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MIMO Sparse Non-Orthogonal Frequency Division Multiplexing for Better Performance

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ABSTRACT: Orthogonal Frequency Division Multiplexing (OFDM) is one of the most significant multicarrier waveform advances because of the specialty of permitting high information rate. However, in OFDM which has large side projections and in this way reducing spectral efficiency and it gets hard to use in 5G applications. Sparse Non-Orthogonal Frequency Division Multiplexing (S-NOFDM) is used to improve the spectral efficiency of OFDM. MIMO Sparse Non-Orthogonal Frequency Division Multiplexing (MIMO S-NOFDM) is a technique which utilizes more than one transmitting and receiving antennas. This proposed system primarily expects to improve the BER performance of S-NOFDM. Additionally, by utilizing more than one transmitting and receiving antennas MIMO S-NOFDM has less fading as compared with the system having single transmitting and receiving antenna. Simulation results shows that the MIMO S-NOFDM has better BER performance in comparison with S-NOFDM and OFDM systems.

KEYWORDS: Cyclic Prefix; FBMC; GFDM; Multicarrier; OFDM; UFMC

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is one of the significant multicarrier waveform technique with high spectral efficiency. In any case, in OFDM it has large spectral side lobes and in this manner causes out-of-band emission. This will bringing down the spectral efficiency of OFDM system and in this way makes it hard to fulfills the needs for the 5G applications. There are numerous other multicarrier waveform technologies like Filter Bank Multicarrier (FBMC), Universal Filtered Bank Multicarrier (UFMC), Generalized Frequency Division Multiplexing (GFDM) have spectral efficiency higher than the OFDM. But, both FBMC, UFMC and GFDM are complex in hardware implementation and furthermore not effectively expandable with Multiple-Input Multiple-Output (MIMO) frameworks. Along these lines, from these technologies OFDM will be considered as the best method for future communications. Since, OFDM will be less complex in hardware implementation and effectively expandable with MIMO system compared with other multicarrier waveform technologies.

Sparse Non-Orthogonal Frequency Division Multiplexing (S-NOFDM) [1] mainly center to improve the spectral efficiency of OFDM. In this system for making S-NOFDM subcarriers, first choosing a subset of OFDM subcarriers and time shifted with various time delays. After time shifted expanded and overlapped subcarriers are gotten and they are non-orthogonal to one another. In S-NOFDM, the subcarriers will be produced from just a subset of OFDM subcarriers which requires less spectral resources and thus improves the spectral efficiency of OFDM.

The proposed system MIMO Sparse Non-Orthogonal Frequency Division Multiplexing (MIMO S-NOFDM) is primarily center to improves the BER performance of S-NOFDM. This proposed system utilizes multiple transmitting and receiving antennas. Including more transmitting and receiving antennas improves the quality and reliability of transmission. The system with multiple antennas has less fading as compared with the system with single transmitting and receiving antennas. Additionally, the proposed system provides better BER performance as compared with the OFDM and S-NOFDM systems.

II. S-NOFDM

For making Sparse Non-Orthogonal Frequency Division Multiplexing (S-NOFDM) [1] subcarriers, first selecting a subset of OFDM subcarriers and afterward time shifted it by some amount. The OFDM carriers generated by Inverse Fast Fourier Transform (IFFT) is given by,

$$g_k[n]=e^{j\frac{2\pi}{N}kn};k,n=0,\ldots,N-1 \quad \text{(Equation 1)}$$

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where $g_k[n]$ is the pulse shape of OFDM system and k, n are the frequency index and time index respectively. Furthermore, N is the total number of orthogonal subcarriers in OFDM.

To make S- NOFDM subcarriers select a subset of OFDM subcarriers and time shift it. The selected subset of OFDM subcarriers are denoted by K where (K < N) and this selected subset of subcarriers is represented by,

$$g_{k_0}[n_0] = e^{j\frac{2\Pi}{k}k_0 n_0}; k_0 n_0 = 0,...., k-1 \quad \text{(Equation 2)}$$

At that point, to making S-NODM subcarriers, the selected subcarriers are time shifted and it is indicated by $g_{k0}[n_0]$which is given by,

$$g_{k_0} m[n] = g[(n_0 - m\Delta) \bmod N] e^{j\frac{2\Pi}{k}k_0 n}; n = 0,..., N-1; m = 0,..., M-1 \quad \text{(Equation 3)}$$

Here, $g_k[n]$ is the pulse shape of S-NOFDM system. The frequency index, time index, and time-shift index are represented by k_0, n, m separately and the amount of unit time shift is denoted by Δ. The number of different selected OFDM subcarriers are K and number of expanding subcarriers at the same frequency are denoted as M. So, the total number of subcarriers can be represented as R=KM. Continually considering Δ<K in order to ensure the overlapping between subcarriers with same frequency. The interval factor is defined as s and it is given by s=Δ/K, and furthermore p is the overlapping co-efficient which is meant by p=1-s. Δis constantly chosen so that getting N=K+(M-1)Δ.

