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SIMULATION OF RADIATION FIELD OF DVB-T2 DIGITAL TELEVISION

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DVB-T2 TV is at the implementation stage in Ukraine. Usually a national organization carries out measurements to quantify the occupied bandwidth using the level of X dB, which is lower than the predetermined 0 dB reference level. It is necessary to find the correspondence between the occupied bandwidth of transmission by $\beta/2$-method and X dB level. Simulation of the radiation field is considered as one of the means for the solution.

Introduction

The Ukrainian State Centre of Radio Frequencies ensures the usage of the radio frequency resource in the interests of all kinds of users, creates the conditions for implementing and developing advanced radio technologies. Radio frequency monitoring procedures were developed on the basis of national and international normative documents, for example [1, 2]. Unfortunately the normative documents provide little information on parameters measurement of the modern digital radio technologies, such as cellular radio communication, the system of broadband wireless access, digital radio-relay communication, satellite and mobile-satellite radio, terrestrial digital TV broadcasting.

Occupied bandwidth is one of the most important parameters which characterizes the effective usage of the radio frequency resource. Due to the implementation of digital TV broadcasting of DVB-T2 standard in Ukraine the occupied bandwidth determination is an essential problem. It is necessary to find the dependence of the measurement results on signal parameters and the channel type. One of the possible approaches is to use the existing software.

Analysis of research and publications

DVB-T2 standard for digital terrestrial television broadcasting offers benefits in capacity up to 50% and the better protection from multipath in comparison with DVB-T. The physical layer channel is divided into Physical Layer Pipes (PLPs). One PLP carries one logical data stream. There is a possibility of transferring several data streams in individual PLPs. In a single radio frequency channel various PLPs can be characterized by different levels of coding, modulation and time interleaving depth.

The block diagram of DVB-T2 includes five sub-systems [3].The first sub-system forms MPEG-2 Transport Streams and/or Generic Streams from input signals. Transmitted data are packaged in Baseband frames (BB-frames) in input mode «A» with one PLP, or in an input mode «B» with several PLPs. BB-frame header includes information about its content.

Subsystem SS2 performs the bit interleaved coding and modulation (BICM). Forward error correction (FEC) includes low density parity check (LDPC – inner coding) and Bose-Chaudhuri-Hocquenghem multiple error correction binary block code (BCH – outer

coding). LDPC ensures the gain in 3 dB in ratio C/N with respect to convolutional coding on the basis of Reed-Solomon code. The output of LDPC coding shall be bit interleaved and de-multiplexed into sub-streams (words) due to modulation format (QPSK, 16-QAM, 64-QAM, 256-QAM), then words are fed to constellation mapper. The Gray mapping of cells into modulation characters (OFDM cells) is accompanied by normalization for obtaining the correct complex cell value. OFDM cell is a signal corresponding to one carrier and can be modulated by one constellation point. The set of OFDM cells creates a FEC block. There is an opportunity to rotate the constellation at which cell values of each FEC block are rotated in a complex plane and additionally imaginary component are delayed by one cell within a block. Channel distortions are distributed along FEC codewords with Pseudo Random Cell Interleaver, from which FEC blocks for each PLP are grouped into interleaving frames. Interleaving frame is mapped onto one or more T2-frames. Also interleaving frames are divided into one or more TI-blocks according to selected interleaving time. T2-frames in the amount of up to 255 frames are united in a super frame, which can contain future extension frames. At the subsystem SS2 output there is T2-MI stream, which characterizes the transport level, includes data, transfer time for T2-frames and is fed into one or more modulators.

The modulator subsystem SS3 uses T2-MI stream to create cell arrays for each PLP and L1 signaling data corresponding to OFDM symbols. Frequency interleaver distributes cell content throughout carriers. In the ODFM generation module the cells are used as frequency factors of inverse fast Fourier transform, the pilots carrying reference information for interference protection are inserted, peak to average power ration is diminished, the guard interval (GI) is inserted, digital-to-analog transform is carried out.

