EMC 2006 18th INTERNATIONAL WROCLAW SYMPOSIUM AND EXHIBITION ON ELECTROMAGNETIC COMPATIBILITY, WROCLAW, 28 – 30 JUNE, 2006
www.emc.wroc.pl

COMPATIBILITY ANALYSIS METHOD OF DVB-T SYSTEM INTERFERED WITH BY OTHER DIGITAL WIDEBAND SYSTEMS

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Abstract: Mathematical DVB-T system receiver model for the compatibility analysis with other digital systems was developed. Calculations of the protection ratios for DVB-T interfered with by other services were presented. The model can be used for calculations of the protection ratios for the interference from other wideband digital radio systems. Simulated calculations using the model were performed and the results which had been received were compared with the measurements published in the literature.
Keywords: DVB-T, Receiver Model, Protection Ratios, Compatibility Analysis.

1. INTRODUCTION

The digital terrestrial television system DVB-T [1] is implemented in many countries. One of the most important things which encourage many countries to analog-digital transitions is the efficient spectrum usage by digital television. In the European Union the year 2012 will be the last year of analog television transmission. Within the ITU the Regional Radiocommunications Conference RRC'04-06 [2] is organized and the second session of the Conference (May-June 2006) will produce full Digital Plan for the Europe, Africa, Middle East, former USSR countries and Iran. The Plan will be based on the digital DVB-T allotments and assignments. Before the Conference many work have been done in order to establish the required protection ratios (PR) for compatibility analysis. Author of the paper (1) was involved in many of the work within CEPT and ITU. The tasks of the preparation groups were mainly focused on the protection of other existing radio systems from the interference which could be produced from DVB-T stations. The opposite direction and problems of protection the DVB-T system is not so good analyzed and described. Some measurements of the protection ratios for DVB-T system interfered with by other systems were done [3] but there were no theoretical methods developed for the PR assessment. In the paper the results of the developed receiver model of the DVB-T system for the PR calculations which were done in the thesis [4] of the author ware presented. Based on the analysis simulated calculations using the model were performed and the theoretical results which had been received were compared with the measurements published in the literature.

2. DVB-T SYSTEM

In the DVB-T system the OFDM transmission methods was selected with 2k or 8k carriers. Each of the carriers could be modulated with by QPSK, 16QAM or 64QAM or with hierarchical methods with the parameters described in Table 1.

The signal can be described as:

$$s(t) = \mathrm{Re}\{e^{2j\pi f_0 t} \sum_{m=0}^{+\infty} \sum_{l=0}^{67} \sum_{k=K\min}^{K\max} c_{m,l,k} \cdot \psi_{m,l,k}(t) \quad (1)$$

where,

l	OFDM symbol number
k	carrier number
m	frame number
K	the number of transmitted carriers
fc	central frequency of RF signal
k'	carrier index related to the centre frequency k' = k – (Kmax – Kmin)/2
Kmax	maximum frequency index
Kmin	minimum frequency index
Cm,l,k	complex symbol for carrier k of the data symbol no. l in frame number m;

Table 1. DVB-T System parameters

System variant	8k	2k
Number of carrier K	6 817	1 705
Useful symbol duration Tu	896 µs	224 µs
Carrier spacing 1/Tu	*1 116 Hz*	*4 464 Hz*
Guard interval Δ	1/4, 1/8, 1/16 or 1/32Tu	
Distance between Kmin and Kmax (bandwidth)	*7,61 MHz*	
Carrier modulation	QPSK, 16QAM, 64QAM	

Two step channel coding system is used in DVB-T: Reed-Solomon coding and next the convolutional coding. In the receiver the Viterbi decoder is used and next the Reed-Solomon decoder.

In the PR measurement process the value of BER=$2*10^{-4}$ after Viterbi decoder is used as a failure criteria which correspond to the QEF (quasi error free) situation after RS decoder (10^{-11}). The BER after Viterbi decoder is also used as a measuring level of the minimum C/N values in ETSI standard [1].

The convolutional code used in DVB-T is punctured convolutional code based on mother generator (171,133) with constraint length 8. The code rates can be 1/2, 2/3, 3/4, 5/6 or 7/8. The corresponding Hamming distances are: 10, 6, 5, 4, 3.

Based on the measurements or on theoretical assumption [4] the BER vs C/N curves for different code rates and modulation schemes can be produced. The curves are used in the compatibility analysis of the DVB-T receiver model.

DVB-T RECEIVER MODEL

The DVB-T mathematical receiver model is based on two assumptions:

- the interfering digital wideband signal can be simulated as a white noise with the spectral density corresponding to the signal,
- each OFDM carrier can be analyzed separately and corresponding BER could be found as a mean value of the individual carriers.

