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CONCEPTUAL DEVELOPMENT AND IMPLEMENTATION OF THE DIGITAL TERRESTRIAL TELEVISION NETWORK IN THE REPUBLIC OF MOLDOVA

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Scientific summary of the doctoral thesis in engineering sciences

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The thesis was developed at the State Enterprise "Radiocomunicatii" (national operator of the Republic of Moldova in the field of terrestrial broadcasting) and the Technical University of Moldova within the "Telecommunications and Electronic Systems" department, Faculty of Electronics and Telecommunications.

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The thesis defense will take place on April 17, 2025, at 2:00 p.m., during the meeting of the Public Defense Committee, as approved by the decision of the TUM Scientific Council on January 20, 2025, at the following address: MD-2045, Republic of Moldova, Chișinău, 9/7 Studentilor St., Building 3, Room 3-208.

The doctoral thesis and the scientific summary can be consulted at the Technical and Scientific Library of the Technical University of Moldova and on the website of the National Agency for Quality Assurance in Education and Research (www.anacec.md).

The scientific summary was sent on 10 march 2025.

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CONCEPTUAL POINTS OF RESEARCH

The topicality of the topic and the importance of the problem addressed

In accordance with the provisions of the Regional Agreement on the planning of the digital terrestrial broadcasting service, signed at the ITU Regional Radio communication Conference (Geneva, 2006) [1], starting with June 17, 2015 the Republic of Moldova (RM) assumed responsibility for the implementation of digital terrestrial television (DTT). This paper is intended for the conceptual development and implementation of the digital terrestrial television (DTT) network in the RM. The choice of the research topic was determined by the reduction of the gap between the rural and urban areas regarding access to diverse information (TV programs), the integration of the region on the left bank of the Dniester River into the information space of the Republic of Moldova. At the same time, the increased interest of the community regarding this new technology was also taken into account. The research topic fully corresponds to the Digital Transformation Strategy of the Republic of Moldova for 2023-2030, approved by the Ministry of Economic Development and Digitalization of the Republic of Moldova, which aims to build a modern digital society, aligned with the European integration agenda.

The purpose of the work is to conceptually develop and implement the DTT network in the Republic of Moldova. In order to reduce operational costs and the resources required for the implementation of the airwaves digitalization project, the task was set to build the first national multiplex "MUX-A" based on the infrastructure of existing terrestrial networks, which belong to the State Enterprise "Radiocomunicatii", the national operator in the field of terrestrial broadcasting.

The objectives of the work are

1. Selection of the "MUX-A" coverage area forecasting model according to international recommendations;
2. Determination of the operating parameters of the DTT network adjusted to the infrastructure of existing terrestrial broadcasting networks;
3. Forecasting the field strength for the service areas of "MUX-A";
4. Development of the signal emission technology in the "shadow areas" of the designed network;
5. Implementation of the project by putting "MUX-A" into operation;
6. Testing the quality parameters of the digital signal received in "MUX-A";
7. Development of recommendations regarding the reception of the digital signal within the single-frequency DVB-T2 terrestrial networks;
8. Estimation of the forecasting accuracy of the electromagnetic field strength in the conditions of the relief and landscape of the RM.

Expected results of the research: conceptual development and implementation of the DTT network in the Republic of Moldova that is technically, technologically and economically efficient.

Scientific research methodology

To achieve the objectives of the thesis, the following research methods were used: linear algebra, analytical geometry, communication theory, radio wave propagation theory, statistics, international recommendations ITU-R P.370, ITU-R P.1546 and ITU-R P.1812, ETSI international standards, regulations, acts and normative documents, planning of research and measurements, measurements of signal quality indices in laboratory and field conditions, comparative analysis of the values of signal quality indices obtained as a result of measurements. For automated forecasting of field strength in the service areas of the national DTT multiplex, the specialized software "ICS Telecom" was used.

Scientific novelty of the work

1. A new method for indirect estimation of inter-symbol interference at the input of the DVB-T2 SFN SISO network receiver and its mitigation method was proposed. Based on the research, the opportunity of using directional receiving antennas with many elements in a DVB-T2 SFN SISO network, strictly oriented in the direction of the incident wave with the highest field intensity, was demonstrated.
2. It was proposed to use the existing infrastructure of fiber optic networks for transmitting the T2-MI stream at the input of DVB-T2 modulators located within the "shadow zones". The implementation of this proposal made it possible to extend the signal by using the existing infrastructure of low-height pylons, H = 27 m, and consequently allowed to significantly reduce operational costs and the time required for the implementation of the DTT network. At the same time, the technical implementation of this proposal made it possible to implement remotely a video monitoring and signaling system for low-power DVB-T2 broadcasting stations located in the "shadow areas".
3. The forecasting accuracy of the field intensity calculated using the ITU-R P. 370, ITU-R P. 1546 and ITU-R P. 1812 models was estimated under the conditions of the relief and landscape of the Republic of Moldova.

Solved scientific problem

The conceptual benchmarks of the DTT network in the Republic of Moldova were developed, the application of which allowed the implementation of the first national multiplex based on the infrastructure of existing terrestrial networks (access roads, technical buildings, electrical networks, towers, pylons, feeders, antennas, security and signaling systems, etc.), belonging to the State Enterprise "Radiocomunicatii", the national operator in the field of terrestrial broadcasting. As a result, the operational costs and the time required for the construction and commissioning of the DTT network were significantly reduced. In the process of conceptual development and implementation of the DTT network in the Republic of Moldova, a series of tests and researches were carried out, as a result of which: the opportunity of applying the recommendations ITU-R P. 1546 and ITU-R P. 1812 for forecasting DVB-T2 signal coverage areas under the conditions of the relief and landscape of the Republic of Moldova was demonstrated; numerical values of the forecasting accuracy performed using the mentioned models were obtained; a recommendation was developed on how to reduce inter-symbol interference at the receiver input to a DVB-T2 SFN SISO network.

Main practical and scientific results submitted for support

The following results are submitted in support of the thesis:

1. Technology for using the ITU-R P.1546 and ITU-R P.1812 recommendations for forecasting DVB-T2 signal coverage areas in the conditions of the relief and landscape of the Republic of Moldova.
2. Development of the recommendation on how to reduce inter-symbol interference at the receiver input to the DVB-T2 SFN SISO network.
3. Development of an alternative method for connecting the population to the digital terrestrial signal in the "shadow areas" of the designed DTT network.
4. Conceptual development and implementation of a technically, technologically and economically efficient DTT network in the Republic of Moldova.

Theoretical importance and applicative value of the work

1. Following the conceptual development and implementation of the DTT network in the Republic of Moldova, the flexibility of the configuration parameters of the DVB-T2 system was demonstrated, which can be easily adapted to the infrastructure of existing terrestrial

networks, which allows to significantly reduce the operational costs for the implementation of the DTT network.

2. Following theoretical and practical research, it was demonstrated that the use by viewers in a DVB-T2 SFN SISO network of directional receiving antennas, with many elements, strictly oriented in the direction of the incident wave with the highest field intensity, can considerably reduce the inter-symbol interference of the signals at the receiver input. Making the mentioned antennas available to viewers in commercial networks in the country has significantly increased the quality of the services provided.
3. Research has shown that the use of Gap Fillers in the "shadow areas" of the Republic of Moldova is not possible, since it requires ensuring the attenuation of signal crosstalk between the input of the transmitting antenna and the output of the receiving antenna of about 100-110 dB. Applying this condition to the infrastructure of existing 27 m high pylons is practically impossible. For the emission of signals in the "shadow areas" of the Republic of Moldova, it is appropriate to use low-power transmitters (provided that the T2-MI flow is brought to the input of DVB-T2 modulators through the infrastructure of existing fiber optic networks).
4. In the process of implementing "MUX-A", from a technological and legislative point of view, the Republic of Moldova has been aligned with new TD standards, along with the most developed European countries, and is currently making efforts to implement the latest generation compression standard H.265.

