DVB-S
Digital Video Broadcast, Satellite

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Contents

1. Introduction

DVB (Digital Video Broadcasting) is a European organization founded in 1993, and its task is to promote international communication standards for digital television applications. Its function is to design and regulate the procedures used in the digital signal transmission of data and services [1].

DVB has developed different broadcast standards depending on the transmission channel.

- Terrestrial: DVB-T and DVB-T2, and for wireless systems DVB-H.
- Cable: DVB-C and DVB-C2.
- Satellite: DVB-S and DVB-S2, and for wireless systems DVB-SH.

Every standard defines the channel coding and modulation, since every channel has a different set of characteristics. But all of them follow the coding of the standard MPEG-2. For all of them, the system input and output signals are MPEG-2 Transport Streams. In this transport stream, there can be either audio or video codified in MPEG-2 as encapsulated data [1].

2. DVB-S (Digital Video Broadcasting by Satellite)

DVB-S is the standard defined for the satellite transmission of digital television. It was created by the European organization DVB in 1995 and it specifies the processes of coding of the channel and the modulation for a good performance of the satellite transmission channels. Same as all the other DVB standards, DVB-S uses MPEG-2.

At the beginning DVB-S was only use for digital television transmission, but due to its simplicity and flexibility it is being used to transmit other types of data. It has been implement in almost all continents (see Fig.1), in some countries DVB-S is used together with other standards [2].

Fig 1. DVB-S in the world [3]**.**

2.1 DVB-S transmission System.

System definition

After the data has been coded following the MPEG-2 standard (which would be explained in Section 3), it needs to go through the next steps before being transmitted to the satellite [4]:

- Multiplexing and randomization for energy dispersion.
- Reed-Solomon Encoder
- Outer interleaver
- Convolutional Coder
- Base band shaping
- QSPK modulation

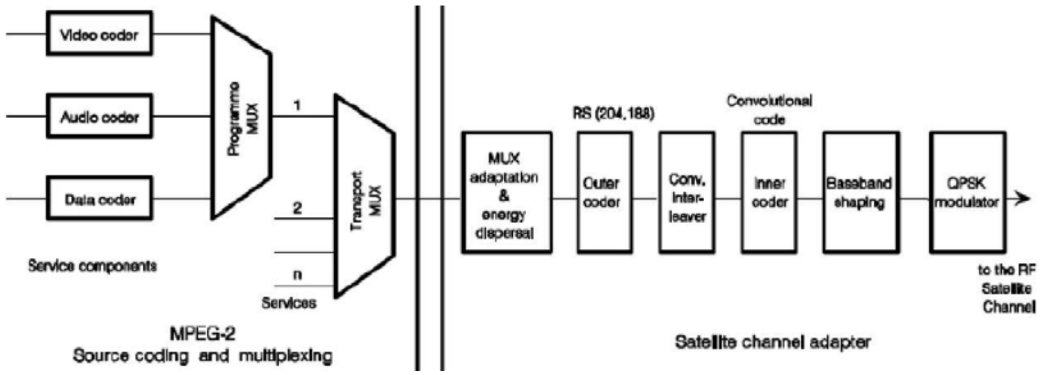

Fig 2. DVB-S transmission system diagram.

Channel Coding

Since it is a satellite transmission, it needs a good protection against errors. That is why it uses a FEC (Forward Error Correction) coding to add redundancy in order to be able to do some error correcting at the receiver.

Adaptation and Spectrum Spread

The energy dispersion is the randomizing of the input signal in order to obtain a spectrum in which the spectral density is equally divided through the bandwidth. For that the signal needs to go through the next blocks [4].

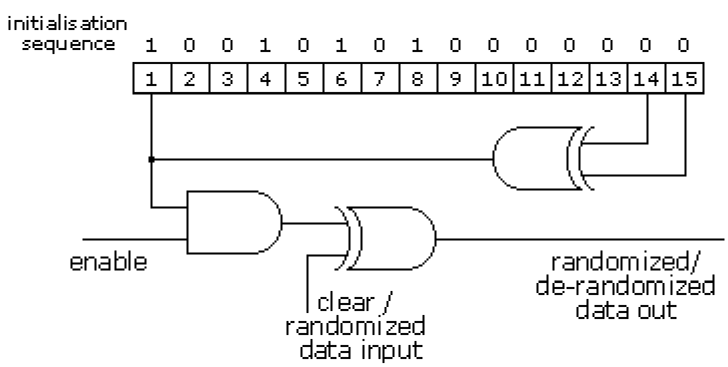

Fig 3. Energy dispersion system.

