A NOVEL ICI SELF CANCELLATION SCHEME FOR OFDM SYSTEM WITHOUT INCREASING HARDWARE COMPLEXITY

Jagadeesh Botcha[1], Kranthi Kumar .K[2], Priscilla Dinkar. M[3]

[1] M.Tech Student, Dept of ECE, TPIST/JNTUK,(India)
[2,3] Assistant professor, Dept of ECE, TPIST/JNTUK,(India)

ABSTRACT

A well known problem of orthogonal frequency division multiplexing (OFDM) is its sensitivity to frequency offset between the transmitted and received signals, which may be caused by Doppler shift in the channel, or by the difference between the transmitter and receiver local oscillator frequencies. This carrier frequency offset causes loss of orthogonality between sub-carriers and the signals transmitted on each carrier are not independent of each other. The orthogonality of the carriers is no longer maintained, which results in inter-carrier interference (ICI). Symmetric symbol repeat (SSR) inters 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,-λ) and combining (1,-μ) scheme is proposed to maximize CIR performance for an estimated normalized frequency offset_ . 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 _ 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 - ICI, OFDM, AWGN, Doppler Shift, Correlative Coding, Symmetric Conjugate, CIR

I. INTRODUCTION

In recent years, direct conversion receiver has drawn a lot of attention due to its low power consumption and low implementation cost. However some mismatches in direct conversion receiver can seriously degrade the system performance, such as in-phase and quadrature-phase (I/Q) imbalance and carrier frequency offset (CFO). The I/Q imbalance is due to the amplitude and phase mismatches between the I and Q-branch of the local oscillator whereas the CFO is due to the mismatch of carrier frequency at the transmitter and receiver. It is known that the I/Q imbalance and CFO can cause a serious inter-carrier interference (ICI) in orthogonal frequency division multiplexing (OFDM) systems. As a result, the bit error rate (BER) has an error-flooring. In assuming that the channel frequency response is smooth, a frequency-domain estimation method has been proposed to jointly estimate the I/Q imbalance and channel frequency response. Recently, exploiting the fact that the size of the DFT matrix is usually larger than the channel length in OFDM systems, a time-domain method was proposed for the joint estimation of I/Q and channel response. Both the frequency-domain and time-domain methods need only one OFDM block for training and can achieve a good performance.

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-Kth and utilizes a data allocation of (1,-λ) to improve CIR performance. To further reduce the effect of ICI, received modulated data signal at . Kth and N-1-Kth 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 an 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 (λ *so*, μ *so*) .The obtained sub-optimal values 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.

II. SYSTEM MODEL

2.1OFDM System

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

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

Where 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

$$y(n) = x(n)e^{j2\pi\varepsilon n/N} + w(n), n = 0,1,2,\ldots\ldots N-1 \tag{2}$$

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

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

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

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

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

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

2.2 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 N- 1- k^{th} subcarrier 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 Fig. 1. The received data signal at the k^{th} subcarrier is thus given by

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

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

$$Y''(k) = Y'(k) - Y'(N-1-k) \tag{7}$$

Using (6) & (7) we have

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

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

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,-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

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

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

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

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

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

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

The optimal values of λ and μ have been found by using an optimization technique known as Nelder Mead Simplex Algorithm [8]. 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 given μ. Thus for every ε , we have a unique optimal value of λ and μand these are denoted by (λo ,μo).The optimum values (λo,μo).are to be used for data allocation and combining the data at k^{th} and N-1-k^{th} subcarriers to maximize the CIR of the OFDM system. But, this will require a continuous CFO estimation.

