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A Novel ICI Mitigation Algorithm for Wide Band OFDM Systems under Rayleigh Channel


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ABSTRACT:

Inter Carrier Interference (ICI) is being introduced in WOFDM due to the carrier frequency offset (CFO), which will degrade the system performance and efficiency at higher modulation levels and it decreases the performance of power amplifiers. Hence, here in this paper, we introduced a novel ICI mitigation algorithm under the two channel environments such as AWGN and Rayleigh. Simulation results have been compared with existing and proposed schemes under these channel specifications and concluded that the Rayleigh has performed far better than the AWGN channel distributions in terms of Bit Error Rate (BER) and Carrier interference Ration (CIR) performance.

Index terms:

OFDM, ICI, Frequency Offset, AWGN, Rayleigh channel, BER and CIR.

I.INTRODUCTION:

Orthogonal Frequency Division Multiplexing (OFDM) is being used for high data rate wireless applications [1]. It is a multicarrier modulation technique which incorporates orthogonal subcarriers. High Peak to Average Power ratio and Inter carrier Interference (ICI) are two main disadvantages of the OFDM systems. In OFDM systems ICI occurs due to frequency offset in between the transmitter and receiver carrier frequencies or Doppler Effect [2]. Many techniques have been developed to reduce the effect of ICI; ICI self cancellation is a simple and convenient technique. ICI self cancellation scheme proposed by Zhao [3] utilizes data allocation and combining of (1,-1) on two adjacent subcarriers i.e. same data is modulated at k^th and $k+1^{th}$ sub carriers using (1,-1) as data allocation and are combined at the receiver with weights 1 and -1. It is one of the most promising techniques to reduce ICI; however, its performance degrades at higher frequency offsets. Yeh, Chang and Hassibi had proposed conjugate cancellation scheme in [4]. In this scheme, OFDM symbol and its conjugate are multiplexed, transmitted and combined at the receiver to reduce the effect of ICI. However, this scheme shows a significant improvement in CIR at very low frequency offsets and its performance degrades as carrier frequency offset increases.

At higher frequency offset >0.25 its CIR performance is worse than standard OFDM system. In [5] the author has proposed Phase Rotated Conjugate Cancellation (PRCC), which is an extension to the scheme proposed in [4]. In this an optimal value of phase is multiplied with the OFDM symbol and its conjugate signal to be transmitted on different path. The optimal value of the phase depends on the frequency offset and hence requires continuous carrier frequency offset (CFO) estimation and feedback circuitry, which increases the hardware complexity [6-7].

Another ICI self cancellation scheme [8] based on generalized data allocation $(1,\mu e^{j\theta})$ has been proposed in the literature to improve CIR performance of ICI self cancellation system, where ξ is the optimal value, which depends on frequency offset. Thus for every normalized frequency offset, a unique value of ξ is to be multiplied with the data which again requires CFO estimation and feedback circuitry [6-7]. A symmetric symbol repeat ICI self cancellation scheme, which utilizes data allocation and combining of (1,-1) at k^{th} and N-1- k^{th}

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Subcarrier. This scheme shows better CIR performance than ICI self cancellation scheme. One of the major advantages of this scheme is to achieve the frequency diversity and hence its performance in frequency selective fading channel found to be better than ICI self cancellation scheme. In this paper, we have proposed an optimal and sub-optimal scheme for SSR ICI cancellation scheme to improve the CIR performance. The scheme is based on SSR ICI self cancellation scheme, in which a data is modulated at two symmetrically placed subcarriers i.e. k^{th} and N-1- k^{th} and utilizes a data allocation of (1,-λ) to improve CIR performance. To further reduce the effect of ICI, received modulated data signal at k^{th} and N-1- k^{th} subcarriers are combined with weights 1 and -ξ. The λ and ξ are the optimal values resulting in maximum CIR. The optimum values of λ and ξ are the function of normalized frequency offset i.e. for every normalized frequency offset; there exist a unique value of λ and ξ. This process requires continuous CFO estimation. To overcome this problem, we have proposed a suboptimal approach to find suboptimal values. The obtained sub-optimal values (λ_{so}, ξ_{so}) are independent of normalized frequency offset. Thus, the proposed scheme does not require any CFO estimation or feedback circuitry and hence eliminates the requirement of complex hardware circuitry.

