

Different Techniques to Remove Inter-Carrier Interference (ICI) in Orthogonal Frequency Division Multiplexing (OFDM) System

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ABSTRACT: In fourth generation wireless broadband multimedia systems OFDM is the expected preference modulation, but channel variations during one OFDM symbol introduce inter-carrier interference (ICI). OFDM is a multi-carrier modulation technique and divides the spectrum into multiple carriers. Doppler shift of the channel or due to mismatching between the transmitter and receiver local oscillator frequencies which results in loss of orthogonality among the sub-carriers and produce Inter-Carrier Interference (ICI). This paper provides the different techniques to Remove Inter-Carrier Interference (ICI) from OFDM in the recent years.

Keywords: Orthogonal Frequency Division Multiplexing (OFDM), Inter-Carrier Interference (ICI), Multi-Carrier Modulation, Oscillator Frequencies, Broadband Multimedia.

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) was first described by R.W. Chang in 1966 at Bell Labs [1]. OFDM is a method of encoding digital data on multiple carrier frequencies and it is a widely known modulation scheme, where serial data stream is divided into parallel streams that modulate a group of orthogonal subcarriers. The OFDM signal consists of a variety of modulated carriers that are similar to each other. When any voice or data signal modulations are added to a carrier, the sidebands are then spread out on either side. Because of the carriers' orthogonality, Doppler frequency shift is no longer preserved, and multipath fading affects the sensitivity of the OFDM network and results in inter-carrier interference (ICI) [2]. Examples of standards that use OFDM are LTE, LTE-Advanced, IEEE 802.16 WiMax, Digital Audio and Video Broadcast, IEEE 802.11a/g local area network (WLANs), and wired-based Asymmetric Digital Subscriber Line (ADSL). This paper presents different ICI cancellation techniques used by the researcher in the recent years.

II. LITERATURE SURVEY AND DIFFERENT ICI CANCELLATION TECHNIQUES

In the recent year, these techniques are used. This section provides the brief theoretical introduction about these techniques. Figure 1 shows the various techniques are used to overcome effects of Inter-Carrier Interference (ICI).

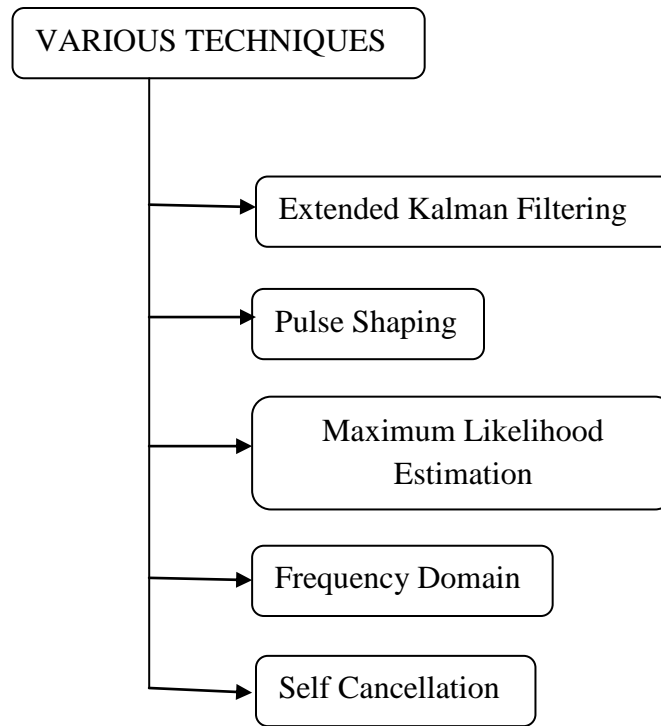


Figure 1. Various techniques are used to overcome effects of ICI.

1.1 Self Cancellation

Self cancellation method is very effective for both flat channels and multipath fading channels and very much easy as well as less complex. This method modulate one data symbol onto a group of sub-carriers with predefined weighting coefficients, suppose first sub carrier is modulated with data symbol 'x' then the second sub-carrier is modulated with data symbol '-x' hence ICI generated between the two sub-carriers mutually cancels each other [3].

