CHAPTER TEN:

ON THE ROAD TO HDTV

High-definition television (HDTV) transmissions are capable of presenting approximately twice the number of active lines (1,080) that analog TV pictures currently provide. The video images have a sharpness that approaches the clarity of 35-millimeter film and are presented in a wide-screen, cinemascopic format with an aspect ratio (picture width to picture height) of 16:9 as opposed to the 4:3 aspect ratio used by conventional analog TV transmission systems. HDTV also features the broadcast of TV programs in stereo with surround sound.

During the early 1980s, Japanese broadcaster NHK conducted a series of experimental HDTV broadcasts of its analog-based MUSE HDTV system using Japan's "Yuri" DBS satellite platform. The primary drawback to this early effort to improve upon the four-decade-old PAL, NTSC, and SECAM TV standards, however, was the large amount of bandwidth required to broadcast a single HDTV service. NHK demonstrated the MUSE system to the U.S. Congress and Federal Communications Commission (FCC) during the mid-1980s in an attempt to gather support for the adoption of MUSE technology as a new international TV broadcasting standard. In the end, however, the FCC decided to wait until a more spectrum-efficient technology was available. The development of digital compression technologies during the early 1990s proved to be the key to making HDTV a reality for TV viewers around the world.

HDTV is just one component of new digital TV standards approved within the past two years by the FCC and the International Telecommunication Union (ITU). These new standards promise to eliminate the flaws inherent in the PAL, NTSC, and SECAM TV systems. For example, the new global standard for terrestrial broadcasting will accurately portray all the colors of the original image as well as employ sophisticated digital filtering and forward error correction (FEC) techniques to detect and mask out noise, ghosting, and electrical interference from automobiles and electronic appliances. Video "crawl" and other analog TV picture artifacts will also be a thing of the past.

A New Global Standard

On May 30, 1997, The International Telecommunication Union agreed on a new global standard for digital terrestrial television broadcasting (DTTB) that promises to deliver end-to-end digital TV with high-definition quality, and also unify television broadcasting systems worldwide. DTTB represents the construction of a digital architecture that simultaneously can accommodate both high-definition television and conventional standard-definition television services in the terrestrial broadcasting environment, at the same time being interoperable with cable delivery, satellite broadcasting, and recording media.

The ITU also unanimously agreed on the convergence toward a single HDTV production standard based on a High-Definition Common Image Format (HD-CIF) that is characterized by using a single matrix of samples (1,920 pixels by 1,080 lines) irrespective of field and frame rate. This has given equipment manufacturers the go ahead to start delivering TV sets to anywhere in the world, thus providing economies of scale never available before, as well as worldwide portability for consumers and vendors.

The HD-CIF format

The ITU recommendation also unifies two competing standards: the U.S. Advanced Television Standards Committee (ATSC) proposal and the European Digital Video Broadcasting (DVB) proposal. Under the ITU Recommendation, the two systems will form a single compatible system that can be implemented on a global basis within the practical physical limitations of the current terrestrial TV channel assignment environment. Moreover, the new digital system will support multi-program transmissions in existing channels through the use of digital video compression technology.

Analog-based terrestrial TV systems leave adjacent TV channels unoccupied to prevent interference between TV stations operating within the same general broadcast coverage area. It has been determined, however, that the new digital TV services could occupy these unused channels without causing interference to existing analog TV stations. National telecommunications authorities therefore will not need to assign any channel frequencies before introducing DTV services, thereby conserving scarce spectrum resources. Moreover, total use of the frequency spectra assigned for terrestrial TV broadcasting worldwide finally can be utilized in an efficient manner.

Under the ITU plan, existing analog TV transmissions eventually will be phased out (within a ten-year time frame as proposed in the US or within a longer period as envisioned for Europe). As terrestrial TV transmissions change from analog to digital, analog TV sets will be fitted with set-top boxes to enable them to decode and process the new digital TV signals. Chips manufacturers already have announced that they are ready to start mass production of the chips required by the decoders to be integrated in the new TV sets. There currently are 1,288 million TV sets worldwide that eventually will need to be replaced. This is a huge market that represents a golden opportunity for those who work in the consumer electronics industry.

