First International Conference on NexGen Technologies
Sengunthar Engineering College Tiruchengode, Namakkal Dist. Tamilnadu (India)
05th- 06th January 2018, www.conferenceworld.in ISBN: 978-93-86171-90-0

# PROGRESSIVE PARALLEL INTER CARRIER INTERFERECE CANCELLATION IN MIMO-OFDM SYSTEM

**B.Jesvin Veancy[1], B.Prassanna Venakatesh[2]**

*[1]Associate Professor, Department of Electronics and Communication*
*Easwari Engineering College, Chennai, (India)*
*[2]PG Scholar, Department of Electronics and Communication,*
*Easwari Engineering College, Chennai, (India)*

## ABSTRACT

*A joint design of sphere decoding and synchronization algorithms for Multiple-Input–Multiple-Output (MIMO) Orthogonal Frequency Division Multiplexing (OFDM) systems is proposed. It is based on progressive parallel inter-carrier interference canceller (PPIC) in wireless multipath channels for high speed wireless transmission. This algorithm can suppress inter-antenna interferences and cancel inter-carrier interferences iteratively and progressively. Using carrier frequency offset (CFO) estimation algorithm the short cycle problem can be solved. The proposed PPIC is superior to PIC both in computational complexity and system architecture. It is very suitable for VLSI implementation and it is a potential candidate for data detection/decoding in future high data rate and high mobility application. The performance analysis and design optimization of low density parity check (LDPC) coded Multiple-Input-Multiple-Output (MIMO) Orthogonal Frequency-Division Multiplexing (OFDM) systems is considered for high speed wireless transmission.*

***Keywords:Carrier Frequency Offset (CFO),Inter-carrier interference (ICI), Low density parity check (LDPC), parallel inter carrier cancellation(PIC), progessive parallel inter carrier cancellation (PPIC).***

## I. INTRODUCTION

Multiple input multiple output (MIMO)- Orthogonal frequency division multiplexing (OFDM) is the corner stone of future broadband wireless access. Wide band transmission with high spectral efficiency and high mobility is required for future mobile radio communications [1-3]. In a MIMO system, as data are transmitted/received through different antennas, many channel impairments need to be dealt with, such as multipath fading, AWGN noise, inter-antenna interference etc [4-7]. To deal with these channel impairments, many types of MIMO detectors such as MAP detector, sphere decoder, MMSE-SIC detector have been proposed [8-10]. For OFDM-based systems, the transmission bandwidth is divided into many narrow subchannels, which are transmitted in parallel [11]. Channel variations during one OFDM symbol leads to loss of subchannel orthogonality known as Inter Sub- Carrier Interference (ICI) which degrades the performance, since IC1 can be seen as additional near-Gaussian noise [12-13].

As delay spread increases, symbol duration should also increase in order to maintain a nearly flat channel in every frequency sub-band. As a result, the ICI effect becomes more severe as mobile speed, carrier frequency, and OFDM symbol duration increases. If it is not compensated, ICI will result in performance loss and an error floor that increases with Doppler frequency. ICI reduction methods such as self ICI cancellation scheme, MMSE equalisation, sphere decoding (SD) algorithm had been introduced [14-16]. In recent years, the message passing data detector/decoder catches the attention of the message passing data detector/decoder is due to that it consists of many small, independent detection/ decoding functions to deal with channel impairments. Hardware could be implemented according to these independent detectors / decoders and operated in parallel, and it potentially leads to a very-high-speed detector/decoder[17-20]. This aspect is particularly important in data transmissions where data rate requirements are high, and processing delay must be low. A popular message passing algorithm on factor graphs is the sum-product algorithm, which efficiently computes all the marginal of the individual variables of the function.

Based on Factor Graph[21], a joint design of message passing MIMO data detector/decoder with a progressive parallel intercarrier interference canceller (PPIC) for OFDM based wireless communication systems is proposed. With the insertion of cyclic prefix in OFDM, the time domain ISI can be avoided. With the message passing MIMO detector known as MPD detector, the space domain inter-antenna interference can be suppressed and with the aid of PPIC, the frequency domain ICI can be cancelled [22-23]. The computational complexity of the proposed PPIC architecture is relatively lower than the standard PIC architecture. The system architecture is also simpler and more suitable for the VLSI implementation.

