DATA DETECTION WITH A PROGRESSIVE PARALLEL ICI CANCELLER IN MIMO-OFDM

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Abstract

For future mobile radio communication system we are in need of high spectral efficiency, high mobility with wide band transmission. For this purpose Orthogonal Frequency Division Multiplexing (OFDM) combined with Multiple Input Multiple Output (MIMO) becomes one of the powerful promising technique. The algorithm proposed in this paper can suppress Inter Carrier Interference (ICI). The performance of Progressive Parallel Interference Canceller (PPIC) is compared with the performance of Parallel Interference Canceller (PIC). The Bit Error Rate (BER) versus Signal to Noise Ratio (SNR) for both the algorithms is also analyzed. PPIC has several advantages over PIC such as complexity, system architecture etc.

Keywords: *Bit error rate (BER), Inter carrier interference (ICI), Orthogonal Frequency Division Multiplexing (OFDM), Multiple input multiple output (MIMO), Progressive parallel interference canceller (PPIC), Parallel interference canceller (PIC), Signal to noise ratio (SNR).*

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1. INTRODUCTION

OFDM is the widely extended technique in modern communication system, which is used to transmit high datarate in the presence of non-line of sight condition. OFDM is used to transmit large amount of data into small amount of bandwidth. The MIMO system uses multiple antennas for transmission and reception of the data signals hence there is need to deal with channel impairment such as multipath fading, various noise, ISI, ICI etc.

The development of techniques to cancel the ICI, plays an important role in the MIMO system and the performance degradation due to ICI is analyzed. ICI is caused by the Doppler shift in OFDM modulation. The Doppler shift is change of frequency due to Doppler effect. The presence of ICI results in system performance degradation with the increase in BER of the system.

Previously the degradation of the system due to ICI is modelled as Gaussian distribution normalized over the Doppler frequency[4],[7],[8]. The ICI self cancellation scheme was proposed in [9],[10]. The ICI from the neighbouring subcarriers can be cancelled out by the low complexity MMSE equalizer [11].

The main contribution of this paper is the data detection using a progressive parallel ICI canceller in the MIMO-OFDM system. For detecting the data using the PPIC canceller, the message type chosen with bit probabilities equal to Log likelihood ratio. The Inter antennal Interference (IAI) in the space domainof the MIMO channel can be reduced using the PPIC technique. The PPIC architecture is much simpler than the PIC architecture and hence easier to implement. This facilitates an extensive use in VLSI applications. MIMO-OFDM receiver using PPIC is as shown in the fig 1.

