Diversity Performance of MIMO-OFDM systems

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Abstract

MIMO-OFDM technology has been utilized widely in wireless communication systems for faster transmission of data. In this paper we have conducted detailed research on diversity performance of MIMO-OFDM Amplify and Forward (AF) system using two subcarrier pairing algorithms for three different fading channels namely Additive White Gaussian Noise [AWGN] channel, Rayleigh fading channel and Rician fading channel. We have observed that the performance of the system remains unchanged irrespective of the pairing algorithm used for all the three fading channels. Our observations are based on the simulations we have carried out by plotting the graphs of FER v/s SNR for all the three fading channels using two subcarrier pairing algorithms: - ordered subcarrier pairing algorithm (OSP) and reverse ordered subcarrier pairing algorithm (ROSP).

1. Introduction

Rapid development has taken place in the field of wireless communication in the last decade. This is mainly due to the need of faster transmission through wireless communication channels and the development of sophisticated signal processing algorithms which can be implemented using VLSI technology. Multiple input multiple output (MIMO) is a wireless technology which enables the use of multiple transmitting and receiving antennas to transfer more data in less time. MIMO system takes advantage of the spatial diversity that is obtained by spatially separated antennas in a dense multipath scattering environment. Orthogonal frequency division multiplexing (OFDM) is a popular technique for transmitting signals over wireless channels. OFDM transforms frequency selective MIMO channels into set of parallel frequency flat MIMO channels and increases frequency efficiency. MIMO-OFDM technology has been researched as the infrastructure for next generation wireless networks. A relay has been used in the system where the received signal from the source is amplified and forwarded to the destination node. Relay transmission helps in achieving diversity. A major drawback of wireless communication system is the effect of fading. Fading occurs due to multipath propagation and shadowing from obstacles affecting wave propagation. To overcome the detrimental effects of fading, multiple copies of data are transmitted from transmitter to receiver. This is known as diversity of the system. We have carried out the diversity analysis of MIMO-OFDM system by implementation of two subcarrier mapping algorithms and checking the subsequent frame error rate for three types of fading channels.[5][8]

2. Different channel models

There are different types of fading models which exist in a communication channel which exhibit fading in a characteristic pattern

2.1 Additive White Gaussian Noise [AWGN] model

It is a channel model in which the only impairment to communication is a linear addition of wideband or white noise with a constant spectral density (expressed as watts per hertz of bandwidth) and a Gaussian distribution of amplitude. The model does not account for fading, frequency selectivity, interference, nonlinearity or dispersion. This type of channel model involves linear addition of wideband or white noise with constant power spectral density.

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2.2 Rayleigh fading model

It is a channel model in which there is no dominant propagation along the line of sight path between the transmitter and the receiver section. The attenuation follows Rayleigh's distribution. Rayleigh fading is a reasonable model when there are many objects in the environment that scatter the radio signal before it arrives at the receiver.[4][7]

2.3 Rician fading model

It is a channel model in which one path of propagation of signal, typically the signal along the line of sight, is stronger than other signals.. In Rician fading, the amplitude gain is characterized by a Rician distribution. [7]

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3. Performance parameters

We will be analyzing the diversity performance of MIMO-OFDM systems by taking help of the following parameters

3.1 Bit Error Rate

Bit Error Rate [BER] is an important parameter which is used to analyze the transmission impairments like noise, jitter and interference in wireless communication systems. Unlike many other forms of assessment, bit error rate, BER assesses the full end to end performance of a system including the transmitter, receiver, relay and the medium between the two. The bit error rate is probability that any given bit of the received data will be in error. A bit error rate of 10^{-6} means that one bit in 10^{6} will be in error. [2]

3.2 Frame Error Rate

The parameter which gives us information about what proportion of frames contain a bit error is known as Frame Error Rate [FER].When serial data is transmitted in a communication channel it becomes tedious to compare the bit error rate due to the presence of a large number of bits. Hence the bits are divided into frames and the comparison of error is done in terms of the frame. For a given protocol or network, let the number of bits per average frame be L. We can determine the probability that a frame of length L will not contain errors. Consider that the bit error rate is B, then, the probability that a given bit is correct is (1 – B). To determine the probability that a frame will contain no errors, consider that every bit in the frame must be correct. If every bit in the frame is correct then the probability that the frame contains no errors is the product of the probabilities that each bit is correct or $(1 – B)^{L}$. The probability that there is an error in the frame, the frame error rate, is $1 - (1 - B)^{L}$. [2]

4. Pairing algorithms

The diversity analysis of amplify and forward MIMO-OFDM systems carried out by implementing these pairing algorithms

4.1 Ordered sub carrier pairing algorithm (OSP)

In ordered sub-carrier pairing algorithm, the strongest gain of the first hop is paired with the strongest one in the second hop, the second strongest gain is paired with the second strongest one, and so forth. This algorithm helps in achieving improved information rate. It also provides an upperbound in amplify and forward relay systems.[1][2]

4.2 Reverse ordered sub-carrier pairing algorithm (ROSP)

In reverse ordered sub-carrier pairing algorithm, the strongest gain of the first hop is paired with the weakest gain of the second hop, the second strongest gain is paired with the second weakest gain, and so forth. It provides a lowerbound in amplify and forward relay systems.

