DOI: 10.5281/zenodo.3949670
UDC 621.391:004

PARAMETERS ESTIMATION OF RECEIVED SIGNAL IN SINGLE-FREQUENCY NETWORK DVB-T2

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Received: 05. 22. 2020
Accepted: 07. 06. 2020

Abstract. This paper deals with the quality parameters of a television terrestrial signal received in the service area of a single-frequency DVB-T2 network, operating in the SISO mode (Single Input Single Output). The aim of the study is a practical assessment of selective fading frequency effect of the total signal and inter-symbol distortion of the signal at the input of the DVB-T2 receiver on the received signal quality. To achieve this goal, measurements of the qualitative indicators of the received signal were made in laboratory conditions. To receive television signals in the SFN DVB-T2 SISO cluster, it is preferable a directional antenna oriented to the incoming wave with the highest field strength. In this case, the interference waves effect of other cluster transmitters will be minimized. DVB-T2 noise-tolerance coding algorithms reliably compensate for the deterioration in the quality parameters of the received signal.

Keywords: *Service zone; DVB-T2; SISO; SFN; MER; CBER, LBER, T2 Gateway, Guard Interval, T2-MI interface.*

Introduction

The second-generation digital terrestrial television broadcasting DVB-T2 system [1] provides greater flexibility and spectral efficiency of the system compared to its predecessor DVB-T, and it is most focused on the deployment of single-frequency networks SFN (Single Frequency Network) [2]. The SFN cluster includes a group of transmitters that emit an information signal in a combined frequency channel without creating significant interference to each other and forming a single service area. At the same time, cluster transmitters emit signals: synchronized in time; at nominally coherent frequencies; modulated by the same data streams [2]. Important advantages of the SFN cluster, in comparison with traditional MFN (Multi Frequency Network) terrestrial broadcasting networks, are the following: more efficient use of the radio frequency spectrum; more uniform distribution of field intensity; the ability to receive a signal from an alternative direction; reduction of the area of shadow zones; increased probability of signal reception in the service area, etc. [3 - 5]. At the same time, the requirement of the absence of shadow zones in the service area needs the installation of transmitters with partially overlapping coverage areas, the so-called zones of mutual interference, in which there is a maximum effect of the signals of the transmitters on each other.

The aim of the study is a practical assessment of frequency-selective fading effect of the total signal and inter-symbol interference at the receiver input on the received signal quality. In the practical part of the study, an assessment was made of the received signal quality indicators in a SFN DVB-T2, operating in the SISO (Single Input Single Output) mode, see Figure 1. This mode of operation implies stationary reception of signals. In order to fulfill the research task, in laboratory conditions, a circuit was mounted simulating the operation of the SFN cluster. Applying two signals simultaneously to the input of the measuring device made it possible to identify how the qualitative parameters of the DVB-T2 received signal change, depending on the difference in levels and time delays of the signals at the input of the measuring device. As a result of the obtained analysis of measurement results, conclusions are drawn regarding methods to assess the quality of the received signal in single-frequency digital terrestrial broadcasting networks.

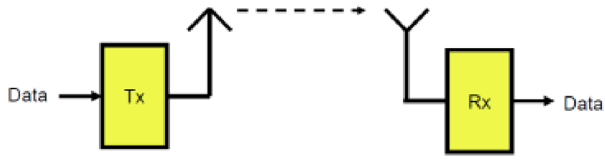

Figure 1. SISO principle demonstration - one signal at the input of the receiver, one at the output of the transmitters.

Operation features of the SFN DVB-T2 cluster

The architectural model of the DVB-T2 single-frequency cluster [1] is presented in Figure 2.

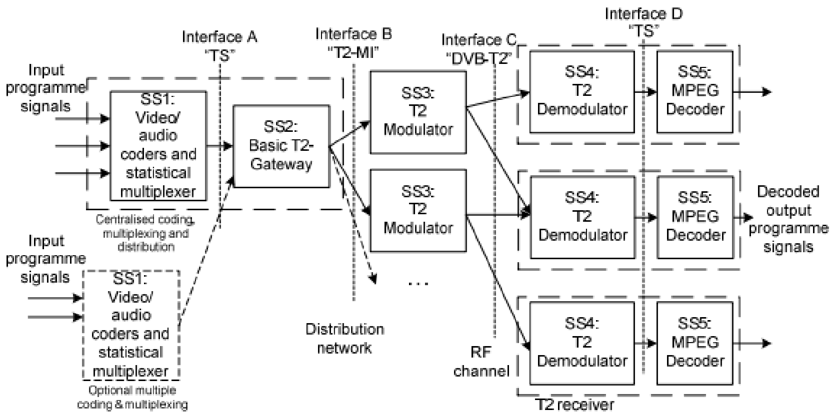

Figure 2. Architectural model of a DVB-T2 single-frequency cluster.