Parul Singh and O.P. Sahu [4] presents inter carrier interference (ICI) in golden coded multiple input multiple output orthogonal frequency division multiplexing (MIMO-OFDM) system and evaluate its bit error rate (BER) performance. Here they used Inter carrier interference self cancellation (ICI-SC) scheme and applied to other full rate full diversity space time block coded MIMO-OFDM system. Simulation results show a significant improvement in BER performance. Shilpi Gupta et al. [5] present ICI Self-Cancellation in FFT-OFDM and DCT-OFDM System, where self-cancellation technique outperforms the other self-cancellation techniques. In this paper, ICI self-cancellation scheme performs better in FFT-OFDM, Improvement in CIR is 3 dB to 4 dB, while compares to DCT-OFDM gives good results without ICI self-cancellation.

1.2 Extended Kalman Filtering

The Kalman filter is a versatile and efficient recursive approximation algorithm (This refers in particular to non-stationary processes such as signals broadcast over a time-variant radio channel) in the field of communication and signal processing techniques that provides adaptive antenna arrays, adaptive equalization of fading dispersive channels and adaptive equalization of telephone channels. A discrete Kalman filter state space model is known as

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

where, the $z(n)$ observation has a linear relation to the desired value $d(n)$. By using the discrete Kalman filter, $d(n)$ can be calculated recursively on the basis of $z(n)$ observation, and the modified estimate in each recursion is optimal in the minimum mean square sense [14].

M. Tejeswara Rao and I. Krishna Rao [6] proposed Kalman filtering (EKF) method for estimation and cancellation of the frequency offset. Here self cancellation and kalam filtering was compared it is found that the self-cancelation method does not require very complex implementing hardware or software and is not efficient in terms of bandwidth since there is a redundancy of 2 for each carrier, where as the EKF approach does not reduce bandwidth efficiency, since the frequency

offset can be determined in each OFDM frame from the preamble of the data series. Sonika Chouhan and Deepak Sharma [7] compared three ICI reduction techniques on the basis of BER performance. These three techniques are Extended kalman filtering (EKF) and ICI self cancellation, Data Conjugate ICI Self Cancellation. The simulation result of proposed system shows that, bit error rate (BER) performance of ICI self cancellation is Better than the BER performance of ELF (Extended Kalman Filtering) and standard OFDM system without ICI cancellation.

2.3 Pulse Shaping

Pulse shaping is used to reduce the amplitude of side lobes, because these side lobes are responsible for the significant decrease in the ICI power. The spectral null during frequency offset does not correspond to the peak value of the individual carrier due to which orthogonality loss occurs and some side lobe power exists at the center of the individual carrier known as ICI power. This pulse shaping offers the various functions such as Rectangular Pulse (REC), Raised Cosine Pulse (RC), Sinc Power Pulse (SP), and Improved Sinc Power Pulse (ISP) [8].

Savitha H. M. and Muralidhar Kulkarni [9] combined two techniques namely Pulse shaping and Maximum likelihood estimation (MLE) to cancel ICI further. They achieve a better bit error rate (BER) performance; here they found that Pulse shaping method is useful for ICI cancellation, whereas MLE technique was useful for good CFO correction factor in the OFDM system. Jayesh Vaghela et al. [10] proposed ISP Pulse Shaping Technique for Performance Analysis of OFDM System. In this proposed system different pulse function like REC,RECT,RC,BTRC,SP,ISP are considered but ISP pulse shapes provides better performance compare to other pulse shaping function.

2.4 Frequency Domain Equalization

The channel's fading distortion causes ICI which introduces the noise enhancement problem. Thus the method of frequency domain equalization is attempted for ICI reduction using correct equalization techniques. The frequency domain can be extracted from the pilot symbol pattern & therefore an effective equalizer can be created as shown in figure 2 [11].

