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THE DEVELOPMENT OF NORMS OF FREQUENCY AND DISTANCE SEPARATION OF DIGITAL BROADCASTING AND TELEVISION OF STANDARD T-DAB AND DVB-T WITH THIN-ROUTE RADIO RELAY STATIONS

The paper addresses the problem of electromagnetic compatibility of digital broadcasting and television, which is planned for the frequency bands 174-230 MHz and 470-862 MHz with existing radio relay stations (RRS) P-409 and P-419. Drafting standards of frequency and distance separation between the means of digital broadcasting and radio relay stations P-409, P-419 were developed with established software.

On November 26th 2008 the State program of digital broadcasting in Ukraine was approved by the Cabinet of Ministers of Ukraine. The aims of program are to implement the decisions adopted by Ukraine at the Regional Radiocommunication Conference of ITU-R in Geneva in 2006, which envisages the transition from analog to digital broadcasting by 2015.

The country must build an infrastructure for digital broadcasting with guaranteed coverage throughout the territory in the bands 174-230 MHz (third TV band), 470-862 MHz (fourth and fifth television band). The third range serves for audio broadcasting in standard T-DAB which is compatible with television standard DVB-T. In the fourth and fifth television bands there will be only digital television broadcasting.

An obligatory step in obtaining permission for broadcasting is positive decision relatively electromagnetic compatibility of digital broadcasting with other radio electronic equipment (REE), including radio relay stations (RRS) P-409M, P-419A. Efficient frequency planning tool is the norms of frequency and distance separation (FDS), which are considered in this work.

Standards DVB-T, DVB-H are based on the algorithm coding audio and video MPEG-2 or MPEG-4 [1] , [2].

Implementation of standards DVB-T, DVB-H stipulates construction single-frequency synchronous network SFN. In single-frequency network synchronization of operation should be provided with satellite transmitters or terrestrial channels. Radiated symbols have to be identical.

In the DVB standard modulation COFDM (OFDM with previous coding) is used. TV signal of 8, 7, 6 MHz bandwidth is formed using orthogonal carrier, the frequencies of which are defined as:

$$f_n(t) = \cos\left[2\pi\left(f_0 + n/\tau\right)t\right],$$

where: f_0 - the lower frequency of range; n - the number of sub-currier 1 до N ; τ - time interval of transmission of one symbol.

During modulation packet data stream is divided by N parts, which modulate carriers with less speed. Carrier frequency offset

$$\Delta f_n = \frac{1}{\tau}.$$

To preserve orthogonality and prevent intersymbol interference that may arise as a result of multipath propagation, each symbol interval obtain protective value of $0{,}25\,\tau$.

In the 8 MHz bandwidth, used in Europe, the maximum carrier number $8 \times 1024 = 8192$ or $8K$. Each carrier is modulated by 4-position quadrature phase shift keying (QPSK) or 16- or 64-position quadrature amplitude modulation (QAM). Accordingly, one modulation symbol on carrier transfers from two to six bits.

Also according to the number of quadrature modulation levels the data stream is divided into: 2 sub-streams for QPSK, 4 sub-streams for 16- position QAM. So during demultiplexing the first bit appears in the first sub-stream etc. Sense of internal interleaving is permutation by definite individual rule in each sub-stream of bits by block with length 126 bits. In parallel outputs of the internal interleaving block the modulation symbol is formed with two, four or six digits. One carrier transfers one symbol. Therefore, using $8K$ mode simultaneously is radiated 48 groups of 126 symbols, that corresponds to 6048 carriers with useful information, or 12×126=1512 carriers using $2K$ mode. QAM-symbols are divided into different sub-channel of OFDM interleaving, which allows to restore the information at a loss OFDM-symbol. Complex signal of OFDM-symbol [3] is written

$$S_n = \sum_{k=0}^{N-1} C_k(nT) e^{i2\pi knT/n}, \qquad (1)$$

where: T - discrete time interval; n - reference number.

Expression (1) identical to the Fourier inversion at sampling interval equals to the ratio of duration of one transmission symbol to the carrier number.

Radiated DVB signal looks like noise-type with Gauss distribution. Spectrum of signal consists of a large number of partial spectral modulated carriers. Due to this spectrum is practically continuous.

Radio frequency masks of DVB-T radiation signal is presented at Fig. 1 [4].