## II. INTER CARRIER INTERFERNCE (ICI) IN OFDM DUE TO FREQUENCY OFFSET

Evaluate the impact of the frequency shift that causes interference between the signals (ICI) while receiving a modulated OFDM symbol. First, we will discuss the transmission and reception OFDM, the effect of the frequency shift and then define the loss of orthogonality and the consequent loss of the signal-to-noise ratio (SNR) due to the presence of the frequency shift.

### 2.1 OFDM Transmission

As discussed in the publication on the understanding of an OFDM transmission, for sending a modulated OFDM symbol, we use multiple sinusoids with frequency separation, where the period of the symbol is. The information to be sent on each sub-carrier is multiplied by the corresponding carrier and the sum of said sinusoidal modulated by the transmission signal. Mathematically, the transmission signal is

$$\mathbf{S(t) = a_0 g_0(t) + a_1 g_1(t) + \ldots\ldots + a_{k-1} g_{k-1}(t)} \quad \mathbf{(1)}$$

$$= \qquad \mathbf{(2)}$$

$$= \frac{1}{\sqrt{T}}\sum_{0}^{k-1} \qquad \mathbf{(3)}$$

### 2.2 OFDM Reception

In an OFDM receiver, the signal received with a correlator bank is integrated during the period. The correlators to extract the information sent on the subcarrier K.

The integrals,

$$\frac{1}{\sqrt{T}}\int_{T}^{\infty} s(t)e^{\frac{-j2\pi mt}{T}} = a_k ,m = k$$

$$= 0 \quad ,m \neq k$$

Where m takes values from 0 till K-1.

### 2.3 Carrier Frequency Offset

In a typical wireless communication system, the signal to be transmitted is upconverted to a carrier frequency prior to transmission. The receiver is expected to tune to the same carrier frequency for down-converting the signal to baseband, prior to demodulation. However, due to device impairments the carrier frequency of the receiver need not be same as the carrier frequency of the transmitter. When this happens, the received baseband signal, instead of being centered at DC (0MHz), will be centered at a frequency , where

**(4)**

The baseband representation is

**(5)**

y(t) is the received signal

s(t) is the transmitted signal

is the frequency offset

The proposed algorithm detects the transmitted data iteratively, by jointly dealing with channel fading effects, AWGN noise and interferences in time domain, frequency domain and space domain. With the insertion of cyclic prefix, the time domain ISI can be avoided. With the message passing MIMO detector (denoted as MPD in the following sections), the space domain inter antenna interference can be suppressed and with the aid of PPIC, the frequency domain ICI can be cancelled. Fig.1, which explains about the message passing data detection and ICI cancellation. Besides, the computational complexity of the proposed PPIC architecture is relatively lower than the standard PIC architecture. The system architecture is also simpler and more suitable for the VLS Implementation.

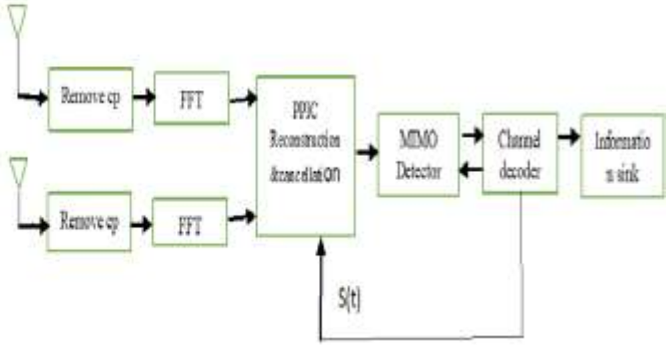


**Fig 1: Block diagram of message passing data detection and ICI cancellation scheme.**

## III. PROGRESSIVE PARALLEL INTER CARRIER INTERFERNCE CANCELLER

The PPIC architecture is modeled as a factor graph. The subcarrier nodes represented as blocks for ICI cancellation execute the function of interference reconstruction and cancellation.As shown in Fig 2, Explain about the PPIC architecture. The message type is soft data symbol. The estimated soft data symbols are exchanged between adjacent subcarrier nodes and stored. At the 1stiteration, the nthsubcarrier node receives and stores the soft symbols from the $(n+1)_{th}$subcarrier node and the $(n-1)_{th}$subcarrier node. These soft data symbols are used for ICI reconstruction and cancellation.

