УДК

PRACTICAL EXPERIENCE IN THE CONFIGURATION AND IMPLEMENTATION OF SFN DVB-T2 CLASTERS IN THE REPUBLIC OF MOLDOVA

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ПРАКТИЧНИЙ ДОСВІД В КОНФІГУРАЦІЇ ТА РЕАЛІЗАЦІЇ СЛАДКІВ SFN DVB-T2 В РЕСПУБЛІЦІ МОЛДОВА

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Анотація. *У цій статті розглянуто технічні аспекти, пов'язані з плануванням, впровадженням і конфігурацією мереж з єдиною частотою DVB-T2, що має приклад досвіду, отриманого при впровадженні першого національного мультиплексного цифрового ефірного телебачення в Республіці Молдова. Представлена інформація може бути цікавою для технічних фахівців у галузі цифрового ефірного телебачення, а також для студентів факультетів телекомунікацій та радіозв'язку.*

Ключові слова: *цифрове ефірне телебачення, DVB-T2, T2 Gateway, SFN, MFN, SISO, „System A”, „System B”, „PLP”, „Multi PLP”, „Single PLP”, „Mode A”, „Mode B”, T2-Frame, FEF, T2-MI, COFDM, зона обслуговування, мінімальна середня напруженість поля, MER, BER, CBER, LBER, C / N.*

Abstract. *In this article the technical aspects related to the planning, implementation and configuration of the networks with a single frequency DVB-T2 have been approached, having as an example the experience gained with the implementation of the first national multiplex digital terrestrial television in the Republic of Moldova. The information presented may be of interest to technical specialists in the field of digital terrestrial television and also to the students of the faculties of telecommunications and radiocommunications.*

Key words: *digital terrestrial television, DVB-T2, T2 Gateway, SFN, MFN, SISO, „System A”, „System B”, „PLP”, „Multi PLP”, „Single PLP”, „Mode A”, „Mode B”, T2-Frame, FEF, T2-MI, COFDM, service area, minimum median field strength, MER, BER, CBER, LBER, C/N.*

INTRODUCTION

The terrestrial broadcasting standard DVB-T2 (Digital Video Broadcasting Terrestrial), is geared to deploy Single Frequency Networks (SFN) in which the broadcasting of a particular group of transmitters is performed on the same carrier frequency.

The important advantages of single-frequency networks in relation to traditional MFN (Multi Frequency Network) broadcasting networks are: efficient use of radio spectrum; significant decrease of the surface areas of the shadow areas in the service area; the ability to reduce the transmission power of the transmitters; field more uniform intensity distribution, etc. The application of SFN technology is facilitated by the Orthogonal Frequency Division Multiplexing (OFDM) method, which under certain conditions, provides at the receiving point a constructive summation of some useful signals of radio frequency (RF).

A single-frequency digital terrestrial television network consists of a group of transmitters that simultaneously emit the same signal on the same carrier frequency without interfering with each other and at the same time providing the same service area. So in a SFN network, the transmitters must emit signals that synchronized over time (transmitted at the same time or with a strictly controlled delay), on consistent nominal frequencies and modulated by the same data streams. The

SFN cluster must be designed to minimize its own interference to the substring frequencies of a transmitter and to use the useful signals emitted by other transmitters.

This article discussed the technical aspects related to the setting of the configuration parameters, and the commissioning of the DVB-T2 single-frequency networks, having as example the experience gained with the implementation of the first national multiplex digital terrestrial television in the Republic of Moldova. The presented information may be of interest to technical specialists in the field of digital terrestrial television and also to students related to telecommunication and radio communication faculties.

1 MODE OF OPERATION DVB-T2 SYSTEM

The DVB-T2 standard divides resources of the DVB-T2 frame (time-frequency) between multiple logical streams, allocating for each of them sub-carrier frequency groups - layers of the physical channel, so called PLP (Physical Layer Pipe). Frame resources are split between the PLP according to the transmission rate required for a particular logic flow, see Figure 1. This multiple modulation mechanism is also called multi-PLP.

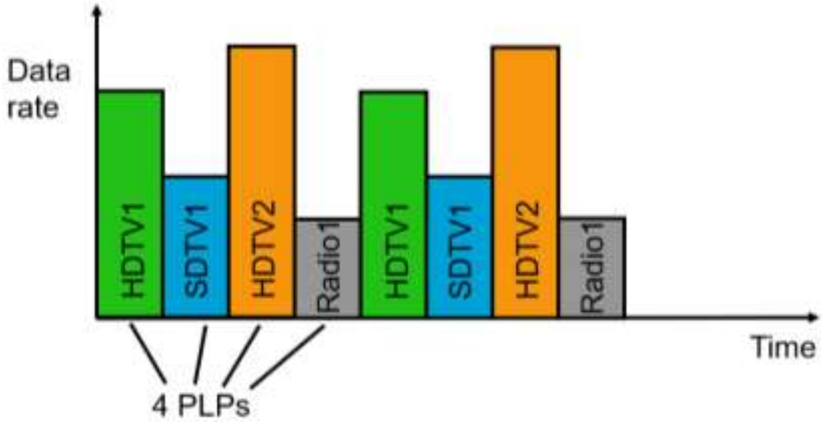

Figure 1 Multiple Modulations in DVB-T2

The SFN DVB-T2 system is based on two types of operation. The first one is called "System A", which does not require multiple modulation, but only one logic flow that is transmitted at the modulator output. In this operating mode, a data stream from the coding and multiplexing station output is applied to the insertion of a DVB-T2 modulator, which also sets the zone configuration parameters. The "System A" does not provide the implementation of SFN networks.

