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MATHEMATICAL MODELING AND MEASURING THE OCCUPIED BANDWIDTH EMISSIONS OF DVB-T2 TRANSMITTERS FOR MONITORING PURPOSES

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Abstract. *DVB-T2 TV is at the implementation stage in Ukraine. Country net includes transmitters in 166 cities. The role of a radiomonitoring service is to ensure efficient use of radio-frequency spectrum particularly by measurements of the emission parameters including occupied bandwidth. It is necessary to find the spectrum level of X dB, which corresponds to occupied bandwidth. The article examines the conformity of the measurements data with the results of mathematical modeling of radiation spectrum standards DVB-T and DVB-T2.*

Keywords: DVB-T2 standard; occupied bandwidth; emission; spectrum; mathematical modeling.

I. INTRODUCTION

The Ukrainian State Centre of Radio Frequencies (USCR) ensures the monitoring of emissions parameters for all radio technologies. Monitoring procedures were developed on the basis of national and international normative documents, for example [1], [2] but normative documents do not provide enough information on parameters measurement of the modern digital radio technologies particularly terrestrial digital television.

Occupied bandwidth is important parameter which characterizes the effective usage of the radio frequency resource. According to Rec. ITU-R SM.328 and Rec. ITU-R SM.443-4 occupied bandwidth is measured by direct method at monitoring station and can be estimated from the *X* dB bandwidth. When using $\beta/2$-method the difference between spectrum reference level and the noise level should be 30 dB. Also according to State standard 30318-95 emission bandwidth is measured at the level *X*=-30 dB from reference level. In addition the difference between this level and the noise level should be 5 dB. So, the reference level should be greater than the background noise on 35 dB.

Experimental studies of the spectrums of digital television, the results of which are provided by USCR as well as measurements conducted by the author, show that the level of noise -30 dB in Kyiv is achievable only under certain conditions. For example, the measurement of the digital television signals from an antenna installed on the roof of the four storey building of National aviation University allows to get the difference in 25 – 28 dB and on the 16th floor is even less. The difference in 30 dB is obtained during the measurement in a separate points at a distance of about 2 km from the transmitter. Emission of signals standards DVB-T and DVB-T2 on eight frequencies was considered. At this spectrums on frequencies 514 MHz and 554 MHz have a difference less then 30 dB.

It is obvious that a reliable estimate of occupied bandwidth in urban conditions both by $\beta/2$-method and the method of *X* dB can be obtained in the measurement process within direct visibility from the transmitting antenna to the receiving point at short distances.

It should be noted that the spectrums of COFDM signals DVB-T and DVB-T2 have a steep slopes. The signal energy is mainly concentrated in the central part of the spectrum. Therefore, the borders of occupied bandwidth by $\beta/2$-method will match the levels of the spectrum much more -30 dB. Normative documents do not have the data on occupied bandwidth of digital television. Simplification of the procedure of determination occupied bandwidth can be obtained at finding the appropriate level *X* dB

II. MATHEMATICAL MODELING

The most perfect mathematical model of digital TV system is the DVB-T2 Common Simulation Platform (CSP) [3]. The CSP corresponds to standard ETSI EN 302 755 [4] and is released in SourceForge.net under the open-source lisence. CSP includes models of a transmitter, channel, receiver, modules which help to choose model components in the selected configuration. In CSP transmitter the signals are formed within the limits of one T2-frame.

In order to find emission bandwidth the CSP models of a transmitter and channels should be supplemented by the block of the spectrum determination. In MATLAB power spectral density is found on the basis of time-plane samples using non-parametric methods such as periodogram and

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Welch method [5]. Periodogram is characterized by fluctuation of assessment with the growing number of counts.

Welch method is developed on the basis of the method Bartlett, in which sample of the signal is divided on sets that do not overlap. For each set of samples the periodogram with averaging is calculated. By Welch method intersection of sets is nonempty set, i.e. the number of sets is growing. Further periodogram is calculated for each set, which are averaged for the whole ensemble of sets.

Common Simulation Platform contains mathematical models of three propagation channels: with additive white noise (AWGN), the level of which is set by the ratio of signal and noise powers, Ricean and Rayleigh channels. Channel models are selected in accordance with official guidelines for DVB-T2 implementation [6]. In Figs 1 – 3 the mode-ling spectrums on the output of Ricean and Rayleigh channels are shown.

