A Kalman Filter Approach to Reduce ICI in OFDM Systems

Pardeep[1], Sajjan Singh[2], S. V. A. V. Prasad[3]

[1]M.Tech Scholar, Department of ECE, BRCM CET, Bahal, Bhiwani, India
e-mail: ps58519@gmail.com

[2]Assistant Professor, Department of ECE, BRCM CET, Bahal, Bhiwani, India
e-mail: sajjantech@gmail.com

[3]Professor, Department of Electronics & Communication Engineering, Lingaya's University, Faridabad, India
e-mail: prasad.svav@gmail.com

***Abstract*— One of the major problem with OFDM system is the Inter channel Interference. When the communication is performed parallel over the multiple channels, then because of the high speed communication, some noise occur itself because of carrier interferences or the overlapping of carrier signal. To achieve the effective communication over in OFDM the reduction of ICI is required. In this present work, a kalman filter based approach is presented. The work is implemented for both the OFDM and MIMO-OFDM systems under different modulation approaches. The result analysis shows the significant improvement over the signal.**

Keywords— **ICI, OFDM, Kalman Filter, QAM, QPSK**

I. Introduction

OFDM signals are one of the most used communication signal that perform the digital communication over the network. It is been adapted by most of the wireless as well as optical network to provide reliable, robust and effective communication over the network. These signals having some difficulties in generation of large banks of phase lock Oscillator and receiver in the analog domain. As other communication mediums, OFDM communication is divided in two main stages called the transmission section and the receiving section[1,2]. The transmitter section basically perform the conversion of the digital data in the transmission signal as well as map them to the sub carrier respective to the amplitude and phase settings. The transformation in this signal form is been done respective to the spectral representation of data under the time domain by using Inverse FFT(Fast Fourier Transformation) [3]. To perform the effective transmission for OFDM signal, the time domain based signal is estimated and then mixed up with the required frequency.

The receiver side operation is just reverse to the transmission side communication. This kind of signal mix the RF signal to the baseband for the processing. Just after this the signal analysis is performed on digital data[4]. FFT is been performed as the complementary function with most appropriate terms specification to define the effective signal generation and the receiving[5]. The block diagram of the OFDM transreciever system is shown in figure 1.

In OFDM systems the communication is performed serially. Each symbol is defined with group of symbols and for the transmission the serial to parallel conversion is been

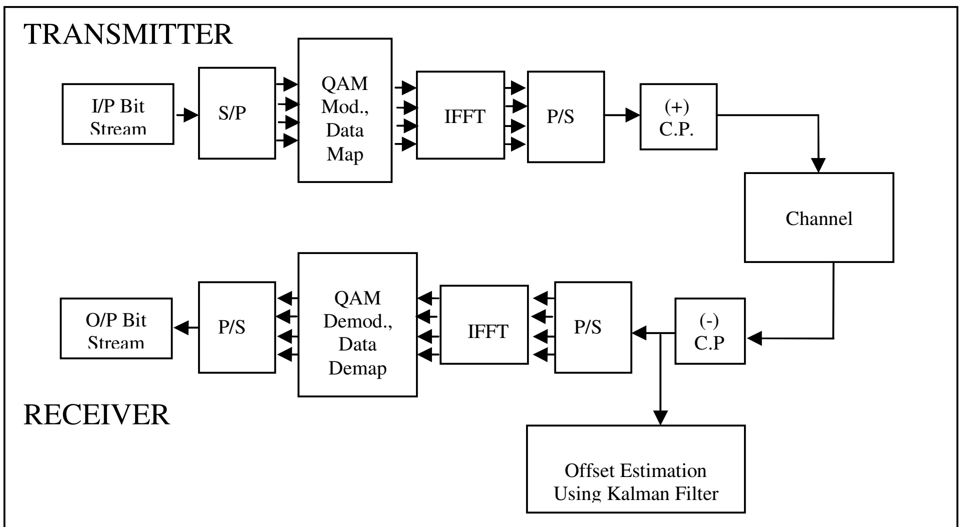

Fig. 1 Modified Block Diagram of OFDM System

ISBN: 978-93-83758-09-8

Performed [5, 6]. The data allocated to each symbol depends on modulation scheme as well as based on number of subcarriers. To perform this conversion, different adaptive modulation schemes are been used. For example, for a subcarrier modulation of 16-QAM each subcarrier carries 4 bits of data, and so for a transmission using 100 subcarriers the number of bits per symbol would be 400.

