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Special Issue on Digital Broadcasting Technologies

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●Vol. 85/Dec. 1998 Mitsubishi Electric **ADVANCE**

Special Issue on Digital Broadcasting Technologies

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TECHNICAL REPORTS

Our cover illustration symbolizes the era of digital TV services in the home, where a wide choice of content, including studio and satellite news gathering (SNG) programs, will form a rich multimedia menu delivered by satellite, terrestrial and cable broadcasting.

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From the Publisher

Please note that the next issue of Advance (Vol. 86), which would normally be published in March, 1999, will be delayed until June. We apologize for the delay. Prepaid subscriptions will be extended accordingly.

Foreword

Digital TV and HDTV—The Final Arrival

*by Dr. Joseph A. Flaherty, FIEE, FRTS**

The time for study, standardization, and debate is over. The time has come to make the analog to digital TV and HDTV transition. Analog television is behind us. The years of work in Japan and the United States to make digital TV and HDTV a reality have given the world a new measure of television quality that will carry us well into the 21st century. All mankind will benefit from our work.

It is now time to implement digital TV and HDTV, to finalize plans, and to move into the digital TV domain. Analog equipment is no longer in manufacturers' product plans, analog developments are at a standstill, and further developments in analog equipment are most unwise.

How will broadcasters compose their digital bouquets? Will there be a mix of HDTV, SDTV and multiplex programming? Will cable and satellite-delivered high definition put HDTV quality just a "channel click" away from a broadcaster's SDTV programs? Different regions of the world will have different answers to these questions based on their culture, their business environment, their competition and their audience. Whatever their individual decisions may be, 21st century television will not be what it has been, nor what it is today.

This is well understood in America, and there has been steady progress toward the implementation of digital TV and HDTV broadcasting services in both the United States and Canada. The United States has completed the DTV/HDTV standardization and regulatory work, established a digital transition schedule, assigned the terrestrial channels, and the transition is underway.

The Canadian "Task Force on the Implementation of Digital Television" has completed its report to the Canadian Government with 17 recommendations to provide:

> *"... the strategic framework needed to ensure that Canadians receive high quality digital television services in a competitive marketplace; and second, to specify the implementation steps that will guarantee a successful transition."*

The ATSC standard was adopted by the FCC and was mandated for terrestrial Digital TV and HDTV broadcasting, and on April 3, 1997, the FCC adopted a digital channel allotment and assignment plan to provide a second digital TV channel to all existing TV stations, and adopted the DTV service rules to govern the DTV and HDTV service. In its final "Report and Order" in the proceeding on digital television, the FCC required, among other things, that the affiliated TV stations of the top four networks (ABC, CBS, Fox, & NBC) in the top ten markets be on-the-air with a digital signal by May 1, 1999, and the affiliates of the top four networks in markets 11-30 be on-the-air with a digital signal by November 1, 1999. All terrestrial TV stations must be on-the-air with their digital signal by 2003.

The FCC set the date for the return of the analog NTSC spectrum at the end of the transition period as 2006. FCC reviews of that date will be conducted periodically.

Under a separate agreement made with the FCC, some group owners, including CBS, agreed to have some top-ten digital stations on-the-air by November 1, 1998. CBS will have its digital TV and HDTV stations in New York, Los Angeles, Philadelphia, and San Francisco on-the-air by this date. CBS along with ABC, FOX, and NBC will have a total of 14 digital TV and HDTV stations on-the-air by then serving 33% of all TV households.

ABC, CBS, NBC, PBS, HBO, MSG, DirecTV, Primestar, and USSB will begin HDTV transmissions this year during various day parts. As to CBS, it will begin its regular HDTV service with five hours of prime evening programs per week beginning November 1, 1998. Additional programs including sporting events will follow.

By May 1, 1999, a minimum of 30 digital TV stations will be on-the-air in the U.S. including seven CBS stations and 23

**Dr. Flaherty is Senior Vice President, Technology, CBS Corporation.*

ABC, Fox, NBC, and PBS stations. Together, these stations will reach 39% of U.S. TV households with DTV and HDTV signals. By November 1, 1999, 12 CBS DTV/HDTV stations will be on-the-air along with 29 ABC, Fox, NBC, and PBS stations for a total of 41 digital stations. At this time 61% of U.S. TV households will be able to access digital TV and HDTV.

In Canada, the Canadian Task Force on the Implementation of Digital Television recommended:

"The Task Force unanimously believes that a common North American standard for terrestrial Advanced Television Services will benefit Canadian consumers and the Canadian broadcasting systems."

Further the Task Force recommended:

"By the end of 2007, two thirds of each broadcaster's schedule and two thirds of new Canadian content productions should be available in the HDTV format."

The Canadian Government is presently considering all the Task Force recommendations. Action on finalizing the regulations is expected later this year.

The ATSC transmission standard supports a hierarchy of open, nonproprietary scanning formats with HDTV at the highest level, and includes SDTV and digital datacasting. Note the dominance of 1080i equipment and the near absence of yet-to-be designed 720p equipment. 1080i will be the mass-market HD format in America.

The latest information from the consumer equipment suppliers in America shows "Native Display Format" — manufacturers plan to decode all the ATSC formats, including HDTV, but plan to display only 1080i and the 480i & p formats. The 720p format will not be displayed in its native quality, but rather, will be converted to 480i, 480p or 1080i for display.

Major consumer equipment manufacturers plan to produce DTV/HDTV receivers beginning this summer for marketing this autumn ready for the 1998 Christmas buying season. Direct view, front and rear projection, and flat screen models will be offered over the next 12 months. Pricing is not broadly known, but some manufacturers are announcing initial DTV/HDTV receivers in the $2,500 to $8,000 and up range. With so many competitors entering the market, prices are expected to fall rapidly.

In production, the widespread use of 1080i as an HDTV production format is in harmony with the ITU Recommendation ITU-R BT.709 which states in part:

"Considering:
- *that parameter values for HDTV production standards should have maximum commonality;*
- *that an active image format of 1920 pixels by 1080 lines provides square pixels sampling, with attendant advantages for interoperability between various applications including digital television and computer imagery;"*

"Recommends:
- *that for new implementations, particularly where interoperability with other applications is important, systems described in Part II (of document ITU-R BT.709) are preferred."*

Part II describes the CIF systems as:

"1080/60/2:1; 1080/60/1:1 and 1080/50/1:1; 1080/50/2:1 with 1920 samples per active line at an aspect ratio of 16:9."

This recommendation was strongly supported by the Technical Committee of the World Broadcasting Unions (WBU-TC) in 1997 in their statement which reads:

"The World Broadcast Unions Technical Committee strongly supports the adoption of unique standard for program production and exchange of high definition television. This will lead to easier and better exchange of HDTV programs, and lower equipment costs. It will accelerate the move to high definition throughout the world."

"The WBU-TC recommends that the unique standard should be the so-called HD-CIF standard which has a 1080 line by 1920 sample x 50Hz/60Hz scanning system. This standard should be used for HDTV production equipment. Studio equipment manufacturers are being encouraged to set in motion the means to provide equipment to this standard."

This statement was reaffirmed at this year's meeting of the WBU-TC in Krakow, Poland on April 26. Thus, we finally have a single worldwide common image format standard for high definition program production and program exchange based on the ITU Recommendation BT.709.

In considering the importance of HDTV broadcasting, it is vital to understand that wide screen high definition is not just pretty pictures for today's small screen TV sets. Rather, it is a wholly new digital platform which will support the larger and vastly improved displays now in development for commercialization HDTV. Viewed on such large wide screen displays will create an entirely new viewing experience in the home, and consumers will want that experience.

Those who believe, or want to believe, that the public will never want wide screen digital HDTV when it is offered, are taking a "bet-the-business" gamble. More-of the-same standard definition, 525 or 625 line, digital transmissions are unlikely to capture the market, unlikely to sell digital receivers in quantity, and will give way to HDTV worldwide!

For its part, America will stick to the digital transition with unwavering enthusiasm.

The American writer, Ralph Waldo Emerson, expressed this best in 1850 when he wrote:

"Nothing great was ever achieved without enthusiasm."

(received 29 May 1998)

Overview: The Present and Future of Digital TV Broadcasting

*by Tokumichi Murakami, Tetsuya Yamaguchi, Dr. Tommy C. Poon, Dr. Paul A. Ratliff and Dr. Tamotsu Nomakuchi**

This report addresses policy, technology and standards development as nations prepare for the advent of the era of digital television, and describes the current state of development of digital broadcasting systems and services. The capabilities of broadcasting equipment developed by Mitsubishi Electric, including codecs, gathering and distribution systems, semiconductor products and consumer receivers, are also introduced.

Digital Broadcasting Systems and Development Schedule

The transition to digital television raises numerous issues including government policy, broadcast technology, consumer electronics and market acceptance. Fig. 1 shows timelines for the introduction of digital services to satellite, terrestrial and cable broadcasting in Japan, the United States and Europe. Table 1 summarizes specifications of

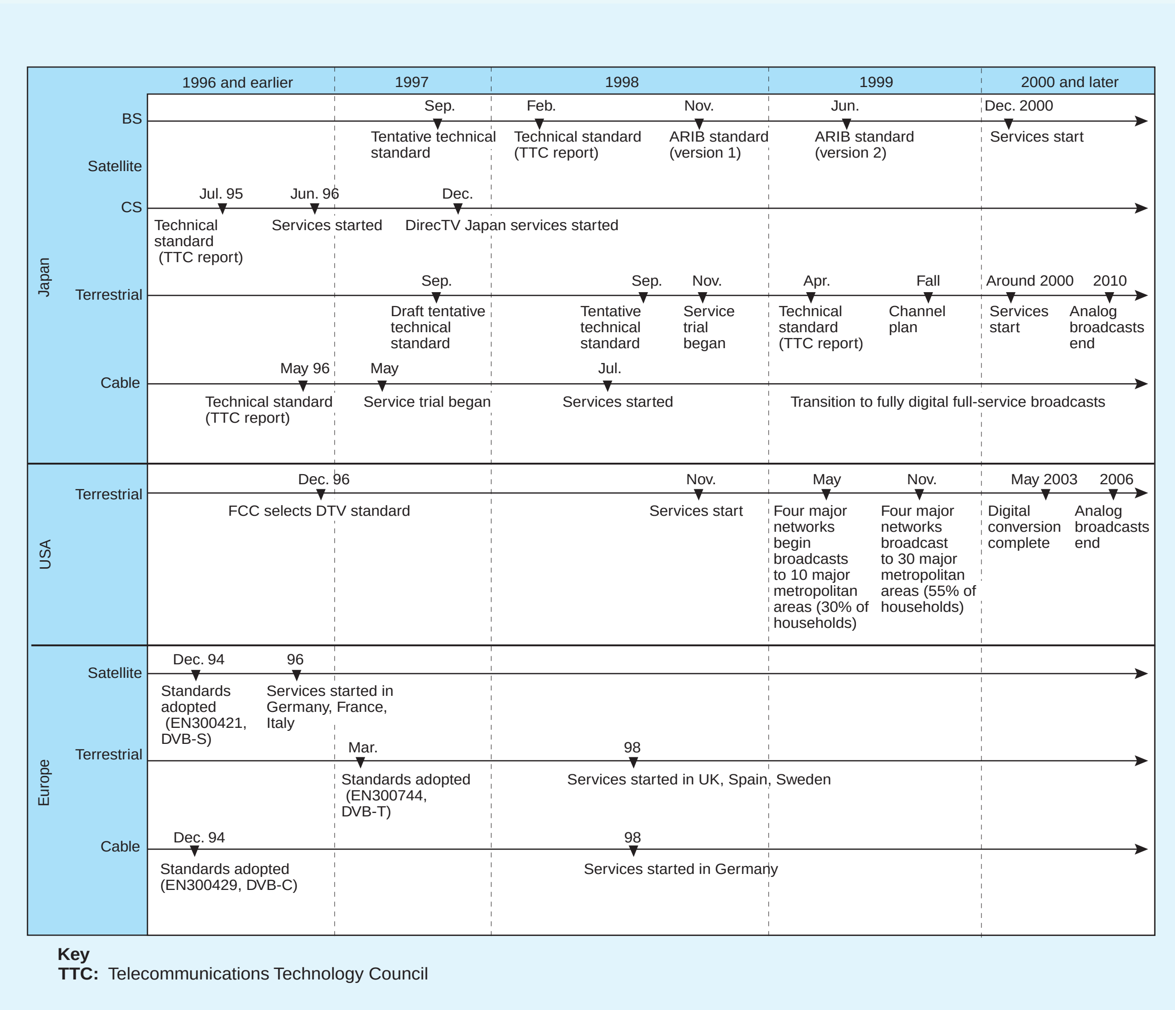

Fig. 1 Digital broadcasting implementation schedules.

*Tokumichi Murakami is with Information Technology R&D Center, Tetsuya Yamaguchi with Koriyama Works, Dr. Tommy C. Poon with ITA, Dr. Paul A. Ratliff with ITE-VIL and Dr. Tamotsu Nomakuchi with Corporate Research and Development.