The first assumption coming from the real wideband digital signal spectrums, which are often called as a “noise-like” due to uncorrelated and randomly spread parts of the spectra which are very similar to the white noise. The assumption was checked by the comparison of the achieved results with the real measurements which will be shown in the next paragraphs.

The second assumption is based on the nature of the OFDM transmission which is in fact parallel transmission of individual modulated carriers.

For each carrier the BER value can be found as a result of the C/(N+I) ratio where N+I value is the sum of the floor level and the level of the interference treated as a noise in the bandwidth of the analyzed carrier.

The PR estimation procedure is based on the measuring procedure made in theoretical way with the noise representing interfering signal and can be written as follows:

1. Initial conditions: the normal DVB-T reception circumstances with C/N about 10dB above C/N minimum. The interfering signal is representing as a white noise with the same spectrum with the level below the noise floor.
2. Step by step increasing the level of the interference and calculation of the DVB-T BER level until the BER reach the $2*10^{-4}$.
3. Calculating PR as the difference between useful and interfering signals in dB.
4. If there is bandwidth difference between the two signals the correction of the levels (PR=C/(I+N) -10logBi/Bc) should also be done.

The procedure could be done for different frequency offset and the PR curves vs. offset could be found.

For the practical reasons the procedure is implemented in computer program in order to facilitate different type of interference spectra and quick PR calculations.

RESULTS OF THE CALCULATION

The model described above was used in computer simulations in order to compare achieved results with the established within ITU PR for the DVB-T system interfering with by DVB-T [3]. The ITU values come from agreement between various administrations based on many different laboratory tests. Comparison of the laboratory results with mathematical calculation can provide good confirmation of the proposed model.

The results of the comparison is shown in Table 2.

Table 2. Simulation of the DVB-T vs DVB-T PR

Modulation	**Code rate**	**ITU PR** (Rec. BT.1368)	**PR calculated**
QPSK	1/2	5	4,91
QPSK	2/3	7	6,56
16-QAM	2/3	13	12,63
64-QAM	2/3	19	19,96

As it can be found in the Table 2 results of the simulations have very good conformity with the ITU values.

Similar calculations and comparisons were done for the PR calculations for DVB-T system interfered with by CDMA2000 system. Two CDMA2000 system variants was analyzed: CDMA2000-1X with bandwidth 1,23MHz and CDMA2000-3X with bandwidth about 4MHz. Measurements of the PR for DVB-T interfered with by CDMA2000 was published at the ITU-R forum [5]. In this measurements few DVB-T receivers were measured and in Table the range of the received results are presented as well as the value chose as the PR for ITU Recommendation. In Table 3 the measured and calculated results for CDMA2000-1X system are shown.

Table 3. Measured and simulated results of the PR for DVB-T interfered with by CDMA2000-1X system.

DVB-T mode	**PR calculated [dB]**	**PR Measured (range) [dB]**	**Difference [dB]**
QPSK 2/3	**2,1dB**	**0dB** (-4dB to 5dB)	2,1dB
QPSK 7/8	**6,5dB**		
16QAM 1/2	**7,8dB**		
16QAM 2/3	**8,6dB**	**8dB** (-3 to 11dB)	0,6dB
16QAM 7/8	**11dB**		
64QAM 2/3	**14,6dB**	**10dB** (4dB to 19dB)	4,6dB

For the CDMA2000-3X system variant the results are presented in Table 4.

Table 4. Measured and simulated results of the PR for DVB-T interfered with by CDMA2000-3X system.

DVB-T mode	**PR calculated [dB]**	**PR Measured (range) [dB]**	**Difference [dB]**
QPSK 2/3	**5,1dB**	**5dB** (5dB to 6dB)	0,1dB
QPSK 7/8	**9dB**		
16QAM 1/2	**11dB**		
16QAM 2/3	**11,3dB**	**12dB** (10 to 13dB)	0,7dB
16QAM 7/8	**13dB**		
64QAM 2/3	**18dB**	**18dB** (17 to 19dB)	0dB

Empty fields in the Table 3 and 4 indicated the missing measured values due to fact that not all but only selected DVB-T system mode was chosen for the laboratory tests. In case of calculations it was simple to get exact results for any DVB-T mode as it can be found in the Tables 3 and 4.

The PR curves calculations for different frequency offsets between DVB-T and CDMA2000 the spectrum masks for CDMA2000 system are shown in Table 5 and 6.

