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MPEG-2 Digital Broadcast Pocket Guide

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Introduction

In 1936, the year of the Berlin Olympic Games, spectators crowded into specially built viewing rooms called Fernsehstuben (literally, television rooms) to catch a glimpse of one of the first-ever television broadcasts. In black and white, 180 lines per frame, and 25 frames per second, it would hardly compare to today's standards for television quality; however, it was the progenitor of modern-day broadcasting, one of the most powerful tools of the Information Age.

In the formative years of the broadcast industry, a handful of vertically integrated companies controlled everything from content creation to broadcast delivery. These firms reached millions of viewers with over-the-air analog signals delivered by their local affiliate stations. Over the years, the advent of new broadcast delivery technologies (namely cable and satellite), coupled with deregulation and the rise of new providers, has made video broadcasting a far more interesting and competitive business.

Driven by technical, financial and regulatory demands, the current transition from analog to digital video services has spawned a market for the creation, manipulation and delivery of MPEG-2 transport streams. In fact, MPEG-2-based protocols have become the worldwide standards for carrying broadcast-quality compressed digital video, audio and data over terrestrial, satellite and cable broadband networks. In short, MPEG-2 has become to digital broadcast what IP is to the Internet.

This pocket guide will help you to become familiar with the basics of MPEG-2 and digital broadcast transmission.

Part I discusses:

- MPEG-2 audio and video compression
- The MPEG-2 system layer.
- The DVB standard (which provides an extension to the MPEG-2 system layer)
- The ATSC standard (which also provides an extension to the MPEG-2 system . . . layer)

Throughout the text in Part I, you will find **bolded** terms that might be new to you. You can find the definition for these terms in the Glossary at the back of the pocket guide.

Part II of the guide provides application-specific test scenarios for MPEG-2 equipment and systems and suggests the best methods for pinpointing and diagnosing MPEG-2 DVB/ATSC errors. It explains:

- Why and how to test digital broadcast equipment and systems
- Why and how to monitor digital broadcast networks.

The pocket guide also contains a Reference Material list and an Index. Because this guide is not exhaustive, we encourage you to consult the Reference Material list for continued study.

1 “Going digital” holds great revenue promise for the broadcast industry and its infrastructure suppliers. Some of the benefits include:

- Increased channel capacity such that more channels can be offered within a fixed amount of broadcast bandwidth.
- Increased programming options including interactivity and Video on Demand (VoD).
- Improved picture quality even with a standard-definition signal.
- Improved security to prevent unauthorized persons from receiving services.

In spite of these opportunities, going digital also creates a considerable technical challenge for development, engineering and operations personnel. Converting content to a digital format is the first step to realizing the benefits listed above, but digitizing alone is not enough. An uncompressed digital video signal requires at least as much if not more bandwidth for transmission than the original analog signal.

Compression is the second crucial step to making digital TV a practical and profitable service. Compression enables the shift to digital television by drastically reducing the amount of data or bandwidth required to transmit a digitized **program**. As a compression and transmission medium for digitized audio and video, today’s digital broadcast industry relies mainly on MPEG-2, the standard developed by the Moving Picture Experts Group.

2. MPEG history

In 1987 the International Electrotechnical Commission (IEC) and the International Organisation for Standardisation (ISO) created a working group of experts tasked to standardize the compression of digital video and audio. This group became known as the **Moving Picture Experts Group**, or MPEG.

When the first official MPEG meeting was held in May of 1988, digital television broadcasting was no more than a vision. The development of audio CDs had proven that analog signals could be digitized to produce high-quality sound, and the implications of digitization combined with compression stretched as far as television, where decreased bandwidth requirements would make room for more programs, internet services and interactive applications.

But developing a method to successfully compress and then transmit digital programs would require extensive research. And making the transition from analog to digital television would impose on the industry an entirely new approach to broadcasting, including new technology, new equipment and new international standards. The MPEG series of protocols answered the need for digital broadcast standardization.

MPEG consists of a family of standards that specify the coding of video, associated audio and hypermedia. These currently include MPEG-1, MPEG-2 and MPEG-4, and will soon be joined by MPEG-7. Though this guide deals mainly with MPEG-2, the digital broadcasting standard, we will discuss **MPEG-1**, **MPEG-4** and **MPEG-7** briefly. Note that, while all the MPEG standards deal with compression, only MPEG-2 addresses the transmission, or movement, of compressed digital content across a network.

The MPEG standards define the syntax, or structure, and semantics of a compressed bit stream and the procedure for decoding the stream back into the original video and audio content. Since neither specific algorithms nor encoding methods are defined by MPEG, these can be improved over time without any risk of violating the standards. This flexibility affords manufacturers the opportunity to gain a proprietary advantage from new technical developments.

For more information about the Moving Picture Experts Group or the MPEG standards, visit MPEG's website at www.mpeg.org.

2.1 MPEG-1

MPEG-1 is the original MPEG standard for audio and video coding. First published in 1993, this standard defines digital audio and video coding at **bitrates** up to approximately 1.5 Mbps. It is a frame-based standard for delivering a single program on a CD-ROM, and its quality is comparable to that of VHS cassettes. Common applications include the storage of sound and pictures for interactive CDs such as video games and movie CDs. MPEG-1 has also been used for digital radio broadcasts.

Soon after work on MPEG-1 began, champions of the “digital television” concept realized that MPEG-1's syntax and structure would not support the complexity and versatility required by digital TV transmission. For this reason, in 1990, work began on MPEG-2,

the standard that would make digital television broadcasting a reality. MPEG-2 was developed as a **frame-** or field-based standard that allows digital broadcasting applications to deliver multiplexed programs efficiently. MPEG-2 is backward compatible with MPEG-1, meaning that MPEG-1 video streams can be processed by MPEG-2 decoders. We will discuss MPEG-2 in greater detail in the next chapter.

2.2 MPEG-4

MPEG-4 represents the latest breakthrough in audiovisual coding. It allows for simultaneous coding of synthetic and natural objects and sound, giving service providers more options for creating games and other multimedia applications. It extends interactive possibilities by allowing the user to manipulate things like views and the viewing perspective.

MPEG-4 supports the application of different compression routines to different parts of a frame, resulting in considerable processing efficiency and allowing for the coding of arbitrarily shaped objects, instead of the standard rectangular video frame. Because of this, it provides even greater compression than MPEG-1 or MPEG-2 and will be used for applications with especially limited transmission capacity. Though digital broadcast will continue to use the MPEG-2 standard, MPEG-4 will serve a variety of applications including networked video applications, computer games and wireless services. In addition, programs compressed using MPEG-4 techniques can be encapsulated into MPEG-2 transport streams.

2.3 MPEG-7

Formally called ‘Multimedia Content Description Interface,’ the MPEG-7 specification will provide standardized descriptions for searching, filtering, selecting and handling audiovisual content. These descriptions, called metadata, will allow users in various applications to search and manage volumes of audio and video files. Applications include digital libraries, multimedia directory services, broadcast media selection and multimedia editing.

The MPEG-7 standard is currently under development and will be released in late 2001.

3 MPEG-2 Compression and Transport

MPEG-2 is a set of standards for building a single digital **transport stream**, or **multiplex**, which can carry a dozen programs or more, depending upon the level of compression used and the communications bandwidth available.

In the following sections, we will discuss the fundamentals of MPEG-2 compression and transport. This standard covers rules for:

- (1) Compressing audio and video content
- (2) Transporting the multiplex across a network
- (3) Encapsulating data into the multiplex

What the MPEG-2 standard does not regulate is the handling of multiple transport streams simultaneously. Because a **set-top box**, or **Integrated Receiver Decoder (IRD)**, operating in a live network environment must be able to manage several transport streams simultaneously, extensions to the MPEG-2 system layer were developed by **Digital Video Broadcasting (DVB)** and **Advanced Television Systems Committee (ATSC)**. These are discussed in detail in subsequent chapters of this guide.

3.1 MPEG-2 Video and Audio Compression

Compressing a video stream can be compared to freeze-drying instant soup. When the soup is packaged, all water is removed to make travel and storage more efficient. Once the dry package reaches the consumer, he or she adds water back into the mixture to re-create the soup. By extracting redundant information from a video or audio stream, MPEG-2 compression shrinks the signal to as much as 180 times smaller than its original size. Once the stream arrives at the viewer's home, the set-top box then re-generates the quasi-original content and presents the program to the viewer.

Compression allows broadcasters to transmit 6-10 times the number of programs or services they once offered, without needing to increase the size of the transmission pipe. With the additional bandwidth, they can offer more programming, **High-Definition Television (HDTV)**, internet services and/or interactive TV.

Because MPEG-2 compression is 'lossy,' the more a signal is compressed, the lower the resulting quality will be. To a degree, MPEG compression techniques maximize the quality of the compressed signal by introducing degradation where it is least likely to be perceived by the viewer. Using these techniques, a signal can be compressed considerably before picture quality is compromised, but where greater compression is required to preserve bandwidth, program quality may be sacrificed.

The MPEG-2 standard allows a flexible trade-off between image quality and bitrate to accommodate a wide range of quality requirements and bandwidth availability. MPEG-2 specifies several different **profiles** and **levels** that allow broadcasters to determine the degree of compression vs. quality that best fits their application. *For more information, see Profiles and Levels on page 10.*

3.1.1 Video Compression

Once video content is digitized, compression can begin. **Video compression** takes advantage of the considerable redundancy that exists within each video frame and between consecutive frames. It also makes use of the human visual system's limited ability to interpret motion. With the use of video compression, up to 98% of the original digital signal can be removed without an unacceptable degradation in image quality.

There are two main types of MPEG video compression, **spatial encoding** and **temporal encoding**. Spatial encoding eliminates redundancy between adjacent pixels in a video frame. It also makes use of the eye's inability to detect certain visual degradations including noise in a "busy" picture area. Temporal encoding minimizes redundancy between the frames in a video sequence.

■ Spatial encoding

Spatial encoding relies on similarities between adjacent sets of pixels in plain areas of a picture. For instance, a picture that contains a blue-sky background will likely contain several rows of identical blue pixels. Spatial encoding can code only one set of these pixels and then indicate that the rest are identical, thus eliminating redundant data from the bit stream.

The spatial encoding process involves the following steps:

1. Discrete Cosine Transform (DCT)
2. Quantization
3. Weighting
4. Scanning
5. Entropy coding

Discrete Cosine Transform (DCT) divides a picture into blocks of 8x8 pixels then transforms the pixel intensities into a series of frequency-based values, or coefficients. Because of spatial redundancy, many of the coefficients end up with zero or near-zero values. These can be dropped from the series of coefficients so the video frame is expressed in as few bits as possible. The result is lossy compression that eliminates some detail, but the level of detail discarded is so fine as to be imperceptible to the human eye.

Sometimes, however, even greater compression is needed, so the word length of the remaining coefficients must be expressed in even fewer bits. Again, reducing additional bits compromises the accuracy of the digitized video stream and introduces some additional degradation into the picture.

Following DCT, the video frame is **quantized**, meaning that coefficients are reorganized in order of visual importance. After quantization, the **weighting** process strategically places degradation, or noise, into more detailed or complex picture areas where the viewer is least likely to notice it. The DCT coefficients are then **scanned** such that the most significant coefficients are sent first, followed by less significant coefficients and finally an indication in the code that the remaining coefficients are all zero.

The final step in spatial coding is **entropy coding**, which resizes coefficients based on the number of times they occur. Frequently repeated coefficients are expressed in the fewest number of bits, thus greatly decreasing the total bandwidth needed to transmit the coefficients.

■ **Temporal encoding**

Temporal encoding eliminates redundancy between sequential frames in the video stream. Imagine, for instance, that you are encoding video that shows the bird’s-eye view of a soccer game. Though the players move from frame to frame, the background scenery—the field itself—doesn’t change. Temporal coding takes advantage of the similarities between sequential frames and encodes only the differences from one frame to the next. This is accomplished through two types of temporal encoding: **inter-frame prediction** and **motion prediction**.