The second type of operation - "System B" is targeted for use of multiple modulations and allows processing of digital streams in a different way. This operating mode is also noted as multi-PLP or "Mode B". As an example, can be modulated 256-QAM (fast-flow, the lowest coverage area) and QPSK (slow-flow, the largest coverage area). As a result to the output of the transmitter's antenna we can obtain different signal modulation and different coverage areas for different TV programs. The "System B" mode is destined for the implementation of SFN networks and provides the division of the data processing between the "T2 Gateway" station and the DVB-T2 network modulators see Figures 2 and 3. In this case, TS streams (Transport Stream) or GS (Generic Stream) from the output of the coding and preventive multiplexing station are applied to the insertion of the "Input preprocessors" module where they are de-multiplexed into logical flows, then applied to the physical layers PLP device "Input processing" ("T2 Gateway"). In the "T2 Gateway" device, is made the planning of DVB-T2 frame and the division of system resources between physical channels PLP. At the same time, the settings of the technical parameters related to the cluster configuration are performed by the network operator through the "T2 Gateway" device.

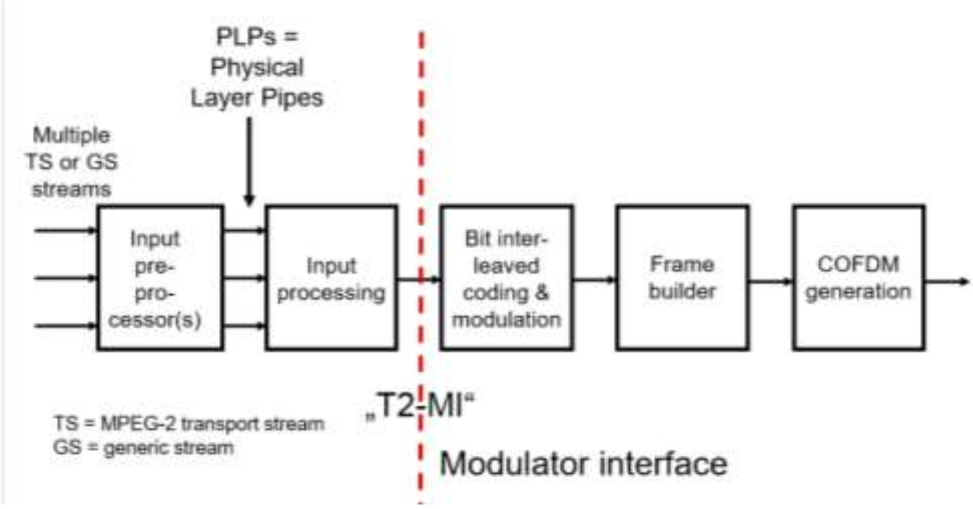

Figure 2 – Divide of processing data flows between the "T2 Gateway" station and the DVB-T2 modulators

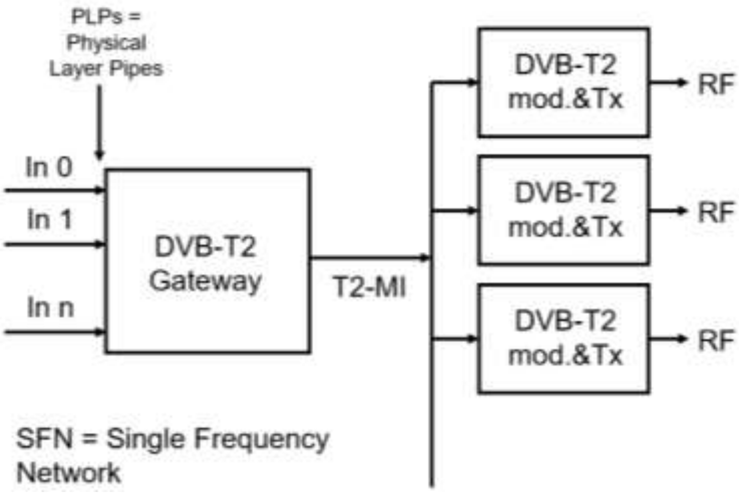

Figure 3 – Structure of "System B" operating mode of the DVB-T2 cluster

The "T2 Gateway" device performs separately for each logic flow, the adaptation and encapsulation in a series of BB-frames (Base band frame), which have a basic logical unit of the DVB-T2 signal. Each BB-frame performs the function of a container, in the data field of which is encapsulated a section of the logic flow.

At the output of T2 Gateway, is formed the digital T2-MI (DVB-T2 Modulator Interface) series, where are encapsulated a BB-frame, containing the logical data, and some data containing different signals and instructions necessary for the operation of SFN cluster, as an example: the synchronization signal at the output of the network modulators, COFD time-out signal; L1 signaling related to DVB-T2 framework resource planning; other instructions. The flow diagram of the T2-MI is shown in Figure 4.

In the implementation of the SFN DVB-T2 networks, may be a special case of "System B" - "Single PLP" (also known as "Module A"), when a single data stream is applied to the T2 Gateway physical input but in the T2-MI stream is a single PLP.

Therefore, the transmission segment of a SFN DVB-T2 network is composed of 3 basic elements: the encoding and multiplexing station of the audiovisual content; "T2 Gateway" station; DVB-T2 modulators. The first two form the central station of the system, the so called "Head End" station.