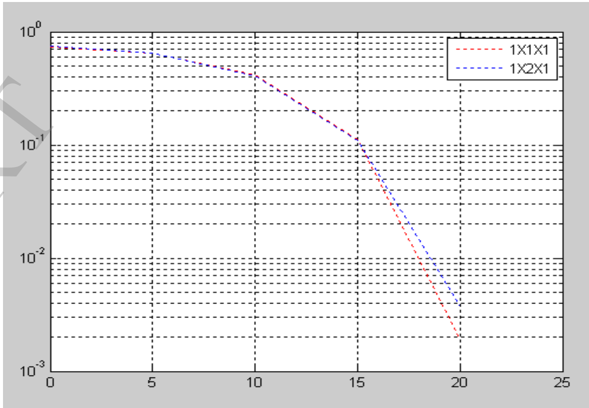
By showing that both the pairing algorithms give the same diversity order of performance, we prove that diversity is independent of the type of pairing algorithm used. [1][2]

5. Simulation results and observations

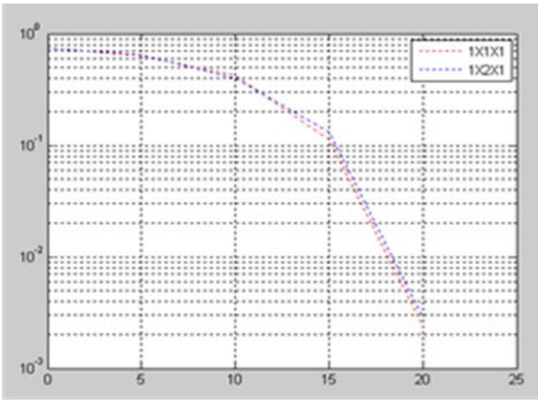
The simulations results and observations are shown below for the three different fading models. The modulation scheme used is quadrature amplitude modulation (QAM).We have performed these simulations using MATLAB R2011a

5.1 AWGN model results

The simulations carried out for AWGN channel model are as follows:-



The above graph depicts graph of Frame Error Rate [FER] versus Output Signal-to-Noise [SNR] ratio for 1*1*1 and 1*2*1 transmitter and receiver antenna inputs with the use of ordered subcarrier pairing technique for AWGN noise channel model.

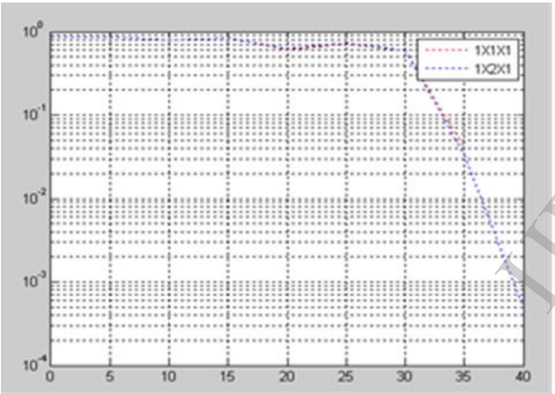


The above graph depicts graph of Frame Error Rate [FER] versus Output Signal-to-Noise ratio [SNR] for 1*1*1 and 1*2*1 transmitter and receiver antenna inputs with the use of reverse ordered subcarrier pairing technique for AWGN noise channel model.

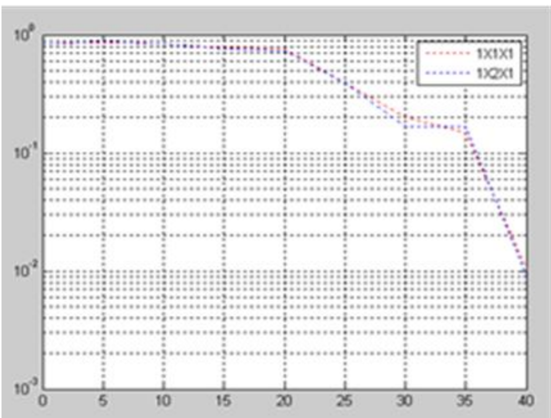
The graphs are plotted for 1x1x1 and 1x2x1 transmitter, relay and receiver antenna inputs. Comparing both the graphs, we observe that the frame error rate goes on decreasing from 10^0 to 10^-3 for signal-to-noise ratio from 0 to 25 db. Also, it is observed that inspite of using ordered subcarrier pairing or reverse ordered subcarrier pairing technique, the performance of MIMO-OFDM system using AWGN channel remains almost the same.[1][9]

5.2 Rayleigh model results

The simulations carried out for Rayleigh channel model are as follows:



The above graph depicts graph of Frame Error Rate [FER] versus Output Signal-to-Noise ratio [SNR] for 1*1*1 and 1*2*1 transmitter and receiver antenna inputs with the use of ordered subcarrier pairing technique for Rayleigh noise channel model.