Table 1 A Summary of Digital Broadcasting Systems

		Japan			US (ATSC)	Europe (DVB)		
Baseband signal		1080i: 1920 or 1440 pels x 1080 lines, 30f/s 480i: 720 pels x 480 lines, 30f/s 480p: 720 pels x 480 lines, 60f/s 720p: 1280 pels x 720 lines, 60f/s (verification required) 1080p: 1920 or 1440 pels x 1080 lines, 60f/s (under study)			1080i: 30f/s 1080p: 24 or 30f/s 720p: 24, 30 or 60f/s 480p: 24, 30 or 60f/s 480i: 30f/s and others (picture format)	576i: 25f/s (4:3 &16:9) 1152i, 1080i/p: 25 f/s (16:9 & 2.21:1) 720p, 576p: 25, 50f/s(16:9& 2.21: 1 or 4:3) and others (for 60Hz countries: 1080i/p: 30f/s, 1080p: 24f/s 720p: 24, 30, 60f/s, 480i: 30f/s, 480p: 24,30,60f/s and others)		
Source coding (video, audio)		MPEG-2 video, MPEG-2 AAC			MPEG-2 video, Dolby AC-3	MPEG-2 video, MPEG-2 audio		
Multiplexing		MPEG-2 transport stream						
Application		Satellite (BS)	Terrestrial (draft)	Cable	Terrestrial	Satellite	Terrestrial	Cable
Transmission	Information rate (Mbit/s)	52.2	23.4	29.2	19.39	29.2 (at 27MHz)	24.1	38.1
	Out coding	RS (204,188)			RS (207, 187)	RS (204, 188)		
	Inner coding	Trellis, convolutional	Convolutional	—	Trellis	Convolutional	Convolutional	—
	Modulation	PSK	OFDM + PSK, QAM	QAM	8-VSB	QPSK	OFDM + PSK, QAM	QAM
	Bandwidth (MHz)	34.5	6	6	6	26~54	8	8

Key
AAC Advanced Audio Coding **RS** Reed Solomon

Note: In the specifications 1080i, 480p, etc., the numerals indicate the number of active lines, the letter "i" indicates interlace scanning and the letter "p" progressive scanning. For terrestrial broadcasting, 544 or 480 pels x 480 lines, 60f/s can also be used.

digital broadcasting systems. Virtually all of the development work in digital broadcasting source coding and multiplexing technologies is based on the standards established by the Moving Picture Experts Group, Phase 2 (MPEG-2).

Japan

National policy is directed toward establishing digital transmission channels for satellite, terrestrial and cable distribution within a few years into the new millennium. The CS satellite has been beaming digital broadcasts to the nation since 1996. The BS satellite will mainly use three digital broadcast formats: 480i, which consists of 720 pels x 480 lines and is similar to conventional TV with interlaced scanning, 480p, similar to 480i, but with progressive scanning, and 1080i, which consists of 1,920 pels x 1,080 lines for HDTV signals. MPEG-2's Advanced Audio Coding (AAC) was selected for high sound quality. Trellis-coded 8 phase-shift keying was chosen as the modulation system for its efficient frequency utilization.

Tentative technical standards have been established for digital terrestrial broadcasting, and practical broadcasting methods are under study. These standards are distinguished from those of other nations by support for robust mobile reception, which is expected to encourage integrated products such as handheld receivers with personal digital assistant (PDA) functions and vehicle-mounted receivers with car-navigation functions. According to the Ministry of Posts and Telecommunications' schedule, test trials of digital terrestrial broadcasting in the Tokyo area will begin in 2000 and country-wide service will begin by 2006. Analog broadcasting will be phased out by 2010.

United States

In 1994, several companies including DirecTV, USSB and Primestar began multichannel digital satellite broadcasts and now serve more than five million subscribers.

The Federal Communications Commission (FCC) has been studying digital terrestrial broadcasting since 1987. In 1993, broadcast-related companies formed the Grand Alliance aimed at integrating standards for digital broadcasting. The Grand Alliance's Advanced Television Systems Committee established the ATSC standard in 1995, which the FCC selected for its Digital Television (DTV) standard in 1996. The final choice among the 18 formats specified in the ATSC standard is left to the discretion of the broadcasting companies.

According to the FCC's implementation schedule, the four major networks will inaugurate digital terrestrial broadcasting services in ten metropolitan areas with the largest numbers of viewers by May 1999 and in the 30 largest cities by November 1999. Other commercial broadcasters will follow by May 2002, and public television stations by May 2003. Analog broadcasting will be phased out in 2006. The four major networks and the Public Broadcasting Network (PBS) began offering digital broadcasting services this fall, 1998. The launching of the space shuttle carrying Senator John Glenn and Astronaut Chiyaki Mukai on October 29 was safely accomplished and simultaneously broadcast by CBS using Mitsubishi Electric's HDTV codec for digital transmissions to major cities including New York and Los Angeles. Interest was high, and the broadcasts were a great success.

Europe

The EU is setting policy for digital broadcasting development in the form of EC Directives, while the Digital Video Broadcasting (DVB) Organization, a private-sector standards body of broadcasters, network operators and manufacturers, together with EU and national government representatives, has developed a family of digital broadcasting standards. The European Telecommunication Standards Institute (ETSI), representing some 34 countries of a 'greater technical Europe,' has established the final standards.

Exploitation began with digital satellite broadcasting services using quadrature phase-shift keying (QPSK), begun by companies such as Telepiu (Italy), Canal Satellite (France) and recently BSkyB (UK). These are based on the DVB-S standard (EN 300421) completed by ETSI in 1994 .

Cable soon followed with the DVB-C standard (EN 300429, also completed in 1994), using up to 256-quaternary amplitude modulation (QAM). In its established markets, cable generally provides a complementary delivery service of largely the same program services available off-air, but not always in the same service area, and some other 'one-stop' attractions to subscribers.

The latest arrival is digital terrestrial TV (DTT) broadcasting, with its more complex, but highly multipath-resistant, coded orthogonal frequency-division multiplexing (COFDM) form of modulation. This employs selectable modulation from QPSK up to 64-QAM on nominal 2000 or 8000 OFDM carrier implementations within a 7 or 8MHz TV channel. From a DVB-T draft in 1995, ETSI released the final standard (EN 300744) in 1997. The UK has recently implemented services with a mix of 'simulcasting' existing analog program services and new digital-only programs supplied by both existing and new commercial providers (ON digital). The rapid deployment of major new digital transmitter networks was facilitated by the UK Digital TV Group's influential implementation standards for interoperability, known as the 'D-book.'

Although the current digital broadcasts in Europe are only standard-definition TV (576i, 50Hz), HDTV forms part of the DVB standards, with commercial services on the horizon, especially as the standards have been extended for use outside Europe in both 50 and 60Hz countries. Indeed, DVB-HDTV has been demonstrated at broadcasting trade shows such as ITVS '95 & '97 and NAB '98.

Digital Broadcasting Standardization

Standardization of digital broadcasts is essential to ensure that various types of broadcasting equipment can be linked (interconnectability), different services can work alongside each other to all receivers (interoperability), and that content can be made available over heterogeneous networks (interavailability). Fig. 2 illustrates the relationships between international, regional and private-sector standards organizations.

Broadcast-related international standards for

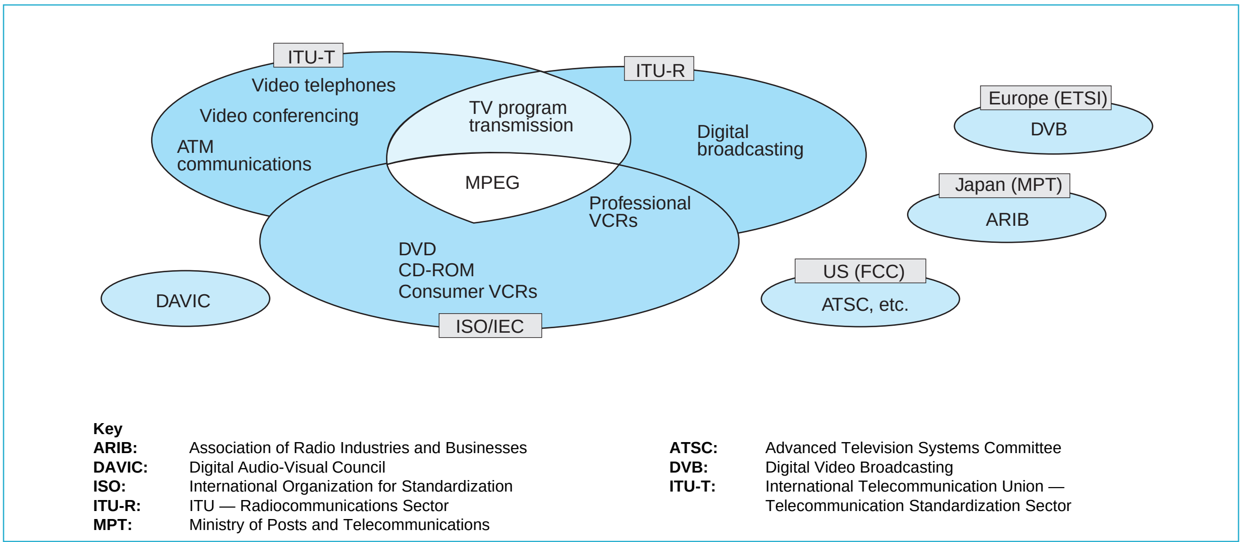

Fig. 2 Digital broadcasting standardization organizations.

program exchange are being drafted by the ISO/IEC and ITU-T Study Group 9 (television and sound transmission), with ITU-R Study Group 10 (broadcasting service—sound) and Study Group 11 (broadcasting service—television). Regional standards organizations—the Advanced Television Standards Committee (ATSC) in the United States, the DVB in Europe and the Association of Radio Industries and Businesses (ARIB) in Japan—determine the broadcasting standards in each world region.

The MPEG standards developed by ISO/IEC have made a huge contribution to the implementation of digital broadcasting. The MPEG-2 generic video and audio source coding and multimedia multiplexing standards have been widely adopted for digital broadcasting as well as for telecommunications and production of prerecorded media.

Digital Broadcasting Systems and Services

Among the keys to future digital broadcasting systems will be interconnectivity of such systems among various nations, interavailability of content, and the applicability of a single set of technologies to satellite, terrestrial and cable transmission channels, as well as to multimedia applications apart from broadcasting. As competition among manufacturers of digital broadcasting systems intensifies, Mitsubishi Electric is assembling demonstration systems compliant with various standards of Japan, the United States and Europe, including ARIB, ATSC, SMPTE, DVB and DAVIC. The corporation has also tested educational and surveillance applications, and is tailoring system specifications to market demand in anticipation of new business developments. Fig. 3 illustrates a demonstration system that will meet Japanese, American and European requirements for digital broadcasting.

Development at Mitsubishi Electric

Mitsubishi Electric has actively participated in international standards work while developing a full range of broadcast-related products, systems and technologies, including satellite newsgathering (SNG) systems, digital TV studio systems compatible with Japanese, American and European standards, digital broadcasting receivers, home multimedia networks, and semiconductor devices. The corporation has also shown high activity in the industry by digital broadcasting demonstrations at the NAB '97 and NAB '98 broadcasting equipment trade shows. The following paragraphs summarize these various activities.

STANDARDIZATION ACTIVITIES. Mitsubishi Electric has been actively involved in ITU's work on video-coding systems for video-telephone and video-conferencing applications as well as on MPEG, DAVIC and other standardization projects. The corporation is also working intensively with domestic and international standards organizations

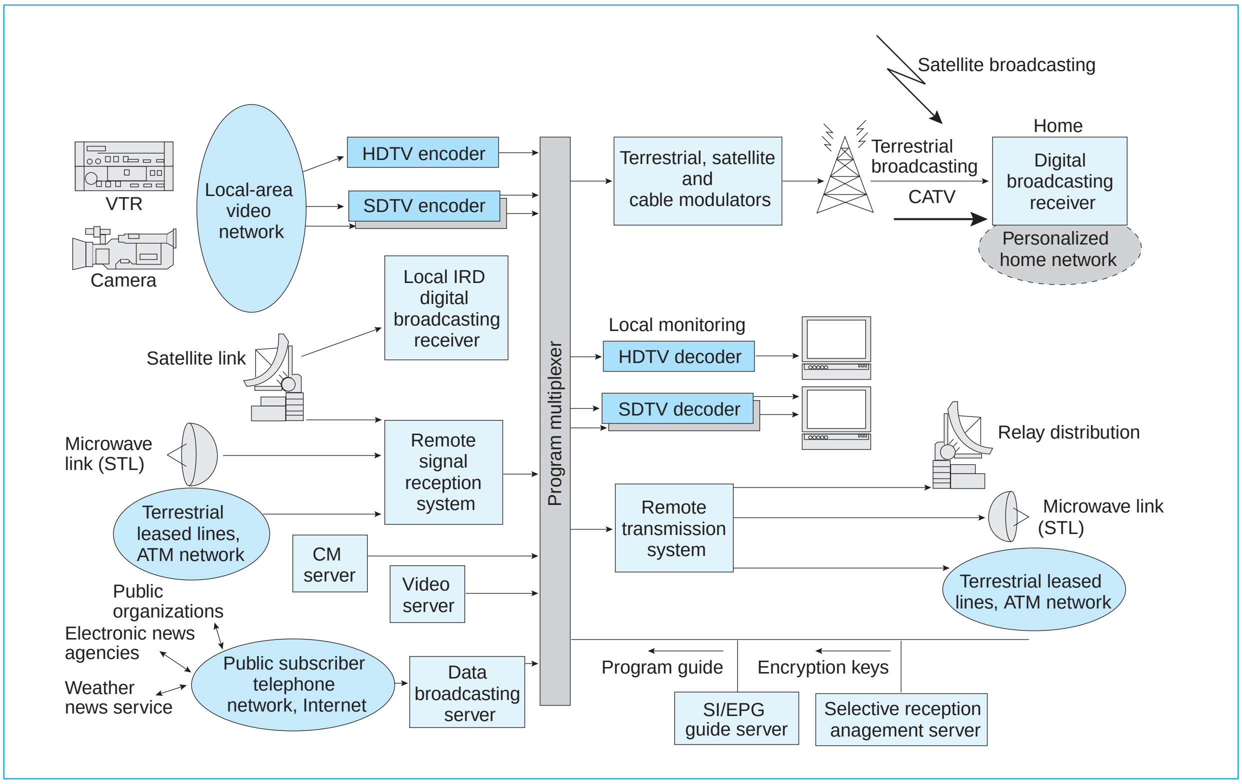

Fig. 3 Digital broadcasting station conforming to Japanese, American and European standards.

on digital broadcasting, testing technologies, drafting standards proposals and contributing to the conceptual model. This pioneering work has enabled the company to lead the market in broadcasting codecs and SI/EPG editing equipment.

GATHERING AND DISTRIBUTION SYSTEMS. SNG codecs are at the foundation of networks for gathering and distributing source material. Mitsubishi Electric's SNG codec products for SDTV include Model VX-3000, a compact MPEG-2-compliant codec for the 480i video format that features a short processing delay, and Model VX-3000M, a high-signal-quality codec compliant with the MPEG-2 4:2:2 profile. Model VX-3000P, a progressive scan codec, is currently being prepared for commercial production. For HDTV signals, the corporation offers the Model MH-2000 MPEG-2-compliant video codec for source contribution and primary distribution.