So, the ICI from the $(n+1)th$subcarrier and the$(n-1)$thsubcarrier are reconstructed and cancelled. At the 2nditeration, the $nth$ subcarrier node receives and stores the soft symbols, which are estimated at the 2nditeration, from the$(n+1)$thsubcarrier node and the $(n-1)$thsubcarrier node, and the soft symbols, which are stored at the 1stiteration, from the $(n+1)$thsubcarrier node and the $(n-1)$thsubcarrier node.These stored data symbols are actually estimated by the $(n+2)$thsubcarrier node and the $(n-2)$thsubcarrier node at the 1stiteration. So, the ICI from the $(n+1)$thsubcarrier, $(n+2)$thsubcarrier, $(n-1)$thsubcarrier and$(n-2)$thsubcarrier are reconstructed and cancelled.

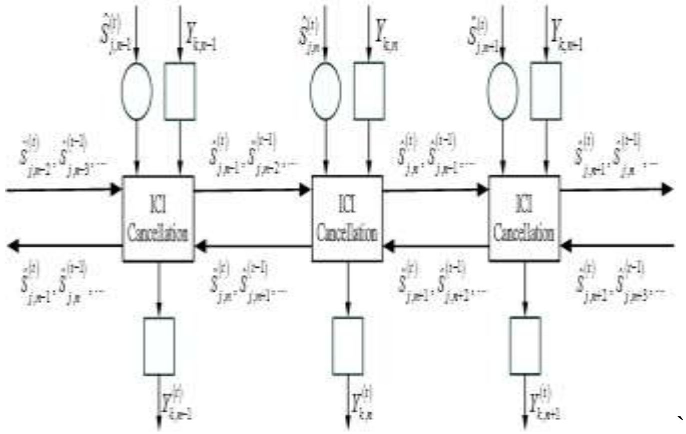


**Fig 2: PPIC Architecture**

In this way, the ICI are reconstructed and cancelled iteratively and progressively from the received signal. At the 1st iteration, the two strongest interfering subcarriers are cancelled. At the 2nditeration, the two strongest and the two adjacent less strong interfering subcarriers are cancelled. At the ithiteration, the ICI from 2iadjacent subcarriers are cancelled.

## IV. SIMULATION RESULTS

The BER performance of the proposed message passing algorithm on factor graph for data detection/decoding and ICI .With interleaving vs. without interleaving. Performance comparison of message passing MIMO detector and MMSE-SIC MIMO detector. Cancellation in bit-interleaved LDPC-coded MIMO-OFDM systems are simulated with $Nt= Nr= 2$ and QAM modulation. Gallager code with codeword length 20 is used. The dimension of the parity check matrix of Gallager code is$15\times20$ with row weight $dc= 4$ and column weight $dv=$ 3.

The FFT size of OFDM modulator is 1024. An $S$-random inter leaver of length 8192, $S= 64$ is used after the LDPC encoding. The multipath channel model is the ITU vehicular A channel. The fading channel model used is the Jakes' model. In the case of imperfect channel estimation, two different models are used to model the variance of channel estimation error:

a) $\sigma 2E$is independent of the SNR.

b) $\sigma 2E$is a decreasing function of SNR.

The carrier frequency is 2.5 GHz, bandwidth is 10 MHz, sampling frequency is 11.2MHz, subcarrier spacing is 10.93 kHz, useful OFDM symbol duration is 91.43 $\mu$s and the length of cyclic prefix is 1/8 .The vehicular speeds are 350 km/h which are corresponding to maximum Doppler frequency 810 Hz and normalized Doppler frequency 0.07.

The performances of the proposed algorithm with interleaving and without interleaving are compared in Fig3. It is obvious that the system performance is not improved with LDPC code without interleaving. This is because the cycle condition of the coded case is more serious than the un coded case as the cycles not only exist in the space domain but also in the frequency domain. In order to optimize the system performance and deal with the short cycle problem, an $S$-random interleave is used after the LDPC encoding. The performance of the proposed algorithm is improved significantly and the length-four cycle problem is solved.

Compared to Minimum Mean Square Equalization with simple inter carrier interference cancellation case, addition of optimal ordering results in around 5.0dB of improvement for BER of $10^{-3}$. The performance is now closely matching with curve 1 transmit 2 receive antenna MRC case.

