ICI Cancelation in OFDM Using Windowing Method in Time Varying Channel

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Abstract— Orthogonal Frequency Division Multiplexing (OFDM) is a hopeful technique for attaining high data rates in mobile environment because of its multicarrier modulation. As the sub carriers are orthogonal in OFDM, the spectrum of each carrier has a null at the center frequency of each of the other carriers in the system. But in time varying channel the orthogonality between subcarriers are distorted due to Doppler Spread (DS) which introduces the Inter Carrier Interference (ICI) that diminishes the system performance. To enhance the OFDM system performance over time varying channels, an ICI self-cancellation scheme driven with the transmitter Hamming and Hanning windowing are implemented. The time domain Hamming and Hanning windows immediately after Inverse Fast Fourier Transform (IFFT) cancel the ICI fractions from adjacent subcarriers significantly. As a result, the frequency domain channel matrix reshaped by the Hamming and Hanning windowing can be closely approximated to a strictly banded matrix. The estimation of the channel matrix is done with the assistance of the pilot tones in the Complex Exponential Basis Expansion Model (CE-BEM). The CE-BEM channel estimation performance is evaluated in terms of bit error rate for proposed system and compared with cyclic prefix OFDM system with time varying channel.

Key words: Orthogonal Frequency Division Multiplexing (OFDM), Inter Carrier Interference (ICI)

I. INTRODUCTION

The ICI among sub-carriers is one of the major problems of the OFDM system. The main cause of ICI is the CFO, induced either due to Doppler shift arises by channel or due to the mismatching of transmitter and receiver oscillator. The ICI may also be caused by the phase noise and timing offset. However, the ICI induced by CFO, phase noise and due to timing offset can be compensated or corrected. Since the Doppler spread or shift is random, its impact can only be reduced or mitigate. Not only due to Doppler spread, the ICI induced due residual frequency offset, which is the result of estimation error, is also required to be mitigated separately. Therefore, a separate method besides of CFO estimation and correction at the receiver is required to reduce the ICI. Several techniques have been introduced in the past to reduce ICI. These include frequency domain equalization, self-cancellation scheme and windowing technique (pulse shaping at the transmitter and receiver windowing), The receiver windowing is one of the best ICI reduction techniques available in the literature. This chapter deals with the study and analysis of receiver windowing techniques and proposed a new window for ICI reduction.

The windowing techniques can be used at both the transmitter and receiver sides. The use of RC window at transmitter side has also been suggested by IEEE 802.11 standards. Some other Nyquist pulse shapes like BTRC, PMSP, ISP, Frank's window and SOCW are also available in the literature. The windowing at the transmitter side is used to reduce the sensitivity to linear distortions. In transmitter windowing method, the window function shapes the cyclic extension part of OFDM symbol and leaving original part of the symbol unchanged. This form of windowing has no effect on the system performance when there is only frequency distortion. To reduce the sensitivity to frequency errors or distortions, the receiver windowing has been used by many authors. The concept of windowing at the receiver end for the reduction of ICI is very well reported in . All these works demonstrated that, the use of a proper Nyquist window will reduce the ICI to the greater extent. The window is applied to the estimated ISI-free part of a received OFDM symbol. The time-limited window which reduces the side lobes and conserves the carrier orthogonality is called Nyquist window. The work reported in demonstrate the effects of several Nyquist windows, including RC, BTRC, SOCW, the frank window, and the double jump window on the performance of OFDM system. The evaluation was based on both the parameters like BER and SIR.

II. PROPOSED METHODOLOGY

A new hybrid technique is proposed to reduce the ICI. This proposed technique is a combination of preceding and PTS methods and it is less complex than PTS method. Furthermore, it reduces the ICI considerably with only few numbers of sub-blocks as compare to PTS technique. These chapters described in detail the system model and ICI as well as power spectral density (PSD) for this model. Simulation results are done to evaluate the ICI and PSD performance. At last, simulation results as well as conclusion is discussed.

