The Elettronika DVB-T Assistant

ELETTRONIKA SRL

|fm|tv|digital|broadcasting|

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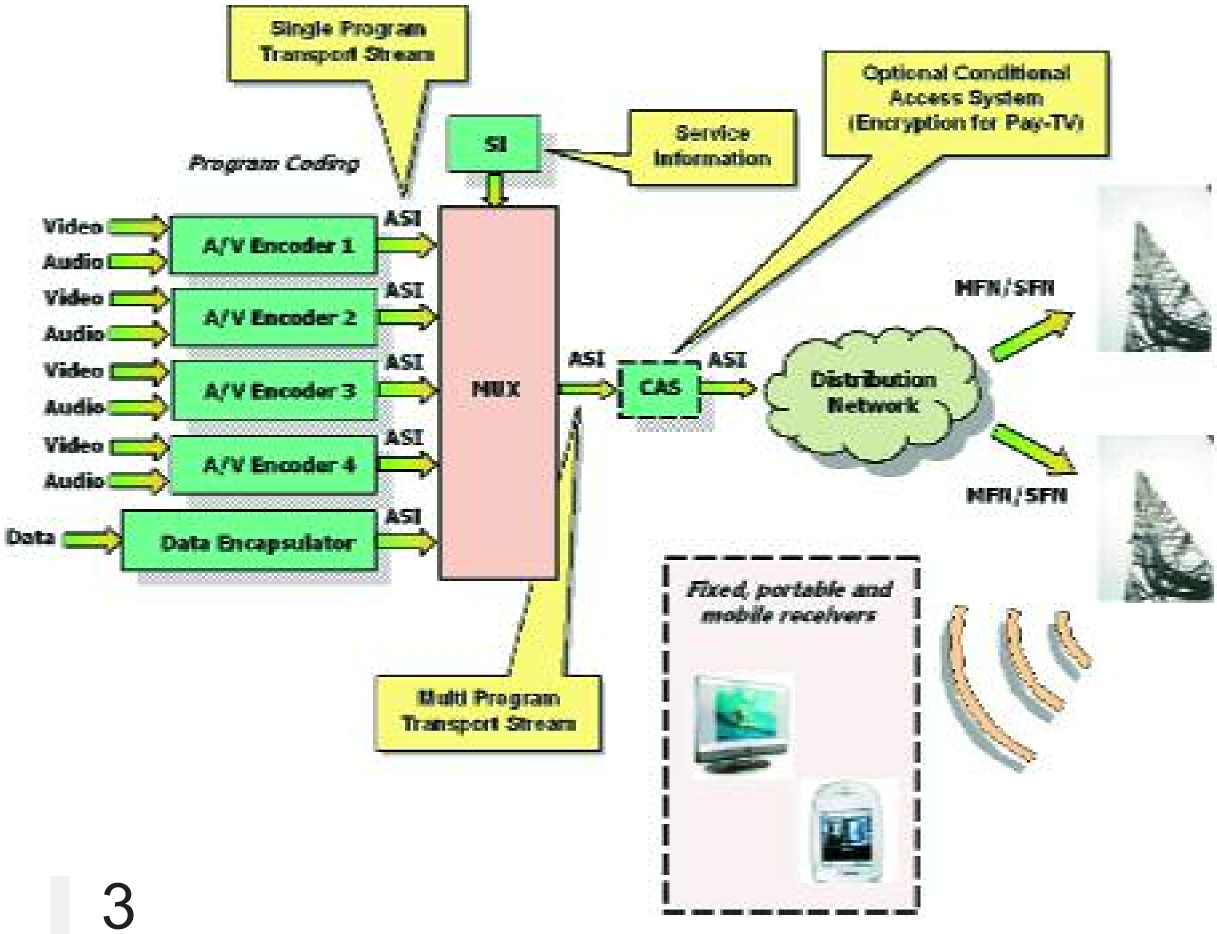
GENERAL

DVB-T is a way to broadcast digital TV content over UHF and VHF carrier frequencies using the COFDM (Coded OFDM) modulation, a smart technique allowing very interesting coverage performances thanks to exceptional robustness against noise, fading and multi-path effects.
Generally more than one TV program is carried over an RF channel, so every broadcaster should create in the production studio a **multiplex** of TV programs to be distributed to all the transmitter sites of the network.
In a DVB-T multiplex not only TV programs can be broadcast to the end users: **additional services** can be transmitted at the same time, as Electronic Program Guides, additional audio signals, FM radios on TV, interactive applications, mobile TV services.
Another great advantage of the DVB-T technique is the possibility to build Single Frequency Networks (SFNs) through exact synchronization of all the transmitters of the network by means of a common GPS reference signal.
The architecture of a DVB-T network can be simply analyzed by dividing it into the most important elements: TV Production Studio, Transmitting sites and Receiving sites.



