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An Efficient Scheme for Inter Carrier Interference Cancellation in High Speed OFDM System

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ASTRACT: 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,-□) 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 □ and ξ are the optimal values resulting in maximum CIR. The optimum values of □ and ξ are the function of normalized frequency offset i.e. for every normalized frequency offset; there exist a unique value of □ 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.

KEY WORDS: OFDM, Inter Carrier Interference, Bit Error Rate, CIR.

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is being used for high data rate wireless applications. It is a multicarrier modulation technique which incorporates orthogonal subcarriers[1]. High Peak to Average Power ratio and Inter carrier Interference (ICI) are two main disadvantages of the OFDM systems. Tehcniques for OFDM frequency division multiplexing have been shown in [2]. In OFDM systems ICI occurs due to frequency offset in between the transmitter and receiver carrier frequencies or Doppler Effect. Many techniques have been developed to reduce the effect of ICI; ICI 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 $k^{th}\ and\ k+1^{th}$ the 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. Another technique known as conjugate cancellation had been proposed by Yeh, Chang and Hassibi [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. Extension to conjugate cancellation is Phase Rotated Conjugate Cancellation (PRCC) [5] in which 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.

Other ICI self cancellation scheme [6] [7] 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 μ is the optimal value, which depends on

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frequency offset. Thus for every normalized frequency offset, a unique value of μ is to be multiplied with the data which again requires CFO estimation and feedback circuitry. 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} 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. The coding and numerical methods have discussed in [8]. Analysis of OFDM in the Presence of Frequency Offset and a Method to Reduce Performance Degradation discussed in [6].

In this paper, we have proposed an optimum data allocation 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 -μ. The λ and μ are the optimal values resulting in maximum CIR. The optimum values of λ and μ are the function of normalized frequency offset i.e. for every normalized frequency offset; there exist a unique value of λ and μ. 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},μ_{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 the hardware circuitry. Multi spectrum spread analysis have been clearly discussed in [9]. About the signal encryption in CDMA has shown clearly in [10].

II.METHODOLOGY

A. OFDM *System*

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

$$x[n] = \frac{1}{\sqrt{N}}\sum_{k=0}^{N-1} X(k)\, e^{j2\pi nk/N}, n = 0,1,2,\ldots\ldots,N-1 \qquad (1)$$

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

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

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

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

B. 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

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

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

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

Using (6) & (7) we have

$$Y''(k) = \sum_{l=0}^{\frac{N}{2}-1} X(l)[S(l-k) - S(N-1-l-k) - S(l+k+1-N) + S(k-l) + W(k) - W(N-1-k)] \qquad ; k = 0,1,2,\ldots,\frac{N}{2}-1 \quad (8)$$

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

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

III.PROPOSED SYSTEM

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

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

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

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

$$Y''(k) = \sum_{l=0}^{\frac{N}{2}-1} X(l)[S(l-k) - \lambda S(N-1-l-k) - \mu S(l+k+1-N) + \mu\lambda S(k-l) + W(k) - \mu W(N-1-k)] \quad ; k = 0,1,2, \ldots, \frac{N}{2}-1 \quad (12)$$

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

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

The optimal values of λ and μ have been found by using an optimization technique known as Nelder Mead Simplex Algorithm. The optimum values of λ and μ 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 μ 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. But, this will require a continuous CFO estimation.

$$CIR_p(\varepsilon, \lambda_0, \mu_0) = \begin{bmatrix} CIR_p(\varepsilon_1, \lambda_{01}, \mu_{01}) & \cdots & CIR_p(\varepsilon_v, \lambda_{01}, \mu_{01}) \\ \vdots & \ddots & \vdots \\ CIR_p(\varepsilon_1, \lambda_{0v}, \mu_{0v}) & \cdots & CIR_p(\varepsilon_v, \lambda_{0v}, \mu_{0v}) \end{bmatrix} \quad (14)$$

Here, $CIR_p(\varepsilon_1, \lambda_{01}, \mu_{01})$ 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* $\varepsilon_L$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