The decision of the modulation and the encoding technique is required to select to solve out the different communication issues. The decision also depends on the number of sub carriers. This modulated data is transmitted on each sub carrier. The modulation scheme is basically the mapping to complex number format. Where the real part represents the phase and the imaginary part represents the quadrature. Collectively it is called IQ constellation. In this present work QAM modulation scheme is been used for the modulation [7, 8].

A OFDM signal consisting number of closely spaced modulated carriers, when modulation of any form like voice, data etc. is applied to the carrier then sidebands spread out either sides. In this case of OFDM the side bands of each carrier overlap, they can still be received without the interference that might be expected because they are orthogonal to each other [9]. Along with this OFDM has following benefits:

- Gives the higher spectral utilization.
- Reduces the multipath distortions.
- It has lower multipath distortion.
- It employs the multimode modulation based on sub-carriers which maximize the channel throughput because of orthoganality principle it uses.

II. ICI

The presented work is about to reduce the ICI in OFDM signal. The reciving signal in OFDM system is represented by equation 1.

$$Y(k) = X(k)S(0) + \sum_{l=0,\, l\neq k}^{N} \sum X(l)S(l-k) + n_k$$
$$k = 0,1,\ldots.N-1 \qquad (1)$$

Here k is sub carriers for which the reciving signal is presented

N is number of subcarrier in the system

X (k) is the modulated signal

nk is the additive Gaussian noise

S is the coefficient to represent the signal in complex form

The major phase of the analysis is the modulation scheme. During this phase, the mapping of the data is performed on two sub carriers under the defined coefficient vectors. The estimation of these weighted values are required to analyze the ICI over the signal on two successive sub carriers [10]. The simplest form of this analysis is represented by self cancellation. The lesser the difference between two consecutive signals, lesser the ICI will be as well as higher the efficiency of the signal will be. In this work, kalman filter based approach is presented to estimate the ICI over the signal.

The kalam filter approach is the statistical measure to identify the non linearity over the signal [11]. It basically estimate the frequency offset in receiving signal as well as optimization of the signal under the impulse response during the transmission of signal. The preamble preceding each frame can thus be utilized as a training sequence for estimation of the frequency offset imposed on the symbols in this frame. To present the concept of kalman filter, the training signal is defined in the time domain and it is been generated under the baseband analysis and with QAM modulation. The frequency offset is been defined over the signal under the frequency shift mechanism. The normalized frequency offset is been used to normalize the sgianl. The training sequence without offset is given as

$$y(n) = s(n)e^{j2\pi n'\varepsilon/N} + w(n), \qquad (2)$$

Here w(n) is the white Gaussian noise

The state space of kalman filter is given as

$$\hat{\varepsilon}(n) = \hat{\varepsilon}(n-1)$$
$$y(n) = e^{j2\pi n'/N\cdot\hat{\varepsilon}(n)} s(n) + w(n) \qquad (3)$$

It is observed that the EKF technique offers fast convergence. The ICI distortion in the following data symbols can be mitigated by multiplying the received signal with a complex conjugate of the estimated frequency offset.

The ICI self-cancellation scheme requires that the transmitted signals be constrained such that,,

$X(1) = -X(0), X(3) = -X(2), \ldots..X(N-1) = -X(N-2)$

Using (3.3), this assignment of transmitted symbols allows the received signal on subcarriers k and k + 1 to be written as [6].

$$Y'(k) = \sum_{\substack{l=0 \\ l=even}}^{N-2} X(l)[S(l-k) - S(l+1-k)] + n_k \qquad (4)$$

$$Y'(k+1) = \sum_{\substack{l=0 \\ l=even}}^{N-2} X(l)[S(l-k-1) - S(l-k)] + n_{k+1} \qquad (5)$$