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TV PRODUCTION STUDIO

The aim of the Production Studio is to build a **Transport Stream (TS)** that is composed by the TV programs, encoded with MPEG-2 encoders and joined in a single stream by means of an MPEG-2 multiplexer. The maximum number of TV programs in a single multiplex (also called "bouquet") is typically four or five, and the digital format used for the MPEG-2 TS is called **ASI** (Asynchronous Serial Interface). The TS in ASI format is to be distributed to all the transmitters of the network. The **distribution** can be done by means of satellite links, terrestrial microwave links, fiber optic links or links over suitable telecom networks. The different distribution methods use different equipment. Fiber optic links and telecom links are implemented by means of **network adapters** that transform the ASI signal into an optical beam or into different electrical signals, according to the chosen network (e.g. Ethernet or G.703). Both terrestrial and satellite links are implemented by means of a digital **QPSK modulator** which modulates the ASI TS signal over an IF carrier (typically 70MHz). The IF carrier is then passed to a suitable up-converter section that feeds a satellite or terrestrial RF transmitter. This signal is sent to each transmitter site directly or through one or more transponders (terrestrial or satellite).

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TRANSMITTING SITE

The RF microwave signal received through a parabolic antenna from the terrestrial or satellite link is down-converted at IF level and demodulated through a **digital IRD** (Integrated Receiver Decoder) in order to get the ASI TS coming from the Studio and to simultaneously decode the TV programs to restore the original audio-video content.
If other distribution systems are used, the proper telecom network adapter must be used in order to recover the ASI Transport Stream and an **MPEG-2 Decoder** with ASI input is used to decode the TV programs and produce the analogue audio-video content.
So, at each transmitter site, the analogue audio-video signals can be used to feed analogue TV and radio transmitters and the ASI signal can be used to feed DVB-T transmitters.

A **DVB-T Transmitter** modulates the ASI TS signal over an IF frequency (36.15MHz) using the COFDM modulation scheme. Then the signal is up-converted to a UHF or VHF channel and amplified to the desired power level by means of a suitable power amplifier chain. The amplifier output is then routed to an output **cavity band-pass filter** which shapes the radiated spectrum in order to avoid disturbances to the adjacent channels. The resultant signal goes to the antenna system, properly designed to cover the desired area.

Different **redundant configurations** may be used in the transmitter site to guarantee the maximum continuity of service in case of failures in parts of the transmitter.

Combined systems to broadcast over different channels using a single antenna system are built using the same techniques adopted by the analogue TV system.

4 RECEIVING SITE

The DVB-T signal is received by means of a standard roof-top UHF or VHF antenna which feeds a DVB-T **set-top box** that demodulates the COFDM signal and decodes the MPEG-2 Transport Stream producing the analogue audio-video programs. The audio-video outputs of the set-top box are sent to a standard TV set by means of standard analogue audio-video interfaces like SCART or coaxial RCA connectors. The set-top box shall be **MHP-compliant** if MHP interactive applications are present in the DVB-T bouquet received.

Reception is also possible by means of Personal Computers or Laptops equipped by internal or external **DVB-T receiver cards**, which usually are connected to the computer with a PCI, PCMCIA or USB-2 interface. The receiver card, connected to a portable antenna, demodulates the DVB-T signal and produces the Transport Stream which is decoded by a **software MPEG-2 decoder** running over the computer platform.

DVB-T reception is also possible through special mobile and/or portable receivers, for example installed inside trains, cars or buses. A different approach is DVB-H, explained later in a dedicated paragraph.

