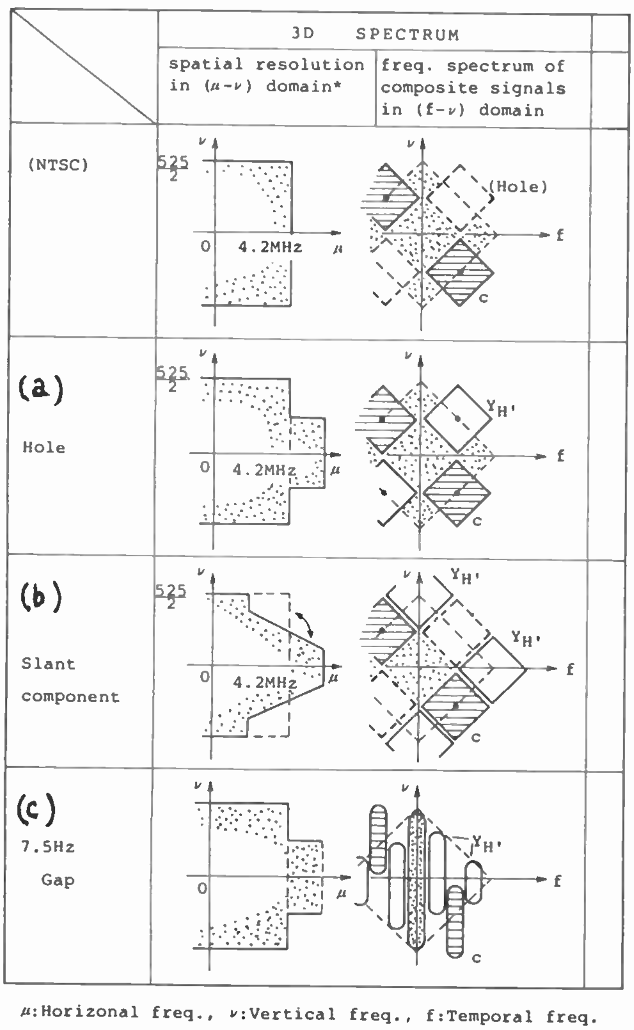


Fig. 3 Spaces for Enhancement Signals in the Frequency Domain

* the case when YH is embedded.

(3) 7.5 Hz Gap

The patent for using this gap was applied for in 1986. However, as is clear in Fig.3(c), the temporal bandwidth is extremely narrow. In addition, multiplexed signals are detected in IDTV sets as moving components. Therefore, multiplexing enhancement signals is not recommended.

Instead, this gap may be used for a "pseudo moving signal", which is multiplexed in the area where undetectable movement at receivers takes place/8/.

[4.3] Considerations on Spaces and Additional Signals

(1) Correlation

The signal correlated with the main signals is desirable for embedding in the Hole, unless other techniques such as "intra-frame averaging"/9/ are applied. This is because:

- Correlated artifacts caused by the embedded signals are not so visible on existing TV sets.
- Motion-adaptive processing, which can use 3-D frequencies effectively, can be applied in EDTV sets.
- Sharp cutoff 3-D filters are not necessary to separate embedded signals.

(2) Multiplexed Signal Power

Low energy components such as horizontal luma or chroma details are preferable.

[4.4] Past Experiments

We have completed several proto-models, and confirmed the improvement of resolutions and the elimination of deficiencies. We have developed sophisticated methods for motion adaptive processing, resulting in excellent dynamic characteristics.

We also performed compatibility tests with the present TV equipment(receivers, various kinds of VCRs, RF transmitters, and so on). We found that almost all the equipment can be used without modification. Even in the worst cases, such as enlargement/reduction in DVEs, NTSC quality can still be reproduced.

[4.5] What Is Expected for EDTV

In the past, signals for broadcasting were believed to be superior to those of home equipment.

Currently, however, the resolution of some home equipment, such as SVHS VTRs and ED-beta VTRs, is higher than that of broadcast signals. Most CRTs are capable of displaying pictures with much higher horizontal resolution, i.e., more than 700 TV lines.

EDTV sets can be up-graded with a small of hardware added to IDTV sets. Therefore, if IDTV sets are used widely, EDTV can be achieved easily without much additional cost.

[5] WIDE-ASPECT EDTV

-present activities & future vision-

We are now studying the next generation of EDTV,

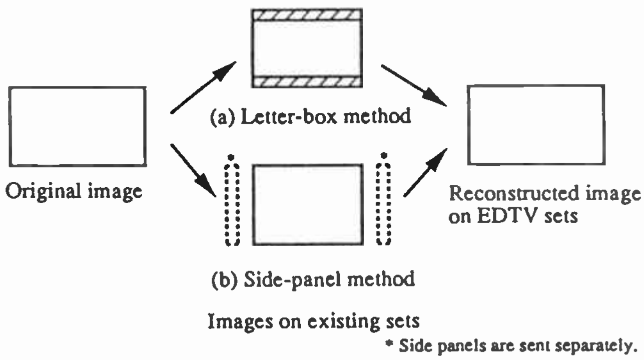


Fig. 4 Wide-Aspect TV letter-box and Side-Panel

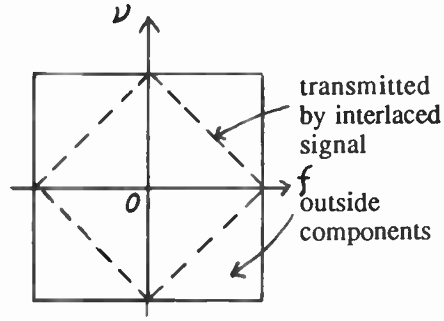


Fig. 5 [f - ν] Spectrum of Pro-Scanned Camera Output

Table.2 Signal Allocations for Wide-Aspect EDTV (Tentative Plan)

		Enhanced System		Augmentation System
Scheme		Letter-Box (1)	(2)	Side-Panel (3)
main Channel	Hole Bars RF-QAM	Y V-T DA	Y H V-T DA (and/or Side-Panel)	Y H **** DA
Sub Channel	*****	****	****	Side-Panel Signal V-T Signal Digital Audio

YH; luma details, DA; digital audio.

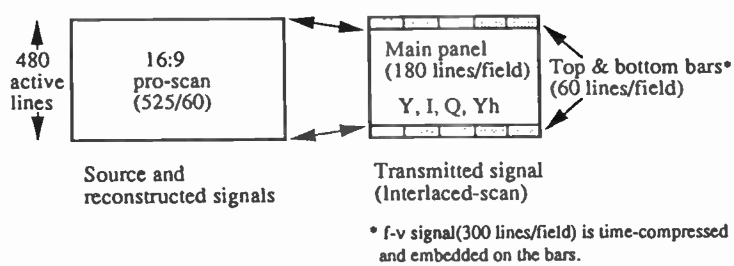


Fig. 7 Signal Format of Source, transmission and Display

i.e., EDTV-II in Japan. The technical points include:
- Choice of a wide-aspect TV scheme, i.e., letter-box or side-panel
- The allocation of various enhancement signals to various spaces.

[5.1] Wide-Aspect EDTV -- Letter-Box & Side-Panel --

We have been studying both schemes, shown in Fig.4, but have not reached a conclusion, although letter-box seems to be preferable in Japan. As is well-known, each has merits and demerits.

The author, however, hopes that standard-aspect (4:3) EDTV will not become a compromise because of too many difficulties with wide-aspect TV.

[5.2] Further Desirable Improvements

The following are from past R&D.

(1) Luma Signals

It is desirable to improve not only stationary but dynamic resolutions The components outside the diamond shape in Fig.5 are effective for the improvement. They can be obtained by pro-scan cameras. This signal assists the scan conversion and improves the vertical-temporal resolution.

(2) Chroma

It is said that the improvement of Q signals described in [4.1](4) is desirable.

(3) Audio

We learned that digital audio is in demand.

(4) Other information

Auxiliary signals such as "pseudo moving signals" and some commands are desirable.

[5.3] Other Spaces and Their Characteristics

In addition to the spaces in the 3D frequency domain, several other spaces have been suggested. Each space has different characteristics, and the placing of enhancement signals must be studied carefully.

There are ways to combine the signals and spaces. The number, however, is reduced by examining the possibilities; some information cannot be multiplexed in a particular space, because they do not fit with each other.

(1) Overscan Region

This is a margin. If it is used, side panel "lows"/9/ are the candidates, because of its small space.

(2) Blanking Regions

These are incompatible, because of renewing synchronization pulses in some existing VTRs.

Audio signals might be candidates, because they are processed almost independent of video signals, and hence, do not cause significant compatibility problems.

(3) Top and Bottom Bar Regions

Because these contain a full [f-v] Nyquist area, the dynamic resolution component is suitable. Therefore, an [f-v] signal, whose example will be shown later in Fig.8, can be transmitted.

The horizontal bandwidth of the [f-v] signal is restricted, but even a narrow-bandwidth [f-v] signal can improve picture quality/11/.

(4) RF-QAM (Quadrature A.M.)

This space is the double-sideband region around the picture RF carrier, as shown in Fig.6. For base-band transmission, another channel is necessary. Audio signals may be suitable/12/, for the same reason as (2).

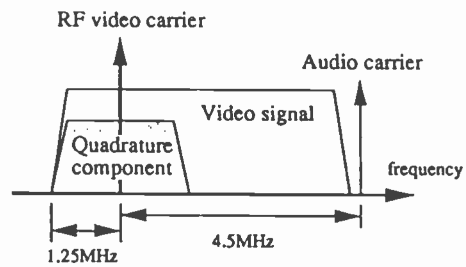


Fig. 6 RF-QAM(Radio-Frequency Quadrature AM)

[5.4] Recommended Schemes for Wide-Aspect TV

Based on the above discussions, several suitable assignments are shown in Table.2.

(1) Letter-Box --first scheme--

Table 2(1) is recommended for the letter-box method. Horizontal luma details are embedded in the Hole, digital audio signals are transmitted by RF-QAM, and the [f-v] signal is embedded in the bars. Digital audio can also be multiplexed in the blanking regions.

This assignent enables motion-adaptive separation of luma, chroma, and luma details, and scan conversion is achieved, assisted by the [f-v] signal.

(2) Letter-Box --second scheme--

Table 2(2) is a modified version of (1). The luma details are multiplexed in the Hole. Chroma details, [f-v] signals, and luma details can be multiplexed in the bars, and digital audio signals are transmitted by RF-QAM or in the blanking regions.

(3) Side-Panel

If the side-panel method is favored strongly from the practical viewpoint, the assignment shown in Table 2.(3) is a possible compromise.

The luma details are embedded in the Hole. The side panel information is sent by RF-QAM, since it has sufficient bandwidth for the side information. However, large-scale modification of video facilities would be required.

[5.5] Proto-model of the Letter-Box Scheme

We have chosen the first letter-box scheme, since it is the simplest.

(1) Hardware based on the proposal

The experimental proto-model is shown in Fig.7. The source, a wide-aspect pro-scan signal with 480 active lines, is transformed into an interlaced-scan signal, and an [f-v] signal, as shown in Fig.8. The latter

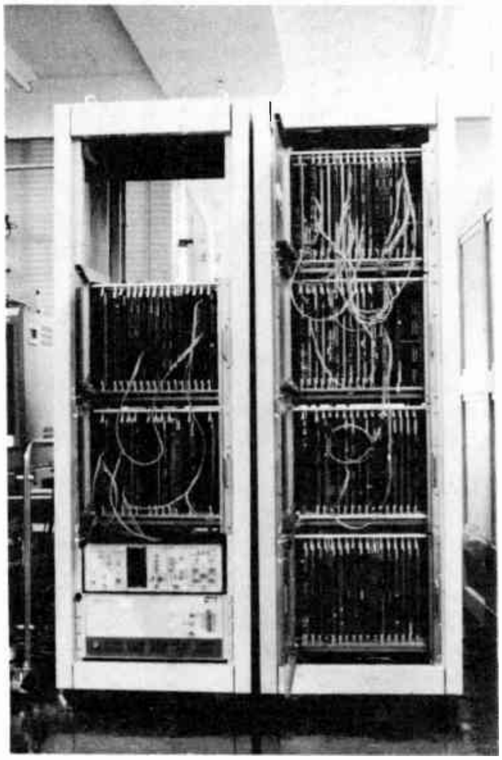


Fig. 8 Experimental Proto-Model
(left; Encoder, right; Decoder)

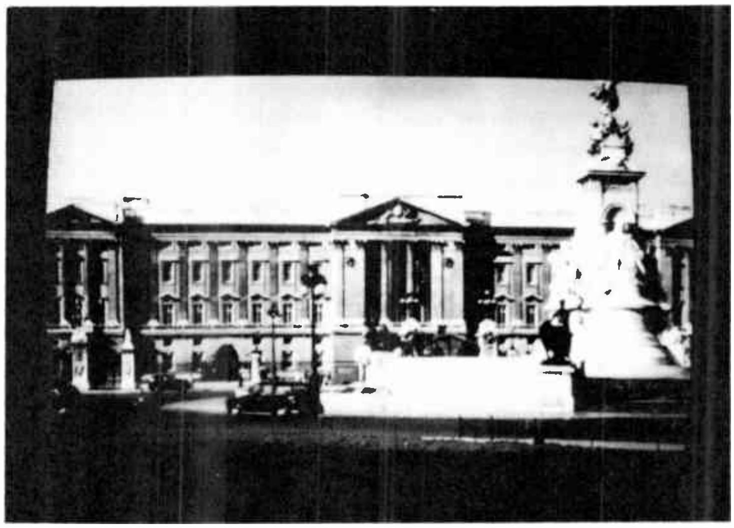
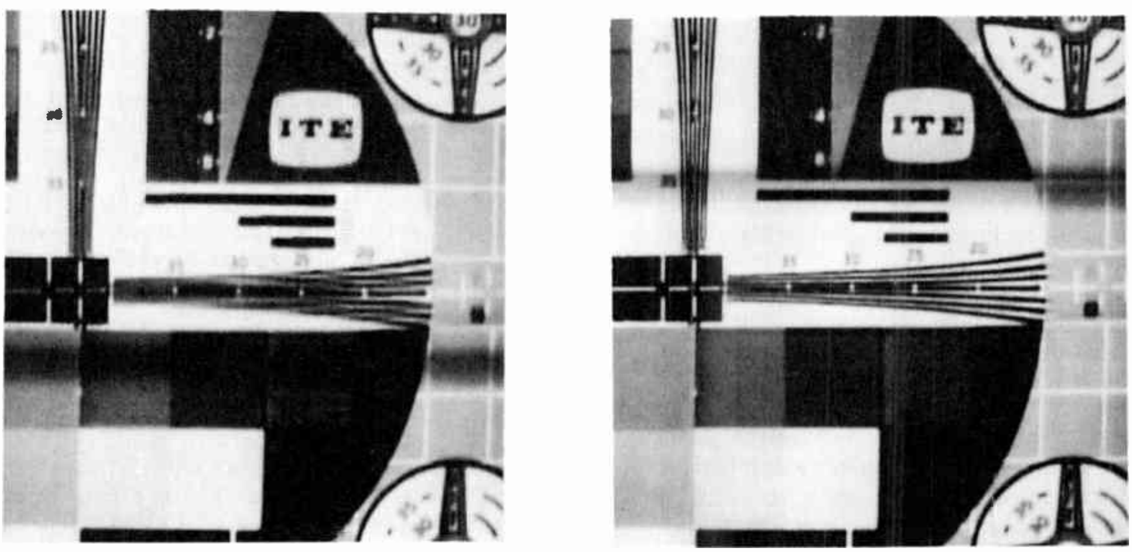


Fig. 9 Picture on Current TV set



(a)Without the signals for enhancement

(b) with the signals for enhancement

Fig. 10 Examples of Reconstructed Images
A part of the ITEJ test chart moving vertically is shown in each photo.

is time-compressed, and multiplexed in the top/bottom bars/10/*.

* The multiplexing of digital audio by RF-QAM/12/ has been studied by our colleagues at the Consumer Electronics R&D Center, Hitachi, Ltd.

(2) Experimental Results

The picture quality was evaluated on existing TV sets and EDTV sets. A picture on an existing set is shown in Fig.9.

Pictures reconstructed on EDTV sets for a multi-pattern chart moving vertically are shown in Fig.11. In Fig.10(a), enhancement signals are not transmitted, so the image is equivalent to that of IDTV sets.

The enhancement signals are transmitted in Fig.10(b), and horizontal wedges are reconstructed clearly by the bar signal. Horizontal luma details are also recovered.

[5.6] Future Wide-Aspect TV

Wide-aspect TV is in great demand by consumers. However, there are many difficulties. Easy management of wide-aspect pictures for operation and processing in broadcasting stations, etc. is the key for introduction to practical use. In the future, the author will examine these easy-management methods.

[6] CONCLUSIONS

The future evolution of ATV depends on the full utilization of the 3D frequency domain. This has become possible due to new algorithms and LSIs.

The author has learned the following from experience.

1) Picture quality improvement by IDTV greatly depends on two factors: first, the properties of source signals, especialy TV cameras and signal processing in the studio, and second, the signal processing at IDTV sets, especially movement detection.

There will be two scenerios, i.e., the desirable scenerio, where IDTV sets will be used commonly due to improved studio equipment, and the undesirable scenerio. Public acceptance in the beginning stages will be very important.

2) Is it logical that broadcast picture quality should be superior to that of home equipment. Therefore, EDTV with high-quality video and audio is in demand. This can be achieved very easily with little additional cost to IDTV sets.

3) Wide-aspect TV is desired by consumers. Some schemes have been suggested after examining the properties of enhancement signals and spaces. Based on these studies, a proto-model has been completed. Easy signal operation seems to be the key for the processing of wide-aspect TV.

Finally, it is our hope that EDTV will be realized by combining our techniques with those of other countries. It is also sincerely desired that our fundamental technologies will conribute to the future world-wide success of ATV.

[Acknowledgement] The author would like to sinserely thank Mr. S.Nagahara for his general suggestions. The author is also indebted to his colleagues, Drs. M. Achiha* and K. Matsui*, and H. Yoshigi, Y. Hirano, K. Ishikura, N. Suzuki and M. Kageyama, for their continuous efforts in the R&D of IDTV and EDTV. (* moved to other organizations)

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PALplus DEVELOPMENTS

Dr. Albrecht Ziemer
German Television ZDF
Mainz, Germany

ABSTRACT

An improved PAL system, called Palplus, is under development in Europe. This paper gives an overview on the basic improvements and the way of introducing the PAlplus system which is foreseen to keep terrestrial broadcasting competitive for the future.

After the launch of the PAL system there was no reason for a long time to improve on this qualitatively good standard for colour television transmissions. Only since the new satellite television, which makes possible qualitatively better transmission methods - the MAC package familiy in Europe, for example -, has this view changed. Which is why it seems to be necessary to continue developing the PAL standard.

The new MAC package family provides in addition to improved image and sound quality the advantage of transmitting the 16 : 9 image format which has been enhanced opto-physiologically and already fixed uniformly for high definition television (HDTV). The European consumer electronics industry is planning to launch wide image sets for 16 : 9 reception in the first half of this year. This will enable 16 : 9 programmes to be received.

The public broadcasting authorities in Switzerland, Austria and the Federal Republic of Germany have therefore formed the PAL strategy group in conjunction with the European consumer electronics industry in order to react to the developments outlined above with an improvement on the terrestrial broadcasting of colour television programmes. In September 1989 this strategy group agreed on a working programme with the aim of adapting the terrestrial broadcasting of colour television programmes qualitatively and in respect of the wider image format to the new methods of satellite transmission. This strategy is intended to enable the terrestrially broadcasted main programmes of the public broadcasting corporations to appear in future in full format on the new wide image sets without being restricted by black stripes on either side.

In Chart 1 those partners involved in the PALplus project are shown, while Chart 2 shows the work structure of the project.

The goals of PALplus are summarized in Chart 3. There are four basic enhancements for the desired improvement of PAL:

- transmission of 16 : 9 pictures for new receivers, which are displayed in ther letterbox format on current 4 : 3 TV-sets
- reduction of cross-effects
- sound improvement
- reduction of ghosts

Top priority in the process is the downward compatibility to the existing PAL broadcasting. That means that PALplus must be capable of being transmitted in the existing 7 MHz channels and being received in acceptable quality via these distribution paths by old 4 : 3-sets. It should be mentioned that terrestrial transmitters in the VHF range and cable systems in Europe work with 7 MHz channels.

The PALplus which the strategy group together with the European consumer electronics industry is developing contains - as mentioned above - a series of improvements. The most important step, however, is the possiblity to transmit the wider 16 : 9-picture format for new TV-sets which will be displayed in a downwards compatible way on 4 : 3 receivers.

While new wide image receivers with a PALplus signal show a 16 : 9 screen-filling picture, the 4 : 3 sets, which have been the norm up to now, reveal PALplus image signals in letterbox format as is usual these days with wide screen and cinemascope films in Europe (see Chart 4).

Letterbox depiction was hereby given preference over side panel technology - which cuts off parts of the picture - for the following reasons:

- no work-intensive format processing of the broadcasting material exists for the 4 : 3 reception (panscan), e.g. live broadcasts cannot be made with panscan,
- there are strong copyright reservations concerning side panel technology,
- the technical realization of side panel transmission involves more complexity on the transmitting and receiving sides, and
- by using side panel technique on the new 16 : 9 receivers the transition from the main panel to the side panels will be seen because noise will be of different nature in these different picture parts. This would cause conditions less than ideal on the receivers of the future.

An important goal of PALplus is also to enhance signal quality. Using corresponding filter techniques cross-colour and cross-luminance effects should be reduced and the horizontal resolution of the luminance signal increased.

Despite the changeover to the 16 : 9 format the same horizontal resolution as with existing 4 : 3 broadcasting has to be attained as a minimum value while retaining the vertical resolution. Thus no effort is being made to achieve an "HD-PAL" as competition for HD-MAC. On the contrary the aim is for a quality enhancement downwardly compatible to PAL.

Furthermore ways are being examined to see whether a digital, data-reduced sound-coding method is capable of being integrated and whether short or long-time echoes can be suppressed (ghost-cancelling).

Chart 5 shows the time schedule for the PALplus project.

Corresponding to the penetration of the market with black-and-white and coloured TV sets, as well as with video recorders, which existed in about five percent of the households after four years and in about 40 percent after ten years, this time schedule is very much in accordance with the developments of the receiver market. There will be a period of time of about four years from the introduction of the 16 : 9 terminal sets at the end of 1990, till 1995 consequently, - provided that the market development is the same - to react to the success of the new 16 : 9 sets and to prepare a corresponding change of format in the programme. Then, during a first period of time, it is regarded as sufficient to broadcast only 16:9-fit existing programmes over PALplus in the format 16 : 9. This refers to features in Cinemascope or to wide screen pictures for example. All other types of programmes could be broadcasted in the format 4 : 3 during this transitional period. Without affecting the majority of the spectators - they can watch pictures over PALplus as usual in the letterbox format - it is thus possible - with a broad acceptance of the programmes - to offer a format filling picture to those who are curious about new technical aspects.

If the wide image format is successful, it will be necessary later on to gradually change to 16 : 9 in the production of TV programmes. Approximately at the turn of the millenium a penetration of the market with 16 : 9 sets of about 40 percent can be expected. This would also be the earliest moment when a total change of the complete programme from 4 : 3 to 16 : 9 could be expected or justified at all. For there would be a great number of conventional 4 : 3 receivers, who would have to accept black stripes at the top and bottom of their screen.

A gradual change from the actual 4 : 3 to the new 16 : 9 format is thus possible from the technical point of view as well as with regard to the programme.

As one can see from Chart 5 PALplus is supposed to be ready for operational introduction in 1995. It is foreseen to give a first technical presentation of the whole system at the Berlin Fair (IFA '91), but this will be on the basis of laboratory equipment only. Further details of this presentation are shown in Chart 6.

The PALplus development was started at the end of 1988. Today a status has been reached in which most of the basic technical problems are solved. So, the PALplus project is on its way according to the given time schedule.

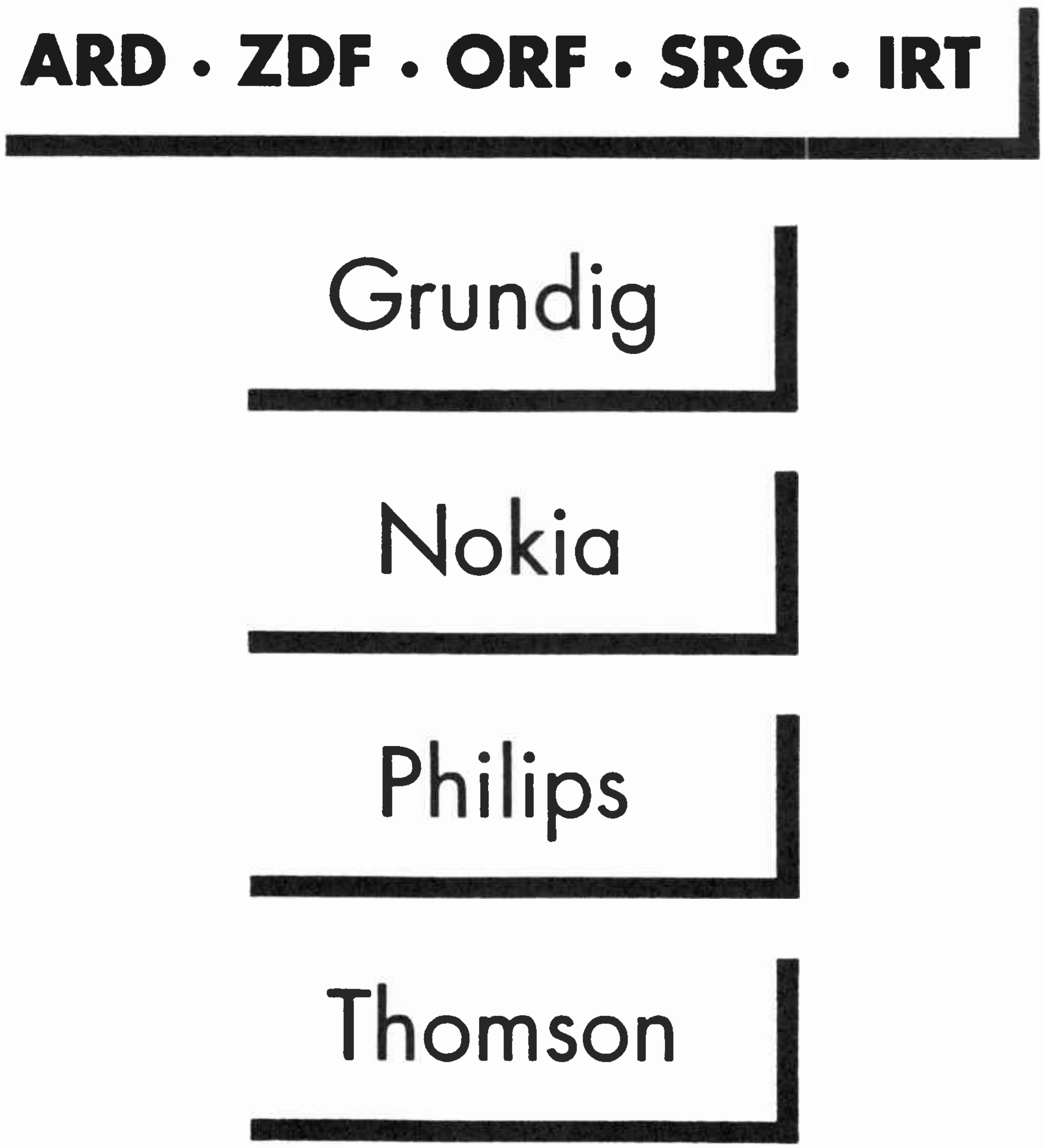


Fig. 1: Partners involved in PALplus project

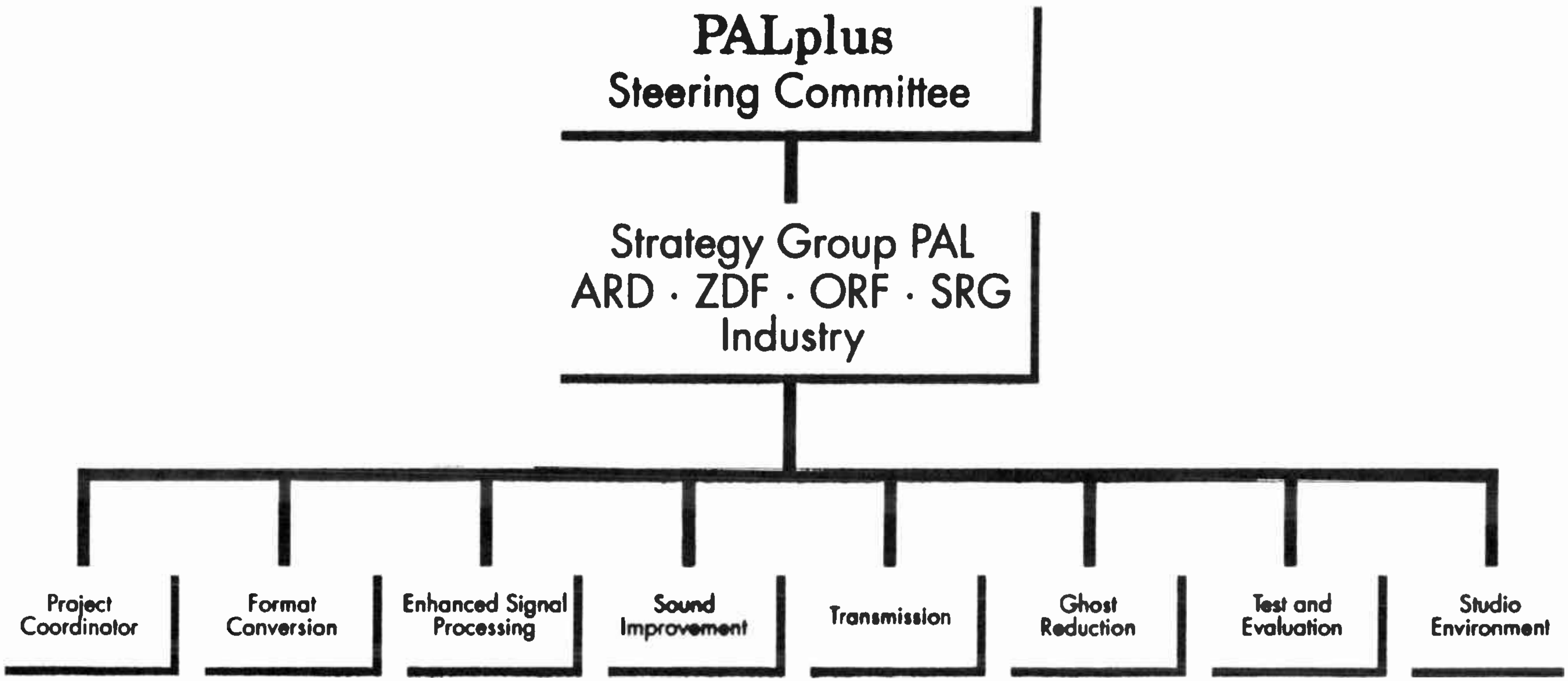


Fig.2: Structure of the work

GOALS OF PALplus

- TRANSMISSION OF 16:9 PICTURES:

  + For a 4:3 compatible transmission of 16:9 pictures a letterbox proposal is under study
  + An augmentation signal buried in the transmitted signal will be used in order to improve the spatial-temporal resolution on new 16:9 displays

- ENHANCED PAL ENCODING / DECODING:

  + Reduction of cross-colour and cross-luminance
  + Extended horizontal resolution

- SOUND IMPROVEMENT:

  + A digital and datareduced 2 channel sound coding system is under study for PALplus

- REDUCTION OF GHOSTS:

  + Short distance ghosts to improve data receotion
  + Long distance and multiple ghosts to improve picture quality

Fig. 3: Goals of PALplus

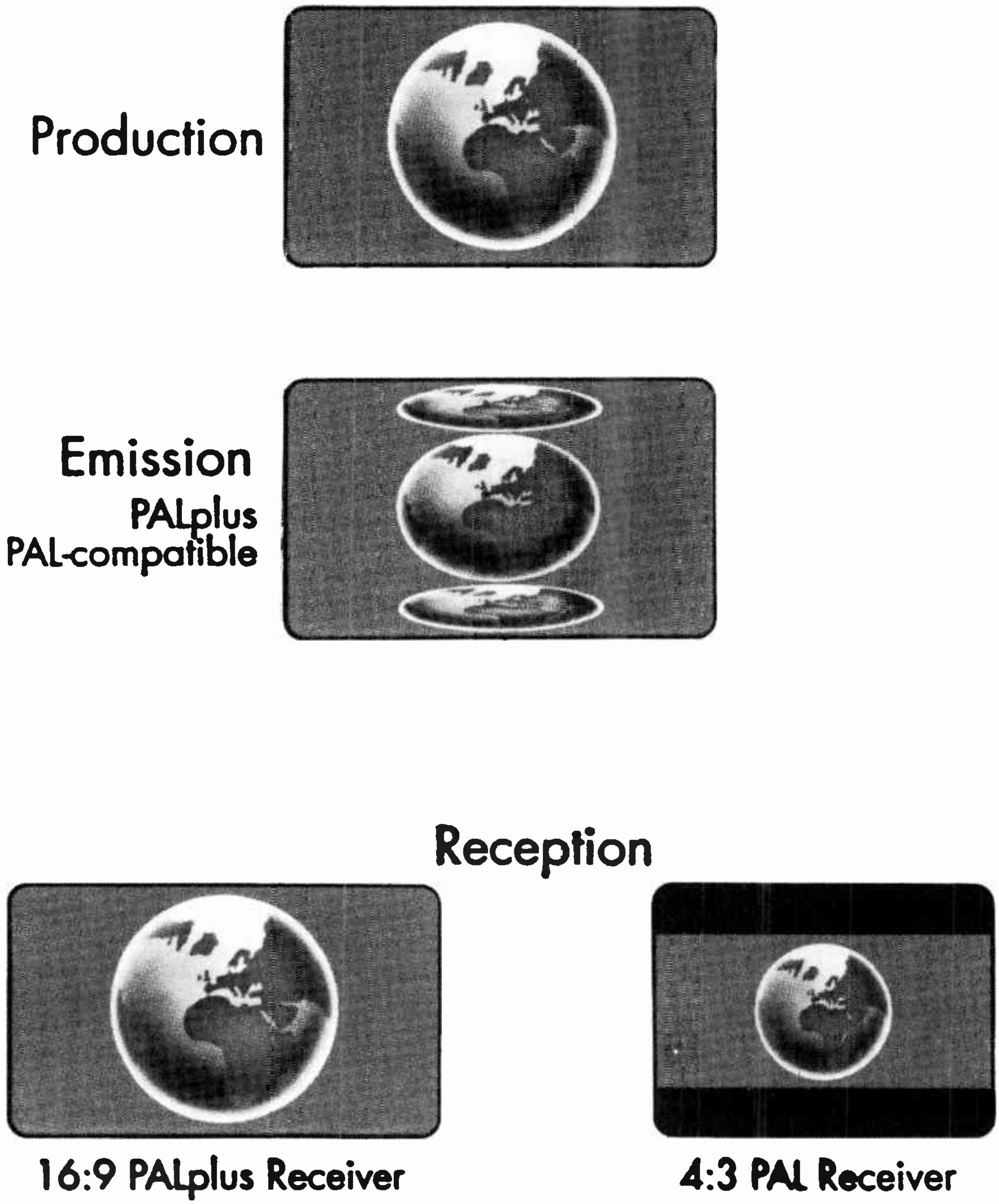


Fig.4: Transmission and reproduction processus of PALplus signals

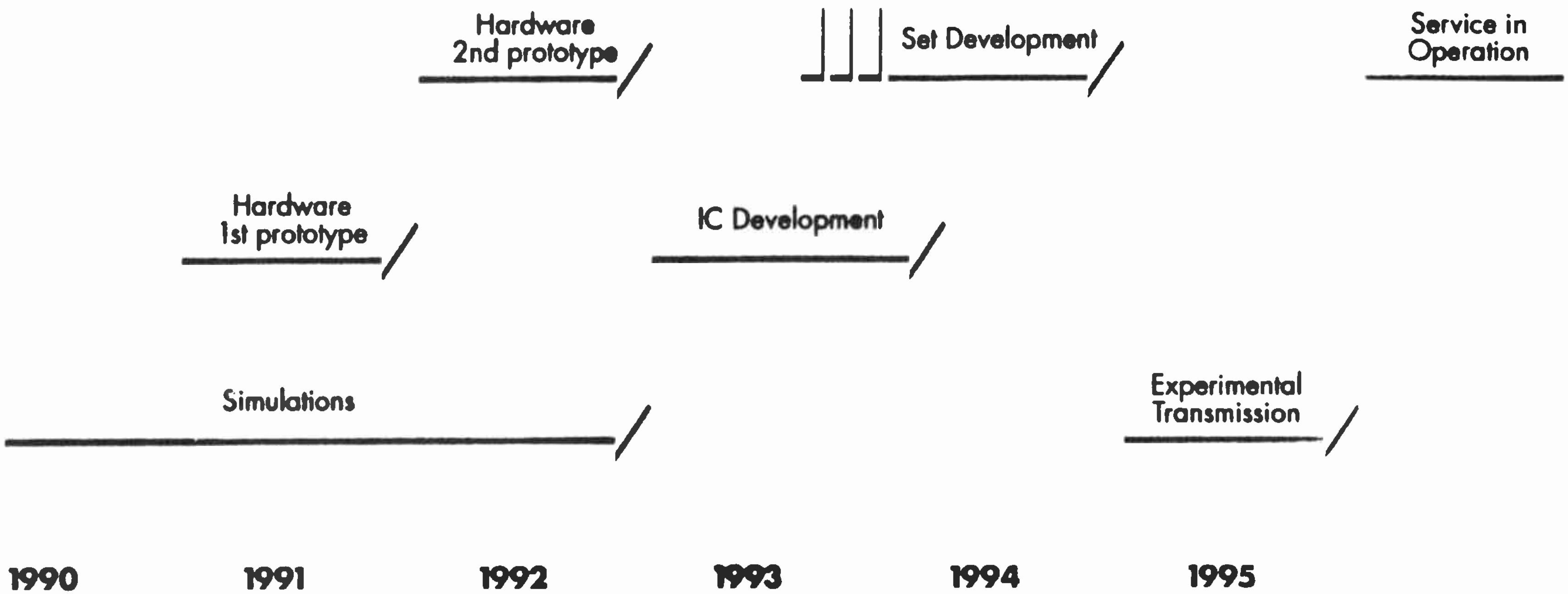


Fig.5: PALplus introduction

PRESENTATION OF THE SYSTEM AT IFA '91

- The basic parameters for PALplus have to be fixed by IFA '91

- The first PALplus prototype (coder and decoder) with the following characteristics will be presented at IFA '91:

  + The horizontal resolution is to be maintained at 5 MHz for IFA '91, since the extended luminance processing is not mature
  + Adaptive Colour plus and combfilters are to be incorporated (depending on filmmode bit).
  + Modulation of the ultrablack helper is to be incorporated.

Fig. 6: Presentation of the System at IFA '91

A NEW SYSTEM OF NTSC-COMPATIBLE WIDE ASPECT ADVANCED TELEVISION—NEW NTSC MODE 1.5

Shin'ichi Aikoh, Yoshihide Kimata, Masayuki Ishida,
Toshiya Ito and Susumu Takayama
Nippon Television Network Corporation
Tokyo, Japan

ABSTRACT

This paper presents a new system of NTSC-compatible wide aspect advanced television, which is considered one of the most promising systems to realize high quality wide aspect terrestrial broadcasting system without losing NTSC compatibility. This new system is situated as an intermediate system between the side panel system (New NTSC Mode 1) and the letter box system (New NTSC Mode 2) both reported previously. That is, in this system (or New NTSC Mode 1.5), wide screen images with an aspect ratio of 9:16 are encoded to be reproduced on the conventional NTSC receivers maintaining about 89% of original wide screen area, although the reproduced original screen areas of Mode 1 and Mode 2 are approximately 70% and 100% respectively. NTSC compatibility and feasibility of the new NTSC Mode 1.5 as a wide aspect advanced television have been confirmed through simulation and experimental hardware evaluation.

INTRODUCTION

With a rapid advance of various image media, new services for next generation TV systems, such as wide aspect screen, high resolution images and high quality audio, are strongly demanded. In realizing these new services, the compatibility with conventional NTSC systems becomes one of the most important matters to be considered, but new service attainment with maintaining NTSC compatibility will be even more desirable from the view point of efficient TV frequency band utilization.

As is well known, there are two typical systems for wide aspect advanced TV, that is, side panel system (New NTSC Mode 1) and letter box system (New NTSC Mode 2). For these systems, we have already carried out simulation and hardware evaluation [1],[2]. In Mode 1, central main portion of the original wide screen images appears on the conventional NTSC receivers with original image size, although about 30% side edge areas are cut on the receiver. Problems for this mode are relatively large cutting area appearance, and difficulty in producing image programs with taking notice of the cutting areas. On the other hand, in the Mode 2, wide screen images are compressed to 3/4 in the vertical direction without side edge cutting areas, but the original wide images become smaller generating about 25% upper and lower blank areas on the NTSC receivers.

As an intermediate system to reduce the problems for Mode 1 and Mode 2, we present New NTSC Mode 1.5 which reduces the side edge cutting area of Mode 1 from about 30% to about 11%, and increases reduction ratio from about 75% in Mode 2 to about 83%. In this new system, wide images with aspect ratio of 9:16 are first horizontally compressed to 3/4 through a 525/1:1 progressive scan camera. Then, the images are compressed again tc 3/4 in the vertical direction, and horizontal low frequency component and high frequency component of side edge portion are multiplexed in the horizontal overscanning area and in the 40 blank lines out of 80 blank lines generated by the vertical compression respectively. Remaining 40 blank lines are

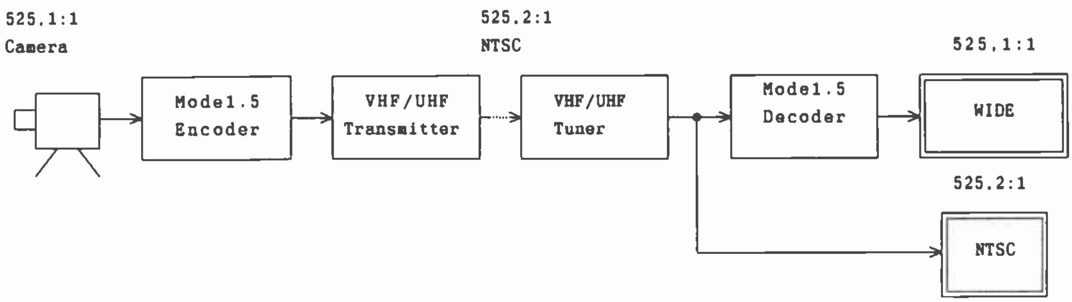


Fig.1 Model.5 system cofiguration.

used to transmit vertical compensation signals, which are adaptively multiplexed according to the detection results of motion picture and still picture. In addition to these compensation signals, horizontal high frequency component of vertical low frequency portions are frequency multiplexed in the central main panel.

This paper mainly presents New NTSC Mode 1.5 algorithm. Experimental hardware and evaluation results are also described.

SYSTEM OUTLINE

Figure 1 shows New NTSC Mode 1.5 system configuration. Wide screen images from a 525/1:1 progressive scan camera are fed to the Mode 1.5 encoder and output in the form of conventional 525/2:1 NTSC after vertical compression, horizontal expansion, vertical/horizontal compensation signals extraction and multiplexing. At the receive side, NTSC decoded signals are inversely processed through horizontal compression, vertical expansion, demultiplexing and regeneration of compensation signals. After these processing, 525/1:1 high quality wide screen images are regenerated on a wide aspect TV monitor. For the NTSC receiver, intermediate image format between Mode 1 and Mode 2 is generated as shown by the left side of Fig. 2.

Compensation signals for higher resolution realization, such as vertical high frequency component (Vh), line difference signal (LD) and high frequency component of side panels, are multiplexed into the upper and lower blank areas obtained by vertical 5/6 compression as shown by the right side of Fig. 2. Low frequency component of the side panels are also multiplexed in the horizontal overscanning areas.

ENCODING AND DECODING ALGORITHM

Figure 3 shows block diagrams of the Mode 1.5 encoder and the decoder. Each block processing is explained hereafter.

(A) Encoder

MATRIX PROCESSING

R, G and B component signals obtained by a 525/1:1 progressive camera are converted to luminance signal (Y), color difference signals (I and Q).

BAND LIMIT & PREPROCESSING

For luminance signal, different processing is carried out depending on the picture characteristics, such as motion picture and still picture. Namely, for motion pictures detected by a motion /still image detector, horizontal and temporal frequency bands are limited to 0-6MHz and 0-30Hz in the range of 0-200/2 cph vertical low component and to 0-0.8MHz:0-15Hz in the range of 200/2-480/2 cph vertical high component respectively. Additionally, the three dimensional cubic band for the vertical high component is preprocessed to be the same component for adjacent even and odd fields by averaging the cubic component of the adjacent two fields. On the other

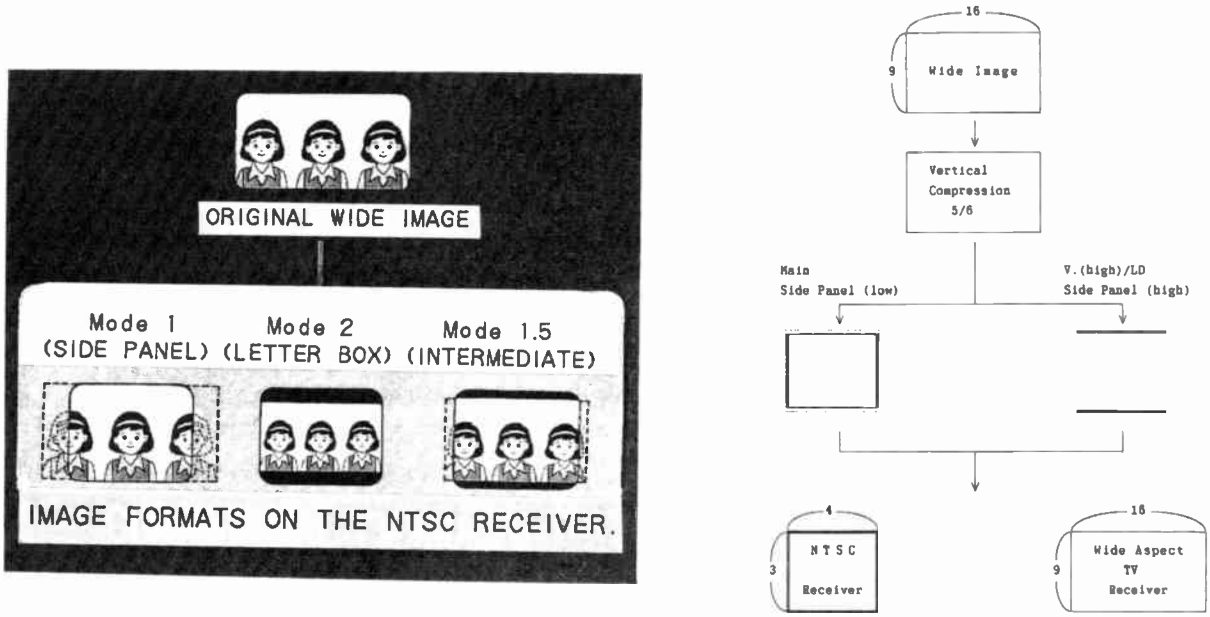
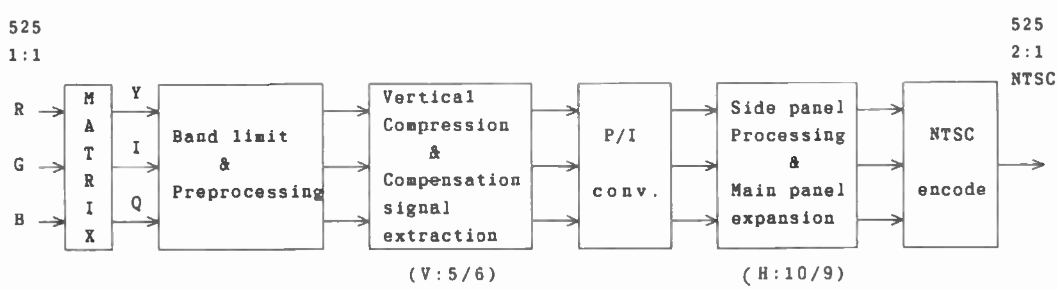
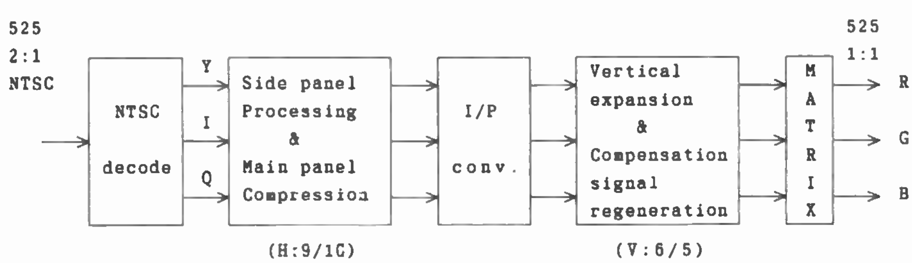


Fig. 2 Concept of Mode 1.5.



Encoder block diagram.



Decoder block diagram.

Fig.3 Encoder and decoder block diagrams.

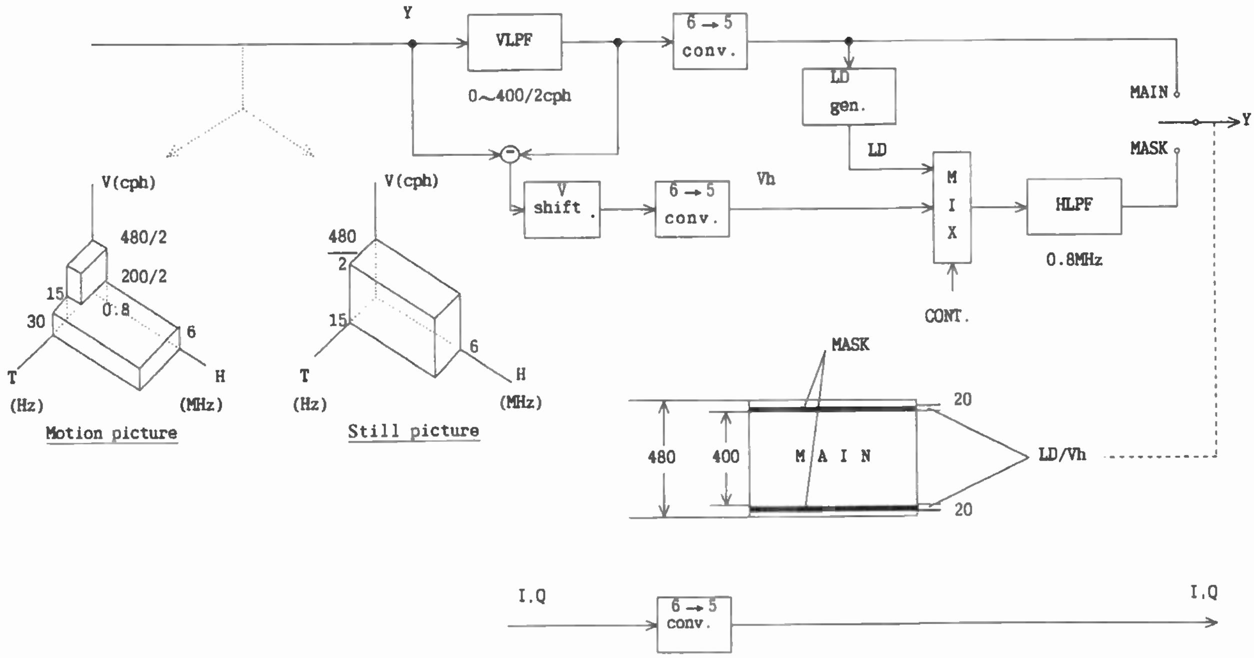


Fig.4 Vertical compression and compensation signal extraction.

hand, for still pictures, vertical, horizontal and temporal frequency bands are limited to 0-480/2 cph, 0-6MHz and 0-15Hz respectively, and vertical high component more than 200/2 cph is also averaged over adjacent two field as process for the motion pictures. Figure 4 shows the three dimensional spectrum for Y after these band limitation. Frequency band for I and Q signals are limited to 0-200/2 cph in vertical direction.

VERTICAL COMPRESSION AND COMPENSATION SIGNAL EXTRACTION

Figure 4 shows the process of this processing block. Spectrum shaped Y signals by the band limitation and preprocessing, are filtered by vertical low pass filter (VLPF) to remove the vertical high frequency component more than 400/2 cph, and converted from 480 scanning line signals to 400 scanning line signals by 6:5 rate conversion (5/6 conv.). This signals are treated as main panel images. From the main panel signals, line difference signals (LD) are extracted as compensation signals to improve vertical resolution for motion pictures. This LD signal is the difference signal between the amplitude:B of the line (interpolation line), which is not transmitted by interlace scanning, and the interpolated amplitude using upper and lower line amplitude:A and C. Therefore, a LD signal is simply indicated as

$$LD=B-1/2(A+C).$$

As is noticed from the equation, the LD extraction processing is a kind of vertical high pass filtering. In order to improve filtering characteristics, in our system, upper and lower two lines each are used for generating LD signals in order to extract only high frequency component.

Vertical high frequency component (400/2-480/2 cph), which is obtained by subtracting the VLPF output from its input, are shifted to vertical low frequency area and converted to 400 scanning line signals by 6:5 rate conversion. This signal is used as vertical compensation signal (Vh) for still pictures and fed to the mixer together with LD signals. At the mixer, LD and Vh are selectively mixed out according to the control signal (CONT.) from motion/still picture detector and multiplexed in the upper and lower mask portion. Although the each

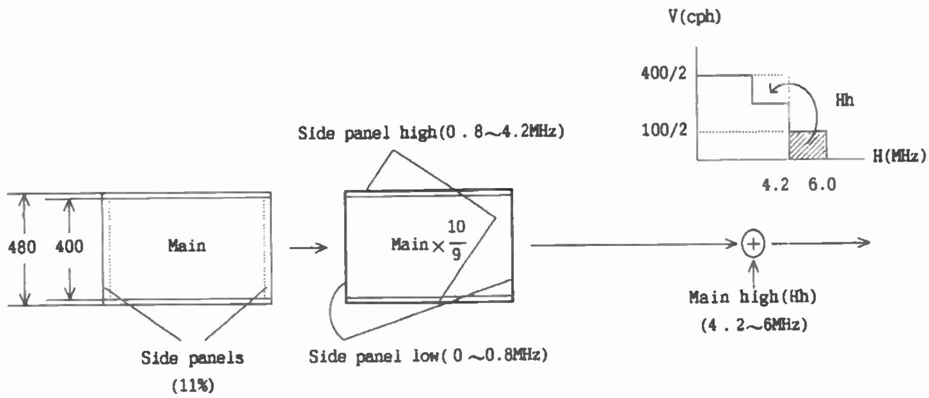


Fig.5 Side panel processing in the encoder.

mask portion contains 40 lines, 20 lines each are used to multiplex LD or Vh adaptively. Color difference signals; I,Q are also vertically compressed by 6:5 rate conversion.

P/I CONV.

Y, I and Q signals processed through vertical compression and compensation signal multiplexing are converted from 525/1:1 progressive signals to 525/2:1 interlaced signals.

SIDE PANEL PROCESSING AND MAIN PANEL EXPANSION

Figure 5 shows the conceptual image of this processing. Luminance signals; Y of side panels (about 11% of original images) is subsampled at a rate of 1/5 containing only its low frequency component (0-0.8MHz) and multiplexed in the horizontal over-scanning area. Remaining high frequency component (0.8-4.2MHz) is multiplexed using 40 scanning lines out of upper and lower mask area. Color difference signals; I,Q of the side panels are also compressed to 1/5 for multiplexing as done with Y. After this compression, horizontal high frequency component (4.2MHz-6MHz) of the main panel in the vertical low frequency component is shifted and multiplexed in the diagonal high frequency portion as shown in Figure 5.

NTSC ENCODE

For Y,I and Q signals after the vertical and horizontal processing are encoded conventionally in the NTSC format.

(B) Decoder

At the receiver, Y, I and Q signals decoded by a NTSC receiver are processed through side panel processing and 9/10 main panel compression in the reverse order of the encoder. In this section, the vertical expansion and compensation signal regeneration process after 525/1:1 conversion (I/P CONV.) is explained in detail.

VERTICAL EXPANSION AND COMPENSATION SIGNAL EXTRACTION

Figure 6 shows the block diagram of this processing. Y signal is first separated to the main panel signal and the upper/lower mask signal. Then the main panel signal is interpolated between a field 1 and a field 2 (Field interpolation), which have been already converted to 525/1:1 progressive signal inserting zero signals to interpolation lines by the I/P conv. process, and becomes the main panel signal for a still picture.

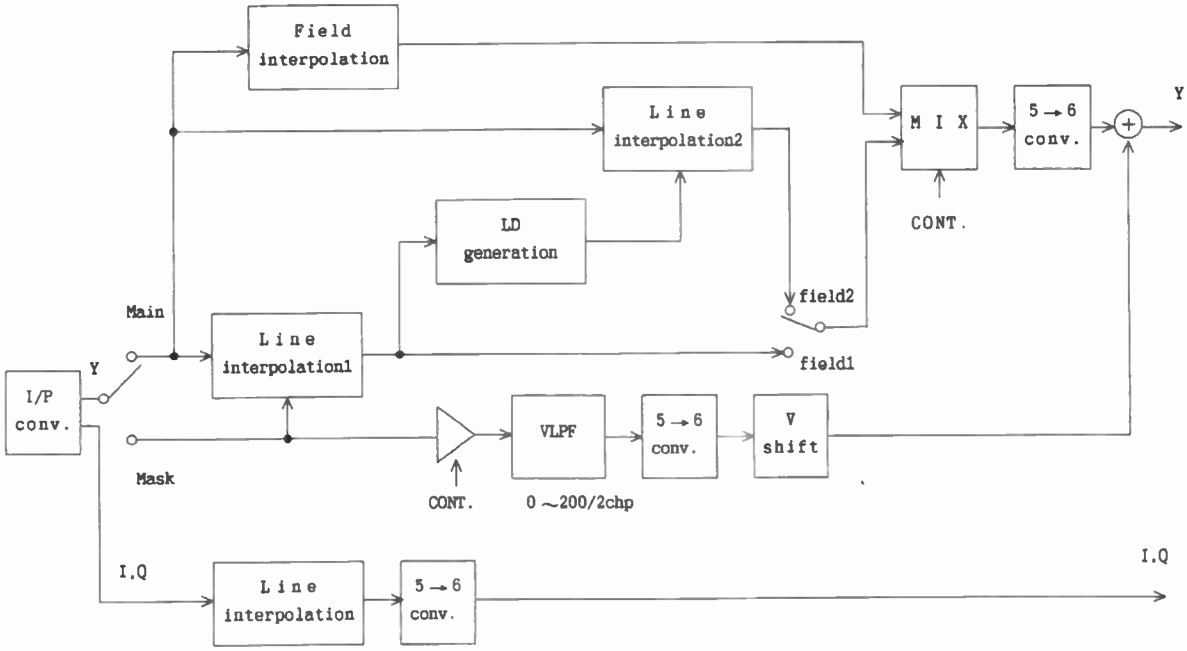


Fig.6 Vertical expansion and compensation signal regeneration.

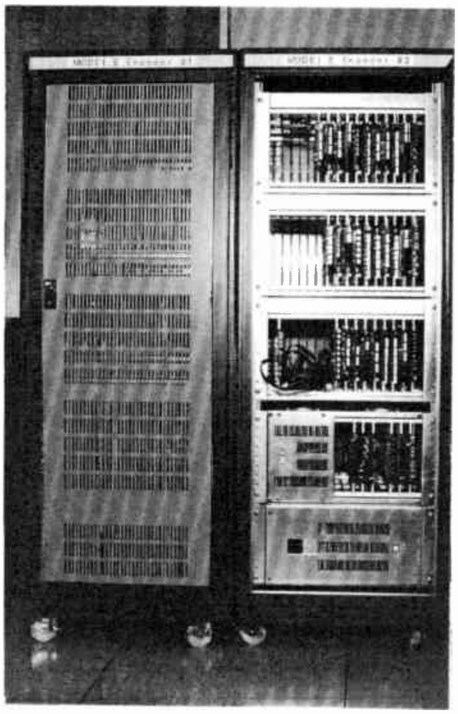
On the other hand, the LD signal demultiplexed from the mask area is first used to interpolate the zero inserted lines of a field 1 (Line interpolation 1), then a new LD signal for the adjacent field 2 is generated from the high resolution images of the field 1. The new LD signal is used for the line interpolation of the field 1 (Line interpolation 2). This new LD signal generation becomes possible, because the vertical high components for the adjacent two fields are averaged and made to be almost identical at the encoder as mentioned above.

The Vh signal for vertical compensation of still pictures are regenerated through 5:6 conversion and frequency shifting. At the mixer, field interpolated images and line interpolated images using LD are selected for still pictures and for motion pictures respectively depending on the motion picture detection results. Additionally, vertical high frequency component up to 480/2 cph for still pictures is compensated by adding Vh to the output from the 5:6 conversion. The I and Q signals are interpolated in lines and go to 5:6 conversion process.

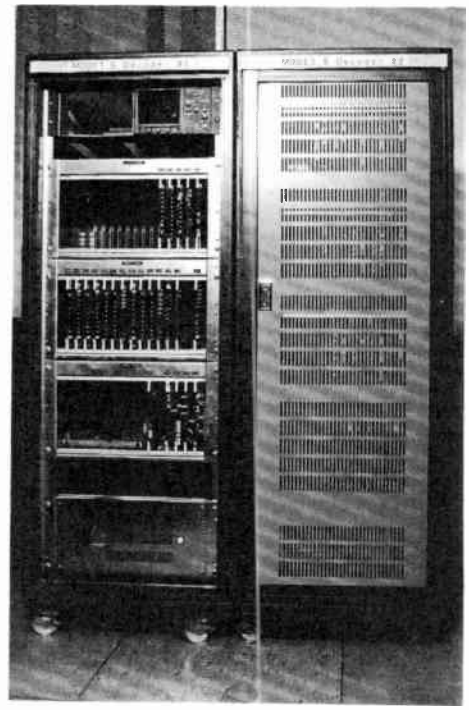
EXPERIMENTAL HARDWARE AND EVALUATION

Photograph 7 shows the outlook of the New NTSC Mode 1.5 experimental hardware system. Input images are basically sampled at 4 Fsc (Fsc: color subcarrier) and processed through the algorithm mentioned above. In the vertical processing block, 13 tap and 47 tap FIR filters are used for vertical and horizontal filtering respectively. The vertical low pass filtering and 6/5 (or 5/6) conversion are realized by single filter using filter coefficient convolution for hardware simplification. In the horizontal processing block, 21 tap and 19 tap FIR filters are used for 10/9 horizontal expansion and 9/10 horizontal compression respectively. For the side panel compression and expansion, 21 tap filtering is carried out.

Photograph 8 shows an encoded picture and a decoded picture as an example. By setting the set up value to about 25 IRE for the upper and lower mask portion, there is almost no interference on the conventional NTSC monitors. For the adaptive processing by motion/still picture detection,



Encoder



Decoder

Photo. 1 Experimental ha-dware system.

Encoded picture.

Decoded picture.

Photo. 2 Mode 1.5 encoded picture and decoded picture.

picture quality is improved by overlapping the motion area and still area at their boundaries in the processing such as the band limitation at the encoder and the mixing at decoder.

CONCLUSION

This paper mainly presented the algorithm of New NTSC Mode 1.5, which is situated as an intermediate system between the side panel system (Mode 1) and the letter box system (Mode 2) for NTSC-compatible wide aspect advanced television. Although further investigation and evaluation will be necessary to decide the best system among these candidates, we intend to contribute progressively to the attractive advanced television realization.

ACKNOWLEDGMENT

The authors would like to thank Mr. K. Kawai, deputy manager and Mr. S. Yasuki; Toshiba Corporation for their useful suggestions and corporation.

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[2] Y. Kimata, Y. Araki, S. Takayama, "STUDY OF THE METHOD OF SIGNAL PROCESSING APPLICABLE TO THE WIDE ASPECT EDTV COMPATIBLE WITH NTSC", NAB Engineering Conference Proceedings, May, 1990.

A RECEIVER-COMPATIBLE WIDER ASPECT RATIO EDTV SYSTEM

A. Takahashi, T. Morita, H. Inoue, H. Nakashima, and H. Uratani
Tokyo Broadcasting System Inc.
Tokyo, Japan

K. Kashiigi, T. Tachibama, H. Makita and M. Ashibe
NEC Corporation
Tokyo, Japan

ABSTRACT

This paper describes a single channel, NTSC compatible, widescreen EDTV system.

An EDTV receiver displays a wide picture in which the center and side panels are stitched together. The picture quality is uniform across the display , and no visible seam is produced. Existing receiver displays a picture in which the side panels are arranged at the top and bottom of the screen. The picture contains a most portion of the wide picture with sufficient definition and size, and the side panels at the top and bottom bars are not disturbing.

The system also offers a picture with extended vertical and horizontal resolution to the EDTV receiver, and yet offers a picture with no interferences to existing receiver. Furthermore, the system is free from the limitations of motion adaptive processing.

INTRODUCTION

At present, several proposals for the second phase of EDTV (EDTV-II) in Japan are being considered. EDTV-II is a single channel compatible system intended for a wider aspect ratio and higher picture and sound quality.

Three different methods have been proposed for the wider aspect ratio. However, in the "sidepanel" method, a picture displayed on existing receiver lacks a considerable part of the wide picture, and a picture displayed on an EDTV receiver may suffer from side panel visibility. In the "letterbox" method, a picture displayed on existing receiver is deficient in definition (in the unit of line/picture height) and size.

To contend with these problems, we have originated the so-called "middle" method, which lies between the above two methods.[1] In this method, a picture displayed on existing receiver contains a most portion of the wide picture with sufficient definition and size, and a picture displayed on an EDTV receiver benefits no side panel visibility. However, in the method, a picture displayed on existing receiver is still unsatisfactory because that the side panels arranged at the top and bottom of the screen is disturbing.

