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Minimization of ICI Using Pulse Shaping in MIMO OFDM

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ABSTRACT: MIMO OFDM system is very popular now days in the field of communication system supporting Multimedia transmission over limited Bandwidth requirement. It is emerged as very reliable, fast and accurate in field of Data transmission over various fading channel. Along with enormous advantages in this system there are some limitations which affect the performance of the system. One of the disadvantages is Inter carrier Interference which generates due to Frequency offset and Doppler delay spread between transmitter and receiver. It severely affects the quality of performance if not minimized properly. In this paper a unique approach named Pulse shaping is being applied with conventional MIMO OFDM system for minimization of Inter Carrier Interference.

KEYWORDS: BER, BTRC, CIR, ICI, ISP, MIMO, OFDM, SIR, SNR, RC

I.INTRODUCTION

As the name states MIMO OFDM; here MIMO stands for Multiple input Multiple Output while OFDM stands for Orthogonal frequency division Multiplexing. This combination provides a highly reliable system as Multiple Antenna array used at both Transmitters as well as in Receiver segment provides high throughput and Fast transmission and reception of signals over the channel on the other side OFDM provides maximum utilization of available Bandwidth. A simple block diagram of above system is drawn below.

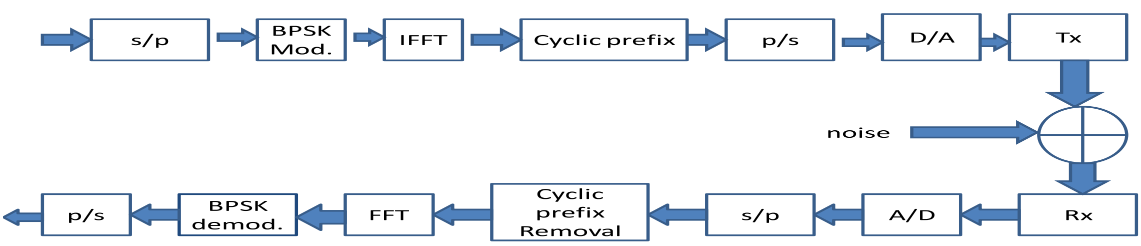

Fig 1: A simple block diagram of MIMO OFDM System

The OFDM system consists of orthogonal subcarriers which carry the modulated symbols. Each OFDM symbol consists of One main lobe along with various side lobes in varying amplitudes in each side left and right both. One of these symbol is shown in following figure.

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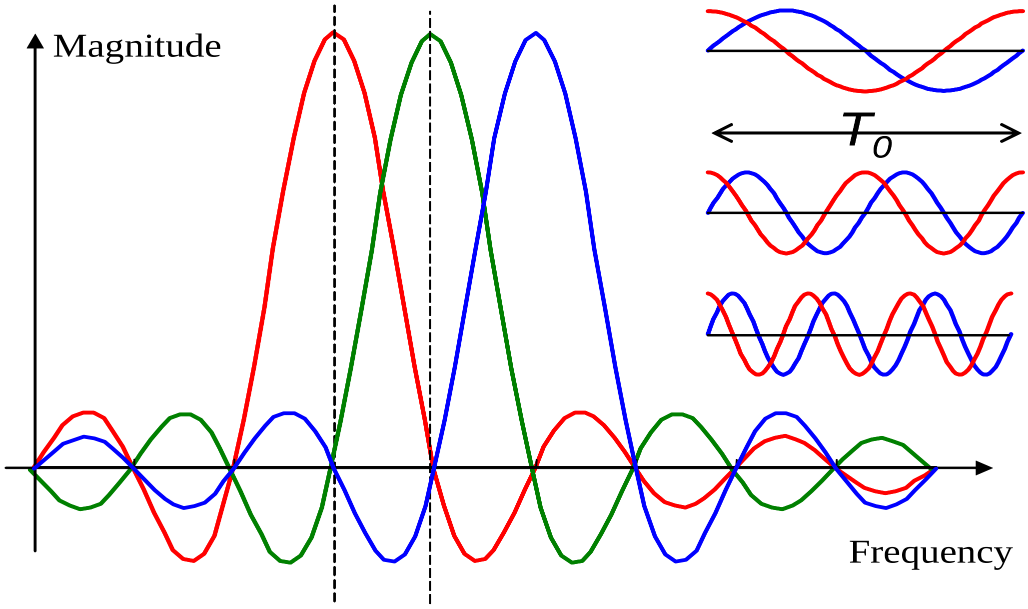