This process aims to obtain a pseudorandom binary sequence PRBS, through a polynomial generator 1 + x14 + x15. It is a 15 positions register with the sequence 100101010000000, which needs to be initialized at the beginning of a group of 8 transport packets. For the randomization, the logic operation XOR is done between the original signal and the binary sequence obtained from the generator.

Reed-Solomon Coding

In every DVB standard an Extern Coding is used but only in DVB-S and DVB-T an extra coding is used, in this case a Reed-Solomon Coding. This is because Satellite communication and Terrestrial communication are more prone to errors.

The chosen Reed-Solomon coding is a coding of (204, 188, t=8), where 16 parity bits are introduced in each transport packet. With this the decoder is able to correct up to 8 error bytes in each packet of 204 received bytes [4].

Interleaving

In order to avoid errors in consecutive packets, the packets are interleaved.

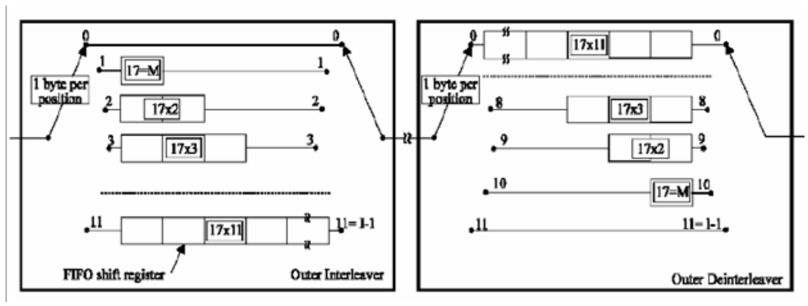

Fig 4. Interleaver.

Fig 4 shows an interleaver with 12 registers. Every byte of the packet is pushed into successive registers. In register 1 there will be bytes 1, 13, 25 and in register 2 there would be 2, 14, 26. The synchronization bytes are always pushed into register 0. Once this is done, a new stream is formed as a concatenation of the registers. Therefore successive errors would be dispersed along the original stream [4].

Convolutional coding

Since the Reed-Solomon coding protection is not enough, a convolutional coder is used on top of it. This makes the signal robust against random errors. After the convolutional coder the data stream will be bigger, but the size of it will be controlled by using a Code Rate [4]. The code rate is the relation between the data rate before the convolutional coder and the data rate after the convolutional coder.

Bandwidth filtering

After the convolutional coding, the signal is filtered to limit its spectral components and try to avoid the interferences between symbols [4].

QPSK modulation

Once the signal is ready to be transmitted, it needs to be adapted to the channel. In this case, a QPSK (Quadrature Phase Shift Keying) modulation is used. It is a constant amplitude modulation in where the information is in the phase of the carrier, which makes it robust enough for the channel. It has a reduced bandwidth [5].

In satellite signal transmission, the signal has to travel through great distances, which translates in big attenuations in the signal. Therefore, it is needed a codification practically immune to noise and with a constant amplitude.

The satellites that can be used in DVB-S are those with transponder bandwidth between 26 and 36 MHz. Therefore, there is the need to choose a symbol transmission rate that gives a spectrum that is smaller than the transponder bandwidth.

2.2 Data insertion in the transport stream

In this section, different methods of data insertion are going to be discussed. There is different ways of inserting the data into the transport packets, some of those methods are discussed below:

2.2.1 Data piping

It is an asynchronous transport method where the data is directly inserted into the payload of the transport packets. There need to be an agreement between the sender and the receiver where it is indicated how the data is going to be distributed through the transport packet. This method is rarely used nowadays [6].

2.2.2 Data Streaming

It is a transport method based in the encapsulation of the data in PES packets. It can be divided into:

Asynchronous Data Streaming

There is no need for synchronization between the data. It is similar to data piping except that the data is packetized into 64 KB packet. This segments are inserted into PES packets where they are divided into 184 bytes units [6].

