ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

*(An ISO 3297: 2007 Certified Organization)*

Vol. 4, Issue 2, February 2016

# Analysis and Modeling of Channel Estimation System Based Communication Systems

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**ABSTRACT**: OFDM is a multiplexing technique developed to cater the requirement of high data rate with robustness against the adverse effects that may occur over the path of transmission. The OFDM based broadband communication system suffers disturbances due to fading over multiple paths that it take to the receiver. In addition to fading, it is also affected by different noises. AWGN and IN are considered to analyze the performance of the system. In order to jointly fight the effect of fading and noise, an MIMO-OFDM system is proposed to achieve space diversity along with the methods of Time domain interleaving(TDI) and symbol blanking that provides time diversity and frequency diversity, with an aim to reduce the Bit error rate
.

**KEYWORDS:** OFDM, IN, interleaving, TDI, MIMO.

## I. INTRODUCTION

In Wireless communication, the transmitted signals are typically reflected and scattered before arriving at receivers along multiple paths. It may result in bit error and affect the system performance badly.Orthogonal Frequency Division Multiplexing (OFDM) serves the requirement of wireless communication of high data rate effectively, considering its robustness to Intersymbol Interference (ISI) and its ability of achieving spectral efficiency.It should also be noted that OFDM finds application in both wired and wireless applications.

BER is an important parameter to be improved upon, that could render a better performance in the wireless scenario [1]. In order to design an efficient OFDM based broadband communication system, the characteristics of fading due to multipath is understood. There are different types of noise as sources of disturbance that ultimately leads to errored bits. Therefore the nature of different types of noise, its characteristics and an appropriate model is required to define these noise and study their effect on the system.A communication system is likely to be affected by a wide variety of internal and external noise, that could be generally modeled as an Additive white Gaussian noise(AWGN). Another type of noise called Impulsive noise is also considered. This paper discusses an SISO-OFDM system with impulsive noise and propose a 2X2 MIMO array to obtain a better BER reduction for the same.

## II. SISO-OFDM SYSTEM WITH IMPULSIVE NOISE

### A. OFDM

The basic principle of OFDM is to split a high-rate datastream into a number of lower rate streams that are transmitted simultaneously over a number of subcarriers.OFDM is used with an aim to increase robustness against frequency selective fading or narrowband interference.The idea evolved from the fact that a single fade or interferer in a single carrier can affect the entire link and may fail to serve the purpose but if a multicarrier system is used then the fading may affect a fewer percentage of subcarriers and thus prevent a greater loss.

An OFDM symbol with starting time $t=t_s$ can be written as below.

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$$S(t)=\mathrm{Re}\left\{\sum_{i=-\frac{N_s}{2}}^{\frac{N_s}{2}-1} d_{i+\frac{N_s}{2}} \exp\left(j2\Pi\left(f_c-\frac{i+0.5}{T}\right)(t-t_s)\right)\right\}, \quad t_s \le t \le t_s+T$$

$$S(t)=0, \quad t < t_s \wedge t > t_s+T \qquad (1)$$

For $d_i$ QAM complex symbols, $N_s$ number of subcarriers, symbol duration T. An OFDM system is extensively adopted in a wide range of standards as Digital video broadcasting-terrestrial(DVB-T)[2], Digitalaudiobroadcasting(DAB) [3], Worldwide interoperability for microwave access (WiMAX) technologies[4] and the 4G LTE-Advanced[5].

Frequency division multiplexing (FDM) is based on the principle of distributing different symbols over non-overlapping subchannels.This helped to avoid interchannel interference but failed to use the available spectrum efficiently due to the presence of guard bands as shown in fig 1. Therfore the concept of using overlapping subchannels with frequency division multiplexing was proposed. In order to avoid interchannel interference (ICI), the adjacent subchannels were so arranged that the sidebands of the adjacent subchannels do overlap but still the signal is received intact. For this the adjacent subchannels must be mathematically orthogonal to each other , as in OFDM [6].