Fig 2: Magnitude versus Frequency curve of an OFDM symbol

Here we can see if orthogonality between subcarriers is lost due to frequency offset or Doppler delay spread between Transmitter and Receiver. The side lobes of each symbol pulse interfere with next symbol pulse and some part of one pulse's sidelobe may reside with main lobe of successive pulse's main lobe.

This Phenomenon is known as Inter Carrier Interference (ICI). If this is not compensated then it may degrade the quality of signal arriving at the receiver.

To counter this error various methods have been proposed .In this paper A unique Pulse shaping approach is being applied to eliminate ICI in an OFDM System.

II.RELATED WORK

In [1] authors used analyzed an Equalization Technique for Orthogonal Frequency-Division Multiplexing Systems in Time-Variant Multipath Channels. In this paper a simple frequency-domain equalization is used to compensate the effect generated due to ICI in a Multipath fading channels. From simulation result it has been shown that the loss of orthogonality caused by the time-variation of a multipath fading channel can be compensated effectively by the proposed equalizer and improved BER results can be obtained with the proposed approach by compensating for the multiplicative distortion and for the ICI from only a few neighbouring sub channels. In [2] authors have Analyzed ICI self-cancellation of data-conjugate method is studied to reduce ICI effectively. CPE (common phase error), ICI and CIR (carrier to interference power ratio) are derived and analyzed by the linear approximation of the phase noise. Then, the performance of the system is calculated using data-conjugate method and result is compared with result of the normal OFDM and the conventional data-conversion method. Results show that CPE is zero in the OFDM of the data-conjugate method. Yet it has a limitation of need of high capacity. In [3] authors analysed windowing techniques for ICI mitigation in multicarrier systems by a band approximation of the minimum mean-squared error (MMSE) block linear equalizer (BLE).by simulation results it is highlighted that receiver windowing is more convenient than transmitter windowing and that receiver windowing is more beneficial for BLE rather than for SLE. In [4] authors compared two methods to mitigate ICI: ICI Self Cancellation (SC) and Maximum likelihood (ML) method. These methods are compared in terms of bit error rate and bandwidth efficiency. Self - cancellation scheme is efficient in case of using high order modulation schemes such as (16-QAM, 16-QPSK) and high frequency offset value, and it does not need very hardware or software complexity for implementation. Though, it is not bandwidth efficient as there is a redundancy of bits for each carrier. On the other hand, the maximum likelihood method also introduces the same level of redundancy but provides better BER performance, since it accurately estimates the frequency offset. Its

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implementation is more complex than the SC method. In [5] Authors studied and analysed Self cancellation scheme on an OFDM system and compared the performance of system with conventional OFDM System. From simulation results it is found that ICI self-Cancellation Performs better than OFDM without Self Cancellation.

III.PROPOSED ALGORITHM

In the OFDM spectrum each carrier consists of a main lobe trailed by a number of side lobes with reducing amplitude. Until the Orthogonality between carriers is maintained; no interference between the carriers is noteworthy as at the peak of the every carrier, there subsist a spectral null. i.e. at that point the component of all other carriers is zero. As a result an individual carrier is easily separated.
When there is a frequency offset occurs between transmitter and receiver; the Orthogonality is lost because now the spectral null does not coincide at the peak of the individual carriers. So some power of the side lobes exists at the Centre of the individual carriers which is abbreviated as ICI power. The ICI power increases as the frequency offset increases. Now the purpose of pulse shaping is to reduce the side lobes. If we can reduce the side lobe significantly then the ICI power can also be reduced significantly. Hence a number of pulse shaping functions are proposed aiming to reduce the side lobe as much as possible [6].
The significant pulse shaping functions are