Synchronous Data Streaming

It is used when there is a constant data rate, where the coder reference clock is transported in order to be able to synchronize the receiver clock [6].

Synchronized Data Streaming

Synchronization between different data streams such as the video and audio stream [6].

2.2.3 Data carousel

It is the periodic transmission of data files through the DVB network. This files have a known size and the can be updated, added or removed from the carousel at any time. The packets have a length DSM-CC (Digital Storage Media Command and Control). Data carousel is used for the teletext in television programs [6].

2.2.4 Object carousel

Same as the data carousel but it adds information about the structure of the data that is being transmitted [6].

2.2.5 Multiprotocol Encapsulation (MPE)

Multiprotocol Encapsulation DSM-CC allows the systems to transport IP data over MPEG-2. In order to do so, every receiver has a 48 bits MAC address that uniquely identifies such receiver. An IP address is also needed and it comes specified in a new SI table, called IP/MAC Information Table (INT) [6].

3. MPEG-2

MPEG was made in order to establish international standards for audio and video codification. For this task, a number of standards were created under the name MPEG-2, standards that have been published as an ISO rule in the ISO/IEC 13818-1 [7]. The MPEG-2 system is one of the transport systems more sophisticated and most widely accepted, that is why DBS uses MPEG-2 [7].

3.1 MPEG-2 Streams

In order to create the transport streams, the programs (audio and video) have to go through a number of processing blocks, which can be seen in the following diagram (Fig 5).

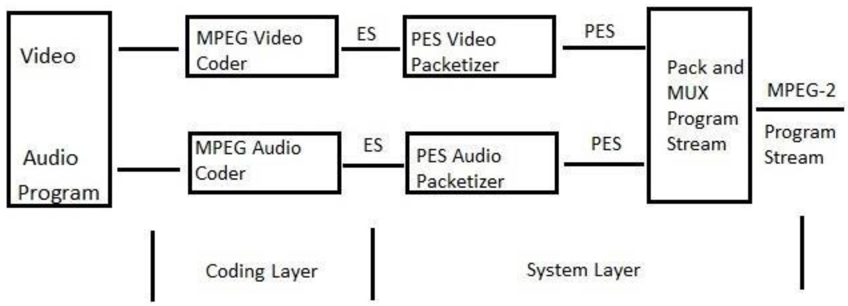

Fig 5. MPEG-2 Block Diagram

We can divide the diagram into two parts:

- Coding layer: In this layer the program gets encoded using MPEG-2 standards.
- System layer: In this layer the data packets are organized and all the signals are multiplexed in order to create one signal stream.

The basic component of a MPEG stream is the ES (Elementary Stream) which is the audio and video signal compressed, as soon as they come out of the Coding layer. These Elementary Streams will then pass to the System Layer where they will be organized into packets of different length called PES (Packetized Elementary Streams) [8].

Once the system has produced these PES, they can be multiplexed in 2 different ways: either into a PS (Program Stream) or a TS (Transport Stream).

- Program Stream: it is the result of combining together all the PES that belong to the same program. These packets have variable length and they are big.
- Transport Stream: It is the result of combining together PES from different Programs. They have a fixed length and they are short.

Due to the limitations of the Program Stream, such as being able of transmitting only one program, DVB system uses the Transport Stream as its standard stream.

3.2 Transport Stream (TS)

The Transport Stream starts with a digital program that contains different types of data (such as video or audio). All this digital data is organized in elementary blocks called Presentation Units. These units are then encoded into access units (Fig 6).

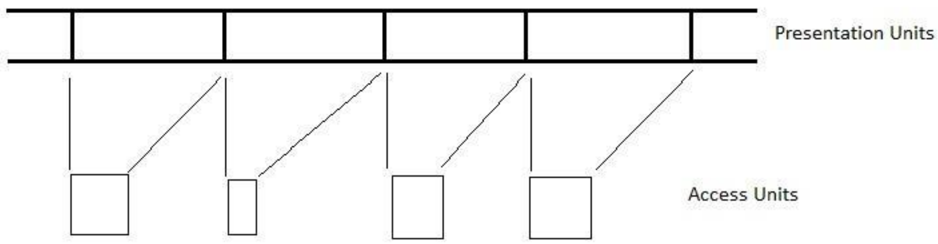

Fig 6. Presentation Units to Access Units

Then the result of the coding of a MPEG sequence of video or audio is a number of access units of video or audio. This is known as the Video Elementary Stream and the Audio Elementary Stream [8].