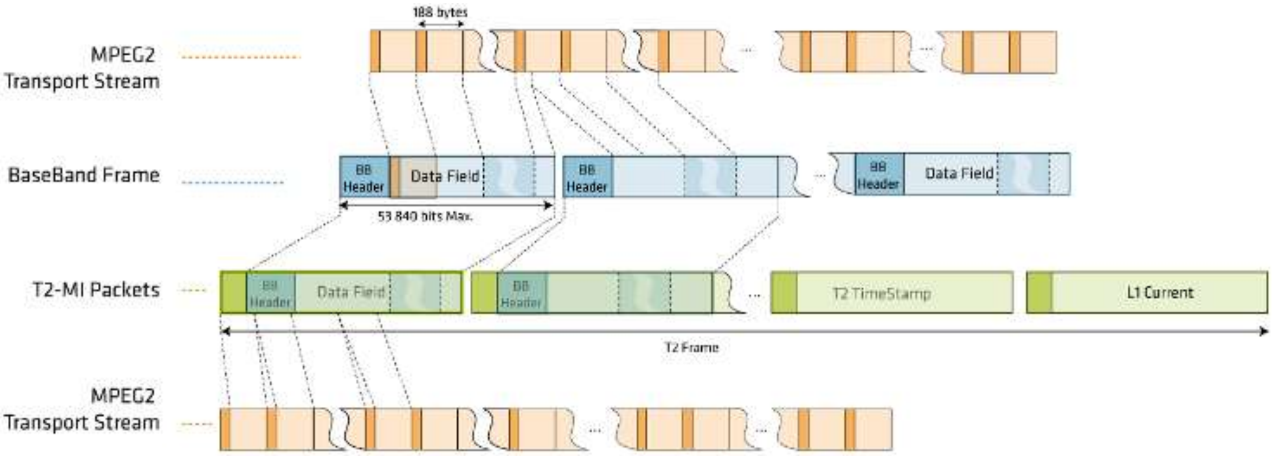

Figure 4 – Flow Diagram of T2-MI

Requirements relating to the creation of a DVB-T2 SFN cluster also require the main restrictions on broadcasting network organization - it is necessary to synchronize one source each transmitter in both time with frequency. This is achieved by applying to the reference signals the 10 MHz and 1 pps at the input of each transmitter in the SFN network and at the same time at the "T2 Gateway" input.

2 IMPLEMENTATION OF THE DVB-T2 SFN NETWORK IN THE REPUBLIC OF MOLDOVA

According to the provisions of the Regional Agreement on Terrestrial Digital Broadcasting Service Planning, signed at the Geneva Regional ITU Conference (RRC-06) since June 17, 2015, Moldova has assumed responsibility for the implementation of digital terrestrial television. According to the final documents RRC-06, the territory of the Republic of Moldova is divided into 6 service areas, see Figure 5.

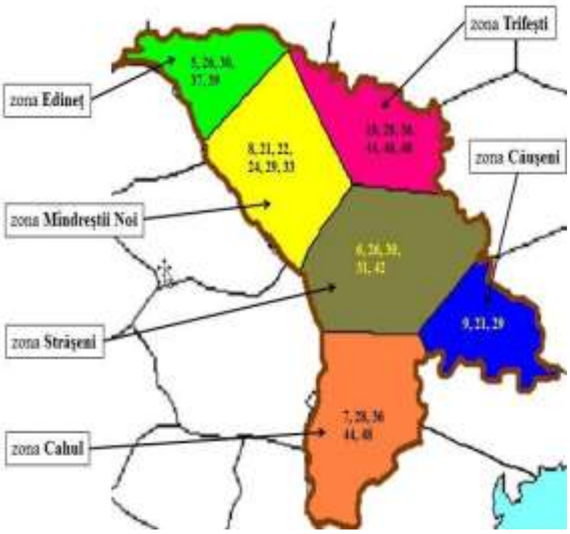

Figure 5 – Map of digital terrestrial television in the Republic of Moldova, according to the final documents RRC-06

For the implementation of national terrestrial digital multiplexes in the Republic of Moldova, DVB-T2 technology has been approved with the allocation of previously intended channels for analogue terrestrial television with 8 MHz bandwidth. In order to optimize resources (rational use of radio spectrum, existing infrastructure, reception of quality signal, etc.), it was decided to create DVB-T2 networks with only one frequency in the service areas. So, using 6 TV channels, it was possible to build in 2015 the first multiplex with national coverage, which was later put into service.

For implementation to the service areas mentioned by the SFN regime, at the multiplexing station has installed the "Head-End" coding and "DVB-T2 Gateway" device at the output of the T2-MI data stream. Through distribution network, the signal was directed to 17 transmitters placed in the territory of the country. The service areas (6 in number) were divided by the carrier frequency settings at the transmitter modulators. All other configuration parameters for SFN DVB-T2 clusters have been set by the "DVB-T2 Gateway" device. So, using a single "DVB-T2 Gateway" device and 17 transmitters, were created 6 SFN serving areas.

For designing and implementing the national multiplex and for creation of service areas were set the following objectives: to use the existing infrastructure of terrestrial broadcasting networks; the distance between the emission adjacent points of existing infrastructure, practically falling within the limit - 80 km; for the transportation of T2-MI flow to the input of modulators (including the shadow areas), can be used the infrastructure of the fiber-optic networks, the access to which exists practically in all localities of the Republic of Moldova; system operating mode - Single PLP; SISO (Single Input Single Output), which provide that all transmitters in the cluster component broadcasting the same signal; calculations, to the median value, in the service area is E_{med} = 54 dB(μV/m), at a height of 10 m above the ground.

Settings of SFN cluster configuration parameters was made through the "T2 Gateway" menu options. In general, the configuration of the SFN DVB-T2 network was performed by the following steps: setting the cluster operating mode; setting the SFN parameters; setting the DVB-T2 frame resources; setting PLP parameters.

