Ijesm
Consulting, help, relaxation
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & MANAGEMENT

APPROXIMATION OF INTER CARRIER INTERFERENCE CANCELLATION IN OFDM SYSTEMS USING KALMAN FILTER

Manish Yadav*, Ashish Dixit & Pallavi Asthana
Department of Electronics & Communication Engineering,
Amity School of Engineering & Technology, Amity University, Lucknow

Abstract
Carrier frequency offset is the major problem associated with OFDM systems as it causes the loss of orthogonality of sub-carriers & hence results into Inter Carrier Interference (ICI). So, the minimization of (ICI) is one of the most important challenges for OFDM system developers. Many possible methods exist to minimize/remove ICI upto the maximum extent. The aim of this paper is to focus on the use of Kalman Filter for ICI cancellation in OFDM system. This paper also shows the simulation result under specified parameters & thus investigates its performance in reducing ICI.

Key-words: OFDM, ICI, Kalman Filter.

Introduction
The word OFDM stands for Orthogonal Frequency Division Multiplexing. It is a bandwidth efficient signaling scheme for digital communication in which the input bit stream is modulated in parallel on a number of sub-carriers which are orthogonal to each other. Relation of orthogonality is the prime feature of OFDM sub-carriers. OFDM based systems are an example of multicarrier systems which are extensively employed in applications such as Tellurian Digital Video Broadcasting (DVB-T), Digital Audio Broadcasting (DAB), IEEE 802.11a standard for wireless Local Area Network (WLAN) etc. One of the major limitations of OFDM systems is that they are very sensitive to frequency offsets. This gives rise to Inter Carrier Interference (ICI).Since OFDM systems ensure the existence of multicarrier hence they are prone to frequent Inter Carrier Interference (ICI).

*** Corresponding Author**

Theory
1. Different possible ways to minimize ICI:

There are many ways to eradicate the problem of ICI. Some of them can be named as:

- Pulse shaping
- Frequency domain equalization
- Time domain windowing
- ICI self cancellation
- Extended Kalman Filtering etc.

Out of the above one of the important methods is being taken into consideration for further exploration. This method is ICI reduction via Extended Kalman Filtering (EKF).

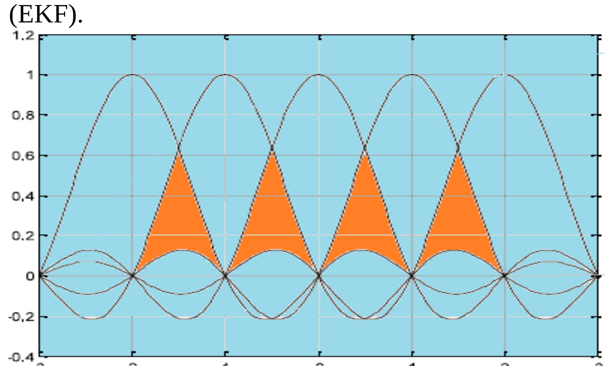

Fig: Sub-carries spacing in OFDM system with ICI

Extended Kalman Filter ICI Cancellation Approach

As it is a well known fact that in OFDM systems ICI generally occurs due to the small differences of carrier frequencies at transmitter & receiver. These differences of frequencies are commonly termed as f*requency offsets*.

Kalman filters are very common in the field of engineering especially termed in communications and signal processing techniques. The Kalman filter is an outstandingly versatile and potent recursive approximation algorithm that has enormous applications in communications, such as adaptive antenna arrays, adaptive equalization of fading dispersive channels, and adaptive equalization of telephone channels.

As a recursive filter, it is particularly applicable to non-stationary processes such as signals transmitted in a time-variant radio channel. In approximating non-stationary processes, the Kalman filter computes & approximates its own performance as part of the recursion and use this information to update the approximate at each step. Therefore, the approximation procedure is adjusted to the time-variant statistical characteristics of the random process.

A state –space model of discreet Kalman filter is defined as

z(n) = a(n).d(n) + v(n)

In this model, the observation *z*(*n*) has a linear relationship with the desired value *d*(*n*) . By using the discrete Kalman filter, *d*(*n*) can be recursively estimated based on the observation of *z*(*n*) and the updated estimation in each recursion is optimum in the minimum mean square sense.

$$y(n) = x(n) e^{j\frac{2\pi n'\varepsilon(n)}{N}} + w(n)$$

i.e.

it can also be written as:

$$y(n) = f(\varepsilon(n)) + w(n)$$

$$\text{Where } f(\varepsilon(n)) = x(n) e^{j\frac{2\pi n'\varepsilon(n)}{N}}$$

.

from taylor series expansion

$$y(n) \approx f(\hat{\varepsilon}(n-1)) + f'(\hat{\varepsilon}(n-1))[\varepsilon(n) - \hat{\varepsilon}(n-1)] + w(n)$$

where $\varepsilon^{\wedge}$(n-1) is the approximation of ε(n-1).

Define

$$z(n) = y(n) - f(\hat{\varepsilon}(n-1))$$

$$d(n) = \varepsilon(n) - \hat{\varepsilon}(n-1)$$

& following relationship

$$z(n) = f'(\varepsilon(n-1))d(n) + w(n)$$

This shows that z(n) are linearly related.

