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Channel Estimation and PAPR Computation for MIMO-OFDM Systems

Palla Parasuram Yadav[1], R.S.K. Vaibhav[2], Prof. R.V.S. Satyanarayana[3]

Abstract: In this paper, we are reducing the PAPR for the existing method which estimates the channel parameters like in-phase and quadrature-phase imbalances (IQI), carrier frequency offset (CFO) through channel response for multiple-input multiple output orthogonal frequency division multiplexing (MIMO-OFDM) systems. By utilizing a new concept called channel residual energy (CRE), without finding the channel response we can estimate both the IQI and CFO by minimizing the CRE. The proposed method single carrier-frequency division multiple access (SC-FDMA) reduces the PAPR approximately equal to one.

Index terms: IQI, CFO, MIMO-OFDM, CRE, channel response, PAPR, SC-FDMA.

I. INTRODUCTION

Because MIMO-OFDM system supports high data rate and low implementation complexity, it has become the more advanced technology in wireless communication systems. The advantages of MIMO-OFDM system is because of orthogonality among sub carriers. But the MIMO-OFDM system suffers from Inter Symbol Interference (ISI) Inter Carrier Interference (ICI) and high PAPR. ISI occurs due to few mismatches such as IQI. The IQI occurs due to the amplitude and phase mismatches between I and Q-branch of the local oscillator but the CFO occurs due to the carrier frequency mismatch between the transmitter and receiver. The IQI and CFO can cause a serious inter-carrier interference (ICI) in OFDM systems. But high PAPR occurs due to orthogonal subcarrier division by IDFT process, which results in loss of orthogonality due to non-linear amplification and hence there by occurrence of ICI.

In the existing method we are estimating I-Q imbalances and CFO by Minimizing the CRE without finding the response of the channel. We can estimate I-Q imbalances and CFO by Minimizing the CRE without knowing the response of the channel. Based On the estimated I-Q imbalance and CFO parameters, we can easily estimate channel responses. We derived a low complexity two-step approach for solving the joint estimation.

But the MIMO OFDM is suffering from high PAPR, which results in loss of orthogonality due to non-linear amplification and hence there by occurrence of ICI. So to compress the PAPR we are proposing a method to convert the MIMO OFDM system into SC-FDMA system without losing MIMO OFDM system characteristics. Hence it is possible to achieve lower PAPR.

II. TRANSMISSION TECHNIQUES

MIMO SYSTEM:

MIMO system has multiple numbers of antennas at both transmitter and receiver whereas SISO uses single antenna at either end. Input and output refers to wireless channel carrying signals, not the device having antennas. It offers different paths to carry data and helps to realize higher capacity and better quality compared to SISO.

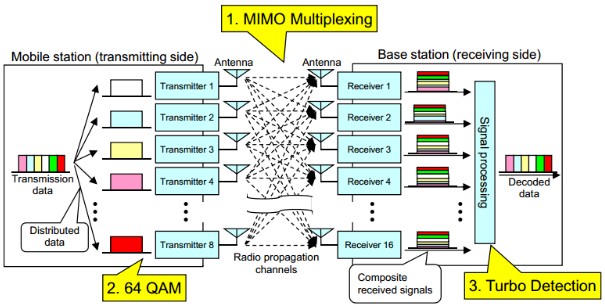

Fig.1 MIMO system

MIMO helps to achieve higher data rates, wider coverage and increased reliability, without additional bandwidth or transmit power. It also helps to realize array gain, spatial diversity gain and spatial multiplexing gain. In addition to that MIMO lowers the level of interference and supports opportunistic communication.

Most MIMO systems fall either of the two categories, single user MIMO (SU-MIMO) or multi user MIMO (MU-MIMO). SU-MIMO is point to point transmission for an individual user, whereas MU-MIMO is point to multipoint and supports multiple users simultaneously.