Interface A

At the input of the system T2 Gateway, one or several transport formed streams are received at the coding (compression) and multiplexing station of the original audiovisual content.

Interface B

From the output of the T2 Gateway through the digital serial interface T2-MI [6] and the transport distribution network protocols, packets containing audiovisual content, instructions for assembling DVB-T2 frames and phase-locked signals of the network are transmitted to the modulators [7].

Interface C

From the output of the transmitting antennas of the modulators, the DVB-T2 radio signals are emitted to the network coverage area. The DVB-T2 radio waveform and its spectral envelope are shown in Figures 3 and 4.

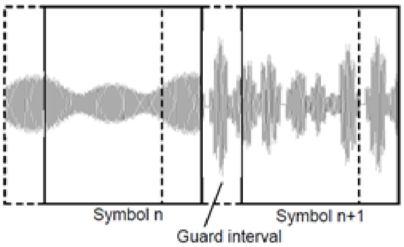

Figure 3. DVB-T2 time waveform.

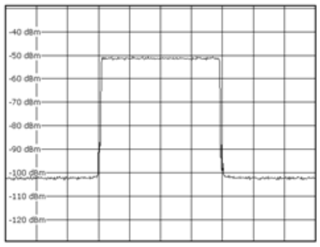

Figure 4. Spectral Envelope of DVB-T2 Signal.

As noted earlier, the output signals of all modulators of a single-frequency network are transmitted in a combined frequency channel. Therefore, the signals can come to the input of the receiving antennas from different directions both direct from the cluster transmitters and reflected, see Figure 5. In conditions of multipath reception, the signals are fed to the input of the receiving antenna with various amplitudes, phases, time delays and angles of arrival. As a result of mutual interference of these oscillations, selective fading frequency of the spectral components of the total DVB-T2 signal occurs at the terminals of the receiving antenna, see Figure 6.

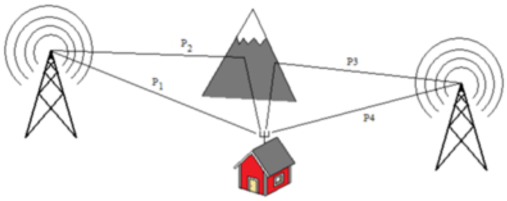

Figure 5. Signals at the input of the receive antenna in a single-frequency cluster.

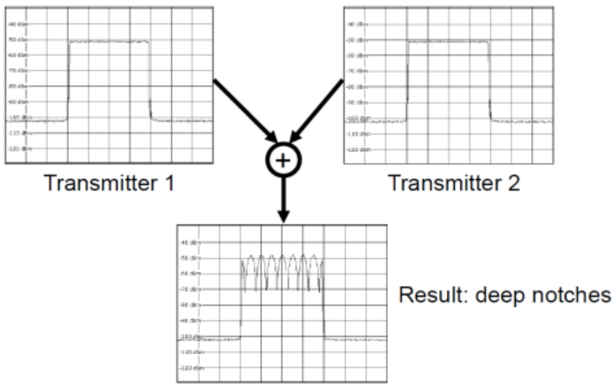

Figure 6. DVB-T2 Frequency Selective Fading.

At the input of the receiver, the length of time delays between incoming signals can reach several hundred microseconds, see Figure 7.

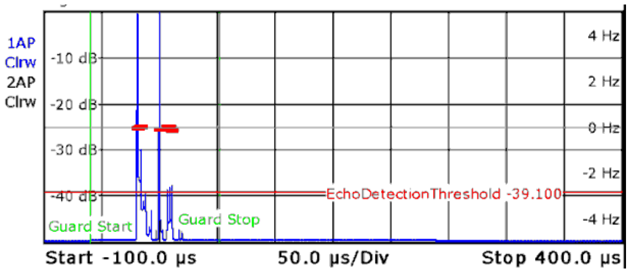

Figure 7. DVB-T2 Receiver Echo.