Inter-frame prediction

Inter-frame prediction takes advantage of the similarities between sequential frames by encoding a complete reference frame only periodically, and then using that frame to predict the preceding and following frames. The reference frame is called an Intra-coded frame, or **I-frame**. I-frames are used as a reference to predict **P-frames** and **B-frames**.

Predicted frames, or P-frames, reference either a previous I-frame or a previous P-frame. This means that instead of transmitting all the DCT coefficients for a P-frame, the encoder transmits only those coefficients that differ from the preceding I- or P-frame. At the decoder, P-frames are re-created using the preceding I- or P-frame as a reference and applying the differentials.

Bidirectionally predicted frames, or B-frames, are predicted in the same fashion from either preceding or subsequent I- or P-frames. Where a P-frame generally requires 1/2 of the data needed to create an I-frame, a B-frame requires only 1/4.

Of course, using only one I-frame as a basis for creating all other frames in a video stream would leave the stream extremely vulnerable to error, since an error in the I-frame would propagate throughout the entire sequence. For this reason, frames are divided into **Groups of Pictures (GOPs)**, usually 12-15 frames long. Each GOP begins with an I-frame, providing for rapid error correction when an I-frame becomes corrupted. GOPs also contain P-frames and B-frames. Below is one example of a Group of Pictures.

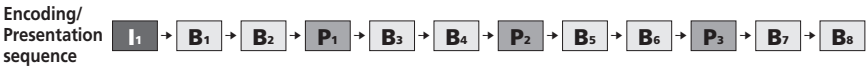


Figure 1: Group of Pictures

Motion prediction

Though objects may change location on the screen, their appearance often remains the same. Motion prediction takes advantage of this similarity by measuring an object’s motion at the encoder and sending a **motion vector** to the decoder. The decoder then uses this vector to shift the specified image from its location in the previous frame to a new location in the next frame. Thus moving objects only need to be encoded once and then moved as necessary between frames.

Typically, motion continues across several frames, so even greater compression can be attained when vectors are transmitted differentially. For instance, if an object’s speed is constant, the motion vectors do not change; only a vector differential of zero is transmitted.

■ Profiles and Levels

To offer broadcasters greater flexibility when it comes to encoding complexity and picture size, the MPEG-2 standard specifies several different compression options known as profiles and levels. Profiles dictate coding complexity while levels specify the number of pixels per frame. The table below shows the various profiles and levels specified by MPEG-2 and the maximum bit rate for each combination.

Levels	Profiles				
	Simple	Main	SNR Scalable	Spatially Scalable	High
High 1920x1080x30 1920x1152x25		80Mbps			100Mbps
High-1440 1440x1080x30 1440x1152x25		60Mbps		60Mbps	80Mbps
Main 720x480x30 720x576x25	15Mbps	15Mbps	15Mbps		20Mbps
Low 352x240x30 352x288x25		4Mbps	4Mbps		

(Profile/Level combinations not shown are not defined as conformance points.)

Table 1: Profiles and Levels

In today’s broadcast environment, the most commonly used combinations are Main Profile at Main Level (MP@ML) and Main Profile at High Level (MP@HL). For more information on profiles and levels, see the MPEG-2 specification.

■ **Decoding the compressed video stream**

Decoding an MPEG-2 video stream reverses the encoding process one for one. An inverse DCT process restores frequency coefficients according to the accuracy of the encoder. The decoder then uses transmitted macroblocks from I- and P-frames to replace redundant macroblocks discarded from P- and B-frames during encoding. Motion vectors specify the location of these macroblocks within the predicted frames.

As explained above, inter-frame prediction requires that frames be sent to the decoder out of sequence and stored temporarily in a buffer. For instance, in order for the decoder to re-create a B-frame, data from both the previous and next pictures must be available. Consider the order in which the frames in the above sequence must be decoded before they can be presented to the viewer:

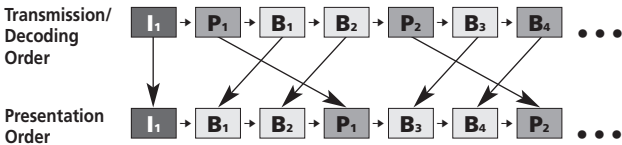


Figure 2: Frames are decoded out of order to support Temporal Encoding

3.1.2 **Audio Compression**

MPEG-2 audio compression exploits the limitations of the human ear. It relies on “masking,” or the ear’s inability to detect a sound in the presence of a similar louder sound. There are two types of masking: **auditory masking** and **temporal masking**.

■ **Auditory Masking**

Auditory masking occurs when two sounds with similar frequencies occur at the same time. If one sound is louder than the other, it will completely drown out the second sound. For example, auditory masking occurs when you try to carry on a quiet conversation in a train station. Passing trains drown out your conversation each time they speed by. In the presence of the sound generated by the train, the quiet voices in the conversation become imperceptible.

The closer two signals are in frequency, the more likely it is that the louder sound will drown out the softer one, though the second sound may be only slightly softer. For example, if two horns are playing at two similar high frequencies, the quieter horn cannot be heard. But a bass drum playing at the same sound level as the quieter horn is likely to be heard, since its frequency differs significantly from that of the louder horn. Because the sensitivity of the ear is frequency dependent, the effect of masking is also frequency dependent. Sounds at lower frequencies must be even closer together in order to be masked than sounds at higher frequencies.

■ Temporal Masking

Temporal masking occurs when a loud sound drowns out softer sounds immediately before and after it. There is a range of time several milliseconds long before and after a loud masking sound during which its masking effects will still be present. For instance, the blast of a train whistle will likely drown out a faint beep that directly follows it.

In order to capitalize on these auditory characteristics, the audio compression algorithms break the audio spectrum into many **sub-bands**. The dynamic range in each sub-band is reduced separately such that the effects of a dynamic range's compression are not noticeable. This means that instead of 16 bits per audio sample in each sub-band, there might only be 2-4 bits per sample. A scaling constant for each band is also used. The allocation of bits per sub-band is divided such that the important frequency ranges receive more weight. The size of a sub-band also varies by frequency in order to match the masking by frequency in the human ear.

An audio signal is compressed in blocks such that the allocation of frequency information can be changed over time and time masking can be used effectively. The typical size of an audio block is 24 milliseconds.

3.2 MPEG-2 Transport: The System Layer

We've talked about compressing and decompressing a single video or audio stream, but MPEG-2 transport streams simultaneously carry many programs or services with audio, video and data all interlaced together. A decoder must be able to sort through the transport stream, organizing the video, audio and data streams by program or service. It must also know when to present each part of the program or service to the viewer. This is where the MPEG-2 **System Layer** comes into play.

The System Layer specifies the structure of the transport stream, the transmission mechanism for MPEG-2 compressed data. Among other things, this structure provides for rapid synchronization and error correction at the decoder. The System Layer also defines **Program Specific Information (PSI)** tables. These act as a table of contents, allowing the decoder to quickly sort and access information in the transport stream.

3.2.1 Creating a Transport Stream

The MPEG-2 transport mechanism is similar to IP transport in that MPEG-2 streams carry data that has been divided into transport packets, each with a **header** and a **payload**. The following process transforms several analog video, audio and data streams into a single transport stream.

Once a video or audio stream is compressed, it becomes an **Elementary Stream (ES)**. From there, it is divided into a **Packetized Elementary Stream (PES)** with variable-length **packets**, each containing a header and a payload. The payload contains a single frame of video or audio. The header includes timing information that tells the decoder when to decode and present the frame.

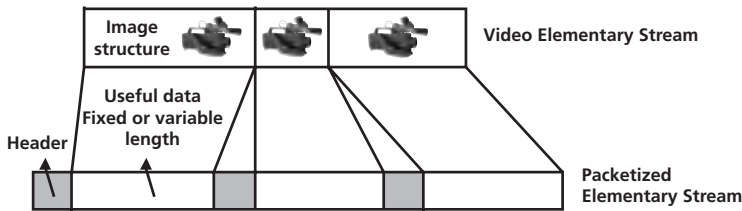


Figure 3: Creation of a Packetized Elementary Stream (PES)

Next, during the encoding process, PESs are further divided into fixed-length **transport packets** of 188 bytes each. This packet size was initially chosen to simplify mapping of MPEG-2 packets over ATM, which uses cells with a payload of 47 bytes ($47 \times 4 = 188$). Like the PES packet, each transport packet also contains a header and a payload.

Once the audio or video stream has been divided into transport packets, it is multiplexed, or merged, with similarly packetized content for other services. A multiplex composed of one or more services is called a transport stream.

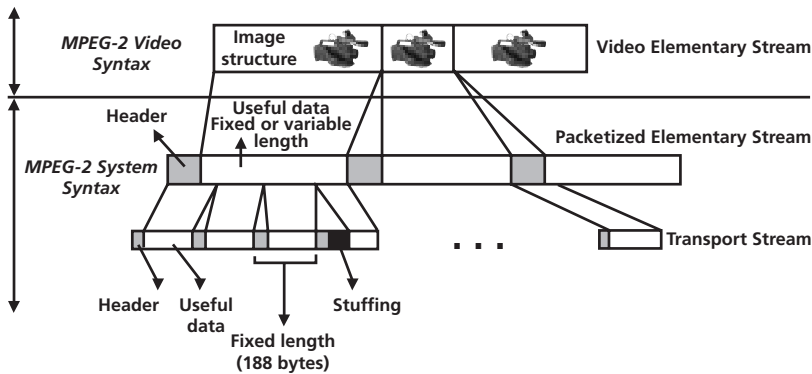


Figure 4: Creation of a Transport Stream

Each packet in the transport stream, whether it contains audio, video, tables or data, is identified by a number called a **PID**, or **Packet Identifier**. PIDs enable the decoder to sort through the packets in a transport stream.

3.2.2 Timing: PCR, PTS and DTS

Timing in the transport stream is based on the 27MHz **System Time Clock (STC)** of the encoder. To ensure proper synchronization during the decoding process, the decoder's clock must be locked to the encoder's STC. In order to achieve this lock, the encoder inserts into the transport stream a 27MHz **time stamp** for each program.

This time stamp is called the **Program Clock Reference**, or **PCR**. Using the PCR, the decoder generates a local 27MHz clock that is locked to the encoder's STC.

As we mentioned earlier, compressed video frames are often transmitted out of order. This means that an I-frame used to regenerate preceding B-frames must be available in the decoder well before its presentation time arrives. To manage this critical timing process, there are two time stamps in the header of each PES packet, the **Decoding Time Stamp (DTS)** and the **Presentation Time Stamp (PTS)**. These tell the decoder when a frame must be decoded (DTS) and displayed (PTS). If the DTS for a frame precedes its PTS considerably, the frame is decoded and held in a buffer until its presentation time arrives.

The following figure shows the timing sequence in the transport stream. Before the transport stream is created, the encoder adds PTSs and DTSs to each frame in the PES. It also places the PCR for each program into the transport stream. Inside the decoder, the PCR goes through a **Phase Lock Loop (PLL)** algorithm, which locks the decoder's clock to the STC of the encoder. This synchronizes the decoder with the encoder so that data buffers in the decoder do not overflow or underflow.

Once the decoder's clock is synchronized, the decoder begins decoding and presenting programs as specified by the PTS and DTS for each audio or video frame.