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MER

The MER (**Modulation Error Ratio**) is the most important parameter of a DVB-T transmitter system because in a single numerical value it summarizes the quality of a transmitter. The MER is related to the DVB-T **constellation** used by the COFDM modulator, which can be QPSK, 16QAM or 64QAM depending on the modulation scheme chosen for each transmitter site. The MER is related to how much the constellation radiated by the DVB-T transmitted is similar to the ideal constellation which would be radiated without any distortion or intermodulation effects.
Any power amplifier (PA) system will introduce distortion over the COFDM spectrum. The more is the PA distortion, the more the constellation differs from the ideal one and the MER value is low.
So the MER value should be maximized and the best way to obtain high MER values with a DVB-T transmitter is to perform a high-quality digital **pre-correction**.
A higher MER value leads to a higher coverage area, so two DVB-T transmitters with the same output power but with different MER values will have different coverage performances.

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POWER AMPLIFIERS

The DVB-T signal has a very high dynamic range (about 12dB of peak-to-average ratio) so **very linear** power amplifier stages have to be used to produce a high-quality COFDM spectrum. As already explained before, the linear behavior of the power amplifier can be greatly improved by using a digital pre-correction system, thus improving the MER value. Generally speaking, an **LDMOS** amplifier is much more linear than a Bipolar or a Mosfet amplifier, so a DVB-T transmitter will have higher performances if built using LDMOS technology.
Another aspect to consider for the amplifiers is the so-called “**back-off**”. To explain the meaning of back-off, let’s consider an example. If we have a 1kW peak power analogue LDMOS TV transmitter which we want to transform to a DVB-T transmitter, we have to replace the analogue PAL exciter with a DVB-T exciter. After all the tuning operations we will see that the maximum DVB-T output power will be most probably around 250W RMS (*Root Mean Square*, which means total average power over

the used bandwidth). The back-off value is the ratio of the DVB-T power to the analogue peak power, which in this case is 1/4, or 6dB. So the quality of a power amplifier can also be measured by the back-off value: the best power amplifiers can work with lower (in dB) back-off values. Typically an LDMOS PA guarantees a 6dB back-off, while a Mosfet or Bipolar PA typically shows a back-off of 7 to 9dB.