Figure 1 shows the illustration of overlapping subcarriers in the time domain. In this figure initially selecting 64 subcarriers and afterward it time shifted by a amount of time. Here, the amount of time shift is selected as 32. After time shifting expanded and overlapped subcarriers are obtained and they are non-orthogonal to one other.

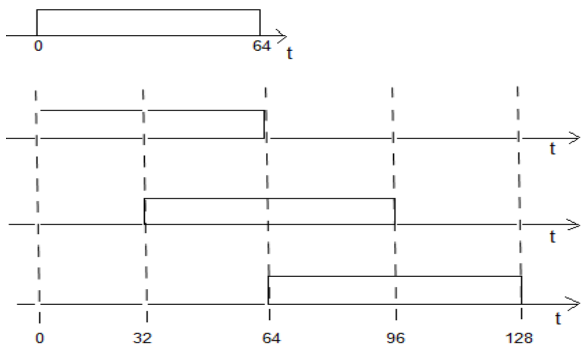

Fig.1. Illustration of overlapping subcarriers in the time domain [1]

Sparse Non-Orthogonal Frequency division Multiplexing (S-NOFDM) is a multicarrier in which the symbols are modulated on sparse subcarriers. The principle of the S-NOFDM digital transmitted is explained in the figure 2. First generating random input b_s and these input bits are then mapped in to symbols by using any one of the symbol mapping method like QAM to get d_s. Then it passes through serial to parallel conversion to obtain d contains N elements. In order to create S-NOFDM subcarriers selecting a subset from it like K then it time shifted to create expanded subcarriers, which is denoted by the sparsest R. After these process it passes through the parallel to serial conversion. Then cyclic prefix(CP) is added to avoids Inter Symbol Interference (ISI). For this, last some bits of incoming data will be cyclically shifted to the front side of that incoming data and thus avoids ISI. Then undergoes digital to analog conversion.

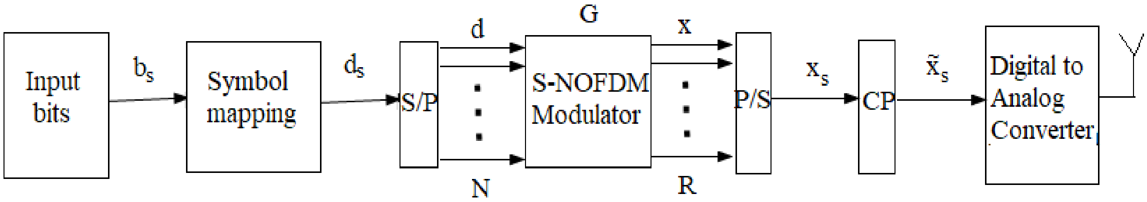

Fig.2. Principle of the S-NOFDM digital transmitter[1]

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At the receiver side to create frequency version of the signal uses Fast Fourier Transform (FFT). Then passes through analog to digital version stage cyclic prefix will be removed. In transmitter side last some bits of the incoming data will be cyclically shifted to the front side. So, in receiver side these cyclically shifted bits will be removed and thus generating the digitized version of the received signal y_s. And then passes through the serial to parallel conversion. Here, the transmission through the wireless channel will be represented as,

$$y_s(r) = x_s(r) * h(r) = n(r); r = 0,1,...,R-1 \quad \text{(Equation 4)}$$

where, x_s the sparsest modulated signal and h(r) is the channel impulse response. So, y_s is obtained as the discrete convolution of $x_s(r)$ and h(r). Then, from R time shifting will be removed and obtain N subcarriers and the recovered data d_s is processed for parallel to serial conversion.

