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A Survey on Spatial Modulation and MIMO System for Emerging Wireless Communication

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Abstract: ***In this paper we have studied about Spatial Modulation (SM) in MIMO system. Spatial modulation is a unique and newly proposed technique. Spatial modulation is a multiple input multiple output technique which provides higher throughput and gain as compared to Quadrature Amplitude Modulation. Spatial modulation is a technique which enhances the performance of MIMO system. Spatial modulation and MIMO technique are used to attracted research for its high energy and spectral efficiency because it is working on single RF chain. This paper has considered the advantages of spatial modulation and MIMO systems, using different technique to improve the bandwidth efficiency. Some of such MIMO systems applications are discussed wherein become a requirement for an emerging wireless communication system.***
Keywords- MIMO (multiple input multiple output), spatial modulation, OFDM (orthogonal frequency division multiplexing), Symbol Error Rate, Inter channel interference.

I. INTRODUCTION

In today's world the demand for large bit rate and high bandwidth efficiency for the coming generation communication systems and nowadays we are sending and receiving signals very frequently and for good communication we require good transceiver system with low error rate. Throughout this paper we will discuss about the MIMO systems and SM which provide advantages like high gain, high bandwidth, compactness etc. Our current wireless communication system works on 4G and experiencing shortage of bandwidth and lack of speed and also high traffic and so mm wave technology comes to the rescue to enable 5G era with Giga bit per second data rates.

In MIMO system, reduces the energy efficiency and consume the large amount of power during the transmission because in MIMO all antennas are functional mode and that time large amount of power deplete that's why this is a drawback in MIMO. So take of controlling transmission which scheme which can improve the transmission efficiency at moment of time is known as Spatial Modulation (SM) that increases the bit rate. Already we have lot of modulation technique like amplitude modulation, angle modulation and digital modulation techniques is also available, amplitude shift keying, frequency shift keying, phase shift keying and QAM but somewhere lack of data speed.

Spatial modulation is a currently proposed technique for multiple input multiple output transmission techniques with a very low system complexity at the receiver side improved data rate [2]. OFDM is a description of digital transmission technique and a method of encoding digital data on multiple carrier frequency and it is promoted for a wideband digital communication and its application such as wireless LAN, digital television, Audio broadcasting and wireless networks 4G/5G mobile communications.

1) *Spectral Efficiency:* Band efficiency is the ratio of data rate in bit per second to the effectively utilized channel bandwidth.

SE = Data rate in bit per second\Total bandwidth in Hz

2) *Energy Efficiency:* It is the ratio of data throughput in bit per second per kilometer square to the energy consumption in joule per second per kilometer square.

EE = Data throughput in bits per second per km^2/Energy consumption in joule per second per km^2