A system described here is a reform of the original middle method. The system conceals the side panels for existing receiver, and extends definition for an EDTV receiver, not increasing interferences in existing receiver. Furthermore, the system is free from the limitations of motion adaptive processing.

OVERVIEW OF THE SYSTEM

The system includes a camera, a high resolution encoder, a wide aspect encoder, a wide aspect decoder, a high resolution decoder, and a display . A block diagram of the system is shown in **Fig. 1**

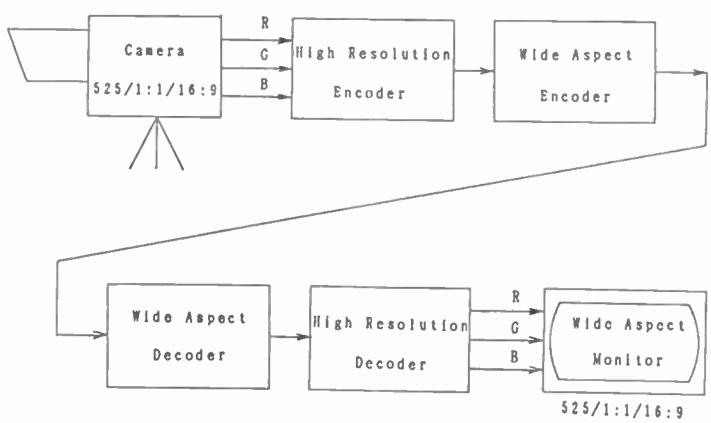


Fig. 1 Block diagram of the system

The camera is a 525-line, 59.94 field/sec progressively scanned camera. The progressively scanned camera is preferred because that it can generate extended vertical detail and make vertical-temporal filtering effective.

At the high resolution encoder, the luminance signal is converted to interlaced format, separating extended vertical and horizontal details from it. Then, these details are hidden in a diagonal high spatial frequency region (the diagonal hole) and the Fukinuki hole respectively.

At the wide aspect encoder, a wide aspect signal is divided into the center and side panels in such a way that they partially share their ends, and both edges are waveform-shaped. Then, the side panels are separated into low and high frequency components, and these components are located at outer and inner parts of the top and bottom of the screen respectively.

At the wide aspect decoder, the side panels are reconstructed from their components, and the waveform-shaped both edges of the center and side panels are discarded. Then, these panels are stitched together in such a way that they partially overlap.

At the high resolution decoder, the extended vertical and horizontal details are recovered from the hidden holes. Then, the resulting signal is converted to progressive format.

The display is a 525-line, 59.94 field/sec progressively scanned display. The progressively scanned display is preferred because that it can improve vertical resolution without interline flicker.

PROCESSING FOR THE WIDER ASPECT RATIO

The Middle Method

At the wide aspect encoder, 16:9 picture is mapped into 4:3 picture by arranging the side panels at the top and bottom of the screen. Geometrical relationship between these pictures is shown in **Fig. 2**. This method is called the middle method. The parameters of the method are shown in **Table 1**, together with those of the sidepanel and letterbox methods.

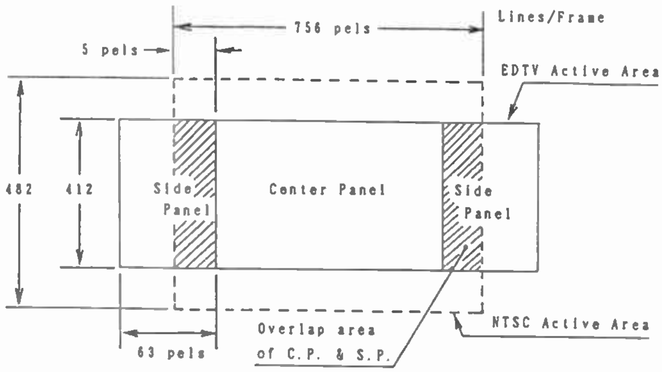


Fig. 2 Relationship between 16:9 and 4:3 pictures

Table. 1 Parameters of the three method

	Letterbox	Middle	Sidepanel
Wide/Standard Relative Height A_v	3/4	6/7 ≒412/482	1/1 Equal Height
Wide/Standard Relative Width A_h	1/1 Equal Width	8/7 ≒872/756	4/3
Wide/Standard Relative Area $A_v \cdot A_h$	3/4	48/49 Equal Area	4/3
Picture Lack on NTSC Receiver $e_1=(1-1/A_h)$	0	1/8	1/4
Def. & Size Loss on NTSC Receiver $e_2=1-A_v$	1/4	1/7	0
Subjective Score on NTSC Receiver $s=-(e1^2+e2^2)$	-0.0625	-0.0360	-0.0625
Aspect Ratio on NTSC Receiver $(4/3)(1/A_v)$	16/9	14/9	12/9

From Table 1, when the picture displayed on existing receiver is compared with the original wide picture, in the case of the middle method, the area is almost equal. In contrast to this, in the cases of the sidepanel and letterebox methods , the height and width are equal respectively.

Again from Table 1, in the middle method, the relative lack of picture is 1/8, and the relative loss of definition and size is 1/7. In comparison with this, in the sidepanel method, the relative lack of picture is 1/4, and in the letterbox method, the relative loss of difinition and size is 1/4.

At this point, the relative lack of image e_1 and the relative loss of definition and size e_2 are both considered to be objectively measured physical errors. In general, human subjective reaction to physical errors is known to be determined by the squared sum of these errors. Therefore, concerning the errors mentioned above, the subjective score $s(=-(e_1^2+e_2^2))$ of the middle method is assessed to be -0.0360. In comparison with this, the scores of the sidepanel and letterbox methods are both assessed to be -0.0625 , poorer than -0.0360. A subjective test also shows the result that the middle method is favorably judged.[2]

Furthermore, in the middle method, the spatially uncorrelated side panels are arranged at the spatially uncorrelated top and bottom of the screen, and the spatially correlated extended details are hidden in the spatially correlated holes in the frequency domain. By contraries, if the spatially uncorrelated side panels are squeezed into the spatially correlated holes in the frequency domain, they may interfere with the picture quality. This is the reason why that the picture quality shows no difference between the center and side panels in the middle method.

Waveform Smoothing

At the wide aspect encoder, a wide aspect signal is decomposed into the center and side panels in such a way that they partially share their ends. Then, both edges are waveform-smoothed. Decomposition and recombination of the center and side panels are shown in **Fig. 3**.

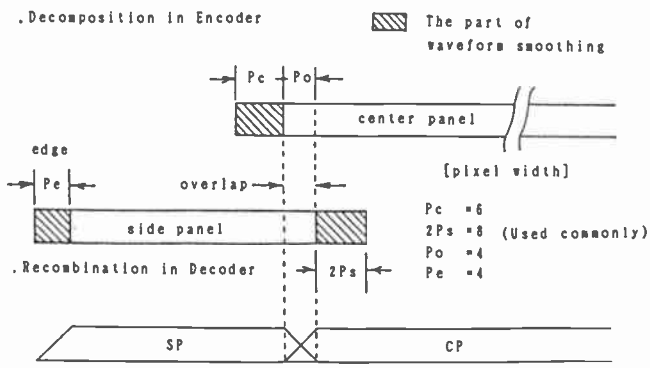


Fig. 3 Decomposition and recombination

Section Po common to the center and side panels is that to be overlapped when these panels are recombinated together at the wide aspect decoder. Section Pc of the center panel and sections 2Ps and Pe of the side panels are those to be waveform-smoothed at the encoder and to be discarded at the decoder, where the section 2Ps is shared by the right and left side panels.

Waveform itself and its period for the waveform smoothing are determined considering the transmission characteristics of the broadcasting network. Typical amplitude and group delay characteristics are shown in **Fig. 4**.[3] It is found from this that transient effects are more effectively eliminated when waveform-smoothed by the cosine squared function than by the linear or cosine functions. Therefore, the system has adopted the cosine squared function given by

$$G(t)=[1+\cos(\pi t/q)]/2q, \quad -q \leq t \leq q \qquad (1)$$

for the waveform smoothing.

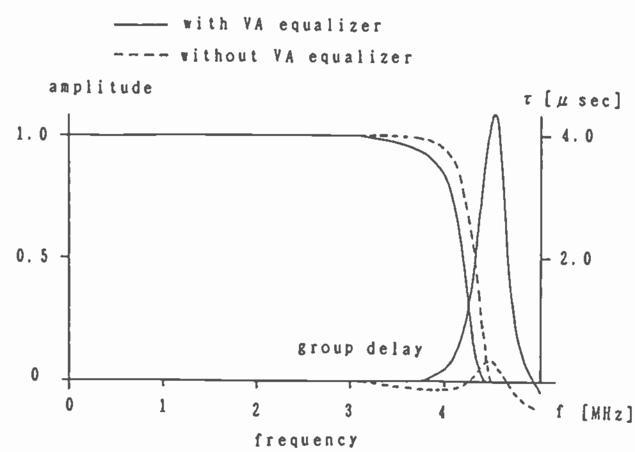
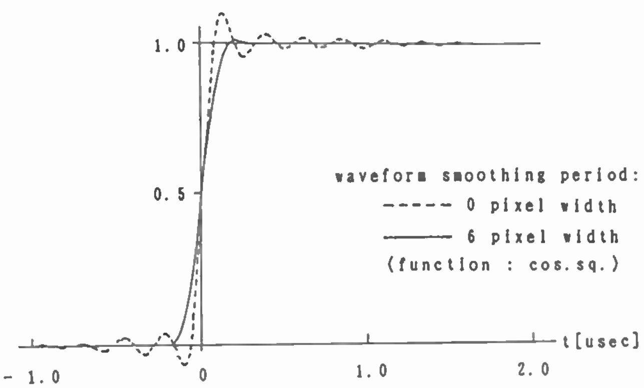


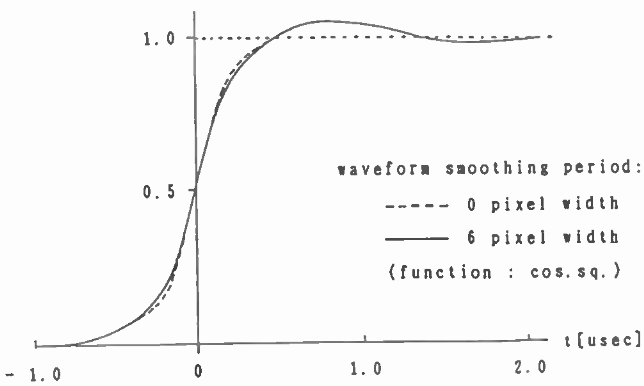
Fig. 4 Transmission characteristics

The transient responses of the luminance and chrominance signals in this case are shown in **Fig. 5**. As for the chrominance signal, the transient effects are scarcely eliminated even by a period of 6 samples. However, since human eye is not so sensitive to color as to brightness, the period may be optimized only for the luminance signal. As for the luminance signal, the relationship between the period in which the waveform is smoothed and the duration in which the transient error exceeds some limit, is shown in **Fig. 6**. It is found from this that there is an optimum value for the waveform smoothing period. The periods shown in Fig. 3 have been adopted based on such an optimum value.

Furthermore, being assisted by the overlap section Po, the center and side panels can be mixed to create a feathered seam instead of a hard transition. By these means, the system avoids a danger of producing a visible seam.

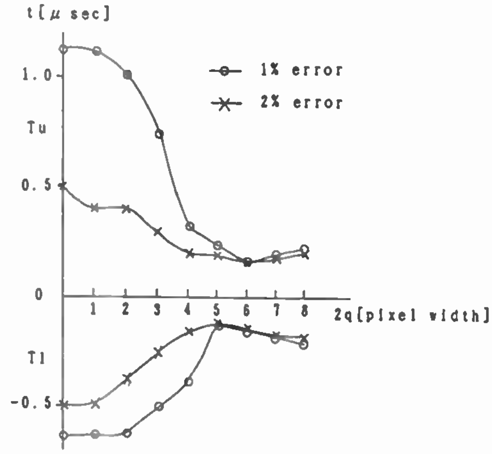


(a) Luminance signal

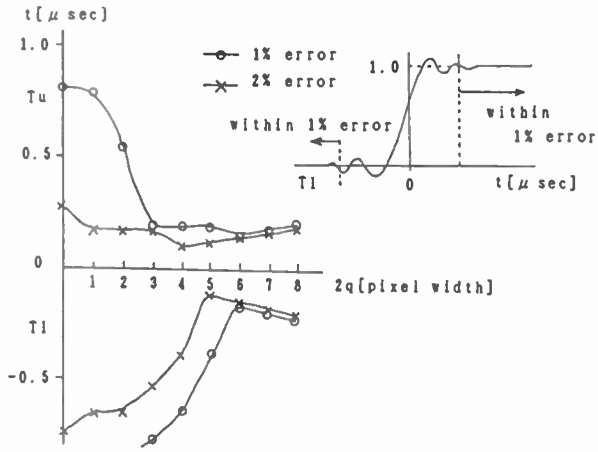


(b) Chrominance signal

Fig. 5 Transient responses



(a) with VA equlizer



(b) without VA equlizer

Fig. 6 Shaping period and transient duration

Side panel Concealment

At the wide aspect encoder, the side panels are arranged at the top and bottom of the screen. As previously mentioned, the side panels at the top and bottom bars occupy about 7 % of the screen individually. Therefore, if the side panels are arranged without any processings as our original method, they may obstruct the view on existing receiver.

To avoid this, the side panels are separated into the objectionable low frequency component and the not objectionable high frequency component. Then, they are arranged in the manner that these components are located at outer and inner parts of the top and bottom bars respectively.[4] This arrangement of the side panels is shown in **Fig. 7**. However, the separation must be such that the side panels can be perfectly reconstructed at the wide aspect decoder.

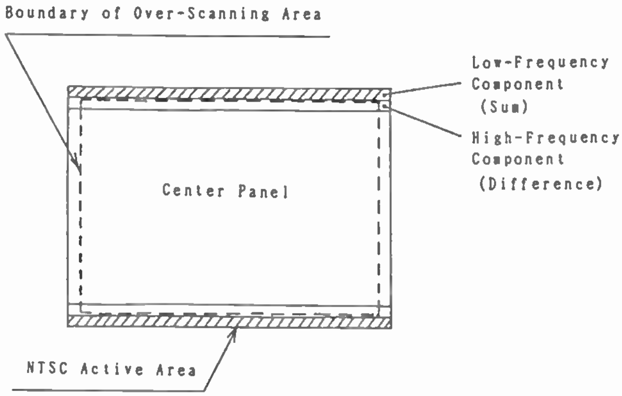


Fig. 7 Arrangement of the side panels

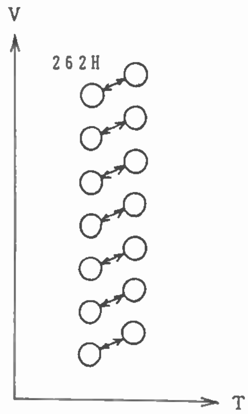


Fig. 8 Location of the object samples

In general, such a separation can be realized by converting n (≧2) samples of the side panels to 1 sample of the "sum" component and (n-1) samples of the "difference" components, using a regular matrix T. In this method, according as the number of samples is made larger, the proportion of the objectionable sum component becomes smaller. Instead, SN ratio of the reconstructed side panels become smaller.

The system has set the value of n in 2, so that the decrease of SN ratio may be minimized. In this case the conversion matrix T and its inverse matrix R are given by

$$T=\begin{bmatrix} a & 1-a \\ -0.5 & 0.5 \end{bmatrix} \quad \text{and} \quad R=\begin{bmatrix} 1 & -2(1-a) \\ 1 & 2a \end{bmatrix}, \quad 0 \leqq a \leqq 1 \qquad (2)$$

respectively. From this, the noise powers of the side panels reconstructed by the inverse matrix R are increased to $\{1^2+[-2(1-a)]^2\}$ and $\{1^2+(2a)^2\}$ times respectively of that of the center panel. Therefore, the system has set the value of a in 0.5 so that the mean of the decrease of SN ratio may be minimized to 1/2 times or -3 dB.

Furthermore, the system has set the interval between the object two samples to be 1 field, i.e. 262 H. The location of these samples is shown in **Fig. 8**. In addition, the horizontal arrangement of the side panels at the top and bottom bars is shown in **Fig. 9**. By these means, the system prevents the side panels at the top and bottom bars from being disturbing.

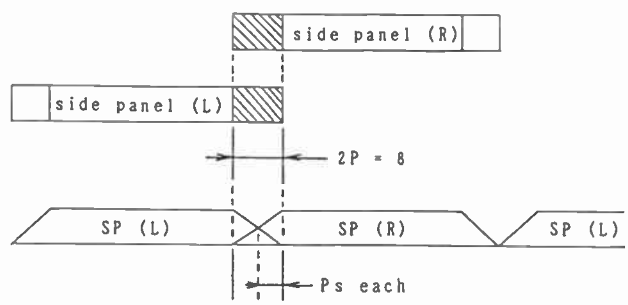


Fig. 9 Horizontal arrangement of the side panels

PROCESSING FOR THE HIGHER PICTURE QUALITY

Subjective Test Results

The system has adopted the extended vertical and horizontal details for enhancing the picture quality, and the diagonal and Fukinuki holes for hiding these enhancement components. This adoption is based on the following subjective test results.[5,6] Equipments used for the subjective test are a 525-line progressively scanned camera, programmable three-dimensional digital filters, and a 525-line progressively scanned display. Observers are 8 experts. Grading scale is comparison 7 scale. Test pictures are 3 still pictures and those they are moved to specific directions. Ratio of viewing distance to picture height is 4. And presentation is random sequence of conditions.

The subjective test consists of the assesment of the picture quality with extended definition and that of the picture impairment with bored hole. The test result on the quality of the still pictures with extended vertical resolution is shown in **Fig. 10**. From this, it is found that the picture quality is improved to grade 1 when the vertical detail is extended from 240 to 480 lph in the horizontal frequency band 0 to 2.1 MHz. Meanwhile, the test result on the quality of the still pictures with extended horizontal resolution is shown in **Fig. 11**. From this, it is found that the picture quality is improved to grade 0.5 when the horizontal detail is extended from 4.2 to 6 MHz with the maximum vertical frequency 480 lph. Therefore, it is concluded that the picture quality is improved when the detail, especially the vertical detail is extended.

On the other hand, the test result on the impairment of the still pictures with bored diagonal hole is shown in **Fig. 12**. From this, it is found that the picture is impaired to only grade -0.3 even if the maximum vertical frequency is decreased from 480 to 240 lph in the horizontal frequency band 2.1 to 4.2 MHz. Meanwhile, the test result on the impairment of the moved pictures with bored diagonal and Fukinuki holes is shown in **Fig. 13**. From this, it is found that with few exceptions, the picture moving vertically or horizontally at the speed 0 to 3 line/field, is impaired to only grade -0.5 even if the both holes are bored. Especially, the picture is little impaired at the speed 3 line/field, because of the storage effect of the camera. Therefore, it is concluded that that the picture is hardly impaired even if the both holes are bored.

Encoding and Decoding

As previously mentioned, at the high resolution encoder, the extended vertical and horizontal details are hidden in the diagonal and Fukinuki holes respectively, then at the high resolution decoder, these details are recovered. The location of these details and holes are shown in **Fig. 14**.[7,8] From this, it is understood that the processing for the higher picture quality can be carried out, individually in the horizontal low (0 to 2.1 MHz), medium (2.1 to 4.2 MHz), and high (4.2 to 6 MHz) frequency bands.

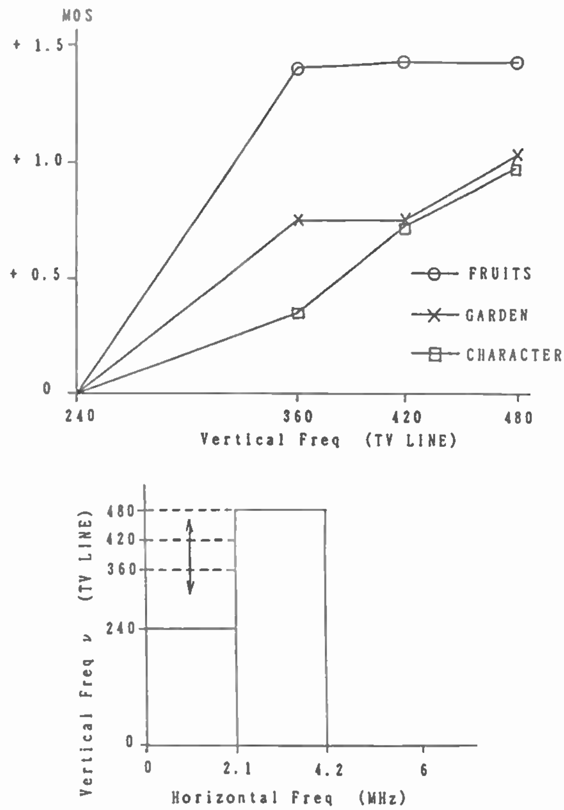


Fig. 10 Improvement by extended vertical details

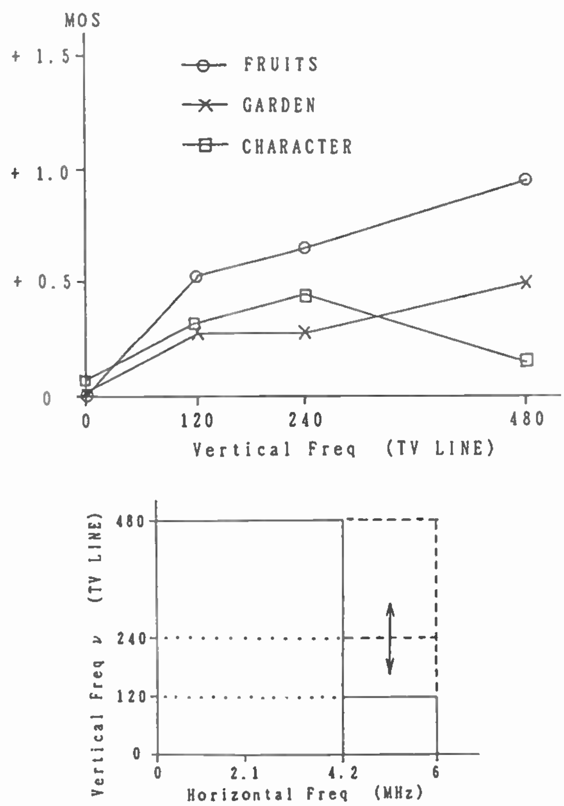


Fig. 11 Improvement by extended horizontal details

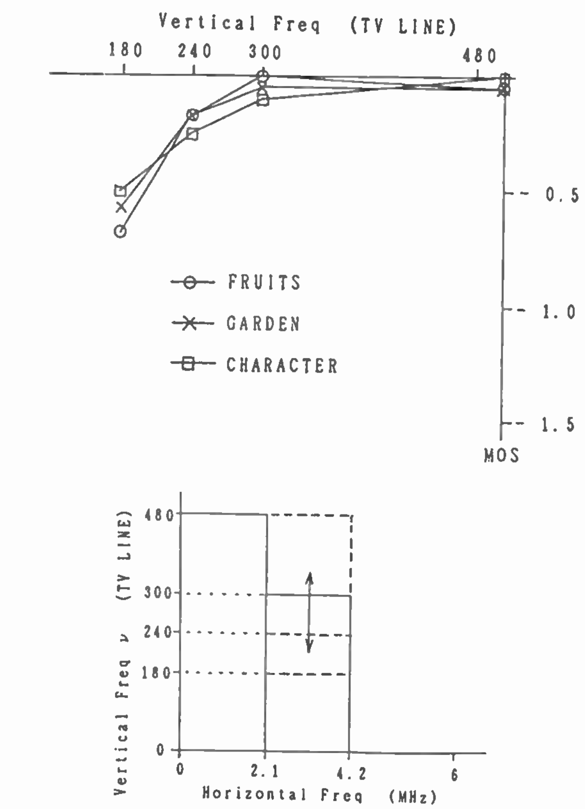
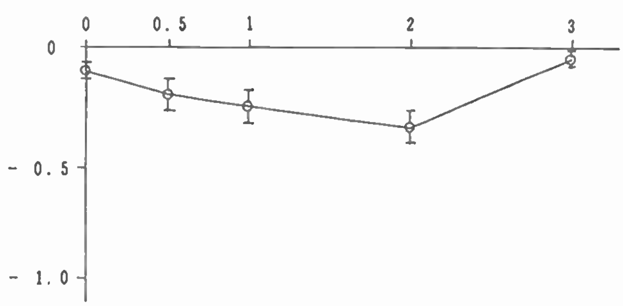
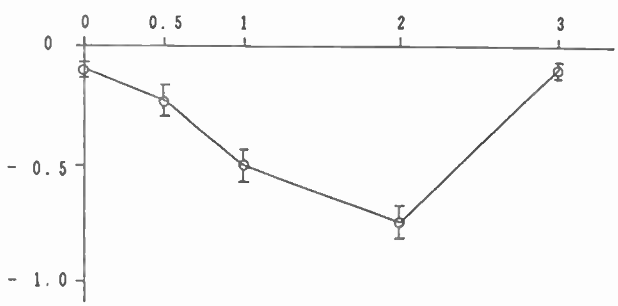


Fig. 12 Impairement by the diagonal hole



(a) Vertical movement



(b) Horizontal movement

Fig. 13 Impairement by the both holes

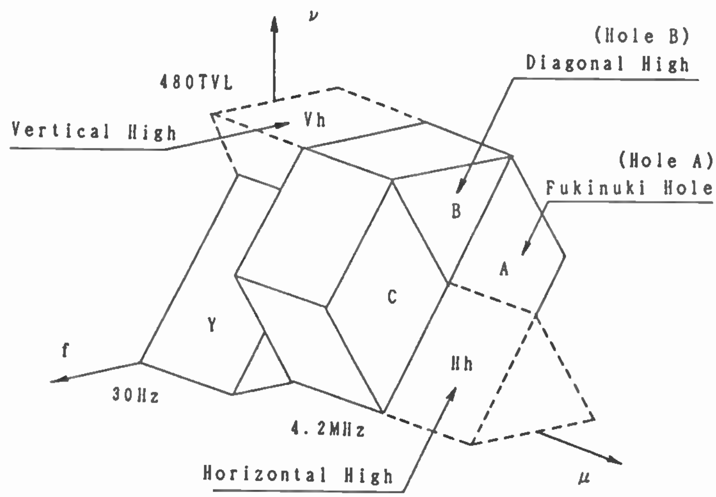


Fig. 14 Locations of the details and holes

Block diagrams of the extended definition encoder and decoder are shown in **Fig. 15**. At the encoder, the luminance signal Y is separated into the low frequency component Y_{low}, the medium frequency component Y_{mid}, the horizontal high frequency component H_h, and the vertical high frequency component V_h, then processed individually.

At the encoder, as for the luminance low Y_{low}, the vertical high component is removed by a vertical low-pass filter (V-LPF), and is converted from progressive to interlace (P→I) by a vertical-temporal low-pass filter (VT-LPF). Then, its horizontal high component is removed by a horizontal low-pass filter (H-LPF).

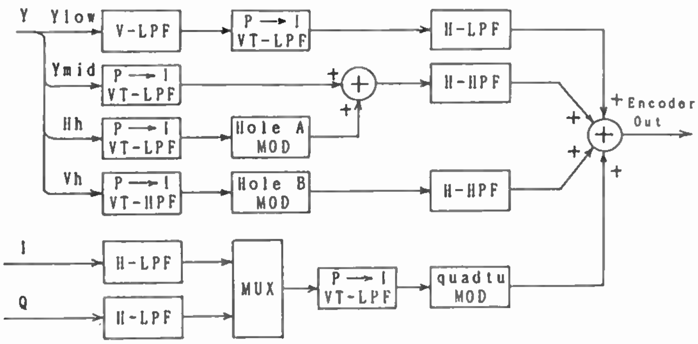
As for the luminance medium Y_{mid}, it is converted from progressive to interlace by a vertical-temporal low-pass filter, and the horizontal high component H_h hidden in the Fukinuki hole is added to it. Then, its horizontal low component is removed by a horizontal high-pass filter (H-HPF).

As for the horizontal high H_h, it is converted from progressive to interlace by a vertical-temporal low-pass filter, and hidden in the Fukinuki hole (Hole A MOD). Then, it is added to the luminance medium Y_{mid}.

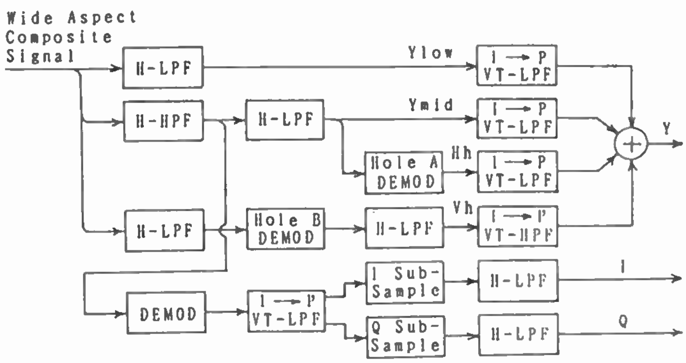
And, as for the vertical high V_h, it is converted from progressive to interlace by a vertical-temporal high-pass filter (VT-HPF), and hidden in the diagonal hole (Hole B MOD). Then, its horizontal low component is removed by a horizontal high-pass filter.

At the decoder, the extended vertical and horizontal details are recovered from the diagonal and Fukinuki holes respectively. Therefore, a picture with extended spatial resolutions is displayed on the EDTV receiver. Without the decoder, the vertical high component in the horizontal low band remains to be removed. Therefore, a picture without interline flicker is displayed on existing receiver.

Furthermore, the above processings are carried out even where motion exists. As a result of this , there are neither unnatural airtifacts nor sudden changes of picture quality caused by the limitations of motion adaptive processing.



(a) High resolution encoder



(b) High resolution decoder

Fig. 15 Block diagram of the encoder and decoder

CONCLUSIONS

One of the receiver-compatible wider aspect ratio EDTV systems for EDTV II in Japan was described.

An EDTV receiver displays a wide picture of which quality is uniform across the display, and in which no visible seam is produced. Existing receiver displays a picture which contains a most portion of the wide picture with sufficient definition and size, and in which the side panels at the top and bottom bars are not disturbing.

Furthermore, the picture displayed on the EDTV receiver has extended spatial resolutions, being free from the limitations of motion adaptive processing. Nevertheless, the picture displayed on existing receiver suffers no interferences.

In the system, any processings for higher sound quality are not included. However, the system can co-exist with many proposals addressing this issue. Finally, we shall be happy, if some elemental technologies of the system are suggestive to the developments of ATV in the United States.

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PROGRAMMING IN HDTV (II): *A World of Its Own*

Tuesday, April 16, 1991

Moderator:
Daniel Le Conte des Floris, French Motion Picture & TV Network, Paris, France

HIGH DEFINITION COMPUTER GRAPHICS
Hirofumi Ito
NHK Enterprises/HD Planets Partnership
New York, New York
Program presented: *Lost Animals*

REAL TIME HD ELECTRONIC INTERMEDIATE PROCESS
John Galt
Sony High Definition Facilities
Culver City, California
Program presented: Demo

OPERA IN HIGH DEFINITION
Dr. Robin Willcourt
HD Pacific Company
Seattle, Washington
Program presented: *War and Peace*

THE LOVES OF EMMA BARDAC
Thomas Mowray and Helmut Rost
German Television ZDF
Mainz, Germany
Program presented: *The Loves of Emma Bardac*

HD—MAJOR LEAGUE STYLE
Brian Ross
John Labatt Broadcast Group
Ontario, Canada
Program presented: *Blue Jays Baseball*

THE CHALLENGE OF INTRODUCING HD BROADCAST SERVICE
Madoka Tsuchiya
NHK (Japan Broadcast Corporation)
Tokyo, Japan
Program presented: *Highlights of HDTV Broadcasting Service*

THE INTEGRATION OF 3-D COMPUTER ANIMATION WITH HD IMAGING
Barry Rebo
Rebo High Definition Studios
New York, New York
Program presented: *Infinite Escher*

HIGH DEFINITION COMPUTER GRAPHICS

Hirofumi Ito
NHK Enterprises/HD Planets Partnership
New York, New York

The challenge of developing full length HD computer graphics programs for broadcast, theatrical. and ancillary use is discussed.

Topics include the development of CG software, using paint systems in HD, and blending live action and HD computer animation to achieve the creative work desired.

PROGRAM: "Lost Animals".
Producer: NHK Enterprises/HD
Planets Partnership.
Director: Hirofumi Ito.
Format: 1125/60.

REAL TIME HD ELECTRONIC INTERMEDIATE PROCESS

John Galt
Sony High Definition Facilities
Culver City, California

65 percent of prime time television originates on 35mm. film, but over 80 percent is post-produced electronically. Clearly the film production industry still prefers 35mm. film as an origination medium, while it recognizes the value of electronic post-production.

The paper explores the applications of the SMPTE 240 M electronic production standard as an electronic intermediate process for images intended for 35mm. film release.

A complete electronic post-production process is described, designed to minimize the losses encountered in the existing photo-mechanical post-production process, while taking advantage of the capabilities of various electronic imaging systems, including computer generated memory, electronic compositing, and the electron beam recording process.

PROGRAM: Demo.
Producer: John Galt.
Format: 1125/60.
Shown on 35 mm. film.

OPERA IN HIGH DEFINITION

Dr. Robin Willcourt
HD Pacific Company
Seattle, Washington

The opera, "War and Peace", was staged on one of the largest opera stages in the U.S. The ability to capture images of 250 actors scattered over 3,600 square feet of stage, and still convey a sense of dynamism, and then to project a sense of intimacy when only three actors were on stage, was vividly demonstrated in the HD production.

For example, the wide screen panoramas still retained textural detail, and helped the richness of the whole production. Angled shots that produced a most dramatic image of one actor, while presenting a quite different impression of another, were achieved by the use of the wide screen and appropriate lenses.

Viewers of this high definition program who have seen the live stage production, aver that the sense of presence and immediacy of a live performance is fully maintained in the HD version.

The true power of the HD medium is to insert itself unobtrusively between the event and the viewer, and to provide a transparent translation from "live" to "electronic".

PROGRAM: "War and Peace".
Producer: HD Pacific Company.
Director: Francesca Zambello.
Format: 1125/60 digital.

THE LOVES OF EMMA BARDAC

Thomas Mowray and Helmut Rost
German Television ZDF
Mainz, Germany

"The Loves of Emma Bardac" is a musical docudrama in which the esthetic objective was to actively visualize the harmony, counterpoint, form, and phrasing of music while simultaneously telling the story of a woman who had love affairs with both of he composers Fauré and Debussy, and who bore a daughter to each of them. The music which they wrote for their daughters by Emma Bardac is realized in this telefilm by the piano-duet team of Katia and Marielle Labeque.

The elements of the production were:
- Performances of 18 short French Impressionist piano pieces;
- Staged dramatic scenes, both studio and location;
- Documentary narration in voice-overs;
- 75 French Impressionist paintings;
- 90 period photographs.

Location photography was done with a Sony 100 HDTV camera and analog VTR, while the Model 300 camera and digital VTRs were used for all studio and insert stage work. Ultimatte, Quantel HD Paintbox and Sony HD DVEs were used liberally.

The $1.4 million production budget required financing from broadcast networks in both PAL and NTSC countries, and from a home-video licensee with CD-video release plans which required preservation of a pure digital soundtrack throughout a post-production process involving almost 1500 edits, each of which was synchronized to music.

HDTV was chosen as the mastering medium because it provided:
1. Live monitoring of the "developed" master on the set;
2. PAL and NTSC down-conversion capability equal to film;
3. The superior editing and special -effects flexibility of an electronic medium;
4. Secure preservation of digital audio throughout production;
5. Shelf life equal to or better than film.

PRODUCER:Thomas Mowray/
Helmut Rost.
Director: Thomas Mowray,
Helmut Rost,
Lee Bobker.
Format: 1125/60. -Digital.

HD—MAJOR LEAGUE STYLE

Brian Ross
John Labatt Broadcast Group
Ontario, Canada

Using the new Telesat Mobile High Definition Production Unit, and through its sister company, Dome Productions, the Group has produced major spectaculars including Canada's Gemini Awards event, which was down-converted for conventional NTSC broadcast, and several major league baseball games.

The creative opportunities and technical challenges of the new production medium as discussed. HD can give the viewer, even the most avid baseball fan, a perspective and a sense of presence that has not been experienced before.

Finally, the manner in which sports and live entertainment production will be effected in the future using HD, is discussed.

PROGRAM: Blue Jays Baseball.
Producer: John Labatt Broadcast Group/Telesat.
Format: 1125/60.

THE CHALLENGE OF INTRODUCING HD BROADCAST SERVICE

Madoka Tsuchiya
NHK (Japan Broadcast Corporation)
Tokyo, Japan

In June, 1989, NHK started a regular one-hour daily HDTV broadcast service. By August, 1990, NHK had produced and broadcast 322 hours of high definition programs, the majority of which were live events including sports.

For soccer's World Cup competition in Italy in 1990, NHK brought HD production and recording equipment to Italy. The production crew travelled 9,000 Km. throughout Italy in covering 15 games.

Sumou wrestling is broadcast live 90 days a year, and is an example of low cost programming shot in HD, and also down-converted to NTSC for conventional broadcast. For wrestling, five cameras are placed around the ring, edit switches being made in real time to assure the best angle of view.

The program shows how some of the special problems faced in live HD production are met and overcome.

PROGRAM: "Highlights of HDTV Broadcast Service".
Producer: Mitahiro Wada.
Director: Madoka Tsuchiya.
Format: 1125/60.

THE INTEGRATION OF 3-D COMPUTER ANIMATION WITH HD IMAGING

Barry Rebo
Rebo High Definition Studios
New York, New York

In producing the story of young boy who convincingly appears to interact within the artworks of the Dutch artist Escher, one of the challenges was to create a shot similar to that of Escher's pencil sketch of two hands drawing each other. The shot was to be from the boy's point of view of his drawing board.

In production, the HD camera was fixed over the drawing board on which shirt sleeves and arms were drawn, but no hands. The boy then simulated drawing the wrists and shirt sleeves of the two arms.

In post-production, a high contrast black and white matte was created on the Rebo "Restore" graphic system, to join the left half of one shot drawing the left sleeve, to the right half drawing the right sleeve, giving the effect of live hands growing out of pencil-drawn arms. This totally convincing illusion had a high production value, but was simple to execute.

PROGRAM: "Infinite Escher".
Producer: Barry Rebo.
Format: 1125/60.

HDTV'S FIRST MARKETS:
A World of Possibilities

Tuesday, April 16, 1991

Moderator:
William Connolly, Sony Advanced Systems, Montvale, New Jersey

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HDTV IN DESIGN SYSTEMS
David Royer
Ford Motor Company
Dearborn, Michigan

PRINTING AND INDUSTRIAL PRESENTATIONS ON APPLICATIONS OF HDTV*
Yukio Oba
Toppan Printing
Tokyo, Japan

HDTV AND HEALTH CARE TRAINING*
Richard Schreier
Health and Sciences Network
Los Angeles, California

TECHNO ART MUSEUM T-BRAIN CLUB ART MUSEUM FEATURING VAN GOGH PAINTING IN HDTV COLLECTION
Shinichi Makino and Kouichi Tabuchi
Toshiba Corporation
Tokyo, Japan

RESULTS OF SECOND EXPERIMENT TO EVALUATE THE USE OF HDTV TECHNOLOGY UNDER OPERATING CONDITIONS DURING AN NSTS LAUNCH
G.W. Beakley, R.S. Prodan and C.R. Caillouet
StellaCom, Inc.
Arlington, Virginia

CAN THE QUALITY OF FILM BE MAINTAINED WHEN TRANSFERRED TO THE HDTV FORMAT?*
Ron Ratner
Club Theater Network
Pompano Beach, Florida

THE MAGIC SYSTEM-1250*
Serge Roux and Michel Oudin
Vision 1250
Brussels, Belgium

HDTV APPLIED IN A COMMERCIAL ENVIRONMENT*
David Niles
Captain New York, Inc.
New York, New York

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*Paper not available at the time of publication.

HDTV IN DESIGN SYSTEMS

David Royer
Ford Motor Company
Dearborn, Michigan

ABSTRACT

After a brief overview of how cars are designed today, and how designers plan to use computer technology to design cars in the future, Mr. Royer will be referring to two different types of computer aided design. The two dimensional Shima Seiki paint system which uses HDTV display technology and various three dimensional modeling computers. During his presentation he will explain the advantages of HDTV over other computer displays.

INTRODUCTION

After a brief overview of how cars are designed today, I will be describing two different types of computer aided design that we are using or experimenting with. A two dimensional paint system and various three dimensional modeling computers.

PAINT SYSTEM

The Shima Seiki Paint System, which uses high definition video to display images is already being used on all programs at Ford Design today. This two dimensional paint system is used as a concept sketch pad and a photographic re-toucher's tool in the design process. The images created or modified on this computer are reviewed on large Sony HDTV monitors or projected by Barco 1001 projectors. The images, which can be stored on hard or optical disks and magnetic tape, can also be copied on thermal and ink jet printers.

WHY HDTV?

. The monitors are much larger than those used on most computer work stations and about the same size as a sketch on paper would be. The projected image only has to be about 10 times larger to be full size. (The typical computer monitor image would have to be almost 20 times larger to be full size.)

. With the wide screen aspect ratio images of cars fill the screen and make more effective use of the resolution available.

. There are HDTV cameras and video tape recorders available today which make it possible to capture images instantly and create animations.

. Since we're using this system internally we don't need to wait for an agreement on a broadcast standard.

CAD

Three dimensional modeling systems are being experimented with in Pilot Studio 2000X. The Engineering draftsmen at Ford are already using this kind of technology on all programs. The designers are developing a similar system, more user friendly to the designer, with various computer companies.

TECHNO ART MUSEUM T-BRAIN CLUB ART MUSEUM FEATURING VAN GOGH PAINTING IN HDTV COLLECTION

Shinichi Makino and Kouichi Tabuchi
Toshiba Corporation
Tokyo, Japan

ABSTRACT

A museum is open at Tokyo featuring van Gogh paintings in HDTV. Up to 200 van Gogh paintings are collected in HDTV file. Visitors can easily retrieve van Gogh pictures in accordance with their favor. HDTV picture files constructed of optical video disc and still picture storages stores van Gogh paintings, and the data stored are sent to the display in accordance with the command by visitor retrieving.

PREFACE

Through the experimental base actual HDTV broadcasting experience via Japanese DBS (Direct Broadcast Satellite) for more than one year, MUSE broadcasting is proved to be feasible for the consumer level HDTV broadcasting. Japan is likely to be slowly moving toward actual HDTV broadcasting. The programs for the HDTV commercial base broadcasting are expanding, aiming at the commencement of HDTV DBS expected at the end of this year.

Toshiba is known as one of the leading Companies in the HDTV equipment field. Toshiba is the only Company which developed MUSE encoder with NHK. This means that Toshiba is the only Company which is developing HDTV whole end to end line-up from camera to display.

The commencement of the HDTV DBS would be promoting the utility of HDTV in every field of the visual communication and application. HDTV is expected as the infrastructure of the new generation visual technology.

HDTV SYSTEM

Potential applications of HDTV spread to wide fields, not only broadcasting, but many areas of industrial applications. Typical examples are;

- Mini-theater,
- Museum,
- Conference,
- Pre/Post production, and
- Street HDTV Display for any kind of promotion.

HDTV is almost 5 times higher in its information handling. This means that the detailed picture can be displayed on its screen. The aspect ratio of 16:9 is designed so as to match human eye acceptance of the natural picture. High quality natural HDTV picture is attractive for all viewers.

HDTV MUSEUM in TOKYO

One of the typical HDTV applications is the utility in 'museum'. Toshiba is contributing to some HDTV Museums in Japan. Techno Art Museum nicknamed as T-Brain is newly open at the north part of Tokyo in November, 1990, featuring van Gogh famous paintings in HDTV file. This is set for the various purposes of art appreciation.

The museum is divided into three sections, one is a mini-theater with 40 seats showing the programmed van Gogh stories with fine paintings, the second consists of three booths for retrieving van Gogh paintings, the last is an NTSC visual workshop for every visitor. The whole equipments are center controlled from the controlling room.

Mini-Theater

The mini-theater is equipped with 150 inch HDTV rear projector. The projection element is constructed of 6 9inch CRT projection units. Every 10 minutes, one of 10 van Gogh picture series programs is shown in this theater. (Several of them will be demonstrated at Toshiba's booth at this NAB HDTV World.) Some are still pictures, while other programs feature van Gogh paintings and beautiful movies.

All HDTV data of van Gogh paintings are stored in Optical Video Disc Files. Movie picture information is stored within HDTV tape. 1 inch VTR, 1/2 inch HD-VCR, and MUSE broadcasting are the HDTV movie program sources of the theater. NTSC signals are up-converted and displayed on the HDTV screen, as well.

Program selection is made by the terminal 10 keys hooked to the lap-top center computer through RS422 serial line interface. Any programs stored in the picture files as well as VTRs can be selected remotely from the display room.

HDTV Retrieval Booth

The museum has three booths for retrieving of the 200 van Gogh paintings. Two booths are equipped with 36 inch CRT displays, while the other has 50 inch rear projection display. Anyone can retrieve his preferable van Gogh paintings through the lap-top computer set in each booth.

At the first time, menu is displayed on the HDTV screen. A visitor can select the picture from the menu. After a few seconds, he can watch his preferable picture on his screen. He can also watch the magnified portion of the picture after he hits the command key.

The control command is sent from his lap-top computer to the host lap-top computer through RS422 serial interface. Three retrieval modes are compared at the initial booth design, which are;

1) Input retrieval information by full key board entry,
2) Input retrieval information by using mouse and click, and
3) Input retrieval information by using 10 key number.

The first 1) input might be instantaneous, if a visitor is accustomed to operating computers. Designing the control software should be done very carefully so as not to induce malfunctioning. 2) is also convenient for a visitor who is familiar with a mouse. The percentage of them are not so high. 3) is the because everyone is used to 10 keys on a telephone or a calculator. As a consequence, input interface is selected as 10 key selection and entry for everyone's convenience.

SYSTEM CONFIGURATION

The system block diagram is illustrated in Figure 1.

Equipments

most common method for the input, museum are listed in Table 1. There are some newly developed equipments provided for the museum. A brief description of the equipments are listed in the following.

HDTV Still Picture Storage

An HDTV still picture storage consists of an HDTV frame store, a 12 inch optical video

TABLE 1 EQUIPMENTS USED IN THIS MUSEUM

1) HDTV STILL PICTURE STORAGE	4 SETS
HDTV FRAME STORAGE	TFS-500
12 INCH OPTICAL VIDEO DISC UNIT	WM-S500A
RETRIEVAL COMPUTER	J3100-GT
2) 1 INCH HDTV VTR	1 UNIT
ANALOG 1 INCH HDTV VTR	TVR1000/TTB1000
3) 1/2 INCH HDTV VTR	1 UNIT
ANALOG 1/2 INCH HDTV VTR (UNIHI)	HV-8900
4) MUSE DECODER	2 UNITS
LSI MUSE DECODER (COMMERCIAL BASE)	TT-MD5A
5) NTSC-HDTV UP-CONVERTER	1UNIT
COMMERCIAL TYPE UP-CONVERTER	TCU-1125
6) ROUTING SWITCHER	1 SET
7) 150 INCH HDTV REAR PROJECTOR	1 UNIT
6 9 INCH CRT TYPE PROJECTOR	PH9150
8) 50 INCH HDTV REAR PROJECTOR	1 UNIT
3 7 INCH CRT TYPE PROJECTOR	P500SR1
9) 36 INCH HDTV MONITOR	2 UNITS
DELTA-GUN COMMERCIAL USE MONITOR	P36HD00
10) 32 INCH HDTV MONITOR	1 UNIT
IN-LINE GUN HIGH BRIGHTNESS MONITOR	P32HI01
11) 21 INCH HDTV PICTURE MONITOR	10 UNITS
12) SYSTEM CONTROLLER	1 SET
LAP-TOP COMPUTER	J3100-SGT
SYSTEM INTERFACE	TIF-100

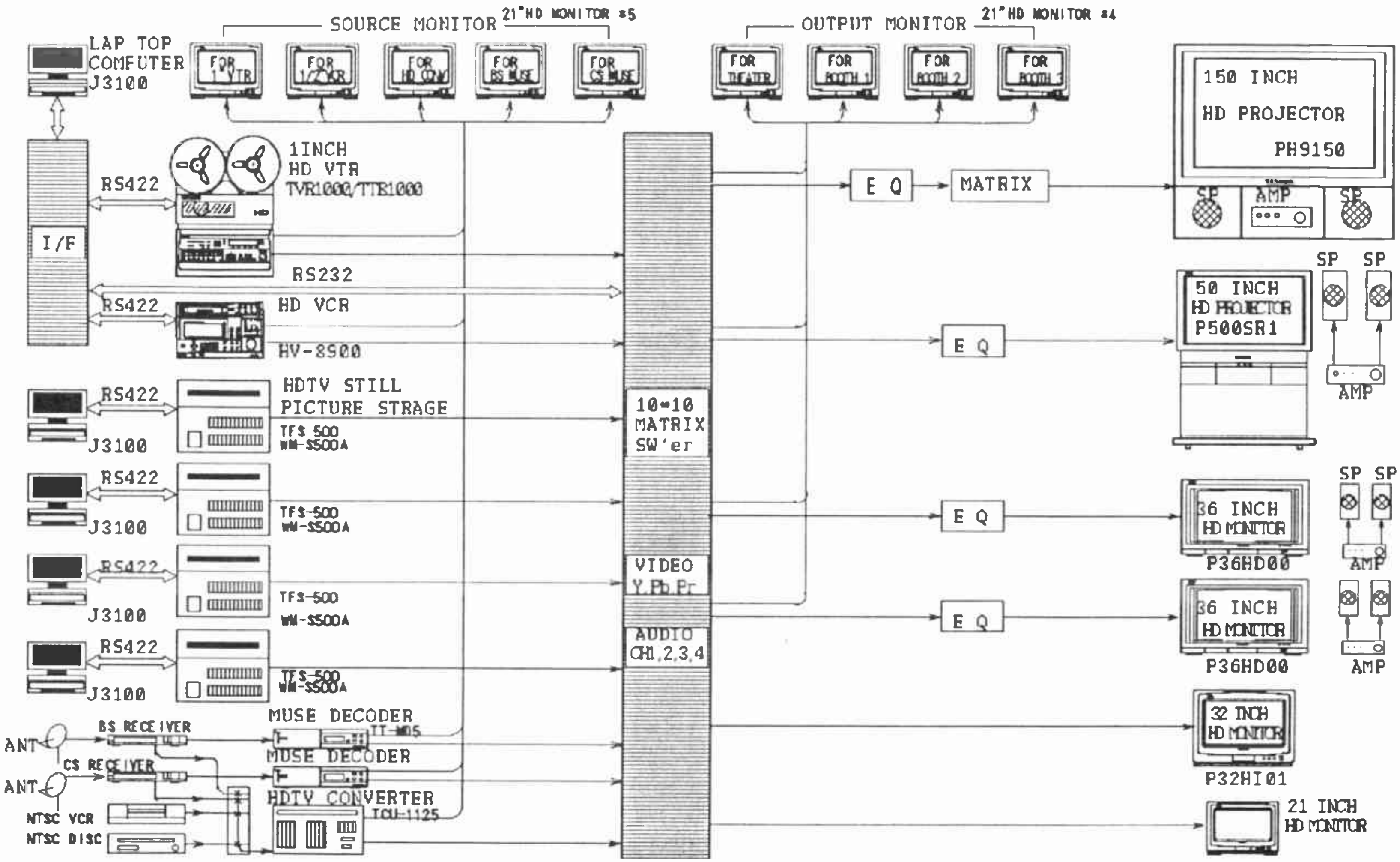


Fig. 1 SYSTEM BLOCK DIAGRAM of T-BRAIN CLUB

disc unit, a CD-ROM player, and a lap-top computer.

The optical video disc is an electronically "writable" type, and can contain up to 600 HDTV fullband pictures. Any pictures can be retrieved by the command through the computer. Sound information such as narration and BGMs(back ground music) is stored within the CD-ROM.

The HDTV frame storage can store up to 72 HDTV fullband frame pictures within one unit. The reproduction modes are computer controlled, which are ordinary reproduction, cut, wipe, and scroll. Thanks to the capability to store 72 frames, a visitor can instantaneously retrieve his favorable picture.

This HDTV frame store is also very powerful for the computer HDTV graphics and animation. Up to 72 computer synthesized picture frames can be stored within this frame storage and can easily be checked if the picture performance is favorable to the author or not before recording them into an HDTV VTR.

In Table 2 the specification of the HDTV frame storage is listed.

The HDTV optical video disc also contains the information of menu and retrieval procedure. These data are recalled after system power turned on. Then, any optical video discs of different content with retrieval information can be applicable when the data are the same format. This is convenient for the interchanging of the museum information. This system is applicable any types of data storage to interchange the information.

TABLE 2: HDTV FRAME STORE

Input signal	Digital Y(1920*1035),Pb(960*1035) Pr(960*1035) SCSI transmition Analog Y(30MHz),Pb(15MHz) Pr(15MHz)
Output signal	Analog Y(30MHz),Pb(15MHz) Pr(15MHz)
Control signal	RS-422,RS-232c (Toshiba protocol)
Audio	CD standard
Effects	Cut Wipe (seven types) Scroll (vertical/horizontal)
Sync. signal	Tri level sync. Internal / External lock
Quantization	eight-bit
Power consumption	100V 50Hz/60Hz 500W
Weight	40Kg(88.21bs)
Dimensions	430(W)*335(H)*620(D)mm (16 15/16"*14"*24 3/8")

HDTV Display

A still picture display is much more difficult to implement than a moving picture display, because display performances such as convergence, uniformity, and shading are easily evaluated by a still picture. This museum is equipped with four different displays.

A 150 inch rear projection display is designed so as to comply with the professional demonstration requirement. This is a bright and carefree display, which is easy to maintain. The specification is listed in Table 3.

A 32 inch CRT display is designed for the future consumer use. The display consists of cost effective components, while keeping the performance excellent. The picture on its screen is natural and attractive. The specification of a 32 inch monitor is listed in Table 4.

TABLE 3: 150" rear projection display

Projection system	Rear projection
Screen size	150 inches
CRT's	9"CRT*6
Number of scanning lines	1125 lines
Picture aspect ratio	16:9
Field Frequency	60Hz
Line Frequency	33.75 kHz
Interlace ratio	2:1
Resolution	H 1000, V 750 (TV lines)
Picture brightness	40 Ft-L
Video input	R·G·B HD,VD
Power consumption	530 W

TABLE 4: 32" CRT display

CRT	Size	32 inches
	Deflection angle	110 degrees
	Neck diameter	37.5 mm φ
	Dot trio pitch	0.6 mm
Number of scanning lines		1125 lines
Picture aspect ratio		16:9
Field Frequency		60Hz
Line Frequency		33.75 kHz
Interlace ratio		2:1
Resolution		H 800, V 750 (TV lines)
Picture brightness		60 Ft-L
Video input		Y/Pb,Pr R·G·B HD,VD
Power consumption		220 W
Weight		Approx.70 Kg
Dimensions		822(W)*619(H)*658(D)mm

REACTIONS FROM VISITORS

At the first time when this museum is demonstrated to the press, the result was fine. Then, many visitors came. As of middle of January, almost two months since its opening, visitor count is around 8000 .

Many students came who study paintings. van Gogh might be one of the typical painter examples. The commentary of the mini-theater is written by a famous professor, which is also a good explanation of the van Gogh.

The retrieval is easily done. Up to now, almost no complains for the procedure raised. At the retrieval booth, some visitors are occasionally devoted to controlling the machine for hours, occupying the booth. They are so impressed that they can watch so many van Gogh paintings even they are in Japan. They also admire van Gogh's painting skill, seeing the details in his enlarged paintings.

The van Gogh paintings data are stored in the digital storage and easily retrieved, it is effectively utilized as the museum data.

ANOTHER MINI-THEATER

Toshiba opened the other mini-theater in Toshiba's Science Institute in Kawasaki City, which is located next to Tokyo. A 200 inch rear projection display is the main equipment. Toshiba produced several programs for the demonstration. Many foreigners visit that facility. Then the software have no dialogue. In other words, we need not translate the theme or content. These attractive programs are bright in its scenery and understandable without dialogue. Through this experience, we understand that programming is the key to success.

The resolution of the display is more than 1000 TV lines. The brightness is also high, because the CRTs for the projector is 6 of 9 inch specially designed ones for HDTV. And computer controlled system is introduced with 1 inch and 1/2 inch analog HDTV VTR.

CONCLUSION

A van Gogh museum is open utilizing the Toshiba's experience in HDTV fields. The equipments for the system are designed and installed so as to be user friendly. Reactions from visitors are well and the system works without any trouble.

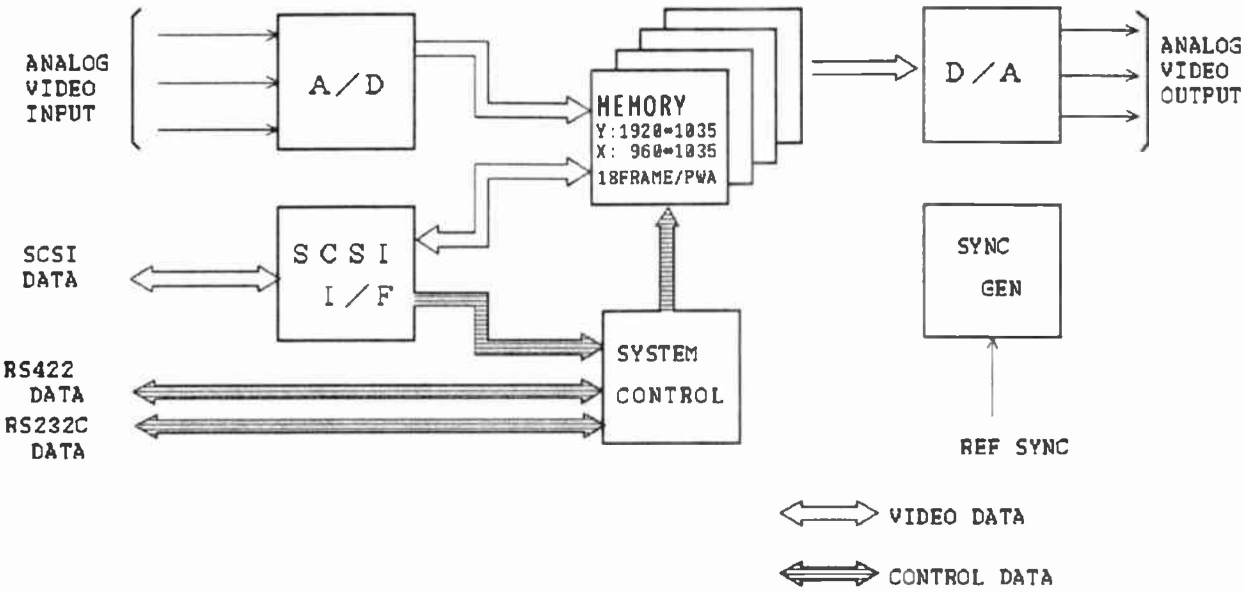


Fig. 2 HDTV FRAME STORAGE BLOCK DIAGRAM

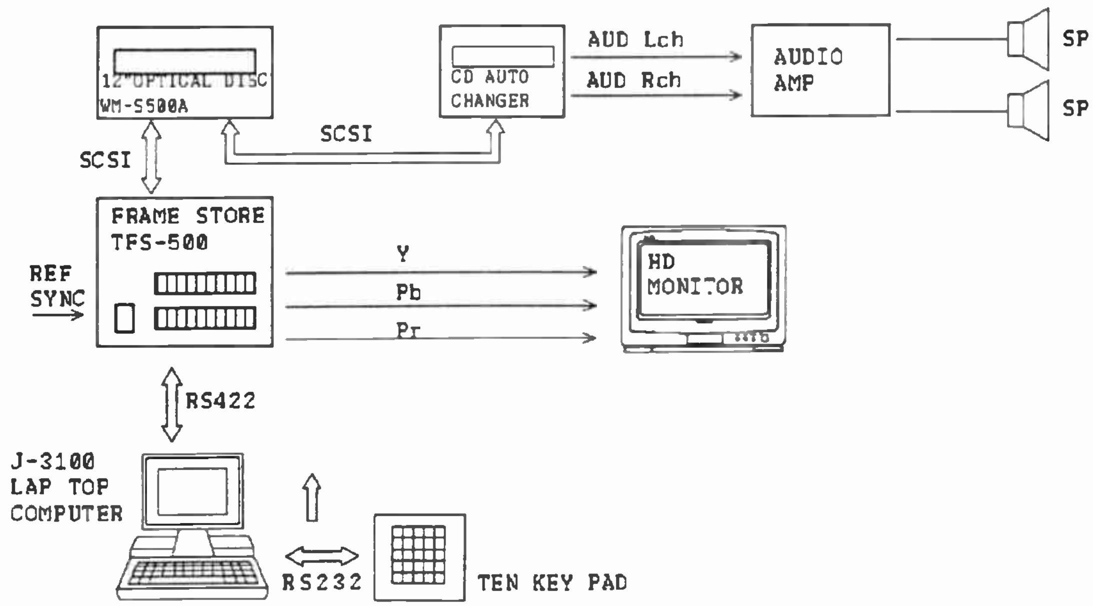


Fig. 3 HDTV STILL PICTURE PLAYBACK SYSTEM

Tokyo international arts museum

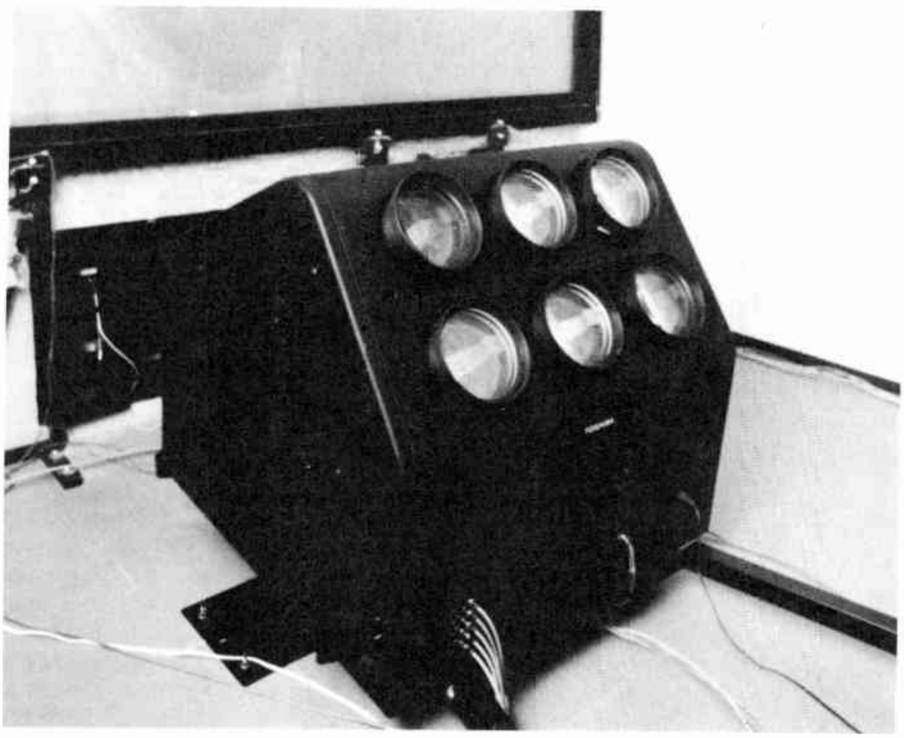
Mini-theater

HDTV retrieval booth

Control room

HDTV still picture storage

150 inches rear projection display



RESULTS OF SECOND EXPERIMENT TO EVALUATE THE USE OF HDTV TECHNOLOGY UNDER OPERATING CONDITIONS DURING AN NSTS LAUNCH

G.W. Beakley, R.S. Prodan* and C.R. Caillouet
StellaCom, Inc.
Arlington, Virginia

ABSTRACT

A second experiment employing High Definition Television (HDTV) technology for use in launch operations, communications and media post-production was conducted in a cooperative effort among NASA, NHK, Rebo Research and TSM. One new objective in this experiment was to use the latest generation HDTV equipment to control via fiber optics an HDTV camera located in an unmanned environment close to the launch pad. It followed a previous experiment in 1989 that determined the adaptability of then available HDTV equipment to the unique operational requirements of launch control and suitability for real-time image analysis. The use of high definition video is being evaluated by NASA for launch support of the National Space Transportation System (NSTS) and for other uses in space. Standard NTSC video cameras are presently employed for operational support of an orbiter launch. The increased resolution and wider field of view of HDTV can offer potential advantages by providing higher quality video with greater detail and realism and a real-time alternative to fast turn-around film. Besides the advantages to NASA's operational support, the use of HDTV can provide the highest quality video material for media dissemination via a new advanced television standard for terrestrial distribution. Such a standard is likely to evolve in the next few years in the U.S. This demonstration of HDTV technology yields valuable experience and insight in the development of television for NASA's present and future activities in the space program.

INTRODUCTION

A high definition television (HDTV) video system, including cameras, tape recorders, and a fiber optic transmission link was established for an experiment which evaluated HDTV as a launch operations support capability during the STS-32 space shuttle mission at the Kennedy Space Center. This report describes the test objectives, the experimental equipment characteristics and deployment, the technical performance, and the operational issues associated with the use of HDTV technology in NASA applications.

The objectives of the experiment are listed in Section I. The HDTV video system and the characteristics of the constituent components are described in Section II. Sections III and IV present the performance tests and results for the cameras and fiber optic link. The remote camera control system is described in Section V. Technical observations on various aspects of the HDTV video system performance are discussed in Section VI. Operational considerations and concerns are addressed in Section VII. Conclusions and recommendations are summarized in Section VIII.

I. OBJECTIVES

A high definition television experiment was conducted in conjunction with the launch of the NASA STS-32 space shuttle mission. This was a follow-up to the HDTV test conducted during the launch of STS-29 [1]. The principal differences in the tests are found in items A and B in the objectives for the STS-32 experiment that follow.

A. Investigate the feasibility of remotely controlling an HDTV camera, lens and pan/tilt unit in an unmanned environment.

B. Evaluate the new generation of HDTV cameras and lenses.

C. Obtain the best recording possible of a space shuttle launch at this stage of high definition television development.

D. Evaluate the feasibility of using available equipment to cover such events under actual operating conditions.

E. Identify the level of support required to use the systems effectively.

F. Explore the advantages and disadvantages of using HDTV for operational support of a shuttle launch.

*Now with CableLabs, Inc.

