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Increasing of CIR Performance of the OFDM System without Increasing Hardware Complexity

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Abstract—Symmetric symbol repeat (SSR) inter carrier interference (ICI) self cancellation scheme has proved to be a simple and convenient technique to reduce ICI caused by frequency offsets. It utilizes data allocation and combining of (1,-1) on two symmetrically placed subcarriers to mitigate the effect of ICI. However, the data allocation factors (1,-1) are not an optimum. In this paper, an optimum data allocation (1, -$\boldsymbol{\lambda}$) and combining (1,-μ) scheme is proposed to maximize CIR performance for an estimated normalized frequency offset combining But, this requires continuous CFO estimation and feedback circuitry. A sub-optimal scheme utilizing sub-optimal pair (λ_{so}, μ_{so}) is also proposed to completely eliminate the requirement of CFO estimation. Simulation results confirm the outperformance of the proposed optimal scheme over conventional SSR ICI self cancellation scheme. Sub-optimal scheme can be applied for the any range of ε and a sub optimum value can be (λ_{so}, μ_{so}) calculated using proposed sub-optimal scheme. The CIR of SSR ICI self cancellation scheme using the proposed sub-optimal approach is also found to be better than conventional SSR ICI self cancellation.

Keywords— *OFDM ; ICI ; CIR; BER*

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. 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. 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. 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.

Another ICI self cancellation scheme [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 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.

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,-$\boldsymbol{\lambda}$) 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 $\boldsymbol{\lambda}$ and μ are the optimal values resulting in maximum CIR. The optimum values of $\boldsymbol{\lambda}$ and μ are the function of normalized frequency offset i.e. for every normalized frequency offset; there exist a unique value of $\boldsymbol{\lambda}$ 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.

The rest of the paper is organized as follows. Section II describes the OFDM system model and the SSR ICI self cancellation scheme. Section III describes the proposed scheme including the method to calculate sub-optimal values of $\boldsymbol{\lambda}$ and μ. Simulation results are presented in Section IV and we conclude in Section V.

II. BACKGROUND

A. **OFDM System**

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

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

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

$$y[n] = x[n] e^{j\frac{2\pi\varepsilon n}{N}} + w[n], n = 0,1,2, \dots\dots\dots, N-1 \qquad (2)$$

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

$$Y(k) = X(k)S(0) + \sum_{l=0, l\neq k}^{N-1} X(l)S(l-k) + W(k), k = 0,1, \dots\dots, N-1 \qquad (3)$$

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

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

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.,

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

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

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

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

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

Using (6) & (7) we have

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

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

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

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

III. PROPOSED SCHEME

In the proposed scheme at the transmitter a data allocation (1,-$\boldsymbol{\lambda}$) 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

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

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

$$Y''(k) = Y'(k) - \mu Y'(N-1-k) \tag{11}$$

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

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

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

The optimal values of $\boldsymbol{\lambda}$ and μ have been found by using an optimization technique known as Nelder Mead Simplex Algorithm. The optimum values of $\boldsymbol{\lambda}$ and μ are calculated for $\varepsilon\ \epsilon[0.03,0.25]$ 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 $\boldsymbol{\lambda}$ 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 acontinuousCFOestimation.

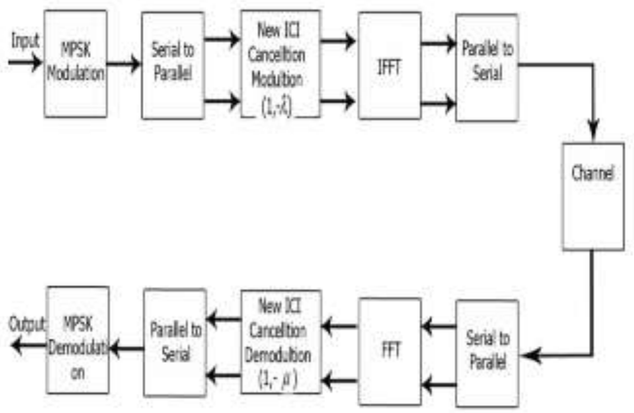

Fig1 Proposed Block diagram of ICI Self cancellatio

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

Here, $CIR_p(\varepsilon_1, \lambda_{01}, \mu_{01})$ corresponds to maximum value of CIR for $\varepsilon_1$and so on and

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

Where, $\varepsilon_H\ and\ \varepsilon_L$ 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

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

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.

In the proposed scheme, $\Delta\varepsilon$ is taken as 0.02 and thus is

12. Applying the above described algorithms, sub-optimal values are λ_{so} =0.6164 and μ_{so}=1.0351.

This optimization and sub-optimization technique can be applied for any range as required.

IV. RESULTS & DISCUSSION

In this paper, we have considered an OFDM system with N=256 subcarriers and QPSK modulation scheme is used to modulate each of the subcarriers. The simulation model of the OFDM system is shown in Fig.1. The computer simulation using MATLAB are performed to evaluate CIR and BER performance. Fig. 2 shows the CIR performance of standard OFDM system, SSR ICI self-cancellation, Proposed SSR ICI self cancellation using optimal & sub-optimal approach. Fig. 3 shows BER performance of the standard OFDM system, conventional SSR ICI self cancellation and the proposed SSR ICI self cancellation using sub-optimal approach.

