

Performance Improvement in OFDM System with Interleaving and Blanking over Impulse Noise Environment

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Abstract— OFDM is a relatively new way to the field of digital communication but is finding more and more use due to its high spectral efficiency and robustness against interfering signal. Impulse noise is one of the major factors that can cause severe bit error performance degradation in OFDM systems. The impulse noise is usually of very short duration compared to symbol duration in parallel transmission. For both wired and wireless transmission, the frequency-selective fading is another significant source of disturbances for OFDM applications. The presence of these types of disturbances cause reliable communication difficult and also affects all the sub carriers in a symbol due to the Fast Fourier Transform operations at the receiver. TDI in conjunction with a two-level threshold-based blanking scheme is used to combat the effects of multipath propagation as well as IN. For the better performance of the system interleaving is used before and after the IFFT operation. An OFDM system with 64 qam modulation is considered. Gated Gaussian model is considered as the impulse noise model and compared the performance of different equalizers.

Keywords— OFDM, Impulse noise, FFT, IFFT, Interleaving.

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is also called multi-carrier modulation scheme. OFDM is also used for wireless local area network and many other modern applications. OFDM used in various applications due to its high spectral efficiency, robustness against interfering signal and to a great extends in avoiding multipath problems [17]. OFDM is also used for W-LAN, next generation mobile radio systems, Digital audio and video broadcast etc., One of the challenging problems in practical applications of digital communication techniques is reliable data transmission over wireless links in spite of man-made noise interference typical in urban environments [2]. The man-made noise created by power lines, heavy current switches and other sources cannot be assumed to be Gaussian, and must be represented by impulsive models. Noises in communications are summarized into two

major types, Impulsive Noise and Background Noise.

OFDM systems are inherently robust to impulsive interference. This interference becomes disadvantage when impulsive noise energy exceeds a certain threshold [4]. The impulse noise could occur due to several reasons such as circuit failure, power switching, and erasure channels [5]. In OFDM systems, impulse noise turns out to be much more catastrophic than the AWGN due to the FFT operation at the receiver, which spreads the impulse noise and thereby severely corrupts the entire symbol [6]. Another important factor that can cause severe bit error rate reduction in the system is the presence of frequency selective fading. This will affect the system and difficult to demodulate the data correctly. Linear precoding techniques are one of the most important techniques that have been extensively used to improve the conventional OFDM system performance by exploiting the multipath channel frequency diversity. These techniques have shown a remarkable improvement in the performance of the OFDM systems over multipath fading channels. In this technique, total number of subcarriers is split into small blocks and spread the data symbols over these blocks by using unitary matrices in order to gain frequency diversity over each block. Unfortunately, this improvement comes at the cost of an increase in system computational complexity. Moreover, these techniques have failed to show an improvement over the impulsive noise environment, which forms another source of disturbance for many digital communication systems. Due to the long symbol time of the OFDM signal, it is more robust against

the impulsive noise effect than the single carrier transmission.

Different approaches for impulse noise suppression are proposed. A simple method of reducing the adverse effect of impulsive noise is to precede a conventional OFDM demodulator with memory less nonlinearity [8, 9]. But these traditional methods provide unsatisfactory system performance improvement. A completely different approach is considered here to remove impulse noise in OFDM system. A time domain interleaving (TDI) technique in conjunction with threshold based blanking scheme is utilized to improve the OFDM immunity over multipath fading channels impaired by impulsive noise without a sacrifice in bandwidth or an increase in the transmit power[1]. For the better performance of the system, interleaving is applied before and after IFFT at the transmitter. And this will reduce the bit error rate of OFDM system.

The paper is organized as follows. Section II briefly reviews OFDM systems and Section III described the proposed scheme.

II. OFDM SYSTEM WITH INTERLEAVER

OFDM uses a subcarrier-based communication concept where the subcarriers are orthogonal to each other over the sample period. This is possible when carriers are harmonic of each other. In this system, each of the subcarriers carries a part of the message and together they deliver the entire message. The mutual orthogonality of subcarriers help in achieving superior performance of OFDM. 64-QAM is used for highest data rate. Normally, interleaver is used before the IFFT operation. For better performance of the system interleaver is used before and after the IFFT operation. Interleaver means it rearranges the order of the sequence and de-interleaver will reconstruct the same order. Hence this interleaver will reduce the error rate in the system and improve the system performance.