G. Collect materials for use in future testing of advanced television systems and in future NASA and media demonstrations of advanced television technologies.

II. SYSTEM DESCRIPTION

Four latest generation HDTV cameras were used in this experiment. Two were Sony HDC-300 high definition cameras [2], the second generation camera made by this manufacturer. These one inch Saticon tube cameras were more sensitive than the HDC-100 cameras used in the STS-29 launch. Two cameras were prototype Ikegami HL-1125 High-gain Avalanche Rushing Amorphous Photo-conductor (HARP) high sensitivity cameras [3]. These cameras use three two-thirds inch HARP tubes with high performance magnetic focus, electro-static deflection electron optics. All cameras operated at 1125 lines per frame, 60 fields per second, 16:9 aspect ratio, 2:1 interlace and with tri-level sync per SMPTE standard 240M. One camera was configured for Green, Blue, Red (GBR) operation, with each output having 30 MHz video bandwidth. The other cameras were configured for luminance and color difference (Y,Pb,Pr), with 30 MHz luminance and 15 MHz color difference.

For this experiment, the HDC-300 cameras used HDTV lenses and the HL-1125 cameras used NTSC lenses due to the unavailability of HDTV camera lenses for a 2/3 inch tube format. The two high definition lenses were Fujinon HR-22X18 lenses, one with 2X extender and one without. The other lenses were a Fujinon A44X9.5-BEP-88MP lens and a Canon J50X9.5B-IE. Two other lenses, a Nikon R7x12A-HD2 lens and Fujinon HA-14X8-BRD-N5 were also available but not used for the launch sequence.

Four camera sites were equipped for this test. Three of the sites were configured around standard-sized passenger vans with rear seats removed and high definition cameras, recorders, and monitors installed. Some of the vans were equipped to record launch audio as well. Each van towed a trailer-mounted generator capable of at least 10kw of electrical power at 117 VAC. The three van crews operated independently during the launch, with pre-determined requirements for views at various launch phases and video operation procedures. Each crew consisted of a camera operator, a video operator, and where allowed, a production assistant/translator. Crew members were American and Japanese engineers with varying degrees of experience in HDTV production.

The fourth site was located in a limited access area because of its proximity to the launch pad (Launch Complex 39, Pad A). This camera site was chosen because of its closeness to the pad and existing optical fiber connectivity with the KSC L-39 Press Site. A high definition camera was mounted on a remotely-controlled pan/tilt unit with control signal and video signal connection to a control trailer at the Press Site. The signal connection was made through the same optical fiber used in the previous high definition test coverage of the STS-29 launch. During the STS-29 test, the camera site was manned for a launch from LC-39, Pad B, which was farther away from the camera site. Since the site is less than 1 mile from Pad A, the camera and lens parameters were controlled by two operators located in a safe place approximately 3 miles from the pad.

Video was recorded at two camera sites with Sony HDV/HDT-1000 analog high definition recorders. These are one inch reel-to-reel machines capable of 20 MHz luminance, 10 MHz color difference and two channel 15 kHz audio recordings using a mixed highs 4 channel format [1]. Two digital Sony HDD/HDT-1000 high definition recorders were used to capture the output from the other two cameras. These are one inch reel-to-reel machines capable of 30 MHz luminance, 15 MHz color difference and eight channel 20 kHz audio recording using SMPTE 240M component format.

Two Panasonic AU-HD1055/AU-HP1055 high definition recorders were used for preliminary scenes such as helicopter views of the pad before launch, but were not used during the launch sequence. These recorders are half-inch reel-to-reel analog high definition recorders capable of 20 MHz luminance, 7 MHz alternate line color difference and four channel 20 KHz audio recording. A major difference from the other high definition recorders is the utilization of alternate line chroma recording to reduce bandwidth requirements. Time was not sufficient for evaluation of these recorders during the tests.

The launch occurred from KSC Launch Complex 39, Pad A. The following camera locations were used:

Camera	Location	Configuration
Camera A	Fire Training Tower (4.0 miles from pad A)	HDC-300 camera, Tripod mounted, manually directed with 22 x 18 zoom lens, 2 times extender (36-792mm), HDV-1000 analog VTR.
Camera B	Beach Access Road, pad A (2.0 miles from pad A)	HARP camera, Tripod mounted, manually directed, with 50 x 9.5 zoom lens, 2x extender (19-950mm), HDD-1000 digital VTR.
Camera C	Lake Site, Astronaut Rd. (4 miles from pad A)	HARP camera, Tripod mounted, manually directed, with 44 x 9.5 zoom lens, 2x extender(19-836mm), HDV-1000 Analog VTR.
Camera D	Beach Road, Remote Tracking, Pad B (0.8 miles from pad A)	HDC-300 camera, Tripod mounted, remotely directed, with 22 x 18 zoom lens (18-396mm), HDD-1000 digital VTR and down-converter located at Press Site.

Camera D, configured in the GBR model, was mounted on a TSM Model HS-110P remote pan/tilt unit. The unit was locally powered and controlled via a simplex 9600 baud digital channel from a computerized TSM ACP-8000 control system in the control trailer. The digital channel was a modified RS-422 circuit carried on a dedicated wideband channel through the high definition fiber link described in Section V. A Sony digital high definition video recorder (DVTR) HDD-1000 recorded the signal from the camera. The source was fed to the DVTR from the fiber optic receiver to provide digital recording of the video. The output from camera D was downconverted to NTSC using a Sony Downconverter and made available to the media.

III. CAMERA TESTS

One Sony HDC-300 camera, one Ikegami HL-1125 HARP camera and five lenses were evaluated in order to ascertain the resultant image quality of the launch material.

A. Sensitivity

The Sony HDC-300 camera was tested with both the standard Nikon 12-84mm, f/1.8 HDTV zoom lens and the Fujinon 22x18 mm f/1.8 HDTV zoom lens. Both lenses provided identical results. The Ikegami HL-1125 was fitted with a Fujinon 9.5-420mm f/1.4, NTSC camera zoom lens. The relative aperture of the lens was measured when imaging a 90% reflecting object with 2000 lux (185 foot-candles) at 3200°K with unity video gain and with gamma correction off.

The sensitivity of the HARP camera in the normal sensitivity model is between one-half and one f-stop more sensitive than the HDC-300, which is about as sensitive as conventional NTSC studio cameras. It should be noted that the HDC-100 cameras tested for the STS-29 launch had approximately one f-stop less sensitivity than the HDC-300 [1].

The Ikegami HL-1125 cameras employ HARP camera tubes which may be used in a high-gain, low light (i.e. high sensitivity) mode. The sensitivity measurements were repeated for a low light level to determine the sensitivity gain in the high sensitivity mode. The illumination level was reduced to 215 lux (20 foot-candles).

The increased gain of the HARP tube in the high sensitivity mode achieves a further increase in sensitivity of one f stop. The new generation cameras do indeed provide much needed higher sensitivity in order to obrain better depth of field during a dawn or dusk launch.

B. Resolution

The camera systems were measured for resolution using a Century Precision Optics test chart. The modulation depth was measured using a waveform monitor on the luminance channel output. With the degradation caused by the optics, and to a lesser extent the amplifiers, the horizontal resolution with modulation depth of 50% occurred at approximately 600 TV lines for the HDC-300 with 22 x 18 mm HDTV lens. The limiting horizontal resolution (10% modulation depth) for the HDC-300 camera systems was extrapolated to over 1000 TVL. The effect of the digital processing lowered the limiting resolution below 1000 TV lines due to the Nyquist limit of 1000 TVL imposed by the sampling frequency. The two HDC-100 cameras tested for the STS-29 launch [1] yielded 600 TVL at 50% modulation depth and 800 TVL limiting. The improved limiting resolution of the second generation Sony camera provides more detail for launch analysis.

C. Signal-to-Noise Ratio

The (un)weighted signal-to-noise ratio is defined as the ratio of a 100% amplitude luminance voltage level to the (un)weighted rms noise voltage amplitude within the video bandwidth on a quiet (black level) TV line. The noise was measured in the green, red and blue channels using a spectrum analyzer. The black level was set at 10% peak white (10 IRE) to avoid black clipping and compression of the noise. The spectral plots were numerically integrated to calculate the total (un)weighted noise power. Details of this measurement are found in reference 4.

The signal-to-noise ratios for the new generation cameras, were roughly equivalent to that of the HDC-100 used in the earlier launch. The weighted signal-to-noise ratios found in these tests fall within saturation values of subjective viewing tests [5], corresponding to nearly imperceptible degradation at the postulated HDTV viewing distance of half that of NTSC.

IV. REMOTE FIBER OPTIC LINK

The fiber optic link from camera D to the press site is shown in Figure 1. The approximate distances of the fiber transmission path are 1.5 km for the section from the press site to the Launch Control Center (LCC), 5.6 km from the LCC to Pad A and 1.3 km from pad A to the camera site. Most of the fiber was single mode, single window fiber for transmission at 1300 nm.

A Rebo Research High Definition Optical Transmission System was used for the transmission of the GBR signals to the DVTR and the transmission of the control signals back to the pan/tilt unit. The Rebo unit called ReFlect uses frequency division multiplexing of the three frequency modulated video component channels of more than 30 MHz baseband video bandwidth each. Although the unit allows full duplex transmission of two sets of video components in two directions on one fiber, it was used in the simplex mode at 1300 nm.

The launch configuration of the ReFlect system carried the green, blue and red video signals from the camera-control unit on the three video channels from the camera site to the operator site. Those channels would normally carry the video from the camera head to the camera control unit. The distance involved in this experiment did not allow operation in the normal configuration. One of the channels from the operator to camera site carried the TSM "RS-422" data in a simplex mode from the TSM control computer to the pan/tilt unit. Another channel to the camera site carried an iris control voltage from a field-designed control unit to the modified Fujinon lens at the camera site. The third channel to the camera site was not used. The three channels in that direction would normally be used for camera head sync, viewfinder video and a spare video channel.

Transmission signal quality tests were made on the fiber optics transmission system with the same equipment used in the camera tests, augmented by a programmable Magni HDTV test signal generator with SMPTE 240M standard red, green, and blue video output signals. The resolution (i.e. baseband bandwidth) and the received video signal-to-noise ratio measurements are presented in the following sections.

A. Amplitude vs. Frequency Characteristic

A multi-burst signal from 2 MHz to 40 MHz from the Magni generator was transmitted through the fiber optic system. At the other end of the fiber, the green output was reasonably flat and clean out to 40 MHz. A slight attenuation of about 1 dB occurred in the amplitude response at about 16 MHz. The Red signal showed a similar attenuation at about 24 MHz. Otherwise the signals were reasonably flat to 40 MHz.

B. Signal-To-Noise Ratio

The unweighted and weighted signal-to-noise ratios in 30 MHz for the green, blue and red channels are given in Table 1.

	Unweighted	Weighted
Green	54 dB	64 dB
Blue	51 dB	61 dB
Red	51 dB	63 dB

Table 1: Rebo ReFlect fiber optic transmission system signal-to-noise ratios.

V. REMOTE CAMERA CONTROL SYSTEM

In support of the remote camera control test objective, Total Spectrum Manufacturing, Inc. (TSM) agreed to provide a Model H5-110P remotely controlled pan/tilt unit with a Model ACP-8000 computerized controller. The system was designed to operate over an 9600 baud RS-422 link but was modified for communication over one of the video channels of the Rebo Research fiber optic link.

The TSM system was field modified to provide direct control of the Fujinon HR22x18SD focus and zoom servos. The TSM system normally provides such control, but the lens interface was unknown up to the time of the test and the lens required significant on-site modification prior to the test. The iris interface was handled external to the TSM system in order to simplify the interface and provide some redundancy to protect the camera system.

The controller consisted of a microcomputer with alphanumeric keyboard and touch screen display and a custom panel with two joysticks and two rotary knobs. The function of each control on the custom panel is programmable as is the rate and response profile of each function and the travel limits of each device. The keyboard and display are used to control the system modes, the setup of single or multiple camera movements, and the storage and retrieval of configurations and preset movements on computer disk. Limits of travel and reference scenes can also be defined for later use. The system can control up to 8 cameras with pan/tilt, lens, and pedestal control if required.

VI. TECHNICAL OBSERVATIONS

A. Image Quality

The pictures reproduced by the HDC-300 cameras were sharp, and the color fidelity was excellent. The HL-1125 cameras with NTSC lenses were reminiscent of the HDC-100 cameras with 35mm film lenses used for coverage of the STS-29 launch.

B. Resolution

The Sony HDC-300 with Fujinon 22x lens exhibits true "high definition" performance, reproducing an uncorrected resolution of 900 TVL at 25% without aperture correction. This is a significant improvement over the HDC-100, even with the shorter Nikon 7x lens. Several checks with a multi-burst chart and a radial resolution chart verified the high resolution numbers of the Sony camera system. Only moderate aperture correction was required to produce pictures of utmost clarity. As in the STS-29 test, the atmospheric distortions caused a serious loss of fine detail at distances greater than a mile from the pad. Convection currents due to thermal gradients caused distortion when viewing the pad at an appreciable distance.

C. Signal to Noise

The Sony HDC-300 cameras appeared cleaner than the HDC-100 cameras under the same conditions even though the usable signal bandwidth is wider. Much of this improvement comes from an improved preamplifier design and some probably comes from the new internal image enhancer.

D. Highlight Handling

The HDC-300 exhibits excellent highlight handling and beam overload control, even at the extremes of the Shuttle Solid Rocket Motor exhaust plume (estimated to be greater than 3 stops brighter than the reference white of the Space Shuttle Orbiter). The new tubes and the automatic beam optimization circuits help the highlight handling, and the improved control of the image enhancer allows the operator to reduce the artifacts at the edges of the overload areas. The improved resolution of the camera system requires less image enhancement for sharp-looking pictures.

The HL-1125 suffers from inadequate beam reserve and no dynamic beam adjustment circuits and seems to lose beam control at roughly 2 to 2.5 stops above reference white. The HARP tubes are early implementations of the technology and should improve as the electron guns and control circuits are optimized.

E. Processing and Recording Artifacts

The HDD-1000 shows significant improvements in digital processing and multi-generation performance. In addition, the luminance and color bandwidths of the recording systems are 50% greater than those of the analog HDV-1000, leading to improved phase response and reduced artifacts in the most visible image areas. The color-difference recording format allows luminance to be recorded at full bandwidth without the separate high frequency matrixing which can cause filter artifacts like ringing to appear in the analog machines. There is a resistive matrix in the system to convert from the GBR signal to YPbPr, but the matrix is strictly resistive and the system includes minimum filtering.

F. System Reliability

1. Temperature

Registration drift was a problem with the Sony cameras, especially the remote tracker camera since, it was not protected or accessible for long periods. Sony has a procedure for improving the temperature stability of the cameras, but that procedure requires controlledenvironmental conditions for longer than one day. It was not deemed practical to attempt the procedure for this test, but it should be done in future tests. A similar procedure has produced excellent results in HDC-100 cameras used in field production.

2. Moisture & Dirt

The Sony HDC-300 cameras seemed to be less susceptible to dust than HDC-100's, probably because there are no fans in the new cameras. However, the camera heads are not sealed and convection ventilation is necessary for cooling, so there is still a potential dust problem. The digital recorders seem to be more sensitive to head clogging than the analog recorders, probably because the digital recorders have more heads than the analog units and the head gap is smaller to accommodate the high recording densities. No perceptible data losses were attributed to head clogs during the mission coverage.

VII. <u>OPERATIONAL CONSIDERATIONS</u>

A. Support Equipment Configurations

Each of the three manned camera sites was supported by a standard-sized passenger van minus the seats, equipped with air conditioning, and pulling a trailer-mounted generator. Each generator was capable of supplying approximately 10 KW of power and each vehicle used approximately 25 amps of 115 VAC or less than 3.5KW. Power consumption is not significantly different between the older and newer equipment. One exception is a significant reduction in size of the digital image enhancer for the Sony HDC-300 camera and a corresponding 50% reduction in the power requirements for the camera system.

Some of the early NHK prototype equipment was designed for 100 VAC operation in Japan and required step down transformers. All production hardware are now delivered with provisions for international operation at 100, 115, or 220 VAC.

Grounding was not a problem at each of the manned sites since the vehicles were isolated from other equipment. At the remote camera site, interference problems possibly related to grounding are suspected of degrading the video signal on the morning of the first launch attempt. Additional care in ground isolation and cable routing resolved the problem. The power consumption of the HD equipment and the high humidity of the ocean air, combined with the low cooling capacity and poor ventilation capability of the vehicle air units caused condensation and heating problems in some of the vehicles during test and set-up periods. This was not a serious problem at launch time but could have been for a summer afternoon launch.

The operation was somewhat cramped in the vans, but the real problem was the difficulty of securing the equipment in the vehicles. The passenger vans were not designed to accommodate operating equipment and it was necessary to stack monitors on other units so that the video operators could see the images and control the cameras. Tie-down straps were attached to the passenger seat anchor points, and devices were strapped to each other for stability.

Cam-style pan/tilt heads with tilt wedge adapter plates were used for all manually directed cameras. The wedge adapters allow tracking of the orbiter through a nearly vertical direction after launch by raising the nominal tilt angle of the camera approximately 30 degrees from the normal pan-head horizon.

The TSM remote control pan/tilt unit was used for the unmanned camera position less than one mile from the pad. The user interface of the TSM system is extremely flexible and can be adapted for different user control requirements. Control locations, rates and response times, as well as soft limits and preset positions and transitions can be programmed by the operator with a minimum of difficulty. The two crew members who operated the system were able to do a reasonable job after one or two days of training. The final test of tracking the orbiter after launch was not completed because of an interface failure in the heavily modified remote control system. It is recommended that automatic tracking be used in subsequent experiments.

Four different types of lens controls were used on the four cameras. The Canon lens had a standard manual zoom control and remote focus at the camera control unit. The Fujinon lens on the manually operated HDC-300 had electric zoom with remote focus, and the lens on the remote camera had all controls available at the control trailer. Either of the zoom controls, which allow the operator to keep his hands on the control bars, seems workable after some practice. The Fujinon lens on the HARP camera had a push rod for zoom and focus, which proved difficult for the operator to control while tilting the camera rapidly during launch. High definition equipment is finally getting somewhat smaller, although it is not yet the size of corresponding NTSC equipment. The Sony HDC-300 camera control units, including digital image enhancers, are approximately 30% of the size of the HDC-100 CCU and the HARP camera control units are approximately half the size. Camera head sizes are not significantly different in tripod mounted applications. The digital recorders are approximately 75% of the size of the analog recorders.

VIII. CONCLUSIONS

The experimental HDTV system test for STS launch coverage was highly successful from both a technicaland operational perspective. The merits as well as the drawbacks in employing HDTV technology in launch support operations were evaluated. The salient observations and their significance are summarized in the following.

The Sony HDC-300 camera and HDD-1000 recorder and the ReFlect fiber link show approximately 50% performance improvement in resolution over the equipment tested in the past. The HL-1125 HARP camera shows promise for low light applications but does not handle highlights adequately for the extremes of a Space Shuttle launch. The TSM pan/tilt control unit shows promise for remote positioning of cameras covering launch. Remote camera set-up controls are necessary for the acquisition of high quality electronic images of launch. Automatic tracking is recommended. More time is needed for on-site installation and testing when non-standard interfaces are used and international partners are involved.

The HDTV camera, distribution, transmission, and recording equipment reproduced clearly superior pictures whose measured performance exceeded the resolution of conventional NTSC by over 100 percent. This corresponds to a more than a four fold increase in pixel density, which is the customary definition requirement for HDTV. Other factors contribute to the improved picture quality including much higher color fidelity and resolution, and greatly reduced scan line visibility.

The high definition HDC-300 camera sensitivity is approximately equal to that of conventional cameras, and the HL-1125 camera's highest sensitivity exceeds this by two f-stops, translating into a four fold reduction of the required scene lighting level for maintaining the identical lens aperture. This would theoretically increase the depth of field. Sharp focus is required to provide a high definition image. Scene lighting and focus requirements are therefore more critical in high definition production than in NTSC production. Equally important is the lens performance, which can be a significant limitation for high definition. The NTSC lenses used for the 2/3 inch HARP cameras exhibited degraded performance in this respect. The subjective picture impairment due to noise was found to be imperceptible in the HDTV cameras and digital video tape recorders, and just perceptible on the analog video recorders. First generation analog recorded video was of excellent quality, but lacked sufficient headroom for maintaining this quality after multiple generations. Digital video tape recorders have circumvented the problem. The equipment evaluated is typical of the new generationcurrently available and is still not well suited for portable applications. This is due to the large size and weight of the recorder and the studio operating configuration of the camera. The large electronic packages also require considerable external support for power and cooling.

Proper operation and maintenance is critical for routinely reproducing images with high resolution and superior picture quality. Stable camera mounts, clean optics and tape heads, accurate camera registration and optical alignment, and careful focusing are necessary for the production of high definition video. Consistent quality comparable to or exceeding that obtained in this experiment requires significantly increased maintenance and operational resources over that currently needed for NTSC television support.

In conclusion, the second generation HDTV equipment is capable of producing significantly improved quality over first generation equipment. However, HDTV equipment needs more stringent set-up, operation, and maintenance than does NTSC equipment to obtain the high quality results. The benefits of HDTV include the near instantaneous availability of high resolution recorded picture material which can be electronically processed and analyzed immediately.

ACKNOWLEDGEMENT

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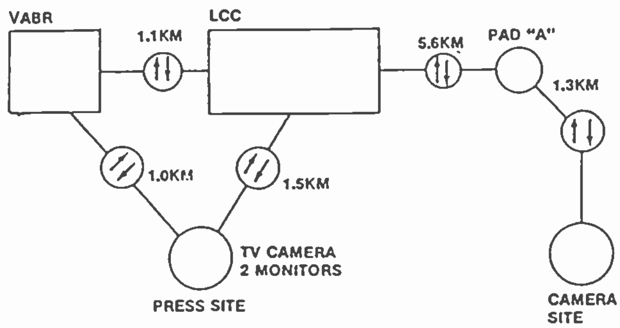

Figure 1.

Fiber Optic System for STS-32 HDTV Experiment

HDTV GLOBAL ISSUES:
HDTV Around the World

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Moderator:
James C. McKinney, Advanced Television Systems Committee, Washington, District of Columbia

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*Paper not available at the time of publication.

HDTV STANDARDS IN A DEVELOPING ENVIRONMENT—EBU PERSPECTIVES

David Wood
EBU
Geneva, Switzerland

Jose Tejerina
RETEVISION
Madrid, Spain

ABSTRACT

The EBU is an organisation of European broadcasters, which has drawn up many standards for broadcasting in Europe. High definition television has been studied for the last ten years. The paper reviews the current state of the EBU studies of HDTV broadcasting and production standards. For DBS at 12GHz the HDMAC system has been developed in the Eureka 95 project. An all digital approach will probably be adopted for a possible new DBS band in the region of 20GHz. Terrestrial systems which would provide PAL- or SECAM-compatible widescreen services are being considered. The HDTV production standard which seems most likely to be acceptable worldwide is a dual-mode pair, termed the Common Image Part.

INTRODUCTION

When to choose? This is often the critical issue in broadcast standards. How do you find the right compromise between timely setting of standards, which are so necessary if a market is to flourish, and yet avoid having systems which are out of date, if not while the ink is drying, at least in a few years.

There is no simple formula. In fact it is probably impossible to do the job perfectly well. The only option is to assemble all the available evidence, and try to choose solutions which look to be long term ones.

Obtaining consensus is also no easy task, even if everyone agrees that the time is right for standards to be set.

The EBU is an organisation which acts in matters of common interest to European national broadcasters. The objective of this paper is to explain the current situation in the EBU regarding HDTV standards for HDTV production and broadcasting. It is a different environment to the North American one, and certain different considerations apply. Nevertheless, our futures are bound up to some extent.

For HDTV broadcasting in the DBS channels allocated at WARC 1977, the HDMAC system is in the process of finalization by the Eureka 95 project, and will probably be adopted by EBU Members if it meets appropriate quality objectives. Outline details of the system have been published, and are reviewed in this paper. The detailed specification is being prepared in the Eureka 95 project. The EBU hopes to make a thorough quality evaluation of the system in its final hardware form.

For HDTV DBS broadcasting in the 20GHz band, should spectrum space become available in Region 1, efforts are concentrated on an all digital solution. In particular, the target is a system capable of delivering more or less the complete HDTV studio quality into the home. This looks like needing a wider bandwidth than an HDMAC system, but in a newly allocated 20GHz band there would be no a-priori constraints on the system bandwidth. At this stage we are not trying to decide on the specific standard. This needs to be decided nearer the service dates, to take advantage of developing technology.

For HDTV or wide aspect-ratio services in the terrestrial broadcasting bands, there are several project groups in Europe studying wide-screen versions of PAL and possibly SECAM. These have levels of definition ranging from conventional to virtually HDTV. Our original hope was to try to agree an EBU proposal this year. This may still be possible, but there are, as this paper is being written, still major points of discussion, which suggest that this time-scale may be difficult to meet.

EBU Members are not un-aware of the considerable efforts in the USA to develop a narrowband HDTV system for terrestrial broadcasting, and that many of the candidates are digital. If such a system can be developed for 60Hz, it should certainly be possible at 50Hz too. There are many voices in Europe calling for the digital terrestrial simulcast possibilities to be looked at. Currently, Europe is examining this possibility with an open minded skepticism.

For HDTV production, after the stalemate situation which developed several years ago between proponents for the universal use of, respectively, 50Hz and 60Hz, efforts have been concentrated on finding a pair of standards with the maximum number of common elements - the dual mode approach. There may be a break on progress here however, because in international forums, the US is hanging fire on production standard parameters for the time being, until the US broadcast standard is decided.

The Sections that follow outline some of these issues.

HDTV BROADCASTING

The HDMAC system

The story of HDMAC is relatively well known.

In the early eighties, the EBU studied the alternative options for satellite broadcasting in the WARC 1977 channels in Europe. The options were to use conventional PAL and SECAM or an extended bandwidth version, a digital system, or an analogue component system. The analogue component system was judged to be, on balance, the best bet. It would provide a bridge to the later addition of HDTV, bring certain quality benefits immediately, and it could be the means to unite Europe behind a single common standard.

The MAC/packet system was developed in 1983 and 1984 against the expectation that it would see extensive service from the mid-80s, and be upgraded to HDTV, as and when broadcasters could afford it, and when flat large screen HDTV receivers were available.

The MAC/packet system was a means to deliver to the home the single worldwide standard for digital television production, the 4:2:2 standard, or a wide-aspect ratio version of it.

We examined the digital broadcasting option. At that time, bit-rate reduction systems using transform methods looked too complex to implement in consumer equipment, and the best that could be achieved in the available bandwidth with receivers of manageable complexity with DPCM was less than PAL quality. At that time there was no contest. Digital systems were too bandwidth-hungry to be useful for broadcasting.

Stimulated by the success in Japan of the development of the MUSE system, European industry embarked on the development of the extension of the MAC system to HDTV in 1985. This was rather earlier than we expected, but manufacturers were anxious not to fall behind Japan in technology.

The HDMAC system developed is amongst the most sophisticated analogue emission systems devised. It was developed by the Eureka 95 project over a period of four years, and is currently at the stage of fine-tuning.

The system provides resolution which is dependent on the picture content, but is intended to provide up to about twice the vertical and horizontal definition of conventional television.

The original 1250/50 HDTV picture is digitally sampled with 1440 samples per line. This 1152 by 1440 matrix is quincunx sub-sampled, and the resulting sampling lattice is considered to be a block structure. The motion speed associated with the major item in each block is calculated and this is used to decide on the definition and number of motion phases to be associated with the block. Information on the motion direction is also established and used to assist motion compensation in the receiver.

There are three modes, or coding paths, that can be used for the blocks: the 80ms path, the 40ms path, and the 20ms path.

If the contents of the block is stationary or near stationary, a four field sequence is associated with the block. That is, the picture in the block is built up over four fields. This is the 80ms path. The definition in this mode is the maximum definition available, and corresponds to the quincunx sampled source picture.

If the contents of the block are moving very quickly, independent motion phases are transmitted. This is the 20ms path. The definition is only about the same as for conventional television in the horizontal and vertical directions. However, since the contents of the block is moving it is less important to maintain the definition.

There is an intermediate mode (40ms) during which the picture is built up over two fields. In this case, motion compensation is also applied.

The final system was chosen after two successive series of subjective assessment shoot-outs of simulations of candidate systems.

One of the important design features of the HDMAC system was that it should be compatible with the conventional MAC system. Therefore the signal has to be arranged to look like a MAC signal. This is done by a process known as line sample shuffling. Samples from adjacent lines are moved together to be on the same line. In this way, a 1250 line signal is arranged to have 625 lines.

The EBU anticipates making a series of formal subjective assessments of the picture quality available with the final hardware system in the near future.

Digital Wideband HDTV systems

The currently allocated 12GHz DBS band in Europe allow for five 27MHz channels per country. Although this basis for allocation, equality for all nations, large or small, has merits, it was thought that by the end of the century, a number of European countries would need more capacity. Furthermore, it seemed that the WARC channel width (rf channel width 27MHz) would limit the picture quality achievable, or the introduction of new services, which we cannot yet foresee.

For all these reasons, the EBU is actively arguing the case for a new allocation around 20GHz for Region 1 for broadcasting services such as wideband digital HDTV.

We do not prejudge what the best broadcast format or modulation method should be, but we are using examples for the purposes of planning exercises, and feasibility demonstrations.

There are currently four project groups in Europe who have notified us that they are developing HDTV digital codecs. Three of these will have a bit rate of 140Mbit/s, and the forth currently operates at 70Mbit/s or 140Mbit/s.

Three of the systems are based on hybrid DCT with motion compensation. They operate in a similar, though not identical way. Digital bit-rate reduction depends on reducing the redundant information contained in the basic sampled version of the picture. In broad terms, there are three kinds of redundancy: spatial, temporal, and statistical. The hybrid DCT codecs exploit all three.

The picture is split into blocks of picture samples, and each block is transformed into the DCT domain by a matrix process. In the DCT domain, it is possible to truncate the coefficient with much less effect on picture quality than truncating signals in the original domain.

The samples to which the transform applies may be the samples themselves or the prediction error associated with successive fields. The systems have a number of modes which can be selected on a block by block basis, depending on the spatial and temporal differences between fields. One of the modes uses motion compensation.

Following the transform processes, the statistical redundancy of the signal is exploited by variable length coding.

The source for the codecs has 1920 samples/line. Some of the project groups are developing both 60Hz and 50Hz versions of the codec, others only a 50Hz version.

The forth 140Mbit/s codec uses sub-band coding, which may have advantages for receiver complexity, and is therefore a very interesting study.

These codecs were designed in two cases for contribution purposes. That is to say, they should allow the possibility of processing after the decoder. This is a more demanding requirement than simply picture quality transparency. They are thus not targeted precisely at the future consumer market, but they will certainly serve well our experimental work, and discussions.

Our current plan is to make a series of subjective assessments of at least three of the codecs this year. In February 1992 we hope to mount a live demonstration of DBS using these systems to illustrate the feasibility of digital HDTV broadcasting in the 20GHz band, and to support our case for the allocation.

At some future point, possibly when the new band has been planned, we would hope to reconcile the systems to provide a unique format for 20GHz DBS broadcasting in Europe.

Terrestrial widescreen systems

Several years ago there seemed a strong possibility that widescreen MAC/packet services would shortly be available to the European public. The quality expectations of the European viewer looked set to rise, and European manufacturers announced plans to produce widescreen tubes and receivers.

The mainstay of European broadcasting is the terrestrial broadcasting network. There are currently about 34 000 terrestrial television transmitters in Western Europe. Terrestrial television will remain very important for many years. Therefore, it seemed most important to also study the possibilities for increasing the quality available with the current PAL and SECAM services.

The hope was that a widescreen system could be developed which would be compatible with conventional PAL and SECAM as appropriate. The widescreen version would provide services for the new widescreen receivers, and be a competitive response, or even a means of survival, in the new future world of wideMAC and HDTV.

A grouping which includes the broadcasters from the German-speaking countries in Europe, and the major European consumer electronics manufacturers, the PALplus group, established a work plan to develop an Enhanced PAL system. This work is now quite well advanced, and trials are taking place which may allow a first demonstration in Autumn of this year.

There is also interest in the United Kingdom in developing a widescreen PAL system.

The EBU Technical Committee established an EBU group to develop an EBU standard for Enhanced PAL/SECAM in 1989. The standard would draw on the work and advice of the various groups developing systems in Europe.

There proved to be a range of views in the EBU group about basic points of philosophy.

The first concerned the acceptability by the public of a letter-box format.

The most straightforward way to create a wide aspect ratio format is to use less than the full 575-lines as active picture lines (431 for a 16:9 aspect ratio). In this case the viewer with a conventional receiver sees black stripes at the top and bottom of the picture. There were different views in the EBU group on whether the picture in this case is still compatible. In some countries in Europe, the public is used to seeing feature films in a letter-box format as part of their normal viewing. In other countries, feature films are almost invariably panned and scanned, because the letter-box format is thought to be very unattractive. If we are to find a unique European system, we need to reconcile these two perspectives.

The second major area of discussion concerns the luminance bandwidth that the system should have. There are two schools of thought. The first is that the system should aim at being as near to HDTV as possible. This might be done by various spectrum folding techniques. The second school of thought is that a more practical luminance bandwidth would be 5.75MHz to 7.3MHz. 7.3MHz would give the same horizontal pixel density as CCIR Rec. 601. The argument here is that additional bandwidth is going to be expensive to provide, and may not even be noticeable, because of screen sizes and tube capabilities.

These debates are still going on in the above two areas, but for the sake of discussion, we have tried in the group to classify systems into two types:

Level 1: The characteristic of this level is that it would not call for major studio re-investment on the part of the broadcaster. The enhanced service would have a 16:9 aspect ratio. The horizontal bandwidth would be 5.75MHz. Certain pre-processing systems could be used by the broadcaster to improve picture quality, such as pseudo constant luminance coding, and dark detail enhancement. In the receiver there could be comb filtering techniques, motion adaptive pro-scan, and Y/C spectral shaping.

Level 2: This level would have increased luminance bandwidth, which might be 7.3MHz, or some argue, an even higher value. This might make use of the unused segments of the spectrum (Fukinuki-type holes) or a particular type of spectrum folding (the Weston/Sandbank system)

The EBU group is also examining ghost cancelling systems, which may provide further quality improvements in terrestrial services. However, in Europe more use is made of the UHF services than in the USA, and thus there is rather less to be gained by ghost cancellation.

The group has discussed system selection criteria, but no firm conclusions have been reached. However it is clear that three factors are of critical importance: the Enhanced PAL/SECAM picture quality, the compatible picture quality, and the receiver complexity. These three need to be evaluated for the candidates, and appropriately weighted.

Europeans have not failed to notice the progress in the USA toward simulcast systems, which would broadcast wide-screen picture in the unused parts of the terrestrial broadcast bands. A growing number of the candidate systems are digital. The bit-rate reduction techniques which have been suggested in North America are quite similar to those which have been implemented in Europe for wideband digital HDTV systems. There is therfore quite a lot of experience in Europe, and in the EBU, with this kind of system.

Among the key questions for us in Europe on this issue are the following:

- what spectrum space, if any, could be made available for terrestrial simulcast in Europe?. The "taboo" channels which you have in the USA do not exist as such in Europe.

- what quality will be achievable in the bit-rates likely to be available for terrestrial broadcasting?. The quality available from digital systems of this kind is very much more dependent on the picture content than the analogue systems that we have today. It is quite possible that a given system would appear transparent to a proportion of programme material, but fail on the remainder. What is needed to characterize a system is a so called "picture content failure characteristic", that relates quality to the proportion of programme material for which is achieved. When we have this kind of information it will be easier to decide if the very high levels of bit rate reduction needed would still produce an acceptable service.

The possibility of establishing a Task Force to coordinate studies of digital television terrestrial systems is being considered.

THE HDTV PRODUCTION STANDARD

For many years, the 60Hz world, including the US, strongly supported the 1125/60/2:1 system, as a single worldwide HDTV production standard.

Most of the 50Hz world was cautious about accepting this, because of the cost of integrating the system into their existing 50Hz infra-structures. The motion-adaptive standards converters which would be needed looked like being relatively expensive, and indeed there were doubts about whether necessary performance could be achieved at the HDTV signal level.

In 1987, European Administrations proposed that the world should adopt a unique system based on progressive scanning and a 50Hz field rate. This provoked no favorable reaction by Japan or North America. The point was often made in the CCIR meetings that, if the 60Hz world accepted 50Hz, they would have precisely the same problems as the 50Hz world would, if it accepted 60Hz.

If you can't get the best, you make the best of what's left. The world seemed destined to have HDTV standards with two field rates. Prompted by the Chairman of CCIR Study Group 11, for the past three years, the focus has therefore been on looking at ways in which we can minimize the differences between the standards, working on the assumption that one of them has to a 50Hz standard, and the other a 59.94Hz or 60Hz standard.

The initial proposal was to align the sampling-frequencies, and therefore bit-rates, of the two standards. This is termed the CDR or Common Data Rate approach. The second proposal, made by Ken Davies of CBC, is now termed the Common Image Format. In this proposal, the same number of lines and active samples/line is used in both 50Hz and 60Hz modes.

In recent times, the Swedish Administration proposed a third option, termed the Common Image Part (CIP), which has some of the features of both the CDR and CIF.

In the EBU, we had extensive discussions with studio equipment manufacturers about which approach would lead to the most cost, quality, and convenience benefits.

Drawing a conclusion from these discussions proved difficult, because manufacturers had different views on many fundamental issues affecting production equipment. It was clear however that each dual-mode approach has advantages in certain circumstances and that they often cancelled each other out when the whole studio system was looked at. When the whole broadcast system was looked at, there was a degree of balance between the approaches, which suggests that the choice will have to be made on grounds other than equipment costs.

In our discussions last year, there seemed to be two great intractables to choosing the system. The first was that for Japan, there is already an installed base of 1125/60/2:1 equipment, which it would be costly and difficult to change. The second was that in Europe, the use of less than 1152 active lines would mean that the production standard was worse in quality than the broadcast standard, and therefore the lower limit on the number of active lines was (and is) 1152.

The Common Image Part (CIP) approach seemed the only way to reconcile the situation, and the proposal that was put to a meeting of the EBU group V1/HDTV in September 1990 was the one shown below in Table I

POSSIBLE CIP OPTIMUM SYSTEM

Field frequency (Hz)	60	50
Active lines/frame	1080	1152
Samples/active line	1920	2048
Sampling-frequency (MHz)	74.25	74.25
Total number of lines	1125	1250
Vert. blanking (lines)	22/23	49/49
Samples/line	2200	2376
Horiz. blanking (us)	3.77*	4.41*
Scanning algorithm	2:1	2:1
bits/sample	8	8
Gross data rate (Mbit/s)	1188	1188
Active bit rate (Mbit/s)	995.3	943.9

* If a progressive version of the standard were implemented, doubling the sampling-frequency could result in an impractically short line blanking time. However, if the progressive version's sampling frequency were 162 MHz, the intervals would be more easily implementable.

However, it would not be true to say that this proposal is universally accepted in the EBU. The remaining problem is the sampling-frequency, and there is some support for another value, 81MHz.

The current position is that both 74.25MHz and 81MHz are being considered. The major difficulty with 81MHz is that it would require a change to the Japanese standard.

In theory then, we might hope for agreement on a dual mode approach, provided the sampling-frequency can be agreed.

However, although Europe and Japan may be able to discuss the matter, the current situation in the United States may well prevent agreement from being reached for several years.

The current US plan is to choose a terrestrial simulcast system in 1992/93. The view that is usually put forward from US sources is that, as a consequences, a production standard is not discussable at the moment. The US candidate systems have several individual optimum source formats, and it is therefore quite possible to see the case for waiting, from the US point of view.

There are however risks in doing so. The first is that by the time the US is prepared to discuss the parameter values, it may be too late to change them for the rest of the world, so we may finish with at least three standards. Of course, the US market is a very large one, and could support its own standard, and the same is true for the 50Hz world. Nevertheless, there will be a cost if we do not achieve agreement. Everyone in the end, will loose money, and we may loose confidence in our ability to agree such things on a worldwide scale.

I am afraid we do not have a recipe for success. It is quite possible to see both sides of the issue. Perhaps the only thing we can do is wait and hope that the situation will be salvageable after the US has chosen a broadcast standard.

CONCLUSIONS

Ten years ago, it began with a dream. The entire world would use the same unique standard for making HDTV programmes, and a second unique standard for broadcasting them.

Economics got in the way of the dream, and we were left to make the best of the situation.

Different HDTV broadcasting systems were developed

In Europe, an HDTV analogue emission system, HDMAC, is in its final stages of development. Digital wideband systems are being studied, although it seems prudent to wait before fixing the final standard.

The next generation of terrestrial television services is also under active study in Europe. A wide-aspect ratio version of PAL/SECAM is a possibility. A digital system may be a candidate, but the spectrum space for such services is less available than in North America.

Whether HDTV studio production standards will be as similar as possible, and as they could be, depends on on broadcasting standards, and perhaps on luck.

Hippocrates pointed out that "art is long, but life is short". HDTV may not only carry art, it may also mirror it, if we are careful.

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PRESENT STATUS OF HDTV IN JAPAN

Masao Sugimoto and Taiji Nishizawa
NHK Science and Technical Research Laboratories
Tokyo, Japan

Introduction

Since the start of television broadcasting service, many kinds of technology to improve picture quality have been developed. Among these, NTSC color television technology was the one of the most important technologies in the past. The 525-line monochrome television system was evolutionallly enhanced to the NTSC color television system through this technology.

Today a new technology which revolutionarily changes existing television systems has been developed. This technology is HDTV or High-definition television. Based on extensive psycho-physical studies, a completely new scanning format containing a wide aspect ratio of 16 to 9 and a number of scanning lines exceeding 1000 lines has been chosen for HDTV. With this new format, entirely different image effects have been realized by HDTV in terms of the sensation of reality and picture sharpness compared to existing television systems.

Due to its outstanding potential, it is expected that HDTV will be used not only for broadcasting but also for various kinds of industrial use. For this reason HDTV is regarded as one of the extremely important high technologies which will dominate the technological and economical powers of each country in the future. Many countries are now working hard to develop their own HDTV systems.

In Japan, HDTV is called "Hi-Vision" and efforts for the practical introduction of HDTV in various fields are being made. For example, daily one-hour experimental HDTV satellite broadcasting was started in June 1989.

In this paper, the present status of HDTV is described primarily focusing on the activities relating to the 1125/60 HDTV system in Japan.

HDTV program production

Studio standard

(1) CCIR Recommendation for a studio standard

At the 17th CCIR Plenary Assembly held in May 1990 in Dusseldorf, Germany, a new recommendation on an HDTV standard for the studio and international program exchange was unanimously adopted. The CCIR has made every effort to establish this recommendation because the CCIR failed to adopt a recommendation for an HDTV studio standard at its 16th Plenary Assembly in 1986. Japan first proposed a new study program on HDTV to the CCIR in 1972, and it took 18 years for the CCIR to establish a recommendation for the HDTV studio standard. This recommendation is widely recognized as a historical one for the CCIR.

The recommendation consists of 27 parameters of which 23 items were unanimously agreed upon as worldwide unified values. Table 1 shows the major parameter values in the recommendation. Those controversial parameter values of field frequency and the number of active scanning lines have not been agreed to yet. They will be discussed further in the current CCIR Study Period from 1990 to 1994.

(2) Other CCIR Recommendations relating to HDTV

At the 17th CCIR Plenary Assembly, five recommendations relating to HDTV were adopted including the recommendation for a studio standard mentioned above. Table 2 gives a brief explanation of these recommendations. These recommendations are also important for implementing HDTV.

(3) 1125/60 HDTV standard

The 1125/60 HDTV system has been used for many years. The BTA (Broadcasting Technology Association) in Japan adopted the 1125/60 HDTV studio standard as the BTA S-001 standard in 1987. Entirely the same standard was also adopted by the SMPTE (Society of Motion Picture and Television Engineers) in the United States as the SMPTE 240M standard in 1987 in corporation with the BTA. Table 3 shows the main parameter values of the 1125/60 HDTV studio standard. Now the BTA and SMPTE are working together to establish the parallel and serial digital interface standards of the 1125/60 HDTV.

In order to prepare for the start of daily 6 to 8-hour HDTV satellite broadcasting in 1991 using BS-3b, the Japanese Ministry of Posts and Telecommunications (MPT) has established the 1125/60 HDTV studio standard based on the CCIR Recommendation and BTA S-001 standard.

Table 1. Basic Parameter Values of the HDTV Studio standard Specified in CCIR Recomendation 709

	Parameter	Value		
Opto/electronic conversion	Overall opto-electronic transfer characteristics at source	$V = 1.009\,L^{0.45} - 0.099$ for $1 \geqq L \geqq 0.018$ $V = 4.500\,L$ for $0.018 \geqq L \geqq 0$ where, L: Luminance of the image for $0 \leqq L \leqq 1$ V: Corresponding electrical signal		
	Chromaticity coordinates (CIE 1931) - For reference primaries see note below - For interim primaries related to current display technology	Primary	Coordinates x	Coordinates y
		Red	0.640	0.330
		Green	0.300	0.600
		Blue	0.150	0.060
	Assumed chromaticity for equal primary signals $E_R = E_G = E_B$ (Reference white)	D_{65} x: 0.3127	D_{65} y: 0.3290	
Picture characteristics	Aspect Ratio	16:9		
	Samples per active line	1920		
	Sampling lattece	orthogonal		
Picture scanning characteristics	Order of sample scanning	Left to right, Top to bottom		
	Interlace ratio	The objective is defined to be progressive scanning. For current implementations, 2:1 interlace or an equivalent sample-rate reduction process may be used.		
Signal format	Derivation of luminance and color-difference signals for analogue coding - Equation for system related to reference primaries, see note below - Equation for interim systems related to current display technology and conventional coding	$E'_Y = 0.2125E'_R + 0.7154E'_G + 0.0721E'_B$ $E'_{PB} = 0.5389\,(E'_B - E'_Y)$ $E'_{PR} = 0.6349\,(E'_R - E'_Y)$		

Note: Administrations are urged to present the results of studies to the Interim Meeting of the next CCIR Study Period to establish these parameter values.

Table 2. CCIR Recomendations relevant to HDTV

	Title	Recommended items
Rec. 709	Basic Parameter Values for the HDTV Standard for the Studio and for the International Programme Exchange	·Opto/electric characteristics (gamma curve) ·3 primary color coordinates ·Chromaticity of reference white ·Aspect ratio ·Samples per active line ·Luminance and color-difference equations
Rec. 710	Subjective Assessment Methods for Image Quality in High-Definision Television	·Viewing conditions: viewing distance, screen size, screen brightness, ambient conditions, etc. ·Assessment methods ·Quality and impairment scales
Rec. 713	Recording of HDTV Images on Film	·Dimensions of image on 35 mm film
Rec. 714	International Exchange of Programmes Electorically Produced by Means of High-Definition Television	Programmes electronically produced should be exchanged in video form.
Rec. 716	Scanned Area of 35 mm Motion Picture Film in HDTV Telecines (Non-Anamorphic Pictures)	·Scanned image dimensions for 35 mm film

Table 3. Main Parameter Values of the 1125/60 HDTV Studio Standard

Item	Parameter			Value	
1	Total lines per frame			1125	
2	Active lines per frame			1035	
3	Interlace ratio			2:1	
4	Aspect Ratio			16:9	
5	Field repetition rate			60.00	Hz
6	Line repetition rate			33750	Hz
7	Signal level Y, G, B, R	Ref. black		0	mV
		Ref. white		700	mV
		Sync		±300	mV
		Set up		0	mV
8	Signal level Pb, Pr	Ref. zero		0	mV
		Ref. peaks		±350	mV
		Sync		±300	mV
		Set up		0	mV
9	Nominal bandwidth	Y, G		30	MHz
		Pb, B		30	MHz
		Pr, R		30	MHz
10	Sync format			Tri-level bipolar	
11	Duration of line blanking			3.77	μs
12	Duration of field blanking			45	lines
13	Digital representation	Samples per active line	Y, G	1920	
			Pb/B	960/1920	
			Pr/B	960/1920	
		Sampling frequency	Y, G	74.25	MHz
			Pb/B	37.125/74.25	MHz
			Pr/B	37.125/74.25	MHz

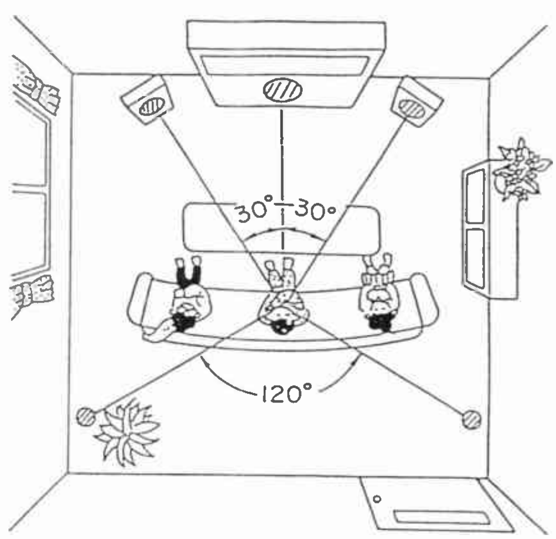

Figure 1. An Arrangement of Loudspeakers for the 3-1 System in a Living Room

(4) Sound system for HDTV

The sound system is also important for HDTV to enhance the sensation of reality and to provide better sound localization characteristics for off-axis listeners. A 3-1 quadraphonic sound system has been developed in which three (left, center and right) front channels and one rear channel(two rear speakers are used for rear right and left positions) are used as shown in Figure 1. The 3-1 sound system was adopted by the MPT for the HDTV standard in Japan.

CCIR is now working to establish a recommendation for HDTV sound systems. In a draft recommendation, a family of multichannel stereo and surround sound systems has been agreed upon in which the conventional 2-channel stereo system, the front 2-channel and rear 2-channel system, the front 3-channel and 1-rear channel system, the front 3-channel and rear 2-channel system, and the front 4-channel and rear 4-channel system are included as family members.

(5) Test pictures for subjective evaluation of picture quality

It is desirable to standardize test pictures for subjectively evaluating the picture quality of HDTV equipment and systems. As a first step, 9 still pictures were selected and standardized throgh the joint work of BTA and ITE Japan and transparent slides of these test pictures (H:272mm x V:153mm in size) have been published. Figure 2 shows one of these test pictures. The BTA is now working to select sequences of moving test pictures.

Figure 2. A Test Picture Standardized by BTA and ITE Japan

Program production

Up to now more than 550 HDTV programs have been produced worldwide using the 1125/60 HDTV system and this number is getting larger and larger. These programs are used not only for daily experimental HDTV satellite broadcasting but also for NTSC broadcasting after down-conversion from HDTV to NTSC signals and for various non-broadcasting uses.

Transmission of HDTV signals

Satellite broadcasting

There are two categories for HDTV satellite broadcasting systems in the CCIR. One is the Narrow RF-band system. This system uses a 27 or 24 MHz RF bandwidth of a 12 GHz band allocated by WARC-77 for ITU Regions 1 and 3 and RARC-SAT-83 for Region 2. MUSE and HD-MAC systems are Narrow RF-band systems. The other is a Wide RF-band system.

MUSE system

(1) Principle of the MUSE system

For the satellite broadcasting of 1125/60 HDTV signals using 12 GHz bands assigned by WARC-77, the MUSE system was developed. In order to send HDTV signals whose base bandwidths are about five times wider than those of NTSC signals within the limited RF bandwidth of 27 MHz, the MUSE system employs a multiple sub-Nyquist sub-sampling technique and utilizes the spatio-temporal characteristics of the human vision system. Figure 3 shows the process of reducing the base bandwidth of HDTV signals using the multiple sub-sampling technique in the MUSE system. The stationary and moving portions of a picture are sub-sampled in different ways. The bandwidth of a MUSE encoded signal is 8.1 MHz.

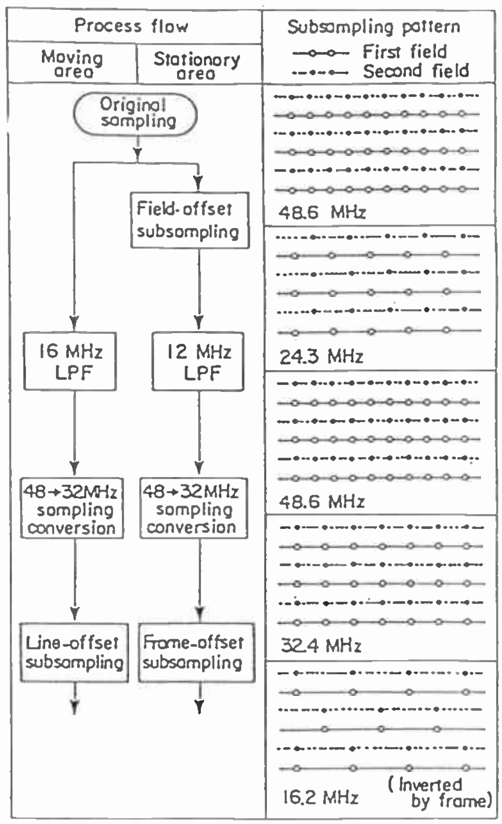

Figure 3. Subsampling Procedure for MUSE System

In the MUSE signal, a four-channel digital audio signal with compact disc quality can be transmitted. Audio signals are time-division-multiplexed during the vertical blanking interval. To obtain a high signal-to-noise ratio, non-linear emphasis is applied. With this emphasis a 9.5 dB gain is obtained.

(2) Satellite broadcasting of MUSE signals

An example of the modulation parameters and the link budget for HDTV broadcasting by the MUSE signal is shown in Table 4. These values are used for transmission via Japanese broadcasting satellite BS-3. A calculated carrier-to-noise ratio of 15.6 dB for the 27 MHz bandwidth with a 60cm receiving antenna is sufficient for satellite broadcasting because subjective assessment tests show that an impairment scale value of 4.5 can be obtained at a CN ratio of 17.5 dB and an impairment scale value of 4 can be obtained at the CN ratio of 14 dB.

It is very important to investigate the relationship between picture quality and waveform distortion of the MUSE signal for actual broadcasting of HDTV using the MUSE system. Subjective assessment tests have been conducted for this purpose, and it has been made clear that the relationship between picture quality and waveform distortion, encountered during transmission, can be described using the logistic function as shown in Figure 4.

Impairment of the MUSE signal caused by noise added during transmission should also be investigated because the MUSE signal is encoded by spatio-temporal sub-sampling. Theoretical and experimental analysis was carried out on the spatio-temporal impairments caused by noise added to the HDTV signal. It has been made clear that the results of this analysis can be applied to estimate noise impairment of the MUSE signal.

Table 4. Modulation Parameters and Link Budget for the HDTV Broadcasting via BS-3

1. Modulation parameters	
Channel bandwidth	27.0 MHz
Frequency deviation	10.2 MHz
Energy dispersal	0.6 MHz
Baseband bandwidth	8.1 MHz
2. Satellite	
TWT power	20.8 dBW (120 W)
Losses (feeder, filters)	-2.3 dB
Antenna gain	40.0 dB
e.i.r.p.	58.5 dBW
3. Propagation	
Free-space attenuation	-205.6 dB
Rain attenuation	-2.0 dB
Up-link C/N loss	-0.2 dB
Total propagation loss	-207.8 dB
4. Receiver	
Antenna gain	38.0 dB (60cm, 70%)
Coupling loss	-0.3 dB
Noise temperature	324.3 K (NF:2dB)*1
Figure of merit (G/T)	10.6 dB/K
G/kBT	184.9 dB
5. Demodulation	
CN ratio	15.6 dB
FM gain	11.9 dB
Emphasis gain	9.5 dB
SN ratio	37.0 dB

*1 including atmospheric noise, 145 K

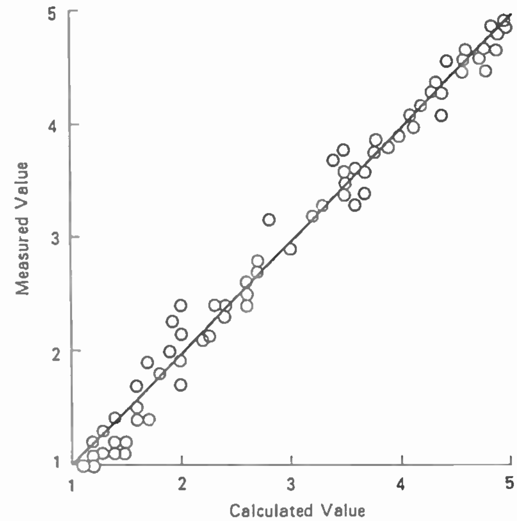

Figure 4. Measured Values and Calculated Values by the Logistic Function on Subjective Ratings

(3) Transmission of MUSE signals via CATV and communications satellite

The MUSE system is also applicable for CATV transmission. FM and VSB-AM transmissions of a MUSE signal have been done using existing CATV systems in Japan and the United States. In the case of FM transmission, the same modulation parameters as for satellite MUSE broadcasting can be used for the CATV system. FM transmission requires a wider bandwidth compared to that for VSB-AM transmission. Figure 5 shows the spectrum of MUSE VSB-AM transmission. In this case, the required bandwidth is 12 MHz. The required CN ratio at the receiver is 48 dB for a noise impairment scale value of 4.5.

It has been confirmed by transmission experiments that at least the same service areas can be realized by MUSE CATV transmission using conventional CATV systems.

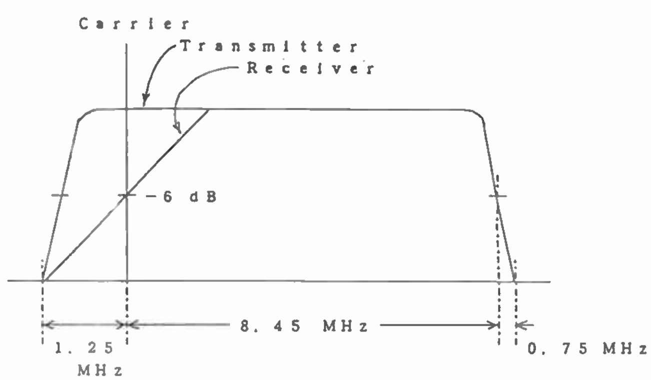

Figure 5. Frequency Spectrum of MUSE VSB-AM Signal

An optical CATV system transmitting multichannel MUSE signals has been developed. Figure 6 shows a block diagram of this system called "Demand access optical CATV." The main feature of this system is a hub for every 300 subscribers. From a center to a hub, 40 FM-modulated channels of MUSE signals are sent by frequency-division-multiplexing and each subscriber can select 4 channels from 40 channels by sending a demand access signal to the hub. A demand access MUSE optical CATV system will be installed in the Tokyo Tele-Port Center in 1994 as a practical system.

FM or VSB-AM terrestrial broadcasting of MUSE signals is also possible. In Mexico, MUSE FM terrestrial broadcasting is scheduled to be started in 1992 using the 12 GHz band.

International transmission of MUSE signals using communications satellites has been done several times. Table 5 shows some examples of these transmissions.

(4) Development of MUSE receivers and a MUSE-NTSC down-converter

A cheap MUSE receiver is essential for the early and wide spread of HDTV broadcasting. 25 kinds of specially designed LSIs for a MUSE decoder have been developed through the joint work of NHK and several manufacturers. Using these first-generation LSI chips MUSE receivers have been made by various manufacturers and these receivers are now on the market for business use. Figure 7 shows MUSE receivers. The upper small box is a MUSE receiver using these LSI chips and the bottom is a MUSE receiver using discrete-type ICs. The size and power consumption of the LSI-type MUSE receiver are about 1/30 of those of the discrete IC type. It is expected that second-generation and highly integrated MUSE LSIs will be developed by manufacturers in the next few years.

Table 5. Major Transmission Experiments

Date	Location	Transmission Media	Event or Memo
Mar.~Sep. 1985	Tukuba	Terrestrial SHF	Expo'85 in Tukuba
Dec. 1986	Tokyo to all over Japan	BS-2	First broadcast experiment
Jan. 1987	Washington D.C.	Terrestrial UHF (2 ch. VSB-AM)	First UHF VSB-AM Transmission
Oct. 1987	Ottawa to North America	ANIK-C2 --> RCA-K1	HDTV'87 Colloquium in Canada
May 1988	Los Angeles	CATV (VSB-AM)	NCTA Convension
Jun. 1988	Nara to Brisbane	CS-3 --> INTELSAT --> AUSSAT	Expositions in Nara and Brisbane
Sep. 1988	Seoul to Tokyo and broadcasting	INTELSAT --> BS-2	Seoul Olympic
Apr. 1989	Washington D.C.	SATCOM-K1(FM) --> CATV(VSB-AM)	FM/AM signal conversion
Jun. 1989	New York to Tokyo and broadcasting	ANIK-C2 --> INTELSAT --> BS-2	USA/Japan programme exchange
Oct. 1989	Tokyo to CATV networks	JCSAT. SCC --> CATV (FM and VSB-AM)	Space-Cable Network
Jul. 1990	Ottawa	ANIK-C2 --> CATV	HDTV'90 Colloquium in Canada

In addition to the development of a MUSE receiver, a MUSE-to-NTSC down-converter has been developed. This converter makes it possible for a user who has an NTSC receiver to receive the MUSE broadcasting signal without purchasing a MUSE receiver. Several manufacturers have developed special LSIs for a down-converter. MUSE-to-NTSC down-converters using these LSIs are now on the market.

(5) Standard for the MUSE system

In the CCIR, no recommendation for the HDTV satellite broadcasting system has been made. Several satellite broadcasting systems developed in Japan, Europe and the United States are described in the CCIR Report.

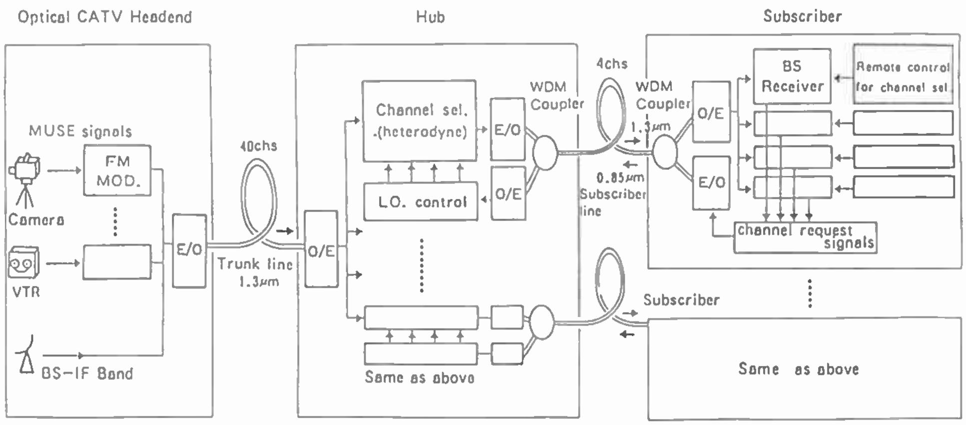

Figure 6. System Configuration of Demand Access Optical Fiber CATV

As mentioned above, in Japan daily one-hour HDTV satellite broadcasting has been in operation since 1989 and the MPT is planning to start practical HDTV satellite broadcasting services. For this purpose the MPT is now preparing a standard for HDTV satellite broadcasting based on the MUSE system.

Figure 7. MUSE Receivers:
LSI Type and Discrete Type

Wide RF-band satellite broadcasting system

As described in the previous section, a Narrow RF-band system such as the MUSE system is designed to be transmitted within a limited RF bandwidth of 27 or 24 MHz. Due to this limitation band compression is indispensable for the system and it causes picture quality degradation to some extent for critical pictures when compared with the original pictures. This picture quality degradation is within the acceptable level for consumers. In addition to the Narrow RF-band systems, requirements exist for studio-quality HDTV satellite broadcasting systems. At the WARC-92 (World Administrative Radio Conference to be held in 1992), a frequency band for the Wide RF-band system will be allocated in the frequency range between 11.7 GHz and 23 GHz.

It is preferred to use a digital satellite broadcasting system for the Wide RF-band system from the points of view of efficient use of the frequency spectrum and satellite transponder powers, etc.. Digital bit-reduction, error correction and digital modulation schemes are important factors for digital satellite broadcasting. In addition to these, satellite and receiver technologies such as a high power TWT and a low noise receiver in this frequency range are also very important. Currently a 70 to 140 Mbit/s digital bit-rate is under consideration for the system.

Digital transmission of HDTV

Several different types of HDTV digital transmission systems have been developed. These systems are categorized as follows.

(1) Full bit-rate transmission system

The total bit-rate of the 1125/60 HDTV digital component signals (Y, Pb and Pr signals) is 1.18 Gbit/s. Bit-serial transmission systems using optical fiber have been developed for short or medium-distance transmission. Figure 8 shows a block diagram of the PST serial transmission system using 3-level modulation.

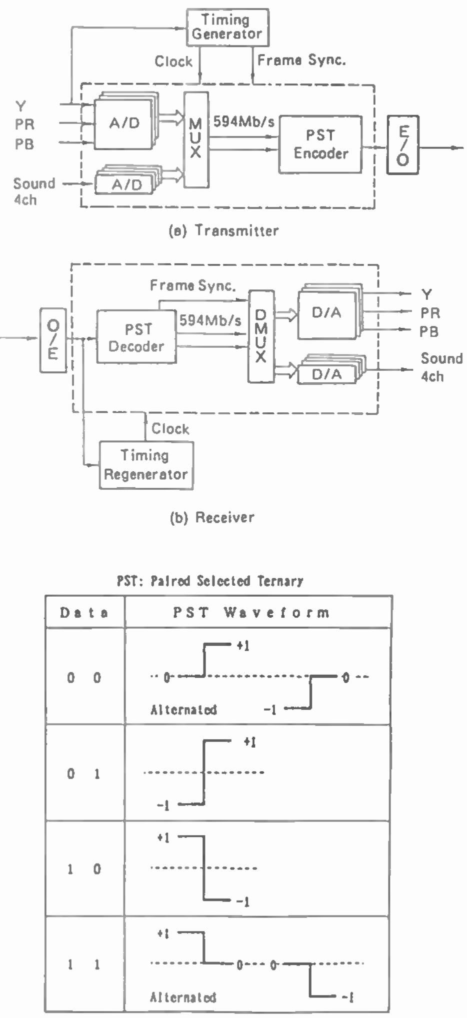

Figure 8. PST Serial Transmission System
and PST Waveform

(2) Bit-rate reduction system for the contribution of HDTV programs

"Contribution" means a medium or long-distance transmission of studio-quality programs between broadcasting stations. For the contribution of HDTV programs, transmission systems using bit-rate reduction are effective from an economical point of view. For this purpose, several systems using different bit-rates from 280 Mbit/s to 140 Mbit/s have been developed. The Hybrid-DCT algorithm is widely used for bit-rate reduction. This coding algorithm has been used in the CCIR Recommendation for the 34 Mbit/s transmission system of 525/60 and 625/50 component signals.