As seen from Fig. 2 the CIR performance of the proposed optimal approach is about 20dB better than the conventional SSR ICI self cancellation scheme. However, the proposed sub-optimal approach also provides better CIR scheme performance over conventional SSR ICI self cancellation scheme, proposed suboptimal approach provides a gain of more than 10dB at $\varepsilon = 0.15$over conventional SSR ICI self cancellation scheme. The CIR performance of proposed SSR ICI self cancellation scheme is slightly worse than conventional SSR ICI self cancellation scheme for $\varepsilon\epsilon[0.03,0.25]$. The BER performance of the proposed SSR ICI self cancellation scheme is very much improved in comparison to standard OFDM system and very close to conventional SSR ICI self cancellation scheme.

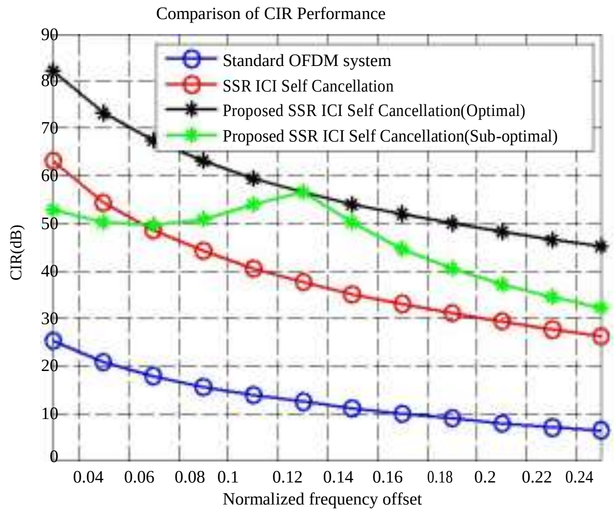

Figure 2. CIR performance comparison of various ICI self cancellation scheme

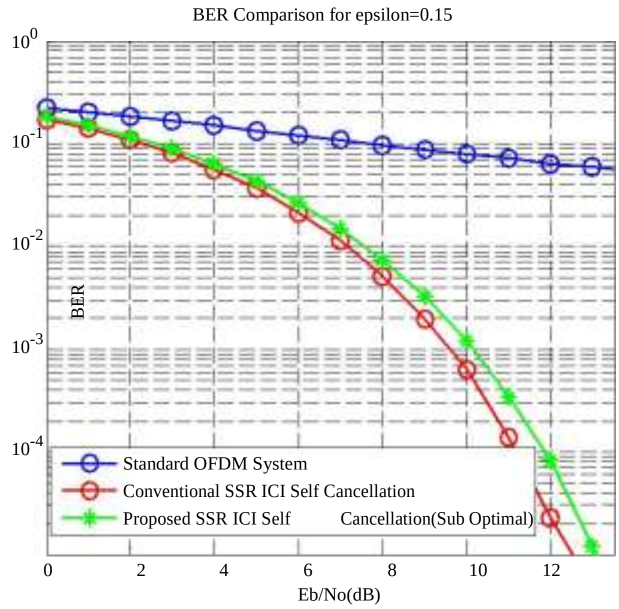

Figure 3. BER performance comparison

V. CONCLUSIONS

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.

REFERENCES

1. Y.Wu and W. Y. Zou, "Orthogonal frequency division multiplexing: A multicarrier modualtion scheme", IEEE

Transaction on Consumer Electronics, vol. 41, no. 3,pp 392-399, Aug. 1995.
2. P.H.Moose, “A Technique for orthogonal frequency division multiple xing frequency offset correction,’’IEEE Trans. Commun., vol.42, pp 2908-2914, Oct. 1994.
3. Y. Zhao and S.G. Haggman, “Intercarrier Interference Self-Cancellation Scheme for OFDM Mobile Communication Systems ’’,IEEE Trans.Commun., vol. 49, no. 7, pp. 1185-1191, Jul. 2001.
4. H.-G. Yeh, Y.-K. Chang, and B. Hassibi, “A scheme for cancelling intercarrier interference using conjugate transmission in multicarrier communication systems," IEEE Trans. Wireless Communication., vol. 6, no. 1, pp. 3-7, Jan. 2007.
5. Chin-Liang Wang and Yu-Chih Huang, “Inter carrier Interference Cancellation Using General Phase Rotated Conjugate Transmission for
6. OFDM Systems” IEEE Transactions on Communications, vol. 58, no. 3, pp. 812-819, March 2010.
7. K.Sathanantham , R.M.A.P.Rajatheva and Slimane Ben Slimane “Analysis of OFDM in the Presence of Frequency Offset and a Method to Reduce Performance Degradation” Global Telecommunications Conference, 2000. GLOBECOM '00. IEEE,vol. 1,pp. 72-76, 2000.
8. Yu Fu and Chi Chung Ko, “A New ICI Self – Cancellation Scheme for OFDM Systems based on a Generalized Signal Mapper”, 5th International Symposium on Wireless Personal Multimedia Communications, vol. 3, pp. 995-999, Oct. 2002.
9. J. H. Mathews, K. K. Fink, Numerical Methods using Matlab, 4th edition, Prentice-Hall Inc. , 2004

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