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Impact of LTE Base Stations on Reception DVB-T2 Signal

Dejan Jaksic [1], Nenad Stanojevic [2], Dragoljub Stefanovic [1], Milos Josipovic [1], Petar Spalevic [2]
[1] Regulatory agency for electronic communications and postal services, Serbia
[2] Faculty of Technical Science Kosovska Mitrovica, Serbia

Abstract **- *This paper presents the results of testing immunity of commercial devices intended for the reception of DVB-T2 signal in the presence of LTE base station signals in the frequency range of 800 MHz. When testing LTE signal is generated within the lowest frequency block defined by Allotment Plan. Based on test results analysis was performed with the calculation of distance between the base station and the receiving TV antennas in which the reception of DVB-T2 signal uncorrectable errors occur. In the analysis the worst case of mutual spatial arrangement of DVB-T2 transmitters, DVB-T2 receiver and LTE base stations was considered .***

Index Terms **- DVB T2, LTE, LTE low pass filter, receiver immunity.**

I. INTRODUCTION

The aim of performed laboratory tests is to assess the impact of base stations in the networks of LTE (Long Term Evolution) in the frequency range 791 ÷ 862MHz on the DVB-T2 signal, and an assessment of the efficiency of removing some interference by using dedicated protective filter on the input of the receiver. Tests, with certain modifications, were carried out in accordance with the plan set out in the document "Requirements for LTE coexistence system 800 and DVB-T2".

Five types of DVB-T2 receivers with different prices and quality were used during testing, four of them are "set-top boxes" (Strong SRT8500, TV Star, Falcon and RK-1000 domestic producers RT-RK), while one is TV receiver with built-in digital tuner (Toshiba 32L2353D). Further on in this document all receivers are listed under the category "A", "B", "C", "D" and "E".

Also, two types of amplifiers were used for correcting the signal to noise ratio (SNR) at the reception of TV signals (Televes 5521, Philips AMP 0070/001). In this way a valid representative of the equipment used for the reception of terrestrial DVB-T2 signal was provided.

To reduce the impact of LTE signal on reception of TV signals we used filters from manufacturer *Spaun* (SLTE30, SLTE60 and SLTE90) which differ in configuration and performance (especially in terms of Q-factor, i.e. the slope of the transmission characteristics). Models SLTE30 and SLTE90 are low-pass filters, while SLTE60 is notch filter. Transmission characteristics of filters (parameter S21) and return loss (S21 parameter) in the range of interest are given in Figures 1., 2. and 3.

