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Design of DCT- SLM and Modified Bartlett Hanning Window Based OFDM systems to Reduce ICI in AWGN Channel

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***Abstract*- Carrier frequency offset (CFO) is a major issue with MIMO Orthogonal Frequency Division Multiplexing and it causes Intercarrier Interference (ICI) and also Inter symbol Interference (ISI). Due to ISI and ICI, we get a low Bit Error Rate (BER) and high Peak to Average Power Ratio (PAPR) at the OFDM receiver side and corrupted data. It is highly required to remove CFO during communication or receiving OFDM symbols. Discrete Cosine Transform Selective Level Mapping (DCT-SLM) is used in this work to reduce CFO. Full Orthogonal communication can prevent ICI or ISI up to a certain level caused by CFO but, it is also required to mitigate ICI at the OFDM receiver side. This work proposed a Modified Bartlett-Hanning (MBH) windowing method at the OFDM receiver side for reduction of PAPR and BER caused by ICI and CFO.**

Keywords*- *CFO, Bit Error Rate, Modified Bartlett-Hanning, Intercarrier Interference, OFDM, Selective Level Mapping, PAPR, Windowing

I. INTRODUCTION

OFDM which is Orthogonal Frequency Division Multiplexing is a 4G method for high-speed data rates in wireless communication of processor-based devices and OFDM utilizes multicarrier modulation for MIMO based communication. The Inter-Carrier Interference (ICI) among sub-carriers channels is one of the bigger challenges of OFDM. In MIMO, the CFO also causes ICI. CFO initiated in OFDM either because of Doppler move arises in sub-carriers or it may be due to a result of befuddling of the transmitter.

OFDM systems, based on signal symbols transmissions, are used in 4G and 5G communication because it supports MIMO for fast communication but to maintain the orthogonality, interleaving of cyclic prefix (CP) in-between signals symbols of sub-carriers is necessary [1]. But, due to high demand some time this CP is becoming narrow which can cause interference and so carrier frequency offset became smaller which results in the Inter-carrier interface and low Bit Error Rate. There is different work done for reducing the ICI and BER. This work is also one of the solutions for reducing BER and ICI, this work uses two methods in 4x4_TxRx MIMO-OFDM, first, this work used DCT-SLM flow for symbols transformation and in SLM instead of one IFFT this work uses small chunks of IFFT at the transmitter side. And finally DCT performs for symbol generation from a signal. Second this work uses the Modified bartlett Hanning window for the size of the Cyclic prefix.

The objective of this work is to reduce PAPR in 4x4 MIMO-OFDM commodification using Selective Level mapping and also using a modified bartlett Hanning Window. This work is organised as the first introduction of technologies used in this work are discussed, the second methodology used in this work where proposed MBH windowing method and SLM discussed, then obtained results and comparative results discussed for the parameter like SNR, BER and PAPR, at last conclusion and possible future scope described.

II. PROPOSED METHODOLOGY

This work uses Windowing based filtering in the OFDM system to diminish CFO and so ICI. The proposed window is a changed variant of the MBH-window family . It is utilized in an OFDM framework to lessen the impact of recurrence offset on the two boundaries i.e PAPR and BER execution . Proposed MBH window family is contrasted and other accessible standard window techniques, for example, RC, FRANK, Bartlett, PMSP, SOCW and BTRC These windows are additionally utilized in OFDM framework. This proposed strategy is a blend of going before and Partial communication grouping (PTS) strategies and it is less complicated than the PTS strategy Furthermore, it lessens ICI extensively with a couple of number sub-blocks when contrasted with the PTS procedure. DCT-SLM is additionally used to synchronize the cyclic prefix (CP) and try not to cover between various groups, DCT-SLM likewise keeps up with the symmetrical covering between signal symbols.

Let input data block is

$$A = \{A_p\} \tag{1}$$

where p resides in an interval of (p = 1,2…M -1),

M is the number of subcarriers in frequency domain data sequences, A^{ϵ} given in equation (2) by multiplying that with sequences of the phase we get eq (3), all A elements given in eq (2) provide results of eq (3)

$$A^{\epsilon} = \{P_P^{\epsilon}\}\ (P = 0,1,2,3 \ldots \ldots N-1) \tag{2}$$

$$A^{\epsilon} = [T_0^{\epsilon} A_0, T_1^{\epsilon} A_1, \ldots \ldots T_{N-1}^{\epsilon} P_{N-1}\ ] \tag{3}$$

where ε = (1,2 …...N)

where $T_P^{\epsilon} = \exp(j\varphi_p^{\epsilon})$ and φ_p^{ϵ} is distributed uniformly between 0 to 2pi. Finally, N data symbols find using IDFT.

$$A^{\epsilon} = IFFT\ (A^{\epsilon}), \epsilon = (1,2, \ldots \ldots N) \tag{4}$$

It is seen that images having comparative data likewise cause ICI. The signs which have the littlest ICI from $X\varepsilon$ (eq. 3) need determination for transmission reasons.

