ARPN Journal of Engineering and Applied Sciences

ADAPTIVE MODULATION FOR ENHANCED OFDM SYSTEMS USING FUZZY LOGIC

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ABSTRACT

In this paper, a modified adaptive modulation is proposed to avoid wireless channel fluctuations that affect particular kind of modulations. The proposed approach is used to fit channel fluctuations in regard to several parameters including modulation order, bit error rate, signal to noise ratio and code rate. In addition, a new parameter is proposed to improve modulation performance which is called modulation error ratio. The communication channel fit is achieved by implementing a fuzzy inference system with optimum characteristics for data transmission in aim to obtain higher received data rate with minimal error. The experimental results prove that our approach considerably improves efficiency, performance over noisy channels.

Keywords: orthogonal frequency division multiplexing (OFDM), bit error rate (BER), modulation error ratio (MER), code rate, fuzzy inference system (FIS).

INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is an active and effective multiple-carrier transmission technique. It is a private state of Frequency Division Multiplexing (FDM) and can be regarded essentially a combination of two well-known techniques including modulation and multiplexing [1], [2], [3]. Those two ,techniques in OFDM behave like a scheme to fight ,multipath fading in wireless channels and also divide the wideband frequency communication channel into a number of parallel sub channels [4],[5]. Such that narrow band and low rate data carriers are transmitted through these sub channels. OFDM is used in the digital wideband communications that is usually used for audio broadcasting (radio) and digital television in addition to wireless networking and access of broadband Internet.

The main characteristic of OFDM is the efficient usage of the spectrum by making all the subcarriers orthogonal to each other. This eventually leads to avoid interference among adjacent carriers. An adaptive modulation techniques have been proposed according to different parameters to avoid the wireless channel fluctuations which affect the performance of any fixed OFDM modulation [4], [5]. In addition, the modulation error ratio is inserted as additional parameter to reach higher performance in the noisy channels.

The guard bands in OFDM receivers can protect them from inter carrier interference by allowing them to use the spectrum with higher efficiency than other systems like TDMA and FDMA. OFDM is also protected from co-channel interference, impulsive parasitic noise, and less affected with sample timing offsets comparing with single carrier communication system [6], [7], [8], [9].

The rest of paper is organized as follows: we explain in next section literature survey, Fuzzy logic system, proposed system and conclusions.

LITERATURE SURVEY

We explore several recent works on improving the performance of OFDM. Let to be started with Kuldeep *et al*. research work that presented an adaptive adjustment technique to adapt to the state of communication channel. This adaptation depends on the code rate, current modulation order, Bit Error Rate (BER) and Signal to Noise Ratio (SNR). In addition to the adaptation, a Fuzzy Inference System (FIS) is used to distinguish uncertain state of communication channel and further improves the OFDM systems performance in terms of error free delivery of data and high transmission data rate. Deepa *et al.* studied the OFDM in respect to the Quadrature amplitude modulation (QAM) technique. The scatter plot, output signal to noise ratio (SNR), variation of bit error rate is analyzed for every type of modulation in OFDM. Also, the exchanging threshold range has been prepared and the system becomes ready to face the adaptive coded modulation (ACM) observing the BER for each SNR in the system [10], [11]. Bello *et al* found that signal power relatively related with noise after analyzing a fixed value of SNR. Also, the bit and packet noise is decreasing if the signal power is decreasing [12], [13], [14]. Harivikram *et al* studied the performance of OFDM systems with and without adaptive modulation. The experimental simulations proved the effectiveness of adaptive modulation in OFDM systems. The authors analyzed the bit error rate performance of spectral efficiency of various digital modulations techniques including QPSK, 16 QAM, 64 QAM. Also, they introduced the concept of High Speed Downlink Packet Access (HSDPA) that is eventually introduced as a new feature in version 5 of the specifications of 3GPP WCDMA/UTRA-FDD standards [15], [16]. Nagare *et al.* proposed a new scheme of adapted modulation using Fuzzy rule base system to strengthen realizable data rate in OFDM systems. The conclusive result of this work that the performance of bit error rate for proposed adaptive modulation is better than the constant modulation scheme [17], [18]. Birla *et al.* enhanced WiMAX system capacity using adaptive modulation and code rate. This research focused on modulation in the physical layer design including BPSK, QPSK, 8QAM, 16QAM, 32QAM,64QAM and convolution codes (CC) with ½, ⅔ codes. Simulations demonstrated that the performance of adaptive system with coding of convolution is better than other modulation alone. It also shows the adaptive system flexibility to work with various desired BER [19], [20]. Qureshi *et al.* suggested that an adaptive modulation and coding scheme via use Fuzzy rule base system. This research work increases the rate of data in OFDM, constant bit error rate and the transport power for each sub-carrier [21], [22]. K. Seshadri Sastry *et al.* proved that the performance of adaptive modulation of OFDM system increases by preserving BER, channel conditions and efficient ability. This can be happened as a result to execute a technology by using Fuzzy logic interface and non-data-aided SNR estimation [23]. Faezah *et al*. presented adaptive transportation schema for OFDM that assists to enhance the output performance with considerable BER. The experimental results prove that the adaptive transport schema is better than the constant transmission system [24].

