Companding Techniques for PAPR Reduction in DVB-T Systems

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***Abstract* — DVB-T (Digital Video Broadcast - Terrestrial) is the most widely used standard for terestrial digital television. One of the main drawbacks of the DVB-T system is the high PAPR (Peak to Average Power Ratio). One way to mitigate the high PAPR is by usig companding techniques. They introduce compression of the signal in the transmitter and expansion of the same signal in the receiver. This paper analyzes the effect of the companding techniques (μ-law and A-law companding) on PAPR reduction in DVB-T systems. The results obtained from the performance analysis can be used for better understanding of PAPR in DVB-T system and lead to development of new options in it's reduction.**

***Keywords* — BER, Companding techniques, DVB-T system, OFDM modulation, PAPR.**

I. INTRODUCTION

Television is the most basic and widely-used multimedia application ever. It has passed many transformations - from the first analog systems to the latest digital ones. New standards and technologies – led by a coalition of broadcasters, leading cellular operators, standardization bodies etc. have set the stage for terrestrial Digital Television (DTV) services. The DVB (Digital Video Broadcast) is the leading standard that provide digital video broadcast via different communication technologies.

The DVB-T (Digital Video Broadcast - Terrestrial) is defined as a Coded Orthogonal Frequency Division Multiplexing (COFDM) system. The OFDM (Orthogonal Frequency Division Multiplexing) modulation has many advantages: it is more bandwidth efficient, overcomes the effect of Inter Symbol Interference (ISI), combats the effect of frequency selective fading and burst errors. It also has some disadvantages: it is more sensitive to carrier frequency offset, suffer in presence of phase noise, have high PAPR (Peak to Average Power Ratio). Mitigating the high PAPR is especially crucial in OFDM systems. There are a couple of different methods for PAPR reduction: clipping reduction, soft reduction, coding techniques, techniques based on scrambling etc.

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The scope of this paper is to analyze the PAPR reduction in the DVB-T systems for 2k mode and 8k mode, by using different companding techniques. The paper concetrates on performance analysis of two companding techniques: μ-law companding and A-law companding (both are simple for implementation in DVB-T systems). Their implementation offer posibilities for improvements in development of more advanced versions of the DVB standards.

The paper is organized as follows. Section II gives a short overview of the standards and technologies of interest, DVB-T, OFDM, μ-law and A-law companding. Section III elaborates the related work for PAPR reduction. Section IV describes the simulation scenario, parameters and results obtained by simulation in Simulink®. Finally, Section V concludes the paper.

II. STANDARDS & TECHNOLOGIES

This section gives brief overview of the DVB-T standard, OFDM Modulation, PAPR and μ-law and A-law companding.

A. DVB-T Standard

DVB (Digital Video Broadcast) Project (officially formed in September 1993) is a market-led consortium of public-sector and private-sector organizations in the television industry, which are committed to design global technical standards for the delivery of digital television. The first phase of the DVB work involved establishment of standards that enable the delivery of digital TV to the consumer via the "traditional" broadcast networks: satellite (DVB-S), cable (DVB-C) and terrestrial (DVB-T), as well as DVB-H (DVB Handheld). The second generation of standards includes DVB-S2, DVB-T2, DVB-C2 and it represents an extension of the first generation.

The DVB-T system is defined as the functional block of equipment performing the adaptation of the baseband TV signals from the output of the MPEG-2 transport multiplexer, to the terrestrial channel characteristics [1]. The following processes are applied to the data stream, as shown on Fig.1: transport multiplex adaptation and randomization for energy dispersal; outer coding (i.e. Reed-Solomon code); outer interleaving (i.e. convolutional interleaving); inner coding (i.e. punctured convolutional code); inner interleaving (either native or in-depth); mapping and modulation and OFDM transmission. The DVB-T system is based on OFDM. Two modes of