II.EXISTING METHOD:

A.OFDM System:

The discrete time OFDM symbol at the transmitter can be expressed as

$$x[n] = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X(k)\, e^{\frac{j2\pi nk}{N}},$$

$$n = 0,1,2,\ldots\ldots,N-1 \qquad (1)$$

where N is total numbers of subcarriers and X (k) denotes the modulated data symbol transmitted on k^{th} subcarrier. Due to AWGN channel and frequency offset, the received OFDM signal can be written as

$$y[n] = x[n]e^{j\frac{2\pi\varepsilon n}{N}} + w[n]$$

$$n = 0,1,2,\ldots\ldots\ldots,N-1 \qquad (2)$$

where ε is the normalized frequency offset and $w[n]$ is the sample of additive white Gaussian noise. The received data signal on k^{th} subcarrier can be written as

$$Y(k) = X(k)S(0) + \sum_{l=0,l\neq k}^{N-1} X(l)S(l-k) + W(k)$$

$$k = 0,1,\ldots\ldots,N-1 \qquad (3)$$

Where $W(k)$ is k^{th} the sample of DFT of additive noise. The sequence $S(l-k)$ is defined as the ICI coefficient between k^{th} and l^{th}subcarriers, which can be expressed as

$$S(l-k) = e^{\left(j\pi(l+\varepsilon-k)\left(1-\frac{1}{N}\right)\right)} \frac{\sin(\pi(l+\varepsilon-k))}{N\sin\left(\frac{\pi}{N}(l+\varepsilon-k)\right)} \qquad (4)$$

The CIR at the k^{th} subcarrier can be written as

$$CIR = \frac{|S(k)|^2}{\sum_{l=0,l\neq k}^{N-1}|S(l-k)|^2} \qquad (5)$$

SSR ICI Self Cancellation Scheme:

In SSR ICI self cancellation scheme [6], the data symbol to be transmitted at the k^{th} subcarrier is repeated at the subcarrier $N-1-k^{th}$ with opposite polarity, i.e.,

$$X(N-1) = -X(0), \ldots.., X(N-1-k) = -X(k)$$

The block diagram of the proposed SSR ICI self cancellation scheme is depicted in Fig1. The received data signal at the k^{th} subcarrier is thus given by

$$Y'(k) = \sum_{l=0}^{\frac{N}{2}-1} X(l)S((l-k) - S(N-1-l-k)) + W(k) \qquad (6)$$

Combining the received data at k^{th} and $N-1-k^{th}$ subcarriers, we have

$$Y''(k) = Y'(k) - Y'(N-1-k) \qquad (7)$$

Using (6) & (7) we have

$$Y''(k) = \sum_{l=0}^{\frac{N}{2}-1} X(l)[S(l-k) - S(N-1-l-k) - S(l+k+1-N) + S(k-l) + W(k) - W(N-1-k)]$$

$$k = 0,1,2,\ldots\ldots,\frac{N}{2}-1 \qquad (8)$$

Thus, CIR of conventional SSR ICI self cancellation scheme can be written as

$$CIR_c = \frac{|-S(-N-1-2k)+2S(0)-S(1-N+2k)|^2}{\sum_{l=0,l\neq k}^{\frac{N}{2}-1}|-S(l-k)-S(N-1-l-k)-S(l+k+1-N)+S(k-l)|^2} \qquad (9)$$

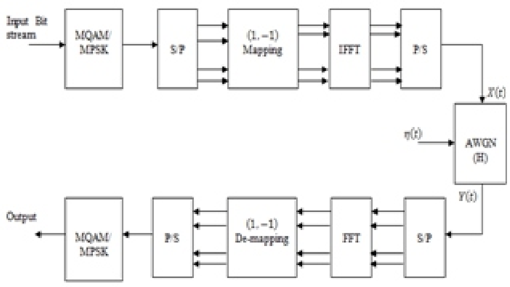

Fig1. SSR ICI self cancellation scheme

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C.Additive White Gaussian Channel:

It adds white gaussian noise to a complex/real input signal. If the input signal is real, then it adds real Gaussian noise and will produces a real output signal. It produces the complex output signal by adding the complex gaussian noise when the input signal is complex. Below are the various modes of noise variance that can be generated by the AWGN Channel:

Specifying the Variance Directly or Indirectly

a.Signal-to-Noise ratio (E_b⁄N_0), where the AWGN calculates the variances from these quantities:

- The ratio of energy per bit to noise PSD,E_b⁄N_0 ,
- Number of bits per symbol N_s
- Input signal power
- Symbol period

b.Signal to noise ratio (Es/No), where the AWGN calculates the variances from these quantities:

- Es/No, the ratio between energy of signal to PSD noise
- Input signal power
- Symbol period

c.Signal to noise ratio (SNR), where the AWGN calculates the variances from these quantities

•SNR
•Input signal power

Changing the symbol period in the AWGN Channel will affects the noise variance added per sample, which can also causes a change in the final error rate.

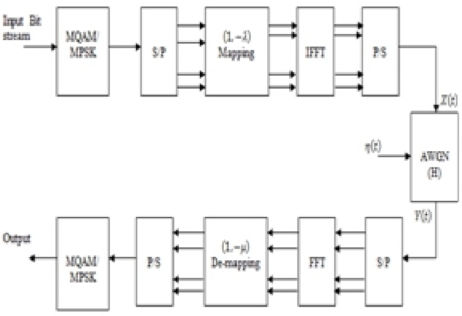

Fig2 Proposed Block diagram of ICI Self cancellation with AWGN Channel

III.PROPOSED SCHEME:

In the proposed scheme at the transmitter a data allocation (1,-λ) is utilized at k^{th} and $N-1-k^{th}$ subcarriers .i.e.

$$X(N-1) = -\lambda X(0), X(N-2) = -\lambda X(1), \ldots X(N-1-k) = -\lambda X(k)$$

Hence, the received data signal at the k^{th} subcarrier is

$$Y'(k) = \sum_{l=0}^{\frac{N}{2}-1} X(l)S((l-k) - \lambda S(N-1-l-k)) + W(k) \quad (10)$$

After Combining the received data at k^{th} and $N-1-k^{th}$ subcarriers with weight 1 and -ξ, we have

$$Y''(k) = Y'(k) - \xi Y'(N-1-k) \quad (11)$$

$$Y''(k) = \sum_{l=0}^{\frac{N}{2}-1} X(l)[S(l-k) - \lambda S(N-1-l-k) - \xi S(l+k+1-N) + \xi\lambda S(k-l) + W(k) - \xi W(N-1-k)]$$

$$k = 0,1,2,\ldots\ldots,\frac{N}{2}-1 \quad (12)$$

Thus, CIR of proposed optimal SSR ICI self cancellation scheme is given by

$$CIR_c = \frac{|-\xi S(2k+1-N)+(1+\lambda\xi)S(0)-\lambda S(N-1-2k)|^2}{\sum_{l=0,l\neq k}^{\frac{N}{2}-1}|-\xi S(l-N+k+1)-S(l-k)-\lambda S(N-1-l-k)+\xi\lambda S(l-k)|^2} \quad (13)$$

The optimum values of λ and ξ are calculated for $\varepsilon \in [0.03,0.25]$ at a very small interval of $\Delta\varepsilon$ which results in maximum CIR for the givenε. Thus for everyε, we have a unique optimal value of and λ and ξ these are denoted by (λ_0,μ_0). The optimum values(λ_0,μ_0) are to be used for data allocation and combining the data atk^{th} and$N-1-k^{th}$ subcarriers to maximize the CIR of the OFDM system. Where, $CIR_p(\varepsilon_1,\lambda_{01},\mu_{01})$ corresponds to maximum value of CIR for $\varepsilon_1$and so on and

$$v = \frac{(\varepsilon_H - \varepsilon_L)}{\Delta\varepsilon} + 1 \quad (15)$$

Where, ε_H *and* ε_L are the lowest and the highest possible values of the normalized frequency offset. Here, we have considered $\varepsilon_H = 0.25$ and$\varepsilon_L = 0.03$. To avoid the problem of continuous ε estimation, sub-optimal pair (λ_{so},μ_{so}) amongst all (λ_0,μ_0) has been found by using the following criterion as

$$(\lambda_{so},\mu_{so}) = \max_{\lambda_0,\mu_0}\left[p - \frac{\sum_{j=1}^{p}(p - CIR(\varepsilon_j,\lambda_0,\mu_0))}{v}\right] \quad (16)$$