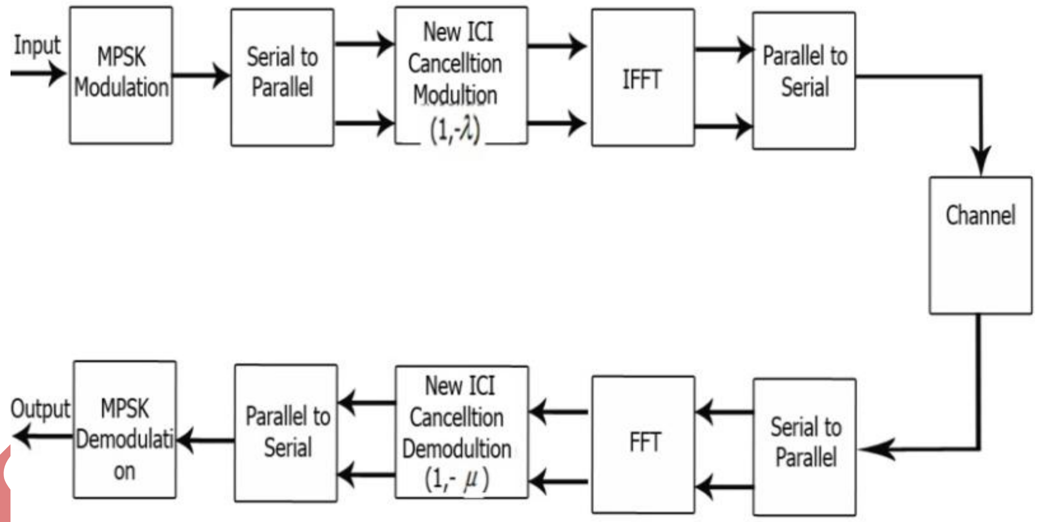

Fig.1. Block diagram for the Proposed Scheme

For each pair of (λ_o,μ_o) , the CIR has been calculated, which forms a CIR matrix as shown

$$CIR_p(\varepsilon,\lambda_o,\mu_o)=\begin{bmatrix} CIR_p(\varepsilon_1,\lambda_{o1},\mu_{o1}) & \cdots & \cdots & CIR_p(\varepsilon_v,\lambda_{o1},\mu_{o1}) \\ \vdots & \ddots & & \vdots \\ \vdots & & \ddots & \vdots \\ \vdots & & \ddots & \vdots \\ CIR_p(\varepsilon_1,\lambda_{ov},\mu_{ov}) & \cdots & \cdots & CIR_p(\varepsilon_v,\lambda_{ov},\mu_{ov}) \end{bmatrix} \tag{14}$$

Here, CIR_p (ε_1,λ_{o1},μ_{o1}) corresponds to maximum value of CIR for ε_1, and CIR_p (ε_2 ,λ_{o2} ,μ_{o2}) corresponds to maximum CIR for ε1 and so on and

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

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

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

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 of ε, (λ_{so},μ_{so}) can be used for data allocation and combining to get a sub-optimal CIR performance. In the proposed scheme, Δε is taken as 0.02 and thus v 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. SIMULATION RESULTS

The simulations were performed for the improved ICI cancellation scheme and the same were compared with the existing schemes and standard OFDM. 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 [6], 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 suboptimal 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 ε=0.15 over conventional SSR ICI self cancellation scheme. The CIRperformance of proposed SSR conventional SSR ICI self cancellation scheme for $\varepsilon \in [0.03,0.08]$. 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. ICI self cancellation scheme is slightly worse than conventional SSR ICI self cancellation scheme for $\varepsilon \in [0.03,0.08]$.

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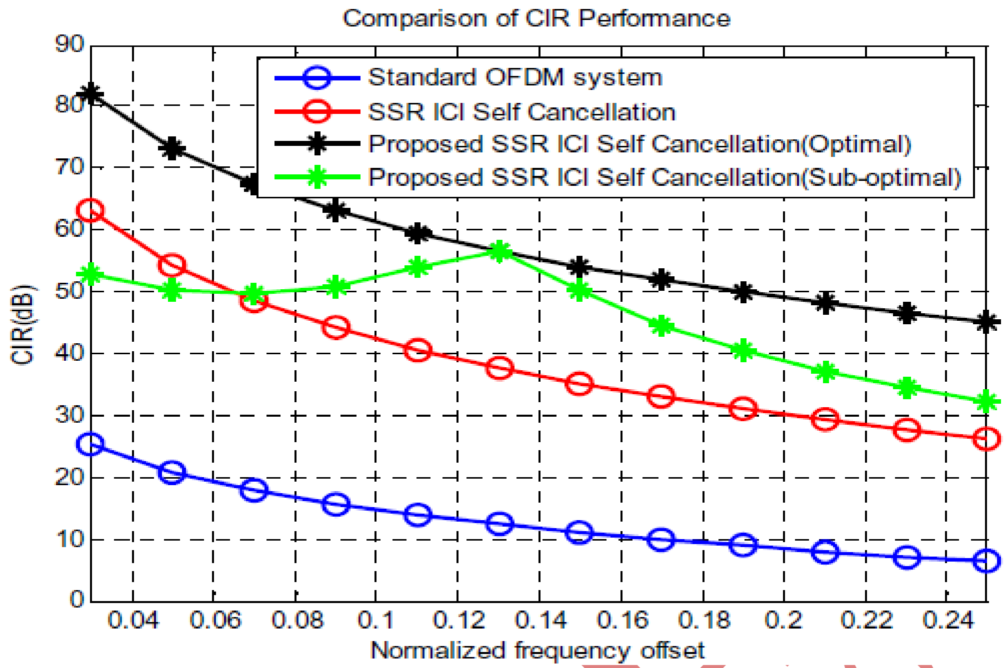