The following conditions are required for the contribution of a program: a) robust coding repetition, which often occurs in program post-production, and b) capability for signal processing such as chroma-key. 280 Mbit/s systems are designed to use two B-ISDN H4-channels and also give transparent picture quality to the original 1.18 Gbit/s signal.

The performance of these systems mentioned above is sufficient for the contribution purpose, but now efforts are being concentrated on developing bit-rate systems lower than 140 Mbit/s even for the contribution purpose. Figure 9 shows the results of a computer simulation on the relationship between the SN ratio of decoded signals and the number of coding repetition for the system using the Vector Quantization algorithm.

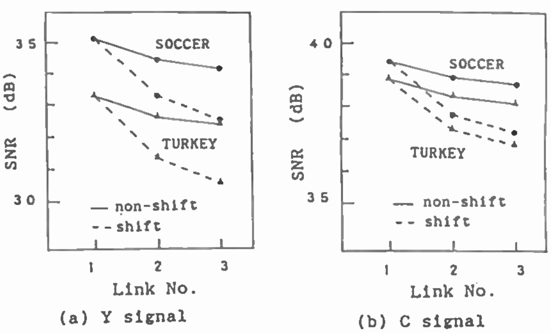

Figure 9. Relationship between Codecs in Tandem and SNR

(3) Bit-rate reduction system for the distribution of HDTV programs

"Distribution" means a transmission of programs from a center to end users or from a user to another user, and usually additional signal processing or post-production is not done at the receiving end. For the distribution of HDTV programs, transmission systems using bit-rates less than 140 Mbit/s will be used because requirements for the picture quality are less severe compared to those required for the contribution of programs and lower transmission costs are desired.

Several types of codecs have been developed. A 100 Mbit/s transmission system based on intra and extrapolation algorithm has been developed. Transmission tests and demonstrations have been done using optical fiber networks. 100 Mbit/s corresponds to the forth hierarchical level of the conventional digital network in Japan. Another type of 100 Mbit/s transmission system based on DPCM has been developed and a transmission test using an Intelsat communications satellite has been done from the United states to Japan. A 100 Mbit/s digital HDTV VTR has also been developed using this codec.

In line with the recent rapid progress on the standardization of B-ISDN, efforts for the development of HDTV codecs operating on 140 Mbit/s (H4 level of B-ISDN) or smaller bit-rates such as 70 or 40 Mbit/s are being made extensively. Many of the codecs are based on the Hybrid-DCT algorithm for bit-rate reduction. Figure 10 shows the block diagram of an encoder based on Hybrid-DCT. The Hybrid-DCT algorithm is becoming more popular. Due to the recent wide use of the DCT or Hybrid-DCT algorithm for image compression systems, various DCT LSI chips are now available on the market. It is expected that the costs of codecs will decrease rapidly with these DCT LSI chips.

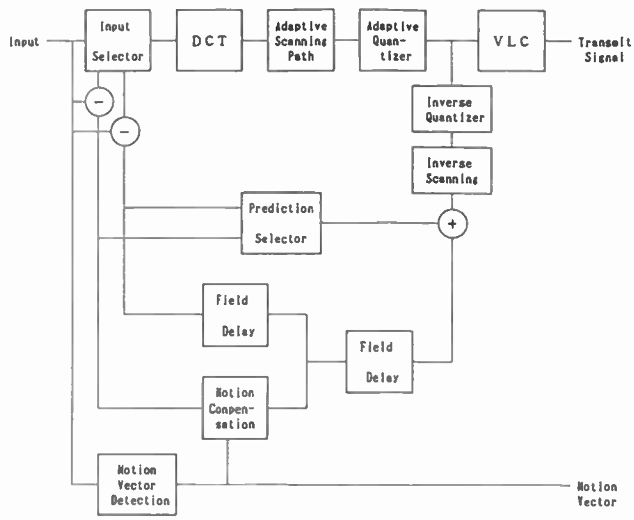

Figure 10. Schematic Diagram of Hybrid DCT Coding Scheme

(4) Digital transmission of MUSE signals

Although the MUSE system was originally designed for analog transmission using FM or AM modulation, digital transmission of MUSE signals is also possible. 130 Mbit/s of digital MUSE signal has been compressed into 60 Mbit/s using intra and interfield DPCM without causing degradation of picture quality. Figure 11 shows the coefficients for prediction. It is anticipated that the digital transmission of MUSE signals will prove more advantageous than FM transmission for a multi-hop transmission using communications satellites in terms of SN ratio and distortion of MUSE signals because no accumulation of noise or distortion occurs. On the other hand in the case of multi-hop FM transmission, noises added in each transmission hop accumulate.

MUSE DPCM is also applied for the digital recording of a MUSE signal.

	Intra-field	Inter-field
Y	0.48C + 0.51D	$0.5F_A + 0.25F_B + 0.25F_C$
C	0.47A + 0.28C + 0.22D	$0.52F_A + 0.35F_B + 0.12F_C$

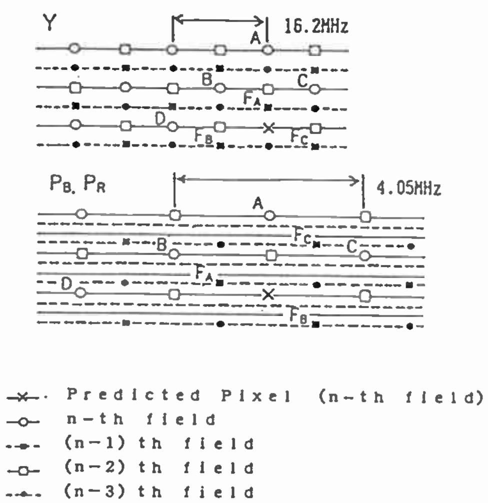

Figure 11. DPCM Prediction in MUSE Digital Transmission System

Non-broadcast application of the 1125/60 HDTV system

For its outstanding features of wide aspect ratio, large screen, high resolution and dynamic and clear sound, HDTV has an inherent potential for wide applications to various industrial fields. In fact, the 1125/60 HDTV system, "Hi-Vision," has been used in various non-broadcast fields such as medical fields, museum systems, multipurpose theaters, movie production, printing and electronic publishing, education, computer graphics and stereoscopic HDTV. In this paper, the High-Definition Gallery System for a museum is described as an application example.

The works exhibited by a museum are usually limited to a fraction of its total collection. In addition to this it is quite a task for visitors to find the pieces they wish to view in a large museum with enormous collections. The High-Definition Gallery System is a very effective means of supplementing museum functions and can help in solving the problems mentioned above. The HD Gallery System operates as follows.

HDTV digital image data of art pieces and textual or narrative descriptions are stored on a optical disc(CD-ROM, etc.) as data in an image data base for retrieval or as a program describing a particular work, artist, etc.. Images retrieved by a viewer or programs are displayed on an HDTV monitor. The first HD Gallery System in the world was installed in April 1989 in the Gifu Prefectural Museum of Art in Japan. Similar gallery systems have been introduced in various museums in Japan. It is expected that the exchange of optical discs and the transmission of image data through digital networks will be done in the near future between museums.

Conclusion

The establishment of a CCIR Recommendation for an HDTV studio standard has been recognized as a great step for the global development of HDTV. It is also necessary to continue international cooperation in the development of HDTV. Practical applications of the 1125/60 HDTV system based on CCIR Recommendations will be accelerated in various fields. Daily 6 to 8-hour HDTV satellite broadcasting is being planned using one of the transponders of the broadcasting satellite BS-3b which will be launched in August 1991. Non-broadcast applications of the 1125/60 HDTV system are also increasing rapidly in many fields. In addition to these activities, it is highly desired that efforts be made in the research and development of technologies such as large-screen flat-panel displays, high-speed and high-density recording, high-speed digital signal processing chips, etc. in order to effectively utilize the inherent potential of HDTV. Furthermore, the research and development of hardware and software systems are highly required to enable the production of high quality HDTV programs efficiently since a large demand for HDTV programs is foreseen in the near future.

THE HARMONIZATION OF BROADCASTING AND NON-BROADCASTING HDTV STANDARDS

Ronald Bedford
Radiocommunications Agency
London, England

Abstract

The development of HDTV has been rapid over the last few years attracting the interest of many industries where the potential of HDTV has many novel and useful applications. The CCIR saw the need to harmonize standards on a worldwide basis as these new technologies developed and consequently established an Interim Working Party (IWP 11/9) to co-ordinate with other international standards making bodies, i.e. the IEC, ISO, CCITT and CMTT.

The Interim Working Party found a great deal of common interest across a wide range of activities, when studying image structure, colorimetry, scanning, image compression, transmission and distribution.

A brief review of the work of the IWP is given together with the recommendations of the IWP on how harmonization of standards between broadcasting and non-broadcasting applications of HDTV can be taken forward.

INTRODUCTION

The CCIR has been primarily concerned with HDTV studio production standards but has also worked on standards for other parts of the "broadcast chain" from production through to reception. On emission topics, effort has been directed at satellite broadcasting, data broadcasting, terrestrial broadcasting and baseband formats, as well as relationships with enhanced television. On programme exchange topics, work has been done on standards for baseband formats, video tape, film and telecine.

It is now considered desirable to co-ordinate these activities with non-broadcasting HDTV communities of users, mainly represented by industrial, scientific, medical, computer displays, telecommunications and printing/publication interests. This would ensure an indispensable feedback channel through which the various requirements of the non-broadcast applications could be conveyed to the CCIR.

The importance of this goal has been repeatedly stressed by the CCIR HDTV Co-ordination Group and widely recognised at the Special Meeting of CCIR Interim Working Party 11/6 (High-definition television) with participation of IWP 11/7 (Digital television standards) which was held in Atlanta (USA) in March 1990.

To this purpose, Study Group 11 established during its Final Meeting in Geneva (October 1989), an Interim Working Party (IWP 11/9) to harmonize high-definition television standards taking into account the requirements of the IEC, ISO, CCITT and CMTT.

Interim Working Party 11/9 met in Tokyo, Japan from 3 to 9 October 1990 to review the progress of work and identify what further steps need to be taken by the CCIR, in consultation with other organs of the ITU, such as the CCITT, and international bodies, such as the IEC and the ISO, to reach early decisions on outstanding parameters of HDTV standards.

The IWP 11/9 produced a report (1); the contents and conclusions of which are subsequently reported in this paper.

HDTV APPLICATIONS

The development of HDTV for broadcasting is well known and seen by many as the major use of HDTV technology in the future. There are however many other uses for high resolution imagery (HRI) and HDTV which are emerging from the development phase. Table I lists those identified by IWP 11/9

The TABLE I clearly shows that with such a wide range to achieve complete harmonization of standards between them and HDTV broadcasting would present many difficulties. However there are many areas where commonality could be advantageous e.g. cost of production of display devices. IWP 11/9 examined the main characteristics of HDTV/HRI systems to see what scope there was for further study by the appropriate international standards making bodies.

(1) Draft New Report "The Harmonization of HDTV Standards between Broadcast and Non-Broadcast Applications", IWP 11/9 Document Number 090, Tokyo 2-10 October, 1990.

TABLE I

SECTOR	APPLICATION
Education	Teaching and training
Advertising & promotion	Electronic billboards, catalogues
Pre-recorded media	Discs and tapes
Motion Pictures	Film production, film post-production, theatre presentation
Industrial uses	Surveillance of production, transport, production inspection
Electronic file systems	Museums, libraries
Video conferencing	High resolution multiple windows
Medicine	Moving and still pictures for surgery, diagnosis
Aeronautical uses	Radar, simulators
Military	Aeronautical uses and surveillance
Computer uses	Computer graphics, home interactive video terminals, image simulation, desktop multi-media
Printing	Graphics, still pictures
Photography	Still images
Scientific	Microscopy, astronomy, simulation

IMPACT OF HARMONIZATION ON NON-BROADCAST APPLICATIONS

Harmonization of High Resolution Imaging (HRI) including HDTV, for broadcast and non-broadcast applications is possible. Furthermore, standards will improve the prospects of harmonization. Recent technology advances which may aid harmonization include:-

- digital technology;
- broadest feasible gamuts and ranges for parameters;
- extensibility and scalability; and
- image descriptor

Harmonization is important since the growth rate of non-broadcasting high definition imaging technology applications is considerably faster than the evolution in broadcast applications. Harmonization efforts must consider the broader range of imaging parameter requirements for non-broadcast applications. Further, they must recognise images are captured, created, stored, and transmitted in many ways. The body of film and hardcopy (paintings, printing, etc) images in the world is very large and will continue to grow.

It would be best to concentrate harmonization efforts on those areas and parameters that are not strongly application specific. For example, such parameters may include colorimetry, fixed aspect ratio, compression, resolution, flexible image encoding, and a header identifier. Architectures and standards developed in this way can have benefit for many years and for many generations of technology advance.

TABLE II (see Page 5) summarises the main factors effecting the development of non-broadcast applications showing the scope for harmonization with broadcast applications. There are gaps in the Table which need to be filled, however it demonstrates the areas where further study could be beneficial.

IMPACT OF HARMONIZATION ON STUDIO STANDARDS

Interim Working Party IWP 11/9 prepared a liaison statement for CCIR Task Group 11/1 responsible for the CCIR Recommendation for a single worldwide HDTV Studio Standard. IWP 11/9 commented on the main parameters in the following way:-

Image Resolution

A maximum resolution requirement of 8000 pixels per line is indicated for the digital storage of scanned pictures, which indicates that the family of about 2000/4000/8000 samples per line would be suitable. One contribution to IWP 11/9 pointed out that on the basis of downward extension, the adoption of 1920 samples incorporates Recommendation 601 and the existing video conferencing family of standards, as part of the extensible family. A similar tentative application is proposed in another contribution to IWP 11/9 based on 2048 samples providing that there is a requirement for a square-sample distribution.

Picture Aspect Ratio

There are varying requirements for picture aspect ratios. There is no strong consistency in the non-broadcasting requirement. Needs include, for example, from 16:9 through 4:3, square (1:1) to "portrait style" in which the image is taller than it is wide.

From a harmonization viewpoint there is no basis to select any particular value for the number of lines per picture, but the concept of a common sampling lattice or flexible standards' architecture could both provide the basis for an extensible family of standards, with simplified conversion capabilities.

Sample Distribution

There is some support for the concept of adoption of a square sample distribution, but this is not universal, nor is it seen as being absolutely necessary. In a television scanning system, a square sample distribution would not necessarily lead to square pixels and vice versa (see CCIR Report 1217) because of interlace and filtering effects and in this context, the current proposals before Study Group 11, based on 1920 samples/line (i.e. 1035, 1080, 1152 active lines), along with others, could be acceptable, especially with the use of agile terminals. However, in most computer display environments each picture element is stored and progressively displayed, so sample and pixel can be considered as synonymous. Here, the sample distribution therefore needs, practically to be square or integer-related.

Digital Representation

The majority of non-broadcasting applications for HDTV involve digital data manipulation and processing. As such, the digital representation of HDTV is more relevant to the needs of non-broadcasting applications than an analogue representation and new models to represent digital HDTV images should be considered.

Although a digital representation is currently being studied, the present emphasis to finalise an analogue representation for studio use, could be seen to be not entirely consistent with the needs of many non-broadcasting applications, and may not be helpful to the establishment of a standard that would continue to be useful in the future.

The present quantization law included in CCIR Recommendation 705 involves linear quantization of the gamma-corrected signals, whereas for non-broadcasting applications some form of log transfer characteristic may be preferred.

Picture Rate

Several contributions to IWP 11/9 indicate a need for a changing range of values for picture rate, such that unforeseen ranges in the future could be accommodated, in non-broadcasting applications: and, further, that a high display rate (which may be much greater than the image rate of change) is often needed with CRT displays. From the harmonization view-point there is little to be gained by adopting a standard with a single value for picture rate for all applications. The picture rate needs to be based on the information in the video header/sub-header, to suit each specific requirement. This may be different at different interfaces within a signal chain.

Colorimetry

There seem also to be tendencies to consider a "reference colorimetry" in non-broadcast applications. This would be needed to retain the same image appearance when passing from one display to another one (e.g. CAD on CRT to print).

For the time being, there are no firm requirements except the following:-

to be able to encompass all release media capabilities, i.e. inks, paints, dyes. This is achieved when Pointer's Real Surface Colours are encompassed, as considered in Study Group 11;

to be able to deal with red/green/blue or yellow/cyan/magenta representations. Whilst CCIR Recommendation 709 interim primaries are adequate for YP_RP_B representations, there are drawbacks with currently specified RGB representations, requiring either a wider signal dynamic range, or a wider colour triangle. The printing industry requires at least yellow, cyan, magenta and black.

Conclusions

Consideration of harmonization requirements suggests that the work of Task Group 11/1 might usefully take the following directions:-

(1) concentrate on the digital representation of HDTV;

(2) adoption of a standard that forms part of a family extensible to higher and lower resolution members;

(3) adoption of the concept of a layered architecture, within which minimum or target parameter values (rather than single, absolute values) can be derived, including the concept of a video index or descriptor;

(4) the methodology for deriving the picture (field/frame) rate should be standardised to ease interoperability and extensibility of broadcast and non-broadcast equipment and software;

(5) consider non-broadcast standardisation work when continuing its studies of colorimetry and transfer characteristics.

IMPACT OF HARMONIZATION ON TRANSMISSION STANDARDS

IWP 11/9 identified the following issues and areas for further study:-

(a) Efforts to match codec design to network transport is key.

(b) With regard to BISDN, various combinations are possible using fixed or variable bit-rate coding and ATM or STM transport. For each alternative, consideration should be given to coding complexity, quality of transported signal and transmission system performance.

(c) Further studies are needed for error correction techniques and cell loss compensation when transmitting HDTV signals over ATM structures of BISDN.

(d) Consideration should be given to satellite transmission of HDTV signals. In particular, special attention should be paid to interworking between satellite transmission and other transmission alternatives.

(e) Consideration should be given to analogue transport of HDTV signals in telecommunications networks, since analogue transport over various media affords the economical implementation of modulating/demodulating hardware in the near term.

Consideration of the aforementioned ideas may facilitate a flexible interfacing of proposed HDTV formats with transmission over telecommunications networks. Liaison between the standards groups addressing coding techniques and transport methods may foster efficient transport of HDTV signals in a telecommunications environment. Intelligent and well-informed decisions regarding compromise and tradeoffs in technologies will also be made possible.

IMPACT OF HARMONIZATION ON EMISSION (SATELLITE, CABLE AND TERRESTRIAL)

IWP 11/9 reached the following general conclusions:-

- Existing emission systems will be used for introduction of HDTV for a mass audience in the near future. Because of frequency constraints, terrestrial emission may not be a real candidate for HDTV in some countries.

- The main HDTV emission parameters have been specified in a way that they fit into the channels of existing or available broadcasting satellites and cable networks.

- Requirements for emission by satellite and cable are different. The MUSE and HDMAC systems have each taken this into account and selected parameters to balance the differing needs. For each system this leads to a single baseband signal format for both satellite and cable reception. This avoids additional cost for signal processing and duplication of parts in cable headends, as well as in the receivers and VCRs.

- Further harmonization between fundamental emission parameters of the two systems will also result in simplifying the design of multi-standard receivers and VCRs.

- The reported channel width of 12 MHz for MUSE and HDMAC on cable might lead to further harmonization of other fundamental parameters or characteristics of these systems.

Cable distribution will be widely used in several countries to supply HDTV to the public. As opposed to terrestrial emission, the basic requirements have not been generally standardised. Further work in this field will be necessary to harmonize cable distribution of HDTV with distribution by other media.

Further studies are needed to obtain detailed information on the emission of HDTV, particularly digital emission, to determine where harmonization may be necessary.

Other issues ripe for study are the determination of how an HDTV receiver might display signals derived from several different emission media, such as terrestrial broadcast, cable and satellite, and perhaps different services.

CONCLUSIONS

Television systems of higher resolution than conventional TV systems (see CCIR Report 624) have been in use for some time for specialised non-broadcast uses. HDTV for broadcasting is a new development, arising at a time when new digitally-based technologies add wide dimensions of application. At present, the standards of HDTV are based on the requirements of broadcasting. While many non-broadcast services and applications may have requirements similar to those of broadcasters, other applications of high-resolution imagery (HRI) may have requirements significantly different. A flexible standards architecture which addresses the range of broadcast and non-broadcast requirements appears to be technically feasible and may be a useful concept to achieve harmonization. This would also further encourage the convergence of the standards for image communications, including HDTV and HRI and may lead to their future integration. It is thus essential that the developers of such standards harmonise their activities, each developing standards in their respective areas of responsibility for HDTV and HRI, that offer the highest level of commonality within the constraints apparent in the various sectors.

TABLE II

Application of HDTV - non-broadcasting areas

	Areas where high definition techniques might be applied	Features different from broadcasting	Quality criteria	Factors constraining parameters	Existing or expected standard	Importance of commonality with broadcasting
Printing, graphics, stills	Where immediacy is required, and HDTV resolution is sufficient	Static images. CMYB required from RGB. Contrast range required may be higher than HDTV	Higher than video in respect of noise, and data compression for redundancy reduction only	Possible use of point-to-point links. Square 'samples' on advantage. Diverse image aspect ratios to be met	Various exist	-
Computer visual displays & CAD	Where high resolution is required,eg. detailed drawings and where HDTV resolution is sufficient	Currently mainly static. Computer-generated images. High display uptdate rate essential. Real time interactive video in future	Legibilitiy important	-	Various exist	Greater interchange of signals foreseen, and displays accepting broadcast signals would be useful and are currently being developed
Medical	Visual diagnosis (eg. endoscopy)	Real-time interactive computer-generated images used in addition to camera-generated images	-	Point-to-point links for remote diagnosis and training	None presently recognized. HDTV desirable	Important in training
	Training				Standard broadcast TV or HDTV	
	Computer assisted diagnosis				Linked to computer practice	
Military, radar, flight simulators	Various (surveillance data) and training	High display rates to avoid operator fatigue. Real-time interactive	Application specific resolutions	Tendency toward square pels and sequential scanning	Wide variety, determined by application. Broadcast standards may be adopted where they happen to be suitable	-
Industrial surveillance	Magnification and inspection of small part of image	Picture sometimes subjected to computer analysis. Images often computer generated	-	Point-to-point links sometimes required	Likely to adopt broadcast standards when they appear	-
Video conferencing	To give increased awareness in face-to-face contact. Increased range of picture material. User definable windows	Real-time interactive	-	Point-to-point links essential. Multi-channel sound and various data included	Low definition "Common intermediate format" derived from telecom specs but related to existing broadcast standards	Displays accepting broadcast signals and video-conference images would be useful
Home interactive video terminals	Windowing of different information. High resolution storage and printout	Real-time interactive	-	Computer interfaces important. Bit rate important	Dependent on type of service	Displays accepting broadcast signals would be useful
Motion pictures	Film production	Greater contrast ratio	Better than HDTV quality may be preferred	May also use computer generation	Likely to adopt broadcast standards or be closely related to them for theatrical presentation	Desirable
	Post production of films					
	Theatrical presentation		Broadcast HDTV studio quality adequate	Will use point-to-point links and VTRs		Highly desirable

ATV TRANSMISSION PROPONENTS FOR NORTH AMERICA:
The World is Watching

Wednesday, April 17, 1991

Moderator:
Michael Rau, NAB, Washington, District of Columbia

ACTV STATUS REPORT*
Jack Fuhrer
David Sarnoff Research Center
Princeton, New Jersey

THE NARROW-MUSE SYSTEM FOR TERRESTRIAL BROADCASTING OF HDTV
Minoru Honda and Yutaka Tanaka
NHK (Japan Broadcast Corporation)
Tokyo, Japan

CURRENT STATUS OF DIGICIPHER DEVELOPMENT FOR THE U.S. TERRESTRIAL BROADCAST STANDARD*
Robert Rast
General Instrument Corporation
San Diego, California

THE ALL-DIGITAL SPECTRUM-COMPATIBLE HDTV SYSTEM
Rich Citta, Carl Eilers, Ron Lee and Jouke Rypkema
Zenith Electronics Corporation
Glenview, Illinois

ATRC DIGITAL SIMULCAST (ADTV)*
Carlo Basile
Philips Laboratories
Briarcliff Manor, New York

Glenn Reitmeier
David Sarnoff Research Center
Princeton, New Jersey

PROGRESS ON MIT-CC SYSTEM*
Jae Lim
MIT
Cambridge, Massachusetts

EXECUTIVE PANEL*
ATV systems proponent executives discuss advanced television strategies.

Speakers—Dr. Joseph Donahue, Thomson Electronics, Washington, D.C.; Dr. James Carnes, David Sarnoff Research Center, Princeton, NJ; Dr. Jerry Heller, General Instrument Corp., San Diego, CA; Dr. Masao Sugimoto, NHK, Tokyo, Japan; Jae Lim, MIT, Cambridge, MA; Wayne Luplow, Zenith Electronics Corp., Glenview, IL

*Paper not available at the time of publication.

THE NARROW-MUSE SYSTEM FOR TERRESTRIAL BROADCASTING OF HDTV

Minoru Honda and Yutaka Tanaka
NHK (Japan Broadcast Corporation)
Tokyo, Japan

INTRODUCTION

NHK has developed the Narrow-MUSE system for the terrestrial broadcasting of the high definition television. The Narrow-MUSE system is designed for simulcasting in which it is important to solve the interrelated interference issues caused by the introduction of ATV service in the existing terrestrial environment.
Therefore, NHK has developed the new modulation method for the Narrow-MUSE signal.
This paper describes the technical characteristics and the modulation scheme of the Narrow-MUSE.

SIMULCASTING

In March 1990, Chairman Sikes of FCC mentioned his opinion clearly that FCC is going to select a simulcast system for the American terrestrial HDTV broadcasting system, because the simulcast system can provide the best picture quality. The basic idea of the simulcasting is shown in Figure 1. In the simulcating system two signals are transmitted simultaneously but separately. A converted NTSC images is transmitted on one of the existing 6 MHz channel while ATV images is transmitted on another 6 MHz channel.

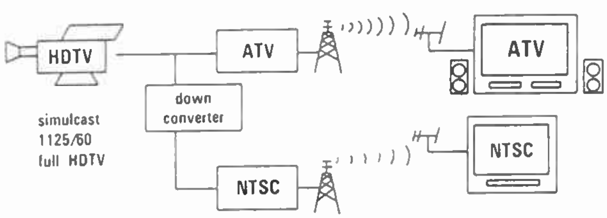

Fig. 1 Simulcast system

According to the studies of FCC advisory committee, the co-channel transmitter spacing must be reduced to about 160km, as opposed to the currently required separations which vary from 240km to 350km, to assign the ATV channel for almost all licensees.
For ATV systems, it is required that they do not produce interference and are not affected by interference in the current channel allocation. So it is very important to cope with the co-channel interference and the various kind of "taboo" interferences.

BASEBAND ENCODING SCHEME

General description

Narrow-MUSE is designed to transmit HDTV signals through the terrestrial VHF or UHF channels whose bandwidth is 6 MHz. Narrow-MUSE uses the same coding scheme as the full-band MUSE (MUSE-E) which was designed for the satellite HDTV broadcasting and has the baseband bandwidth of 8.1 MHz.[1]
The Narrow-MUSE codec is built using MUSE-E codec with a simple adapter. The adapter consists of a line-number converter, and interface circuits. The simplified block diagram of the Narrow-MUSE codec is shown in Figure 2. For the decoder, prototype LSIs designed for MUSE-E decoder can be used.[2]

Function of the adapters

For encoding and decoding Narrow-MUSE signals, the codec for the MUSE-E system can be used with adding an adapter which consists of a line-number converter and interface circuits. The HDTV signal is first reduced to a 750/60 signal, then arranged in the 1125/60 format by adding dummy lines. The coding process is performed by a MUSE encoder, after which 750 lines are taken out and are broadcast.

Figure 3 shows the frame format of Narrow-MUSE. The baseband bandwidth of the encoded signal is 4.86 MHz.

At the decoder, the 750 line signal is again arranged into 1125 format and is interpolated back to a full-band signal with 750 lines. Finally, it is converted to an 1125 signal and displayed.

Although the number of lines are reduced to 750, the vertical resolution is almost the same as 1125 format when displayed on a 1125 monitor with a Kell factor of around 0.65.

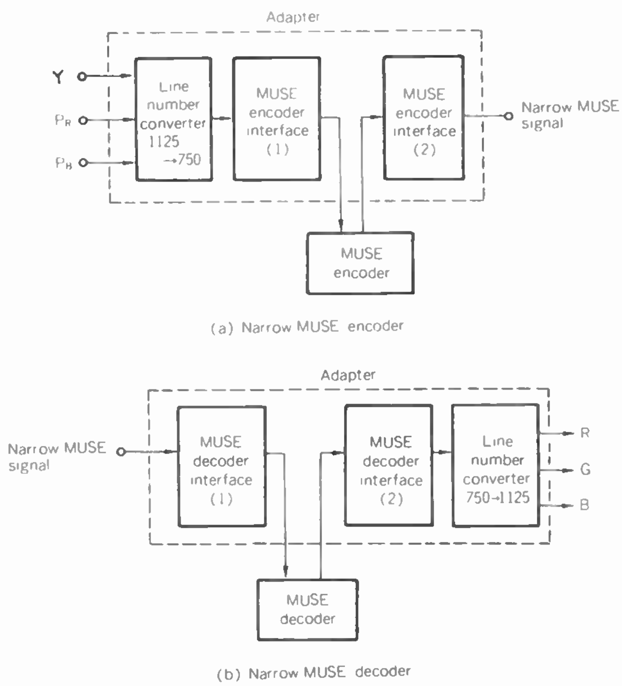

Fig. 2 Narrow-MUSE system using MUSE system and its adapters

Audio signals

Audio signals are transmitted digitally. To transmit four channel audio signals with high quality, near-instantaneous compounding DPCM technique is employed. The bit rate after encoding is 1.35 Mbit/s including error correction and ancillary data. Encoded audio signals are multiplexed during the vertical blanking interval of the video signal as a ternary code. Since the video signal and the audio signal are time-domain-multiplexed, there is no interference between these two signals.(3)

MODULATION SCHEME

General description

A new signal processing is introduced for the analog modulation of Narrow-MUSE to reduce the interference with existing NTSC service. The block diagram of a frequency-multiplexing modulation method is shown in Figure 4.

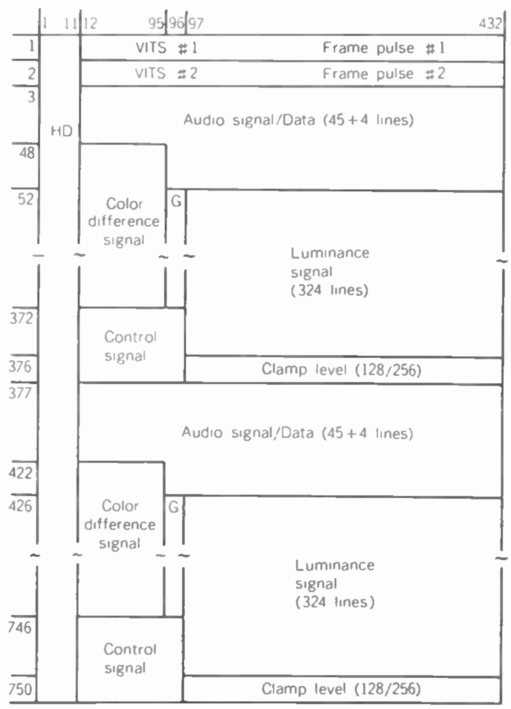

Fig. 3 Narrow-MUSE signal format

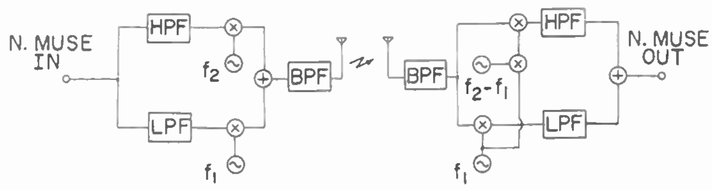

Fig. 4 Block diagram of modulation schemes

In the transmitter, the Narrow-MUSE signal is divided into two parts, that is, the low frequency component with high energy and the high frequency component with low energy. The low frequency component(from D.C. to about 800 kHz below) is modulated by VSB-AM with a carrier frequency of f1.
At the same time, the high frequency component(more than about 800 kHz) is modulated by SSB with another carrier frequency of f2.
Thereafter, these components are frequency-multiplexed again and are transmitted.
As for the sync pulse, it is transmitted only via low frequency channel.

In the Narrow-MUSE receiver, the carrier wave of f1 is obtained by a PLL circuit. The low frequency component and the sync pulse are reproduced by a synchronous detection circuit. In order to reproduce high frequency component, a carrier frequency of f2 is necessary.
This carrier frequency is made from the sync pulse and f1.

This modulation process produces a window which does not contain video information. The spectrum allocation is shown in Figure 5(a).

Interference

The Narrow-MUSE signal using this modulation scheme is robust against the interference from the NTSC co-channel service, because the low frequency component with high energy of the NTSC signal exists at the window area where no Narrow-MUSE information exists. In addition the Narrow-MUSE signal does not cause interference to the existing co-channel NTSC service because the low frequency component with high energy of the Narrow-MUSE signal is filtered away by a Nyquist filter of NTSC receivers. The characteristic of a Nyquist filter in an NTSC receiver is shown in Figure 5(b).

Also the audio signal of NTSC and the Narrow-MUSE video signal do not cause serious interference with each other because the audio carrier of NTSC is located at the very high frequency edge of Narrow-MUSE, and the energy of Narrow-MUSE around there is low.

After all, a reduction of more than 25dB in the effect of co-channel interfering are obtained.

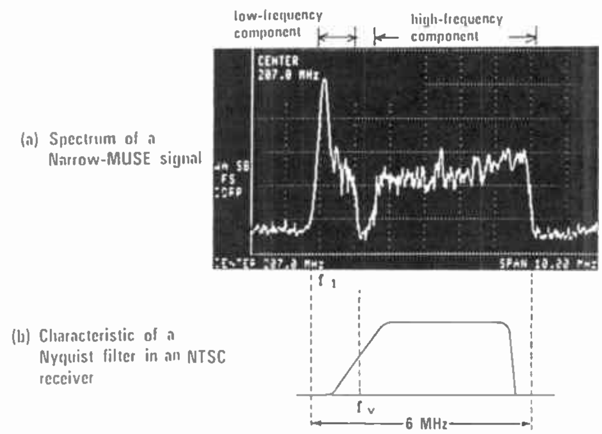

Fig. 5 Spectrum of the Narrow MUSE signal and an IF characteristic of an NTSC receiver

CONCLUSION

NHK has developed experimental equipment of the Narrow-MUSE for the ATV system in the United States. A new signal processing is introduced for the modulation of Narrow-MUSE to reduce the interference with existing NTSC service. All equipment including a baseband codec and a modem is available now.

Transmission tests using these equipment is now conducted at NHK Laboratories to prepare for the ATTC testing which begin in July, 1991.

Narrow-MUSE, which was originally designed for the HDTV terrestrial broadcasting can also be used for the HDTV cable television system. And program materials for the Narrow-MUSE service is becoming available widely, because Narrow-MUSE uses 1125 format as the input signal. Almost all HDTV equipment now available on the market is based on this format called SMPTE 240M. So it has been confirmed that Narrow-MUSE can be used for the terrestrial broadcasting of HDTV.

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THE ALL-DIGITAL SPECTRUM-COMPATIBLE HDTV SYSTEM

Richard Citta, Carl Eilers, Ron Lee and Jouke Rypkema
Zenith Electronics Corporation
Glenview, Illinois

ABSTRACT

The All-Digital Spectrum-Compatible HDTV (DSC-HDTV) System is a natural extension of the previous, already partially digital Spectrum-Compatible HDTV (SC-HDTV) System.

The video source and display scanning standards have remained the same consisting of progressively scanned 787.5 lines/frame, 59.94 frames/second video. (This corresponds to 1575 lines/NTSC frame.) The aspect ratio is 16:9, the horizontal deflection frequency is 47.203 kHz, three times NTSC, and the video bandwidth that can be accommodated is 34 MHz.

Transmitter and receiver signal processing are performed on square pixels in a 720 line by 1280 pixel array, conforming to the Common Image format. Additional pixels are assigned to guard bands for processing tolerances.

The video compression algorithm uses motion-compensated transform coding in both the spatial and temporal domains. The required video bandwidth is thus reduced to 5.4 MHz. The video compression aspects are described in a companion paper "A High Performance Digital HDTV Codec" by A. Netravali et. al.

The DSC-HDTV System is a simulcast system using a 6 MHz channel in the existing TV bands. The all-digital transmission results in pictures free of thermal noise ("snow") throughout the service area. Other picture impairments are avoided by forward error correction using a Reed-Solomon code and by reference signal-assisted ghost canceling/channel equalization.

Compared to SC-HDTV, the DSC-HDTV transmission signal now has a more noise-like character which has further reduced the visibility of interference into an NTSC cochannel. A new effective system has been devised to reject NTSC cochannel interference into a DSC-HDTV receiver.

A DSC-HDTV transmitter has a service area equal to that of an NTSC transmitter while radiating at least 12 dB less power, with a smaller antenna, without aural transmitter and without notch diplexer.

ALTERNATE HDTV DELIVERY METHODS: *Worlds Apart?*

Wednesday, April 17, 1991

Moderator:
Wendell Bailey, NCTA, Washington, District of Columbia

BROADBAND TECHNOLOGIES OF THE FUTURE
Norman Epstein
GTE Telephone Operations
Irving, Texas

TRANSITION TO HDTV—A CABLE OPERATOR'S SCENARIO*
Walter Ciciora
American Television and Communications (ATC)
Stamford, Connecticut

HDTV MUSE SIGNALS ON CABLES AND OPTICAL FIBERS
Yozo Utsumi
NHK (Japan Broadcast Corporation)
Tokyo, Japan

DBS MARKET ECONOMICS IDEAL FOR HDTV*
Robert Hubbard
U.S. Satellite Broadcasting Co.
St. Paul, Minnesota

INTERNATIONAL HDTV SERVICE VIA INTELSAT
Edward A. Faine and William R. Schnicke
COMSAT
Washington, District of Columbia

THE FUTURE OF HIGH-DEFINITION TV IN EUROPE IS SATELLITE TELEVISION*
Philippe-Olivier Rousseau
Eutelsat
Paris, France

PROJECT OF AN ELECTRONIC CINEMA SERVICE IN MEXICO CITY USING TERRESTRIAL HDTV/MUSE-E BROADCASTING*
Carlos Nunez Arellano
Televisa
Mexico City, Mexico

*Paper not available at the time of publication.

BROADBAND TECHNOLOGIES OF THE FUTURE

Norman Epstein
GTE Telephone Operations
Irving, Texas

ABSTRACT

Advances in digital communication technologies have fostered the availability of economical interactive broadband digital networks. These networks can provide customers with advanced services such as High Definition Television (HDTV), video conferencing, interactive educational services, home shopping, and other services in addition to providing basic telephone service. Prototypes of these future broadband networks are currently providing information on the development and deployment of integrated broadband networks.

Digital technologies are rapidly being introduced that permit the delivery of a wide variety of services over integrated networks. These technologies provide an extraordinary improvement in transmission quality, efficiency, cost, and the ability to integrate and manage multiple signals. Coupled with optical fiber media, digital technology enables the economical delivery of multiple broadband signals with a virtually unbounded bandwidth capacity.

For several years, GTE Telephone Operations has been engaged in research on the characteristics and deployment of multiservice broadband networks. The results of this research have indicated several areas that need additional industry work to achieve the full potential of broadband technologies.

This paper presents a telephone company perspective on the development and possible uses for these emerging broadband digital technologies. It also discusses the need for further work on enabling issues that are facing the industry.

INTRODUCTION

Modern telecommunication networks are constantly increasing in complexity and sophistication. Switching and transmission facilities are rapidly migrating to the exclusive use of digital signals and components.

The deployment of digital technologies began in the telephone industry in the early 1960s. What began as an attempt to avoid cable replacements in metropolitan areas has resulted in a revolution in the industry's architecture and service capabilities. For instance, GTE Telephone Operations serves more than 70% of its customers with digital access lines. This figure could grow to 90% by 1995. In the same period, transmission facilities are being upgraded to optical fiber and digital transmission formats.

The telephone industry has reaped several benefits from this migration to digital technology. Some of the key advantages that have been realized are listed below:

- Increased transmission quality.
- Improved reliability and security.
- Lower costs for equipment, engineering, and maintenance.
- A higher degree of equipment compatibility.

The quest for a US HDTV standard has also advanced rapidly to an all digital design. Now the majority of HDTV proponents are proposing digital systems (i.e., Zenith, General Instrument, Phillips, and Sarnoff). Among the benefits being highlighted for these digital HDTV systems are:

- Better picture quality due to more sophisticated error correction techniques and less vulnerability to signal level variations above a given threshold.
- Smaller satellite antennas for DBS customers due to the lower receive signal power required for digital signals.
- Better economics and easier interoperability between all media.
- Simplified switching, multiplexing, and program security.

These developments have created an environment for the convergence in the delivery of video and information services. Future broadband networks will be capable of delivering switched Broadband and Narrowband services for residential and business customers. They could provide access to a broad range of business products, services, educational programs, medical support, as well as conventional telephone services.

Because of the promise of these broadband technologies, GTE has been active in the research of many of the issues impacting development and deployment of broadband components and networks. The next section summarizes these activities and presents some of the conclusions that have been reached.

VIDEO RESEARCH EFFORTS AT GTE

Cerritos Test Bed

The GTE broadband test bed in Cerritos, California is being used to experiment with the transmission of broadband services. One important test in Cerritos is the provision of video on demand and video phone service to selected test customers in Cerritos. This test uses proprietary technology developed by GTE Laboratories that includes a broadband switch and other advanced components.

Video on demand gives customers a choice of as many as 100 programs that can be selected and viewed based on the customer's schedule. It also provides access to full VCR features, such as pause or fast forward, to enhance their viewing control. The video phone service allows both parties to see each other as they communicate.

The video on demand and video phone service require the provision of interface equipment on the customer's premises. This equipment includes interface circuitry for telephones, data equipment, televisions, camcorders, VCRs, and an infrared keypad. In addition, the equipment performs the following functions: termination and origination of the optical transmission signals, multiplexing signals, and operational and application software functions.

One of the tests GTE is conducting in Cerritos substitutes optical fiber for coaxial cable to deliver television signals to the customer premises. Telephone service is also delivered over the same optical fiber facilities. The interface equipment consists of optical transmission and receiving equipment and interface circuitry for both the television and telephone. A standard CATV converter box is used to perform channel selection and the descrambling of premium channels.

An additional service being tested in Cerritos is GTE MainStreet. The customer can access a shopping service with their television and an infrared keypad in their living room. The MainStreet service simulates shopping, browsing, ordering, money transfer, etc., in a shopping mall or the hometown's main street. The GTE MainStreet service uses coaxial transmission facilities to the home and the telephone network as the transmission facility from the home. GTE is also experimenting in Cerritos with placing GTE MainStreet completely on optical fiber facilities. One definite advantage of optical fiber is that it permits the use of upstream and downstream signals for interactive services on the same facility.

One other important facet of the Cerritos project is feedback from our customers. They have expressed two particular needs which have specific relevance to this paper. Customers do not like the number of boxes (such as VCR, CATV converter box, TV receiver, a/b switch) required on their premises. Also, they do not like the requirement of multiple infrared keypads. The customer definitely sees a need to consolidate the number of boxes and develop one standard infrared keypad that would work with the TV receiver, VCR, and CATV converter box.

The second need is that customers have expressed a positive reaction to the VCR functions (pause, rewind, fast forward, etc.) associated with playing a video tape in their VCR. Future inter-active video services using optical fiber facilities should have interface circuitry that allow customers to maintain these VCR functions as programming is being viewed.

Fiber Ready TV

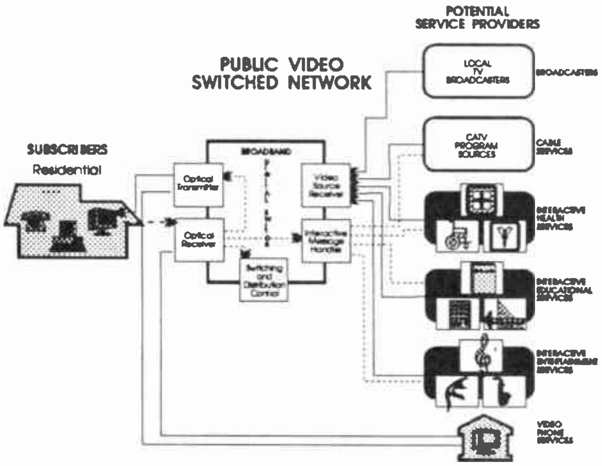

Figure 1
The Public Video Switched Network (PVSN)

GTE presented an experimental Public Video Switched Network (PVSN) at the 102nd NARUC Annual Convention in Orlando, FL (see Figure 1). The PVSN uses the GTE broadband switch to route advanced services from audio/data/video providers to home and business customers. The "Fiber-Ready" television concept provides a customer friendly interface to the network. Advanced services provided through the network are Video Dial Tone, Video Gateway, Video Guide, Premium Channels, Videophone, and the Electronic Library.

The "Fiber-Ready" television used in the PVSN addresses some of the same issues for NTSC television signals that the Electronic Industries Association (EIA) is addressing for HDTV. The "Fiber-Ready" television allows the consumer easy access to services from multiple networks. The consumer's remote control and an on-screen menu are used to select between services offered from the off-air broadcast, CATV, Direct Broadcast Satellite (DBS), the in-home VCR or a broadband fiber network. The "Fiber-Ready" television is illustrated in Figure 2. The receiver was built using a commercially available television receiver and retrofitting it with an optical fiber interface. The fiber compatible television has the functions found in today's consumer television sets, as well as additional circuits needed to process optical signals.

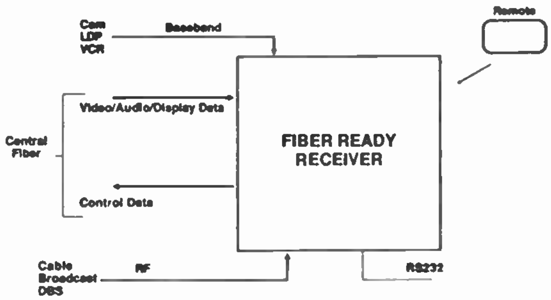

Figure 2
NTSC Fiber Ready Receiver Interface Diagram

Figure 3 illustrates the optical interface functions that provide two-way communication with the PVSN central office. A downlink optical receiver accepts audio, data, and video at 140 Mbit/sec. This optical signal is converted to electrical signals needed by the television receiver's video and audio processors. An uplink optical transmitter is used to relay keystrokes from the consumer's remote keypad. The uplink data is used to configure the broadband switch in the central office for program selection. A second unit, a "Fiber-Ready" camera, can be connected to the network to provide a two-way video connection.

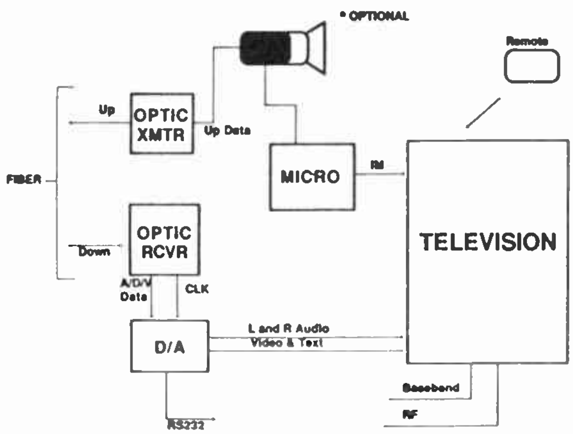

Figure 3
Fiber Ready Receiver Optical Interface Functions

VISTAnet

A new communications network, called VISTAnet[1] (see Figure 4), has been designed to move computer information over long distances at speeds which may ultimately reach 2.48 billion bits per-second. The network allows UNC-CH cancer researchers to access a CRAY supercomputer in Research Triangle Park in Durham, NC, some 18 miles away. The fiber-optic network uses very-high-speed, broadband digital switches provided by GTE and BellSouth Services.

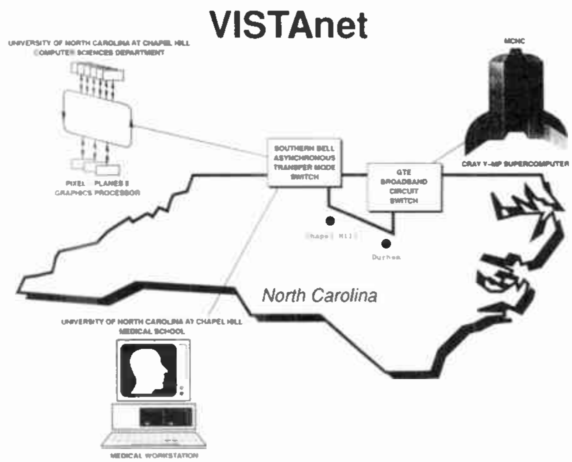

Figure 4
VISTAnet

Using VISTAnet, clinical oncologists at the UNC Medical Center can transmit CAT-scan images of cancer patients to the CRAY supercomputer. High-definition, three-dimensional graphics of the images are produced with a UNC-designed, state-of-the-art graphics computer (Plexi-Planes 5) located at UNC-CH's department of Computer Science.

Working interactively with these computers, the doctors can immediately study various radiation-dose distributions for certain common tumors, avoiding delays often associated with this type of analysis.

OPEN INDUSTRY ISSUES

Through its research in broadband networks, GTE has identified several issues that are critical to realizing the full potential of the future digital broadband networks. Three of the key issues are:

- Optical Fiber Deployment
- Standard Customer Television Interface
- Standard Video Supplier Interface

Optical Fiber Deployment

Fiber deployment is crucial to the full development of the potential of interactive broadband networks. Further development of this technology is needed to allow its economical extension to the home.

Today's CATV and telephone networks employ fiber in their trunking portion and copper pairs or coax in their customer access portion. Economic considerations often constrain the network provider from deploying fiber directly to the home. This situation has generated the use of hybrid video delivery systems. In these systems, fiber is deployed to a node at the curb and then interfaced

1 Participants include: University of North Carolina-Chapel Hill (UNC-CH), Microelectronics Center of North Carolina (MCNC), BellSouth Services, Corporation for National Research Initiatives, and GTE Corporation.

with coax to the home. The fiber/coax interface cost is thus distributed among multiple customers.

The ideal target would be to extend the optical fiber to the home. Further research and development could lead to improved economics of placing this last run of fiber to the home. Then the broadband network can provide its full capability as an information connection between the customer's home and the world.

The Video Supplier Interface

The use of the full potential of broadband networks will be fostered by the development of a standard interface that will allow access to customers by multiple video sources.

The broadband network interface for the video supplier requires video switching capability at 100's of Mb/s. Many video program providers or Video Enhanced Service Providers (VESPs) can then direct information to, and retrieve information from, specific customers. Research at GTE Laboratories indicates it is possible to route digital NTSC signals, digital HDTV, and data signals to hundreds of customers from a remote switching site. They have demonstrated switching performance of more than 800 Mb/s in a laboratory-scale experiment.

Using the switch technology developed at its Laboratories (see Figure 5), GTE will replace an analog switch installed in its Cerritos test bed with a digital switch. This switch will provide video-on-demand and related broadband services to a sample population of customers in Cerritos, California.

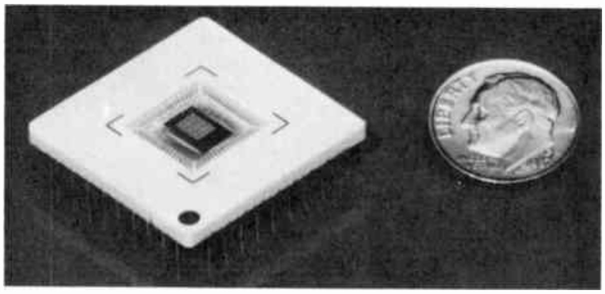

Figure 5
64 Input by 16 Output Switch Chip Module

GTE is also preparing to use these developments to install a high-performance cross-connect in its Parkwood central office in Research Triangle Park, NC, as part the VISTAnet project discussed above.

GTE is continuing research on the design and operation of this broadband switching technology to provide a satisfactory video supplier interface.

The Customer Interface

The development of a standard customer interface for television receivers is vital to the development of HDTV in the United States. The potential of broadband networks can also be realized by the adoption of such a standard.

The FCC's efforts to select a broadcast HDTV standard allows for alternate media to select HDTV transport standards. This means that HDTV may be transported differently over microwave, CATV, fiber, and satellite. However, the HDTV signal format at the TV set must conform to the HDTV standard selected by the FCC (since the set will be designed to work with the broadcast TV signal). From a practical viewpoint, TV manufacturers will not build different receivers for each alternate media. This prompted the industry to consider standardization of the Multiport TV receiver concept.

The EIA Advanced Television Committee (ATV) formed the EIA ATV Multiport Receiver Subcommittee to address interoperability issues. This committee is also defining the external receiver interfaces required to effectively and economically interface with different HDTV services. A key objective of the committee is to retain compatibility with NTSC. This subcommittee has developed a generic reference model of an HDTV television receiving system which is compatible with NTSC. This model includes a foundation on which to build future analog and digital HDTV services.

CONCLUSION

This paper has addressed some of the key issues and considerations which affect the broadband network interfaces necessary to provide Advanced Television and HDTV services to the public. Broadband networks could be designed to incorporate flexible customer interfaces and video supplier interfaces. GTE is involved in a number of video projects which are investigating the characteristics required for these interfaces. GTE research has identified the potential for providing advanced video and information services to the customer over a digital broadband network. This research is aimed at developing digital broadband networks that make sense technically and economically.

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HDTV MUSE SIGNALS ON CABLES AND OPTICAL FIBERS

Yozo Utsumi
NHK (Japan Broadcast Corporation)
Tokyo, Japan

ABSTRACT

HDTV distribution on cables and optical fibers is paid great attention in Japan where the HDTV broadcast service via satellite broadcasting is strongly promoted toward next century, as supplemental systems of DBS and future more channel CATV systems. The transmission systems of HDTV on cable and optical fiber CATVs are described in this paper. HDTV MUSE(Multiple Sub-Nyquist Sampling Encoding)-VSB•AM and MUSE-FM transmission on coaxial cable CATV systems via communications satellites, and HDTV MUSE-FM transmission on a newly developed demand access optical fiber CATV system are explained.

INTRODUCTION

NHK has been broadcasting HDTV experimental programs for an hour per a day via broadcasting satellites, BS2b and BS3a since June 1989. Full-fledged HDTV satellite broadcasting via BS3b for eight hours per a day is planned to start in November 1991 by using the MUSE system.

And the MUSE system has been also successfully tested over communications satellites under the auspices of INTELSAT and other organizations, for cable television transmission, and for optical fiber transmission.

We performed a MUSE transmission experiment through two transmission systems in cascade, comprising of a communications satellite and cable facilities, with cooperations of NCTA and HBO in April 1989. At that time, the MUSE-FM signal was uplinked from the HBO Communications Center in Long Island, New York, to SATCOM K1 and downlinked to two cable headends in the Washington suburbs. At the cable headends, this signal was transformed into the MUSE-VSB•AM signal, and transmitted to remote subscriber locations. The typical results of this experiment are as follows: the unweighted SN ratio is greater than 39 dB and the picture quality is greater than 4 on a 5 grade subjective evaluation[1][2]. In October 1989, Japanese Space-cable-net project where NHK joined, performed MUSE-VSB•AM and MUSE-FM transmission experiments on cables via a communications satellite, JC-SAT or Superbird. Six Japanese urban style cable facilities were used in these experiments, and successful results were obtained.

The first half of this paper describes the outline and experimental results of these transmission tests.

In addition, remarkable progress has been achieved in FM-FDM transmission of video signals for optical fiber CATV systems[2],[3],[4].

We developed a demand access optical fiber CATV system for HDTV MUSE signals. On a trunk-line, 40 MUSE-FM signals can be transmitted over about 30 km. At the hub, arbitrary 4 MUSE-FM signals are selected by channel request siganals from an individual subscriber, and can be transmitted on each subscriber line of about 19 km. The CN ratio through this total system is greater than 17.5 dB which is the perceptible noise limit of MUSE-FM transmission with 27 MHz bandwidth[2]. This demand access optical fiber CATV system will be introduced as an operational CATV system of Tokyo Teleport Town in the Tokyo bay area in 1994, where various state-of-the-art communication systems are envisaged to pave the way for a future modern city.

The second half of this paper describes the outline and experimental results of this demand access optical fiber CATV system for HDTV.

HDTV CABLE TRANSMISSION EXPERIMENT VIA SATELLITE

MUSE-VSB•AM Transmission on Coaxial Cable

A MUSE transmission system compresses the baseband bandwidth of HDTV signals, which have five times as much information as current TV signals, to just double, without deteriorating picture quality. This means an HDTV picture can be transmitted through a narrow bandwidth, and therefore MUSE can be effectively applied to CATV systems.

The transmission spectrum for MUSE-VSB•AM is shown in Figure 1, and a VSB filter is used on the transmitting side and a Nyquist filter on the receiving side. It has 12MHz bandwidth, and can be transmitted in a channel adjacent to current TV channels.

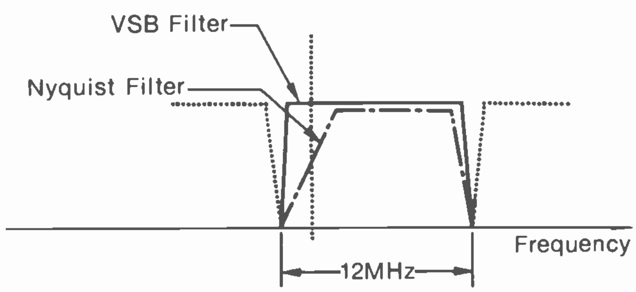

Figure 1 MUSE-VSB•AM Transmission Spectrum

The required CN and CTB (Composite Triple Beat) ratios are the main factors in limiting the number of cascaded amplifiers for coaxial cable systems. The relationship between the number of amplifiers and the required CN (4MHz bandwidth) and CTB ratios for MUSE-VSB•AM transmission is shown in Figure 2. Also shown in the figure are the regions where the CN ratio gives a picture quality of grades 4 and 5 using a five-point comment scale. For the calculation, the performance of trunk amplifiers is assumed as follows: CN ratio = 60 dB, CTB ratio = -90 dB. It can be seen from the figure that a picture quality of grade 4 requires a CN ratio of about 46dB for MUSE. HDTV transmission requires a higher CN ratio in comparison with NTSC.

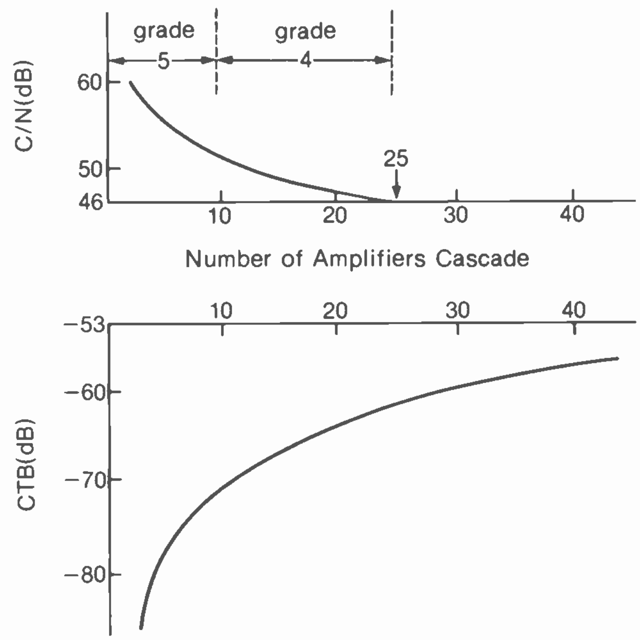

Figure 2 CN and CTB Ratios in a Cascade (MUSE-VSB•AM)

MUSE-VSB•AM Transmission Experiment in NCTA Demonstration

The setup of this transmission experiment is illustrated in Figure 3. In this experiment, a MUSE signal was transmitted through two transmission systems in cascade, comprising a communications satellite and cable facilities.

At the satellite transmitting end of the HBO Communications Center in Long Island, New York, an HDTV studio signal was encoded into the MUSE signal, which was transmitted by frequency modulation to the communications satellite, SATCOM K1.

At the cable headends, the MUSE-FM signal received from the satellite was transformed into the MUSE-VSB•AM signal. This signal was multiplexed with many channels of conventional broadcast waves transmitted via the other satellites and ground microwaves. These multiplexed

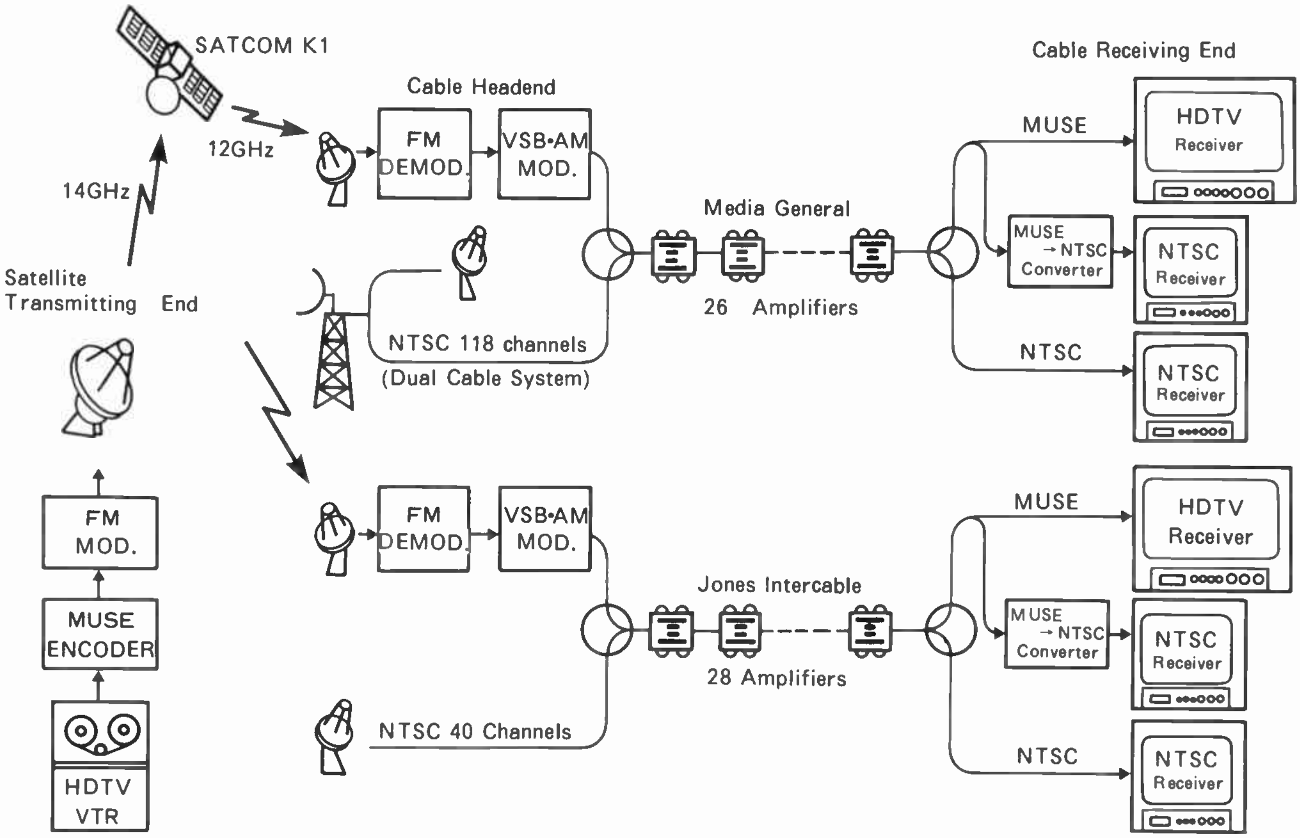

Figure 3 Experimental Setup of HDTV Cable Transmission via Satellite

signals were transmitted to the cable receiving ends through multistage amplifiers and coaxial cables. The cable systems involved in this transmission experiment were Media General which owns state-of-the-art system in Fairfax, Virginia, and Jones Intercable, which owns more conventional system in Anne Arundel, Maryland.

At the cable receiving ends, the received MUSE signal was decoded and displayed on an HDTV monitor. The MUSE signal was also received by a conventional TV set, with a simple and low cost MUSE-NTSC converter.

Items	Data	Comments
Downlink EIRP	50.0 dBW	
Receiving Antenna Gain	49.5 dB	Antenna Diameter 3.1m
Uplink CN Ratio	30.0 dB	
Total CN Ratio	23.7 dB	
Transmission Bandwidth	36 MHz	
Frequency Deviation	17 MHz	Without Energy Dispersion
FM Improvement	17.7 dB	
Emphasis Improvement	9.5 dB	
Received Unweighted SN Ratio	50.9 dB	

Figure 4 Transmission Parameters of Satellite Link

Items	State-of-the-art System	Conventional System
Company	Media General	Jones Intercable
Number of NTSC Channels	118(Dual Cables)	40
NTSC Transmission Method	HRC*	Standard
Number of Subscribers	167,000	32,000
Modulation Method	VSB・AM	VSB・AM
Transmission Bandwidth	12 MHz	12 MHz
Video Carrier Frequency	330.30 MHz	331.25 MHz
Channels for HDTV	42, 43	42, 43
Adjacent Channels	41, 44	41
Number of Amplifiers	26	28
Cable Length	13 km	20 km

* Harmonically Related Carrier

Figure 5 Outline and Transmission Parameters of Cable Facilities

Facilities	Satellite System		Cable system				
	Frequency Deviation (MHz)	Received CN Ratio (dB)	Received CN Ratio (dB)	Modulation Depth (%)	Unweighted SN Ratio (dB)	CTB (dB)	Grade of Picture Quality
State-of-the-art System	16.8	23.5	44.5	83.3	41.0	-44	4
Conventional System	16.8	24.0	44.3	70.0	39.1	-53	4

Figure 6 Experimental Results

The typical transmission parameters of SATCOM K1 are shown in Figure 4. The outline and the typical transmission parameters of cable facilities are shown in Figure 5.