Most of the multi-carrier waveform technologies are concentrated on eliminating the out-of-band emission. But, this

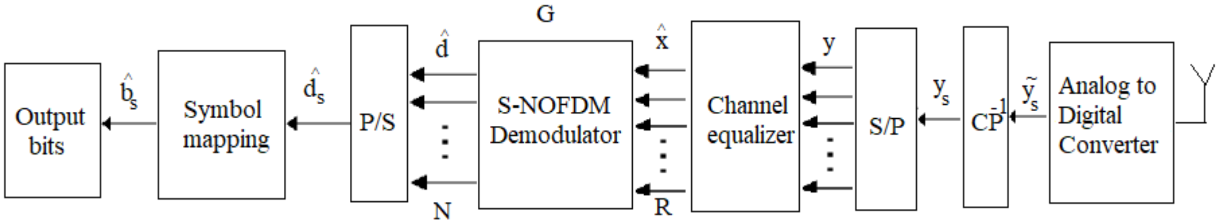

Fig.3. Principle of the S-NOFDM digital receiver[1]

system will be focused on reducing number of sub carriers. Due to this, S-NOFDM system will have equivalent out-of-band emission as OFDM system but less sub-carriers will be used. This S-NOFDM system's spectral efficiency is N/K times higher than that of the OFDM system. Because, in S-NOFDM system a subset K is selected from N number of OFDM subcarriers and also K is less than N. Also, due to the expanded and overlapped subcarriers in S-NOFDM system, it's system symbol duration is same as that of OFDM system. So, by using same transmitted data and symbol rate S-NOFDM system has less subcarriers and symbol duration as compared to OFDM.

Most of the non-orthogonal modulation technologies are mainly focussed to eliminate out-of-band emission. But this S-NOFDM system mainly focus to improves the spectral efficiency of OFDM system. The spectral efficiency of a multicarrier system is given by,

$$\eta = \frac{\log_2(N_s)}{N} \quad \text{(Equation 5)}$$

where N_s is the number of bits per symbol and N is the number of input symbols.

S-NOFDM system has high spectral efficiency by thinking about two realities. In OFDM system N is the number of input bits. But, in S-NOFDM system it becomes K. Because in S-NOFDM system, selecting a subset from N and K is less than N. So, in S-NOFDM system $\log_2(N_s)$ / N is changed to $\log_2(N_s)$ / K. Since, K is less than N the value of η is increases in S-NOFDM system. S-NOFDM also uses less spectrum to obtained same data used in OFDM. Also, with the help of expanded and overlapped subcarriers, S-NOFDM have same symbol duration as that of OFDM for same transmitted data.

III. PROPOSED SYSTEM

Orthogonal Frequency Division Multiplexing (OFDM) and Sparse-Non Orthogonal Frequency Division Multiplexing (S-NOFDM) systems transmitting the same data through single transmitter and received by a single receiver subsequent to going through the channel. In this proposed system creating multiple copies of the same data based on number of transmitters are required and then the same data will be transmitted through different antennas.

MIMO Sparse Non-Orthogonal Frequency Division Multiplexing (MIMO S-NOFDM) utilizes more than one transmitting and receiving antenna. In this proposed system uses 2x2 MIMO system. So, it uses two transmitting and receiving antennas. Here, receives two signals but requires only one signal. So, it is necessary to determine which received signal is the best. In order to predict the best signal, need to decide the signal with less fading and furthermore the channel through which this signal passes. The best received signal is the signal which passes through the channel having maximum power.

In this proposed system uses two transmitting antennas and so there are two channels. Hence, it is necessary to determine the index of the channel which having highest power. After determining the index value creating the copy of

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the channel which having maximum power. Then the channel with high power has less fading. Thus the best received signal is the signal which passes through the channel having highest power. By using more than one transmitting and receiving antennas the fading will be reduced than single transmitting and receiving antenna.

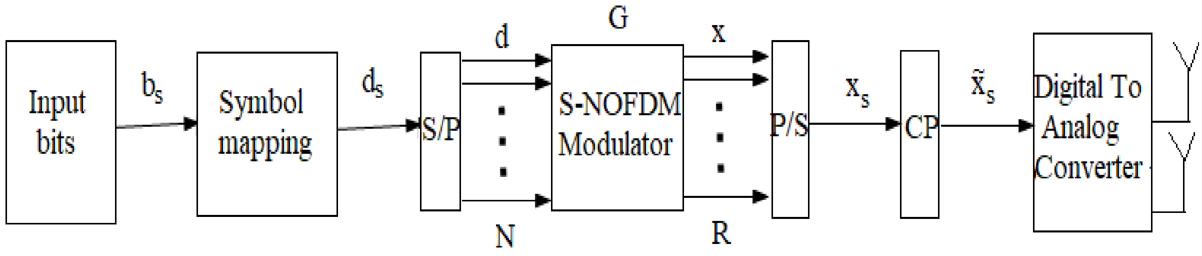

Fig.4. Block diagram of MIMO S-NOFDM transmitter

In the transmitter section randomly transmits the input bits provided by the data source and then they are mapped on symbols. Like S-NOFDM system here also select a subset of orthogonal subcarriers and then it time shifted to create expanded and over-lapped subcarriers. Then, cyclic prefix is added to reduce the inter symbol interference. In S-NOFDM system uses only single transmitter and receiver. But, in this proposed system uses more than one transmitting and receiving antennas to reduce the fading. Here, uses two transmitting and receiving antennas. After this finding the channel having maximum power and the best received signal is the signal which passes through the channel having maximum power.