3 CONFIGURATION PARAMETERS OF THE SERVICE AREAS

Figure 6 shows the configuration of the cluster operation mode: Single PLP. We can see that if the external synchronization signals disappear, the system will extend the operation for 15 minutes without hazard warning signal (clock reference / holdover timeout).

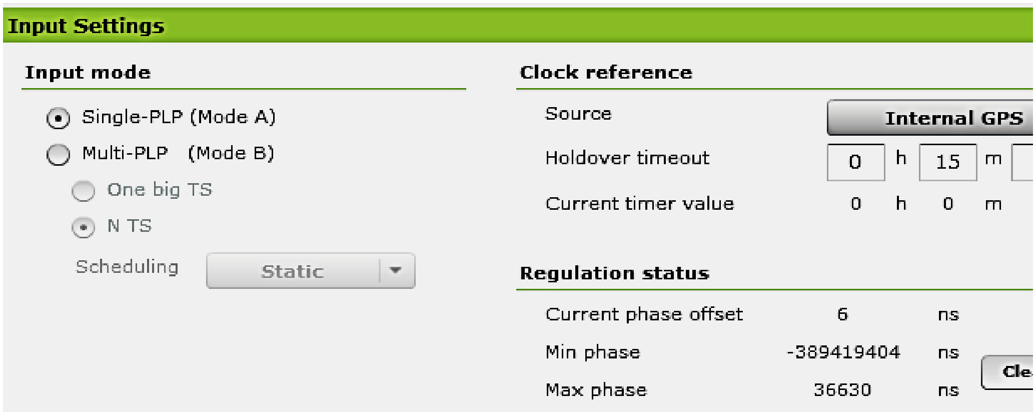

Figure 6 – DVB-T2 Gateway Device Menu: **Input Settings** option

Figure 7 shows the configuration of the SFN network parameters. From the image we can observe the following: for system operation is selected the basic profile of DVB-T2 standard; the network operates under the SISO mode (Single Input Single Output); T2-MIP packages (DVB-T2 Modulator Information Packet), intended for the ether synchronization of re-transmitters in shadow areas; synchronization of the COFDM symbol emission moment from the network modulators output - just over 900ms after receiving the 1pps impulse.

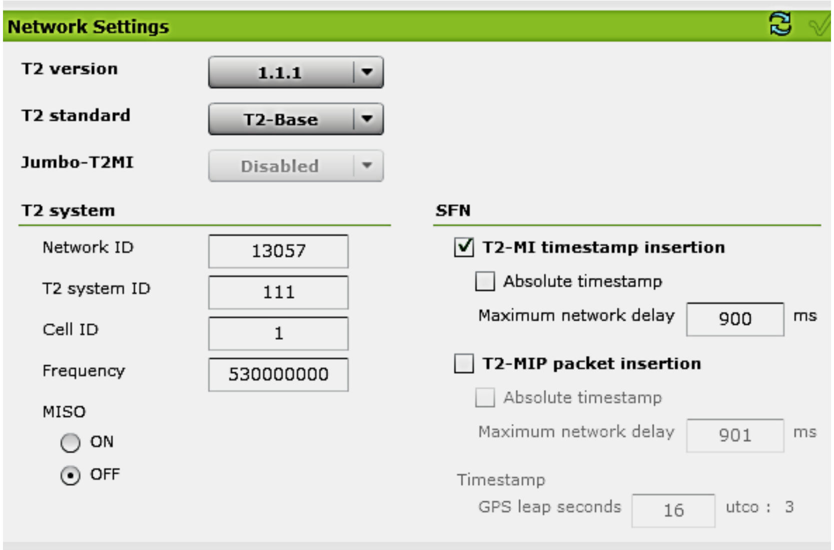

Figure 7 – DVB-T2 Gateway Device Menu: **Network Settings** option

Figure 8 shows the operating principle of SFN cluster in SISO mode.

Figure 8 – Demonstration of the SISO principle - one signal at the input of the receiver, one at the output of the transmitters

Figure 9 shows the settings of DVB-T2 frame resources, which are divided into three parts: Frame structure; Signaling modulation; Data modulation.