3.2.1 PES packetizing

In MPEG there are 3 different types of Elementary Streams [8]:

- Video Stream: coding of video signals
- Audio Stream: coding of audio signals
- Data Stream: coding of any kind of data.

Every Elementary Stream will be divided into packets of different size which are the PES that can have a maximum length of 64 KB. Each PES contains a short header and an extension where the audio and video data is allocated.

PES-packet structure

Every ES is packetized in variable length packets called PES. This packets have a length of 64 KB, and have a minimum header of 6 bytes [9].

- Start code: 3 bytes its always 0000 0000 0000 0000 0000 0001
- Stream ID: shows what type of data is in the stream, either audio, video or data.
- PES packet length: exact length of the packet (maximum of 64 bits).

After the header, there is an optional header extension with:

- Bits ”10”: always present
- PES scrambling control: defines the type of codification used.
- Priority of the packet.
- Data alignment indicator: indicates if the video or audio streams starts right after the header.
- Copyright: existence of copyrights.
- Original packet or copy: defines if the elementary stream is the original stream.
- Flags: indicate which optional fields of this header are present in the packet. This fields contains amongst others the PTS (Presentation Time Stamps) and the DTS (Decoding Time Stamps)
- PES Header length: total length of the header.
- Padding bits.

After this there comes the payload of the elementary stream (Fig 7).

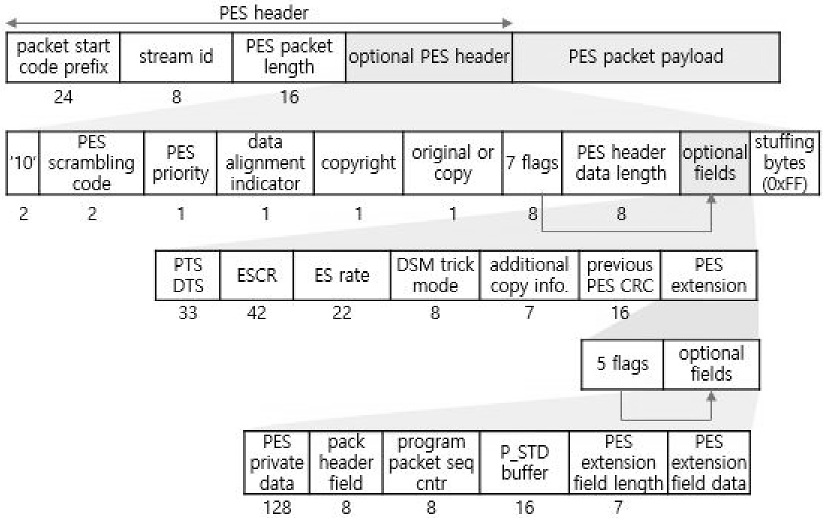

Fig 7. PES packet [10]**.**

Multiplexing the PES packets

The length of the PES packets is too long to form a unique signal to transmit, when this signal should carry several programs each of them with several elementary streams.

For a better transmission, the PES packets are divided into smaller packets with a length of 188 bytes, where the first 4 bytes are the header and the other 184 bytes are the payload. This packets are the Transport Packets. A Transport Packet contains data from only one PES, if there is any leftover space it is filled with the Adaptation Field. This field also contains the PCR Program Clock Reference, to synchronize the user clock with the program clock.

The collection of all the Transport Packets that are being transmitted in a certain moment is called the MPEG-2 Transport Stream. In the Transport Stream there is also packets with no data, to help with the bandwidth capacity and packets with information about the service offered.

Transport packet structure

- Synchronization byte: in order to be able to synchronize the system and the data stream.
- Transport Error indicator: indicates if the packet is corrupt
- Payload Unit Start Indicator: indicates if the first byte of the payload is also the first byte of a PES packet.
- Transport Priority: gives priority to certain packets if necessary.
- PID: Identify the packets that belong to the same PES
- Scrambling control: indicates if the data is scrambled or not.
- Adaptation Field Flag: indicates the existence or not of an adaptation field in the header.
- Continuity counter: increments by 1 unit every time a packet is sent from a certain source. This allows the demodulator to know if a packet has been lost or not.