(a) Rectangular pulse (REC)

(b) Raised cosine pulse (RC)

(c) Better then raised cosine pulse (BTRC)

(d) Sinc power pulse (SP)

(e) Improved Sinc power pulse (ISP)

The system where these functions are applied is explained below:

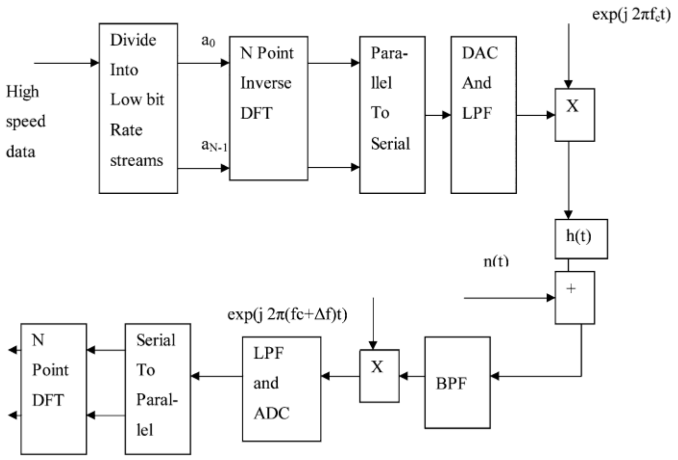

Fig 3: An OFDM system proposed with Pulse Shaping

In the above system pulse shaping functions are applied to section 1 and 2 of above block diagram. These Pulse shaping functions, when multiplied with input data symbol. They reduce ICI contents to a much satisfactory level. The reduction is done as when side lobes of OFDM get condensed, the ICI contents are also minimized automatically.
The equations used for simulation are as follows:
The complex envelope of one radio frequency (RF) N-subcarrier OFDM block with pulse shaping is expressed as:

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$$x(t) = e^{j2\pi f_c t} \sum_{k=0}^{N-1} a_k p(t) e^{j2\pi f_k t}$$

(1)

When frequency offset happens it introduces the Phase error θ is introduced in subcarrier frequency , thus received symbol have format:

$$r(t) = e^{j(2\pi \Delta f t+\theta)} \sum_{k=0}^{N-1} a_k p(t) e^{j2\pi f_k t}$$

(2)

fc is the carrier frequency, fk is the subcarrier frequency of the kth subcarrier, p(t) is the time limited pulse shaping function and ak (k = 0, 1, . . . , N −1) is the data symbol transmitted on the kth subcarrier. ak is assumed to have zero mean and normalized average symbol energy.

fk − fm = (k − m)/T (3)

where (1/T) is the minimum subcarrier frequency spacing required.

The output of the mth subchannel correlation demodulator gives the following decision variable for transmitted symbol am

$$\hat{a}_m = \int_{-\infty}^{\infty} r(t) e^{-j2\pi f_m t} dt$$

(4)

Equation (4) can be written as:

$$\hat{a}_m = a_m e^{j\theta} P(-\Delta f) + e^{j\theta} \sum_{\substack{k=0 \\ k\neq m}}^{N-1} a_k P\left(\frac{m-k}{T} - \Delta f\right)$$

(5)

The first term in (5) contains the desired signal component whereas the second term represents the ICI. It is clear that for zero _f and _, there is no ICI if the Fourier transform P(f) of p(t) have spectral nulls at the frequency ±(1/T), ±(2/T), . . . (ensure subcarrier orthogonality).