As a result, in the multipath channel there is a time overlap of the received signals. This phenomenon, called inter-symbol interference, leads to the mutual dependence of the signals received by the receiver at adjacent clock intervals, which greatly complicates their demodulation. To attenuate the effect of inter-symbol distortions in the DVB-T2 system, GI (Guard Intervals) are introduced in front of each transmitted COFDM symbol, see Figures 3 and 7. During the follow-up of the guard interval, signal reception is prohibited in the system. When designing an SFN cluster, the distance between the transmitters is chosen so that the difference in the delay of signals from neighboring transmitters does not exceed the duration of the guard interval [8].

In this way, in the zone of mutual interference of a DVB-T2 single-frequency network, the following physical processes take place at the terminals of the receiving antenna: 1. Induced voltage at the load of the receiving antenna is the sum of the induced voltages from all incoming waves; 2. Frequency-selective fading of the spectral envelope of the signal occurs; 3. There is inter-symbol interference of signals arriving with different time delays.

Interface D

During the reception of a DVB-T2 signal, demodulation is initially performed. As a result, we get the binary form of the received COFDM symbols. Due to signal attenuation and interference in the channel, part of the data will be received with errors. In the combined frequency channel, due to frequency selective fading and the resulting inter-symbol interference, the qualitative parameters of the signal after its demodulation tend to deteriorate (compared to the mode when one transmitter is operating in the network).

Channel decoder

At the stage of channel decoding of the DVB-T2 signal, the operations of digital processing of the received transport stream are performed, aimed at ensuring a given noise immunity of the received signal, including partial error correction using cascaded LDPC and BCH codes.

Statement for research

For the study, it was decided to use the network of the first national multiplex operating in Republic of Moldova, which operates in the DVB-T2, SFN, SISO, Single PLP modes. Network configuration parameters are presented in Figures 8 and 9. At the same time, it should be noted that the FFT (Fast Fourier transform) dimension - 32k and the relative length of the GI (guard interval) - 19/256, determine the physical duration of the GI, which for a given configuration is 266 μs.

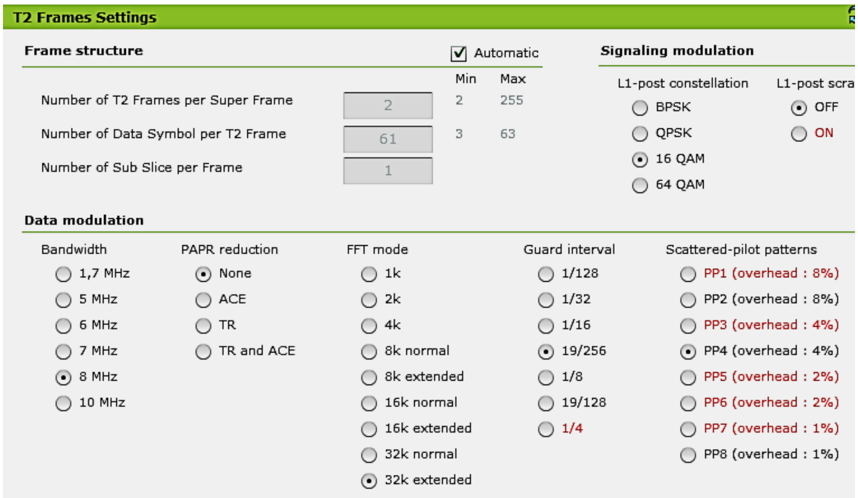

Figure 8. DVB-T2 frame time-frequency resource settings.

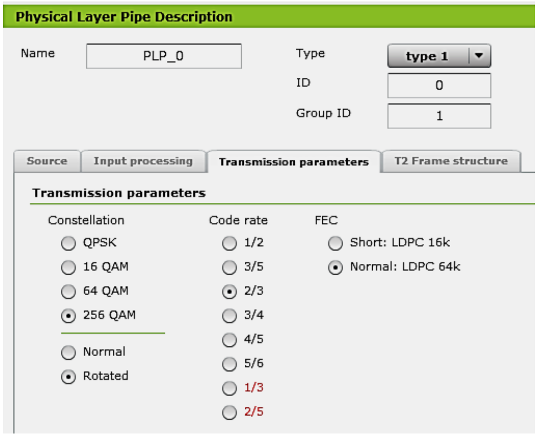

Figure 9. Physical Layer Pipe settings (PLP) of studied cluster.