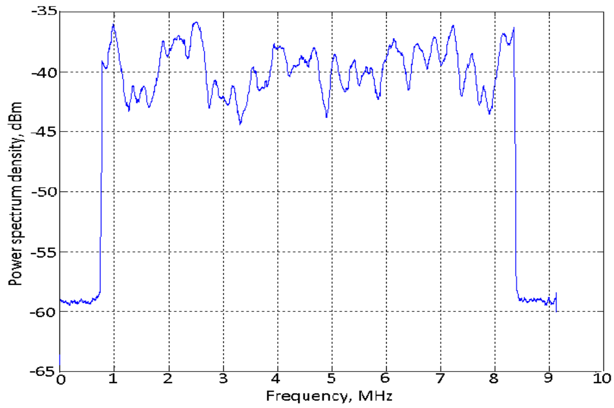

Fig. 1. Signal spectrum in Ricean channel

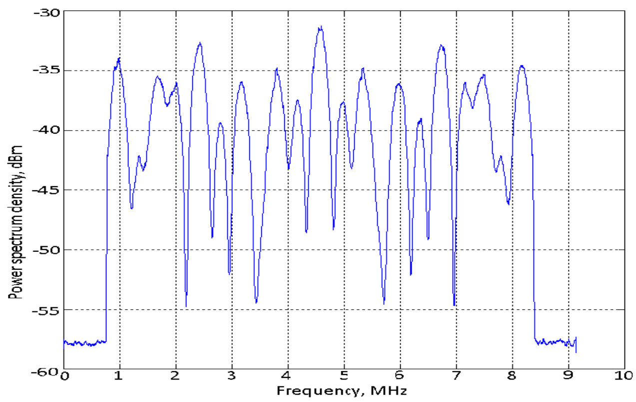

Fig. 2. Signal spectrum in Rayleigh channel with lower delays

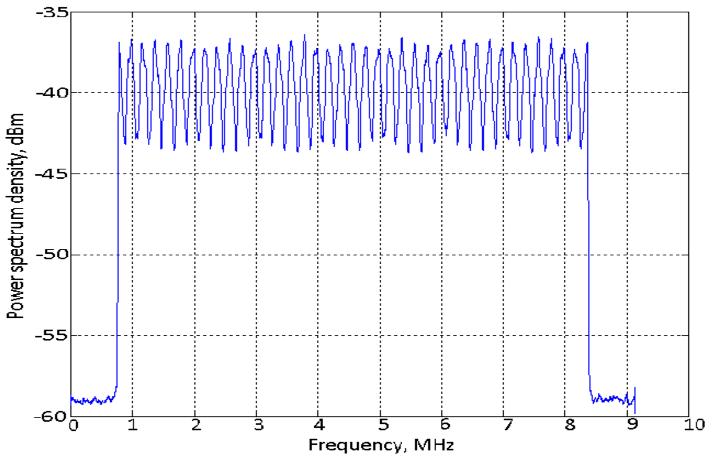

Fig. 3. Signal spectrum in Rayleigh channel with greater delays

The comparison results of modeling with normative spectrum on Fig. 4 [6] shows significant distortions of the spectrum at the wave propagation in simulated channels. Also results shows qualitative agreement with Rec. ITU-R SM.1875 in part of influence waves propagation on the spectrum form.

The experience of the measurement during emissions monitoring indicates that such distortions of the spectrum form are not observed and spectrum is similar to modeling results on output of AWGN channel.

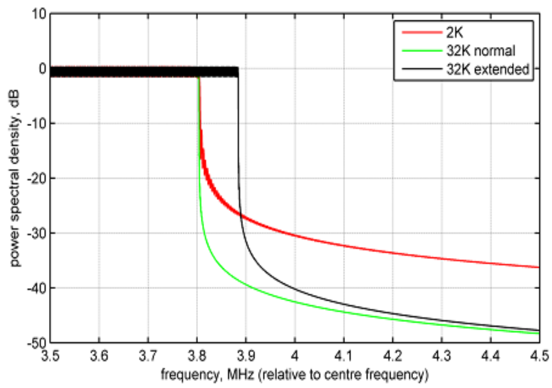

Fig. 4. Normative spectrum of digital terrestrial television

Table 1 includes the width of the slopes of the regulatory spectrum (see Fig. 4) at levels -20 and -30 dB from reference level.

TABLE 1

Slope width of the normative spectrum

Level from reference, *dB*	Slope width, *kHz*		
	Mode 2 *k*	Mode 32 *k*	Mode 32 *k* extended
-20	20,7	2	2
-30	185	10,5	10,5

The width of the slopes of the spectra according to the simulation can be found in Table 2.

TABLE 2

Slope width by modeling data at level -20 dB

Channel	Slope width, kHz	
	Left	Right
AWGN	2,6	8
Ricean	8,3	8,3
Rayleigh	28,2	8,5
Rayleigh with lower delays	14,3	17,8
Rayleigh with greater delays	7,6	8,3

The width of the spectrum slopes at mode 8 *k* and level of -20 dB for AWGN channel, Ricean channel and Rayleigh channel with greater delays is approximately equal to 8 kHz, which is the width of the slopes of the regulatory spectrum (see Table 1).