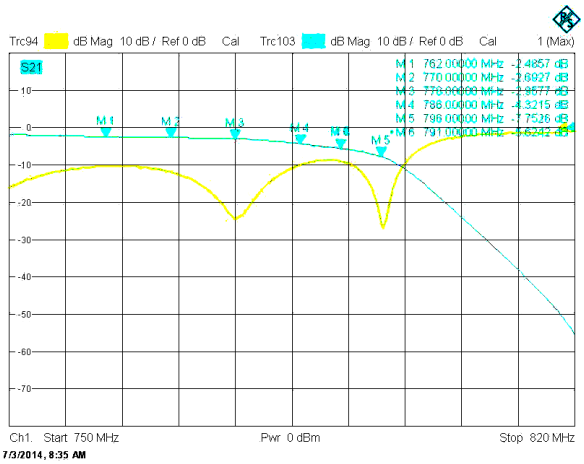

Fig. 1. Characteristics of filter SLTE30

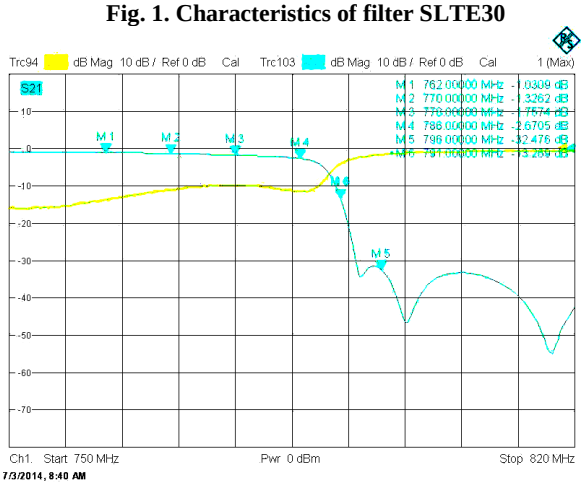

Fig. 2. Characteristics of filter SLTE60

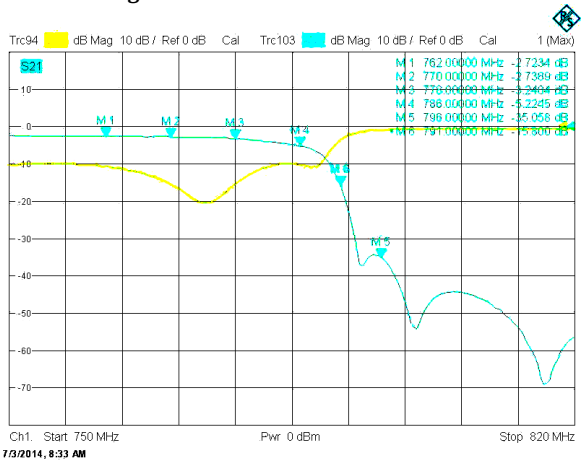

Fig. 3. Characteristics of filter SLTE90

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II. DESCRIPTION OF TESTING METHODS

To improve the method of testing the impact of LTE signal on DVB-T2 reception, we divided measurements tests at 3 phases: receiver immunity checking, efficiency of signal filtering at receiver input checking and efficiency of signal filtering at input of antenna amplifier checking.

A. Receiver immunity checking

In this phase immunity of different DVB-T2 receivers was tested. We used two signal generators, combiner and band-pass filter, which connection block diagram is shown in Figure 4.

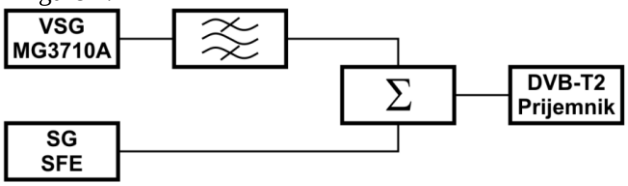

Fig. 4. Block diagram of equipment connecting

As a source of DVB-T2 signal test sequences a signal generator Rohde & Schwarz SFE – Broadcast Tester is used. Characteristics of the generated DVB-T2 signal are given in Table 1.

Table 1. Characteristics of DVB-T2 signal

Encoding metod	COFDM
Modulation	256-QAM
FEC	2/3
FFT	32k ext.
Guard interval	1/16
Pilot pattern	PP4
Bandwith	7,77 MHz
Bitrate	45,24 Mbit/s

We used Anritsu MG3710A signal generator to generate an interfering LTE signal. For all measurements interfering LTE signal width of 10 MHz is generated at a central frequency of 796 MHz, to include two lowest basic frequency blocks defined in the Plan allocation of radio frequencies to operate in the frequency bands 791-821 / 832-862 MHz. The appearance of the spectrum of useful and interfering signal on channel 60 (786 MHz central frequency) is shown in Figure 5.

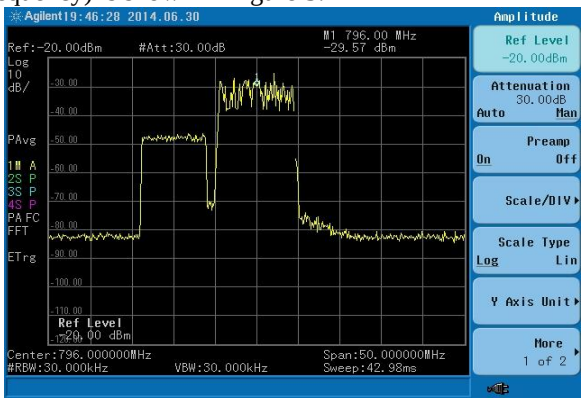

Fig. 5. Spectrum of DVB-T2 and LTE signals at the receiver input.