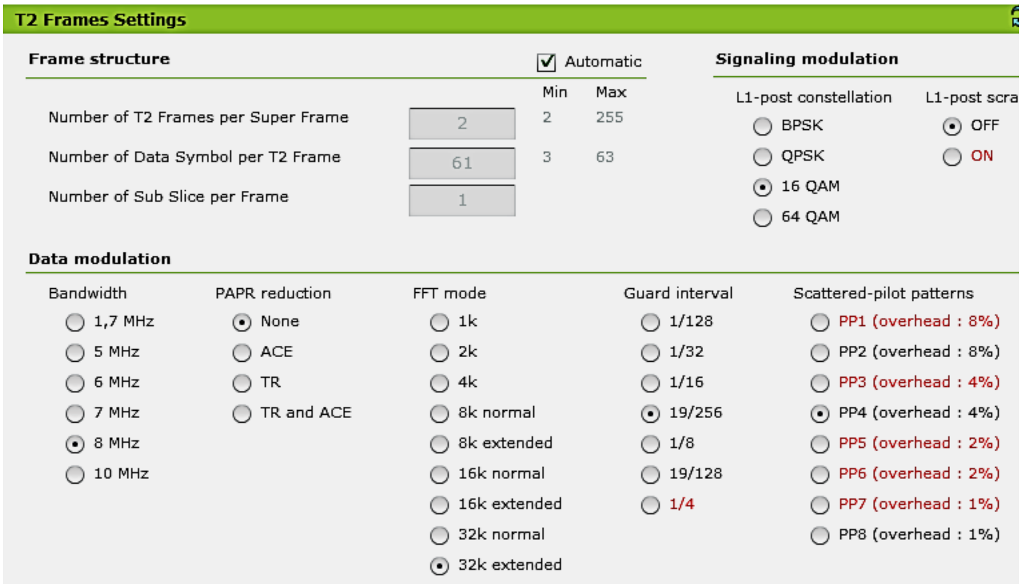

Figure 9 – DVB-T2 Gateway Device Menu: **T2 Frames Settings** option

Figure 10 – DVB-T2 Gateway Device Menu: **Advanced/FEF Settings** option

Frame-structure of DVB-T2 signal consists of Super Frames, which are divided into T2-frames, consisting of COFDM symbols. At the same time, in the Super Frames can be included FEF fields (Future Extension Frames), reserved for future use. From Figure 9, we notice that is selected the automatic forming of frame-structure. From the image shown in Figure 10, we notice that the FEF fields in the super-frame structure are not activated. The structure of DVB-T2 frame is shown in Figure 11.

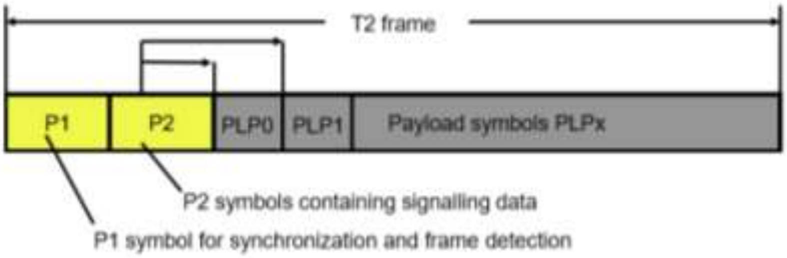

Figure 11 – Structure of the DVB-T2 frame

In the **Signaling modulation** option we set the constellation of signal transmitted on the sub-carrier frequencies of COFDM symbols located in the P2 preamble, see figure 11. In this preamble, the L1 signaling data is required to correctly decrypt the physical PLP strains into the receiver. Preamble P2 may consist of one or more COFDM symbols.

Data modulation option provides: parameter settings of the COFDM symbol (Bandwidth, FFT mode (Fast Fourier transform), Guard interval); the settings for reducing the signal factor of DVB-T2; scattered-pilot frequency template settings, intended for transmitting in frame the necessary special signals for correct demodulation in the receiver of RF signal.

Figure 12 shows the location of subcarrier orthogonal frequencies in a COFDM simulator. In the frequency band of the channel (symbol), there are thousands subcarrier frequencies, that are placed uniformly. The FFT mode parameter sets the number of subcarrier frequencies in the radio channel band of the DVB-T2 system.

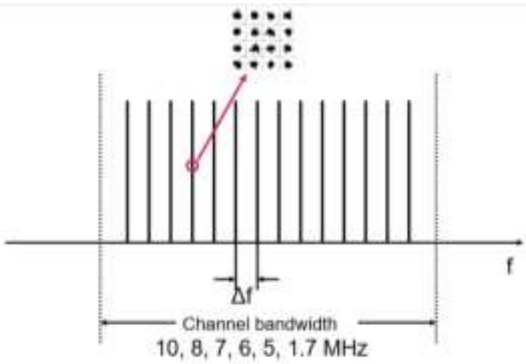

Figure 12 – Location of subcarrier frequencies in the COFDM symbol

As a consequence of increasing the number of subcarrier frequencies, it can be possible to increase the duration of the transmission of a COFDM symbol and, respectively, to increase the duration of its guard interval, which is beneficial for the implementation of single frequency networks.

Figure 13 shows the link between duration of the COFDM symbol and FFT size parameter. For the implementation of single-frequency networks and stationary signal reception, is recommended the FFT-32k mode.

in 8 MHz channel bandwidth

	FFT size	Symbol duration [ms]	Carrier Spacing [kHz]
Best for SFN	32K	3.584	0.279
	16K	1.792	0.558
	8K	0.896	1.116
	4K	0.448	2.232
	2K	0.224	4.464
Best for mobile	1K	0.112	8.929

8K, 16K and 32K mode: normal or extended carrier

Figure 13 – Dependence between the FFT size parameter and duration of COFDM symbol

The extension of the channel frequency band allows to increase the number of subcarrier frequencies in the COFDM symbol. Figure 14 demonstrates how the band extends (32k and 32k extended modes). In the channel with 8 MHz width, passing the FFT size parameter from 32k to 32k extended allows to increase the bandwidth of channel from 7.61 MHz to 7.77 MHz.

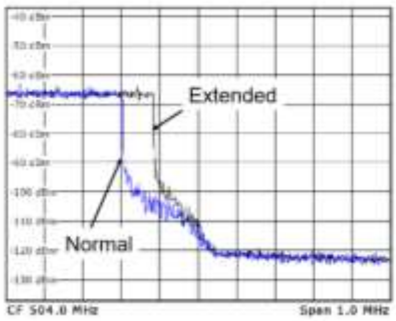

Figure 14 – Radio channel band edge in the 32k and 32k extended

To avoid the reciprocal interference between the subcarrier orthogonal frequencies of the DVB-T2 signal, before each COFDM symbol are provided guard intervals GI (Guard Interval), see Figure 15.

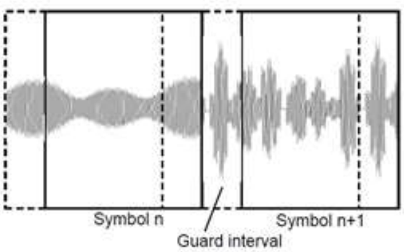

Figure 15 – RF DVB-T2 signal: Guard interval of the COFDM symbol

During the guard interval, the signal reception in the system is forbidden. The orthogonally of the subcarrier frequencies can be restored in the received COFDM signal, even if there are echoes at the receiving point. This is available as long as echoes do not exceed the limit of the guard interval, see Figure 16.