FUZZY LOGIC SYSTEM

Fuzzy logic (FL) provides an easy way for arriving at a specific conclusion based upon vague, noisy, ambiguous, imprecise, or missing input information. It is an approach to control problems simulates how a person would make decisions, only much faster. Fuzzy Logic includes a simple, rules-based IF X AND Y THEN Z way to solve control problem instead of the trying to model a system mathematically. The Fuzzy Logic model is experimentally -based, depending on an operator's experience instead of technical understanding of the system. These terms are inaccurate and very descriptive of what must actually happen [25].

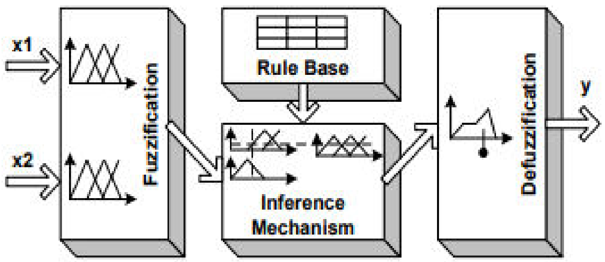

Figure-1. Fuzzy logic systems [26].

Fuzzy Logic demands some numeral parameters for working such as what is considered important error and important rate of change of error, but accurate values of these parameters are generally not crucial unless very reacting performance is demanded in which case experimental tuning would define them. These values can be "tweaked" once the system is working for optimizing performance and don't have to be symmetric. Fuzz Logic is usually tolerant so that the system perhaps works for the first time without any tweaking. Fuzzy logic, based on Fuzzy Inference System, is a strong system which assists in decision making based on input parameters values. In this paper, this fuzzy system has been taken into discussion for choosing best modulation method or technique which suits the most communication channel which uncertain and continuously changing and grants better performance for error free delivery of data [27].

The proposed work in this paper is suggested and implemented an adaptive modulation technique by applying a fuzzy logic algorithm to improve the performance of the communication system taking in account important parameters like Modulation Error Ratio (MER), Signal to Noise Ratio (SNR), Code Rate and Bit Error Rate (BER) as inputs to change the modulation to select one that is fits with the states of the inputs to reach to optimum performance for the communication system.

PROPOSED SYSTEM

The proposed approach is a modified adaptive OFDM system controlled by Fuzzy Logic System as shown in Figure-2 below. It can change the order of exist modulation to another selected modulation based on the values of the inputs of MER, BER, SNR and Code Rate in both parts of communication system including modulator in transmitter and demodulator in receiver.