The signals from the two generators at the receiver input lead through the combiner. For additional isolation of the signals we included the band-pass filter whose transfer characteristic is given in Figure 6.

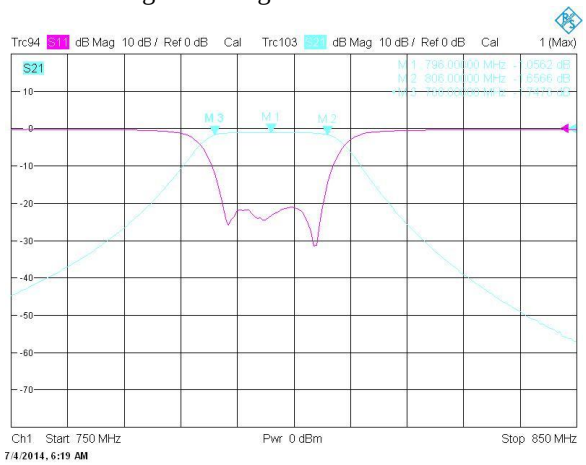

Fig. 6. Transfer characteristics of a band-pass filter

During the testing, the level of the signal generator Rohde & Schwarz SFE is adjusted to get predefined levels in required operating range (-70 to -20 dBm) at the receiver`s input. In each of the predefined levels, interfering LTE signal level is raised up to the limits at which arise uncorrectable reception errors, which is monitored visually as noticeable noise. Maximum level of interfering signals in the measurement is limited to +20 dBm. Example of noticeable interference phenomena is shown in Figure 7.

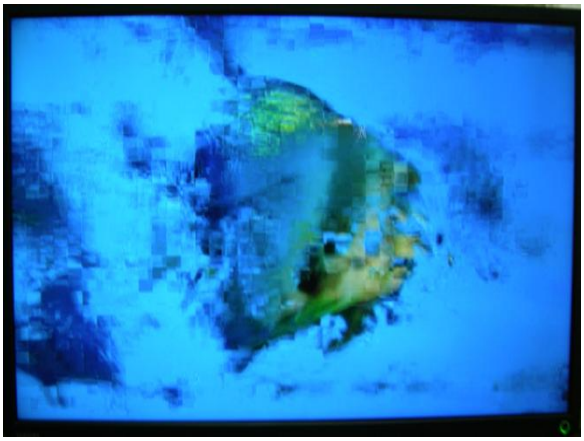

Fig. 7. The appearance of uncorrectable errors in the reception of digital TV signals

Testing was done on all channels in the range of 50. to 60. TV channels. Since there was not decrease of immunity at lower channels, it was concluded that all investigated receivers are built with the direct-conversion, i.e. with zero intermediate frequency. The immunity test results of all DVB-T2 receivers at signal level of -50 dBm are given in Figure 8. On the graph Pom represents the level of interfering LTE signal at the receiver input.

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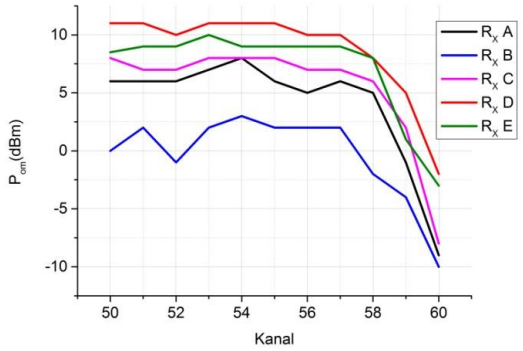

Fig. 8. The level of interfering signal that causes interference in reception

Based on these results, it was found that the highest immunity, i.e. the least sensitivity to the impact of LTE signals on adjacent channels shows receiver "D". In contrast, most sensitive to the impact of this type of interference is the receiver "C". The initial idea was to carry out the testing in the following stages with these two receivers, which simulate the best and worst cases that will arise in practice. That idea has changed because of the inconsistency of measurement results obtained with the receiver "C". Instead, further testing were carried out with receivers "D" and "A".