The work uses Discrete Cosine transform (DCT) along with Selective Level Mapping (SLM) Technology for the reduction of Peak average to power ratio (PAPR) caused by Carrier Frequency Offset (CFO) in Orthogonal Frequency Division Multiplexing (OFDM) Communication. The reason for using this unique combination is that SLM methods does not perform effective mapping however when we first transform the signal symbols into small cosine signals of lower and higher frequencies using DCT SLM,it gives us a very good mapping of symbols and this reduces the PAPR causes by CFO.

This work DCT-SLM combinational flow diagram is shown in figure-1 below, in figure-1 first we select the input data from the source generator. Then the data gets converted into signal symbols using Serial to parallel converter, the number of symbols depends on the MIMO channels used for the system, this work has 4 Tx channels hence we develop 4 signal symbols at once. The signal symbols then get pre-modulated using $(B_1, B_2, \ldots\ldots B_U)$ frequencies. Each pre-modulated signal is then processed through the Inverse Fast Fourier Transform (IFFT) and then this IFFT transformed signal later gets filtered using proposed Modified Bartlett Hanning (MBH) windows filters and passed through parallel to serial conversion , at last DCT performs before actual signal Space-time block coding and others OFDM process.

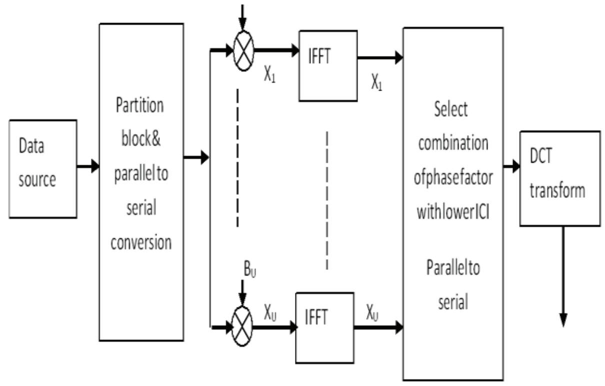

Fig 1 Basic blocks of proposed PTS, DCT-SLM technique

The objective of numerous FFT demodulation and the mix is to lessen ICI which yields Pre-handling given ideal, different re-testing of gotten signal . Multiple FFT demodulators are utilized to surmised ideal collector front-end for arbitrary reasons time-changing channels. Multiple FFT demodulators incorporates a method for anticipating Doppler shift from combiner loads proposed beneficiary replaces customary, single FFT demodulator with a couple (e.g two) FFTs and combiner whose results are joined in a way that limits post-recognition blunder recipient additionally integrates spatial variety consolidating, a versatile channel assessor and a stage expectation technique to follow channel reaction across OFDM blocks.

Regulation causes sharp discontinuities at image limits , Phase irregularity at image limits makes the sub-transporter range leave the band, bringing about ICI. To keep away from this, windowing strategies are utilized for each OFDM image Windowing, products each OFDM image with a window work .So, sufficiency makes smooth progress to zero at image limits.

