Literature Review on Multiple-Input Multiple-Output- Orthogonal Frequency Division Multiplexing

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Abstract- Wireless Communication Wireless communications is one of the most active areas of technology development and a rapidly growing branch of the wider field of communications Systems. In the modern day world we are living today, communication has become an integral part of our lives in different forms. Communicate with one another via the avenues of telephones (fixed and mobile), radio and television, the internet on both mini and macro computer terminals, just to mention a few. Notwithstanding the type of communication Systems being used, the three major components of the communication Systems remain the same for all. These include source, channel and sink (transmitter, channel and receiver respectively). Both the transmitter and the receiver could either be fixed or mobile, and they are separated by the channel. The channel can be wire line or wireless. Irrespective of the type of channel, its effects on the transmitted signal from the transmitter through the channel to the receiver are similar. In this review paper we have presented the literature review on MIMO-OFDM which is very significant for wireless communication.

Keywords- Multiple-Input Multiple-Output (MIMO) - Orthogonal Frequency Division Multiplexing (OFDM); channel estimation; multipath propagation; MMSE; diversity.

I. INTRODUCTION

OFDM has become a widely accepted multi-carrier modulation method for signals transmission over wireless channels. Several wireless technologies and standards such as digital audio broadcasting (DAB), digital video broadcasting (DVB), high-rate wireless LAN standard such as the IEEE 802.11a, high-performance radio LAN type two (HIPERLAN/2), multimedia mobile access communication (MMAC), and the IEEE 802.16a metropolitan area network (MAN) standard, are all based on OFDM technique. OFDM is also seen as a potential candidate for the future generation of the mobile wireless Systems, especially the fourth generation (4G) Systems. The OFDM concept is based on the splitting of data stream with a high-rate into a number of lower rate streams that are transmitted simultaneously over a number of subcarriers. Thus, there is an increase in symbol duration for the lower rate parallel subcarriers which in turn reduces the relative amount of dispersion that is caused by multipath delay spread, in time. Though, in a bid to completely eliminate the inter symbol interference (ISI), a guard time is introduced in every OFDM symbol. As such, OFDM technology is seen as a scheme that transforms a frequency selective fading channel to a set of parallel flat fading sub-channels. Consequently, the receiver structure is drastically simplified, and the time domain waveforms of the sub-carriers become orthogonal to each other. In contrast to the normal Frequency Division Multiplexing (FDM) scheme where the subcarriers are non-overlapping, the signal frequency spectrum associated with different subcarriers overlap in frequency domain. The introduction of guard band between the different carriers in the conventional FDM, in a bid to get rid of the interchange interference, results in an inefficient use of the scarce and costly frequency spectrum resource. The overlapping of these subcarriers in the OFDM Systems makes possible efficient utilization of available bandwidth without causing the inter-carrier interference (ICI). Direct implementation of OFDM Systems is computationally complex because of the large number of subcarriers involved which would require an equal number of sinusoidal oscillators for coherent demodulation. Though, a breakthrough to the OFDM implementation came in 1971 when Weinstein and Ebert proposed an effective way of implementing the scheme through the application of Discrete Fourier Transform, which drastically reduces the implementation complexity of the OFDM modems. This substantial reduction in implementation complexity was attributable to the simple realization that the DFT makes use of a set of harmonically related sinusoidal and co sinusoidal basis functions, whose frequency is an integer multiple of the lowest nonzero frequency of the set, which is referred to as the basis frequency.

Advantages and Disadvantages of OFDM Systems

The various advantages and disadvantages of OFDM Systems can be highlighted as follows: Advantages of

OFDM Systems:

a. OFDM has immunity to delay spread. Hence the scheme is an efficient way to deal with the problem of multipath.
b. ii. It has resistance to frequency selective fading because each of the subchannels in OFDM is almost flat fading.
c. It exhibits efficient bandwidth usage, since the subchannels are kept orthogonal in the time domain but overlap in the frequency domain.
d. The implementation of OFDM Systems is simple by using FFT (Fast Fourier Transform).
e. The system's receiver complexity is low because of absence of multi-taps equalizer/detector.
f. OFDM possesses high flexibility in terms of link adaptation.
g. OFDM is robust against narrowband interference, because such interference affects only a few numbers of the subcarriers.