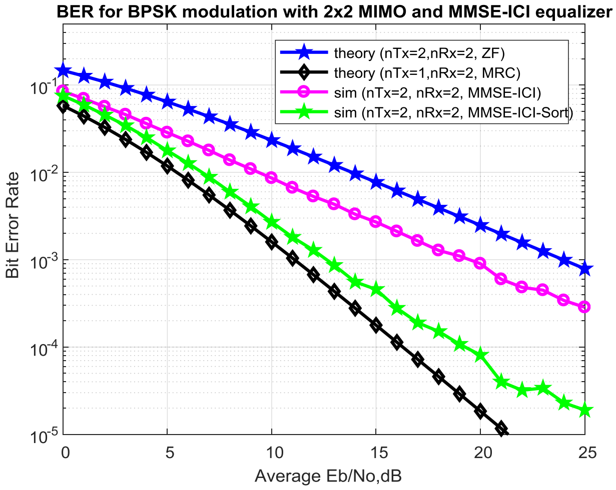


**Fig 3: BER modulation with 2x2 MIMO and MMSE-ICI**

The comparison of MPD and MMSE-SIC is shown in Fig.3. When the $Eb/N0$ is smaller than 12 dB, the performance of MPD and MMSE-SIC are almost the same. However, when the $Eb/N0$ is larger than 12 dB, MPD outperforms MMSE-SIC. When the BER is $10^{-5}$, the performance of MPD is 1∼2 dB better than MMSE-SIC at the $2nd$and$3rd$iteration. MMSE-SIC still has an error floor when the$Eb/N0$ is larger than 12 dB. which cancels 12 adjacent interfering subcarriers at every iteration, and an ICI Self-canceller. Fig 4, explain about the performances of PPIC ICI canceller and PIC ICI canceller are almost the same. Before the $6th$ iteration, although the PIC ICI canceller cancels more interfering subcarriers than PPIC ICI canceller, it does not outperform PPIC ICIcanceller. The reason is that if the estimated data symbols are not accurate enough, the ICI may be increased instead of reduced after cancellation. For the ICI self-cancellation, a data pair $(S,-S)$ is modulated on to two adjacent subcarriers where $S$is a complex data symbol.

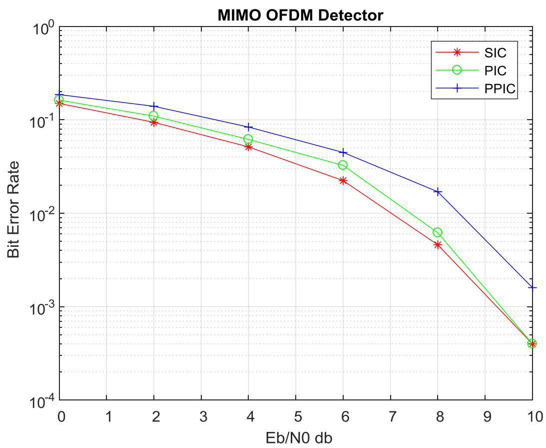


**Fig 4: PPIC to various ICI cancellation**

In comparison with Fig 5, the minimum average quadratic equalization with the case of interference cancellation between simple vectors, in addition to the optimal sorting results in about 5.0 dB improvement for BER of $10^{-3}$. The performance now closely matches the MRC frame of the transmitting 1 receiving antenna of curve 1.

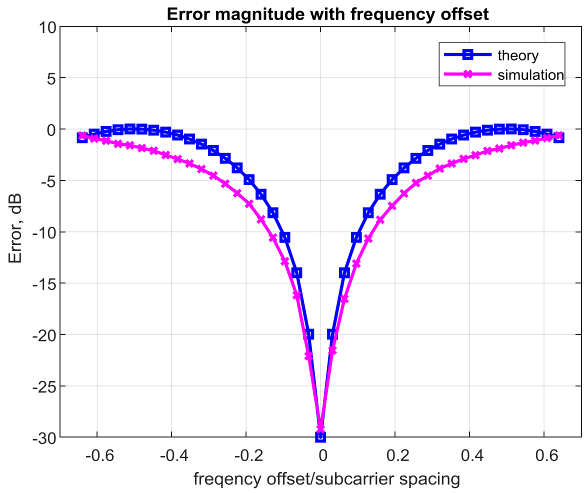


**Fig 5: Frequency offset ofPPIC algorithm under $E_b/N_o$= 30**

## V. CONCULSION

A joint design of message passing MIMO data detector/decoder with PPIC ICI canceller for OFDM-based wireless communication systems is proposed. The proposed algorithm can suppress inter-antenna interferences in space domain and cancel inter-carrier interferences infrequency domain iteratively and progressively. With a proper designed message passing schedule and CFO Estimation, the short cycle problem will be solved. Computer simulations will show that the performance of MPD outperforms MMSE-SIC.

## REFERENCES

[1] J.G. Andrews, A. Ghosh, and R. Muhamed, *Fundamentals of WiMAX Understanding Broadband Wireless Networking*, Upper Saddle River, NewJersey: Prentice Hall, 2007.