The experimental results of this MUSE cable transmission via satellite are shown in Figure 6. The received CN ratios of the satellite link at both cable headends are greater than 23 dB, and the received CN ratios at both cable receiving ends are greater than 44 dB (8.1 MHz). Thus, excellent HDTV pictures whose picture qualities are grade 4 at least and whose unweighted SN ratios after demodulating are greater than 39 dB, can be obtained.

MUSE-FM and MUSE-VSB・AM Transmission Experiment in Japanese Space-cable-net Project

Japanese Space-cable-net project performed MUSE-VSB・AM and MUSE-FM transmission experiments on cables via a communications satellite.

At the satellite transmitting end of the NHK Broadcasting Center in Tokyo, MUSE-FM signal with 27 MHz bandwidth was transmitted in Ku band to JC-SAT or Superbird.

At five cable headends in Hokkaido, Tokyo, Koofu, Nagano and Nagoya, the MUSE-FM signal was received by a 1.8m diameter parabolic antenna, and frequency converted down to the Super-high band, and transmitted to the cable receiving ends through multistage amplifiers and coaxial cables, where the muximum number of amplifiers was 16 and the muximum transmission distance was 7 km. At the receving end, the MUSE-FM signal was frequency converted up to the BS-IF band, and receivd by a BS tuner with the unweighted SN ratio of 41 dB.

At a cable headend in Osaka, the MUSE-FM signal was received by a 3.6m diameter parabolic antenna, and transformed into the MUSE-VSB・AM signal, and transmitted on cables, where the number of amplifiers was 9 and the transmission distance was 4.5 km. At the receiving end, the MUSE-VSB•AM signal was demodulated with the unweighted SN ratio of 47 dB.

These transmission experiments have proved that excellent HDTV pictures can be achieved by MUSE-FM or MUSE-VSB•AM cascaded transmission comprising a satellite and cable facilities.

HDTV Demand Access Optical Fiber CATV System

Frequency Allocation of MUSE-FM Signals

The frequency allocation of MUSE-FM signals on the trunk line is shown in Figure 7. At the trunk line, 40 MUSE-FM signals are allocated with the frequency interval, 38.36 MHz, used in Japanese satellite broadcasting. At the subscriber line, any selected four channels are transmitted on the BS-IF band (1-1.3 GHz).

MUSE signals have the following transmission parameters: 8.1 MHz video bandwidth, 10.2 MHz frequency deviation, 27 MHz bandwidth, 11.9 dB FM improvement and 9.5 dB emphasis improvement.

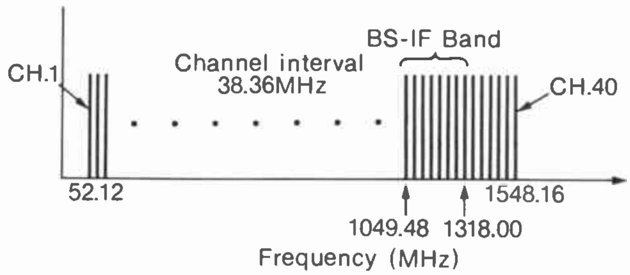

Figure 7 Frequency Allocation of MUSE-FM on Trunk Line

System Configuration

The system configuration of an optical fiber CATV system for HDTV is shown in Figure 8.

At the CATV headend, MUSE signals are frequency modulated and combined with the re-broadcasting MUSE-FM signals. Forty channels of FM signals are transmitted over 30 km to a hub through a single mode fiber by intensity modulation of an LD (1.3 μm).

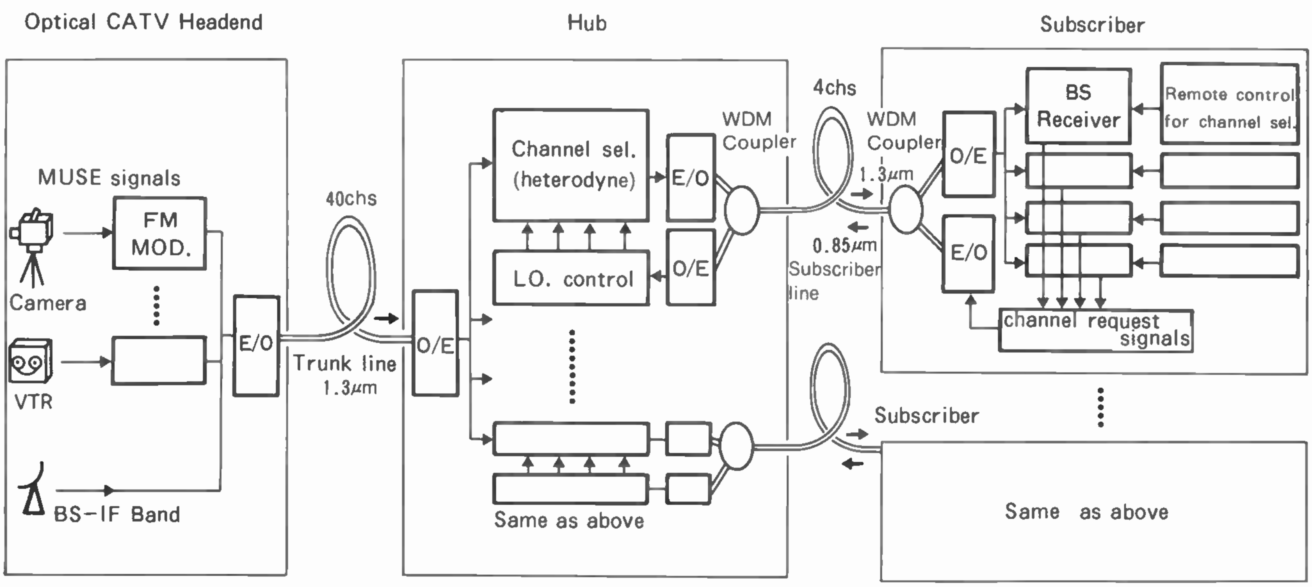

Figure 8 System Configuration of Demand Access Optical Fiber CATV

At the hub, these signals are transformed into electrical signals. Any 4 signals can be selected by channel request signals from an individual subscriber employing a heterodyne technique. The selected four signals allocated in the BS-IF band, modulate a low cost LD (1.3 μm), and are transmitted to each subscriber through a single mode fiber.

At the subscriber, these signals are transformed into electrical signals, and distributed to four conventional home receivers used for satellite broadcasting, and then demodulated. The channel request signals are sent to the hub through the same fiber used for a down stream. The digital signal format of the remote controlled channel selector at the television sets

Items	Trunk Line	Subscriber Line (Down stream)	Subscriber Line (Up stream)
Optical Source	InGaAsP-LD	InGaAsP-LD	GaAlAs-LD
Wavelength	1.3 μm	1.3 μm	0.85 μm
Threshold Current	5 mA	20 mA	12 mA
Bias Current of LD	40 mA	45 mA	16 mA(Max.)
Optical Power	-2 dBm(10/125)	-2 dBm(10/125)	-10 dBm(6/125)
Optical Isolator	Isolation: 60 dB	not used	not used
Optical Fiber	10/125 SMF	10/125 SMF	
Optical Coupler	-	2 x 2 type (1.3 μm/0.85 μm)	
Optical Receiver	InGaAs-APD	Ge-PD	Si-PD

Figure 9 Optical Transmission Parameters

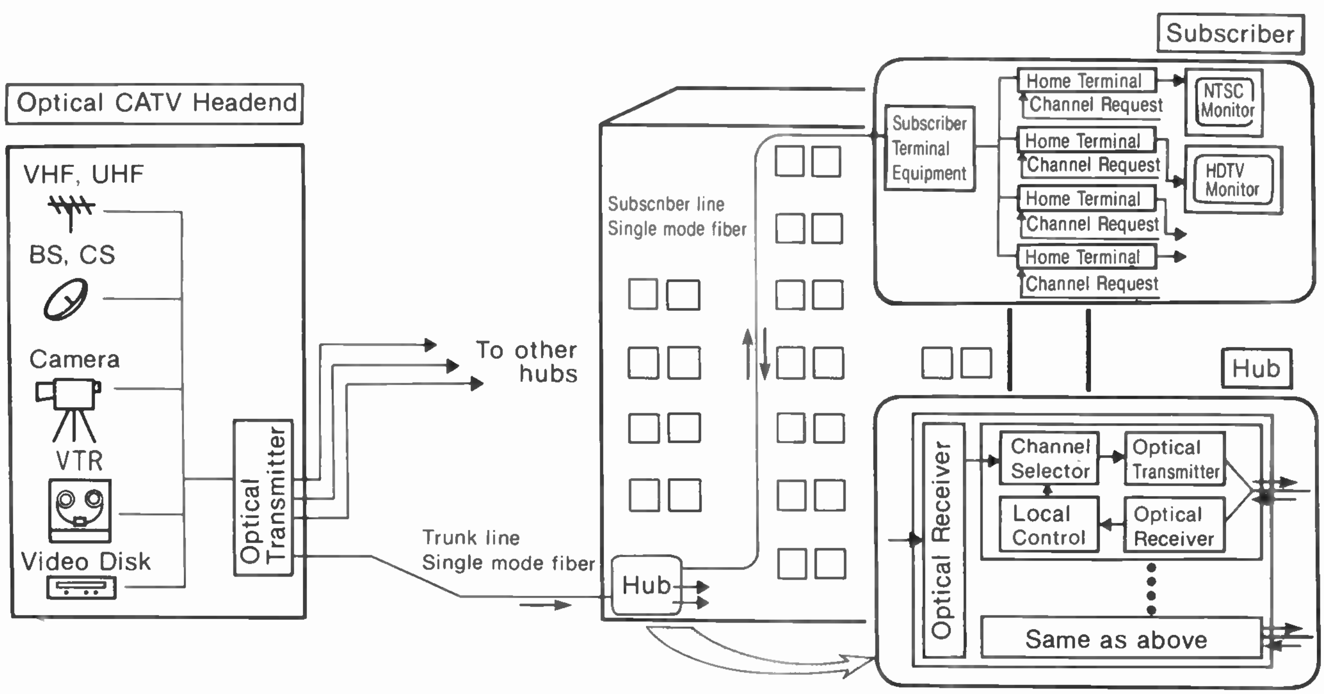

Figure 10 Demand Access Optical Fiber CATV System

is adopted for the transmission of channel request signals.

The optical transmission parameters are shown in Figure 9. Optical fiber couplers are used at both ends of the subscriber lines to obtain bi-directional transmission.

This demand access optical fiber CATV is suitable for the system of condominium style houses in urban areas as shown in Figure 10. This system can be also applied to individual houses.

Experimental Results

The relationship between the received CN ratio and the received optical power, P_R, when multiplexing 40 MUSE-FM signals on a trunk line, is shown in Figure 11. In this figure, the dashed line indicates the CN ratio when all channels are not modulated, and the solid line indicates the effective CN ratio including distortion power as noise when all channels except the measured channel are modulated. In the frequency allocation chart shown in Figure 7, we can avoid the second-order distortions, but third-order distortions drop into the FM transmission band. The effective CN ratio degrades as the optical modulation depth m increases, because many third-order distortions are also frequency modulated and added in random frequency and phase, and behave like random noise. Therefore, the optical modulation depth giving the maximum CN ratio can be determined when P_R is given. In the design for 30 km transmission on the trunk line, P_R is -17 dBm since the output of the optical transmitter is -2 dBm, and the optical loss of the fiber is assumed as 0.5 dB/km. In the case of Figure 11, the maximum CN ratio can be obtained as 22 dB.

The relationship between $(C/N)_{total}$ and the transmission distance of the subscriber line after 30 km transmission of the trunk line with 40 channels on the trunk line, is shown in Figure 12. The independent broadcasting means all signal resources of HDTV MUSE programs are controled in the headend. On the other hand, the rebroadcasting means MUSE-FM programs are received from a satellite and frequency converted at the headend, and transmitted on optical

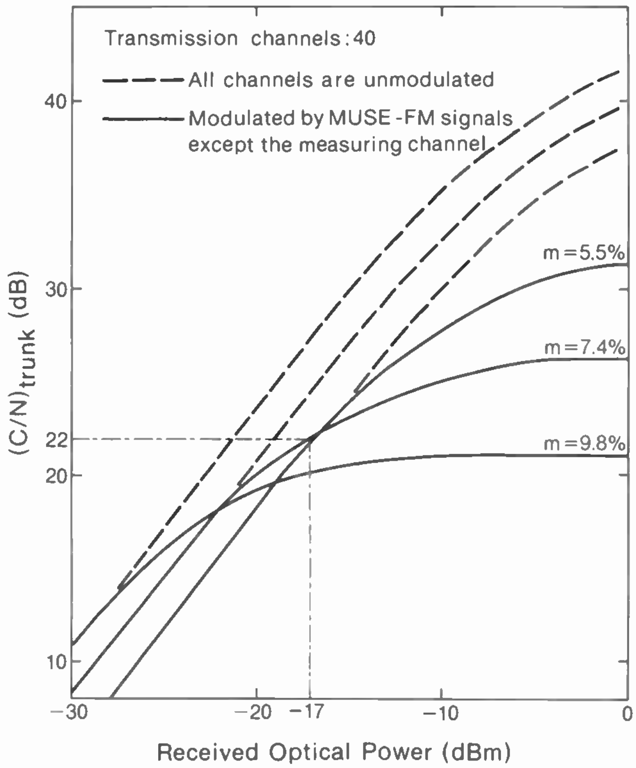

Figure 11 Received CN Ratio on Trunk Line
(dashed line : unmodulated
solid line : modulated)

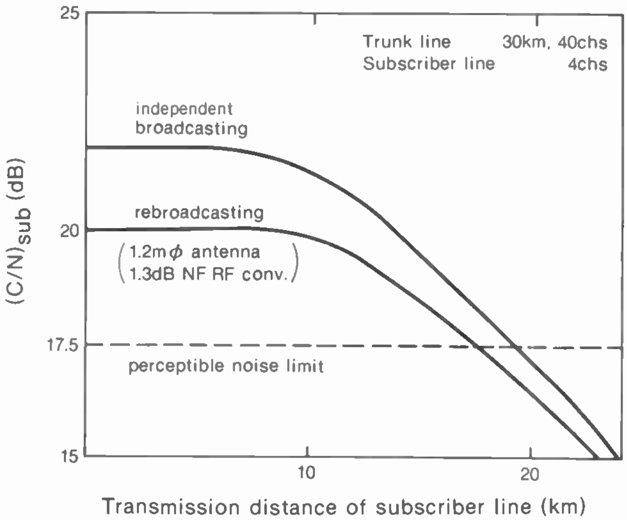

Figure 12 Total CN Ratio of Demand Access Optical Fiber CATV System

fibers.

In the case of independent broadcasting, 4 MUSE-FM signals can be transmitted over more than 19 km on the subscriber line under the condition of greater CN ratio than the perceptible noise limit of 17.5 dB.

In the case of rebroadcasting HDTV from a satellite on CATV, the CN ratio at a subscriber, $(C/N)_{total}$ is given by the following equation:

$$\frac{1}{(C/N)_{total}} = \frac{1}{(C/N)_{sat}} + \frac{1}{(C/N)_{trunk}} + \frac{1}{(C/N)_{sub}},$$

where $(C/N)_{sat}$ is the received CN ratio of the satellite link at the headend, $(C/N)_{trunk}$, $(C/N)_{sub}$ is the CN ratios of the trunk and the subscriber lines, respectively. We obtained $(C/N)_{sat}$ of 25 dB with a parabolic antenna of 1.2 m diameter and a RF converter of 1.3 dB noise figure. If we design the system with $(C/N)_{total}$ of 17.5 dB, which gives the perceptible noise limit, the required CN ratio for the cascaded transmission on the trunk and subscriber systems is greater than 18.4 dB.

In the case of rebroadcasting from a satellite, 4 MUSE-FM signals can be transmitted over more than 17 km on the sabscriber line in this system.

CONCLUSION

The feasibility of HDTV services on coaxial cables has been demonstrated by these MUSE-VSB• AM and MUSE-FM transmission experiments. The standardization of these HDTV transmission systems on coaxial cables in Japan are being examined by the Ministry of Posts and Telecommunications with the cooperation of NHK.

A demand access optical fiber CATV system for HDTV MUSE signals has been developed, and the possibility of the FTTH (Fiber To The Home) of HDTV has also been recognized. This demand access optical fiber CATV system will be introduced as a state-of-the-art operational system in the Tokyo bay area in 1994.

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INTERNATIONAL HDTV SERVICE VIA INTELSAT

Edward A. Faine and William R. Schnicke
COMSAT
Washington, District of Columbia

ABSTRACT

The development of a commercially viable international HDTV service via INTELSAT is underway. This paper describes HDTV activities on INTELSAT since 1987 when initial tests using the NHK MUSE analog system were conducted. Several demonstrations throughout the Pacific Basin are described, including the use of HDTV for the coverage of the Seoul Olympic games to Japan. In 1989, tests were made with the digital DITs system, developed by KDD and Canon taking advantage of a COMSAT Laboratories - developed COPSK Modem providing digital transmission at 140 Mbps over a 72 MHz transponder. Finally, tests in 1990 using the Scientific-Atlanta HDB-MAC system, the first HDTV system which is backwards compatible with NTSC broadcast signals, are described. The future prospects for commercial HDTV via INTELSAT are summarized, noting the advanced capabilities provided by the coming generations of INTELSAT spacecraft.

INTRODUCTION

While the world-wide debate on HDTV production, emission and transmission standards rages on, American, Canadian and Japanese equipment manufacturers and transmission facility providers have been using the INTELSAT system for international transmission of HDTV programming on an experimental and commercial basis for over three years. Extensive HDTV field trials have been conducted on the INTELSAT system resulting in a wealth of data for dimensioning satellite configurations for future transmissions of HDTV programming. This paper provides a summary overview of the international field trials and commercial transmissions conducted to date using the three known commercially-available emission systems, namely: the NHK MUSE system, the KDD/Canon DITs system and the Scientific-Atlanta HDB-MAC system. Each of the above emission systems uses the NHK-developed 1125/60 production standard as its source. The paper also addresses the future potential of HDTV over the INTELSAT system in the context of new generation INTELSAT satellites that will become available in the next few years, all of which will have higher power and will therefore be able to cater to the use of smaller-size earth stations than are used today for the transmission and reception of international HDTV programming.

MUSE

NHK (Japan Broadcasting Corp.) developed the MUSE system, based on the 1125/60 production standard, to broadcast HDTV signals via satellites using frequency modulation with a carrier bandwidth of 27 MHz.[1] Transmission experiments using the MUSE signal via Japanese domestic satellites began in 1986. In 1987, loopback transmission tests of the MUSE signal over an INTELSAT V satellite were conducted in Japan using the Ibaraki INTELSAT Standard A (32 meter) earth station.

Based on the results of these experiments, international transmissions from Japan to Australia and from Korea to Japan were successfully carried out in 1988[2], and from the U.S. to Japan in 1989.[3] The first was a three-hop transmission using the Japanese domestic CS-2b communication satellite, the INTELSAT V satellite, and Australia's domestic AUSSAT K2 satellite. The second was a two-hop transmission using an INTELSAT V satellite and the Japanese BS-2b broadcast satellite. The third was a three-hop transmission using the ANIK C-2 satellite, the INTELSAT V satellite, and the Japanese BS-2b broadcast satellite. The results of these transmissions, including the system configuration and received signal quality, are detailed in the following sections.

Transmission From Japan To Australia

In July 1988, the MUSE signal was transmitted from Nara, the ancient capital of Japan, to the Japanese Pavilion at World Expo 88 in Brisbane, Australia. Figure 1 shows the transmission configuration.

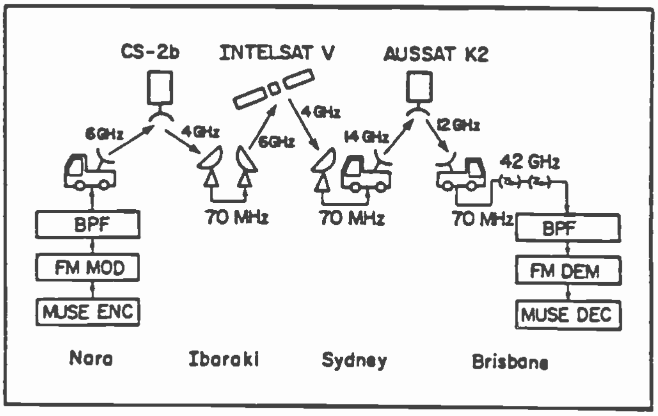

FIGURE 1. SYSTEM CONFIGURATION FOR TRANSMISSION FROM JAPAN TO AUSTRALIA

An HDTV program produced in Nara was encoded into a MUSE signal and frequency modulated. It was then fed through a coaxial cable to a transportable earth station with a 3.0 meter antenna, and then relayed by the Japanese CS-2b satellite at C-band to the Ibaraki INTELSAT Standard A earth station, where it was relayed over an INTELSAT V satellite to the Sydney INTELSAT Standard A earth station. In Australia, the HDTV signal was relayed from Sydney to Brisbane via the AUSSAT K2 satellite in Ku-band using transportable earth stations with 4.6 meter antennas for both transmission and reception. In Brisbane, two terrestrial radio links in the 42 Ghz band were used to provide the program to the Japanese Pavilion. Although the bandwidth of the transponders utilized on the three satellites and terrestrial links differed, the MUSE carrier was bandwidth-restricted to 27 MHz and interconnected by an IF signal from one transmission facility to another.

A Carrier-to-Noise Ratio (CNR) of 17.5 dB, corresponding to a just perceptible level of impairment, was the preestablished target CNR for the MUSE of all links was 17.6 dB and offered good picture quality from the standpoint of noise impairment.

Transmission From Korea To Japan

HDTV programs of the Seoul Olympic Games, held in September 1988, were transmitted from Korea to Japan and broadcast by the configuration shown in Figure 2.

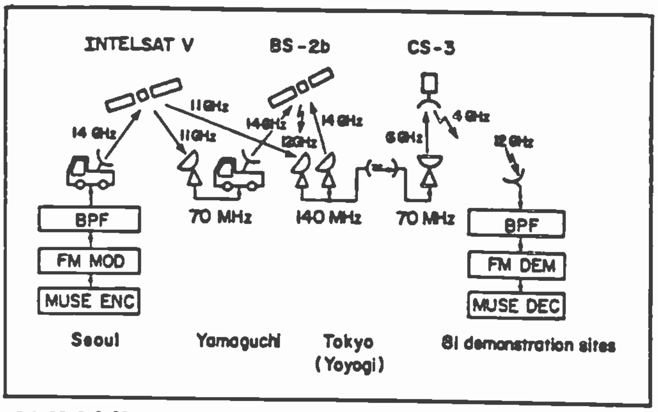

FIGURE 2. SYSTEM CONFIGURATION FOR TRANSMISSION FROM KOREA TO JAPAN

In Seoul, HDTV program materials were gathered at the International Broadcasting Center from the Main Stadium through an optical fiber link. These signals were encoded into MUSE format, frequency modulated, then provided by coaxial cable to a transportable earth station with an 8.0 meter antenna. This signal was then transmitted to Japan using a Ku-band transponder onboard an INTELSAT V satellite.

Two sites were available for reception in Japan: the Yamaguchi INTELSAT Standard A earth station and the Yoyogi earth station, located in the NHK Broadcasting Center in Tokyo. These two diversity receiving sites were switched, depending on local weather conditions to maintain high CNR.

The received signal at either station was retransmitted to the Japanese BS-2b broadcast satellite and received by 75 centimeter antennas at 81 receiving points throughout Japan. For retransmission from Yamaguchi, a transportable earth station with a 2.5 meter antenna was used. For retransmission from Yoyogi, the fixed main earth station in the NHK Broadcasting Center was used. In addition, the received signal at Yoyogi also was fed to the NTT earth station in Tokyo and distributed to NTT's seven earth stations via the Japanese CS-3 communication satellite. It was then provided to additional demonstration sites through terrestrial links in the 11 GHz band. As before, at each repeater point, the 27 MHz MUSE signal was interconnected by an IF signal.
The measured CNR in Tokyo for the two-hop transmission was 18.3 dB, slightly greater than in the transmission from Japan to Australia. Thus picture quality was satisfactory from the viewpoint of noise impairment.

Transmission From U.S. To Japan

On June 3, 1989, a global broadcast called "Our Common Future" was held for raising worldwide environmental awareness. The broadcast originated at Lincoln Center in New York city and featured numerous stars of rock, folk and classical music, as well as World leaders such as Prime Minister Brian Mulroney of Canada, U.S. President George Bush and Soviet President Mikhail Gorbachev. "Our Common Future" was seen, via INTELSAT, in more than

100 countries reaching one billion people, but only one country, Japan, (with the exception of two sites in the U.S.) saw the event in HDTV. The HDTV program produced at Lincoln Center was encoded into a MUSE signal, frequency modulated, and fed through a coaxial cable to two transportable earth stations, one of which accessed a U.S. domestic satellite for delivery to the two HDTV viewing sites in the U.S., while the other accessed the Canadian ANIK-C2 satellite, which relayed the MUSE signal to the Lake Cowichan INTELSAT Standard A earth station on the West Coast of Canada. That station then relayed the MUSE signal via an INTELSAT V satellite to Tokyo, where, similar to the Seoul Olympic Games, it was uplinked to the Japanese BS-2b broadcast satellite for distribution to 75 centimeter antennas at 89 viewing sites throught Japan.

The above transmissions show that international and domestic transmission of HDTV using the MUSE signal can be done by existing satellites and earth stations. An HDTV signal can be transmitted from any one place to any other place in the world via a two- or three-hop satellite transmission using INTELSAT satellites in conjunction with domestic communication or broadcast satellites.

DITs

KDD (Kokusai Denshin Denwa Co., Ltd.) and Canon developed the DITs system, also based on the 1125/60 production standard, to broadcast HDTV signals via satellite using digital modulation and a carrier bandwidth of some 60 Mhz, thereby requiring a 72 Mhz satellite transponder.[4] The DITs HDTV Codec takes a full-baseband HDTV signal and compresses the signal by a factor of roughly five down to 140 Mbps or 120 Mbps. The output rate is selectable by switch. The higher rate, 140 Mbps, is a standard rate in the international digital hierarchy, and 120 Mbps is the standard rate in the INTELSAT TDMA system.

In the Spring/Summer of 1989, experimental transmissions using DITs were conducted over an INTELSAT V satellite between the U.S. and Japan.[5] The transmission tests were conducted in two phases. The objective of the first phase was to investigate the transmission performance in two modes at 140 Mbps:

a) one-way transmission from the U.S. to Japan in the cross-strap mode of operation, i.e., C-band uplink in the U.S.; Ku-band uplink in Japan; and

b) loop-back transmission in the U.S. at C-band.

The objective of the second phase was to investigate two additional modes at both 140 and 120 Mbps, namely:

a) two-way simultaneous transmission between the U.S. and Japan - C-Band uplink and downlink in the U.S.; Ku-band uplink and downlink in Japan; and

b) loop-back transmission in Japan at Ku-band.

The test configuration for the first phase, shown in Figure 3, consisted of a HDTV video camera and video tape recorder (VTR) which provided a full-baseband HDTV signal to the DITs Codec where it was compressed to 140 Mbps and phase modulated by the COMSAT 140 Mbps COPSK MODEM and uplinked to the INTELSAT V satellite by the INTELSAT Standard A (30 meter) AT&T

earth station at Triunfo Pass, California. The DITs signal was downlinked by the INTELSAT V satellite at Ku-band and received by a fixed and a transportable earth station in Tokyo, with 5.5 and 2.6 meter antennas, respectively. The received DITs signal was received, demodulated, decoded and the full-baseband HDTV signal recovered. For completeness, C-band to C-band loopback tests using the INTELSAT Standard A earth station were also conducted.

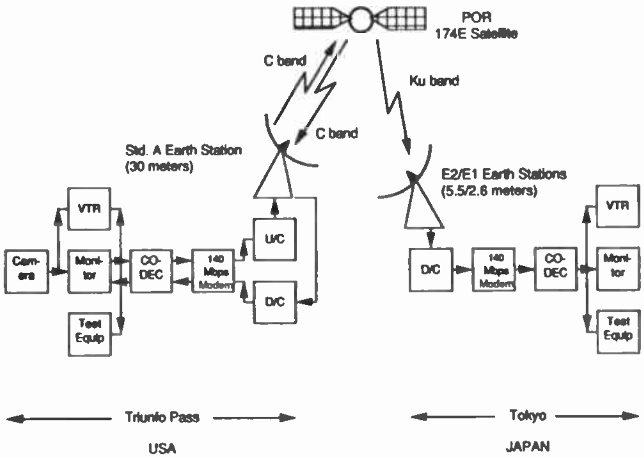

FIGURE 3. U.S. - JAPAN HDTV FIELD TRIAL CONFIGURATION — PHASE 1

Besides the DITs Codec, the other key digital technology used in the transmission was the 140 Mbps Coded Octal Phase Shift Keying (COPSK) MODEM developed by COMSAT Laboratories. The digital modulation technique used today in many telecommunication satellite systems is QPSK or Quadrature Phase Shift Keying. The COPSK MODEMs used in the field trial are rare and special and are in fact prototypes for units now being considered for satellite restoration of undersea fiber optic cables.

The test configuration for the second phase of the field trial is shown in Figure 4.

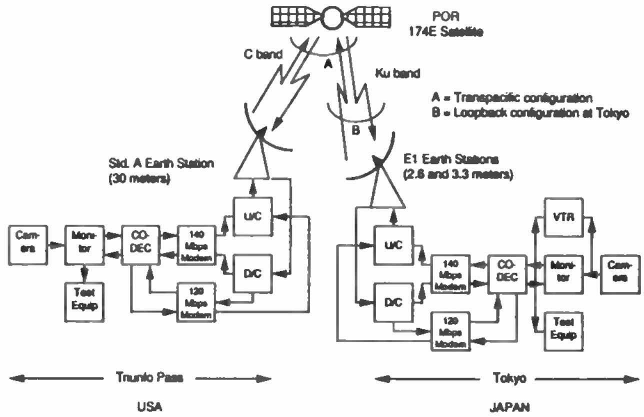

FIGURE 4. U.S. - JAPAN HDTV FIELD TRIAL CONFIGURATION — PHASE 2

The DITs signal flow was similar to that just described in the first phase. However, as shown in Figure 4, both 140- and 120-Mbps MODEMs were used and the fixed earth station used in the second phase had a antenna diameter of 3.3 meters, rather than 5.5 meters.

Prior to the transmission testing, the threshold Bit Error Rate (BER) of the DITs Codec had been determined in the laboratory. It was found that the threshold BER at which the influence of transmission errors can be ignored is 1 x 10-4. The objective of the field trial was to determine for each configuration tested, the CNR required to produce a BER of 1 x 10-4. With this information in hand, one can then dimension a transmission system -- determine earth station sizes and the like -- for commercial delivery of HDTV via INTELSAT satellites.

The CNR required to obtain a BER of 1 x 10-4 in each configuration tested, for transmission rates of 140- and 120-Mbps, is summarized in Table 1.

TABLE 1. REQUIRED CNR FOR DITs HDTV TRANSMISSION VIA INTELSAT [1/]

	120 MBPS	140 MBPS
IF LOOPBACK	12.6	12.2
C-C LOOPBACK	13.0	13.5
KU-KU LOOPBACK	13.0	13.5
C-KU LOOPBACK	13.0	13.2
KU-C TRANSPACIFIC (3.3 METER FIXED)	14.2	14.7
KU-C TRANSPACIFIC (2.6 METER TRANSPORTABLE)	16.5	-

1/ REQUIRED CNR TO OBTAIN BER OF 1 X 10^{-4}.

First, the IF loopback test indicated that a CNR of 12.5 dB would be needed to obtain a BER of 1 x 10-4. This test included everything but the satellite link; the camera was connected to a Codec/MODEM pair back-to-back, so the full baseband HDTV signal was encoded, modulated, demodulated, decoded and the full baseband HDTV signal recovered. In the other configurations with the satellite link inserted, the C-C U.S. loopback, Ku-Ku Japan loopback and C-Ku U.S.-Japan Transpacific tests resulted in only a slight CNR degradation of about 1 dB. In the Ku-C Japan-U.S. Transpacific tests the CNR degradation was more than 2 dB, but that was due to inadequate uplink provisioning, which would be rectified in a commercial setting. It is therefore concluded from the results summarized in Table 1 that the CNR required to obtain the threshold BER of 1 x 10-4 are 13.5 dB for 140 Mbps COPSK DITs transmission and 13.0 dB for 120 Mbps QPSK DITs transmission. With the above information, appropriate transmission configurations for DITs HDTV exchange between the U.S. and Japan were determined assuming the use of an INTELSAT V, a13.0 dB CNR for a threshold BER of 1 x 10-4, 2 dB of downlink margin and INTELSAT Standard A(30 meter), E3(8 meter), E2(5.5 meter) and E1(3.5 meter) earth stations. The results are shown in Table 2, which shows the resultant CNR and availability for various combinations of earth stations.

TABLE 2. CNR AND AVAILABILITY

Trans / Recv	Std. A (C-band)	transportable (Ku-band)	Std. E-1 (Ku-band)	Std. E-2 (Ku-band)	C/N(dB) AVAILABILITY (%)
Std. A	23.4 dB 20.4 dB	18.1 dB 18.6 dB	18.3 dB 18.8 dB	20.2 dB 20.7 dB	TOTAL-C/N
(C-band)	99.99 % 99.99 %	99.85 % 99.55 %	99.67 % 99.66 %	99.97 % 99.98 %	AVAILABILITY
transportable	16.4 dB 19.4 dB	14.6 dB 15.6 dB	14.7 dB 15.6 dB	16.3 dB 19.8 dB	TOTAL-C/N
(Ku-band)	99.20 % 99.95 %	0 % 61.32 %	0 % 61.32 %	99.94 % 99.93 %	AVAILABILITY
Std. E-1	17.9 dB 20.4 dB	15.6 dB 15.6 dB	15.7 dB 15.8 dB	17.4 dB 20.7 dB	TOTAL-C/N
(Ku-band)	99.85 % 99.97 %	0 % 98.99 %	93.20 % 99.28 %	99.74 % 99.96 %	AVAILABILITY
Std. E-2	20.9 dB 23.4 dB	18.6 dB 18.4 dB	18.9 dB 18.7 dB	20.8 dB 24.1 dB	TOTAL-C/N
(Ku-band)	99.99 % 99.99 %	99.95 % 99.93 %	99.87 % 99.92 %	99.96 % 99.99 %	AVAILABILITY
Std. E-3	23.3 dB 25.2 dB	20.6 dB 21.1 dB	20.7 dB 21.4 dB	23.0 dB 26.4 dB	TOTAL-C/N
(Ku-band)	99.99 % 99.99 %	99.95 % 99.97 %	99.96 % 99.97 %	99.98 % 99.99 %	AVAILABILITY

In a given row, the upper CNR and availability numbers are for the Japan-U.S. direction and the lower numbers for the U.S.-Japan direction. To interpret Table 2, take the case of an E1, or 3.5 meter, earth station transmitting to another E1 station. The availability would be 93.2 % in the Japan-U.S. direction, or 99.28% in the U.S.-Japan direction. By 99.28% availability, it is meant that the BER would be better or equal to the threshold BER of 1 x 10-4, 99.28% of the time over the course of a year.

The following is concluded from Table 2. Setting aside combinations of E1 stations, DITs HDTV transmissions over

INTELSAT would have a 99.9% or greater availability for all other earth station groupings. Further, for E1 stations, it would be desirable that the interfacing station be an E3, or larger, station. For E2 stations, it is desirable that the interfacing station be an E2, or larger, station.

Based on the above, it is concluded that DITs HDTV transmission via INTELSAT is commercially viable. The field trial results clearly demonstrate it would be possible to exchange DITs HDTV via INTELSAT using small-size transportable earth stations in the E1 to E3 class (3.5 to 8 meter diameter range) and achieve a 99% or greater availability. In fact, in October, 1989, the transportable 2.6 meter diameter antenna earth station used in the field trial was used commercially to transmit DITs HDTV programming via INTELSAT from Japan to the SMPTE Conference in Los Angeles. The receiving earth station located outside the conference hall was an E2.

HDB-MAC

Scientific-Atlanta developed the HDB-MAC system, based on the 525-progressive and/or 1125/60 standard, to broadcast HDTV signals via satellites using frequency modulation with a carrier bandwidth of 36 MHz.[6] HDB-MAC is the first emission system to be INTELSAT-tested that is backward (NTSC)-compatible and security encrypted. In March, 1990, the HDB-MAC system was used in the first international two-way HDTV video teleconference.[7] The HDTV videoconference linked the MAST Industries home office in Andover, Massachusetts with its regional office in Hong Kong. Mast Industries, the design and procurement arm of The Limited, Inc., a world-wide clothing retailer, used the videoconference to evaluate and select designs and materials for future fashions. High definition pictures of designs and materials developed by 1125/60 standard HDTV equipment installed in MAST offices were encoded into a HDB-MAC signal, frequency modulated and routed over fiber optic cables within Hong Kong to the Hong Kong INTELSAT Standard A (30 meter) earth station and relayed by an INTELSAT V satellite in C-band to an INTELSAT Standard B (11 meter) earth station in Brewster, Washington. The HDB-MAC signal then was relayed via the GE Astro K1 satellite in Ku-band from Brewster to Andover using transportable earth stations with 5 meter antennas for both transmission and reception. A similar path carried the HDB-MAC signal back to Hong Kong, although a different INTELSAT V satellite with different accessing earth stations was used on the return path. Good picture quality was obtained, prompting Martin Trust, President of MAST Industries, to remark " In our business, color, texture, style, quality and timeliness are essential factors in making buying decisions. Now we have direct communications between Hong Kong and the home office with the clarity and intimacy of a face-to-face meeting. With these (HDTV) technologies we can make decisions on the spot, expediting our buying process."

FUTURE POTENTIAL OF HDTV VIA INTELSAT

To date, all HDTV transmissions via INTELSAT have been relayed by current generation INTELSAT V satellites. In the next several years, INTELSAT will be replacing its current fleet of INTELSAT V satellites with new generation INTELSAT VI and INTELSAT VII satellites, as well as augmenting the system with a specialized all-Ku-band satellite known as INTELSAT-K. These satellites have higher e.i.r.p. than the current INTELSAT V satellites. At C-band, the INTELSAT VI and INTELSAT VII have 2 db and 4 db higher e.i.r.p than the INTELSAT V satellite, while at Ku-band they have 3.5 dB and 5.5 dB higher e.i.r.p. in the East Spot beam, with about the same e.i.r.p. in the West Spot beam as the INTELSAT V satellite. The increase in e.i.r.p. can be used to cater to the use of smaller-size antennas and/or to improve picture quality. The most dramatic reduction in antenna size for future HDTV transmissions is expected to occur at C-band. For example, the reference antenna size for the INTELSAT V satellite was a Standard A (30 meters), while for the INTELSAT VI satellite it is a revised Standard A (18 meters) and for the INTELSAT VII satellite it will be an Standard F3 (9 meters). It should be possible, for example, to receive high quality HDTV via an INTELSAT VII satellite at C-band with 9 meter antennas, rather than the 30 meter antennas used today. The first INTELSAT VI satellite was launched successfully in 1989 for transatlantic service; the first INTELSAT VII launch is planned for early 1992.

The most exciting prospect on the INTELSAT horizon is the anticipated arrival of the INTELSAT-K satellite in the Atlantic basin in early 1992. This Ku-band satellite with broadcast satellite parameters, 50 dBW e.i.r.p. and 54 MHz transponders, offers exciting possibilities for international HDTV delivery. Assuming full use of an INTELSAT-K 54 MHz transponder, high quality HDTV could be delivered directly into antenna sizes as small as 1.8 meters. If the past two years of HDTV via INTELSAT can be characterized as bright, the future looks even brighter.

SUMMARY AND CONCLUSION

HDTV via INTELSAT is a commercial reality. Three different HDTV emission systems have been employed in commercial end-to-end settings delivering a wide range of HDTV programming in a variety of earth station configurations involving two- and three-hop satellite links. Moreover, as the INTELSAT system is replenished with new generation INTELSAT VI, VII and K satellites in the next several years, improvements are anticipated in the delivery of international HDTV through the use of smaller-size antennas coupled with the attainment of better picture quality.

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TESTING THE ATV SYSTEMS:
Is There a World of Difference?

Wednesday, April 17, 1991

Moderator:
Joel Chaseman, Chairman, Chaseman Enterprises International, Bethesda, Maryland

STATUS OF TESTING OF ADVANCED TELEVISION SYSTEMS
Mark Richer, PBS, Alexandria, Virginia; Peter Fannon, ATTC, Alexandria, Virginia; Craig Tanner, Cable Television Laboratories, Inc., Boulder, Colorado; Dr. Paul Hearty, Advanced Broadcast Systems Test Center, Ottawa, Canada

CREATING A LABORATORY TO TEST ANALOG AND DIGITAL ADVANCED TELEVISION SYSTEMS FOR TERRESTRIAL TRANSMISSION IN NORTH AMERICA
Charles W. Rhodes and James M. DeFilippis
Advanced Television Test Center
Alexandria, Virginia

DIFFICULTIES OF DESIGNING SUBJECTIVE TESTS*
David Niles
Captain New York, Inc.
New York, New York

*Paper not available at the time of publication.

STATUS OF TESTING OF ADVANCED TELEVISION SYSTEMS

Mark Richer
Public Broadcasting Service
Alexandria, Virginia

Craig Tanner
Cable Television Laboratories, Inc.
Boulder, Colorado

Peter Fannon
Advanced Television Test Center
Alexandria, Virginia

Paul Hearty
Advanced Broadcast Systems Test Center
Ottawa, Canada

ABSTRACT

The FCC Advisory Committee on Advanced Television Service is investigating the issues involved in establishing a new advanced television standard. Working Party 2 of the Systems Subcommittee was established to conduct tests of proposed systems and provide information to help the Advisory Committee in its recommendations to the FCC. Three test laboratories have been selected to perform these test procedures: The Advanced Television Test Center (ATTC), Cable Television Laboratories (CableLabs), and The Advanced Television Evaluation Laboratory (ATEL) of Canada.

THE FCC ADVISORY COMMITTEE

In 1987, the FCC established the Advisory Committee on Advanced Television Service to investigate the technical, economic, and spectrum issues involved in establishing a new terrestrial broadcast standard. The Advisory Committee consists of three subcommittees: the Planning Subcommittee which is responsible for planning the attributes of advanced television service, the Systems Subcommittee which will specify the transmission/reception facilities appropriate for providing advanced television service, and the Implementation Subcommittee which will establish a scheme for implementation of advanced television service.

The Systems Subcommittee established Working Party 2 (SSWP-2) to conduct tests of proposed systems and provide information to help the Advisory Committee in its recommendations to the FCC.

TEST PROCEDURES

SSWP-2 has developed extensive test procedures to be used to evaluate the performance of the advanced television (ATV) systems selected by the Advisory Committee. These procedures are based upon a list of attributes and conceptual tests developed by the Planning Subcommittee. These test procedures have been divided into five categories:

Objective Tests

Objective test procedures include: image quality tests such as resolution and chromaticity/colorimetry: audio performance measurements, terrestrial transmission tests including tests for susceptibility to random and impulse noise, multipath and airplane flutter, interference tests (ATV/NTSC and ATV/ATV) such as Co-channel, Adjacent Channel and UHF taboo.

Cable Tests

The objective of these tests is to identify the parameters required for the planning and implementation of ATV systems in the existing cable television environment. These tests include such areas as: discrete frequency interference, minimum carrier to noise requirements, effect of microreflections and intermodulation distortion. Tests through fiber optic transmission systems will also be performed including discrete frequency interference and signal to distortion measurements.

Video Subjective Tests

There are three types of video subjective tests: ranging, rating, and expert observation and commentary. The purpose of ranging is to establish the threshold of visibility of an impairment, the point where the impairment renders the signal unusable, and some steps in between. During rating tests a group of non-expert observers watch television pictures and decide on their quality or on the effect of an impairment. During expert observation and commentary tests, expert observers watch television pictures and offer non-quantitative comments on the pictures.

Audio Subjective Tests

The audio subjective test are divided into two categories, quality and transmission impairment. During quality tests, audio experts will listen to program material to determine its intrinsic quality. Expert observation and commentary will be used to describe the characteristics of each system with various impairments.

Field Tests

Field test procedures are not designed to yield comparative data. The primary goals of these tests are to verify the performance and operability of the selected ATV system(s) under real world conditions and to identify flaws not discovered during laboratory testing. Another important objective of the field tests is to provide a comparison of impairments to NTSC and ATV in the field These tests will include tests through existing cable television systems.

TEST LABORATORIES

Advanced Television Test Center (ATTC)

The ATTC was established in 1988 to conduct thorough and impartial tests on ATV systems and provide results to the FCC, its Advisory Committee and the broadcast industry. ATTC is sponsored by CBS, Capital Cities/ABC, EIA, INTV, NAB, NBC, PBS, and MSTV, and is working in cooperation with Cable Television Laboratories, Inc. and the Advanced Television Evaluation Laboratory.

ATTC has supported development of the Advisory Committee's detailed Test Procedures and, on the basis of the now-completed Procedures, has developed facilities to undertake laboratory-based objective, broadcast-related, as well as joint broadcast-cable, tests. In addition, ATTC will prepare digital video tape recordings for non-expert viewer subjective tests of interference effects and basic received quality to be conducted at ATEL. ATTC will also prepare digital audio tape recording for subjective listening tests (to be conducted at a laboratory to be designated).

Preparation of ATTC laboratory space has been completed at its Alexandria, Virginia site, and all major equipment items have been designed, purchased, and either installed or under construction. The first of six ATV systems on the Advisory Committee's "Test Sequence & Calender" (November 14, 1990) is ACTV, and is expected to be delivered for testing to begin April 1991.

Cable Television Laboratories (CableLabs)

Cable Television Laboratories, Inc. (CableLabs) was established in May, 1988 as a research and development consortium of cable television system operators representing more than 85% of the cable subscribers in the United States. It also has members representing 20% of Canada. Cable Labs funds R & D projects that will help members take advantage of future opportunities and meet future challenges in the television industry. It also transfers relevant technologies to member companies and industry suppliers. In addition, CableLabs acts as a clearinghouse to provide information on current and prospective technological developments that are of interest to the cable television industry.

CableLabs' ATV testing effort is centered in leased offices and laboratory space at ATTC in Alexandria, Virginia. The Cable Test System (test bed) has been installed at CableLabs' facility at the ATTC, and is being debugged and interfaced to the ATTC plant. It is expected to be ready for operation in time for the joint ATTC/CableLabs run through of testing, and for the start of official testing in April.

Advanced Television Evaluation Laboratory (ATEL)

The Advanced Television Evaluation Laboratory (ATEL) is an off-premises laboratory of the Communications Research Centre, Department of Communications (Canada) and is located near Ottawa, Canada. The ATEL was developed to provide the special environment and facilities needed to conduct video subjective assessments of television systems under the rigorously controlled conditions needed to ensure valid and repeatable results.

The video subjective assessments called for by the Advisory Committee are to be carried out at the ATEL. The ATEL's activities in this regard are supported by a consortium of interests from government and industry in Canada. The members of this consortium currently consist of the Canadian Broadcasting Corporation, The Communications Research Centre (Canada), the Department of Communications (Canada), Leitch Video International (Canada) , Rogers Engineering (Canada), Tektronix (Canada), and Telesat Canada.

At present, the ATEL is well along in its start up exercises, with facility and methods prove-ins scheduled to begin February 1991 and tests of terrestrial ATV systems scheduled to begin in May 1991.

FIELD TESTS

Field tests are scheduled to start at the conclusion of laboratory testing. System(s) will be selected for field testing by Systems Subcommittee Working Party 4, (System Standard). SSWP-2 is currently working with ATV system proponents and broadcast transmision equipment manufacturers to plan the field tests.

CREATING A LABORATORY TO TEST ANALOG AND DIGITAL ADVANCED TELEVISION SYSTEMS FOR TERRESTRIAL TRANSMISSION IN NORTH AMERICA

Charles W. Rhodes and James M. DeFilippis
Advanced Television Test Center
Alexandria, Virginia

Testing of ATV systems in the laboratory of the Advanced Television Test Center is scheduled to begin in April 1991. This has required the development of new testing techniques, new test material and RF Test Beds for both terrestrial and CATV media, and the means to digitally record test pictures on four different formats. This paper summarizes some of the work to date.

Testing of advanced television (ATV) transmission systems for terrestrial broadcasting in the United States involves two problems whose solutions hopefully lead to the same system or approach to be recommended to the FCC. The first problem is which of the proposed ATV systems offers the highest quality picture and sound? The second problem is which system or systems are compatible with the existing NTSC broadcasting transmitter channel assignments, power, and spacings so that the new ATV transmitters will not cause interference, yet still provide a satisfactory service area? The twin issues of interference and coverage arise from the fact that ATV transmissions are expected to use the existing TV broadcast bands.

Moreover, in the U.S. and Canada over 60% of the audience receive television programming via Cable TV Systems. Therefore, any ATV signal must also be deliverable by CATV systems.

Picture and sound performance of ATV systems will be assessed in the Advanced Television Test Center (ATTC) laboratory over the next fourteen months. The ATTC plant itself was implemented by CEI Inc., under contract to ATTC. There are, at this writing, six different systems, each employing one of four different scanning formats. There are two interlaced picture signal formats of 1125 and 1050 lines, at 30 and 29.97 frames/second, respectively, and two progressive scan formats of 787.5 and 525 lines, 59.94 Hz frame rates. Some proponents share identical video formats, such as 787.5 used by both Zenith/AT&T and MIT, and 1050 used by both the Advanced Television Research Consortium (NBC, Sarnoff, Philips, Thomson) and General Instrument. Two others have individual formats: NHK uses 1125, and ACTV uses 525. By the way, one system--ACTV--is an Enhanced NTSC approach, and the other five systems are Simulcast HDTV ones.

While each of these four different scanning formats provides the same number of pixels per second to the encoder, the compromises between horizontal resolution, vertical resolution, and temporal resolution differ. Therefore, ATTC must measure resolution vertically, temporarily, and diagonally, in addition to measuring horizontal resolution. Some of the encoding schemes trade off dynamic resolution for improved static resolution, so both static and dynamic resolution are to be measured.

Static measurements are made with a Zone Plate Generator (ZPG) and displayed on a very high resolution picture monitor, as shown in Slide #1. The photograph clearly shows the limited horizontal resolution, which is determined by available bandwidth.

When the Zone Plate moves, we test the dynamic resolution. Of course this cannot be shown with a slide; but, by means of a device we call the Active Video Gate, we can capture one single frame of a moving test pattern so that it can be studied as a still picture, as shown in Slide #2. We took these photographs of an NTSC signal which suffered loss of dynamic resolution in passing through a digital noise reducer.

Chrominance resolution is to be tested in a different way since the available ZPG generates luminance signals only. We will measure the step response using special color test patterns, as shown in Slide #3. On the left, you see a background whose color is that of the R-Y chromaticity axis, while in the foreground there is a rectangle whose chromaticity is the complement of the background, i.e. Y-R. These two color patches have the same brightness so they are iso-luminant. As both colors lie along the R-Y axis, neither will generate any B-Y signal. The left part of the test pattern generates a chrominance step along the R-Y axis, while the right part of the pattern generates a B-Y step, and no luminance change occurs at the chrominance transitions. Therefore, we can measure the rise time of both the R-Y and B-Y channels. In the case of ACTV, this test signal is generated as I & Q which have quite different bandwidths, and hence will have different rise times.

The range of colors which can be transmitted will be tested with the color ramp signal shown in Slide #4. The ramp goes from zero to 100% color. NTSC transmission is limited to 75% amplitude, saturated colors. It is expected that ATV systems will clip highly saturated color signals just as NTSC does. This can be detected and measured with this signal. The two color test signals just described were devised by ATTC and approved by the FCC's Advisory Committee on Advanced Television Service. As these are not yet commercially available, they are both generated by a computer in the PIXAR machine.

The PIXAR is a high definition, multi-scan format, electronic, still store. It is a commercial product. For the Test Center application, however, a considerable amount of custom software was developed by Century Computing, Inc. under contract to ATTC. Vicom Systems, which manufactures the PIXAR, developed a new sync board for the PIXAR which produces sync drives for each scan format, including three formats (1125, 787, 1050) which have unequal field lengths, something new to broadcast television.

NASA took the still pictures, under the close supervision of PS/WP-6, which is one of the many working parties and subcommittees of the FCC Advisory Committee which guide our work. NASA shot these using Kodak 35mm Ektar film and, once approved by PS/WP-6, they were scanned at the Eastman Kodak Research Laboratory in 2048 active lines per picture, each line consisting of 3072 pixels per color. These signals were then digitized by Kodak in 16 bit PCM, stored on magnetic tape, and delivered to ATTC in this form. The data tapes can be down-loaded to the PIXAR disc storage where they can be readily accessed.

Needless to say, these scanning and digitizing operations were not done in real time. Each frame took some ten minutes to scan. These data tapes should be useable for many years without any loss in color or other picture properties. Hopefully, at least some of these will be used as HDTV test pictures in the future.

To use these pictures, they are first electronically cropped to 1728 lines of 3072 pixels per color to provide the required aspect ratio of 16:9. (All proposed systems use this ratio.) Then the data are digitally filtered or re-sampled to create new data files in each of the video formats: 525, 787.5, 1050 and 1125 lines. These new files can be loaded in the RGB frame buffers of the PIXAR and can be read out of the frame buffer in real time, with either progressive scan at a frame rate of 59.94 Hz or interlaced scan at 29.97 or 30 Hz. Therefore, the PIXAR provides both still test pictures, and it generates two dimensional test patterns, as you have seen.

Dynamic test material in the form of video taped scenes involving real objects moving in real time have been produced under the direction of PS/WP-6 in the formats. These signals were digitally recorded on Sony high definition digital video tape recorders by Captain of America at their studios in New York.

The Sony HDD-1000 high definition video tape recorder (HD-DVTR) was designed for the 1125 line format. However, the requirement for evaluating ATV systems was also to record in the other three formats--525, 787 and 1050 lines--for which there were no commercially available tape recorders. This required that an invention be made. ATTC devised a Format Convertor which enables any of these formats to be digitally recorded, using the available HD-DVTR machines. Tektronix, Inc. designed the actual hardware and was contracted to manufacture the device. The Format Convertor is shown in Slide #5.

The ATV signal from a system under test is fed to ATTC as a modulated signal in the 41-47 MHz band by the proponent. The RF Test Bed, designed and built by Harris Corporation for ATTC, converts the ATV signal to the VHF or UHF band. The Test Bed can evaluate the performance of an ATV system with respect to the interferences listed in Table I, and it can be used to evaluate the sensitivity of an ATV signal to multipath or to noise. Multipath may be due to reflections from fixed structures or from aircraft in flight. In the latter case, called "airplane flutter", the reflected signal is shifted in frequency by the Doppler effect. We are able to change the delayed signal carrier frequency in 1 Hz increments to simulate this effect. Other transmission impairments which can be evaluated with the RF Test Bed include random noise, impulsive noise and CW interference due to carriers of radio transmitters. The RF Test Bed is under computer control and perhaps more importantly, its status is tracked by the computer to document test conditions without the possibility of error. The control software, developed by ATTC Software Engineering, was able to interface with the Test Bed within one week of delivery to the Test Center. The softwre was developed using Labview, a process control software package from National Instruments, running on an Apple Macintosh P.C. The Test Bed is shown in Slide # 6.

The proponent will supply both the modulator and demodulator, as well as the encoder and decoder. A proponent's system must be in hardware--no simulations--and, under the Advisory Committee's rules, it is to present the full audio and video television system that the proponent plans to submit to the FCC as the new standard.

Quality of ATV pictures and sound will be evaluated through the RF Test Bed with all sources of interference, noise, and echo switched off. In this way, the inherent limitations on quality which are imposed by the 6 MHz bandwidth available are evaluated. The demodulator is required to have an all-channel TV tuner because we must assess how much interference there is from adjacent channels, or UHF Taboos. These interferences get into the ATV receiver through the tuner, generally through non-linear effects which occur in the tuner.

Quality of pictures will be evaluated subjectively at the Advanced Television Evaluation Laboratory (ATEL) of the Canadian government's Communications Research Centre (CRC) which has vast experience in such work. At the ATTC, Expert Viewers determine the range of interest at which subjective viewers in Canada will assess picture quality. The digital tape recording of the RGB video output of the ATV demodulator will be delivered to ATEL, where the subjective quality of picture impairment will be tested.

The quality of the program audio will also be evaluated subjectively from tapes created at ATTC. At this writing the responsibility for conducting these tests is being determined.

Since June 1990, there has been a decided swing from analog or hybrid analog-digital transmission schemes toward more "all-digital" ATV systems. While some details of the FCC Advisory Committee's Test Plan, devised and approved by SS/WP-2, will require some fine tuning, and the methods of analysis will be somewhat different from what was appropriate for analog systems, it appears that the ATTC plant and its RF Test Bed are entirely suitable, and we do not anticipate changes because of digital systems. However, the currently approved Test Plan may have to be modified to accommodate "all-digital" systems.

ATTC and Cable Television Laboratories (CableLabs) have entered into an agreement to test ATV systems at ATTC, using resources of both organizations. CableLabs has installed a CATV Test Bed whose elements address both metallic and fibre-optic cable. Through the FCC Advisory Committee a cable transmission Test Plan was also developed, which will be undertaken under CableLabs direction, in coordination with the broadcast oriented testing done by ATTC. The three testing laboratories--ATTC, CableLabs and CRC--have co-operated with each other to make possible on behalf of the FCC Advisory Committee and the industry what I call "one-stop testing" for ATV system proponents. This streamlines the testing process for the proponents and, in so doing, speeds the decision process in which the results of this laboratory testing will play a significant role.

The broad range of data gathered in this work will be made available to the FCC Advisory Committee to assist it in making its recommendations to the FCC, which has announced its goal for reaching a decision on a single terrestrial advanced television standard by June 1993. Hopefully, the work of CableLabs, Communications Research Centre in Canada and the Advanced Television Test Center will provide the means for broadcasters to play the key role in devising that future television service for the American public.

RF SPECTRUM FOR TERRESTRIAL HDTV: *It's a Crowded World*

Wednesday, April 17, 1991

Moderator:
Dr. Thomas Stanley, FCC, Washington, District of Columbia

CONSIDERATIONS FOR PLANNING AN HDTV SERVICE IN A DIGITAL ENVIRONMENT*
Victor Tawil
MSTV
Washington, District of Columbia

RADIO SPECTRUM FOR TRANSMISSION/EMISSION OF ADVANCED TELEVISION SYSTEMS
Donald M. Jansky
Jansky/Barmat Telecommunications, Inc.
Washington, District of Columbia

STUDY OF TELEVISION CO-CHANNEL INTERFERENCE*
Antoon Uyttendaele
Capital Cities/ABC, Inc.
New York, New York

*Paper not available at the time of publication.

RADIO SPECTRUM FOR TRANSMISSION/EMISSION OF ADVANCED TELEVISION SYSTEMS

Donald M. Jansky
Jansky/Barmat Telecommunications, Inc.
Washington, District of Columbia

1.0 INTRODUCTION

In its First Report and Order, "In the Matter of Advanced Television Systems and their Impact on the Existing Broadcast Service", some of the FCC's tentative findings were:

- "Any spectrum needed for a broadcast ATV system will be obtained from the spectrum currently allocated to broadcasting television".
- "We have determined, based on the record compiled in this proceeding, that we will select a "simulcast" high definition (HDTV) system, that is, a system that employs design principles independent of the existing NTSC technology service for ATV service."[1]

As defined by the Commission the term "Simulcast" is a contraction of "Simultaneous broadcast" and means the broadcast of one program over two channels to the same area at the same time. The term HDTV indicates a system that uses new technology and provides a major improvement in TV service.

This paper describes the progress in making available spectrum for an ATV terrestrial broadcast system in the U.S. This includes: A) Description of spectrum critera, B) The spectrum characteristics of systems being considered, and C) The state of development of planning factors.

2.0 SPECTRUM CRITERIA FOR A NEW TERRESTRIAL HDTV SIMULCAST SYSTEM

The FCC Advisory Committee on ATV in cooperation with the Advanced Television Test Center (ATTC), has now set the schedule for testing the six proponent ATV systems. Some of this testing will include the spectrum use related characteristics of these systems. The pertinent working parties have now adopted the spectrum criteria and methodology for determining if the criteria is met for these systems. The criteria consists of:

a. The ATV System must afford the opportunity for substantially all existing television stations to have an improved service to an area comparable to that receiving NTSC service,

b. This requirement must be achieved with ATV-to-NTSC and ATV-to-ATV minimum cochannel spacing in the order of 160 km (100 miles).

c. Specifically the ATV spectrum use criteria that the systems must meet are:

(1) minimize interference to existing NTSC stations;

(2) insensitivity to interference from NTSC or other ATV stations; and

(3) provision of satisfactory ATV service at a carrier-to-noise ratio lower than that applicable to the NTSC service.

Any new HDTV system must satisfy these criteria. The criteria statement went on to comment on use of UHF "Taboo" Spectrum.

"Although both the VHF and UHF television bands are expected to be utilized in any simulcast ATV system adopted, studies show that most of the accommodation must come from the UHF band. Characteristics of NTSC receivers have required that restrictions be placed on the use of as many as sixteen channels other than the same or first adjacent channels. Those channels, so restricted, are referred to as "taboo" channels. Utilization of these taboo channels is essential to provide the spectrum needed for terrestrial simulcast broadcasting of ATV. Laboratory tests will demonstrate if that threshold is satisfied by any ATV system, or the extent that some taboo restrictions must be retained for the protection of NTSC or ATV reception."[2]

With regard to the information to be obtained from the ATTC tests, the following has been agreed:

The laboratory will provide data on the noise-limited service afforded by each proposed ATV system and interference to and from NTSC and ATV-to-ATV interference. For the cochannel case, interference to NTSC will be made at two NTSC receiver input levels corresponding, approximately, to receiver inputs at the Grade B and Grade A signal contours. ATV power levels will be referenced to a common base. Unlike NTSC, where the peak of sync provides a constant reference for power determination, ATV systems are not expected to include comparable capability. Consequently, the selection of a reference for the ATV systems will require a degree of subjectivity. However, the power reference so determined is expected to provide a common base permitting systems to be compared.

Service predictions for each ATV system studied will start with the undesired ATV signal level, above or below the reference power at the receiver input, causing objectionable cochannel interference to NTSC reception. Then, using propagation data appropriate to the television band, and assuming 160-kilometer cochannel spacing and height above terrain similar to that used for NTSC, the permissible transmitted level of power above the reference will be determined. The degree of interference to NTSC permitted will be comparable to that above the reference will be determined. The degree of interference to the NTSC permitted will be comparable to that caused by NTSC-to-NTSC at typical cochannel spacing.

Having determined the permissible ATV transmitted effective radiated power, test data on service limitations imposed by noise, and interference from NTSC-to-ATV, will be applied to predict the extent of the ATV service. Available propagation data pertinent to the television band will be used again, in conjunction with the permissible power level determined as described in the previous paragraph. The calculations will provide a determination of the extent that ATV service will be interference-limited or noise-limited.

In the event that the foregoing does not yield an ATV service area at 160-kilometer spacing comparable to the service area provided by NTSC, cochannel spacing will be increased until that objective is achieved. An analysis will then be made of the accommodation statistics applicable to the increased cochannel spacing.

In the event that laboratory testing demonstrates the need to retain taboo restrictions for particular ATV systems, spectrum analyses will be made to evaluate the impact of those restrictions on accommodation.

Using data of the nature described above, the Advisory Committee will "provide an analysis of the extent that proponents have satisfied the criteria. Success of use of spectrum will be measured by the size of the ATV service provided simultaneously with maximum accommodation of either increasing cochannel spacing to improve service area size, or limiting channel usage because of taboo restrictions".[3] An indication of the variables involved in making these determinations may be found in Figure 1. The numbers in this figure (provided by Zenith to the work of Planning Subcommittee, Working Party-3, Spectrum availability) are hypothetical, but seem to indicate the interactions which must be evaluated to determine the extent that each system can fulfill the spectrum criteria.

3.0 SYSTEMS BEING CONSIDERED

It now appears that as a consequence of unexpectedly rapid development, that most of the proposed systems will now have digital modulation systems.

The digital ATV (HDTV) emission systems now being proposed in the United States can use a single 6 Mhz, VHF or UHF channel. They are expected to provide HDTV quality of performance with little impairment due to noise, multipath or other interference. Such high quality can be achieved with relatively low decoder complexity.

The expected high quality is achieved through use of highly efficient, and in each case unique, compression algorithms. The all digital systems are expected to use much lower transmitting power, and may be compatible with the planning factors described above.

The appeal of such systems has been expressed in a paper given by researchers with the U.K.'s Independent Broadcasting Authority (IBA).[4]

"It is quite possible to cover the same service area with a low power digital service because typical carrier/noise ratios (C/N) for digital signals are about 15 db whereas the analogue television service requires a C/N of greater than 40 dB for a (CCIR) grade 4 picture. Moreover, it is quite possible using "today's' technology to improve the noise figure of receivers so that transmitting the digital signal at 30 dB less power than the analogue TV signal can provide the same coverage."

A description of a generic digital system is provided in Figure 2. The system can provide high definition digital video, CD quality digital audio, and data and text services over a single 6 MHz, VHF or UHF channel. The system is capable of providing for conditional access. The encoder accepts high definition video and produces a modulated data stream.

The multiplexer combines the various data streams into one. The FEC encoder adds error correction overhead bits and provides approximately 20 Mbit/s of data to the modulator.

The demodulator receives IF signals from the VHF/UHF tuner and provides the demodulated data. There is an adaptive equalizer to correct for multipath. The FEC decoder corrects virtually all random or burst errors and provides error free data to the demultiplexer, which separates the video, audio, and text and control data. The decoder provides the high definition video output.

Efficient signal transmission is accomplished by a complex modulation format.

Satisfactory reception can be achieved at a C/N significantly lower than that required for present NTSC reception.

4.0 THE STATE OF DEVELOPMENT OF ATV PLANNING FACTORS

Planning factors will form the structure for determining the basic service area(s) for the new ATV service.