Figure 10 shows the functional diagram of the transmitting and receiving path of the DVB-T2 system. The aim of the study is to assess the quality parameters of a signal in a single-frequency DVB-T2 network after its demodulation and decoding.

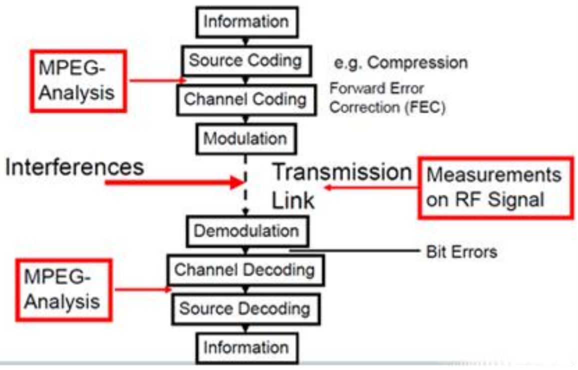

Figure 10. Transmit and receive path of the DVB-T2 system.

Selective review of DVB-T2 signal quality parameters

The root means square modulation error ratio MER (Modulation Error Ratio) [6] estimates the position of the received symbol on the plane of the signal constellation. MER depends on the influence of all factors in the transmission path and is a measure of the total interference effect in the transmission system, see Figure 11.

Like the signal/noise ratio (S/N), the MER value is usually expressed in decibels. If only noise effects are taken into account, MER and S/N will be equivalent. Really MER [dB] ⩽ S / N [dB].

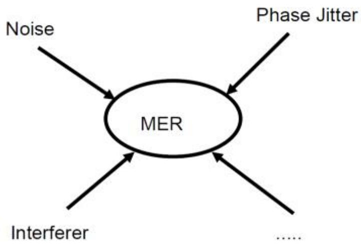

Figure 11. The total impact of interference in the transmission system.

The Bit Error Ratio (BER) [6] is defined as the ratio of erroneously received bits to the total number of bits received at the same time.

This parameter was measured at two points of the receiving path - after the demodulator, the so-called CBER (Chanel Bit Error Ratio), see BER 1 in Figure 12, and after the LDPC decoder, the so-called LBER, see BER 2 in Figure 12.

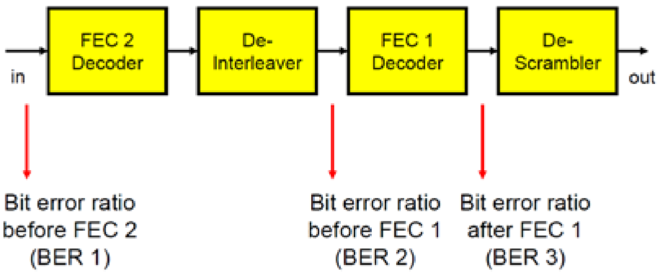

Figure 12. Anticipatory error correction in the receiver.

The points of the receiving path, where the parameters of the received DVB-T2 signal are evaluated, are shown in Figure 12.

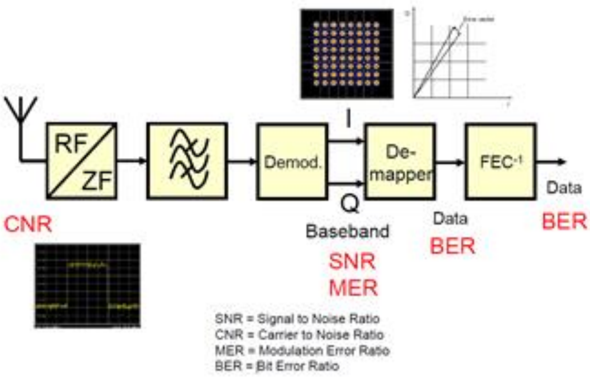

Figure 12. Receiving path points where the parameters of the received DVB-T2 signal are evaluated.

Laboratory Measurement Results for DVB-T2

In order to fulfill the research task, in laboratory conditions, a circuit simulating the operation of the SFN cluster was mounted.

For this, through the T2-MI interface, the transport stream of the current first national multiplex of Republic of Moldova was sent to the input of two DVB-T2 transmitters operating in channel 22.

From the outputs of the transmitters, the signal was applied to the input of the addition bridge.

The total signal was fed to the input of the ETL Rohde & Schwarz meter. Initially, the quality of the signal was measured in the MFN mode (from the output of one of the transmitters).

