ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

MIMO-OFDM Wireless Channel Prediction by Exploiting Spatial-Temporal Correlation

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Abstract:
Multiple input multiple output orthogonal frequency division multiplexing (MIMO-OFDM) is considered to be a promising technique for reliable high data-rate wireless transmission systems, which can provide high spectral efficiency and high data rate transmission over frequency selective channels. Recently, adaptive multi-user resource allocation and precoding techniques are introduced to modern MIMO-OFDM systems to further improve the spectral efficiency and the system performance.

However, the benefit of these techniques significantly rely on the accurate (to some level) channel state information (CSI) at the transmitter. In frequency division duplex (FDD) systems, CSI can only be estimated at the receiver and then be fed back to the transmitter. While in mobile environments with the time varying channel, the CSI fed back to the transmitter would be outdated due to the feedback delay, which results in significant performance degradation.

An effective mean to overcome the feedback delay is the channel prediction technique discussed in this paper, which predicts future channel coefficients based on the history data. So the Channel prediction is an appealing technique to mitigate the performance degradation due to the inevitable feedback delay of the channel state information (CSI) in modern wireless systems. We first propose a general MIMO-OFDM channel prediction framework, which exploits both the spatial and temporal correlations among antennas.

Then we derive two predictors which select data for auto-regressive (AR) predictors in different ways based on the proposed framework. The first predictor cooses the data set via minimizing the mean square error (MSE) of prediction model. The second predictor chooses the data in a heuristic way, which aims to reduce the computational complexity. Our algorithms can be applied to improve the precoding performance in multi-user MIMO-OFDM systems. Simulation results show that the proposed methods can overcome the feedback delay effectively, even when the channel changes rapidly.

Index Terms:
MIMO-OFDM, channel prediction, spatial temporal correlation, AR model.

1. Introduction:
Wireless technologies have evolved remarkably since Guglielmo Marconi first demonstrated radio's ability to provide continuous contact with ships sailing in the English Channel in 1897. New theories and applications of wireless technologies have been developed by hundreds and thousands of scientists and engineers through the world ever since. Wireless communications can be regarded as the most important development that has an extremely wide range of applications from TV remote control and cordless phones to cellular phones and satellite-based TV systems. It changed people's life style in every aspect. Especially during the last decade, the mobile radio communications industry has grown by an exponentially increasing rate, fueled by the digital and RF (radio frequency) circuits design, fabrication and integration techniques and more computing power in

chips. This trend will continue with an even greater pace in the near future. The advances and developments in the technique field have partially helped to realize our dreams on fast and reliable communicating "any time anywhere". But we are expecting to have more experience in this wireless world such as wireless Internet surfing and interactive multimedia messaging so on. One natural question is: how can we put high-rate data streams over radio links to satisfy our needs? New wireless broadband access techniques are anticipated to answer this question.
For example, the coming 3G (third generation) cellular technology can provide us with up to 2Mbps (bits per second) data service. But that still does not meet the data rate required by multimedia media communications like HDTV (high-definition television) and video conference.

Problem Statement:

In MIMO-OFDM system, the output is the superposition of multiple sub-carriers. In this case, some instantaneous power outputs might increase greatly and become far higher than the mean power of the system when the phases of these carriers are same. This is also defined as large Peak-to-Average Power Ratio (PAPR). High PAPR is one of the most serious problems in MIMO-OFDM system. To transmit signals with high PAPR, it requires power amplifiers with very high power scope. These kinds of amplifiers are very expensive and have low efficiency-cost. If the peak power is too high, it could be out of the scope of the linear power amplifier.

This gives rise to non-linear distortion which changes the superposition of the signal spectrum resulting in performance degradation. If there are no measures to reduce the high PAPR, MIMO-OFDM system could face serious restriction for practical applications. To combat high PAPR, one intuitive solution is to adopt amplifiers to have larger trade-off range. However, these types of amplifiers are generally expensive and have low efficiency-cost, and therefore are of no practical use. On the other side, certain algorithms were introduced and been proved have a good performance of high PAPR reduction.
Hence, in this thesis, some currently promising PAPR reduction methods are studied and compared. The performance of these reduction schemes are evaluated by using simulation software, Mat lab

2. MIMO Communication Systems:

Digital communication using Multiple-Input Multiple-Output (MIMO) systems is one of the most significant technical breakthroughs in modem communication. MIMO systems are simply defined as the systems containing multiple transmitter antennas and multiple receiver antennas. The use of multiple antenna technique has gained overwhelming interest throughout the last decade. The idea of using multiple antenna configuration instead of a single one has proven to be successful in enhancing data transfer rate, coverage, security and overall the performance of radio networks.