The MIMO S-NOFDM receiver is just reverse of the transmitting section. After finding the best received signal passes through analog to digital conversion. At the transmitter section some of the last bits from the incoming data will

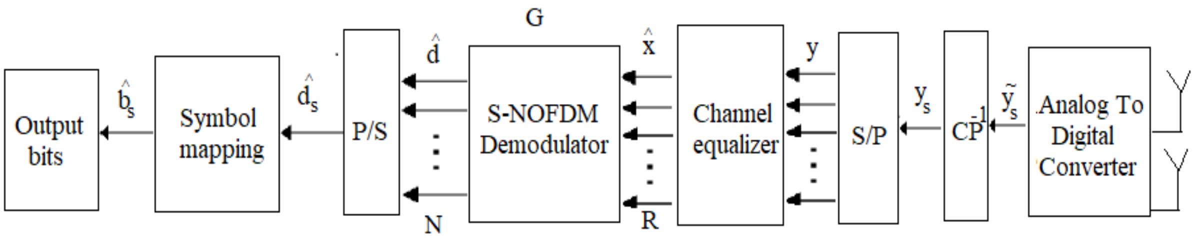

Fig.5.Block diagram of MIMO S-NOFDM receiver

be cyclically shifted to the front side of that data to reduces the inter symbol interference. So, at the receiver side this cyclic prefix will be removed and passes through channel equalizer. In thus system $x_s(r)$ be the vector of subcarriers in the frequency domain and h(r). Channel equalizer is used to apply the inverse of the frequency response of the channel to restore the signal after the channel.

After passing through channel equalizer it is given to S-NOFDM demodulator. Here input is R which is the expanded subcarriers. In S-NOFDM demodulator which removes the time shift and then provided back to the N orthogonal subcarriers. Then the demodulated signal is recovered and the recovered data is processed for parallel to serial conversion.

IV. ADVANTAGES

S-NOFDM system uses only one transmitting and receiving antenna. But, in MIMO S-NOFDM system uses more than one transmitting and receiving antennas. In the case of transmitting multiple data's, the fading while using more than one transmitting and receiving antennas is less as compared to the system having one transmitting and receiving antenna. Since this system uses multiple transmitting antennas there are multiple received signals. Thus, if any one of the antenna will experiences a deep fade the others will have best signal. So, the proposed system MIMO S-NOFDM has less fading as compared with the S-NOFDM system. And also MIMO S-NOFDM systems provides better BER performance as compared to S-NOFDM system.

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V. SIMULATION RESULTS

For simulation purpose various parameters will be considered like selected subset of OFDM subcarriers (K), number of expanding subcarriers (M), interval factor (s). In the case of S-NOFDM system, it uses only one transmitting and receiving antenna. But, in MIMO S-NOFDM system more than one transmitting and receiving antennas are considered. The system with more than one transmitting and receiving antennas having less fading as compared with the system having one transmitting ant receiving antenna. Since, this proposed system uses two transmitting antennas there are two received signals. Here, the best received signal is selected by predicting the maximum power of the channel. All figures below compares the BER versus SNR in AWGN and Rayleigh channel.

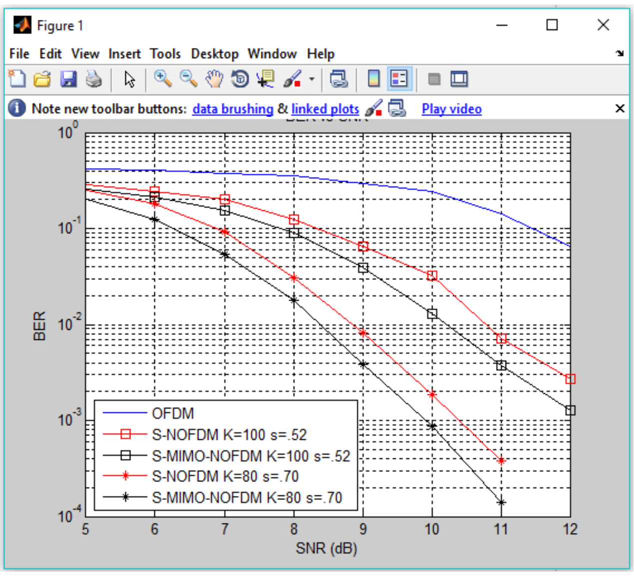

Fig.6. BER performance with respect to interval factor s with a fixed M=3 in AWGN channel