MPEG-2 Profiles, Levels and Layers

The MPEG-2 compression standard is a key component of the new digital TV standards adopted by the FCC and the ITU. As we previously discovered in Chapter Two, MPEG-2 is actually a family of systems, with each system having an arranged degree of commonality and compatibility.

MPEG-2 supports four different Levels: High, High-1440, Main and Low Level.

The High and High-1440 Levels support high-definition (HDTV) and advanced-definition TV (ADTV) pictures with 1,920 × 1,080 and 960 ×576 sample matrices, respectively. Both of these Levels support two spatial resolution Layers, respectively, called the Enhancement Layer and the Base Layer, which broadcasters can use to deliver standard-definition TV (SDTV) signals, as well as ADTV or HDTV signals simultaneously. This is accomplished by using the low-resolution Base Layer to deliver an SDTV signal with a 4:3 aspect ratio while at the same time using one or more Enhancement Layers to deliver the additional data required to produce higher resolution TV pictures with the wider 16:9 aspect ratio. Together, the enhancement and low-resolution Layers deliver all the information that the HDTV set needs to produce a high-resolution picture. SDTV sets receive the data they require exclusively from the Base Layer, while ignoring the data contained in one or more Enhancement Layers.

All digital bitstreams and set-top boxes are classified according to video frame rate, either 25 or 30 frames per second, depending on the accepted standard in each country of operation. Set-top boxes with dual frame rate capabilities also are possible. Although digital bitstreams are set for one of the two frame rates, an MPEG-2 transport stream may carry video program material that is intended for more than one type of digital TV set or set-top decoder.

MPEG-2 also supports five different Profiles: Simple, Main, SNR Scalable, Spatial Scalable and High. Each profile consists of a collection of compression tools. For example, a Main Profile may use up to 720 pixels per line at Main Level, or up to 1,920 pixels per line at High Level. The new DTV standard adopted by the FCC for use in the United States will operate at Main Profile, High Level (MP@HL).

America's Grand Alliance

In 1983, the Advanced Television Systems Committee (ATSC) was formed to coordinate the technical details of implementing a new Advanced Television (ATV) standard for the United States. In 1987, the Federal Communications Commission (FCC) responded to requests from U.S. broadcasters by initiating an ATV rulemaking and establishing an FCC Advisory Committee on Advanced Television Service (ACATS) for the purpose of recommending a new TV broadcast standard for the United States.

The FCC initially defined ATV as any system that results in improved television audio and video quality. Between 1987 and 1995, hundreds of companies and organizations worked together within the numerous subcommittees, working parties, advisory groups and special panels of ACATS to develop a competitive process by which TV system proponents were required to build prototype hardware that would then be thoroughly tested. Along the way, the FCC made several key spectrum decisions concerning the introduction of a new U.S. television standard. In 1990, for example, the Commission decided that new ATV broadcasters would share frequency bands and channel allocations with existing analog-based TV services. The Commission also elected to adopt a "simulcast" approach, whereby the new ATV signals would be broadcast over currently unusable channels and that broadcasters would be temporarily assigned a second channel to accomplish the transition to the new ATV standard.

Six systems, four of which were all-digital, underwent extensive testing in 1991 and 1992 at the Advanced Television Test Center (ATTC) in Alexandria, Virginia. In February 1993, ACATS decided to limit further consideration to the four all-digital systems. Test results showed that all four digital systems provided impressive results, with no single digital system exhibiting a superiority that would warrant its selection over the others as the new U.S. TV standard. ACATS decided to order supplementary tests to evaluate improvements that had been made to individual systems since initial testing.

At the same time, ACATS also adopted a resolution encouraging the competing system manufacturers to try to find a way to merge their efforts by combining the best features of each proposed digital system.

Formed in May 1993, the Digital HDTV Grand Alliance created a "best of the best" system upon which today's DTV standard is based. Members of the consortium are General Instrument Corporation, Lucent Technologies, MIT, Philips Electronics North American Corporation, the David Sarnoff Research Center, Thomson Consumer Electronics, and Zenith Electronics Corporation.