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

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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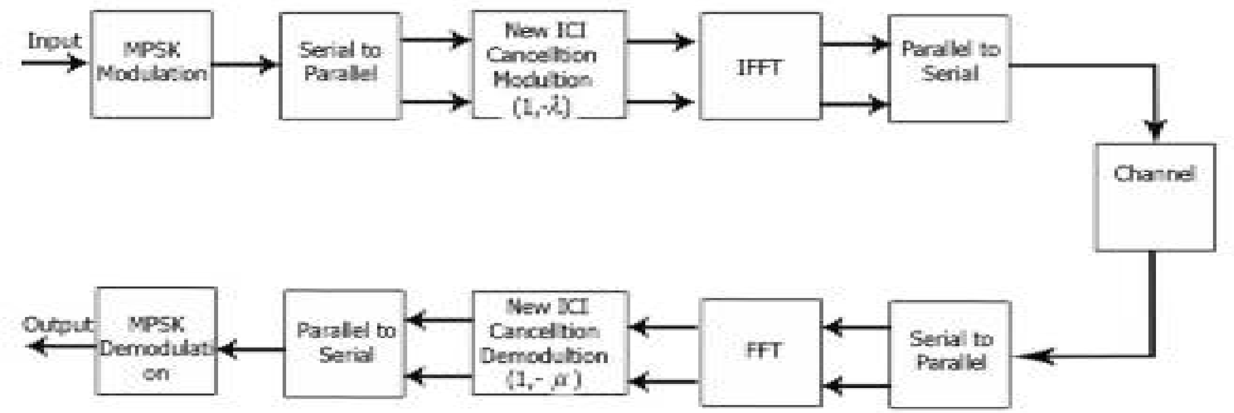
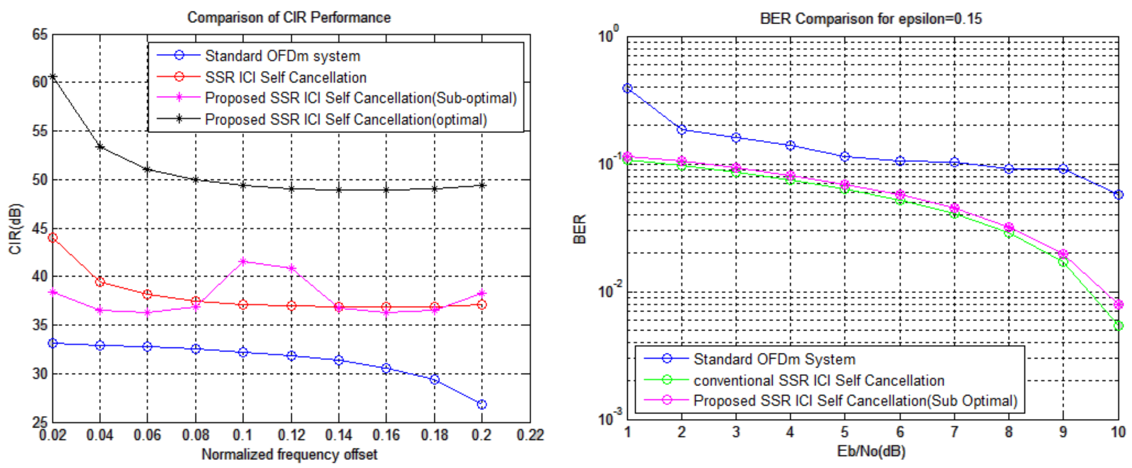


Fig1 Proposed Block diagram of ICI Self cancellation

IV.RESULTS

In this, we have considered an OFDM system with N=64,128 and 256subcarriers, M-QAM and M-PSK modulation schemes to modulate each of the subcarriers. The computer simulation using MATLAB 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. 2 (a) shows the CIR performance of standard OFDM system, SSR ICI self-cancellation and proposed optimal, sub-optimal approaches with AWGN. It shows that the proposed algorithm under the AWGN channel conditions has highest CIR performance. It has the CIR of 60.23dB, where the existing and standard OFDM has the CIR values of 44.32dB and 33.28dB.Fig. 2 (b) shows BER performance of the standard OFDM system, conventional SSR ICI self cancellation and the proposed approach. As seen from Fig. 2 (a) 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 for $\varepsilon\epsilon[0.03,0.25]$. 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.



(a) (b)