DIGITAL BROADCASTING SYSTEMS. Mitsubishi Electric is developing the various equipment required to implement digital broadcasting systems including digital broadcasting codecs, program multiplexing units, SI/EPG editing equipment, video banks, CM servers and data broadcasting servers. Digital broadcasting codecs include Model MH-1100 for HDTV, Model BC-1100 for SDTV, both with a film mode for handling cinematic material. Program multiplexer Model TM-1100 implements efficient multiplexing of multiple signals that can include SDTV programs, SI/EPG signals and data.

DTV RECEIVERS. In preparation for the November 1998 start of digital television broadcasts in major American cities, Mitsubishi Electric has developed a 73-inch DTV receiver that can handle all 18 ATSC formats as well as conventional NTSC signals. The DTV receiver, which includes a digital broadcasting decoder and a 73-inch projection TV, converts 1080i and 720p HDTV, among other video signal formats, to HDTV-quality 1920 pel x 1080 line signals for display on the screen. The corporation is also developing personal computers and AV equipment with IEEE1394 interfaces to handle electronic program guides and other auxiliary data to be incorporated into digital broadcasts.

DIGITAL BROADCASTING LSIS. Mitsubishi Electric is developing semiconductor devices (LSIs) that will lower the size and cost and increase the performance of digital broadcasting transmitting and receiving equipment. The company has independently developed several MPEG-2-compliant LSIs for video coding and motion compensation, and has developed five LSIs for DTV receivers in cooperation with Lucent Technologies: an 8-VSB demodulator, an MPEG-2-compliant demultiplexer, MPEG-2-compliant video and audio decoders, and a display controller.

NAB '97 AND NAB '98 DEMONSTRATION SYSTEMS. At NAB '97, Mitsubishi Electric supplied the HDTV codecs for a ATSC-sponsored demonstration of DTV transmission. Encoders at NBC-affiliated station WHD in Washington DC and CBS-affiliated KLAS in Las Vegas sent high-quality HDTV video and audio signals to a decoder at the ATSC booth in the show's Las Vegas venue, demonstrating the feasibility of digital broadcasting.

At NAB '98, the corporation demonstrated the Model MH-1100 HDTV codec, Model BC-1100 multichannel SDTV codec, Model TM-1100 program multiplexer, and an SI/EPG compiler. Also, in association with the DVB organization, Mitsubishi Electric demonstrated terrestrial 60Hz HDTV broadcasting for the first time in DVB format. Furthermore, using a Mitsubishi HDTV encoder, Station KLAS conducted a terrestrial broadcast of HDTV video from the Nagano Olympics which was received and displayed by major equipment manufacturers. Throughout this testing, Mitsubishi Electric codecs demonstrated video and audio capabilities amply suitable for professional use.

FUTURE DEVELOPMENTS. Mitsubishi Electric is actively involved in supporting the spread of digital broadcasting both within and beyond Japan, the United States and Europe. One of the key areas currently under development is MPEG-4, a standard for multimedia data encoding that will facilitate the task of incorporating data transmissions into digital TV broadcasting and open the door to more sophisticated multipurpose services integrating broadcasting, telecommunication and personal-computer functions. The corporation will focus much of its effort on development of digital broadcasting codecs, parlaying its advanced technologies into future products that will offer enhanced functionality and performance, compact dimensions and lower prices.

Cooperation from all sectors—governments, manufacturers, service providers, content production houses and viewers—will be needed to implement digital broadcasting on a global scale. The remainder of this special issue introduces Mitsubishi Electric's work in the field of digital broadcasting and illustrates the possibilities of these new services. ❑

A Model Digital Broadcasting Station

*by Susumu Oka and Norihiko Nakazawa**

Mitsubishi Electric has assembled a model digital broadcasting station to test equipment and systems for delivering digital programming via satellite, terrestrial and cable broadcasting networks in Japan, Europe and the United States. The model station serves as a testbed for checking specifications compliance and optimizing the design of production systems.

Digital Broadcasting Systems

MPEG-2-based video and audio coding and multiplexing technologies are at the focus of standards and equipment development as European, American and Japanese broadcasting stations prepare to deliver new services using digital signal formats.

Digital broadcasting stations will provide a variety of new services over satellite, terrestrial broadcasting and cable distribution networks using a content-gathering, distribution and broadcasting system similar to that illustrated in Fig. 1. System equipment based on computers and high-speed networks must be developed and optimized while complying with the requirements of the relevant international and regional standard organizations including the International Standardization Organization (ISO), International Engineering Consortium (IEC), Digital Audio-Visual Council (DAVIC), Advanced Television Systems Committee (ATSC), Digital Video Broadcasting (DVB) and the Association for Radio Industries and Businesses (ARIB).

A Model Digital Broadcasting Station

Mitsubishi Electric is developing digital broadcasting equipment and has assembled a model

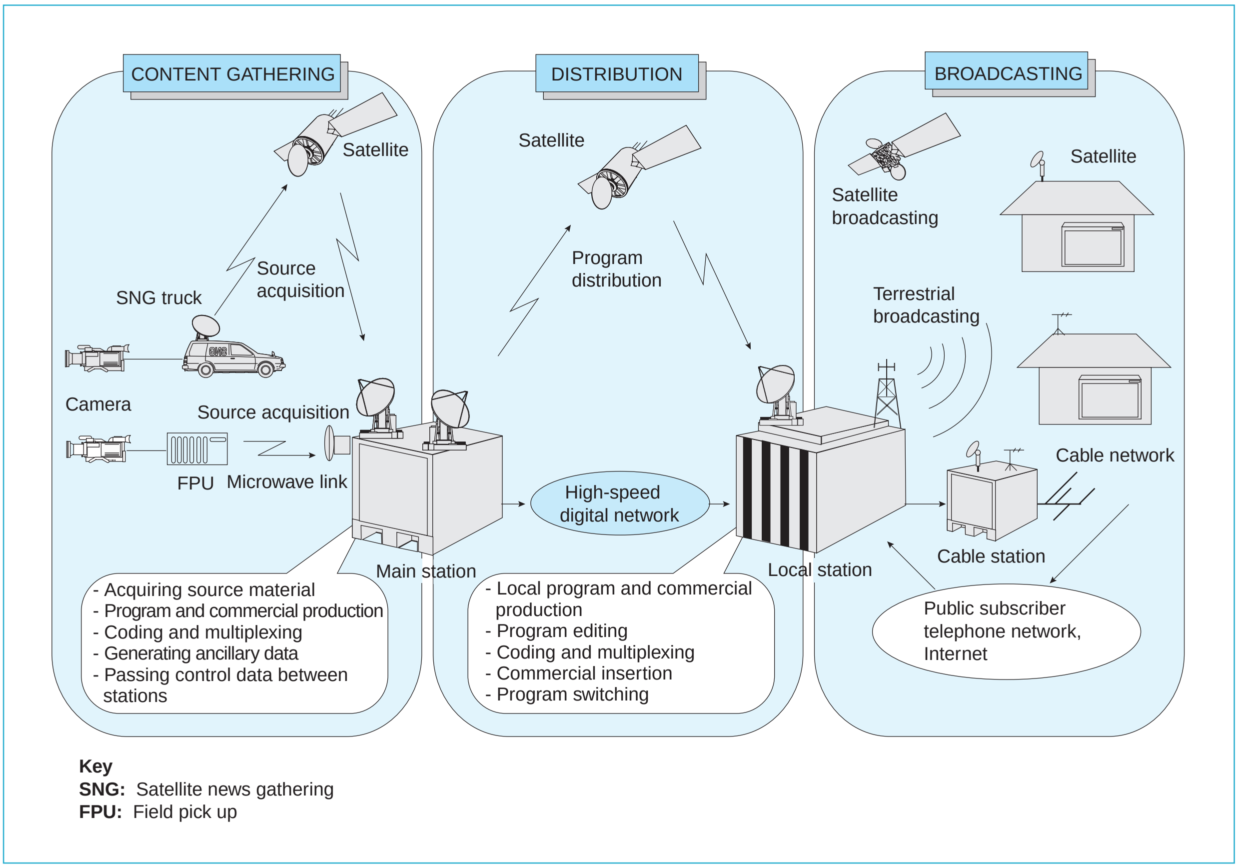

Fig. 1 A digital content-gathering, distribution and broadcasting system.

**Susumu Oka and Norihiko Nakazawa are with the Information Technology R&D Center.*

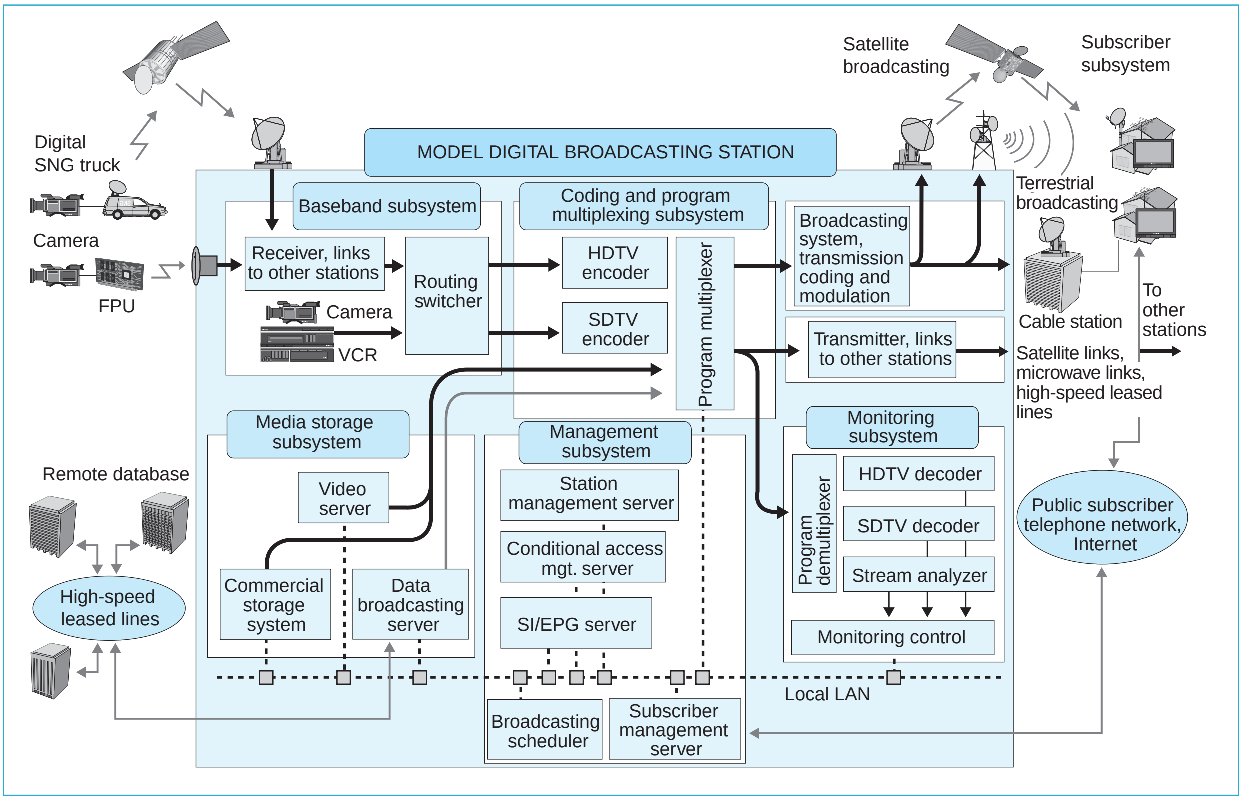

Fig. 2 A model digital broadcasting station.

digital broadcasting station (Fig. 2) that will serve as a testbed for developing commercial systems.

The model station is configured as functional blocks. The baseband subsystem handles raw uncompressed video streams received from digital cameras and VCRs or other stations. The coding and multiplexing subsystem compresses and multiplexes program source material. The media storage subsystem includes media storage equipment and a data-broadcasting server. The management implements program-transmission control, electronic program guide (EPG) and conditional access functions. The monitoring system is used to verify the normality of the outgoing transmissions.

The other key element in the system is the subscriber subsystem, a compatible digital broadcasting receiver that decodes the compressed and multiplexed programs, delivering video, audio and data content to the viewer.

Evaluating Using the Model Station

Fig. 3 shows a verification model developed to ensure the compatibility of our model station equipment with the satellite, terrestrial and

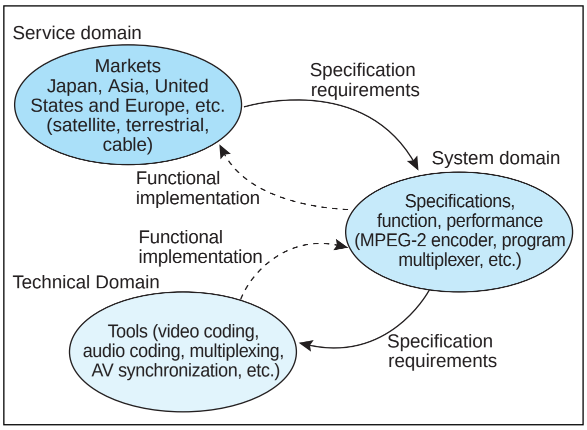

Fig. 3 Verification classes for model station.

