Buletinul Ştiinţific al Universităţii "Politehnica" din Timişoara

Seria ELECTRONICĂ şi TELECOMUNICAŢII
TRANSACTIONS on ELECTRONICS and COMMUNICATIONS

Tom 49(63), Fascicola 2, 2004

Terestrial Digital Video Broadcasting (DVB-T). System performances simulation

Şerban Georgică Obreja[1], Adrian Florin Păun[1]

Abstract: This paper analizes the performance of a Terrestrial Digital Television system. The performances are estimated using a Matlab Simulink model for the DVB-T system.

Keywords: DVB_T system, terrestrial broadcasting, OFDM, QAM modulation, bit error rate, channel coding

I. INTRODUCTION

DVB-T is the standard for Digital Television Terrestrial Broadcasting defined for Europe. The DVB family standards allows for digital video and audio broadcasting as well as transport of multimedia services. For terrestrial broadcasting the system was designed to operate within the existing UHF spectrum allocated for analogue television. The system was developed for 8MHz channels but it can be reconfigured also for 7or 6MHz channels. The net bit rate available in the 8MHz channel ranges between 4 and 32 Mbit/s, depending of channel coding parameters, modulation type and guard interval.

The Coded Orthogonal Frequency Division Multiplexing modulation system was chosen, being suitable for the multipath propagation environment of terrestrial radio channels. The system uses a large number of carriers per channel allowing the reduction of symbol rate over one carrier. In this way the symbol interval is increased and a better protection to multipath propagation is obtained. The OFDM may operate with two modes: 8k FFT mode and 2k FFT mode. The system can select between different levels of QAM modulation and different inner code rates and also allows two level hierarchical channel coding and modulation. Moreover, a guard interval with selectable width separates the transmitted symbols, which allows the system to support different network configuration: "8k mode" for large single frequency networks and "2k mode" for small or mobile networks

II. DVB-T System

Figure (1) shows block diagram of a DVB-T transmitter. The input data are divided into groups of 188 bytes, which are scrambled and coded by an outer shortened Reed-Solomon code (204,188,t=8). This code can correct up to eight erroneous bytes in a frame of 204 bytes. The coded bits are interleaved by a convolutional interleaver that interleaves byte- wise with a depth of 12 bytes and then again coded by a rate 1/2, constraint length 7 convolutional code with generator polynomials (171,133 octal). The rate of this latter code can be increased by puncturing to 2/3,3/4,5/6, or 7/8. The convolutionally encoded bits are interleaved by an inner interleaver mapped onto QPSK, 16QAM, or 64QAM symbols.

To obtain reference amplitude and phase to perform coherent QAM demodulation, pilot subcarriers are transmitted. For the 8k mode, in each symbol there are 768 pilots, so 6,048 subcarriers remain for data. The 2k mode has 192 pilots and 1,512 data subcarriers. The position of the pilots varies from symbol to symbol with a pattern that repeats after four OFDM symbols. The pilots allow receiver to estimate the channel both in frequency as well as in time, which is important as for mobile receivers there can be significant channel changes within a few OFDM symbols.

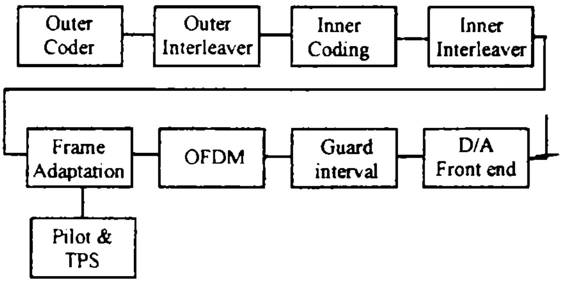

Fig. 1 DVB-T transmission system block diagram

Terrestrial DVB use OFDM with two possible modes, using 1,705 and 6817 subcarriers, respectively [1]. These modes are known as 2k and 8k modes, respectively, as these are the size of FFT/IFFT needed to generate and demodulate all subcarriers.. Basically, the 2k system is a

---

[1] Politehnica University of Bucharest,Electronics and Telecommunications Faculty, Telecommunications Departament, Bd. Iuliu Maniu Nr 1-3, 061071,Bucuresti, e-mail serban@radio.pub.ro

simplified version which require an FFT/IFFT that is only a quarter of the size that is needed for the 8k system. Because the guard time is also four times smaller, the 2k system can handle less delay spread and less propagation delay difference among transmitters within a single frequency network but is less sensitive to the Doppler effect. The FFT interval duration for the 8k system is 896μs while the guard time can have four different values from 28 to 224 μs. The corresponding values for the 2k system are four times smaller.