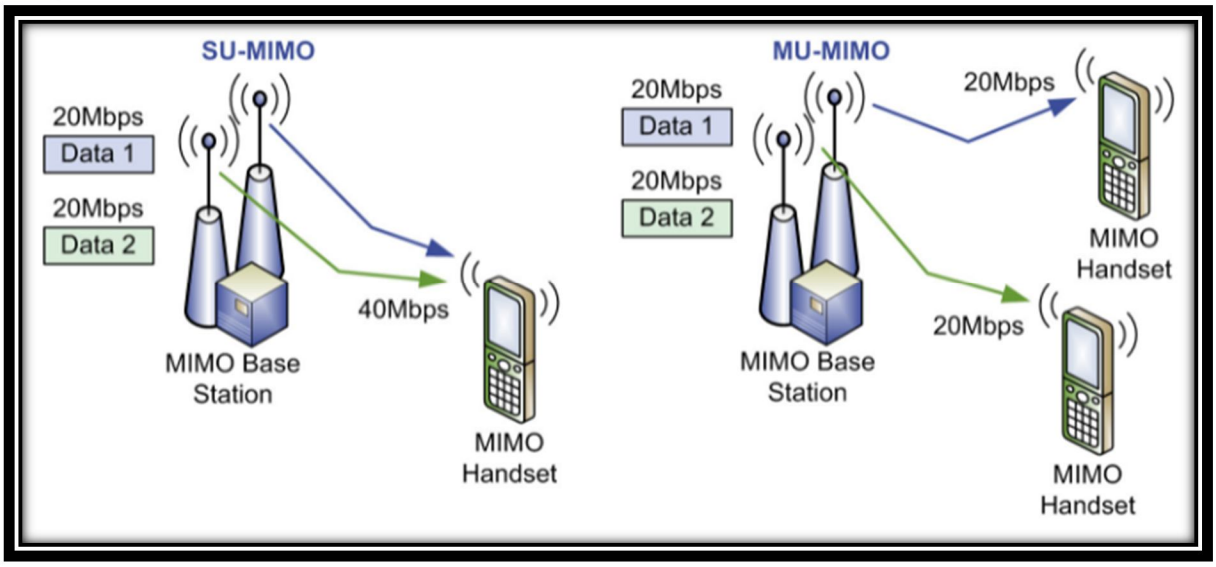

Fig. 1 Compare with SU-MIMO & MU-MIMO [17]

Above figure shows the example of MIMO system. First part shows the SU-MIMO and second part shows the MU-MIMO systems. Data is transmitting both SU-MIMO & MU-MIMO system but MU- MIMO increases the gain overall the system capacity.

a) Single user- MIMO- It consists of only one antenna and antennas are connected both transmitter side and receiver side.
b) MU-MIMO has been consists of large number of antenna are connected transmitting and receiving end.
c) Massive MIMO- It contains the greater than the hundred of antennas are used. The increased use of massive MIMO and smart antenna system increased the spectrum efficiency and user throughput

II. MIMO SYSTEM

Already we had single input and single output (SISO), multiple input single output (MISO), single input multiple output (SIMO). These techniques have some limitations like less efficiency, low SNR. These problems are overcome by using MIMO technique. So, the MIMO techniques is without wired technology that uses no single input and no single output antennas but large number of antennas are connected at the transceivers. So, the multiple transmitters and multiple receivers to transfer more data synchronously. A MIMO technique introduce the solution of increasing the bandwidth efficiency& this technique could use in 5G and 6G because in today scenario large amount of data are consume for digital classes, digital home, taking with one-another.

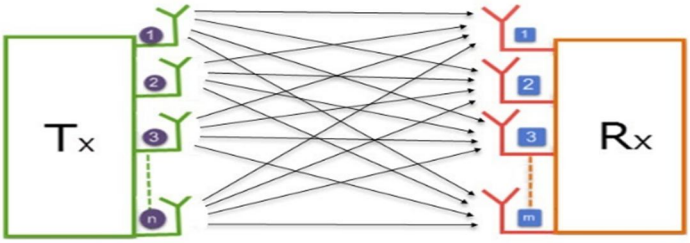

Fig.2 Basic block diagram of MIMO system [18].

1) In above diagram, large number of transmitting and receiving antennas have connected at the sending and receiving end.
2) MIMO is not energy efficient because when all multiple antenna will active they will dissipate energy.
3) As every antrenna consists of circuit of RF amplifiers so the operartional amplifier and power amplifier which required power to run and dissipate energy.
4) In case of MIMO, when multuple antenna's work at a time so all antenna's containing circuitry inside them and in working condition and will dissipated energy.
5) More number of antenna then more number number of power is comsume but for energy efficient MIMO is connected to spatial modulation(SM) because of SM at a time one antenna is active for transmitting the information.

A. Application of MIMO System

1) MIMO Smart Antenna: Smart is nothing but it adapts the array of antennas. This technique has used in 5G, LTE, UTMS and radio telescope.

2) Multi user beam forming antennas: This technique allocated large number of antennas with Wi-Fi router synchronically. By this technique magnify the speed of data with minimize the time.

3) MIMO antenna for millimeter wave frequency:

4) Digital home by using SM-MIMO concept.

5) Application of MIMO system uses different area like LTE (Long Term Evolution), Wi-Fi and other radio wireless and RF technologies are using the new MIMO wireless technology to increase the capacity and spectral efficiency with reduces interference paths [20].

6) MIMO system have worked both MISO and SIMO techniques, combined result shows the massive MIMO which maximize the SNR.

III. SPATIAL MODULATION

Spatial modulation is a novel auspicious modulation technique that manages the bit rate and bandwidth efficiency. Spatial modulation has worked in two modes. First one is information bits are pointed in constellation diagram in the signal and second one is transmitting antenna chosen for a particular spatial domain [3]. In [3][4] analysis of SM have using only one antenna in active mode while other antenna in passive mode at that time minimize the ICI(inter channel interference) and remove the inter antenna synchronization during the transmission of information.

