I.J. Intelligent Systems and Applications, **2016, 5, 49-54**
Published Online May 2016 in MECS (http://www.mecs-press.org/)
DOI: 10.5815/ijisa.2016.05.07

Fuzzy Logic Based Modified Adaptive Modulation Implementation for Performance Enhancement in OFDM Systems

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Abstract—Adaptive modulation is one of the recent technologies used to improve future communication systems. Many adaptive modulation techniques have been developed for the improving the performance of Orthogonal Frequency Division Multiplexing (OFDM) system in terms of high data rates and error free delivery of data. But uncertain nature of wireless channel reduces the performance of OFDM system with fixed modulation techniques. In this paper, modified adaptive modulation technique has been proposed which adapts to the nature of communication channel based upon present modulation order, code rate, BER and SNR characterizing uncertain nature of communication channel by using a Fuzzy Inference System which further enhances the performance of OFDM systems in terms of high transmission data rate and error free delivery of data.

Index Terms—Adaptive Modulation, Bit Error Rate (BER), Coding Rate, Fuzzy Inference System (FIS), Orthogonal Frequency Division Multiplexing (OFDM), Signal to Noise Ratio (SNR).

I. Introduction

Orthogonal Frequency Division Multiplexing System (OFDM) is a multiple-carrier transmission technique, which divides the higher spectrum into many small carriers, i.e. it divide the wideband frequency channel into a number of parallel narrowband sub channels, and each low-rate data carriers are transmitted over different sub channels. Orthogonal Frequency Division Multiplexing technique (OFDM) is basically a combination of both modulation and multiplexing techniques. It is considered to be a special case of Frequency Division Multiplexing (FDM), in which multiple user access is achieved by dividing the available bandwidth into several channels which are allocated to different users [1]. However; Orthogonal Frequency Division Multiplexing System (OFDM) uses the available bandwidth spectrum very efficiently by spacing different communication channels as closer as possible. This efficient spectrum allocation can be achieved by making all available carriers orthogonal to one another, so the interference between the closely spaced carriers is removed. In an OFDM signal each carrier has a very narrow bandwidth, thus output symbol rate is low. This fact of low symbol rate results the OFDM signal having a high tolerance towards the multipath delay spread. The main reasons to use OFDM are to enhance the strength against narrowband interference and frequency selective fading. In a distinct carrier system, a distinct fade or interference can cause the whole link to fail. On the other hand, in a multicarrier system, only a small fraction of the subcarriers will be affected [2]. OFDM also overcomes the problems with both TDMA and FDMA. In FDMA many carriers are spaced from each other in that way the signals can be received using any conventional filters and demodulators. In such that receivers guard bands are placed between carriers which lowers the spectrum efficiency. In OFDM sub carriers are orthogonal to one another so the signal can be received without intercarrier interference. OFDM efficiently use the spectrum by allowing over-lapping of carriers.OFDM also removes the ISI through use of a cyclic prefix (CP).OFDM provides protection against impulsive parasitic noise and co-channel interference .OFDM is less responsive to sample timing offsets as compared to single carrier systems [3].

In this paper, a modified adaptive modulation technique has been implemented using Fuzzy Inference System which makes OFDM system adaptive to communication channel. This Fuzzy system takes into consideration input parameters such as Present modulation, Coding Rate, SNR and BER and gives better modulation order among others so as to enhance the overall performance of OFDM system in terms of efficient, fast and error free delivery of data.

II. Related Work

K. Seshadri Sastry et al. [4] discover the OFDM system with adaptive modulation by using fuzzy logic interface (FIS) which improves system capacity by maintaining good error performance. Adaptive modulation systems by using ordinary hardware decision circuits are ineffective to decide or to change modulation order according to given conditions. So, by using fuzzy logic in the decision making interface which makes the systemmore efficient.

Atta-ur-Rahman et al. [5] implement a method which

enhance capacity of system in Rayleigh fading channel where the Genetic Algorithm (GA) with FRBS based Adaptive allocation performs better than water filling (WF) with FRBS based adaptive resource allocation.

Harivikram et al. [6] investigated OFDM system with adaptive modulation and coding rate performs very well than normal OFDM system i.e. without adaptive modulation and coding rate and it also maintains the bit error rate and spectrum efficiency of the OFDM system.