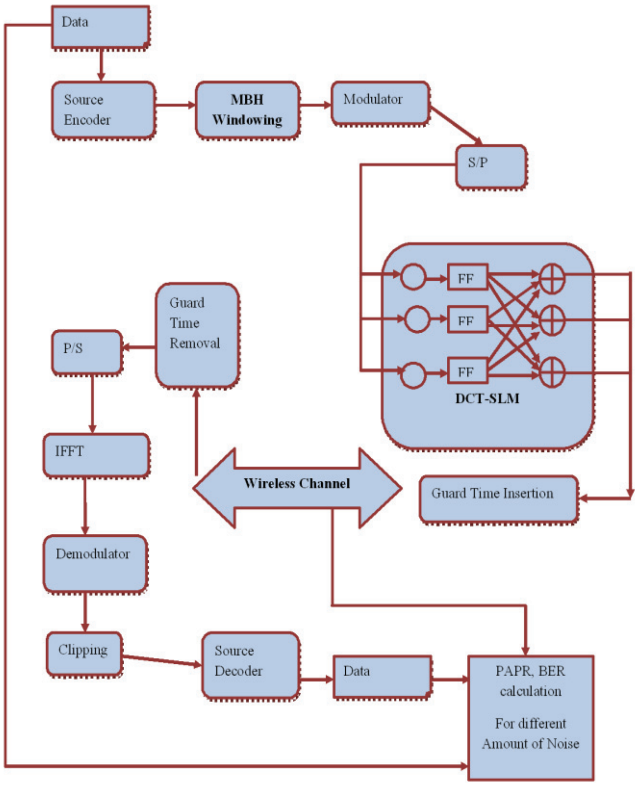

Fig 2 Proposed OFDM flow diagram

An OFDM signal comprises unfiltered subcarriers. Therefore out-of-band-range diminishes rather leisurely, with speed contingent upon the number of sub-transporters. Mostly utilized is raised cosine window, which is characterized as

$$0.5 + 0.5\cos\left(pi + mpi/BT_s\right) \qquad 0 \le m \le BT_s \quad (5)$$

$$Window(m) = BT_s \le m \le T_s \quad (6)$$

$$0.5 + 0.5\cos\left(\left(m - T_s\right) pi/BT_s\right)\right) \qquad T_s \le m \le (1 + B)T_s \quad (7)$$

where B is the roll-off factor. Another class of windows that are smoother at ends compared with triangular windows is cosine windows, however closer to one at middle side-lobe levels should be reduced by smoother taper at ends, while distortion of desired window response bound m = 0 is reduced by broader middle section to reduce side-lobe level further, we may consider an even lot gradual taper at ends of window sequence by using raised cosine sequence various windows in this category.

Proposed window Modified Bartlett-Hanning (MBH) is a linear combination of modulated rectangular windows from Euler's formula proposed, the window is defined by: -

$$Window_{Prop}(m) = \begin{cases} 0.68 - 0.32cos\left(\frac{2pim}{N} - 1\right) & for \quad 0 \le m \le (N-1)/2 \\ 0.32 - 0.68sim\left(\frac{2pim}{N} - 1\right) & for \quad (N-1)/2 \le m \le N-1 \\ 0 & OtherWindowise \end{cases} \quad (8)$$

III. RESULTS

MATLAB is used for designing the communication systems, and communication tools box. MATLAB provides signals generators, modulators and channels simulation environments. This work includes proposing an MBH window in OFDM systems development, this work has been designed for 4 transmitters and 4 receiver MIMO-OFDM, and 64-bit IIFT and FFT modules are used. STBC encoder and decoders are also used from the MATLAB communication library. the OFDM flow is designed as per the proposed PTS, DCT-SLM technique as was shown in figure-3.

This work is simulated for the following parameters: -

- Selected IFFT 16 and 8 carriers channels selected for, the Modulation used are BPSK, QPSK, 16-PSK, 8-PSK and 64-PSK,
- 20-dB Amplitude clipping used in the wireless channel
- Input signal SNR used for the signal is 0 to 30-dB.

Results of OFDM channel modelling transmission in this work. The results obtained on the MATLAB command window after the code execution are: -:

- Peak – Root Mean Square (RMS) power ratio of the channel at the start: 4.86329 dB
- Peak - RMS power ratio of the channel at the last: 1.4378298 dB
- Transmitting time of 128kb data symbols: 4.069966 Seconds
- Receiving time of 128kb data symbols: 2.01542 Seconds
- Data loss during OFDM-MIMO communication = 0.0006418% (673 out of 1048576)
- Errors in Total communication = 43021 (out of 1048576)
- Bit Error Rate (BER) in 128kB data communication is = 0.041028%
- Error in Phase(average) = 12. 982
- Received data Error= 0.084806144%