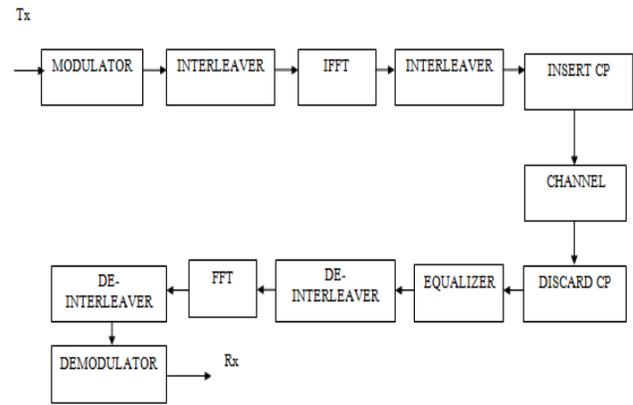


Fig 1. OFDM system with interleaving

Fig 1 shows the OFDM system used. Multi-carrier modulation is a method of transmitting data by splitting it into several data's, and sending each of these components over separate carrier signals [14]. After modulation interleaver is used to interleaves the QAM modulated data streams. Interleaver means it rearranges the order of the sequence and de-interleaver will reconstruct the same order. Hence this interleaver will reduce the error rate in the system and improve the system performance. In OFDM systems a high-speed serial data stream is split into a number of parallel slow data streams. These data streams are carried in multiple orthogonal subcarriers by means of Inverse Discrete Fourier Transform. Add all symbols and transmit together.

Technique used here is based on interleaving, in conjunction with a two-level threshold-based blanking scheme to combat the adverse effects of multipath propagation as well as IN for OFDM based communications systems. Unlike traditional interleaved single carrier and OFDM systems where the information symbols are spread over a larger number of transmission blocks the TDI system interleaves the time domain samples after the IFFT which are composed of a mixture of all information symbols. This results in a significant improvement in uncoded BER that can never be achieved with conventional interleaving. Proposed blanking scheme in conjunction with TDI enables the proposed system to efficiently combat IN even in frequency-selective channels.

III. IMPULSE NOISE MODEL

The Gated Additive White Gaussian Noise model is often used to simulate the impulsive noise. The additive noise is composed of two parts. The first one is characterized as a Gaussian process with zero mean and variance σ_g^2 . The second part is characterized as a Gaussian process with zero mean and variance σ_i^2 , modulated by a signal [17]. Fig.2 shows the block diagram of the system used to simulate the noisy components.

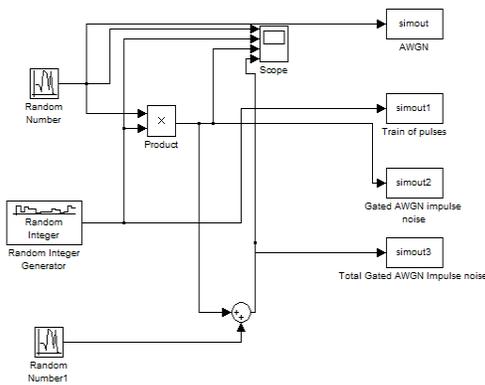


Fig 2. Simulink diagram of the noise simulator GAWGN

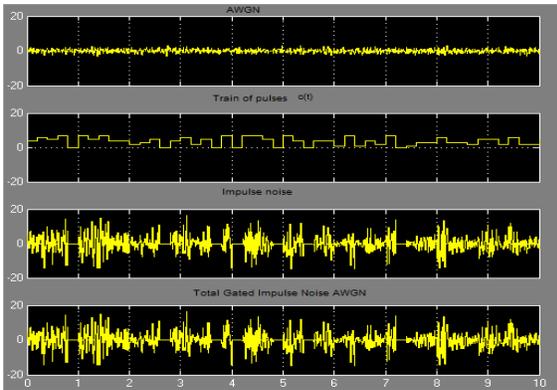


Fig 3. Waveforms of Gated Gaussian model

Fig 3 shows the Waveform of gated AWGN noise components. The modulating signal is used in this analysis to characterize the addition of noise. Random variations in the amplitude of the modulating signal alter the variance of the Gaussian noise modulated. It can be observed in Fig 3 that for the instants in which $c(t) = 0$, the noise continued to attack the signal. When $c(t)$ takes non-zero values

and modulates the noise. The amplitude modulated signal can attack the signal during the time of one or several symbols.