7 THE DVB-T MODULATION

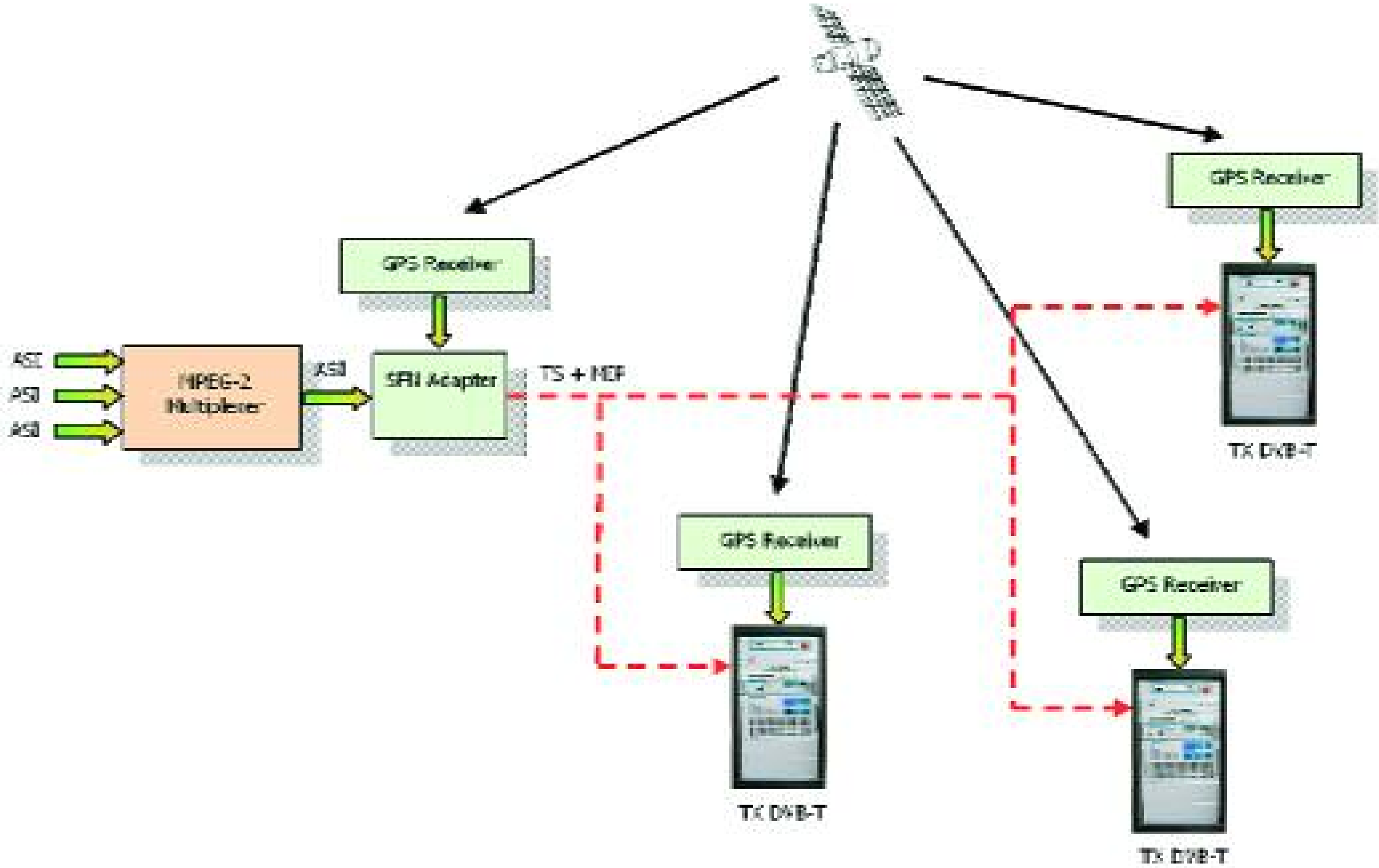
The DVB-T modulator is characterized by many **network parameters** which can be programmed by the broadcaster to choose the suitable radiated signal: channel bandwidth (6MHz, 7MHz, 8MHz), IFFT mode (2k, 8k), constellation (QPSK, 16QAM, 64QAM), FEC rate (1/2, 2/3, 3/4, 5/6, 7/8) and Guard Interval (1/32, 1/16, 1/8, 1/4). Each combination of these parameters leads to a different behavior of the transmitter, in terms of **channel capacity** (which is the maximum bit-rate carried) and of **signal robustness** (measured by the minimum S/N ratio required at the receiver side to correctly decode the audio-video programs). The right combination of the above parameters should be carefully selected in order to implement the optimal trade-off between total bit-rate and signal robustness. Let's consider an example in order to better understand this problem. A UHF DVB-T transmitter is configured with 8MHz bandwidth, 8k IFFT mode, QPSK constellation, 2/3 FEC rate and 1/4 Guard Interval. From the ETSI EN 300 744 recommendation we find that this combination of parameters leads to a total maximum bit rate of 6.64Mbit/s, which is useful to transport one only MPEG-2 TV program with high broadcast quality. So the channel capacity of this **DVB-T mode** is very low. But we find that the minimum S/N ratio required at the receiver side is about 5.7dB for fixed reception, and this means that this DVB-T mode is very robust against noise because a DVB-T set-top box will show a perfect image even with the signal situated only 5.7dB over the noise floor.
Let's consider another UHF DVB-T transmitter with the same bandwidth and IFFT mode, but this time with 64QAM constellation, 5/6 FEC rate and 1/32 Guard Interval. From the same ETSI recommendation we find that this combination of parameters leads to a total maximum bit rate of

30.16Mbit/s, which is useful to transport up to five MPEG-2 TV programs with high broadcast quality. So the channel capacity of this mode is much higher. For this mode we find that the minimum S/N ratio required at the receiver side is about 20dB for fixed reception. So, the higher bit-rate has been paid by a lower signal robustness because the signal level at receiver side must be at least 20dB over the noise floor in order to allow a perfect image on the TV set. So if the two transmitters have equal output power, the first will show a much wider coverage area compared to the second one.
So each time the right DVB-T mode should be carefully selected after considering which is the best trade-off between bit-rate and coverage.

8 SINGLE FREQUENCY NETWORKS

Single Frequency Networks are the best way to implement DVB-T networks with very high **spectrum efficiency**. The typical use of SFN networks is to build small-medium DVB-T networks for metropolitan or regional areas. A nation-wide MFN DVB-T network can be profitably implemented by means of many regional SFNs, each tuned to a different frequency. The basic principle of SFN networks is that all the transmitters of the network must radiate exactly the same data at exactly the same output frequency. So the headend equipment located in the production studio and all the transmitters need a **common reference synchronization signal** in order to synchronize the data (Transport Stream) and the output frequencies (local oscillators).
This synchronization is implemented by means of the GPS signal, available simultaneously in all the world.
In **studio**, an equipment called **SFN Adapter** connected to a **GPS receiver** must be located after the multiplexer in order to insert a synchroni-zation signal in the ASI TS. The TS is then distributed to each transmitter site by means of a **very accurate distribution network** which takes care of the absolute integrity of the original TS.
Each DVB-T **transmitter** shall be equipped with a **GPS receiver** in order to be synchronized with each other and to compensate the transmission