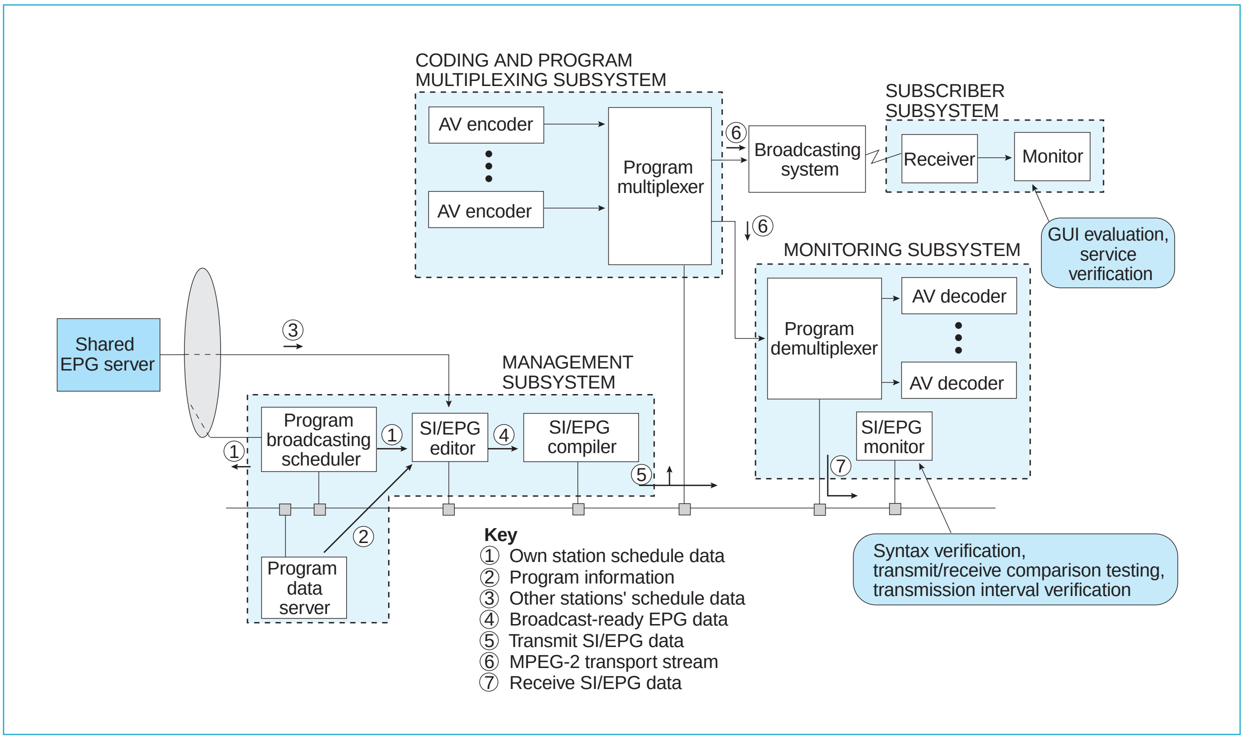

Fig. 4 Verification flow for an electronic program guide.

cable broadcasting services of Japan, Europe and the United States. Conformance verification addresses standards compatibility and related technical issues. Compliance verification addresses system specifications and connectivity issues. Interoperability verification addresses backward compatibility with analog broadcasting services and other adaptations required to meet viewer and market needs.

Fig. 4 shows the verification model for a proposed electronic program guide (EPG) service that will allow verification of the EPG data syntax, transmission interval, and viewer display functions.

A complete testbed for digital broadcasting systems, Mitsubishi Electric's model station is an important milestone on the road to delivering digital program content worldwide. ❑

Digital Broadcasting and Home Networks—A DAVIC Perspective

*by Yoshiaki Kato and Shinji Akatsu**

This article reports on standardization activities for MPEG-2-based high quality audiovisual services by the Digital Audio Visual Council (DAVIC). DAVIC is an industry association working towards consensus on interoperability standards for future audiovisual services in applications areas ranging from digital broadcasting to home networks.

The DAVIC Digital Video Distribution System

DAVIC was established in June 1994, when MPEG-2 standards had been completed and broad-band networks such as asynchronous transfer mode (ATM) were becoming commercially available. DAVIC has been working on industrial standards for interoperability of equipment, systems, applications and content in digital broadcasting, interactive video systems and point-to-point communications. Fig. 1 shows the DAVIC system reference model. The DAVIC model includes a service provider system, a delivery system and a set-top box. It also specifies a number of reference points in the system (A1, A9, etc.) The delivery system consists of a core network of ATM or other high-speed backbone network and an access network that delivers content to individual users through subscriber link technologies, such as asymmetric digital subscriber line (ADSL), fiber to the curb (FTTC), hybrid fiber coax (HFC), or satellite. The application program interface (API) standards for the set-top box include the MHEG-5 runtime engine and a Java virtual machine which is hardware and operating-system independent.

Five logical information flows are defined between subsystems.

S1 is a realtime unidirectional stream of MPEG-2 encoded video and audio data, and flows from the server to the set-top box.

S2 is a bidirectional flow between the server and the set-top box for application control and application data that is managed by the user-to-user protocol specified in the MPEG-2 digital storage media command and control (DSM-CC) standards.

S3 carries session control signals under the MPEG-2 DSM-CC user-to-network protocol.

S4 carries connection control signals that manage an individual call.

S5 carries network control signals for the delivery system. Fig. 2 shows the protocol stack at point A9 in the system reference model.

DAVIC Home Network

Consumer electronic equipment with digital control interfaces will eventually be integrated into a home network. Home networks will link a digital broadcasting receiver or set-top box with

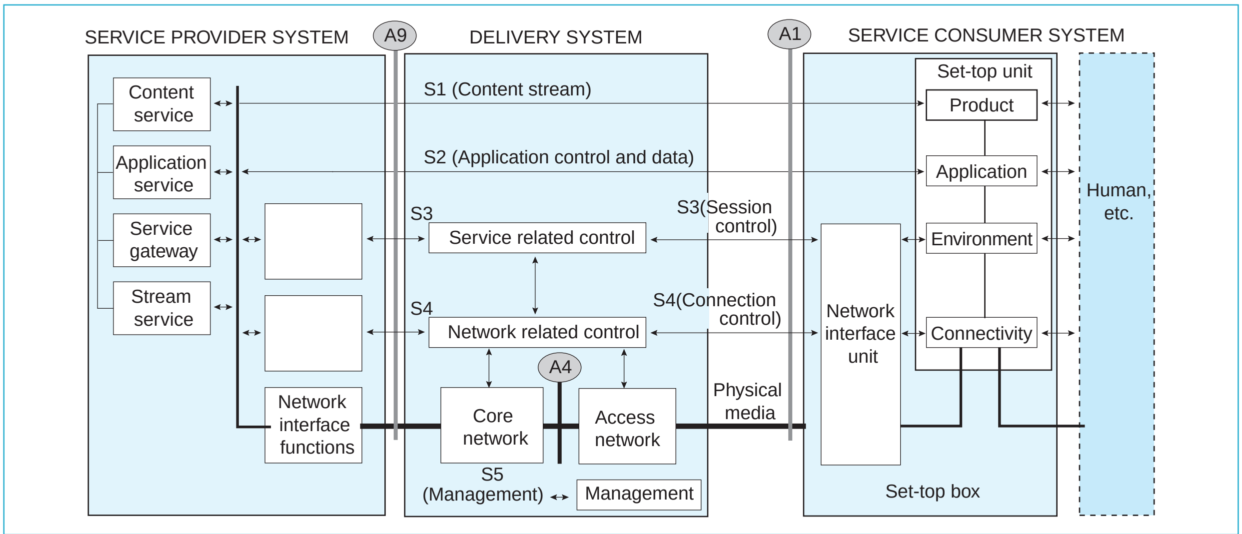

Fig. 1 The DAVIC system reference model.

*Yoshiaki Kato and Shinji Akatsu are with the Information Technology R&D Center.

S1		S2		S3	S4	S5
Application specific layer						SNMP MIB
MPEG-2 ES, private data	MPEG-2 private data	DSM-CC user-to-user		DSM-CC user-to-network	Q.2931	ASN.1 BER
		Other RPC	OMG-IDL			
MPEG-2 PES	MPEG-2 tunnel		OMG UNO			SNMP
MPEG-2 TS			TCP	TCP/UDP	SSCF	UDP
AAL5		IP			SSCOP	IP
		AAL5			ASSL	AAL5
ATM						
Physical layer						

Fig. 2 DAVIC protocol stack at reference point A9.

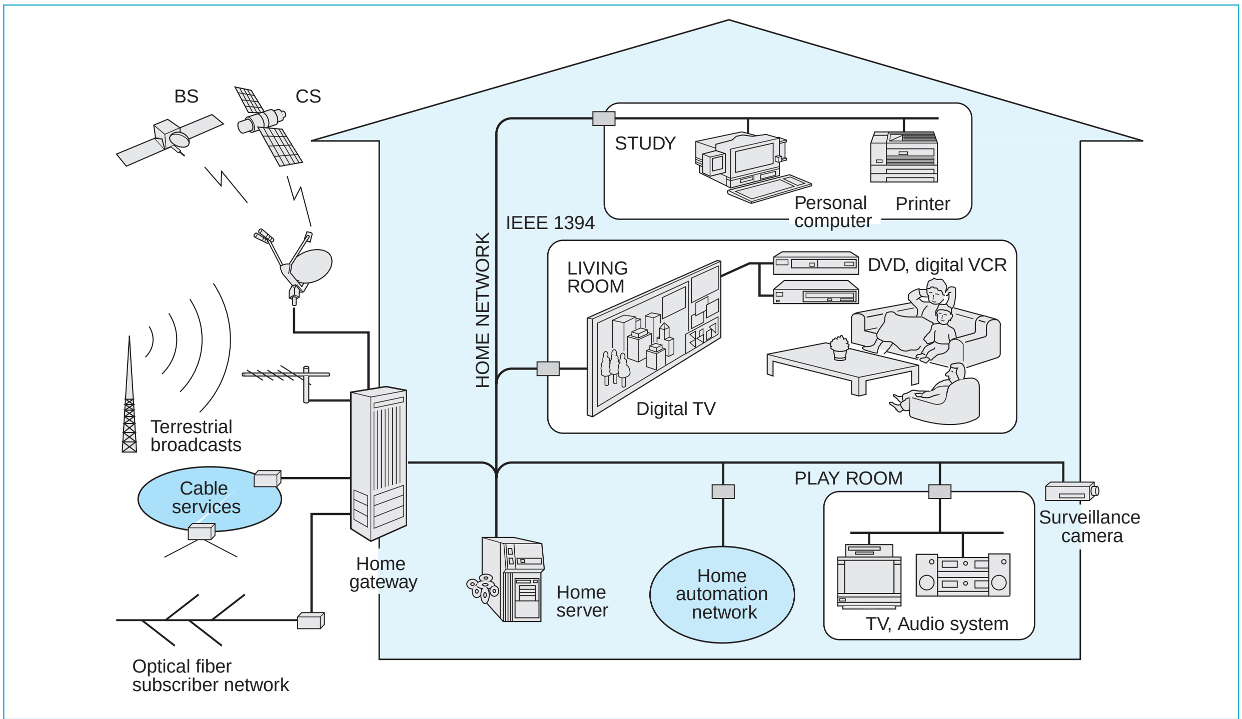

Fig. 3 Home network configuration.

personal computers, home entertainment systems and other information appliances. DAVIC is currently conducting studies on the base architecture and implementation technologies for home networks, and has selected the IEEE 1394 high-speed serial bus for in-home LAN applications. IEEE 1394 achieves transfer rates of 100~400Mbps with a quality-of-service guarantee for realtime data. It also offers benefits of low cost and a simple, "plug-and-play" installation. Fig. 3 illustrates the relationship between a home network and a digital broadcasting receiver. The home gateway provides terminals on the home network with seamless access to external content sources such as satellite and terrestrial broadcasts, and cable and optical fiber based subscriber services. The gateway routes MPEG data streams to digital broadcasting receivers, personal computers and audiovisual equipment. The home server provides large-capacity data storage and playback capabilities to emulate video-on-demand functionality.

DAVIC specifications are currently being presented to the ISO and IEC for adoption as international standards. The standards promise to serve as a foundation for seamless multimedia communications using MPEG-2 encoded content and other high-quality audiovisual services. ❑

References

Digital Audio Visual Council, DAVIC 1.3 Specifications (1997).

MPEG Coding Technologies

*by Kohtaro Asai and Fuminobu Ogawa**

Video compression technology makes it possible to improve the picture quality of digital broadcasts or to send multiple programs over the same channel. MPEG-2 has been developed as an international standard for performing video compression. This article discusses the present and future development of MPEG-2 and related encoding technologies useful for digital broadcasting.

Moving Picture Experts Group (MPEG) is the name for Working Group 11 of JTC1/SC29, a joint technical committee of the ISO and IEC standards organizations. It also names the international standards developed by this working group. MPEG began its work in 1988. The MPEG-1 compression standard, completed in 1993, was designed for bit rates up to 1.5Mbps and is suitable for storage media such as video CDs. The MPEG-2 compression standard, completed in 1994, can handle the higher picture quality needed for digital television and is rapidly finding applications in digital broadcasting and storage media such as DVD. Table 1 lists the nine parts that comprise this standard. The standard specifies rules for encoding and decoding the bit sequences that constitute moving picture data.

Fig. 1 shows the relationships between the first three parts, which we will now describe. To avoid excessive complexity in MPEG-2 video application equipment, the standard defines application classes based on profiles and levels

Table 1 A List of the Component Parts of the MPEG-2 Standard (there is no Part 8)

Part 1	Systems (packet multiplexing and synchronization control)
Part 2	Video coding
Part 3	Audio BC (backward compatible)
Part 4	Compliance test
Part 5	Technical report
Part 6	DSM-CC (CC: command and control)
Part 7	Advanced Audio Coding (AAC)
Part 9	Real Time Interface (RTI)
Part 10	Compliance test for DSM-CC

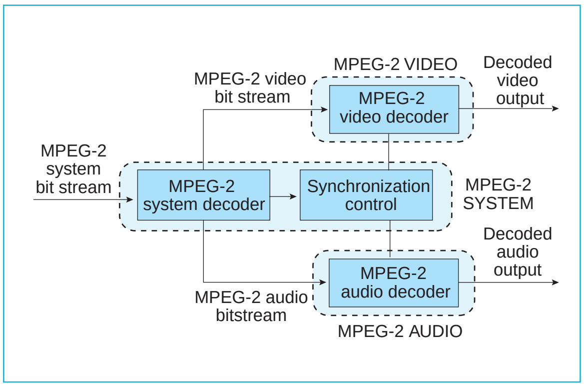

Fig. 1 The three main parts of MPEG-2.

(Fig. 2). Profiles specify the sets of encoding tools associated with syntax, while levels specify resolution and other video parameters. Profiles for digital broadcasting are primarily Main, Simple and 4:2:2. Main adds a bidirectional compensation function to Simple, while 4:2:2 has a high-density color signal suitable for high quality images. In terms of levels, Main corresponds to standard television, while High and H-14 are suitable for HDTV applications. The standard is suitable for a wide range of picture formats, as the format is unspecified. Interlace and progressive scanning formats can also be selected to suit the application.