The results of these measurements were further compared with the results of measurements performed in the SFN mode.

Applying two signals simultaneously to the input of the measuring device made it possible to identify how the qualitative parameters of the DVB-T2 signal change after its demodulation, depending on the difference in levels and time delays of the signal at the input of the measuring device. Selected measurement results [9] are presented in Tables 1 and 2 and also in Figures 13 - 18.

Table 1

Quality parameters of the received DVB-T2 signal, time offset about 2 μs

Regime	**MFN**	**SFN**				
Parameters	1	1	2	3	4	5
Level $_{(1+2)}$		-37.1	-37.7	-38.4	-38.6	-35.5
Level $_{1}$, dBm	-49.7	-37.8	-38.0	-38.5	-38.6	-35.6
Level $_{2}$, dBm		-41.6	-44.9	-51.2	-58.4	-58.5
Δ Level, dB		-3.8	-6.9	-12.7	-19.8	-22.9
Time offset, μs		2.46	2.45	2.4	2.39	2.4
MER PLP rms, dB	41.5	33.9	38.1	39.3	40.1	38.9
MER PLP peak, dB	40.5	14.2	21.5	26.6	27.0	26.6
Amplitude, dB	0.5	14.04	9.21	4.62	2.15	1.74
Phase, deg	1.62	85.29	59.17	30.80	15.60	12.11
BER before LBER	3.0e-8	2.4e-4	5.5e-7	1.0e-11	5.5e-9	1.0e-11
BER before BCH	1.0e-11	0.0e0	0.0e0	0.0e0	0.0e0	0.0e0
Quality Value, %	82	65	69	71	75	76
Note	Figure 15	Figure 16			Figure 17	

Table 2

Quality parameters of the received DVB-T2 signal, time offset about 100 μs

Regime	**MFN**	**SFN**				
Parameters	1	1	2	3	4	5
Level $_{(1+2)}$		-58.5	-48.8	-51.9	-49.2	-47.5
Level $_{1,}$ dBm	-49.7	-58.5	-52.8	-57.9	-58.0	-58.2
Level $_{2,}$ dBm		-55.5	-48.2	51.6	49.1	-47.5
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
MER PLP peak, dB	40.5	3.3	15.5	15.0	23.3	23.1
Amplitude, dB	0.5	64.86	13.48	10.42	7.15	5.84
Phase, deg	1.62	1450.54	22.17	24.83	12.56	10.9
BER before LBER	3.0e-8	1.9e-2	2.3e-4	4.5e-5	1.6e-6	1.6e-7
BER before BCH	0.0e0	3.8e-3	0.0e0	0.0e0	0.0e0	0.0e0
Quality Value, %	82	27	44	46	55	59
Note	Figure 15	Figure 18	Figure 19	Figure 20		

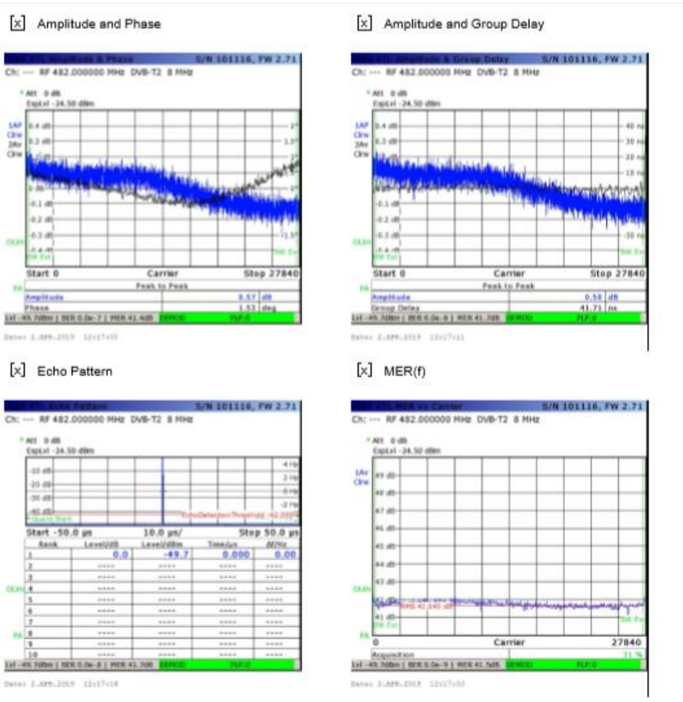

Figure 13. DVB-T2 Signal Form and Values parameters measured in the MFN mode: Level -49.7 dBm; Amplitude 0,57 dB; Phase 1.53 deg; Group Delay, MER(f); MER (PLP, rms) 41.7 dB.

