Performance improvement on spectral efficiency and peak to average power reduction for 5G system

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ABSTRACT
Filter bank multicarrier with offset quadrature amplitude modulation (FBMC/OQAM) system which can offer higher data rate 1 Gbps and improved bandwidth efficiency because of not require of cyclic prefix (CP) to avoid interference from the adjacent channels compared to fourth generation (4G) orthogonal frequency division multiplexing (OFDM) and other wireless systems. Because of these advantages FBMC/OQAM are used in fifth generation (5G) technology. In this FBMC/OQAM system, bandwidth capacity will be further increased by using multiple input multiple output (MIMO) channel. But in our proposed scheme we can use hyper-MIMO channel, in which at base station (BS) more number of transmitting antennas are used that for the improve the spectral efficiency performance better than traditional MIMO channel. But the most important drawback of hyper MIMO FBMC/OQAM is the higher peak to average-power ratio (PAPR) that degrade overall system performance in 5G. In 4G technology, to reduce PAPR a number of techniques are used. In our proposed system we can use mu-law non-linear companding technique and precoding discrete cosine transform (DCT) to reduce PAPR value for multicarrier modulation system compare to other systems.

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1. INTRODUCTION
The number of subcarriers in a wireless system are usually independent with each other but they are in same phase and may be aligned to produce constructive superposition that will produce the high values of envelope peaks. The huge power variation in the transmitted information signal is usually measured by PAPR parameter which is considered as severe problem in fifth generation (5G) systems. To decrease this peak to average-power ratio (PAPR) problem at 5G, many researcher are now using filter bank multicarrier with offset quadrature amplitude modulation (FBMC/OQAM) system [1, 2]. To higher the throughput value as well as increase the reliability of particular wireless system and for more coverage, multiple input multiple output (MIMO) system are used with FBMC/OQAM. At both the MIMO transmitter and receiver, a number of multiple antennas are used [3, 4]. FBMC/OQAM with MIMO is a one among the most promising technology in wireless system of 5G [5–7]. A new scheme discrete cosine transforms (DCT) precoding with non-linear mu-law companding which is applied to MIMO FBMC/OQAM model for improving the spectral efficiency and also the reduction in PAPR is proposed in this paper. At the end of this paper, simulation
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3. RESEARCH METHOD

3.1. Spectral efficiency (SE) analysis of MIMO FMBC/OQAM

For FBMC/OQAM system which use SISO antennas, as per the Shannon capacity theorem its spectral efficiency is expressed [15], [16] as,

\[ SE_{\text{SISO}} = W \log_2 \left(1 + \frac{W}{N} \right) \]  (5)

in (5), W is the bandwidth of system and \(S/N\) is a SNR of the received signal. When forward error coding (FEC) and M-QAM modulators are not present at that time only in (5) is valid. This spectral efficiency is better for FBMC/OQAM system when SNR increases, which equal to low SNR values of 4G-OFDM system [17]. Spectral efficiency of flat-fading MIMO FBMC/OQAM based on Shannon Capacity theorem is expressed as,

\[ SE_{\text{MIMO}} = W \sum_{n=1}^{N} \log_2(1 + MT_{UE} \psi_n) \]  (6)

where, variable M denotes the total antenna numbers used in base station, N is number of user equipment (UE) in service at BS, \(T_{UE}\) is the UE transmitting power which may be considered as equal for all user of the system and \(\psi_n\) define the fading of large-scale for the \(n^{th}\) user. In (6) signal to noise ratio of MIMO is expressed by,

\[ \left(\frac{S}{N}\right)_{\text{MIMO}} = MT_{UE} \psi_n \]  (7)

in (6) gives the relation between spectral efficiency and signal to noise ratio of MIMO system (M>>N).

3.2. MIMO PAPR measure in FBMC/OQAM system

By considering MIMO at FBMC/OQAM system, huge PAPR is a main drawback and it is defined as the high (or) maximum power of a FBMC/OQAM transmitting symbol and its average power [18], [19]:

\[ \text{PAPR} = 10 \log_{10} \left( \frac{P_{\text{peak}}}{P_{\text{avg}}} \right) \]  (8)

then FBMC/OQAM signal PAPR is expressed by,

\[ \text{PAPR}_{\text{OF}}[S[n]] = 10 \log_{10} \left( \frac{\text{Max}[|S[n]|^2]}{E[|S[n]|^2]} \right) \text{indB} \]  (9)

in (9), \(E[\cdot]\) is an expectation operation. Consider a MIMO FBMC/OQAM system that use ‘i’ transmitting antennas and ‘j’ sub-carriers [20]. Then PAPR is expressed [12], [13] as,

\[ [\text{PAPR}]_j = \text{max}[\text{PAPR}_1, \text{PAPR}_2, \ldots, \ldots, \text{PAPR}_M] \]  (10)

\[ [\text{PAPR}]_i = \text{PAPR}(S_i[n]) = \frac{\text{Max}[|S_i[n]|^2]}{E[|S_i[n]|^2]} \]  (11)