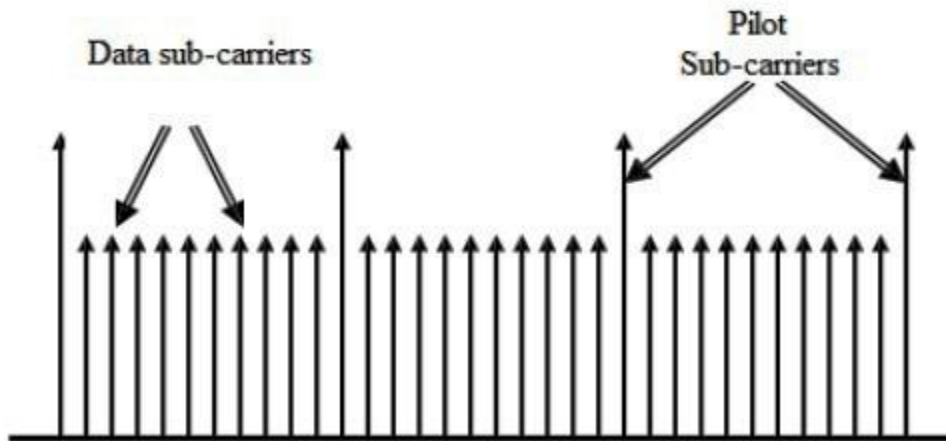


Figure 2 Pilot subcarrier arrangements [11]

Won Gi Jeon et al. [12] present new frequency-domain equalization technique to reduce the time-variation effect of a multipath fading channel. The equalization of the obtained OFDM signal is achieved by assuming that the channel impulse response (CIR) differs linearly over a block duration and by compensating for the ICI terms that significantly affect the performance of the bit-error rate (BER). The proposed equalizer will effectively compensate for the time-variation of a multi-path fading channel if the relative Doppler frequency shift is within the range of $0.005 < \Delta f_D < 0.1$. J. Ahn and H.S. Lee [13] proposed the frequency domain equalization technique to account for the fading distortion in the flat Rayleigh fading channel with less noise enhancement.

2.5 Maximum Likelihood Estimation

The frequency offset is first statistically calculated using a Maximum likelihood algorithm in this Maximum Likelihood Estimation process, and then cancelled at the receiver. In this the OFDM symbol is repeated and before transmission is made comparison of the phases of each of the subcarriers between the successive symbols. If the frequency offset value is

expected then the distortion of ICI in the data symbols will be reduced by multiplying the received symbols with a complex conjugate of the frequency shift and applying the FFT [15].

$$X(n) = \text{FFT}\{Y(n)e^{-j2\pi\epsilon n/N}\}$$

Biao Chen [16] proposed Maximum Likelihood Estimation of OFDM Carrier Frequency Offset, it is found that this system has an identical form to that of a previously proposed blind OFDM carrier frequency offset estimate by Liu and Tureli and it was developed using the signal model with virtual carriers. Sabitha Gauni [17] present n Maximum Likelihood Estimation based Correction of Fractional CFO in OFDM Systems, in which a frequency offset estimation used as and correction scheme. No knowledge of the training sequence is required on the MLE technique. For lower order modulation, the BER output at low SNR (as $M = 4$, QPSK) is good, because the order of modulation is increased to increase the data rate ($M = 64, 256, 4096$), the complexity of the estimation and correction scheme is also increased.

III.CONCLUSION

To reduce the effect of ICI in OFDM system there are different techniques are present like Self cancellation method, Extended Kalman Filtering, Pulse shaping, frequency-domain equalization technique and Maximum Likelihood Estimation. This paper provides the literature survey of different techniques to Remove Inter-Carrier Interference (ICI) in Orthogonal Frequency Division Multiplexing (OFDM) System, proposed by different researcher in the recent year. This system reduces the Intercarrier Interference (ICI) effect and is an impairment well known to degrade performance of Orthogonal Frequency Division Multiplexing (OFDM) transmissions. This is main feature scope of developing this type of system.

