International Journal of Scientific Research and Management Studies (IJSRMS)
ISSN: 2349-3771 Volume 3 Issue 1, pg: 55-60

A REVIEW OF MIMO SYSTEMS IN WIRELESS COMMUNICATION

Abhishek Tandon, Keshav Mehrotra, Ruchi Varshney
ECE Department, Moradabad Institute of Technology,
Moradabad, Uttar Pradesh, India.

ABSTRACT
In this paper we have presented an overview of MIMO systems in Wireless communication systems which are the breakthrough in wireless communication technology nowadays. MIMO systems are used to improve the noise and interference performances of a channel. In this paper, the use of MIMO systems to improve channel capacity and BER is also highlighted. The discussion then proceeds further towards the advancements in this technology in modern scenario which includes merger of OFDM with MIMO. By the use of MIMO-OFDM, very high data rates are achieved.

KEYWORDS: *MIMO, OFDM, BER, SNR, AWGN.*

I. INTRODUCTION

Multiple Input Multiple Output (MIMO) systems are a natural extension of developments in antenna array communication. MIMO systems consist of multiple transmitting antennas at the transmitter and multiple receiving antennas at the receiver. The advantages of MIMO communication, which exploits the physical channel between many transmit and receive antennas, are currently receiving significant attention.

MIMO systems provide a number of advantages over single-antenna-to-single-antenna communication. Sensitivity to fading is reduced by the spatial diversity provided by multiple spatial paths. Under certain environmental conditions, the power requirements associated with high spectral efficiency communication can be significantly reduced by avoiding the compressive region of the information-theoretic capacity bound. Here, spectral efficiency is defined as the total number of information bits per second per Hertz transmitted from one array to another.[1]

Impressive improvements in capacity and bit error rates (BERs) have increased the recent interest in multiple-antenna systems. Along with the gains, however, comes a price in hardware complexity. The radio front end has complexity, size and price that scale with the number of antennas. It is possible to alleviate this cost and at the same time capture many of advantages of MIMO systems by a technique known as antenna selection.

Capacity of the channel increases linearly with signal-to-noise ratio (SNR) at low SNR, but increases logarithmically with SNR at high SNR. In a MIMO system, a given total transmit power can be divided among multiple spatial paths, driving the capacity closer to the linear regime for each mode, thus increasing the aggregate spectral efficiency [6, 7]. MIMO systems enable high spectral efficiency at much lower required energy per information bit. The graph of channel capacity versus no. of antenna elements is shown in figure 1. From the graph, it is clear that MIMO capacity has linear relationship while SIMO/MISO capacity has logarithmic relationship with the number of antenna elements. Thus, making MIMO, the subject of discussion for efficient wireless communication.

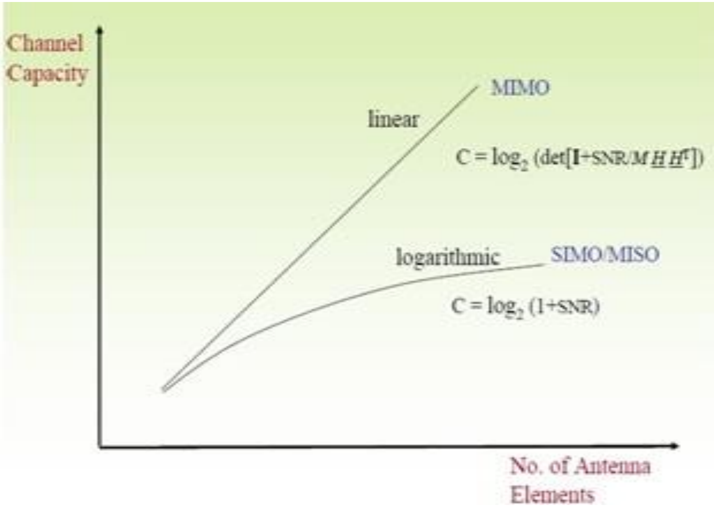

Fig. 1: Graph showing the variation of channel capacity with number of antenna elements.

II. SYSTEM MODEL

It is common to represent the input/output relations of a narrowband, single-user MIMO link by the complex baseband vector notation

$$y = Hx + n \quad \ldots(1)$$

where x is the (nT×1) transmit vector, y is the (nR×1) receive vector, H is the (nR×n) channel matrix, and n is the (nR×1) additive white Gaussian noise(AWGN) vector at a given instant in time. Throughout the paper, it is assumed that the channel matrix is random and that the receiver has perfect channel knowledge. It is also assumed that the channel is memory less, i.e., for each use of the channel an independent realization of H is drawn. Figure 2 shows the general working of an NxM MIMO system. At the input of a communication system, discrete source symbols are mapped into a sequence of channel symbols. The channel symbols are then transmitted or conveyed through a wireless channel that by nature is random (as shown in figure 3). In addition, random noise is added to the channel symbols. In general, it is possible that two different input sequences may give rise to the same output sequence, causing different input sequences to be confusable at the output.