delay of the distribution network. The result of this global synchronization is that in the areas covered by more than one transmitter the resulting interference will be perfectly constructive. The additional requirement in order to allow this condition is that the **distance** between each transmitter of the network and the adjacent ones must be lower than the distance covered by the signal during the selected Guard Interval value.



9 DVB-T TRANSPOSERS AND GAP-FILLERS

At the end of the planning and design phase of a DVB-T network, the next step is the installation of the transmitters for a real evaluation of the coverage with the radiated signal. Apart from rare cases of exceptionally favourable geographical situations, there are a certain number of *shadow zones*, which are areas reached by a signal too weak to be correctly decoded by the DVB-T receivers.

The coverage of the shadow zones is implemented by means of repeating

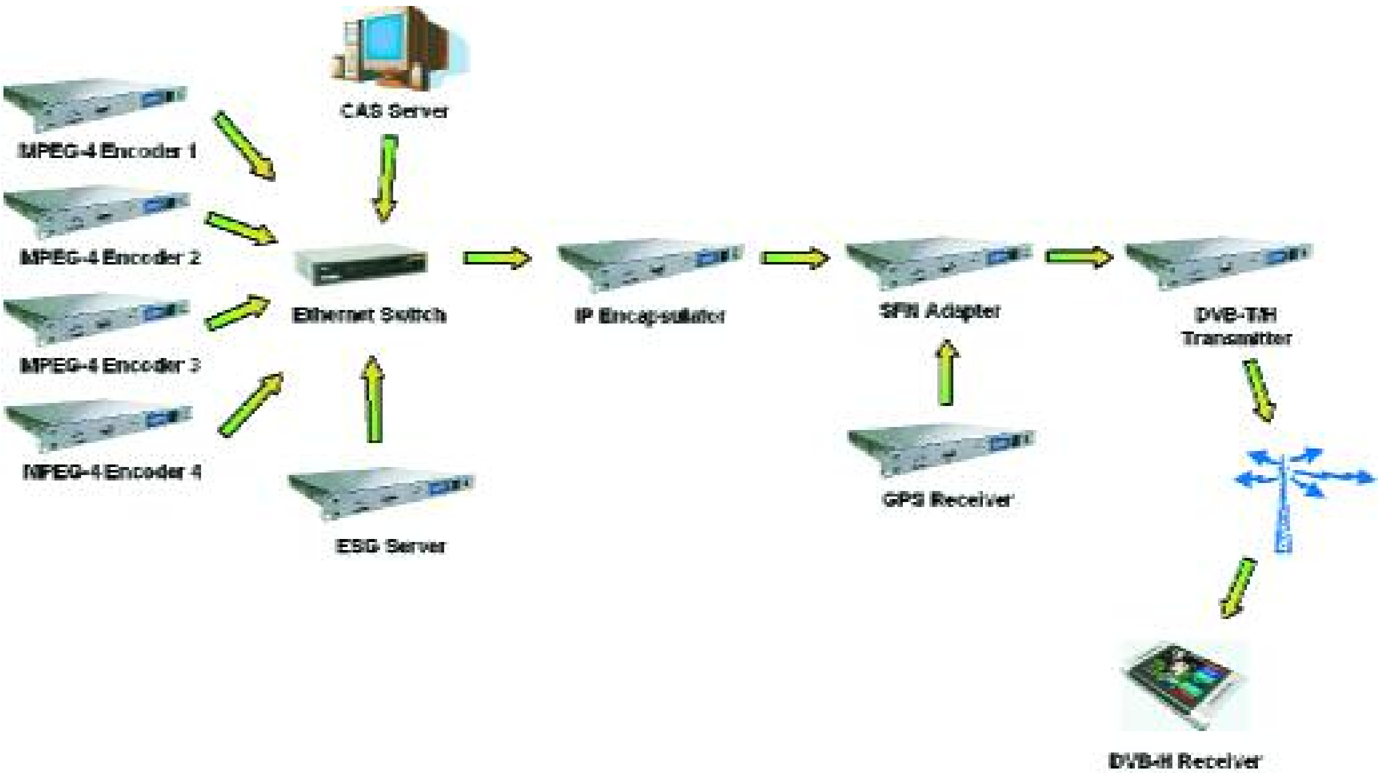
equipment of small-medium power, called **transposers** when the frequency of the transmitted signal is different from the frequency of the received signal and called **gap fillers** when the radiated signal is transmitted on the same frequency of the received signal.
Obviously in case of an MFN network both type of equipment can be used (after evaluating which kind of solution is optimal for each location) to cover the shadow areas, while in SFN networks the gap filler is the only allowed solution.
The gap filler is usually installed on mountains or hills in such a position to receive a satisfactory signal strength with the transmitting antenna designed with a radiation diagram useful to optimally cover the shadow area. The typical problem of a gap filler installation, due to structural reasons, is the unavoidable RF coupling between the signal radiated from the transmitting antenna and the signal picked up by the receiving antenna. If the coupling level is too high, this turns into a dangerous situation because the return path from the transmitting to the receiving antenna can lead to a positive feedback path which can easily damage the equipment hardware.
If the gap filler is installed within an SFN network the problem is worsened because, besides the return from the transmitting antenna, the receiving antenna picks up also the echoes coming from the other distant transmitters of the network. The solution to this structural problem is solved by the use of a **Digital Echo Canceller** in the digital processing section of a gap filler.