From literature review, it was reviewed that scheme for reducing ICI belonging to frequency domain achieves good results than domain of time parameters because of its ability to achieve less ICI with minimized distorted values in I/P signals & thereby not producing any distortion. By dealing techniques in freq. domain PTS with DCT-SLM was choose to be best frequency domain methods just by reducing ICI when done comparison with other techniques. Hybrid technique uses interleave at input end & also using de-interleave at receiver.

A. *Partially Transmitting Sequencing of Data*

Consider input block of data as X = {X_K}, where value of k resides in interval of (k = 1,2…N -1), N denoting no.of sub carriers used. In frequency domain (FD) data sequences,$^{\varepsilon}$($\varepsilon =$ 1,2 .....M) by multiplying with sequences of phase.

$$X^{\in} = \{P_K^{\in}\}\ (K = 0,1,2,3 \ldots \ldots . N-1)$$

All X elements given above are providing following given results

$$X^{\in} = [P_0^{\in} X_0, P_1^{\in} X_1, \ldots \ldots P_{N-1}^{\in} X_{N-1}\ ]$$

where $=$ (1,2 .....M)

where $P_K^{\in} = \exp(j\varphi_k^{\in})$, $\varphi_k^{\in}$ is distributed in uniform fashion in [0, 2π].

To get M candidates' using IDFT in domain of time

$$X^{\in} = IFFT\ (X^{\in}), \in = (1,2, \ldots \ldots M)$$

It was observed that even candidates having same information provides various ICIs & the signal having smallest ICI from X^{ε} needs selection for transmission purpose.

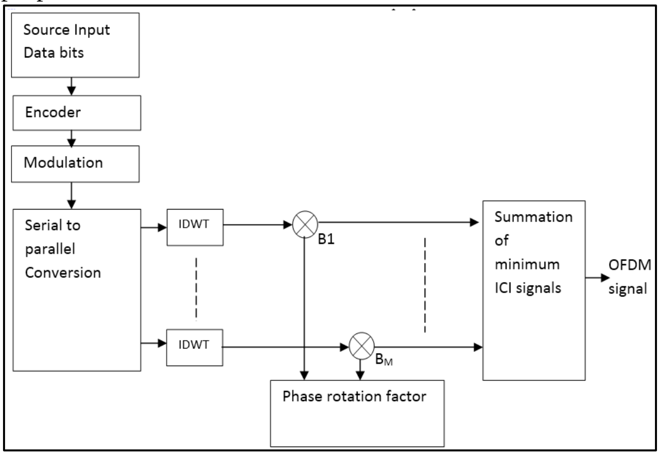

Fig. 1: Basic Block of PTS Scheme

B. *Selective Level Algorithm Technique*

Selection Mapping algorithm is a scheme used to mitigate ICI in system. aim behind scheme is phase rotation. Signal having less ICI value needs selection from all various independent phase sequences that is showing same sort of information at input end. Suppose block of input end may be represented like $X = [X1, X2, ...X_{N-1}]^T$

When multiplication with phase sequences of input blocks is done of independent nature it results

$P^u = [P_0^u, P_1^u, \ldots\ldots\ldots P_{N-1}^u]$, u= (1,2,3,….U)

Where U denotes phase sequences number

Here we keep data length of an input & also sequence of phase as same. Afterwards obtain domain of time signal by applying IFFT & hence we will obtain blocks with various ICI & phase sequence.

