Impulsive Noise Reduction in OFDM Transmission with 256 QAM Modulation Scheme

Prashant Gupta
Department of Electrical Engineering
Jabalpur Engineering College Jabalpur, India

Abstract— The high data rate Orthogonal Frequency Division Multiplexing (OFDM) with high spectral efficiency and its ability to soften the possessions of multipath makes them appropriate in wireless application. Impulsive noise twists the OFDM transmission and thus methods must be explored to conquer this noise consequence. Various efficient impulsive noise reduction schemes are already proposed for low order modulation and higher order modulation such as QPSK, 16QAM and 64QAM. In this paper, impact of Middletons Class A man-made noise is simulated and reduced in OFDM transmission by using 256 QAM modulation scheme.
Key words: OFDM, Impulsive Noise, 256QAM, Class A noise, Middletons Class A noise

I. Introduction

Orthogonal Frequency Division Multiplexing (OFDM) is a digital signal modulation technique that breaks the high data rate modulated stream into several slow modulated narrowband close spaced subcarriers. It is also less sensitive for frequency selective fading. Thus OFDM technique is effectively executed in the cellular communication standards like LTE / LTE-A, Wi-MAX, etc. and likewise entranced much consideration in past decades. Digital Audio/Video TV guidelines have additionally embraced OFDM making it suitable for high information throughput.

The Operation of OFDM is normally degraded by the impulsive noise. Impulsive noise is a non-Gaussian noise and has terrible impact in OFDM communication. Due to the wide frequency component of multiple impulsive noise, the OFDM system's performance is corrupted. Research scholars are examining the solutions for modifying this type of noise, and consequently enhancing systems performance in terms of mean square error and bit error rate. Numerous methods are conveyed in literature which effort to overpower the effect of impulsive noise on original transmitted signal [7].

The median filter is the conventional method for elimination of impulsive noise, this method lefts the noisy effect in signal [4]. Clipping and Nulling are some other impulsive noise suppressing techniques [5], [8]. The combined effect of clipping and nulling improves the Bit Error Rate (BER) performance metric in OFDM systems [9]. The multiple impulsive noises in received OFDM signal can be removed by sample replacement algorithm [6]. The replica signal subtraction method is used to resolve the problem of impulsive noise arises between the OFDM samples in time domain [10]. The iterative manner for impulsive noise reduction method generates the replica of impulsive noise and subtracted from the received OFDM signal [11]. For high data rate of 64QAM based OFDM transition, impulsive noise reduction algorithm is proposed in [12]. This paper proposed impulsive noise reduction technique which is better than conventional methods for 256QAM based OFDM transmission.

Remaining sections of this paper is organized as: Section II briefly explains the principle of OFDM model, Section III reviews the impulsive noise, Section IV explains about proposed method followed by MATLAB simulation results of proposed method in Section V. At the end section VI concludes the paper which is followed by acknowledgement and the references.

II. OFDM Model

Orthogonal Frequency Division Multiplexing (OFDM) is a multicarrier modulation scheme, in this scheme transmission is done over a dispersive channel. The conventional block diagram of OFDM model is shown in figure 1. OFDM splits the high data rate streams into low data rate streams in parallel and modulated separately on different orthogonal sub-carriers. Input bit stream data is passed through fast error correction (FEC) encoder. Encoded data stream is then modulated, here deferent modulation methods can be used like QPSK, DQPSK, 8QAM, 16QAM, 64QAM, etc. The introduction of EFC encoder insertion and cyclic redundancy at the transmitter reduces the complexity to only Fast Fourier Transform (FFT) processing on the receiver side. These subcarriers are multiplexed and passed through the channel, which is responsible for adding impulsive noise and white Gaussian noise in the transmitted OFDM signal. At the receiver end, the signal is demodulated and passed through the adaptive filter block for impulsive noise reduction in the OFDM signal [4-6, 10].