3.3. DCT precoding

First FBMC/OQAM signal PAPR value is reduced by using DCT that is, autocorrelation value of the input data sequence is reduced [21], [22]. Mathematically, DCT applied to input data sequence Iₙ with the length of N is given as,

\[ y_k = x(k) \sum_{n=1}^{N-1} l_m \cos \left( \frac{\pi(2n+1)k}{2N} \right) k = 0,1,2,\ldots,N - 1 \]  (12)

in (12) \(N\) defines as total subcarriers used. \(\chi(k)\) is the window function and as:

\[ x(k) = \begin{cases} \frac{1}{\sqrt{N}} & \text{if } k = 0 \\ \frac{1}{\sqrt{N}} & \text{if } k \neq 0 \end{cases} \]  (13a)

\[ x(k) = \begin{cases} \frac{1}{\sqrt{N}} & \text{if } k = 0 \\ \frac{1}{\sqrt{N}} & \text{if } k \neq 0 \end{cases} \]  (13b)

3.4. Non-linear mu-law companding

Finally, the FBMC-OQAM signal is converted into an analog signal that is to be transmitted through the AWGN channel, but before that it will be compressed by using nonlinear mu-law companding block to improve spectral efficiency and it is expressed [23], [24] as,

\[
C(S[n]) = sgn(S[n]) \frac{ln(1 + Mu|S[n]|)}{ln(1 + Mu)}
\]

(14)

at receiver, compressed FBMC/OQAM signal is expanded by using function of inverse companding [25] that is, an opposite operation of the transmitter and it is as (15).

\[
NC^{-1}[r_k] = sgn(r_k) \left( \frac{1}{Mu} \right) \left( 1 + Mu \right)^{|r_k|} - 1
\]

(15)

4. RESULTS AND DISCUSSION

The simulation results of our proposed system, shows that MIMO FBMC/OQAM system performance improvement. Figure 2 show that when antennas number increases in base station (BS), then the SNR of the FBMC/OQAM signal also increases. Because of this, the system spectral efficiency of MIMO FBMC/OQAM also improved compare SISO system.

Figure 3 shows that PAPR reduction using non–linear mu-law companding with various mu-law ratios. Here mu-law ratio value 500 gives the better PAPR reduction than others. Table 1 shows that the PAPR reduction in different schemes.

Figure 2. Average SNR in a MIMO system with multiple antennas at the BS

Figure 3. PAPR reduction in MIMO FBMC-OQAM with different mu-law ratio
Table 1. Reduction in PAPR of various existing models

<table>
<thead>
<tr>
<th>Techniques</th>
<th>PAPR in dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>traditional MIMO and FBMC</td>
<td>12.7</td>
</tr>
<tr>
<td>MIMO–FBMC+a-law</td>
<td>4</td>
</tr>
<tr>
<td>MIMO–FBMC+mu-law</td>
<td>3.8</td>
</tr>
<tr>
<td>MIMO–FBMC+Precoding DCT+a-law</td>
<td>3.3</td>
</tr>
<tr>
<td>MIMO–FBMC+Precoding DCT+mu-law</td>
<td>2.8</td>
</tr>
</tbody>
</table>

Figure 4 shows the reduction in PAPR performance of MIMO FBMC/OQAM system using different schemes. Our proposed scheme MIMO FBMC/OQAM and precoding of DCT along mu-law companding gives low PAPR value that will be 2.8 dB, compare to other schemes. Figure 5 shows that bit error rate performance of MIMO FBMC-OQAM against SNR which is based on precoding of DCT along with mu-law scheme of companding and precoding of DCT with linear companding of a-law. It is mostly observed that the better bit error rate (BER) performance occurs with the use of precoding of DCT and mu-law companding.

Figure 4. MIMO FBMC/OQAM PAPR reduction of different techniques

Figure 5. BER vs SNR of MIMO with FBMC/OQAM for different techniques
5. CONCLUSION

This research proposal, dealt with performance analysis of the proposed FBMC with QAM based MIMO system concentrate mainly on the reduction of PAPR, Bit Error Rate performance and spectral efficiency by using DCT with non-linear mu-law companding. From our simulation results, we observe that our proposed system produces the low PAPR compared to other reduction PAPR techniques. In addition to this, performance of BER also analyzed in terms SNR that increasing the number antennas which is good compare to other techniques but our proposed system has acceptable complexity. This proposed system will be extended by using FEC concepts.

REFERENCES

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