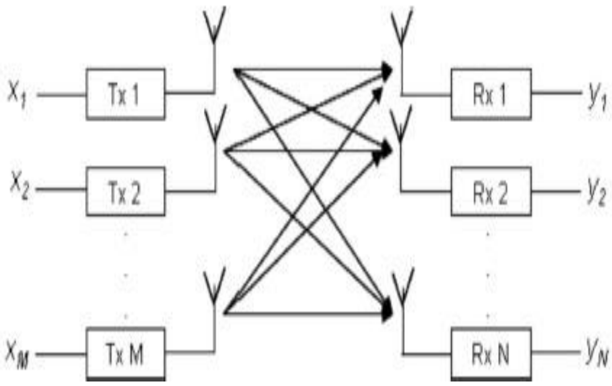

Fig. 2: An NxM MIMO System

To avoid this situation, a non-confusable subset of input sequences must be chosen so that with a high probability, there is only one input sequence causing a particular output. It is then possible to reconstruct all the input sequences at the output with negligible probability of error.[2] A measure of how much information that can be transmitted and received with a negligible probability of error is called the channel capacity. A general block diagram of an NxM MIMO system is shown in figure 3 where N represents number of receive antennas while M represents number of transmit antennas. In the figure, $x_1, x_2 \ldots x_M$ are the symbols to be transmitted by $1^{st}, 2^{nd}, \ldots M^{th}$ transmitting antenna and

$y_1, y_2, \ldots y_N$ are the symbols received by 1st, 2nd, … Nth receiving antenna respectively at the transmitter and receiver sides.

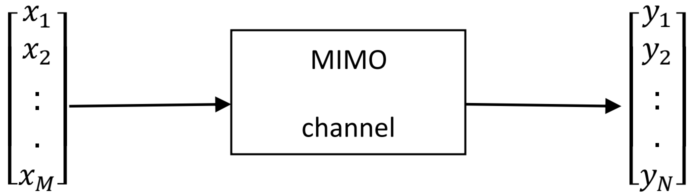

Fig. 3: General Block Diagram of an NxM MIMO System

III. DISCUSSION

Regarded as a breakthrough in wireless communication system design, multiple antenna systems fuel the ever increasing data rate requirements of advanced technologies like LTE, WLAN etc.
The use of MIMO systems in wireless communications have led us to overcome several problems related to wireless communication like fading, multipath, etc. The concept of spatial diversity is used to increase the reliability of data and spatial multiplexing is used to increase the data rates of the communication channels. There is usually a primary (direct) path from transmitter to receiver and some of the transmitted signals take other paths to the receiver like bouncing off objects, ground or layers of atmosphere. The signals traversing indirect path arrives at the receiver with a delay and often gets attenuated. A common strategy for dealing with weaker multipath signals is to ignore them but the energy in this case is wasted. The strongest multipath signals may be too strong to ignore and also can degrade the performance of the wireless equipment. The strongest signal in each moment in time is received and adds different delays to received signals to force the peaks and troughs back to alignment this concept is used in MIMO and thus MIMO takes advantage of multipath. Multipath occurs when the different signals arrive at the receiver at various times.
Instead of increasing data rate or capacity, MIMO can also be used to exploit diversity. Transmit diversity schemes are already known from WCDMA release 99 and will also form part of LTE as one MIMO mode. In case the channel conditions do not allow spatial multiplexing, a transmit diversity scheme will be used instead, so switching between these two MIMO modes is possible depending on channel conditions. Transmit diversity is used when the selected number of streams (rank) is one. The same data is coded and transmitted through different antennas which effectively double the power in the channel. This improves SNR for cell edge performance.
In MIMO systems the trade-off exists between the spatial multiplexing and the spatial diversity. Pure spatial multiplexing allows for full independent use of the antennas. However, it gives limited diversity benefit and is rarely the best transmission scheme for a given BER (Bit Error Rate) target.[3]
The possibility of a linear capacity growth with the number of antennas is good, especially knowing that increased power (SNR), coding the symbols within a block can result in additional coding and diversity gain, which can help improve the performance and robustness, even though the data rate is kept at the same level. It is also possible to sacrifice some data rate for more diversity.[4]