III. MEASUREMENTS

Experimental studies conducted in Kyiv not greater 2 km away transmitter using a spectrum analyzer R&S U3772 Advantest indicate that the width of the slopes of the spectrum depends on the parameters *RBW* and *VBW*. At *SPAN* = 10 MHz and *RBW* = *VBW* = 100 кГц width of the spectrum slopes on more than one order greater correspondent values of mathematical modeling, Table 3.

Similar results were obtained using a spectrum analyzer R&S FSH8. Fig. 5 presents the left side of the spectrum of radio emission with the central frequency of 818 MHz. Measurements were carried out in the area Sq. Tolstoy in Kyiv at *RBW* = *VBW* = 10 kHz. The frequency difference between labels is 18.8 kHz and between levels of -100 dB and -120 dB is 25.9 kHz. It is much smaller than the data Table 3.

TABLE 3

Average slope width of spectrum of emissions on eight frequencies at *RBW* = *VBW*=100 kHz

Standard	Slope	Slope width at the level -20 dB, kHz	Slope width at The level -30 dB, kHz
DVB-T2	Left	111,0	188,8
	Right	160,8	196,5
DVB-T	Left	136,3	223,3
	Right	131,3	203,0
DVB-T2, DVB-T	Left and right	134,8	202,9

Decrease of *RBW* and *VBW* values leads to more steep slopes particularly at level -20 dB, Table 4.

TABLE 4

Average slope width of spectrum of eight emissions at *RBW* = *VBW*=10 kHz

Standard	Slope	Slope width at the level -20 dB, kHz	Slope width at The level -30 dB, kHz
DVB-T2	Left	12,95	59,9
	Right	11,4	103
DVB-T	Left	19,7	156,3
	Right	27,5	175,7

Changing the bandwidth of the intermediate frequency *RBW* = 1 kHz leads to a further reduction of the width of the left slope. Width of the left slope at the level of - 20 dB is 6.8 kHz.

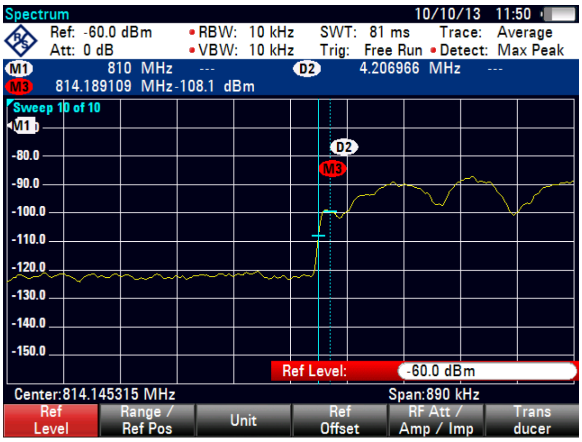

Fig. 5. The left side of the emission spectrum with the central frequency of 818 MHz

Similar results were obtained for the emission standard DVB-T2 at the frequency of 698 MHz. At sequential decrease of bandwidth *RBW* and *VBW* the width of the slopes becomes closer to the value of the regulatory spectrum. For example for *RBW* = 100 Hz and *VBW* = 300 Hz the slope width at the level of - 20 dB is approximately equal to 3 kHz. Further reduction of the bandwidth to *RBW* = 30 Hz and *VBW* = 100 Hz provides almost the normative width of the slope for mode 32 *k*. At level -20 dB slope width is equal 2.5 kHz, standard value is 2 kHz; at level -27.3 dB slope width is 10 kHz, the standard value at the level of -30 dB is 10.5 kHz.

IV. Conclusion

Results of mathematical modeling of emission spectrum using the modified platform CSP coincide with the spectrum provided by the regulations on the system of digital TV DVB-T2 and are different from the results of measurement provided by USCR in part of the slopes steepness.

Search the reasons of the discrepancy of the measurement and modeling results showed that the choice of small values of the bandwidth of spectrum analyzers by intermediate and video frequency provides values of the slopes width close to normative values. However measurement of parameters of emission at such regimes is unacceptable to practice due to slow response.

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О. А. Басанський. Математичне моделювання та вимірювання займаної ширини смуги частот радіовипромінювання DVB-T2 передавачів для радіомоніторингу

Досліджено вимірювання займаної ширини смуги частот радіовипромінювання цифрового телебачення під час моніторингу з метою спрощення методики оцінки.

Ключові слова: стандарт DVB-T2; займана ширина смуги частот; спектр; математичне моделювання.

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А. А. Басанский. Математическое моделирование и измерение занимаемой ширины полосы частот радиоизлучения DVB-T2 передатчиков для радиомониторинга

Исследованы измерения занимаемой ширины полосы частот радиоизлучения цифрового телевидения во время мониторинга с целью упрощения методики оценки.

Ключевые слова: стандарт DVB-T2; занимаемая ширина полосы частот; спектр; математическое моделирование.

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