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The choice of DVB-T2 signal transmission technology in the shadow areas of the Republic of Moldova

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***Abstract*—This article presents the results of research into the opportunity to use Gap Fillers in the shadow areas of the first national digital terrestrial television multiplex of the Republic of Moldova. A basic condition related to the expansion of the population's access to the DVB-T2 signal in the "shadow areas" was - the use of the existing terrestrial broadcasting infrastructure. It was demonstrated that, to achieve the proposed goal, the use of Gap Fillers is not appropriate, but for the signal emission in the "shadow areas" it is necessary to use low-power DVB-T2 transmitters. In this case, the transport of the T2-MI flow to the entrance of the mentioned transmitters will be ensured by means of the existing fiber optic networks.**

Keywords—Gap Filler, digital terrestrial television multiplex, DVB-T2, SFN, T2-MI, "Echo" signal, isolation, "shadow areas".

I. Introduction

During the years 2016-2018 S.E. "Radiocomunications" put into operation in the Republic of Moldova the first national digital terrestrial television multiplex, so called "MUX-A". For the "MUX-A" implementation, 6 DVB-T2 SFN SISO service areas were built. Therefore, using the infrastructure of the existing terrestrial broadcasting networks, 8 high-power transmitters and 9 medium-power transmitters were put into operation throughout the country. In accordance with the technical specifications of the DVB-T2 networks [1], the T2-MI digital data stream was transported to the input of 17 transmitters, mentioned above, via IP networks. The implementation of "MUX-A" ensured access to the DVB-T2 signal for about 95% of the country's population. At the same time, due to the peculiarities of the relief, in the Republic of Moldova there are about 60 localities located in the so-called "shadow areas", where the terrestrial signal cannot be received. Between the years 1970 - 2008, low-power analog TV signal retransmission stations of the f_1/f_2 type were installed in the mentioned localities, but for the suspension of the broadcast antennas in the overwhelming majority of cases, typical masts of a height of 27 m were built. Resulting from the need to expand the population's access to terrestrial digital signal, Î.S. "Radiocomunications" took the decision to research the opportunity of using in "shadow areas" the low-power f_1/f_1 repeaters, so-called Gap Fillers. A basic condition related to the expansion of the population's access to the DVB-T2 signal in the "shadow areas" was - the use of the existing infrastructure of low-power analogue TV signal retransmission stations.

Gap Filler, is an f_1/f_1 terrestrial digital signal repeater with signal processing and amplification, see Figure 1 [2]. Consequently, a certain part of the signal (the echo) from the output of the transmitting antenna will return back to the input of the Gap Filler (with a delay, relative to the other input signals, equal to the signal processing time).

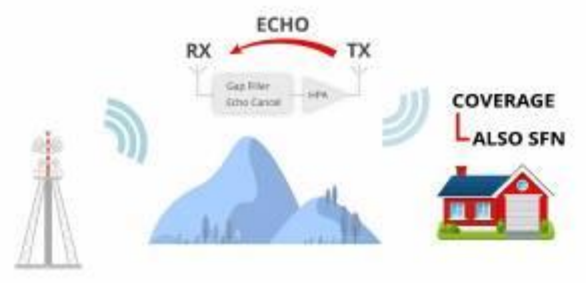

Figure 1. Gap-Filler in a digital Terrestrial Broadcasting Network

So, one of the important functions of the Gap Filler is to suppress its own echo. According to the technical specifications of the manufacturers [3,4], the echo level at the Gap Filler input should not exceed the signal level at the network input by more than 12-15 dB (depending on the manufacturer's model). When this ratio at the Gap Filler input is exceeded, the signal idices at the repeater output drift outside the MER < 24 dB quality tolerances. As a result, the protection algorithms stop the Gap Filler from working. Therefore, to ensure reliable operation of the Gap Filler, adequate signal isolation (not less than 80 dB [2]) must be ensured between the transmitting and receiving antennas. At the same time, the requirement to limit the echo level also imposes a limitation on the output power of the Gap-Filler. Unfortunately, there are other factors that limit the effectiveness of using a Gap-Filler, such as: 1. The amplitude of the signal from the repeater output, as well as the echo, can vary according to weather conditions; 2. The phase difference between the signal from the repeater output and the echo may change due to antenna vibrations due to wind; 3. Multipath signal reception conditions can be disturbed by waves reflected from local objects located near the input or output antennas of the repeater, etc.