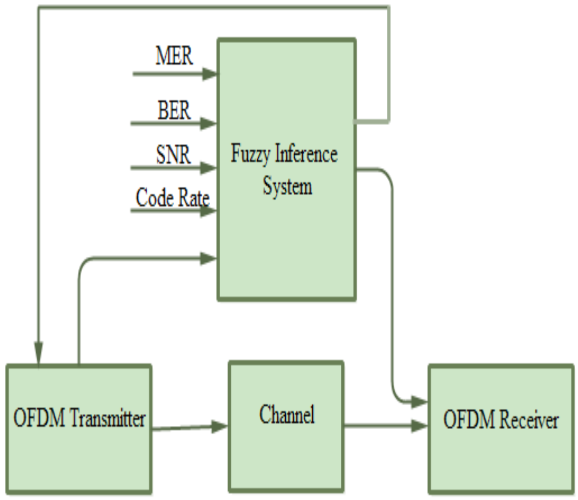

Figure-2. Fuzzy inference system based OFDM system.

The proposed approach is a modified adaptive OFDM system controlled by Fuzzy Logic System as shown in Figure-2 below. It can change the order of exist modulation to another selected modulation based on the values of the inputs of MER, BER, SNR and Code Rate in both parts of communication system including modulator in transmitter and demodulator in receiver. The processed communication signal at transmitter side is passed through the Fuzzy logic system to decide the suitable order of modulation using Fuzzy rules. After determining the most suitable modulation, the signal is transmitted through the communication channel to the receiver side.

EXPERIMENTAL RESULTS

The proposed method has been designed using Fuzzy logic toolbox of Matlab software. The system is modeled with five Fuzzy inputs and single Fuzzy output.

Each one of these Fuzzy inputs and output is represented by a group of triangular membership functions. The first input represents modulation parameter with nine membership functions started from 4QAM (2^{nd} order) to 1024QAM (10^{th} order). The modulation error rate (MER), signal to noise ratio (SNR) and bit error rate (BER) are the second, third and fourth input parameter respectively. These Fuzzy parameters contain with three membership functions. The code rate (CR) is the fifth input parameter with four membership functions. The Fuzzy inference system (FIS) is of type Mamdani type and the table below shows the range values of these inputs.

Table-1. Parameters of FIS with their values.

	Input variables	Values
1	Present Modulation	4QAM to 1024QAM
2	MER	1×10^{-4} to 10
3	SNR	-10dB to 20dB
4	CODE RATE	2/3, 3/4, 5/6, 7/8
5	BER	$1\times e^{-6}$ to 1

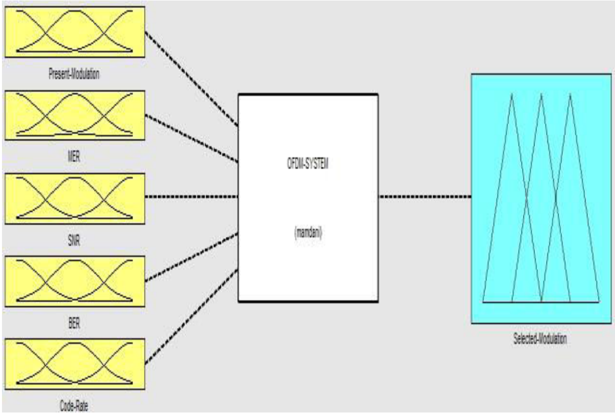

Figure-3. Fuzzy interface system.

The proposed method has been designed using Fuzzy logic toolbox of Matlab software. The system is modeled with five Fuzzy inputs and single Fuzzy output as shown in the Figures 4, 5, 6, 7, 8 and 9. The vertical axis in all these figures represents "the degree of membership in the input or output parameter Fuzzy functions" in the range [0-1] while the horizontal axis represents "only the input or output Fuzzy parameter". Each one of these Fuzzy inputs and output is represented by a group of membership functions. The first input represents modulation parameter with nine bell shape membership functions started from 4QAM (2^{nd} order) to 1024QAM (10^{th} order). The modulation error rate (MER), signal to noise ratio (SNR) and bit error rate (BER) are the second, third and fourth input parameter respectively. These Fuzzy parameters contain three bell shape membership functions. These functions are named low, medium and high respectively. The low membership function is used for low input range values of input parameter while medium membership function is used for medium values of input parameter. Lastly, high membership function is used for high values of input parameter. The code rate (CR) is the fifth input parameter with four triangular shape membership functions from (2/3) to (7/8). The selected output modulation is the Fuzzy output which consists of nine bell shape membership functions with range from (4 QAM) to (256 QAM).