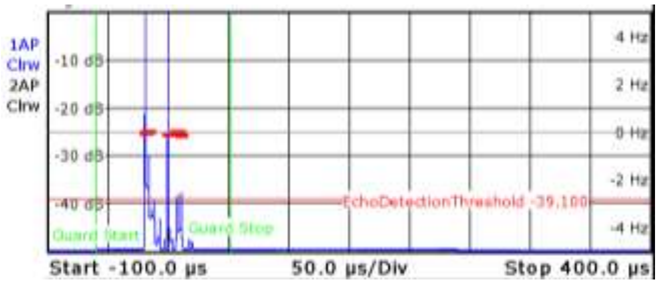

Figure 16 – DVB-T2 signal echoes at the reception point

The Tg length of the guard interval depends on the number of subcarrier frequencies in the COFDM symbol selected for the DVB-T2 system (1k, ..., 32k, where k = 1024) and must satisfy the condition $Tg \geq d/Vc$, where d- the distance between the adjacent transmitters; Vc - Propulsion velocity of electromagnetic waves. The delay value between the arriving signals at the reception point depends on difference in the length of the propagation paths and may reach several hundred microseconds. For network settings (32k ext. and 19/256 interval guard time) - the distance between the neighboring transmitters of the DVB-T2 cluster should not exceed 80 km.

The scattered-pilot PP4 (SISO) template is shown in Figure 17. Parameters of this template show a compromise between the system's noise resistance and the data transmission speed of the network.

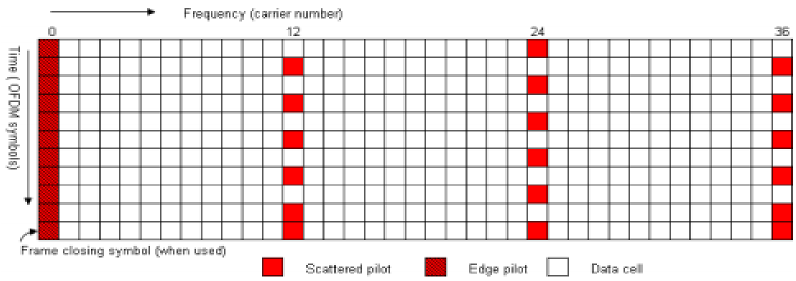

Figure 17 – Template: Scattered pilot pattern PP4(SISO)

The COFDM technology is characterized by the relatively high peak-to-peak ratio of the RF signal, called crest factor or PAPR (Peak to Average Power Ratio), see Figure 18. For this reason, the DVB-T2 signal is sensitive to nonlinear distortions in the final power amplifier cascades.

The technical data of the final power amplifiers from the transmitters that is used in clusters building, gave the possibility not to activate special options to reduce the PARP value of the RF signal in the system.

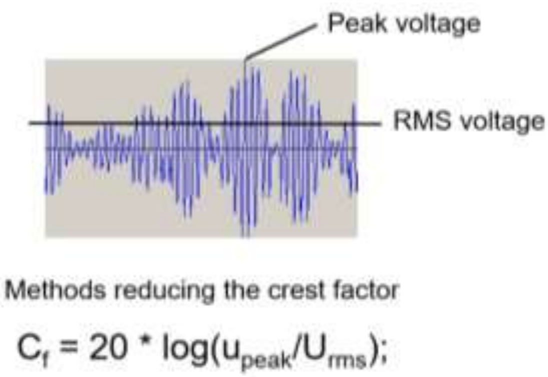

Figure 18 – DVB-T2 signal crest factor

The **Physical Layer Pipe Description / Transmission parameter** option provides the PLP physical channel transmission parameters setting. From the image shown in Figure 19, we can observe the following: the type 1 data stream is transmitted in a single physical layer PLP0; the frequency modulation PLP0 - QAM-256 is used with the signal constellation rotation; speed of protection code 2/3; the length of the encoded BB frame is 64800 bits (after the LDPC encoder).

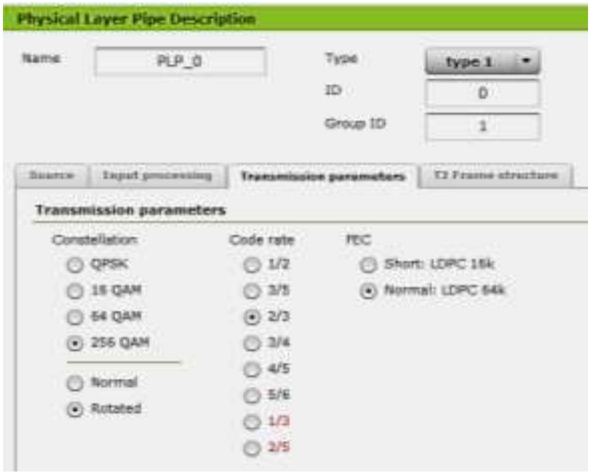

Figure 19 – DVB-T2 Gateway Device Menu:

Physical Layer Pipe Description/Transmission parameters option

The DVB-T2 standard establishes how highway flows digital fragments are placed inside the frame and in the Super Frame. In this sense, there are 3 types of highway flows - PLP common, PLP type1 and PLP type 2. Common PLP contain co-data for multiple PLPs (such as tables PSI / SI).