B. Efficiency of signal filtering at receiver input checking

In the second phase we investigated what contribution in terms of increasing immunity can be achieved by adding a dedicated protective filters. Block diagram of equipment connections is identical to the used in the previous stage with the addition of a protective filter on receiver input, as shown in Figure 9.

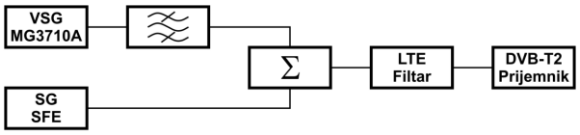

Fig. 9. Block diagram of equipment connecting

Both receivers that are subject to further testing (A and D) were tested in combination with all three filters (SLTE30, SLTE60 and SLTE90). As in the previous phase was not observed deviation results in remote frequencies, further testing were carried out in the range of 57. to 60. TV channels.

The test results for receiver "A" are given in Figures 10. ÷ 13., where the graphs show the levels of the useful and interfering signal at the receiver input, that is, at the entrance to the interference suppressor filter, when it is used. For better transparency, results are given in separate graphs for each of the TV channels from the specified range.

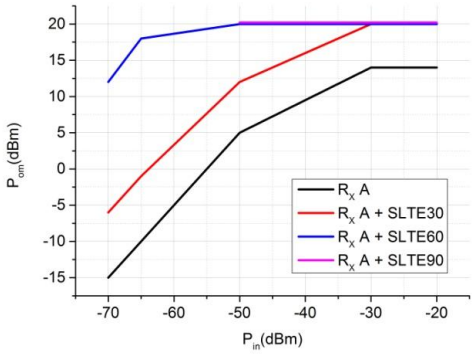

Fig. 10. Receiver „A" set to CH 57

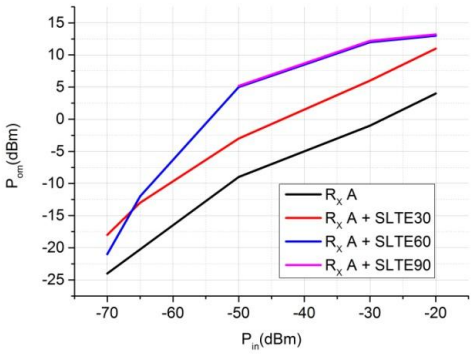

Fig. 11. Receiver „A" set to CH 60

The test results for receiver D are given on the next Figures.

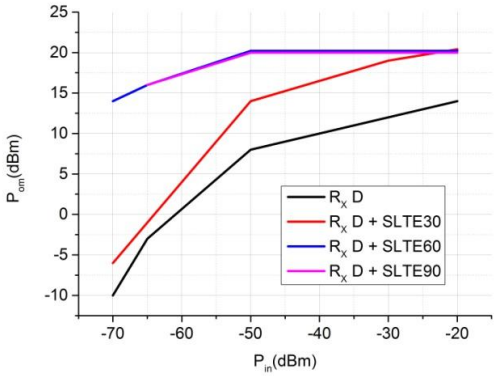

Fig. 12. Receiver „D" set to CH 57

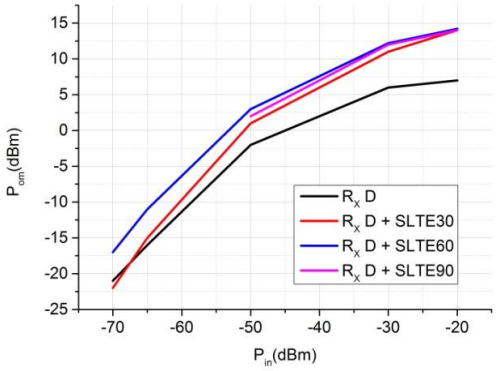

Fig. 13. Receiver „D" set to CH 60

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Because of the higher insertion loss of filter SLTE90, measurement results for the values of input levels that are close to the threshold of sensitivity of the receiver are not given.

