An Extensive Comparative Analysis of MIMO-OFDM Wireless Communication System

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Abstract: In this review paper we have studied Radio transmission that has allowed people to communicate without any physical connection for more than hundred years. When Marconi managed to demonstrate a technique for wireless telegraphy, more than a century ago, it was a major breakthrough and the start of a completely new industry. May be one could not call it a mobile wireless system, but there was no wire! Today, the progress in the semiconductor technology has made it possible, not to forgot affordable, for millions of people to communicate on the move all around the world. Orthogonal Frequency Division Multiplexing (OFDM) is a multicarrier communication scheme widely adopted in the wireless communication industry. The system's operational principle is sending a large number of parallel narrow-band channel using different subcarriers for each channel. The orthogonality concept prevents crosstalk between sub-carriers, preventing the interference and hence it consumes a lot of spectrum.

Keywords: Channel Estimation, Decision-Directed (DD), Signal-to-Noise Ratio (SNR), Bit Error Rate (BER).

I. INTRODUCTION

During the last few decades, wireless communication systems have been under major development. The requirements have shifted from the low data rate voice services to real time video transmissions. Support for higher data rates has become more essential and the development towards more advanced wireless systems is still ongoing. Multiple antennas are currently included in many of the wireless standards to achieve the required data rates. This increases the complexity of signal processing algorithms in the receiver. However, the complexity and power consumption of the wireless device should be moderate. This poses challenges in developing algorithms and architectures for the mobile receiver.

Broadband Wireless Communications

Nowadays, wireless broadband communications can provide its users with radio access to broadband services based on public wired networks, with data rates exceeding 2 Mbps [10]. However, multimedia and computer communications are playing an increasing role in today's wireless services, which are presenting new challenges to the development of wireless broadband communication systems. The next generation of broadband wireless communication systems such as 4G is therefore anticipated to provide wireless subscribers with high quality wireless services such as wireless television, high speed wireless Internet access and mobile computing.

II. MIMO SYSTEM

The explosion of interest in MIMO systems dates from the middle of the 1990s. The first papers by Foschini and Gans, Foschini and Telatar focus on this topic. However, what is not widely known is the fact that eight years before Telatar's work, another paper was written by Winters. This research showed that with appropriate signal processing in the transmitter and the receiver, the channel capacity (a theoretical upper bound on system throughput) for a MIMO system is increased as the number of antennas is increased, proportional to the minimum number of transmit and receive antennas, which implies that the possible transmission rate increases linearly. This basic finding in information theory is what led to an explosion of research in this area.

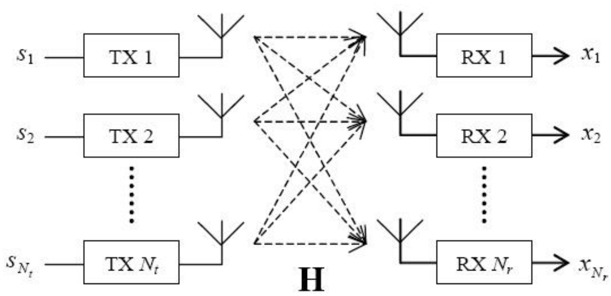

Fig. 1.1 MIMO System

Nowadays, MIMO technology has attracted the most attention in wireless communications, since it can offer significant increase in data throughput and link range without additional bandwidth or transmit power. It achieves this by higher spectral efficiency (more bits per second per Hertz of bandwidth) and link reliability through diversity gain (reduced fading). Because of these properties, MIMO is a current

Spatial diversity is a part of antenna diversity techniques in which multiple antennas are used to improve the quality and reliability of a wireless link. Usually in densely populated areas, there is no clear Line of Sight (LoS) between the transmitter and the receiver. As a result, multipath fading effect occurs on the transmission path [7]. In spatial diversity several receive and transmit 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.

The same signal is fed through a single antenna or multiple antennas, and the same signal is captured by a single antenna or multiple antennas. Several antennas are placed in a distance from each other. There are various obstacles on the signal's path. However, it can be noticed in the figure that from transmitter TX2 there is a clear LoS to receiver RX2. Despite the multipath fading effect having occurred in other receivers, the receiver can get a fairly good signal. In the case of base stations in a macro cellular environment, with large cells with high antennas, a distance up to 10 wavelengths is needed to ensure a low mutual fading correlation.