Approval of the obtained results

The main scientific results were presented at the following conferences:

1. 9th Edition, International Conference on Microelectronics and Informatics, "ICMCS-2017", TUM, Chisinau, Moldova, October 19-21, 2017.
2. 12th International Conference "Technologies of the Information Society (ТИО 2018)", Moscow Technical University of Communications and Informatics (MTUCI), Moscow, Russia, March 14-15, 2018.
3. 6th Edition, International Conference on Telecommunications, Electronics and Informatics "ICTEI 2018", TUM, Chisinau, Moldova, May 23-25, 2018.
4. International Conference "Systems of Signal Synchronization, Generating and Processing in Telecommunications (Synchroinfo 2018)", Minsk State Academy of Communications, Minsk, Belarus, 4-5 July 2018.
5. 13th International Conference "Technologies of the Information Society (ТИО 2018)", Moscow Technical University of Communications and Informatics (MTUCI), Moscow, Russia, March 20-21, 2019.
6. Technical and Scientific Conference of Students, Master's and PhD Students, TUM, Chisinau, Moldova, March 26-29, 2019.
7. 21st International Conference "Wave Electronics and its Application in Information and Telecommunication Systems" (WECONF 2019), St. Petersburg State University of Aerospace Instrumentation (SUAI), Sankt-Petersburg, Russia, June 3-7, 2019.
8. International Conference "Systems of Signal Synchronization, Generating and Processing in Telecommunications (Synchroinfo 2018)", P.G. Demidov Yaroslavl State University, Yaroslavl, Russia, July 1-3, 2019.
9. 10th International Conference on Electronics, Communications and Computing "ECCO 2019", Chisinau, Moldova, October 23-26, 2019.
10. 11th International Conference on Electronics, Communications and Computing "ECCO 2021", Chisinau, Moldova, October 21-22, 2021.

CONTENT OF THE THESIS

The introduction outlines the actuality and relevance of the thesis topic, as well as the purpose, objectives, and scientific novelty of the research.

Chapter 1 describes the process of implementing DT technologies worldwide, highlighting the advantages of DT technologies compared to analog television systems. The technical and practical aspects related to the implementation of DTT in the Republic of Moldova are studied and researched, namely: the advantages of TD systems; the choice of the digital terrestrial broadcasting standard; the allocation of the radio spectrum for the implementation of the project; the choice of the digital signal coding system; the technical features and advantages of the DVB-T2 (Digital Video Broadcasting – Terrestrial) terrestrial broadcasting standard; the technical features and synchronization elements of single-frequency DVB-T2 networks; the problems of ensuring digital terrestrial broadcasting in "shadow areas"; the experience of implementing DVB-T and DVB-T2 networks in other countries. Following the approach of the mentioned technical aspects, the problem of conceptual development and implementation of the DTT network in the Republic of Moldova was formulated, some preliminary recommendations were formulated for the implementation of the project.

TD systems have undeniable advantages in relation to analog television systems, namely:

- The radio frequency spectrum is managed much more efficiently, in the frequency band of a channel that can transmit several TV programs, including with the high resolution of the HD (High Definition) image.

- The digital image is of better quality than the analog one: it is clearer, contains more details, because it is resistant to interference and noise.

- The viewer has access to several additional facilities, such as the EPG (Electronic Program Guide) table, support in several languages, titles in different languages, etc.

Currently, several TD systems are in operation in the world [2,3]:

1. DVB (Digital Video Broadcasting) – systems implemented in the European Union countries, Russia, Australia, Ukraine, RM, in most African countries.

2. ATSC (Advanced Television Systems Committee) – systems implemented in the United States of America, Canada, Mexico, Argentina, Taiwan and South Korea.

3. ISDB (Integrated Services Digital Broadcasting) – systems implemented in Japan, South America and other countries of the world.

4. DMB (Digital Multimedia Broadcasting) – systems implemented in South Korea, China, Cuba, Hong Kong and other countries.

DVB represents a series of standards in the field of digital television developed by an international consortium operating under the name DVB Project, today including about 300 companies from 35 countries. These standards are known under the following names: DVB-T, DVB-T2 – for terrestrial broadcasting; DVB-H, DVB-SH, DVB-H2 – for portable devices; DVB-S, DVB-S2, DVB-S2X – for satellite transmission; DVB-C, DVB-C2 – for cable transmission.

The DVB-T [4] and DVB-T2 [5] systems provide technical solutions for the implementation of DTT networks. The implementation of these technologies allowed the reorganization of the radio spectrum previously intended for analogue terrestrial television, freeing up the upper part of the spectrum (694-862 MHz) for other new telecommunications services. According to the statistical data from July 2022 on the distribution of DTT standards, the DVB-T and DVB-T2 standards prevail in the world. Due to its geographical location, the digital terrestrial television standards DVB-T and DVB-T2 have been adopted in the RM, but in the near future only the DVB-T2 system will be used.

Due to the application of the COFDM (Coded Orthogonal Frequency Division Multiplexing) principle [6], the DVB-T and DVB-T2 digital terrestrial television systems are well adapted for the implementation of DTT in conditions when the signal reaches the reception point through several propagation paths. Due to this fact, the mentioned standards have been applied for the implementation of DTT (in the VHF and UHF bands) in most countries of the world. The decision to implement the DVB-T2 standard has been accepted by the administrations of Austria, the United Kingdom, Germany, Denmark, India, Spain, Italy, Kazakhstan, Slovakia, Ukraine, Romania, Belarus, Finland, the Czech Republic, Sweden, South Africa, Russia, Albania, Algeria and many other countries. Moreover, in a large number of countries the transition to the DVB-T2 standard has already been completed, such as in Andorra, Austria, Colombia, the Czech Republic, the Republic of Macedonia, Luxembourg, Portugal, Romania, France, Saudi Arabia, Germany, Greece, Hungary, Iceland, Serbia, Slovakia, the United Kingdom, etc. At the same time, at the global level, a migration trend from DVB-T technology to DVB-T2 technology and from the MPEG-2 compression system to MPEG-4 and MPEG-H is observed.

According to the provisions of the Regional Agreement on the planning of the digital terrestrial broadcasting service, approved at the Regional Radiocommunication Conference RRC-06 (Geneva, 2006) [1] and ratified by the Law of the Parliament in 2008 [7], starting with June 17, 2015, the Republic of Moldova assumed the responsibility of completing the digitalization of terrestrial television networks [8]. This responsibility was assumed by 104 countries. At the aforementioned conference, a new frequency plan was adopted that defined the use of transmission bands III (VHF – 174-230 MHz) and bands IV/V (UHF – 470-862 MHz) for digital terrestrial broadcasting. According to the final documents of RRC-06, the territory of the Republic of Moldova was divided into 6 national service areas [1].

The location of the national DTT areas on the territory of the Republic of Moldova is represented in Figure 1. In order to rationally use the radio spectrum, a decision was made to implement DTT networks by applying SFN (Single Frequency Network) technology. Thus, 6 channels from the UHF frequency band were allocated for the implementation of "MUX-A".

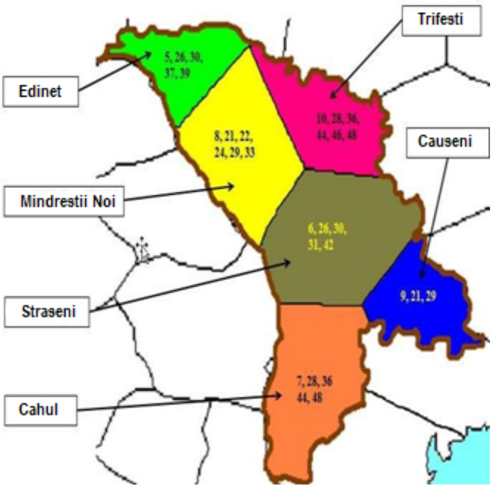

Figure 1. Location of national DTT zones on the territory of the Republic of Moldova

The operation of TD systems is possible only under the condition of applying MPEG (Moving Pictures Experts Group) technologies for coding (compression) of digital signals [3]. Currently, two digital video signal compression standards are widely used in the world: H.262/MPEG-2 and H.264 AVC/MPEG-4. Recently, the H.265 HEVC/MPEG-H standard has also been developed, which has undeniable advantages in terms of system capacity. This standard is already beginning to be implemented in many countries around the world.