Disadvantages of OFDM Systems:

a. The scheme is sensitive to frequency offsets (caused by frequency differences between the local oscillators in the transmitter and the receiver), timing errors and phase noise.
b. It exhibits quite a high peak-to-average power ratio (PAPR) in comparison with single carrier system that seeks to lower the power efficiency of the Radio Frequency (RF) amplifier.

MIMO-OFDM Systems

The multiple transmitting and receiving antennas can be employed with OFDM to enhance the communication capacity and quality of mobile wireless Systems. MIMO as described above is known to boost capacity. In the case of high data-rate transmission, the multipath nature of the communication environment causes the MIMO channels to become frequency-selective. Though, as elucidated earlier, OFDM transmission scheme can convert such frequency-selective MIMO channels into an array of parallel frequency-flat MIMO channels by which the receiver complexity is drastically reduced. The combination of these two powerful techniques, MIMO and OFDM to form Multiple Input Multiple Output-Orthogonal Frequency Division Multiplexing (MIMO-OFDM) Systems, is very attractive, and is considered one of the most promising solutions to improve the signal rate of broadband wireless communication Systems. A schematic diagram of a MIMO-OFDM system is shown in Fig. 1. Assuming a MIMOOFDM system employing MT transmit and MR receive antennas with N OFDM subcarriers, channel encoded bits are first interleaved with a channel interleaver π and then mapped onto a number of data symbols via some modulation type such as Quadrature Amplitude Modulation (QAM) or Multilevel Phase Shift Keying (M-PSK). These symbols are then passed through the transmit diversity processor (e.g. a space-time encoder) that transforms them into MT different signals. Each of these signals forms an OFDM block, and they are passed through classical OFDM modulators (IFFT followed by cyclic prefix insertion) of K carriers.

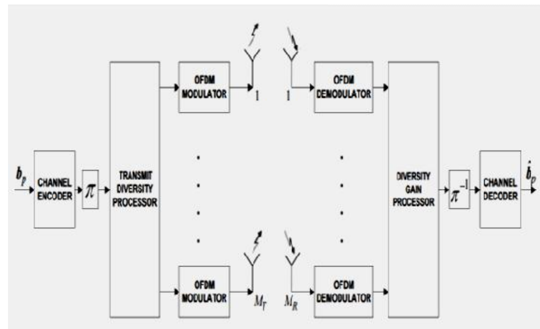

Fig.1 Diagram of MIMO-OFDM system

The resulting OFDM symbols are transmitted simultaneously from the individual transmit antennas. At the receiver, the individual signals are passed through OFDM demodulators which first discard the cyclic prefix and then perform the K-point FFT on the received signals. The outputs of the OFDM demodulator are passed through the diversity gain processor in a bid to achieve transmit diversity gain. The diversity gain processor's outputs are de-interleaved with a channel de-interleaver π^{-1} and then demapped from the QAM or M-PSK constellations. Thereafter channel decoder is used to decode the transmitted bits. Detailed of the basic concepts of the MIMO-OFDM system are well documented. Irrespective of the techniques being employed in wireless communication System (such as OFDM, MIMO, or MIMO-OFDM techniques) to combat the effects of the channel on the transmitted signals, the availability of the channel state information (CSI) at the receiver end of the communication system remains a crucial factor for effective functioning of these techniques as well as for the successful recovery of the transmitted signal.

II. SYSTEM MODEL

Consequently, the cost of extra antennas at base station can then be paid by service provider. The Multiple-Input Multiple-Output (MIMO) combined the performance gains that are achievable in both the transmit antenna diversity and the receive antenna diversity Systems with the use of multiple antennas at both end of the communication link.

The main idea behind MIMO is that signals sampled in the spatial domain at both ends are combined in such a way that they either create effective multiple parallel spatial data channels (therefore increasing the data rate), and/or add diversity to enhance the bit-error rate (BER) performance of the Systems. The idea of spatial diversity is that in the presence of random fading occasioned by multipath propagation, the signal-to-noise ratio (SNR) is significantly improved by combining the output of decorrelated antenna elements. The early 1990s witnessed new proposals for using antenna arrays to increase the capacity of wireless links thereby creating several opportunities beyond just diversity [1].

Performance gain in MIMO Systems The performance benefits available as a result of using the MIMO Systems are largely due to spatial multiplexing gain, diversity gain, array gain, and interference reduction. Each of these is briefly described below with assumption of having MT and MR numbers of transmit and receive antennas respectively. Spatial multiplexing gain: Spatial multiplexing technique is the simultaneous transmission of multiple data signals from transmitter to the receiver, with both equipped with more than one antenna. Consequently, MIMO system is able to offer a linear capacity proportional to the minimum number of either the transmit antennas or the receive antennas, in comparison with Systems employing single antenna at one or both end of the links, for no extra power or bandwidth expenditure [2].