On graphs it can be seen that the receivers are much more sensitive to the impact of interference when operated in the 60. TV channel, than when they work at lower frequency channels. Within the level range of the input TV signal which is around border of sensitivity of the receiver, the level of interfering signal that causes visual interference is typically around 10dB lower if the receiver is set to channel 60.

Also, on the graphs is clearly visible contribution of protective filters. In all cases, the lowest contribution to increased immunity of the receiver provides a low-pass filter with the simplest configuration (SLTE30), while the contribution of the second low-pass filter (SLTE90) and the notch filter (SLTE60) are similar, noting that the filter SLTE90 brings higher attenuation in the passband. The minimum filter contribution is established when receiver operates on channel 60.

C. Efficiency of signal filtering at input of antenna amplifier checking

At this phase we checked immunity of DVB-T2 receiver at whose input is connected a broadband antenna amplifier, as well as the contribution of dedicated filters in terms of increasing immunity in this configuration. During testing we used two receivers (A and D), which were the subject of examination in the previous phase and two types of widely used antenna amplifiers: Televes 5521 (with a nominal 10dB gain) and Philips AMP 0070/001 (with a nominal gain 20dB).

Immunity of different reception configurations (receiver + amplifier) in the presence of LTE signal is analyzed in the same way as in previous phases, when we tested immunity of receiver themselves. Protective filters (SLTE30, SLTE60 and SLTE90) are connected to the input of the antenna amplifier successively and their contribution to reducing the impact of interfering signals is checked. Block diagram of equipment connections is given in Figure 14.

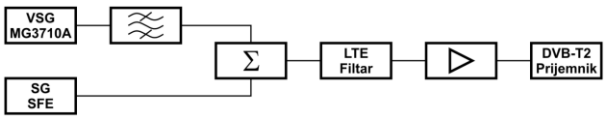

Fig. 14. Block diagram of equipment connecting

The test results are given in Figures 15 ÷ 20. Graphs show the levels of useful and interfering signal at the amplifier`s input, or at the input of the protective filter when it is used. On the graphs amplifier AMP Philips 0070/001 is marked as "AMPA" while the amplifier Televes 5521 is marked as "AMPB". For better transparency of results separate graphs are given for each TV channel.