However, in case of handheld devices, because of lack of space, half a wavelength is enough for the expected result. The reason behind this space is usually in the macro/cell scenario, the fading of which is caused by multipath correlations that have occurred in the near zone of the terminal. Therefore, from the terminal side, different paths arrive in a much wider angle, thus requiring smaller distances, whereas from the transmitter side, the path angle is relatively slow. That is why a larger distance is required [8].

Recognized spatial diversity techniques involving multiple transmit antennas are, for example, Alamouti's transmit diversity scheme [9] as well as space-time trellis codes [10] invented by Tarokh, Seshadri, and Calderbank. For systems in which multiple antennas are available only at the receiver, there are well-established linear diversity combining techniques dating back to the 1950's [11].

Mobile Communication Systems

The evolution of mobile communication systems has progressed rapidly. The first international cellular networks were deployed in the 1980s, while national car phone systems were employed during the previous decades. The Nordic mobile telephony (NMT) system was the first cellular network used in the Nordic countries [1]. It was based on analog cellular technology, as well as the systems deployed shortly after NMT in North America and Japan. The second generation (2G) cellular systems were pioneered by the Groupe Spécial Mobile (GSM) with a European cellular standard now known globally as the Global Systems for Mobile Communications [2]. The GSM is a digital system using time division multiple access (TDMA) with frequency hopping and frequency shift keying [3]. Simultaneously, TDMA based 2G standards were developed in the USA and Japan. General packet radio services (GPRS) were included in the GSM standard to enable data transfer and the operating bandwidth was tripled with the introduction of the enhanced data-rates for global evolution (EDGE) [4].

Multiple Antenna Communications

Multiple antennas can be used in the transmitter, receiver or both to improve the reliability of the transmission or to increase the data rates. Spatial diversity allows multiple antenna systems to utilize multipath propagation by taking advantage of fading and the channel delay spread [16]. Due to the multiple paths for a signal, combining them in the receiver can restore and improve the received signal quality. The diversity order increases with the number of spatial streams. Single-input multiple-output (SIMO) antenna configurations can be used for array gain, i.e. enhancing the signal at the receiver by combining the signals from the transmit antennas [10]. SIMO transmission can also be utilized to obtain receive diversity and the diversity order is equal to the number of receive antennas. Multiple-input single-output (MISO) channels can be exploited to achieve transmit diversity [8]. Assuming independently faded streams, the diversity order in the MISO system is equal to the number of transmit antennas [7].

Multiple-input multiple-output (MIMO) schemes can also be used to obtain a diversity gain or an array gain, but unlike in the MISO and SIMO systems, MIMO systems offer also spatial multiplexing (SM) gain [9]. The capacity increase provided by spatial multiplexing is achieved by demultiplexing the data onto different transmit antennas. The capacity grows linearly with the number of transmit and receive antenna pairs in spatial multiplexing MIMO systems if the channel can be estimated in the receiver and the channel paths are independent [2]. Given independently fading MIMO streams, the diversity order of a MIMO system is the product of the number of transmits and receives antennas.

Multicarrier Communications & Cellular Systems

The fading channels exploited by MIMO systems can cause intersymbol interference (ISI) [9]. OFDM suppresses the ISI and it is therefore combined with MIMO transmissions in many communication systems, such as the 3GPP LTE and LTE-A and the WiMAX systems [4]. The idea of OFDM was proposed by Chang in the 1960s [2] and the performance of the OFDM system was considered in [4]. The discrete Fourier transforms (DFT) based time-limited multi-tone system was described in [5]. OFDM for mobile communications was proposed in [4], where the results showed significant improvements in performance. OFDM is a multicarrier (MC) technique where the frequency band is divided into several narrow-band subcarriers which are transmitted in parallel. The duration of each symbol can then be increased, which reduces ISI if the delay spread of the channel is smaller than the duration of the symbol [6]. A MIMO-OFDM transmission system is illustrated in Figure 1. The transmission from each antenna can be reflected from buildings or other structures and arrive at the receiver with delay and attenuation. Due to the delay in the reflected paths, interference from the previous OFDM symbol is added to the received symbol. Therefore, a cyclic prefix (CP), which contains replicated symbols from the end of the block, is added to the beginning of each block. This eliminates the ISI if the length of the CP is larger than that of the channel [7]. Equalization in the receiver also becomes simpler as ISI is not present. To prevent interference from adjacent subcarriers and to improve the spectral efficiency by overlapping the subcarriers, orthogonality between the carriers is applied [3].