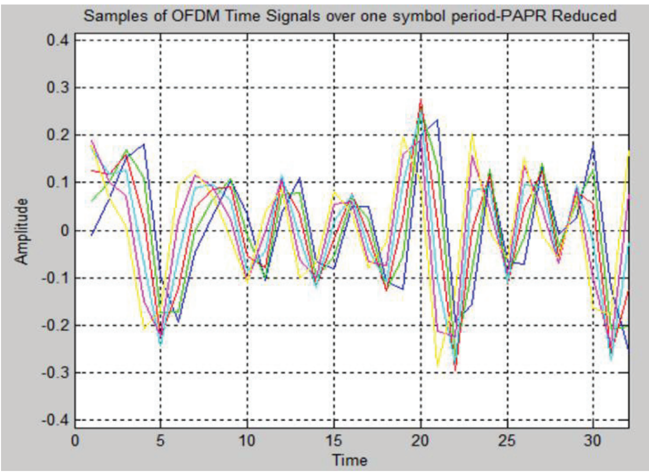

Fig 3 Multiple channels of ODFM amplitude graph

Figure 3 above shows the OFDM amplitude plot for all 4 sub-carrier channels, here it can be seen that signal amplitude is different at any specific time, it is so because all signal symbols are orthogonal to each other using the STBC encoder. Figure 4 shows the received data signal and its phases after 16-PSK, it may be seen that the received data signal has all 16 symbols received incorrect phase.

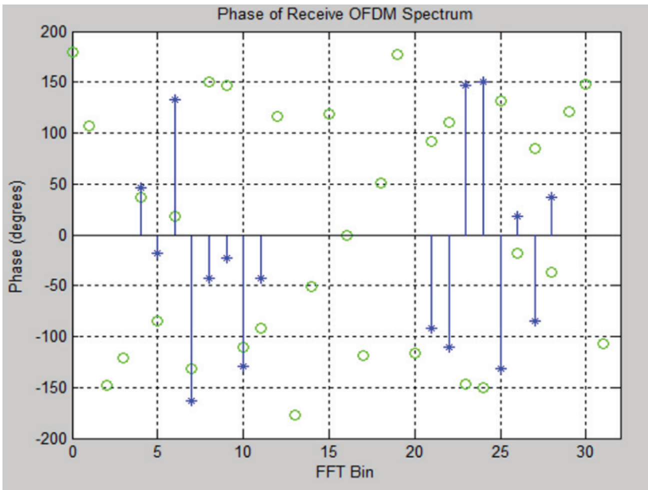

Fig 4 16-PSK OFDM signal & its phases

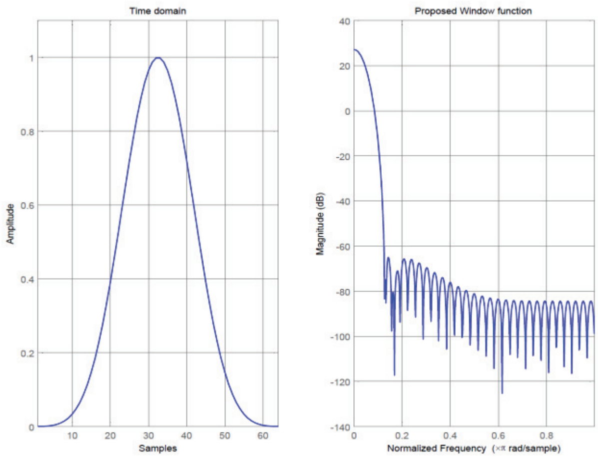

Fig 5 Window function in this work

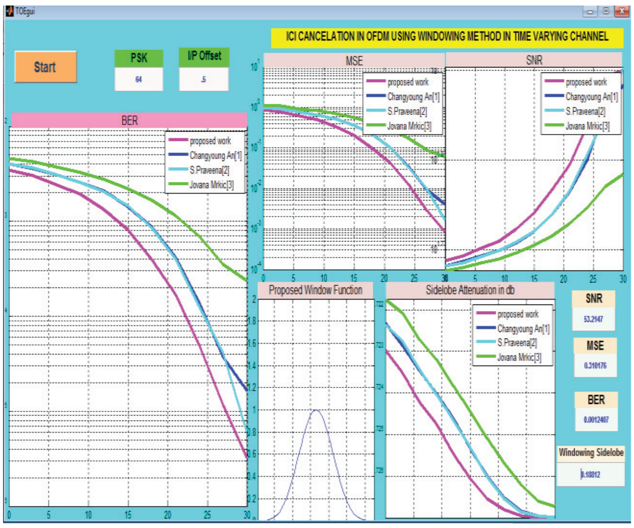

Fig 6. MSE, BER, attenuation in sidelobe, SNR observed for 50Hz test signal with 64-PSK modulation and different amounts of noise

Figure 5 shows the window function normalized frequency response observe in this work, here we may observe that this work has low sidelobes and a thick main lode for better resolution in frequency transformation. Figure-6 below shows the Graphical User Interface design for simulation of the proposed MBH-Windowing based CFO reduction method.