$X^u = [X_0^u, X_1^u, \ldots\ldots\ldots X_{N-1}^u]^T$

Selection of min. ICI scheme is done & then it is transmitted. There is another parameter known as CCDF which is being used to measure probability & thereby indicating as value particular block exceeding given threshold. CCDF showing ICI of SLM system will be

$$P(ICI > ICI0) = (1 - (1 - e^{-PAPR0})^{\alpha N})^U$$

- N= Sub-carriers number
- N_{IFFT} =N IFFTs operation
- U=independent phase sequence
- ICI0= threshold value
- α= oversampling facto

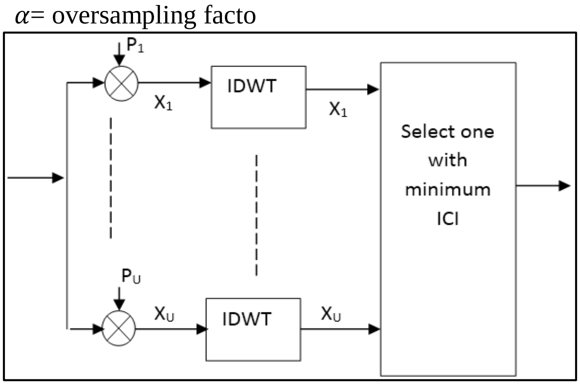

Fig. 2: Basic Block of Conventional SLM Technique

C. *Proposed Multi-FFT Demodulation & Combiner*

Proposed procedure is a DCT-SLM TECHNIQUE, point behind plan containing a blending of two proper strategies. It consolidates DCT & furthermore SLM system. essential square is demonstrated as follows (Figure 4.3). At transmitting end, initially flood of information will get changed by lattice of DCT & later on this information which has ndergone change will prepared by SLM square. In event that it's goes through IFFT hinder, information square goes by dealing with DCT framework then every one of coefficients autocorrelation of IFFT input got diminished, & consequently ICI may be reduced. Here information goes through SLM unit & afterward will work with DCT unit. Here considering case if DCT network is utilized after SLM then it additionally do diminishing of ICI of flag. O/P flag of ICI will be lessened. piece of transmitters appeared beneath.

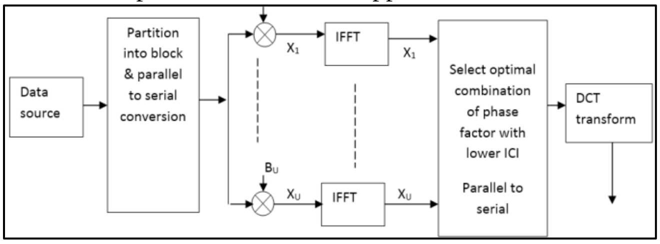

Fig. 3: Basic Blocks of Proposed PTS, DCT-SLM Technique

The goal of multiple-FFT demodulation & combining is to reduce ICI in outputs. Pre-processing based on optimal, multiple re-sampling of received signal. Multiple FFT demodulators are used to approximate optimal receiver front-end for arbitrarily time-varying channels. Multiple FFT demodulators includes a technique for predicting Doppler shift from combiner weights. Proposed receiver replaces conventional, single FFT demodulator with a few (e.g. two) FFTs & combiner whose outputs are combined in a manner that minimizes post detection error. Receiver also incorporates spatial diversity combining, an adaptive channel estimator & a phase prediction procedure to track channel response across OFDM blocks.

The block diagram above shows the work flow of the proposed work and steps of the owr are following:

1) Step 1: input data which can be an any image, discrete signal or a video
2) Step2: Source encoder which encode the signal hamming code is been used in the work
3) Step 3: channel encoder quasi OSTBC is implemented in the work of 4x4 antennas
4) Step 4: Modulator which digitally modulate the signal with three option QPSK, 16 PSK or 64 PSK
5) Step 5: serial to parallel conversation which separates the frequency carriers
6) Step 6: : proposed PTS-DCT technique based multi IDWT perform on the sub carrier signals which are already in frequency domain into time domain
7) Step 7: insert the guard time generally known as cyclic prefix
8) Step 8: communication through channel in proposed design it is AWGN channel wit variable amount of noise
9) Step 9: guard time removal
10) Step 10: parallel to serial conversion