The power of the desired signal (σm) and ICI component (σICIm) can be written as

$$\sigma_m = |a_m|^2 |P(\Delta f)|^2$$

$$\sigma_{\text{ICI}}^m = \sum_{\substack{k=0 \\ k\neq m}}^{N-1} \sum_{\substack{n\neq m \\ n=0}}^{N-1} a_k a_n^* P\left(\frac{k-m}{T} + \Delta f\right) P\left(\frac{n-m}{T} + \Delta f\right)$$

(6)

Therefore, the ICI power depends on the desired symbol location m, the transmitted symbol sequence, the pulse shaping function and the number of subcarriers.

Average ICI power is given by

$$\overline{\sigma_{\text{ICI}}^m} = \sum_{\substack{k=0 \\ k\neq m}}^{N-1} \left| P\left(\frac{k-m}{T} + \Delta f\right)^2 \right|$$

(7)

And SIR is calculated by following equation:

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$$\text{SIR} = \frac{|P(\Delta f)|^2}{\sum_{\substack{k=0 \\ k\neq m}}^{N-1} \left|P\left(\frac{k-m}{T} + \Delta f\right)^2\right|} \tag{8}$$

IV.SIMULATION RESULTS

The simulation is done using REC, RC, BTRC, SP AND ISP Pulse shaping functions which are represented as P(t) in time domain and as P(f) as in Frequency domain. Simulation results show that ISP pulse shape performs better as compare to other pulse mentioned. It shows improvement in BER, SIR and lower ICI power. This is shown in following figure.

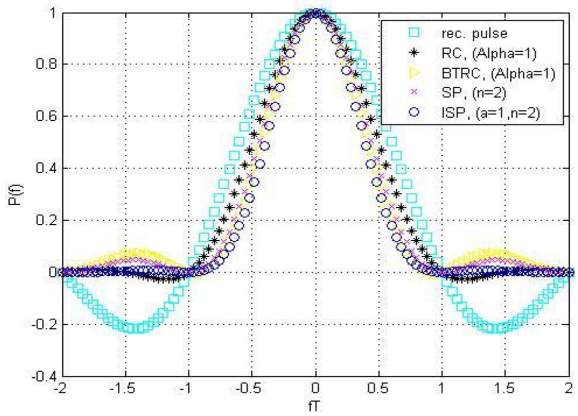

Fig 4: Spectral representation of various Pulses

Simulation Results Compare Power Spectral density of various pulses as shown in fig 4. The purpose of pulse shaping is to reduce the main lobe as well as side lobe, as the side lobes contain the ICI power and the main lobe contains peak power. It is observed that the magnitude spectral of side lobe is maxi-mum for rectangular pulse and minimum for ISP pulse shapes. From the results it is clear that amplitude of ISP pulse shape is the lowest at all frequencies when compared with the previously reported pulse shapes and it has a fast decaying rate decreasing the lobes of sinc function. These properties help in providing better performance due to both PAPR & ICI reduction.

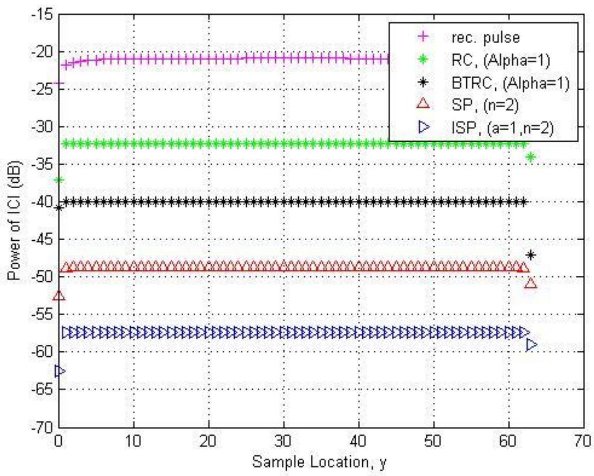

Fig 5: Comparison of ICI power of different Pulses

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Fig 5 shows the variation of the ICI power for different sample locations in a 64-subcarrier OFDM system for Δf.T = 0.05. The ICI power drops for samples located near sample locations 0 and N-1, because these samples have fewer interference samples. In this figure the pulse shape parameters are selected as following; α= 1, m = 2, and a =1. The ISP pulse shape for a = 1, the ICI power is -57.45 dB which is 8.79 dB better than that of SP pulse shape.