In the above expression, p represents the maximum CIR of a particular row of the matrix given by (14) and the second term represents the mean deviation of the CIR of that row from the peak (p) of that row. Thus irrespective of the value ofε, (λ_{so},μ_{so})can be used for data allocation and combining to get a sub-optimal CIR performance.

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A.Rayleigh Distribution:

Rayleigh fading is a rational model, when an environment that consists of many objects can scatter the transmitted signal before the arrival of signal at receiver. The central limit theorem holds that, the channel impulse response can be modelled well as a gaussian process irrespective of individual components distribution when there are enough much scatter [10]. When we apply Central Limit Theorem (CLT) to the large number of paths, then each path can be modelled with time as the variable as circularly symmetric complex Gaussian random variable (GRV), which is known as Rayleigh channel model [11]. When there is no prevalent component to the scatter such model will have the mean of zero and the phase between 0 and 2π radians. Therefore the channel response envelope is Rayleigh distributed.

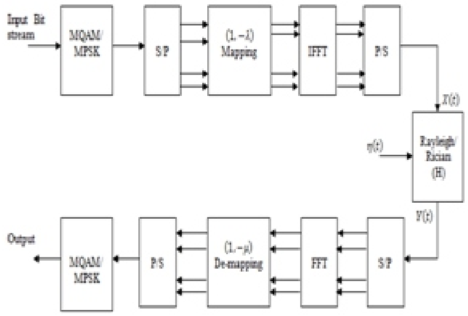

Fig3 Proposed Block diagram of ICI Self cancellation with Rayleigh Channel

A circularly symmetric complex GRV is of the form,

$$Z = X + iJ$$

where the real and imaginary parts are zero mean i.i.d. GRV's.

For circularly symmetric complex random variable,

$$E[Z] = E[e^{j\theta} Z] = e^{j\theta}[Z]$$

A circularly symmetric complex GRV is completely specified by the variance

$$\sigma^2 = E[Z^2]$$

The magnitude $|Z|$, which has the PDF of $\wp(z)$, is called as Rayleigh random variable

$$\wp(z) = \frac{z}{\sigma^2} e^{-\frac{z}{2\sigma^2}}, z > 0$$

IV.EXPERIMENTAL RESULTS:

In this paper, we have considered an OFDM system with N=64,128 and 256 subcarriers, M-QAM and M-PSK modulation schemes to modulate each of the subcarriers. The simulation model of the existing and proposed schemes with AWGN and Rayleigh channels is shown in Fig.1, Fig2 and Fig3.

The computer simulation using MATLAB 2014a are performed to evaluate the Carrier Interference Ratio (CIR) and Bit Error Rate (BER) performance of existing and proposed schemes with respect to the normalized frequency offset and SNR. Fig. 4 shows the CIR performance of standard OFDM system, SSR ICI self-cancellation and proposed optimal, sub-optimal approaches with AWGN. Fig. 5 shows BER performance of the standard OFDM system, conventional SSR ICI self cancellation and the proposed approach. As seen from Fig. 4 the CIR performance of the proposed optimal approach is about 60.23dB far better than the sub-optimal and conventional schemes. The CIR performance of proposed scheme is slightly worse than conventional SSR ICI self cancellation scheme forεϵ[0.03,0.25]. The BER performance of the proposed scheme is very much improved in comparison to standard OFDM system and very close to conventional SSR ICI self cancellation scheme in [3].