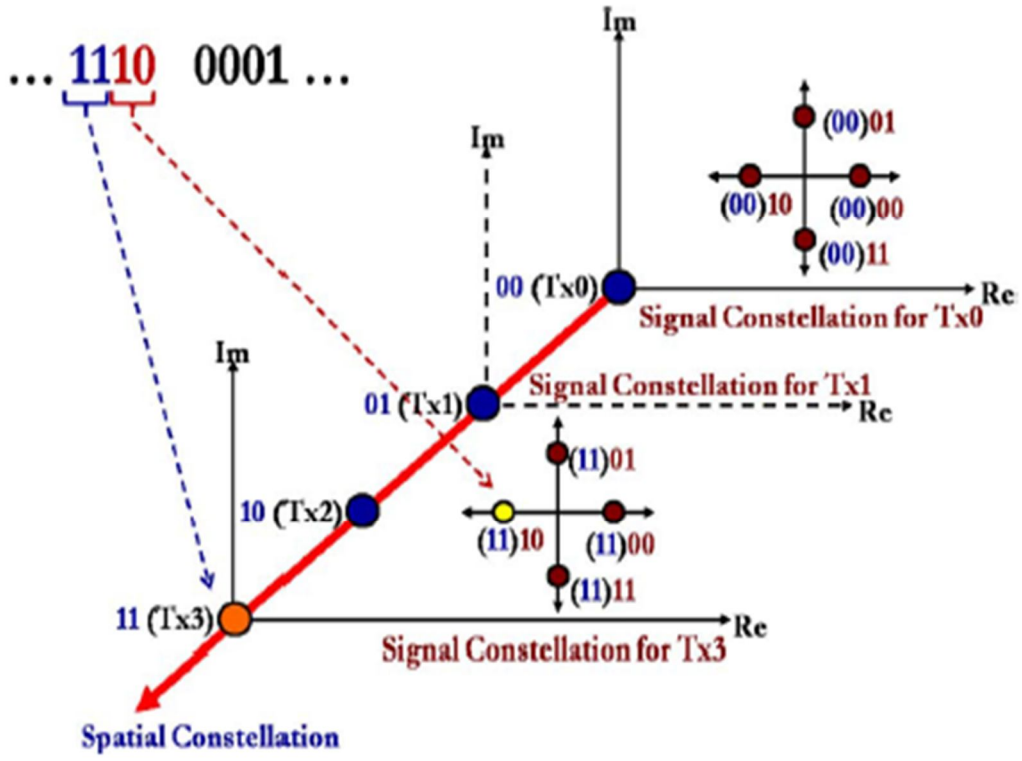

Fig.3 Cubic like Constellation diagram, data is pointed in space [6]

As compare to spatial modulation and SSK (spatial shift keying) SM is better than the SSK because in SSK constellation is not used. BUT in SM constellation function is used that's why its efficiency is higher than SSK [1].

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A. Transmitter & Receiver With Optimal Detection

In [2], author discuss about the spatial modulation and the order of sub optimal detection. MRC (maximum ratio combining) shows the detection of transmit antenna number.

$$ě = \arg\max kj$$

$$ň = F(kj)$$

ě and ň shows the estimated antenna & symbol vector, F represented the constellation of function. So the mapping of data is one by one and estimated data is ě and ň.