The key compression methods are motion compensation and discrete cosine transform (DCT) coding. Motion compensation removes data redundancies over time, while DCT removes data redundancies over space. Motion compensation can be bidirectional and can be conducted at frame and field levels. Bidirectional compensation offers superior performance at scene changes or when one object moves in front of another.

In the area of audio coding, the MPEG-2 Backward Compatible (BC) standard was established in November, 1994, and the Advanced Audio Coding (AAC) standard in April, 1997. BC is based on the MPEG-1 coding algorithm, which is a combination of bandwidth multiplex coding and adaptive quantization based on an auditory perception model. BC has been extended to handle the multiple audio channels associ-

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	Simple profile	Main profile	SNR scalable profile	Spatially scalable profile	High profile	422 profile	Multiview profile
High Level Up to 1920 pel/line Up to 1152 lines		MP@HL Up to 80Mbit/s			HP@HL Up to 100Mbit/s	422@HL Under discussion	MVP@HL Up to 130Mbit/s
H-1440 Level Up to 1440 pel/line Up to 1152 lines		MP@H-14 Up to 60Mbit/s		Spt@H-14 Up to 60Mbit/s	HP@H-14 Up to 80Mbit/s		MVP@HL Up to 100Mbit/s
Main Level Up to 720 pel/line Up to 576 lines	SP@ML Up to 15Mbit/s	MP@ML Up to 15Mbit/s	SNR@M Up to 15Mbit/s		HP@ML Up to 20Mbit/s	422@ML Up to 50Mbit/s	MVP@HL Up to 25Mbit/s
Low Level Up to 352 pel/line Up to 288 lines		MP@LL Up to 4Mbit/s	SNR@LL Up to 4Mbit/s				MVP@HL Up to 8Mbit/s

Key: (grey) : Undefined

Fig. 2 Profiles and levels specified in MPEG-2.

ated with stereo and multilingual broadcasts. In AAC, MPEG-1 compatibility is sacrificed for higher coding efficiency. AAC includes three profiles: Main, where sound quality is given priority; Low Complexity (LC), which minimizes code processing cost and hardware scale; and Scalable Sampling Rate (SSR), a variable bandwidth option which further reduces decoder complexity by lowering the signal bandwidth to suit the particular application.

The MPEG-2 System part handles multiplexing and synchronization. Multiplexing is the task of breaking audio and/or video streams into packets. A transport stream (TS) and program stream (PS) are defined. A TS can transport multiple programs using fixed-length packets, and is used in channels that are subject to errors. A TS can also transmit information about programs and program data streams for implementing electronic program guide (EPG) and program selection functions. A PS, which has a undefined packet length and can carry only a single program, is intended for DVD and other recording media.

Digital Broadcasts and MPEG-2

Different countries are implementing a variety of MPEG-2 based digital TV broadcasts. The Digital Television (DTV) system being developed in the United States defines 18 picture formats. The final selection among these numerous alternatives is being left to the marketplace, and each of the television networks has announced different policies. In Japan, the MPEG-2 Main profile and Main level (MP@ML) have been adopted for CS digital broadcasts, and the High level has been adopted for BS digital broadcasts. For audio encoding, the United States has adopted Dolby Laboratories' AC-3 system, while Europe is using BC. Japan has adopted BC for its CS broadcasts and the newly established AAC standard for broadcasts. Both BS and CS employ MPEG-2 multiplexing, while different methods are being used for error-resistant framing and modulation.

The Present and Future of MPEG Standards

MPEG work is underway to complete version 1 of the MPEG-4 standard by a target date of December 1998. MPEG-4 will likely be used through lossy, low-speed channels such as wireless communications and Internet connections. Its low bit-rate capabilities may also be used for multiplex programming or data transfer via digital broadcasting channels. MPEG-4 consists of System, Visual and Audio parts. The System part handles multiplexing and synchronization management, and defines scene description

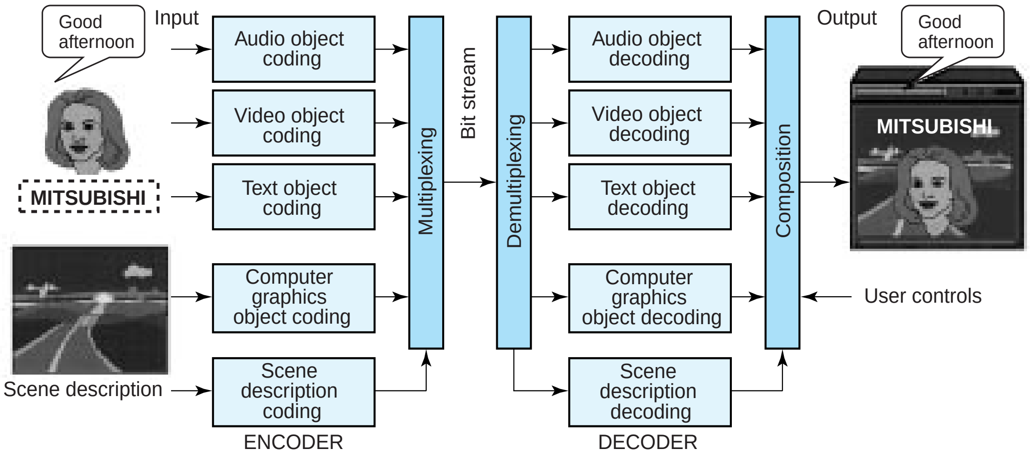

Fig. 3 MPEG-4 coding and decoding.

methods. Scene description combines multiple AV objects into a single composite screen (Fig. 3). The visual part permits objects recorded in the image to be handled as independent logical objects. In a continuation of the natural image object coding in MPEG-2 and other standards, the MPEG-4 visual part defines texture and object shape coding methods. Audio coding methods can be selected to suit the particular audio object type, typically voice or music. Coding tools for high-quality audio and speech synthesis are also defined.

Studies for MPEG-7, the successor to MPEG-4, have begun in earnest. MPEG-7 targets standards for supplementary information about program content such as description, affiliation and characteristics that will facilitate program searches. The standards are planned for completion in the year 2001.

The MPEG standards are based on coding technologies developed for video conferencing and other multimedia applications. Mitsubishi Electric has actively participated in standards development since commercial video conferencing systems have been available and is continuing to contribute to the development of international standards. The standards prescribe the narrowest set of conditions required to ensure compatibility, giving manufacturers wide latitude to select function and performance to suit hardware constraints and application requirements. Mitsubishi Electric has been pioneering equipment and systems in step with standardization activities, retaining proprietary technologies for commercial implementations of existing standards while continuing research toward new standards. ❑

Digital Broadcasting Codecs

*by Okikazu Tanno and Takashi Honda**

Digital broadcasting coder-decoders (codecs) are a critical component of developing digital broadcasting technologies. Mitsubishi Electric has developed two codecs and a program multiplexer for program distribution, terrestrial and satellite broadcasts and cable delivery. This report introduces the Model MH-1100 codec for HDTV applications, the Model BC-1100 codec for SDTV applications and the Model TM-1100 program multiplexer.

Performance Requirements

Image quality is the dominant requirement on codecs for broadcasting applications, since the quality of the compressed video signal determines the quality available to broadcasting services. For example, a codec capable of delivering HDTV quality images in the 6MHz bandwidth used by current analog TV broadcasts would make the transition to digital broadcasting highly attractive. A second major requirement is functionality to support multiplexing of several program channels and data for electronic program guides and other purposes. Fig. 1 shows the basic configuration of Models MH-1100, BC-1100 and TM-1100 for implementing various digital broadcasting functions.

The Model MH-1100 HDTV Codec

Mitsubishi Electric has been developing coding technologies for HDTV applications for several years. The corporation's previous products include Model MH-1000, an MPEG-2 compliant HDTV codec, and Model MH-2000, a transportable MPEG-2-compliant HDTV codec for satellite newsgathering applications. The newly developed Model MH-1100 is an ATSC -compliant codec for HDTV applications. Exhibited at the NAB '98 broadcasting equipment show in the United States, it combines high image quality with excellent movement tracking. Fig. 2 shows a photograph of the codec and Table 1 lists the major specifications. Its main features are described below.

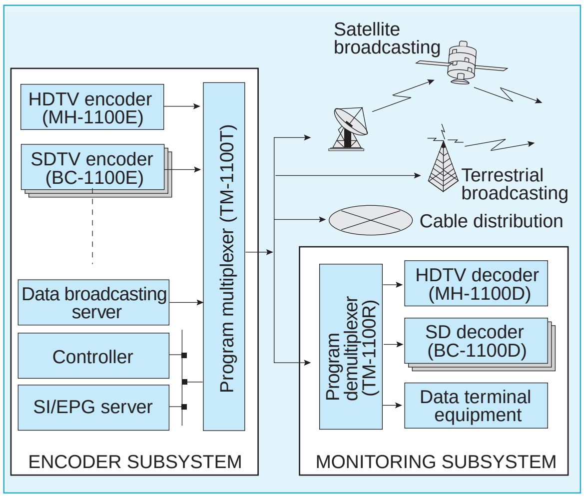

Fig. 1 Basic configuration.

Table 1 Major Specifications of Model MH-1100

Video	
I/O interface (Y,Pb, Pr)	SMPTE292M-compliant digital serial SMPTE260M/274M-compliant digital parallel SMPTE240M/274M/RP160-compliant analog
Field rates	59.94Hz, 60Hz
Picture formats	1,920 pel x 1,080 lines, 1,440 pel x 1,080 lines
Chroma formats	4:2:0, 4:2:2
Coding system	MPEG-2 MP@HL
Film mode	Automatic film-clip detection and 3:2 pull-down
Video bitrate	Up to 100Mbps
Data multiplexing	EIA-708-compliant closed captions
Audio	
I/O interface encoder	AES/EBU 6-channel digital x 2 6-channel analog x 2 SMPTE299 embedded 8 channels AC-3 (IEC958) streams x 2
I/O interface decoder	AES/EBU 6-channel digital x 2 SMPTE299 embedded 8 channels AC-3 (IEC958) streams x 2
Coding systems	AC-3 5.1 channel, PCM
Bitrate	AC-3 5.1 channel, 32kbps~512kbps, PCM 1,152kbps/channel
Others	
Low-speed data transfer	RS-422A parallel synchronous at 64, 128 or 192kbps
Media multiplexing format	MPEG-2 transport stream (TS)
Transmission interface standards	RS-422A parallel, DVP-SPI, DVB-ASI, SMPTE 310M, ECL serial/parallel, DS-3, ATM
Form factor	19-inch rack-mounting chassis

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Fig. 2 Model MH-1100E encoder.

Realtime Coding and Decoding: Mitsubishi Electric has developed original parallel processing LSIs that perform realtime coding and decoding of HDTV video streams by dividing the image into six phases that are processed in parallel. ES buffers provide adequate capacity for each phase while a smoothing function eliminates irregularities at phase boundaries. Model MH-1100 can perform realtime coding and decoding of high-definition images at bitrates up to 100Mbps.

Image-Quality Control: Performance in this area varies considerably with the manufacturer. The MH-1100 has achieved a 10~20% improvement in image quality over previous equipment by using an adaptive design in which a preprocessor analyzes the image characteristics and selects an appropriate group of pictures (GOP) configuration. The digital signal processors (DSPs) that perform the coding operations adjust the quantization value accordingly in macroblock units.

Automatic Detection of 3:2 Pulldown: HDTV programs often incorporate film clips that have been converted from the original 24 frames/second to 30 frames/second. The MH-1100 automatically detects the extra fields in this material and removes redundant information, freeing capacity for higher picture quality or for auxiliary data channels.

Closed Caption Support: The MH-1100 supports transmission and reception of EIA-708- compliant closed captions required in the United States for hearing-impaired viewers.

Table 2 Major Specifications of Model BC-1100

Video	
I/O interfaces	Composite analog (SMPTE 170M) or digital serial composite or component (SMPTE259M)
Field rate	59.94Hz
Picture format	704 pel x 480 lines, interlaced
Chroma format	4:2:0
Coding system	MPEG-2 MP@ML
Film mode	Automatic film clip detection and 3:2 pull-down
Video bitrate	3~15Mbps
Data multiplexing	EIA-708 compliant closed captions
Audio	
I/O interfaces	AES/EBU 6-channel digital x 2 AC-3 (IEC958) streams x 2
Coding system	AC-3 5.1 channels (external unit)
Audio bitrate	32~512kbps for AC-3 5.1 channel stream
Others	
Low-speed data transfer	RS-422A parallel synchronous at 64, 128 or 192kbps
Media multiplexing format	MPEG-2 transport stream (TS)
Transsmission interface standards	DVB-SPI, RS422A parallel
Form factor	19-inch rack-mounting chassis

Model BC-1100 SDTV Codec

Developed for standard-definition broadcasting applications, this codec has the specifications listed in Table 2 and the following features.

High Picture Quality Technologies: Model BC-1100 performs MPEG-2 MP@ML coding using proprietary control technologies that ensure high image quality.

Automatic Detection of 3:2 Pulldown: As with Model MH-1100, Model BC-1100 detects incorporation of 24 frame-per-second material and adjusts coding procedures accordingly.

Closed Caption Support: I/O and transmission of EIA-708-compliant closed captions is supported.

Dynamic Bitrate Allocation: This is supported for applications in which multiple codecs are used with Model TM-1100 program multiplexer.