Fig. 2 (a) CIR performance and (b) BER performance Comparison

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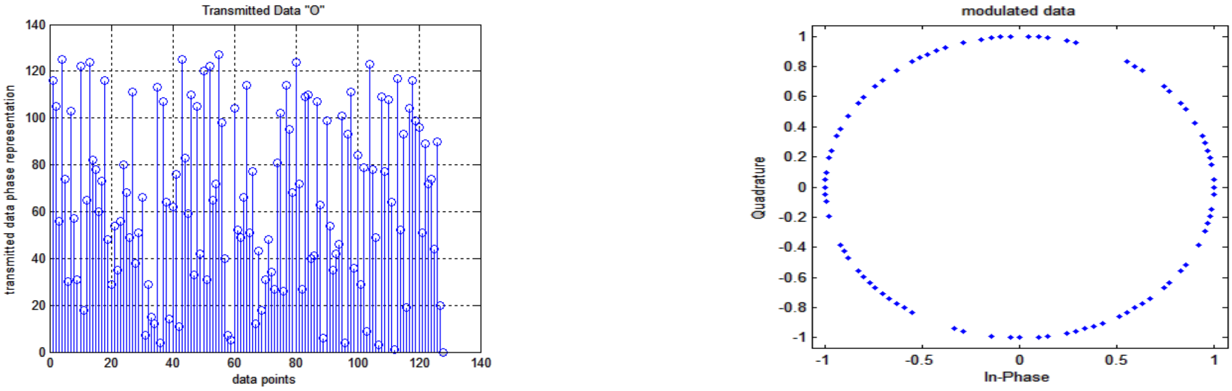
Fig3 (a) and (b) shows that the transmitted data and modulated data with 128 subcarriers and 128-PSK. The performance of the proposed scheme with higher modulation levels has shown in fig4 and fig5. We tested it with 128-QAM and N=128 subcarriers and we got the CIR of 63.9932 dB, which is an improved performance than the fig2 results.



(a) (b)