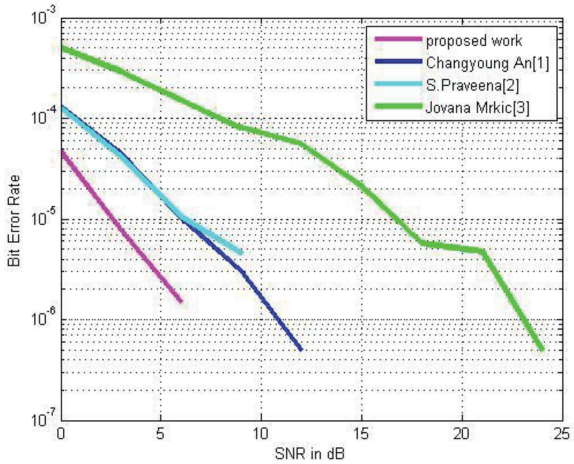

Fig 7. BER obtained when 4PSK modulation comparative observation

Table 1 shows the Observed results for the different types of modulation methods 4,16 and 64-PSK.Table-1 shows the SNR, MSE and BER results obtained for a proposed design.

TABLE I. OBSERVE THE RESULTS

PSK	SNR DB	MSE DB	BER DB	Sidelobe attenuation DB
4	75.9381	0.0017367	7.0108e-06	0.17931
16	60.2945	0.0607614	0.000243045	0.187622
64	53.2147	0.310176	0.00124889	0.188124

Figure 7 shows the Simulating results and comparative graph for the BER at different amounts of input noise ranging from 0 dB to 30 dB. It can be seen that the proposed work has the least BER. Figure 6 Results obtained for 4-PSK.

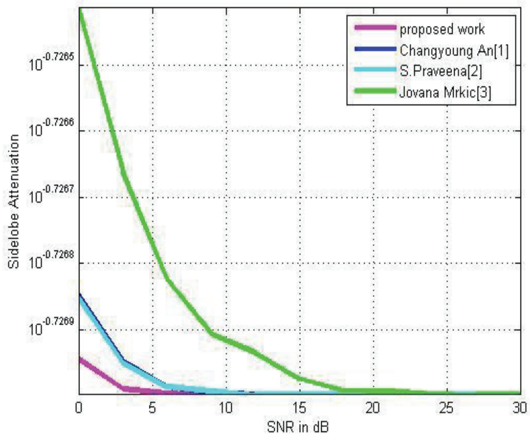

Fig 8 Attenuation in Sidelobe comparison for 50Hz test signal with 4-PSK modulation and different amounts of noise

Figure 8 shows the Simulating results and comparative graph for the sidelobe attenuation at different amounts of input noise ranging from 0 dB to 30 dB. It can be seen that the proposed work has the highest Side-lobe attenuation. Figure 7 Results obtained for 4-PSK.

TABLE II. COMPARATIVE RESULTS

Input 50Hz sinusoid signal with 15 dB AWGN and modulated using 4-PSK				
Method	Signal to Noise Ratio	Mean Square Error	Bit Error Rate	Attenuation in Sidelobe
M. H. Mahmud [1]	72.843	0.0018932	8.4529e-06	0.147
S. Gokceli [2]	72.214	0.002860	8.882e-06	0.133
X. Liu [3]	70.981	0.009289	9.1025e-06	0.1265
This work	75.9381	0.0017367	7.0108e-06	0.17931

Table 2 above shows the Comparative results, it may be seen that for the 4-PSK modulation and when input signal noise is 15 dB, the proposed work is having least BER and MSE in comparison with M. H. Mahmud [1], S. Gokceli [2] and X. Liu [3]. From the table, it can also be seen that the proposed work is having highest SNR and sidelobe attenuation.

IV. CONCLUSION

This work has designed a Modified Bartlett and Hanning (MBH) based window which adjusts the OFDM signal symbols received through multiple sub-carriers on MIMO communication. The MBH reduces the Carrier frequency offset and so in this work, we get lower BER and high SNR in the received signal. This work also uses DCT-SLM for offset adjustment. The simulation parameters are set as a sampling frequency of 10KHz, and a signal frequency of 60Hz and the work is tested for different modulations e.g 4-PSK, 16-PSK and 64-PSK. It is found that the proposed work has a minimum Bit Error rate (BER) in comparison with other similar works for any modulation selected. This work is also tested for different Input signals and different amounts of AWGN noise added to it. The noise amount added to the signal is between 0 dB to 30 dB, and for any noisy signal, this work has minimum BER and sidelobe attenuation. In near future, this window method can be tested on Massive MIMO or Multi-user MIMO.

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