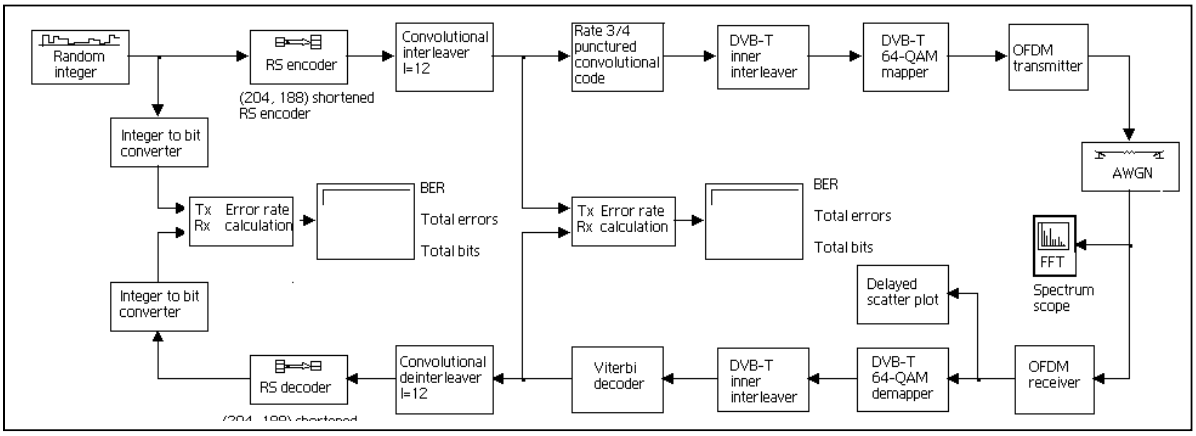

Fig. 1 Simulink model of a DVB-T system

operation, a "2K mode" (2048 carriers) and an "8K mode" (8192 carriers), are defined for the DVB-T transmissions.

B. OFDM, PAPR

OFDM is a special form of Multi Carrier Modulation (MCM). In this technique, the high-rate serial data-stream is converted to low-rate parallel data-streams in the transmitter side. Also the available channel bandwidth is divided into a number of sub-channels where each sub-channel is nearly ideal and orthogonal to others. The low-rate data-streams are modulated to a given set of sub-channels on different frequencies simultaneously [2].

One major drawback of OFDM is its high PAPR. Large PAPR means large amplifier backoffs, which reduces power efficiency of the Radio Frequency (RF) amplifier. Another disadvantage of PAPR is that it increases the complexity of the Analog to Digital and Digital to Analog convertors. For sampled signal, PAPR is defined:

$$PAPR = \frac{\max |s_n|^2}{E\left[|s_n|^2\right]} \qquad (1)$$

where s_n is the sampled signal, $\max|s_n|^2$ is the maximum power of the transmitted signal and $E[|s_n|^2]$ is the average power of the transmitted signal, [3].

C. μ-law companding, A-law companding

Companding techniques are signal processing techniques that compress the signal on the transmitter side and expand it on the receiver side. They are commonly used in systems where higher resolution for lower amplitude signals and lower resolution for higher amplitude signals must be provided.

The μ-law companding generaly is used in digital telephone systems of USA and Japan. μ -law compression, according to this standard is defined as:

$$F(x) = \operatorname{sgn}(x)\frac{\ln(1+\mu|x|)}{\ln(1+\mu)} \qquad -1 \le x \le 1 \qquad (2)$$

where μ is parameter of compression (μ =255 for USA and Japan), and x is normalized value of the input signal.

The A-law companding is recommended standard by Comite Consultatif International Telephonique et Telegraphiques (CCITT), which is used in digital telephone systems across Europe. Compression in this standard is defined with:

$$\begin{aligned} F(x) &= \frac{\operatorname{sgn}(x)A|x|}{(1+\ln A)} \qquad 0 \le |x| \langle 1/A \\ &= \operatorname{sgn}(x)\frac{(1+\ln A|x|)}{(1+\ln A)} \qquad 1/A \le |x| \le 1 \end{aligned} \qquad (3)$$

where A is the compression parameter (A =87.6 in Europe), and x is the normalized value of the input signal.

The μ -law and A-law expansions are defined with inverse functions of (2) and (3).

The purpose of this paper is to describe the implementation of these two types of companding in the basic DVB-T system, their roll in PAPR reduction, as well as the influence on the performance parameters.

III. Related work

There are number of papers in the literature that propose PAPR reduction. They are applied to various systems, which are based on OFDM modulation. Authors in [3] analyze and consider the effects of the clipping method for PAPR reduction. Clipping method is a simple method with minimal computing complexity that only cuts off the amplitudes which are above a certain threshold. The work presented in [4] includes soft compression method in a simplified version of the DVB-T system. The implementation of this method, as well as of the previous one, is only on the transmitter side. Authors in [5] propose a companding transform scheme, which compresses large signals while enhancing small signals, for efficient reduction of PAPR in OFDM signals. The proposed method achieves a significant reduction of PAPR. The work done in [6] shows the influence of Forward Error Correction (FEC) on the OFDM channel bandwidth. It is presented that companding together with FEC coding results in a further improvement in the Bit Error Rate (BER) performance and provides further reduction in PAPR, albeit the reduction is not significant. In [7] the improvement on BER performance and PAPR, due to the companding techniques, is studied and it is compared with the performance due to clipping within OFDM transmissions.