In 2016, jointly with a group of specialists from the State Enterprise "Radiocommunicatii", technical tests of H.265 encoders were carried out with the aim of applying, in the near future, this modern technology to the formation of national TD multiplexes. Real tests, which were carried out in the municipality of Chisinau on channel 58, demonstrated the efficiency of the new compression technology. Thus, based on the arguments presented to the Ministry of Information Technology and Communications, by the Decision of the Government of the Republic of Moldova [9], H.264 and H.265 technologies were approved as national compression standards.

The architectural model of the DVB-T2 SFN cluster is represented in Figure 2. The broadcast segment is composed of 3 basic elements: the audiovisual content encoding and multiplexing station; the "T2 Gateway" stream processing station; the DVB-T2 modulators. The first two form the central station of the system, the so-called "Head End" station. The encoding and multiplexing station generates the TS (Transport Stream) or GS (Generic Stream) streams which are subsequently applied to the input of the "T2 Gateway" device [10]. Its function is to generate at its output the T2-MI (DVB-T2 Modulator Interface) serial stream, with digital packets adapted for their further processing in the network modulators. The T2-MI stream is transmitted to the modulators input via a distribution network.

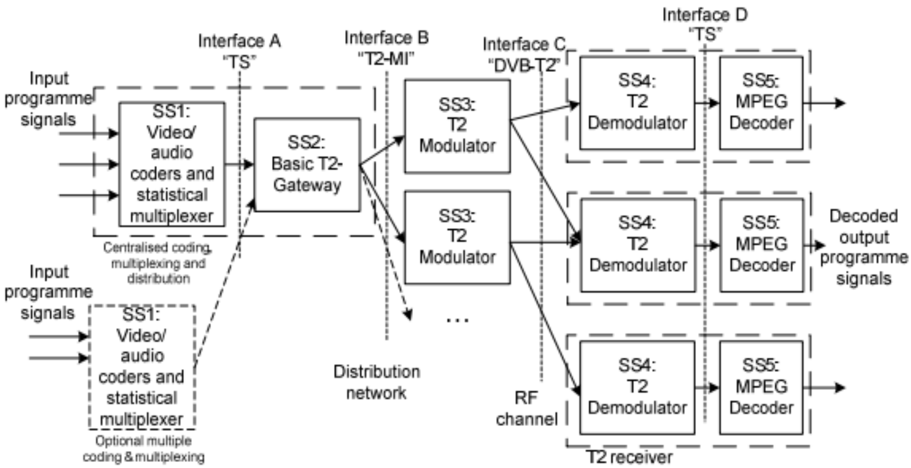

Figure 2. Architectural model of the DVB-T2 SFN system [11]

The implementation of the SFN network provides for the placement in the "C Interface" of a cluster of several identical DVB-T2 signals with the binding of their time-frequency resources to a single synchronization system. To achieve this goal, identical data contained in the digital packets of the T2-MI stream are applied to the input of the network modulators. At the same time, the 10 MHz and 1 pps reference synchronization signals are applied to the input of each modulator in the SFN network and to the input of the “T2 Gateway” device. For these purposes, GPS, GLONASS global positioning receivers or other high-precision external reference sources can be used. The 1 pps signal (one pulse per second) has a duration of 100 ns and is formed by dividing the 10 MHz reference frequency.

To ensure signal coverage in the “shadow areas”, it is proposed to place low-power repeaters in the field. In the case of implementing a single-frequency terrestrial network, low-power f1/f1 repeaters, the so-called Gap Fillers, can be applied. At the same time, due to the presence of echoes of the own signal at the Gap Filler input, there are a number of technical limitations related to its operation. Based on the above, in the process of designing and implementing "MUX-A", the task was set to investigate the opportunity/possibility of applying Gap Fillers in the "shadow areas" of the Republic of Moldova.

After addressing the issues of developing and implementing DTT in the Republic of Moldova, the following conclusions were drawn:

1. For the construction of "MUX-A" it will be necessary to implement the following technical components: audiovisual content coding and multiplexing station; "T2 Gateway" station for generating the T2-MI digital stream; IP network for distributing the T2-MI digital stream; 6 DVB-T2 SFN networks;.

2. In the process of implementing "MUX-A" it will be necessary to adjust the system configuration parameters to the infrastructure of existing terrestrial broadcasting networks. The use of the existing infrastructure will allow to essentially optimize the use of material resources and will influence the final tariff for the provision of DTT services by national audiovisual operators.

3. Designing and implementing a DVB-T2 SFN network is a complex problem. Simultaneously with the choice of emission, coding and modulation parameters of the signal, it is also necessary to implement network synchronization elements. For reliable operation of the multiplex, it will be necessary to include in the technological chain the external reference signals 10 MHz and 1 pps and the internal signal for synchronizing the phase of the emitted signals.

4. From a technological and legislative point of view, following the implementation of DTT, the Republic of Moldova will align with new standards in the field of DTT, along with the most developed European countries.

5. In **Chapter 1,** the study of the issues of conceptual development and implementation of DTT in the Republic of Moldova was carried out. The advantage of the DVB-T2 standard in relation to other systems was demonstrated. In conclusion, the purpose of the work - conceptual development and implementation of the DTT network in the Republic of Moldova - is justified. Also, the main objectives of the project - development of "MUX-A" configuration parameters; forecasting of field strength for national service areas; implementation of the project by putting "MUX-A" into operation; testing of quality parameters of the signal received within the DVB-T2 SFN cluster - are current.

Chapter 2 describes the technology for implementing the national DTT multiplex in the Republic of Moldova, such as:

1. Selection of the coverage area prediction model within "MUX-A"

Several calculation models can be used to forecast terrestrial signal coverage areas, including “point-to-surface” models described in the International Telecommunication Union Recommendations ITU-R P.370, ITU-R P.1546 [12] and ITU-R P.1812 [13]. These recommendations are “point-to-surface” forecasting methods for terrestrial services in the frequency range from 30 MHz to 3000 MHz. Specialists of the State Enterprise

“Radiocommunications” have been successfully using the ITU-R P.1546 recommendation for a long time, which demonstrates satisfactory accuracy. At the same time, performing the calculations using the recommendations ITU-R P.370, ITU-R P.1546 and ITU-R P.1812, we can see that, based on the same configuration parameters of the terrestrial network, the predicted values of the field strength, the surface and the shape of these predicted areas differ from each other. Based on the above, the objective was put forward to select the model for forecasting the coverage areas within the "MUX-A". In order to achieve the proposed objective, the calculation of the DVB-T2 signal coverage areas for the channel 58 broadcasting station, located in the municipality of Chisinau, Lech Kacyznschi str. 3 was carried out. Following the analysis, it was established that the normalized quality of the DVB-T2 signal predicted by the recommendation ITU-R P.1546 was also confirmed by the calculation results performed using the recommendation ITU-R P.1812. At the same time, the contour of the assumed coverage area is more uniform in the case of applying the ITU-R P.1546 model. Based on the arguments presented above, a proposal was submitted to use the ITU-R P.1546 recommendation for forecasting DVB-T2 signal coverage areas within the “MUX-A” framework.

At the same time, it was considered appropriate to develop a recommendation for the application of the ITU-R P.1546 and ITU-R P.1812 models for forecasting coverage areas, given the relief and landscape of the Republic of Moldova. In this regard, a proposal was submitted to estimate the forecasting accuracy of coverage areas in the “MUX-A” service area after its implementation.

2. Forecasting the coverage areas of the service areas within the “Mux-A”

To forecast the coverage areas with DVB-T2 signal, it was necessary to develop the following technological elements of the national multiplex: choosing the system operating mode; configuring the networks (planning the transmission parameters, planning the time-frequency resources of the frame, etc.); calculating the minimum median field strength at the boundaries of the coverage areas; forecasting the coverage areas of the terrestrial networks. Configuring the technical parameters of the system and planning the coverage areas with DVB-T2 signal was carried out in the light of some basic requirements - maximum use of the infrastructure of the existing terrestrial broadcasting networks and ensuring the maximum capacity of the system.

The emission of COFDM symbols, from the output of the DVB-T2 modulator, provides for two operating modes SISO (Single Input, Single Output) and MISO (Multiple Input, Single Output) [5]. The SISO mode provides that all the modulators of the cluster emit the same signal. In the MISO mode, the cluster modulators are divided into two groups. The first group of modulators transmits COFDM symbols as in the SISO mode. The second group of modulators transmits COFDM symbols processed according to the Alamouti algorithm. Therefore, two groups of signals arrive at the receiver input. Applying the MISO mode allows to reduce inter-symbol interference in the system, but at the same time reduces the system capacity.