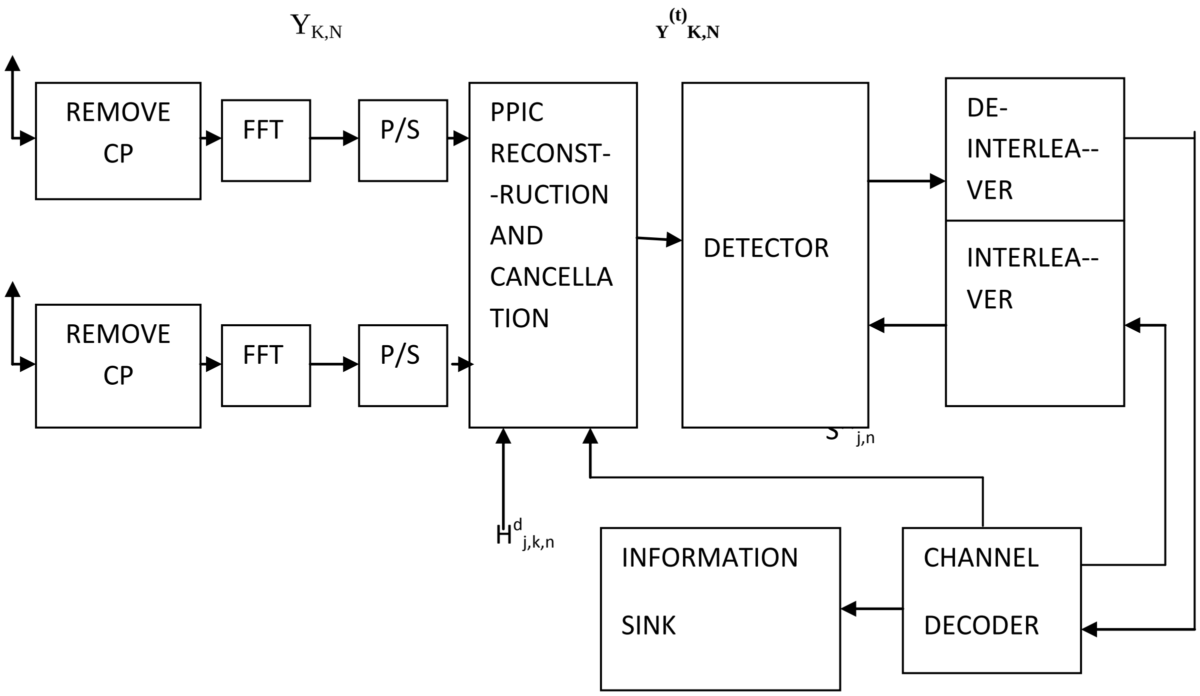

Fig 1: MIM0-OFDM Receiver using PPIC

2. SYSTEM MODEL

2.1 Message Passing and LDPC Decoding

The Linear density parity check code (LDPC) is constructed from the parity check matrix, represented by means of a bipartite graph or factor graph. The factor graph consists of symbol nodes denoted by 'v', representing the symbol in the transmitted codeword and the check nodes denoted by 'c', representing the parity check constraints. Each check node is connected to the symbol nodes, on which it keeps a check by means of an edge.

During each iterative round of the Belief Propagation (BP) iterative algorithm, the message is passed from one node to the neighboring node through the edge. The message passing from a symbol node 'v' to the check node 'c' is represented by 'Qvc' and the message that passes from check node to symbol node is represented by 'Rcv' and the probability of a zero being transmitted from the symbol node 'v' is represented by 'pv(0)'. LDPC decoding algorithm is understood with less complexity and more stability from log-likelihood-ratio (LLR) domain.

The sequential message-passing decoding algorithm, partitions the check nodes of the LDPC code into various subsets. Then these subsets are considered as subgraphs, containing check nodes and variable nodes. The message passing decoding algorithm is used to decode each sub graph in the sequential order. This algorithm can be efficiently adopted in the LDPC decoder when the fully parallel processing mode cannot be implemented. During the first iterative round, though the complexity of the sequential message-passing decoding algorithm remains the same as that of the parallel decoding algorithm, the convergence speed is faster in the proposed algorithm. The check node will receives messages from its neighbors and it will processes the messages, and then finally passes the updated messages back to its neighbors again in a cycle. The output message of a variable node is a function of all incoming messages to the node except for the incoming message on the edge where the output message will be sent finally. In the new sequential message passing decoding algorithm, there are two steps. In the first step the messages are calculated at all variable nodes and then sent to the check nodes. In the second step the messages at all check nodes are calculated and then sent to the variable nodes.Both the steps are performed simultaneously. In the sequential message-passing decoding algorithm, the check nodes are partitioned into the 'p' subsets. The messages from variable nodes are updated to the check nodes of the same subset, then the variable nodes of the other subsets update the messages to the check nodes, which corresponds to one iteration for the rest subset of check nodes. To the remaining subsets of check nodes the decoding procedure is applied sequentially.

The figure 2 shows the message passing on factor graph 2x2 MIMO channel and LDPC decoder. The message can be extended to nxn MIMO channel for better performance,