The use of multiple antennas both at the transmitter and the receiver, which is commonly referred as MIMO, is a popular research area in wireless communications because of its reliability and spectral efficiency. Communication theories show that MIMO systems can provide a potentially very high capacity that, in many cases, grows approximately linear with the number of antennas. With the growth of applications that demand better quality of services, higher throughput and bandwidth, MIMO communication has emerged as a promising technology.

The ideas behind the MIMO communication are either creating a multiple data pipes to increase the data rate and/or adding diversity to improve the reliability. In this paper, from the next session antenna concepts will be discussed from the very basic level for proper understanding the MIMO method. The main feature of MIMO systems is space-time processing. Space-Time Codes (STCs) are the codes designed for the use in MIMO systems. In STCs, signals are coded in both temporal and spatial domains.

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3.0 Antenna Basics:

An antenna is a metallic object which acts as a medium for receiving and transmitting electromagnetic energy. It acts as a transitional structure between the transceivers and the free space. Officially the Institute of Electrical and Electronics Engineers (IEEE) defines an antenna as "The part of a transmitting or receiving system that is designed to radiate or receives electromagnetic waves". By moving electrons in the antenna, electromagnetic waves are formed. The antenna is connected to a transmitter which is designed to output current as a function of time. This current is an electromotive force (EMF) which forces free charge in the conductive element of the antenna to travel back and forth along the transmitting antenna. In the receiving antenna, there is free charge in the conductive element.

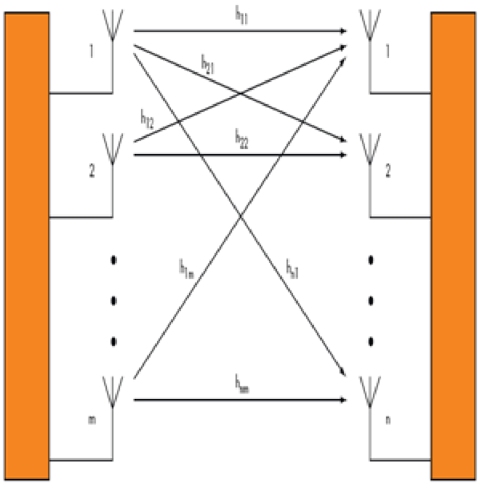
They are affected by the movement of charge in the transmitting antenna. As there is usually a long distance between the transmitting antenna and the receiving antenna, that movement of charge in the receiving antenna is much smaller than the quantity of charge and movement in the transmitting antenna. This small and somewhat distorted signal is then amplified by the receivers. In order to understand the basic antenna principle, there are some parameters which have been taken into account. The basic antenna parameters include radiation pattern, antenna efficiency, bandwidth, directivity and antenna gain.

4.0 Multiple Antenna Techniques:

Traditionally, wireless communications mainly focused on voice and smaller data transfers, whereas most high-rate data transfer products were using wired communications. In recent years, however, there has been a dramatic boost in wireless multimedia applications, such as cell phones having an integrated camera, emailing capability and GPS. As a result, the focus has now shifted towards wireless high speed data transfers which traditional antennas are not capable of delivering because of multipath and co-channel interference.

Apart from the needs of high speed data transfers, there is also an issue of quality control, which includes low error rate and high capacity. In order to maintain certain Quality of Service (QoS), multipath fading effect has to be dealt with. As the transmitted signal is reflected onto various objects on its way to the receiver, the signal is faded and distorted. This phenomenon is called multipath fading. Co-channel interference refers to the interference caused by different signals using the same frequency. Hence as an alternative, multiple antennas can be used to reduce the error rate as well as, improve the quality and capacity of a wireless transmission by directing the radiation only to the intended direction and adjusting the radiation according to the traffic condition and signal environment.

All multiple antennas are equipped with several antennas either in the transmitter or the receiver or both of them. A sophisticated signal processor and coding technology is the key factor in multiple antennas. Multiple antenna technique can be broken down into three categories, Spatial Diversity (SD), Spatial Multiplexing (SM) and Adaptive Antenna System (AAS).Antennas are placed at a distance from each other. Thus if one antenna experiences a fade, another one will have a LoS or a clear signal. Figure 6 shows the basic principle of Spatial Diversity.