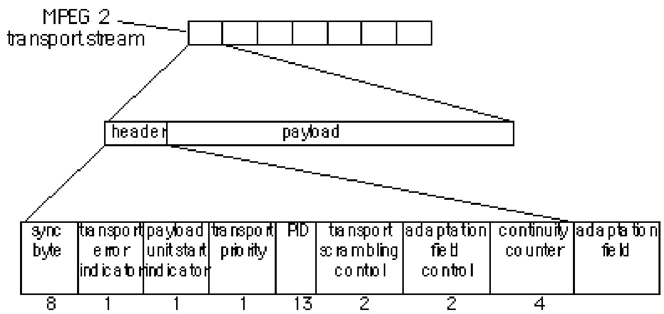

Fig 8. TS packet [11]**.**

Program Specific Information

Since a MPEG-2 transport multiplex can transport several programs, each of this programs formed by one or more PES, there is a need for a way to guide and simplify the demultiplexing process in the decoder. For this purpose, MPEG-2 defines 4 types of tables that together conform the PSI (Program Specific Information). These are:

- Program Association Table (PAT)
- Conditional Access Table (CAT)
- Program Map Table (PMT)
- Private

4. Reception of the message

In this section, the reception of a message is explained. The receptor follows the same steps as the transmitter but in reverse order.

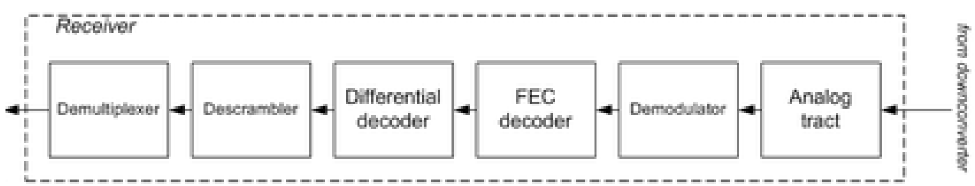

Fig 9. DVB-S receiver block diagram.

4.1 Synchronization of the Transport Stream

The decoder needs to find first the synchronization bytes inside the transport stream. This bytes always have a value of 0x47 and are in each one of the Transport Packets every 188 bytes.

4.2 Reading the contents

Once the decoder is synchronized with the transport stream, it searches for the packets that compose the Program Specific Information (PSI). The PSI describes the structure of the transport stream and the relations between the PIDs and the different programs in the stream. This helps the decoder in the demultiplexing and presenting the programs in the receiver. The PSI is formed by 4 tables:

Program Association Table (PAT)

The use of this table is obligatory and it shows the number of programs inside the transport stream. It is transmitted periodically every 0.5 seconds. The PID of the packets containing the PAT is 0x0000. In the payload of the PAT, there is a list with the PIDs of the programs that are being transmitted. This PIDs lead to the Program Map Tables (PMT), where the programs are described as well as the stream that compose each program [12].

Program Map Table (PMT)

This table consist in transport stream packets in which the payload has a list of the PIDs of the elementary streams that form a program. Each program in a Transport Stream has an associated PMT. The PMTs are in packets with arbitrary PIDs (except values 0x0000 and 0x0001) [12].

Access to a program

In order to access a program the decoder will select all the packets which PIDs where indicated in the PMT payload of the corresponding program. The decoder will demultiplex this packets to get the PES. If the elementary streams are not encrypted, they can be decoded by the MPEG-2 decoder.

Conditional Access

Conditional Access is used to limit the access of some users to certain programs or contents. In order to encrypt the contents DVB-S uses the Common Scrambling Algorithm (CSA).

The information needed to decrypt a program is sent in the Transport Stream through the messages EMMs (Entitlement Management Message) and ECMs (Entitlement Control Message). The EMMs contain the rights of each user to access a service or not. The ECMs contain the encrypted Control Word.

In order to find this messages inside the transport stream, there is another table with PID 0x0001 called Conditional Access Table (CAT) [13].

Program Synchronization

In order to decode the audio and video, more synchronization is needed. For that it is used the Program Clock Reference (PCR) which is in the optional header of the transport packet and the Decoding Time Stamps (DTS) and Presentation Time Stamps (PTS), that are in the header of the PES [13].