The PLP-type 1 stream in the DVB-T2 frame does not fragment, only one time is allocated to its location within the COFDM. For type 2 fragments streams can be assigned segments different time (from 2 to 6480). This improves their protection against disturbing impulses and fed the signal at the reception.

The rotation of the signal constellation within the PLP, see Figure 20, is performed in order to improve its protection against disturbances in the telecommunication channel.

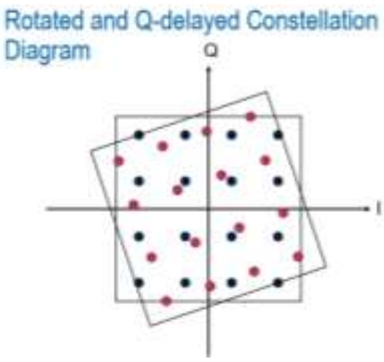

Figure 20 – Signal constellation rotation within PLP

In order to protect the data, BB frames from the modulator input are cascaded with BCH (Bose - Chaudhuri - Hocquenghem) and LDPC (Low Density Parity Check Codes) codes. So BB-frames turn into FEC frames, see Figure 21. The total length of the FEC frame is 64800 bits. The control bit portion of the FEC-frame may vary from 15 to 50%. As an option, a shorter FEC frame length is allowed - 16,200 bits.

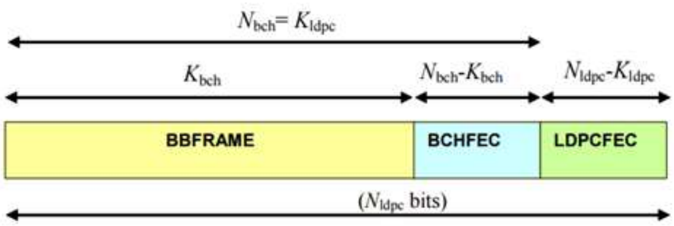

Figure 21 – Structure of the FEC-frame

Figure 22 shows the **Physical Layer Pipe Description / T2 Frame structure option**. From the picture we notice that the transmission speed of PLP data in the network is 36.5 Mbit / s.

Figure 22 – DVB-T2 Gateway Device Menu:

Physical Layer Pipe Description/T2 Frame structure option

In Figure 23 we can visualize the structure of the T2-MI flow generated at the "T2 Gateway" device exit after the SFN cluster configuration procedure has been completed. We can see that 3 elements are encapsulated in the T2-MI flow packet data field: BB-frames; L1 signaling related to resource frame planning; COFDM symbol emulation timing signals from the output of the network modulators.

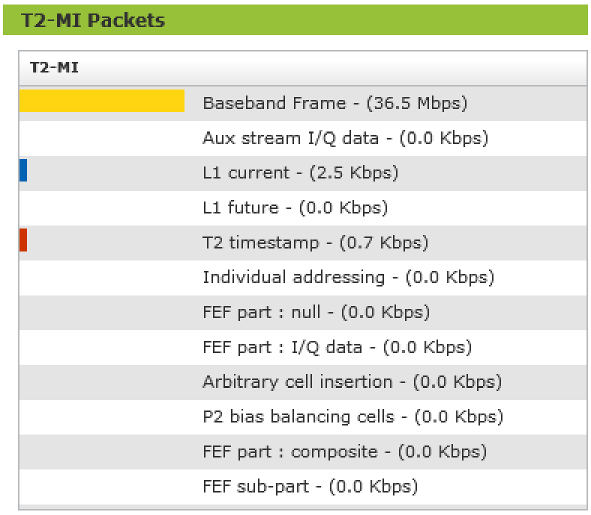

Figure 23 – DVB-T2 Gateway Device Menu: **Monitoring/Output/T2-MI Packets** option

Figure 24 shows the technical parameters of the frame structure and COFDM symbols after finishing the system setup procedure.

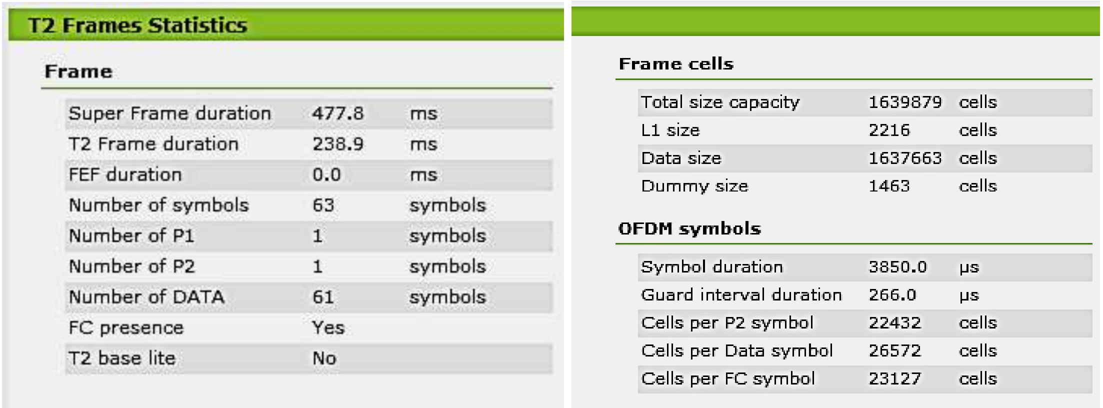

Figure 24 – DVB-T2 Gateway Device Menu:
Monitoring/Output/T2-Frames Statistics option

4 PARAMETERS OF THE DVB-T2 SIGNAL RECEIVED IN THE SERVICE AREAS

In this chapter, as an example, are presented the quality parameters of the DVB-T2 signal received at several control points of the Straseni cluster. In the composition of cluster, on Channel 31, there are 3 DVB-T2 emitters installed on the existing technological surfaces of the CS Radiocomunicatii, see Table 1.