Table 5. Spectrum mask of the CDMA2000-1X terminal (uplink) [5]

Frequency [MHz]	**Value [dB]**
-6	-63
-4	-66
-1,98	-51
-1,125	-31
-0,75	-7
0	0

Table 6. Spectrum mask of the CDMA2000-3X terminal (uplink) [5]

Frequency [MHz]	**Value [dB]**
-9	-55
-6	-48
-3,5	-38
-2	-30
-1,88	0
0	0

Based on the spectrum masks the interfering signals were simulated as a white noise with the spectra corresponded to the masks and the PR calculations were performed for different frequency offsets. Some examples of the analyses are presented on Figure 1 and 2.

As it can be seen calculated values are very close to the agreed values of the PR agreed within ITU based on the measurements. In that case the proposed model was clearly confirmed. Based on the same model the protection ratios for other interfering systems were calculated and described in details in [4]. As a one example of that simulation the protection ratio curve for the DVB-T system interfered with by DVB-RCT (*Digital Video Broadcasting -Return Channel Terrestrial)* [6] multi-carrier 0,94MHz bandwidth was shown on the Figure 3. In that case the spectrum mask for DVB-RCT used in simulation was derived from the ETSI standard [6] and is presented in Table 7.

Table 7. Spectrum mask for DVB-RCT system, multi-carrier, 0,94MHz

Δf [MHz]	Mask value [dB]
-4,47	-100
-1,47	-90
-0,485	-60
-0,47	-30
0	-30

Figure 1. Protection Ratio DVB-T 16QAM code 2/3 interfered with by CDMA2000-1X

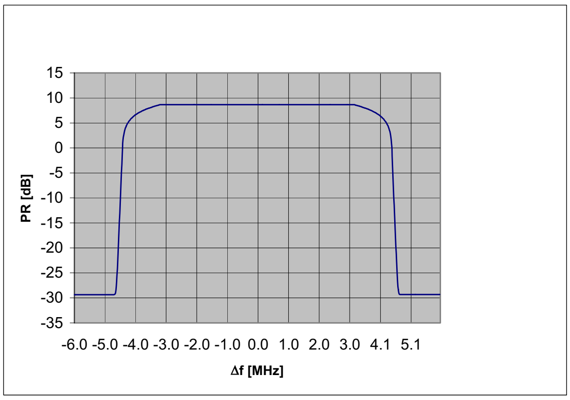


Figure 2. Protection Ratio DVB-T 64QAM code 2/3 interfered with by CDMA2000-3X

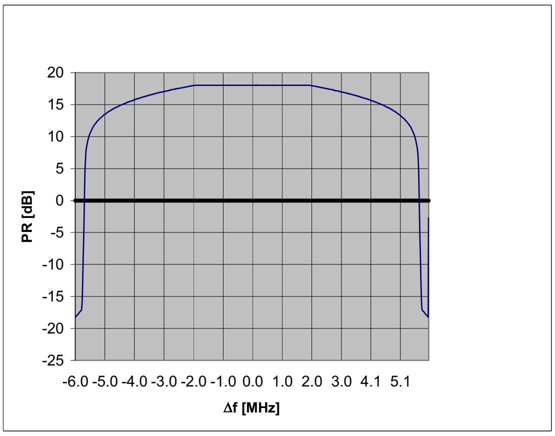
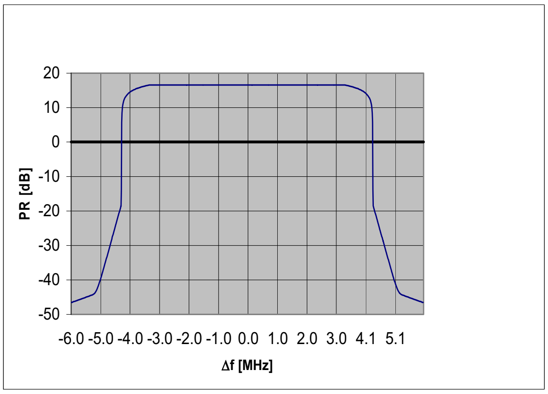


Figure 3. Protection Ratio DVB-T 16QAM code 2/3 interfered with by DVB-RCT 0,94MHz



CONCLUSIONS

The receiver model principles for protection ratios calculations used for DVB-T system interfered with by other digital wideband systems were presented in that paper. Full detailed description can be found in [4]. Some examples of PR calculations were presented. In many cases the results of calculations were confirmed by measurements or by values agreed within ITU. The outcome of the modeling is the statement that in PR determinations interfering wideband digital signal can be simulated by white noise having the same spectrum. It could be used either in the PR calculations or PR measurements. In the ITU-R preparations for RRC'04-06 Conference [2] the main aim was the establishing of the PR for other existing systems which should be protected from the DVB-T emissions. In the future the protection of the DVB-T system from other systems sharing the same frequency bands will be similarly important and the methods presented in that paper could be very useful, especially for quick estimation of possibility of introductions new systems in the same band or in case where the measurements are very difficult and/or expensive.

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