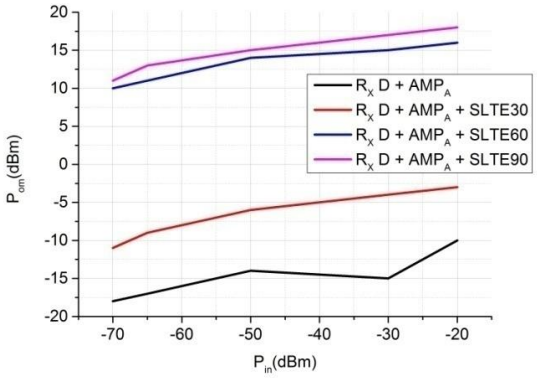

Fig. 15. Receiver „D“ and amplifier „A“ at CH 57

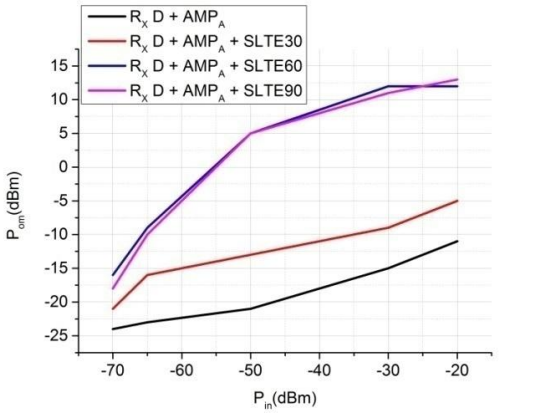

Fig. 16. Receiver „D“ and amplifier „A“ at CH 60

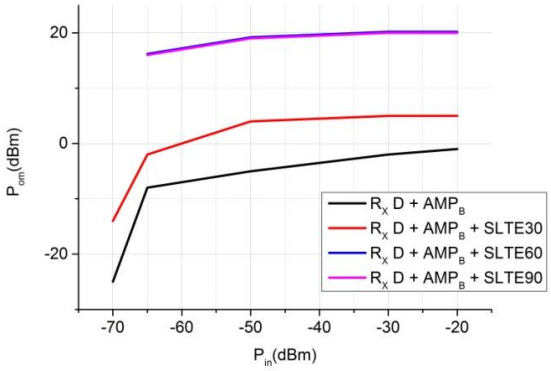

Fig. 17. Receiver „D“ and amplifier „B“ at CH 57

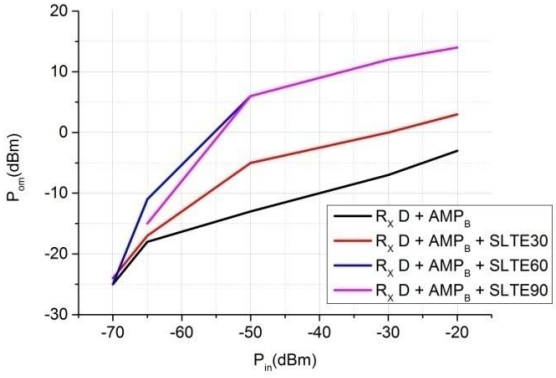

Fig. 18. Receiver „D“ and amplifier „B“ at CH 60

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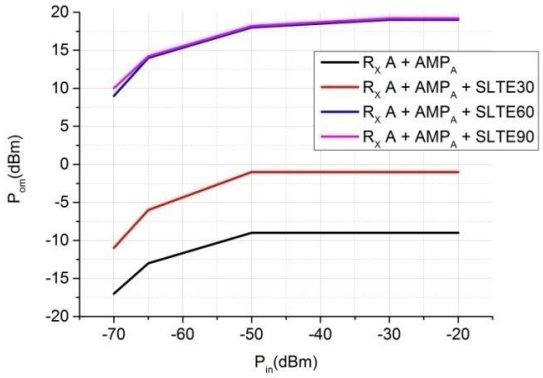

Fig. 19. Receiver „A“ and amplifier „A“ at CH 57

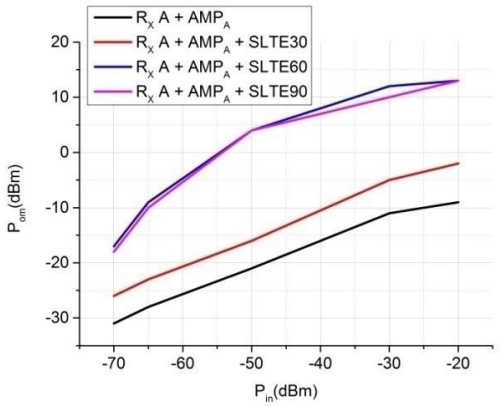

Fig. 20. Receiver „A“ and amplifier „A“ at CH 60

As expected it was found that in configurations with RF amplifiers receivers are much more sensitive to the presence of interference, especially in the adjacent channels. It is evident that much greater contribution to increasing the immunity of the receiver provide a higher quality filters. Generally the smallest contribution filters give when receiver is set to 60. TV channel, especially when the useful signal level is close to the threshold of sensitivity of the receiver.

III. ANALYSIS OF TEST RESULTS

The research included different types of DVB-T2 receivers and antenna amplifiers and found that immunity of receiving system to the presence of disturbing LTE signal varies significantly depending on the appliance's configuration. It was also found that the application of dedicated protective filter achieves increase of the receiver immunity, and that contribution of filters depends on their internal configuration and complexity.

For the purpose of analysis of the potential interference to TV signals generated by the operation of LTE base stations, parameters of the Plan allocation of radio frequencies to operate in the frequency bands 791-821/832-862 MHz (hereinafter Allotment Plan) have been adopted. In the Allotment Plan the maximum spectral density of the equivalent isotropic radiated power of the base station is determined by 64 dBm / 5 MHz. In further calculations the assumption is adopted that the base station which is the source of interference transmits with equivalent isotropic radiated power of 67 dBm and with the occupied bandwidth of 10 MHz (transmission includes two lowest frequency block).