The demodulator subsystem SS4 receives RF signal and in case of consumer receiver outputs the stream of one PLP. The subsystem SS5 receives data stream and extracts video, audio signals.

36 organizations from European countries were participants of B21C projects [4] devoted to research of DVB-T2 system including modeling usage. Fig. 1 presents blocks of the physical layer, which were used for the simulation. BICM block includes the LDPC Encoder, the Bit Interleaver, and the Mapper to constellation. The Cell Interleaver rearranges modulation symbols in each FEC frame and the Time Interleaver - only through an integer number of FEC-frames. In the last blocks pilot signals and GI are inserted and the signal transformation to the time domain is done.
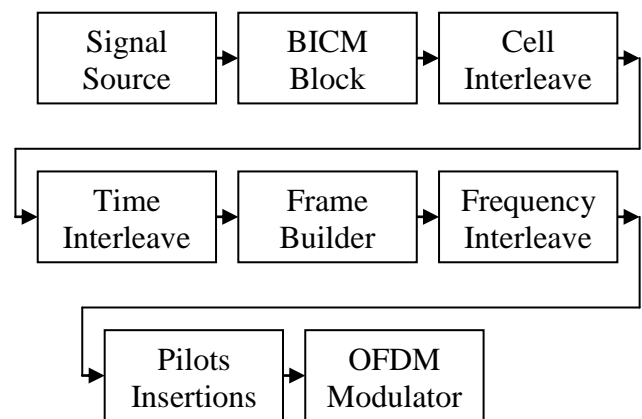

Fig.1. Physical level model of signal forming in DVB-T2.

The DVB-T2 Common Simulation Platform (CSP) [5] was collaboratively developed in MATLAB by AICIA, BBC, Pace, Panasonic and SIDSA. The CSP corresponds to standard ETSI EN 302 755 [6] 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, modules for determining the DVB-T2 dependent parameters. Input and output signals are represented by vector or matrix and in case of multiple PLPs the additional output matrixes with ordering information are created. In CSP transmitter the signals are formed within the limits of one T2-frame. CSP blocks do not remember other T2-frames.

Problem definition

It is necessary to research the possibility of CPS usage for determining the X dB level on DVB-T2 spectrum which corresponds to the occupied bandwidth by $\beta/2$-method.

Analysis of simulation results

Using CPS with DVB-T2 parameters: bandwidth BW= 8 MHz; f=729.833 MHz; 64-QAM; FFT size 8 K; code velocity 5/6 and definite channel, the signal spectrum on channel output is found by Welch method. During simulation the ratio of signal to AWGN was 20 dB. In fig. 2 – fig. 4 the signal spectrums on the output of AWGN (Gaussian noise), Ricean and Rayleigh channels are shown.

Fig. 3. Signal spectrum in Ricean channel
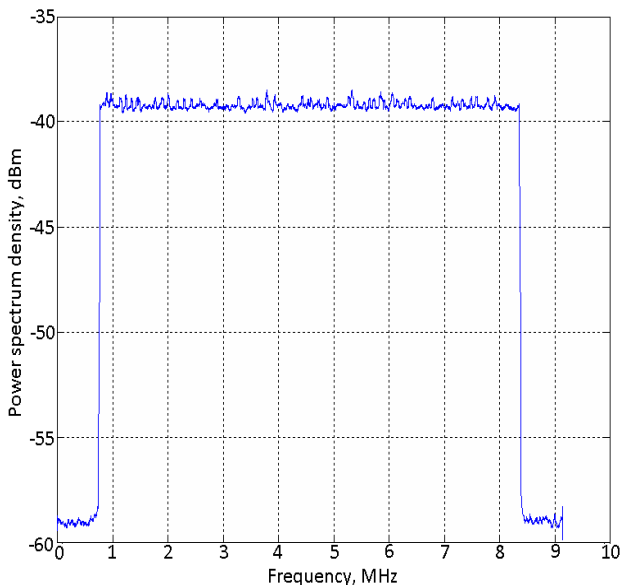