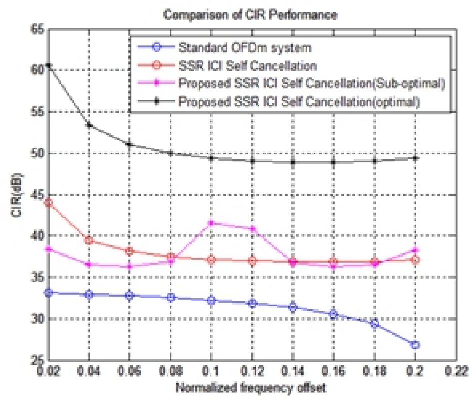

Fig 4 CIR performance Comparison

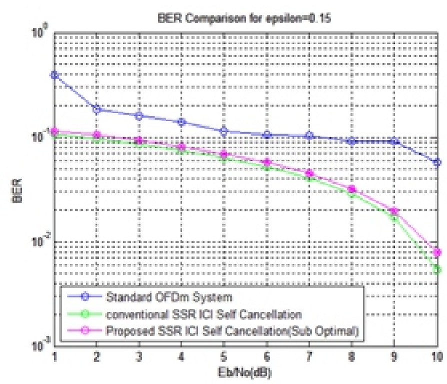

Fig 5 BER performance Comparison

Fig6 shows that the transmitted data and modulated data with 128 subcarriers and 128-PSK. The performance of the proposed scheme with higher modulation levels has shown in fig7 and fig8.

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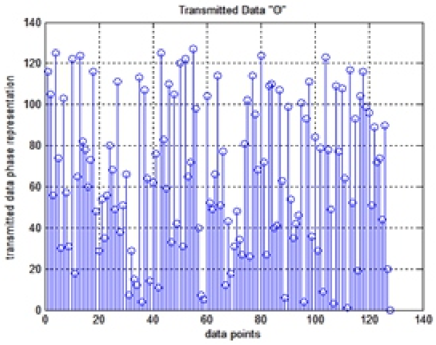
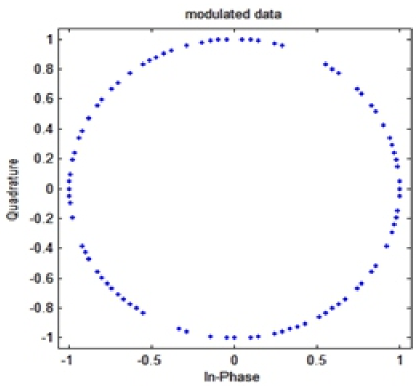
We tested it with 128-QAM and N=128 subcarriers and we got the CIR of 63.9932 dB, which is an improved performance than the fig4 results.



(a)



(b)

