International Journal of Enhanced Research in Science Technology & Engineering, ISSN: 2319-7463
Vol. 3 Issue 9, Sept.-2014, pp: (181-192), Impact Factor: 1.252, Available online at: www.erpublications.com

A Fuzzy Logic Approach to Adaptive Coding & Modulation in OFDM

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Abstract: Adaptive coded modulation is one of the key technologies used to enhance the capabilities of future communication network. Many adaptive modulation techniques have been investigated for the enhancement of transmission rate in combination with OFDM under AWGN channel .OFDM will provide much higher bandwidth efficiency. This is due to the fact that in OFDM the spectra of individual subcarriers are allowed to Overlap. The OFDM system always suffers with the problem of increase in bit error rate and decrease in spectral efficiency. Various modulation techniques are available for OFDM communication like 4QAM, 8QAM and higher modulation techniques. Lower modulation techniques like 4QAM and 8QAM reduce the bit error rate but decrease the spectral efficiency. So a technique is required which provides better tradeoff between them. So, adaptive coded modulation is the answer to this problem. The proposed work in this paper is to design a Fuzzy rule based system (FRBS) for coded modulation.

Keywords: Fuzzy inference system (FIS), orthogonal frequency division multiplexing (OFDM), Quadrature amplitude modulation (QAM).Signal to noise ratio (SNR), Bit error rate (BER).

I. Introduction

Adaptive Orthogonal Frequency Division Multiplexing is one of the successful candidates for many 3rd and 4th Generation Systems. In this technique a single very high data stream is divided into several low data rate streams. Then these streams are modulated over different orthogonal subcarriers. Concept of adaptive communication is though not new, however, it was confined to adaptive modulation only in past decade. The combination of adaptive modulation with OFDM was proposed as early as 1989 by Kalet[1] which was further developed by Chow [2] and Czylwik [3]. Specifically the results obtained by Czylwik showed that the required SNR for the BER target 10-3 can be reduced by 5dB to 15dB compared to fixed OFDM depending on the scenario of radio propagation [4].

Fuzzy Logic is a problem-solving control system methodology that lends itself to implementation in systems ranging from simple, small, embedded micro-controllers to large, networked, multi-channel PC or workstation-based data acquisition and control systems. It can be implemented in hardware, software, or a combination of both. FL provides a simple way to arrive at a definite conclusion based upon vague, ambiguous, imprecise, noisy, or missing input information. FL's approach to control problems mimics how a person would make decisions, only much faster.

In theoretical terms generally only two decision levels are considered i.e. either 0 or 1. But in real world practice decisions lie in between these two levels also. Like water is hot and after a particular temperature valve should be shut off, depending upon the quality of services you are offering tip to waiter or depending upon the distance of object camera lens should be focused automatically. So these are the few applications areas which require decision levels more than two. Depending upon the conditional information output should be set. So fuzzy logic proves to be boon for these type of applications. Various decision levels are set into fuzzy logic and it gives decision by that information. The underlying concept in fuzzy logic is that it requires linguistic variables that are a variable whose values are words rather than numerals. Fuzzy logic is so efficient in decision making that these days it is also used with artificial intelligence technologies to decide the variants of AI (Artificial Intelligence) . Fuzzy logic is all about the relative importance of precision: How important is it to be exactly right when a rough answer will do? Fuzzy logic is an easy way to map input variables into output.

II. Literature survey

Albertazzi et.al. in 2004 proposed Fuzzy Rule Based System assisted Adaptive Coding and Modulation scheme and analyzed in contrast to other adaptive techniques as well as fixed techniques. It is shown that FRBS is more powerful in terms of throughput and bit error rate especially when bit error rates are 10^{-2}, 10^{-3},10^{-4} .

Birla et.al. in 2012 presented capacity enhancement of WiMAX system using adaptive modulation and code rate in MATLAB. This paper focusing on the physical layer design that is modulation (BPSK, QPSK, 8QAM, 16QAM, 32QAM,64QAM are used in this work) and convolution codes(CC) with ½, ⅔ codes.