Model TM-1100 Program Multiplexer

Model TM-1100 was developed to support new services that will be available through digital broadcasting such as multichannel broadcasts, electronic program guides and general-purpose data transmissions. Fig. 3 shows Model TM-1100 configured for multiplex program transmission. The multiplexer performs packet multiplexing according to specified rules to combine TS data

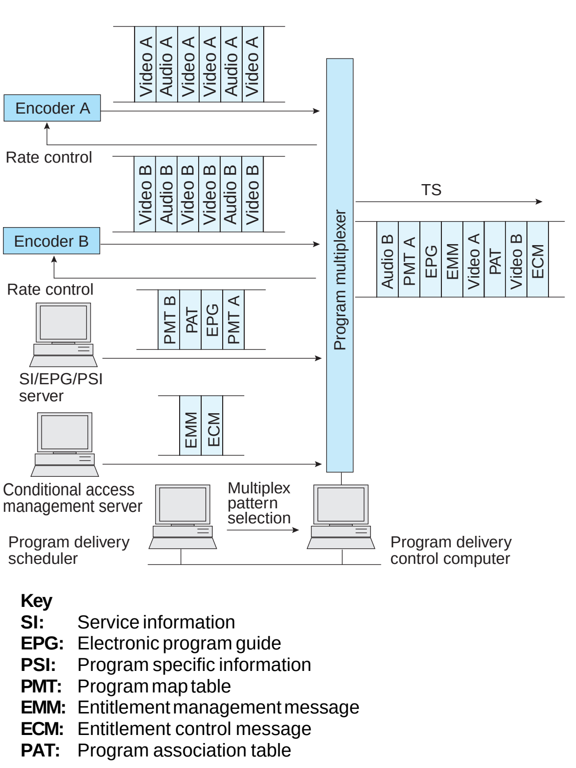

Fig. 3 Program multiplex operation.

Table 3 Major Specifications of Model TM-1100

Input	
MPEG-2 TS	RS-422A parallel (proprietary specifications, 70Mbps max., 8 channels max.), DVB-SPI/ASI (70Mbps max., 8 channels max.)
Broadband data	100BASE-TX (1 channel)
Auxiliary data transfer	RS-422A parallel (2 channels)
Time data	GPS receiver interface (NMEA-0183, RS-232C, 4.8kbps)
Output	
Transmission interface	DVB-ASI (120Mbps max.) x 2 channels DVB-SPI (120Mbps max.) x 1 channel RS-422A parallel (120Mbps max.) DS-3 (44Mbps max.) x 2 channels SMPTE310M (19.39Mbps) ECL serial/parallel (120Mbps max.)
Multiplex	
Format	MPEG-2 TS
Multiplex method	Fixed-rate and dynamic-rate bandwidth allocation, TS remultiplexing with time stamp compensation and packet ID editing
Others	
Control interfaces	RS-232C, 100BASE-TX, front panel controls, alarm output relay contacts
Form factor	19-inch rack-mount chassis

streams from codecs, program specific information (PSI) and service information/electronic program guide (SI/EPG) data from the management system and entitlement control message/entitlement management message (ECM/EMM) data from the conditional access system to deliver a single TS packet stream. Table 3 lists the major specifications. The features are described below.

Variety of Multiplex Patterns: To suit the needs of a variety of applications, Model TM-1100 can be set for fixed-rate multiplexing, in which each program is assigned a constant rate; statistical multiplexing, in which bandwidth is dynamically assigned to program channels; or opportunistic multiplexing in which the codecs are set for variable-rate operation and the remaining bandwidth is allocated to other services.

Sixteen-Channel Capacity: Multiplexing of up to 16 channels can include HDTV, SDTV, audio and other program material.

TS Remultiplexing: The TM-1100 uses time stamps in incoming TS data streams to recover the clock signal and compensate for transmission delays prior to multiplexing with other streams. The multiplexer can also add, edit and delete PSI data, and modify packet identification codes.

Support for Electronic Program Guide Services: The multiplexer can receive SI data and electronic program guide (EPG) information from a server at specified intervals and multiplex this data with the program streams. PSI data can also be taken from a server and incorporated into a TS packet stream.

Support for Data-Broadcasting Services: The multiplexer can receive information over a high-speed LAN from a data-broadcasting server and multiplex this data into a TS packet stream.

Support for Various TS Transmission Interfaces: A variety of TS I/O interface standards are supported to meet the needs of digital broadcasting applications in Japan, Europe and the United States, including satellite, terrestrial and cable services. These include DVB-ASI/SPI, SMPTE310M and DS-3.

Models MH-1100, BC-1100 and TM-1100 are suitable for configuring scalable systems for DTV and private network broadcasting applications including program editing, distribution, storage, broadcasting and monitoring. Their commercial availability marks a significant step closer to implementation of digital broadcasting services on a large scale. ❑

An SNG Codec

*by Ken'ichi Asano and Gen Sasaki**

The satellite newsgathering (SNG) networks deliver video and audio source material over satellite links to broadcasting stations and networks for production of news, sports and other programming. SNG networks have shifted from analog to digital transmission technologies in which codecs are used to compress the bandwidth of digital signals. Mitsubishi Electric has developed SNG codecs for Japan's four commercial broadcasting networks.

SNG Networks

Each of Japan's broadcasting networks has an SNG network using the commercial Superbird or JC-SAT communication satellites to collect or relay source material for news and other programs. These networks support wide-bandwidth and live-transmission capabilities over wide areas independent of terrestrial infrastructure. This means they can be used virtually anywhere, including locations where other facilities are unavailable.

Fig. 1 illustrates the configuration of a typical SNG network. The network can comprise several types of earth station: main earth station, sub earth station, affiliated earth station, mobile earth station and portable earth station. Video and audio sources recorded on site are transmitted from a mobile or portable earth station via satellite channel to earth-station facilities at the broadcasting center. In addition, a bidirectional communication line called an "order wire" can be set up over the same link to allow program production staff to discuss source content, editing and other issues, even while the content is being transmitted. Programs can be relayed between broadcasting earth stations in the same way.

Each earth station, whether portable or fixed, has an antenna, digital signal transmitter and receiver, a video codec to compress and decompress the video and audio signals, and cameras, VTRs and other baseband equipment.

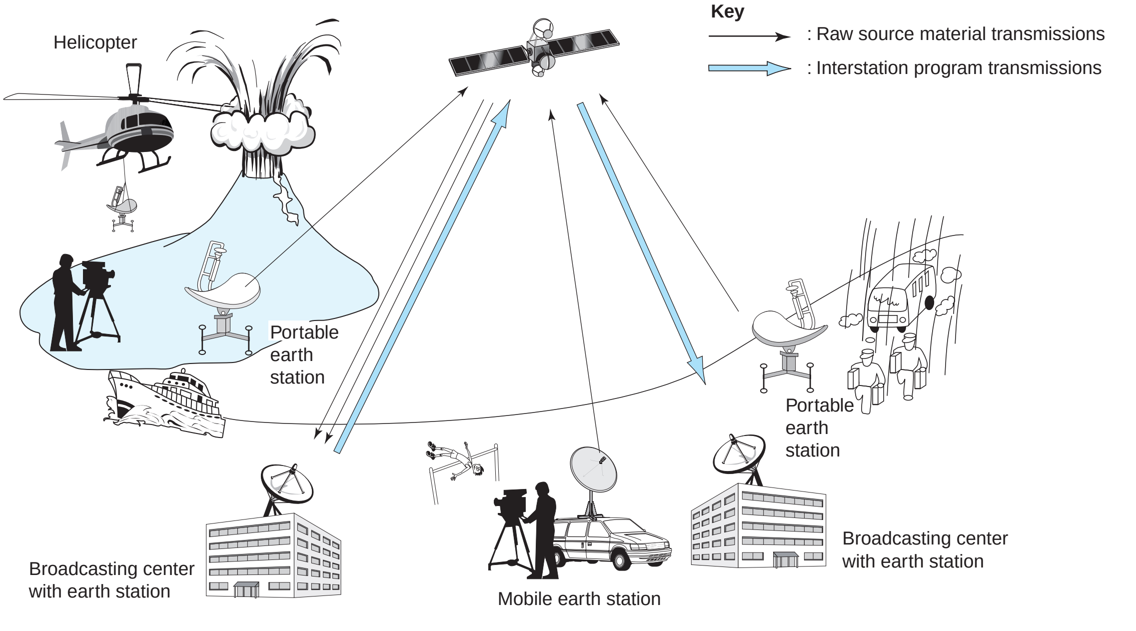

Fig. 1 A satellite newsgathering network.

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Fig. 2 VX-3000 Series codec.

Video Codec

Video codecs have made it possible to convert analog SNG networks to digital because codecs increase link utilization efficiency and increase the tolerance of the satellite link to fading and other error sources. At the transmitter, the codec compresses the source data, which can include video and audio streams and auxiliary data, then multiplexes the compressed data, adds robust error-correction codes and performs digital modulation. At the receiver, the codec demodulates the incoming signal, performs error correction, and then decodes the original video, audio and auxiliary data.

SNG codecs support several special functions suited to SNG applications. First, they support high picture quality—better than analog networks—to provide a sufficient margin for editing and other processing. Second, they offer short processing delay, which supports realtime conversations in live on-site reports. Third SNG codecs are light enough for mobile or portable use. Fourth, they use strong error-correction codes that prevent line disturbances from disrupting transmissions.

Mitsubishi Electric has developed and is delivering MPEG-2-compliant VX-3000 Series SNG codecs with these attributes. Fig. 2 shows a photograph of a VX-3000 Series codec. An original coding-control technology provides high picture quality for broadcasting use while the unit is small enough for portable applications. The codecs are already in operation at Japan's four commercial networks.

Codecs are one of the cornerstones of digital broadcasting technology, pumping video and audio streams with maximum efficiency over satellite links from remote sites to the program production centers of the major broadcasting networks. ❑

DTV Receiver

*by Kenji Tsunashima and Takashi Kan**

By using a digital television (DTV) receiver chipset consisting of five different chip types, Mitsubishi Electric engineers have succeeded in constructing a compact DTV receiver decoder conforming to the United States Advanced Television Systems Committee (ATSC) DTV standards[1]. The monitor is based on a newly developed 73-inch high-resolution projection TV set.

DTV Broadcasting Decoder

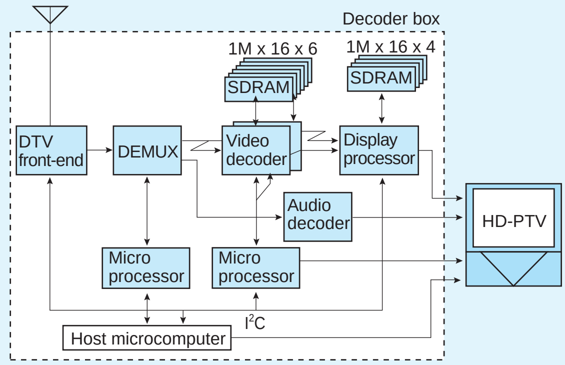
A block diagram of the DTV broadcasting decoder appears in Fig. 1. The decoder consists of the core chipset of five different LSIs: (1) an 8-vestigial sideband (VSB) demodulator; (2) demultiplexer (DEMUX), video decoder, audio decoder and display processor); (3) a DTV tuner; (4) SDRAM memory and (5) a microprocessor. DEMUX and video decoder are controlled by a dedicated microprocessor. The host microcomputer, connected with the system primarily via an I²C bus, integrates control over a broad range of other functions including channel tuning.

8-VSB-DEMODULATOR. The construction of the signal reception front-end using this demodulator appears in Fig. 2. A signal from the 8-VSB demodulator is input to a double-conversion type DTV tuner. The first intermediate frequency (IF) of this DTV tuner is 920MHz and the second IF is set at 44MHz. The second IF output from the tuner is passed through a surface acoustic wave (SAW) filter, then converted into a low frequency passband signal with a center frequency of 5.38MHz by a down converter. Subsequent analog/digital conversion of the down-converter output signal yields a 10-bit digital signal which is then input to the 8-VSB demodulator using the 21.5MHz clock pulse (i.e., twice the symbol rate) supplied by the 8-VSB demodulator itself.

TRANSPORT STREAM PROCESSING. The DEMUX chip is controlled by an external microcomputer, and performs the following processing.

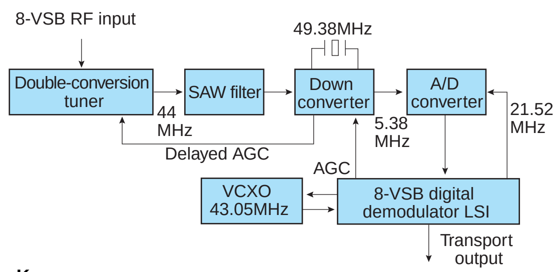
1. Separation of Video and Audio Data

Video and audio data are separated, and video data is sent to a video decoder in the packetized elementary stream (PES) format specified by the MPEG-2 standard. The audio data is fed to an audio decoder in elementary stream format. The audio data is first stored in DRAM, then, to maintain audio and video synchronization, it is delayed before output by an appropriate amount based on the presentation time stamp.



Key
HD-PTV: High definition for Projection TV
DEMUX: Demultiplexer

Fig. 1 Block diagram of the DTV receiver.



Key
AGC: Automatic gain control
VCXO: Voltage controlled crystal oscillator
VSB: Vestigial sideband
SAW: Surface acoustic wave
A/D: Analog-to-digital

Fig. 2 Architecture of the DTV receiver front-end.

2. Channel Tuning

Tuning is performed based on system information stipulated in the ATSC standard "Program and System Information Protocol for Terrestrial Broadcasting and Cable"[2]. At receiver setup,

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the virtual channel table (VCT) is extracted from the transport stream by the DEMUX unit, tuning frequencies are associated with virtual channels, and this information is sent to the host microcomputer. During tuning, the host microcomputer receives a virtual channel number from the projection TV and sends it to the microcomputer controlling the DEMUX chip while setting the tuner frequency. The DEMUX unit uses the VCT to determine the video and audio PIDs corresponding to the virtual channel, and extracts packets for the respective PIDs as video and audio data.

VIDEO DECODER. A decoder for high-definition television (HDTV) images must be capable of high-speed operation and data exchange with external memory and, to ensure this, two video decoders are operated in parallel[3]. The compressed video signal is supplied by the DEMUX to the two video decoders in PES format. Of these two chips, one handles decoding for the top half of the screen and the other handles that for the bottom half. During decoding of either half of the image, reference must be made to parts of the decoded image in the other half for motion prediction processing. This means providing a decoder communication interface between the two chips for the exchange of decoded image data.