The allotment plan for NTSC television that is currently in use in the United States was adopted in 1952. It was based on certain technical assumptions regarding the receiver, propagation phenomenon, and NTSC system characteristics. The plan was applied to both VHF and UHF spectrum allocated to television broadcasting. The adopted terrestrial HDTV system must co-exist with the presently operating VHF and UHF NTSC stations.

4.1 NTSC Characteristics

The NTSC allotment plan was based on limits of noise and interference. In general, the allotments have been controlled primarily by cochannel mileage separation requirements of 155 to 220 miles. The closer spacing applies in the densely populated Northeast part of the United States and results in performance in this area that is interference limited rather than noise limited. A summary of the maximum power and antenna height for the different categories of spectrum are in Figure 3.

Each station has two defined grades of service, Grade A and Grade B. The Grade B service area defines the assumed service area of a station. The planning factor to provide a good quality picture (3.5 on the CCIR scale) originally required a C/N of 30 dB at the edge of the Grade B service area. For the CCIR recommended service, separation distances of cochannel stations are based on a D/U (Desired-to-Undesired) ratio of 28 dB. The radii of the Grade B service areas range from 55 to 65 miles.

The stations operating in this framework are on the channels determined by the above cochannel separation criteria, as well as adjacent channel separation criteria, and avoidance of so-called UHF "Taboo" channels, i.e., ±2, ±3, ±4, ±5, ±7, ±8, +14, -15. These restrictions were necessitated by the visual and aural carrier frequencies and NTSC receiver characteristics. These constraints must be considered for the introduction of an HDTV system.

4.2 HDTV Planning Factors

The point of departure to develop planning factors for an Advance Television Allotment Plan was the factors used in the development of the NTSC channel Allotment Plan. Figure 4 represents the status of development of the ATV parameters. These factors take account of the new information which would have to be added for ATV channels. In general the factors fall into three categories: a) those which can be identified now; b) those which can be determined in the near future; c) those which can not be determined until after tests of proponent systems have been carried out.

The status of development of these factors are as follows:

- (1) Maximum Ht Above Average Terrain (HAAT)

  The antenna heights indicated are the existing maximum values. These values were used since such antennas do exist and could possibly serve as the supporting structure for the ATV antennas. Antennas exceeding these heights would be subject to an appropriate reduction in allowable effective radiated power.

  (2) Geometric Mean Frequency

  This factor is used to determine the effective length of the receiving antenna, or the dipole factor (item 9). The value for any specific channel might differ from these geometric mean values, but for this generalized approach these values are appropriate. (The maximum difference of the value is 2 db for channels 2-6; but only 1 db for 7-13 and UHF).

(3) ATV Effective Radiate Power (ERP)

This very important parameter is under development and has been the subject of considerable discussion.

(4) Thermal Noise

The indicated value is the inherent noise within 6 Mhz across 75 ohms.

(5) Receiver Noise Figure

The values indicated are typical values that may be expected for new ATV receivers.

(6) S/N Ratio (interference to carrier)

This parameter can not be determined until ATTC/CRC tests are performed.

(7) Line Loss

The indicated figures are based on 35 feet of RG-59U.

(8) Receiver Antenna Gain

Information has been requested from receiver manufacturers.

(9) Dipole Factor

The indicated values are based on a 75 ohm impedance and the geometric mean frequency for the band, i.e. Dipole Factor = 25 log 48.34/F in MHz.

(10) Location Probability

Appropriate service statistics are under development, and when determined, values will be added based on existing time and location probability functions.

(12) F (50,90) Field

Values will be added based on existing time and location probability functions after the service statistics are determined.

(13) Time Probability

Values will be added after service statistics have been determined.

(14) Time Probability Factor

Values will be added after service statistics have been determined.

(15) (50,50) Field

With the FCC's F (50,50) propagation curves, the transmitting antenna height (1), and ERP (3), this value will determine the service contour.

(16) Urban Noise

For ATV Service Grade II no allowance is indicated to overcome urban noise.

However, for Service Grade I, if necessary urban noise factors of 14 db for channels 2-6, 7 db for channels 7-13, and 0 db for VHF should be used.

(17) Rural Noise

For ATV Service no allowance is indicated to overcome rural noise.

(18) Required Median Field

This is the required field associated with ATV Service Grade II. It may be calculated from

$$E = N, + N_R + \frac{S}{N} + L\text{-}G - K^d + L + T + N^6 + NR$$

or

(18) = (4)+(5)+(6)+(7) - (8)(9)+(11)+ (14)+(16)+(17)

(19) Receiver Antenna Discrimination

It has not been determined if this factor is necessary.

(20) Cross-Polarization Factor

It has not been determined if this factor is necessary.

The factors above determine the noise-limited service area, in the absence of interference from other stations. This area will be based on ERP, antenna height, and typical receiving systems for specified availability statistics. The existing rules for NTSC define two grades of service, Grade A, defined by an inner contour, and Grade B defined by an outer contour. It has been suggested that if two contours are necessary for the ATV service, these should be ATV Service Contour I (inner), and ATV Service Contour II (Outer). However, as the chosen ATV system will more likely than not be digital it has been suggested that since for such systems the signal drop-off will be rapid at a certain single distance, that therefore, only one service area should be defined. In this case it would be an interference limited service area that would approximate that of the Grade B NTSC service area.

Items 21-25 in Figure 4 will be used to determine the extent of interference from other stations permitted within the ATV service area resulting from the maximum mileage separation for cochannel, and adjacent channel, and taboo-related stations.

5.0 Summary

As this paper has indicated considerable progress has taken place toward defining the parameters which will provide for the availability of radio frequencies to be used for a terrestrial simulcast HDTV system in the United States. The planning framework is being developed and methods for evaluating the information from the tests of proponent systems are being identified.

It appears that as a consequence of FCC foresight and associated technological development it may be quite possible to provide the necessary spectrum to support such a U.S. terrestrial ATV system.

References

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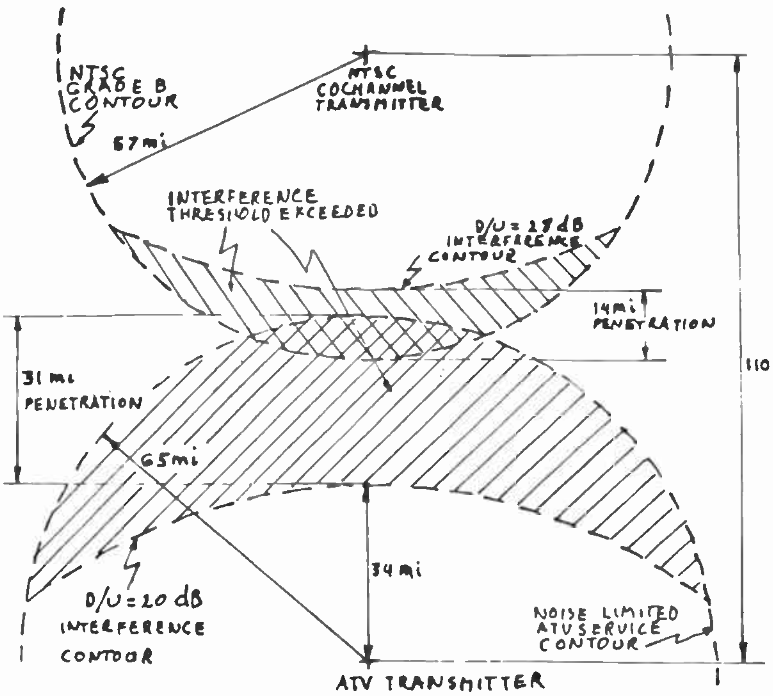

Example of ATV into NTSC and NTSC into ATV CoChannel Interference Penetration at minimum (110 miles) spacing.

CONDITIONS

NTSC ERP	37	dBk
NTSC HAAT	1250	Feet
ATV ERP	25	dBk
ATV HAAT	1250	Feet
NTSC Grade B	57	Miles
NTSC Grade B Penetration	14	Miles
NTSC/ATV Antenna F/B Ratio	6/12	dB
Antenna Gain	13	dB
Line Loss	5	dB
Receiver Noise Figure	10	dB
ATV C/N Threshold	20	dB
NTSC/ATV D/U Threshold	28/20	dB

Figure 1

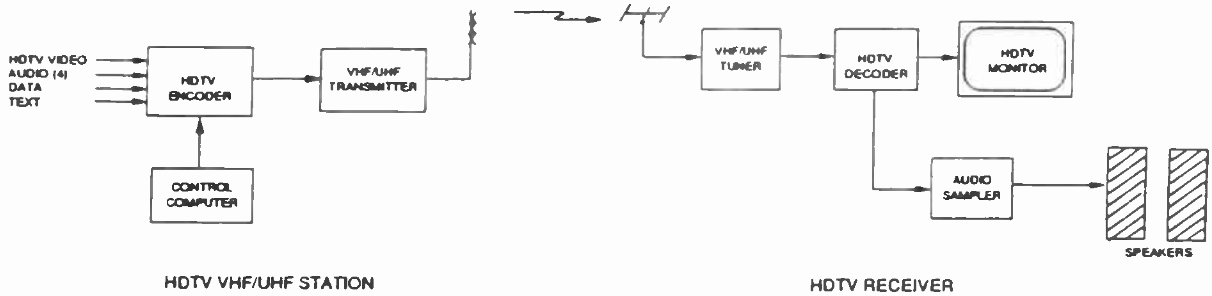

Figure 2 System Block Diagram

ANNEX I
DIGEST OF BASIC FCC ALLOCATION RULES

(See Part 73, Subpart E, of FCC Rules for complete description)

Maximum Allowable Effective Radiated Power

Zone	Low-band VHF	High band VHF	UHF
All	100 kW	316 kW	5000 kW

Minimum power is 100 watts for all bands. If maximum antenna height (see below) is exceeded, erp must be reduced appropriately.

Maximum Allowable Antenna Height, Above Average Terrain

Zone	Low-band VHF	High band VHF	UHF
I	1000'	1000'	2000'
II	2000'	2000'	2000'
III	2000'	2000'	2000'

Minimum Cochannel Spacings

Zone	VHF	UHF
I	170 miles	155 miles
II	190 miles	175 miles
III	220 miles	205 miles

Grade B Cochannel D/U Protection Ratios Used in Planning

VHF and UHF	
OFFSET	NONOFFSET
28 dB	45 dB

Figure 3

Advanced Television Service Grade II

	PLANNING FACTORS		UNITS	CHANNELS 2-6 ZONE– I	CHANNELS 2-6 – II, III	CHANNELS 7-13 – I	CHANNELS 7-13 –I & III	CHANNELS 14-69 – I	CHANNELS 14-69 II & III
1.	Maximum Height Above Average Terrain (HAAT)		feet	1000	2000	1000	2000	2000	2000
2.	Geometric Mean Frequency		MHz	69	69	194	194	615	615
3.	ATV Effective Radiated Power (ERP)		dBK						
4.	Thermal Noise	(N_t)	dB/μV	2.6	2.6	2.6	2.6	2.6	2.6
5.	Receiver Noise Figure	(N_s)	dB	5	5	5	5	10	10
6.	S/N Ratio (reference to carrier)		dB						
7.	Line Loss	(L)	dB	2	2	3	3	5	5
8.	Receiver Antenna Gain	(G)	dB						
9.	Dipole Factor	(K_d)	dB	-3	-3	-12	-12	-22	-22
10.	Location Probability	(L)	50%						
11.	Location Probability Factor	(ΔL)	dB						
12.	F (50,90) Field		dBμV/m						
13.	Time Probability		90%						
14.	Time Probability Factor		dB						
15.	F (50, 50) Field (includes correction)		dBμV/m						
16.	To Overcome Urban Noise	(N_u)	dB	0	0	0	0	0	0
17.	To Overcome Rural Noise	(N_r)	dB	0	0	0	0	0	0
18.	Required Median Field		dBμV/m						
19.	Receiver Antenna Discrimination		dB						
20.	Cross-Polarization Factor		dB						
21.	Co-channel D/U no offset	a. ATV-NTSC	dB						
		b. NTSC-ATV	dB						
		c. ATV-ATV	dB						
22.	Co-channel D/U nominal offset	a. ATV-NTSC	dB						
		b. NTSC-ATV	dB						
		c. ATV-ATV	dB						
23.	Co-channel D/U Precise offset	a. ATV-NTSC	dB						
		b. ATV-ATV	dB						
		c. ATV-ATV	dB						
24.	Adjacent Channel D/U (Lower)	a. ATV-NTSC	dB						
		b. NTSC-ATV	dB						
		c. ATV-ATV	dB						
25.	Adjacent Channel D/U (Upper)	a. ATV-NTSC	dB						
		b. NTSC-ATV	dB						
		c. ATV-ATV	dB						

6. Taboos — see separate list

LL/NBC

Figure 4

NEW HDTV TECHNOLOGY AND SYSTEMS: *Setting the World on Fire*

Thursday, April 18, 1991

Moderator:
Dr. William Sawchuk, Communications Research Center, Ontario, Canada

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NEW SYSTEMS CONCEPTS ON HDTV SYSTEM
Geng-Sheng Kuo
National Central University
Chung-Li, Taiwan

ALL DIGITAL MULTIRESOLUTION CODING OF HDTV
D. Anastassiou and M. Vetterli
Image and Advanced Television Laboratory,
Columbia University
New York, New York

PRODUCTION FACILITIES FOR DAILY HDTV SATELLITE BROADCAST
Kiyotaka Okada
NHK (Japan Broadcast Corporation)
Tokyo, Japan

STEREOSCOPIC HIGH DEFINITION TELEVISION—EXPERIMENTAL SYSTEM AND A CONSIDERATION ON PROGRAM PRODUCTION
I. Yuyama, M. Tadenuma and H. Yamanoue
NHK (Japan Broadcast Corporation)
Tokyo, Japan

THE ANTENNA AS A BOTTLENECK IN THE IMPLEMENTATION OF A COLLOCATED HDTV/NTSC TRANSMISSION SYSTEM
Dr. O. Bendov
Dielectric Communications Antennas
Voorhees, New Jersey

RF COMPONENTS FOR ATS TRANSMISSION
T.J. Vaughan
Micro Communications, Inc.
Manchester, New Hampshire

THE ROLE OF FILM IN THE ERA OF ADVANCED TELEVISION: AN ECONOMIC AND TECHNOLOGICAL ANALYSIS
C. Bradley Hunt
Eastman Kodak Company
New York, New York

A HIGH PERFORMANCE DIGITAL HDTV CODEC*
Arun Netravali, Eric Petajan, Scott Knaner, Kim Matthews, Robert Safranek and Peter Westerink
AT&T Bell Laboratories
Murray Hill, New Jersey

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*Paper not available at the time of publication.

NEW SYSTEMS CONCEPTS ON HDTV SYSTEM

Geng-Sheng Kuo
National Central University
Chung-Li, Taiwan

ABSTRACT

The purpose of this paper is to briefly review the receiver and display systems for HDTV, and to propose a personal computer (or workstation)-based, software-oriented information management system between the receiver and display systems in order to take advantage of the HDTV high-quality display system in benefiting all multi-media information services. From systems integration viewpoint, and information manipulation and management consideration, the computer-based, software-oriented information management system has been proposed and concreted at a conceptual level, which intends to integrate a variety of HDTV emission systems and a variety of BISDN-based multi-media information services together through software utilities residing in the system.

This system can also provide with end-users the capabilities to manipulate and organize a variety of different information resources and media. A set of user-control features will be considered to associate with the system in order to improve the utilization of information resources. In addition, the BISDN-based distributed computing environment has also been considered as a potential application platform for this proposed system.

In closing, this system is going to play the role as the only integration point between end-users and all available information resources. Its systems architecture should be based on special-function modules and be easily expandable to meet future growing needs.

INTRODUCTION

Based on current investigation, there are five major systems configurations for the transmission of HDTV system [1]. They are recording media, satellite direct broadcasting, for example, Japan's Multiple Sub-Nyquist Sampling Encoding (MUSE) system, satellite and cable distribution, terrestrial broadcasting systems, and the future telecommunications Broadband ISDN (BISDN) [1]. All end-users of the HDTV system will use HDTV receiver and display systems to accept their desired information services. In order to make HDTV information service successful and to take advantage of its high-quality display system, several considerations should be made seriously.

From end-users' perspective, all the HDTV information sources should be received by the receiver virtually in the future. The receiver and display systems should be versatile enough for providing many different information services. In addition, it is necessary to create a personal computer (or workstation)-based, software-oriented information management system located between receiver and display systems to increase the utilization of all information-related services.

The primary purpose of this paper is to investigate some new systems concepts on this proposed computer-based, software-oriented information management system for the HDTV system. First, HDTV emission systems will be studied. Second, receiver and display will be considered in order to provide a variety of new multi-media information services, for example, medical information system, education information system, banking information system, and some other multi-media information systems. Finally, a computer-based information management system will be outlined in a very high-level conceptual description.

HDTV EMISSION SYSTEMS

As mentioned in [1], currently there are several emission systems available or under development. How to utilize all information sources should be considered as early as possible in order to increase the compatibility among them and minimize conversion cost and effort. The advantages of this consideration will increase the capability of sharing information sources.

RECEIVER AND DISPLAY SYSTEMS

Receiver and display systems play the role of user-information interface between a variety of information sources and end-users. It is a reasonable expectation that receiver can accept all available information sources in order to increase the utilization of HDTV high-quality display system and the value of HDTV system.

PERSONAL COMPUTER-BASED INFORMATION MANAGEMENT SYSTEM

This topic is the main effort of this paper. In order to simplify user-system interface, it is necessary to build a personal computer-based information management system which locates between receiver and display systems [4]. This system will intend to integrate all information resources used or required by the residential and business environment end-users.

In order to achieve rapid information service creation, cost effectiveness, over-all systems flexibility, customized control, single-point systems integration, and simplified user-information interface, the proposed information management system is required.

The basic functional requirements of this proposed information management system include:

- managing all incoming information from different information sources through receiver,
- storing all information in a multi-media database,
- manipulating information in an intended fashion or media,
- combining a variety of information segments from different resources to some specific layout,
- synchronizing all information segments in right time order,
- controlling information display in the high-quality HDTV display system, and
- intercepting information services in an intended fashion.

Furthermore, user customization and control capabilities are necessary ingredients for guaranteeing the success of this system.

The proposed system is based on a 386 or 486 CPU and the Unix operating system with high-speed network-based client-server distributed capabilities. A high-speed network-based windowing system will be required in order to increase network transparency; of course, the windowing system can cover local as well as remote environments [2]. Based on that, the display system can expose many different scenes and views with many flexible features to increase the performance of information services and utilization of information resources. Its systems architecture should be based on special-function modules and be easily expandable to meet future growing needs

It is very clear that the high-speed BISDN will play the role of a principal infrastructure of multi-media communications systems. The network-based distributed computing environment is going to be the potential application platform [3] for this information management system.

CONCLUSIONS

Currently, a conceptual study has already been done. From systems integration viewpoint and information utilization consideration, this proposed information management system will play a valuable role in the HDTV system as well as BISDN-based multi-media information services.

This PC-based software-oriented system is a very reasonable and natural approach for desired goals in the distributed computing environment. The software-oriented flexibility is another crucial point which will manipulate digital information objects in a much easier way.

It is our intention to associate this information management system in the distributed computing environment for personal specific requirements. Based on the client-server systems model, it is easy to share all network-based information resources.

Our next effort will be centered on the systems design and software technologies for this proposed information management system. In addition, some digital signal processing techniques and algorithms will be studied thoroughly in order to improve the performance of information manipulation and versatility of information organization.

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ALL DIGITAL MULTIRESOLUTION CODING OF HDTV

D. Anastassiou and M. Vetterli
Image and Advanced Television Laboratory
Columbia University
New York, New York

Abstract: Fully digital HDTV broadcasting is now considered optimum by the majority of the FCC proposals for the American terrestrial Advanced Television system. One essential problem for finding the optimum digital video representation for such broadcasting is robustness, so that graceful quality degradation is achieved in the presence of the inevitable channel errors, rather than having sudden communications disruption whenever the bits start being misinterpreted. We show that multiresolution coding leads to a convenient solution to this problem. Another additional advantage of multiresolution coding is the possibility of achieving compatibility, i.e. the ability to conveniently derive video signals of lower resolutions using a subset of the coded bits.

We present a specific coding scheme achieving high-compression (about 15 Mbits/s) with distribution quality. We also present another approach for high-quality pyramidal coding. Both approaches are related to the forthcoming MPEG video coding standardization effort.

I Introduction

Digital transmission of Advanced Television (ATV) including High Definition Television (HDTV) is considered natural via optical fibers, more difficult via Direct Broadcast Satellite (DBS), and even more so via traditional terrestrial channels. Both Japanese (MUSE) and European (HD-MAC) DBS systems are mainly based on analog transmission, but there has been successful recent experimental fully digital HDTV transmission of some Italian soccer championship games in June 1990 using the Olympus Satellite [1]. Terrestrial transmission is less "digital friendly", due to complicated channel noise like multipath distortion and cochannel interference, and also due to the requirement of long-range reception, even at less than perfect quality. Despite these difficulties, most American proposals to the FCC for terrestrial ATV transmission are fully digital.

Transmission of digital video, including HDTV, is limited by the errors induced by the channel. Sophisticated compression (source coding) techniques, involving motion compensation, are needed to fit the signal into limited capacity channels. For example, it is believed that the 6 MHz terrestrial channel cannot efficiently handle rates higher than 20 Mbits/s. At such high compression rates, if even one bit of the coder output is misinterpreted by the receiver, total communications disruption will occur, because the decoder will confuse all subsequent codewords. There are various error protection schemes designed to counter isolated bit errors. In the presence of severe burst errors, concealment can cover the lost area of the video signal. Reinitialization techniques can also be used whenever transmission has been disrupted. However, guaranteeing graceful degradation in the presence of channel errors is a challenging joint source/channel coding problem. We have described the advantages of multiresolution coding, together with analysis of the corresponding signal processing concepts in [3].

In this paper, we focus on multiresolution coding in which video signal coding is built on a pyramid of increasing resolutions, containing a number of hierarchical levels. Each level of hierarchy guarantees a certain quality level and has different protection. In the presence of channel errors, the low priority channels will first be disrupted, but this will result in graceful degradation, because the decoder interpolates approximate values of the missing samples from those of lower resolution. In figure 1, we show this concept of hierarchical coding for progressive video sequences. Generalization to interlaced sequences, as discussed below, is possible but nontrivial.

We present a technique for ATV coding at approximately 15 Mbits/s, which, when used in a 6 MHz terrestrial channel, can achieve graceful degradation as the distance between transmitter and receiver increases [5]. We also describe a multiresolution scheme for high quality HDTV coding utilizing hierarchical motion estimation [3]. Both approaches are related to the forthcoming MPEG video coding standardization effort [2].

II All-Digital HDTV

Digital HDTV has many advantages, the most obvious of which is flexibility. Once the signal is represented by a sequence of zeros and ones, then it can be digitally processed in any desirable way, and, assuming error-free transmission environment, the signal quality at the receiver will be identical to that of the transmitter, avoiding any intermediate processing step of conversion into analog form. Digital representation is transparent to any video format. Having higher reach, it will require fewer repeaters for cable TV distribution. It has lower transmitter power requirements. Digital algorithms can also be transcodable for efficient conversion between different delivery mechanisms. The same standardized algorithms may be used for all media, and it is possible to define a digital hierarchy, with various bit rates, so that a hierarchical multiresolution approach can handle all levels. Such an hierarchy can start at 15 Mbits/s for 6 MHz terrestrial transmission, and build upon it for satellite and fiber transmission, which can afford higher rates. Fully digital representation also facilitates communication of video signals with multimedia workstations, in which the hierarchical multiresolution element (variable window sizes for pictures as well as transformations from progressive to interlaced formats and vice versa) is also desirable.

Digital transmission has drawbacks as well. The receivers will be more complex (hence more expensive) compared with their analog counterparts. Modulation of digital signals requires more bandwidth for the same quality, unless very sophisticated compression techniques are used. When the limits of digital video compression are pushed, quality artifacts, like "blocking effects" when block coding is used, start appearing for very complex and fast changing pictures. In fact, maximum compression with constant signal quality results in variable bit- rate (VBR). However, VBR coders can be used only in digital fiber-based packet switched telecommunication networks. When constant rate is required, then the coder incorporates a buffer at its output, whose state feeds back to the coder, thus varying signal quality. Another essential consideration is robustness, so that bit misinterpretations will not have catastrophic effects. Error correction is normally needed, or some other form of combined source channel coding approach, like hierarchical transmission, as is described below.

There are currently efforts to investigate fully digital HDTV communication schemes connecting multimedia workstations with high resolution displays, handling full-motion video. For this, it is essential to come up with an optimum representation for motion video in multimedia workstations, considering the trade-offs with respect to processing, architectures, bus and other communication bandwidth and storage aspects.

The net bitrate generated by uncompressed HDTV is approximately 1 Gbit/s. It has been thought that digital "contribution quality" HDTV, between studios, should be in the 300 Mb/s range to permit further editing, while "distribution quality" HDTV, to the home, should be in the 45-100 Mbits/s range. We have found, however, that the above bit rates can be substantially reduced with use of sophisticated signal compression techniques. This is in accordance with recent results from various sources, which have convinced many experts that the future of HDTV lies in a totally digital technology.

III Data Compression

Since the spectrum is too crowded and the demand for many TV channels is strong, there is an obvious need for signal compression, by not sending anything which is not visible to the human eye, and by exploiting the inherent redundancy of the video signal.

Analog compression, e.g. for satellite or terrestrial transmission, typically include some form of three dimensional (spatio temporal) downsampling of the analog video signal, using downsampling factors like four or six. The signal is then interpolated at the receiver. This can be done using linear, or even nonlinear interpolation. The interpolation process can be digitally assisted with a bit stream of the order of 1 Mbit/s, which can be sent during the vertical blanking interval, resulting in a mixed analog-digital approach. It is possible to consider sending both bits and samples within the 6 MHz of the allowed terrestrial transmission, but the performance of hybrid modulation techniques is difficult to be predicted.

Fully digital video coding is done in various ways. The tradeoffs involved include the compression ratio, the quality of the coded signal, and the complexity of implementation, especially for the receiver. For HDTV applications, quality must be excellent and complexity low, so it is difficult to achieve high compression ratios.

Motion compensation is an important element for high compression. Video scenes typically contain repeated frames of objects which are essentially unchanged from frame to frame, except for some displacement due to their motion. Modeling based on such considerations leads to motion related operations, which have been known to improve the coding performance of video compression techniques, and the accuracy of interpolated pixel values. In the former case, a frame is typically predicted from the previously coded frames, and motion compensation leads to smaller prediction error. In the latter case, a frame is temporally interpolated between two known frames, and use of motion compensation avoids the appearance of multiple objects resulting from linear interpolation. Therefore, a fundamental understanding of three dimensional motion models for HDTV quality video signals is essential. However, it must be noted that motion estimation is extremely beneficial as long as it is accurate. Whenever it is inaccurate, it may create severe quality problems. To minimize receiver complexity, motion vector are typically evaluated at the encoder site from the original signal, and then sent as side information to the decoder.

Coding must consider the channel problems which result in inevitable transmission errors, in which case reception quality degradation should be graceful. Use of hierarchical coding schemes guarantee that such degradation is graceful, because a number of digital transmission channels is used, each with a priority assignment capable of handling a certain bit error rate, so that a transmission error will merely result in a lower resolution signal. Design of such a digital transmission system, with various levels of hierarchy, is a combined source and channel coding problem, in which each level of hierarchy will guarantee a certain quality level.

IV The MPEG Digital Video Coding Scheme

An ISO effort (MPEG [2]) has been launched, and is nearing completion, for standardization of video coding at 1-1.5 Mbits/s. The approach suggests coding interlaced video by horizontal downsampling by two, and also dropping the even fields, resulting in a "source input format" which can be thought as containing progressively scanned frames.

The frames are downsampled by N (where N is typically 15) and these frames are compressed using intraframe video coding. Intermediate frames are also downsampled by M (typically M=3 or 2) and are compressed recursively by motion compensated interframe coding. The remaining frames are interpolated from the nearest past and future coded frames and are also compressed by motion compensated interframe coding. In all cases, motion estimation is achieved by block matching after separating the frame into "macroblocks" of size 16x16 pixels. Compression is achieved by applying DCT coding on blocks of size 8x8. The MPEG effort will provide a standard decoding mechanism, but allows flexibility in the chosen coding scheme, as long as it is compatible with the decoder.

From the above description, it is apparent that MPEG provides a multiresolution approach to video coding, and is therefore within the spirit of this paper.

The second phase (MPEG-2) of the MPEG video coding standardization effort deals with coding of interlaced video at rates up to 10 Mbits/s. We have proposed [4] a technique for MPEG-2, by coding the even fields, assuming that the neighboring odd fields have been coded with MPEG-1. The technique uses a multiplicity of recursive (predictive) modes, including averaged hybrid recursive/interpolative modes, and achieves high quality coding of interlaced video at 4 Mbits/s. The technique is described in detail in [5]. Subjective evaluation experimentation was done at Columbia

University using a RAM-based HDTV simulation system connected to an HDTV monitor. An average compression improvement of 40% was found in the even fields, when compared with independent MPEG-1 coding of the even fields, with the same observed quality. This translates to about 20% overall bit rate savings for interlaced video coding, compared with independent field coding.

Other advantages of this approach are the following:

1. All modes are MPEG-type, so generalization of hardware is easy.

2. Any error propagation is stopped whenever the encoder selects use of purely interpolative modes, without otherwise notifying the decoder, resulting in a finite-memory system.

3. Robustness: this is a pyramidal technique, offering graceful degradation in the presense of noise, by assigning higher protection for the coded bits of the odd fields than those of the even fields. When the even fields cannot be coded, they can be interpolated.

4. Compatibility: it is desirable to have first independently coded the odd fields, not only for MPEG-1 compatibility, but also because they can be used for resampling to other interlaced standards. For example, if an MPEG-type technique is used for HDTV coding, a Standard TV version can be created from the odd HDTV fields.

V An ATV Coder for 6 MHZ Terrestrial Transmission

The above mentioned approach for MPEG-2 is designed for good quality encoding of standard-TV signals at about 3 Mbits/s. Since an HDTV image is roughly five times larger than a standard TV image, it follows that the same algorithm can also be used for HDTV coding at approximately 15 Mbits/s.

The proposed approach for interlaced ATV coding consists of four levels of hierarchy using temporal downsampling, providing four classes of fields, each building upon the previously coded classes. These are the "intraframe" odd fields, the "predicted" odd fields, the "interpolated" odd fields, and finally the remaining odd fields.

The even fields are coded as follows: there is access to the previous ("co-sited") even field, and to both past and future odd fields. Figure 2 shows the fields that are involved in this method. A large number of modes can be selected, including the intrafield mode, but we found the following four modes to be most useful:

1. Averaged mode between the previous co-sited even field and the future odd field.

2. Averaged mode between the past and future odd fields.

3. Single mode using the co-sited field.

4. Single mode using the future odd field.

If Advanced Television is progressive, rather than interlaced, then the final layer of the even fields is deleted, and coding is similar to MPEG-1.

Compression is achieved by hybrid motion compensated predictive/DCT coding. Due to its hierarchical multiresolution nature, the technique provides convenient solutions to the channel coding problem with graceful degradation in the presence of channel errors. It also provides a straightforward approach for compatibility with the interlaced Standard-TV format.

Regarding channel coding, the lines of the video signal can be separated into various categories. Figure 3 shows a possible separation of these lines into three categories of fields: the predicted fields (1), the interpolated fields (2), and the even fields (3). More levels can be defined if we consider the "intra" fields and the horizontal resolution enhancement before coding the even fields. Digital modulation is performed so that various levels of error protection are assigned in each of these channels. Lowest error protection is assigned to the highest levels of hierarchy (in this case to the even fields), so that if transmission becomes excessively noisy, the first channel to be lost will be that of the even fields. In that case, the receiver must interpolate the missing lines from the decoded lines of the odd fields. If transmission becomes further impaired, then the next level of hierarchy is lost, and interpolation of more signal values is needed. We are currently examining techniques in which such interpolation is achieved using motion compensation, in order to avoid excessive jerkiness in the displayed video.

Coded HDTV sequences at 15 Mbits/s have distribution-quality, while at 30 Mbits/s they are nearly indistinguishable from the original when displayed in real-time.

VI HDTV/Standard-TV Compatibility

If compatibility with Standard-TV resolution is desired, we suggest the following approach: dropping the even fields will yield a (K/2)/(L/2)/1 signal. Converting that signal, with high quality, into, say, a useful (K/2)/L/2 is not straightforward, although the total number of samples is identical. A simple transfer of values and filtering will create some motion artifacts. This may be acceptable for some applications. More accurate results are obtained if assisted by side motion vector information. Such motion vector information, however, can be directly transmitted, as an aid in coding the even fields from the odd fields for HDTV coding. HDTV coding is achieved by the hybrid recursive/interpolative scheme described in [5], and the lines of the even fields of the (K/2)/L/2 signal are interpolated from all the lines of the (K/2)/(L/2)/1 frames using motion information, as described above. However, care must be taken to avoid error propagation when using recursive modes. It is best to independently send to the standard TV decoder a choice among the forward, backward, and averaged modes, incorporating the odd fields only. For higher compression of the low resolution signal, it is appropriate to perform horizontal downsampling before coding the (K/2)/L/1 signal, in which case extra bits must be sent for the enhancement in the horizontal dimension, when coding the HDTV signal.

VII A Multiresolution High Quality Coder Using Hierarchical Motion Estimation

In [3], we describe a three dimensional pyramidal scheme for high quality coding, for example contribution quality transmission and storage. The advantage of pyramids over the often advocated subband coding are numerous, and include a free choice of interpolation filters, the ability to include motion easely as well as a tight control over quantization effects. The basic principle is explained in figure 4, where a hierarchy of lower resolution sequences (both in space and time) are derived from the original sequence. Then, the higher resolution is predicted from the low resolution, and the difference between the actual and the predicted value is computed and coded. This process is repeated until the full resolution sequence is obtained, but can be stopped at any level if only a partial resolution is desired. Quantization feed-back can be performed so as to guarantee a quality which depends only on the last quantization step (unlike transform or subband coding, where quantization errors can actually add up). This easy way of guaranteeing a bound on the quantization error is particularly useful in coding for contribution quality, where post-processing puts stringent requirements on maximum errors in the decoded signal.

While the prediction of spatial higher resolutions is done using usual linear filtering, the temporal prediction is based on motion vectors that are calculated at the encoder. Thus, odd frames are predicted from even frames, and the prediction error is calculated and encoded. This motion based interpolation is similar to MPEG schemes [2]. The motion estimation is done in a hierarchical fashion, leading to smooth and accurate estimates on the average.

The coding method, being multiresolution in nature, blends well with appropriate channel coding techniques. Here, channel coding can be both for recording and transmission purposes. For example, appropriate formatting of the data on magnetic tape will permit easy fast forward and reverse modes by decoding only one of the subresolution sequences. For transmission purposes, the lower resolution sequences will get better protection than the higher resolution added details, thus leading to graceful degradation in presence of channel impairments. Schematically, it is shown in figure 5 that a digital broadcast will still have the so-called threshold effect when the minimum SNR is not maintained, but that a multiresolution transmission will have a stepwise degradation.

VIII Conclusions

We have described two multiresolution techniques for fully digital Advanced Television coding. One technique achieves high compression and is suitable for terrestrial broadcasting within the allocated bandwidth of 6 MHz.

The other technique achieves high quality and is based on joint spatiotemporal downsampling utilizing hierarchical motion estimation. It is appropriate for transmission via optical fiber networks or for digital storage and has compatible subchannels.

Due to their multiresolution nature, both techniques achieve graceful degradation as the channel error effects intensify (e.g. as the distance between transmitter and receiver increases).

Such joint source channel coding using multiresolution decomposition of the source coding and appropriate prioritization in the transmission has been investigated for some time [6], and more research is currently underway in order to define the optimum choice of resolutions for this joint process.

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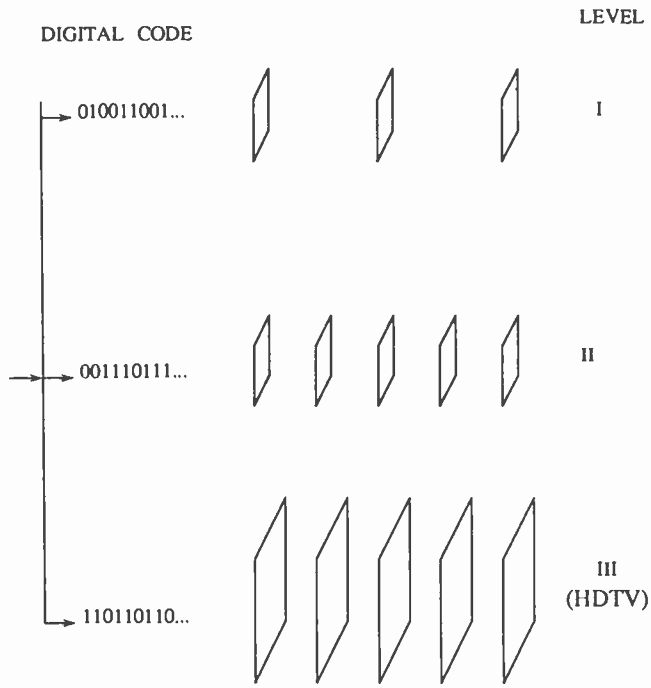


Figure 1: Hierarchical multiresolution coding.

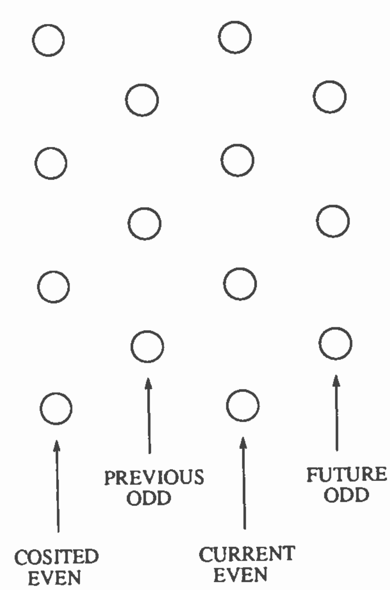


Figure 2: Identification of fields for interlaced video coding.

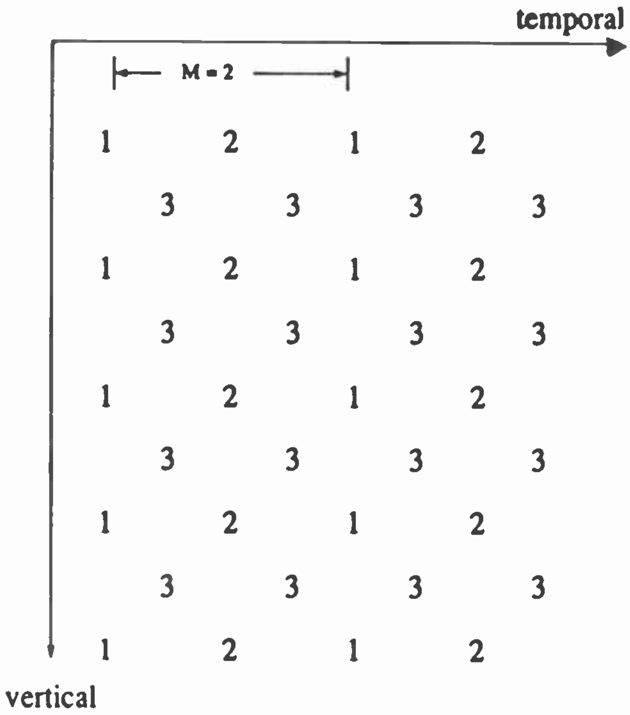


Figure 3: Levels of hierarchy in an MPEG-like approach.

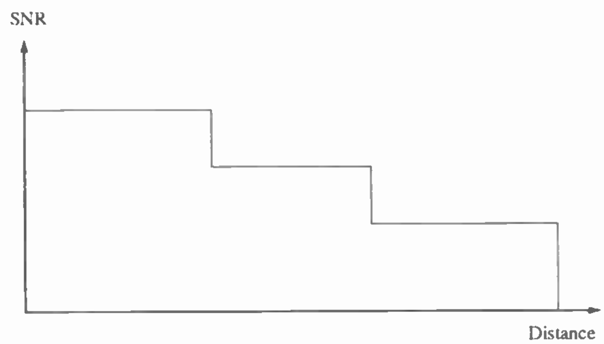


Figure 5: Graceful degradation of multiresolution transmission.

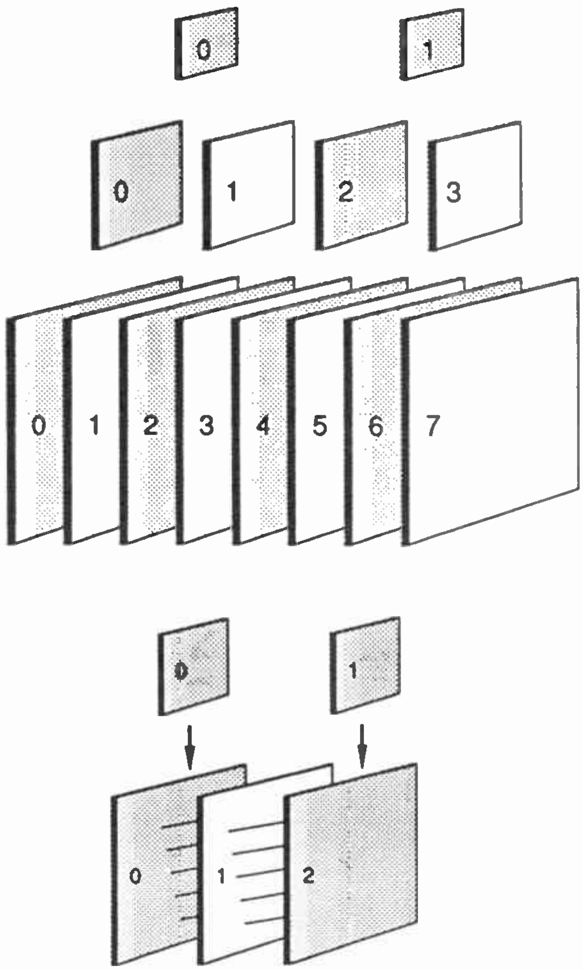


Figure 4: Three dimensional pyramid decomposition and back interpolation.

PRODUCTION FACILITIES FOR DAILY HDTV SATELLITE BROADCAST

Kiyotaka Okada
NHK (Japan Broadcast Corporation)
Tokyo, Japan

ABSTRACT

Daily one-hour broadcast of HDTV using one of the two channels of Japan's broadcast satellite has been in operation for more than 18 months on an experimental basis. With MUSE (Multiple Sub-Nyquist Sampling Encoding) technique, the broadcast is carried out usually from 2 to 3 p.m. The MUSE signal is received and displayed at about 150 locations throughout Japan. The public enjoys the program very much.

To produce the HDTV programs required for the daily HDTV broadcast, a lot of facilities and equipment have been provided. Those facilities and equipment have been increased step by step for many years, based on the long term prediction of the demand that comes from the hour of broadcast.

Cameras and VTRs attained the performance what we hoped for. VTRs can record without losing the details of the live picture. Lighter VTRs are emerging. Post production facilities are substantiated. OB Vans are in full operation. More equipment is being added. Steady preparation for the longer hour broadcast is thus being made.

Those facilities are operated based on the SMPTE 240M (1125/60/2:1) standard. Day and night the program production is being conducted actively using the facilities.

INTRODUCTION

In Japan, the satellite broadcast with a 525-line television system has already been in regular service. It operates 24 hours per day, except for periods of the eclipse. The system used for this service is the NTSC plus digital sound. The ownership of the DBS receiver for NTSC broadcast stood at 3.5 million as of December 1990.

In addition, a daily broadcast of HDTV has been in operation since 3rd of June 1989 on an experimental basis through one of the two channels of the broadcast satellite. The service on Channel 11 is switched to HDTV for one hour per day, usually 2 p.m. to 3 p.m. The signal emitted in this period is the MUSE signal. Received HDTV pictures can be displayed at about 150 locations throughout Japan.

Programs, that have been used up to now through the daily broadcast, included such materials by off-line productions as the Seoul Olympic games, Asian games, and other live materials. Such famous tournaments in Japan as Sumo wrestling and baseball by junior high schools also took place live. On the first day of the HDTV broadcast, some live programs came from New York through ANIK-C2, INTELSAT-V and BS-2.

In order to maintain smooth operation of a regular HDTV broadcast, a lot of equipment and systems have been provided for the program production facilities. Such an amount of equipment could not suddenly be put into service, they have been implemented during several years based on a long-term prediction at NHK. Throughout the HDTV production facility here, the audio system is so designed that it can handle a four-channel audio program. An outline of these installations is shown in the figure 1. Some explanation is given in the following sections.

PRESENT STATE OF DBS BROADCAST

When the daily one hour HDTV Broadcast got started, what we utilized was the second generation of the DBS, that was BS-2. Now the third generation of DBS: BS-3 is being utilized. When the regular one hour HDTV broadcast started, there was no back-up system in MUSE for the uplink to the satellite. Now the redundant system is provided to increase the reliability. The steadier MUSE broadcast has been maintained since the completion of the secondary earth station. As it is located 45.4 km away from the pivotal main earth station, space diversity transmission can be carried out. The signal transmission between the two earth stations is carried out in digital format through optical fiber. The reliability of the uplink against the rain attenuation has increased to 99.999% in time, which means for 5 minutes a year the rain attenuation will render both stations inoperable. In the past 17 months, there would have never been a time to utilize the space diversity scheme, however, for the weather had never been threatening during the HDTV broadcast.

The number of the receiving points throughout Japan is expected to be over 150. All NHK local stations in Japan have installed MUSE and other HDTV play-back and display equipment. At those receiving points, they receive the MUSE signal and display the picture, thus appealing the fascinating nature of the HDTV to the public.

PROGRAMS PRODUCED

The number of HDTV programs produced and documented so far is 370. It is still increasing. If live broadcasts are included, the number easily surpasses 400. The programs include sporting events, such as Seoul Olympic games, Asian games, High-school baseball games, Sumo tournament, skiing events, etc.

Theater performance includes Kabuki play, metropolitan opera, and "Ring of the Niebelung".

Feature programs include such as one dealing with an artist and his drawings: "Frederic Remington". Other events are Emperor's enthronment on November 12, 1990, aerial shot of the West Coast of the American Continent, and one featuring wild birds, etc. The number of programs is eventually countless.

NTSC AND HDTV SIMULTANEOUS PRODUCTION

NHK has long been broadcasting the popular Sumo tournament live regularly in NTSC, six times a year, 15 days a tournament. To broadcast it in HDTV as well, HDTV cameras and other equipment must be set up in addition to NTSC equipment. That form of production was carried out many times, but the conclusion is that now is high time to start producing HDTV programs for NTSC broadcast. Since the autumn of last year, we have experimentally been carrying out the simultaneous live production of Sumo for both HDTV and NTSC. The program for NTSC is obtained through the down converter that converts HDTV pictures into NTSC pictures.

HDTV to NTSC Down Converter

NTSC pictures are obtained by converting HDTV pictures, first by converting the number of scanning lines, and then field frequencies from 60.00 to 59.94 Hz, by skipping one field every 16.6 seconds. Skipping can not be noticed most of the time, except for the very rapid motion area in the picture. There are many ways to avoid the visibility of the field or frame skipping. One is to find the point in time, of camera cut-change and skip the field or frame then. The other is to randomize the skipping method, skip at one time, blur at another, and skip at cut-point, making it almost undetectable by the human visual system. These methods are implemented and used.

The converter sets the aspect ratio either to that of letter box or to 3:4 with side panels deleted. Obtained 525 component signal is fed to NTSC encoder, which encodes it into NTSC signal.

NTSC Encoder

The important aspect of NTSC production through HDTV is that there is a tendency Y signal has much higher frequency component, which creates cross-color interference that gives out 15 Hz flickering picture component in NTSC. This is a rather annoying interference.

To reduce the cross-color interference, comb-filter is being used before the encoding process for NTSC. This reduces the interference enough for a practical program production.

Bi-media Program Production

As is stated above, a couple of Sumo tournament programs has been produced based on this concept. Basically it works well, but philosophy differs. NTSC programs at NHK are produced in a rather high key. Whereas HDTV programs are in a neutral key. HDTV programs make some sacrifice to produce attractive NTSC programs on this point. There is another concern. Aspect ratio for HDTV and NTSC differs, which gives rather complicated situation. NHK has two NTSC networks, one is terrestrial broadcast, the other is direct satellite broadcast. NHK tries to differentiate the two networks, by applying different aspect ratios to two means of broadcast. It seems that producers may have to solve the problem.

This type of bi-media production clearly shows that the sensitivity of the HDTV camera has increased to accommodate the lighting condition that is normally applied to NTSC program production. It also shows we have entered into the stage where HDTV prodcution is everday affairs.

Every year, on the night of December 31st, NHK has a grand song parade. Last time the program was produced entirely by HDTV equipment and broadcast live through DBS and terrestrial network in NTSC. We naturally expect the production of this kind will increase very quickly.

HDTV PRODUCTION EQUIPMENT

HDTV Cameras

A few years ago the sensitivity of an HDTV camera was not high enough to shoot a poorly illuminated scene, but now it has been increased to the point where the sensitivity is nearly equal to that of a conventional TV camera. A HARP (High gain Avalanche Rushing Amorphous Photoconductor Target) HDTV camera can shoot a scene illuminated for the NTSC production with a good signal to noise ratio of 45 dB. The camera employs 2/3" pickup tubes with the sensitivity of f2.8 for 200 lx. The magnetic focus and static deflection can, in combination with the diode gun function, produce a high resolution picture.

Other cameras using SATICON tubes are the major force in HDTV production. Their sensitivity is at f4.5 for the 2000 lx illumination.

Although the CCD cameras for HDTV are still under development, some manufacturers have already produced a prototype. The maximum number of picture elements implemented so far on the pickup panel is two million, enough for HDTV. NHK has also developed a 2/3" CCD camera whose pixel number is 800 thousnad. It gives the resolution of 1000 TVL, by employing the dual green arrangement. CCD cameras will emerge on the market in a few years.

Digital VTRs

The manufacturers have already stopped producing analog VTRs. Main VTRs on the market are in digital format. Digital VTRs can record and play back an HDTV program produced according to the SMPTE 240M HDTV standard. They can record the Y signal of 30 MHz and Pb, Pr signals of 15 MHz. Hence, it is impossible to distinguish a live picture from a recorded one. They can also deal with the eight-channel audio signals. A total of 23 digital VTRs, besides 16 anlog VTRs, are functioning at NHK. They are now the major force for the HDTV produciton.

1/2" VCRs

In addition to the D-VTRs for the program production, the 1/2" VCR has been developed mainly for industrial application in mind, such as for mini-theaters, museums and so on. A total of 10 manufacturers in Japan have been producing it. The features of the VCR include: high density wide band recording, a special cassette designed for this purpose, component recording system, and digital signal processing although the input and output are in analog format. The signal to noise ratio of 41 dB in 20 MHz bandwidth is obtained with 63 minute recording time. It can also deal with four-channel digital audio.

Where the allowable power consumption and weight are limited, as in the case of an aerial shooting on-board a helicopter, we are sometimes obliged to use them for the usual program production.

CRTs and Projection Systems

CRTs are being manufactured up to 41" in size. They are used for program production, as they have enough resolution and dynamic range. In order to implement the feel of reality in the displayed picture, it is desirable to display the images using at least 50" or 60" projectors. Editing rooms are provided with this kind of projectors in addition to CRTs, as they are essential to the program production.

So far, NHK has contributed toward constructing the projection display system. Now many manufacturers are producing the front and rear projectors. High-quality projectors that can deal with studio quality pictures are on the market. The rear projector can display pictures in a relatively bright environment, whereas the front projector requires an almost completely dark room. Up to 150" rear projectors and 300" front projectors are available. The resolution of rear projectors is around 900 TVL, and that of front projectors is around 1000 TVL.

For the home viewer, a less bulky rear projector or another flat type of display is essential. Gas-discharge and liquid crystal displays are promising candidates for home use. NHK is continuing the research into the flat gas-discharge display system.

Telecine System

It is expected that one of the most attractive programs for the HDTV broadcast will be the movies produced to date. The conversion from film to video requires the telecine system. NHK has developed a laser telecine system and put it into practical use. The 35 mm film that runs continuously is converted to video in real time. It has a noise reducer, contour corrector, and other basic functions that are required for the transcoding of the film.

Recently we have installed an electronic motion stabilizer for the laser telecine system. It incorporates motion-compensation technique developed for the correction of the pictures taken by telephoto lens. The compensation unit detects the jitter in the still area of the film, in successive frames, selected by the operator and calculates the motion vector of the jitter. By applying the vector in reverse direction of it, the accumulated jitter through various film transport systems, including film cameras and optical printers, is compensated and the stabilized pictures are obtained. The accuracy of the compensation, which is done in real time, is up to 1/4 of the scanning line. This gives the electronic special effect with film and video stabilized, good performance.

The movies of great popularity will be readily converted into video in high quality when we start regular full-fledged HDTV broadcast.

Down Converter to PAL

So far so many programs have been produced in HDTV and converted to either NTSC or PAL in post production, and been broadcast on conventional TV systems.

A story titled "Ginger Tree" has been produced in HDTV and broadcast in PAL in the Great Britain. Here, the down-converter from HDTV to PAL played a very important role. In the HDTV to PAL converter, the line number is first converted to 625/progressive from 1125/interlace. Then the 60Hz frame, 625 line picture is converted to 50Hz field, interlaced picture, using the motion vector compensation, which is the life-line of this converter. After that the obtained signal is encoded into PAL. Converted picture quality is very good. NHK and EBU have carried out the subjective evaluation test against the converted pictures and concluded that the converted picture is good enough to be used for PAL program production.

Digital Video Effect

Special video effect made possible by the advanced digital technique is also vailable for the HDTV production. The main reason why electro-cinematography is popular is that special effect is readily available in HDTV, whereas the optical special effect applied to the film is time-consuming and expensive. Although the DVE system for conventional TV is at the moment far advanced than that for HDTV, three-dimensional DVE system for HDTV is now under development.

Up-Converter

HDTV programs sometimes need NTSC pictures to be inserted for reference or for other purposes. In that case, NTSC pictures must be converted to HDTV pictures. First NTSC pictures are decoded into RGB component signals. To obtain a high quality picture, the NTSC decoder is critically important. It must separate the chrominance signal from the composite signal with least cross-talk between Y signal and C signal. The decoder must be constructed in digital technique. For the decoding in stationary area, frame delay is used to get a high quality picture. For the moving area, comb-filtering is required to separate the chrominance information.

After obtaining clean RGB signals, the scanning line number is converted from 525 to 1125. At the same time the field frequency is changed from 59.94 Hz to 60.00 Hz by repeating a field or frame. Up-converted signal is usually incorporated into DVE, where composite picture is obtained. This makes it easier to solve the aspect ratio problem in up-conversion.

Field Pick-Up System

When a multi-origination program is broadcast live, picture contribution system is required. NHK has developed an FPU system for that purpose. The RGB signals from a camera are time-division-multiplexed to get a composite signal, with audio signal multiplexed during the vertical blanking period. The technique of multiplexing is called "TCI", time compressed integration. The signal is frequency modulated and sent through the 42 GHz radio wave to the broadcast station. The system has been used to broadcast sporting events, and other information programs.

Frame-Synchronizer

When a program requires live pictures taken in the field, the signal must be transmitted to the studio with the sync generated independently. When the received signal has a different sync, it is impossible to mix the two TV signals in a video switcher. Frame synchronizer works as a buffer between the two TV signals so that the inbound signal through the synchronizer has its sync replaced with the studio sync. There occurs a delay of the video signal when it is put through the equipment. This is compensated by delaying the audio signal by the corresponding amount of time. Then the two video signals can be mixed together.

PRODUCTION FACILITIES

There are a lot of equipment to be used for the production and post-production of HDTV programs. All audio equipment are designed to handle the four-channel surround audio system. The broadcast of an HDTV program with four-channel audio has been carried out many times and the effectiveness of the system is verified.

There are three editing rooms, which were desinged differently each other. At the end of 1989 an HDTV studio was completed. The floor area of it is about 500 m². The studio incorporates two cameras, a video switcher, a four-channel surround audio mixer, and a lighting console. The lighting is also controlled by a hand-held remote control terminal. The studio is very useful for shooting newscasters or introductory speech for pre-recorded program segments.

Post Production Facilities

They consist of three editing rooms, a multi-purpose copy room and a transmission room (a switching center).

Editing Rooms

Three editing rooms are designed differently each other based on the requirement estimation on various kind of assignment. The largest one, Editing Room 1, is equipped with four VTRs, a digital video effect (DVE), a video matte, an Ultimatte, a flying spot scanner for opaque cards, and a 50" display. The key elements of this room are the switcher and the editing system.

Copy Room

A multi-purpose copy room is provided, and used for film-to-HDTV conversion as well as HDTV-to-NTSC down conversion. It is equipped with an analog HDTV-VTR, a digital HDTV-VTR, a 1/2" cassette HDTV-VTR, a laser telecine, an HDTV-to-NTSC down converter, and a 50" display.

Transmission Room (a switching center)

Audio/video switching matrix is used to facilitate major function of this room. Inputs to the matrix are two analog and two digital VTRs, a field pickup unit, an electronic character generator. Paint Box, Pattern Generator, Electronic Animator, and an up-converter of NTSC-to-HDTV are also available.

The outputs of the transmission room are fed to two MUSE encoders in parallel for a safety reason. The output signal is also supplied to HDTV-to-NTSC converter, HDTV-to-PAL converter, and to other rooms for audition and for demonstration.

OB Vans

A total of seven OB Vans are operated at NHK to produce HDTV programs. Among them, OB Van 1 has a capacity of three cameras, one VTR, a character generator called Sports Coder, an electronic character generator, a switcher, and an audio mixer. Other van called Relay Assist Van incorporates a MUSE encoder, a DVE accompanied by an up-converter, a VTR and an editor. The three of the rest are called Video-Location Cars, and each car is equipped with a camera and a VTR.

There are a total of three small OB Vans overseas, two in New York, one in Paris. Each one has an HDTV camera and a VTR for program production.

In addition to those, some private company has a couple of OB Vans for HDTV program production. When under a very tight schedule, these privately owned OB Vans are also used.

Those OB Vans are fully utilized to produce programs required to maintain HDTV broadcast.

BS Operation/Control Room

As far as the program flow is concerned, the room shown in the figure controls the signals to be sent to the feeder link of the satellite. For the HDTV broadcast, frequency modulated MUSE signals are received here. After some frequency conversion, they are sent out to the feeder link.

A 24-hour monitoring for the two channels of the satellite broadcast both in NTSC, and in NTSC plus HDTV can be done in this room.

In an equipment room, there are two frequency modulators for the MUSE signal, a frequency discriminator and two MUSE decoders, one for the output monitoring, and the other for the reception from the satellite. Optical fiber transission is employed for input and output signals to this room.

CONCLUSION

NHK started a regular experimental HDTV broadcast in June 1989. After the successful launch of the third generation of DBS, steady HDTV broadcast is being maintained. It is evident that HDTV broadcast has entered into the stage of practical use. The broadcast time of HDTV is expected to increase steeply starting this fall.

The production of NTSC programs using HDTV equipment is becoming a daily event. Standards conversions between HDTV and conventional television are effectively incorporated.

Day and night the HDTV program production is being carried out, in preparation for the full fledged HDTV broadcast, utilizing the various HDTV equipment, with the performance of evey equipment improved.

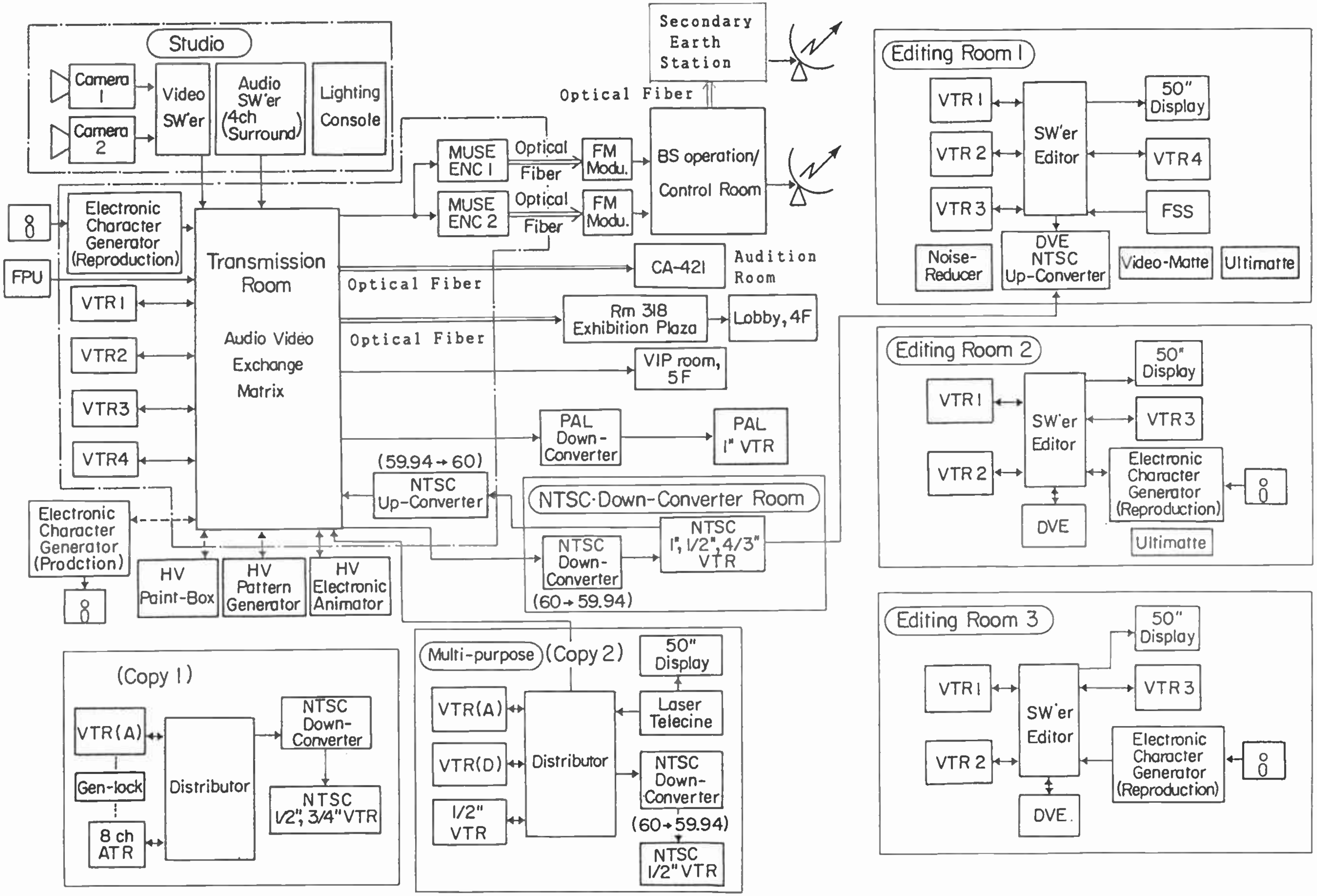


Fig. 1 Outline of HDTV Production Facility

STEREOSCOPIC HIGH DEFINITION TELEVISION—EXPERIMENTAL SYSTEM AND A CONSIDERATION ON PROGRAM PRODUCTION

I. Yuyama, M. Tadenuma and H. Yamanoue
NHK (Japan Broadcast Corporation)
Tokyo, Japan

ABSTRACT

This paper describes an experimental stereoscopic television system with Hi-Vision facilities and gives a consideration to the production of stereoscopic television services.
The system was developed to study the ultimate broadcasting services which we can expect to see realized in the future.
Experimental programs were also produced to survey methods of program production.
This system is also expected to have good applicability for the medium-size theaters in the near future.

INTRODUCTION

Stereoscopic vision has been a long time dream of people. In the Paris International Exposition of 1890, the first stereoscopic movies were already being demonstrated only five years after the invention of movie film.

A new broadcasting service offering high-definition television (Hi-Vision) is now being operated in Japan on a daily basis. NHK began its study of Hi-Vision in 1964, the year the Tokyo Olympic Games were held. Subsequently, in a series of feasibility studies, two possible ways were considered as future broadcasting services.

One was a way of enlarging the display screen size in order to realize a "sensation of reality". Hi-Vision was developed using this concept.
With the results of psychological examinations[1,2], it became clear that a viewing angle of over 30 degree was necessary with adequate horizontal and vertical resolutions.

The other method considered was stereoscopic television or three-dimensional television, which might bring a "sensation of depth" to the broadcasting service. Some studies were done. One suggested the possibility of reducing the color information from one of the pair of pictures on the left or right[3]. Another studied a parallax barrier displays or lenticular techniques[4]. As a result of these feasibility studies, it became clear that stereoscopic television would be an attractive service. However it posed some difficult problems that needed solving, such as "eye fatigue" and so on. Therefore, we decided to began our study of HDTV first targeting a kind of "sensation of depth" brought out through a wide screen.

Today, HDTV has grown up into a most promising media form. Thus it is a time to begin again to develop the distant future broadcasting services including stereoscopic television with well-developed Hi-Vision facilities.

BASIC CONSIDERATIONS IN PRODUCTION

Cues for "Sensation of Depth"

There are more than ten different cues considered necessary to obtain a "Sensation of Depth." We could classify these cues into three major categories.

Binocular parallax: We have two eyes and each of them observes objects from a slightly different direction. In the brain, this difference causes a "sensation of depth" after fusion a process.
The angle of the right and left eye sight line is another piece of information to determine absolute viewing length and is called "convergence."

Experiences: If pictures are such as random dot stereograms, there is no other cue than binocular parallax. But, ordinary pictures have information which we can correspond to our experiences and recognize the depth.
Larger size images are considered to be closer than the smaller ones, closer objects conceal farther objects, etc..
In order to reinforce these cues, it is necessary to remove cues which tell the actual distance between observers and the screen, by widening the screen and employing a longer viewing distance.

Motion parallax: The average distance between right and left pupils is 65 mm. If this distance is greater, binocular parallax becomes larger. Object motion or camera motion due to track-shooting, -changing the relative configuration of objects and camera-, is equivalent to expanding the length between the two pupils. On the other hand, panning shot is equivalent to expanding the viewing angle.