The configuration parameters of the “MUX-A” were set through the “T2 Gateway” station options. The system configuration was divided into four stages [14]:

- *setting the cluster operating mode;*
- *setting the SFN network parameters;*
- *setting the DVB-T2 frame time-frequency resources;*
- *setting the physical channel (PLP) parameters.*

For the operation of "MUX-A" the following operating modes were chosen: SISO; "System B"; "Single-PLP". The application of the "System B" mode allowed the implementation of terrestrial SFN networks within the "MUX-A". In this case, 6 frequencies/channels were required for the implementation of "MUX-A".

Figure 3 shows the setting of the SFN network parameters. From the image we can see the following: for the operation of the system the basic profile of the DVB-T2 standard is selected; the MISO mode is not activated; the T2-MIP packets (intended for synchronization of low-power repeaters within the "shadow areas") are not activated; synchronization of the emission moment of COFDM symbols from the output of the network modulators - strictly over 900 ms after receiving the 1 pps synchronization pulse [15].

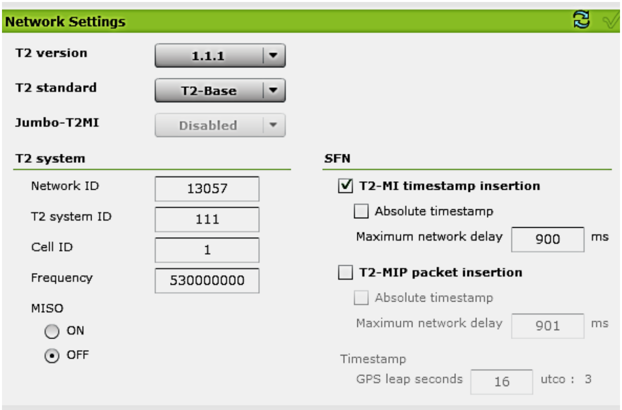

Figure 3. “T2 Gateway” device: Network Settings option

For the implementation of "MUX-A" the following time-frequency resource settings of the DVB-T2 frame were installed: Channel frequency band – 8 MHz; FFT mode parameter – 32k extended; Guard interval – 19/256; Scattered-pilot patterns – PP4; PAPR redaction – was not activated.

The FFT mode (Fast Fourier Transform) parameter sets the number of subcarrier frequencies in the channel band of the DVB-T2 system. To increase the number of subcarrier frequencies in the composition of the COFDM symbol, the channel frequency band extension (32k extended) was applied. In a channel with a width of 8 MHz, the transition of the FFT size parameter from 32k to 32k extended allowed to increase the useful channel bandwidth from 7.61 MHz to 7.77 MHz.

The guard interval values in the DVB-T2 system, for the 8 MHz channel, are inserted in Table 1 [16]. For the implementation of SFN networks and stationary signal reception, the FFT - 32k mode is recommended. In this case, the duration of the COFDM symbol is 3.584 ms.

Table 1. Guard interval duration in the DVB-T2 system, for the 8 MHz channel

		GI-Fraction						
		1/128	**1/32**	**1/16**	**19/256**	**1/8**	**19/128**	**1/4**
FFT	***T_U* (ms)**	**GI (µs)**						
32k	3.584	28	112	224	266	448	532	*n/a*

For the 32k extended network settings and the guard interval duration 19/256 - the distance between neighboring transmitters within the DVB-T2 cluster [17] falls within the limit of 80 km (3*108 m/s*266*10-6 s = 79.8*103 m). At the same time, we note that the distance between all adjacent sites of existing terrestrial broadcasting networks (located within the "MUX-A" service areas) does not exceed the distance of 80 km.

The PP4 (SISO) scattered-pilot frequency template has been activated. The parameters of this template represent a compromise between the system's resistance to disturbances and the data transmission speed in the network.

COFDM technology is characterized by a relatively high ratio between the peak and average levels of the RF signal, the so-called PAPR (Peak to Average Power Ratio). Because of this, the DVB-T2 signal is quite sensitive to nonlinear distortions in the final stages of power amplifiers. When setting the "MUX-A" parameters, special options for reducing the PARP value were not enabled. This was possible due to the use of DVB-T2 transmitters from leading global manufacturers (GATES AIR, USA) when implementing the network.

For data transmission within the "MUX-A" the following physical channel parameters were set: PLP0 frequency modulation - QAM-256 with signal constellation rotation; protection code rate 2/3; length of the encoded BB-frame is 64800 bits (after the LDPC encoder). The rotation of the signal constellation of the physical channel is performed in order to improve the protection of the signal against interference in the telecommunication channel.

The data transmission speed in the system obtained as a result of its configuration is 36.5 Mbit/s. Therefore, based on the H.264 AVC/MPEG-4 compression system, up to 15 TV programs in SD format can be transmitted within the "MUX-A" (36.5/2.5 ≈ 14.6).

The calculation of the C/N ratio (carrier/noise) and the value of the minimum median field intensity Emed for the designed broadcasting system was carried out based on the international recommendation "Report ITU-R BT.2254-3 (03/2017), Frequency and network planning aspects of DVB-T2". The C/N ratio characterizes the resistance of transmission systems to noise and interference. Establishing the value of this ratio is necessary to determine the minimum admissible signal power at the receiver input and is of fundamental importance for network planning. The calculation of the Emed value for the service areas within the “MUX-A” was carried out for fixed signal reception, for the case when the receiving antenna is located at a height of 10 m above the ground. The calculations were developed for the reference frequency 650 MHz. As a result of the calculations, the values were established: (C/N) “MUX-A” = 20.4 dB; Emed r = 54.7 dBμV/m for “location probability” 95 %. The final Emed values for the national service areas are listed in Table 2.

Table 2. Calculation of the Emed value for national service areas, within "MUX-A", ("location probability" 95%)

Area	CH	F, MHz	Fr, MHz	Emed r, dBμV/m	Corr, dB	Emed, dBμV/m
Causeni	21	474	650	54.7	-2.7427	52.0
MN	22	482	650		-2.59733	52.1
Trifesti	28	530	650		-1.77275	52,9
Edinet	30	546	650		-1.51441	53,2
Straseni	31	554	650		-1.38807	53,3
Cahul	36	594	650		-0.78254	53,9

The calculation of the DVB-T2 signal coverage areas, transmitted within the "MUX-A", was carried out using a specialized software "ICS Telecom". The specialized software was applied for each location. The following were introduced into the automated calculations: the geographical coordinates of the emission point; the height of the mast base above sea level; the height and azimuth of the emission antenna suspension; the maximum apparent radiated power of the emission antenna; the directivity diagrams of the emission antenna in the horizontal and vertical planes; the minimum median value Emed of the field intensity for the service areas; the calculation step, over every 1 degree, starting with 0 degrees.

The forecasting of the DVB-T2 signal coverage areas, within the "MUX-A", was based on the Notices and Specifications issued by the National Radio Frequency Management Service (SNMFR): no. 06/1-239 of 26.03.2018 for high-power stations (SRTV stations); no. 06/1-322 of 14.02.2017 for medium-power stations (STV stations); no. 06/1-190 of 19.02.2019 and 06/1-450 of 15.05.2019 for low-power stations (broadcasting stations located in the "shadow areas"). The coverage areas of the broadcasting stations, stipulated in the aforementioned Notices, ensure access to 99% of the RM population to the "MUX-A" audiovisual content. The coverage area of "MUX-A" for a 95% reception probability is presented in Figure 4.