This paper analyzes the impact of the μ and A companding law in terms of PAPR reduction in DVB-T system. The latest version of digital terrestrial standard, DVB-T2, has incorporated PARP method [8].

All aspects of the simulation scenario are elaborated in the following section.

IV. Simulation Analysis

This section compares and analyzes the performances of the DVB-T system in terms of the PAPR reduction for two companding techniques: μ-law and A-law. Two modes of DVB-T system are studied and simulated: 2k mode and 8k mode.

A. Simulation platform

The simulation analysis in this section is performed in Simulink, which is integrated with MATLAB R2009b, [9]. Simulink is a platform for multi domain simulation and model-based design of dynamic systems. It provides an interactive graphical environment and customizable set of block libraries that enable to accurately design, simulate, implement and test control, signal processing, communications, and other time-varying systems.

The used model simulates part of ETSI EN 300 744 standard [1] for transmission of terrestrial digital television signals. The existing demo presents DVB-T system in 2k mode (2048 carriers) with nonhierarchical transmission. This model contains the following blocks: data source-random integer, RS encoder/ decoder, convolutional interleaver/ deinterleaver, punctured convolutional code/ Viterbi decoder, Inner interleaver/ deinterleaver, 64 Quadrature Amplitude Modulation (QAM) mapper/demapper, OFDM transmitter/ receiver and Additive White Gaussian Noise (AWGN) channel, as presented in Fig.1.

In this paper additional modifications are made on the Simulink model (which is designed only for 2k mode of DVB-T system) to simulate the 8k mode. The changes affect the data stream structure of all blocks [10].

The implementation of both companding techniques for PAPR reduction in the DVB-T system is done in a similar manner. The companding process is given in Fig.2. The signal in the time domain is divided into a real and imaginary part. The process of compression is done separately for the real and the imaginary part of the signal. Afterwards the real and the imaginary part are converted into a complex signal, which is transmitted in the channel. On the receiver side all steps are repeated before the OFDM receiver, whereas an expansion is performed instead of compression.

B. Parameters

In order to evaluate the performance of the DVB-T systems in terms of the proposed comanding techniques, the Bit Error Rate (BER) is used as the main metric.

The AWGN channel in the model given in Fig.1, allows the signal to be transmitted from the transmitter to the receiver. The typical values of the Signal to Noise Ratio (SNR) for an AWGN channel in a DVB system simulation vary between 5 and 30 [4].

The companding techniques aim to decrease the ratio between the maximum and the minimum values of the signal. The PR (companding profile) [8] is the main metric that defines the commanding technique behavior. PR is defined as the ratio between the peak value of the compressor V, and the peak value of the input signal P(s):

$$PR = \frac{V}{P(s)} \tag{4}$$

In this paper two different PR are used (PR=*1* and PR=*2*) for the PAPR reduction in the DVB-T system. When PR=*1*, smaller amplitudes of the signal are amplified and the peaks remain the same. In the case when PR=*2*, both, the peaks and the smaller amplitudes are amplified. The smaller amplitudes will have much greater amplification in comparison to the peak values.

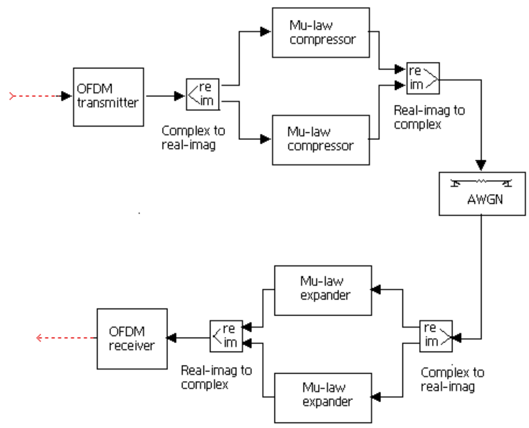

Fig.2 Realization of μ-law companding technique in DVB-T system

C. Simulation results

The simulation analysis investigates the BER performance of the DVB-T system when different commanding techniques and profiles are used. The BER performance of the μ-law companding technique in dependence of the SNR, for both 2k and 8k modes is depicted in Fig.3. The performance of the plain DVB-T system is almost identical for both, 2k and 8k modes. It is evident that the system for PR =*1* has worse performance than the plain DVB-T system, while for PR=*2* the system introduces noticeable improvements in terms of the BER.