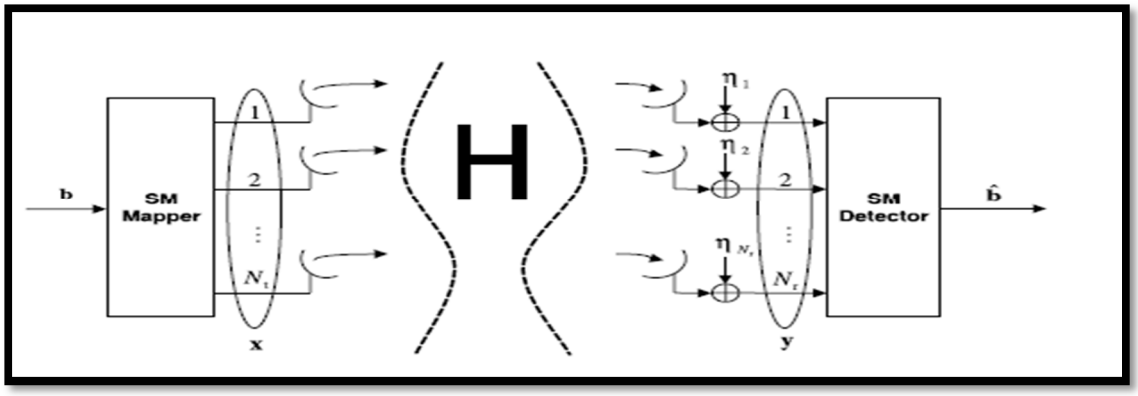


Fig. 4 System model of Spatial Modulation [4].

In [4], above diagram is proposed by Jeyadeepan Jeganathan, Ali Ghrayeb for enhancing the spectral efficiency and minimizing the delay and author drive type optimal detector with spatial modulation system significantly performance is better than OFDM has become a widely accepted technique to combat ISI present in frequency selective channel, such as the ones conveying very high data rates, the original approx. 4 dB gain [2].

$$B=Hx+Y$$

Where, channel may be correlated and uncorrelated for sending and receiving the information of $N_t \times N_r$ By using the Spatial modulation at the transmitter side and receiver side used the SM detector which reduce the complexity of the system and improve the efficiency using the spatial modulation and mapping bits are mapped in a sequence order. Y represents the white Gaussian noise, x represented the space vector.

Channel capacity of SM-MIMO system is given below:
The mathematical expression is given as: Capacity of Channel = BW log 2(1 + SNR)
C-denoted the capacity, B-denoted the bandwidth of channel, SNR= signal power/noise power.

IV. RECENT PROPOSEL AND RELATED WORK ON SM IN MIMO SYSTEM

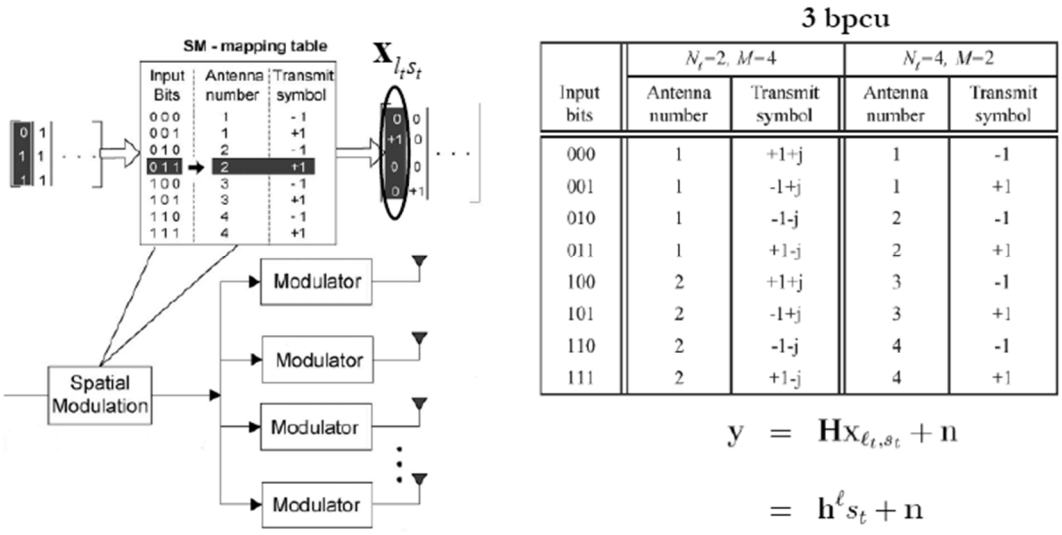
The author studied the paper on the spatial modulation and MIMO system:

Read Y. Mesleh, Harald Hass and Sinan Sinanovic proposed a unique MRC–based receiver design for SM, wherein independently detects the data bits conveyed by the two information carrying units. This technique carrying out receiver has been examining over independent and identically distributed Rayleigh fading channels and compared to conventional schemes. More ever, simulation results have been acquiring over channel correlation, Rician Fading channel and pairs multi antennas. This results have clearly investigated the SM that offers better error performance than conventional MIMO with a less receiver complexity wherein same bandwidth efficiency [3]. In this paper also spatial modulation techniques is used to provide better energy efficiency and low complexity. Message bits are mapping in the domain of antenna combination of signal constellation and select the active antenna combination and by using the BPSK modulation technique with four antennas.