Horizontal Pixels	Vertical Lines	Aspect Ratio		Picture Rate (Fields/sec)			
640	480	4:3	4:3	60 I	60 P	30 P	24 P
704	480	16:9	4:3	60 I	60 P	30 P	24 P
1,280	720	16:9			60 P	30 P	24 P
1,920	1,080	16:9		60 I		30 P	24 P

Figure 10-1. Display formats of the U.S. Digital TV (DTV) Standard

On December 24, 1996, the Commission approved the Grand Alliance's system as the new digital TV (DTV) standard for the United States (Figures 10-1 and 10-2). Since then, the DTV standard has been formally adopted by the telecommunications authorities of Canada, South Korea, and Taiwan and currently is being considered for adoption in Argentina, Australia, Brazil, China, Mexico, and Singapore.

The DTV Modulation Subsystem

The DTV standard employs compression technology that is based on MPEG-2 at Main Profile, High Level (MP@HL) and includes the use of Bi-directional Frame (B-Frame) motion compensation techniques that improve picture quality. The DTV digital modulation subsystem for terrestrial broadcast applications is based on 8-VSB (vestigial sideband) transmission technology, which ensures a broad coverage area, reduces interference with existing analog broadcasts, and provides immunity from interference into the digital signal. Terrestrial broadcasters will transmit at a maximum bit rate of 19.28 Mbit/s, which can support a single HDTV program or as many as five standard-definition television (SDTV) programs with a visual quality that is superior to analog NTSC TV signals.