The transmitted signal is organized in frames. Each frame has duration of T_F, and consists of 68 OFDM symbols. Four frames constitute one super-frame. Each symbol is constituted by a set of K = 6 817 carriers in the 8K mode and K = 1 705 carriers in the 2K mode and transmitted with a duration T_S. It is composed of two parts: a useful part with duration T_U and a guard interval with duration Δ. The guard interval consists in a cyclic continuation of the useful part, T_U, and is inserted before it. Four values of guard intervals may be used according to table 5. The symbols in an OFDM frame are numbered from 0 to 67. All symbols contain data and reference information.

Since the OFDM signal comprises many separately-modulated carriers, each symbol can in turn be considered to be divided into cells, each corresponding to the modulation carried on one carrier during one symbol.

In addition to the transmitted data an OFDM frame contains:

- Scattered pilot cells;
- Continual pilot carriers;
- TPS carriers.

The pilots can be used for frame synchronization, frequency synchronization, time synchronization, channel estimation, transmission mode identification and can also be used to follow the phase noise.

The carriers are indexed by k ∈ [Kmin; Kmax] and determined by Kmin = 0 andKmax = 1 704 in 2K mode and 6 816 in 8K mode respectively. The spacing between adjacent carriers is $1/T_U$ while the spacing between carriers Kmin and Kmax are determined by $(K-1)/T_U$. The numerical values for the OFDM parameters for the 8K and 2K modes are given in tables 1 and 2.

Table 1

8K mode				
Guard Interval Δ	1/4	1/8	1/16	1/32
Duration of symbol part T_U	8192xT 896μs			
Duration of guard interval Δ	2048xT 224 μs	1024xT 112 μs	512xT 56 μs	256xT 28 μs
Symbol duration $T_S=\Delta+T_U$	10240xT 1120 μs	9216xT 1008μs	8704xT 952 μs	8448xT 925 μs

Table2

2K mode				
Guard Interval Δ	1/4	1/8	1/16	1/32
Duration of symbol part T_U	2048xT 224μs			
Duration of guard interval Δ	2512xT 56 μs	256xT 28 μs	128xT 14 μs	64xT 7 μs
Symbol duration $T_S=\Delta+T_U$	2560xT 280 μs	2304xT 252μs	2176xT 238 μs	2112xT 231 μs

The emitted signal is described by the following expression:

$$s(t)\mathrm{Re}\left\{e^{j2\pi f_c t}\sum_{m=0}^{\infty}\sum_{l=0}^{67}\sum_{k=K_{\min}}^{K_{\max}} c_{m,l,k}\times\psi_{m,l,k}(t)\right\}$$

where

$$\psi_{m,l,k}(t)=$$

$$=\begin{cases} e^{j2\pi\frac{k'}{T_U}(t-\Delta-l\times T_S-68\times m\times T_S)} & pT_S<t<(p+1)T_S \\ 0 & else \end{cases}$$

- k - the carrier number
- l – OFDM symbol number
- m – transmission frame number
- K – number of transmitted carriers
- T_S – symbol duration
- T_U – inverse of the carrier spacing
- Δ – guard interval
- f_c – central frequency
- $k' = k - \frac{(K_{\max}+K_{\min})}{2}$
- $c_{m,l,k}$ – complex symbol

The apparent complexity of these equations can be simplified if it is noted that the waveform emitted during each transmitted symbol period depends solely on the K complex values $c_{m,l,k}$ which define the complex amplitude of the K active carriers for that period. Each symbol can thus be considered in isolation; for example, the signal for the period from t= 0 to t=T_S is given by:

$$s(t)\mathrm{Re}\left\{e^{j2\pi f_c t}\sum_{k=K_{\min}}^{K_{\max}} c_{0,0,k}\times e^{j2\pi k'(t-\Delta)/T_U}\right\}$$

There is a clear resemblance between this and the inverse Discrete Fourier Transform (IDFT):

$$x_n=\frac{1}{N}\sum_{q=0}^{N-1}X_q e^{j2\pi nq/N}$$

Since various efficient Fast Fourier Transform algorithms exist to perform the DFT and its inverse, it is a convenient form of implementation to use the inverse FFT (IFFT) in a DVB-T modulator to generate N samples x_n corresponding to the useful part, T_U long, of each symbol. The guard interval is added by taking copies of the last $N\Delta/T_U$. of these samples and appending them in front. This process is then repeated for each symbol in turn, producing a continuous stream of samples which constitute a complex baseband representation of the DVB-T signal. A subsequent up-conversion process then gives the real signal s(t) centered on the frequency f_c

The OFDM symbols constitute a juxtaposition of equally-spaced orthogonal carriers. The amplitudes and phases of the data cell carriers are varying symbol by symbol according to the mapping process. The power spectral density Pk (f) of each carrier is given by the following expression:

$$P_k(f)=\left[\frac{\sin\pi(f-f_k)T_S}{\pi(f-f_k)T_S}\right]^2$$

The overall power spectral density of the modulated data cell carriers is the sum of the power spectral densities of all these carriers. A theoretical DVB transmission signal spectrum is illustrated in figure 2 (for 8 MHz channels). Because the OFDM symbol duration is larger than the inverse of the carrier spacing, the main lobe of the power spectral density of each carrier is narrower than twice the carrier spacing. Therefore the spectral density is not constant within the nominal bandwidth of *7,608 259* MHz for the 8K mode

