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An Extensive Literature Review on Efficient 4G Wireless Communication System

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Abstract-The communication industry is one of the fastest growing industries. The cellular systems started in the 80's with 1G have now reached to 4G. The growing demand of high data rates are increasing exponentially with time. The typical goals of a communication engineer are high speed communication for which the data rate should be high, better quality of signal for which we have to minimize the bit error rate as low as possible and less power consumption. The 4G system ensures us data rate of 1Gbps which cannot be achieved by SISO systems and hence we go for MIMO system. The various benefits of MIMO are discussed in this study. The implementation of Alamouti scheme is also discussed and then the various methods of channel estimation are discussed and simulated. The proposed MIMO system has distinguished advantages over the conventional SISO systems and this is being implemented in 4G cellular, MIMO radar and in various other emerging communication technologies.

Keywords - 4G, Wireless Communication, MIMO, OFDM, High Data Rate, Cellular System.

I. INTRODUCTION

In Europe the Global system for mobile communication started and became very popular for almost 20 years. Then the 3G (third generation) cellular system came into existence and it allows high speed data transmission as well as internet access. It also supported voice activated calls. Then the 4G system has become a hot topic. It ensures us data rate more than 100Mbps i.e. almost no waste of time and multi mega bit internet access. But the real challenge involved in 4G is how to design such a network. The conventional SISO (single input and single output) systems can never reach the barrier of 100Mbps. Multiple-input multiple-output (MIMO) communication technology has received significant recent attention due to the rapid development of high-speed broadband wireless communication systems employing multiple transmit and receive antennas. Information theoretic results show that MIMO systems can offer significant capacity gains over traditional single-input single-output channels. This increase in capacity is enabled by the fact that in rich scattering wireless environments, the signals from each individual transmitter appear highly uncorrelated at each of the receive antennas. When conveyed through uncorrelated channels between the transmitter and the receiver, the signals corresponding to each of the individual transmit antennas have attained different spatial signatures. The receiver can exploit these differences in spatial signatures to separate the signals originating from different transmit antennas.

Many MIMO techniques have been proposed and are usually targeted at different scenarios in wireless communications. The Bell-Labs Layered Space Time (BLAST) system is a layered space-time architecture originally proposed by Bell-Labs to achieve high data rate wireless transmission. In this scheme, different symbol streams are simultaneously transmitted from all transmit antennas (i.e., they overlap both in frequency and in time). The receive antennas yield the superposition of all the transmitted symbol streams and recover them via proper signal processing. On the other hand, in Space-Time Coding (STC) systems [3] the same information symbol stream is transmitted from different transmit antennas in an appropriate manner in order to obtain transmit diversity. Hence, in STC systems the MIMO channel is exploited to provide more reliable communications, whereas in the BLAST system the MIMO channel is used to provide higher rate communications. Note that by employing higher level signal constellations, STC systems can also achieve higher throughput. A general overview of the capacity results for MIMO systems as well as for BLAST and STC techniques.

Multiple-input multiple-output (MIMO) systems can offer significant capacity gains over traditional single-input single-output (SISO) systems. However, multiple antennas require multiple RF chains which consist of amplifiers, analog to digital converters, mixers, etc., that are typically very expensive. An approach for reducing the cost while maintaining the high potential data rate of a MIMO system is to employ a reduced number of RF chains at the receiver (or transmitter) and attempt to optimally allocate each chain to one of a larger number of receive (transmit) antennas which are usually cheaper elements. In this way, only the best set of antennas is used, while the remaining antennas are not employed, thus reducing the number of RF chains required. With an enormous amount of yearly publications, research into multiple antennas has helped it to evolve pretty quickly. Up to now, there have been hundreds of research papers and research works behind it. There have been many different types of proposals towards the implementation of such a technology. In this study, antenna concepts will be discussed from the very basic level for proper understanding the MIMO method. This paper can be helpful for any individual who would like to have a brief look into the world of multiple antennas.

As technologies are progressing, a need for enhanced services and higher data rates is created. Previously wireless connections were mostly voice cantered, and the needs of high speed data were mainly taken care of by wired connections. However, now that there are mobile phones with cameras and built in GPS (Global Positioning System), in order to meet the constant needs of various wireless systems, antenna structures also have to be changed. One possibility is to merge the signal processing functionality with multiple antenna elements. Then what is called, “intelligent antennas” are created [6]. Their characteristics and functions can vary over the specific system requirements.

They can greatly increase the capacity, quality and service given by the antenna itself. Advanced antennas are also needed to overcome the wideband effects, improved power delivery and also interferences. As the world is moving towards 4G, LTE (Long Term Evolution) and beyond that, advanced antennas are the key parts that have to be modified to support those technologies.