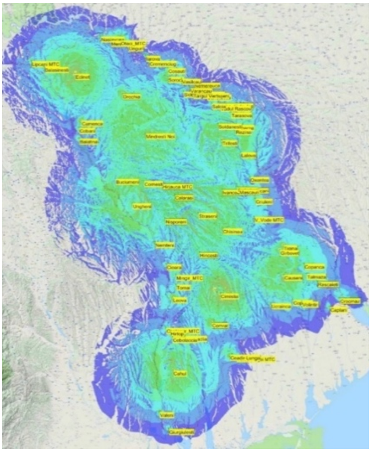

Figure 4. Coverage area of "MUX-A", field strength E ≥ Emed, location probability 95 %

3. Development of digital signal transmission technology in the "shadow areas"

As a result of the need to expand the population's access to the digital terrestrial signal in the "shadow areas" of the Republic of Moldova, a technical solution had to be developed regarding the mode of signal transmission in the mentioned territorial areas [18]. In this regard, it was important to investigate the opportunity of using a specialized technical device in the "shadow areas" – the low-power repeater of the f1/f1 type, the so-called Gap Filler [19]. A basic condition related to the investigation of the possibility of applying the Gap Filler was the adjustment of its technical operating parameters to the infrastructure of existing terrestrial networks in the "shadow areas" of the Republic of Moldova, namely, the typical 27 m high masts. The Gap Filler is a repeater of the digital terrestrial signal of the f1/f1 type, with signal processing and amplification. Consequently, a certain part of the signal (echo) from the output of the transmitting antenna returns back to the input of the Gap Filler, see Figure 5.

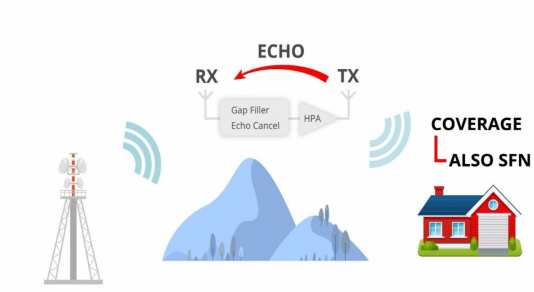

Figure 5. Gap-Filler in a digital terrestrial broadcasting network [20]

According to the technical recommendations of the manufacturers, the echo level at the Gap Filler input should not exceed the signal level at the network input by more than 12-15 dB. Therefore, to ensure reliable operation of the Gap Filler, adequate isolation [20] of the signal between the input of the transmitting antenna and the output of the receiving antenna must be ensured.

In order to investigate the possibility of applying repeaters, type f1/f1, in the "shadow areas" of the designed network, field tests of the Gap Filler were carried out, the manufacturer of which was the TRedess company. As a result of the tests, it was concluded that the operation of the Gap Filler based on the existing infrastructure of the State Enterprise "Radiocommunicatii" is not possible, since due to the low height of the existing pylons, it will not be possible to ensure the appropriate level of the echo/signal ratio at the Gap Filler input. At the same time, a decision was made: for the signal transmission in the “shadow areas” of the Republic of Moldova, it is necessary to apply low-power DVB-T2 transmitters (50-100 W). In this case, the transport of the T2-MI digital stream to the input of the mentioned transmitters will be ensured through existing fiber-optic networks, access to the infrastructure of which is practically available in any locality of the Republic of Moldova. At the same time, the application of IP networks for the supply of the T2-MI input signal in the “shadow areas” of the Republic of Moldova will allow for remote monitoring of the technical parameters of DVB-T2 transmitters, as well as for video monitoring of low-power digital broadcasting stations.

Chapter 3 addresses some practical issues related to estimating the total signal level induced at the terminals of the receiving antenna, depending on the reception conditions. The accuracy of the predicted field intensity under the relief and landscape conditions of the Republic of Moldova was estimated. Thus, this chapter includes five main sections.

1. Implementation of “MUX-A”

During 2016–2019, the State Enterprise “Radiocomunicatii” put into operation the first national DTT multiplex in the Republic of Moldova. For the implementation of “MUX-A”, 6 DVB-T2 SFN SISO networks were built. Thus, using the infrastructure of existing terrestrial broadcasting networks, 8 high-power transmitters and 15 medium-power transmitters were put into operation throughout the country. High-power and medium-power transmitters make the greatest contribution to ensuring viewers’ access to the DVB-T2 signal. The implementation of “MUX-A” ensured access to the digital signal for approximately 95% of the country’s population. At the same time, due to the peculiarities of the relief, in the RM there are approximately 60 localities located in the so-called "shadow areas", where the digital terrestrial signal cannot be received. In order to expand the population's access to the digital signal in the "shadow areas", a proposal was submitted to build digital terrestrial broadcasting sites on the existing infrastructure of analog TV signal retransmission stations. The cessation of analog TV broadcasting was completed in May 2022. Also, during this period, the construction of DVB-T2 broadcasting sites in the "shadow areas" began (30 sites were built at the end of 2022). In the first half of 2023, another 30 sites were built. Thus, the construction of the “MUX-A” in the Republic of Moldova was completed and access to the multiplex signal was ensured for 99% of the country’s population and 97% of the country’s territory.

2. Implementation of the multi-PLP operating mode within the “MUX-A”

At the stage of ceasing TV broadcasting in analog format, the need arose to increase the percentage of the population connected to the DVB-T2 signal (including in the “shadow areas”). For this purpose, it was proposed to obtain a larger coverage area for some TV programs. The achievement of this goal was made possible by implementing the multi-PLP operating mode of the DTT multiplex. Thus, the goal was set – to create within the data stream transmitted to viewers a physical layer consisting of 3 TV programs with a lower modulation index in relation to the broadcast parameters of the initial data stream.

The data stream of the “MUX-A” was divided into two physical layers – PLP_0 and PLP_ 1. The emission parameters of the PLP_0 stream were set – 16 QAM modulation, protection code rate 3/4. The choice of emission parameters of the PLP_1 stream – 256 QAM modulation, protection code rate 2/3.

The calculated carrier/noise ratio value for the PLP_1 physical layer is 20.4 dB (see page 16). As a result of calculating the carrier/noise ratio for the PLP_0 physical layer, the value of 12.5 dB was obtained. Therefore, the difference in the carrier/noise ratios is:

(C/N) “PLP_1” - (C/N) “PLP_0” = 20.4 dB - 12.5 dB = 7.9 dB.

10 ^0.79 = 6.17

Thus, the results obtained are equivalent to increasing the transmission power of the PLP_0 signal in relation to the PLP_1 signal by 6 times. Accordingly, we can also say about the improvement of reception conditions and the increase in the coverage area of the PLP_0 stream in relation to the PLP_1 stream.

The implementation of the multi-PLP regime allowed to increase without investments the percentage of the population connected to the DVB-T2 signal. The capacity of the configured system is (7.9 + 22.3) Mb/s = 30.2 Mb/s. Thus, we will be able to transmit up to 12 TV programs in SD format within the "MUX-A" (30.2/2.5 ≈ 12).

3. Testing the quality of the service provided in the Străseni service area

Concurrently with the implementation of “MUX-A”, the quality parameters of the signal [21, 22] received in the Străseni cluster, channel 31, were tested. At the time of the tests, the mentioned cluster consisted of 3 DVB-T2 transmitters located in the localities of Străseni, Hîncesti and Ivancea. The signal tests were carried out in 6 control points of the cluster. The quality index measurements were carried out in two operating modes:

1. Tx mode – only one of the network transmitters operated, the consecutive receiving antenna was strictly oriented in the direction of the transmitting antenna of this transmitter;

2. SFN mode – 3 transmitters operated, the consecutive receiving antenna was strictly oriented in the direction of each transmitting antenna.

The results obtained are presented in Table 3. The R&S HL 040 directional reference antenna was used for the measurements.