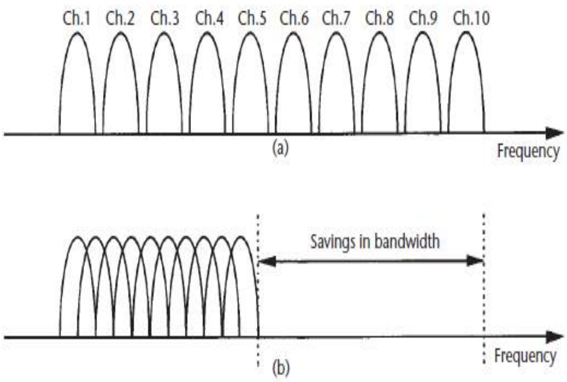


Fig1. Spectral efficiency of FDM (a) and OFDM (b)

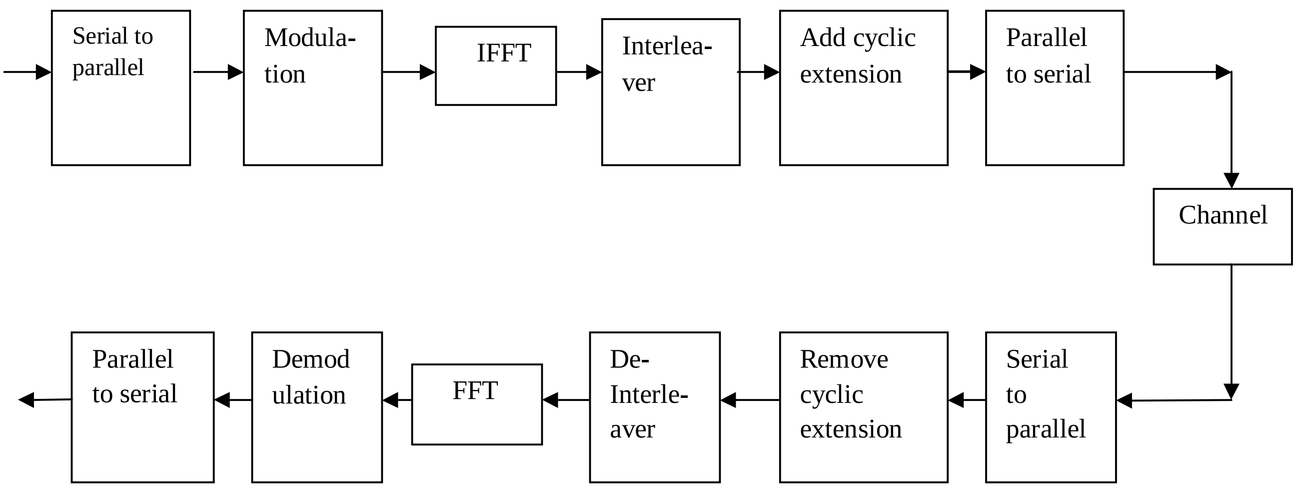


Fig 2. Block Diagram for the OFDM transceiver

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ISSN (Print): 2320-9798

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The parameters that are to be considered while designing an OFDM system are the number of subcarriers, guard time,symbol duration, subcarrier spacing, modulation type per subcarrier,and the type of forward error correction(FEC)coding. The parameters are chosen so as to meet the system requirements such as available bandwidth, required bit rate, tolerable delay spread, and Doppler values. An OFDM symbol is obtained as a sum of all subcarriers in an OFDM symbol interval. The block diagram of the SISO-OFDM system under discussion is as in fig.2.

**B. MODULATION**

In order to transmit digital data over a band-pass channel, it is required to modulate the incoming data onto a carrier wave. QAM could be used as the modulation technique, but if all subcarriers are modulated using very high modulation orders, then a single impulsive sample might be enough to destroy all data bits in the OFDM symbol.256-QAM suffered degradation but orders less than 256 performed satisfactorily without any degradation. It is inferred that the BER improvement is inversely proportional to the modulation order M. Hence the system under discussion use QPSK to obtain a better BER performnace[7]. In order to choose an appropriate modulation technique for designing the system. The system under discussion makes use of QPSK modulation. Quadriphase-shift keying(QPSK) carries the information in phase where the phase of the carrier takes on one of four equally spaced values such as Π/4,3Π/4,5Π/4,7Π/4 and is mathematically represented as below.

$$S_i(t) = \begin{cases} \sqrt{\frac{2E_b}{T_b}}\cos(2\pi f_c t + (2i-1)\pi/4), 0 \le t \le T \\ 0 \quad , elsewhere \end{cases} \qquad (2)$$

where $E_b$ is transmitted signal energy per bit, $T_b$ is bit duration.