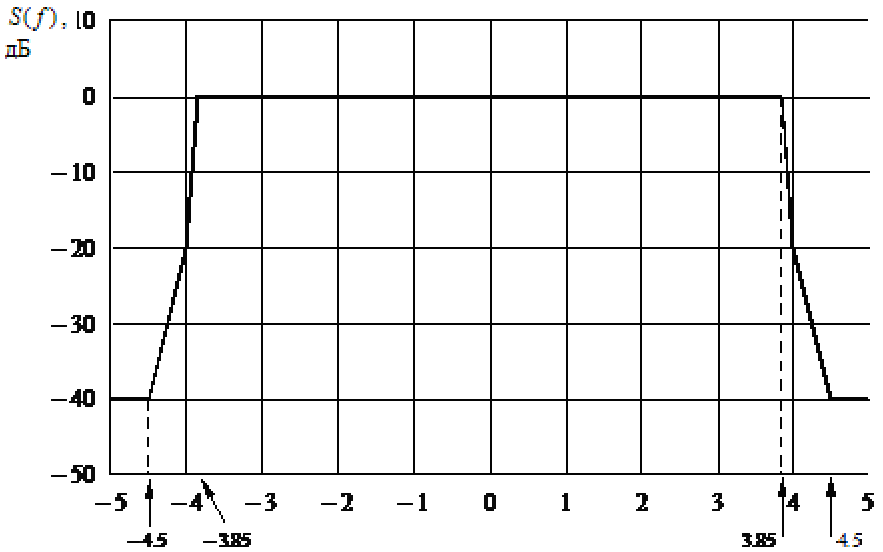

Fig. 1 Radio frequency mask of digital television with bandwidth of 8 MHz

Typical antenna system can be built on the basis of firm ELTI sectored antennas TVA 31/50 or TVA 24/50, which have a similar structure and different number of radiators (respectively 4 and 2). TVA 24/50 can radiate waves with horizontal or vertical polarization (depending on the spatial position) in a working range of 470-862 MHz, directivity factor 6.8 ... 9 dB (with respect to the dipole), bandwidth in E and H planes $2\theta_{0,5}^{E} = 56^o$, $2\theta_{0,5}^{H} = 49^o$.

At placing four antennas TVA 31/50 or TVA 24/50 in the horizontal plane radiation pattern can be considered isotropic. In order to obtain greater directivity in the vertical plane using antenna TVA 31/50 or TVA 24/50 these aerials form antenna arrays with number of racks from 1 to 16.

Designs from one, two and three aerials in horizontal plane and antenna racks in vertical plane can provide radiation in azimuthal sectors $\varphi = 0...90^0$, $\varphi = 0...180^o$, $\varphi = 0...270^o$ correspondingly.

Parameters of antenna systems based on TVA 31/50 are given in the table 1.

Table 1

Parameters of antenna systems standard DBV-T / H with horizontally polarized aerials TVA 31/50

Parameter	Number of antenna racks in the vertical plane at non-directional radiation in the horizontal plane				
	1	2	4	6	8
Number of radiators TVA 31/50	4	8	16	24	32
Maximum input power, kW (analogue)	10	20	40	60	80
Maximum input power, kW (digital signal)	8	16	32	48	64
Gain at a frequency of 665 MHz with respect to the dipole, dB	4,87	7,88	10,89	12,65	13,9
SWR in a wide range	≤ 1.12	≤ 1.12	≤ 1.12	≤ 1.12	≤ 1.12
SWR in the working channel	≤ 1.05	≤ 1.05	≤ 1.05	≤ 1.05	≤ 1.05

RRS P-409, P-419 [5-9] belong to a thin-route stations, designed to build a radio relay lines, and perform some other functions. P-409 has three frequency bands, P-419 – four. The transition from one to another frequency band of P-409 is carried out by replacing the antenna and removable elements of transceiving path. RRS P-419 in the third and fourth frequency bands uses one antenna. In case of good matching antenna with the feeder the overlapping factor is equal two. Restrictive lines of directional diagrams (DD) antennas RRS P-409, P-419 were built. Equations of restrictive lines DD Z-shaped antenna with a screen in the E-plane is presented in the Table 2.

Table 2

Equations of restrictive lines DD Z-shaped antenna with a screen in the E-plane at a 180 MHz

Sector, degrees	Equation	Sector, degrees	Equation
0…15	$F(\theta) = 1$	0…-15	$F(\theta) = 1$
15…35	$F(\theta) = -0{,}0275\theta + 1{,}4125$	-15…-35	$F(\theta) = 0{,}0275\theta + 1{,}4125$
35…78	$F(\theta) = 0{,}45$	-35…-78	$F(\theta) = 0{,}45$
78…110	$F(\theta) = -0{,}00895\theta + 1{,}148$	-78…-110	$F(\theta) = 0{,}00895\theta + 1{,}148$
110…156	$F(\theta) = 0{,}11$	-110…-156	$F(\theta) = 0{,}11$
156…180	$F(\theta) = 0{,}01 + 1{,}45$	-156…-180	$F(\theta) = -0{,}01 + 1{,}45$

Detail description of procedures of EMC evaluation is considered in [10].

Software for calculation norms FDS was developed based on the above data. Norms of frequency and distance separation are intended for use in frequency planning of digital television broadcasting networks standards DVB-T, DVB-H and selection locations for transmitters in order to ensure their electromagnetic compatibility with radio relay stations P-409 and P-419.