II. MIMO TECHNOLOGY

The typical aspirations of a system designer are high data rate, low bit error rate, low power consumption, low cost and easy implement ability. The MIMO system ensures us very high data rates even more than 1Gbps while minimizing the bit error rate. By Shanon’s theorem the rate of transmission is always less than or equal to the capacity. Practically it is less than the capacity. The capacity depends on the bandwidth of the channel and SNR of the channel. Both the bandwidth and signal to noise ratio are characteristics of the channel. The SNR can be improved either by reducing noise power or by increasing signal power. Reduction in noise power is not possible while increase in signal power requires more power for transmission which should be avoided for a good design. The improvement of bandwidth is not possible. However there are techniques like OFDM (orthogonal frequency division multiplexing) which assure us efficient use of the channel i.e. spectral efficiency. But however the use of multiple antennas at the transmitter and at the receiver that is use of MIMO meets the ongoing requirements in 4G. The bit error rate in MIMO is very less as compared to conventional SISO systems.

Mimo Systems &Capacity

As the name suggests MIMO uses multiple antennas both at the transmitter and at the receiver as shown below.

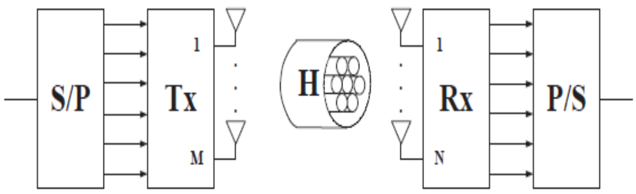

Figure 1. MIMO system modeling

MIMO-OFDM

OFDM stands for orthogonal frequency division multiplexing. It is a method that uses the spectrum in the most efficient way. Typically the channel is irregular and frequency selective fading is prominent, OFDM divides the frequency selective channel into a number of sub-channels which are orthogonal to each other but having frequency-flat response so that frequency selective fading can be avoided. Multiple input multiple output (MIMO) technology allows mobile networks to obtain higher signal to noise ratio to achieves considerable performance gain. It provides the significant performance improvement for the fourth generation (4G) communication systems. This paper,

They compare the performance of least mean square (LMS) and recursive least square (RLS) channel estimation (CE) algorithm for MIMO orthogonal frequency division multiplexing (OFDM) systems. The simulation results show that the RLS has better mean square error (MSE) performance compared with LMS algorithm.

The RLS CE algorithm has better anti-noise as well as tracking ability. But the RLS CE algorithm suffers from higher complexity than LMS CE algorithm. In addition, when the number of receiving antenna is greater than transmitting antenna then the performance is increase significantly in both algorithms and vice versa.

III. LITERATURE SURVEY

In 2007 Adachi, F., worked on "New Direction of Wireless Technology, “The 3rd generation (3G) mobile wireless communications systems based on direct-sequence code division multiple access (DS-CDMA) technique were put into services, with much higher data rates than the present 2G systems, in many countries and their deployment speed has since accelerated. 3G systems will be continuously evolving with high speed downlink packet access (HSDPA) technique, multiple-input/multiple-output (MIMO) antenna technique, etc, for providing packet data services of around 14 Mbps as the mid-term evolution and of 50~100 Mbps as the long-term evolution. However, the capabilities of 3G wireless networks will sooner or later be insufficient to cope with the increasing demands for broadband services. The evolution of 3G systems will be followed by the development of 4G systems, that support extremely high-speed packet data services of e.g., 100 M~1 Gbps. The most important technical challenge for the realization of 4G systems is two-fold: (a) to overcome the severely frequency-selective fading channel, and (b) to significantly reduce the transmit power from mobile terminals.

In 2009 Adhikari, S., worked on "Critical analysis of multi-antenna systems in the LTE downlink,". Long Term Evolution (LTE) is an emerging 4G wireless access technology. It is showing a lot of promise in field trials and gaining acceptance among the major wireless vendors such as Verizon-Vodafone, NTT-Docomo, KDDI, China Mobile, T-Mobile and others. Multi-Antenna or Multiple-Input Multiple-Output (MIMO) systems which involve the use of more than one antenna at the transmitter and receiver are a primary enabler of the high spectral efficiency and data rate sought to be achieved by LTE. This work is novel in the following 2 aspects: (A) It provides deep physical interpretations into the function and performance of MIMO in LTE. Such insights would not have been published elsewhere in the literature (B) Performance evaluation of MIMO obtained from simulation results based on a full fidelity implementation of the latest version of the LTE Radio Interface standards (3GPP TS 36.211 and 36.213). MIMO performance is explained for various ITU channel models (Pedestrian A, Vehicular A, Typical Urban), Doppler spreads (5, 70, 300 Hz) and antenna correlation conditions (High, Low). The treatment is fully compliant with the specifications laid down in the LTE performance standards 3GPP TS 36.101 and 36.104. The simulated MIMO performance is compared against a twofold system: Theoretical expectations that are derived in this work and LTE 3GPP performance benchmarks. The author has also compared simulated results with data provided by the LTE-SAE Trial Initiative (LSTI) an industry partnership of telecom vendors and operators. The data show a close match. Due to its proprietary nature, such data is not shown in this paper. Readers with access to LSTI data are encouraged to compare them with results provided in this paper.