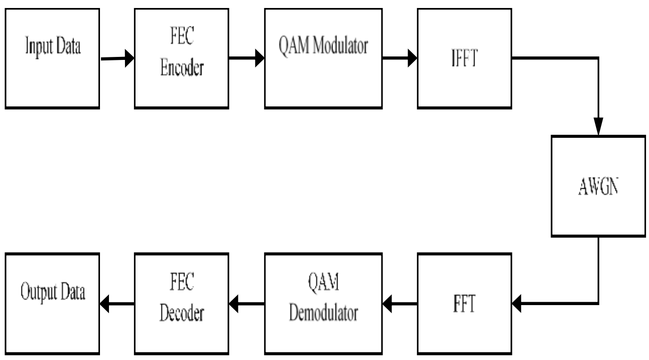

Fig. 1: Basic Model of OFDM Communication

III. Impulsive Noise

Broadly speaking, man-made interference can be 'intelligent' where the interfering signal carries meaningful information or 'unintelligent' where the interfering signal carries no (conventional) information. The latter includes partial discharge (PD), switching transients and combustion engine ignition noise. This work deals with 'unintelligent' interference having impulsive characteristics which may dominate close to a source of PD. Seminal work [2, 3] focusing on the realization of a tractable analytical model for combined man-made and natural radio noise serves following purposes:

1) It provides a realistic and quantitative description of man-made and natural electromagnetic (EM) interference,
2) It guides experimental protocols for the measurement of such interference,
3) It can be used to identify optimal communication systems and their performance comparison with the sub-optimal systems.

Middleton's three models (class A, B and C) are statistical physical models which include the non-Gaussian components of natural and man-made noise [3]. These models are canonical in nature i.e. their mathematical form is independent of the physical environment. The distinction between the three models is based on the relative bandwidth of noise and receiver.

Middleton Class A Model refers to impulsive noise with a spectrum that is narrow compared to the receiver bandwidth and includes all pulses which do not produce transients in the receiver front end [2]. Its probability density function (pdf), derived in [1], and is:

$$f_x(x) = e^{-A} \sum_{m=0}^{\infty} \frac{A^m}{m!\sqrt{2\pi\sigma_m^2}} e^{-\frac{x^2}{2\sigma_m^2}} \qquad (1)$$

$$\text{Where} \quad \sigma_m^2 = \frac{\frac{m}{A}+\tau}{1+\tau}$$

Middleton Class A Model refers to impulsive noise with a spectrum that is narrow compared to the receiver bandwidth and includes all pulses which do not produce transients in the receiver front end [2]. Its probability density function (pdf), derived in [1], and is:

$$f_x(x) = e^{-A} \sum_{m=0}^{\infty} \frac{A^m}{m!\sqrt{2\pi\sigma_m^2}} e^{-\frac{x^2}{2\sigma_m^2}} \qquad (1)$$

$$\text{Where} \quad \sigma_m^2 = \frac{\frac{m}{A}+\tau}{1+\tau}$$

is noise variance, A = v_tT_s is impulse index, v_t is mean impulse rate and T_s is mean impulse duration. Equation is a weighted sum of Gaussian distributions. By increasing impulse index, A, the noise can be made arbitrarily close to Gaussian and by decreasing A it can be made arbitrarily close to a conventional Poisson process. The model assumes that the individual impulses are Poisson distributed in time. Small values of A mean that the probability of pulses overlapping in time is small. Large values of A mean that this probability is large. In the latter case the central limit theorem can be invoked resulting a distribution that tends to Gaussian. The scale factor τ is the ratio of powers in the Gaussian and Poisson (non-Gaussian) components, i.e.:

$$\tau = \frac{X_G^2}{X_P^2} \qquad (2)$$

Middleton Class B Model refers to impulsive noise with a spectrum that is broad compared to the receiver bandwidth. Class B noise impulses produce transients in the receiver. Although it can accurately model a broadband impulsive noise environment its practical applications are limited because of the complicated form of its pdf which has five parameters [6] and an empirically determined inflection point [9].