**C. FFT/IFFT**

Generally an OFDM symbol consists of a sum of subcarriers that are modulated by using PSK or QAM modulation. An OFDM symbol with starting time $t=t_s$ can be written as below.The equivalent complex baseband representation of an OFDM symbol represented in (2.1) may given as below.

$$S(t)=\mathrm{Re}\left\{\sum_{i=-\frac{N_s}{2}}^{\frac{N_s}{2}-1} d_{i+\frac{N_s}{2}} \exp\left(j2\Pi\frac{i}{T}(t-t_s)\right)\right\}, \quad t_s \le t \le t_s+T$$

$$S(t)=0,\ t<t_s \wedge t>t_s+T \qquad (3)$$

The real and imaginary parts correspond to the in-phase and quadrature parts of the OFDM signal that has to be multiplied by the sine and cosine of the desired carrier frequency to produce the final OFDM signal. The complex baseband OFDM signal as equation(1) is same as the nverse Fourier transform of $N_s$ QAM input symbols, for which discrete time equivalent ,the inverse discrete fourier transform (IDFT) is given by, $S(n)=\sum_{i=0}^{N_s-1} d_i \exp(j2\,\Pi\frac{in}{N})$ (4) Practically this transform can be efficiently implemented by the inverse fast fourier transform(IFFT). An N point IDFT requires a total of $N^2$ complex multiplications. This complexity in computation can be greatly reduced to just N/2 $\log_2(N)$ complex multiplications by using the IFFT algorithm.FFT is employed at the receiver.

**D. CHANNEL**

Performance of a wireless communication system is mainly governed by the wireless channel environment. The wireless channel is dynamic and unpredictable, which makes an exact analysis of the wireless communication system complex. If an OFDM symbol in frequency domain can be represented as

$X[n,m]=\sum_{k=0}^{k-1} X[n,k]e^{j2\pi mk/K} \quad 0 \le k,m \le K-1$ (5)

where $X[n,k]$ is the data at $k^{th}$ subcarrier of the $n^{th}$ OFDM symbol, k is the number of subcarriers and m is the time domain sampling index. The channel between the transmitter and receiver may be modeled as a multi-tap channel with the same

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statistics. The typical channel at time 't' is expressed as below. $h(t,\tau)=\sum_{l=0}^{L-1} \alpha_l(t)\delta(\tau)$ (6)
where L is the number of taps, $\alpha_l$ is the l$^{th}$ complex path gain and $\tau_l$ is the corresponding path delay. The matrix notation for the n$^{th}$ OFDM symbol is given as

H=Fh (7)

Where H is the column vector containing the channel at each subcarrier, F is the unitary FFT matrix and h is the column vector containing the channel impulse response taps.Then the n$^{th}$ received OFDM symbol may be given as

Y=diag(X)H+W (8)

Y[n,k]=H[n,k]X[n,k]+W[n,k] (9)

Where H and W are column vectors representing the channel and noise at each subcarrier for the n$^{th}$ OFDM symbol respectively [8]. For various OFDM systems that does not involve mobility such as PLC, the channel may be considered fixed for the entire frame period[19]. If the channel parameters need to be updated more frequently, then time-domain [9] or blind techniques[4] may be used,where Blind Channel estimation methods exploit the statistical behaviour of the received signals and require a large amount of data.

**E. IMPULSIVE NOISE**

Impulsive noise may be defined as unpredictable noise. Impulsive noise is a short duration noise. During the occurrence of such impulses, the PSD of the noise rises considerably and may cause bit or burst errors in data transmission. The impulsive noise is modeled using Gated Bernoulli-guassian (GBG) model[10]. The model for amplitude distributions of the IN is obtained using the of Middleton class-A model [11]. Since it is mainly caused by the power fluctuations in the devices like routers contained in the network. Hence it is analysed in a detailed manner in Powerline communication (PLC). It is a man-made noise that causes error bursts in the transmitted signal. The most crucial properties of powerline networks degrading the performance of high-speed communications are signal distortion due to frequency-dependent cable losses, multi-path propagation, and noise. This noise cannot be described by an additive white Gaussian noise (AWGN) model.