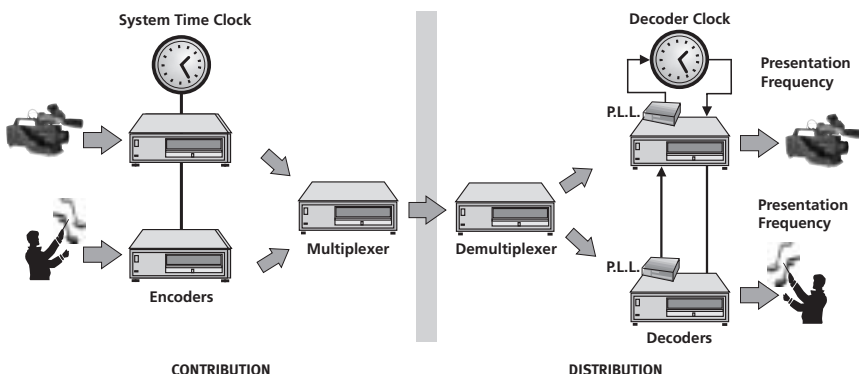


Figure 5: Transport stream timing

3.2.3 MPEG-2 PSI Tables

Because viewers may choose from multiple programs on a single transport stream, a decoder must be able to quickly sort and access video, audio and data for the various programs. Program Specific Information (PSI) tables act as a table of contents for the transport stream, providing the decoder with the data it needs to find each program and present it to the viewer.

PSI tables help the decoder locate audio and video for each program in the transport stream and verify **Conditional Access (CA)** rights. The tables are repeated frequently (for example, 10 times/second) in the stream to support random access required by a decoder turning on or switching channels. The following table gives a basic overview of the PSI tables.

PSI Tables	PID
Program Association Table (PAT) – A root directory for the transport stream, the table provides the PID value for the packets containing the PMT associated with each program.	0x0000
Conditional Access Table (CAT) – This table provides the PID value for the packets containing each Entitlement Management Message (EMM) . EMMs update the subscription options or pay-per-view rights per subscriber.	0x0001
Program Map Table (PMT) – The PMT lists the PID values for the packets containing a program’s video, audio, clock reference and data components. It also lists the PID value for each Entitlement Control Message (ECM) in the stream. ECMs enable a decoder to descramble the audio, video and data for a program.	Found in PAT.
Network Information Table (NIT) – Not defined by MPEG-2.	–

Table 2: PSI Tables

■ Program Association Table (PAT)

The Program Association Table (PAT) is the decoder’s first stop when attempting to locate a program. The decoder quickly finds the PAT because it is always located on PID 0x0000. Like the index of an atlas, it tells the decoder where to find the “map” for each program in the transport stream. This map is contained in the Program Map Table (PMT) for each program. The PAT tells the decoder the PID value for the packets containing each program’s PMT.

The PAT may also contain the PID value for the packets containing the Network Information Table (NIT), which provides access to other transport streams in the **network**.






Contents of Transport Stream		
	Prog. 1	PMT PID 0x0065
	Prog. 2	PMT PID 0x0032
	Prog. 3	PMT PID 0x0056
	Prog. 4	PMT PID 0x0120
	NIT	PID 0x0016

Figure 6: PAT (PID 0x0000)

■ Program Map Table (PMT)

Each Program Map Table (PMT) literally maps out a specific program, listing the PID values for the packets containing the program's video, audio and data components. With this information, the decoder can easily locate, decode and display the program's contents.

The PMT also indicates the PID value for a program's Entitlement Control Message (ECM). The ECM supplies the decoder with the keys necessary to descramble the audio and video for a program.





Components of Program 1		
	Video	PID 0x0131
	Audio English	PID 0x0132
	Audio German	PID 0x0133
	ECM Prog. 1	PID 0x0150

Figure 7: PMT Program 1 (PID 0x0065)

■ Conditional Access Table (CAT)

The MPEG-2 syntax enables broadcasters to transmit proprietary Conditional Access information in the transport stream in the form of Entitlement Management Messages (EMMs). EMMs update the subscription options or pay-per-view rights for each subscriber or for groups of subscribers.

The Conditional Access Table (CAT) tells the decoder where to find Entitlement Management Messages (EMMs) in the transport stream by listing the PID value for the packets containing each EMM. The CAT is always found on PID 0x0001.





Location of EMMs	
 EMM A	PID 0x0061
 EMM B	PID 0x0076
 EMM C	PID 0x0038
 EMM D	PID 0x0109

Figure 8: CAT (PID 0x0001)

■ Network Information Table (NIT)

The Network Information Table (NIT) provides information regarding a network on which various transport streams reside. This table is specified, but not defined, by MPEG-2. However it is defined by DVB and will be discussed in the next chapter. The ATSC standard does not use this table.

3.2.4 Decoding with PSI tables: a summary

The following steps outline the process followed by a decoder to display a certain program, in this case, Program 1:

1. Create the PAT. To do this, extract the contents of packets with PID=0x0000 and build the PAT.
2. Read the PAT to identify the PID of the packets carrying the PMT for Program 1. The PAT shows the PMT PID for Program 1 is on PID=0x0065.
3. Extract the contents of the packets with PID=0x0065 and build the PMT
4. Read the PMT for Program 1 to find the PIDs that identify the audio and video packets and PCR for Program 1. The PMT shows the video to be in packets with PID=0x0131, the German audio in packets with PID=0x0132 and the English in packets with PID=0x0133. In most cases, the PID for the video stream also carries the PCR.
5. In the PMT, find the ECM PID for Program 1. The PMT shows the ECM to be in packets with PID=0x0150.
6. Locate packets with PID=0x0150 and extract the ECM for Program 1.
7. Extract the video for Program 1 from packets with PID=0x0131.
8. If the user has selected the German sound track, locate and extract the audio track from packets with PID=0x0132. If the user has requested the English sound track, locate and extract the audio from packets on PID=0x0133.
9. Using the ECM on PID 0x0150, descramble the video and audio for Program 1.
10. Assemble the video and audio into PESs.
11. Use the PTS and DTS in the header of each PES packet to determine when to decode and present the packet's contents to the viewer.

While MPEG-2 PSI tables enable the decoder to decipher the programs on a single transport stream, they do not provide enough information to support the numerous programs and services available on an entire network of transport streams. The Digital Video Broadcast (DVB) standard defines a set of tables, called **Service Information (SI)** tables, that extend the capabilities of the MPEG-2 system layer such that a decoder can receive and decode any number of programs and services across a network of transport streams.

Though this pocket guide focuses mainly on the System Information specified by DVB, the standard also addresses other parts of digital transmission, such as transmission mechanisms and data services. For more information on these aspects of the DVB standard, visit the DVB website at www.dvb.org.

4.1 DVB History

The DVB Project began in September 1993 when public and private television organizations from across Europe signed an agreement to work together for the creation of a digital broadcasting standard. Because the DVB Project united major players in the European broadcast market, it provided a forum through which a truly unified digital television system could be created. In time, the organization developed international standards for satellite, cable and terrestrial transport. The Project now includes over 220 participants in more than 30 nations worldwide.

4.2 DVB SI Tables

DVB Service Information (SI) tables give service providers the tools necessary to offer programs and services across a large network of transport streams. These tables are added to the MPEG-2 transport stream during encoding or multiplexing. They work together with the MPEG-2 PSI tables to give the decoder access to all available programming across an entire network.

SI tables also provide information for the **Electronic Program Guide (EPG)**, which shows viewers a description of all current and upcoming **events**, along with their start time and duration.

Like all other packets in the transport stream, those that contain SI tables are identified by PID number. The following table gives a basic overview of the SI tables.

SI Tables	PID
Network Information Table (NIT) – This table shows the physical organization of the network and its characteristics.	0x0010
Time and Date Table (TDT) – The TDT provides the present UTC time.	0x0014
Service Description Table (SDT) – This table describes the services in a network and gives the name of the service provider.	0x0011
Event Information Table (EIT) – This table defines all events in the network, providing their description, start time and duration. It is used in creation of the Electronic Program Guide (EPG).	0x0012
Bouquet Association Table (BAT) – The BAT describes the services available in a given bouquet , or group of services that can be purchased as a single product.	0x0011
Running Status Table (RST) — The RST updates the timing status of events when scheduling changes occur.	0x0013
Timing Offset Table (TOT) — The TOT contains the UTC time and date and the local time offset.	0x0014
Stuffing Table (ST) — This table invalidates the remaining sections of a table when one section has been overwritten.	0x0010 to 0x0014

Table 3: SI Tables

4.2.1 Time and Date Table (TDT)

The Time and Date Table (TDT) provides the present UTC date and time, which can be adjusted according to time zone and presented on the screen for the viewer.

4.2.2 Network Information Table (NIT)

The Network Information Table (NIT) contains network characteristics and shows the physical organization of the transport streams carried on the network. The decoder uses the tuning parameters provided in this table to change channels at the viewer’s request when the desired program is not on the current transport stream. Tuning parameters are specific to the type of transmission assigned to the network, whether it be terrestrial, cable or satellite.

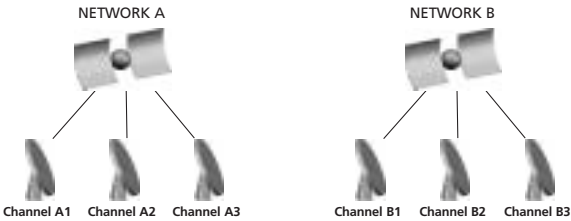


Figure 9: The NIT defines the network organization and provides tuning information for the channels in the network.

4.2.3 Service Description Table (SDT)

The Service Description Table (SDT) defines the services available on the network and gives the name of the service provider. A service is a sequence of events that can be broadcast as part of a schedule.

Two types of SDTs, “Actual” and “Other,” are required by DVB. The SDT Actual describes the services available on the transport stream currently being accessed by the viewer, while the SDT Other describes services available on all other transport streams in the network.

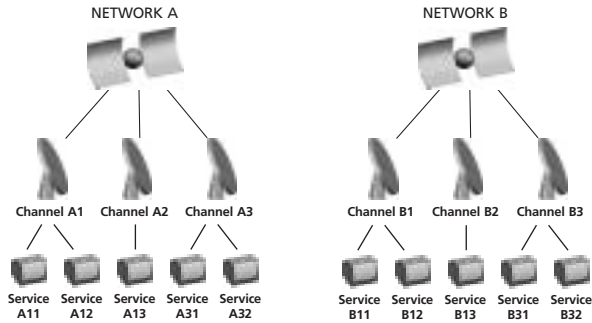


Figure 10: The SDT describes the services available in the network.

4.2.4 Event Information Table (EIT)

The Event Information Table (EIT) defines all events in the network, including their description, start time and duration. According to MPEG, an event is a collection of elementary streams with a common time base set to start and end at the same time. We often refer to events as “TV programs.”

Three different types of EITs can be transmitted simultaneously: the EIT Present, the EIT Following and the EIT Schedule. The EIT Present describes the events currently being broadcast on the transport stream being accessed by the viewer, while the EIT Following provides information about the next events to be broadcast on the same transport stream. The EIT Schedule lists all events available on the network for anywhere from the next few hours to the next few days, depending on the service provider’s implementation. The EIT Schedule provides the main source of information for the Electronic Program Guide (EPG).

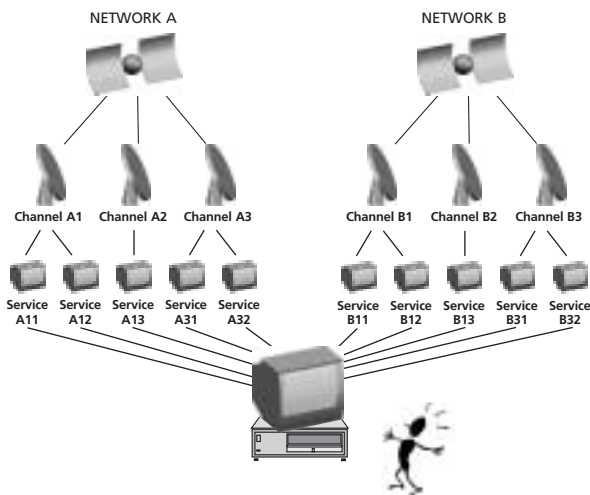


Figure 11: The EIT provides the event information used to create the EPG, which displays current and upcoming events for several days.