Middleton Class C Model Class C noise is a linear sum of class A and class B noise. In practice class C noise can often be approximated by Class B [6].

IV. Proposed Method

Proposed algorithm to reduce impulsive noise in OFDM transmission for 256QAM modulation scheme is shown in figure 3. In figure 3, (a) show the proposed model and (b) shows the process of OFDN block which is implemented in (a). In this proposed model, r_k is received signal in time domain with additive impulsive noise, X_n is the FFT of r_k, which is equalized through zero forcing equalizer. Zero Forcing Equalizer (ZFE) is a form of Linear Equalizer which is used to restore the signal after the Channel. ZFE is the inverse of the channel frequency response of the channel. If the channel response of the channel is refereed as *F(f)* then the ZFE will be *C(f) = 1/F(f)*. Thus the combined effect of both channel and ZEF will be flat frequency response as *F(f).C(f) = 1*. Symbol $\hat{d}_n$ represent the equalized signal which is remapped to $\tilde{d}_n$ and then re-generate the signal $\tilde{s}_k$ by applying IFFT after multiplication of transfer function. Regenerated the time domain OFDM signal $\tilde{s}_k$ and received time domain OFDM signal r_k is now compared for each time samples 'k'. Deference signal $|r_k - \tilde{s}_k|^2$ is now compared with threshold value $R_T = 0.06 * (2\sigma^2)$ which is represented by $|r_m - \tilde{s}_m|^2 > R_T$, where r_m represents additive impulsive noise and m is time ample number. If impulsive noise is detected then r_m is replaced by $\tilde{s}_m$ and this process is performed iteratively till condition $|r_m - \tilde{s}_m|^2 < R_T$ satisfied for updated signal r_k. This process is sufficient to reduce the impulsive noise for low order modulation schemes like QPSK and 16QAM. But for higher order modulation scheme like 64QAM and 256QAM this process does not reduces satisfactory amount of impulsive noise. Till generation of signal $\tilde{s}'_k$ against the obtained signal by passing it through OFDM process again, is suitable for reducing impulsive noise for 64QAM modulation scheme. For 256QAM modulation scheme obtained signal $\tilde{s}'_k$ is again compared with threshold by condition $|r_m - \tilde{s}'_m|^2 > R_T$ and if impulsive noise is detected then r_m is replaced by $\tilde{s}'_m$ and process is performed iteratively till condition $|r_m - \tilde{s}'_m|^2 < R_T$. If noise is not detected then obtained signal is again passed through OFDM process and signal $\tilde{s}''_k$ is generated. Condition $|r_m - \tilde{s}''_m|^2 > R_T$ is tested again and sample r_m is replaced to the re-generated sample $\tilde{s}''_k$ for $|r_m - \tilde{s}'_m|^2 > R_T$ otherwise obtained signal is OFDM demodulated to final bit data.

V. Simulation Result

This section evaluates the proposed algorithm for reducing the additive impulsive noise under Class A noise environment. Algorithm is simulated in MATLAB platform. Simulation parameters for 256QAM based OFDM is shown in Table I. The parameters used for simulating impulsive noise are mentioned in Table II and it is illustrated in figure 4. Figure 5 and figure 6 shows the scatter plot of transmitted signal through 256QAM modulated OFDM and received signal. Figure 7 and 8 show its spectrums. BER comparison agents CNR (dB) for Gaussian noise, previous method and proposed method is shown in Table II as well as in figure 9.

VI. CONCLUSION

This paper proposes an impulsive noise reduction method under the impulsive multi-path channel. This method is evaluated under the Middleton's Class A noise environment for 256QAM modulated OFDM transmission scheme. A per the result analysis it is found that proposed method is much efficient than conventional methods to achieve better BER in high CNR environment.