In order to investigate the possibility of using f_1/f_1 low-power repeaters in "shadow areas", field tests of the Gap Filler, produced by the TRedess company, were carried out at the ground signal relay station located in the Holercani town. The tests were carried out in the DVB-T2 SFN SISO channel 31 cluster, using the existing infrastructure of analogue TV repeaters (already decommissioned).

II. The infrastructure of the retransmission station

The external appearance of the relay station in the town of Holercani is shown in Figure 2. The height of the pylon H = 42 m, the height of the pylon base above sea level h = 108 m. On the pylon are suspended: a receiving antenna LAP 4/5-50/16 and 2 transmitting antennas - TVA 31/50 and TVA 51/50. The technical parameters of the receiving and transmitting antennas are presented in Tables I and II. The external appearance of the transmitting and receiving antennas is shown in Figure 3.

TABLE I. TECHNICAL PARAMETERS OF THE LOG-PERIODIC RECEIVING ANTENNA LAP 4/5-50/16

Parameter	Antenna LAP 4/5-50/16
Polarization	H
Azimuth, gr	240
Orientation	Towards broadcasting station № 2
Reception	Channel 31
Suspension above the ground, m	40
Amplification coefficient, dBd	9.0
Number of panels	1

TABLE II. TECHNICAL PARAMETERS OF TVA 31/50 AND TVA 51/50 BROADCAST ANTENNAS

Parameter	Antenna	
	TVA 31/50	***TVA 51/50***
Polarization	H	V
Azimuth, gr	130	135
Broadcast channel	31	31
Suspension above the ground, m	34	33
Amplification coefficient, dBd	11	11
Number of panels	1	1

Figure 2. The exterior of the relay station in the town of Holercani

Figure 3. External appearance of the antennas: TVA 31/50 and TVA 51/50 (from the left); LAP 4/5-50/16 (from the right)

III. Measurement of signal isolation

Since the primary mode of echo reduction is to provide isolation between the transmit and receive antennas, as the first step of the study, the $A_{tx\text{-}rx}$ crosstalk attenuation on the 564 MHz frequency between the input of the transmit antennas and the output of the receive antenna was measured. At the same time, the dynamics of the $A_{tx\text{-}rx}$ change was evaluated according to the value of the angle Δφ between the directions of maximum amplification of the transmitting and receiving antennas, and according to their polarization. The results of the measurements are presented in Tables III, IV, where L - is the distance between the antennas, Δφ – is the angle between the directions of the maximum radiation of the antennas.

TABLE III. $A_{TX\text{-}RX}$ VALUE MEASUREMENT RESULTS BETWEEN TVA 51/50 TRANSMIT ANTENNA INPUT AND LAP 4/5-50/16 RECEIVE ANTENNA OUTPUT

Polarization	L, m	Δφ, gr	$A_{tx\text{-}rx}$, dB f=564MHz
V-H	6	105	88.84

TABLE IV. $A_{TX\text{-}RX}$ VALUE MEASUREMENT RESULTS BETWEEN TVA 31/50 TRANSMIT ANTENNA INPUT AND LAP 4/5-50/16 RECEIVE ANTENNA OUTPUT

Polarization	L, m	Δφ, gr	$A_{tx\text{-}rx}$, dB f=564MHz
H-H	7	110	92.37
		55	73.02
		0	74.15

From the results of the presented measurements, the following preliminary conclusions were drawn:

1. Changing the polarization of the transmit antenna relative to the polarization of the receive antenna provides no noticeable gain in improving $A_{tx\text{-}rx}$ signal isolation. At the same time, this technical action can be used to put into operation a Gap Filler in the shadow area of the DVB-T2 SFN cluster;
2. To ensure maximum isolation of the signal between the input of the transmitting antenna and the output of the receiving antenna, an angle of 180º must be ensured between their maximum radiation directions. With the practical implementation of the Gap Filler in the shadow area of a DVB-T2 SFN network, this angle must (at least) exceed 90 degrees. At the same time, in the case when it will be necessary to install a transmitting antenna with a circular directivity, this requirement will not be able to be met, and the necessary amount of signal isolation can only be ensured by increasing the distance between the suspension heights of the receiving antennas and emission, consequently, for the practical realization of this scenario it will be necessary to be provided with a sufficient height of the pillar.

IV. Input signal level measurement

In order to estimate the level of DVB-T2 SFN signals at the entrance of the tested Gap Filler and at the same time their arrival time, measurements were made at the feeder output of the receiving antenna. The results of the measurements are shown in Figure 4. From the image we can see that at the entrance of the Gap-Filler, there are 3 falling waves, transmitted on channel 31 by three transmitters: Station № 1 - signal level (-64.6 dBm); Station № 2 - signal level (-54.3) dBm; Station № 3 - signal level (-86.7) dBm. The receiving antenna is oriented in the direction of Station № 2. Thus, three DVB-T2 signals are applied to the input of the Gap Filler, shifted in time relative to each other by 80.934 µs and 72.934 µs. The level of the second signal is maximum. The summary level of the signal has a value of (-54.2) dBm.