10 DVB-H

DVB-H is an extension of the DVB-T standard in order to allow optimal reception to **handheld receivers**. These receivers are mostly battery-powered cellular phones with a small screen moving at speeds which can reach up to about 200km/h. So the DVB-T standard added to the previous DVB-T standard some techniques (time slicing, additional FEC, 4k mode, 5MHz bandwidth) in order to optimize the mobile reception and extend the cell phones battery life to a maximum extent.
DVB-H is backwards compatible with DVB-T, so existing DVB-T networks can be upgraded in order to include some DVB-H services. **UHF channels 21-55** are the preferred channels for DVB-H broadcasting

because they allow the best trade-off between maximum allowed speed, SFN cells size, receiving antenna size and immunity to GSM signal interference. Currently no DVB-H cell phones support VHF operation. When a new DVB-H network has to be put into service, some new equipment is needed because the DVB-H services encoding and streaming is different from the DVB-T programs generation.
Then a careful planning phase is necessary, in absolute cooperation with **cellular network operators** and with **cell phones manufacturers**. Here is a list of the DVB-H equipment, with a short description of their function.

MPEG-4 Encoder: encodes video with MPEG-4 and audio with AAC and produces the signal over an IP output. An encoder is needed for every DVB-H service to be broadcast.
ESG Server: adds Electronic Service Guide to the transmitted stream. ESG allows DVB-H cell phones to lock to the available DVB-H services and to decode them.
CAS Server: adds Conditional Access (encryption keys) information to the transmitted stream. CAS allows reception only by the authorized users (smart cards management).
Ethernet Switch: joins the IP streams generated by the encoders, the ESG server and the CAS server.
IP Encapsulator: transforms the IP stream coming from the Ethernet switch into an MPEG-ASI Transport Stream and manages the time slicing and MPE-FEC DVB-H features. It adds also the SI tables as per ETSI standard.
SFN Adapter + GPS receiver: for SFN synchronization (if SFN operation is needed).
DVB-T/H Transmitter: for COFDM modulation and RF broadcasting.
DVB-H Receiver: cell phone with integrated DVB-H receiver chipset and with decryption capability. The decryption needs a SIM card with a pre-loaded software application which allows the reception of only the DVB-H services broadcast by the operator who is selling the SIM cards.



11 SYSTEM UPGRADE FROM ANALOG TO DIGITAL

Upgrading an **analog TV transmitter** to a DVB-T transmitter requires a few steps, to be performed carefully. The Elettronika Customer Service is always ready to guide you in this process.

First of all you should care of the frequency to be used for broadcasting the DVB-T channel, asking for the relevant license to the Telecommunications Ministry. Usually the final analog switch-off is anticipated by an **experimentation** period in which both analog and digital signals can be broadcast.

You may decide to broadcast the two signals simultaneously using two different channels and an antenna combiner. Or you may decide to broadcast analog and digital on the same channel at different hours, for example analog during the day and digital during the night. To implement this scheme Elettronika will install a timer-driven transmitter switch, programmable to switch at the desired hours.