Cameras

Lenses: Generally a slightly wider angle lenses than standard lenses are better, because they show a larger difference in size between far objects and near objects while keeping both well in focus. On the other side, long focal lenses are also effective because they leave everything except the main subject out of focus.

Configuration of right and left cameras: In the first type, a pair of cameras are mounted side by side. The least distance between the two lenses (interaxial distance) is limited by either the width of the camera or the diameter of the lens and is usually more than the distance between human pupils.
In order to make the distance between two cameras as close as that of human pupils, a half mirror(silver-coated semi-transparent mirror) is used as a second type of the camera.
The third type uses an L-type relay optical unit to separate the two cameras. However, this type cannot make the interaxial distance as long as the diameter of a lens.

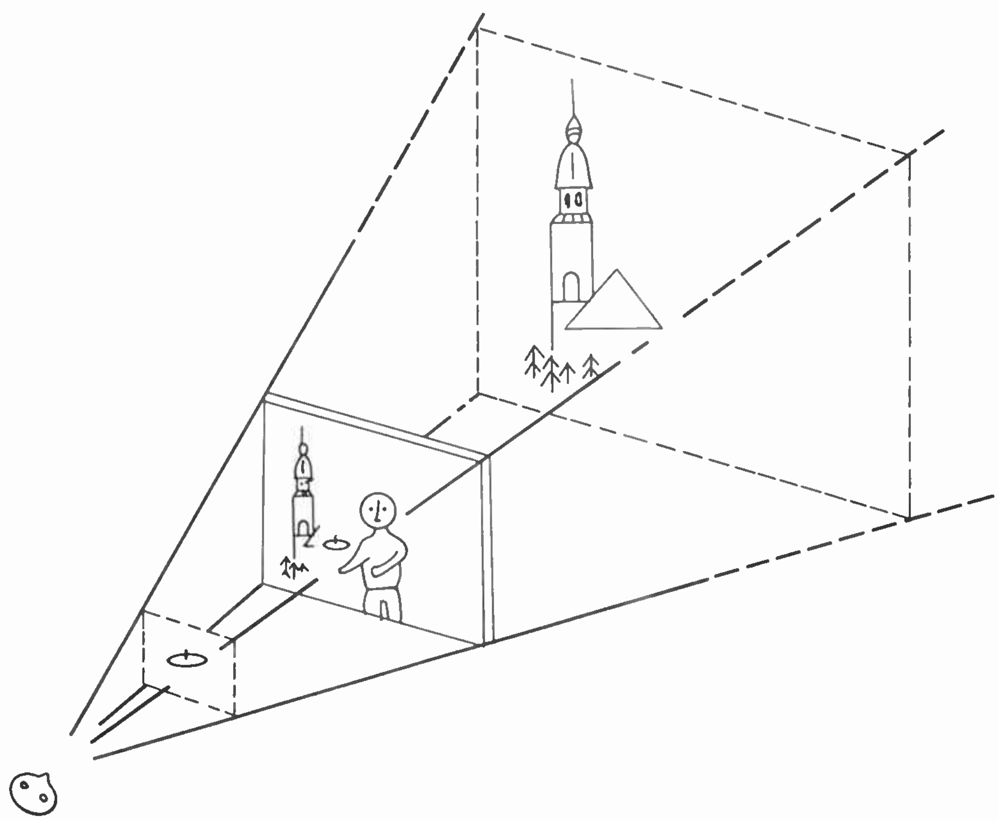


Fig. 1 Reproduced stereoscopic space

Convergence position of cameras: In the binocular parallax system, the limit of the convergence angle and divergence angle is 24 degrees and -1 degree respectively. Moreover, both the convergence point and the screen must share the same focal depth.
A pick-up system which keeps the convergence point at an infinite distance meets these conditions. However, this system has undisplayed areas around the right and left frame of the screen. Moreover, the convergence point and focal point are always different and this tends to cause eye fatigue.
Further the declining a pair of polarized glasses or a poor contrast ratio with liquid crystal glasses may cause a ghost, that is a cross talk between the right and left pictures may occur. If convergence point is on the main subject, this problem may be reduced.

Reproduced Stereoscopic Space

Reproduced images by a binocular parallax system are limited within a quadrangular pyramid as shown in figure 1. The images reproduced by observers who watch the pictures from a long distance are prolonged compared to the images from a close distance. Moreover, reproduced images chase after the movement of an observer especially with a small-sized screen. This phenomenon is quite different from real images. Figure 2 shows those reproduced images against the observer's location to the screen.
There exists, therefore only a small area where the configuration of reproduced images is analogous to that of actual objects.

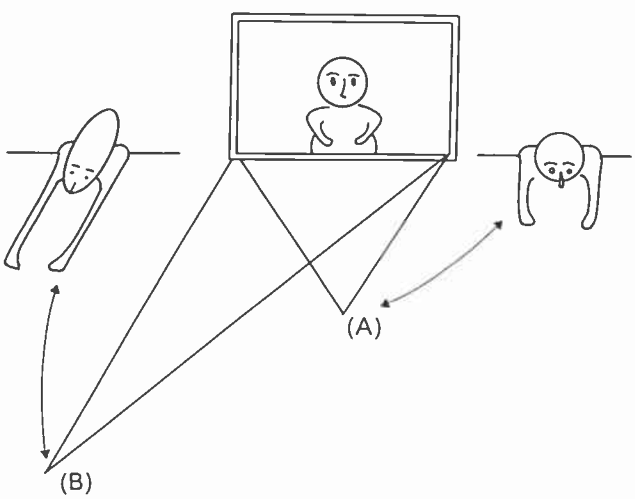


Fig. 2 Viewing position and reproduced images

In case of ordinary two-dimensional pictures, relative viewing distance (viewing angle) is the basic parameter. However, in case of stereoscopic pictures, absolute viewing distance is also essential.
According to the absolute viewing distance, the reproduced depth of objects varies and in some cases exceeds the stereoscopic limit as shown in figure 3.
Another major consideration for stereoscopic pictures is the screen frame. When the subject locates at the side edge of the screen, there will be some part of the subject where only the right or left image is provided. This causes a very strange feeling and eye fatigue. When the subject is at the top or bottom edge of the screen, the reproduced position of the image is drawn back to the frame shown in figure 4.
Therefore, a subject protruding from a screen has to keep its locus in the center of the screen in order not to touch the frame. In program production, it is necessary to give mobility to the camera either by crane or tracking facility. And, in case of a frame-in or frame-out shot, the depth positions of the in and out points must be carefully considered.

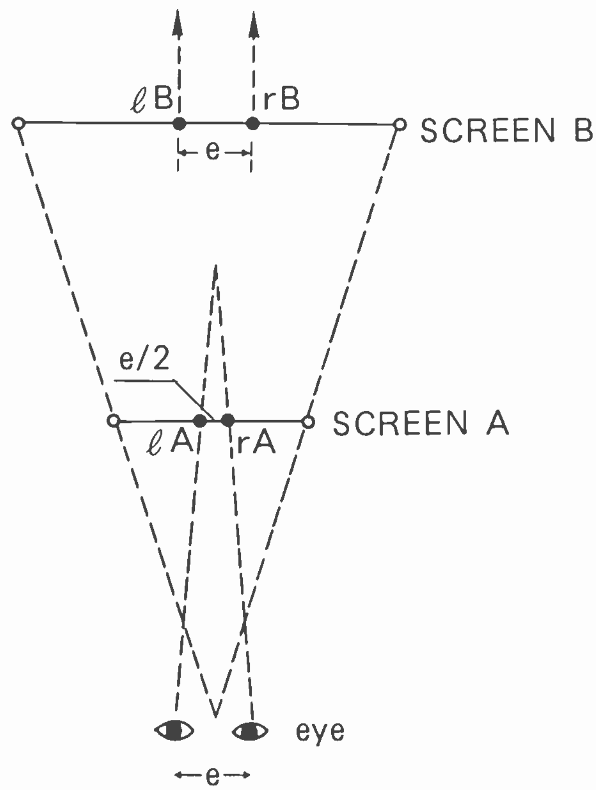


Fig. 3 Screen size and reproduced depth

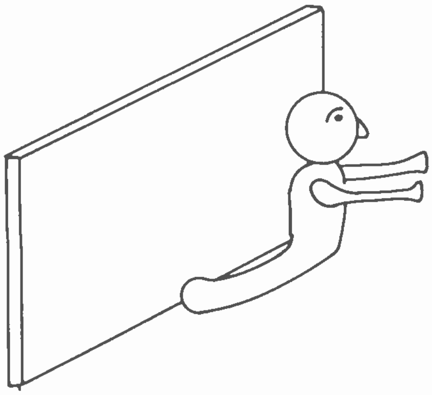


Fig. 4 Screen frame and protruded object

FEATURES OF VIDEO PRODUCTION

Instantaneous Monitoring of Stereoscopic Effects

The picture effects of stereoscopic images can be estimated to some extent by geometric consideration by an expert. This is called a slide-rule or tape measure, since very careful measurement are necessary and the results cannot be known until the film is developed. However, as stereoscopic effects are caused by many psychological aspects aside from geometric considerations, instantaneous monitoring of stereoscopic effects with video facilities is essential in producing pictures.

Effective Adjustment of Right and Left Cameras

Because the degrees of transparency of a half mirror vary according to the angle of incidence, the signal levels of the right and left cameras are different. Video signal processing can easily adjust this unbalance.

If there is vertical parallax, viewers will be uncomfortable. With field-sequential monitoring of right and left pictures, we can easily avoid vertical parallax.

Generally speaking, the lenses of a pair of right and left cameras or projectors do not have exactly the same focal length and this cause a difference in the size of a pair of stereoscopic pictures. This distortion will be removed by digital convergence of the scanning circuit in the cameras.

Smooth Motion Reproduction

Television pictures can produce smooth motion reproduction due to their high 60Hz field rate and stability. This is important for stereoscopic pictures because mechanical jitters especially in the vertical direction cause undesirable vertical parallax.

Effectiveness of Post-Production

For example, in case of chroma-keying of two-dimensional pictures there are only a background picture and a foreground picture to be composed. But, in case of stereoscopic pictures, we have to consider the depth position of a picture to be composed with a picture that already has several different depth items. With video processing, it becomes easy to do this while directly viewing the stereoscopic effect.

Application to Other Fields

Through video technologies, it becomes possible to display real time stereoscopic pictures to many observers at one time. This leads stereoscopic pictures not only to an entertainment but also to other applications such as medical uses or educational uses, etc., composing a broad front of research and development.

EXPERIMENTAL SYSTEM

In order to survey the possibilities of stereoscopic Hi-Vision and production methods, an experimental system was developed.

Pickup System

Stereoscopic cameras: A pair of hand-held Hi-Vision cameras with 2/3-inch HARP pickup tubes, which are ten times more sensitive than normal saticon tubes, were used to obtain so-called pan-focus pictures. The cameras are 11 cm in width and are not so slim as to realize the interaxial distance of human pupils when mounted side by side. In order to have a short interaxial distance, one of a pair of cameras is mounted upside down and the distance becomes 97 mm. The weight and size of the camera are almost the same as those of a previous generation studio camera. The stereoscopic effects of this camera are a little bit exaggerated, but camera's mobility is attractive, especially when programs are produced at an outside location as shown in figure 5.

The second type of camera developed employs a half mirror to bring the interaxial distance as close as that of human pupils. The transparency of this half mirror is about 30%, however, the high sensitivity HARP tubes recover the light loss and maintain good focus both for far objects and near objects. This camera is rather heavy, but using it with a crane retrieves the mobility.

Fig. 5 Stereoscopic camera and a crane

Recording and monitoring: In outside program production, two digital Hi-Vision VTRs were used to record the right and left signals, and one analogue cassette VTR(UNIHI) was used for recording the switched signals of right and left sources on a field-by-field basis. These switched signals were used for monitoring the stereoscopic effects in a van by both directors and engineers.

Display Systems

60 Hz field-sequential stereoscopic display: This system is employed for monitoring of outside production as mentioned above. The system is also used with single VTR for post-production and editing, because it is troublesome to determine an editing point by operating two VTRs synchronously. In this system, right and left signals are switched alternately and displayed on a conventional Hi-Vision monitor, viewers wear a pair of glasses comprising liquid crystal shutters which alternately open and close depending on the field for the right and left eye.

It lacks slightly a vertical resolution and causes very strong flickers of 30Hz. Video engineers can easily recognize the effects of the stereoscopic pictures and edit the signals in spite of these defects. After the data points have been decided and stored in the memories, the right and left pictures are edited sequentially under the automatic control of the stored data. However, this display system is not good for public demonstration, because ordinary observers can easily notice these defects, especially the 30 Hz flicker.

The field sequential stereoscopic system utilizes the human visual characteristics of a kind of temporal band-pass filter which is effective in smoothing intermittent presentations. That is, either the right or left stereo-pair picture can be displayed at a half rate of the field frequency of the combined signal. With regard to the choice of the field frequency for the conventional television system, the required value for flicker-free display has been measured several times, and the results have shown that 60Hz was necessary for a bright display.

In the case of the field sequential stereoscopic television system, it was thought that the field frequency required for a flicker-free display would be lower than that for a conventional television system due to time-interlacing. Psychological testing[5] suggests that more than 55Hz(under a condition of peak luminance of 180 cd/m^2 and a viewing angle of 30 degrees) is necessary to avoid flicker, this means 110Hz for the total field frequency when the stimulations for the right and left eyes are given in time alternation.

120 Hz field-sequential stereoscopic display: A 120Hz stereoscopic Hi-Vision projector has been developed for this purpose which projects right and left pictures alternately on a 110-inch screen. The required signal bandwidth is 60MHz for each of the R, G and B components, the achieved brightness of the pictures is slightly less than that of the conventional Hi-Vision projectors because of its high speed scanning rate, and the

resolution is about 900 to 1000 TV lines in the horizontal direction.

In order to obtain a stereoscopic image, two methods were tested. One employs PLZT(lead(plumbum), lanthanum, zirconium, titanium ceramics) devices in front of the projector lenses which alternate the polarizing axis of the light of the projector according to the alternation of the right and left signals. Observers wear a pair of polarized glasses for separation of the right and left pictures. There are some reports of using the PLZT device with a similar method, however, so far as we have tested, scattering of the light in the PLZT device causes flare on the images. The picture quality is inferior from the viewpoint of the HDTV standard. The PLZT device can work at very high speed rate and is generally a good device. Accordingly, we are expecting improvements to be made in the optical characteristics of this device.

In another method, observers wear a pair of glasses comprising liquid crystal shutters or PLZT shutters. In this case, the optical scattering by the PLZT device does not affect picture quality to the extent it does in the case mentioned above. However, the PLZT device is expensive and requires high voltage to operate, while the shutter is cheaper and easier to handle.

The liquid crystal shutter is used for this purpose. But the liquid crystal shutter works slowly for 120Hz light switching and causes a ghost image, especially in the lower part of the screen. In spite of these defects, the 120Hz field sequential system has an advantage in that there are no geometrical or brightness differences between the right and left pictures. Therefore, this system could be used for studies in basic experiments regarding stereoscopic perception.

Double-decked projectors with polarizing filters:
The system shown in figure 6 is a conventional method for stereoscopic display. For the time being, it exhibits the best picture quality among the possible systems and can be used for demonstrations aimed at many observers at one time.

In order to study and consider a stereoscopic television service, this system can be used as an experimental display. The hórizontal resolution of the projector is more than 1000 TV lines. The linear polarizing filters in front of the projector lenses and polarized glasses for observers are used because of their better optical cross talk characteristics than circular polarizing filters.

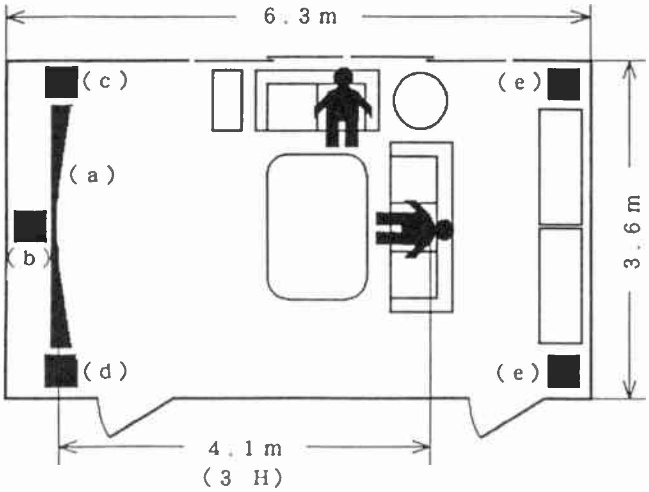
Fig. 6 Double-decked projectors

Assumed Display Space

The size of the living room in the Japanese home has been growing in recent years. A maximum living room size equivalent to sixteen standard tatami mats (26 square meters) was presumed for the stereoscopic picture viewing space of the future. A layout example of a 110-inch Hi-Vision display in a 14-mat (23 square meter) living room is shown in figure 7. The 3H relative viewing distance of the assumed 110-inch display translates into an absolute viewing distance of 4.1 meters.

In addition, the use of a small or medium-scale video theater was also assumed. Figure 8 shows the hall used for demonstration at the NHK Labs, together with its favorable viewing range. The 3H relative viewing distance of the 180-inch display employed gave an absolute viewing distance of 6.5 meters.

This indicates that the display space assumed for stereoscopic Hi-Vision is midway between the space required for stereoscopic pictures in a conventional film theater and the space required for a CRT receiver at home.



(a) 110-inch screen
(b) Center speaker
(c) Right channel speaker
(d) Left channel speaker
(e) Rear speakers

Fig. 7 Home video space

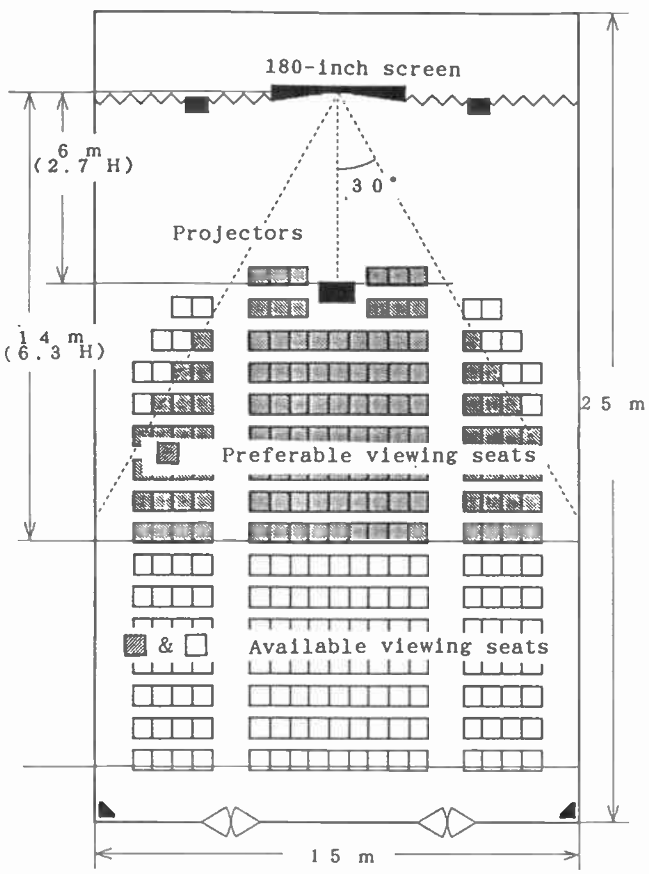


Fig. 8 Preferred Viewing area for 180 inch display

EXPERIMENTAL PROGRAMS

The production methods of stereoscopic television programs would possibly differ from the conventional production methods for theater films. One reason for this is the long absolute viewing distance of about 20 meters for a conventional film theater[6], compared with the medium distance of the stereoscopic Hi-Vision system. The second reason is that the moving resolution for film systems is 24 fields (frames), while that of Hi-Vision systems is much higher at 60 fields. Other differentials can also be postulated, but at present they are not evident.

The differences cited in the first reason mean that the stereoscopic image in a theater would be reproduced primarily away from the screen, closer to the viewer. By contrast, reproduction for stereoscopic Hi-Vision is reproduced mainly in the area immediately in front and behind the screen. And because the filming distance of the relatively numerous middle-distance shots in a program and the viewing distance to the screen are almost the same, a filming method was used for stereoscopic Hi-Vision wherein the parallax of the left and right images was made to approach zero for the middle-distance shots, with the picture being reproduced at the position of the screen's surface.

In the case of the home display space, many of the scenes should be positioned to reproduce in back of the screen. On this basis, a short four-minute motion picture called "You are not alone" was produced in 1989.

In the program made for showing in small and medium-sized halls, allowance was made for a certain amount of viewing distance to the screen and for service in the hall venue, thus several scenes which seemed to jump out of the screen toward the viewers were also included. This resulted in a 16-minute fantasy program, titled "Waffen," produced in 1990.

The assumed screen size is up to 180 inches in diagonal with a relative viewing distance of three to six times picture height. Whether shooting in a studio or on open location, careful consideration was given to the assumption that all the images projected on that screen should be naturally accepted.

Four different focal length lenses from 10 mm to 135 mm were used, though mostly the 10mm focal length lens was used, the authors, however, thought this 10 mm focal length was slightly shorter as a standard. Some scenes were taken at night, yet good picture quality was maintained due to the high sensitivity of the HARP tubes.

Computer graphics is a good application of stereoscopic pictures, visualizing otherwise invisible images for audiences. In this program, stereoscopic computer graphics of the Earth and the Galaxy in motion were produced. In producing stereoscopic pictures of the Galaxy, special consideration was required. If there were many stars set in the same scanning line, it might be difficult to achive a correct fusion, because the audience cannot recognize which pair of the stars are the correct pair of right and left images. In the production of this image, stars were shown as a nebulae and the stereoscopic effects were monitored with a CRT display.

To make the best use of Hi-Vision's good temporal definition characteristics--mentioned in the second reason above--scenes were produced using shots of moving trucks and cranes. Stereoscopic Hi-Vision produces smooth movement, with the stereoscopic effect of the moving shots being extremely large due to the synergistic effect of binocular and motion parallax.

As a stereoscopic post-production technique, the effect of chroma-keying on the impact of the program was great, and the full use of the video system's advantages enabled relatively simple use of multilayered chroma-keying without deterioration of picture quality.

SUMMARY

People have long been waiting for stereoscopic programs. A stereoscopic Hi-Vision system was developed in order to realize the so-called pan-focus pictures, with a stereoscopic camera composed of super high-sensitive pickup tubes. Digital convergence enabled the complete matching of the convergence of the stereoscopic double decked projectors.

Two experimental programs were produced, and the system's efficacy was verified. The stereoscopic screen effects are highly likely to spawn services not available in conventional television.

Hereafter, consideration of a future broadcasting system will be carried out in concert with basic research on the mechanism of human vision.

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THE ANTENNA AS A BOTTLENECK IN THE IMPLEMENTATION OF A COLLOCATED HDTV/NTSC TRANSMISSION SYSTEM

Dr. O. Bendov
Dielectric Communications Antennas
Voorhees, New Jersey

INTRODUCTION

Within the broadcast community, the problems of how to build and where to install a new HDTV broadcast antenna have been deferred. That bridge has been reached and it must be crossed now.

Structural and picture quality requirements point to one solution. That solution requires a low gain antenna for the transmission of the HDTV signal. The lower gain (shorter length) HDTV antenna and the NTSC antenna can be integrated into one unit for a direct replacement on existing towers with little or no reinforcement.

In contrast, HDTV systems which require high gain antennas similar to NTSC antennas, will be most difficult to collocate due to tower overload and wind sway. Even if collocation is not important, their picture quality will not be satisfactory in all directions. Combining channels on a single, higher gain antenna, will further deteriorate picture quality for all channels.

Specifically, successful HDTV systems for terrestrial broadcasting must operate on lower ERP without loss of coverage, enough so, as to implement the collocation of a low gain HDTV antenna with the NTSC antenna. An ERP of -12 dB relative to NTSC will satisfy the requirements for picture quality and will allow installation of the new antennas on most existing towers.

MECHANICAL LIMITATIONS ON THE IMPLEMENTATION OF A HIGH ERP HDTV SYSTEM

As an example of what is mechanically impractical and, from the picture quality standpoint, undesirable, consider the case of a locale where the existing channels 2-6 are assigned HDTV channels with an ERP similar to that of NTSC.

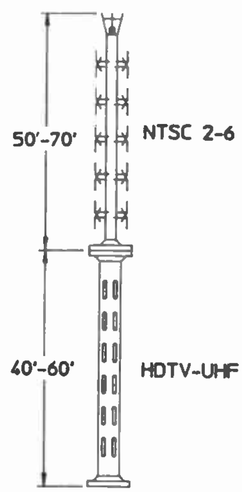
Assuming that the existing antennas are not part of a multiple antenna installation, the broadcasters have two options:

a. Replace the existing NTSC antennas with stacked HDTV/NTSC antennas for each existing tower.

b. Build a new community tower for multiple NTSC antennas and install the new HDTV antennas on the old towers.

Having built several versions of the first option, we calculated the expected increase in tower loading for such stacked configurations.

Figs. 1, 2 and 3 show the typical stacked configurations where the NTSC channel is 2-6 and the HDTV channel is either UHF or VHF. The wind load numbers show that both the shear and the overturn moment of the stacked configuration will exceed the existing loads by several hundred percent. In other words, a new tower will be required.

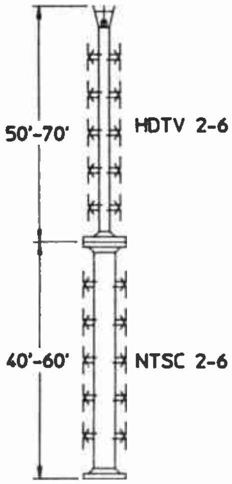


AVERAGE VALUES - NO ICE

SHEAR (lbs.)		
INDIVIDUAL:	NTSC	3,500
	HDTV	2,500
STACKED:	NTSC+HDTV	12,500
INCREASE OVER NTSC		360%

MOMENT (ft.lbs.)		
INDIVIDUAL:	NTSC	92,000
	HDTV	63,000
STACKED:	NTSC+HDTV	700,000
INCREASE OVER NTSC		760%

FIG.1 HIGH ERP IMPLEMENTATION

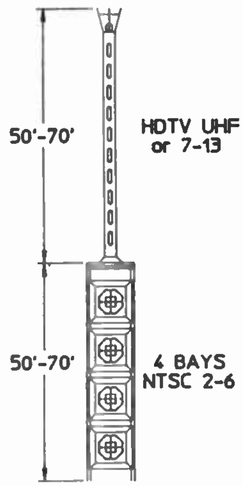


AVERAGE VALUES - NO ICE

SHEAR (lbs.)		
INDIVIDUAL:	NTSC	3,500
	HDTV	3,500
STACKED:	NTSC+HDTV	8,400
	INCREASE OVER NTSC	240%

MOMENT (ft.lbs.)		
INDIVIDUAL:	NTSC	92,000
	HDTV	92,000
STACKED:	NTSC+HDTV	396,000
	INCREASE OVER NTSC	430%

FIG.2 HIGH ERP IMPLEMENTATION



AVERAGE VALUES - NO ICE

SHEAR (lbs.)		
INDIVIDUAL:	NTSC	3,500
	HDTV	3,200
STACKED:	NTSC+HDTV	24,000
	INCREASE OVER NTSC	680%

MOMENT (ft.lbs.)		
INDIVIDUAL:	NTSC	92,000
	HDTV	123,000
STACKED:	NTSC+HDTV	700,000
	INCREASE OVER NTSC	760%

FIG.3 HIGH ERP IMPLEMENTATION

To better visualize the scope of this problem, consider some major metropolitan areas such as New York, Chicago or San Francisco. The probability of replacing the existing towers with similar ones which can support twice as many full ERP channels is nil.

While a new tower for stacked antennas is being built where possible, a rather poor NTSC transmission from a standby facility on another tower is expected. This, assuming tower space during the construction period of approximately a year can be found for the standby antenna.

If the option of replacing most towers with new ones, each supporting twice as many high gain antennas, is unattractive, consider the second option: a new NTSC community antenna tower is built, and the old individual towers are used for the new HDTV antennas.

Here too there is considerable first hand experience. Assuming that real estate, location, zoning, FAA and financing issues pose typical problems, the gestation period for the new NTSC tower for the multiple antenna is likely to be three to nine years. Translating these scenarios into a nationwide requirement may result in untenable delay in the implementation of HDTV broadcasting.

MECHANICAL FEASIBILITY OF THE LOW ERP HDTV SYSTEMS

In contrast to the high ERP HDTV systems, low gain antennas associated with the low ERP HDTV systems are implementable in the real world of broadcasting. The basic parameters of a low ERP system are shown in Fig. 4. Since the expected antenna gain is approximately one fourth that of the NTSC antenna, its wind load is manageable. A typical implementation of the HDTV/NTSC stack is shown in Fig. 5.

The implementation in Fig. 5 is based on a new class of antennas. These antennas are "field convertible" in the sense that the design includes all the necessary hardware to convert from NTSC antenna to an NTSC/HDTV stack. The new stack is wind load compatible with the NTSC antenna. That is, minor, if any, tower reinforcement will be required. New towers will not be required except perhaps in some major metropolitan areas. Furthermore, no prior knowledge of the assigned HDTV channel is required. In the design of Fig. 5, the VHF antenna was mechanically and electrically split into upper and lower halves. At the conversion time, the upper half would be replaced by the HDTV antenna.

The ERP loss to the NTSC channel after conversion is relatively low and is not expected to exceed -2 dB in most cases. In the typical example shown, it is -.3 dB. Even though the example shown assumes a channel 2-6 for NTSC and UHF for HDTV, the convertible antenna concept is not restricted to any channel combination.

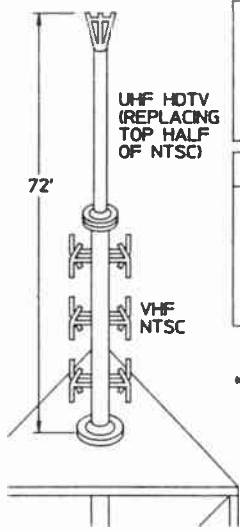
BANDWIDTH REQUIREMENT AND TYPICAL ANTENNA CAPABILITIES

While the mechanical problems associated with full ERP, HDTV systems, are serious by themselves, the

CHAN.	ERP (KW)	ANT. GAIN HP	ANT. GAIN CP	TRANSMITTER POWER (KW) HP	TRANSMITTER POWER (KW) CP
2-6	7	1.5	1	5	10
7-13	21	3	2	10	20
14-69	328	15	8	30	60

RELATIVE TO NTSC
1/4 TRANSMITTER POWER
1/4 ANTENNA GAIN
1/16 ERP

FIG.4 BASIC PARAMETERS OF LOW ERP (-12DB) HDTV SYSTEM



UHF HDTV	
POLARIZATION	CIRCULAR
GAIN*	6.50
TRANSMITTER	60 KW
ERP	328 KW

VHF NTSC	
POLARIZATION	CIRCULAR
GAIN*	1.36
TRANSMITTER	75 KW
ERP	93 KW

* For horizontal polarization only, the GAIN will be twice the shown values and the TX power required will be halved to achieve the shown ERP.

FIG.5 'FIELD CONVERTABLE' IMPLEMENTATION OF LOW ERP NTSC/HDTV ANTENNA

picture quality performance of such systems can be safely predicted to be marginal.

The picture quality of any antenna is a function of elevation angle. If the antenna is not omnidirectional, picture quality is also a function of the azimuthal angle. In particular, picture quality deteriorates at the field minima of the elevation and azimuthal patterns. The picture quality also depends on the antenna gain and its internal distribution method of feed amplitudes and phases to the individual radiators.

Three different bandwidth definitions are required to characterize the picture quality of TV antennas. They are the input, output and polarization bandwidth.

The INPUT BANDWIDTH is normally specified as a VSWR ratio at the antenna input. It allows one to determine the magnitude of the reflection from the antenna toward the transmitter. If the transmitter is not of the parallel output design, the reflection will be bounced back and radiate as an echo. The specification of just the magnitude of the reflection coefficient, which is typical of NTSC, is not enough. This is so because the HDTV system is expected to require symmetry across 6 MHz in both the phase and amplitude of the reflection from the antenna unless a complex, and an on-site adjustable equalization correction is built into the transmitter.

The OUTPUT BANDWIDTH of the antenna refers to two separate responses over the channel: the NORMALIZED AMPLITUDE RESPONSE and the PHASE DEVIATION from linear phase. The derivative of the PHASE DEVIATION is the group delay. For HDTV, the specification for the OUTPUT BANDWIDTH may be as tight as +-1 dB for the amplitude response and +-10 degrees for the phase across 6 MHz for entire transmission system, not just the antenna. The ideal response will also be symmetric with respect to the center of the channel. The normalization of the amplitude response is with respect to the gain variation of the antenna across the channel.

The OUTPUT BANDWIDTH of any antenna depends on three factors: the internal feed distribution system to the radiators, the gain of the antenna, and the Q of each radiator in the presence of the surrounding excited radiators. The OUTPUT BANDWIDTH can be calculated using all three factors.

To illustrate the effects of the gain and the internal feed system on the OUTPUT BANDWIDTH, consider two typical omnidirectional, high gain UHF antennas. The only difference between the two is in the internal feed system. Fig. 6 shows the amplitude response and phase deviation of an END-FED antenna. The corresponding bandwidth of a CENTER-FED antenna is shown in Fig. 7. In these and the Figures that follow, the assumed HDTV system windows of +-1 db for the amplitude and +-10 degrees for the phase are overlaid. While the CENTER-FED antenna appears to be within the windows, there is little margin left for the transmitter. The high gain END-FED antenna meets the requirements only for large distances from the base of the antenna.

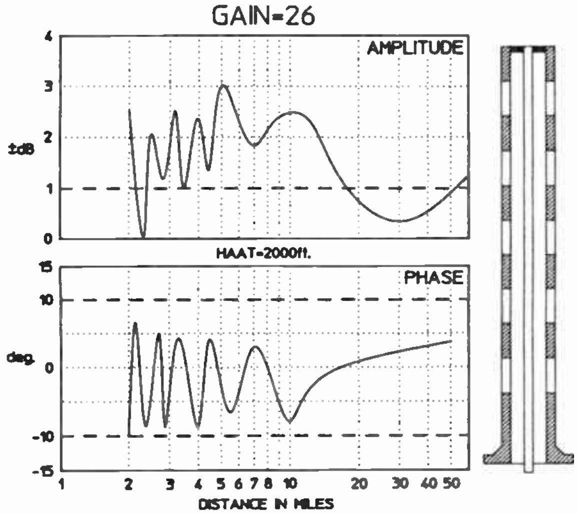


FIG.6 CALCULATED MINIMUM OUTPUT BANDWIDTH OF AN END-FED ANTENNA OVER 6 MHz.

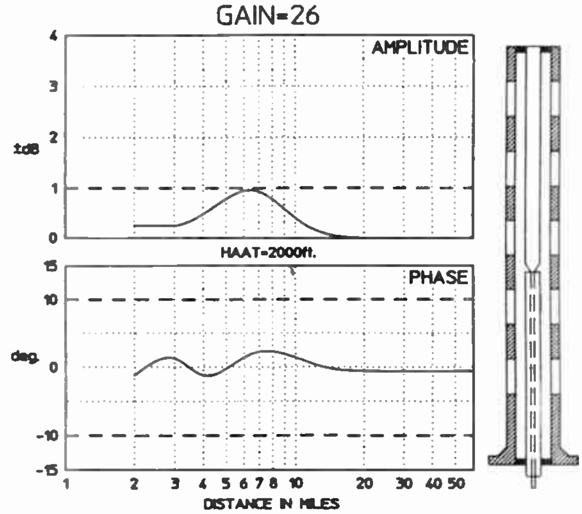


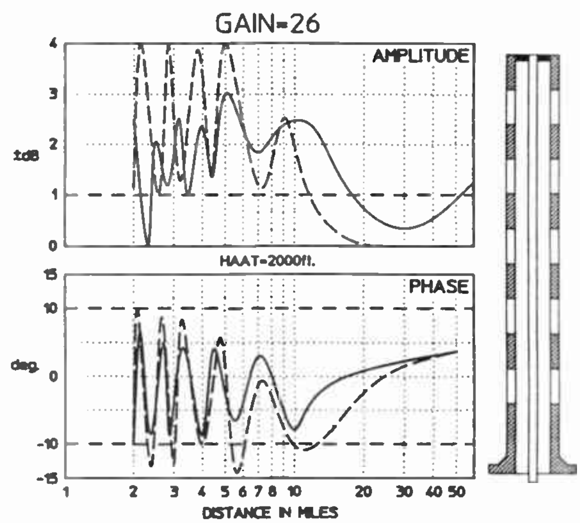
FIG.7 CALCULATED MINIMUM OUTPUT BANDWIDTH OF A CENTER-FED ANTENNA OVER 6 MHz.

The calculations of Figs. 6 and 7 are realistic because they include the response due to the Q of the radiators in addition to the spacing variation, in wavelengths, between radiators. Were the response calculation made on the basis of spacing variation alone, the results of Figs. 6 and 7 would be substantially improved but unrealistic.

The essential problem of END-FED antennas is that the main beam tilt varies with frequency. In the early 1950's RCA developed a technique to overcome this problem in a certain class of antennas which were medium gain Traveling Wave Antennas for channels 7-13. It is based on using high Q slots, with Q values on the order of 10-20, to correct for the error due to the space variation, in wavelengths, between slots. The details of the technique were eventually published[1]. Claims to the contrary notwithstanding, it cannot be successfully applied to high gain UHF antennas in which the slots are spaced approximately one wavelength apart. A simple calculation shows that the Q necessary for the correction of a high gain END-FED UHF antenna is approximately 20. Fig. 8 compares the OUTPUT BANDWIDTH of a high gain UHF antenna with and without the high Q "correction" for the beam steering.

So far this discussion has centered around high gain antennas with different internal feed systems. If the gains of the two antennas were reduced by a factor of two, the center fed antenna would stay within the +-1 db and +-10 degrees windows over 6 MHz; the end fed antenna would not. This is illustrated in Fig. 9 for the END-FED antenna, and in Fig. 10 for the CENTER-FED antenna.

We conclude that high gain, high ERP, HDTV systems, will be impractical to implement due to their inherent major mechanical and video flaws. Therefore, the solution for HDTV terrestrial broadcasting must be based on a low ERP system with a low gain antenna. This is true regardless of the modulation system.



—— NO CORRECTION ----- WITH CORRECTION

FIG.8 THE EFFECT OF HIGH Q "CORRECTION" ON AN END-FED ANTENNA.

So far the assumption has been that the antenna is truly omnidirectional. When the antenna is a panel antenna, or worse, a directional panel antenna, additional video distortion as a function of azimuth is imposed on the

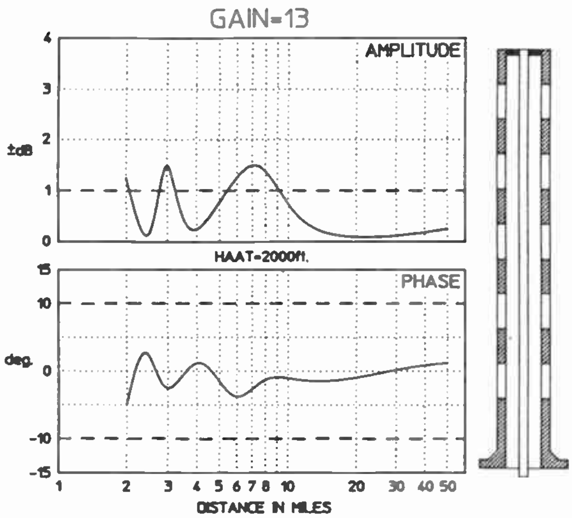


FIG.9 CALCULATED MINIMUM OUTPUT BANDWIDTH OF AN END-FED ANTENNA OVER 6 MHz.

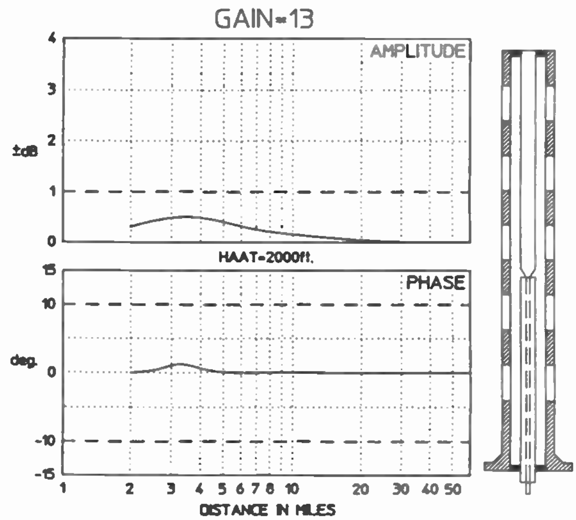


FIG.10 CALCULATED MINIMUM OUTPUT BANDWIDTH OF A CENTER-FED ANTENNA OVER 6 MHz.

transmission system. This is due to the large distance, typically .5 wavelength, from the center of the support tower to the phase center of the panel. The phase center of the panel is not the back screen. Rather, it is just about .25 wavelength in front of the back screen which means that the minimum distance from the tower center to the phase center is approximately .5 wavelength. Such measured amplitude response is shown in Fig. 11. In Fig. 12, the panel response is shown as a function of the number of channels used in the VHF and UHF bands. It can be seen that for multiple channel operation, an additional distortion in some azimuthal directions can be expected.

Naturally, the calculated amplitude response of the same panel antenna is much more favorable than the measured data. For example, Fig. 13 depicts a typical calculation of the antenna shown in Fig. 11. The reasons for the difference are the unpredictable backlobes of each panel in the presence of the tower members and the variation with frequency in the forward pattern of a single panel.

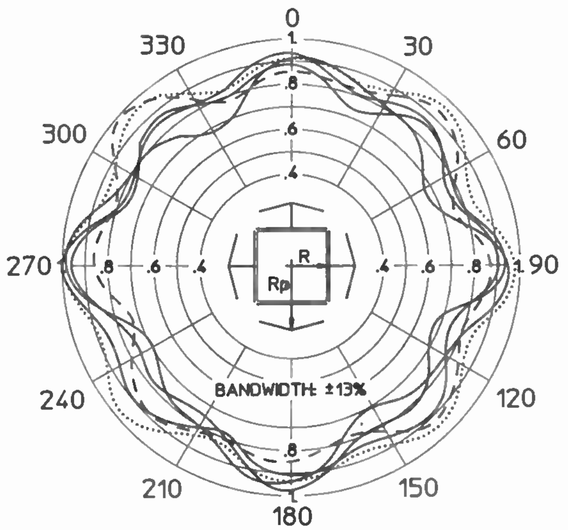
As the dimension of the face of the tower increases beyond the minimum which is determined by the physical size of the panels, the video distortion around the azimuth increases quite rapidly.

The basic antenna issues for high picture quality transmission extend beyond those of gain and feed system. They are shown in Fig. 14 for comparison between NTSC and HDTV. While some help is expected from the error correction and channel equalizer circuits of the future, the rules of thumb for antenna selection are simple: no panels, especially for UHF; no diplexing; no waveguide; symmetrical sideband response for both the input and the output of the antenna.

Upon the advent of HDTV, the predominant polarization for transmitting and receiving antennas is expected to be circular. Circular polarization will minimize the effects of multipath distortion. It will also even out field strength variation as a function of distance from the receiver. In the environment of circular polarization, a new measure, heretofore unused, must be recognized. This measure is the POLARIZATION BANDWIDTH or AXIAL RATIO BANDWIDTH. The optimum transfer between the transmitting antenna and the receiving antenna will occur when the two are "matched" in polarization. In practical terms, this means that the axial ratio of the transmitting antenna will be as close as possible to 0 dB across 6 MHz in all directions of interest. The axial ratio of the receiving antenna will then be adjusted by the channel equalizer to account for polarization distortion due to the path between the transmitter and the receiver.

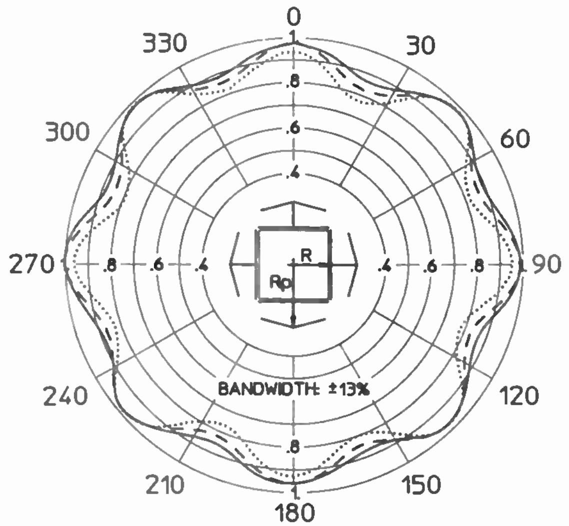
LIMITATIONS OF MULTIPLEXED SYSTEMS

The suggestion has been made that the solution for the HDTV transmission problems lies in multiplexing two or more channels on one antenna. This antenna may be the existing NTSC antenna or a new "master" antenna designed to accommodate all the HDTV channels in a



R - Distance to back of the screen .25 wavelengths.
Rp - Distance to phase center .5 wavelengths.

FIG.11 MEASURED AMPLITUDE RESPONSE OF A PANEL ANTENNA ON A MINIMUM SIZE TOWER FACE.



R - Distance to back of the screen .25 wavelengths.
Rp - Distance to phase center .5 wavelengths.

FIG.13 CALCULATED AMPLITUDE RESPONSE OF A PANEL ANTENNA ON A MINIMUM SIZE TOWER FACE.

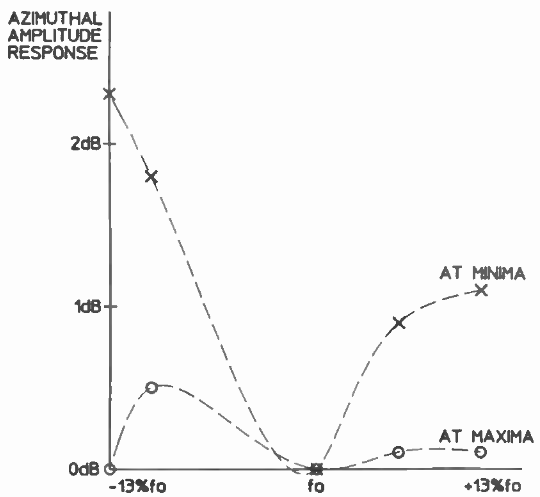


FIG.12 MEASURED AZIMUTHAL AMPLITUDE RESPONSE OF OMNIDIRECTIONAL ANTENNAS OVER MULTIPLE CHANNELS.

given market. This approach will only be acceptable to those who are willing to accept degraded picture quality, without improvement over NTSC.

Consider first the case of diplexing an adjacent HDTV channel on the existing NTSC antenna. The OUTPUT BANDWIDTH of the NTSC antenna is limited by its high gain, and in most UHF antennas, by the internal feed system. The INPUT BANDWIDTH will have to be "optimized", i.e. compromised, to accommodate two channels with little hope for symmetrical sideband response. The POLARIZATION BANDWIDTH which is very difficult to maintain over 6 MHz, will be less than desirable for 12 MHz.

There is also the diplexer to consider. In most cases, it is made of several cavities between two 3 dB hybrids. It has one "narrow band" input and one "wide band" input. Which input will be assigned to the NTSC channel? Would the additional amplitude and phase (group delay) distortion be acceptable?

Now consider the case of the so-called "broad band" antennas. These are the panel and Batwing antennas which have been used for multiplexing NTSC channels. These antennas do not have sufficiently broad band radiators over multiple channels. Therefore, they utilize the quadrature feed system, the purpose of which is to mask the radiators' problem and present a low VSWR to the transmitter at the input of the antenna. Between the input to the antenna and the radiators, the VSWR is not necessarily adequate for all channels.

Another problem associated with multiplexing channels on one antenna is the spacing between layers of radiators along the antenna structure. For best overall results, the spacing is close to one wavelength. But which wavelength for more than one channel? Clearly, another compromise in picture quality for one, or all future users of the common antenna, can be expected.

For the panel antenna there is an additional and substantial handicap. The OUTPUT BANDWIDTH deteriorates rapidly around the azimuth if the supporting tower face size exceeds .5 wavelength at the highest channel. This is particularly true at UHF. To illustrate this point, the calculation of Fig. 13 which applies to the minimum tower face size of .5 wavelength (12" at channel 14!) was repeated for a tower face size of one wavelength. The results show an additonal deterioration of the +-.6 dB over the amplitude response shown in Fig. 13. As mentioned earlier, the calculated response is typically more optimistic than the "as built" performance of the antenna.

HDTV	NTSC
LOW GAIN	HIGH GAIN
HEAVY NULL FILL	SOME NULL FILL
POLE TYPE	PANEL OR POLE
CENTER-FED UHF	END-FED UHF
COAX LINES	WAVEGUIDES
6 MHz DSB FLAT OUTPUT	4 MHz VSB INPUT
NO DIPLEXING	IN-BAND DIPLEXING

FIG.14 COMPARISON OF ANTENNA CHARACTERISTICS

PICTURE QUALITY CONTOURS

From the beginning of TV broadcasting, we have been concerned primarily with field strength contours rather than with picture quality. We still need to develop the grade contours and interference protection limits to satisfy legal and commercial requirements. However, high field strength is not a predictor of the expected picture quality. Rather, good picture quality is a predictor of adequate field strength.

A new tool is needed to assess the engineering merits of any installation. The picture quality contours would be employed as overlays on the field strength contours.

Such picture quality overlays can be standard overlays calculated by the consulting engineer. The algorithm for the best case, or minimum distortion, can be easily developed for all known broadcast antennas. Such picture quality contours could replace questionable near field and range tests. The only data required for the best case calculation are the type of feed, the type of radiator, the feed phase and amplitude into each of the radiators and the transfer functions of the transmitter and waveguide.

There are a number of ways to depict picture quality contours. One approach is to start with two calculations. First, the amplitude response in dB's as a function of distance from the tower is plotted. The second calculation is that of the phase distortion as a function of distance from the tower. Such calculations, assuming no transmitter or waveguide distortion, are shown in Figs. 6-10. The phase distortion is due partly to the waveguide or transmission line and partly to the typical distribution of feed phases and amplitudes to the radiators. The effect of local multipath could also be included.

Once calculated, these two curves can be transformed into TASO, SIN(X)/X, or some other picture quality grades, and plotted as contours. For directional and panel antennas, more than one radial will have to be calculated since the picture quality of such antennas is also a function of azimuth. For fully digital transmission, the picture quality contours may require no more than three grades: picture, no picture and maybe.

CONCLUSION

To summarize, the "best" HDTV system which cannot be implemented in a timely manner in the real world, is of little value to the broadcasting community.The only systems that will meet the mechanical and electrical constraints posed by the antennas are the low ERP systems. The expected benefits of these systems are:

- Substantial improvement in picture quality relative to the quality obtainable from high gain antennas
- Minimum interference with adjacent channels
- Simple installation on most existing towers
- Minimum investment

Together, these benefits mean nothing less than the best chance at market share for broadcasters. Failure to recognize this may help accelerate the introduction of fiber optics cablecasting and other distribution systems.

ACKNOWLEDGEMENT

The author would like to thank his colleague, Mr. A.Skalina for his comments and the computations of the video response.

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RF COMPONENTS FOR ATS TRANSMISSION

T.J. Vaughan
Micro Communications, Inc.
Manchester, New Hampshire

INTRODUCTION

What is High Definition T.V.? How is it going to effect the broadcaster? This is a question we are hearing more often from all areas of the broadcast industry. What equipment will I have to replace? Is that new RF equipment I just installed usable? Are my antenna and tower able to handle the new service? Hopefully, this paper will answer some of these questions.

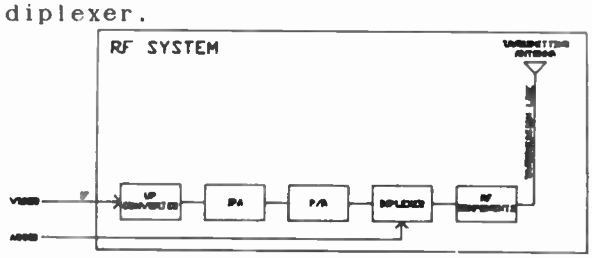
The FCC will choose a high definition system (now referred to as ATS or Advanced Television System) in the spring of 1993. Various industry committees are in the process of setting standards and test plans for the different systems being proposed. The system will consist of; a non-compatible, all (or part) digital, single channel signal. Stations will initially be allowed to simulcast NTSC and ATS signals on two different channels. After the simulcast period, transmission will revert to a single ATS channel.

This paper presents some of the considerations for the broadcaster to examine with regard to the new ATS technology. We will discuss; what the ATS signal is, how it is transmitted, what RF equipment is required and what the trade-offs will be. It is assumed that most VHF stations will be assigned a UHF channel during the simulcast period and that all UHF stations will be assigned a second UHF channel. Special consideration will be given to UHF transmission systems.

COMPARISON OF NTSC & ATS

The current NTSC transmission system consists of; a VSB amplitude modulated composite video signal, a suppressed subcarrier amplitude modulated color signal, over a 4.2 MHz video bandwidth and a frequency modulated aural signal.

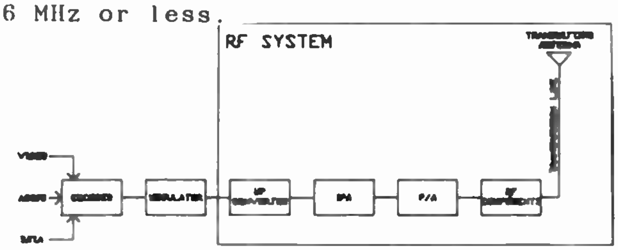
The video and color signals are combined at low levels and the aural signal is combined at high level in a diplexer.



NTSC SYSTEM

In general, the all-digital ATS systems consist of; digitally encoded video signal, a number of digitally encoded aural signals, data and control signals.

These signals are all fed, after encoding to a multiplexer to obtain one data stream. Some type of error correction and processing is then applied to the stream before it goes to the modulator. Various data compression schemes are used to reduce the transmission bandwidth to 6 MHz or less.



ATS SYSTEM

The RF system of each are essentially the same in that they both start at the IF level and terminate in the antenna.

There are very significant differences between analog transmission such as NTSC and digital systems like ATS. Items such as interference, ghosting and signal quality are all handled differently.

Analog systems are much more susceptible to problems from secondary signals since they directly modify the amplitude information contained in the transmission. The interference is displayed on the screen as it is received. Signal quality of an analog system degrades proportionately to the received signal level. The picture slowly becomes filled with noise, the color signal is lost and eventually, it becomes unwatchable.

Digital transmission is very different. Since it is made up of small units of information, staggered in frequency. Secondary signals do not directly modify the information. Pieces of the information may be affected by the interference but up to a certain limit, these can be ignored. It is this error limit which makes digital reception different. Below the limit, there is little change in picture quality beyond the limit where the picture is completely unwatchable. The transition is abrupt and no slow degradation occurs. Digital transmission is not completely interference free however. Overall channel amplitude, phase and group delay variation can have a negative effect on signal quality.

The result of these factors is that significantly lower carrier to noise ratios are allowable for digital signals. Tests have demonstrated that a grade A quality signal is receivable at a C/N ratio of 19dB for digital, compared to 45dB for NTSC.

POWER TRADE-OFF

Preliminary specification established by the Advisory Committee on Advanced Television System Subcommittee Working Party 2, has established that the ERP for ATS peak transmission can be 10dB less than NTSC transmission and the ATS average transmission will be 5dB less than the peak values.

The 26dB difference between high quality ATS and NTSC signals permits the lowering of transmitted power while at the same time effectively increasing the Grade A signal. This can be seen in fig 2.

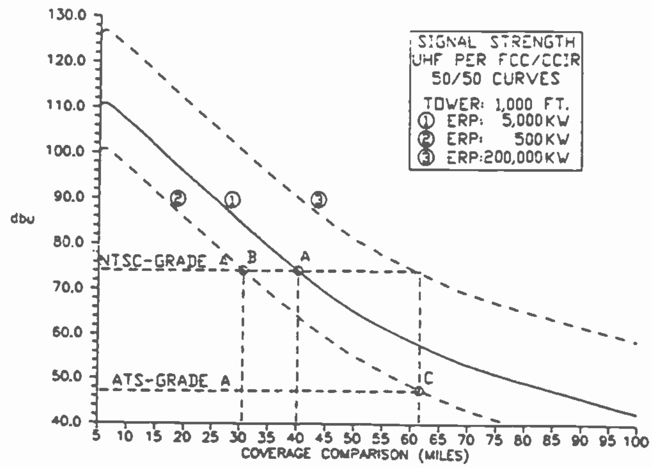


FIGURE 2

Curve 1 - HAAT 1000 Ft, ERP 5.000kW
Curve 2 - HAAT 1000 Ft, ERP 500 kW
Curve 3 - Effective increase of due to digital signal

As can be seen in figure 2, the Grade A NTSC signal would extend to 40 miles (point A). A 10dB reduction in NTSC signal would reduce the contour to 30 miles (point B), but because of the 26dB difference in C/N between the NTSC and ATS quality level, the ATS Grade-A (47dBu) signal will extend to 64 miles (point C). This would be equivalent to a 200,000kW ERP-NTSC signal.

Because of error bit rates and other factors, the 26dB difference has been reduced to 10dB. The 10dB reduction can be used to reduce the antenna gain or the transmission power.

	NTSC		ATS	
ERP (kW)	5.000	5000	500	500
Gain-Antenna	50	25	25	5
Tx (kW)	120	240	15	120
Line Size	W/G	W/G	3 1/8	W/G

TRANSMITTER CONSIDERATION

The transmitter specification for the NTSC Transmission System applies to the RF generator up to the diplexer output. The RF components, transmission line and antenna are essentially transparent contributing little degradation to picture quality, as long as reflections are very low.

The ATS transmitter will not require high level combining of visual and aural, so diplexer will not be required. The ATS transmitter has been defined as to include all the RF components up to the input to the antenna transmission line.

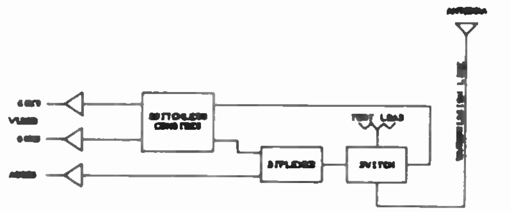
Typical transmitter system specifications for both systems is shown below:

		NTSC	ATS
Freq. Response	(dB)	± 0.5	± 1
Group Delay	(NS)	±60	±50
Diff. Gain	(%)	5	3
Diff. Phase	(deg)	3	3
ICPM	(deg)	4	2
Return Loss	(dB)	38	20
HUM	(dB)	55	50
Transient Response(%)		2	1.5

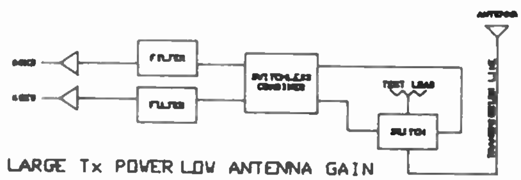
Present day transmitters from the RF input to the antenna output should be capable of meeting the ATS specifications. Frequency response and group delay will have an impact on the specifications of the antenna.

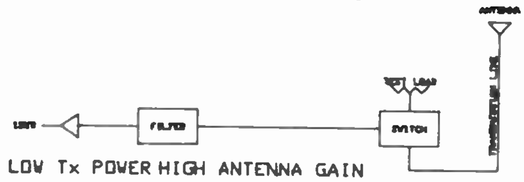
Most high power antennas are high-Q and some of the waveguide components are dispersive; this will contribute to group delay.

RF components for the two systems are shown in the enclosed block diagrams.



NTSC RF COMPONENTS





ATS RF COMPONENTS

Because of the lack of reliability of high power generators and the requirement for 24 hours of operation, almost all current NTSC transmitters are redundant systems. Dual power amplifiers and switchless combiners are used. The switchless combiner permits hot switching of the down transmitter, without loosing air time. Test loads are necessary to permit the transmitter to be tuned into a reflectionless resistive load.

The 10dB ERP difference between the ATS and NTSC transmitter can be used to reduce the transmitter power, the antenna gain, or a combination of either. Low antenna gain means smaller antennas but large transmitters and transmission line. Whereas smaller transmitters and transmission line could result in antenna's as large or larger than present day antennas, but smaller transmitters and transmission line.

Because of a close spacing of channels, it is expected that higher out-of-band attenuation will be required and as a result, additional filtering will be required. These will contribute to group delay and non-flatness in the pass band.

The NTSC signal is very sensitive to reflections. It is generally accepted that 3% antenna reflections are objectional. Reflections as high as 10% will produce no ghosting problem with the ATS signal; although a 20dB (10%) reflection will load the amplifier causing power variation and distortions. Power output variation of a Klystrom can vary by 25% and change pass band slope by 3dB with reflections of 1.15 VSWR or 23dB Return Loss. This would be typical of the daily expansion of the transmission line, due to sun loading. This power change can be corrected with high power isolators (Ref-1).

ANTENNA CONSIDERATIONS

A simulcast period will precede the full use of ATS. During the simulcast period, both the NTSC and ATS will be transmitted. The antenna requirements before, during and after the simulcast period may differ.

Before Simulcast

Antenna's and RF components purchased before the simulcast period must satisfy the broadcast's present needs but not exclude the possibility of being used or being converted to a simulcast antenna. At a very minimum, any new tower should be capable of handling the loads of an NTSC and ATS antenna and transmission line.

During Simulcast

During the simulcast period, both signals will be transmitted. The antenna must be capable of radiating both channels or two separate antennas will be required, each with the same "foot print" or azimuth radiation pattern. It is assumed that most VHF stations will be given a second VHF or UHF channel and that all UHF stations will be given a second UHF channel.

The band width requirement for an antenna that would radiate both a VHF and UHF channel simultaneously is beyond the state of the art.

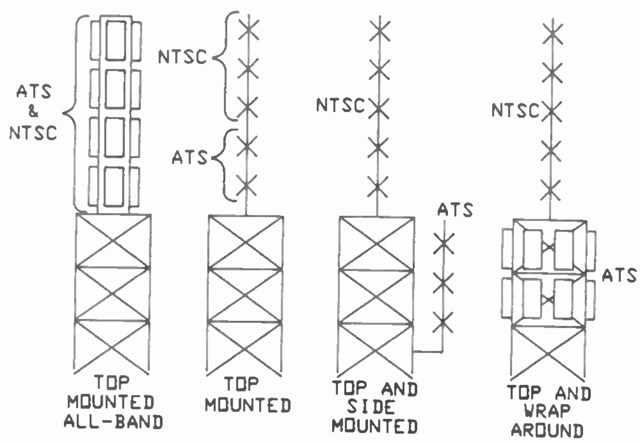
Broadband antennas are available or could be designed to handle all low VHF channels (2-6), all high VHF channels (7-13) and all UHF channel (14-69).

After Simulcast

It is expected that the antenna required after the simulcast period will be smaller in size and have lower power handling requirements probably greater than the 10dB difference listed here. It is also assumed that if all second ATS channels are UHF, that when the FCC eliminates the NTSC transmission, they will leave all stations with their second channel. If this is so, we will have an all UHF TV market. It should also be noted that some LPTV stations operate at 50kW ERP, which is only 20dB below the present full service level. If digital transmission permits the full service station to operate 10 to 20dB below their present levels, we will have a total market of 3600 stations. 1600 full service and 2000 LPTV, all operating in the UHF band at about the same power level.

TYPE OF ANTENNA

The type of antenna that can be used will depend on how they are mounted.

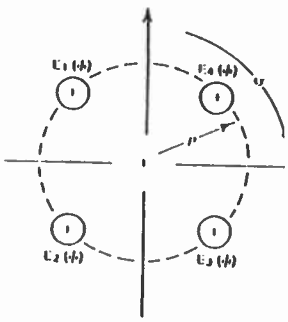


Some of the currently used antennas are listed below:

	Top Mounted	Side Mounted
VHF Low Band	Batwing	Butterfly
	TDM	H. Panel
	CPV	Doublett
VHF High Band	Batwing	Arrowhead
	Slot	Ring
	Slot & Dipole	
UHF	Coax Slot	Slot & Dipole
		Slot & Direct
	Slot & Direct	Wrap Around
	W/G Slot	

Azimuth Patterns

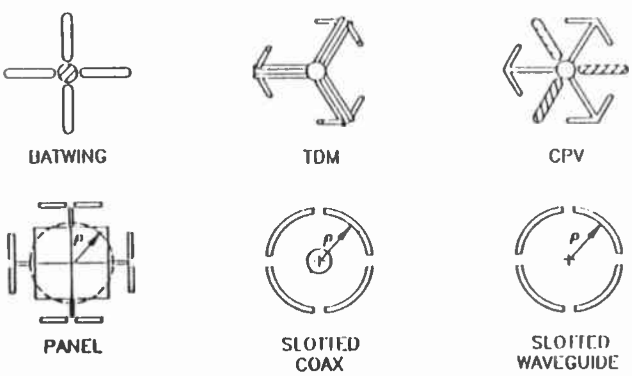
The ripple content of the azimuth pattern is dependent on the element pattern and the distance to the phase center of the radiating element.



$$E(\phi) = \sum_{n=1}^{N} E_n(\phi) A_n e^{j(2\pi\rho\cos(\phi-\phi_n)+\psi_n)}$$

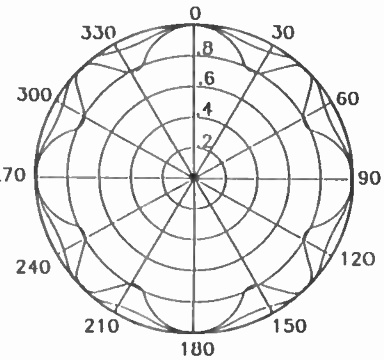
Where: $E(\theta)$ = element pattern
ϕ = azimuth angle
ψ_n = phase of nth element
A_n = amplitude of nth element
ρ = distance to phase center (in wavelengths)

Some antennas such as cross dipoles or turnstyles have the value of ρ at zero. Others, such as panels or slotted coax or waveguide, have a value of ρ from 0.25λ to 2.0λ .



The ideal element pattern for a three-sided tower is $E=\cos(\theta)$, and for a four-sided tower $E=\cos^2(\theta)$. For a very large tower, the number of elements and the coefficient of the element pattern and element displacement are chosen for minimum ripple. The ripple content of four panels with a $\cos^2(\theta)$ element pattern and phase center spacing of $\rho = 0.5\lambda$ and 1.5λ is shown below.