By using this formula select the antenna.

$$ř = \log_2(Ş_t) + \log_2(B)$$

$Ş_t$ shows the number of transmit antenna and B shows the symbol with logarithmic scale. By using these techniques spectral energy is increases, simple transmitter and receiver design. But lacking in spectral efficiency [3].



3 bpcu

Input bits	N_t=2, M=4		N_t=4, M=2	
	Antenna number	Transmit symbol	Antenna number	Transmit symbol
000	1	+1+j	1	-1
001	1	-1+j	1	+1
010	1	-1-j	2	-1
011	1	+1-j	2	+1
100	2	+1+j	3	-1
101	2	-1+j	3	+1
110	2	-1-j	4	-1
111	2	+1-j	4	+1

$$y = Hx_{\ell_t, s_t} + n$$

$$= h^{\ell} s_t + n$$

Fig: 5 Basic block diagram of spatial modulation-selecting active antenna [3].

Above figure shows the selecting antenna and constellation symbol of QAM symbol mapping.

1) In [2], author used for the simulation result the Rayleigh fading channel with Gaussian noise for minimizing the complexity. Analytical and simulation results are compare between the V-BLAST MMSE, SM and MMRC QAM whose technique are better for spectral efficiency with maximum signal to noise ratio. V-BLAST occurs the error propagation problem and advantages of spatial modulation totally avoid the inter channel interference.

2) The authors Jaydeepan Jeganathan, Ali Ghrayeb and Leszek Szczecisk have proposed the optimal detection at the receiver side for spatial modulation which indicate the significant performance over V-BLAST coding technique conventional SM and results are compare with analytical and optimal detection [4]. Optimal detection is techniques to compare the data estimated value and original data.

3) The authors Ahmad Alshamali and Basma Quza have proposed uncorrelated and Correlated nakagami Fading channels where analysis of framework to compute the average probability of error. The results are match closely with existing technique and proposed technique and performance of spatial modulation increases indifferent order of QAM [5]. This channel improves the performance of spatial modulation.

4) In [7], minimize the antenna index by using the Huffman coding at the transmitter side. Further result shows the simulation in Adaptive GSM and conventional GSM. Advantages of GSM when increases constellation size then increase the signal to noise ratio (SNR) with average bit error rate. In this, first one data is encoded by Huffman coding and transmit to the spatial modulation

5) In [8], author described the performance of spatial modulation named as fully quadrature spatial modulation and it is sub class of spatial multiplexing by using the transmit antenna array bit rate is increases. Analytical and simulation results are compare between the existing technique SM and QSM with F-QSM.

6) In [9][10], spatial modulation have proposed by generalized spatial modulation(GSM) which is a special case of SM occurs the higher spectral efficiency by increasing the QAM modulation order. In SM-MIMO and GSM-MIMO, transmission energy is same but improvement in spectrally. As compare to conventional MIMO SE and EE both are improved. Simulation results are compare V-BLAST and STBC coding

7) In [11], author presented the spectrally efficient adaptive generalized spatial modulation by using the technique constellation size increases. In SM-MIMO two types of constellation occurs. First one is spatial constellation and second one is signal constellation. First type of constellation selects the active antenna and covert into spatial domain and then converts into symbol (using QAM).