And the ICI coefficient S’ (l-k) is denoted as

$$S'(l-k) = S(l-k) - S(l+1-k) \qquad (6)$$

ISBN: 978-93-83758-09-8

ICI modulation introduces redundancy in the received signal since each pair of subcarriers transmit only one data symbol. This redundancy can be exploited to improve the system power performance, while it surely decreases the bandwidth efficiency [12]. To take advantage of this redundancy, the received signal at the (k + 1)th sub carrier, where k is even, is subtracted from the kth sub carrier. This is expressed mathematically as

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

$$\sum_{\substack{l=0 \\ l=even}}^{N-2} X(l)[-S(l-k-1)+2S(l-k)-S(l-k+1)]+n_k-n_{k+1} \tag{8}$$

Subsequently, the ICI coefficients for this received signal becomes

$$S''(l-k) = -S(l-k-1) + 2S(l-k) - S(l-k+1) \tag{9}$$

When compared to the two previous ICI coefficients |S (l-k)| for the standard OFDM system and |S' (l-k)| for the ICI cancelling modulation, |S'' (l-k)| has the smallest ICI coefficients, for the majority of l-k values, followed by |S' (l-k)| and |S (l-k)|.

The equations used in Kalman filter are called as Time Update and Measurement Update equations as given below:

Time Update Equations are as follows:

$$\hat{x}_k^- = f\left(\hat{x}_{k-1}, u_{k-1}, 0\right) \tag{10}$$

$$P_k^- = A_k P_{k-1} A_k^T + W_k Q_{k-1} W_k^T \tag{11}$$

Measurement Update Equations are as follows:

$$K_k = P_k^- H_k^T \left(H_k P_k^- H_k^T + V_k R_k V_k^T\right)^{-1} \tag{12}$$

$$\hat{x}_k = \hat{x}_k^- + K_k\left(z_k - h\left(\hat{x}_k^-, 0\right)\right) \tag{13}$$

$$P_k = \left(I - K_k H_k\right) P_k^- \tag{14}$$

slot based system and the process will be performed on each slot. The work is about to remove the interference noise and some other errors from the signal. For this some external error is included in the form of Noise. The noise considered here is the Gaussian noise. As in case of data is transmitted in the form of block so that the serial to parallel

III. PROPOSED WORK

The presented work is about the detection of ICI over the signal by using Kalman Filter approach. In this proposed work, here the error signal is measured by analysing the BER in transmission and receiving signals:-

1. In the simplest form, the ICI detection is performed based on power measurement on FFT demodulator. If the signal is higher than average, it means some interference is present over the signal. But method having the drawback of this method is that it will work if there is strong ICI for weak ICI it will not work. In case fading selective frequency this method will not work.
2. To resolve this problem Kalman Filter Improved interference detection is proposed. According to it if ICI is not present, magnitude of signal is taken to resolve the cases of small error over the signal.
3. In the proposed approach, at first the PAPR reduction is been implemented to improve the smoothness over the signal i.e. to remove the non linearity over the signal.
4. After that the averaging of different adjacent signals is taken to improve the ICI detection capability.
5. To take, this error reduction, a kalman filter based approach is been taken for BER analysis over the signal.
6. A threshold value is been taken to subtract from the averaging signal to perform the error reduction.
7. A symbol by symbol averaging and mapping filter is been used to accumulate the OFDM symbols.
8. A non recursive filter is been implemented with two threshold values, if the average and accumulated value is large than threshold2 then 1 is taken as the signal value it shows ICI is present. If value is less than threhsold2. It means no ICI present and represented by 0.

In this present work at first the OFDM spectrum is define with the specific parameters. These parameters include the channel length, block size, frequency offset etc. Under these all constraint the OFDM signal is generated. As the signal generated it may have some internal interference noise in it. This signal is divided in number of sub blocks as the proposed system is a

conversion is performed. As the blocks are defined each block defines the number of bits parallel transferred. Now respective to the subcarrier specification the mapping is performed using the modulation scheme. The modulation considered here includes the BPSK, QPSK and the QAM. While specifying the modulation scheme the numbers of

ISBN: 978-93-83758-09-8

combination bits are specified. According these bits the mapping vector is generated and the effective communication is performed. Once the modulation is performed the next work is to convert the signal to the time domain. For this conversion the fast Inverse fourier transformation is performed. Once this conversion is performed now the data is ready for the transmission and the communication is performed.