REFERENCES

- [1] <https://www.nutaq.com/blog/introduction-orthogonal-frequency-division-multiplex-ofdm>
- [2] B. Sathish Kumar, K. R. Shankar Kumar and R. Radhakrishnan, "An Efficient Inter Carrier Interference Cancellation Schemes for OFDM Systems", (IJCSIS) International Journal of Computer Science and Information Security, Vol. 6, No. 3, 2009, pp. 141-148.
- [3] Sandeep Sarowa, Sunil Aggrawal and BS Sohi, "Performance Evaluation of ICI Cancellation Techniques for High Speed Communication", International Journal of Electronics, Electrical and Computational System (IJECS), Volume 7, Issue 3, March 2018, pp. 37-44.
- [4] Parul Singh and O.P. Sahu, "Interference Cancellation in Golden Coded MIMO-OFDM System", Advanced Research in Electrical and Electronic Engineering, Volume 2, Number 9 April-June (2015) pp. 49-52
- [5] Shilpi Gupta, Upena Dalal and Vishnu Narayan Mishra, "Performance on ICI Self-Cancellation in FFT-OFDM and DCT-OFDM System", Hindawi Publishing Corporation Journal of Function Spaces Volume, 2015, pages 7.
- [6] M. Tejeswara Rao and I. Krishna Rao, "Performance of ICI Cancellation in OFDM System Using Different Reduction Techniques", International Journal of Science and Research (IJSR), Volume 4 Issue 2, February 2015, pp. 924-927.
- [7] Sonika Chouhan and Deepak Sharma, "Comparison of ICI Cancellation Schemes for BER Performance Improvement of OFDM System", International Review of Applied Engineering Research, Volume 4, Number 5 (2014), pp. 437-444.
- [8] Dhanya. P. Murali and Praveen Yadav, "Review On ICI Reduction Techniques In OFDM System". IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE), Volume 9, Issue 3 Ver. VI (May – Jun. 2014), PP 08-11.
- [9] Savitha H. M. and Muralidhar Kulkarni, "A Novel Hybrid Scheme using MLE with Pulse Shaping for ICI Cancellation in OFDM Systems", 2012 International Conference on Computer Communication and Informatics (ICCCI -2012), Coimbatore, INDIA, IEEE, Jan. 10 – 12, 2012.
- [10] Jayesh Vaghela, Omkar Pabbati and Divyangna Gandhi, "Performance Analysis of OFDM System Using ISP Pulse Shaping Technique", International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE) Volume 5, Issue 5, May 2016, pp. 1531-1535.
- [11] Naveed Ur Rehman, Zhang Lei and Muhammad Zahid Hammad, "ICI Cancellation in OFDM Systems by Frequency Offset Reduction", Journal of Information Engineering and Applications, Vol.4, No.9, 2014, pp. 1-8.
- [12] Won Gi Jeon, Kyung Hi Chang and Yong Soo Cho, "An Equalization Technique for Orthogonal Frequency-Division Multiplexing Systems in Time-Variant Multipath Channels", IEEE Transactions on Communications, Vol. 47, No. 1, January 1999, pp. 27-32.



- [13] J. Ahn and H.S. Lee, “Frequency domain equalisation of OFDM signals over frequency non selective Rayleigh fading channels”, IEEE, Electronics Letters, Volume: 29, Issue: 16, 5 Aug. 1993.
- [14] Manish Yadav, Ashish Dixit and Pallavi Asthana, “Approximation Of Inter Carrier Interference Cancellation In OFDM Systems using Kalman Filter”, International Journal Of Engineering Sciences & Management (IJESM), Vol. 2, Issue 1: Jan-Mar: 2012, pp. 84-86.
- [15] Raghuraj Sharma and Anjana Goen, “A Review on Different Schemes to Remove ICI in OFDM System”, International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol. 5, Issue 5, May 2016, pp. 3553-3557.
- [16] Biao Chen, “Maximum Likelihood Estimation of OFDM Carrier Frequency Offset”, IEEE Signal Processing Letters, Vol. 9, No. 4, April 2002, pp. 123-126.
- [17] Sabitha Gauni, Anshul Soni and R. Kumar, “Reduction in Complexity in Maximum Likelihood Estimation and Correction of Fractional CFO in OFDM Systems”, Commun 82, 1567–1584 (2015).