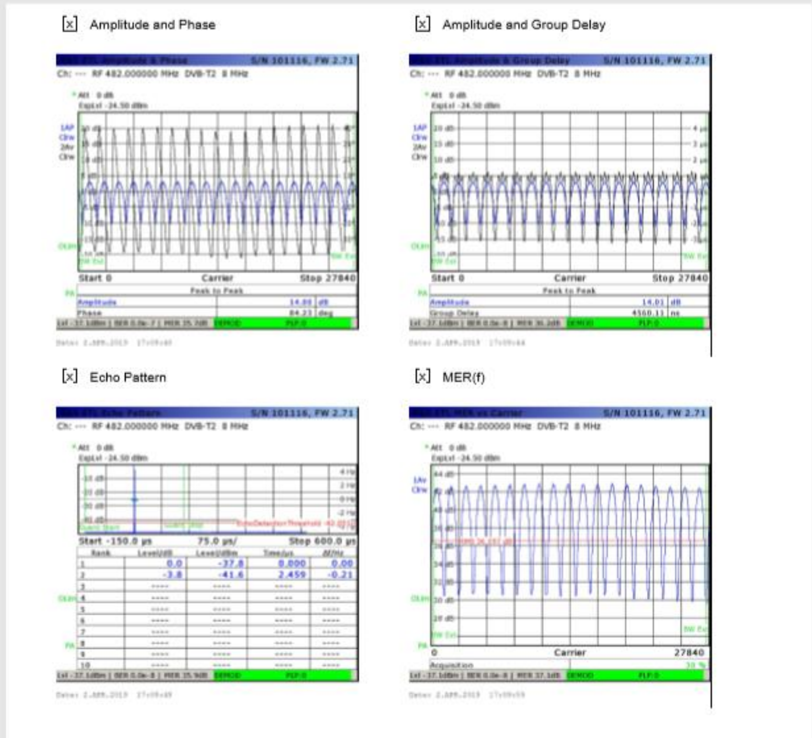

Figure 14. DVB-T2 Signal Form and Values parameters measured in the SFN mode: Level, -37.1 dBm; Δ Level, - 3.8 dB Δ Level, dB Amplitude 14.04 dB; Phase 85.29 deg; MER(f); MER (PLP, rms) 33.9 dB; Time offset 2 μs.