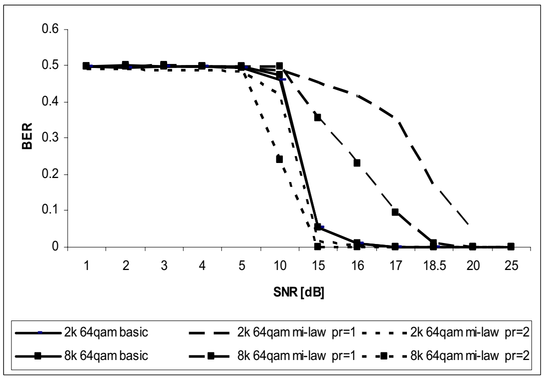

Fig.3 μ-law companding in DVB-T system in 2k and 8k mode

Fig.4 presents the effects of the A-Law companding technique on PAPR reduction in 2k and 8k DVB-T system. In first case for PR=*1*, the BER is increased in both modes (2k and 8k). In case when PR=*2*, there is a performance improvement for both models i.e. BER is reduced. It should be noticed that in the system with more carriers (8k), the improvement is more significant.

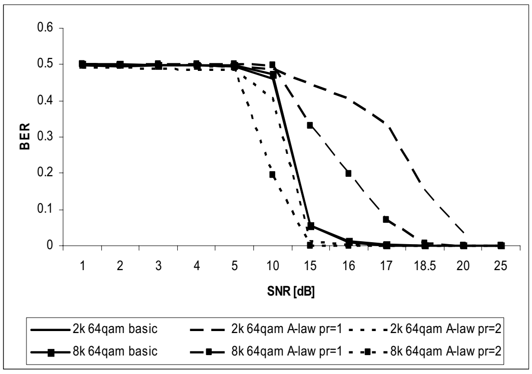

Fig.4 A-law companding in DVB-T system in 2k and 8k mode

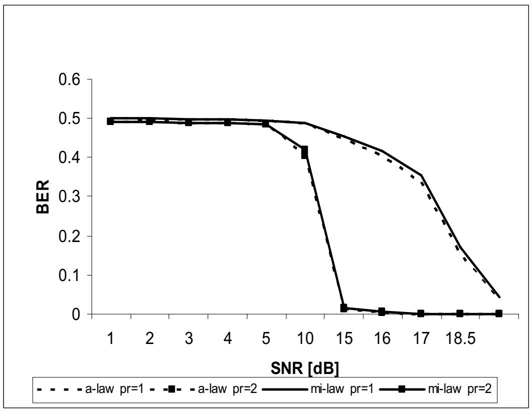

Fig.5 μ-Law companding vs. A-Law companding in 2k DVB-T system

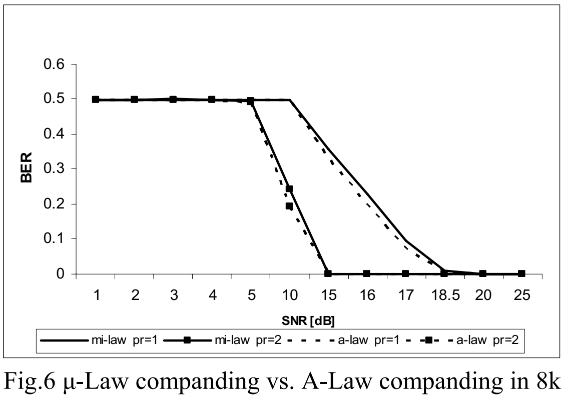

Fig.6 μ-Law companding vs. A-Law companding in 8k DVB-T system

A comparison of the BER performances of the two companding techniques is given in Fig.5 and Fig.6. Both companding profiles are taken into consideration: PR=*1* and PR=*2*. The obtained results are very similar for the 2k DVB-T and for the 8k DVB-T system. Both companding techniques give almost the same error probability in all cases, with a slight advantage of the A-Law companding method.

V. CONCLUSIONS

DVB-T is the leading standard for digital terrestrial television. One of its biggest drawbacks is its high PAPR that reduces the efficiency of the receiver. There are a number of techniques for PAPR reduction. This paper proposes the implementation of the μ-Law and A-Law companding techniques for the PAPR reduction.

The results in the paper show that the performances of μ-Law companding and A-Law companding technique for PAPR reduction largely depend on the companding profile, PR. When PR=*1* the companding techniques have worse BER performance in comparison to the plain DVB-T system. When PR is larger than *1*, the companding techniques introduce performance gain (lower BER) in comparison to the plain DVB-T system. The commanding techniques have better performance gain for the 8k mode, where the decrease of the BER is larger in comparison to the 2k mode. The utilization of the companding techniques can lead to decreased BER for the right choice of the companding profile. The A-law companding technique gives slightly better results than the μ-Law companding technique.

The main advantage of the proposed companding techniques is their low complexity and its simple implementation, while providing better performance of the DVB-T system.

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