The decoded video data in macro-block format is passed from the video decoder to a display processor chip[4] for format conversion. At

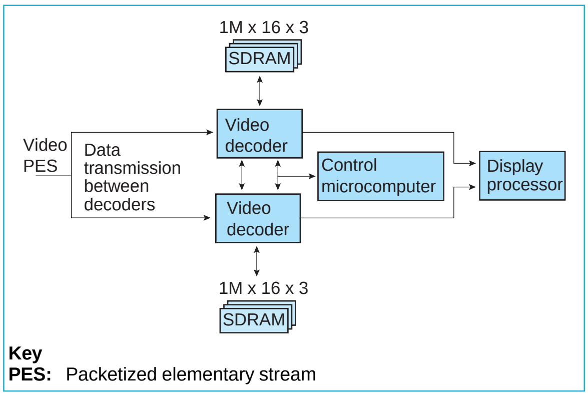

Fig. 3 Construction of the video decoder subsystem.

the display processor, the data is converted from macro blocks to raster-scan format and, for HDTV formats, it is also converted into an 1080-line interlaced image for output (Fig. 3).

High-Resolution Projection TV

We have developed a high-resolution projection TV which both accepts these signals from the DTV broadcasting decoder and also receives NTSC broadcasts. When receiving NTSC broadcasts, and digital TV broadcasts other than HDTV, the image up-converter circuit converts the data to image signals appropriate for HDTV display. In developing this high-resolution projection TV, we added the following improvements to the optical subsystem:

1. Development of a High-Resolution 9" CRT
A newly-developed electron gun produces a high intensity (I_k=6mA) beam with a spot diameter about 30% smaller than previous types, to maintain good image resolution even at high brightness levels.

2. Precision Lens for the 9" CRT
A large-diameter precision lens matched to the 9" CRT was also developed to provide a 40% improvement in the resolution characteristic, for 960 horizontal dots.

3. Adoption of a Fine-Pitch Screen
By opting for an 0.72 mm pitch, the finest pitch of any 73"-wide screen in current use, degradation of image detail was minimized.

Development Problems

DTV STORAGE FUNCTIONS. In order to cope with diversifying storage formats, more sophisticated recording and playback technologies are needed, such as simultaneous recording of multiple programs, simultaneous recording and playback, and multichannel playback. At present, Mitsubishi Electric is using relatively expensive computer hard disks on a trial basis to study responsiveness, access speed, capacity and other performance parameters, with the aim of creating a multifunctional storage device for HDTV.

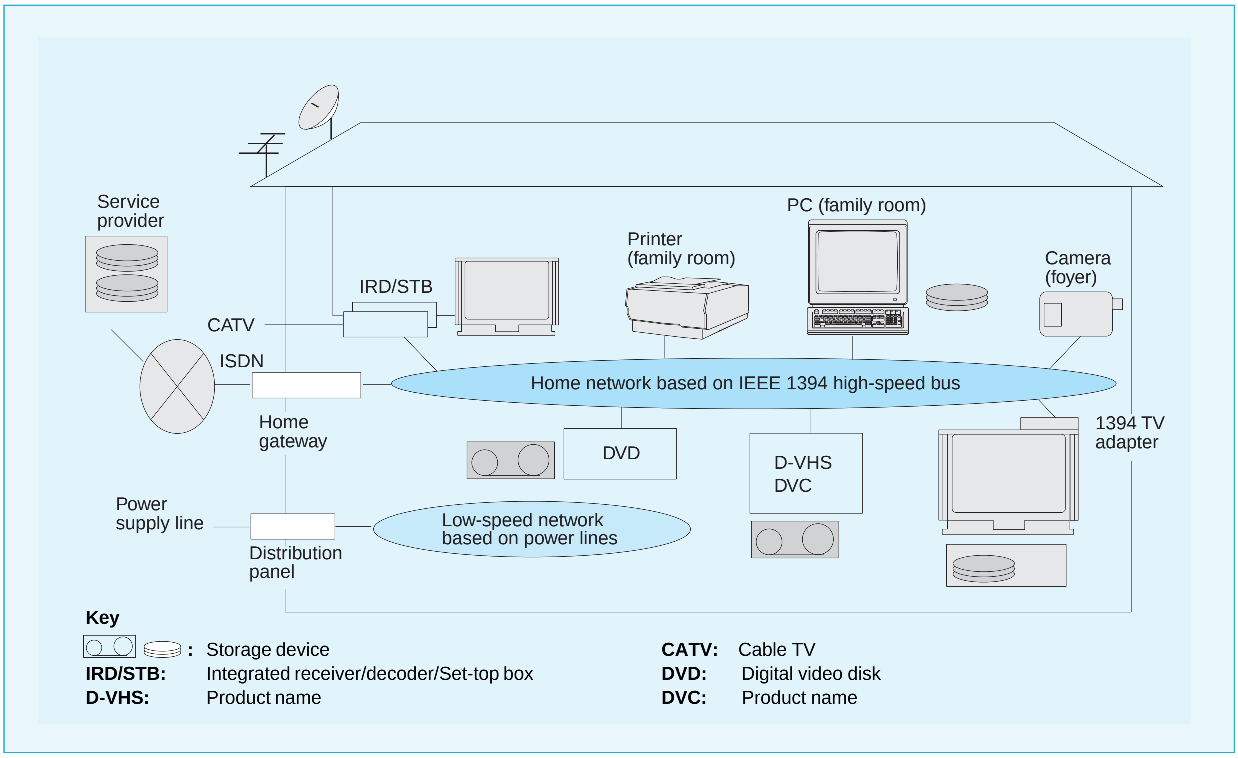

Fig. 4 Home network based on an IEEE 1394 bus and storage device.

In the future, in addition to developing the storage device itself, it will be necessary to develop an inexpensive and efficient means of producing media for DTV data storage. Innovations will probably include high-speed parallel access, a hierarchical design combining different media types, and a recording method suited to image and audio data.

HIGH-SPEED INTERFACE FOR DTV (IEEE 1394). We are now studying the application of the IEEE 1394 serial bus as a high-speed interface connecting digital TVs with other home-use audio and video equipment, and with communication devices, set-top boxes, PCs and other products.

In the past, Mitsubishi Electric has tested and evaluated 1394 interface boards for use with personal computers, satellite broadcasting-receiver integrated receiver/decoder (IRD), color printers and other devices in addition to a 1394 adapter for TV sets, in order to explore the possibilities of the IEEE 1394 bus. But in order to utilize it as a high-speed DTV interface, a number of problems must first be solved, including definition and standardization of copy-protection functions and of the control command set (Fig. 4).

In closing, we wish to thank the engineers at Lucent Technologies (U.S.) who participated in the joint development of the DTV chipset. ❑

References

[1] United States Advanced Television Systems Committee, ATSC Digital Television Standard (1995-9).

[2] United States Advanced Television Systems Committee, Program and System Information Protocol for Terrestrial Broadcasting and Cable (1997-12).

[3] Duardo, O., Hsieh, S., Wu, L., Boo, J., Khurjekar, A., Hingorani, R., Wilford, P., Bolton, B., Morinaka, H., Okada, K., Hosotani, S., Sumi, T., DaGraca, P., Yamamoto, H., Poon, T.: An HDTV Video Coder IC for ATV Receivers, IEEE Transactions on Consumer Electronics, 43, No.3, 628~632 (1997-8).

[4] Hosotani, S., Yazawa, M., Matsuo, N., Sugawa, S., Hayashi, N., Shinohara, T., Imamura, Y., Takashima, M., Okada, K., Sumi, T.: A Display Processor Conforming to All DTV Formats with 188-Tap FIR Filers and 284Kb FIFO Memories, IEEE Transactions on Consumer Electronics, 43, No.3, 837~845 (1997-8).

DTV LSIs

*by Tetsuya Matsumura and Siro Hosotani**

In this article we introduce key devices used in digital TV (DTV) transmission equipment and DTV receivers. Among LSIs used in transmission equipment, we report on chipsets consisting of a video-encoding LSI and a motion-estimation LSI. These chips are provided with resolution expandability: a single chipset is capable of realtime encoding at standard-definition TV (SDTV) resolution (480-line interlaced or 480i), and multiple chip combinations support 720-line progressive (720p) or 1080-line interlaced (1080i) and other resolutions. As devices used in receiving terminals, we describe a chipset comprising five LSIs developed jointly with U.S. Lucent Technologies.

LSIs for DTV Transmission Equipment

The MPEG-2 international standard[1] governs video encoding for digital broadcasts, and digital TV (DTV) transmission equipment must transmit video with broadcasting-level image quality. In order to satisfy this need, Mitsubishi Electric has been engaged in development of a video encoding chipset consisting of a realtime DTV video-encoding LSI and motion-estimation LSIs[2]. In this section we briefly describe the chipset, and then discuss the motion-estimation LSI in some detail.

CHIPSET OVERVIEW. Fig. 1 shows the configuration of an encoding unit based on the video-encoding chipset. The encoding module, consisting of a single encoding LSI, multiple (from two to eight) motion-estimation LSIs, and frame-memory chips, is capable of realtime encoding at SDTV resolution of 480i (MP@ML i.e., Main Profile at Main Level). By employing several such video-encoding modules in parallel, still higher resolutions—480p, 720p, and 1080i—can be accommodated. For instance, 480p and 1080i resolutions are handled by configuring two (n=2) and six (n=6) video-encoding modules in parallel, respectively. The problem of parallel memory access between modules (overlapping) during motion compensation in parallel operation was overcome by providing the encoding LSIs with a dedicated interface. In order to enhance flexibility, the D30V high-performance media processor developed by Mitsubishi Electric was adopted as an internal processor, giving a dramatic improvement in rate control, mode discrimination and other adaptive processing specific to video encoding.

MOTION-ESTIMATION LSIS. In order to create the high-quality images required for DTV broadcasts, it is necessary to employ the full-search method, one of the most accurate motion-estimation techniques, and search over a broad range. In order to do so, a motion-estimation LSI was developed specifically for wide range, full search motion estimation. The single motion-estimation LSI, the ME3, performs searches over a range of +63/–64 pixels horizontally and +31/–32 pixels vertically.

Fig. 2 is a block diagram of the ME3 motion-estimation LSI. The ME3 consists of an input unit for digital image data (template macroblock data, or TMB, and search window, or SW, data); an operation unit for computation of mean

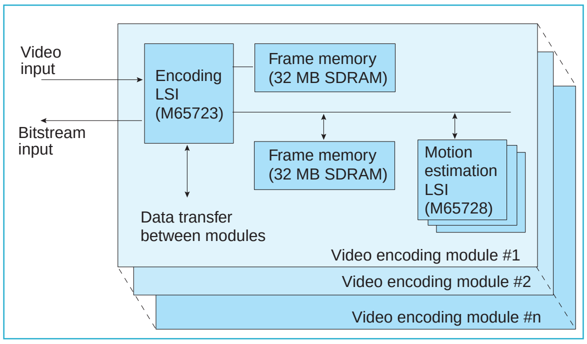

Fig. 1 The video encoding chipset.

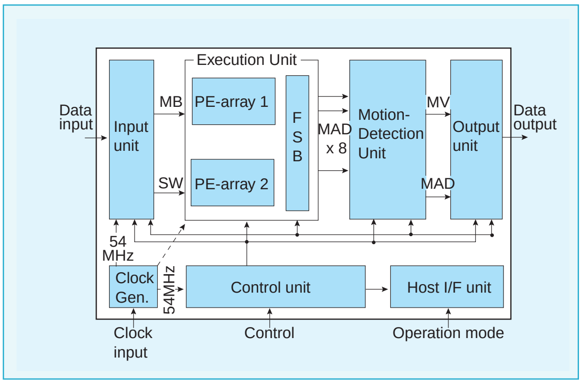

Fig. 2 ME3 block diagram.

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absolute difference (MAD) values used as evaluation values; a motion detection unit for motion vector (MV) estimation through comparison of evaluation values; and an output unit for output of results. The operation array unit adopts a dual-array architecture, with high-efficiency processor arrays (PEs) consisting of 512 PEs arranged in two parallel planes. Each PE array performs full-search block matching, and outputs the MAD of the SW and TMB. This is accomplished by loading the TMB data into the PE array in advance, then shifting the SW data in the vertical direction. In each shift operation, the MAD value is calculated in the execution unit. The dual-array architecture enables searches for four different modes by combining the search methods for each array with the SW data. Each PE array consists of four PPEs of 128 PEs each; either shared SW data or different SW data is supplied, depending on the search mode. The results for each operation unit are added by the final summation block (FSB). Table 1 gives the specifications of the ME3. The ME3 was fabricated using 0.35µm CMOS three-layer metal processes. The chip size is 8.5 x 8.5 mm^2, and it integrates 1.9 million transistors. A photomicrograph of the chip appears in Fig. 3.

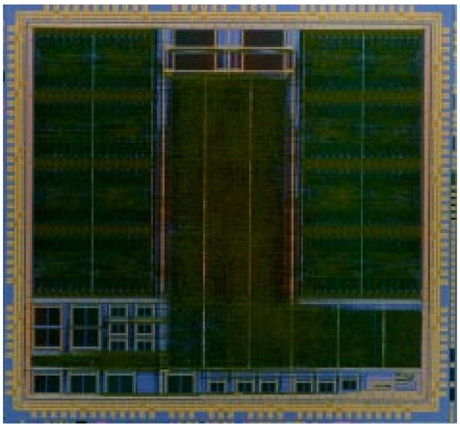


Fig. 3 Photomicrograph of ME3 chip.

Table 1. ME3 Chip Specifications

Technology	0.35µm CMOS and 3-layer metal
Chip size	8.5mm x 8.5mm
Number of transistors	1.9 million
Power supply	3.3V
Clock frequency	54MHz
Power dissipation	1.4W
Package	160pin QFP

LSIs for DTV Receivers

In this section we describe in some detail our strategy for receiver chipsets for the ground DTV broadcasts defined in the Advanced Television Systems Committee (ATSC) standards which are to apply in the U.S. from the end of 1998, as well as a display processor (the M65680WG) with functions for converting various image formats into a desired monitor format.