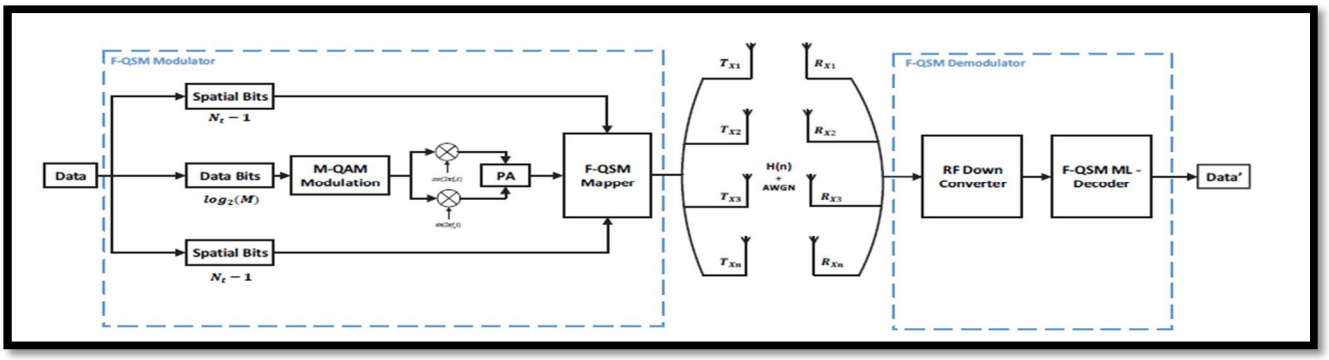


Fig 6. Block diagram of F-QSM system model [8].

Above fig shows the system model of F-QSM system. In this system input data bits are separated three different modulation scheme spatial bits, data bits and spatial bits that's why its efficiency is increases as compare to QSM system. This system is increasing the data rate exponentially [8].

In [16], author shows the improvement the performance of quadrature spatial modulation under the nakagami-m fading channel. Performance of QSM is increases when the value of m (nakagami–m fading channel) increases the spectral efficiency. System model are same as a spatial modulation system model but only difference is that use the nakagami-m fading channel for reducing the multipath fading

V. ADVANTAGES

A. SM removes (inter antenna synchronization) IAS and (inter channel interference) ICI by using single RF chain.

B. SM does not require a single RF chain at the receiver. In SM, during transmission only single radio antenna is change the direction while added antennas are kept constant.

C. SM provided 3- dimensional constellation diagram which introduces a multiplexing gain in the spatial domain that increases with the number of transmit–antenna.

D. In SM, active antenna is less as compare to transmitting antennas because active antenna is selected by the mapping of indexing.

E. SM gives a high spectrally efficient code with an equivalent code rate greater than on SM have capable to do work in multiple–access technique for distinct pairs of transmitters and receivers normally occupy individual spatial positions. If every receiver uses the individual set of channel of all the transmitters for data detection uses multi user detection than several users could share the same wireless method of communication.

F. SM gives a high throughput of the system than convention allows complexity MIMO system.

G. Less power supply as compare to other modulation.

VI. CHALLENGES

A. In present scenario, there is lot of requirement of data rate because all things depend on data rate like social media, online classes, Google meet, Google. Mainly the problem is need of high speed data.

B. Challenges of spatial modulation is to strike an attractive compromise between wireless network's area spectral efficiency and energy efficiency. In SM-MIMO at least two antennas should be in active mode [3].

C. In [2], transmitting and receiving antennas are different in SM data rate is not boosting same as a spatial multiplexing. In MIMO large amount of antenna are used for enhancing the data rate by using different technique like STBC code, almouti code but by using SM-MIMO energy efficiency increase and minimize the complexity.

D. In [15], SM-MIMO used the Rician fading and Nakagami fading channel because of which more bits have been encoded by the constellation diagram. Trade off between the latency, energy efficiency and B.W.

E. Hardware tested of SM-MIMO is very big problem for implement the transmitter and receiver because transmitter and receiver contains the one fourth part of wave dipole and half wave dipole, presenting a dipole is a big task [6].

F. MATLAB software is used to show how message information are send from transmitter to receiver by using digital signal processing, it is also a big task.

VII. FUTURE WORK

The future scope of Spatial Modulation for point to point and point to multi point communication is a productive spatial modulation based on molecular communication scheme, in which a transmitted symbol is consist of two parts, that is a centralized derived symbol and capacity derived symbol. We could make a digital home for multi user by using MIMO technique. We used OFDM aided with MIMO system and spatial modulation than the performance of data speed is improved up to 30 to 300G Hz. For emerging and 5G communication OFDM and SDMA techniques are used in 5G technology. These used with SM-MIMO and at the receiver side neural network connected latency is also improved.