4.2.5 Optional DVB SI tables

Four optional DVB SI tables can also be included in the stream. They are:

Bouquet Association Table (BAT) – A Bouquet is a commercial offering, or group of services that can be purchased as a single product. The Bouquet Association Table (BAT) describes the services available in a given bouquet.

Running Status Table (RST) – This table carries information used to update the timing status of events in the system when scheduling changes occur. This saves broadcasters from having to retransmit an entire table when only a portion of the content changes.

Timing Offset Table (TOT) – This table contains the UTC time and date, along with the local time offset.

Stuffing Table (ST) – This table invalidates the remaining sections in a table when one section has been overwritten. This maintains the integrity of the section _ number field.

Like the DVB specification, the Advanced Television Systems Committee (ATSC) standard expands the MPEG-2 system layer to support the simultaneous transmission of multiple transport streams in a broadcast network.

As we mentioned previously, the MPEG-2 system layer only enables a decoder to locate the programs and services available on a single transport stream. To broaden this capability the ATSC defined its own set of tables called **Program and System Information Protocol (PSIP)** tables. These give the decoder access to tuning parameters, program ratings and event descriptions for all channels in the network. In conjunction with MPEG PSI, ATSC PSIP tables make a larger number of products and services available to the viewer.

5.1 ATSC History

In May of 1993, the U.S. Federal Communications Commission (FCC), prompted several broadcast industry leaders to join what it called the HDTV Grand Alliance. It commissioned the Alliance to build a U.S. standard for Advanced Television (ATV) broadcasting and called upon the Advanced Television Systems Committee (ATSC) to develop and document the detailed specifications of the new standard. ATSC Digital Television Standard (A/53), the document produced by the ATSC membership, was accepted in 1996 by the FCC for digital terrestrial television broadcast in the U.S. The standard is geared mainly toward terrestrial broadcast, but it also includes provisions for Cable TV (CATV) transmission.

Though ATSC was initially a North American organization, its charter has been modified to include members from other countries. It now serves more than 200 members in several nations worldwide.

5.2 ATSC PSIP Tables

ATSC's Program and System Information Protocol (PSIP) tables provide the decoder with the necessary information to access all channels and events available on an MPEG-2/ATSC network. They provide tuning information that allows the decoder to quickly change channels at the click of the remote control. In addition, they include provisions for viewer-defined program ratings, and they provide event descriptions to support the creation of the Electronic Program Guide (EPG). The following table gives a basic overview of the PSIP tables.

PSIP Tables	PID
Master Guide Table (MGT) – The MGT acts as an index for all other tables in the PSIP standard. It indicates table sizes, version numbers, and PID values for all tables.	0x1FFB
System Time Table (STT) – The STT consists of only one packet that shows the current date and time.	0x1FFB
Rating Region Table (RRT) – This table transmits program-rating systems for each country that uses a rating standard. It allows viewers to filter certain programs based on their content.	0x1FFB
Virtual Channel Table (VCT) – This table lists all the channels in the transport stream and defines their characteristics. It includes each channel's name, stream components and navigation identifiers. It carries the source_id for each program, which the EIT uses to locate and display information for the EPG.	0x1FFB
Event Information Table (EIT) – This table defines the events associated with each virtual channel listed in the VCT. It provides event descriptions, start times and durations.	Found in MGT.
Extended Text Table (ETT) – The ETT carries text messages describing either channels or events. These messages appear in the EPG to give viewers more detailed information than is available in the EIT. This table is optional.	Found in MGT.

Table 4: PSIP Tables

5.2.1 Master Guide Table (MGT)

The Master Guide Table (MGT) acts as an index for all other PSIP tables. It defines

- Table sizes, necessary for proper decoding;
- Version numbers, which help to identify the tables that need to be updated;
- PID values, which enable the decoder to locate the packets that contain the EITs and ETTs.

MGT	PID 0x1FFB
For all PSIP tables:	For EIT and ETT:
Table Type	PID Value
Table ID	
Table Version	
Table Size	

Figure 12: The MGT acts as an index for all PSIP tables

5.2.2 System Time Table (STT)

The System Time Table consists of only one packet, which serves as a reference for the current time of day. This information enables the decoder to start advertised events on schedule.

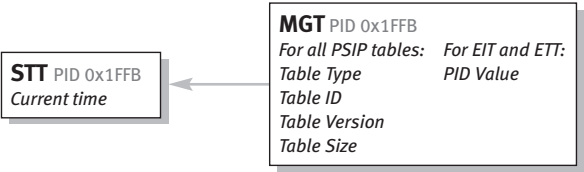


Figure 13: The STT shows the current time

5.2.3 Rating Region Table (RRT)

The Rating Region Table (RRT) transmits program rating systems for each country that uses a rating standard. The information in this table allows viewers to filter certain programs based on their content.

The decoder uses information in the MGT to locate and create the RRT.

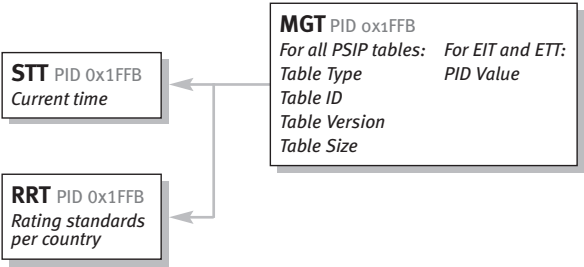


Figure 14: The RRT contains rating standards per country

5.2.4 Virtual Channel Table (TVCT for terrestrial, CVCT for cable)

The Virtual Channel Table (VCT) lists all the channels in the transport stream and defines their characteristics. This includes the channel name, the stream components, stream types, and navigation identifiers. The VCT also carries the source_id for each program, which the EIT uses to locate and display channel information for the EPG.

The decoder uses information in the MGT to find and build the VCT.

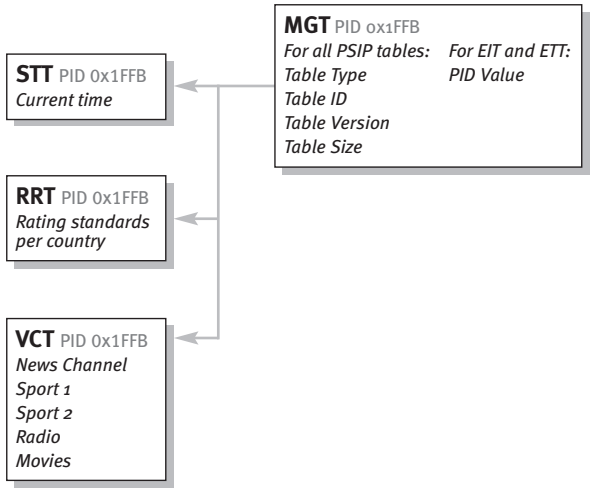


Figure 15: The VCT identifies each channel in the transport stream

5.2.5 Event Information Table (EIT)

The Event Information Table (EIT) defines the events associated with each of the virtual channels listed in the VCT. It provides event descriptions, start times and durations. The decoder uses these to create the EPG.

According to the ATSC specification, between four and 128 EITs must be in the transport stream at any given time. Each EIT provides event information for a three-hour time period, so up to sixteen days of programming can be advertised in advance in the EPG. EIT-0 always contains information for the current three-hour time block, while EIT-1 defines programming for the next three hours.

The PID value for each EIT is defined in the MGT, and the VCT supplies the channel identifier, or Source ID, for each event in the EIT.

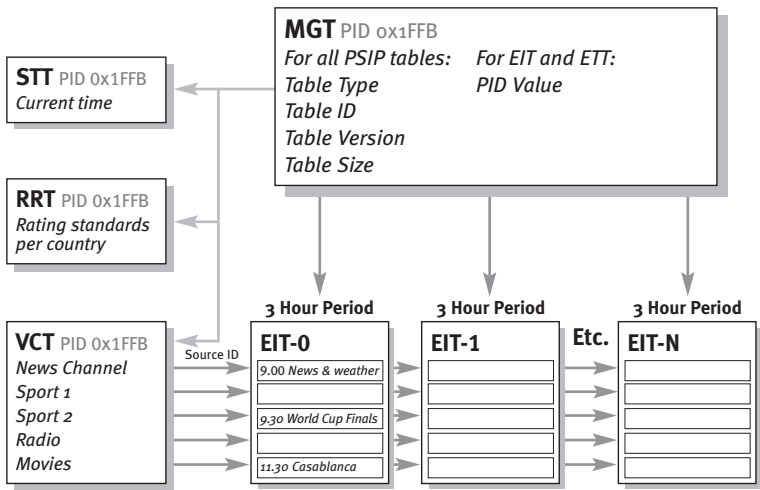


Figure 16: The EIT describes events in the transport stream.

5.2.6 Extended Text Table (ETT)

Extended Text Tables (ETTs) carry text messages describing both channels and events; hence, there are two types of ETTs: Channel ETTs and Event ETTs.

ETT messages are displayed in the EPG to give viewers more detailed information than is available in the EIT. For example, Channel ETTs may contain information about the price of a channel or its coming attractions. Event ETTs might include a short paragraph describing a specific event, such as a movie. ETTs are optional, and the PID number for each ETT is defined in the MGT.

6 MPEG-2 Testing and Monitoring: Why, What , and How

The MPEG-2 DVB/ATSC transport stream provides a bandwidth-efficient medium for delivering digital programs and services from the broadcaster to the viewer. But because its contents are tightly compacted to make the best use of available bandwidth, the MPEG-2 transport stream is vulnerable to errors. As it travels from one link in the broadcast chain to the next, the stream constantly changes as programs, streams and tables are added, updated or removed. During the transmission process, any number of errors can appear in the transport stream, causing service degradation or disruption.

Error-prone transmissions are especially detrimental to service quality since, unlike the occasional noise or fuzz in an analog picture, errors in digital images are much more obvious and unpleasant to the viewer. A single bit error can severely degrade picture quality or completely interrupt a service. Similarly, because the set-top box depends on a hierarchical set of PSI/SI/PSIP tables to decode and present services, a single table error can trickle through the system, causing service interruption or problems in the EPG.

Guaranteeing quality in such an environment requires rigorous testing of each piece of equipment in the broadcast network. For manufacturers and developers, this means stress testing each new design to ensure interoperability and reliability. For system integrators it involves stringent validation of each piece of equipment in the broadcast network. For broadcasters and network operators it requires continuously monitoring the network in real time and performing real-time analysis of troubled transport streams as soon as errors appear.

The complexity of digital broadcast transmission makes traditional analog test and monitoring methods obsolete and drives the need for a new generation of measurement products and systems. This chapter provides specific examples to illustrate why and how to test and monitor in the digital broadcast environment. It also discusses the most effective methods for verifying and maintaining the integrity of digital broadcast equipment and systems.

6.1 Testing MPEG-2 systems and equipment

MPEG-2 testing can be divided into two activities: validation and troubleshooting.

- Validation involves verifying that the output of a network or system is MPEG-2 DVB or ATSC compliant and that there are no errors.
- Troubleshooting involves locating and resolving errors that appear in the stream.

The following sections highlight several test scenarios you might expect to see during equipment evaluation, system integration and in-field troubleshooting. They suggest quick, efficient methods for equipment and system validation and error isolation using Acterna's DTS-300 Digital Broadcast Test Platform as a sample test tool.

The DTS-300 system combines comprehensive real-time transport stream generation, creation, analysis and recording capabilities in a single unit. It provides the most complete real-time analysis and stream creation capabilities on the market. Its intuitive

structure and familiar Windows NT interface make it an ideal tool for MPEG-2 experts and beginners.