Draft Norms of frequency and distance separation are presented as tables containing the data for different versions of electronic means applications. Tables corresponding to three cases of mutual orientation of broadcasting antennas and RRS aerials, namely:

- toward the peaks of both antenna directional diagrams (main to main);
- in the direction of maximum antenna pattern DVB-T - the maximum of the first side lobe of antenna pattern RRS (main to 1-st side);
- in the direction of maximum antenna pattern DVB-T - maximum of the back and side lobes of antenna pattern RRS (main to back side).

It is assumed that all power except feeder losses (accepted = -1.5 dB) is applied to the terminals of corresponding sector antenna in the direction of RRS.

During defining drafts FDS gain value of antenna DVB-T transmitter $G_0 =$ 10,89 dBi (against dipole) is used. Antenna gain is connected with the directivity factor D by aerial efficiency η_A: $G = D\eta_A$. For dipole $D = 1{,}64$. In the considered band efficiency value can be assumed η_A=0,95. Then $G_{\lambda/2} \approx 1{,}6$. Example of drafts FDS is contained in Table 5.

Table 5

Draft norms of frequency and distance separation of RRS P-409M(MA) and digital broadcasting and television of standard T-DAB and DVB-T

Conditions of determination FDS norms	DVB-T transmitter output power, W											
	10		50		100		400		1200		5000	
Frequency of radiation f =470-480MHz	$D^{1)}$, km	$\Delta f^{2)}$, MHz	$D^{1)}$, km	$\Delta f^{2)}$, MHz	$D^{1)}$, km	$\Delta f^{2)}$, MHz	$D^{1)}$, km	$\Delta f^{2)}$, MHz	$D^{1)}$, km	$\Delta f^{2)}$, MHz	$D^{1)}$, km	$\Delta f^{2)}$, MHz
Antenna orient-tation Rec.-Trans.: main to main	9,5	0	16,4	0	20,6	0	28,8	0	36,6	0	48,3	0
	9,5	3,7	16,4	3,7	20,5	3,7	28,8	3,7	36,6	3,7	48,3	3,7
	8,7	3,8	15,1	3,8	19,1	3,8	27,2	3,8	34,7	3,8	46,1	3,8
Hanging height of DVB-T antenna (Trans.): 250m	6,3	3,9	10,8	3,9	13,7	3,9	21,4	3,9	28,1	3,9	38,2	3,9
	3,2	4,0	5,5	4,0	7	4,0	11,1	4,0	16,2	4,0	24,5	4,0
	0,7	4,1	1,1	4,1	1,4	4,1	2,2	4,1	3,2	4,1	5,2	4,1
	0	4,2	0	4,2	0	4,2	0,6	4,2	0,9	4,2	1,5	4,2
Hanging height of RRS antenna (Rec.) : 19,5m	0	4,3	0	4,3	0	4,3	0	4,3	0,7	4,3	1,1	4,3
	0	4,4	0	4,4	0	4,4	0	4,4	0	4,4	0,7	4,4
	0	4,5	0	4,5	0	4,5	0	4,5	0	4,5	0	4,5
	0	4,6	0	4,6	0	4,6	0	4,6	0	4,6	0	4,6
	0	4,7	0	4,7	0	4,7	0	4,7	0	4,7	0	4,7

1) D - separation by distance
2) Δf - separation by frequency.

Frequency and distance separation norms simplify attainment of electromagnetic compatibility digital broadcasting and television with existing radio relay stations P-409 and P-419 in the bands 174-230 MHz and 470-862 MHz.

References

1. *Довідник* з радіомоніторингу / Під аг. Ред.. П.В. Слободянюка. – Ніжин: ТОВ «Видавництво Аспект-Поліграф», 2008. -588 с.
2. *ETSI TR101 190:* 2004 Digital Video Broadcasting (DVB); Implementation guidelines for DVB terrestrial services; Transmission aspects.
3. *Вишневский В.М., Ляхов А.И., Портной С.Л., Шахнович И.В.* Широкополосные беспроводные сети передачи информации. – М.: Техносфера, 2005. – 592 с.
4. *Recommendation* ITU-R BT.1206. Spectrum shaping limits for Digital Television Broadcasting.
5. *www*.interpolitex.rasu.ru/index.php.
6. *www*.radioscanner.ru/photo/antennas/relay.php
7. *vkmtuci*.edu.mhost.ru/texcba/rrlspravka.htm
8. *www*.omskindustry.ru/firm.asp?skl=7579
9. *www*.techtorg.ru/firm.asp?skl=7579
10. *Іванов В.О., Решетнік М.В., Бондаренко Д.П.* Алгоритм розрахунку норм частотно-територіального рознесення радіоелектронних засобів. – К.: Вісник ДУІКТ. – 2007. – Том5(3). – С.262 – 270.