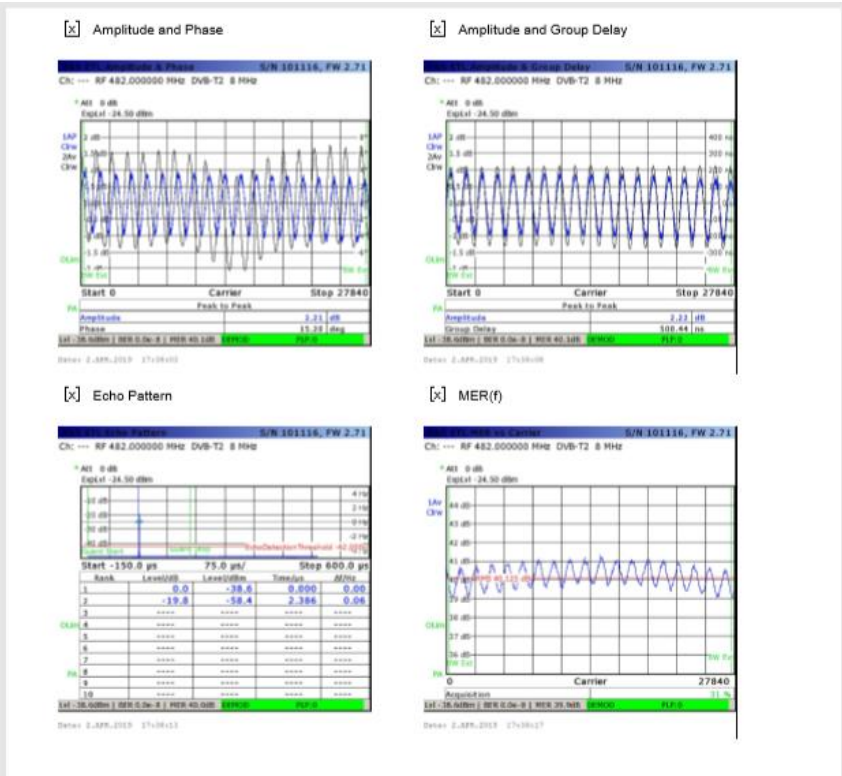

Figure 15. DVB-T2 Signal Form and Values parameters measured in the SFN mode: Level, -38.6 dBm; Δ Level, -19.8 dB; Amplitude 2,15 dB; Phase 15.6 deg; MER(f); MER (PLP, rms) 40.1 dB; Time offset 2 μs.

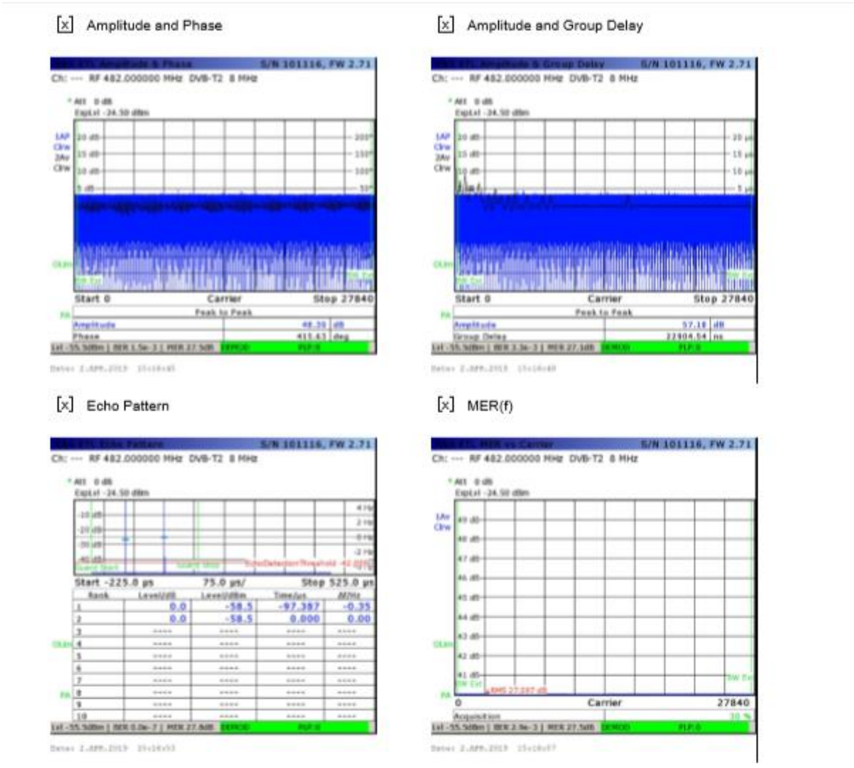

Figure 16. DVB-T2 Signal Form and Values parameters measured in the MFN mode: Level -58.5 dBm; Δ Level, 0 dB; Amplitude 64.86 dB; Phase 1450.54 deg; MER(f); MER (PLP, rms) 27.3 dB; Time offset 100 μs.

