Analysis and Improvement of Spectral Efficiency Using Modified Channel Shortening Filter in MISO OFDM System

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Abstract- **Orthogonal frequency division multiplexing is a flexible block modulation scheme used to reduce the computational cost of the receiver by using a cyclic prefix as a guard interval .The spectral efficiency depends on the cyclic prefix length in orthogonal frequency division multiplexing systems .The cyclic prefix length must be greater than or equal to the delay spread of the channel impulse response in order to avoid inter block interference and inter carrier interference. Spectral efficiency can be improved by using channel shortening filter in orthogonal frequency division multiplexing systems. MISO OFDM is used for the enhancement of spectral efficiency, since the MISO systems decreases complexity and noise at transmitter and receiver cost is also reduced. A channel shortening filter yields low spectral efficiency In order to improve the spectral efficiency, a modified channel shortening filter structure that exploits the null space and provides independent equivalent channels to the receiver has been used. The spectral efficiency of the modified channel shortening filter in MISO OFDM system has been improved by 20 to 40% when compared to channel shortening filter. The performance of modified channel shortening filter is better for the parameters such as spectral efficiency, Signal to noise ratio, block error rate, and channel gain.**

Keywords: **cyclic prefix, null space, MISO OFDM**.

I .INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is a method of encoding digital data on multiple carrier frequencies. It is the most common multiplexing scheme used in communication systems. It is a frequency division multiplexing scheme used as a digital multicarrier modulation method. In OFDM system, the spectral efficiency depends on the Cyclic Prefix (CP) length which is used to reduce the Inter-Block-Interference (IBI) and Inter-Carrier Interference (ICI).The cyclic prefix length must be greater than or equal to the delay spread of the channel impulse response in order to avoid inter block interference and inter carrier interference. The length of the CP is reduced by using the Time-domain Channel Shortening filters (CSF) [3]. Orthogonal frequency division multiplexing is one of the latest modulation techniques used to combat the frequency-selectivity of the transmission channels. It is mainly be used in fourth generation wireless system. The common modulation techniques used in OFDM system are Binary Phase Shift Keying (BPSK),Quadrature Phase Shift Keying (QPSK) and Quadrature Amplitude Modulation (QAM) [2]. This cyclic Prefix of length L is a circular extension of the IFFT-modulated symbol, obtained by copying the last L samples of the IFFT-modulated symbol, obtained by copying the last L samples of the symbol in front of it [1].

The coherent FFT demodulator will ideally retrieve the exact form of transmitted symbols. The data are serial converted and the appropriated demodulation scheme will be used to estimate the transmitted symbols [7].

II. SYSTEM MODEL OF MISO OFDM

Consider a MISO OFDM system with n_T number of transmitters and a single receiver. A channel shortening filter is used at the transmitter side to reduce the inter block interference and inter carrier interference. Initially a single bit of data is transmitting through a single equivalent channel and analyzing the improvement of spectral efficiency by using various parameters like channel gain, decision delay, cyclic prefix etc. Additive White Gaussian Noise (AWGN) is the noise generated at the receiver [8]. An MISO -OFDM system with simple channel shortening filter is shown in Fig 1.

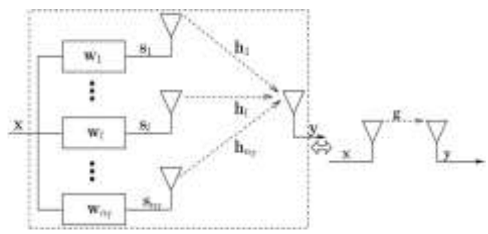

Fig1. MISO OFDM system with simple channel shortening filter

Fig1.Shows the simple channel shortening filter in MISO OFDM system. 'X' be the input vector, 'W' be the time domain filter, 'H' be the impulse response of the channel. 'Y be the received signal. In MISO OFDM system multiple numbers of transmitters and a single receiver is used. While transmitting a signal through the channel a noise will be added up. The received signal is expressed a

$$y_k = \sum_{l=1}^{\eta_T} h_l^T s_{l,k:k-D} + \eta_k \quad (1)$$

$s_{l,k:k-D}$ = Vector of samples

η_k = Additive white Gaussian noise

h = Impulse response

Equivalent channel is represented as

$$g = \underbrace{[H_1, \dots H_l, \dots H_{\eta_T}]}_{H} w = Hw \quad (2)$$

$$H_l^T = \begin{bmatrix} h_{l,0} & h_{l.1} & \cdots & h_{l,D} & 0 & \cdots & 0 \\ 0 & h_{l,0} & h_{l,1} & \cdots & h_{l,D} & \ddots & \vdots \\ \vdots & \vdots & \ddots & \ddots & \ddots & \ddots & \vdots \\ 0 & 0 & \dots & h_{l,0} & h_{l,1} & \cdots & h_{l,D} \end{bmatrix}$$