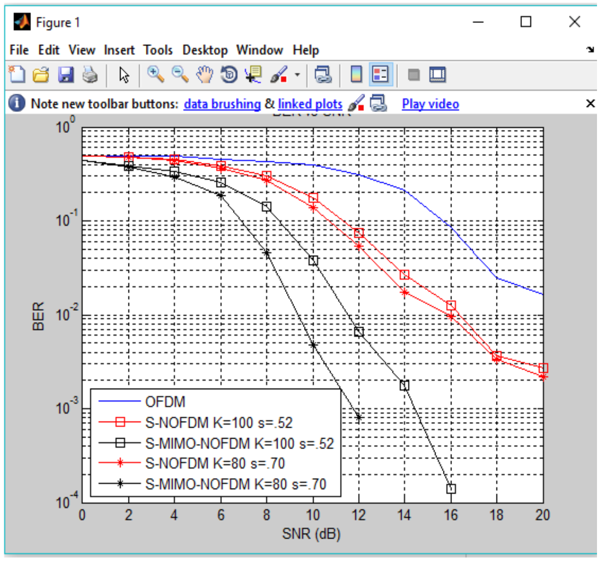

Fig.7. BER performance with respect to interval factor s with a fixed M=3 in Rayleigh channel

In figure 6, compares the BER performance of the OFDM, S-NOFDM and MIMO S-NOFDM. Here, taking the values for interval factor (s) as 0.52 and 0.70 and for K as 80 and 100 for both S-NOFDM and MIMO S-NOFDM systems. And M is taken as a fixed value of 3 in AWGN channel for both the systems. The graph shows that the BER performance of the proposed system is better than that of both OFDM and S-NOFDM systems.

In figure 7, taking same values for s, K and M but considering the Rayleigh channel. Here, also set s as 0.52 and 0.70 and for K as 80 and 100 with a fixed value for M as 3 in both S-NOFDM and MIMO S-NOFDM. The graph shows that the BER performance of the proposed system in Rayleigh channel is better than that of both OFDM and S-NOFDM systems.

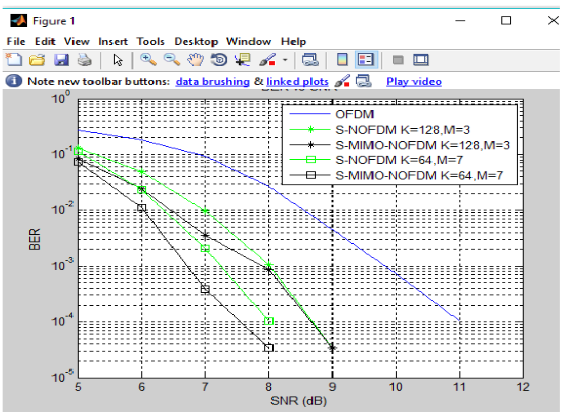

Fig.8. BER performance with respect to expanding ratios M with a fixed s=0.50 in AWGN channel

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In figure 8, compares the BER performance of the OFDM, S-NOFDM and MIMO S-NOFDM. Here, considering values for K as 80 and 100 and M as 3 and 7 for both S-NOFDM and MIMO S-NOFDM systems and a fixed value for s as 0.50 in AWGN channel for both the systems. The graph shows that the BER performance of the proposed system is better than that of both OFDM and S-NOFDM systems.

VI. CONCLUSION

OFDM is an idea which came in to presence from years ago have many advantages like it is highly reliable to users and deals almost perfectly with many wireless transmission scenarios. Data rate is increased day by day and there is a need for a better technology for future communication due to high data rate. OFDM will be considered as a best technology for 5G networks due to it's high spectral efficiency. But, due to the large side lobes it is difficult to meet the requirements for 5G. Most of the other multicarrier wave form technologies are complex and difficult with MIMO sytems. The S-NOFDM system used to improves the spectral efficiency of OFDM with less subcarriers. The proposed system MIMO Sparse Non-Orthogonal Frequency Division Multiplexing (MIMO S-NOFDM) uses more than one transmitting and receiving antennas. Here, this proposed system uses two transmitting and two receiving antennas. Thus, proposed system faces less fading compared with the system having single transmitting and receiving antenna. Simulation results also shows that the proposed system provides better BER performance compared with OFDM and S-NOFDM system.

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