Fig. 3 (a) Data of Transmitter (b) modulated data

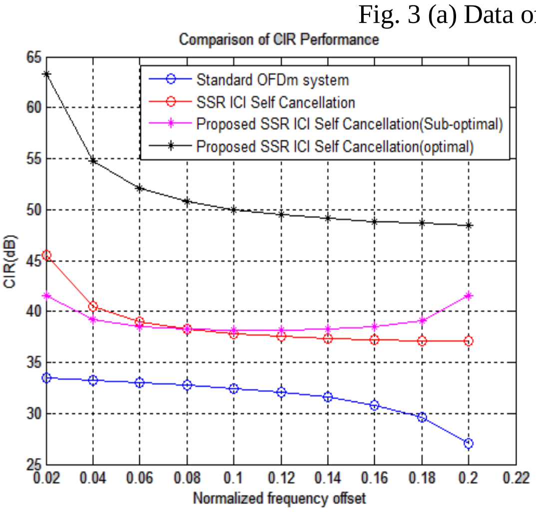


Fig. 4 CIR Performance with N=128 and 128-QAM

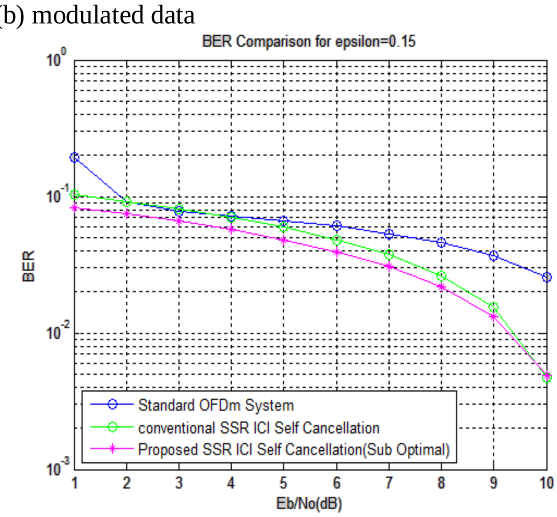


Fig.5 BER performance with 128-QAM and N=128

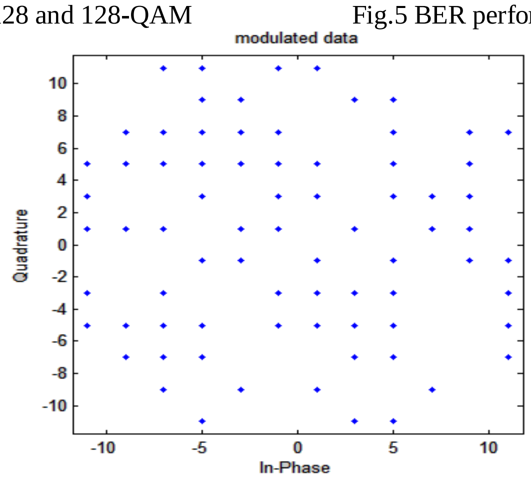


Fig.6 Modulated data with 128-QAM

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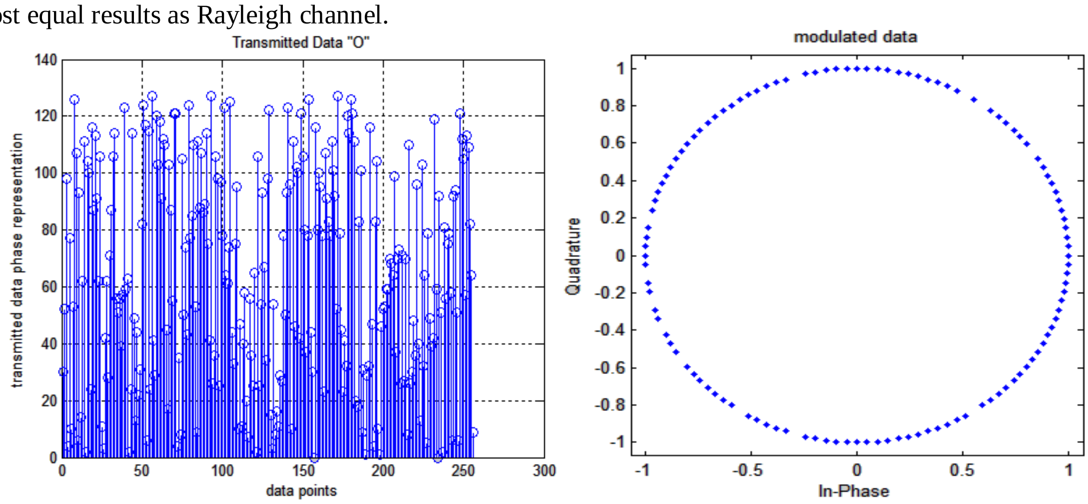
The modulated output of 128-QAM in presence of AWGN is shown in fig6 and it has got the CIR which is shown in fig4. Further CIR improvement can be achieved by using Rayleigh distribution instead of AWGN. Fig7 shows the performance of the proposed scheme in presence of Rayleigh channel distribution with 128-PSK and 256 subcarriers. We can see that the proposed scheme has got maximum CIR of 71.325with the Rayleigh distribution. Fig7 shows the transmitted data with 256 subcarriers and modulated data with 128-PSK and the fig10 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]. Fig10 shows the performance of Rician, which has got almost equal results as Rayleigh channel.



(a) (b)

Fig. 7 (a) Transmitted Data of N=256 and (b) modulated data with 128-PSK

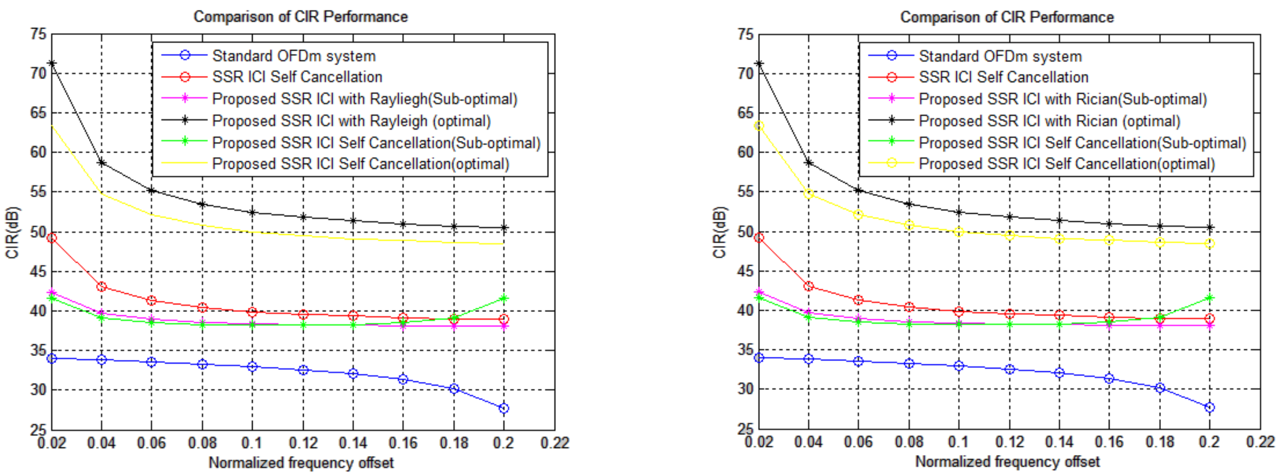


Fig10. CIR performance with N=256 and 128-PSK under Rayleigh, Rician channel models

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Table I
Simulation parameters

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

V.CONCLUSION

The proposed scheme very well improves the CIR performance of the OFDM system without increasing hardware complexity. The proposed sub optimal scheme completely removes the requirement of CFO estimation. However, the proposed scheme is slightly less efficient than conventional SSR ICI self cancellation in terms of BER.

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