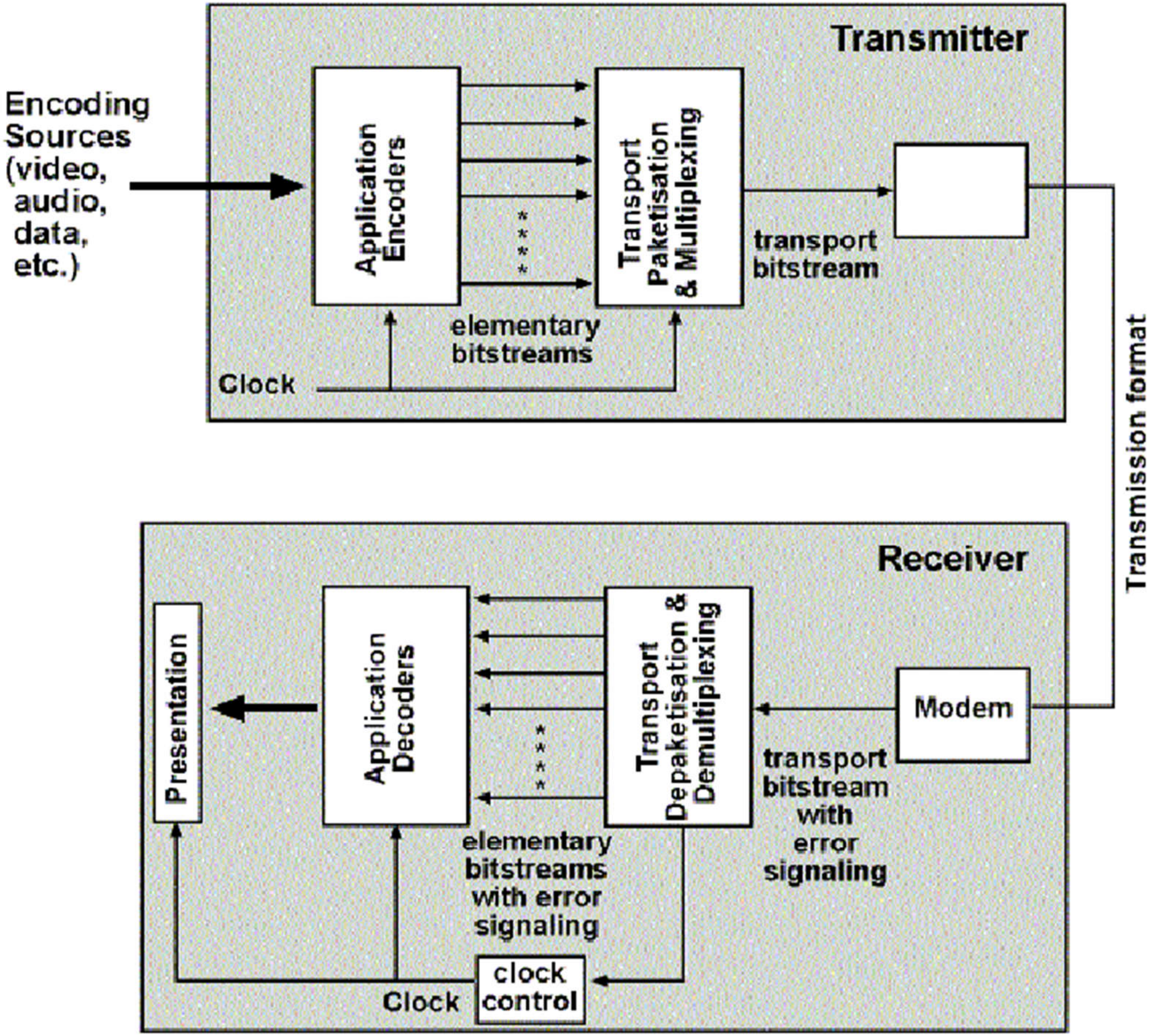

Figure 10-2. Sample organisation of functionality in a transmitter-receiver pair for a single Grand Alliance HDTV programme.

For cable TV distribution, DTV signals can be transmitted at a higher data rate mode (38.56 Mbit/s) that uses 16-VSB to permit the transmission of two HDTV signals or multiple SDTV signals over a single 6-MHz-wide cable TV channel. The higher bit rate is possible because the cable environment is more robust than the terrestrial TV environment.

Digital DTH service providers DirecTV and USSB have announced plans to begin transmitting HDTV program services, including the new HBO HDTV channel, to U.S. subscribers via the Galaxy satellite located at 95 degrees west longitude. Satellite delivery of HDTV signals will use QPSK modulation schemes that are more suitable for transmission within broadband satellite transponder bandwidths.

DTV Compression System

Compression is an essential component of any high-definition TV transmission system. If we assume the use of 8 bits for the video luminance component and 4 bits for each of the two color difference components (Cr and Cb), we can see that the transmission of 60 progressively scanned pictures per second would require an uncompressed data rate of almost 2 Gbits/s for the active video only:

1,080 lines × 1,920 pixels × 60 frames per s ×16 bits (8 luminance and 8 chrominance) = 1,990 Mbits/s

It readily can be seen that a compression ratio in the order of 50:1 is required to transmit an HDTV signal within the 6-MHz-wide bandwidth of a single terrestrial or cable TV channel.

The DTV Transport Packet

Like MPEG-2, the DTV standard features a packetized data transport structure that permits the transmission of virtually any combination of video, audio, and data packets, as well as the optional selection of progressive rather than interlace video scanning for computer interoperability. This gives terrestrial TV broadcasters and cable TV operators tremendous flexibility to provide a wide variety of video, audio, voice, data, and multimedia services. Many of these services can be provided concurrently with a full HDTV program service, while others may be provided in place of an HDTV program service at different times of the day. For example, a local TV channel station could broadcast HDTV programs during the evening "prime time" viewing hours. During other portions of their schedule, the station may elect to deliver as many as five SDTV programs simultaneously, some of which could provide local schools and individuals with educational TV services.