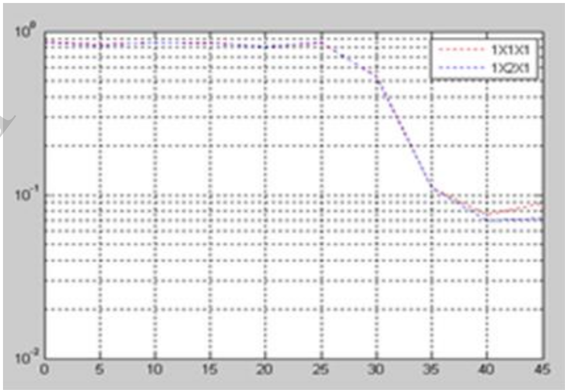


The above graph depicts graph of Frame Error Rate [FER] versus Output Signal-to-Noise ratio [SNR] for 1*1*1 and 1*2*1 transmitter and receiver antenna inputs with the use of reverse ordered subcarrier pairing technique for Rayleigh noise channel model.

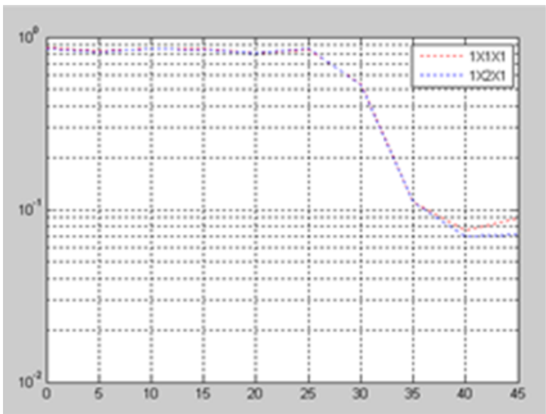
The graphs are plotted for 1x1x1 and 1x2x1 transmitter, relay and receiver antenna inputs. Comparing both the graphs, we observe that the frame error rate goes on decreasing from 10^0 to 10^-2 for signal-to-noise ratio from 0 to 40 db. Also, it is observed that inspite of using ordered subcarrier pairing or reverse ordered subcarrier pairing technique, the performance of MIMO-OFDM system using Rayleigh channel remains almost the same.[9]

5.3 Rician model results

The simulations carried out for Rayleigh channel model are as follows:



The above graph depicts graph of Frame Error Rate [FER] versus Output Signal-to-Noise ratio [SNR] for 1*1*1 and 1*2*1 transmitter and receiver antenna inputs with the use of ordered subcarrier pairing technique for Rician noise channel model.



The above graph depicts graph of Frame Error Rate [FER] versus Output Signal-to-Noise ratio

[SNR] for 1*1*1 and 1*2*1 transmitter and receiver antenna inputs with the use of reverse ordered subcarrier pairing technique for Rician noise channel model.

The graphs are plotted for 1x1x1 and 1x2x1 transmitter, relay and receiver antenna inputs. Comparing both the graphs, we observe that the frame error rate goes on decreasing from 10^0 to 10^-1 for signal-to-noise ratio from 0 to 45 db. Also, it is observed that inspite of using ordered subcarrier pairing or reverse ordered subcarrier pairing technique, the performance of MIMO-OFDM system using Rician channel remains almost the same. [9]

6. Conclusion

The various simulation results effectively demonstrate that the performance of the MIMO-OFDM system (i.e. BER) remains the same irrespective of the type of pairing used namely the Ordered Subcarrier Pairing (OSP) and Reverse Ordered Subcarrier Pairing(R-OSP).

It is also observed that the frame error rate of the system goes on decreasing as the signal to noise ratio increases. After a certain threshold limit, the frame error rate in each type of fading communication channel reduces by a drastic amount. It is also observed that the system performance is a function of the number of subcarriers. As the number of subcarriers increase, the system performance must improve theoretically because increased number of subcarriers will increase the robustness of the system. However as the number of subcarriers increase, the pairing mechanism takes time. At the same time the receiver complexity also increases and so does processing time. Hence a trade-off has to be established between the number of subcarriers, the modulation scheme to be utilized and the processing time which is desired. The type of channel also plays a quite important role because the performance changes with the type of channel. With these conclusions an application oriented MIMO-OFDM system can be designed as per the requirements.

7. References

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