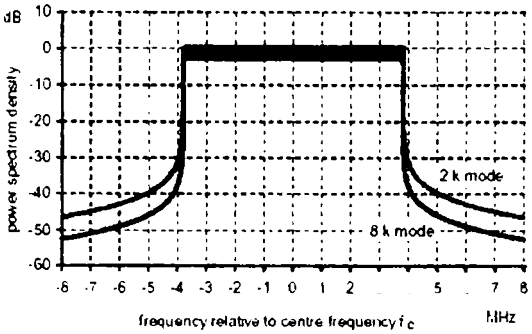

Fig. 2 The theoretical OFDM signal spectrum

III SIMULATED SYSTEM

We have implemented in Simulink the DVBT transmitter and receiver system. We didn't include in our model the synchronization block. We used the following parameters for DVBT system: ½ code rate for the convolutional coder, $\Delta/T_u=1/4$, 16 QAM modulation and 2k mode for OFDM signal. For radio transmission we used an AWGN channel model combined with an multipath Rayleigh fading channel.

We have 1704 carriers with only 1512 useful carriers. The symbol period is $T_s=280\mu s$. In every symbol we have 1512 useful carriers and 4 bits per carrier (one 16QAM symbol). We have a convolutional code with rate ½ and a Red Solomon code with the ratio 204/188. It results that the useful information rate is $r_D=4/2*188/204*1512*10^6/280=9{,}9529$ Mbiţi/s.

In a superframe (4 frames of 68 symbols each) there is an integer number of Red Solomon block (204) so there is no need for bit stuffing.

The spectrum of the simulated 2k OFDM signal is given in figure 3 and time representation in figure 4.

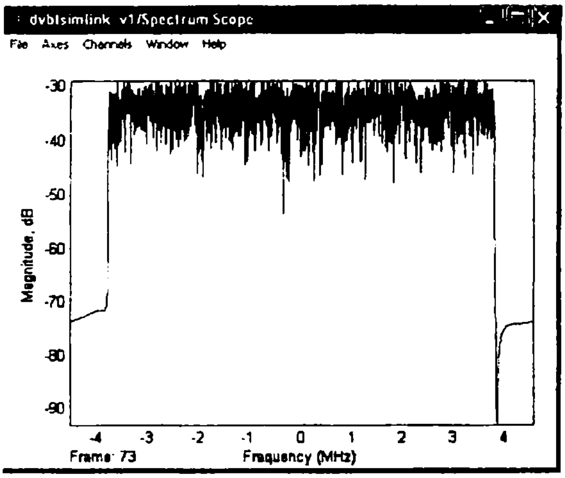

Fig. 3 The simulated OFDM signal spectrum

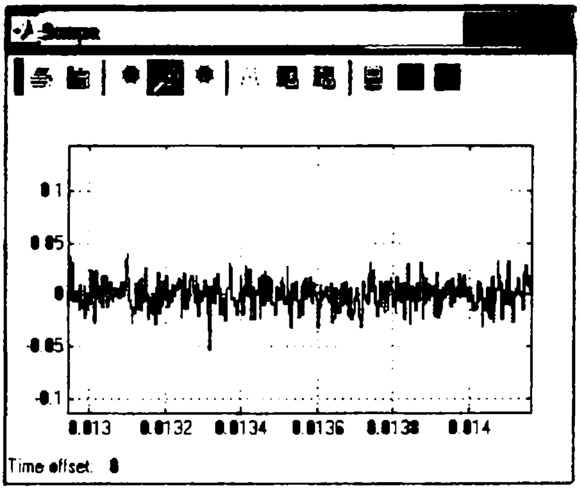

Fig. 4 The OFDM signal time representation

We can see that the that we have a relatively large peak to average power ratio which brings disadvantages like increased complexity of the A/D and D/A converters and reduced efficiency of the RF amplifier.

In figure 5 it is presented the received 16 QAM constellation

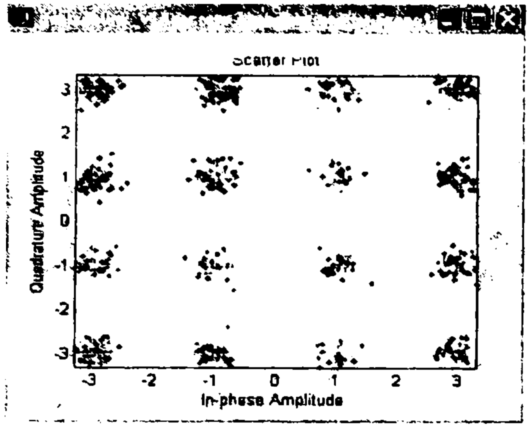

Fig. 5 The received 16 QAM constelation

We have simulated the system behavior for different S/N ratios. The resulted BER is presented in the diagram in the figure 6.