Figure 4. Measurement of input signal levels and their arrival time

So, the peculiarities of the Holercani relay station (geographical location, height of the pylon, suspension height of the receiving antenna, gain of the receiving antenna) ensure a sufficient level of the signal from the Gap Filler (-54.2) dBm. However, in the Republic of Moldova, the vast majority of existing analogue signal repeaters are located at the edge of the service areas with DVB-T2 signal, but the height of the pylons (from their composition) is 27 m. Under these conditions, the DVB-T2 signal level of at the entrance of the repeaters it will be lower. For the purpose of correct network planning it is necessary to estimate this level. For this, we will assume that the field intensity at the entrance of the repeater reception antenna reaches the level of the admissible threshold Emed = 53 dBµV/m (for channel 31), but the R&S HL 040 reference antenna is used for reception. At the same time, we will assume that the losses in the feeder- of the receiving antenna is about 2 dB (estimated length of the feeder (½)" about 30 - 35 m).

The field strength measurement at the input of the receiving antenna can be performed by measuring the voltage at the antenna terminals connected to a 50 Ohm load. The field intensity value E [dμV/m] in this case is calculated by formula (1) [5]:

$$E = U_{50\Omega} + F_a + A_f \tag{1}$$

where Fa [dBm^{-1}] is the antenna factor in the direction of maximum radiation; $U_{50\Omega}$ [dμV] is the signal level at the output of the feeder of the reception antenna, Af [dB] are losses in the feeder. Table V shows the R&S HL 040 antenna factor.

TABLE V. R&S HL 040 ANTENNA FACTOR

Frequency, MHZ	Antenna factor, dBm^{-1}
500	16.37
550	17.27
600	17.96

Applying Formula 1 and the data of Table V we will calculate the signal voltage at the output of the feeder of the reception antenna:

$U_{50\Omega}$ = 53 dBμV/m – 17.3 dBm^{-1} – 2 dB = 33.7 dBμV =

= (- 73.3) dBm.

(- 73.3) dBm= (-54.2) dBm - 19.1dB

Therefore, the signal level at the entrance of the repeater implemented on the H = 27 m pillar and located at the edge of the service area can be reduced by about 19 dB compared to the signal level at the entrance of the Holercani repeater. In this case we can conclude about the need to ensure an isolation value of the A_{tx-rx} signal around 100 – 110 dB, which in local conditions will not be possible.

V. Gap Filler Testing

In order to continue the planned research, testing of the Gap Filler, produced by TRedess, was carried out. The mentioned repeater was connected consecutively to the TVA 31/50 and TVA 51/50 transmission antennas installed on the H= 42 m pillar in the town of Holercani. In the course of the research, the DVB-T2 terrestrial signal quality indicators were measured at the input and output of the Gap Filler. The measurement results were compared and analyzed.

In Figure 5 shows the constellation of the DVB-T2 signal from the feeder output of the receiving antenna. In this case, the input signal level has a value of (-53.0) dBm, but the MER (PLP, rms) indicator is 33.1 dB.

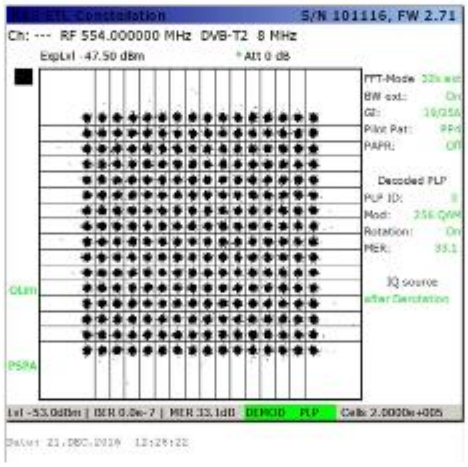

Figure 5. DVB-T2 signal constellation at the feeder output of the receiving antenna

In Fig. 6 shows the levels and time lags of the signals transmitted by the Gap Filler connected to the artificial antenna. The maximum power of the Gap Filler was set to 75 W. The value of the MER parameter is 30.9 dB. Only the signal transmitted from station № 2 was highlighted on the device screen. From the image we notice that, in addition to direct signals, at the input of the Gap Filler there are also signals reflected from local objects in the vicinity of the receiving antenna. The levels of these echoes are significantly lower and their delay time is insignificant (tenths, units of microseconds).