Fig. 4. Signal spectrum in Rayleigh channel

Fig.2. Signal spectrum in AWGN channel

Model of Ricean fading channel characterizes fixed rooftop antenna reception and includes 21 rays. The output signal is defined by [3]:
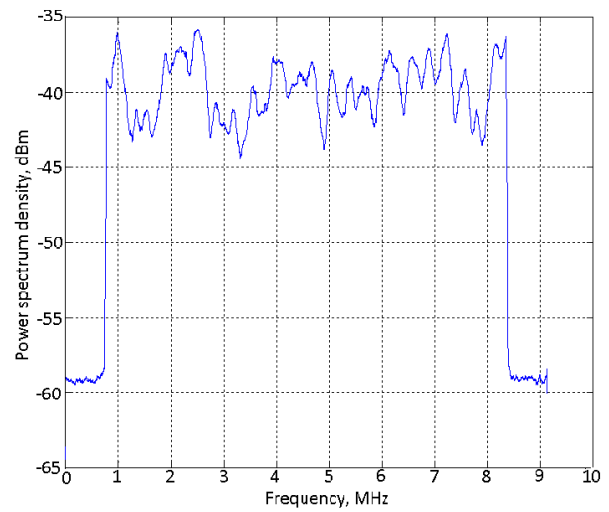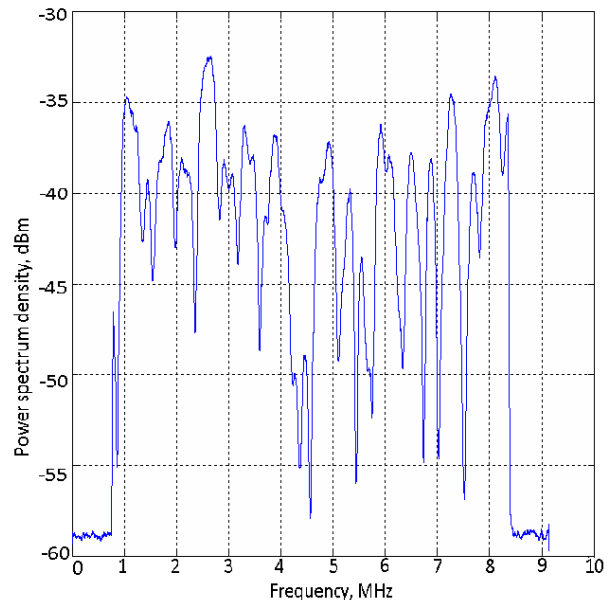
$$y(t) = \frac{\rho_0 x(t) + \sum_{i=1}^{n} \rho_i e^{-j\theta_i} x(t - \tau_i)}{\sqrt{\sum_{i=0}^{n} \rho_i^2}},$$

where: $x(t)$ - input signal; ρ_0 and ρ_i - correspondingly attenuation of direct and ith path (table 1); n=20; θ_i and τ_i - correspondingly phase shift and time delay of ith path relatively to direct (table 1).

Table 1: Parameters of Ricean (without direct path) and Rayleigh channels

Номер променя	Амплітуда променя	Затримка, мкс	Фаза, рад.
1	0.057662	1.003019	4.855121
2	0.176809	5.422091	3.419109
3	0.407163	0.518650	5.864470
4	0.303585	2.751772	2.215894
5	0.258782	0.602895	3.758058
6	0.061831	1.016585	5.430202
7	0.150340	0.143556	3.952093
8	0.051534	0.153832	1.093586
9	0.185074	3.324866	5.775198
10	0.400967	1.935570	0.154459
11	0.295723	0.429948	5.928383
12	0.350825	3.228872	3.053023
13	0.262909	0.848831	0.628578
14	0.225894	0.073883	2.128544
15	0.170996	0.203952	1.099463
16	0.149723	0.194207	3.462951
17	0.240140	0.924450	3.664773
18	0.116587	1.381320	2.833799
19	0.221155	0.640512	3.334290
20	0.259730	1.368671	0.393889

Model of Rayleigh fading channel describes portable indoor or outdoor reception. Output signal is defined without taking into account Doppler effect:

$$y(t) = \frac{\sum_{i=1}^{n} \rho_i e^{-j\theta_i} x(t - \tau_i)}{\sqrt{\sum_{i=0}^{n} \rho_i^2}},$$

where: ρ_i, θ_i and τ_i - are given in table 1.