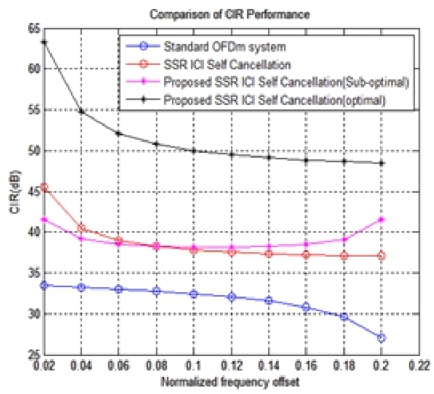


Fig6. (a) Data of Transmitter (b) modulated data

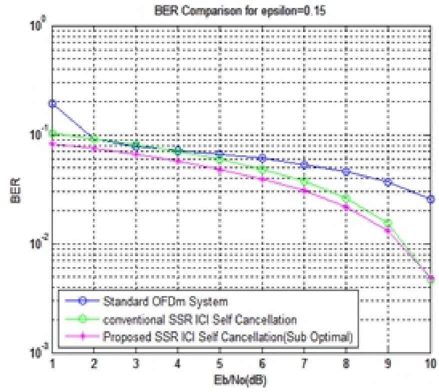


Fig7. CIR Performance with N=128 and 128-QAM

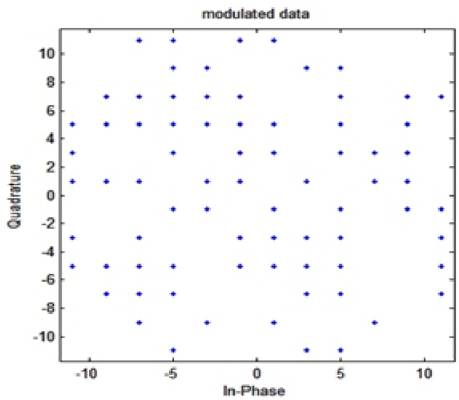


Fig8. BER performance with 128-QAM and N=128

The modulated output of 128-QAM in presence of AWGN is shown in fig9 and it has got the CIR which is shown in fig7.Further CIR improvement can be achieved by using Rayleigh distribution instead of AWGN. Fig10 shows the performance of the proposed scheme in presence of Rayleigh channel distribution with 128-PSK and 256 subcarriers. We can see that the proposed scheme has got maximum CIR of 71.325with the Rayleigh distribution. Fig9 shows the transmitted data with 256 subcarriers and modulated data with 128-PSK and the fig11 shows the comparison between the conventional schemes with AWGN and with Rayleigh. It can be observed that while increasing in the frequency offset still the CIR performance stable with the proposed Rayleigh approach and has maximum CIR of 51dB. It's much higher than the other conventional ICI reduction techniques [3-8].

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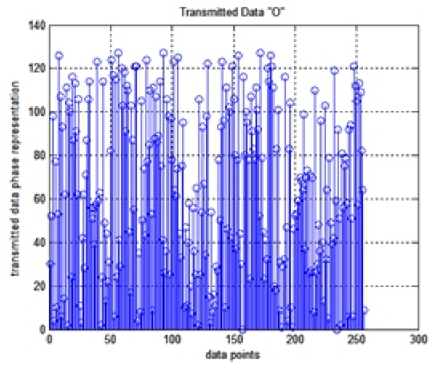
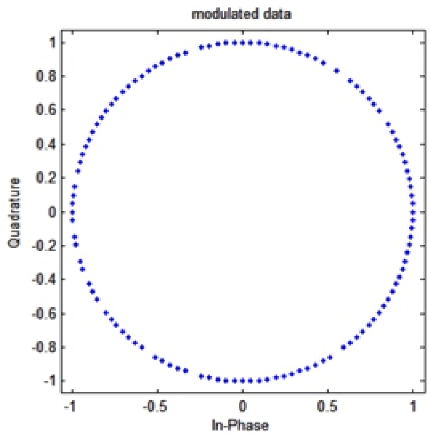


(a)



(b)

Fig10. (a) Transmitted Data of N=256 and (b) modulated data with 128-PSK.

Table I:Simulation parameters:

Parameters	Specifications
FFT & IFFT size	8
No. of Subcarriers	64, 128 and 256
Cyclic prefix	1
Channel model	AWGN and Rayleigh
Modulation scheme	QAM, QPSK
Constellation points	4, 8,16, 32, … and 128
OFDM block size	8

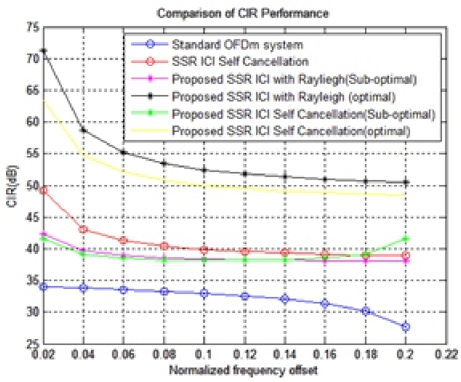


Fig11. CIR performance with N=256 and 128-PSK under Rayleigh channel model

V.CONCLUSION:

Here, we introduced a new ICI self cancellation algorithm in presence of various channel environments for higher modulation levels with increased subcarriers. And also we had compared the simulation results with the existing algorithms with the proposed scheme under the AWGN and Rayleigh distributions. After observing the simulation results the Rayleigh has performed well with N=256 and 128-PSK as well as 128-QAM. We achieved the maximum CIR of 71.325dB. The proposed scheme well improved the performance of CIR and also decreases the bit error rate with increasing signal to noise ratio values.

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