Fig.2 CIR performance comparison of various ICI Self cancellation scheme

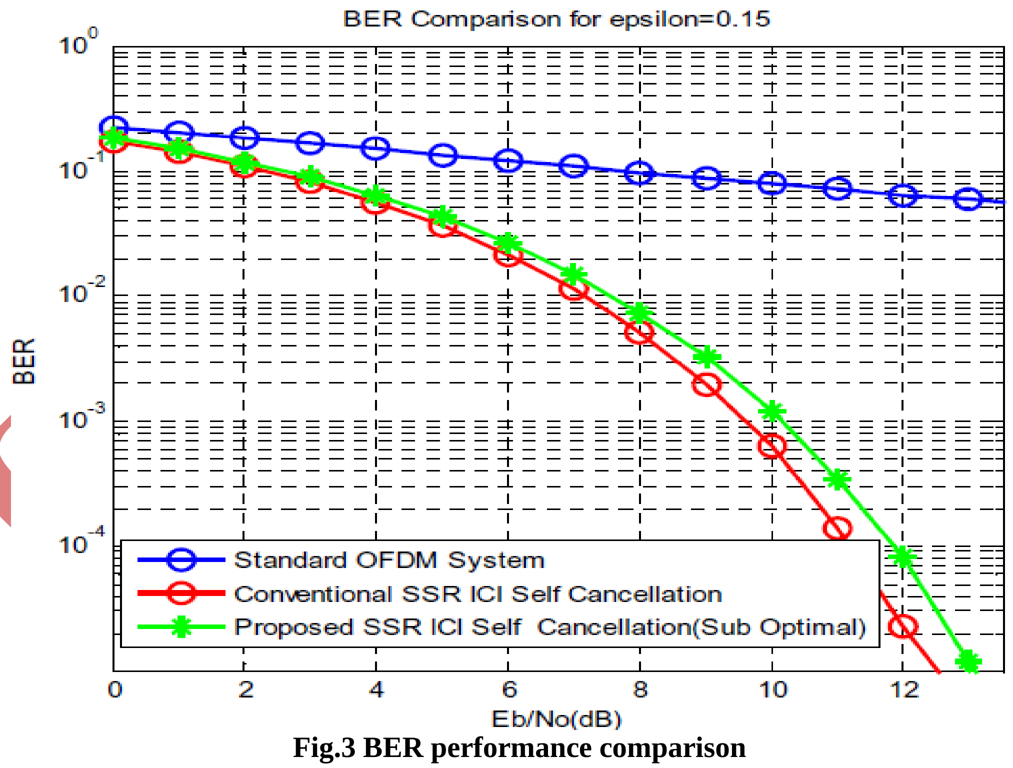

Fig.3 BER performance comparison

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 modulation schem, 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, ―Intercarrier Interference Cancellation Using General Phase Rotated Conjugate Transmission for OFDM Systems‖ IEEE Transactions on Communications, vol. 58, no. 3, pp. 812-819, March 2010.

[6] K.Sathananantham , R.M.A.P.Rajatheva and Slimane Ben Slimane ―Analysis of OFDM in the Presence of Frequency Offset and a Method to Reduce Performane Degradation‖ Global Telecommunications Conference, 2000. GLOBECOM '00. IEEE,vol. 1,pp. 72-76, 2000.

[7] 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.

[8] J. H. Mathews, K. K. Fink, Numerical Methods using Matlab, 4th edition, Prentice-Hall Inc. , 2004. 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.