Table 2: Rayleigh channel parameters

Path num.	The channel with lower delays		The channel with greater delays	
	Attenuation, dB	Delay, μs	Attenuation, dB	Delay, μs
1	2.8	0	0	0
2	0	0.05	9	5
3	3.8	0.4	22	14
4	0.1	1.45	25	35
5	2.6	2.3	27	54
6	1.3	2.8	28	75

In another Rayleigh channel models [7] the wave propagation with longer and shorter paths are considered, table 2. Fig. 5 depicts signal spectrums using given channel models.
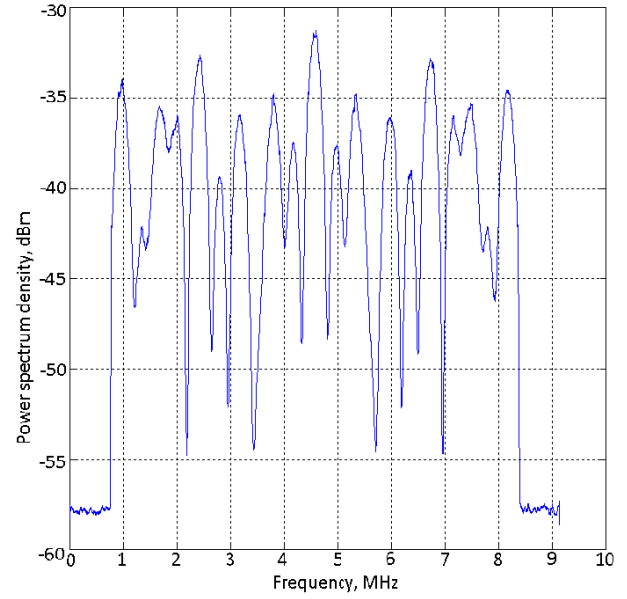
a)
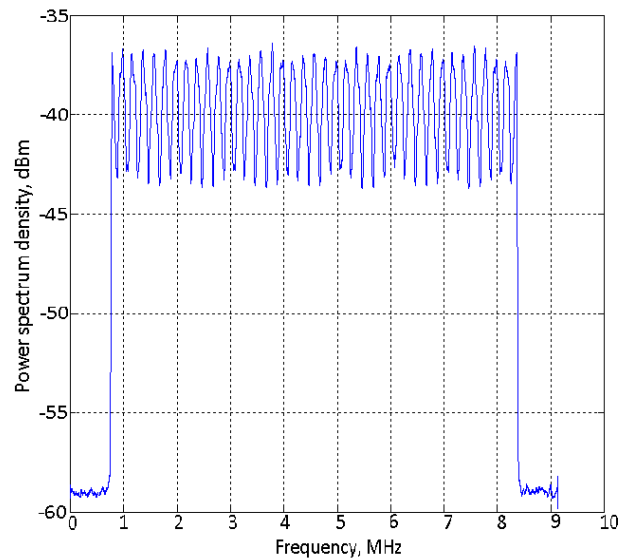
b)

Fig. 5. Signal spectrum in Rayleigh channels: a) – with lower delays; b) – with greater delays.

Simulation results can be compared with normative spectrum [3] in Fig. 6 and signal spectrums on the basis of monitoring at a short distance from the transmitter in Kyiv, example for f=714 Mhz is on Fig. 7.