Decision delay Δ is defined as

$$G_i = \begin{cases} 0, & if\ i < \Delta \\ *, & \Delta \le i < \Delta + N_{cp,} \\ 0, & i \ge \Delta + N_{cp} \end{cases} \quad (3)$$

* = Arbitrary value with in cyclic prefix length.

$w = \Phi b$ (4)

Φ = Orthonormal vector

b = Optimal value chosen based on the maximization of energy

$arg\{max_b\, trace(b^H \underbrace{\Phi^H H^H H \Phi}_{C} b\}$ and

$w^H w$ =1 (5)

Since $w^H w = b^H \Phi^H \Phi b = b^H b$

The equation (5) can be rewritten as

$arg\{max_b\, trace(b^H C b)\, and b^H b = 1\}$

C = Positive semi definite matrix

From equation (5) b_{opt} value is obtained.

$b_{opt} = e_{max}$ Where the e_{max} is the eigenvector corresponding to the maximum Eigen value λ_{max} of matrix C. The average Signal to Noise Ratio (SNR) is given by

$SNR = \lambda_{max}/\sigma^2$ (6)

λ_{max} is the equivalent channel energy .The decision-delay parameter Δ that affects C and λ_{max} must be chosen so as to maximize the energy of the equivalent channel.

A. SPECTRAL EFFICIENCY

Spectral efficiency or bandwidth efficiency refers to the information rate that can be transmitted over a given bandwidth in a specific communication system. It is a measure of how efficiently a limited frequency spectrum is utilized by the physical layer protocol, and sometimes by the media access control or the channel access protocol. It is measured in bits/sec/Hz

$$C_{mcsf} = \frac{1}{N_f + N_{cp}} \sum_{i=1}^{N_f} log_2(1 + SNR) \quad (7)$$

B. MODIFIED CHANNEL SHORTENING FILTER

Modified channel shortening filter is used at the transmitter and receiver side in order to improve the spectral efficiency by reducing the interferences and noise .In modified channel shortening filter a block of data is transmitting instead of a single bit. Block of data is transmitting through more than one equivalent channel. The MISO OFDM system with modified channel shortening is shown in Fig 2.

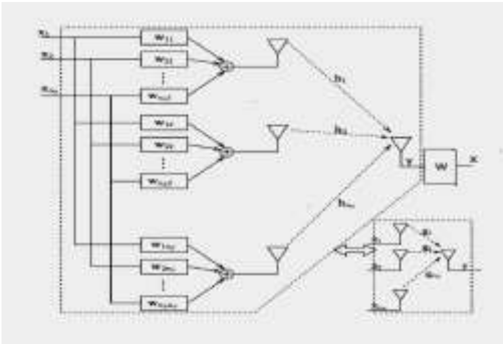

Fig 2. MISO OFDM system with modified channel shoretening filter using n_s layers.

Fig 2.shows the MISO OFDM system with modified channel shoretening filter using n_s layers.In modified channel shortening filter instead of transmitting a single bit of data ,a block of data is transmitting through more than one equivalent channel.It is used at the transmitter side and receiver side.Modified channel shortening filter shows better performance in the enhancement of spectral efficiency when compared to simple channel shortening filter.simple channel shortening filter and modified channel shortening filter are analysed by various parameters such as channel gain,spectral efficiency,decision delay,block error rate,signal to noise ratio.The spectral efficiency of the modified channel shortening filter can be written as

$$C_{mcsf} = \frac{1}{N_f+N_{cp}} \sum_{i=1}^{N_f} log_2(1+\frac{SNR}{nS}) \quad (8)$$

C. BLOCK DIAGRAM OF MISO OFDM

The block daigram of MISO OFDM is shown in Fig 3.