[2] J. G. Proakis, and M. Salehi, *Digital Communications*, 5th ed. New York:McGraw-Hill, 2008.

[3] A.Goldsmith, *Wireless Communications*, Cambridge, United Kingdom:Cambridge niversity Press, 2005.

[4] B.Vucetic, and J. Yuan, *Space-Time Coding*, West Sussex, England: John Wiley& Sons, 2003.

[5] A.J. Paulraj, R. Nabar, and D. Gore, *Introduction to Space-Time Wireless Communications,* Cambridge, United Kingdom: Cambridge University Press,2003.

[6] T.Ha, *Theory and Design of Digital Communication Systems*, Cambridge, United Kingdom: Cambridge University Press, 2010.

[7] T.S. Rappaport, *Wireless Communications: Fundamentals and Applications*, 2ded., Upper Saddle River, New Jersey: Prentice Hall, 2002.

[8] D.Tse, and P. Viswanath, *Fundamentals of Wireless Communication*,Cambridge,United Kingdom: Cambridge University Press, 2005.

[9] C.W.Therrien, and M. Tummala, *Probability for Electrical and ComputerEngineers*, Boca Raton, Florida: CRC Press LLC, 2004.

[10] R.Prasad, *OFDM for Wireless Communications Systems*, Boston, Massachusetts:Artech House, 2

[11] S.Sesia, I. Toufik, and M. Baker, *LTE - The UMTS Long Term Evolution*, WestSussex, Engl Wiley & Sons, 2009.

[12] B.Sklar, *Digital Communications Fundamentals and Applications*, 2d ed., UpperSaddle River, New Jersey: Prentice Hall, 2001.

[13] X.Zhu, and R. D. Murch, "Performance Analysis of Maximum LikelihoodDetection in a MIMO Antenna System," *IEEE Transactions on Communications*,vol. 50, no. 2, pp. 187–191, February 2002.

[14] A.D. Kora, A. Saemi, J. P. Cances, and V. Meghdadi, "New list sphere decoding (LSD) and iterative synchronization algorithms for MIMO-OFDM detection with LDPC FEC," IEEE Trans. Veh. Technol.,vol.57,no. 6, pp. 3510-3524, Nov. 2008.

[15] L. Ben, G. Yue, and X. Wang, "Performance analysis and design optimization of LDPC-coded MIMO OFDM systems," IEEE Trans. Signal Process., vol. 52, no. 2, pp. 348-361, Feb. 2004.

[16] K. Sathananthan and C. Tellambura, "Probability of error calculation of OFDM systems with frequency offset," IEEE Trans. Commun., vol. 49, no. 11, pp. 1884-1888, Nov. 2001

[17] Y. Zhao and S. G. Haggman, "Intercarrier interference self-cancellation scheme for OFDM mobile communication systems," IEEE Trans. Com-mun., vol. 49, no.7, pp. 1185-1191, July 2001

[18] Y. Wang, S. Zhu. and Y. Li, "A method to improve the bandwidth effi-ciency of self ICI cancellation in OFDM systems," in Proc. International Conf. Signal Process., vol. 2, pp. 1633-1636, 2002

[19] B. M. Kurkoski, P. H. Siegel, and J. K. Wolf, "Joint message-passing decoding of LDPC codes and partial-response channels," IEEE Trans. Inf. Theory, vol. 48, no. 6, pp. 1410-1422, June 2002

[20] B. Lu, G. Yue, X. Wang, and M. Madihian, "Factor-graph-based soft self-iterative equalizer for multipath channels," EURASIP J. Wireless Commun. Netw., vol. 2005, no. 2, pp. 187-196, 2005.

[21] Yu Fu and Chi Chung ko, " New IC1 Self-Cancellation Scheme for OFDM Systems based on a Generalized Signal Mapper" IEEE Trans. Inf. Theory, vol. 48, no. 6, pp. 1410-1422, June 2002

[22] Mark Russell and Gordon I. Stuber, "Interchannel Interference Analysis of OFDM" IEEE Trans. Com-mun., vol. 49, no.7, pp. 1185-1191, July 2001

[23] Ye (Geoffrey) Li and Leonard J. Cimini, " Interchannel Interference of OFDM in Mobile Radio Channels" EURASIP J. Wireless Commun. Netw., vol. 2005, no. 2, pp. 187-196, 2005IEEE Trans. Com-mun., vol. 49, no.7, pp. 1185-1191, July 2001