OFDM SYSTEM:

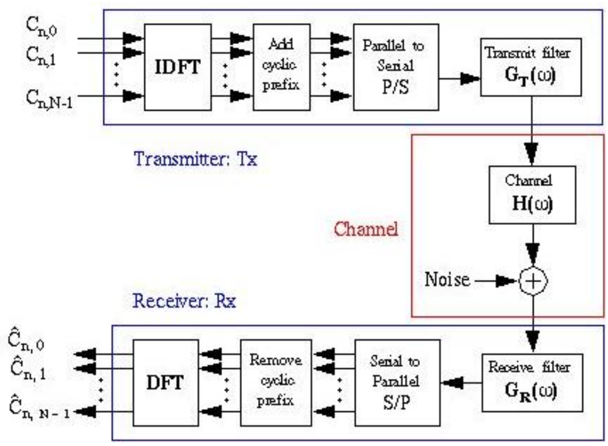

Fig.2 OFDM system

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OFDM is special case of multi carrier modulation and in this bandwidth is divided into set of parallel overlapping, yet orthogonal sub bands which are independent to each other. Data is first split into independent streams, which modulate different sub-carriers and then multiplexed to create OFDM signal. Sub-carrier is used to indicate orthogonal sub-bands.

OFDM eliminates need for bank of oscillators for modulation and demodulation because it can be implemented digitally using FFT. FFT is computationally efficient process of DFT. Cyclic prefix which is cyclic extension of OFDM signal in empty guard interval in the frequency domain. This enables to maintain the orthogonal characteristics of the transmitted signal even in severe transmission conditions. It allows densely packed and overlapping sub-carriers and offers spectral efficient transmission technique. OFDM converts frequency selective fading into flat fading, which simplifies processing at receiver to recover the data.

MIMO-OFDM SYSTEM:

MIMO adds complexity in system design. However, complexity can be appreciably reduced if used with multi carrier technique. OFDM is multi carrier technique, which converts a wideband frequency selective channel into a number of narrowband flat fading conditions. Combining MIMO with OFDM lowers computational complexity, handles multipath propagation effectively and fulfils the need for high data rate performance.

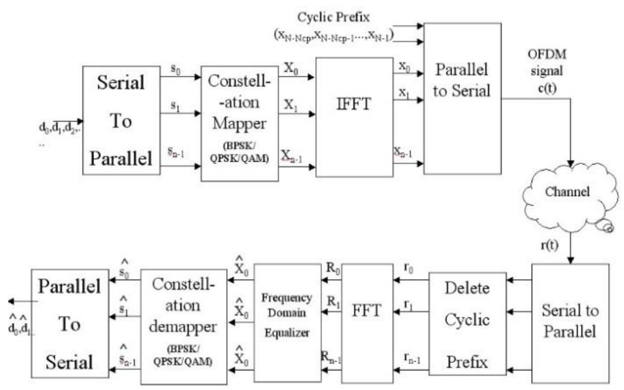

Fig.3 MIMO-OFDM system

Fig.3 shows an MIMO OFDM system having □ number of the transmit antennas and □ receive antennas. We obtain the □×1 vector x□ after taking the □-point IDFT of s_j which is input vector that contains modulation symbols. We insert acyclic prefix (CP) of length □−1to avoid inter symbol interference between OFDM symbols and then the signal is transmitted from the □th transmit antenna. Let the impulse response of the channel from the □th transmit antenna to the □th receive antenna be $h_{\square,j}(\square)$. We assume that the lengths of all the channels are ≤ □ so that there is no Inter block interference between adjacent OFDM blocks after CP removal

INPUT DATA:

Here to operate the MIMO-OFDM system we are taking random digital data as the training sequence for the system. For the estimation of I-Q imbalances and CFO by CRE using the existing method needs only one OFDM block for training sequence where as a low complexity two-step approach needs two repeated sequences for the estimation. In general we take □×1 input vector, but for repeated sequence we take two $\frac{M}{2}\times 1$ vectors as input. This data is modulated using PSK modulator or QAM modulator and modulated symbols are used as the training symbols.

We applied the proposed SC-FDMA method to the same data whatever given to the above system to compress the high PAPR of the existing system nearly equal to one by retaining the original characteristics of the MIMO-OFDM system.

Software tools used:

MATLAB software is used as a tool for the computation of SNR, MSE and PAPR of the MIMO-OFDM and SC-FDMA systems by estimating the CRE.

Hence output results were simulated with the help of MATLAB tool box.

III. PROPOSED SC-FDMA TECHNIQUE AND PAPR COMPUTATION

The schematic block diagram of a SC-FDMA system is shown in Fig. 3. PAPR is inherently low compared to the case of OFDMA which produces a multicarrier signal because the overall transmit signal in SC-FDMA is a single carrier signal. Fig. 4 shows how input data stream is converted into SC-FDMA transmit symbols. The input data occupies N (< M) subcarriers among the total M subcarriers. T is the symbol duration of the input data symbol in the time domain and the input symbol duration compressed to $\tilde{T} = \frac{N}{M}T$ after going through SC-FDMA modulation.