Table 3. Quality indices of the signal received in the Straseni cluster, channel 31

№ p.r.	Signal parameters	Orientation of the R&S HL 040 directional reference antenna					
		Straseni station		Hincesti station		Ivancea station	
		T_x	SFN	T_x	SFN	T_x	SFN
1	E, dB(μV/m)	-	78.1	70.7	72.1	-	51.2
	MER, dB	-	30	33.1	30.9	-	16.8
	C/N, dB	-	36.8	29.6	30.7	-	10.6
	CBER	-	9.2E-04	1.1E-04	3.0E-04	-	8.6E-02
	LBER	-	1.0E-09	1.0E-07	1.0E-08	-	1.0E-07
2	E, dB(μV/m)	60.3	60.7	63.4	63.4	49	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	3.1E-03	5.0E-03	8.9E-04	8.6E-04	8.8E-02	9.6E-02
	LBER	1.0E-08	1.0E-08	1.0E-09	1.0E-08	1.0E-07	5.9E-07
3	E, dB(μV/m)	52	52.3	48.8	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	5.8E-02	5.8E-02	-	-	-	-
	LBER	1.0E-07	1.0E-07	-	-	-	-
4	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	-	6.8E-02	6.5E-05	4.3E-05	-	7.5E-02
	LBER	-	1.0E-08	1.0E-08	1.0E-09	-	1.0E-07
5	E, dB(μV/m)	51.9	52.4	56.1	56	41	46.9
	MER, dB	21.8	20.6	26.4	25.5	-	-
	C/N, dB	11	11.4	15.3	15.1	0.2	6
	CBER	4.7E-02	4.8E-02	1.2E-02	1.4E-02	-	-
	LBER	1.0E-08	1.0E-08	1.0E-09	1.0E-08	-	-
6	E, dB(μV/m)	63.8	66	88.7	88.3	51.1	68.2
	MER, dB	28.4	17.6	34.9	33.3	21.2	25
	C/N, dB	22.7	25	47.2	46.7	10.1	27.2
	CBER	1.8E-03	1.6E-02	5.7E-05	1.8E-04	5.9E-02	1.4E-02
	LBER	1.0E-08	1.0E-09	1.0E-08	1.0E-09	1.0E-08	1.0E-07

After estimating the quality indices of the DVB-T2 signal received via the directional antenna in the Straseni cluster, the following conclusions were drawn:

1. At all 6 test points, signal reception was possible from at least one of the emission directions, which demonstrates the efficiency of using SFN technology to reduce shadow areas in the service area.

2. At control points no. 1, 2, 4, 6 the field intensity at the entrance of the receiving antenna exceeds the field intensity threshold from 2 directions, E > Emed = 53 dBμV/m). At control point 5 the field intensity at the entrance of the receiving antenna exceeds the field intensity threshold from one direction. These data speak of the good quality of the signal in the service area and the correct planning of the network.

3. Control point no. 3 is located in the "shadow area", which is characteristic of the relief conditions of the Republic of Moldova. At the same time, signal reception was also possible in this case from the direction of the Straseni station, with the field intensity E = 52 dB(μV/m).

4. It is appropriate to compare the quality indices of the signal received in the DVB-T2 SFN SISO cluster by means of antennas with circular and directional diagrams.

Therefore, the decision was made to compare the parameters of the signal received by means of reference antennas with circular diagrams RSH 4786 and directional diagrams R&S HL 040. To perform the measurements, a control point was chosen located on a height at the exit from the city of Chisinau, with geographical coordinates N46º58'42.7" and E 28º46'17.2". The measurement results are presented in tables 4 – 6.

Table 4. Measurement results at point no. 7, R&S HL 040 receiving antenna oriented in the direction of Hincesti station (Station 1 – Hincesti transmitter, Station 2 – Straseni transmitter)

Tehnical parameters	Station 1 – On Station 2 – Off	Station 1 – On Station2 – On	Station 1 – Off Station 2 – On
U, dB(μV)	54.5	54.9	31.4
MER, dB	34.2	32.6	-
C/N, dB	29.6	29.8	6.1
CBER	3.20E-04	2.50E-04	-
LBER	1.00E-08	1.00E-08	-

Table 5. Measurement results at point no. 7, R&S HL 040 receiving antenna oriented in the direction of the Străseni station (Station 1 – Străseni transmitter, Station 2 – Hîncesti transmitter)

Tehnical parameters	Station 1 – On Station 2 – Off	Station 1 – On Station 2 – On	Station 1 – Off Station 2 – On
U, dB(μV)	55.5	55.4	32.2
MER, dB	29.1	28.8	-
C/N, dB	30.0	29.9	7.1
CBER	9.60E-04	1.10E-03	-
LBER	1.00E-09	1.00E-09	-

Table 6. Measurement results at point no. 7 with the circular antenna RSH 4786

Tehnical parameters	Station 1 – On Station 2 – Off	Station 1 – Off Station 2 – On	Station 1 – On Station 2 – On
U, dB(μV)	45.8	48.2	51.6
MER	-	-	20.6
CBER	-	-	1.8e-2
LBER	-	-	1.0-8

After comparing the quality indices of the signal received via the directional antenna and the circular antenna, the following conclusions were drawn:

1. As a result of using the circular antenna for reception, the quality indices of the received DVB-T2 signal had a negative dynamics.

2. The use of the circular antenna for receiving signals in the DVB-T2 SFN SISO cluster does not allow to reduce the effect of mutual interference of signals arriving at the reception point from different directions.

4. Simulation of the operation of the DVB-T2 SFN SISO cluster in laboratory conditions

For a more detailed estimate of the degree and nature of signal interference at the reception point, a set of equipment was mounted in laboratory conditions that simulated the operation of a DVB-T2 SFN SISO terrestrial broadcast cluster, channel 22.

Initially, the quality indicators of the transmitted signal in the Tx mode (from the output of one of the transmitters) were measured. The results of these measurements were further compared with the results of measurements carried out in the SFN SISO mode (both transmitters were included in the work). Applying two DVB-T2 signals to the input of the ETL measuring device made it possible to identify the dynamics of changes in the parameters of the demodulated and decoded signal, depending on their levels and arrival times at the receiver input.

Table 7 shows the selective results of measurements in the case when signal2 reaches the receiver input with a delay of about 100 μs relative to signal1.

Table 7. Quality parameters of the received DVB-T2 signal, Time offset 100μs

Operating mode	**T_x**	**SFN**				
Parametrii	1	2	3	4	5	6
Level $_{(1+2)}$		-55.5	-48.2	51.6	49.1	-47.5
Level $_{1,}$ dBm	-49.7	-58.5	-48.8	-51.9	-49.2	-47.5
Level $_{2,}$ dBm		-58.5	-52.8	-57.9	-58.0	-58.2
Δ Level, dB		0	4.0	6.0	8.8	10.6
Time offset, μs		-97.4	-97.7	-97.3	-97.4	-97.6
MER PLP rms, dB	41.5	27.3	33.6	36.7	38.0	38.6

From the data listed in Table 7, we note that in the SFN mode, inter-symbol interference occurs at the receiver input, the intensity of which significantly depends on the difference between the levels of the Level1 and Level2 signals. Therefore, we can conclude that in a DVB-T2 SFN SISO network it is not advisable to have signals with comparable levels at the receiver input, because in this case the mutual interference of the signals is maximum and there is a high probability of complete degradation of the received signal. At the same time, analyzing the case Δ Level = 0 dB from Table 7, we note that the summary value of the signal level Level (1+2) (dBm) increased by 3 dB. However, in the SISO transmission mode, this doubling of the summary signal level is not admissible, because it will lead to complete degradation of the received signal.

5. Estimating the accuracy of field strength forecasting

To estimate the accuracy of field strength forecasting under the conditions of the relief and landscape of the Republic of Moldova, the predicted electromagnetic field strength values for 6 test points located in the Straseni service area were compared with those obtained from field measurements (see Table 3). All calculations (forecasts) were performed in accordance with the international recommendations ITU-R P.370-7, ITU-R P.1546-5 and ITU-R P.1812-3 using the specialized software "ICS Telecom".

The final results of the research are visualized in Table 8, where: E – measured value of field strength at the control point; EITU-R – predicted value of field strength at the control point.

Table 8. Estimation of the field strength forecasting accuracy in the DVB-T2 signal coverage area

Definirea evenimentului	Numărul evenimentelor			
	$N_{P.370-7}$	$N_{P.1546-5}$	$N_{P.1812-3}$	$\sum N_{P.}$
$\lvert E_{ITU-R} - E \rvert \leq 3$ dB	2	5	6	13
$3 < \lvert E_{ITU-R} - E \rvert \leq 6$ dB	3	2	2	7
$6 < \lvert E_{ITU-R} - E \rvert \leq 10$ dB	4	1	1	6
10 dB$< \lvert E_{ITU-R} - E \rvert$	1	2	1	4

Following the estimation of the field strength forecasting accuracy performed within the Straseni service area, we can draw the following conclusions:

1. The ITU-R P.1812-3 and ITU-R P.1546-5 models demonstrated a forecasting probability of 60% and 50% respectively in the range of precision values | EITU-R - E | ≤ 3 dB. This range of forecasted values can be considered almost perfect, since their accuracy can be compared with the measurement error value (± 2.5 dB).