VIII. CONCLUSION

This paper is summarized some of the recent works of SM-MIMO system and also presented the survey of SM-MIMO system. More ever, this investigated the performance analysis of spatial modulation in MIMO system for improving the bandwidth efficiency and data rate. If spatial modulation is used with QAM data rate is improved but not more than the Spatial Modulation used with MIMO system. Modulation as well as OFDM systems used in MIMO system for enhancing the data rate and spectral efficiency. SM is a technique which considered all digital modulation like PSK (phase shift keying), SSK (Space shift keying) and QAM (quadrature amplitude modulation), large number of multiple–antenna processing in a unique fashion to achieve large bit rate rates. There are still greater numbers of issues to be overcome in SM-MIMO mainly the loss of efficiency in higher order of MIMO system.

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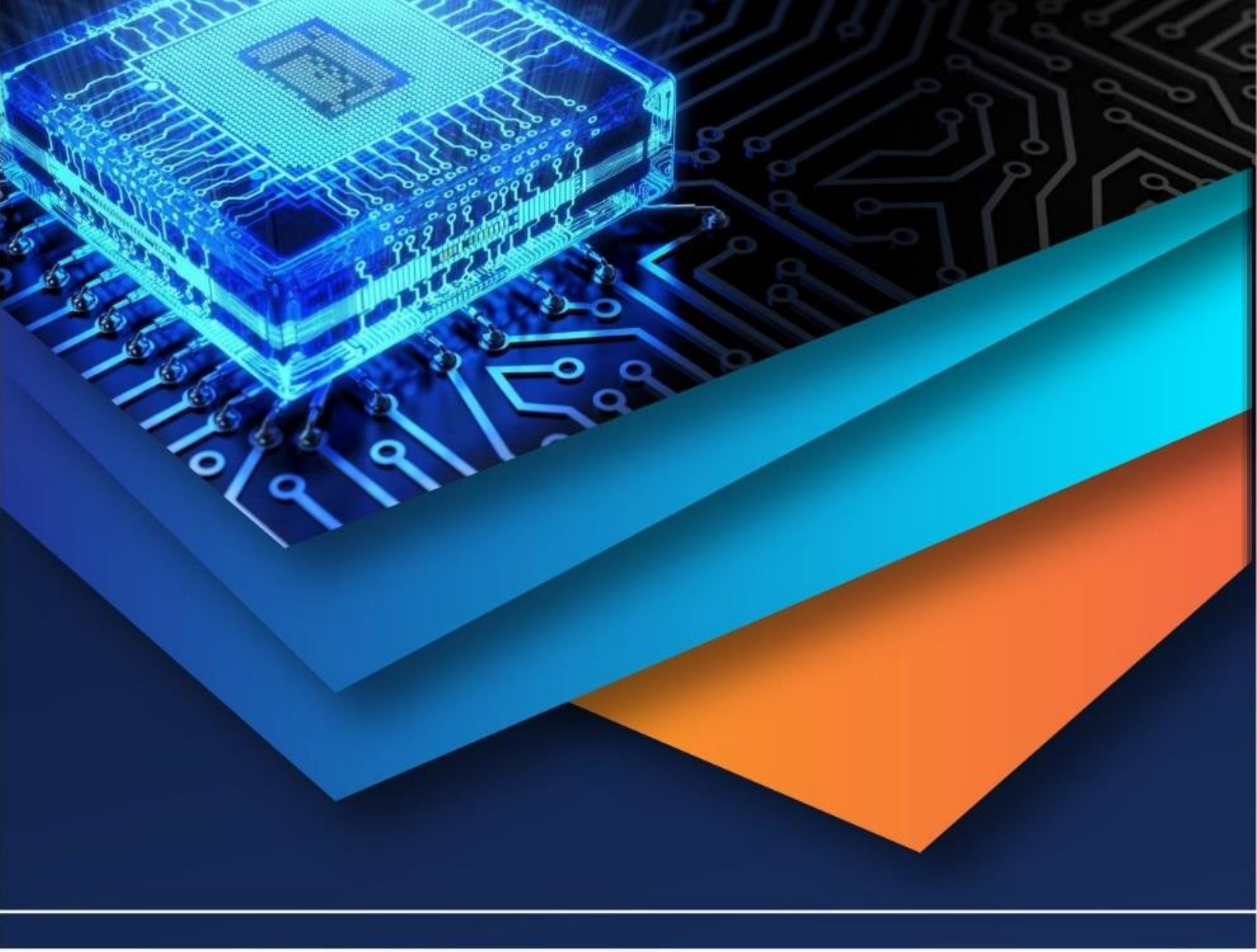

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