IV. SIMULATION & RESULTS

The presented work is implemented in Matlab 7.8 environment and the obtained results from the system are given as under. The parameters taken for presenting work are given as under:-given as under. The parameters taken for presenting work are given as under:-

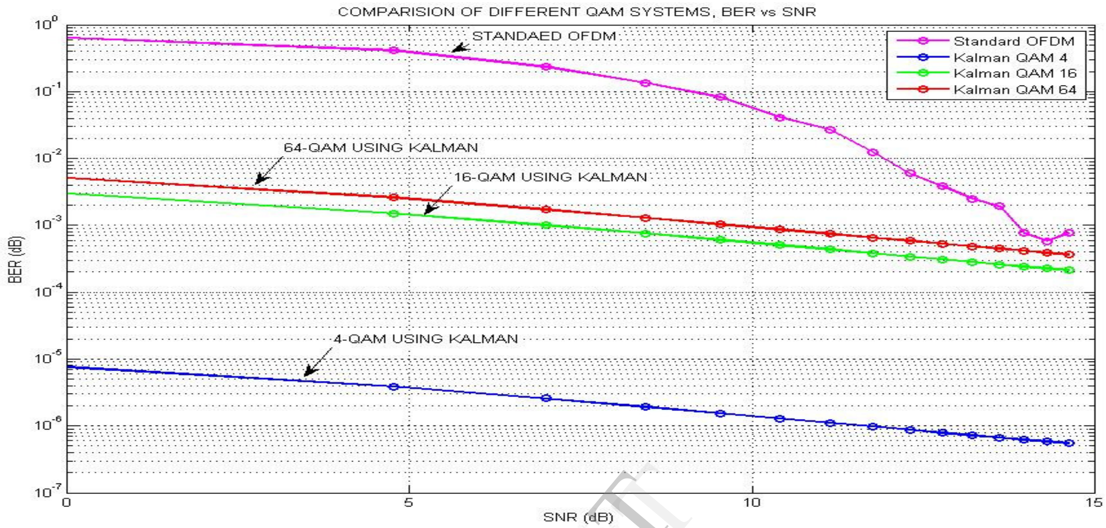

Figure 2 : Comparison different QAM systems

Figure 2showing the comparative analysis of Different QAM systems. The analysis is here performed between Proposed and Existing OFDM systems under different QAM Modulations. The comparision is here performed for OFDM 4, 16 and 64. As we can see, the BER for the OFDM using Kalman Filter for QAM 4 is least among all methods whereas standard OFDM is giving the highest BER among all methods.