Figure 6. The levels and time lags of the signals at the output of the Gap Filler, connected to the artificial antenna

In Figure 7, the echo of its own emission signal is demonstrated, reaching the input of the Gap Filler. The repeater is connected to the TVA 51/50 transmission antenna, the transmission power is 10 W. The angle between the maximum radiation directions of the transmission and reception antennas is 105 degrees. On the screen, only the signal emitted by the transmitter of station № 2 is highlighted. From the drawing, we notice that, in addition to the signal of the transmitter of station № 2 (Time - (76.541 µs), Level (- 12.7 dB)), at the input of the repeater there is also the echo of its own signal (Time - (81.087 µs), Level (0.0 dB)). Thus, the echo level at the input of the Gap Filler exceeds the level of the input signal by 12.7 dB. The appearance of the echo of its own input signal negatively affects the quality of the Gap Filler output signal, MER (PLP, rms) is 28.3 dB. Therefore, simultaneously with signal processing and amplification, one of the important tasks of the Gap Filler is the partial suppression of its own echo. In Figure 8 shows the levels and time lags of the signals transmitted by the Gap Filler. Only the signal of station № 2 is highlighted on the screen of the device. The image shows that, in addition to the direct signal of station № 2 (Time – (81.144 us), Level (0.0 dB)), there is also an echo of the signal at the output of the Gap Filler own (Time – (85.984 us), Level (- 32.0 dB) Thus, we notice that the Gap Filler's own echo has been suppressed by 44.7 dB (12.7 dB + 32.0 dB).

Afterwards the 20 W emission power of the Gap Filler was set. In Figure 9 shows the echo of the own signal from the input of the Gap Filler. Only the signal emitted by station № 2 is highlighted on the screen. From the drawing we notice that, in addition to the signal of station № 2 (Time – (76.524 us), Level (- 14.6 dB)), at the input of the repeater there is also the echo of its own signal (Time – (81.113 us), Level (0.0 dB)). Thus, the echo level at the input of the Gap Filler exceeds the level of the input signal by 14.6 dB. We notice that the value of the MER quality indicator (PLP, rms) has decreased to 28.1 dB, but the operational margin of this indicator has become quite narrow – about 4 dB (28dB - 24dB).

In Figure 10 shows the echoes of the own signals from the input of the Gap Filler for the case when it is connected to the TVA 31/50 broadcast antenna, Pout = 20 W, Δφ = 110 gr. The signals of stations №1, № 2 and № 3 are highlighted on the screen. The signal of station № 2 is located in the middle of the screen: direct signal - (Time (- 4.546 us), Level (- 12.8 dB)); the echo of the own signal - (Time – (0.000 us), Level (0.0 dB)). Thus, the echo level of the own signal at the input of the Gap Filler exceeds the level of the input signal by 12.8 dB, but the MER parameter at the output has reached a value of 28.2 dB

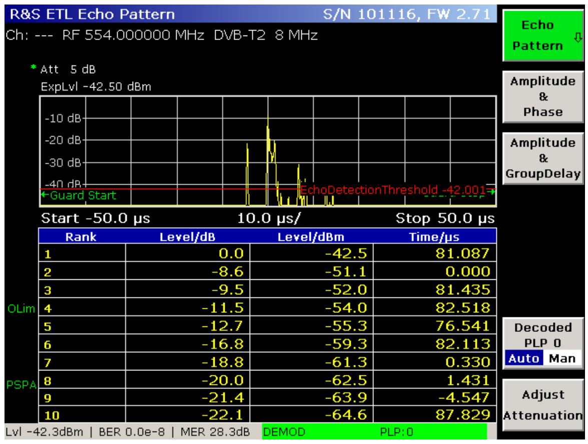

Figure 7. The echo of its own signal at the input of the Gap Filler (P_{out} = 10 W), TVA 51/50 transmission antenna, Δφ = 105 gr.

Figure 8. The levels and time lags of the signals transmitted by the Gap Filler (Pout = 10 W), TVA 51/50 broadcast antenna, Δφ = 105 gr.