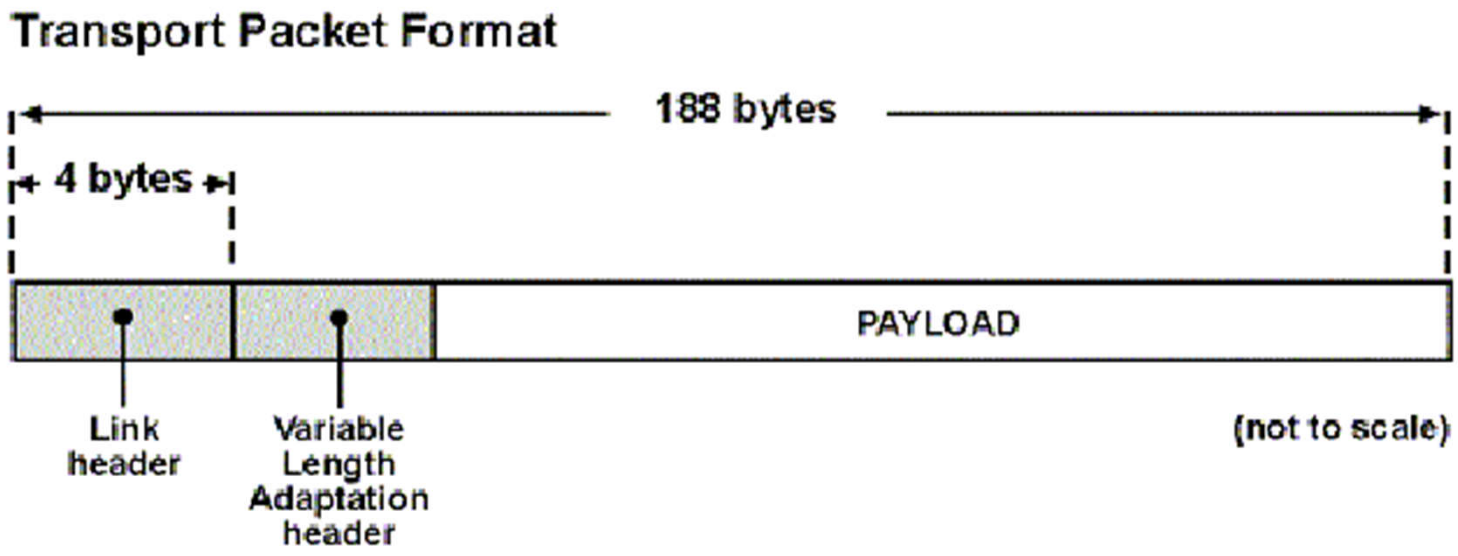

Figure 10-3. The transport bit stream consists of fixed length packets with a fixed and a variable component to the header field.

The DTV standard also can support the delivery of ancillary data services, such as weather forecasts or stock quotes, that would be available only to those viewers who wished to subscribe to them. Broadcasters also may elect to transmit CD-quality audio services as part of the 19.28 Mbits/s digital bitstream.

Each DTV transport packet has a fixed length and contains a data "payload" preceded by a transport header that identifies the contents of each packet and the nature of the data that it carries. The transport header field contains both a fixed-length link layer and a variable-length adaptation layer (Figure 10-3). These fixed- and variable-length components provide the required flexibility for the allocation of channel capacity among various video, audio, and auxiliary data services. The entire channel capacity also can be reallocated in bursts for data delivery as may be required to authorize a universe of decoders just prior to the airing of a pay-per-view event.

The fixed-length link layer uses a 4-byte header field that begins with the "sync_byte" that each decoder uses to establish packet synchronization. Another important element in the link header is a 13-bit field called the PID or packet ID, which provides the mechanism for multiplexing and demultiplexing digital bitstreams.

The encoder duplicates those packets containing information that is essential to the smooth and continuous operation of the system. The "continuity_counter" field within the link header allows the decoder to identify these duplicate packets, then access them in the event that the original packet was received in error or discard them if they are not required. The transport packet’s link header also describes whether or not any payload is encrypted. If it is, the header flags the algorithm or electronic "key" that the decoder must use to unscramble the payload contents.

The adaptation layer is a variable-length field that handles the synchronization of the real-time decoding and presentation processes for each program contained within the digital bitstream. The adaptation headers of selected packets transmit the timing information that the decoder requires to maintain presentation/display synchronization. The "program_clock_reference" (PCR) field contains a sample of a 27-MHz clock, which indicates the expected time at which the decoder completes the reading of that field. The decoder compares the phase of its internal or "local" clock to the PCR value to determine whether or not the decoding process is synchronized. The PCR value therefore serves as a reference that the decoder uses to adjust the clock rate.

The adaptation layer also identifies fixed points in the elementary bitstream at which insertion of local programming (e.g., commercials) is allowed, includes capabilities for supporting new functionality, and defines data that is private and with a format and meaning that is not defined in the public domain.