Faezah et al. [3] have been investigated adaptive transmission scheme for OFDM, which results the adaptive transmission scheme is better than the fixed transmission system. Adaptation algorithm helps to improve the throughput performance with considerable BER performance.

K. Seshadri Sastryet al. [7] implement a method by using Fuzzy Logic Interface and Non-Data-Aided SNR estimation which results adaptive modulation for OFDM system increases performance of system by maintaining channel conditions, bit error rate and capacity efficiently .

Qureshi et al. [8] proposed an adaptive modulation and coding scheme by using Fuzzy Rule Base System (FRBS), where product codes are used with M- QAM which increases the data rate in an OFDM system with a fixed bit error rate and transmit power for each subcarrier.

Atta-ur-Rahman Fuzzy et al. [9] proposed a Rule Based System based adaptive modulation with coding scheme which shows that FRBS is more powerful in terms of throughput and bit error rate.

Khem Kumar et al. [10] proposed a method of an adaptive modulated OFDM system by using fuzzy Inference system (FIS) which results the Bit Error Rate and modulation order of QAM techniques of the system performs better than the fixed system because of its adaptive nature.

Parminder Kaur et al. [14] presented that OFDM system provides the high spectral efficiency, high data rate, but further by using neuro-fuzzy approach and machine learning approach, the quality of service (QoS), data rate, Signal to Noise Ratio (SNR), Bit Error Rate (BER), Inter Symbol Interference (ISI), fading and capacity of the systemcan be improved.

In this research paper, efforts are made to enhance the performance of OFDM system in terms of transmission speed and error free delivery of data by proposing a Fuzzy logic based modified adaptive modulation system based upon present modulation, code rate and parameters representing uncertain nature of communication channel such as SNR and BER at given time.

III. Fuzzy Inference System

Fuzzy system suitable for tasks involving logic has been proposed as an addition to classical formal logic. They were first developed in set theory. The “fuzzy set” has been employed to expand classical sets, which are characterised by some margins. This addition allows a degree of flexibility for each object which belongs to a particular set. This quality is realized by membership functions which give fuzzy sets the capacity of modeling linguistic, fuzzy expression [11]. Fuzzy logic is considered to be a novel way for developing reasoning and decision making models by handling imprecise information, in which truth can assume a value between 0 and 1. This information is referred to as fuzziness: so, fuzziness does not come from randomness, but it comes from the uncertain and imprecise nature of conceptual thoughts and concepts. Fuzzy reasoning realizes a form of reasoning that, by using particular mathematical inferences which provides conclusions based on a set of fuzzy IF-THEN rules. Fuzzy logic is a suitable technique of describing the behaviour of systems which are either too complex or too unclear to be agreeable to precise mathematical analysis. Classical systems cannot deal withimprecise or imperfect information, because they do not provide any means of representing vague propositions and this is not having any provisions which can make an inference from such uncertain propositions. Fuzzy logic system is based upon IF-THEN rules and can be characterised in terms of their primary constituents: fuzzification, rule base, inference, and defuzzification. A generalized Fuzzy Inference System is shown in figure 1 [12], [13].

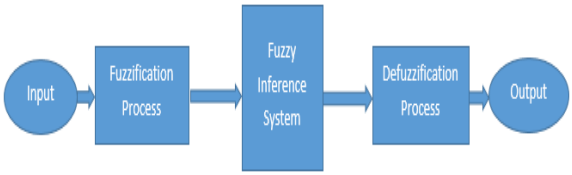

Fig.1. Fuzzy Inference System

Fuzzy logic based Fuzzy Inference System is a powerful system which helps in decision making based upon input parameters. In this research paper, this fuzzy system has been taken into consideration for deciding best modulation technique which suits the most in uncertain and continuously changing communication channel and gives better performance for error free delivery of data.