6.1.1 Equipment Evaluation

Evaluating broadcast equipment involves assessing the capability or reliability of a unit prior to its deployment into a network. This responsibility falls mainly on developers, manufacturers, broadcasters and network operators. At a minimum, it involves three main steps: (1) validating output, (2) measuring performance, and (3) verifying interoperability.

■ Validating output

Validating an encoder, multiplexer, set-top box, or other piece of broadcast equipment requires detailed analysis of the unit's output. Operators verify that the unit does what they expect it to do with little or no error.

In order to validate a multiplexer, for example, operators play a known good test stream into the unit and then analyze its output using a transport stream analyzer. The Analyzer found in the DTS-300 completely dissects the output transport stream and displays its contents in several easy-to-read views. With all analysis done in REAL TIME, these views allow operators to quickly

1. Verify that the output transport stream is synchronized and the rate is correct
2. Check that all PIDs in the stream contain the correct information and are being transmitted at the proper rate
3. View each program, its parameters and contents
4. Validate the contents of each table and descriptor in the stream and check their repetition rates
5. Measure the level of PCR jitter the system produces
6. Pinpoint and diagnose any errors present in the stream

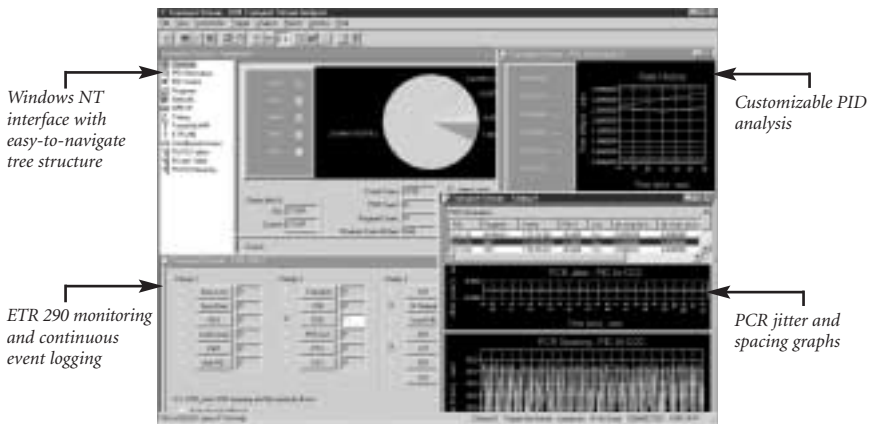


Figure 17: DTS-300 Analyzer offers in-depth real-time analysis with a user-friendly interface.

Without this level of in-depth validation, operators may be led to believe a system is working properly simply because the output stream is synchronized or the decoder can display a picture. But in reality, errors such as dropped packets or corrupted tables can create problems that will adversely affect channel hopping, user-defined program ratings, or Conditional Access rights.

■ **Measuring performance**

The second step in evaluating broadcast equipment involves measuring performance. Once an operator has determined that a unit can successfully output a simple test stream, he or she must find out what the unit cannot do—in other words, find its limitations. This will help in pinpointing a unit’s strengths and weaknesses and comparing two or more units being evaluated simultaneously.

In order to explore the capabilities and limitations of a multiplexer, for example, the operator needs a dynamic test stream that stretches the limits of the MPEG-2 DVB or ATSC standards. Using the DTS-300’s Stream Creation capability, a user can create a complex, systematically varied test stream using small video and audio files combined with table and timing information that is created on the fly. For example, the user can:

- 1. Create a library of streams whose output rate varies from 1kbps to 214Mbps (the range specified by the DVB ASI standard). Feed these streams to the unit under test and simultaneously analyze its output with the DTS-300’s Analyzer. This measures the minimum and maximum bit rate capacities of the unit under test.
- 2. In the same stream, insert and delete programs on the fly and measure the unit’s capacity to handle dynamic streams.
- 3. Insert errors into the stream to see how the unit reacts to unreferenced PIDs, missing tables or synchronization errors.
- 4. Create a test stream in which PCR jitter increases over time and measure the unit’s ability to handle jitter.

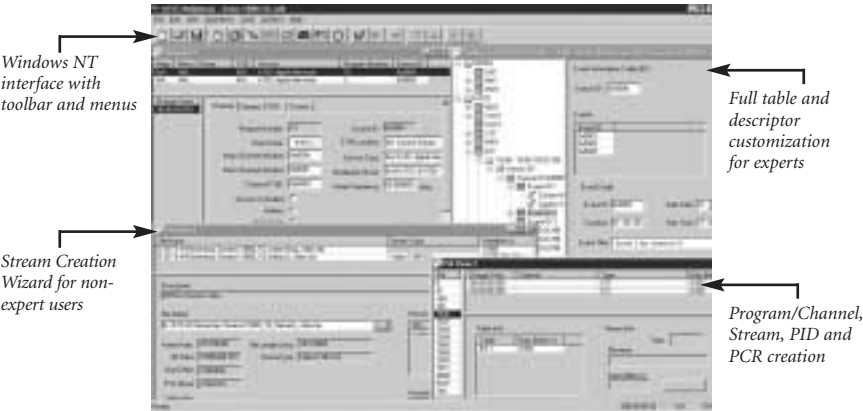


Figure 18: DTS-300’s Stream Creation capability provides powerful yet easy-to-use test stream generation.

The DTS-300's Stream Creation capability enables operators to simulate these and many more real-world situations that are difficult to find on live or captured input streams. Not only that, it allows them to specify innumerable testing conditions in a single test sequence, saving time and disk space.

With the created test stream running as input to the unit under test, operators can use the Analyzer to simultaneously examine the unit's output and check for errors. The DTS-300 system allows them to create the input test stream and analyze the output stream in real-time from a single unit. This minimizes the cost of performance evaluation.

The DTS-300's revolutionary approach to creating and storing test streams allows operators to save an entire library of test scenarios in the space needed for one captured transport stream.

■ **Verifying interoperability**

Since MPEG-2 only specifies the structure of the transport stream and not the method by which it is created, different manufacturers have devised different methods for creating and handling the transport stream. Their equipment may offer varying degrees of compliance to the standards and may or may not be interoperable with other broadcast equipment.

Because digital broadcast systems rely on equipment made by various manufacturers, each element in the system must be rigorously tested for interoperability. Each unit must reliably receive and/or transmit fully compliant MPEG-2 DVB or ATSC transport streams to keep transmission through the broadcast chain as clean and error-free as possible.

To ensure interoperability, developers and network operators feed known good test streams through multiple pieces of broadcast equipment, mimicking the broadcast chain. By analyzing the output of the chain, as described on page 28, they can pinpoint errors in the system and isolate a faulty piece of equipment.

6.1.2 System Integration

System integration requires not only the validation of individual pieces of equipment, but also the verification of entire broadcast systems. Integrators rely on the successful interoperability of various manufacturers' equipment, and they work to fine-tune each element in the broadcast chain for optimum overall performance.

■ **Setting up the system**

System integrators validate equipment at every step in the setup process. Using the methods discussed on page 28, they analyze the output of a system as they build it, verifying each new piece as it is added. Using a DTS-300 Analyzer they:

1. Examine the stream's contents in real time including all programs, channels, PIDs, tables and descriptors
2. Measure the system's bandwidth usage and efficiency

3. Use the colored indicators on the ETR 290/Monitoring screen, along with continuous event logging, to quickly pinpoint and diagnose errors
4. Isolate a faulty piece of equipment so it can be replaced or repaired

■ Acceptance testing and baselining

Once the system is implemented and operational, integrators must perform acceptance testing and baselining prior to going live. This proves the status and integrity of the system at the time it was implemented.

Detailed reports generated by a DTS-300 Analyzer simplify this process by outlining the configuration and status of the system.

They show:

1. The contents of the system including programs, PIDs, tables and descriptors
2. Transmission rates per PID, table, program and transport stream
3. Scrambling status of each program in the system
4. Bandwidth efficiency per stream type and over all

Reports are fully customizable and can reflect several days or weeks of analysis. They can also be generated according to a user-defined schedule.

6.1.3 In-field Troubleshooting

As we discussed earlier, MPEG-2 transport streams are both complex and vulnerable. Any number of errors can occur during transmission, and field technicians must be able to pinpoint and resolve MPEG-2-related errors quickly and effectively. A portable transport stream analysis tool that is both comprehensive and easy to use enables field-service personnel to rapidly diagnose and resolve MPEG-2 transmission errors.

Though this book cannot cover all the issues support technicians might face in the field, the following example illustrates how a transport stream analyzer, like the one found in Acterna's DTS-300, helps technicians diagnose one of the most common issues: service disruption. Any number of other issues can be diagnosed using a similar procedure.

To determine the cause of a service disruption, use the following procedure:

1. Connect the Analyzer to the problem transport stream and open the application.
2. In the left-pane tree structure, click on ETR 290/Monitoring. The ETR 290/Monitoring display uses colored lights to show an at-a-glance overview of transport stream status. It also identifies all errors occurring on the stream according to DVB's recommended priorities for transport stream monitoring. By clicking on any button in the top pane you display related errors in the bottom pane.

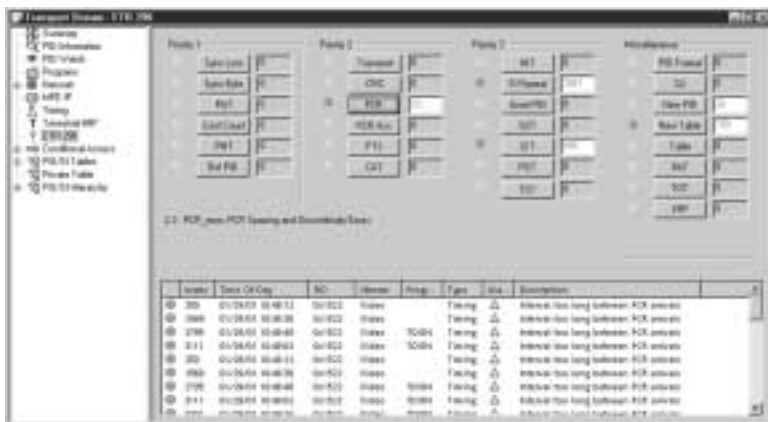


Figure 19: The DTS-300's ETR 290/Monitoring display uses colored lights to help operators pinpoint and isolate errors in the transport stream.

■ If the ETR 290 view shows timing errors

Figure 19 shows that several PCR spacing errors have occurred on the video PID 0x1522. To view PCR spacing and jitter on this PID, open the Timing view by clicking on the Timing icon in the left pane.

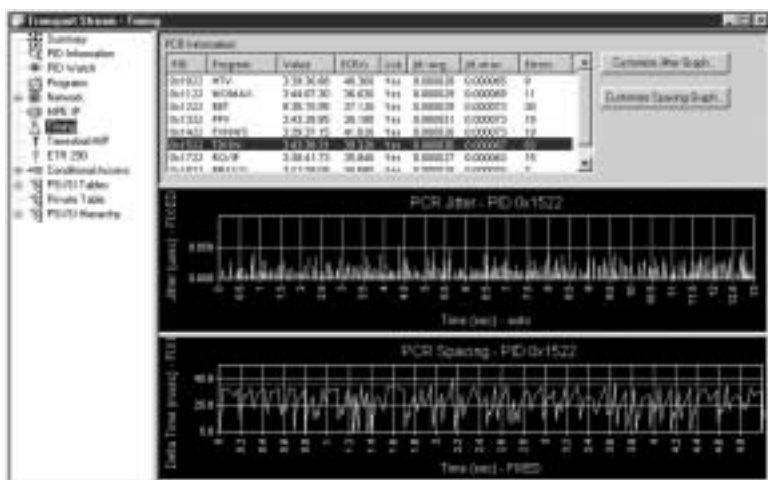


Figure 20: The DTS-300 Timing Display tracks PCR jitter and spacing over time.