Minimum Mean Square Estimation

In MMSE estimation here there are calculating the second order statistics of the channel to minimize the MSE let $\bar{g} = [g_n]^T$ is sampled channel impulse response and $\bar{n} = [n_n]^T$ (0,…………N-1) is the AWGN channel noise matrix $\bar{H} = FFT_N(\bar{g}) = F\,\bar{g}\ And\ \bar{N} = F\,\bar{n}$ and corresponding auto covariance matrix are $R_{gg},, R_{HH}\ and\ R_{YY}$ and corresponding cross covariance matrix is given by R_{gY}, It is derived that.

$$R_{HH} = E\{\bar{H}\,\bar{H}^H\} = F\,R_{gg}F^{\,H}\ (2.5)$$

$$R_{gY} = E\{\bar{g}\,\bar{Y}^H\} = R_{gg},F^H\ X^H\ (2.6)$$

$$R_{YY} = E\{\bar{Y}\bar{Y}^H\} = XFR_{gg}F^H\ X^{\,H} + \sigma_N^2\ I_N\ (2.7)$$

$\hat{g}_{mmse} = R_{{g}^{Y^{-1}}}\ Y^{HH}$ Final MMSE estimation is given by:

$$\hat{H}_{mmse} = F\,\hat{g}_{mmse}\ (2.8)$$

Minimum mean square error has greater performance, and so the least square estimation, but it increases the complexity. Used in low SNR circumstances LMMSE are widely applied to cut complexity [3].

III. LITERATURE REVIEW

Wireless communication has become one of the fastest growing industries during the last few decades. Over 2 billion users are involved and make it one of largest research and business fields [1]. With the development of mobile devices, many technical challenges have arisen such as video streaming, online-gaming and real-time video meeting. Hence, the 3rd and 4th generations of cellular systems such as WiMAX [2], LTE, and LTE Advanced [3] have been deeply studied and deployed in many developing and developed countries. Though, a higher quality of service is required for the current systems, that is, higher data rate, higher spectral efficiency and more reliable link. These features must be provided with lower cost (reduced size of equipment and less energy consumption). MIMO-OFDM has been employed in LTE-Advanced. A tradeoff between complexity and performance may be required in the sense that the suboptimal detection methods have lower complexity at the expense of poorer performance compared to ML receivers. In addition, hundreds of subcarriers have been exploited in such systems, which make the receiver design more complicated than narrow-band MIMO systems.

Sahrab, A.A.; Marghescu, I. [1] presented a Multiple-Input Multiple-Output (MIMO) systems that offer considerable increase in data throughput and link range without additional bandwidth or transmit power by using several antennas at transmitter and receiver to improve wireless communication system performance. At the same time, Orthogonal Frequency Division Multiplexing (OFDM) has becoming a very popular multi-carrier modulation technique for transmission of signals over wireless channels. OFDM eliminate Inter-Symbol-Interference (ISI) and allows the bandwidth of subcarriers to overlap without Inter Carrier Interference (ICI). A MIMO-OFDM modulation technique can achieve reliable high data rate transmission over broadband wireless channels. This research deals with the analysis of a MIMO-OFDM system by using a MATLAB program. The performance of the system is evaluated on the basis of Bit Error Rate (BER) and Minimum Mean Square Error (MMSE) level.

Randhawa, N.S.; Khurana, S. [2] described a MIMO-OFDM is the foundation for more advanced wireless local area network (Wireless LAN) and mobile broadband network standards because it achieves the greatest spectral efficiency and, delivers the highest capacity, data throughput and higher data rates. But, as the environment is wireless, the information being sent in such systems causes attenuation, path dispersion and ISI (Inter Symbol Interference). The ISI causes Bit Error Rate and degrades the performance of the system. The literature gives linear and nonlinear equalizers to overcome this ISI. The work focuses on hybridizing the results of linear and nonlinear equalizers and the use of optimal detection to minimize ISI with improved SNR and higher receiver diversity. The outcomes carried out in MATLAB shows an improvement of BER (0.001 at 12 dB SNR) when using the proposed equalizer compared to the existing equalizers. An enhancement in error rate performance has carried out.