11) Step 11: Demodulator which digitally demodulate the signal with three option QPSK, 16 PSK or 64 PSK
12) Step 12: clipping process which will use time domain ICI reduction
13) Step 13: channel decoder based on quasi OSTBC of 4x4 antennas
14) Step 14: source hamming code decoder
15) Step 15: recovered the data signal
16) Step 16: ICI and BER measurement
17) Step 17: ICI, BER calculation for different SNR

The main characteristic of wireless mobile channel is multipath propagation. Multipath propagation caused by multipath mobile channel can be described from both time and space. In the point of view of space, within the direction of movement of mobile station, the received signal amplitude changes with distance. From time domain, because of different length of the various paths, the arriving time of signal is different. In this way, after base station sends a pulse signal, the signal received not only contains the pulse, but also includes all delayed version of signals. Extension of time could be measured from the signal received first to the last one.

An important feature of wireless channel is time-varying, which is the transfer function of channel changes within time. So, the transmitter sends the same signal at different time, but the signals received by receiver are not the same. Doppler shift is one concrete manifestation of the time varying in the mobile communication system. When the mobile station is performing communication in mobility, the received signal frequency will change. In multipath conditions, each multipath wave has a frequency shift, called Doppler spread. The shift of frequency in the mobile received signal caused by the mobility is called Doppler frequency shift, and it is relative to the speed of mobile users.

$$f_d = \frac{v}{\lambda}\cos(\theta) \qquad f_c = \frac{v}{c}\cos(\theta) = f_m\cos(\theta)$$

Where v is speed of mobile station, λ is radio wavelength, f_c is carrier frequency of transmitter, c is speed of light, θ is angle between radio and mobile station, f_m is the maximum Doppler frequency shift, respectively.

For capturing the time-varying nature of the channel, methods have been proposed to model it as uncorrelated random process. In this modeling approach, the channel fading taps are assumed to follow Gaussian zero mean Rayleigh fading process when the line-of-sight propagation is absent, or Gaussian non-zero mean Rician fading process when the line-of-sight-propagation is present. As an alternative, Basis Expansion Model (BEM) has recently gained popularity in time varying channel estimation applications, due to its reduced computational complexity.

The choice of the BEM basis (or kernels) has thus given rise to intense debate among academics, since different basis types will provide distinct performance in various communication environments. Inspired by discrete Fourier transformation, Complex Exponential BEM (CE BEM) has been proposed.

In this thesis, we will restrict our attention on the Basis Expansion Model based channel estimation technique. Due to the simplicity of implementation, CE-BEM has gained popularity and been intensively investigated recently for time-varying channel estimation applications. This model is inspired by the Fourier analysis, which seek to represent an arbitrary function as a finite sum of its harmonics. Recall our general representation of the discrete-time base-band signal model:

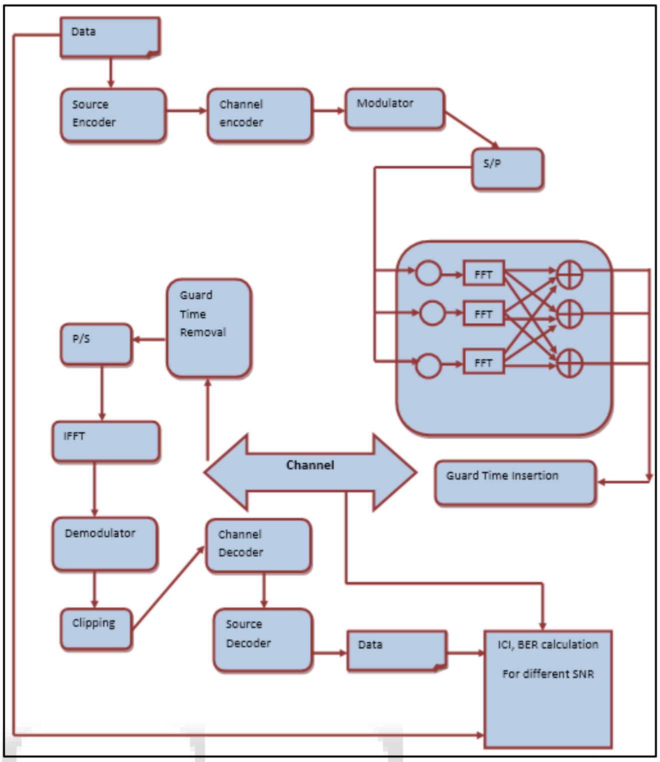

Fig. 4: Proposed OFDM Flow Diagram

$$y[n] = \sum_{l=0}^{L} h_l[n]s[n-l] + v[n] \quad n = 0,1,2 \ldots \ldots n$$

Where $h_l[n]$ is the discrete-time channel response. We assume a block transmission scheme, where N_b symbols are transmitted block-wise. We assume the windowed block is periodic with fundamental frequency $W_f = \frac{2\pi}{N}$ then according to discrete Fourier transformation; we can convert the function into its Fourier series representation of order N, or estimate the function with less ordered finite sums, where each term will have a harmonic frequency of multiple of W_f Then, during the arbitrary block interval $\{t, t_r + NT_s\}$ Where T_s is the symbol interval, the channel impulse response can be represented by complex exponential basis expansion of order

$$h_l(n) = \sum_{l=-q}^{q} h_q(l)e^{jw}q^n$$

where $h_q(l)$ represents the basic coefficient of order , corresponding to delay of l,Q , is the basis expansion order, which is fixed for all the books, $L = [\tau_d/T_s]$ with τ_d equal to the maximum delay spread,

$$W_q = \frac{2\pi}{N_b}\left(q - \frac{Q+1}{2}\right) \quad q = 1,2 \ldots \ldots . Q$$

And $N_bT_s$is the continuous time block interval As we can see, $h_q(l)$ is a uninary function of, which is assumed to be invariant over the block interval for a given order, but can be time-varying in subsequent blocks. Finally, the CE-BEM representation of the discrete-time base-band signal model can be expressed as:

$$y[n] = \sum_{l=q}^{L} \left(\sum_{q=-G}^{G} h_q(l) e^{iw} q^n \, s[N-1] + \, v[n] \right) \quad n = 0,1 \ldots \ldots N$$

CE-BEMare orthogonal if their integral is zero over an interval and if their MSE signals multiply them together, then for that interval two signals are orthogonal. By using an IFFT for modulation we implicitly chose the spacing of the subcarriers in such a way that at the frequency where we estimate the received signal all other signals are zero. In order for this orthogonally to be preserved the following must be true:

1) The receiver and the transmitter must be absolutely synchronized. This means the modulation frequency assumed by the transmitter and receiver must be same and the same time-scale for transmission (which typically is not the case).
2) There must be very high quality analog components, which are part of transmitter and receiver.
3) There should be no multipath channel. It is seen that for two sequential sub-carriers the difference between the ICI co-efficient are very small. Here we do not modulate one data symbol in to one sub-carrier, instead at least in to two sequential sub-carriers. If the data symbol 'd' is modulated in to the first sub-carrier then '-d' is modulated in to the second sub-carrier. Hence the ICI generated between the two sub-carriers almost mutually cancels each other we propose to implement the CE-BEM channel estimation for symbol detection. Benefiting from high-efficiency ICI self-cancellation, the integrated systems outperform prior ICI self-cancellation schemes with significantly lower BER floors and higher symbol rates under fast time-varying channels