In this section, for each subcarrier mapping mode we analyze the PAPR of the SC-FDMA signal. We consider the IFDMA case for distributed subcarrier mapping mode. We will assume M = Q·N for the next derivations, and follow the notations in Fig. 4.

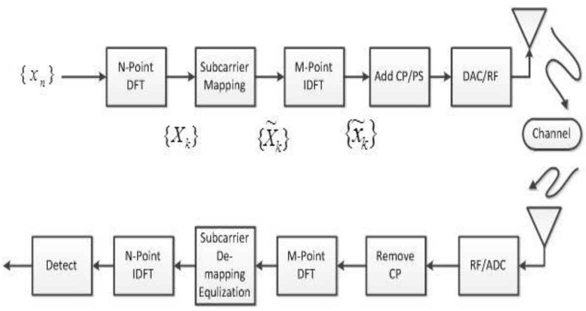

Fig.4 SC-FDMA block diagram

M: total number of carriers

N (< M): subcarriers occupied by the input data

$\{\tilde{X}_k: k = 1,2,3,\ldots\ldots\ldots.M-1\}$ are frequency domain samples after Subcarrier mapping, and $\{\tilde{x}_k: k =$ 1,2,3,……….M−1 are time symbols after IDFT.

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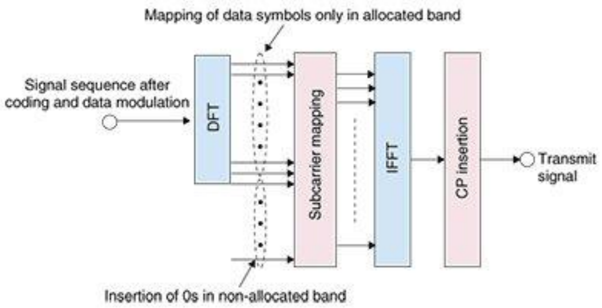

Fig. 5 Mapping of SC-FDMA transmits symbols.

The complex pass band transmit signal of SC-FDMA x(t) for a block of data is represented as

$$x(t) = e^{j\omega_c t} \sum_{k=0}^{M-1} \tilde{X}_k \, r(t - m\tilde{T}) \qquad (1)$$

Where ω_c is the carrier frequency of the system and r(t) is the baseband pulse. We are using a raised-cosine pulse which is a widely used pulse shape in wireless communications in our research and it is defined as follows in the time domain.

$$r(t) = \mathrm{sinc}\left(\pi \frac{t}{\tilde{T}}\right) \frac{\cos\left(\frac{\pi \alpha t}{\tilde{T}}\right)}{1 - \frac{4\alpha^2 t^2}{\tilde{T}^2}} \qquad (2)$$

Where α is the roll off factor which ranges between 0 and 1. The PAPR is defined as follows for transmit signal x(t).

$$\mathrm{PAPR} = \frac{\text{peak power of } x(t)}{\text{average power of } x(t)} = \frac{\max_{0 \le t \le M\tilde{T}} |x(t)|^2}{\frac{1}{M\tilde{T}} \int_0^{M\tilde{T}} |x(t)|^2 \, dt} \qquad (3)$$

Without pulse shaping, that is, using rectangular pulse shaping, symbol rate sampling will give the same PAPR as the continuous case since SC-FDMA signal is modulated over a single carrier. Thus, PAPR without pulse shaping with symbol rate sampling can be expresses as follows.

$$\mathrm{PAPR} = \frac{\max_{m=0,1,2,\ldots,M-1} \tilde{x}(t)}{\sum_{m=0}^{M-1} |\tilde{x}_k|^2} \qquad (4)$$

We first examine the PAPR of transmit symbols for each block with pulse shaping numerically before investigating the PAPR of transmit symbols without pulse shaping analytically.

IV. SIMULATION RESULTS

EXISTING SYSTEM:

AWGN is the Channel noise. The QPSK symbols are used as the training data. M=1024 is the size of the DFT matrix. L-1=64 is the CP length and the length of the channel is L=65.