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ARPN Journal of Engineering and Applied Sciences

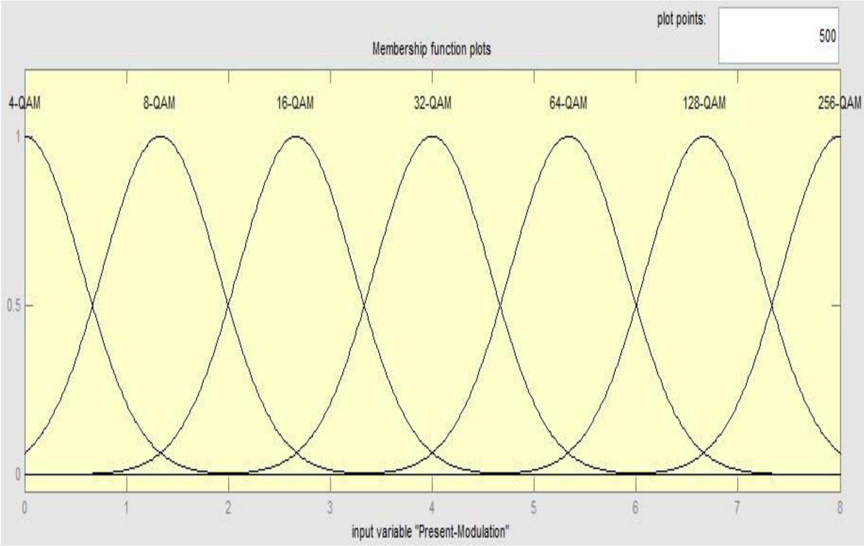

Figure-4. Membership functions of present modulation (First input).

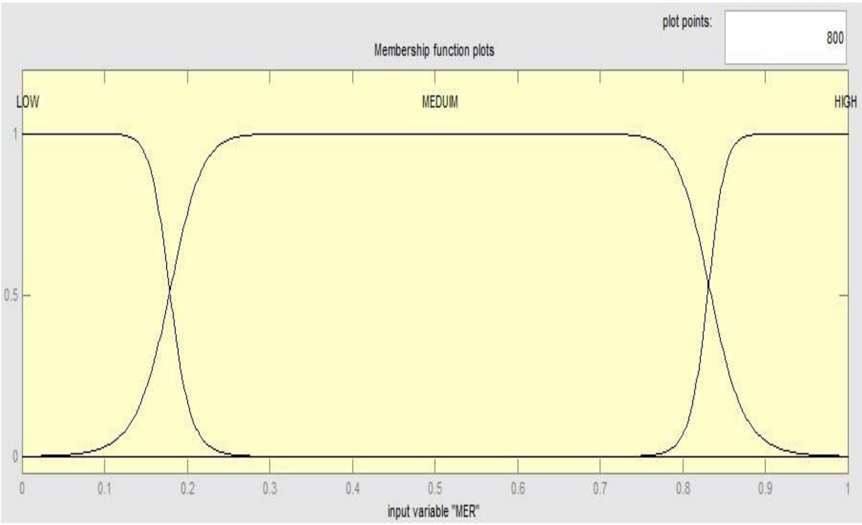

Figure-5. Membership functions of MER (second input).