IV. Proposed Scheme

In this paper, authors have proposed a scheme of modified adaptive OFDM modulation system based on fuzzy inference system (FIS), in which modulation order is changed according to the values of signal to noise ratio, bit error rate, exiting modulation order and coding rate. OFDM model work in two parts modulation and demodulation, Incoming bits are pass through in different stages of modulation process then after passing through channel, these channel pass the output to fuzzy logic interface, fuzzy box compare the present order of modulation which is coming from OFDM channel and change it according to the values of SNR and BER (Figure.2). Fuzzy Inference System work with some set of rules and output of this system controls both modulation and demodulation of the OFDM system to improve the overall efficiency of the system.

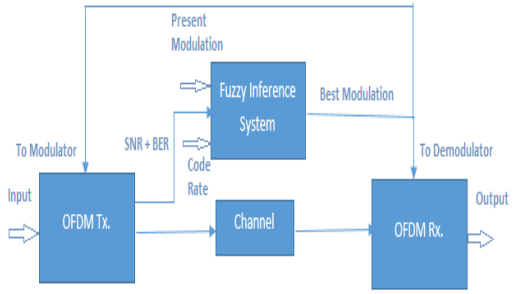

Fig.2. Fuzzy Inference System based OFDM System

V. Simulations and Results

Fuzzy Inference system is modeled in Fuzzy Inference system editor of Fuzzy Logic toolbox in MATLAB. This Fuzzy Inference system consists of four input functions: SNR, BER, Present Modulation and Code Rate and one output function Best Modulation. Every input and output function have different membership function. Fuzzy System is implemented by using Fuzzy logic tool of MATLAB 2009b in window 7 with i5 processor. FIS can be created by using either Sugeno or Mamdani types of fuzzy tool .But here we use mamdani type of FIS. Table 1 show the parameters with their values which are used to create Fuzzy Inference System (FIS).

Table 1. Parameters of FIS with Their Values

Input variables	Values
SNR	0 to 30 dB
BER	of 10^{-5} to 1bits/s/Hz
Present Modulation	QPSK,4QAM,8QAM,16QAM,32QAM,64QAM,128 QAM,256QAM,512QAM
Code Rate	1/4,1/3,1/2

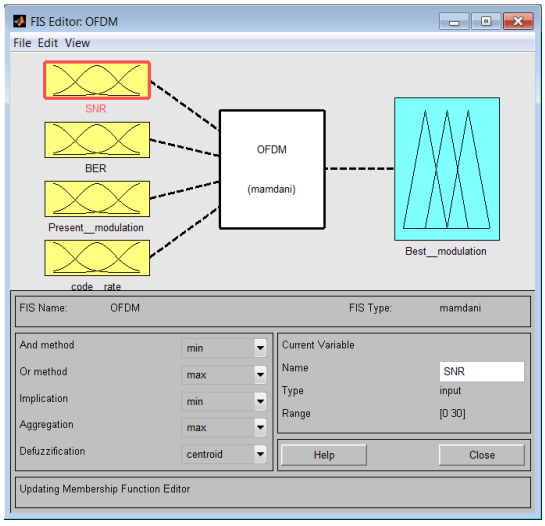

Fig.3. Fuzzy Inference System

Membership functions of different Input and Output parameters are described as follows:

- Membership functions of input SNR are low, medium, and high with the range of 0 to 30 dB (Figure 4).
- Membership functions of input BER are low, medium, high with range of 10^{-5} to 1bits/s/Hz (Figure 5)
- Membership functions of input present modulation are QPSK,4QAM,8QAM,16QAM,32QAM,64QAM,128 QAM,256QAM,512QAM (Figure 6)
- Membership functions of input Code rate are 1/4,1/3,1/2 (Figure 7)
- Membership functions of output best modulation are BPSL, QPSK, 4QAM, 8QAM, 16QAM, 32QAM, 64QAM, 128QAM, 256QAM, 512QAM, 1024QAM (Figure 8).