IV. TDI BLANKING

An efficient solution to mitigate the effects of impulse noise is to apply blanking, where the received samples with high amplitudes are set to zero. The contaminated samples are detected and suppressed by comparing the received samples values with a particular threshold, T_1 . Hence, the output of the blanking nonlinearity is,

$$K_n = \begin{cases} y_n & y_n < T_1 \\ 0 & \text{Otherwise} \end{cases}$$

Where y_n is the received sample. The sample blanking threshold T_1 should be selected to minimize the BER. Additional threshold T_2 is considered for the better performance of impulse noise mitigation scheme. T_2 denotes the number of samples with amplitudes larger than T_1 . In each symbol, if the number of samples with $|Y_n| \geq T_1$ exceeds T_2 , the entire symbol is considered corrupted and is blanked subsequently. This approach is called symbol blanking.

V. RESULTS

MATLAB software was utilized for the simulation. The OFDM system considered here has $N=128$. All data symbols are QAM modulated. The channel is assumed to be time invariant. Fig 4 shows the transmitted OFDM signal. Constellation plots are utilized to identify the effect of distortions in the system.

In the simulation, the noiseless time-domain signal is transmitted through an impulse noise channel or an AWGN channel at 25 dB SNR in combination with impulse noises. Here assume a OFDM system with QAM-64. Fig.5 shows a FFT constellation using QAM-64 modulation scheme without any noise.

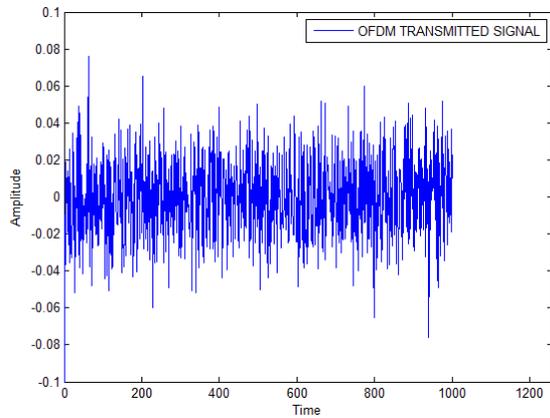


Fig 4 Input Signal

In presence of channel noise and various channel effect such as erasure and fading, the received time domain signal is a noisy version of the original signal. Due to their distinct features, the AWGN and the impulse noise manifest themselves distinctly at the output of the DFT unit at the receiver. Fig 2 shows the signal which is added by the impulse noise. By comparing the amplitude of signals shown in Fig 4 and 6, we can identify the effect of impulse noise

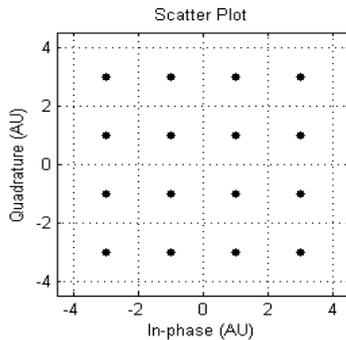


Fig. 5 FFT constellations without noise

The simulation of FFT constellation plot shows that the output signals of the DFT are randomly scattered around the modulation symbols, this is shown in Fig.7. It is seen that severe noise affects all output constellation Points. Hence mitigation of impulse noise and fading is necessary. Mitigation of impulse noise is carried out by interleaving in conjunction with two-threshold based blanking. Fig 8 shows the effect of blanking non-linearity.

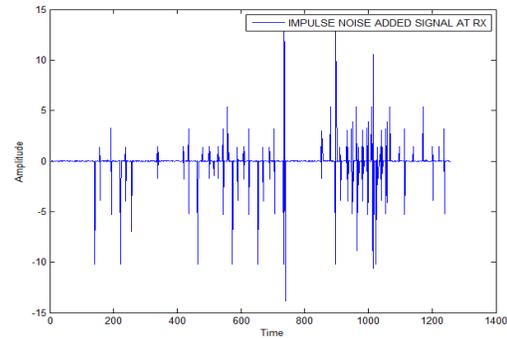


Fig 6. Impulse noise added signal

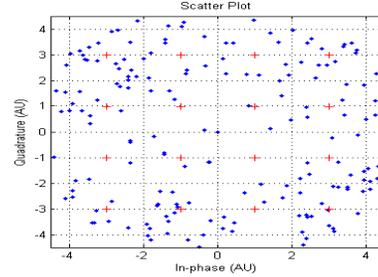


Fig .7 FFT constellations in presence of impulse noise.