Antenna Array

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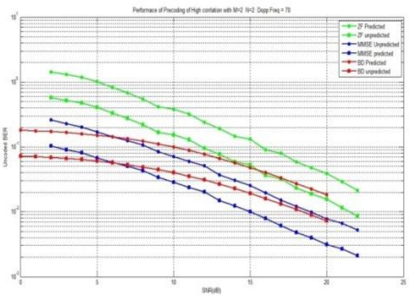
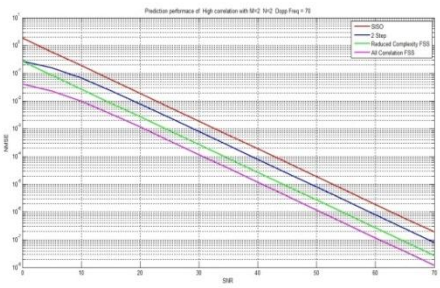
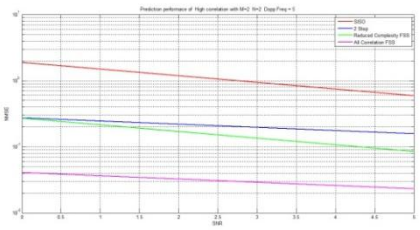
Single element antennas are not always sufficient for required antenna gain and radiation pattern. Combining several single element antennas into an array provides a much better solution. When multiple active antennas are joined together to a common source in order to achieve a directive radiation pattern, this is called an antenna array. Each individual antenna is known as the element of an array antenna. The radiation pattern from the array in a linear medium is determined by vector addition of the components of the electromagnetic fields radiated from the individual antennas or elements. This process is also known as the principle of superposition. Antenna arrays can be one, two or three dimensional. A typical array antenna is shown is figure 7.

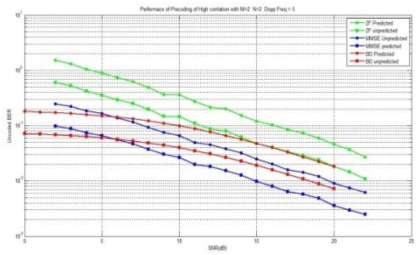
5.0 MULTIPLE-INPUT MULTIPLE OUTPUT

Multiple-Input Multiple-Output (MIMO) uses multiple antennas on both the transmitter and receiver. They have dual capability of combining the SIMO and MISO technologies. They can also increase capacity by using Spatial Multiplexing (SM). The MIMO method has some clear advantages over Single-input Single-output (SISO) methods. The fading is greatly eliminated by spatial diversity; low power is required compared to other techniques in MIMO.



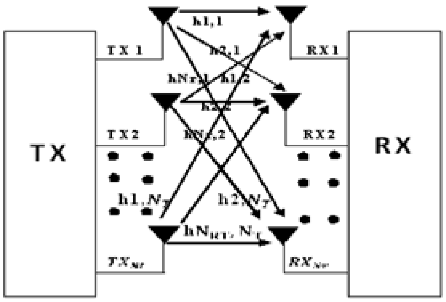






6.0 MIMO Channel:

Multiple-Input Multiple-Output (MIMO) systems yield vast capacity increases when the rich scattering environment is properly exploited. When examining the performance of MIMO systems, the MIMO channel must be modeled properly. The MIMO channel models used throughout this thesis are described in this section. The primary MIMO channel model under consideration is the quasi-static, frequency non-selective, Rayleigh fading channel model. Figure 25 shows a block diagram of a MIMO system with N_t transmit antennas and N_r receive antennas.



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7.0 CONCLUSION:

There are two main contributions in our work. First, wederive a novel channel prediction framework for MIMO-OFDM systems which takes both spatial and temporal correlations into account. Second, we propose two MIMO prediction algorithms which select the useful data for AR modeling. The FSS predictor employs the optimal data selection strategy, which requires huge computations. In contrast, the reduced-complexity FSS predictor chooses the data in a heuristic way, whose computational complexity is quite low. The performance of the two proposed algorithms is nearly the same in2×2 antenna case. As the antenna increase up to 4×2, the FSSpredictor offers slightly better performance compared with the reduced-complexity FSS predictor. Simulation results show that the prediction performance can be effectively improved by exploiting the spatial correlation, especially when the spatialcorrelation is relatively high.

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