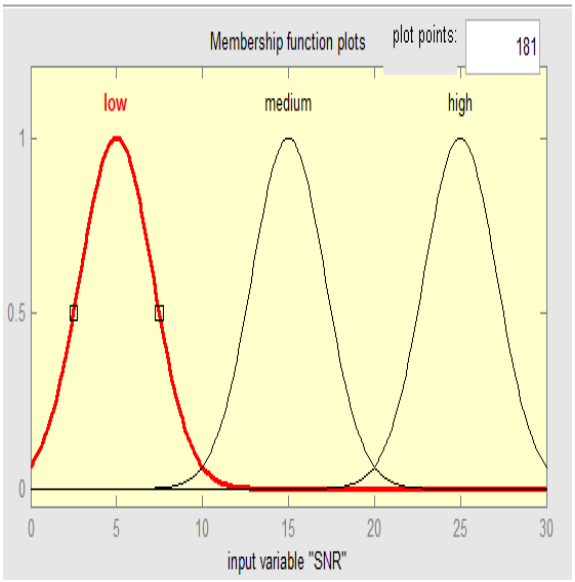

Fig.4. Membership Functions of SNR

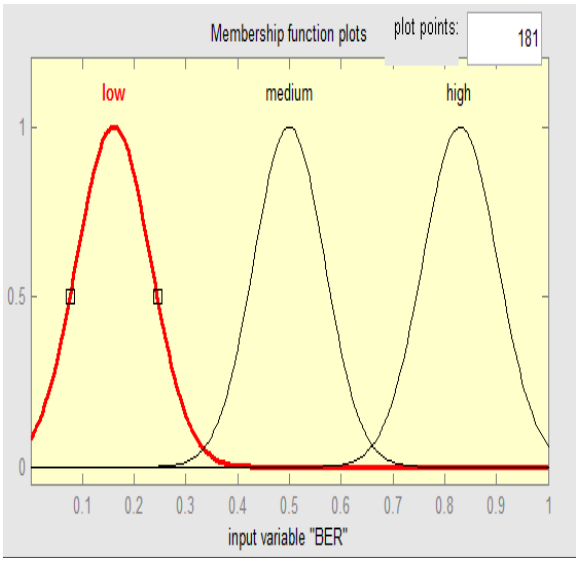

Fig.5. Membership Functions of BER

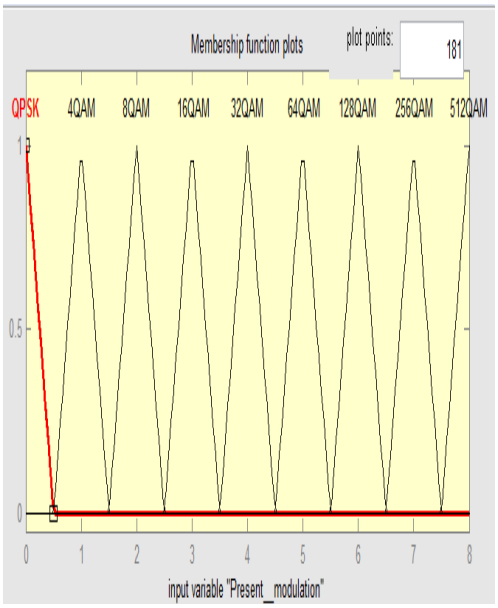

Fig.6. Membership Functions of Present Modulation

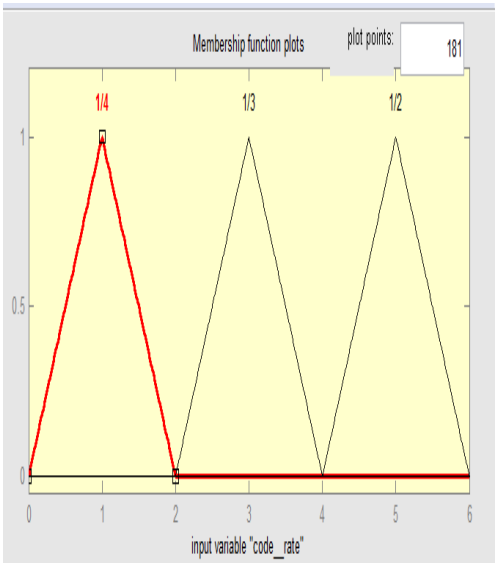

Fig.7. Membership Functions of Code Rate

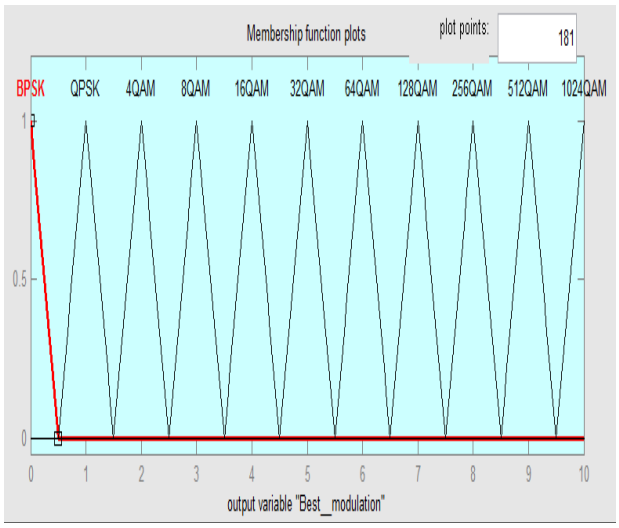

Fig.8. Membership Functions of Best Modulation

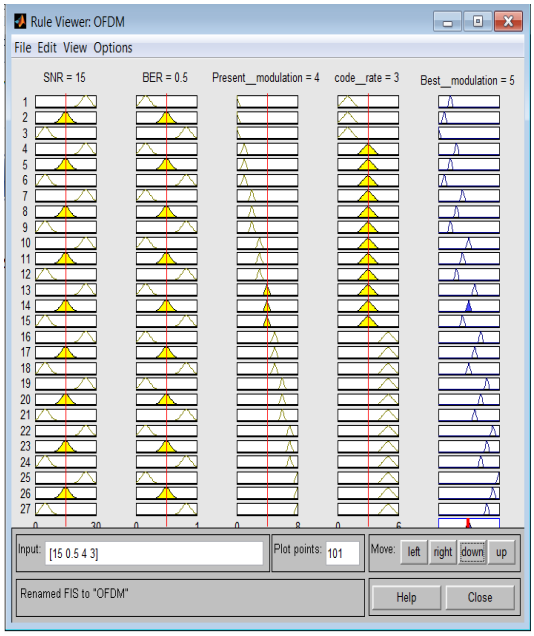

Fig.9. Rule viewers of Fuzzy Inference System

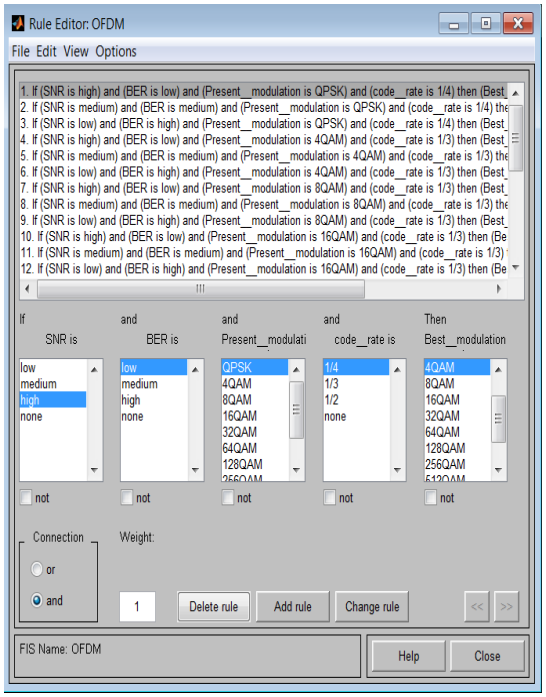

Fig.10. Rules of Fuzzy Inference System

In this system IF-Then rules are used to make decision about best modulation technique. The rule are set in Fuzzy inference system (FIS) .When the Signal to Noise Ratio (SNR) or Modulation order of present signal is low then the output modulation order decreases by order 1, but if Signal to Noise Ratio (SNR) or Modulation order of present signal is high, then the output modulation order increases by order 1.Now if Signal to Noise Ratio (SNR) or Modulation order of present signal is medium then the output modulation order will remains same. If SNR is High, BER is Low, Present Modulation is 4 QAM and Code Rate is 1/4 then Best Modulation is 8 QAM".

The Rule viewer of FIS gives the better description of all fuzzy logic set of rule (Figure 10). Figure11 shows different surface views of FIS. These surface views gives degree of correlation among all input variables for a particular

Now the validation of data is done by using MATLAB 2009b and results are shown in table 2 given below.