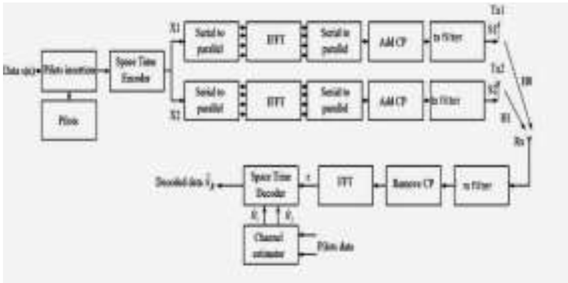

Fig 3 Block diagram of MISO OFDM

Fig 3 shows the block diagram of MISO OFDM system with modified channel shortening filter at the transmitter and receiver side.Binary data is given as input.Pilot insertion is used as a reference for channel estimation.Data is conerted from serial to parallel for performing modulation process.The modulation technique commonly used in MISO OFDM system are Binary Phase Shift Keying(BPSK),Quadrature Phase Shift Keying(QPSK),and Quadrature Amplitude Modulation(QAM).After modulation Inverse Fast Fourier Transform(IFFT) is used to convert frequency domain signals in to time domain signals.After the conversion parallel data is converted back in to serial data. A cyclic prefix is inserted in order to eliminate the inter-symbol and inter-block interference. This cyclic prefix of length L is a circular extension of the IFFT-modulated symbol, obtained by copying the last L samples of the IFFT-modulated symbol, obtained by copying the last L samples of the symbol in front of it [10]. Modified channel shortening filter is used to shorten the length of the channel impulse response at least be equal to the cyclic prefix length to reduce the interferences as well as to improve the spectral efficiency. The data is transmitted through the Additive White Gaussian Noise Channel (AWGN).

At the receiver inverse operation is performed. Modified channel shortening filter is used at the receiver to adjust the channel impulse response. After the filtering process cyclic prefix is removed and data is converted back to parallel for demodulation process. Fast Fourier Transform (FFT) is used to convert time domain signals in to frequency domain signals. After that data is converted back to serial to retrieve the original data.

III. NUMERICAL RESULTS

Considering a MISO OFDM system with 256 subcarriers and cyclic prefix length of 16. Channel shortening filter and modified channel shortening filter are compared in MISO OFDM systems by using MATTLAB Software for analyzing the spectral efficiency, signal to noise ratio, decision delay, cyclic prefix length, Channel Gain, block error rate etc. Channel shortening filter and modified channel shortening filter are used to improve the spectral efficiency by shortening the channel impulse response. Fig 4 shows the decision delay VS channel gain comparison.

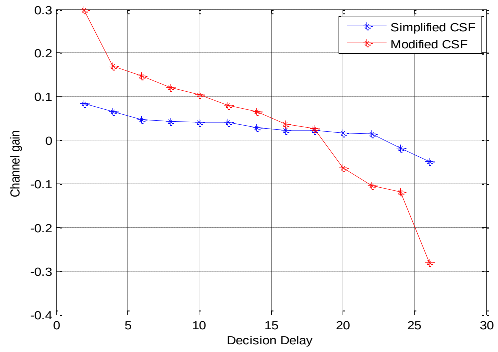

Fig 4. Decision delay Vs Channel gain

The Fig 4 shows the comparison of Decision Delay Vs Channel Gain .In channel shortening filter when Decision Delay is zero, the channel gain is high .But when decision delay increases, and there is degradation in channel gain. In the case of modified channel shortening filter initially the Channel Gain is very high as compared to channel shortening filter, but there is a only a small degradation in channel gain as compared to channel shortening filter.

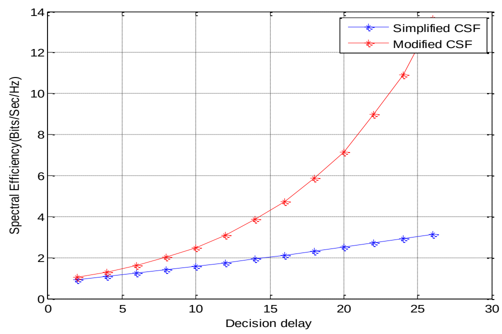

Fig 5.Decision delay Vs Spectral efficiency

The Fig 5 shows the performance comparison of Decision Delay Vs Spectral Efficiency in channel shortening filter and modified channel shortening filter. In channel shortening filter when decision delay increases there is only a small increment in Spectral Efficiency. But in the case of modified channel shortening filter when Decision Delay increases there is a large increment in spectral efficiency. So modified channel shortening filter has better performance as compared to channel shortening filter.