Adopting the assumption that for the reception of TV signals directed antenna with a gain of 10 dBi is used, based on the expression of signal attenuation in free space:

$$L_p(dB) = 32{,}5 + 20\log f(MHz) + 20\log d(k \quad (1)$$

there were calculated boundary distances from the base station, below which errors in the reception occurre. Also, the calculation is made for the worst case, which means that the base station antenna and receiving TV antenna are facing each other, i.e. both of them are in the main lobe of the opposite antenna radiation diagram. We considered four receiving configurations consisting of the test receivers and the amplifiers.

The calculation is based on the DVB-T2 signal levels at the receiver input (i.e. the amplifier input) from - 50 to - 60 dBm, whereby it is assumed that the DVB-T2 signal is broadcasted on 57. or 60. TV channel. The calculation results are given in Table 2.

Table 2.

Receiv. Config.	Pin DVB-T2 (dBm)	The distance from the base station (m) at which interference occurs					
		Receiving at CH 60			Receiving at CH 57		
		No filter	SLT E30	SLT E60	No filter	SLT E30	SLT E 60
RxA	-50	450	220	90	90	40	< 15
	-60	1110	500	350	280	120	25
RxD	-50	200	140	110	60	35	< 15
	-60	630	500	350	140	110	20
RxA + AMP_A	-50	1780	1000	100	450	180	20
	-60	3150	1720	310	630	250	30
RxD + AMP_B	-50	710	280	80	280	110	20
	-60	1120	710	280	400	160	25

Therefore, in case that receiver designated as "A" is used for reception, digital TV signal is broadcasted on channel 60. and the signal level at the receiver input is -50 dBm (59 dBµV/75Ω), interference will occur if the base station antenna is located between the receiving antenna and the TV transmitter and at a distance of less than 450 meters from the receiving antenna. If a protective filter, with the same characteristics as low-pass filter SLTE30, is connected to the input of the, interference will occur if the base station antenna is located at a distance less than 220 meters from the receiving antenna. Using the filter with characteristics equivalent to band-stop filter SLTE60, provide conditions

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that interference will occur only if the base station antenna is located at a distance of less than 90 meters from the receiving antenna. All other results in Table 2 should be interpreted in the same way.

In addition to the described effect of reduced sensitivity due to the presence of strong signals outside the working channel, but in the working range of the receiver, interference in reception may also occur due to the existence of unwanted radiation of the LTE transmitter that is generated directly in the working TV channel. Of course, the influence of interference generated in this way is not possible to reduce with the use of filters, or in any other way applied at the receiver site.

In order to carry out an analysis of this kind of influence, in laboratory conditions is determined maximum SNR which produces uncorrectable reception errors, i.e. visual perceptual disorders. The measurements were carried out on two receivers that were used in previous phases of testing (receivers "A" and "D") and at various levels of the input DVB-T2 signal. Results of the measurements are given in Table 3.

Table 3.

Level of the DVB-T2 signal at the input of the receiver (dBm)	S/N ratio which produces interference (dB)	
	Receiver „A"	Receiver „D"
-30	18	18
-50	19	18
-65	22	18

Having in mind that in the Allotment Plan spectral density of the equivalent isotropic radiated power of unwanted radiation for the LTE base stations in the frequency bands below 790 MHz is limited to 0 dBm / 8 MHz, this value is adopted for calculation of the minimum distance between the base station antenna and receiving TV antenna when interference will not occur. In this case, unwanted radiation generated by the LTE transmitter for TV receiver present noise in the channel. As in the previous analysis, the worst case scenario in terms of mutual arrangement and orientation of the antennas is considered. The calculation results are given in Table 4.

Table 4

Level of the DVB-T2 signal at the input of the receiver (dBm)	Distance from the base station (m) at which interference occurs	
	Receiver „A"	Receiver „D"
-30	25	25
-50	260	240
-65	2100	1330

The calculation results show that, in the case that level of unwanted radiation from LTE base station is close to the maximum allowable values as defined in the Allotment Plan, the effect of such "channel noise" will be dominant, while the impact of this type of interference cannot be reduced by using filters or in any other way applied at the receiver site. It is expected that the measurements which will be carried out on samples of LTE base stations in our country will show significantly lower levels of unwanted radiation than the maximum allowed.