Bello et. al . in 2013 analyzed that for a constant value of SNR, if we are decreasing the signal power then it implies that noise is also decreasing & therefore bit loss & packet losses are also reduced. These losses are almost zero for a very low value of signal power such as 0.4 watt & SNR greater than 15dB, but transmission will not be faithful practically with this much low power.

Chatzidiamantis et .al. in 2012 proposed a new algorithm to utilize the BER information at the receiver based on Error Estimation Coding (EEC) to realize a simple adaptive modulation selection scheme. Compared to the adaptive modulation and coding selection schemes (AMC), which are based on SNR, our scheme needs less computational time and resources to decide which modulation type, is best suited for the current channel conditions.

Deepa et. al. in 2014 studied the OFDM for different Quadrature amplitude modulation technique(QAM).The scatter plot and their output signal to noise ratio, dependent bit error rate analyzed for every type modulation in OFDM .After observing the BER for each SNR in the system, switching threshold range has been prepared and system is ready to face the Adaptive coded modulation. The result showing the switching of modulation technique.

Faezah et .al. in 2009 first investigated the OFDM system performance of uncoded adaptive modulation using quadrature amplitude modulation (QAM) and phase shift keying (PSK), then to further enhance the system, Convolutional coding to OFDM system is empolyed. The obtained results show that a significant improvements in terms of bit error rate (BER).

Harivikram et.al. in 2013 provided a background of the High Speed Downlink Packet Access (HSDPA) concept; a new feature which has been introduced in Release 5 specifications of the 3GPP WCDMA/UTRA-FDD standards.

Islam et.al. in 2009 analysis of an Wimax (Worldwide Interoperability for Microwave Access) system adopting concatenated Reed-Solomon and Convolutional encoding with block interleaver has been carried out. The BER curves were used to compare the performance of different modulation.

Mohamed et. al. in 2010 described current trends in WiMAX systems for achieving high speed mobile wireless access services and outlined the technologies supporting these systems. The performance of the WiMAX-PHY layer based on the IEEE 802.16e standard, was evaluated and assessed at different: (i) modulation schemes; (ii) coding rates; (iii) FEC coding schemes, and (iv) Noise levels.

Nagare et. al. in 2013 considered only adaptive modulation. First it investigated the OFDM system performance of uncoded adaptive modulation using quadrature amplitude modulation (QAM) and phase shift keying (PSK). To further enhance the system, it employs convolutional coding to OFDM system. The obtained results show that a significant improvements in terms of bit error rate (BER) and throughput can be achieved demonstrating the superiority of the adaptive modulation schemes compared to fixed transmission schemes.

Rao et. al. in 2012 analyzes the CPVR and VPVR schemes over i.n.i.d. Nakagami fading channels when the best user is chosen in a multiuser environment. Closed-form expressions have been derived for the average channel capacity, spectral efficiency, and BER with uncoded /coded M-QAM. Numerical results have shown that, by selecting the best user, we can still considerably improve the performance through the diversity gain. In addition, the impact of time delay on BER has also been studied.

Sastry et.al. in 2010 presented an adaptive modulated OFDM system which uses NDA (Non-data Aided) SNR estimation using fuzzy logic interface. The proposed system is simulated in MATLAB 7.4 and The results of computer simulation show the improvement in system capacity**.** As demand for high quality transmission increases increase of spectrum efficiency and an improvement of error performance in wireless communication systems are important. One of the promising approaches to 4G is adaptive OFDM (AOFDM). Fixed modulation systems uses only one type of modulation scheme (or order), so that either performance or capacity should be compromised Adaptive modulated systems are superior to fixed modulated systems, since they change modulation order depending on present SNR

Sharma et. al. in 2012 discussed various digital modulation techniques such as BPSK (2bits), QPSK (4 bits), QAM, 16 QAM and 64 QAM. It had designed simulation environment in MATLAB with various configurations of OFDM technique. The main objective of this work is to measure Bit Error Rate with different modulation schemes and come to the best configuration to achieve better utilization of bandwidth. Authors have studied existing configurations with analog and digital modulation techniques and compared the results.

Sharma et. al. in 2011 presented to exploit the fading dynamic along with the adaptive modulation coding to achieve a higher energy efficiency in the purposed FD-AMC approach the frame transmission is suspended judiciously during the outages, thereby saving energy particularly harsh channel condition.