VII. ACKNOWLEDGEMENT

Number of Sub-carriers (N)	1024
Modulation Scheme of Sub-carriers	256QAM
Carrier Frequency	80Hz
Channel Model	Two-Path Multi-path Channel
DUR (Desired to Undesired Ratio)	10 dB
Delay Time of Second Path	3.0 μs
Impulse Index (A)	0.01
Impulse to Gaussian Noise Ratio (τ)	0.01

TABLE 1: OFDM Simulation Parameters

Sampling Frequency (F)	10Hz
Total Time (T)	8000 s
Average Time between Samples (β)	1s
Mean of Log Amplitude (A)	10dB
Standard Deviation of Log Amplitude (B)	5dB
Mean of Additive Gaussian Noise (M)	0
Standard Deviation of Gaussian Noise (σ)	0.3

TABLE 2: Impulsive Noise Simulation Parameters

CNR(dB)	BER of Gaussian Noise	BER of Previous Method	BER of Proposed Method
0	0.4753	0.4521	0.4217
5	0.4471	0.3725	0.3047
10	0.4005	0.3078	0.2954
15	0.3471	0.2845	0.2412
20	0.2942	0.2047	0.1948
25	0.2413	0.1846	0.1035
30	0.1874	0.0258	0.0189
35	0.1351	0.0005	0.0002
40	0.0675	0.0001	0.00001
45	0.0112	0.00001	0.00001
50	0.0001	0.00001	0.00001

TABLE 3: CNR v/s BER of Gaussian Noise, Previous method and Proposed method

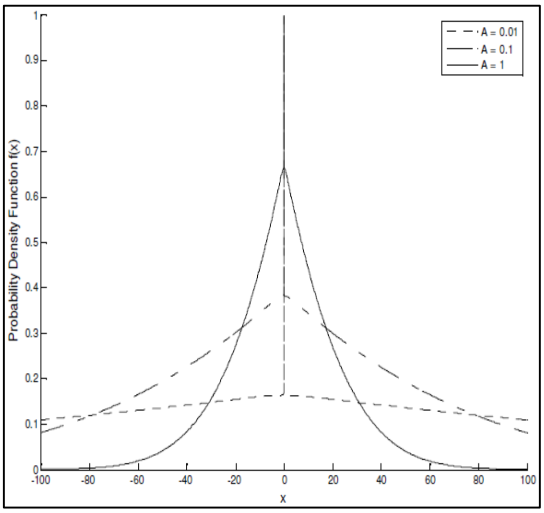

Fig. 2: shows the pdf of Middleton class A noise with various values of A for τ = 0.001.