IV. ADVANCEMENTS IN MIMO

OFDM is a key technology which stands for Orthogonal Frequency Division Multiplexing. It is a method of encoding digital data on multiple carrier frequencies. It is a specialized FDM (Frequency Division Multiplexing) in which all carrier signals are orthogonal to each other. This technology is employed in 4G wireless systems such as for instance LTE (Long Term Evolution) is 4G cellular standards. Another competing 3.75G standard is WiMAX (Worldwide Interoperability for Microwave Access). These both are dominant standards and both of these are based upon OFDM. Another standard is LTE-A (Long Term Evolution Advanced) is also based on OFDM. So, OFDM is a key wireless broadband technology. Here, by broadband it means that a wireless system which has a large bandwidth which means that OFDM is a broadband technology which operates on a huge bandwidth or a very large band for example a GSM system has a bandwidth of 200kHz but an OFDM system can have a bandwidth of 20MHz. Since it has a large bandwidth therefore naturally the data rates are higher and the higher data rates are used in 3G & 4G wireless systems. These higher data rates are of the order of hundreds of Mbps. So LTE and LTE-A which are based on OFDM are operated thereby at cellular systems and can enable very high data rates, this is possible because of OFDM.[5] Considering a communication system has bandwidth (B) and a single carrier of certain frequency. Now for instance if B=10MHz. So, this is a broadband system of bandwidth 10 MHz. The communication system that is implemented over this bandwidth has a symbol time (T) given by:

$$T = \frac{1}{B} \quad \ldots (2)$$

$$T = \frac{1}{10 * 10^6}$$

$$T = 0.1\ \mu s$$

However, the delay spread (T_d) is defined as the difference between the time of arrival of the earliest significant multipath component (typically the line-of-sight component) and the time of arrival of the latest multipath components. T_d of a wireless system is approximately 2-3μs. Therefore, symbol time is much less than delay spread. Here, delay spread is 20 times that of symbol time.

As from the property of wireless channel that when delay spread is larger than the symbol time this leads to a problem of ISI (Inter Symbol Interference). So, symbol time (T) has inverse relation with bandwidth (B) means more is the bandwidth of the channel, lesser is the symbol time and if this T is less than T_d this leads to a problem of ISI. When interference occur this leads to a degradation or loss of performance for wireless communication system. Therefore ISI leads to degradation in performance and this is a significant challenge in broadband wireless system. In order to overcome this problem instead of taking the entire bandwidth (B) it is split into sub bands (smaller bands). Earlier, there was single carrier and now there are multiple carriers in each sub band and this is termed as subcarrier. If it is assumed that bandwidth (B) is split into N sub bands then bandwidth of each sub band (B_s) is given by:

$$B_s = B/N \ldots (3)$$

For example: If B = 10 MHz and N = 1000 then bandwidth of each sub band is,

$$B_S = \frac{10\text{MHz}}{1000} = 10000 = 10\text{kHz}$$

Also, symbol time of each sub band (T_s) is given by,

$$T_s = \frac{1}{B/N} = \frac{N}{B} \quad \ldots (4)$$

$$T_s = \frac{1}{10\text{kHz}} = 100\mu s$$

Now, if this symbol time of each sub-band (T_s) is compared with delay spread (T_d) then T_s is much greater than T_d. Therefore, there is no Inter Symbol Interference (ISI) in this system which has multiple sub bands and subcarrier in each band and such a system is called as Multi Carrier Modulated (MCM) system. This system is the basis of OFDM system.

The use of OFDM modulation with in MIMO-structured systems creates a strong system that has the ability to successfully reject fading and fulfils the need for high throughput. The increased capacity of MIMO channels can be translated into increased throughput provided that proper coding is done prior to transmission.

V. CONCLUSION

MIMO will ultimately benefit every major wireless industry including mobile telephones, wireless LAN industries and many other industries as well. Also, LAN industry is leading the way in mobile innovations. That is why MIMO-OFDM is the foundation of all proposals for the IEEE 802.11n standard MIMO-OFDM. For the same throughput, MIMO-OFDM achieves a range that is about 3 times larger than non-MIMO systems. This significant improvement in range-rate performance makes MIMO-OFDM the ideal solution not only for wireless LAN, but also for home entertainment networks and 4G networks).The areas where MIMO techniques add significant value to wireless system includes WLAN – WiFi 802.11n, Mesh Networks (e.g., Muni Wireless), WMAN – WiMAX, 4G, Cellular, RFID, Mobile satellite TV, Satellite radio, Digital Home. In general, MIMO exploits the multipath by spatial diversity as well as spatial multiplexing techniques. The improvement in wireless communication performance, at no cost of extra spectrum (only hardware and complexity are added), is largely responsible for the success of MIMO as a topic for new research and hence it is considered as an independent subject. The MIMO multiplies speed to deliver high bandwidth application such as streaming multimedia.