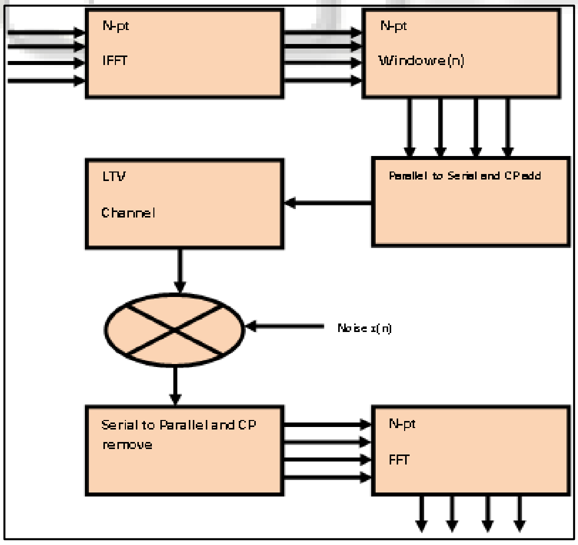

Fig. 5: Block Diagram of Proposed Work

D. System Model

In this present work, we have considered the Linear Time Varying (LTV) channel h(n,l) denotes the n^{th} sampling response in the tap $i^{th}$of the LTV channel in a symbol interval. Assume the number of OFDM subcarriers N is 256 in that 16 subcarriers are pilot signal $N_p$so total transmitting data $N=N-N_p$ is 240 subcarriers, and then at the transmitter side, the binary information is first grouped and by using different mapping scheme according to the modulation it is mapped into complex–valued symbols, such as BPSK, QAM. The mapped signals are modulated into N orthogonal subcarrier by the Inverse Fast Fourier Transform (IFFT). After the IFFT unit, the time-domain OFDM signal can be expressed as

$$x(n) = \sum_{k=0}^{N-1} X(k) \, e^{\left(\frac{2\pi jnk}{N}\right)} \qquad k = 0,1 \ldots\ldots N-1$$

Where X(k) is the data symbol of each subcarrier, k is the sub carrier index and n is the time domain sample index of an OFDM signal.

The multiplexed IFFT output is given to time domain N-point window (n) . A cyclic prefix (CP) is then added to the obtained output. Finally obtained signal $x_g(n)$ is transmitted through the channel. The received signal can be represented by

$$y_g(n) = x_g(n) \otimes h(n) + \, z(n) \qquad 0 \le n \le N-1$$

Where z(n) is independent and identically distributed Additive White Gaussian Noise (AWGN) sample in time domain and h(n) is the discrete time channel impulse response.

At the receiver side, after removing CP, the received samples are sent to a FFT block to de- multiplex the multi-carrier signals. The k^{th} sub-carrier output in frequency domain can be represented by

$$y(k) = x(k) h(k) + \, z(k) \qquad 0 \le k \le N-1$$

Where Z(k) is AWGN noise and H(k) is the channel impulse response in frequency domain respectively. The channel impulse response in time domain can be represented by complex exponential basis expansion of order Q is represented in equation above OFDM is a modulation technique where multiple low data rate carriers are combined by a transmitter to form a composite high data rate transmission.

E. Proposed Mixed Windowing Technique

Modulation causes sharp discontinuities at symbol boundaries. Phase discontinuity at symbol boundaries make sub-carrier spectrum to go out of band, results in ICI. To avoid this, windowing techniques is employed for each OFDM symbol. Windowing, multiples each OFDM symbols with a window function. So, amplitude makes a smooth transition to zero at symbol boundaries.

An OFDM signal consists of unfiltered subcarriers. Therefore the out-of-band-spectrum decreases rather slowly, with the speed depending on the number of sub-carriers. Mostly used is the raised cosine window, which is defined as

$$0.5 + 0.5\cos(\pi + n\pi/\beta T_s) \qquad 0 \le n \le \beta T_s$$
$$w(n) = \beta T_s \le n \le T_s$$
$$0.5 + 0.5\cos((n - T_s)\,\pi/\beta T_s)) \qquad T_s \le n \le (1+\beta) T_s$$

Where β is the roll-off factor. Another class of windows that are smoother at the ends compared with the triangular window is cosine windows, but closer to one at the middle. The side-lobe levels should be reduced by the smoother taper at the ends, while the distortion of the desired pulse response bound n = 0 (Garimella, 2008) is reduced by broader middle section. To reduce the side-lobe level further, we can consider an even more gradual taper at the ends of the window sequence by using the raised cosine sequence. The various windows in this category are:

1) Proposed Window

The Proposed window is the linear combination of modulated rectangular windows from Eulers formula. proposed window is defined by

1. $W_{Prop}(n) =$

$$\begin{cases} 0.8 - 0.2cos\left(\frac{2\pi n}{M} - 1\right) & for \quad 0 \leq n \leq M-1 \\ 0 & otherwise \end{cases}$$

2) Hamming Window

This window is optimized to minimize the maximum (nearest) side lobe, giving it a height of about one-fifth that of proposed windows. Hamming window is given

$$W_{prop}(n) = \begin{cases} 0.74 - 0.26cos\left(\frac{2\pi n}{M} - 1\right) & for \quad 0 \leq n \leq M-1 \\ 0 & otherwise \end{cases}$$

III. Results

MATLAB recreation is performed & examination of results is gotten on premise of ICI esteem, BER & comparing CCDF in traditional framework, framework utilizing just DCT & framework which is proposed in which half breed strategies are received such as SLM, PTS & DCT .Here three distinct recordings of three unique sizes are considered & ICI esteem, BER FOM & relating CCDF is computed by considering no. of edges & SNR in connection to parameter of channel for frameworks. Number of edges & SNR of AWGN may be changed by adjusting distinctive esteems. Channel utilized is AWGN channel. After execution it is seen that Inter Carrier Interference control proportion is extensively less for framework which is actualized & BER debasement is not increasingly when no. of casings are expanded when done examination with frameworks which utilizes DCT & furthermore regular framework as DCT is having higher vitality compaction property.

For the following parameters:

- IFFT size: 32
- Number of carriers: 8
- Modulation(1=BPSK, 2=QPSK, 4=16PSK, 8=256PSK): 4
- Amplitude clipping introduced by communication channel (in dB):20
- Signal-to-Noise Ratio (SNR) in dB: 30

The obtain results are as below:

Summary of the OFDM transmission and channel modeling:

Peak to RMS power ratio at entrance of channel is: 2.967185 dB

Peak to RMS power ratio at exit of channel is: 1.593394 dB

#******** OFDM data transmitted in 4.069966 seconds ********#

- Data loss in this communication = 0.069187% (420 out of 607048)
- Total number of errors = 37052 (out of 606628)
- Bit Error Rate (BER) = 0.61825699%
- Average Phase Error = 18.588999 (degree)
- Percent error of data at the received data= 84.806144%
- From above results it can be observe that proposed work ICI is 2.96 db and BER is 0.6182.

Figure 6 below modals presented GUI developed for the proposed Windowing based ICI cancelation method.