Channel parameters used for mathematical modeling, except for the channel with the greater time delays lead to unacceptable distortions of the spectrum.
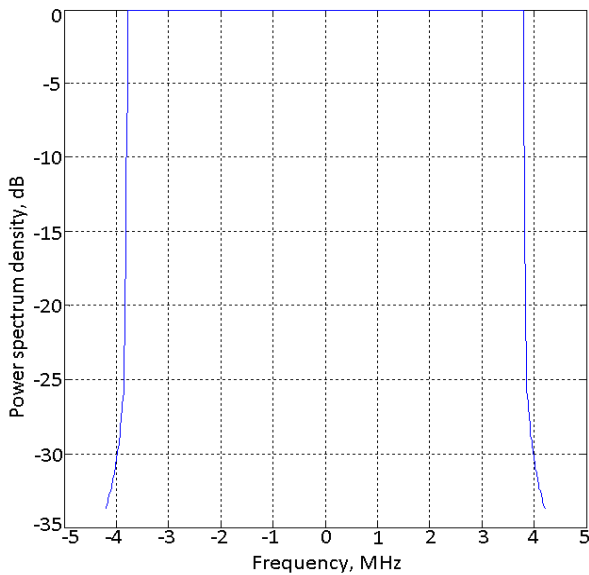
Fig. 6. The normative signal spectrum

Fig. 7. measured signal spectrum

The experience of the measurement during radio monitoring shows that such distortions of the spectrum form are not observed.

It is known that the spectrum rolls farther extend for smaller number of carriers. In normative spectrums to the level -30 dB corresponds the slope width about 20 kHz for 32K and about 160 kHz for 2K. Similar results can be obtained with the help of simulation. But experimental spectrums have slopes approximately 1.5 times wider, which may be caused by an imperfect power amplifier and antenna system.
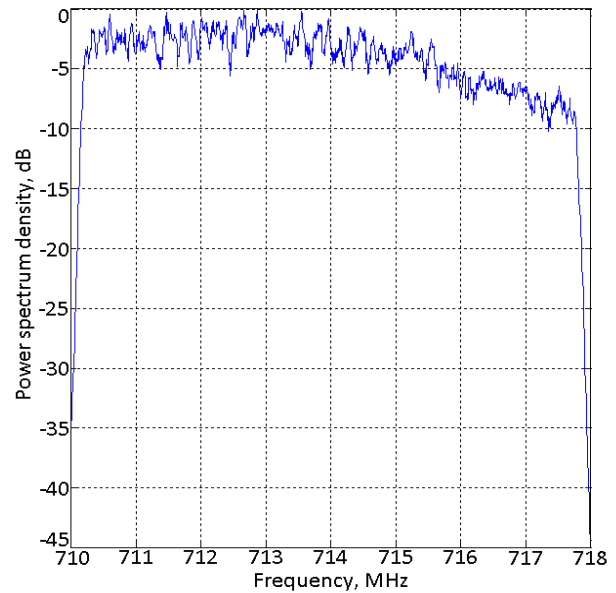
Conclusions

The correspondence between the occupied bandwidth of transmission by $\beta/2$-method and X dB level can be found on the basis of experimental data or it is necessary to modify CSP with the account for the real width of spectrum slopes.

References

1. *Recommendation* ITU-R SM.443-4. Bandwidth measurement at monitoring stations.
2. *Recommendation* ITU-R SM.1138. Determination of necessary bandwidths including examples for their calculation and associated examples for the designation of emissions.
3. *Digital Video Broadcasting (DVB);* Implementation Guideline for a Second Generation Digital Terrestrial Television Broadcasting System (DVB-T2). DVB Document A133, February 2012. www.dvb.org/technology/standards/a133_DVB-T2_Imp_Guide.pdf
4. *B21C Project D07* Part A. Report on Simulating Chains and Outcomes. 2009. http://www.google.com.ua/url?sa
5. *Haffender O.* BBC Research White Paper WHP196. DVB-T2: The Common Simulation Platform. http://downloads.bbc.co.uk/rd/pubs/whp/whp-pdf-files/WHP196.pdf
6. *ETSI EN 302 755.* Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for a second generation digital terrestrial television broadcasting system (DVB-T2). V1.3.1. http://www.etsi.org