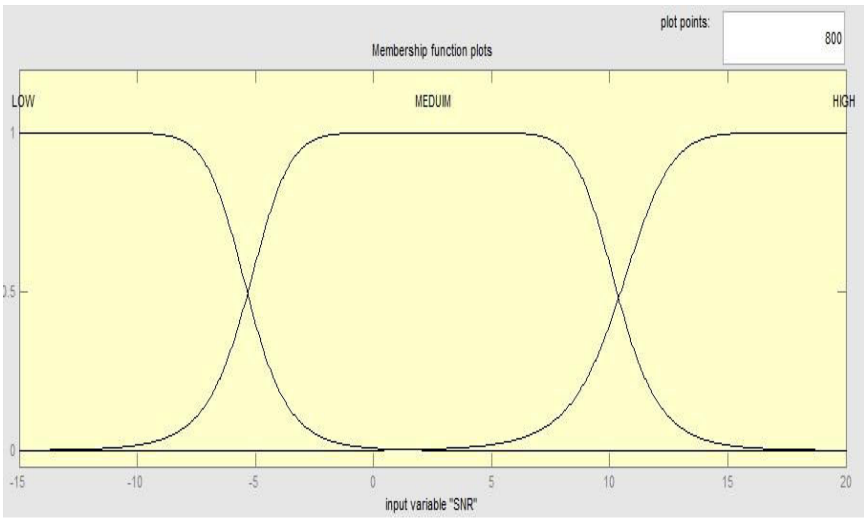

Figure-6. Membership functions of SNR (third input).

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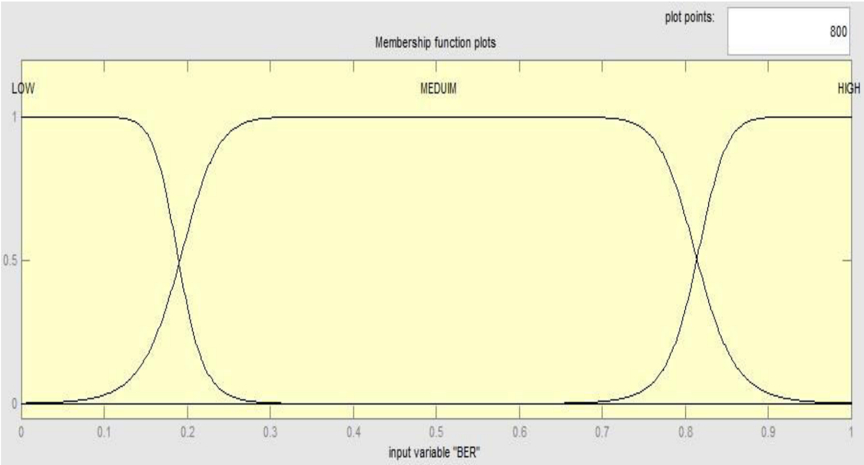

Figure-7. Membership functions of BER (fourth input).

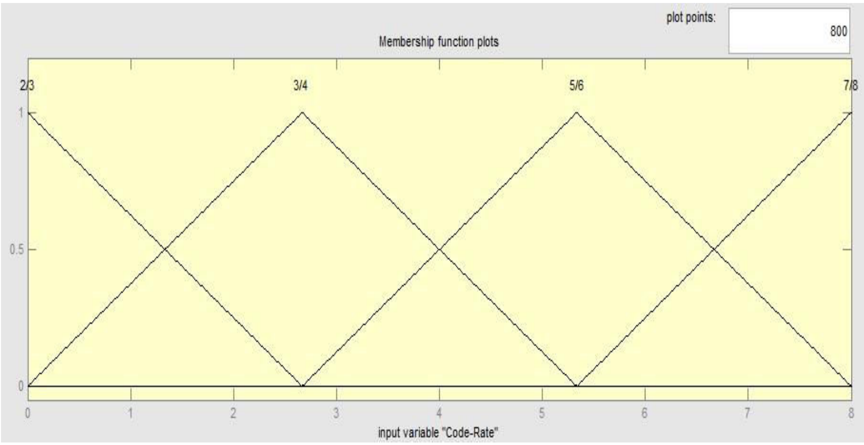

Figure-8. Membership functions of code rate (fifth input).