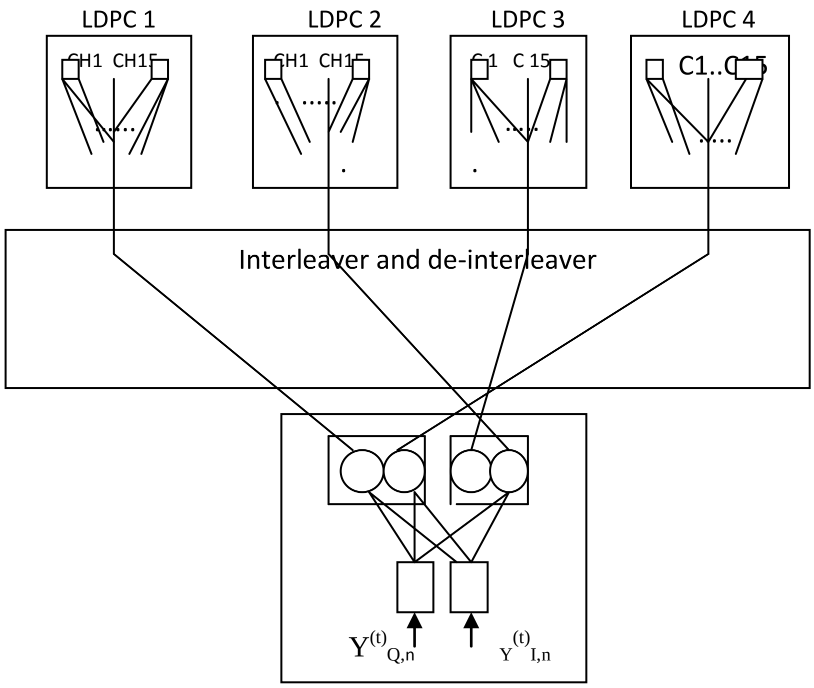

Fig 2: 2X2 MIMO Channel LDPC Decoder

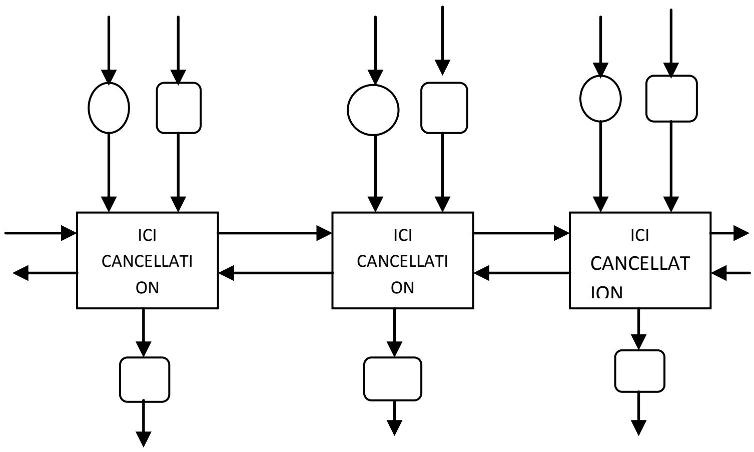

Fig 3: PPIC architecture

Using the proposed algorithm, the multiple-antenna interferences and inter-carrier interferences can be reduced simultaneously with repeated iterations, until the minimum criterion is achieved. The estimation is done on offset QPSK or 16-QAM soft data symbols.

2.2 Message Passing Schedule and Interleaving

In message passing algorithms, the bipartite graphs gives accurate solution. But when the factor graph has many lengthy cycles it is not possible to achieve the exact solution. Thus there is a need to increase the number of iterations in order to reduce the BER at high SNR. This is addresses as the short cycle problem of message passing algorithm. This can be overcome by first feeding the received frequency domain signals to the PPIC ICI canceller. Then the signal is given to the MPD and then to LDPC decoder. The factor graph does not hav eany free cycle but the MIMO detector and the LDPC decoder gives rise to a lot of short cycle problems. The solution to this is given by the LDPC code and random interleaver with proper message passing schedule. These algorithms reduce the value of the outgoing log-likelihood ratio messages at variable nodes by means of the additive factor.

In this paper, in order to improve the system performance, LDPC code is used in the frequency domain. The encoder and decoder of the short codeword length LDPC code, are simpler than a long-length LDPC code. The use of Gallager code worsens the cycle condition as the cycles problem exist both in the space and frequency domain. In order to solve this short cycle problem, a properly designed frequency domain random interleaver should be used with LDPC code. In the designed criterion the coded bits of the same codeword are interleaved and sent to various subcarriers. At the receiver, the messages are detected from a particular subcarrier are de-interleaved onto different channel decoders.

Then using a properly designed message passing schedule, the information bit is passed in both domains i.e space and frequency in order to solve the short cycle problem. There are totally, seven steps are included in the message passing schedule:

1. The soft data symbols are estimated and then fed back to the LDPC decoder. They are then exchanged between adjacent subcarrier nodes and stored.
2. The ICI is cancelled from the received signals and then again the ICI cancelled signals are fed forward to the MPD.
3. Similarly after the bit messages L are generated by the channel are passed to bit nodes.
4. After the messages $L\ (k\rightarrow q)$ are generated and de-interleaved,the messages are passed to code bit nodes and then to check nodes of every LDPC decoder. The messages generated in a subcarrier are sent to various LDPC decoders.
5. The messages $L\ (q\rightarrow v)\ V\ (v\rightarrow u)$ generated check nodes are passed to code bit nodes and then interleaved.
6. Each message generated by the code bit node of the same LDPC decoder are sent to bit nodes that are belong to the different subcarriers. The messages L are then passed on to the channel nodes from the bit nodes.
7. The soft decision of data bits and symbols of the same data are obtained and then fed back to the PPIC canceller. By performing detection, decoding and ICI cancellation iteratively the system performance can be jointly optimized.