REFERENCES

[1]. Daniel W. Bliss, Keith W. Forsythe, and Amanda M. Chan, “MIMO Wireless Communication” Lincoln Laboratory Journal Volume 15, Number 1, 2005.
[2]. Jaya Misra, RakeshMandal, “A Review on Various Approaches to Reduce Intersymbol Interference in MIMO – OFDM System” IJIRST –International Journal for Innovative Research in Science & Technology| Volume 1 | Issue 8 | January 2015.
[3]. ShahabSanayei and Aria Nosratinia, University of Texas at Dallas, “Antenna Selection in MIMO Systems,” IEEE Communications Magazine, October 2004.
[4]. UpenaDalal, “Wireless Communication”, OXFORD university press, pp. 636-669, 2009.
[5]. Betsy Jose and Mr.B.Sathish Kumar, “Design of MIMO OFDM SDM Systems for High Speed DataTransmission,” International Journal of Information & Computation Technology. ISSN 0974-2239 Volume 4, Number 1 (2014), pp. 1-8.
[6]. BengtHolter, “On the capacity of themimo channel- a tutorialintroduction”,Norwegian University of Science and Technology,Department of Telecommunications, 2001.
[7]. Arif Khan, Rein Vesilo,“A Tutorial on SISO and MIMO Channel Capacities”, Department of Electronics, Macquarie University NSW, Sydney Australia.
[8]. Zhang Xinyu and Tian Jingyun, “Study on Capacity of Channel in MIMO System”, International Conference on Communication Software and Networks (*ICCSN), IEEE 2011*.
[9]. GU Zheng-gang, "Analysis of the capacity for MIMO system," Journal of Ningbo Polytechnic, Vol. 14th, 2010.
[10]. Li, Ye (Geoffrey) et al., "Signal Detection for MIMO-OFDM Wireless Communications", 2001 IEEE, pp. 3077-3081.
[11]. Erik G. Larsson, Ove Edfors, “Massive MIMO for next generation wireless systems” IEEE Communications Magazine, February 2014.
[12]. M. Corson, R. Laroia, J. Li, V. Park, T. Richardson, and G. Tsirtis, “Towards proximity-aware internetworking,” IEEE Wireless Communications Magazine, vol. 17, no. 6, pp. 26–33, Dec. 2010.
[13]. M. Maddah-Ali, A. Motahari, and A. Khandani, “Communication over MIMO X channels: Interference alignment, decomposition, and performance analysis,” IEEE Trans. Inform. Theory, vol. 54, no. 8, pp. 3457–3470, Aug. 2008.
[14]. Taesang Yoo *and* Andrea Goldsmith, “Capacity and Power Allocation for Fading MIMO Channels With Channel Estimation Error” IEEE Transactions On Information Theory, VOL. 52, NO. 5, MAY 2006.
[15]. Jiyu Sun, Hong Xie, Dongming Li, “Capacity in MIMO Channels Based on Different Power Allocation” Fifth International Conference on Internet Computing for Science and Engineering, 2010.

ABOUT THE AUTHORS

Ruchi Varshney: She received the degree of Bachelor of Technology in Electronics and Telecommunication engineering from J.K Institute Allahabad, Allahabad University, India in 2002 and Master of Technology degree in Micro Electronics- VLSI Design from Uttar Pradesh Technical University, Lucknow in 2009. She is currently working as an Assistant Professor with the department of Electronics and Communication Engineering, Moradabad Institute of Technology, Moradabad, Uttar Pradesh, India. Her current research interests include Artificial Neural Networks, MIMO systems and pattern recognition. She is a live member of Indian Society for Technical Education.

Keshav Mehrotra: He is pursuing the course of Bachelor of Technology from Moradabad Institute of Technology, Moradabad from Electronics and Communication branch. His areas of research interest include wireless communication systems, MIMO-OFDM technology, design of compact Integrated Circuits and Microelectronic devices.

Abhishek Tandon: He is pursuing the course of Bachelor of Technology from Moradabad Institute of Technology, Moradabad from Electronics and Communication branch. His areas of research interest include Switching Theory and Logic Design, wireless communication systems and MIMO-OFDM Technology.