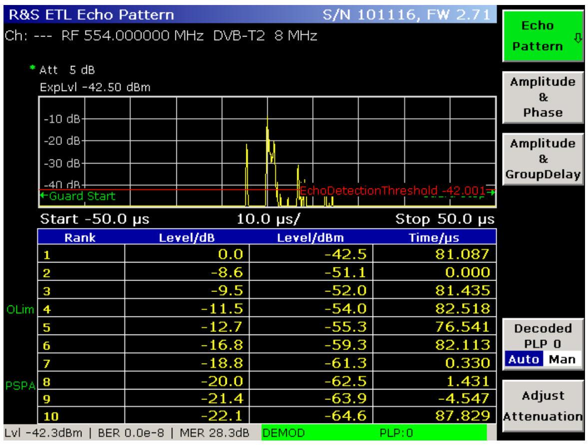

Figure 9. The echo of its own signal at the input of the Gap Filler (Pout = 20 W), TVA 51/50 transmission antenna, Δφ = 105 gr.

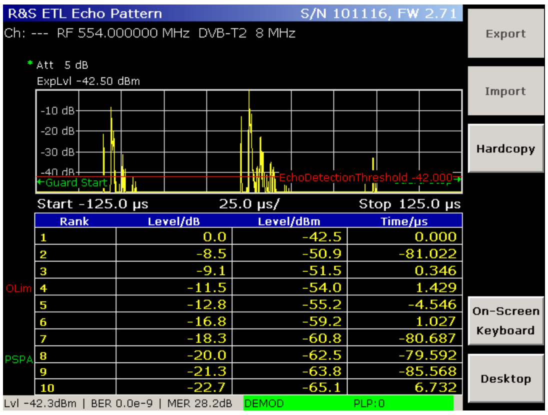

Figure 10. The echo of its own signal at the input of the Gap Filler (Pout = 20 W), TVA 31/50 transmission antenna, Δφ = 110 gr.

In Fig. 11 we can visualize the signal from the output of the Gap Filler. All signals retransmitted to the viewer are highlighted on the screen:

- the signals of the direct falling waves of the transmitters of the SFN network;
- the suppressed echoes of the Gap Filler's own signal;
- waves, reflected from local objects placed in front of the reception and emission antennas.

Figure 11. The levels and time lags of the signals transmitted by the Gap Filler (Pout = 50 W), TVA 31/50 broadcast antenna, Δφ = 110 gr.

The final reports regarding the testing of the Gap Filler, manufactured by TRedess, in the DVB-T2 SFN cluster (channel 31) are presented in Tables VI and VII. To complete the tables, the following abbreviations were used: $P_{in\text{-}tx}$ - signal level at the input of the antenna emission; Pout-rx - signal level at the feeder output of the receiving antenna; Pecho - the Gap filter's own echo level; ΔP = (Pecho - Pout rx) – the ratio between the Gap Filler's own echo level and the network input signal level.

TABLE VI. FINAL TEST RESULTS OF THE GAP FILLER, CONNECTED TO TVA 51/50 TRANSMIT ANTENNA

$P_{in\text{-}tx}$, dBm	$P_{out\ rx}$, dBm	P_{echo}, dBm	ΔP, dB	MER, dB	Δφ, gr	L, m
40	- 55.3	-42.5	12.8	28.3	105	7
43	- 55.7	- 41.1	14.6	27.9	105	7

TABLE VII. FINAL TEST RESULTS OF THE GAP FILLER, CONNECTED TO TVA 31/50 TRANSMIT ANTENNA

$P_{in\text{-}tx}$, dBm	$P_{out\ rx}$, dBm	P_{echo}, dBm	ΔP, dB	MER, dB	Δφ, gr	L, m
40	- 55.3	-48.3	11.5	29.0	110	6
43	- 55.2	- 42.5	12.7	28.2	110	6
47	-	-	-	25.6	110	6

VI. Conclusions

Following the testing of Gap Filer on the existing infrastructure of the retransmission station located in the town of Holercani, the following conclusions were drawn:

1. The reliable operation of the Gap Filler in local conditions can only be ensured with 10W(40 dBm) amplification power. In this case, the operational reserve of the MER quality parameter will be around 4-5 dB. Increasing the emission power will lead to the degradation of the MER parameter.
2. Exploitation of Gap Fillers based on the existing infrastructure of Î.S. Radio communication is not appropriate for the following reasons: a) due to the low height of the existing pylons, it will not be possible to ensure the appropriate level of signal isolation; b) due to the low level of the input signal, it will not be possible to reduce the echo/signal ratio from the Gap Filler input.
3. For signal emission in the "shadow areas" of the Republic of Moldova, it is appropriate to use DVB-T2 transmitters of low power (50 W). In this case, the transport of the T2-MI flow to the entrance of the mentioned transmitters will be ensured by means of the existing fiber optic networks, access to the infrastructure of which is practically available in any locality of the Republic of Moldova.

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