Sharma et. al. in 2013 analysis of physical layer of WiMAX system using simulink is done. Firstly, BER for different addative modulation techniques are evaluated in AWGN channel. Then performance is evaluated using simulink models. It is observed that for a particular value of Bit error rate SNR value for BPSK, QPSK is lower then 16QAM and 64QAM. So 64QAM has highest value of SNR.

III. Proposed work

To design the fuzzy logic system two inputs are provided to a fuzzy inference system. The fuzzy inference system consists of all rules defined for desired output. Before discussing the inference system more first the major constituent of inference system i.e. membership function will be discussed.

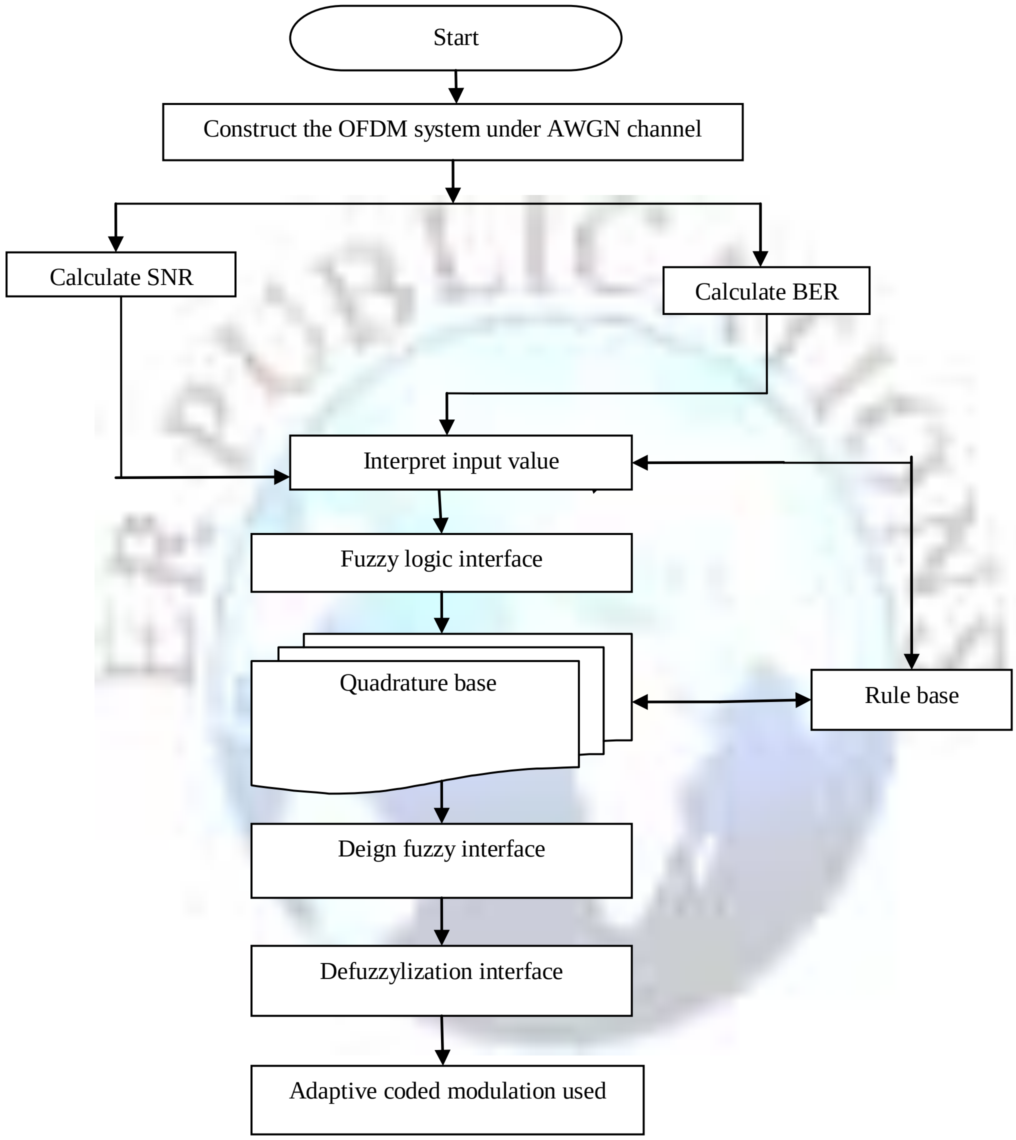


Figure1: Flow chart of proposed work

In Adaptive code modulation scheme first of all we construct an OFDM system .In second step calculate BER for each SNR. Transfer BER and SNR as input to the fuzzy logic system. Study BER for each SNR for each modulation technique in OFDM system. Design membership function for input and output variable. Design fuzzy rule set using IF and THEN rules. Save the fuzzy logic structure. Change the modulation technique per output of fuzzy logic system. Transfer new data again with the new modulation technique. Compare the BER and this process repeat again and again till the all proposed modulation technique.

Design Model

The main problem lies with fuzzy logic is to design the rules set and membership function range values. If these are defined correctly then decision will be accurate otherwise erroneous decisions may take place. So before designing the