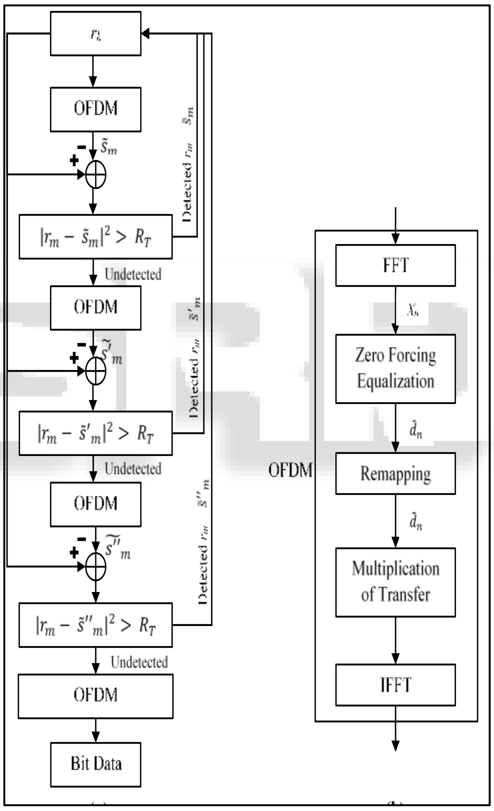

Fig. 3: Proposed Algorithm Block Diagram

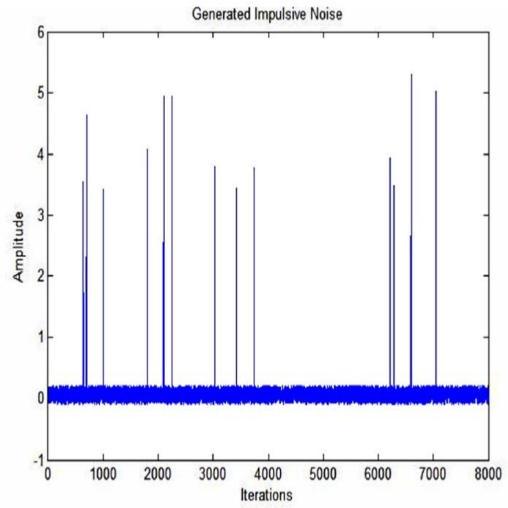

Fig. 4: Impulsive Noise Signal

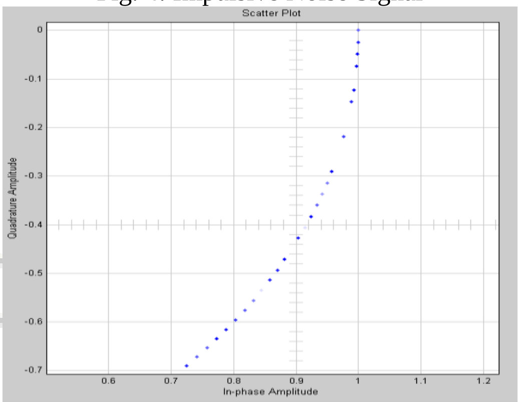

Fig. 5: Transmitted Signal Scatter Plot

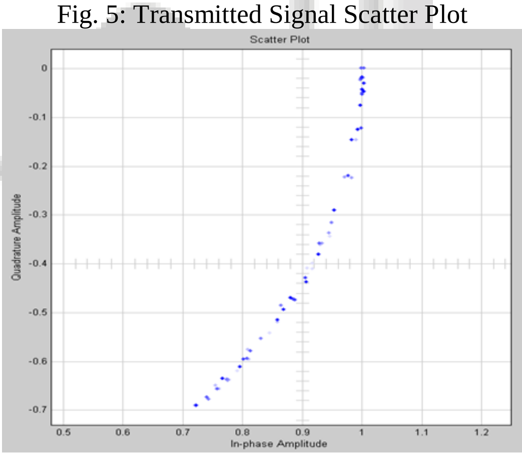

Fig. 6: Received Signal Scatter Plot

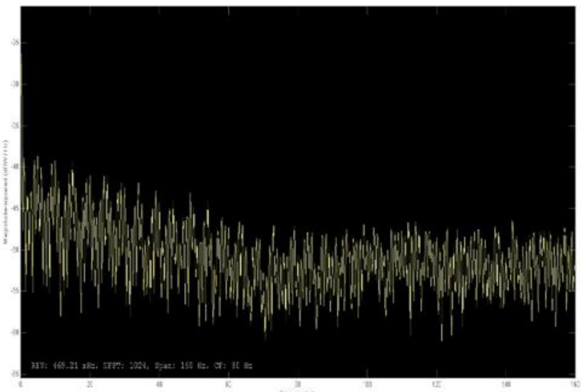

Fig. 7: Transmitted Signal Spectrum

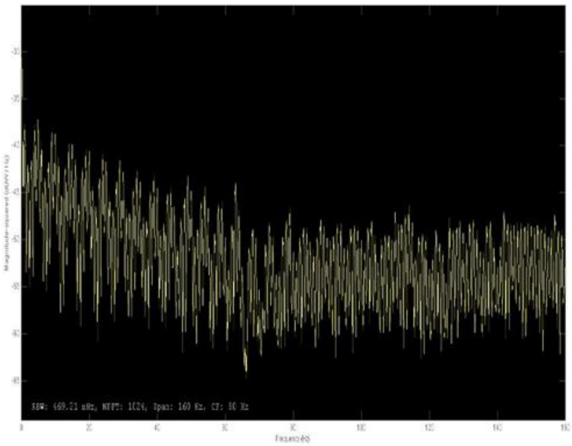

Fig. 8: Received Signal Spectrum

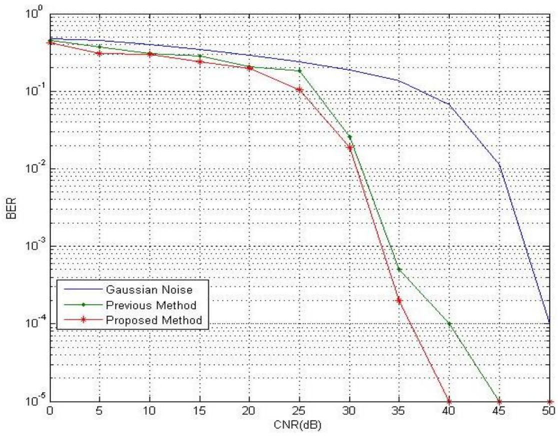

Fig. 9: BER characteristics against CNR

REFERENCES

[1] A. Spaulding and D. Middleton, "Optimum Reception in an Impulsive Interference Environment--Part I: Coherent Detection," Communications, IEEE Transactions on, vol. 25, pp. 910-923, 1977.

[2] D. Middleton, "Canonical and Quasi-Canonical Probability Models of Class A Interference," Electromagnetic Compatibility, IEEE Transactions on, vol. EMC-25, pp.76-106, 1983.

[3] D. Middleton, “Non-Gaussian Noise Models in Signal Processing for Telecommunications: New methods and results for Class A and Class B noise models”, IEEE Transactions on Information Theory, vol. 45, no. 4, pp. 1129-1149, May 1999.

[4] S. V. Vaseghi, “Advanced Digital signal processing and noise reduction,” 4th ed. John Wiley & Sons Ltd, pp.355, 2000.