The value of ρ for a panel antenna is dependent on the panel width. The value for coaxial slotted antenna is dependent on the size of the coax line, which in turn, is dependent on the power handling capability of the line.



The value of ρ for waveguide slotted lines is dependent on the mode of operation which is a minimum of a half wavelength.

The ATS system specification of frequency response and group delay are impacted by the RF components, transmission line and antennas. VSWR variations and transmission loss will effect the frequency response while waveguide transmission lines and antennas will effect the group delay.

If broad-band components are used, the VSWR over the full band can be kept to less than 1.10, which will result in an amplitude variation of less than 0.01dB. If all coax components are used, there will be only a linear phase shift with no effect on group delay. Waveguide components are dispersive e.g. the phase variation across the band is non linear. Typical group delay variation for waveguide components will be on the order of 10 NSEC.

This can be pre-corrected in the transmitter. Linear phase variations and space vector variation due to tower reflections, line length (coax) variations pattern and amplitude changes will have no effect on group delay.

Circular polarized antennas will probably not be used for ATS transmission. The original perceived advantage of circular polarization of ghost cancelling never became a reality because a market never developed for CP receiving antennas. The other advantage for circular polarized transmission which is the doubling of power is negated by the 26dB improvement obtained by going to ATS.

TRANSMISSION LINE CONSIDERATION

Tall towers are transmission line limited. The wind load stress developed in the tower legs by the transmission line are much greater than the stress developed by the antenna.

The ERP (Effective Radiated Power) is the product of the antenna gain times the antenna input power. Typical values for NTSC system on a 2000 ft tower is shown below:

		LoV	HiV	UHF
ERP	(kW)	100	316	5,000
Antenna Gain		5	12	50
Antenna Pwr	(kW)	20	25	100
Transmission Line		3 1/8	6 1/8	W/G
Efficiency	(%)	66	70	83
Tx Power	(kW)	30	35	120

NTSC PARAMETERS

The parameters for an ATS system depend on whether we use a high antenna gain and low transmit power, or low antenna gain and high transmit power. A range of ATS values are shown below for a 2,000 Ft tower.

		A	B
ERP	(kW)	500	500
Antenna Gain		50	5
Antenna Pwr	(kW)	10	100
Transmission Line		3 1/8	W/G
Efficiency	(%)	30	83
Tx Power	(kW)	33	120

ATS PARAMETERS

It is apparent that even 3 1/8 line may be marginal. The transmitter power must be high enough to overcome the transmission line loss.

The optimum system would be to combine the NTSC and ATS signal at the transmitter output in a channel combiner and use a single transmission line and a broad-band antenna.

TOWER

A major item in the cost of implementing an ATS system will be the tower cost. Although all towers are designed with some safety factors, it is unlikely that a new ATS transmission line and antenna can be added without first doing a tower stress analysis. This will determine whether modifications such as increasing critical member size will permit the tower to be used. The advantage of using the existing tower is:

(A) Cost
(B) Add ATS without losing air-time
(C) Eliminate problems in getting permits from FCC, FAA and other local ordinances.

The cost of a tall tower is directly related to the amount of steel used in the structure. This, in turn, is related to the various functional design parameters and the environmental conditions of which wind and ice are the dominant ones.

All current design standards and code consider the forces due to wind and horizontal static loads dependent on the velocity of the wind and the shape and configuration of the tower members and the ancillary items. These horizontal forces are distributed within the tower structure to the guy cables which, in turn, carry them to the ground.

The guy cables impose downward forces of the tower legs which, along with the gravity forces (weight), are transferred to the tower base. The resulting stresses produced in the tower members must be less than allowable (safe) values established by a design standard for the size and grade of material used.

Since the sizes of the tower legs are dependent on both the wind and gravity loads, they have a relationship to the total weight of the structure and, hence, its cost.

The two scenarios for ATS consideration in this paper are (A) High antenna gain and low transmit power or (B) Low antenna gain and large transmit power. To determine the effect of each tower, stress study's were run (Ref 2).

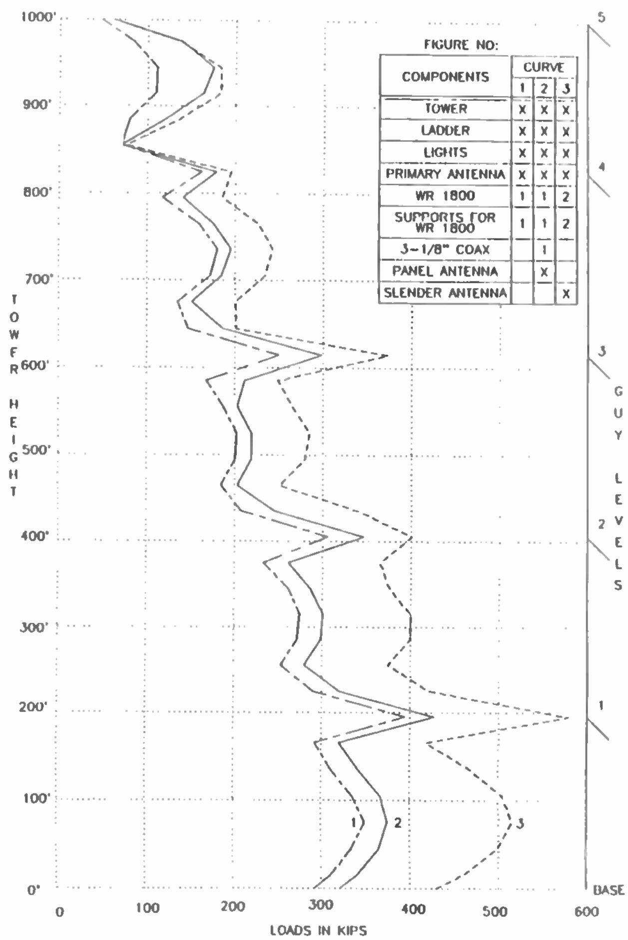
For reference purposes, a leg stress analysis was prepared for a 1,000 Ft. tower with one high power (120kW) high gain (50) antenna fed by a waveguide run. The tower included ladder and lights. A basic wind speed of 85 mph was used per ANSI/EIA standard RS-222-D (86). This is shown as fig 1 of the enclosed stress chart.

The graph represents the maximum calculated force in any individual leg throughout the height of the tower.

The stress analysis was repeated. Two antennas were added to the tower.

fig 2 - High gain antenna fed with a 3 1/8 coax line

fig 3 - Low gain antenna fed with a second waveguide



If we integrate the area under these curves, we will see that leg stresses are increased by 9.6% for the large antenna and small line and 47% for the small antenna and large line.

It is quite apparent that using a large antenna and small line will result in significant tower and transmitter power savings. The ATS antenna and transmission will have to be analyzed on a case by case basis.

CONCLUSION

The ATS RF system transmitter requirements are not significantly different from the NTSC transmitters. Equipment in use today can be used with this new service.

Some RF components, such as Diplexers, will have to be removed, but the RF chain will still include UP Convertors, Power Amplifiers, Combiners, Switches, Transmission Line and Antennas.

System planners have established that the Effective Radiated Power for ATS will be 10dB lower than the level now used for NTSC.

The major design consideration is whether to take the 10dB reduction in transmitter power and keep the same antenna gain, or reduce the antenna gain but keep the same transmitter power.

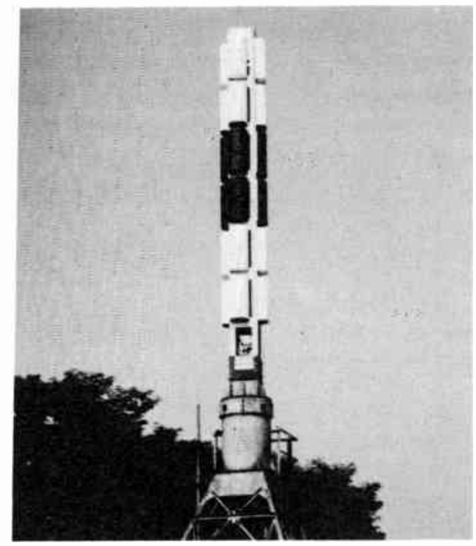
Stress studies on towers show that the transmission line contributes six times more than the antenna, concluding that we will want to use small transmitters with high gain antennas.

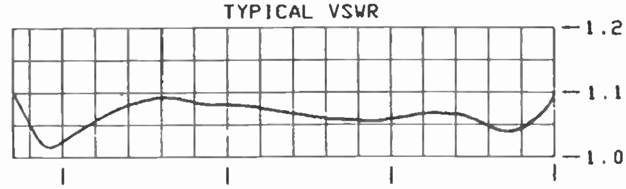
Much higher antenna reflection (20dB return loss) will be permitted with the ATS signal.

Broad-band antennas with non-dispersive transmission lines will be required to reduce the overall contribution to group delay. Group delay is more critical with ATS transmission.

The optimum system would be to combine the NTSC signal and the ATS signal in a channel combiner and use one transmission line and one antenna. The above mentioned equipment is available with today's technology.

Enclosed is a photo and VSWR plot of a multi-channel, six bay, omni directional, all band antenna.





Credits:

To John Windle of Stainless, Inc., who calculated the stress charts, and to Jim Stenberg for his technical contributions.

References:

1. "HIGH POWER ISOLATOR FOR UHF TV" by T. J. Vaughan (MCI) and Dr. E Pivit (ANT Telecomm.) NAB Symposium - 1989

2. "TALL TOWERS FOR SUPER POWER TV" by T. J. Vaughan (MCI) and J. Windle (Stainless, Inc.) NAB Symposium - 1988

THE ROLE OF FILM IN THE ERA OF ADVANCED TELEVISION: AN ECONOMIC AND TECHNOLOGICAL ANALYSIS

C. Bradley Hunt
Eastman Kodak Company
New York, New York

ABSTRACT

Motion picture film will continue to play an important role as an imaging medium with the emergence of new advanced television systems. The various ATV systems being proposed and implemented throughout the world will produce an increasing demand for high-quality programming. When selecting a production medium to create this programming, television producers must consider many factors. These include image quality, artistic flexibility, compatibility to the various television systems, both today and in the future, and cost.

A technical performance comparison made between the new Eastman EXR color negative films and current HDTV cameras shows that film has significant performance advantages including resolution, speed, and signal-to-noise. Kodak is undertaking several research programs in the film/electronic interface. These include the development of a new experimental, high-performance CCD HDTV telecine and of a high resolution digital image manipulation system for motion picture film.

Based on this outlook and our investments in the future, film should continue to be the dominant origination medium selected by television producers because of its ability to produce high-quality programming with worldwide compatibility to any of the proposed high definition television systems.

INTRODUCTION

For those of us involved in the art and science of motion imaging, 1990 is a significant year. It marks the start of the second century of motion picture film. And, it begins the decade that will, no doubt, usher in the era of a new, advanced television system that promises to deliver high-quality, wide-screen television images to the home.

In the past, film played an important role during the era of black-and-white television and is doing so currently in the era of color television. As we embark upon the future era of high definition television, film's prominent role should continue for four reasons.

First, film is and will continue to be the highest quality image capture medium for the production of television programming. Second, film-produced programs are and will continue to have worldwide compatibility. The fact is film is an accepted production standard throughout the world. Third, the flexibility of film imaging is important to the creative community. Whether it's changing the mood by shooting a high speed emulsion under low light or shooting film at 96 frames per second for dramatic emphasis, film offers creative flexibility. Finally, film is futureproof. Film produced programs can be converted and displayed in any future television standard, even beyond HDTV. And since film imaging is a media-driven system, future technological innovations in imaging performance can be easily incorporated by the industry with very little financial or standardization impact. Quality, compatibility, flexibility, and futureproofness provide considerable economic value to the user.

As part of our strategic planning process at Kodak, we have developed a vision of the future. We believe that no one technology, neither film nor HDTV, will dominate the future. Each will work together, capitalizing on its own set of advantages and capabilities, to define the future. And we believe that this future will be driven, not by technology, but by the search for higher quality.

In fact, the one thing that both film and HDTV scientists, manufacturers, and producers agree on is the need for better quality television images. After all, it was the dream to deliver improved television images to the home that helped lead to the development of HDTV. And it is this pursuit of higher quality images which motivates the development of new film products by Kodak and other film manufacturers.

Consumers are also becoming more quality conscious. They are trading in their old televisions for 25-inch and larger color televisions with stereo sound. They are packing away their LP records and buying new compact disc players. And I believe that consumers will be ready to buy when wide-screen, advanced television receivers and programming become available. And these higher quality television receivers are going to make consumers even more critical about picture quality.

That is why film's superior imaging qualities will be even more important in the future. Film's special capability for capturing and reproducing visual information was recognized very early by the developers of HDTV systems. They benchmarked the film image as the quality standard and have always spoken of trying to equal "the quality of 35 mm film".

The creative community is equally attracted to film. Time and again we are told by producers, directors and cinematographers that what they want for quality images is that elusive something called "the film look."

PERFORMANCE COMPARISON

Many people have asked the question, "how does film compare to HDTV?". Our scientists have conducted a significant amount of technical analysis in order to better understand the imaging performance differences between film and HDTV. I would like to share some of the results of this analysis with you.

At the 1989 SMPTE Technical Conference, we presented our work in a technical paper titled, "A Comparison of Color Negative Films and HDTV Cameras for Television Program Production". We examined both 16 mm and 35 mm film formats and included the following color negative film stocks:

Eastman EXR Color Negative films 5245, 5296, 7245
and
Eastman Color Negative film 7292;

We compared these films to the published specifications for commercially-available HDTV cameras.

The film world and the television world use different terminology and measurement techniques in defining performance. In order to create comparable data, we had to make some assumptions in our analysis.

For example, the Modulation Transfer Function, or MTF of film defines film's resolution performance and is generally plotted against cycles per millimeter on the film plane. However, television hardware resolution is defined in TV lines per picture height. To compare the response of the various film formats with an HDTV camera, the film plane MTF is multiplied by the image height to convert to cycles per picture height. Henceforth, one cycle per picture height on the film is equivalent to two TV lines per picture height.

Figure 1 shows MTF curves for different film formats and an HDTV camera. The HDTV camera data comes from a published NHK report, as camera manufacturers do not typically publish MTF data. The 35 and Super 35 mm and 16 and Super 16 mm camera film MTF curves represent the data for the green record of EASTMAN EXR Color Negative films 5245 and 7245, respectively. These curves include the MTF of a camera lens. In terms of image capture, each of the film systems provide superior resolution performance.

Next, these captured film images must be converted into an HDTV signal on a telecine. Figure 2 shows the film curves after they have been cascaded with the MTF characteristics of our experimental CCD HDTV telecine which will be described later. Without any aperture correction, the 35 mm film formats have similar MTFs to the HDTV camera, and the 16 mm formats have lower MTF response. Aperture correction can be used to eliminate the losses incurred in the telecine conversion step.

One can think of film as a wide-band RGB image recording system. But the limiting resolution of each of the film systems is defined by the 30 MHz bandwidth of the currently proposed HDTV standards. This corresponds to a limiting resolution of about 900 TV lines per picture height. Images stored on film, however, can be retrieved and converted in the distant future when even higher resolution television systems are proposed and developed. This is why we say "film imaging is futureproof."

Turning now to exposure sensitivity, another calculation is needed to compare film and HDTV. The equivalent exposure index for a television camera can be calculated using a simple equation derived from the ISO standard for exposure meters and using the video field rate of one sixtieth (1/60th) of a second. Figure 3 shows that the equivalent exposure index of current HDTV cameras equals that of films in the medium speed range.

Examining the noise and granularity data in Figure 4, we can see that the equivalent system noise of the 35 mm format is close to that of the HDTV systems. The low speed film, 5245, has slightly lower noise, while the higher speed film, 5296, has slightly higher noise. In the Super 16 format, EASTMAN EXR Color Negative film 7245 has slightly higher noise, while the high speed 7292 film has significantly higher noise.

These objective performance data, however, are only a snapshot in time. HDTV cameras will improve And film too will improve. We have recently introduced a new line of Eastman EXR Color Negative films based on our innovative tabular or T-grain emulsion technology. The use of these first-generation T-grain films are changing the artform and redefining the state-of-the art of high-definition imaging.

Over the 40 years that the Eastman color negative family of motion picture films have evolved, significant advances have been made in higher film speeds and improved image structure -- from the first Eastman Color Negative Film 5247 with an exposure index of 16 in daylight to the latest Eastman EXR Color Negative Film 5296 with an exposure index of 500 in tungsten light. During the next ten years, we expect that the further refinement of the T-grain technology breakthrough will lead to a four-fold improvement of faster, finer-grained films.

OTHER FILM ADVANTAGES

In addition to its superior imaging performance, film has a great deal of flexibility. It has a broad dynamic range in exposure latitude. And filmmakers can choose from a wide assortment of emulsions that vary in speed, sharpness and other imaging characteristics. For example, cinematographers can choose a high speed emulsion for low light situations, or a fine-grain emulsion for extremely sharp images -- simply by changing the camera magazine. These choices allow them to create images with the exact mood, quality and emotional tone they want.

Flexibility also comes from other elements of the film system such as the camera. Using relatively portable 35mm motion picture film cameras and battery belts, a cinematographer can literally shoot anywhere.

Another very important factor to cinematographers is the film camera's ability to operate at variable frame rates. This is especially important in motion control photography for the creation of special effects. When photographing miniatures, film exposures can be increased up to four seconds per frame for greater depth of field.

At the heart of the film imaging system, of course, is the film itself, a world-wide standard for nearly a century. A roll of 35mm camera film can be run through any 35mm motion picture camera anywhere in the world. The latest color negative film emulsion can be loaded in a twenty-five year old motion picture camera to produce a high-performance, state-of-the-art imaging system at very low cost.

In other words, film is a media-driven imaging system. The technology is in the film itself. The latest breakthroughs in film technology can be used in any film camera, with no need to update it. That, of course, is what gives film its great economic advantage over electronic production systems.

HDTV -- and video in general -- is a hardware-driven imaging system. The technology is incorporated within the camera and recording equipment. So each major advance in technology means a new generation of equipment which must be purchased. Each new generation of equipment makes the previous one obsolete. We have seen this happen in the past and we expect that this innovation cycle will continue with HDTV equipment.

FILM IS "FUTUREPROOF"

As I mentioned earlier, film is and will remain "futureproof." Film, and programs produced on film, will not become obsolete. Film today is compatible with all current television systems. And it will be compatible with any future HDTV system. This feature of film is becoming more important as it becomes clearer that the world will have several different HDTV electronic production standards.

By the way, this is also the view of the American government in a report prepared for Congress on the effect of HDTV standards on U.S. entertainment industries. It concluded that the lack of an HDTV production standard will not affect the U.S. industry because it will continue to (quote) "produce television programs in 35mm film and convert them to accommodate multiple HDTV standards" (end quote). The report was based on extensive interviews with production studios, TV networks, cable companies, equipment manufacturers and industry associations.

In a world of multiple HDTV production standards, film will continue to fulfill the role of being the worldwide standard and primary medium of choice for the production of television entertainment programming -- just as it has been, in the U.S., for the past 25 years.

On the question of a common HDTV production standard, a decision has once again been postponed for another four years. We believe that the Common Data Rate proposal still has the best chance of reaching worldwide agreement. This proposal appears to incorporate the most elements of commonality of these competing HDTV standards. This proposal also has advantages in reducing the cost and complexity associated with television standards down-conversion and HDTV digital recording equipment. There are also benefits in higher-quality, down-converted images when an HDTV production standard is chosen that is related to a country's transmission standard.

We think the great advantage of HDTV origination will be the same as that of current video origination -- its immediacy. Therefore, it will be ideally suited for "live performance" and "real-time" events -- sports, news programs, concerts, special events, game shows, and soap operas. All of these will be brought to the viewer with a visual quality they could only dream about before.

Further, imaginative artists will continue to explore HDTV's ability to create new and startling kinds of television programming. Talented people like Zbig Rybczynski, Barry Rebo, and David Niles will emerge using the creative potential of HDTV video effects and computer graphics equipment to produce exciting and innovative television imagery.

As I said before, programs produced on film will be compatible with any television standard around the world, both today's and those envisioned in the distant future. This advantage of film has considerable economic value due to the rapid growth of the global television markets' demand for programming. This growth is being driven by the implementation of new cable and satellite delivery systems. In addition, the privatization of television, being seen in Europe, is expected to increase their current demand for programming by ten fold.

Producers are already aware of this. That's why many of them are now creating film negative masters of their programs. It has become common in the industry for producers to save time and money in post-production by shooting on film, then transferring and editing on videotape. But that leaves them with only a tape master. By using a computerized edit list to conform the original film negative into a program master, they can make better PAL and SECAM transfers for overseas release, and be prepared for future HDTV transfers.

This is exactly the approach used by 20th Century Fox with the hit TV show, L.A. Law. Ed Nassour, V.P. of TV Post-Production at 20th Century Fox believes that conforming the negatives into a film master after video editing increases the value of their TV programs. He realizes that programs originated on videotape -- or existing only in video masters -- will have limited value in future HDTV syndication markets.

KODAK R&D INVESTMENTS

All of these factors have led us to undertake several new research and development programs that will support film origination in the era of HDTV. Two of them I've already referred to -- our new generation of EXR motion picture films and the development of a high-performance CCD HDTV telecine.

High-Performance CCD HDTV Telecine

The experimental telecine was designed to fully translate the superior image quality of film to any of the proposed HDTV standards. It uses a combination of proprietary components we developed and manufacture -- including two new CCD linear array sensors for high sensitivity and low noise, an advanced illumination system and optics, and a unique digital signal processing architecture. We've been showing film transfers made on this telecine to various industry leaders around the world and the "reviews" have been universally enthusiastic.

High Resolution Electronic Intermediate System

Another research project we are pursuing is the development of a high resolution digital image manipulation system for motion picture film. We call it the High Resolution Electronic Intermediate System.

The system, shown in Figure 5, consists of:
- a high resolution film scanner for converting film images into digital data;
- an image computing workstation and various peripherals for storing and manipulating the images; and
- a high-resolution film recorder for outputting the results back onto film.

Although designed to electronically create special effects for theatrical film, it will allow television producers to create high-quality special effect film elements for inclusion in the film master. It is based on a high resolution digital image standard for motion picture film that is presently being developed in engineering committee work within the SMPTE.

The key to the success of the system is that by operating in non-real-time it can have the resolution needed to operate transparently between film input and film output with no loss of film quality. Such a system requires a minimum of 2000 to 3000 vertical scanning lines to fully capture the image information in a frame of 35 mm film. This is twice the resolution of any of the proposed HDTV standards.

The system will scan 35 mm film images and convert them to high resolution digital data. This data will be manipulated at an image computing workstation. Images can be color-graded, painted, and composited with computer-created graphics or film-originated images. And film artifacts such as dirt and scratches can be removed. The digital images on tape can then be output back to film.

Keykode™ Numbers

Finally, we have developed and introduced Keykode numbers. Keykode numbers are a machine-readable edge numbering system for our film stocks. They represent the film edge numbers in bar code format. Obviously, this will help simplify the job of conforming film negatives to video edit decisions that I mentioned earlier. With Keykode numbers, the bar coded film edge numbers are automatically read in during the film-to-tape transfer step and stored with the matching video time code. After the video edit, the corresponding film edge numbers can be retrieved and used for conforming the negative into a film master.

SUMMARY

As you can see, we are making R&D investments in the future of film because we believe it will play a vital role in the era of advanced television. We think that film will continue to be the standard for image quality that HDTV program producers, distributors and viewers will demand. Film will remain a futureproof production medium with worldwide compatibility to all current and future high definition television systems. Television program producers will continue to use film because of both its creative flexibility and its economic value in exploiting a growing global HDTV market.

I, for one, look forward to the day when I can enjoy the full quality of film-originated images on my home television. I know I share the hope with many of you that this day comes very soon. Thank you.

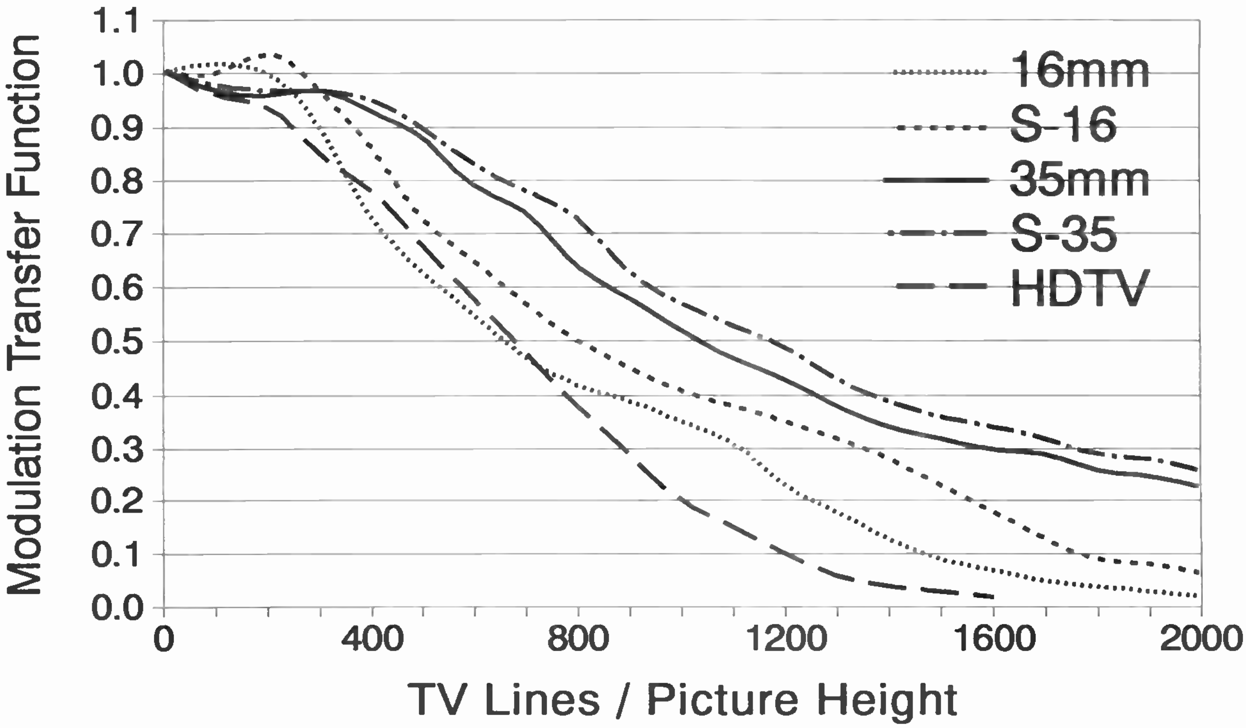


Figure 1. Camera Negative Film and HDTV Camera MTF Curves.

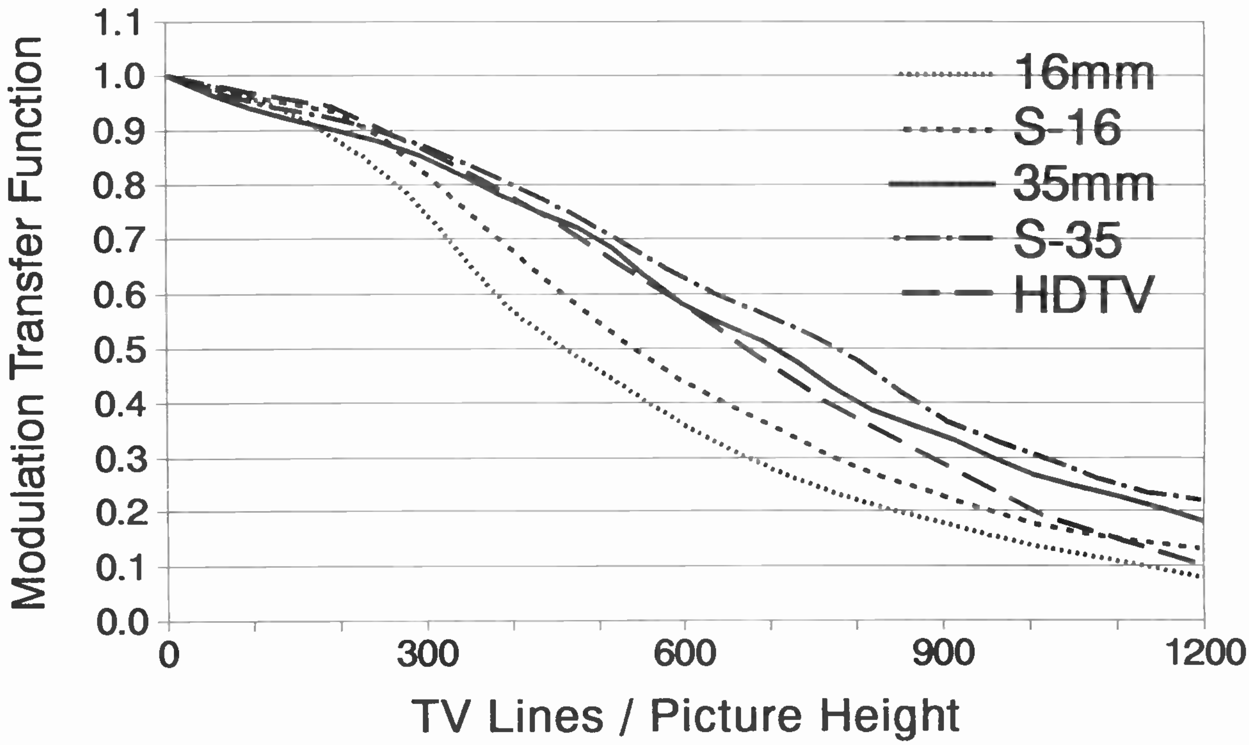


Figure 2. Camera Film With Telecine System MTF Curves.

Image Format	Illum. (lux)	E.I.
35mm:		
EXR 5245	4300 (D)	50
EXR 5296	430 (T)	500
16mm:		
EXR 7245	4300 (D)	50
ECN 7292	690 (T)	320
HDTV:		
Video Camera	1600 (T)	160

Figure 3. Equivalent Exposure Indicies for Film and HDTV Cameras.

Film Format	EXR 7245/5245	ECN 7292	EXR 5296
16mm	-42dB	-37dB	
Super-16	-44dB	-39dB	
35mm	-49dB		-44dB
Super-35	-50dB		-45dB
HDTV			
Video Camera	-46dB		

Figure 4. Equivalent System Noise for Film and HDTV Cameras.

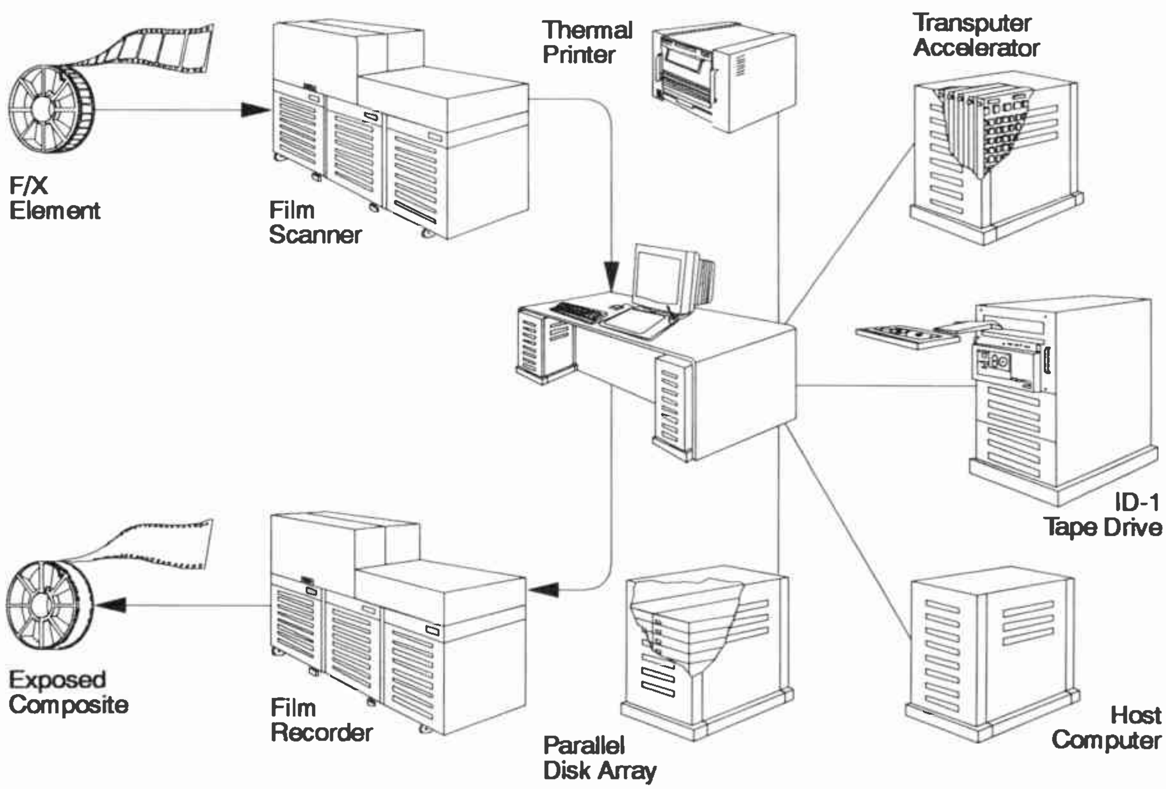


Figure 5. High Resolution Electronic Intermediate System

HDTV DISPLAY TECHNOLOGY:
Windows on the World

Thursday, April 18, 1991

Moderator:
Greg DePriest, Toshiba America, Wayne, New Jersey

FLAT PANEL DISPLAY TECHNOLOGY
P. Pleshko
IBM Corporation
Purchase, New York

PROJECTION DISPLAYS FOR HDTV*
Dr. Lee Todd
Data Beam Corp./Hughes Display Products
Lexington, Kentucky

CRT TECHNOLOGIES FOR HDTV APPLICATIONS
John A. van Raalte
Thomson Consumer Electronics
Lancaster, Pennsylvania

ULTRA WIDE REAR PROJECTION SYSTEM
Akira Yoshida, Setsurou Arai, Seiji Murakami,
Akinori Masuko and Masaki Ishii
Toshiba Corporation
Tokyo, Japan

Yasuo Yoshizawa and Masayuki Ishida
Nippon Television Network Corporation
Tokyo, Japan

*Paper not available at the time of publication.

FLAT PANEL DISPLAY TECHNOLOGY

P. Pleshko
IBM Corporation
Purchase, New York

ABSTRACT

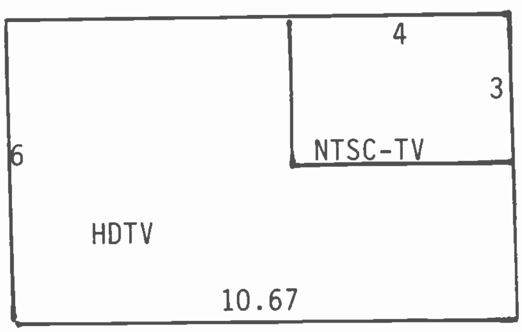
Several flat panel display technologies are promising candidates for HDTV applications. The impact of the HDTV application on the screen requirements and the status of the technologies are reviewed.

INTRODUCTION

HDTV screen requirements differ from current NTSC-TV requirements in viewing angle, screen height, screen resolution and screen aspect ratio.

The objective of HDTV, is to more fully "surround" the viewer with the picture on the screen. Thus, for the same viewing distance, the picture is twice as high. Since it is twice as high, but the viewer's resolution capability is constant (same viewing distance), there are also twice as many lines on the screen. To continue this "surrounding" of the viewer, the width of the screen is also wider by 2.67 times.

This comparison is shown in the picture below, in which the smaller box is the current NTSC-TV screen size, and the larger box is the HDTV screen size.



The different parameters for the two TV systems are shown in the table following.

System Type	Viewing Distance	Viewing Angle (Deg)	TV Lines	Screen Aspect Ratio
HDTV	3H	30	1050	16:9
NTSC-TV	(6-7)H	10	525	4:3

If today's typical 25" TV set is scaled up to the HDTV format, the resulting screen diagonal would have to be 61 inches! Needless to say, with current CRT display technology limited today to under 50 inch diagonals, this is out of reach. However, there are two standard tubes being developed today for HDTV applications. These tubes have diagonals of 32 and 36 inches, with 21 and 23 inch tube neck lengths respectively for a 110 degree deflection angle tube implementation. These tubes weigh 78 and 103 pounds respectively.

Herein lies the interest in flat panel display technology for HDTV applications. First of all, the depth and volume of the flat panel is expected to be at least 7x and 3x less. Next, extrapolating the current display subassemly weight per unit area, the weight is expected to be at least 2x less. And, finally, the power required by the flat panel display is more than 3x less than for the CRT, at the same brightness. Thus, from a technology parameter perspective, flat panels have many demonstrated advantages over the CRT, which make them attractive for the HDTV application.

The only parameter that has not already been proven to be better than the CRT, is the cost. Herein lies the manufacturing challenge for the flat panel technologies. In addition to the challenge of manufacturing large size panels with good yield, they also have to be manufactured with a low cost process.

FLAT PANEL TECHNOLOGIES

Requirements

The HDTV screen requirements have recently been presented in a paper addressing HDTV [1] These requirements were based on the capability of the CRT, and are given below only for those parameters which reflect the on the technology requirements.

Brightness	100 foot-lambert (peak)
Contrast	100:1
Color gamut	Full color (8 bits/color)
Screen Diagonal	More than 50 inches
Pixel number	More than 1.5M triads
Power Consumption	Less than 300 watts

Even though much has been demonstrated in monochrome flat panel displays we will restrict our comments to the color implementations of each technology, since this is the main thrust of TV applications.

Emissive Display Technologies

Emissive display technologies have intrinsically wider and constant viewing angles for all gray levels. In addition, the response times are also fast. This makes them of great interest for HDTV. The leading candidates are the plasma technologies and the electroluminescent technologies. Currently, only the ac plasma technology has demonstrated brightnesses approaching the 100 foot-lamberts desired. Even though this demonstration has been made on panels of smaller physical size and less than 1.5M pixels, it is a characteristic of the ac plasma display, that the brightness is independent of the size of the panel, because of the memory in the panel.

In the electroluminescent (EL) flat panel technologies, only the ac EL has demonstrated color in a panel implementation, to date. This demonstration is at a brightness level of about 10 foot-lamberts, an order of magnitude less than the objective.

Non-emissive Display Technologies

These technologies are the liquid-crystal display (LCD) technologies. The passive-addressed LCD is the lowest cost flat panel technology. The (active-matrix) thin-film-transistor liquid-crystal display (TFT/LCD) has demonstrated the best color performance to date. Together, they set benchmarks for cost and performance respectively for the flat panel contending technologies. Currently, the industry for the most part is investing in the TFT/LCD technology because of performance. Cost is still something to be improved, but with so much industrial activity in this technology, the synergy of this total activity should maximize the chances for success.

SUMMARY/CONCLUSIONS

Improvements in the flat panel display technologies are being achieved at such a rapid pace, that none of the contenders mentioned above can be definitely eliminated technical reasons, at this point. Of course, the technologies with memory have the advantage that if the brightness can be demonstrated for small screen resolutions, they will also be achievable for the higher resolutions. These are the ac plasma and the TFT/LCD display technologies which havealready demonstrated the capability of providing the required brightness, contrast, number of colors and power. Still remaining for all of the technologies, however, are the manufacturing challenges of large panel yield and low manufacturing cost.

REFERENCES

[1] Morizono, M., Technologlical Trends in High-Resolution Displays Including HDTV, SID International Symposium Digest, paper 3.1, pp. 4-7, May 15-17, 1990.

CRT TECHNOLOGIES FOR HDTV APPLICATIONS

John A. van Raalte
Thomson Consumer Electronics
Lancaster, Pennsylvania

ABSTRACT

HDTV represents one of the most exciting technological developments and commercial opportunities of the coming decade. HDTV will give the consumer better image quality, higher resolution, and improved uniformity, contrast, brightness, signal-to-noise, and colorimetry. These performance objectives present challenges for the display manufacturers — whichever display technology is used — but also for the broadcasters and the television set manufacturers.

This paper reviews the features of CRT technologies that have led to their dominance in entertainment and professional displays, as well as recent developments and improvements in CRT performance that make it the choice technology for future HDTV applications.

We also discuss the limitations and trade-offs that exist in color CRT technologies which must be considered in the design of an HDTV CRT that best meets future market and consumer requirements.

INTRODUCTION

It took almost fifty years following the invention of the CRT by Karl Ferdinand Braun for the CRT to become a consumer product with the commercialization of black and white (B&W) television following World War II. By 1949 RCA scientists had already demonstrated a prototype shadow mask CRT which has since become the dominant color display device worldwide.

The basic shadow mask concept (Fig. 1), originally invented by Harold Law at RCA Laboratories, is still incorporated in every direct-view color TV receiver, HDTV monitor, or CAD terminal sold around the world; annual worldwide color CRT production today exceeds 100 million units.

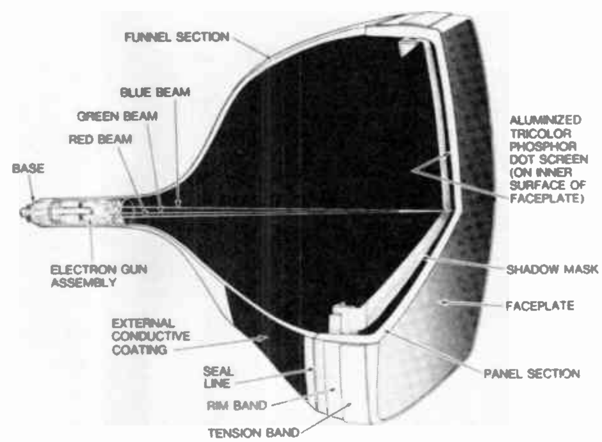


Fig. 1: Principal Components of Shadow Mask CRT

The CRT has at times been considered a "mature" product, leading to predictions that new displays would soon replace it in more demanding applications. Such predictions, heard almost since the shadow mask CRT was first introduced commercially in 1953, are surprising, however, when one considers the tremendous — and on-going — advances made in color CRTs and in their performance. A detailed comparison between H. Law's original shadow mask CRT (Fig. 2a) or the first commercial color CRT (Fig. 2b) and today's color picture tubes quickly points out the dramatic technological changes and improvements that have taken place over the past 40 years: screen shapes have changed from round to rectangular and square-cornered; screen sizes have increased from the original 15V (=15 inch diagonal) to 35V (available commercially) or 45V (demonstrated in prototypes); deflection angles have increased from 45° up to 114°; tubes lengths have been drastically reduced; resolution has increased from a few hundred lines to over 2000 lines; and screen brightness has increased from 15 footlamberts in original B&W CRTs to well over 100 fL in current television sets.

Fig. 2a: Dr. H. Law with first shadow mask color CRT made at RCA Laboratories in 1949

The color CRT continues to dominate the display industry because of its versatility, excellent performance, inherent low cost, and ability to meet numerous and varied display requirements. Moreover, there is no evidence that the rate of progress in CRT technologies and performance is diminishing. The huge, on-going investments in CRT technologies and new manufacturing facilities (over $ 1 billion in the USA alone in the last few years) enable us to predict confidently that the CRT can and will meet the needs of the emerging HDTV markets.

Fig. 2b: RCA 15GP22; first commercial shadow mask color CRT (1953)

SHADOW MASK CRT OPERATION

The basic concept underlying direct-view color CRTs is quite simple. Three separately modulated electron beams are converged and scanned horizontally and vertically, by means of a deflection yoke mounted on the neck of the tube, across a cathodoluminescent (phosphor) screen. A shadow mask containing small openings or slits is positioned between the gun and screen such that each electron beam lands on only one color of three adjacent phosphor dots or stripes, thereby guaranteeing "color purity". The phosphor dots or stripes (three different primary colors) are screened onto the panel by means of photolythographic techniques using the shadow mask as the stencil; this means that the mask and panel are uniquely linked together and must remain matched during the CRT manufacturing process.

In order to perform the shadowing task (i.e., to prevent each electron beam from seeing the other two colors through the mask apertures) the total mask transmission must be less than 33%. In actuality, the mask transmission is typically around 20-25% for a number of practical reasons including dimensional tolerances in the tube, mask or panel contour variations, thermally induced changes in the mask contour, gun and yoke alignment tolerances, and beam landing variations produced by ambient magnetic fields (i.e., caused by the interaction of the electron beams and magnetic fields that penetrate the tube volume due to imperfect degaussing and shielding techniques).

KEY SHADOW MASK CRT FEATURES

Essentially all of the features necessary to render excellent grayscale, color images are incorporated in the shadow mask CRT.

Resolution:
The resolution capability of color CRTs is determined primarily by the number of mask apertures and the size of the electron beam spot on the screen. In order to avoid Moiré or sampling effects there are generally 1.2-1.4 times as many mask apertures or phosphor triads as there are pixels in the image. For current entertainment TV, which is limited by the NTSC broadcast system, this means at least 550 apertures along the major axis of the shadow mask. For higher-definition displays, such as monitors, computers, or CAD systems, where the pixel count is greater, the mask aperture pitch must be reduced accordingly. This places tighter requirements on the etching processes used to fabricate the mask and tighter tolerance limits on the mask-to-panel registration, but this is well within the current state of the art; for instance, Sony currently manufactures a 20" x 20" Trinitron tube with approximately 1640 horizontal apertures.

The second determinant of picture resolution is the spot size of the electron beam. Great strides have been made recently in improving electron gun designs in order to reduce spot size. Higher anode voltages and longer or multi-lens gun designs generally allow spot size to be reduced, admittedly increasing system complexity and cost.

Color Uniformity:
The human visual system is exceedingly sensitive to color, hue, or brightness non-uniformities. For many other display technologies, such as matrix displays, this translates into very tight requirements on pixel dimensional uniformity and drive electronics linearity/uniformity. Since the color CRT "paints" the picture with three separate electron beams, each corresponding to one primary color, the color and brightness uniformity come essentially for free; hue is controlled by appropriately balancing the intensities of the three beams.

Brightness:
Television images must be viewable in a variety of ambients, including relatively well-lit rooms. Thus, the display must be bright and contrasty in order to reproduce the source material faithfully.

The display brightness is determined by the luminous efficiency of the phosphors and the power of the exciting electron beam. Only about 20% of the electrons reach the screen to produce visible light, but the phosphors used in CRTs are among the most efficient light sources known to man. Similar, but less efficient phosphors are used in fluorescent lamps, in projection CRTs, in color plasma displays, and to backlight color LCDs (liquid crystal displays). Luminous efficiency is measured in Lumens per watt (L/w); shadow mask CRTs typically achieve $\geq$8 L/w, compared to 1L/w or often much less for many flat panel display technologies. Since the total display power scales with display area and brightness, the system's luminous efficiency becomes particularly critical in large, bright HDTV displays.

Contrast:
One of the most important, but not always recognized, aspects of good displays is their contrast capability. Since ambient light can easily degrade display contrast, critical viewing operations, e.g., broadcast monitoring or video editing, are often performed in subdued ambients. In the case of the CRT, ambient light can be reflected by the outside or inside glass panel surfaces, or may be scattered by the phosphor layer itself.

A number of techniques have been developed to improve the contrast of CRTs. These include the use of dark (light absorbing) glass, matrix screens, pigmented phosphors, and anti-glare or anti-reflection coatings. Dark glass, i.e. with reduced optical transmission (T), reduces the emitted light by a factor of T, but reduces the ambient light that is back-scattered by the phosphor layer by a factor of T-squared, thereby improving the display contrast by a factor of T. Many years ago panel transmissions of 65-85% were common; nowadays, standard glass transmission in the U.S. is 52%. Recently, some darker glasses have been introduced to further improve the display contrast, admittedly at the expense of some display brightness or resolution.

Phosphor pigmentation, a technique originally introduced by RCA in the mid-70s and now used worldwide, covers each phosphor grain with a pigment-coating that passes the emitted spectral component but absorbs the other colors; in this manner the reflected light from the phosphor layer is attenuated significantly, and hence the display contrast improved without the brightness penalty that accompanies increased glass absorption.

Matrix screens, originally introduced by Zenith and RCA, surround each phosphor dot or stripe with a black, light-absorbing "stencil". Since each phosphor dot or stripe is separated from the adjacent one by an unexcited area which is required for dimensional tolerances and magnetic effects, the blackening of this inactive screen area reduces the reflected light and increases the display contrast.

Specular reflections from the front surface of the CRT panel can also be annoying, particularly in bright ambients. Thomson has recently introduced an optional, low-cost anti-glare coating on most of its CRTs which diffuses specular reflections (~4% at each glass/air interface) to well below 1%. Even better reflection-reduction techniques are used in some high-performance computer or military CRT displays, namely the use of true anti-reflection coatings. These multi-layer, dichroic coatings, unfortunately, are quite costly since they are produced by vacuum deposition techniques onto curved glass sheets that must subsequently be laminated to the completed CRT. These coatings, which are also used on expensive photographic equipment, can reduce the front-surface reflections below 0.25%.

Addressing:
Quite possibly the single greatest strength of the CRT is its simplicity of addressing. NTSC television signals — the current U.S. broadcast standard — require that some 150K pixels of each primary color be addressed with 8 bits (256 levels) of grayscale information at a 30 Hz refresh rate; HDTV signals will contain about four times as much information. A television receiver using a color CRT requires only three active drivers (video modulators) operating at ~4.5 MHz for NTSC, or ~15-20 MHz for HDTV, compared to over one thousand drivers for X-Y-addressed, flat panel displays, or almost a million active devices in the case of active matrix LCDs.

Not only is the number of drivers small in the case of the CRT, but also the requirements for linearity or uniformity are quite minimal, since each driver addresses a different color (beam). The human eye is not very sensitive to gamma (grayscale) distortions but quite sensitive to brightness non-uniformities which plague most other display technologies that use multiple video drivers. The cost implications of the addressing simplicity are largely responsible for the dominance of the CRT in most applications.

CRT WEAKNESSES

While the CRT is an excellent display device it is not, by any means, perfect. A number of weaknesses or deficiencies are often cited when comparing CRTs with other displays:

Flatness:
While the same information can in fact be displayed on a curved or flat screen, there is little doubt that consumers would prefer a flat display if it were available. Virtually all commercial CRTs have curved faceplates because they must support atmospheric pressure (14 Lbs/sq. inch, or ~5000 Lbs for a 27V tube) and this curvature allows the tube panels to be about 1.5x thinner (lighter) than they would be if the faceplate were flat. Nevertheless, it is important to realize that CRTs can be made with flat faceplates if the application warrants it; for instance, Zenith currently markets a flat-faced (tension mask) 14V CRT for computer monitors, and Sony's super fine pitch 20"x20" Trinitron has an almost flat faceplate (135 inch outside radius). Flatness, in a CRT, is more expensive, not only because of the extra glass weight and glass cost, but also because the manufacturing processes (thermal processing) are slowed significantly, and the re-

ceiver electronics required to provide good focus, raster linearity, and convergence become more complex. Also, in domed-mask CRTs at least, panel flatness usually aggravates problems caused by microphonics and resulting mask motions.

Size and Bulk:
One disadvantage of CRTs compared to flat panels is their depth and weight. Typical CRTs are about as deep as they are wide because of the length of the electron gun and the depth of the deflection region. Also, the CRT must be strong enough to support atmospheric pressure, which makes it relatively heavy in large sizes, e.g. 56.4 Lbs and 121 Lbs for Thomson's 27V and 35V tubes, respectively. Ultimately, the size and weight of CRTs pose practical limits for consumer applications, but these limits are not as hard and fast as some people thought a few years ago; presently the largest CRT sold commercially is 35V, while tubes as large as 45V have been demonstrated in the laboratory.

HDTV REQUIREMENTS

The principal objective of HDTV is to provide significantly better, more "lifelike" TV images to the consumer. While the details of the HDTV standards are still being debated, there is general agreement that a wider aspect ratio than the current 4x3 aspect ratio is required; the 16x9 format, which is not quite as wide as some movie formats but quite a bit more panoramic than the NTSC standard, is favored and most common in HDTV monitors today. In Europe, where higher-definition TV signals are more readily available, Thomson has already introduced a 34V 16x9 TV receiver capable of displaying either 16x9 or 4x3 images. A number of Japanese firms have similarly introduced 16x9 sets in Japan and the US market can be expected to take off as soon as appropriate signal sources become available.

In terms of resolution, we foresee an increase of a factor of 1.5-2x in both horizontal and vertical resolution, i.e. 3-4 times as many pixels of information, probably displayed at 60 Hz frame rate, rather than the current 30 Hz interlaced format. As stated previously, this will increase the bandwidth requirements for the video drivers accordingly, i.e. to around 20 MHz, but this is not a problem; the super fine pitch Sony 20"x20" monitor uses 300 MHz video amplifiers.

Size and Resolution Considerations:
The 40-year-old NTSC system represents a superb compromise or trade-off between bandwidth, resolution, color, and the desired compatibility with then-existing B&W signals. Based on detailed measurements of the human visual system, it can be shown that NTSC resolution is as good as can be appreciated on a 25V receiver at typical (8-9 ft) viewing distances. Conversely, if higher resolution images are introduced and typical viewing distances remain unchanged, then larger CRTs are required; this is the reason why HDTV is invariably mentioned in conjunction with larger display sizes.

A method to quantify image quality, based on JND's (just noticeable differences), was introduced by Carlson and Cohen in 1978. One JND is defined as a change in image quality that can be perceived by 75% of the viewers in side-by-side comparison; ten JND's represent a difference that is perceptible in ~ 100% of cases. This methodology allows us to predict the optimum resolution for a display or TV receiver, given the screen size and viewing distance. Thus, a 34V 16x9 CRT with 1000 lines of horizontal resolution, as recently introduced by Thomson in Europe (Fig. 3), is virtually indistinguishable from a similar display with 1400 lines resolution at 9 ft viewing distance (about 3 JND's difference).

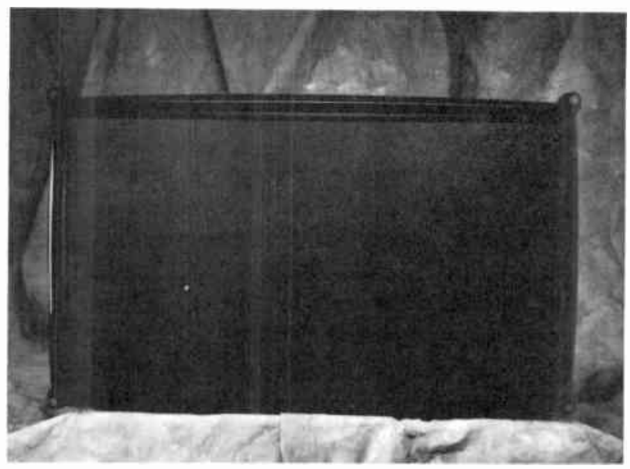


Fig. 3: Thomson 34V 16x9 CRT introduced into European market for EDTV/HDTV applications

Clearly, there are important consequences to the CRT manufacturer as screen sizes or resolution increase. One of the most important ones is cost. While CRTs exist today whose resolution capability exceeds that of any proposed HDTV system, such CRTs are costly because they are difficult to mass-produce, and because a number of parameters have been traded for the higher resolution. Thus, existing HDTV monitors that are used for video production and quality control applications tend to be significantly dimmer than standard television receivers. (e.g. 20-30 fL versus more than 100 fL for standard TV receivers). This reduction in brightness is due to a slight reduction in mask transmission to maintain color purity and a limitation in beam currents to avoid space charge effects that cause excessive beam spot growth. Existing CRTs, developed for HDTV monitors, CADCAM applications, or even higher-resolution industrial or military applications, clearly prove that the shadow-mask CRT can meet future HDTV requirements for resolution and size, but the desire for a mass-producible, low-cost, consumer display implies that resolution be traded carefully. Perception studies teach us that the notion of "limiting resolution", which exists in the motion picture industry, does not have much significance in television displays; rather, it is the resolution with good MTF (modulation transfer function) that is important in HDTV applications.

FUTURE DEVELOPMENTS

Given the current state of the art, what improvements in CRT technologies can be expected in the next decade? Or, putting it a different way, what opportunities are there for CRT designers to further advance the state of the art and to improve the performance of CRTs?

Higher Resolution:

As stated previously, higher resolution means more apertures in the shadow mask, tighter alignment tolerances between the mask and the screen during photolythographic screening, as well as tighter control over the mask-to-screen distance. This distance, which we call "Q-spacing," is typically maintained to within ±15 mils in order to insure uniform spacing of the phosphor dots and beam landing locations. With the development of higher resolution CRTs comes the need to form the glass panel and mask contours more accurately; techniques for doing this are being developed on an on-going basis.

A major contributor to the errors in Q-spacing during normal operation of the tube is the thermal expansion of the mask which intercepts some 75% of the beam power. Both general expansion ("doming") and local expansions ("blisters") occur in domed masks depending on the video signal. Some cancellation of these effects has been incorporated into CRTs for a number of years in the form of bi-metal clips which move the whole mask assembly towards the screen as it heats up in order to compensate for the mask's thermal expansion. This forward motion of the whole mask-frame assembly, however, cannot compensate for all purity errors due to doming or blistering. These problems also get worse in CRTs with flatter faceplates which are becoming increasingly popular.

A somewhat different color CRT, known as the Trinitron, is manufactured by Sony and uses a shadow mask consisting of fine metal strands that are stretched over a cylindrical frame. The faceplate of the Trinitron is also cylindrically shaped and, consequently, must be somewhat thicker in order to withstand atmospheric pressure. While the extra bulk translates into higher cost, the one-dimensional tension in the mask avoids doming and blistering due to mask heating. The Trinitron does not lose color purity until mask heating causes individual strands to lose their tension; this allows the Trinitron to achieve relatively high brightnesses and a very fine mask pitch.

Another type of tension mask tube (14V) was introduced by Zenith a few years ago for computer monitor applications. This tube has a flat, thin (1 mil) foil dot-mask that is stretched two-dimensionally and anchored to the flat faceplate. Here again the tension in the mask avoids doming and blistering, though thermally-induced color purity problems can still occur, as in the Trinitron. The flat faceplate is very attractive for high-performance displays and a true anti-reflection coating can be applied (laminated) with relative ease to provide an excellent, high-contrast display. The flat faceplate is, of course, weaker and therefore must be significantly thicker (heavier) than a spherical panel would be; Zenith is optimistic, however, that they will be able to extend this technology to larger CRTs suitable for HDTV applications.

Other techniques for reducing the thermal problems in domed-mask CRTs have also been developed recently. Special coatings, e.g. bismuth oxide, which contain heavy elements and thus elastically scatter more of the incident electrons, can be applied to the mask, thereby reducing absorbed energy and, consequently, mask temperature.

Yet another type of coating is sometimes used in higher-performance CRTs: a thin, heat-absorbing "ADP" (anti-doming protection) coating is applied on the inside of the screened faceplate thereby increasing the radiative cooling of the mask.

Finally, a different mask material, INVAR, has recently been introduced commercially in higher-definition or larger CRTs to reduce the thermal expansion of the mask. INVAR, an alloy of iron and nickel primarily, has a coefficient of expansion that is about ten times smaller than for the commonly used AK steel; consequently, the amount of blistering or doming induced by bright pictures is significantly reduced.

For example, Thomson uses bismuth oxide in its 31V, 34V (16x9), and 35V tubes with AK steel masks, as well as its relatively flat 20V tubes in Europe, and offers INVAR in higher-performance 27V, 31V, 34V (16x9) and 35V tubes. Virtually all HDTV monitor CRTs today utilize INVAR masks as well, despite the fact that INVAR increases the cost of the tubes significantly due to the higher cost of the metal itself and the more critical INVAR etching and forming processes.

Beam Spot Size:
The size of the electron beam spot on the screen sets one of the limits for the system resolution. This spot size is determined primarily by the physical dimensions of the electron sources (cathodes) and various aberrations in the gun lenses (electron optics). Additionally, the beam spot size increases due to space charge interactions between the electrons at higher current levels; this space charge spreading is difficult to reduce and represents one of the principal reasons for the limited beam currents used in HDTV monitors today.

The deflection yoke, which performs a number of functions other than simple horizontal and vertical deflection, such as self-convergence and raster shape corrections, also contributes to spot distortions, spot growth, or astigmatism at various places on the screen.

New electron guns are being developed to reduce the beam spot size in commercial CRTs, especially near the screen periphery where the spot performance is often degraded. These designs greatly benefit from sophisticated computer-aided modeling techniques that have replaced the empirical approaches to gun design of the past. These new guns tend to be more complex, with tighter dimensional tolerances, but the resulting beam spot improvements are largely responsible for the significant CRT resolution and brightness improvements in the last decades (Fig. 4).

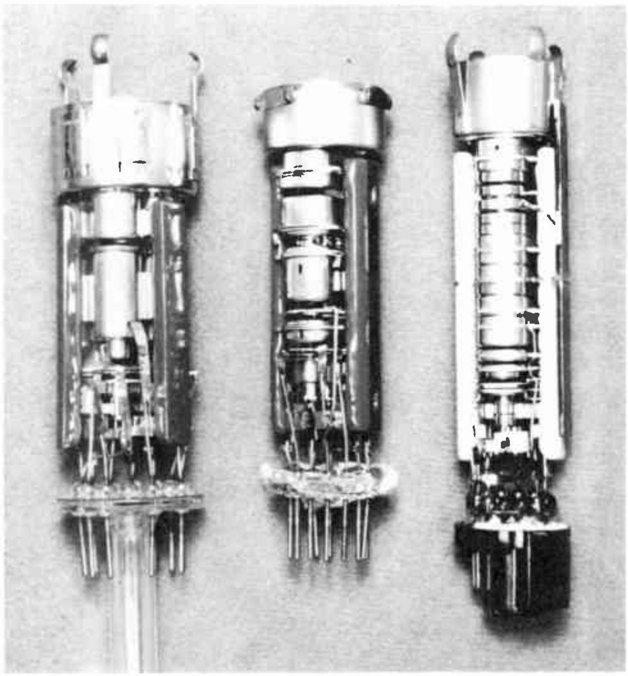


Fig. 4: Examples of commercial Electron guns:
Left: Delta gun for dot-mask CRT;
Center: Commercial in-line 27V gun;
Right: Multi-element gun with internal bleeder resistor (Toshiba 30V).

Sophisticated electron guns often include multiple electron lenses, dipole and quadrupole lens elements, and dynamic signals applied in synchronism with the horizontal and vertical deflection signals, to improve center-to-edge spot uniformity. Longer gun designs and larger tube necks can also be used effectively to improve spot size and to minimize space charge effects, admittedly at the expense of somewhat higher deflection power.

Beam spot sizes also decrease with increasing anode voltage, especially at higher beam current levels. Thus, over the years, the anode voltages used in commercial TV sets have increased gradually, approaching 30 kV in medium-sized sets and 32 kV in larger (30V-35V) sets; we can reasonably expect increases to 34-35 kV in the future for HDTV applications.

Brightness and Contrast:
As stated previously, the brightness and contrast of any consumer display are critical. Many of the improvements in screen brightness that have occurred over the years are the result of gradual improvements in phosphor materials synthesis and processing, in screening (the application of those phosphors to the screen), in the reduction of dimensional tolerances and optimization of mask transmission, in filming and aluminizing (the process whereby a reflective aluminum film is placed behind the phosphor layer in order to reflect more of the emitted light towards the viewer), and increases in electron beam power (current and anode voltage). These trends can be expected to continue, though no major breakthroughs are anticipated in this area.

A major limitation to screen brightness, in the past, has been the thermally induced distortions in the mask. Here the introduction of INVAR, possibly coupled with other coatings, and improved glass forming and mask forming techniques can be expected to bring about significant improvements in the future that will be of great benefit to HDTV applications.

Signal to Noise Performance:
Anyone who has seen digitally generated images knows that there is a quality or clarity in those images, sometimes defined as "depth," that is absent when the signal-to-noise is lacking. Many of us enjoy the sound from digitally mastered CDs and have seen good examples of laser disc-generated video; both are examples of near-noise-free signal reproduction. It is this feature, for instance, that allows us to differentiate between a live TV broadcast and one that was reproduced from film; film is inherently noisy and, in this respect, inferior to television.

The potential of HDTV is tremendous, but it will not succeed unless the signal quality is improved over what most viewers receive today, i.e. improvements are required in video generation (mastering), signal processing, and video signal broadcast or distribution. We, the CRT manufacturers, have made — and continue to make — the necessary investments in new products and technologies to assure the success of the emerging HDTV industry. The shadow-mask CRT is uniquely able to reproduce noise-free, high-quality, high-resolution images with negligible distortion, at an affordable cost; no other display technology can make that claim today!

ULTRA WIDE REAR PROJECTION SYSTEM

Akira Yoshida, Setsurou Arai, Seiji Murakami,
Akinori Masuko and Masaki Ishii
Toshiba Corporation
Tokyo, Japan

Yasuo Yoshizawa and Masayuki Ishida
Nippon Television Network Corporation
Tokyo, Japan

ABSTRACT

In Japan, one hour experimental HDTV broadcasting a day using MUSE system has been started by using broadcast satellite BS-2b. On the other hand, application of HDTV for various industrial uses such as medical use, movie, printing and so on are studied as well as broadcasting. For these utilizations, many kinds of HDTV equipment are already developed.

We have recently developed an ultra wide screen rear projection display system by using existing HDTV equipment, which aspect ratio is 16:3 and screen size is 134 inches wide and 25 inches high.

This system consists of an ultra wide screen of 16:3 aspect ratio, three 50 inches rear projection monitors and HD still picture reproduction system.

As a display part, three 50 inches rear projection monitors are arrayed horizontally and the ultra wide screen is placed in front of these monitors. Each projected image is linked on the screen and becomes one ultra wide image. HD still picture reproduction system consists of three digital frame memories, three optical discs and connected to three monitors individually. A picture signal is readout from the optical disc and stored in the digital frame memory, an audio signal is readout from a compact disc. Each digital frame memory and compact disc player are controlled by the laptop computer and are synchronized frame by frame.

In this system, smoothness of linking three images is very important and we incorporated some ideas to link three images naturally on the screen. This paper describes the details of the system and the technique we developed to make the borders of images smooth.

AUTHOR INDEX

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The Second Annual NAB HDTV World Conference and Exhibit is scheduled for April 13-April 16, 1992 in Las Vegas, Nevada. The conference provides an excellent opportunity for broadcasters, program producers, research laboratories, and manufacturers to present advanced television tutorials, system and equipment descriptions and technical papers on state-of-the-art advanced television technologies.

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