The Timing view shows jitter and spacing in real time for any PCR PID in the stream. Excessive PCR jitter reflects a problem in the encoder or multiplexer. The equipment may need to be adjusted or sent back to the manufacturer for repair.

■ If the ETR 290 screen shows an error in the PAT or PMT for the service

If such an error appears in the ETR 290 view, examine the contents of the erroneous table in real time. To do this, select the table you want to see in the left pane. The corresponding display appears in the right pane.

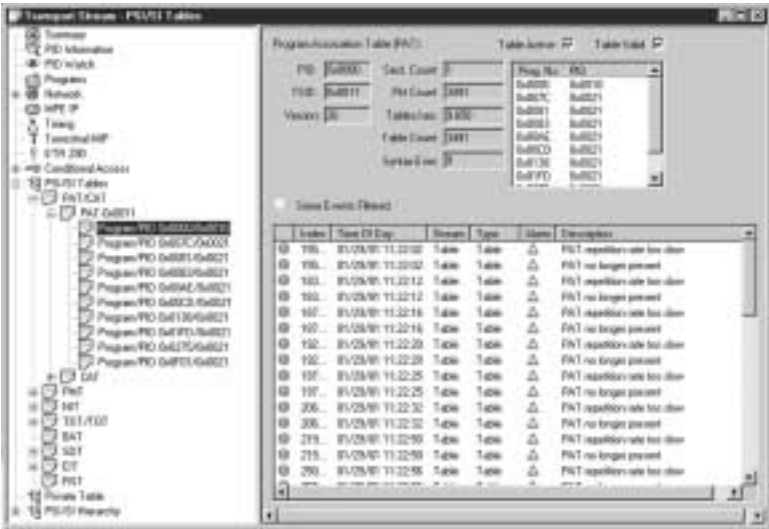


Figure 21: The DTS-300 Analyzer performs full table and descriptor decode and analysis

Using the table displays, you can verify that the PAT is present in the stream and that it correctly references the PMT PID for the missing service or program. You can also look at the PMT to make sure it references the correct audio and video PID for the program. In addition, you can verify table rates using the Tables Summary display.

■ If the ETR 290 screen shows a Conditional Access error

If the ETR 290 screen shows a Conditional Access error, such as a missing ECM or an invalid key change, go to the Conditional Access display by selecting the Conditional Access icon in the left pane.

Monitoring in the MPEG-2 network improves:

- Quality of Service
- Network Maintenance

■ **Quality of Service**

In a fiercely competitive market like digital television, customers expect the highest level of service quality. To meet customers’ expectations, operators must provide uninterrupted access to error-free programming on what could be several hundred services. In addition, providers advertising special services such as pay-per-view programming must be sure they can deliver these services flawlessly.

Issues that seriously affect customer satisfaction can be divided into two categories: Service Disruption and Poor Service Quality. Service Disruption prohibits viewers from accessing the programs and services they paid for. Poor Service Quality delays access to programs or causes poor picture quality.

Service Disruption

- Service interruption
- Unavailable pay-per-view services

Poor Service Quality

- Poor picture or sound quality
- EPG not navigable
- Ineffective rating blockouts
- Delayed channel changing

The following sections outline the common causes of these problems and how they can be detected and resolved with continuous monitoring.

Service Disruption

Service Interruption

Service interruptions occur when errors in the transport stream prevent the set-top box from decoding the stream. When this happens, the set-top box either stops decoding certain programs or crashes completely. In place of programming, the viewer sees only a blank screen. This type of error produces an immediate increase in the volume of calls to service centers.

Considering the complexity of the MPEG-2 transmission mechanism it is easy to see how a small error can cause a service interruption. For example, a re-multiplexer takes multiple streams of audio, video, data and tables and reshuffles them to make efficient use of the RF spectrum. During this complicated process, any number of errors can occur. For example, a bit error in the packet header of the PAT may change its PID value, making it impossible for the decoder to find this table. Without this table, the decoder cannot access any table or present any program in the stream.

Of course, there are other types of errors that can cause service interruption. Failed equipment, missing PIDs, and incorrect Conditional Access information can also cause service interruption. In order to guarantee high Quality of Service (QoS) and decrease costs at call centers, broadcasters and network operators must be able to keep service

interruptions to an absolute minimum. The only way to do this is to closely monitor and control the contents of each transport stream in the network in real time—all the time.

Unavailable pay-per-view services

Customers who have paid a premium to view a certain event, such as a movie or a boxing match, are especially unforgiving of service disruptions. For pay-per-view services, disruptions most often occur when there are errors in the Entitlement Control Messages (ECMs). These carry the keys used by the decoder to descramble the audio and video for a pay-per-view event.

Because these descrambling keys change every 5-30 seconds, ECMs must be transmitted without error and in proper alignment to the audio and video for their associated programs. ECMs also rely on the PMT, which must be error free to enable successful descrambling of a program by the set-top box. If errors occur in the ECMs or PMT, the set-top box may not be able to descramble pay-per-view programs, and the customers who paid for them could be without service.

Continuous monitoring immediately alerts operators when Conditional Access errors occur. This enables them to quickly resolve issues affecting a pay-per-view service and minimize annoyance to the viewer.

Poor Service Quality

Poor picture or sound quality

Digital television customers usually complain of poor picture or sound quality in terms of:

- Jumbled pictures — where macroblocks from multiple video frames are mixed into a single frame
- Blockiness — where the edges of macroblocks become visible
- Freezing — where a single image remains on the screen for longer than the appropriate frame interval
- Lip Sync — where images, such as moving lips, are not aligned with the associated sound
- Clicks or gaps in the audio

These problems, all related to the transport stream structure, can be caused by:

- Bit errors in the transport stream
- Dropped video or audio packets
- Overflow of buffers in the set-top box
- Incorrect PCR/PTS/DTS time stamps
- Invalid encoding of data in the audio or video stream
- Inadequate compression of the video or audio signal

Because picture quality is a major concern to customers, broadcasters must constantly monitor each transport stream in the network to catch potential quality issues like those mentioned above before they affect the viewer. These types of errors can be quickly identified through continuous monitoring and event logging at multiple points along the broadcast chain. Once the source of a picture quality error is identified, it can usually be resolved by replacing or resetting a malfunctioning encoder, multiplexer or set-top box.

EPG not navigable

Digital TV customers depend on the Electronic Program Guide as their main source of information about available programming. An effective EPG provides event descriptions and start times for several days or weeks of programming. It can also provide advertising for the network and help sell additional services like pay-per-view events and movies.

An effective Electronic Program Guide can be a key selling point for the digital TV service, but if it does not work properly, customers will not be able to access event schedules or easily navigate between programs. They are likely to become frustrated and dissatisfied with the service.

Proper EPG creation in the set-top box requires that the following tables arrive at the correct rate and with the correct information. In addition, some systems define private tables to deliver EPG information instead of using the EIT.

DVB Tables

- Service Description Table (SDT)
- Event Information Table (EIT)
- Bouquet Association Table (BAT)
- Time and Date Table (TDT)

ATSC Tables

- Master Guide Table (MGT)
- Virtual Channel Table (VCT)
- System Time Table (STT)
- Rating Region Table (RRT)
- Event Information Table (EIT)
- Extended Text Table (ETT)

Data in all tables, standard and private, must be consistent in order for EPG navigation to work properly. If tables are corrupted or late, users might not even see the EPG, or they might see incorrect data. For example, if a channel is incorrectly labeled in the SDT, a user may select this channel in the EPG but see a different one on the screen.

Because tables are constantly being updated in the stream, MPEG-2 transmission runs considerable risk for table errors. In order to ensure proper table delivery and successful EPG creation by the set-top box, network operators have to know immediately when table errors occur so they can be resolved with minimal impact to the viewer.

Ineffective rating blockouts

Customer-defined rating blockouts offer parents control over what TV programs their children can access at home. For example, they can choose to block out all movies or programs intended for adult audiences. This customization of the set-top box is made possible through rating information found in the EIT.

Because improper transmission of this information could allow children to view programs deemed unsuitable by their parents, operators must continuously monitor the transmission of rating information in the EIT.

Delayed channel changing

In an analog set-top box, tuning required a simple change in RF frequency. In the digital realm, however, tuning is a much more complicated process. At a minimum, it requires that the decoder:

1. Tune to the RF frequency of the transport stream containing the selected channel and lock to the signal
2. Find and decode the PAT
3. Find and decode the PMT
4. Find and decode the ECMs for the service
5. Find and descramble the video and audio for the service
6. Find an I-frame in the video and begin decoding and presenting the audio and video data.

Considering the complexity of this process, scanning from one channel to the next in a digital system may be more time-consuming than customers expect. Because of this natural delay, tuning speed becomes a competitive issue among service providers.

Efficient tuning requires that the set-top box receive all the above tables and ECMs free of error and at the appropriate rate. For instance, if the PAT is only repeated once every 10 seconds, then it will take the set-top box at least 10 seconds to tune to a new channel.

Multiplexers, remultiplexers, and PSI/SI/PSIP generation equipment control the creation of the table and ECM data necessary for tuning. Continuous monitoring at the output of each of these devices immediately alerts operators as to errors that will degrade tuning efficiency.

■ Network Maintenance

Continuous monitoring of the MPEG-2 transmission network improves network performance and quality of service over time. By simultaneously monitoring the network at different points along the broadcast chain, operators can detect the initial stages of failure in a piece of equipment. The equipment can then be repaired or replaced before the failure occurs, minimizing or eliminating down time.

In addition, many errors detected through continuous monitoring won't immediately affect service quality, but they do show signs of degradation in the network. If these errors go unchecked, they can become increasingly detrimental and damaging to service quality.

6.2.2 Monitoring Methods: Continuous Monitoring vs. Scanning

We've discussed several issues operators must be concerned about when monitoring network quality. The question now is, what can be done to prevent these issues from affecting service quality and impacting customers?

There are at least two methods of network monitoring: scanning and continuous monitoring. While different variations of these methods may vary in scope, scanning involves rotating through a network, monitoring a single transport stream at a time for a number of minutes or seconds and then moving on to the next transport stream. By contrast, continuous monitoring provides real-time analysis on all transport streams in the network at all times.

■ Scanning

Scanning systems are usually less expensive than continuous monitoring systems because they require fewer probe units and less hardware. But these systems only examine one transport stream in the network at a time. Properly characterizing errors in a stream often requires one minute or more of continuous monitoring for each stream. This could mean that in a network of 10 transport streams, each stream is only monitored once every 10 minutes. Of course, for larger systems, the delay is even greater. This causes two main concerns:

1. Errors left undetected for ten minutes or more may cause severe service degradation before the operator becomes aware of them.
2. Random errors that last for only a short time could go undetected for extended periods. These errors could indicate serious problems that need immediate attention, such as bit errors or PCR jitter.

As we mentioned previously, the broadcast network is a complex real-time system that literally changes constantly. With a monitoring system that allows operators to examine only a portion of the network at a time, errors can perpetuate in unmonitored streams causing service degradation unbeknownst to the operator.

Though it is not the best primary source for network monitoring, scanning may be appropriate as a secondary monitoring tool at less critical locations in the network where transport stream content is not being created or changed, such as the output of a modulator.

■ Continuous Monitoring

Compared to scanning, continuous monitoring provides a much better defense against customer-affecting errors in the network. Real-time monitoring of all transport streams allows operators to quickly troubleshoot and resolve errors as they appear anywhere in the network. Because of this, operators easily recover the cost of continuous monitoring by reducing calls to customer service centers and minimizing churn in the customer base.