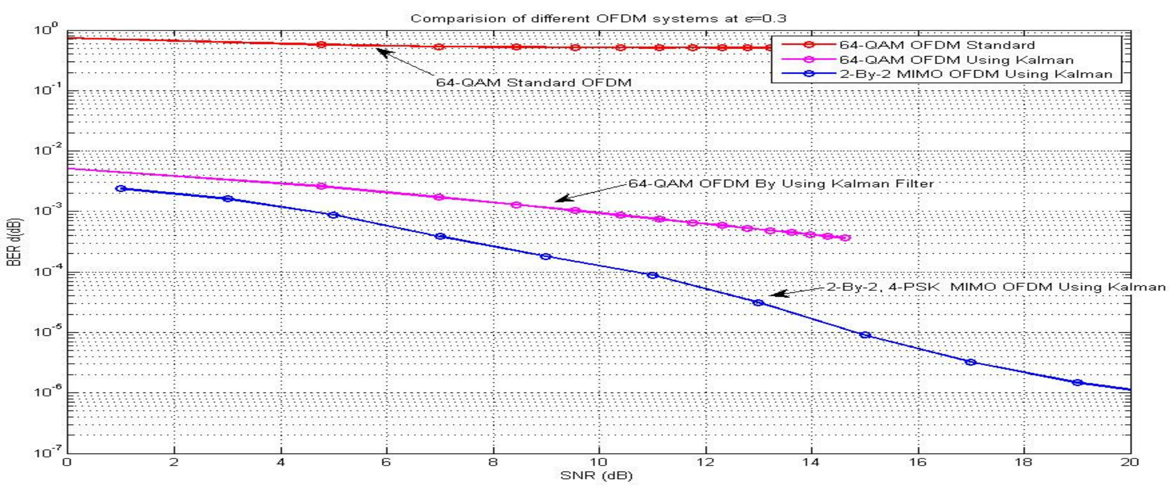

Figure 3: Comparison of different OFDM systems at ε=.3

ISBN: 978-93-83758-09-8

Here figure 3 is showing the comparative analysis of Different OFDM systems. The analysis is here performed between Existing and Proposed OFDM systems. The results are obtained for QAM64 modulation and 4PSK Modulations. As we can see, the BER for the OFDM using Kalman Filter under 4PSK is least among all methods whereas standard OFDM is giving the highest BER.

V. CONCLUSIONS

In this paper, the performance of OFDM systems in the presence of frequency offset between the transmitter and the receiver has been studied in terms of the Carrier-to-Interference ratio (CIR) and the bit error rate (BER) performance. Inter-carrier interference (ICI), which results from the frequency offset, degrades the performance of the OFDM system. One method is explored in this project for mitigation of the ICI i.e. ICI self-cancellation (SC) using kalman filter approach. The obtain results shows that the significant improvement over the signal linearity is achieved.

REFERENCES

[1] S.Weinstein and P.Ebert, “Data transmission by frequency-division multiplexing using the discrete Fourier transform,” IEEE Trans. Commun.,vol.19, pp. 628-634, Oct.1971.

[2] L.J. Cimini, “Analysis and Simulation of a Digital Mobile Channel Using Orthogonal Frequency Division Multiplexing”, IEEE Transactions on Communication no.7 July 1985.

[3] P.H. Moose, “A technique for orthogonal frequency division multiplexing frequency offset Correction”, IEEE Trans. Commun., 42, pp.2908–2914, October 1994.

[4] Russell, M.; Stuber, G.L.; “Interchannel interference analysis of OFDM in a mobile environment”, Vehicular Technology Conference, 1995 IEEE 45th, vol. 2, pp. 820 –824, Jul. 1995.

[5] J.J. van de Beek, M. Sandell and P.O. Borjesson, “ML estimation of time and frequency offset in OFDM systems”, IEEE Trans. Signal Process., 45, pp.1800–1805, July 1997.

[6] Yao Xiao, “Orthogonal Frequency Division Multiplexing Modulation And Inter-Carrier Interference Cancellation,” B.S., Dalian University of Technology, May-1998.

[7] J. Armstrong, “Analysis of new and existing methods of reducing intercarrier interference due to carrier frequency offset in OFDM,” IEEE Transactions on Communications, vol. 47, no. 3, pp. 365 – 369, March 1999.

[8] Y.Zhao and S. Häggman, “Intercarrier interference selfcancellation scheme for OFDM mobile communication systems,” IEEE Transactions on Communications, vol. 49, no.7, pp. 1185 – 1191, July 2001.

[9] Y. Fu, S. G. Kang, and C. C. KO, “A new scheme for PAPR reduction in OFDM systems with ICI self-cancellation,” in Proc. VTC 2002- Fall, 2002 IEEE 56th Vehicular Technology Conf., vol. 3, pp 1418–1421, Sep. 2002.

[10] X.Cai, G.B.Giannakis,”Bounding performance and suppressing inter-carrier interference in wireless mobile OFDM”, IEEE Transaction on communications, vol.51, pp.2047-2056, no.12, Dec.2003.

[11] Tiejun (Ronald) Wang, John G. Proakis, and James R. Zeidler “Techniques for suppression of intercarrier interference in ofdm systems”. Wireless Communications and Networking Conference, 2005 IEEE Volume 1, Issue, 13-17 pp: 39 - 44 Vol. 1, March 2005.

[12] S.Driz, M.Bouziani and J.M.Rouvaen, “Inter-Carrier Interference Cancellation for OFDM Systems”, ACTA ELECTRONTECHNICA, Volume 50, Number 3, 2009.