In 2013 Bin Guo; Wei Cao; An Tao; and Samardzija, D., worked on "LTE/LTE-A signal compression on the CPRI interface,". The Centralized, Cooperative, Cloud Radio Access Network (C-RAN) is a next-generation wireless access network architecture based on centralized processing, collaborative radio, and real time cloud infrastructure. In this architecture, different access technologies (Global System for Mobile Communications (GSM)/Time Division Synchronous Code Division Multiple Access (TD-SCDMA)/Wideband Code Division Multiple Access (WCDMA)/Long Term Evolution (LTE)) can be supported on the same hardware platform in a baseband pool system, which can largely reduce system costs. Long Term Evolution (LTE) and Long Term Evolution-Advanced (LTE-A), which are based on Orthogonal Frequency Division Multiplexing (OFDM) and multiple input multiple output (MIMO) technologies, are regarded as the main wireless access technologies in the evolution from 3G to 4G. A variety of novel technologies such as multi-antenna MIMO, carrier aggregation (CA), and coordinated multipoint have been introduced in LTE/LTE-A to improve system performance, especially in the C-RAN architecture. However, one of the technical challenges for the C-RAN architecture is the fiber bandwidth required for data transmission between the remote radio unit (RRU) and the baseband unit (BBU). They propose using a low-latency baseband signal compression algorithm to solve this problem by reducing the fiber data rate. Using the characteristics of the LTE signal data, They remove the redundancy in the spectral domain. They also leverage block scaling in conjunction with using a linear or nonlinear (non-uniform) quantizer to minimize quantization error. This algorithm effectively reduces the amount of data transmitted between the BBU and RRU, and facilitates the deployment of LTE in the C-RAN architecture. They verified the robustness of the algorithm via simulations and lab tests. The proposed algorithm yields good system performance at a 1/2 compression rate and at a 1/3 compression rate in a practical propagation environment.

In 2004 Del Re, E. and Pierucci, L., worked on "Multiple antenna systems: frontier of wireless access," Multiple antenna systems are the new frontier for wireless communications including the actually third generation mobile communication systems, called Universal Mobile Telecommunication System (UMTS), the wireless LAN, and the wireless PAN up to the future 4G mobile system focused on the seamless integration of the existing wireless technologies. The use of multiple antenna systems improves the overall system performance in term of capacity and spectrum efficiency achieving high data rate wireless services. The work highlights the two main techniques: smart antennas with adaptive beamforming to cancel the interference signals (from the other users or multipath) and MlMO systems to exploit the space-time properties of wireless channels.

In 2011 Maslennikov, R.; Trushanin, A.; Shkerin, M.; Shashanov, M.; and Czerepinski, P., worked on "Analysis of multiple antenna transmission for HSUPA,". The 3-rd generation (3G) mobile wireless systems, such as WCDMA HSPA, continue to evolve along with the LTE and LTE Advanced standards, often described as 4G. Currently, multiple antenna transmission schemes such as closed-loop beam forming transmit diversity (CL-BFTD) and MIMO spatial multiplexing are considered by the 3GPP for HSPA uplink (HSUPA) to enhance its performance. In this paper, They review the technical approaches proposed in order to introduce multiple antenna transmission modes into

HSUPA. The introduction is followed by the performance analysis of HSUPA, assuming that stations are equipped with two transmit antennas. The analysis is performed using system-level simulations and considers the macro cell deployment with the ITU Pedestrian A and Vehicular a channel models. The results of the analysis demonstrate that the application of CL-BFTD can improve the average system throughput by up to 20-25%, owing to a lower mobile station transmit power and reduced inter-cell interference. The current analysis of the MIMO transmission scheme with two parallel spatial channels reveals throughput gains approximately up to 10%, observed at low user station density in the system deployment.

IV. PROBLEM IDENTIFICATION

Compared to the existing technology, which operates only in unlicensed spectrum and over much smaller ranges and larger bandwidths, optimizing the capacity of 4G is more crucial if it is to prove commercially viable. So there is a need to increase the average throughput by approximately a factor of four or more, while also increasing the coverage area and reducing outage probability. There are several major shortcomings of 4G which are still a headache to the engineers, which are BER, Datarate, LOS and NLOS coverage and Radio Cards. General concept of 4G is that, it provides high speed data rate within its maximum range (30 miles). If 4G operates the radio signals to its maximum range then the Bit Error Rate (BER) increases. So, it is better to use lower bit rates within short range to get higher data rates. Mobile 4G uses Customer Premises Equipment (CPE), which is attached to computers (either desktop or laptop or PDA) and a lower gain omni-directional antenna, is installed which is difficult to use compared to fixed 4G.