CHIPSET STRATEGY. The receiver set chipset, developed jointly with Lucent Technologies of the U.S., has functions necessary for DTV receivers, and is in complete conformity with the

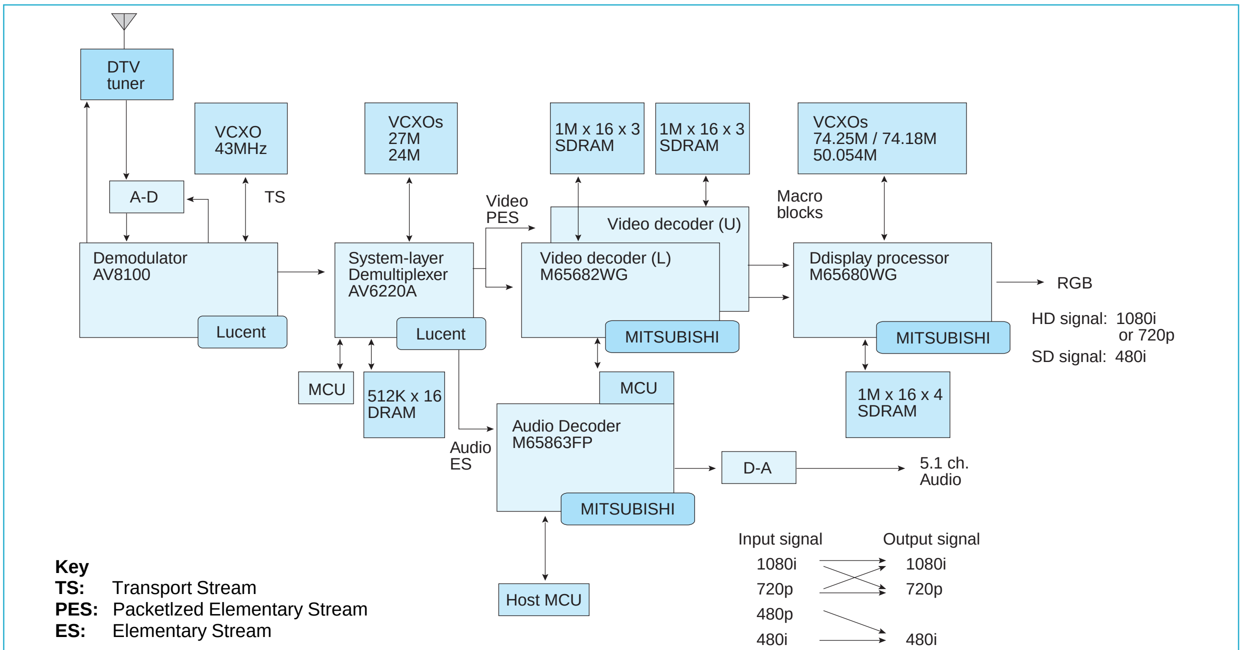


Fig. 4 Block diagram of a DTV receiver.

ATSC standard adopted by the Federal Communications Commission[4]. The chipset consists of five different kinds of chip (six chips in all), comprising:
(1) an LSI for 8-VSB (vestigial side band) digital demodulation (the AV8100A), (2) the system layer demultiplexer (AV6220A—Note: these two type designations are Lucent's), (3 & 4) two video-signal decoder LSIs (M65682WG) with MPEG-2 MP@HL decoding functions, (5) a Dolby digital 5.1 channel audio signal decoder LSI (M65863FP), and (6) a display processor for conversion of all the HDTV formats recommended in the ATSC standard into signals for display on a 720P or 1080I monitor (M65680WG). Fig. 4 shows an example of the block diagram of a DTV receiver.

DISPLAY PROCESSOR. The display processor LSI receives the output of the MPEG-2 video decoder (MP@HL) and performs the signal processing necessary for display on the display monitor. On SDTV input, the signal is converted to a format supported by NTSC monitors, but whenever any of the HDTV formats in the 18 formats recommended by the ATSC is input, the data is converted into 1920 x 1080 interlaced or 1280 x 720 progressive video images, and after performing such display processing as edge enhancement and inverse matrix conversion, the result is output as an RGB analog signal. The operating clock rate and sync signal output timing vary with the format, but are as a rule generated automatically.

Because in DTV there are image sources in up to 18 different formats, format conversion is indispensable in order to display video on a specific monitor. These conversions are accomplished by a format-conversion filter. However, given that there are as many as 18 formats, and that image degradation due to format conversion is forbidden by the HDTV specification, a vast filter, unlike anything seen before, is required—with a total of 172 taps, including ten each of five different kinds. A major problem in LSIs for DTV format conversion is that of reducing the required gate counts of the format-conversion filter. In order to solve this problem, an automatic filter generation program, which extracts the optimum configurations of filters shared in hardware through systematic computer calculations, has been developed. A single-chip display processor is now capable of picture-rate conversion processing including block-raster conversions, three types of scan-format conversions, color-interpolation, edge-enhancement, and inverse-matrix conversion, and has an internal three-channel D/A converter. Fig. 5 is the block diagram of this processor.

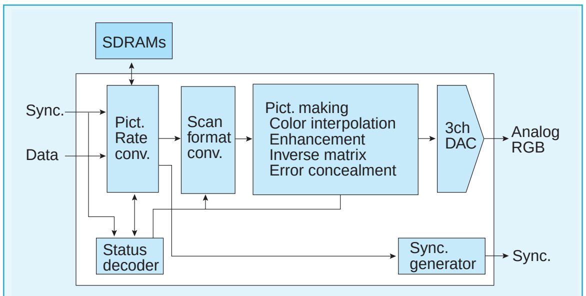


Fig. 5 Display processor block diagram.

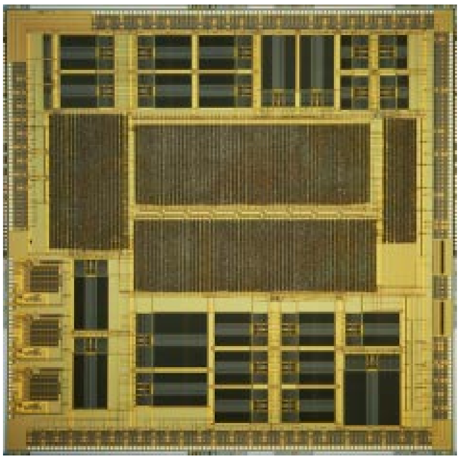


Fig. 6 Photomicrograph of display processor.

Table 2. Display-Processor Chip Specifications

Process	0.5 m CMOS two-layer metal
Chip area	14.9 x14.9 mm^2
Power supply voltage	3.3V
Power dissipation	2.9W
Clock frequencies	54/54.05, 74.18/74.25, 13.5/13.51 MHz
Number of transistors	1.9 million
Internal memory	284kB
Number of filter taps	188
Package	388-pin plastic BGA

Table 2 gives the chip specifications, and Fig. 6 is a photomicrograph of the display processor, an 0.5μm CMOS two-layer metal device integrating 1.9 million transistors and measuring 14.9 x 14.9mm^2. Total integrated memory is 284kB, and there are a total of 188 filter taps, including those for edge enhancement, etc.

By developing chipsets that integrate the key functions required for digital TV transmission and reception, Mitsubishi Electric is laying the foundation for new generations of equipment that will bring digital TV to its huge potential audience, quickly and at minimum cost. ❑

References: see page 28.

Data Broadcasting Service

*by Yukio Yokoyama and Heikan Izumi**

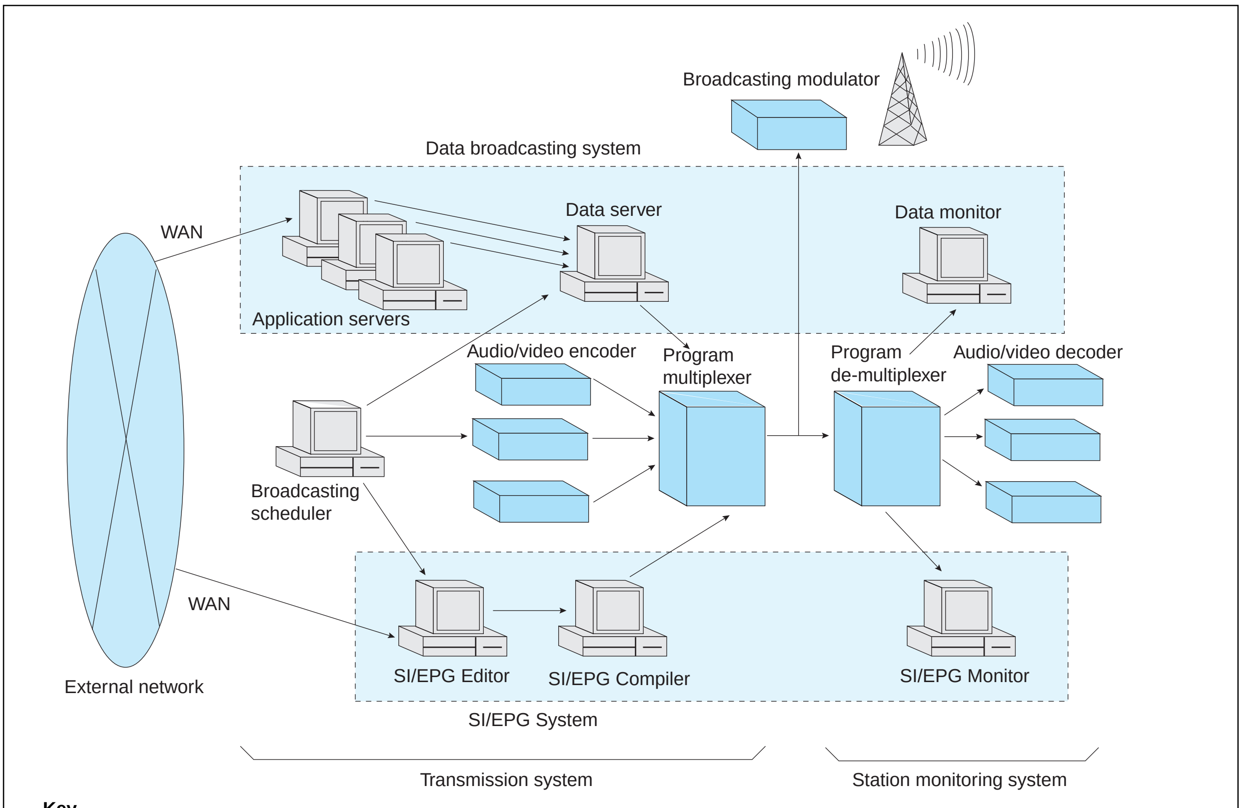
With the emergence of digital television broadcasts, and as channels proliferate and the affinity between television and computers grows, more sophisticated and attractive data-broadcasting services are expected. This article addresses the contents of electronic programs conforming to the U.S. advanced television systems committee (ATSC) standards and related data-broadcasting services, and gives a brief overview of Mitsubishi Electric's system for data-broadcasting services.

The SI/EPG System

In the system information/electronic program guide (SI/EPG) system, channel and program information are broadcast together with the program contents, so that users can view program guides on their TV screens and make program selections. Mitsubishi Electric has developed for the U.S. DTV market an SI/EPG system that enables SI/EPG data to be edited on a personal computer for output to a program multiplexer we have produced (Fig. 1).

The SI/EPG system is intimately related to the station's MPEG encoder equipment, program multiplexer, broadcasting scheduler and other equipment. It consists of the following three devices:

The SI/EPG editor receives program information from the station's broadcasting scheduler and from other stations, and other SI/EPG information necessary for digital TV is added or edited.



Key
WAN: Wide Area Network
SI-EPG: System Information/Electronic Program Guide

Fig. 1. Configuration of a system for data broadcasting services.

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The SI/EPG compiler converts this data to a bitstream in the program and system information protocol (PSIP) standard format specified by the ATSC, and sends the result, together with the schedule, to the program multiplexer.

The SI/EPG monitor receives the SI/EPG information from the program de-multiplexer and displays it, to confirm that the information is correctly distributed.

The main features of this system are as follows:

- It conforms to the ATSC's PSIP standard.
- It provides GUI-based user-friendly editing.
- It schedules compiling & other operations.
- It provides flexible links with station information systems.

The Data-Broadcasting System

A variety of data-broadcasting services are provided by broadcasting other information along with images and audio. In the age of digital broadcasting, these data-broadcasting services are based on the MPEG-2 transport stream (MPEG-2 TS). The following services are possible:

- News, stock prices, worldwide web files and other data can be broadcast for display or storage at receiving sites.
- Data can be transmitted in synchronization with image and audio broadcasting to display related information.
- A network can be configured with broadcasts for the downlink and telephone lines for the uplink, making possible online shopping and other interactive services.

Fig. 1 shows the data-broadcasting system now under development.

The broadcasting scheduler manages information on broadcasting programs and schedules. In addition to audio/video programs, it also manages information on data broadcasting. An application server stores the data to be broadcast, and takes any one of a variety of forms depending on the service. The data server receives data from different application servers, converts this to the data broadcasting protocol, and transfers it to the program multiplexer according to the broadcasting schedule. Data-broadcasting protocols currently supported are the data-carousel protocol, used for periodic re-broadcasting, and multiprotocol encapsulation, used when attaching IP packets or other data units. The data monitor is located within the station, and is used to verify the contents of data broadcasts.

Digital broadcasting, and the new standards being developed for it, support the integration of TV and a wide range of information services. Mitsubishi Electric is commited to developing the systems and hardware to implement these promising new services. ❑

References (continued from page 26)

[1] ISO-IEC/JTC1 SC29, DIS 13818, Part 2, 1994.

[2] A. Hanami, S. Scotzniovsky, K. Ishihara, T. Matsumura, S. Takeuchi, H. Ohkuma, K. Nishigaki, H. Suzuki, M. Kazayama, T. Yoshida, K. Tsuchihashi, "A 165-GOPS Motion Estimation Processor with Adaptive Dual-Array Architecture for High Quality Video-Encoding Application", Proc. IEEE CICC, 9.1.1-9.1.4, 1998.

[3] T. Yoshida, Y. Shimazu, A. Yamada, E. Holmann, K. Nakakimura, H. Takata, M. Kitao, T. Kishi, H. Kobayashi, M. Sato, A. Mohri, K. Suzuki, Y. Ajioka, K. Higashitani, "A 2V 250MHz Multimedia Processor", Proc. IEEE ISSCC, pp. 266-267, Feb., 1997.

[4] FCC ATSC: FINAL TECHNICAL REPORT, Oct. 31, 1995.

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