**F. INTERLEAVING**

Interleaving was a concept developed as an alternative to combat burst errors which is otherwise treated by the use of FEC codes, coding methods, puncturing of codes etc., To act against burst error , symbols from two or more codewords are interleaved before transmission on the channel. Number of codewords that are interleaved is referred to as the depth of interleaving. Consider there are 'm' codewords each of length N . Now to obtain interleaving the data is written row-by-row into a mxN matrix and read out column-by-column before sending it over the channel. Interleaving help to achieve both time diversity and frequency diversity.

**(1)Frequency Domain Interleaving (FDI)**

Earlier in single-carrier systems,the impulsive noise (IN) was mitigated using clipping and blanking. It was extended to OFDM, by embedding pilots in OFDM signal to detect and correct the samples contaminated by IN. A frequency domain IN cancellation technique for DVB-T, in which the IN is estimated and subtracted after the DFT was used in [12]. But the limitation of the aforementioned techniques is that they are not optimized for IN channels. Hence, it showed performance improvement only over weakly and moderately distributed IN channels. FDI are the interleaving process that is applied before the IFFT stage in the OFDM system and hence the name.

**(2) Time Domain Interleaving(TDI)**

To overcome the defects in FDI, Time domain Interleaving (TDI) is used in the SISO-OFDM system under discussion. It performs in such a way that the IN bursts are spread over every first sample of the OFDM symbol after deinterleaving. The FFT applied after deinterleaving averages the IN burst errors over an entire OFDM symbol[10]. It is called as it is used after the IFFT.

**G. SYMBOL BLANKING**

The effect of noise may add up into the amplitude of the received signal and hence to the power. These are rectified by applying the concept of clipping. A threshold is set $\tau_1$ and if the the received samples has an amplitude above it, such samples are set to zero and hence eliminated [13], [14]. The concept is further extended in the system under discussion wherein another threshold $\tau_2$ is set relative to the number of samples crossing the level $\tau_1$ . If the number of samples

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crossing the level $\tau_1$ exceeds the value of $\tau_2$ then that symbol is blanked completely [7]. The symbol blanking may result in the loss of noise-free symbol due to the PAPR problem that is inherent in an OFDM system [12], [3].

## III. SIMULATION RESULTS

Monte Carlo simulations are used to evaluate the performance of the proposed system over frequency-selective multipath fading channels. The OFDM system considered in this paper has $N$ = 128 and $\bar{N}$ = 16. All data symbols are QPSK modulated.

The channel is assumed to be time-invariant throughout the duration of each interleaving block. In addition, full channel state information and perfect synchronization are assumed throughout this work. Each simulation run consists of 2.56 × 106 independent OFDM symbols. The multipath fading channel model considered in this work corresponds to a Rayleigh frequency-selective channel with normalized delays of [0, 1, 2, 3, 4] samples and average gains [0.35, 0.25, 0.18, 0.12, 0.1].

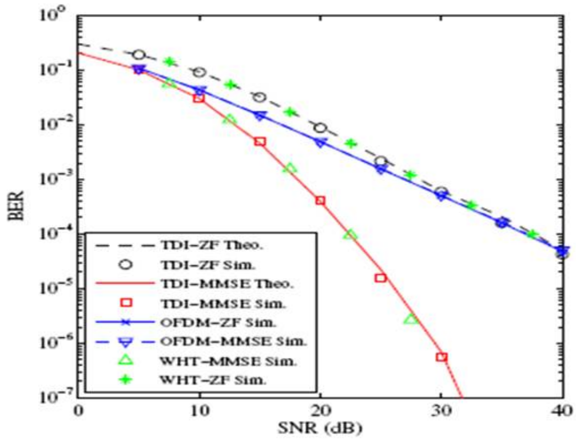


Fig.3BER of TDI and conventional OFDM using ZF and MMSE equalizers.