[5] Z H. A. Suraweera, C. Chai, J. Shentu, J. Armstrong, “Analysis of Impulse Noise Mitigation Techniques for Digital Television Systems”, in Proc. 8th Int. OFDM workshop, pp.172-176, 2003.

[6] T. Hirakawa et al, “Improving Influence of Impulse Noise to OFDM Signal by Recovering Time Domain Samples,” 14th Int. Conf. computers in Education, pp.327-328, 2006.

[7] W. Zhou, B. Xie, S. Jun-de, “Link level simulation and performance estimation of WIMAX IEEE 802.16e”, in 2nd Int. Conf. Pervasive Computing and Applications, pp.667– 671, 2007.

[8] Sergey, et al, "Analysis and Comparison of Several Simple Impulsive Noise Mitigation Schemes for OFDM Receivers", IEEE Trans. Communications, vol. 56, ED-1, pp.5-9, 2008.
[9] A. Mengi and A. J. H. Vinck, "Successive Impulsive Noise Suppression in OFDM," IEEE. Int. symp. Power line communications and its Applications, pp. 33-37, 2010.
[10] T. Umatani, K. Ohno and M. Itami, "A study on scheme of reducing influence of impulse noise in OFDM under multi-path channel", Dig.Tech. papers Int. Conf. Consumer Electronics, pp.119-120, 2010.
[11] T. Kitamura, K. Ohno and M. Itami, "Impulsive noise reduction using it`s replica signal under class-A impulsive channel," 15th Int. symp. wireless personal multimedia communications, pp.463-467, 2012.
[12] H. Yasui, A. Nakamura and M. Itami, "Reducing Impulsive Noise in OFDM Transmission Using Higher Order Modulation", IEEE International Conference on Consumer Electronics (ICCE), pp. 422-423, 2015.