IV. CONCLUSION

Considering that this testing is limited in scope to the use of single sample of several types of DVB-T2 receivers and protective filters, it can be expected that the results achieved in the practical realization of LTE networks vary somewhat in relation to the measured or calculated values. Nevertheless, these results clearly establishe mechanisms of interference to reception of DVB-T2 signal and quantifie their individual impact. The results also determine the contribution that different protective filters provide in terms of increasing the immunity of different receiving configurations.

Likewise, significantly greater impact is determined in the coexistence of signals in adjacent channels, which is the case in areas where DVB-T2 signal is broadcasted at the highest frequency 60. TV channel. The analysis showed the importance of the performance of the LTE base stations transmitters, primarily in terms of suppression of unwanted radiation.

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AUTHOR BIOGRAPHY

Dejan Jaksic finished Faculty of Technical Sciences - Kosovska Mitrovica. His areas of interest and research are: Wireless Telecommunications, Signal Processing, Software Development. He is author and co-author of number of scientific and professional papers published in international and domestic journals and international and domestic conferences. He participates in a project DVB/T2 - Digital Switch Ower in Serbia. He is currently employed as senior adviser at Regulatory Agency for Electronic Communications and Postal Services.

Nenad Stanojevic in 2012 finished Faculty of Electrical Engineering, module: Electronics and Telecommunications at the University of Kosovska Mitrovica. He is currently PhD student in the program Electrical and Computer Engineering at the Faculty of Technical Sciences, University of Kosovska Mitrovica. Hi is co-autor of two sceintific papers published in international journals. His area of interesed is Wireless Telecommunications, Digital Telecommunications and Optical Telecommunications.

Dragoljub Stefanovic took his B.Sc. and M.Sc. degrees at the School of Electrical Engineering, University of Belgrade, Serbia, in 1990 and 2014, respectively. From 1990 he worked in Ei Pionir UKT company as R&D engineer, Laboratory Chief and R&D department Head. 2011 he joined Regulatory Agency for Electronic Communications and Postal Services, currently as Monitoring Division Head.

Milos Josipovic finished Master Academic Studies at Faculty of the Electrical Engineering, University of Belgrade, Serbia. In 2013 he graduated at the study program Electrical Engineering and Computer Engineering module System Engineering and Radio Communications. In the period from 1999 to 2006 he was employed in the Ministry of Federal Republic of Yugoslavia and Republic of Serbia responsible for the field of telecommunications. Since 2006 he has been employed at the Regulatory Agency for Electronic Communications and Postal Services, currently as Chief Advisor. His areas of interest and research are: Wireless Telecommunications, Signal Processing, Databases, Software Development, Cyber security and Robotics. He is author and co-author of a few professional papers published in domestic journals and international and domestic conferences.

Prof. Petar Spalevic finished Faculty of Electrical Engineering at the University of Pristina, Serbia. He completed his postgraduate studies at the Faculty of Electronic Engineering in Niš, where in 1999 he defended his master's thesis entitled "Complex coherent optical telecommunication systems". In 2003 he defended his doctoral dissertation entitled "Performances of IM-DD optical systems in the presence of disturbances that occur along the nonlinear-dispersive optical fiber" at the Faculty of Electrical Engineering University of Niš, Serbia. He is author and co-author of number of scientific and professional papers published in international and domestic journals and international and domestic conferences. In 2015 he was elected as a full-time professor at the Faculty of Technical Sciences in Kosovska Mitrovica, University of Pristina. Beside Faculty of Technical Sciences he works as full-time professor at the Singidunum University too. He participates in a number of projects financed by the Ministry of Education, Science and Technological development of Serbia. His areas of interest are: Wireless Telecommunications, Optical Telecommunications, Statistical Communication Theory, Object Oriented Modeling, and Object Oriented Programming.