Fig 8 shows that the most of the noises are removed, and it is easy to demodulate and significantly facilitates the succeeding error control decoding. Fig 9, shows the effect of impulse noise and fading, and compares the bit error rate of OFDM without noise, OFDM with blanking, interleaving and blanking method. The performance of OFDM without impulse noise is shown in the figure as the base line. Blanking method is carried out by comparing signal with the threshold values. In general, OFDM has poor performance in impulse noise channels.

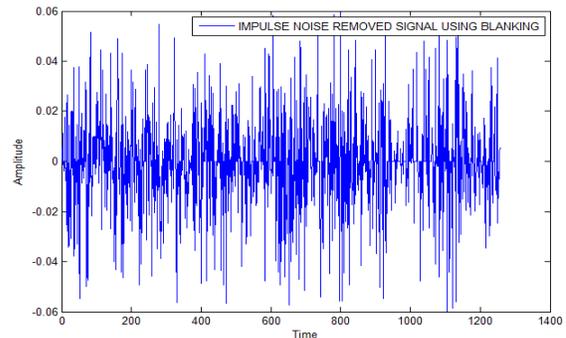


Fig 8. Signal at the receiver after Blanking non-linearity

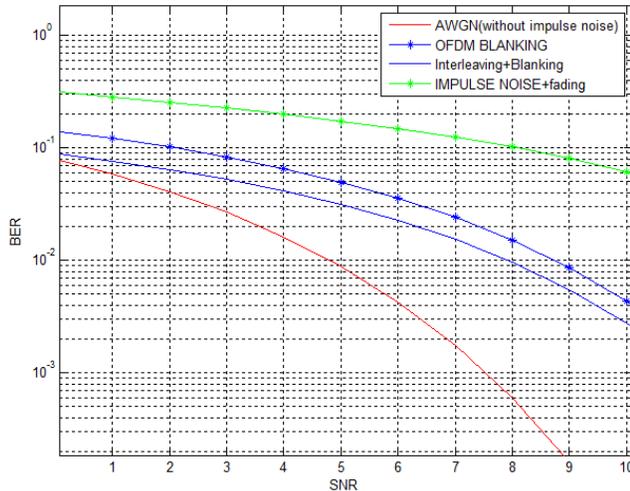


Fig 9. Bit error rate performance of the OFDM system

In standard OFDM system interleaving is used before IFFT in the transmitter part and de-interleaving is used after FFT block in the receiver part. By comparing these systems, standard OFDM system has high bit error rate. This is due to the presence of Impulse noise in the OFDM system. To improve the performance of the system, interleaving is used before and after IFFT. The bit error rate performance this system is shown in Fig 10. The results clearly shows that the interleaving surely outperforms the other considered systems.

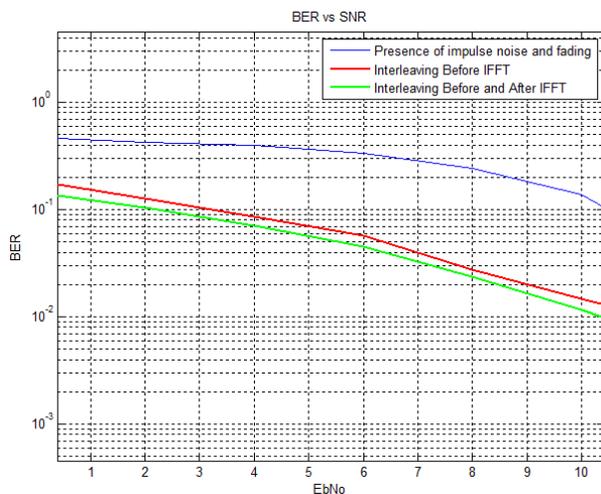


Fig 10: Bit error rate performance of proposed system

The performance of the OFDM system has been enhanced without sacrificing bandwidth or increasing transmits power. This enhancement was achieved by exploiting the time diversity which is

ensured by the use of a block interleaver of depth N samples positioned after the IFFT process at the transmitter and a block deinterleaver located after the equalization process at the receiver. A blanking process has been proposed to suppress the enhanced noise and improve the overall system performance. The use of the interleaver breaks the correlated behaviour of the multipath fading channel, and spreads the impulsive noise samples over the impulse free OFDM symbols as well. The Interleaving-OFDM system used before and after IFFT has shown a substantial improvement in BER performance over different channels.

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