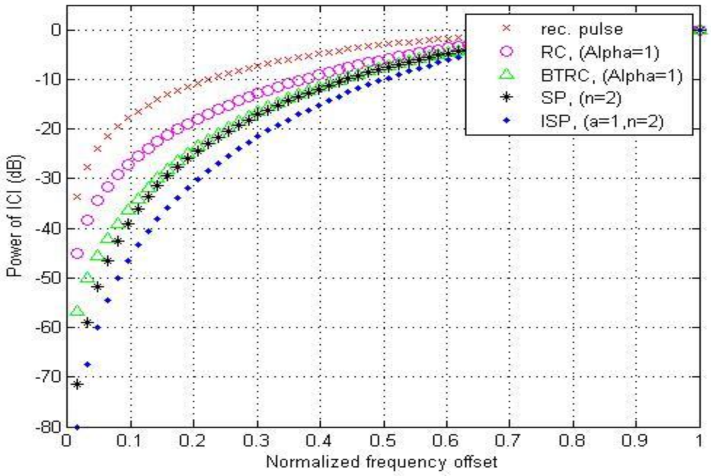

Fig.6 Average ICI Power Performance for Different Pulse

The average ICI power of a 64-subcarrier OFDM system is illustrated in Fig.6, with respect to the normalized frequency offset. In this figure, the pulse shape parameters are selected as the following; a = 1, m = 2, and a = 1. As seen in this figure, the average ICI power performance is better with ISP pulse shapes as compared to all other pulse shapes

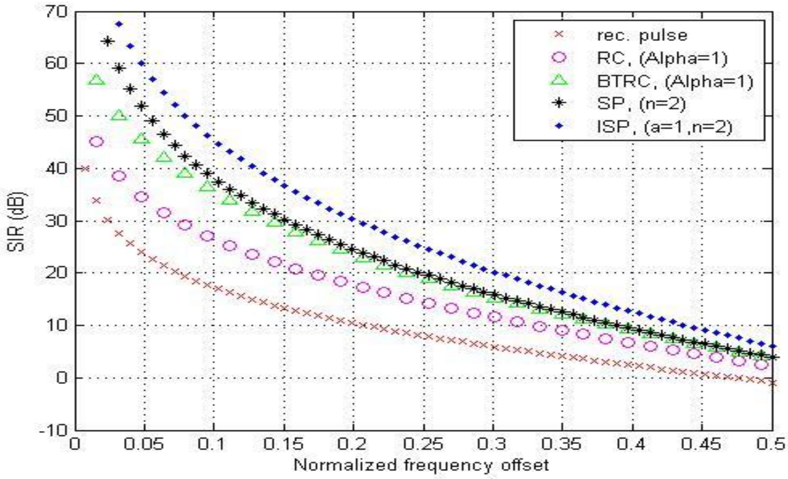

Fig 7 SIR Performance for Different Pulse Shapes

Fig.7 compares the SIR for different pulse shaping functions in a 64-subcarrier OFDM system plotted as functions of the normalized frequency offset; ΔfT . For RC and MRC, the roll off parameter is equal to one. The degree of sinc functions is selected as n = 2, and for ISP pulse shape a = 1. SIR performance is better using ISP pulse shape.

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V. CONCLUSION AND FUTURE WORK

The simulation results shows that among all the above discussed pulse shaping functions ISP pulse is proved to be better performing than other pulses. It improves not only CIR and SIR but also limits ICI with increasing roll off factor α and degree of sinc function "n". Besides this Bandwidth requirement is less for above proposed methods. The system is studied for AWGN and Rayleigh Fading channel it can also be simulated with other Fading Channels.

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BIOGRAPHY

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