Chaudhary, S.R.; Thombre, M.P. [3] investigated the wireless broadband communication has gained attention due to ever growing demands of multimedia and internet services. The major challenges faced by wireless communication are availability of resources like bandwidth and transmission power. Also the wireless channel suffers from impairments like fading and interference. Technologies that achieved above requirements are Multiple Input Multiple Output (MIMO) and Orthogonal Frequency Division Multiplexing (OFDM). Channel impairments must be mitigated at the receiver by using equalization techniques. In this research, BER performance improvements of MIMO-OFDM systems using different equalization techniques such as Zero forcing (ZF), Minimum mean square error (MMSE) and Maximum likelihood (ML) are exposed and compared. Outcomes are carried out under Rayleigh frequency flat channels.

Peng Xu; Jiangzhou Wang; Jinkuan Wang [4] investigate the uplink transmission in multi-cell multi-user multiple input multiple output (MIMO) orthogonal frequency division multiplexing (OFDM) systems. The approach exploits the space-alternating generalized EM (SAGE) iterative process to decompose multi-cell multi-user MIMO problem into a series of single-cell single-user SISO problems, which reduces the complexity drastically. Analysis on mean square error (MSE) of H-inf in the presence of PC is also presented. The result shows that increasing the number of pilot subcarriers cannot mitigate PC, and a clue for relieving PC can be obtained. The H-inf realizes better suppression to PC than the LS and ML algorithms. Its performance is close to the optimal MMSE algorithm and can be improved as the increase in the length of channel impulse response (CIR). By using the SAGE process, the performance of the H-inf does not degrade in case of a large number of antennas at base station (BS).

Song Noh; Zoltowski, M.D. [5] proposed Semi-Blind/Blind channel estimation for multiple-input multiple-output (MIMO) orthogonal frequency-division multiplexing (OFDM) systems has received a lot of attention in recent years. A new linear precoder for blind channel estimation is proposed in which only a small number of subcarriers carry symbols that are linearly precoded to effect the inter-symbol correlation needed for the blind channel estimation scheme to function properly. The proposed precoding scheme leaves most of the subcarriers intact, thereby minimizing the number of symbols that have to be jointly estimated via either Maximum Likelihood (ML) or MMSE. An optimal precoder under the sparse structure is developed, which insures that the precoder matrix is well-conditioned to minimize any noise enhancement that may occur in the process of MMSE based joint symbol estimation.

Senning, C.; Burg, A. [6] presented an architecture for an MMSE filter matrix computation unit for signal detection in MIMO-OFDM communication systems. Authors propose to compute the required matrix inverse based on Cholesky decomposition, followed by a Gauss-Jordan matrix inversion of the resulting triangular matrix. The high dynamic range required by this approach is traditionally conquered with custom floating-point formats or with fixed-point number representations with a large number of bits. In this research a block-floating point scheme with only two normalization steps throughout the computation of the MMSE filter matrix is sufficient to achieve a BER performance close to that of a double precision floating point implementation for MIMO-OFDM systems with 64-QAM modulation. The corresponding circuit complexity is superior to that of a pure fixed-point implementation.

IV. PROPOSED METHODOLOGY

The performance of MIMO-OFDM communication systems is studied on the basis of BER and using MMSE (aids in the elimination of ISI thus improving overall performance) level with Alamouti and SM algorithms. Further enhancement of performance may be achieved through maximum diversity STBC. The modulation type (BPSK, QPSK, 16QAM, and 64QAM) are clearly affecting the performance. In the case of AWGN channel the performance of single carrier and OFDM systems are comparable but the overall performance of the second one is higher having in mind that the OFDM systems achieve a higher capacity, coverage and reliability.

V. CONCLUSION

Multi-input and multi-output (MIMO) and orthogonal frequency division multiplexing (OFDM) have attracted significant attention, and become promising techniques for high data rate wireless communication systems. They have been widely studied and employed for 4G systems such as WiFi Emerging from this migration is the multiple-input multiple-output (MIMO) Systems. From the spectral efficiency angle of wireless communication is the emergence of orthogonal frequency division multiplexing which find deployment in both single antenna and multiple antenna wireless communication Systems. The concepts of MIMO and the OFDM were collective with the emerging intent of exploiting the advantages of both techniques. This combination has given the development to MIMO-OFDM wireless communication Systems with the expectation of having spectrally efficient, high data rate system that is robust to frequency selective fading channels.

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