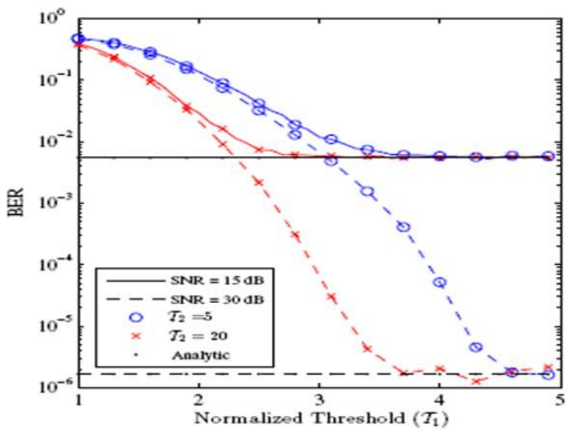


Fig.4. BER versus the threshold $\tau_1$ for different values of $\tau_2$ and SNR.

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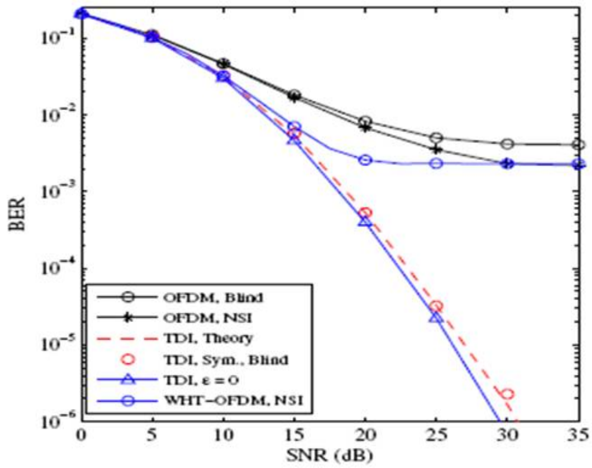


Fig.5. BER using MMSE equalizer in the presence of IN.

The IN is modeled as GBG process, where the bursts position is uniformly distributed within the OFDM symbol period. Unless it is specified otherwise, the burst gating factor probability $p$ = 0.01, the burst width $\kappa = (N+ \bar{N})/2$, the signal-to-IN ratio SIR = −20 dB and SNR ≜.$\gamma$. All the following results shows a better performance for TDI using MMSE equalizer than with a ZF equalizer.

**IV. PROPOSED SYSTEM**

The system discussed is designed to work in a broadband multipath channel under the influence of Impulsive noise. It was developed on the fact that systems so far assumed the impulse noise duration, as a factor smaller than the sample duration of an OFDM sample. But it did not apply to application where the OFDM sample itself was very small. In that case the Impulsive noise may affect the entire OFDM symbol.

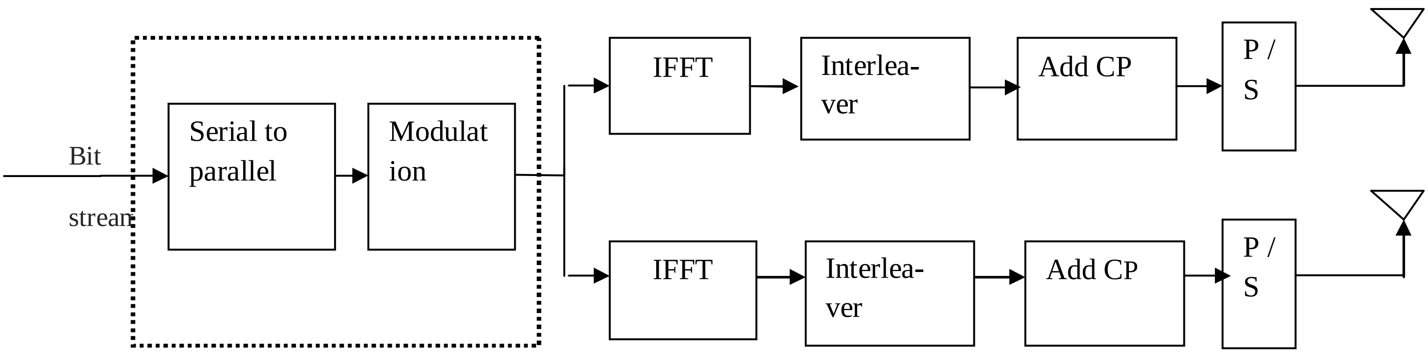


Fig.6 MIMO-OFDM transmitter[8]