One example of a continuous network monitoring system is the Digital Broadcast Monitoring System from Acterna. On a single monitoring screen, the system displays a set of colored alarms that show the status of the network. When an error occurs anywhere in the network, the system sends a red-colored alarm to the operator indicating which transport stream contains the error. At the click of a button, the operator can access detailed real-time analysis of the problem transport stream and quickly diagnose the error.

Thus the system gives operators top-level network supervision as well as continuous real-time analysis of all transport streams in the network. This enables operators to immediately recognize and resolve any number of errors in the transport stream including bit errors, missing PIDs, table content and rate errors, Conditional Access problems and timing issues.

For an example of how continuous monitoring affects service quality, suppose the following:

Excessive PCR jitter appears on video PID 0x0070 in transport stream 0x0049 of a 50-channel network. The Digital Broadcast Monitoring System will immediately generate an alarm in the top-level supervision window. At first sight of the alarm, the operator can immediately drill down to access real-time analysis of transport stream 0x0049. He can examine the jitter levels for PCR PID 0x0070 and adjust the multiplexing or encoding equipment to solve the problem without delay.

Remember that detecting the same problem through scanned monitoring could delay the resolution for 10 minutes or more.

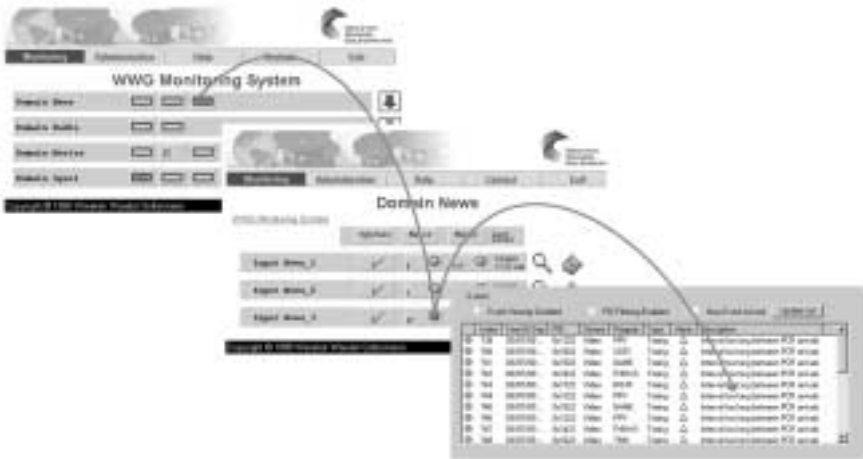


Figure 23: The Digital Broadcast Monitoring System combines top-level network monitoring with detailed real-time analysis of every transport stream.

6.2.3 Where to Monitor

Once you determine which monitoring method is best for you, you must select strategic points in your network where monitoring will be most effective.

Because errors can appear anywhere along the broadcast chain, operators must choose their monitoring points carefully. Here are a few tips to help operators determine where to monitor. Monitoring probes should:

1. Be placed as close to the customer as possible to determine the Quality of Service (QoS) being received by the viewer.
2. Monitor the service being received by as many customers as possible in order to reduce monitoring costs.
3. Be placed where errors are most likely to occur, for instance, where the transport stream is being created or changed (at the output of the encoder, multiplexer or remultiplexer).
4. Be able to detect errors in as many pieces of equipment as possible in order to provide maximum coverage with a minimum number of probes.

Secondary monitoring probes can be used to isolate network problems at locations where the transport stream does not change, for example, at the output of a modulator. This is where a scanning probe would be most effective.

7 Conclusion

The MPEG-2 standards for compression and transmission have made digital television a reality. Coupled with DVB or ATSC, MPEG-2 is being used to transmit entire networks of digital programming and services to customers all over the world. As it expands and converges with other new technologies, it will likely reshape the way we see and use television.

In this pocket guide we have attempted to familiarize you with the complexities of digital broadcast transmission and to give you a greater understanding of why and how to test and monitor in the digital broadcast environment. We hope the explanations and descriptions in the guide have been helpful to you. As we mentioned previously, this guide is not exhaustive, and we encourage you to consult the Reference Material list on page 53 for additional study resources.

8 Glossary

AC-3. The audio compression standard adopted by ATSC and DVB and owned by Dolby.

Advanced Television Systems Committee (ATSC). The digital broadcasting standard developed in the US and used in several countries worldwide.

ASI. See DVB Asynchronous Serial Interface.

ATM. Asynchronous Transfer Mode.

ATSC. See Advanced Television Systems Committee.

ATV. Advanced Television.

Auditory Masking. A phenomenon that occurs when two sounds of similar frequencies occur at the same time. Because of auditory masking, the louder sound drowns out the softer sound and makes it inaudible to the human ear.

BAT. See Bouquet Association Table.

BER. Bit Error Rate.

B-frame. A bidirectionally predicted picture, or a picture created by reference to preceding and subsequent pictures.

Bitrate. The rate at which a bit stream arrives at the input of a decoder.

Block. A set of 8x8 pixels used during Discrete Cosine Transform (DCT).

Bouquet. A set of programs or services sold as a single entity.

Bouquet Association Table (BAT). A DVB table that describes a set of services grouped together by a broadcaster and sold as a single entity.

Broadcaster. A person or entity that provides a sequence of scheduled events or TV programs to the consumer.

CA. See Conditional Access.

Cable Virtual Channel Table (CVCT). An ATSC table that identifies a set of one or more channels within a cable network. The table includes major and minor channel numbers, carrier frequency, short channel name, and information for navigation and tuning.

CAT. See Conditional Access Table.

CATV. Community Access Television, otherwise known as Cable TV.

Channel. (In ATSC) A digital medium that stores or transports an MPEG-2 transport stream. Called a “program” by MPEG-2.

COFDM. Coded Orthogonal Frequency-Division Modulation.

Compression. Reduction of the number of bits needed to represent an item of data.

Conditional Access (CA). A system used to control viewer access to programming based on subscription.

Conditional Access Table (CAT). PSI table that identifies EMM streams by their PID value.

Continuous Monitoring. The monitoring method that provides continuous real-time monitoring of all transport streams in a network.

CVCT. See Cable Virtual Channel Table.

DAVIC. Digital Audio Visual Council.

DCT. See Discrete Cosine Transform.

Decoding Time Stamp (DTS). Time stamp found in the PES packet header that indicates the time at which an audio or video frame will be decoded.

DigiTAG. Digital Television Action Group.

Digital Television. A general term used to describe television that has been digitized. It can refer to Standard Definition Television or High Definition Television.

Digital Video Broadcasting (DVB) Project. A European consortium that has standardized digital TV broadcasting in Europe and in other countries.

Discrete Cosine Transform (DCT). Temporal-to-frequency transform used during spatial encoding of MPEG video.

Downlink. Communication link from a satellite to earth.

DTV. See Digital Television.

DTS. See Decoding Time Stamp.

DVB. See Digital Video Broadcasting Project.

DVB Asynchronous Serial Interface (ASI). A standard coaxial DVB interface for MPEG-2 transport streams.

DVB-C. The DVB standard for broadcasting digital TV signals by cable. The RF spectrum in digital cable TV networks has a frequency range of approximately 46MHz to 850MHz.

DVB-S. The DVB standard for broadcasting digital TV signals via satellite.

DVB Synchronous Parallel Interface (SPI). A standard parallel DVB interface for MPEG-2 transport streams.

DVB-T. The DVB standard for broadcasting digital terrestrial TV signals.

ECM. See Entitlement Control Message.

EIT. See Event Information Table.

Electronic Program Guide (EPG). Display that describes all programs and events available to the viewer. It functions like an interactive TV guide that allows users to view a schedule of available programming and select an event for viewing.

Elementary Stream (ES). A bit stream that includes video, audio or data. It represents the preliminary stage of the Packetized Elementary Stream (PES).

EMM. See Entitlement Management Message.

Entitlement Control Message (ECM). A message in the transport stream that carries the keys used by the decoder to descramble the audio, video and data for a program.

Entitlement Management Message (EMM). A message in the transport stream used to update the subscription options or pay-per-view rights for an individual subscriber or for a group of subscribers.

Entropy Coding. The process by which DCT coefficients are resized according to the number of times they appear in the bit stream. The most frequently repeated coefficients are expressed in the smallest word length, decreasing the total number of bits need to represent a single frame.

EPG. See Electronic Program Guide.

ES. See Elementary Stream.

ETR 290. ETSI recommendation priorities for monitoring MPEG-2/DVB transport streams.

ETSI. European Telecommunication Standard Institute.

ETT. See Extended Text Table.

Event. A collection of elementary streams with a common time base and an associated start time and end time. An event is commonly referred to as a “television program.”

Event Information Table (EIT) (for ATSC). The ATSC PSIP table that carries event information including titles and start times for events on all the virtual channels within the transport stream. ATSC requires that each system contain at least 4 EIT tables, each representing a different 3-hour time block.

Event Information Table (EIT) (for DVB). The DVB SI table that supplies the decoder with a list of events corresponding to each service and identifies the characteristics of these events. Four types of EITs are defined by DVB: 1) The EIT Actual Present/Following supplies information for the present event and the next or following event of the transport stream currently being accessed by the decoder. 2) The EIT Other Present/Following defines the present event and the next or following events on transport streams that are not currently being accessed by the decoder. This table is optional. 3) The EIT Actual Event Schedule gives the decoder a detailed list of events in the form of a schedule that goes beyond what is currently or next available. This optional table references events for the transport stream currently being accessed by the decoder. 4) The EIT Other Event Schedule gives the decoder a detailed schedule of events that goes beyond what is currently or next available.

This optional table references events for transport streams that are not currently being accessed by the decoder.

Extended Text Table (ETT). The optional ATSC PSIP table that carries long descriptions of events and channels. There are two types of ETs: Channel ETs, which carry channel descriptions, and Event ETs, which carry event descriptions.

FEC. See Forward Error Correction.

Forward Error Correction (FEC). A method for protecting the transport stream against error. FEC adds error control bits before RF modulation. With these bits, errors in the transport stream may be detected and corrected prior to decoding.

Frame. Lines of spatial information for a video signal.

GOP. See Group Of Pictures.

Group of Pictures (GOP). A set of pictures, usually 12-15 frames long, used for temporal encoding of MPEG-2 video.

HDTV. See High Definition Television.

High Definition Television (HDTV). Digital television with resolution approximately twice as high as that of Standard Definition television (SDTV) for both horizontal and vertical dimensions. HDTV has an aspect ratio of 16x9 as compared to the 4x3 aspect ratio of SDTV.

IEC. International Electrotechnical Commission.

IEEE. Institute of Electrical and Electronics Engineers.

I/F. Interface.

I-frame. An intra-coded frame, or a frame encoded without reference to any other frame. I-frames act as references for predicted (P-frame) and Bidirectionally predicted (B-frame) pictures in a compressed video stream.

Integrated Receiver Decoder. A receiver with an MPEG-2 decoder, also known as set-top box.

Inter-frame prediction. A compression technique that periodically encodes a complete reference frame and then uses that frame to predict the preceding and following frames.

Interoperability. The ability of a system to use the parts or equipment of another system.

IRD. See Integrated Receiver Decoder.

ISO. International Standardization Organization.

ITU. International Telecommunications Union (UIT).

Jitter. See PCR Jitter.

Level. A range of picture parameters and combinations of picture parameters specified

by MPEG-2. The level of a video signal generally indicates the number of pixels per frame.

Low Voltage Differential Signal (LVDS). An electrical specification used by some manufacturers, usually on a parallel interface. It is a balanced interface with a low signal voltage swing (about 300mV). This specification is used for DVB SPI.

LVDS. See Low Voltage Differential Signal.

Macroblock. A group of 16x16 pixels used for motion estimation in temporal encoding of MPEG-2 video.