DTV Scanning Formats

The DTV standard does not require broadcasters to use a specific scanning format, aspect ratio, or number of lines of video resolution. Instead, DTV offers each broadcaster a variety of options from which to choose. The available video formats include 24-, 30-, and 60-frame-per-second progressive scan with an advanced-definition 1,280 × 720 (number of active picture elements per line times the number of active lines) matrix of samples, and 24- and 30-frame-per-second progressive scan with a high-definition 1,920 × 1,280 matrix of samples. The DTV system also is capable of generating a 60-frame-per-second interlaced scan with a 1,920 ×1,080 matrix of samples to allow for the migration to a 60-frame-per-second 1,920 ×1,080 progressive scan format as soon as it becomes technically feasible to do so. The 60- and 30-frames-per-second rates best accommodate video source material using interlace scanning; the rate of 24 frames per second is advantageous for the transmission of all film-based source materials.

Standard-definition 640 ×480 and 704 ×480 sample matrices also are available. Although the NTSC standard is a 525-line system with 756 pixels per line, only 483 of these lines are "active" lines, with the remaining "inactive" lines contained in the vertical blanking interval.

The DTV standard features square pixels and progressive scanning so that the new DTV sets can readily interact with various personal computer platforms. Companies such as Zenith Electronics and Intel Corporation are developing PCI demodulator cards that will allow personal computers (PCs) to receive DTV broadcasts.

The DTV Audio Standard

One major difference between an MPEG-2 DVB-compliant signal and a DTV signal is that the former uses a modified version of MUSICAM for the creation of CD-quality digital audio, whereas DTV uses the 5.1-channel Dolby AC-3 surround sound compression system that state-of-the-art theater sound systems already use throughout the world.

Dolby AC-3 samples the audio at 48 kHz, which is locked to the DTV 27-MHz master clock system, with a bit rate maximum of 384 Kbits/s. Dolby AC-3 supports a wide variety of primary and ancillary audio services. The five-channel complete main (CM) service features left, center, right, surround sound left, and surround sound right audio channels. A low-frequency enhancement (LFE) also is available that has a frequency response range of 3 Hz to 120 Hz. A music and special effects (ME) service also is available that supports a separate dialogue channel that can be used to deliver a secondary-language audio sound tracks. Other audio services that are supported by Dolby AC-3 include commentary, emergency broadcasting, voice-over, and auxiliary channels for the visually and hearing impaired.

KEY TECHNICAL TERMS

The following key technical terms were presented in this chapter. If you do not know the meaning of any term presented below, refer back to the place in this chapter where it was first presented or refer to the Glossary before taking the quick check exercises that appear below.

- *advanced definition television (ADTV)*

- *Advanced Television Standards Committee (ATSC)*
- *aspect ratio*
- *digital terrestrial television broadcasting (DTTB)*
- *Dolby AC-3*
- *DTV standard*
- *DTV transport packet*
- *fixed-length link layer*
- *high definition common image format (HD-CIF)*
- *high definition television (HDTV)*
- *matrix of samples*
- *program clock reference (PCR)*
- *progressive scan*
- *standard definition television (SDTV)*
- *sync byte*
- *variable-length adaptation layer*

QUICK CHECK EXERCISES

Check your comprehension of the contents of this chapter by answering the following questions and comparing your answers to the self-study examination key that appears in the Appendix.

Part I. True or False. Mark each statement below "T" (true) or "F" (false) in the blank provided.

__________ 1. DTV will offer broadcasters the option of delivering their signals in either the standard 5:4 aspect ratio or in a wide-screen, 12:9 aspect ratio that more faithfully reproduces the dimensions of film-based materials.

__________ 2. The U.S. DTV standard supports various arrays of horizontal lines and vertical picture elements or "pixels" that can be displayed on the TV screen.

__________ 3. The ITU's HD-CIF format is characterized by the use of a single matrix of samples (1,920 pixels by 1,080 lines) irrespective of field and frame rate.

__________ 4. The MPEG-2 High Level and High-1440 Level can both support high-definition (HDTV) and advanced-definition TV (ADTV) pictures with 1,920 ×1,080 and 960 ×576 sample matrices.

__________ 5. A single MPEG-2 transport stream is not capable of delivering standard TV and HDTV signals simultaneously.

__________ 6. The transition from analog to digital TV for terrestrial delivery of broadcast signals means that more than 1.2 billion TV sets worldwide eventually will need to be replaced or augmented