2. At the same time, the ITU-R P.1812-3 and ITU-R P.1546-5 models demonstrated a forecasting probability of 80% and 70% respectively in the range of precision values | EITU-R - .E | ≤ 6 dB.

3. The ITU-R P.370-7 model demonstrated lower forecasting accuracy (compared to the ITU-R P.1812-3 and ITU-R P.1546-5 models), namely, the forecasting probability is 20% in the range of accuracy values | EITU-R - E | ≤ 3 dB, the forecasting probability is 50% in the range of accuracy values | EITU-R -.E | ≤ 6 dB.

4. Given the relief and landscape of the Republic of Moldova, when forecasting the coverage areas of digital terrestrial television signals, it is necessary to use two recommendations: ITU-R P.1546-5 and ITU-R P.1812-3. In this case, the ITU-R P.1546-5 recommendation will allow for a clearer identification of the supposed boundaries of the projected coverage area, and the ITU-R P.1812-3 method will make it possible to reveal the supposed “shadow areas” in more detail.

GENERAL CONCLUSIONS AND RECOMMENDATIONS

The general conclusions formulate the main results obtained as a result of the conceptual development and implementation of the first DTT multiplex in the Republic of Moldova:

1. In the process of conceptual development and implementation of the DTT network in the Republic of Moldova, a number of tests and researches were carried out, such as: estimating the quality parameters of the received signal in the service area of the multiplex; estimating the conditions for signal reception in a single-frequency digital terrestrial network; developing recommendations for optimal reception of the multiplex signal; estimating the accuracy of forecasting the coverage areas with a digital terrestrial signal in the conditions of the Republic of Moldova. As a result of the tests and researches, the following conclusions were reached:

1.1. Mutual interference of information signals in a DVB-T2 SFN SISO terrestrial network is practically inevitable. As a result, the quality parameters of the received signal tend to deteriorate. Implementing a number of technical measures related to network planning and implementation, correct signal reception allows minimizing the effect of these interferences in the system.

1.2. The quality indices of the signal received in a DVB-T2 SFN SISO network visibly correlate with the difference between the levels of the signals reaching the receiver input. If two signals with the same levels reach the receiver input, the value of the input summary level increases by 3 dB (relative to dBm). At the same time, in this case, the maximum degradation of the received signal occurs. As the difference between the levels of the signals at the receiver input increases, the intensity of mutual interference of the signals decreases.

1.3. For stationary signal reception in a DVB-T2 SFN SISO network, it is recommended to use a directional antenna with many elements, which will be strictly oriented in the direction of the incident wave with the highest intensity. The directional properties of the receiving antenna will allow to reduce the effect of mutual interference of network signals arriving from other directions.

1.4. Following the estimation of the field strength forecasting accuracy (in the conditions of the relief and landscape of the territory of the Republic of Moldova) the ITU-R P.1812-3 and ITU-R P.1546-5 models demonstrated a forecasting probability of 60% and 50%, respectively, in the range of accuracy values | EITU-R -E | ≤ 3 dB. At the same time, the ITU-R P.1812-3 and ITU-R P.1546-5 models demonstrated a forecasting probability of 80% and 70%, respectively, in the range of accuracy values | EITU-R - E | ≤ 6 dB.

1.5. In the conditions of the Republic of Moldova, for forecasting the coverage areas with terrestrial broadcasting signal, it is recommended to use the recommendations ITU-R P. 1546 and ITU-R P. 1812 together. In this case, the recommendation ITU-R 1546 will allow to highlight more clearly the supposed boundaries of the coverage area, and the recommendation ITU-R 1812 will allow to highlight more clearly the supposed “shadow areas”.

2. For the implementation of “MUX-A” the following operating and configuration parameters of the system were established: DVB-T2, System B, SFN, SISO, Multi-PLP; channel bandwidth 8 MHz; carrier frequency regime 32K extended; PLP_0 stream parameters - signal constellation QAM-16, protection code rate – 3/4; PLP_1 stream parameters - signal constellation QAM-256, protection code rate – 2/3; pilot frequency template PP4; coding system H. 264. The capacity of the configured system is 30.1 Mb/s and allows transmitting 12 TV programs in SD format.

3. For the forecasting of the coverage areas of "MUX-A" the international recommendation ITU-R P.1546 was selected. At the same time, the value of the minimum median

field intensity Emed = 54.7 dBμV/m for the frequency of 650 MHz was established. The design of the coverage areas with the DVB-T2 signal was carried out for fixed reception of the signal, provided that the receiving antenna is suspended at a height of 10 m from the ground surface.

4. Following the synthesis of the system operating and configuration parameters, the following technical objectives were achieved: reliable operation of "MUX-A" under conditions when the signal reaches the reception point from different directions; efficient use of the radio frequency spectrum; ensuring the maximum capacity of the system within the set of configuration parameters; adjusting the locations of digital terrestrial broadcasting stations to the infrastructure of existing terrestrial networks.

5. "MUX-A" was built in the period 2015-2019. During the construction, the following technical components of the system were implemented: the "Head End" audiovisual content encoding and multiplexing station; the "T2 Gateway" station for generating the T2-MI digital stream; the IP network for distributing the T2-MI digital stream; 6 DVB-T2 SFN SISO networks (Edinet, Mândrestii Noi, Trifesti, Străseni, Căuseni, Cahul cluster service areas); multiplex synchronization elements. In order to implement DVB-T2 SFN SISO networks on the existing terrestrial network infrastructure, 23 high, medium and low power digital terrestrial broadcasting sites were built.

Thus, in the first stage of construction of the national DTT multiplex, access to the DVB-T2 signal was ensured for 95% of the country's population.

6. In the next stage of construction of "MUX-A" it was necessary to extend the DVB-T2 signal into the "shadow zones". For this purpose, the possibility of using specialized repeaters of the f1/f1 type, the so-called Gap Fillers, for the emission of the signal into the "shadow zones" was investigated. As a result of the research, it was demonstrated that in the "shadow zones" of the Republic of Moldova the application of Gap Fillers on the existing infrastructure of the State Enterprise "Radiocommunicatii" is not possible for the following reasons:

a) in the "shadow zones" omnidirectional emission antennas must be used, and (in this case) the appropriate level of signal isolation can be ensured only by increasing the vertical distance between the receiving and transmitting antennas;

b) the appropriate level of signal isolation cannot be ensured due to the low height of the existing pylons H = 27 m;

c) due to the low signal level at the input of the receiving antenna it will be difficult to reduce the echo/signal ratio at the input of the Gap Filler.

7. As a result of the research, an alternative method of signal emission in the "shadow areas" of the RM was proposed. It was proposed: to use the infrastructure of existing fiber optic networks for transmitting the T2-MI data stream to the input of DVB-T2 sites. The practical application of this proposal allowed to eliminate the Gap Fillers, and the emission of the DVB-T2 signal was organized using low-power transmitters, which are about 30% cheaper than the Gap Filler. As a result, the need to reconstruct the existing pylons H = 27 m or to build new pylons with a height of about 40-50 m disappeared. Considering that in the "shadow areas" located in the Prut, Raut and Nistru river basins, approximately 60 DVB-T2 stations had to be installed, the operational costs and time required to complete the "MUX-A" implementation process were significantly reduced (to the maximum).

8. Starting with June 2022, the construction of digital terrestrial broadcasting sites in the "shadow areas" began. At the end of 2022, 30 low-power transmitters were installed. In the first half of 2023, another 30 sites were built. Population access to new TD services reached approximately 99% of the country's territory and 99% of the country's population.

9. The use of IP networks for the provision of the T2-MI input signal in the "shadow zones" allowed (simultaneously with the emission of the DVB-T2 signal) to remotely monitor

the technical parameters of DVB-T2 transmitters, as well as video monitoring of low-power digital broadcasting stations.

10. The use of the existing terrestrial network infrastructure for the construction of "MUX-A" allowed to significantly (to the maximum) reduce operational costs and the time required for the implementation of the project. The general objectives of the research were achieved - conceptual development and implementation of a technically, technologically and economically efficient digital terrestrial television network in the Republic of Moldova.