Table 2. Validation of Data

SNR	BER	Present Modulation	CR	Output	Actual Output
1	0.67	2	3	2	4QAM
21	0.1	3	3	5	32QAM
11	0.34	3	3	4	16QAM
1	0.67	3	3	3	8QAM
21	0.1	4	5	5	32QAM
11	0.34	4	5	5	32QAM
11	0.34	6	5	7	128QAM
1	0.67	6	5	6	64QAM
11	0.34	5	5	6	64QAM
1	0.67	5	5	5	32QAM
2	0.7	6	5	6	64QAM

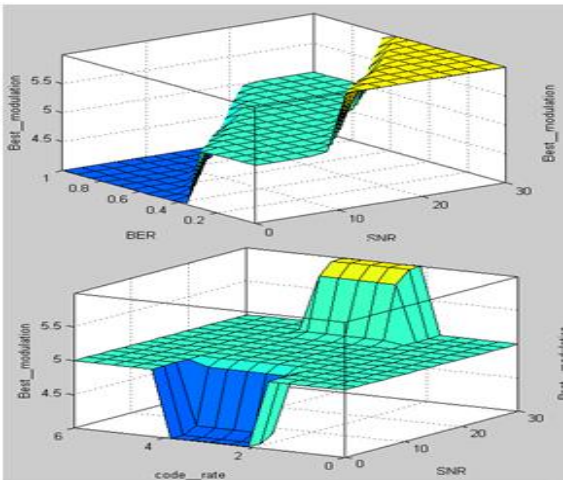

Fig.11. Different Surface Views of FIS

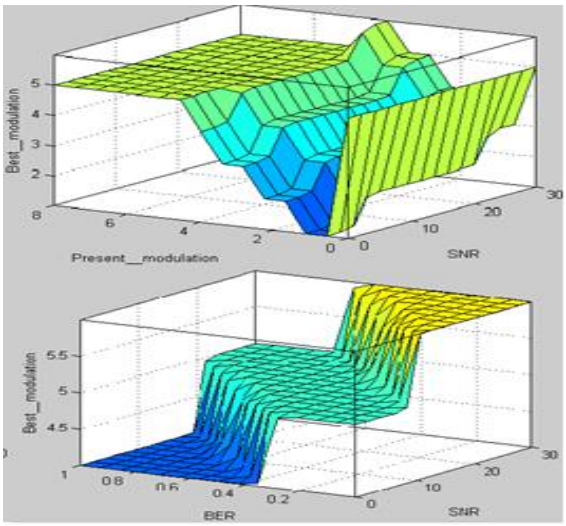

Fig.12. Different Surface Views of FIS

Finally, in this research work, Fuzzy Inference system has been designed by taking into consideration present modulation, code rate , SNR and BER which reveals the nature of communication channel . This Fuzzy system gives best modulation technique as output which is most suitable for OFDM system for a given communication channel at a particular time. As a result of this, this implementation of modified adaptive modulation using fuzzy logic system enhances the performance of OFDM system to great extent in terms of error free and high speed delivery of data.

VI. Conclusion

The proposed approach of modified adaptive modulation based on Fuzzy Inference System enhances the performance of an OFDM system. In this approach, Fuzzy Inference System uses present Modulation, SNR, BER and Coding Rater as input parameters and gives best modulation as output which is then feedback to modulator and demodulator of OFDM system to improve overall efficiency of the system. As fixed modulation system works on some fixed conditions, but modified adaptive modulation of OFDM by using FIS gives the better performance and improves the capacity of the system by getting adaptive to environment of communication channel. So, Fuzzy logic system is a technique which helps to make the OFDM system adaptive in nature, that it can choose a better modulation order with coding rate according to the value of SNR and BER and enhances the performance of OFDM system in terms of fast and error free delivery of data.

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How to cite this paper: Kuldeep Singh, "Fuzzy Logic Based Modified Adaptive Modulation Implementation for Performance Enhancement in OFDM Systems", International Journal of Intelligent Systems and Applications (IJISA), Vol.8, No.5, pp.49-54, 2016. DOI: 10.5815/ijisa.2016.05.07