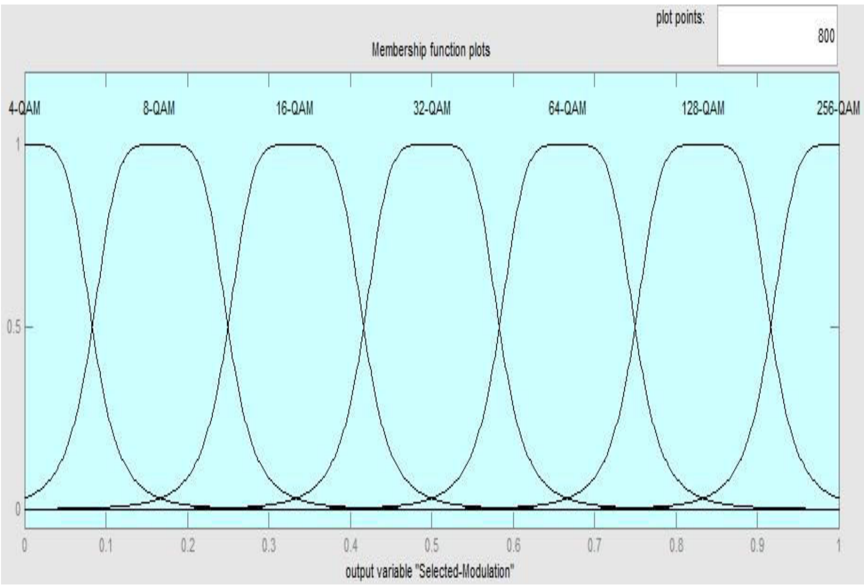

Figure-9. Membership of selected output modulation (output).

By using IF THEN Rules the decision of the most fit modulation technique in both transmitter and Receiver according to Fuzzy rules shown in Figure-10 below.

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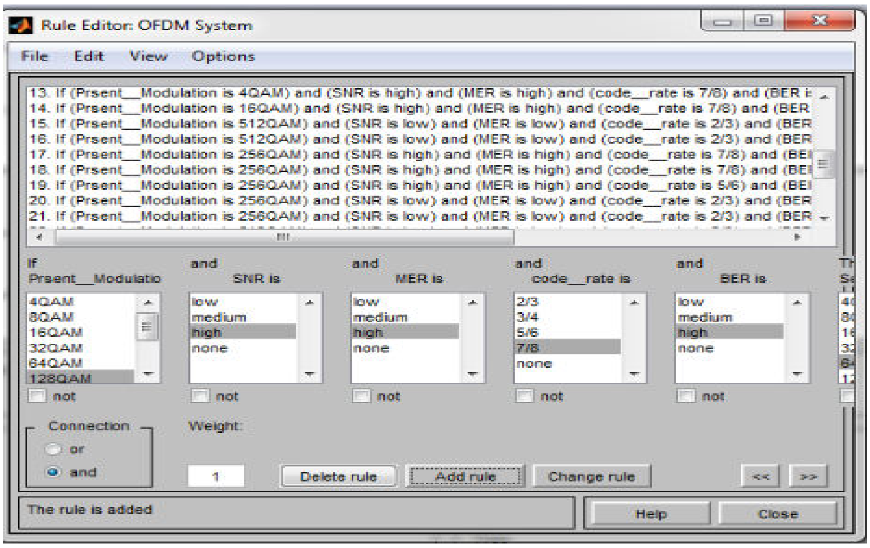

Figure-10. Rules of fuzzy inference system..

There is also another 3D surface color graph generated by Matlab software that show the relationship among input parameters (on X and Y axes) and normalized output (on Z axis) as shown in the Figures 12 and 13. Form these figures, we can notice that the order of selected modulation increase ascendingly with the increase of the input parameters especially the BER, MER, SNR and present modulation. Where the Blue color in the surface graph indicates that if the input Fuzzy parameters values in the LOW range then the order of selected modulation is of low order range however Yellow color in this surface graph refers to the highest order of selected modulation for the highest values of input Fuzzy parameters. In addition, the Green color in this surface graph refers to the medium order of selected modulation whenever input Fuzzy parameters have medium range values. Hence, we can say that the Fuzzy inference system selects the most suitable modulation for OFDM system adaptively to reach finally optimum performance.