Additional data synchronization

For the synchronization of other services and events transmitted in the transport stream, it is used another set of tables that are Service Information (SI) tables.

Network Information Table (NIT)

Gives information about the physic parameters of the network that are needed to transmit the transport stream. This table is program number 0 and has a PID of 0x0010 [13].

Service Description Table (SDT)

Describes the services contained in a transport stream. Contains information such as the name of the services, name of the provider and parameters of that service. It has a PID of 0x0011 [13].

Event Information Table (EIT)

Contains information about events of the program, such as starting time, duration… It has a PID of 0x0012 [13].

Time and Date Table (TDT)

It contains the UTC (Coordinate Universal Time) and the actual date. Helps configure the internal clock on the receiver. It has a PID of 0x0014 [13].

Bouquet Association Table (BAT)

Gives the information about the bouquets (collection of services for the user) and the services in it. It has a PID of 0x0011, same as the SDT, the information transmitted is the same only than in SDT is for only one channel and BAT is for several channels [13].

Running Status Table (RST)

Updates the information related to an event, only if it has been a change in that event. It has a PID of 0x0013 [13].

Time Offset Table (TOT)

Gives information about the time and date, as well as the difference with the local time and date. It has a PID of 0x0014 [13].

Stuffing Tables (ST)

They are used to invalidate tables that can no longer be used, therefore they have the PID of the table that they are going to invalidate [13].

5. Conclusions

DVB-S is the most widely used standard for satellite television. DVB-S uses the MPEG-2 standard for coding the data, as well as Forward Error Coding, Reed Solomon Coding and Convolutional coding to make the signal robust against the high amount of error that comes with Satellite transmission. It also uses QPSK to modulate the signal, which makes the information be encoded in the phase instead of the amplitude, which also helps with making the signal robust enough for the channel.

The data is divided into Transport Packets and it is inserted in them through a number of techniques such as data piping, data streaming, data carousel, object carousel or multiprotocol encapsulation. In order to be able to correctly decode the Transport Stream, there are four different types of tables (Program Association Table (PAT), Conditional Access Table (CAT), Program Map Table (PMT) and Private Tables), that are transmitted together with the data in the Transport packets. This tables help the decoder to be able to differentiate each program that is transmitted in the Transport Stream, and know the packets that belong to each program as well as being able to synchronize the program.

Since 2003, there is a second generation of DVB-S called DVB-S2, which improves the previous standard and allows the use of broadcast services, HDTV and interactive services such as Internet access [14].

References

[1] https://en.wikipedia.org/wiki/Digital_Video_Broadcasting.

[2] https://en.wikipedia.org/wiki/DVB-S.

[3] [http://www.songtaotech.com/dvb-s.asp.

[4] http://www.etsi.org/deliver/etsi_en/300400_300499/300421/01.01.02_60/en_300421v010102p.pdf.

[5] http://www.etsi.org/index.php/technologies-clusters/technologies/broadcast/dvb.

[6] http://www.etsi.org/deliver/etsi_tr/101200_101299/101202/01.01.01_60/tr_101202v010101p.pdf.

[7] https://en.wikipedia.org/wiki/MPEG-2.

[8] https://www.uic.edu/classes/ece/ece434/chapter_file/chapter7.htm.

[9] http://dvd.sourceforge.net/dvdinfo/pes-hdr.html.

[10] http://ktword.co.kr/abbr_view.php?m_temp1=1618&id=716.

[11] http://www.abdn.ac.uk/erg/research/future-net/digital-video/mpeg2-trans.html.

[12] https://en.wikipedia.org/wiki/MPEG_transport_stream#PAT.

[13] http://www.etsi.org/deliver/etsi_en/300400_300499/300468/01.03.01_60/en_300468v010301p.pdf.

[14] https://en.wikipedia.org/wiki/DVB-S2.

[15] https://www.dvb.org/.

[16] https://en.wikipedia.org/wiki/MPEG_transport_stream.

[17] https://en.wikipedia.org/wiki/Reed%E2%80%93Solomon_error_correction.

[18] https://en.wikipedia.org/wiki/MPEG_transport_stream.