FIS, behavior of application model in every case has to be studied. Like in our proposed work, inputs in fuzzy logic have been taken as BER and signal to noise ratio (SNR) depending upon the values of both output modulation technique switching will be done. So it has to be studied first that which modulation technique is giving better BER for particular SNR. That specific range will take part in designing the membership function of fuzzy logic set. The membership functions for proposed work will be discussed in the next section.

Membership Function for Proposed Scheme

Three set of membership functions are defined, two for input variables: SNR and BER; and third for output variable: modulation index. MATLAB provides a user interface for designing the membership functions as shown in figure 4. it shows two inputs and one output functions which are connected through mamdani inference system. The range of membership function is decided by considering each modulation technique independently for same FFT size, number of subcarriers and number of OFDM symbols.

Based upon that the range for SNR input has been decided between [1, 34] and for BER it is [0.02, 0.09].

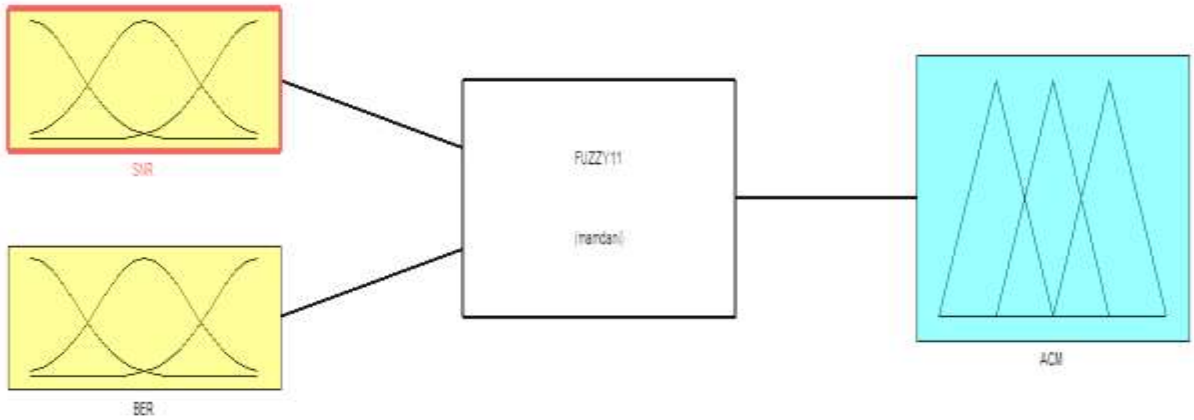


Figure 2: Fuzzy Logic user interface

A flow chart for proposed scheme is presented in this chapter in figure 5below. In this fig5. shown that first of all we construct the OFDM system for AWGN channel. Then calculate the BER for each signal to noise ratio value, after that transfer the value of BER and SNR as input to the fuzzy.