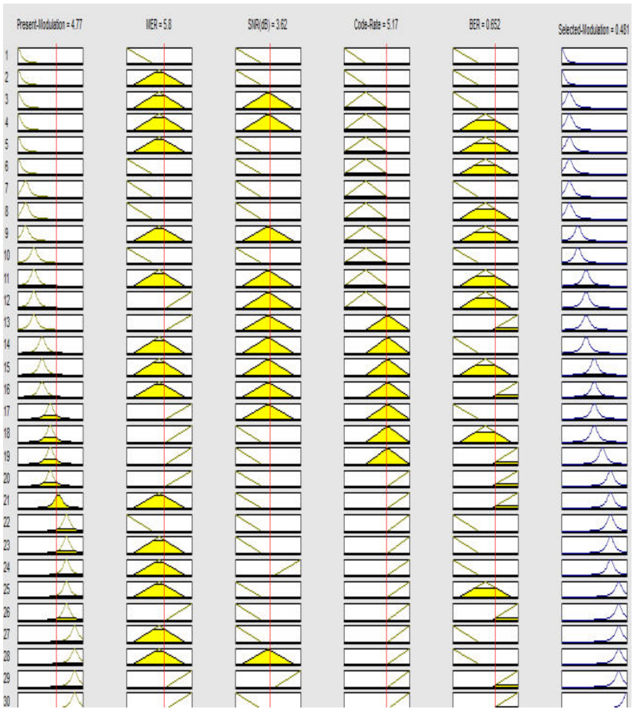

Figure-11. Rule viewer of fuzzy inference system.

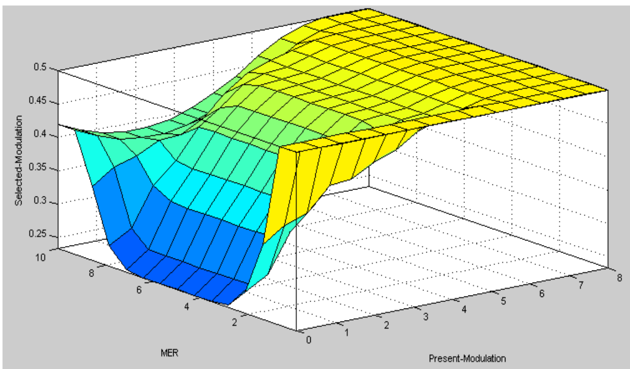

Figure-12. Surface viewer of OFDM system with (MER and present-modulation) as inputs.

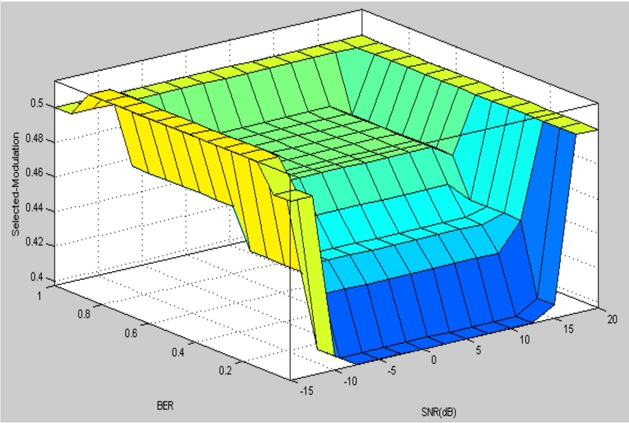

Figure-13. Surface viewer of OFDM system with (BER and SNR) as inputs.

CONCLUSIONS

The research in this paper proposed a new approach to improve the performance of OFDM systems using Fuzzy logic. The most suitable modulation technique is selected adaptively based on the values of certain parameters including MER, SNR, BER and Code Rate. Such dynamic usage of modulation techniques improved the efficiency and performance of communication systems.

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