Upgrading your analog transmitter into a DVB-T one needs the replacement of the analog exciter with a DVB-T exciter. The existing power amplifier can be used for the digital signal after applying the appropriate back-off to the output power. Then you will need to change your analog output band-pass filter to a new, more selective, cavity filter for DVB-T operation. Please refer to the FAQ section below for help in selecting the right output filter.

The **number of channels** that you may broadcast in your bouquet is not a fixed value, it is a matter of *trade-off* between video quality and channel capacity. In any case it is recommended to encode a TV program with at least 3.5-4Mbit/s in MPEG-2 in order to guarantee a satisfactory video quality. A general rule of thumb is that a program with high sport content needs more encoding bit-rate than a program with low details and low motion like news or documentaries.

Also the existing microwave **links** can be upgraded to digital. As for the transmitters, also the links can carry more programs over a single RF carrier. The existing microwave link can be reused to build a digital link by replacing the analogue FM modulator with a QPSK modulator with IF output and ASI input. The IF output of the link receiver is to be converted to L-band with a very simple and cheap module and supplied to a digital QPSK demodulator with integrated decoder which will recover the ASI signal and the analog audio/video signals of one TV program.

12 FREQUENTLY ASKED QUESTIONS

- Is it better to use a critical or a non-critical cavity filter at the transmitter output?

- A non-critical filter is usually made with six cavities and in most cases it gives enough out-of-band signal suppression. In some cases extra attenuation is needed, especially when the DVB-T signal interferes with very low analogue TV signals present in the same area in the adjacent channels. In this case a critical mask filter, usually made with eight cavities, is used. It has to be considered that the better out-of-band performance of the critical filter is paid by a higher insertion loss, due to the higher number of cavities.

- How can I choose the best value for the Guard Interval?

- The highest value of the Guard Interval (1/4) guarantees the highest immunity to multi-path conditions. The lowest value (1/32) guarantees the lowest immunity to multi-path. So if you find that multi-path distortion is strongly affecting the reception in your coverage area, you should increase the Guard Interval value. It has to be considered that, while keeping constant the other network parameters, an increase of the Guard Interval always leads to a bit-rate reduction of the DVB-T mode. For example a DVB-T mode with 8MHz, 64QAM constellation , 2/3 FEC and 1/32 Guard Interval has a maximum bit-rate of 24.13Mbit/s. If only the Guard Interval is increased to 1/4, then the maximum bit-rate will be 19.91Mbit/s, so a higher immunity to multi-path effects is paid with a lower channel capacity.

- When the 2k IFFT mode is preferred to 8k mode?

- The 2k mode is preferred for mobile DVB-T reception because this mode is more tolerant to the Doppler Effect generated by moving receivers. But the 2k mode is less suitable for SFN networks because it allows lower maximum distance between each transmitter of the network and the others.

So if mobile reception is an important point in your network you should use 2k mode, while if you are building an SFN you should prefer the 8k mode because it allows using a lower total number of transmitters in the network.

- What do I need to encrypt some DVB-T programs?

The encryption is implemented by means of a Conditional Access System (CAS) which is installed in the Production Studio just between the MPEG-2 Multiplexer and the TS distribution network.

The Conditional Access System is composed by a Scrambler, a CAS Server and a billing system. The Scrambler and the CAS Server work together to insert encryption keys inside the selected programs and the billing system is used to manage the billing fees paid by the subscribers. Only the authorized subscribers can have access to the encrypted programs, and the authorization control is performed by means of a smart card purchased by the subscriber. Different subscription approaches can be used: monthly subscription after a monthly fee payment, pay-per-view with a pre-paid smart card, or other different billing schemes.

- Can the DVB-T platform support High Definition programs?

Yes, it is possible. The High Definition (HD) programs are better encoded using MPEG-4 encoders, because an HD program encoded with MPEG-2 compression would need about 20Mbit/s, while it would need only 6-7Mbit/s using an MPEG-4 encoder. So an HD MPEG-4 encoder is needed for every HD program that you wish to add to your bouquet, the output of these encoders will be totally compliant to the ASI input of your multiplexer, so you can simply add these programs to the multiplexer. The end users who want to view these HD programs shall be equipped with an HD TV-set and with an HD MPEG-4 compliant DVB-T set-top box that will allow reception of both high definition and standard definition programs.

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