The technical parameters of the reception points (p.r.) are presented in Table 2, where Hr - the altitude of the point, and Ha - the height of the suspension of the antenna.

Table 3 shows the azimuth at the receiving points in the direction of the emission points and the distance between the reception and emission points.

For the measurements was used the reference directional antenna R&S HL 040.Directional diagram of the receiving antenna is shown in Figure 25. During measurement the receiving antenna was raised to a height of 10 meters above the ground.

The following signal technical parameters were measured at the studied control points of the SFN DVB-T2 cluster: electromagnetic field strength at the antenna input — E; RMS modulation error ratio - MER (Modulation Error Ratio); bit error rate after demodulation - CBER (Channel Bit Error Ratio); the bit error rate after the internal coder is LBER; the ratio of levels of carrier / noise - C / N.

The DVB-T2 signal quality indicators were measured (alternately for each of the 3 transmitters) in two modes: 1. Tx - only one of the network transmitters was switched on, the receiving antenna was oriented to this transmitter; 2. SFN - all three transmitters are turned on, the orientation of the receiving antenna is maintained in accordance with the first paragraph. The measurement results are presented in table 4.

Table 1 – Technical parameters of emission points

Parameters	Station-1	Station-2	Station-3
Geographic coordinates	E 28.33’57.7” N 47.07’17.5”	E 28.34’02.1” N 46.49’26.9”	E 28.48’51.2” N 47.17’45.6”
The altitude of the pillar base, m	329	273	202
Height of antenna suspension, m	283	70	110
Polarization of antenna	H	H	H
Antenna type	Omni	Omni	Omni
PAR (W)	2536	1325	392

Table 2 – Technical parameters of reception points

No	Geographic coordinates	H_r m	H_a, m
1	28E42'37.24" 46N56'41.44"	216	10
2	28E41'16.79" 46N54'40.18"	93	10
3	28E40'13.9" 46N52'53.22"	245	10

Table 3 – Distance and azimuth between reception points and emission points

R_x – T_x		Station 1	Station 2	Station 3
R_{x1}	Distance, km	22.6	17.3	39.8
	Azimuth, °	303	218	10
R_{x2}	Distance, km	25.2	13.4	43.9
	Azimuth, °	337	222	11
R_{x3}	Distance, km	27.9	10.2	47.4
	Azimuth, °	342	230	12

Table 3 – The technical parameters of DVB-T2 signal at the reception points

Control point number	Measured parameters	Station Direction 1		Station Direction 2		Station Direction 3	
		T_x	SFN	T_x	SFN	T_x	SFN
1	E, dB(μV/m)	60.3	60.7	63.4	63.4	49.0	51.8
	MER, dB	27.3	25	30.1	29.4	18.9	13.3
	C/N, dB	19.3	20.3	22.2	22.3	7.9	10.9
	CBER	3.10E-03	5.00E-03	8.9E-04	8.6E-04	8.8E-02	9.6E-02
	LBER	1.00E-08	1.00E-08	1.00E-09	1.00E-08	1.00E-07	5.9E-07
2	E, dB(μV/m)	52	52.3		49.2	41.1	48.9
	MER, dB	20.9	20.7				
	C/N, dB	11.1	11.9	7.8	8.2	0.3	7.9
	CBER	5.80E-02	5.80E-02				
	LBER	1.00E-07	1.00E-07				
3	E, dB(μV/m)	48.1	53.6	71.4	71.4	43.7	52.7
	MER, dB		17.6	34.9	34.6		16.5
	C/N, dB	6.4	12.5	30.3	30.3	2.6	11.8
	CBER		6.80E-02	6.50E-05	4.30E-05		7.5E-02
	LBER		1.00E-08	1.00E-08	1.00E-09		1.0E-07

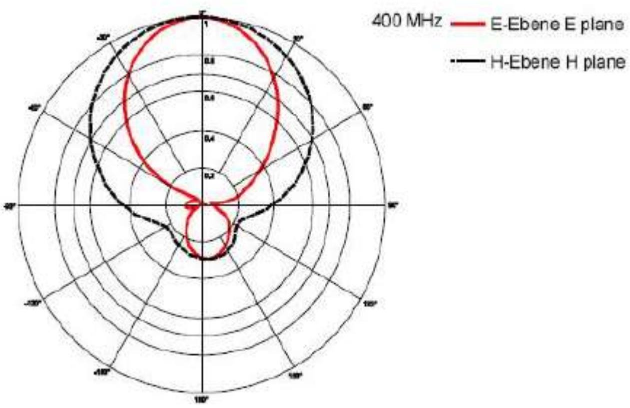

Figure 25 – Directivity diagram of the receiving antenna R&S HL 040

5 CONCLUSIONS

Following the technical and practical aspects related to the implementation of SFN DVB-T2 networks in the Republic of Moldova, we can make the following conclusions:

1. Infrastructure and configuration parameters of the first national digital terrestrial multiplex in the Republic of Moldova ensures the satisfactory quality of the DVB-T2 signal in the cluster service areas;

2. For construction of national digital terrestrial multiplexing, SFN technology is a priority. Measurement results demonstrate the efficiency of single-frequency networks in creation of service areas;

3. The DVB-T2 standard is quite flexible in view of configuring the technical parameters of SFN cluster and adopting them on the existing infrastructure of terrestrial broadcasting networks;

4. Making the most of the existing infrastructure in the network implementation process, SFN DVB-T2 is optimal from the point of resource optimization, which is reflected in the final tariff for the provision of digital television services to operators in the audiovisual field.

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