III. LITERATURE SURVEY

A. Idris, N. I. A. Razak and M. Sabry[1] presented the study about Channel estimation that is a one of important technique to improve the performance of Orthogonal Frequency Division Multiplexing (OFDM), and the Decision-Directed (DD) channel estimation is focus on this paper because of the ability of decreasing bit error rate (BER) in the OFDM performance. By implemented channel estimation, the OFDM system deals with other problem which is an effect in channel fading due to complexity. Various diversity techniques are used in OFDM system in order to combat the effects of channel fading and to improve the system performance. Diversity may be implemented in three different domains namely time, frequency and space. The simulation result shows that the Decision-Directed channel estimation adapted with diversity scheme improved the performance of OFDM system in terms of increasing SNR and decreasing BER.

Ye Li, N. Seshadri and S. Ariyavisitakul, [2] proposed the transmitter diversity is an effective technique to improve wireless communication performance. In this research, authors investigate transmitter diversity using space-time coding for orthogonal frequency division multiplexing (OFDM) systems in high-speed wireless data applications. They develop channel parameter estimation approaches, which are crucial for the decoding of the space-time codes, and authors derive the MSE bounds of the estimators. The overall receiver performance using such a transmitter diversity scheme is demonstrated by extensive computer simulations. In summary, with the proposed channel estimator, combining OPDM with transmitter diversity using space-time coding is a promising technique for highly efficient data transmission over mobile wireless channels

J. Akhtman and L. Hanzo, [3] An advanced decision-directed channel estimation scheme was proposed, by authors that is suitable for employment in a wide range of multi-antenna multi-carrier systems as well as for communications over the entire range of practical channel conditions. Mean square errors as well as the bit error rate performances achieved by the proposed system are documented. Authors report a virtually error- free performance of a rate 1/2 turbo-coded 8times8-QPSK-OFDM system, exhibiting an effective throughput.

Z. Wei and Y. Zhang, [4] presented in their research study that estimation technology is one of the key technologies in the Orthogonal Frequency Division Multiplexing (OFDM) system, and the Decision-Directed channel estimation algorithm is paid close attention because of the superiority of decreasing means square error (MSE) and bit error rate (BER). In this research, a Decision-Directed channel estimation algorithm based on linear minimum mean square error (LMMSE) was proposed, and it is simulated in the white Gaussian noise channel and multipath Rayleigh channel. The result shows that this algorithm has obvious superiority comparing to the other Decision-Directed algorithm in terms of decreasing MSE and BER.

H. Minn, Dong In Kim and V. K. Bhargava [5] reduced complexity channel estimation for OFDM systems with transmit diversity is proposed by exploiting the correlation of the adjacent subchannel responses. The sizes of the matrix inverse and the FFTs required in the channel estimation at every OFDM data symbol are reduced by half of the existing method for OFDM systems with nonconstant modulus subcarrier symbols or constant modulus subcarrier symbols with some guard tones. The complexity reduction of half FFTs size and some matrix multiplications is still achieved for constant modulus subcarrier symbols with no guard tones. The price for the complexity reduction is a slight BER degradation and for the channels with small relative delay spreads, the BER performance of the reduced complexity method becomes quite comparable to the existing method.

IV. PROBLEM IDENTIFICATION

Improving MIMO-OFDM techniques were studied for wireless systems using channel estimation and diversity techniques. Decision-Directed (DD) channel estimation is a method used initials OFDM symbol to decode the current OFDM symbol and use equalizer to make the decision.

DDCE technique apply with transmit diversity allows system available for channel tracking but the previous results are not up to mark. Still the performance of the MIMO OFDM system may be further improved.

V. CONCLUSION

There has been an explosion in wireless technology now a day. This growth has opened a new dimension to future wireless communications whose ultimate goal is to provide universal personal and multimedia communication without regard to mobility or location with high data rates. To achieve such an objective, the next generation personal communication networks will need to be support a wide range of services which will include high quality voice, data, facsimile, still pictures and streaming video. These future services are likely to include applications which require high transmission rates of several Mega bits per seconds (Mbps).

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