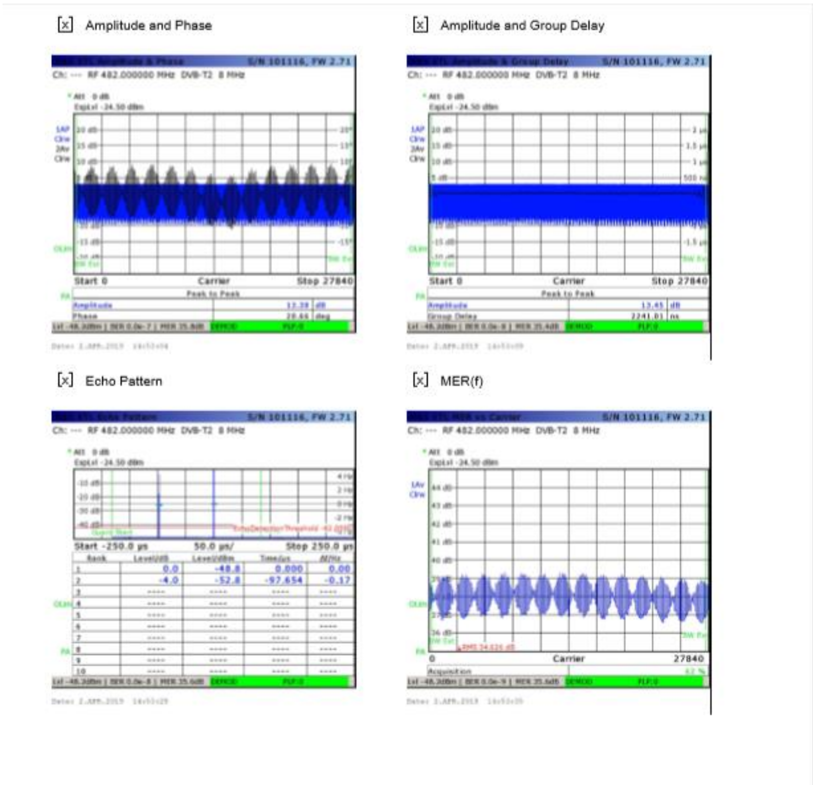

Figure 17. DVB-T2 Signal Form and Values parameters measured in the SFN mode: Level -48.8 dBm; Δ Level, -4.0 dB Amplitude 13.48 dB; Phase 27.17 deg; MER(f); MER (PLP, rms) 33.6 dB; Time offset 100 μs.

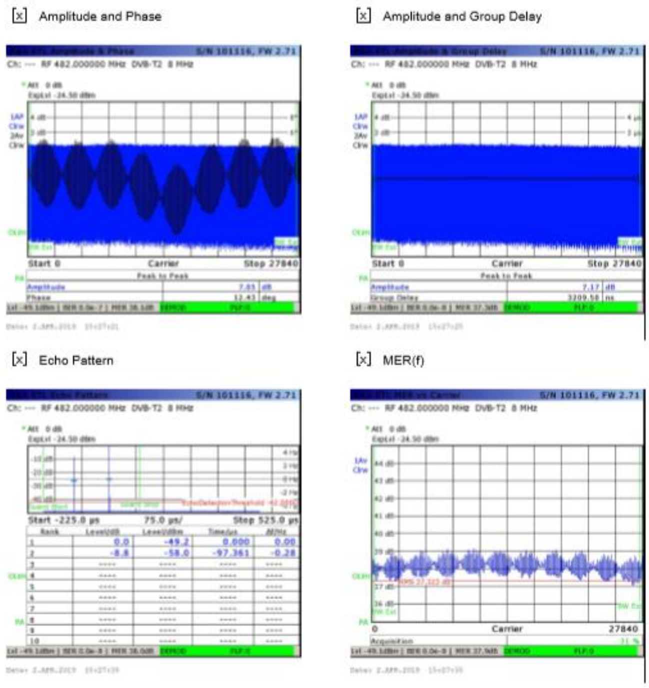

Figure 18. DVB-T2 Signal Form and Values parameters measured in the SFN mode: Level -49.2 dBm; Δ Level, -8.8 dB Amplitude 7.15 dB; Phase 12.56 deg; MER(f); MER (PLP, rms) 38.0 dB; Time offset 100 μs.

Conclusions

During the study, measurements were made of the qualitative parameters of the received signal in a single-frequency cluster DVB-T2. The analysis of the results of laboratory measurements, allowed to draw the following conclusions:

1. Qualitative parameters of the received signal depend on the value of the total level of all signals received at the input of the receiver, on the difference between the levels of these signals and on the duration of the time delay between the moments of arrival of the signals;

2. If two direct signals with the same levels arrive at the receiver input, the value of the total input level increases by 3 dB. However, in this case, the maximum degradation of the received signal is observed.

3. As the difference between the levels of the received signals increases, the mutual interference of the signals decreases, however, the effect of their presence is felt even with a level difference of 20 dB;

4. In the event that signals having a time shift relative to each other arrive at the input of the receiver, the nature of the interference effect in the channel frequency band changes, namely, the rate of change of the amplitude and phase of the signal (after its demodulation) increases.

5. DVB-T2 noise-tolerance coding algorithms reliably compensate for the deterioration in the quality parameters of the received signal;

6. To receive television signals in the SFN DVB-T2 SISO cluster, it is preferable to use a directional antenna oriented to the incoming wave with the highest field strength. In this case, the interference effect of waves of other cluster transmitters will be minimized.

Acknowledgments. The work was approved at the International Conference on Electronics, Communications and Computing, ECCO – 2019.

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