7. *Marshall P.* Digital Television Project: Provision of Technical Assistance. Issue 1.1, March 2005. http://www.digitalelevision.gov.uk/pdf_documents/publications/art_v1-2.pdf

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Цифрове телебачення стандарту DVB-T2 впроваджується в Україні. Моніторинг радіовипромінювань, а саме займаної ширини смуги частот (ЗШСЧ) звичайно проводиться на рівні *X dB* від рівня, що прийнятий за нульовий. Потрібно встановити відповідність між ЗШСЧ за $\beta/2$-методом та рівнем *X dB*. Математичне моделювання поля випромінювання розглядається як один із засобів для досягнення вказаної мети.

Цифровое телевидение стандарта DVB-T2 внедряется в Украине. Мониторинг радиоизлучений, а именно занимаемой ширины полосы частот (ЗШПЧ) обычно проводится на уровне *X dB* от уровня, который принято нулевым. Необходимо установить соответствие между ЗШПЧ по $\beta/2$-методу и уровнем *X dB*. Математическое моделирование поля излучения рассматривается как одно из средств достижения данной цели.

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The article includes information about operational principle of DVB-T2 TV. The simulation is carried out using the DVB-T2 Common Simulation Platform (CSP) as a basis. The calculation signal spectrums on the output of AWGN (Gaussian noise), Ricean and Rayleigh channels are obtained. Channel parameters used for mathematical modeling lead to unacceptable distortions of the spectrum. The experience of the measurement during radio monitoring shows that such distortions of the spectrum form are not observed.
The correspondence between the occupied bandwidth of transmission by $\beta/2$-method and *X dB* level can be found on the basis of experimental data or it is necessary to modify CSP with the account for the real width of spectrum slopes.

Цифрове телебачення стандарту DVB-T2 впроваджується в Україні. Моніторинг радіовипромінювань, а саме займаної ширини смуги частот (ЗШСЧ) звичайно проводиться на рівні *X dB* від рівня, що прийнятий за нульовий. Потрібно встановити відповідність між ЗШСЧ за $\beta/2$-методом та рівнем *X dB*. Математичне моделювання поля випромінювання розглядається як один із засобів для досягнення вказаної мети.
Стаття містить інформацію про принцип дії телебачення стандарту DVB-T2. Під час моделювання платформа CSP використовувалася як базис. Отримані спектри на виході каналу поширення з Гаусівським шумом, Райсівського та Релеєвського каналів. Параметри

каналів, які використовувалися для моделювання, призводять до неприпустимих спотворень спектрів. Досвід радіомоніторингу свідчить, що під час вимірювань таких спотворень не спостерігається.

Відповідність між ЗШСЧ за $\beta/2$-методом та рівнем X dB можна знайти за експериментальними данними або потрібно внести зміни до CSP щоб отримати реальну ширину схилів спектра випромінювання.

Цифровое телевидение стандарта DVB-T2 внедряется в Украине. Мониторинг радиоизлучений, а именно занимаемой ширины полосы частот (ЗШПЧ) обычно проводится на уровне X dB от уровня, который принято нулевым. Необходимо установить соответствие между ЗШПЧ по $\beta/2$-методу и уровнем X dB. Математическое моделирование поля излучения рассматривается как одно из средств достижения данной цели.

Статья включает информацию о принципе действия телевидения стандарта DVB-T2. Во время моделирования платформа CSP использовалася в качестве базиса. Получены спектры на выходе канала с Гауссовским шумом, Райсовского Релеевского каналов. Параметры каналов, которые использовались для моделирования, приводят к недопустимым искажениям спектров. Опыт радиомониторинга свидетельствует, что во время измерений таких искажений не наблюдается.

Соответствие между ЗШПЧ по $\beta/2$-методу и уровнем X dB можна найти по экспериментальным данным или необходимо внести изменения в CSP, чтобы получить реальную ширину скатов спектра излучения.