Input variable

Membership function for BER

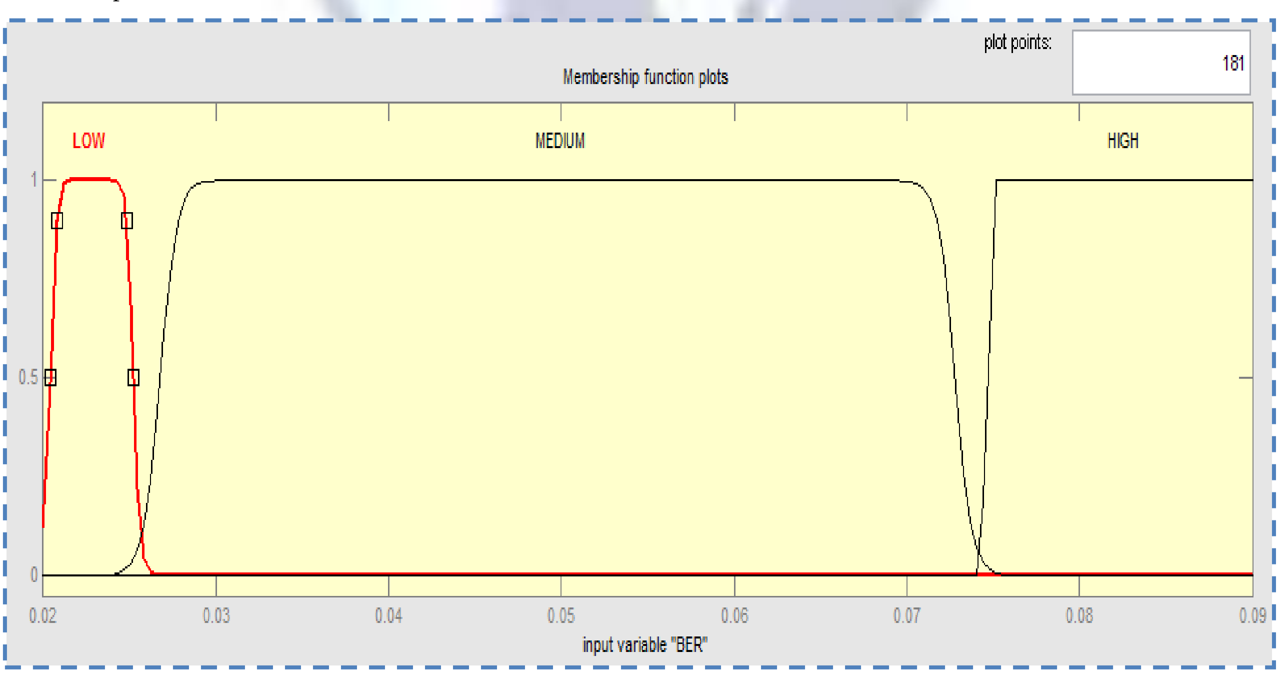


Fig.3: Flow chart for proposed fuzzy logic scheme for ACM

Table1: Membership function for BER

Type	Range		
LOW	0.0024	6.42	0.0228
MEDIUM	0.023	24	0.04978
HIGH	0.07427	0.0752	0.09