Master Guide Table (MGT). The ATSC PSIP table that identifies the size, type, PID value, and version number for all other PSIP tables in the transport stream.

Megaframe Initialization Packet (MIP). A transport stream packet used by DVB-T to synchronize the transmitters in a multi-frequency network.

MGT. See Master Guide Table.

MHEG. Multimedia & Hypermedia Expert Group.

MIP. See Megaframe Initialization Packet.

Motion Prediction. The process that reduces redundancy in a video signal by measuring an object's motion at the encoder and sending a motion vector to the decoder in place of the encoded object.

Motion Vector. A pair of numbers that represents the vertical and horizontal displacement of a region from one frame to another.

MP@HL. Main Profile at High Level. MPEG-2 specifies different degrees of compression vs. quality. Of these, Main Profile at High Level is the most commonly used for HDTV.

MP@ML. Main Profile at Main Level. MPEG-2 specifies different degrees of compression vs. quality. Of these, Main Profile at Main Level is the most commonly used.

MPEG. Moving Picture Experts Group, also called Motion Picture Experts Group. The standards body responsible for the development of MPEG-2, the standard for digital television broadcasting.

MPEG-1. The original MPEG standard for audio and video coding. The standard does not specify parameters for transmission.

MPEG-2. The standard that defines motion video and audio compression (ISO/IEC 13818). It applies to all layers of transmission (video, audio and system).

MPEG-4. The standard that specifies simultaneous coding of synthetic and natural objects and sound.

MPEG-7. Multimedia Content Description Interface. Standardizes descriptions for searching, filtering, selecting and handling audiovisual content.

MPTS. Multiple Program Transport Stream. An MPEG-2 transport stream that contains several multiplexed programs.

Multiplex (n). A digital transport stream containing one or more programs or services in a single physical channel. (v). To sequentially incorporate several data streams into a single data stream in such a manner that each may later be recovered intact.

Network. A set of MPEG-2 transport streams transmitted via the same delivery system.

Network Information Table (NIT). The DVB table that contains information about a network including its orbit, transponder, etc. DVB specifies two types of NITs. The NIT Actual is a mandatory table containing information about the physical parameters of the network currently being accessed by the decoder. The NIT Other contains information about the physical parameters of networks not currently being accessed. The NIT Other is optional.

NIT. See Network Information Table.

NvoD. Near Video on Demand. This service allows for a single TV program to be rebroadcast consecutively with a few minutes of difference in starting time. For example, a movie could be transmitted at 9:00, 9:15 and 9:30.

Packet. See PES Packet or Transport Packet.

Packet Identifier (PID). A unique integer value that identifies elements in the transport stream such as tables, data, or the audio for a program.

Packetized Elementary Stream (PES). A stream containing variable-length packets of video, audio or data.

PAT. See Program Association Table.

Payload. All the bytes in a packet that follow the packet header. For packets of audio or video, the payload contains audio or video data from the PES packet.

PCR. See Program Clock Reference.

PCR Jitter. Small, rapid variations in PCR values due to deliberate or accidental disturbances in the transport stream.

PES. See Packetized Elementary Stream.

PES Packet. The structure used to carry a single frame of audio or video data. It consists of a header and a payload.

PES Packet Header. The leading bytes of a PES packet, which contain ancillary data for the packet.

Phase Lock Loop (PLL). The process by which the decoder uses the PCR to lock its system time clock to the original system time clock of the encoder.

PID. See Packet Identifier.

PLL. See Phase Lock Loop.

PMT. See Program Map Table.

Presentation Time Stamp (PTS). A time stamp that indicates the moment at which a frame of audio or video must be presented to the viewer. Found in the PES header, the PTS is transmitted at least once every 0.7 seconds.

P-frame. A predicted frame, or a picture coded using references to a previous I- or P-frame.

Profile. A defined subset of the syntax specified in the MPEG-2 video coding specification. Different profiles indicate different levels of coding complexity for a picture.

Program. For ATSC, see Channel. For DVB, see Service.

Program and System Information Protocol (PSIP). The ATSC protocol for transmitting system information in the transport stream. Mandatory PSIP tables include MGT, STT, RRT, VCT and EIT.

Program Association Table (PAT). The MPEG-2 table that identifies all programs in the transport stream and provides the PID value for the PMT associated with each program.

Program Clock Reference (PCR). A time stamp in the transport stream used to synchronize the decoder's clock with the original system time clock of the encoder. The PCR is transmitted at least every 0.1 seconds.

Program Map Table (PMT). The MPEG-2 table that indicates the PID values for packets containing the audio and video components of a program. It also provides the PID value for the program's PCR.

Program Specific Information (PSI). The MPEG-2 specification for table data used by the decoder to demultiplex a transport stream and regenerate the programs it contains. PSI tables include PAT, CAT, PMT and NIT.

PSI. See Program Specific Information.

PSIP. See Program and System Information Protocol.

PTS. See Presentation Time Stamp.

QAM. Quadrature Amplitude Modulation. A type of modulation for digital signals used in CATV transmission (DVB-C). Amplitude and phase of a carrier are modulated in order to carry information.

QPSK. Quadrature Phase Shift Keying. A type of modulation for digital signals used in satellite transmission (DVB-S).

Quantization. Part of the spatial encoding process, it re-orders DCT coefficients according to their visual importance.

Rating Region Table (RRT). An ATSC PSIP table that defines ratings systems for different regions or countries. The table includes parental guidelines based on Content Advisory descriptors within the transport stream.

Reed-Solomon (RS) Protection Code. Refers to (usually) 16 bytes of error control code that can be added to every transport packet during modulation.

RRT. See Rating Region Table.

RS. See Reed-Solomon Protection Code.

RST. See Running Status Table.

Running Status Table (RST). The DVB SI table that indicates a change of scheduling information for one or more events. It saves broadcasters from having to retransmit the corresponding EIT when a change occurs. This table is particularly useful if events are running late.

Scanning. (1) Video compression: the process of transmitting the most significant DCT coefficients first, followed by less-significant coefficients, and finally an indication in the code that the remaining coefficients are all zero. (2) Network monitoring: a monitoring method that uses a single probe to monitor several transport streams. The probe rotates through the transport streams, monitoring each stream for a given period of time.

SDT. See Service Description Table.

SDTV. See Standard Definition Television.

Section. A syntactic structure used for mapping PSI/SI/PSIP tables into transport packets of 188 bytes.

Service. A collection of one or more events under the control of a single broadcaster. Also known as a program.

Service Description Table (SDT). The DVB SI table that describes the characteristics of available services. Two types of SDTs are specified by DVB: the SDT Actual and the SDT Other. The SDT Actual is a mandatory table that describes the services within the transport stream currently being accessed by the decoder. The SDT Other describes the services contained in transport streams not currently being accessed by the decoder.

Service Information (SI). The DVB protocol that specifies transmission of the data required by a decoder to demultiplex the programs and services in the transport stream. Mandatory DVB SI tables include TDT, NIT, SDT and EIT.

Set-top Box. A digital TV receiver, or an IRD.

SI. See Service Information.

SMPTE. Society of Motion Picture and Television Engineers.

SNMP. Simple Network Management Protocol. The standard protocol for system and network administration.

Spatial Encoding. The process of compressing a video signal by eliminating redundancy between adjacent pixels in a frame.

SPI. See DVB Synchronous Parallel Interface.

SPTS. Single Program Transport Stream. An MPEG-2 transport stream that contains one unique program.

ST. See Stuffing Table.

Standard Definition Television (SDTV). Refers to digital television that has a quality equivalent to NTSC or PAL.

STB. See Set-top Box.

STD. See System Target Decoder.

STC. See System Time Clock.

STT. See System Time Table.

Stuffing Table (ST). An optional DVB SI table that authorizes the replacement of complete tables due to invalidation at a delivery system boundary such as a cable head-end.

System Layer. Portion of the MPEG-2 specification that deals with the combination of one or more elementary streams of video, audio or data into one or more transport streams for storage or transmission.

System Target Decoder (STD). A hypothetical reference model of the decoding process defined by MPEG-2.

System Time Clock (STC). The 27MHz clock of the encoder upon which transport stream timing is based.

System Time Table (STT). An ATSC PSIP table that carries the current date and time of day. It provides timing information for any application requiring schedule synchronization.

Table. The transmission medium for system information necessary for the decoder to access and decode programs and services in the transport stream. Tables are divided into subtables then into sections before being transmitted. Several different tables are specified by MPEG, DVB and ATSC.

TDT. See Time and Date Table.

Temporal Encoding. The process that compresses a video signal by eliminating redundancy between sequential frames.

Temporal Masking. The phenomenon that happens when a loud sound drowns out a softer sound that occurs immediately before or after it.

Terrestrial Virtual Channel Table (TVCT). The ATSC table that identifies a set of one or more channels in a terrestrial broadcast. For each channel, the TVCT indicates major and minor channel numbers, short channel name, and information for navigation and tuning.

Time and Date Table (TDT). A mandatory DVB SI table that supplies the UTC time and date. This table enables joint management of events corresponding to services accessible from a single reception point.

Time Offset Table (TOT). Optional DVB SI table that supplies the UTC time and date and shows the difference between UTC time and the local time for various geographical regions. The PID for this table is 0x0014.

Time stamp. An indication in the transport stream of the time at which a specific action, such as the arrival of a byte or the presentation of a frame, is to take place. See also PCR, DTS, and PTS.

TOT. See Time Offset Table.

Transponder. Trans(mitter) and (res)ponder. The equipment inside a satellite that receives and re-sends information.

Transport Packet. 188-byte grouping of data found in a transport stream. Each packet contains a header and a payload.

Transport Packet Header. The leading bytes in a transport stream packet. The header contains ancillary data for the packet.

Transport Stream. A stream of 188-byte transport packets that contain audio, video or data belonging to one or several programs.

T-STD. See System Target Decoder.

TVCT. See Terrestrial Virtual Channel Table.

Uplink. Communication link from earth to a satellite.

UTC. Co-ordinated Universal Time.

VCT. See Virtual Channel Table.

Video Compression. The process used to reduce the number of bits needed to represent a video frame.

Virtual Channel Table (VCT). The ATSC table that describes a set of one or more channels or services. For each channel, the table indicates major and minor channel number, short channel name, and information for navigation and tuning. There are two types of VCTs, the TVCT for terrestrial systems and the CVCT for cable systems.

VoD. Video on Demand.

VSF. Vestigial Sideband Modulation. The terrestrial modulation method used in the ATSC. It can have either 8 (8 VSB) or 16 (16 VSB) discrete amplitude levels.

Weighting. During video compression, it is the process by which degradation, or noise, is strategically placed in more detailed or complex picture areas where the viewer is least likely to notice it.

9 Reference Materials

9.1 MPEG Specifications

ISO/IEC 13818-1 - Information Technology - Generic Coding of Moving Pictures and Associated Audio: Systems. Recommendation H.222.0, 15 April 1996.

ISO/IEC 13818-2 - Information Technology - Generic Coding of Moving Pictures and Associated Audio: Video, 15 May 1996.

ISO/IEC 13818-3 - Information Technology - Generic Coding of Moving Pictures and Associated Audio: Audio, 15 May 1995.

ISO/IEC 13818-4 - Information Technology - Generic Coding of Moving Pictures and Associated Audio: Compliance, 24 March 1995.

ISO/IEC 13818-9 - Information Technology - Generic Coding of Moving Pictures and Associated Audio: Real-time jitter, 12 December 1996.

9.2 DVB Specifications

European Standard (Telecommunications Series): Digital Video Broadcasting (DVB); Specification for Service Information (SI) in DVB Systems, EN 300 468 V1.3.1, February 1998.

European Telecommunication Report: Digital broadcasting systems for television, implementation guidelines for the use of MPEG-2 systems; Guidelines on implementation and usage of service information, ETR 211, August 1997.

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