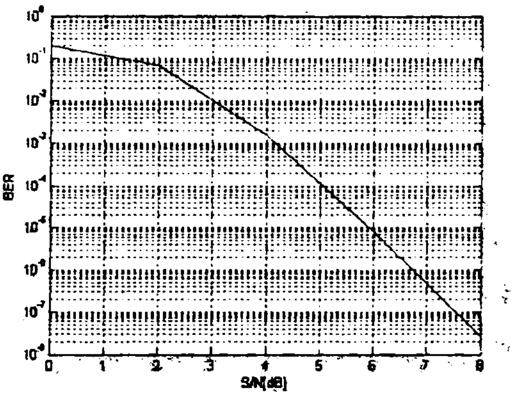

Fig. 6 BER(S/N)

V. CONCLUSIONS

We have implemented in Simulink an DVBT communications system and we have analyzed its performance for 2k mode and 16 QAM modulation. We intend to complete the model by implementing also the 8k mode, and the 64QAM and QPSK modulations.

We intend to adapt this system for the DVBH (DVB for mobile communications) standard. The DVB system performance study permits the

REFERENCES

[1] ETS 300 744, "Digital broadcasting systems for television, sound and data services; framing structure, channel coding, and modulation for digital terrestrial television,. *European Telecommunication Standard*, Doc. 300 744, 1997.

[2] R. V. Nee and R. Prasad, *OFDM Wireless Multimedia Communications*, Norwood, MA: Artech House, 2000.

[3] J. A. C. Bingham, "Multi-carrier modulation for data transmission: An idea whose time has come", *IEEE Communications Magazine*, vol.28, no. 5, pp. 5-14, May 1990.

[4] A. V. Oppenheim and R. W. Schafer, *Discrete-Time Signal Processing*, Englewood Cliffs, NJ: Prentice Hall, 1989

[5] Yiyan Wu, William Y. Zou, "Orthogonal Frequency Division Multiplexing: A Multi-Carrier Modulation Scheme", *IEEE Transaction on Consumer Electronics*, Vol. 41,No. 3, August 1995, pp. 392 - 399

[6] William Y. Zou, Yiyan Wu, "COFDM: An Overview , *IEEE Transactions onBroadcasting*, Vol. 41, No. 1, March 1995, pp. 1 - 8

[7] R. R. Mosier and R. G. Clabaugh, "Kineplex, a bandwidth-efficient binary transmission system", AIEE Transactions, Vol. 76, January 1958,

[8] Robert Chang, "Synthesis of Band-Limited Orthogonal Signals for Multichannel Data Transmission", The Bell System Technical Journal, December 1966, pp. 1775 -1796

[9] Robert Chang, "Orthogonal frequency division multiplexing", US. Patent 3,488445, filed November 14, 1966, issued January 6, 1970

[10] S. B. Weinstein, Paul M. Ebert, "Data Transmission by Frequency-Division Multiplexing Using the Discrete Fourier Transform", IEEE Transactions on Communication Technology, Vol. COM-19, No. 5, October 1971, pp. 628 - 634

[11] Carl Magnus Frodigh, Perols Leif Mikael Gudmundson, "Adaptive channel allocation in a frequency division multiplexed system", US. Patent 5,726,978, June 22, 1995, Issued: March 10, 1998

[12] S. O'Leary, F. Ryan, B. Wynne, and C. Gilliam, "Interactive digital terrestrial television—The wireless return channel and the EU sponsored WITNESS project," *IEEE Trans. Broadc.*, vol. 47, pp. 160–163, June 2001.

[13] R. Mhiri, D. Masse, and D. Schafhuber, "Synchronization for a DVBT receiver in presence of co-channel interference." *IEEE PIMRC-02*, (Lisbon, Portugal), Sept. 2002. submitted.

[14] P. Hoeher, S. Kaiser, and P. Robertson, "Two-dimensional pilotsymbol-aided channel estimation by Wiener filtering," in *Proc. IEEE ICASSP-97*, (Munich, Germany), pp. 1845–1848, April 1997.

[15] Y. Li, "Pilot-symbol-aided channel estimation for OFDM in wireless systems," *IEEE Trans. Veh. Technol.*, vol. 49, pp. 1207–1215, July 2000.

[16] M. Sandell, *Design and Analysis of Estimators for Multicarrier Modulation and Ultrasonic Imaging*. PhD thesis, Lulea University of Technology, Lulea, Sweden, 1996.