The information passed through the edges of the bipartite graph varies with time and frequency since the channel gains may vary with respect to time. Hence the edges corresponding to the deep- faded channel gain, can be ignored completely. By this method the complexity of the proposed algorithm is reduced as the number of edges of the bipartite graph is reduced.

There are many ways to find the order of the edges to be ignored. For example, the edges with channel gains less than 5 dB than the average channel gain can be ignored or the four edges corresponding to the 4 dB smallest channel gains can also be ignored.

The former method involves the number of ignored edges, varies with time and frequency, but in the latter the number of ignored edges are fixed.

The computational complexity of the PPIC ICI canceller is less compared to other systems, due to the progressive architecture. As the iterative process continues, the computational complexity of all iterations of PPIC gradually decreases. But in the case of PIC architecture the computational complexity is constant for every iteration.

The low complexity of PPIC makes it attractive for realizing the ICI cancellation for the OFDM-based, high data rate, high mobility, wireless MIMO communication systems. Moreover, the architecture of PPIC is very much simpler than PIC, as it is similar to an array called systolic array. Every subcarrier node is connected only to the adjacent two subcarrier nodes and exchanges messages with them. As shown, if the adjacent twelve interfering subcarriers are intended to be cancelled, each subcarrier node of the PIC architecture is connected to the adjacent twelve subcarrier nodes, and receives messages from them in the same way as PPIC but the speed is better in PIC.

This complicates the system architecture design of the standard PIC ICI canceller. Based on factor graph, the parallel structure of the proposed message passing MIMO data detector/decoder with PPIC ICI canceller is very much suitable for VLSI implementation, especially for high speed analog detector/decoder. Since the iteration operation is actually a transient response and the high demand of computational complexity can be reduced.

3. SIMULATION RESULTS

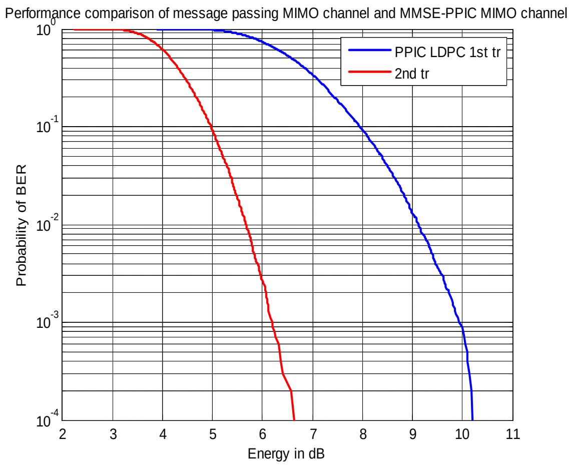

Fig 4 Performance comparison of message passing in MIMO channel and MMSE-PPIC LDPC in 1st transmitter and 2nd transmitter

Here PPIC LDPC 1st transmitter gives better performance than the 2nd transmitter.

Since we are using 2x2 MIMO channel the graph is plotted between two transmitter and here two receiver as shown below.

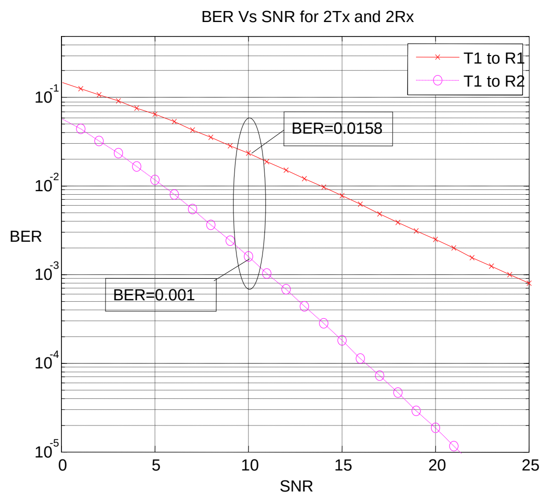

Fig 5: BER and SNR comparison of transmitter 1 to receiver 1 and transmitter 1 to receiver 2.