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ADNOTARE

la teza ***Elaborarea conceptuală și implementarea rețelei de televiziune digitălă terestră în Republica Moldova*** prezentată de Iacob Mihail pentru conferirea gradului de doctor în științe inginerești la specialitatea 231.02 „Ingineria și tehnologia comunicațiilor electronice”.

Structura tezei: este constituită din introducere, 3 capitole, concluzii generale, bibliografie (114 titluri), 8 anexe inserate în 138 pagini text de bază, 56 tabele, 118 figuri. Rezultatele cercetării au fost publicate în 20 de publicații științifice.

Cuvinte-cheie: televiziune digitală terestră, DVB-T, DVB-T2, T2 Gatway, MFN, SFN, SISO, „System A”, „System B”, „PLP”, „multi-PLP”, „Single PLP”, T2-Frame, T2-MI, COFDM, zona de servicii, „zonă de umbră”, ITU-R P.1546, ITU-R P.1812, MER, BER, CBER, LBER, C/N, Gap Filler.

Domeniul de studiu: televiziunea digitală terestră.

Scopul tezei: elaborarea conceptuală și implementarea rețelei de televiziune digitală terestră în Republica Moldova.

Obiectivele de cercetare. Selectarea modelului de prognozare a intensității câmpului; elaborarea parametrilor de operare și configurare a sistemului; prognozarea intensității câmpului; sinteza tehnologiei de emisie a semnalului în „zonele de umbră”; implementarea multiplexului național; testarea parametrilor de calitate ai semnalului; elaborarea recomandărilor în vederea recepționării optimale a semnalului și diminuării interferențelor în sistem; estimarea preciziei de prognozare a intensității câmpului.

Noutatea și originalitatea științifică. În premieră a fost propusă o metodă nouă de estimare indirectă a interferențelor inter-simbol în sistemul DVB-T2 SFN SISO și modul de diminuare a acestora la intrarea receptorului; a fost propusă și implementată o metodă alternativă de emisie a semnalului DVB-T2 în „zonele de umbră” ale rețelei proiectate; a fost estimată precizia de prognozare a intensității câmpului în condițiile reliefului și landșaftului Republicii Moldova.

Problema științifică soluționată. Au fost elaborate reperele conceptuale ale rețelei de televiziune digitală terestră în Republica Moldova, aplicarea cărora a permis a implementa primul multiplex național pe baza infrastructurii rețelelor terestre existente ce aparțin Î.S. „Radiocomunicații”, operator național în domeniul radiodifuziunii terestre.

Semnificația teoretică și aplicativă. A fost demonstrată necesitatea aplicării în sistem a antenelor de recepție direcționale orientate în direcția undei de cădere cu cea mai înaltă intensitate; a fost propusă și implementată tehnologia de emisie a semnalului digital în zonele de umbră ale Republicii Moldova, adaptată la infrastructura rețelelor terestre existente (rețele fibro-optice, piloane H = 27 m); a fost demonstrată oportunitatea aplicării modelelor ITU-R P.1812 și ITU-R P.1546 pentru prognozarea intensității câmpului în condițiile Republicii Moldova.

ANNOTATION

for the thesis "Conceptual development and implementation of the terrestrial digital television network in the Republic of Moldova", presented by Iacob Mihail for the conferral of the degree of Doctor in engineering sciences in the specialty 231.02 " Electronic Communications Engineering and Technology".

The structure of the thesis: It consists of introduction, 3 chapters, general conclusions, bibliography of 114 of titles, 8 appendices, 138 text pages, 56 tables and 118 figures. The research results were published in 20 of scientific publications.

Keywords: digital terrestrial television, DVB-T, DVB-T2, T2 Gatway, MFN, SFN, SISO, „System A”, „System B”, „PLP”, „Multi PLP”, „Single PLP”, T2-Frame, T2-MI, COFDM, service area, shadow area, ITU-R P.1546, ITU-R P.1812, MER, BER, CBER, LBER, C/N, Gap Filler.

Research field: digital terrestrial television.

The purpose of the thesis: Conceptual development and implementation of the digital terrestrial television network in the Republic of Moldova.

The objectives: Field strength forecasting; elaboration of system configuration parameters; synthesis of signal emission technology in shadow areas; implementation of the multiplex; testing signal parameters; development of recommendations for optimal reception of the signal and reduction of interference in the system; evaluation of the accuracy of field prediction.

Scientific novelty and originality: For the first time, a method was proposed for indirect estimation of inter-symbol interferences in the DVB-T2 SFN SISO system and how to reduce them at the receiver input; an alternative broadcast to the DVB-T2 signal was proposed and implemented in the shadow area of the projected network; the forecasting accuracy of the field intensity was estimated for the relief and landscape conditions of the Republic of Moldova.

The scientific problem solved: The conceptual benchmarks of the terrestrial digital television network in the Republic of Moldova were developed, the application of which allowed to implement the first national multiplex based on the infrastructure of the existing terrestrial networks belonging to S.E. "Radiocommunications", national operator in the field of terrestrial broadcasting.

Theoretical and practical importance: The necessity of applying directional receiving antennas in the system, oriented in the direction of the incident wave with the highest intensity, was demonstrated; digital signal emission technology was proposed and implemented in the shadow areas of the Republic of Moldova, adapted to the infrastructure of existing terrestrial networks (fiber-optic networks, H = 27 m pylons); the feasibility of applying the ITU-R P.1812 and ITU-R P.1546 models for field intensity forecasting was demonstrated.

АННОТАЦИЯ

диссертации „Концептуальная разработка и внедрение сети наземного телевизионного вещания в Республике Молдова”, представленную Якобом Михаилом на соискание ученой степени доктора инжинерных наук по специальности 231.02 „Инженерия и технология электронных комуникаций”.

Структура диссертации: состоит из введения, 3 глав, общих выводов, библиографии 114 названий, 8 приложений, 138 текстовых страниц, 56 таблиц и 118 рисунков. Результаты исследования были опубликованы в 20 научных публикациях.

Ключевые слова: цифровое наземное телевидение, DVB-T, DVB-T2, T2 Gatway, MFN, SFN, SISO, „System A”, „System B”, „PLP”, „Multi PLP”, „Single PLP”, T2-Frame, T2-MI, COFDM, зона обслуживания, теневая зона, ITU-R P.1546, ITU-R P.1812, MER, BER, CBER, LBER, C/N, Gap Filler.

Область исследований: цифровое наземное телевидение.

Цель диссертации: Концептуальная разработка и внедрение сети цифрового наземного телевидения в Республике Молдова.

Задачи работы: Выбор модели расчета напряженности поля; разработка режимов работы и конфигурации системы; прогнозирование интенсивности поля; выбор технологии трансляции сигналов в теневых зонах; внедрение национального мультиплекса; тестирование параметров сигнала; разработка рекомендаций по оптимальному приему сигнала и снижению помех в системе; оценка точности прогноза напряженности поля.

Научная новизна и оригинальность: Впервые предложен метод косвенной оценки межсимвольных помех в сети DVB-T2 SFN SISO и способы их уменьшения на входе приемника; предложен и реализован альтернативный способ трансляции сигнала в теневых зонах проектируемой сети; проведена оценка точности прогнозирования напряженности поля для рельефно-ландшафтных условий Республики Молдова.

Решенная научная задача: Выполнена концептуальная разработка сети наземного цифрового вещания в Республике Молдова, что позволило построить первый национальный мультиплекс на базе инфраструктуры существующих наземных сетей, принадлежащих Г.П. „Радиокоммуникаций”.

Теоретическая значимость и прикладная ценность работы: Показана необходимость применения в сети направленных приемных антенн, ориентированных в направлении направлении наиболее мощного сигнала; предложена и внедрена технология вещания в теневых зонах, адаптированная к существующей наземной инфраструктуре (волоконно-оптические сети, опоры H=27 м); показана целесообразность применения моделей ITU-R P.1812 и ITU-R P.1546 для прогнозирования напряженности поля.

IACOB Mihail

CONCEPTUAL DEVELOPMENT AND IMPLEMENTATION OF THE DIGITAL TERRESTRIAL TELEVISION NETWORK IN THE REPUBLIC OF MOLDOVA

231.02. Electronic communications engineering and tehnology

Scientific summary of the doctoral thesis in engineering sciences

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