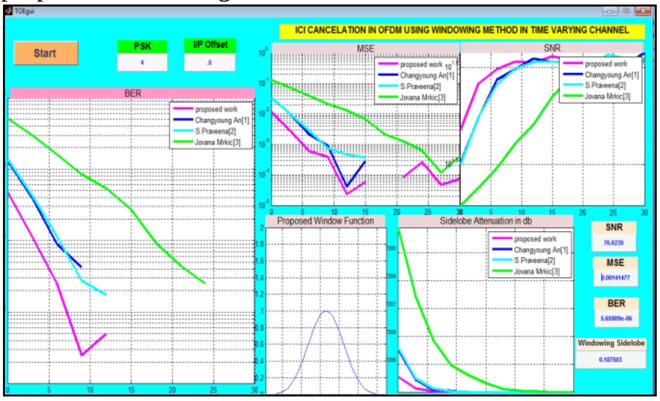

Fig. 6: MSE, BER, PSNR & Side-lobe Attenuation Obtain when 4PSK Modulation

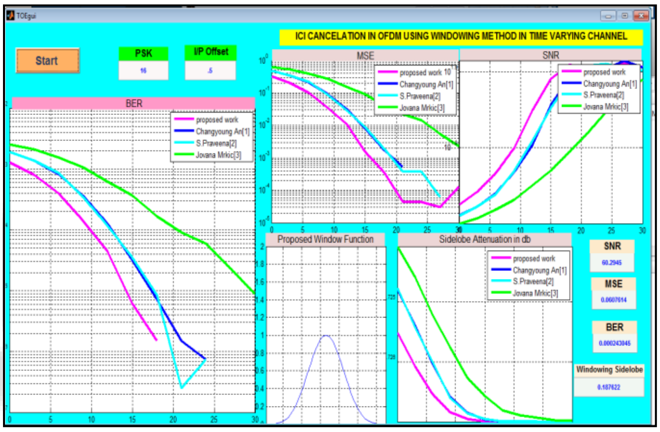

Fig. 7: MSE, BER, PSNR & Side-lobe Attenuation Obtain when 16PSK Modulation

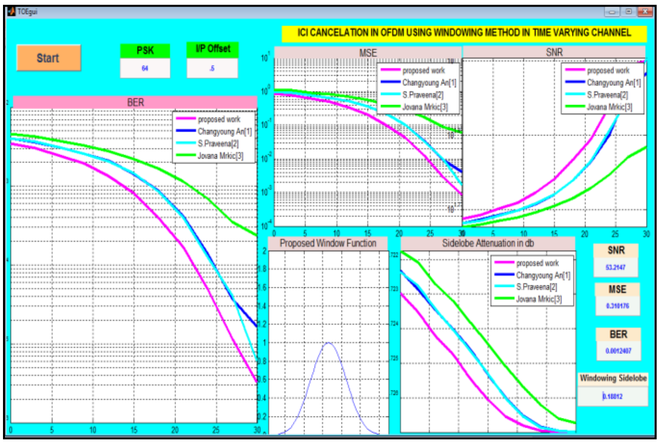

Fig. 8: MSE, BER, PSNR & Side-Lobe Attenuation Obtain when 64PSK Modulation

PSK	SNR db	MSE db	BER db	Side lobe attenuation db
4	76.3046	0.00152273	6.09091e-06	0.187503
16	60.2945	0.0607614	0.000243045	0.187622
64	53.2147	0.310176	0.00124889	0.188124

Table 1: Observe results

Observe results at Input noise 15 db and 4PSK modulation				
Work by	SNR	MSE	BER	Side lobe Attenuation
Changyonge en et al [1]	66		8.8e-06	
S. Praveena et al [2]	59.325	0.009874		0.58742
Jovana Mrkic et al [3]	63.89		10.0202e-06	0.689
Proposed	76.3046	0.00152273	6.09091e-06	0.187503

Table 2: Comparative results

IV. Conclusion

In this work, we applied the Hamming and Hanning windowing in the OFDM transmitters to remove the ICI power in the fast time varying channels prior to receptions. As the results of the ICI self-cancellation, the system renders a strictly banded channel matrix with negligible banded approximation errors. Under the CE-BEM channel estimation, simulation result shows that the proposed ICI self-cancellation scheme outperform significantly with lower BER floors under time varying channel. It is concluded that multi-fft detection techniques has been applied to find out MSE & BER performance of system using 16 QAM modulation scheme. MSE & BER value has significantly improved by multi-FFT detection using 16 QAM as compared to QPSK. In postulation OFDM is picked as a multicarrier correspondence framework due to inborn properties & these days all interchanges identified with remote are upgrading this MC framework due to multipath vigor condition. In proposal downside identified with ICI was decreased by consolidating half & half plans which include complex PTS conspire with DCT - SLM blend. Here ICI diminishment up-to 5.2 db has been gotten when done examination with ordinary OFDM framework having ICI estimation of 14.db.It has likewise been acquired no. of cycles identified with PTS does not impact framework working. Truth be told less no. of cycles quick is framework. Here no. of emphasess are considered as 4. For tweak reason 64 QAM is utilized. It has gotten that BER execution is additionally great & FOM of framework is likewise expanding as edge tally is expanding. Finally CCDF is additionally plotted against ICI esteem.

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