It shows that transmitter 1 to receiver 2 gives better SNR than transmitter 1 to receiver 1. Let us consider SNR for 10 db, the transmitter 1 to receiver 2 the BER is 0.001 and for the transmitter 1 to receiver 1 the BER is 0.0158.

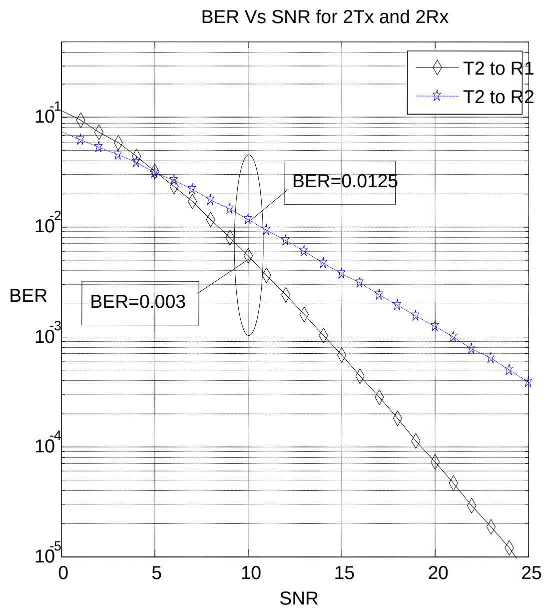

Fig 6: The BER and SNR comparison of transmitter 2 to receiver 1 and transmitter 2 to receiver 2

And it shows that transmitter 2 to receiver 1 gives better SNR than the transmitter 2 to receiver 2. Let us consider SNR for 10 db, the transmitter 2 to receiver 1 the BER is 0.003 and for the transmitter 2 to receiver 2 the BER is 0.0125.

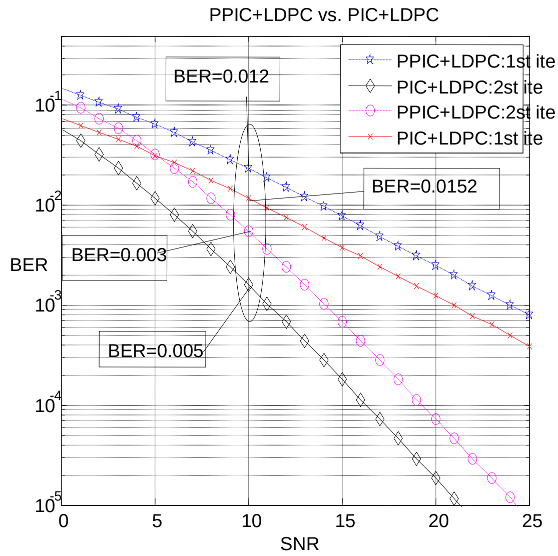

Fig 7: Performance of PPIC+LDPC VS PIC+LDPC is compared.

Here PPIC will give better performance than PIC and the BER of PPIC is compared to be low than BER of PIC. Let us consider SNR for 10 db, BER of PPIC LDPC for 1st transmitter is 0.012 db, whereas BER of PIC LDPC for 1st transmitter is 0.0152 db.

Here BER of PPIC LDPC for 2nd transmitter is 0.003 db, whereas BER of PIC LDPC for 2nd transmitter is 0.005 db.

4. CONCLUSIONS

The PPIC ICI canceller for OFDM based wireless communication systems with MIMO data detector/decoder is proposed. The proposed algorithm, provides reduction in the IAI in the space domain and ICI in the frequency domain simultaneously. The short cycle problem is solved, by properly designed message passing schedule and random interleaver. The simulation output shows the performance comparison of PPIC LDPC and PIC LDPC. Due to its low complexity the PPIC ICI canceller is very useful for data detection/decoding in environments with high mobility and high data rate wireless MIMO-OFDM communication systems. In future , the technique can be explored with various types of modulation and comparison with other ICI suppressing techniques can be analyzed.

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BIOGRAPHIES

Sabitha Gauni graduated from Madras University , Tamil Nadu in 2000 as a Bachelor of Engineering degree in Electronics and Communication Engineering. She received the Master of Technology degree in VLSI Design from SRM University, India in 2007. She has been working as Assistant Professor with SRM University, Chennai, India. She is pursuing PhD in the Department of Electronics and Communication Engineering, SRM University, Chennai, India. Her research interests are Signal Processing, Wireless Communication, Electromagnetism and MIMO-OFDM systems.

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