Membership function for BER

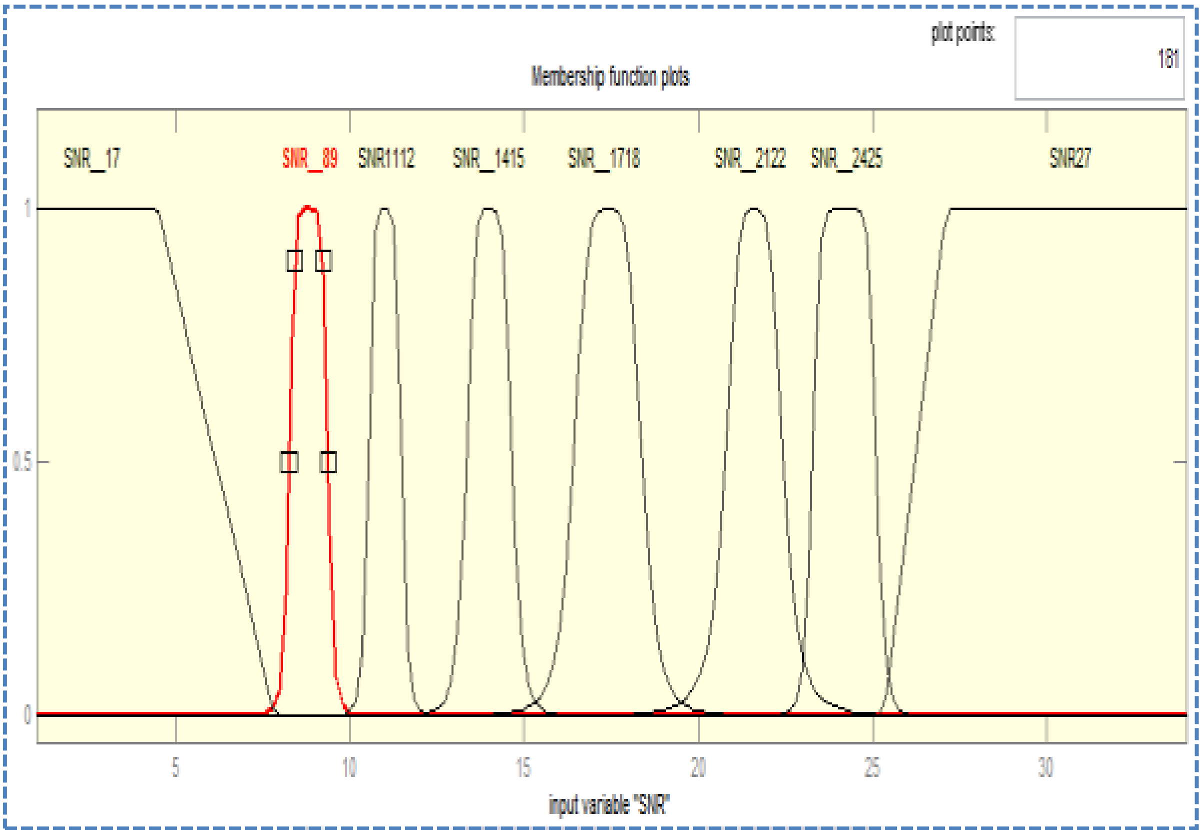


Figure 4: Representation of Membership function for SNR

The shape of the membership functions has been kept bell shape Gaussian function because of their smoothness and conciseness. Initial and last membership function named SNR_17 and SNR27 as shown in figure 8 are kept trapezoidal type.

Table 2: Membership function of SNR

Type	Range		
SNR_17	0	4.47	7.841
SNR_89	0.566	3.54	8.819
SNR_1112	0.467	0.297	11
SNR_1415	0.6654	2.62	14
SNR_1718	0.9773	2.31	17.4
SNR_2122	0.835	1.935	21.6
SNR_2427	0.912	4.09	24.2
SNR_27	25.3	27.12	34