It proposed a combination of Time domain interleaving(TDI) and symbol blanking to overcome the error bursts that occured through Impulsive noise. This helped in achieving time diversity and frequency diversity. It is understood from a survey of different literature works that BPSK is best suited when only two bits need to be represented. QPSK is suited well for the environment under discussion than QAM and the system uses it. It makes use of interleaving to obtain time diversity and frequency diversity. The complexity of the post TDI filtering is higher than the pre-TDI filtering since no virtual subcarriers can be used[12] suggests that adopting OFDM for IN channels might impact the

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ISSN (Print): 2320-9798

# International Journal of Innovative Research in Computer and Communication Engineering

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performance negatively. Thus in order to improve the performance of the existing system with impulsive noise further , the concept of Multiple input multiple output (MIMO) is proposed.

The proposed system is to make use of a 2x2 MIMO array with an aim to obtain space diversity. Here, the same information signal is sent from two separate antennas that are far apart. It is called single-stream beam forming. different long-term channel impairments such as path loss and shadow fading which are experienced by different links. This provide independent fading channel to same information-bearing signal. The same signal is emitted from each of the transmit antennas with appropriate phase and gain weighting such that the signal power is maximized at the receiver input.

The benefits of beam forming are to increase the received signal gain by making signals emitted from different antennas add up constructively and to reduce

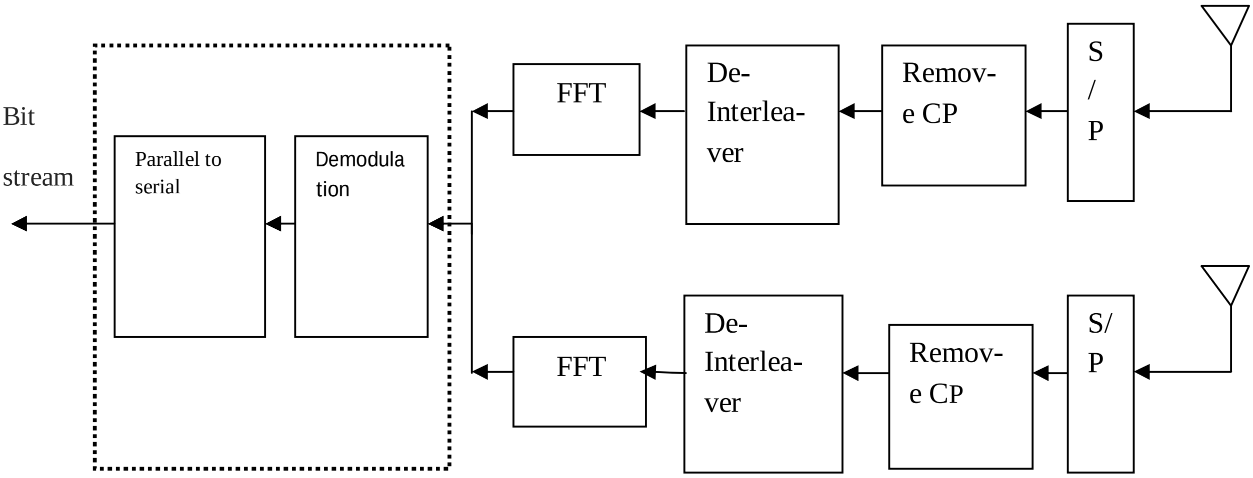


Fig.7 MIMO-OFDM receiver [8]

the multipath fading effect. Diversity gain could be achieved. Thus the proposed system is to make use of the concepts of TDI and the MIMO technique with an aim to achieve a simple OFDM system providing all time, frequency and spatial diversity.

## V.CONCLUSION

The paper analysed an SISO-OFDM system and its performance over multipath fading channel with impulsive noise. It is understood that it offers considerably good performance by reducing the bit error rate. The impulse noise is modeled with a short duration in such a way that it does not affect an entire OFDM symbol as such. It is proposed to employ a 2X2 MIMO array to the system discussed, to improve the system performance by reducing the BER.

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