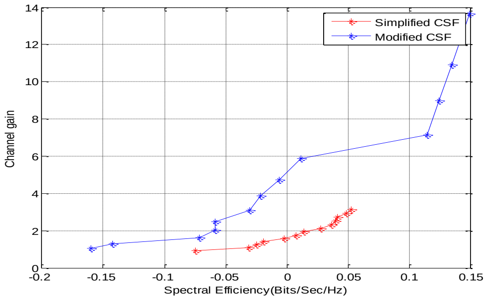

Fig 6. Channel gain Vs Spectral efficiency

The Fig 6.shows the comparison of Spectral Efficiency Vs Channel Gain In channel shortening filter when channel gain increases there is only a small increment in Spectral Efficiency. But in the case of modified channel shortening filter when channel gain increases there is a large increment in Spectral Efficiency. Modified channel shortening filter has better performance as compared to channel shortening filter. In modified channel shortening filter, block of data is transmitted through the channel for analyzing the improvement of spectral efficiency.

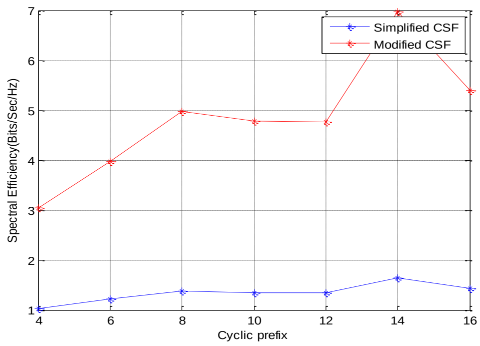

Fig7. Cyclic prefix Vs Spectral efficiency

The Fig 7 shows the comparison of Cyclic Prefix Vs spectral efficiency. In the case of channel shortening filter when Cyclic Prefix length increases, there is only a small increment in Spectral Efficiency. But in the case of modified channel shortening filter, when Cyclic Prefix length increases, there is a large increment in Spectral Efficiency. Comparison shows that modified channel shortening filter has better performance as compared to channel shortening filter.

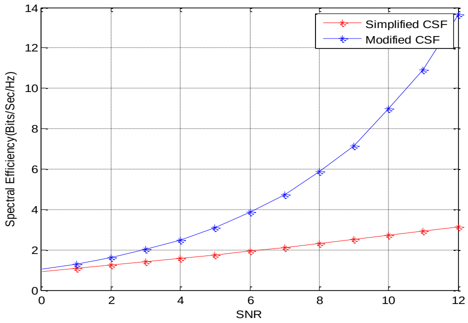

Fig8. Signal to Noise Ratio (SNR) Vs Spectral efficiency

The Fig 8. Shows the performance comparison of signal to noise ratio Vs Spectral Efficiency of the channel shortening filter and modified channel shortening filter .From the analysis it shows that modified channel shortening filter has better Spectral Efficiency as compared to channel shortening filter .In channel shortening filter, when SNR increases there is only a small increment of spectral efficiency. But in the case of modified channel shortening filter, when SNR increases there is a large increment in Spectral Efficiency.

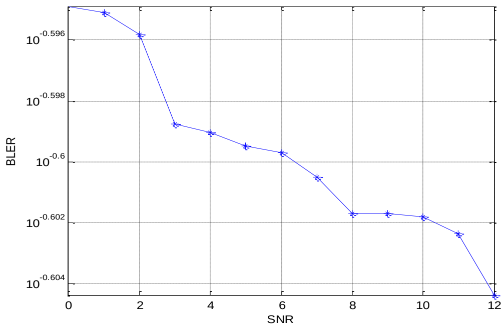

Fig 9. Block Error Rate Vs Signal to Noise Ratio

The Figure 9 shows the comparison of Block Error Rate (BLER) Vs Signal to Noise Ratio (SNR).When BLER decreases SNR increases. When SNR increases Spectral efficiency Increases. BLER can be analyzed by using modified channel shortening filter.

IV. CONCLUSION

The spectral efficiency improvement of MISO OFDM using modified channel shortening filter is proposed in this paper. The channel shortening filter uses single bit for data transmission in to the transmitter. But this modified channel shortening filter uses a block of data bits for the transmission. The performance evaluation of the systems is done in MATLAB software. The parameters which are used for the performance comparison are signal to noise ratio, spectral efficiency, cyclic prefix, channel gain and decision delay. For all the parameters the proposed Modified channel shortening filter shows the better performance when compared with channel shortening filter. The spectral efficiency of the modified channel shortening filter is improved by 20 to 40% when compared to channel shortening filter.

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