Mobile 4G covers 10 kilometers with 10 Mbps speeds in line -of-sight (LOS) environment but in urban areas, it is only 2 kilometres coverage due to non-line-of-sight problem. In this situation, mobile 4G may use higher gain directional antenna for excellent coverage and throughput but problem is that it loose its mobility. In all networks (including wireless and wired network)-the allocated bandwidth is partitioned among the users. In case of 4G, it happens in radio sector. Some times the performance of that particular network may drop due to increasing users. The more radio cards are needed to install on that particular network's base station to accelerate the performance of the network. Besides all above shortcomings, there is a major impact of weather conditions like rain, fog and droughts etc on 4G networks.

V. PROPOSED METHODOLOGY

The focus of the 4G development in the MATLAB software is based on the adaptive modulation techniques. The OFDM model consists of basic model (without cyclic prefix) and model with cyclic prefix. The OFDM simple model which the data stream is first subdivided into a number of sub-streams where each one has to be modulated over a separate carrier signal, called sub carriers. The data bits are directly mapped to the complex modulation symbols by using adaptive modulation techniques which are BPSK, QPSK, 16-QAM or 64-QAM. The resulting modulated signals are then multiplexed before their transmission by applying the Inverse Fast Fourier Transform (IFFT). Thus the multiplexed signal passes through the AWGN channel. In the receiver, OFDM symbols are detected by using adaptive modulation techniques detector and sub carriers are demodulated by the FFT, which is the reverse operation of the IFFT. The values are then de-mapped into binary values and finally parallel to serial converter converts the binary values to the serial and sends out the information bits. For the second model, it uses the concept of cyclic prefix that adds additional bits at the transmitter end and then the receiver removes these additional bits in order to minimize the inter symbol interference, improve the bit error rate and reduce the power spectrum.

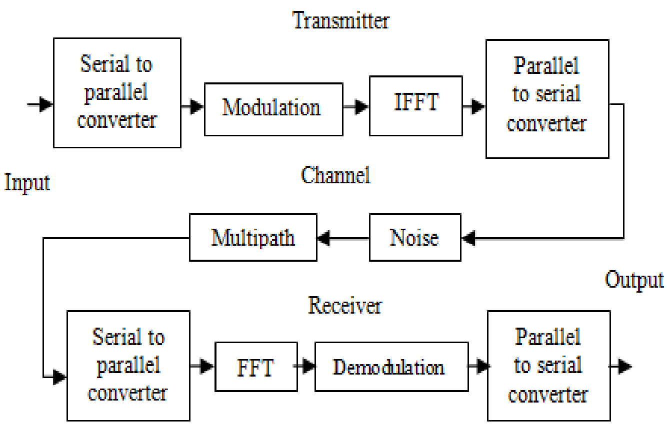

Fig. 4G OFDM Basic Model

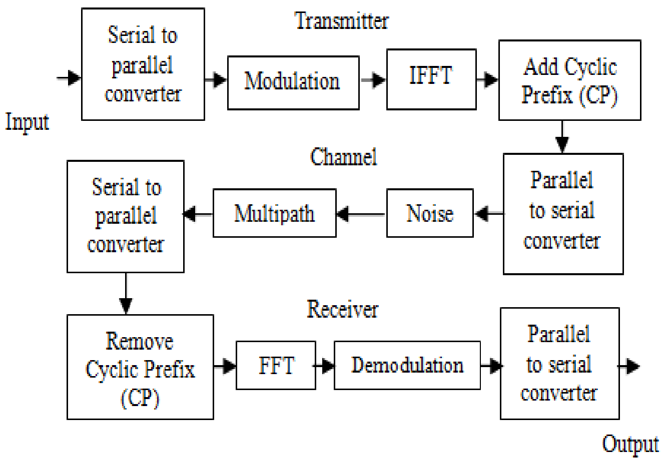

Fig. 4G OFDM Model with Cyclic Prefix

VI. CONCLUSION

A brief study of MIMO is done. It is quite clear that MIMO meets the requirements of 4G. Hence it can be used. It provides enormous data rate while limiting the probability of error as verified both theoretically and by simulation. The MIMO can be accomplished with OFDM resulting in MIMO-OFDM which uses the spectrum efficiently. The channel estimation problem is solved by using LMS and RLS algorithms. We see that the MIMO radar system is a breakthrough in military research and advancement. The MIMO technology will play an important role in coming generation wireless standards. The MIMO is being implemented in advanced radar systems. It ensures us better performance. In military this has become a very popular and important field of research.

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