The MSE performance is shown in Fig. 6-8. For comparison, we plotted the MSE of the IQ-CFO-FD method proposed in [7] also. The MSEs of the IQ parameters estimation is shown in Fig.6. The MSEs of the CFO and channel response estimation are shown in figures 7 and 8. We also plotted the Cramer-Rao lower bound (CRLB) on the CFO and channel response Estimation and shown in these figures.

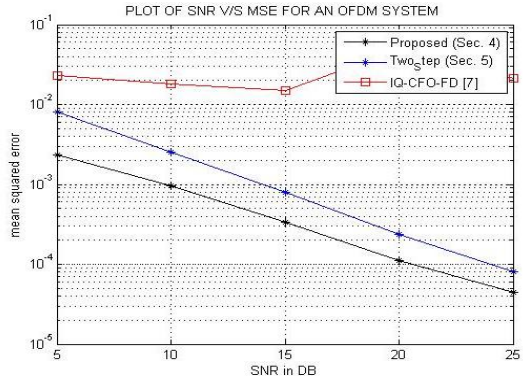

Fig 6.MSE of IQI

From these figures we found that the performance of the existing method is good and they are robust for different mismatched parameters. And also it is found that our proposed methods performance is outstanding in both cases of IQ-CFO FD method.

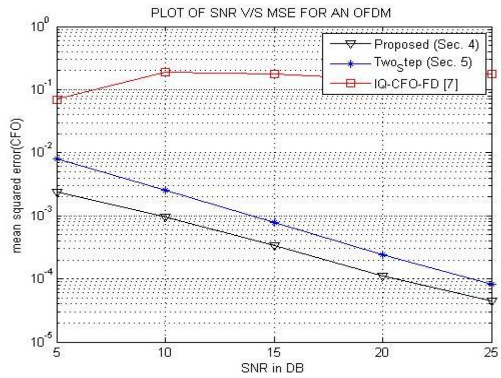

Fig 7.MSE of CFO

From Fig. 7, we see that our proposed methods provide a good performance for the estimation of CFO and their performance is very close the CRB in both cases.

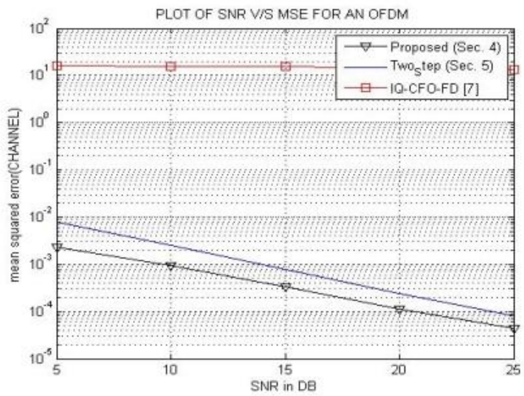

Fig 8.MSE of channel responses

PRPOSED SYSTEM:

The PAPR for the MIMO-OFDM system is directly proportional to the number of subcarriers. Hence high PAPR is obtained for the system and it is more than 15 dB. But using our proposed SC-FDMA method PAPR is reduced and it is approximately equal to one for both

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subcarrier mapping techniques with pulse shaping and without pulse shaping. The PAPR values of SC-FDMA and MIMO-OFDM system are compared in the below table for different modulations schemes are shown in the tabulation.

COMPARISON TABLE FOR PAPR:

Table .1 comparison of PAPR

Modulation Technique	EXISTING SYSTEM "MIMO-OFDM" PAPR(dB)	PROPOSED SYSTEM "SC-FDMA" PAPR (dB)	
		With Pulse Shaping	With out Pulse shaping
QPSK	**18.62**	**5.407**	**0**
16-PSK	**60.42**	**2.062**	**0**
32-PSK	**61.86**	**1.09**	**0**
64PSk	**62.26**	**1.10**	**0**
QAM	**28.6**	**5.4**	**0**
GMSK	**23.2**	**5.3**	**2.25**
OQPSK	**27.3**	**5.2**	**1.34**

V. CONCLUSION

Here in this paper, we compressed the high PAPR of the existing method using the proposed SC-FDMA method approximately equal to one, thereby decreasing the further ISI and ICI due to non-linear amplification which is caused by high PAPR. And also it is possible to retain the MIMO-OFDM characteristics by the proposed SC-FDMA method.

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