Now considering the certain assumptions true [6]; the state equation to approximate the offset can be as

$$\varepsilon(n) = \varepsilon(n-1)$$

The pseudo (code for EKF) of computation can be given with state error

$$p(n) = [1 - k(n)H(n)]p(n-1)$$

&

update approximate

$$\hat{\varepsilon}(n) = \hat{\varepsilon}(n-1) + \text{Re}\left\{k(n)\left[y(n) - x(n)e^{\frac{j2\pi n'\hat{\varepsilon}(n-1)}{N}}\right]\right\}$$

On applying offset correction scheme[5][6],

$$\hat{x}(n) = FFT\left\{y(n)e^{-j\frac{2\pi n'\hat{\varepsilon}}{N}}\right\}$$

Results

The Matlab simulation results of EKF ICI cancellation approach under the following parameters are shown by figures given below:

Parameters	Specifications
FFT Size	64
Preamble size	256
Sub-carriers size	512
Signal constellation	BPSK,QPSK
No. of OFDM frames	256

The extended Kalman filter (EKF) method for approximation and cancellation of the frequency offset for OFDM system results shows that this method does not reduce bandwidth efficiency as the frequency offset can be approximated from the preamble of the data sequence in each OFDM frame. For high frequency offset the Kalman filter does perform extremely well. It gives a significant boost to performance. Significant gains in performance can be achieved using the EKF method for a large frequency offset. This is attributed to the fact that EKF method approximate the frequency offset very accurately and cancel the offset using this approximated value. For ε=1 & ε=4, BER is satisfactory for both QPSK & BPSK.

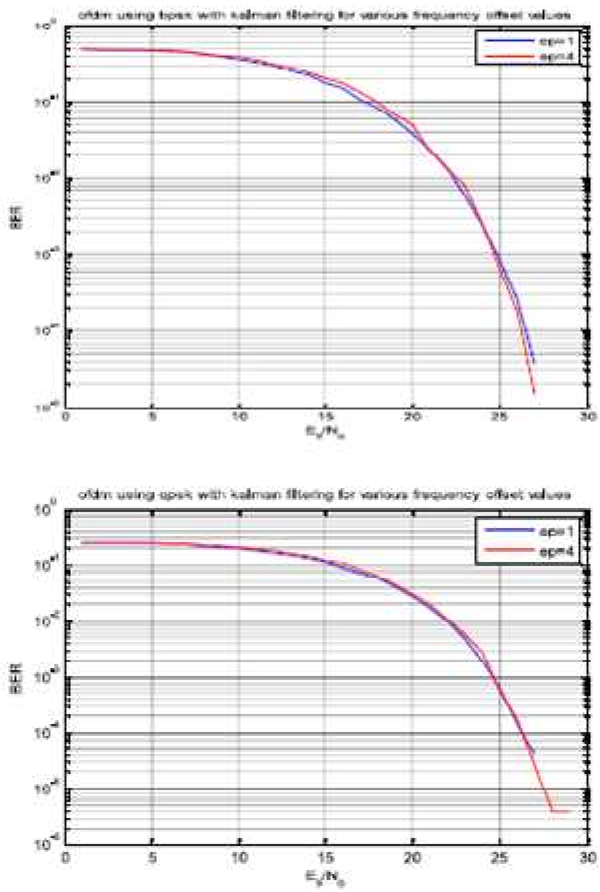

Fig: BER performance of OFDM system with EKF

References

1. http://en.wikipedia.org/wiki/Kalman_filter
2. www.cs.unc.edu/~welch/media/pdf/kalman_intro.pdf
3. http://www.cs.ubc.ca/~murphyk/Software/Kalman/kalman.html
4. http://www.srlst.com/ijist/ijist-Vol4N2/ijist42-1-14.pdf
5. http://www.complextoreal.com/chapters/ofdm2.pdf
6. http://www.ijcaonline.org/volume17/number7/pxc3872851.pdf
7. http://onlinelibrary.wiley.com/doi/10.1002/dac.1138/abstract;jsessionid=A046D27AD7929DA467FA674E121CE480.d04t01?userIsAuthenticated=false&deniedAccessCustomisedMessage=
8. http://www.communicationresearchwork.com/ofdm.pdf
9. T. S. Rappport, Wireless Communications, principles and practice, 2^{nd} Edition, Prentice-Hall publications, 2007.
10. Simon Haykin, Digital Communications, Wiley Publications Ltd, Singapore, 2008.
11. P. H. Moose, A technique for orthogonal frequency division multiplexing frequency offset correction, IEEE Trans. Commun., vol. 42, no.10, pp. 2908 2914, 2010.
12. Charan Langton, Orthogonal frequency division multiplexing (OFDM) tutorial.
13. N.A. Dhahi. Optimum finite-length equalization for multicarrier transceiver IEEE Trans. Commun., vol. 44, pp. 56 64, Jan. 2011.
14. H. M. Mourad, Reducing ICI in OFDM systems using a proposed pulse shape, Wireless Person. Commun, vol. 40, pp. 41 48, 2011.