Membership function for modulation technique

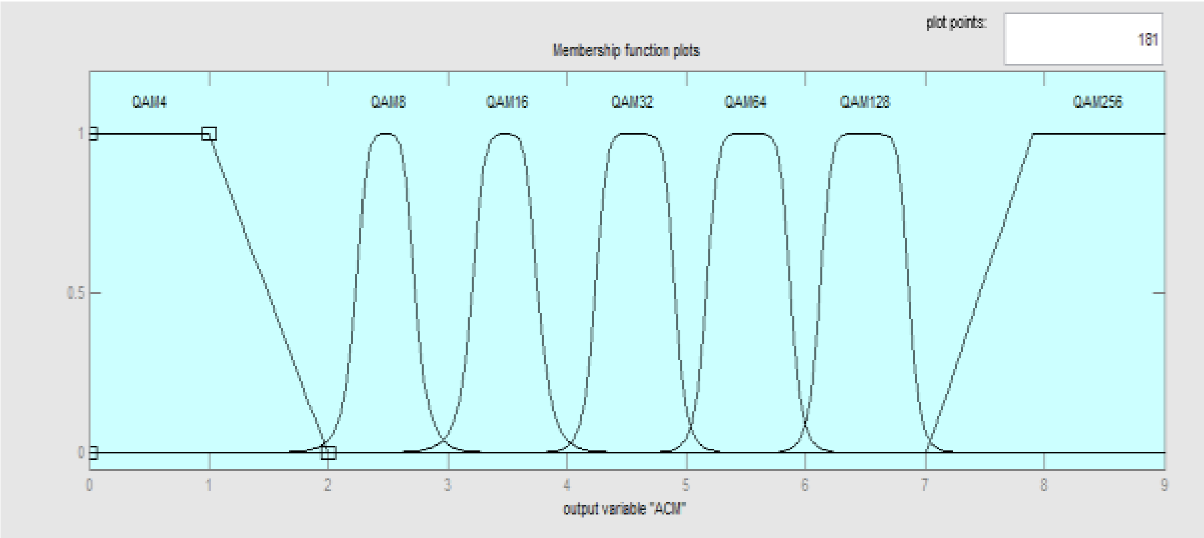


Figure 5: Representation of membership function for modulation technique

Table 3: Membership function of modulation technique

Type	Range		
4QAM	0	1	2
8QAM	0.2474	2.38	2.48
16QAM	0.2757	2.5	3.48
32QAM	0.332	3.58	4.569]
64QAM	0.351	3.802	5.52
128QAM	0.369	4.088	6.49
256QAM	7.01	7.9	9

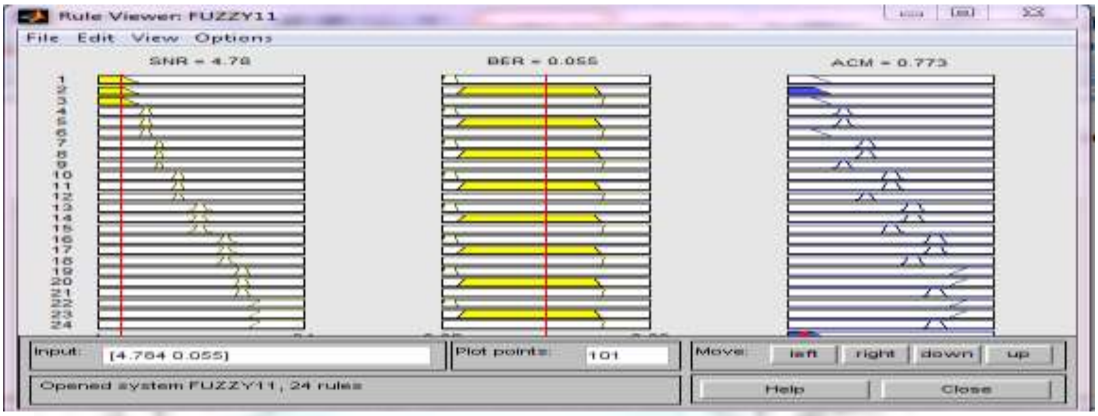
Rules Implications

Like fuzzy editor in MATLB provides the facility to design the membership function in membership editor, likewise it also have facility to design fuzzy rules in rules editor. A total of 24 set of rules are defined for decisions. These rules are given below:

- 1. If (SNR is SNR__17) and (BER is LOW) then (ACM is QAM4)
- 2. If (SNR is SNR__17) and (BER is MEDIUM) then (ACM is QAM4)
- 3. If (SNR is SNR__17) and (BER is HIGH) then (ACM is QAM4)
- 4. If (SNR is SNR__89) and (BER is LOW) then (ACM is QAM8)
- 5. If (SNR is SNR__89) and (BER is MEDIUM) then (ACM is QAM8)
- 6. If (SNR is SNR__89) and (BER is HIGH) then (ACM is QAM4)
- 7. If (SNR is SNR1112) and (BER is LOW) then (ACM is QAM16)
- 8. If (SNR is SNR1112) and (BER is MEDIUM) then (ACM is QAM16)
- 9. If (SNR is SNR1112) and (BER is HIGH) then (ACM is QAM8)
- 10. If (SNR is SNR__1415) and (BER is LOW) then (ACM is QAM32)
- 11. If (SNR is SNR__1415) and (BER is MEDIUM) then (ACM is QAM32)
- 12. If (SNR is SNR__1415) and (BER is HIGH) then (ACM is QAM16)
- 13. If (SNR is SNR__1718) and (BER is LOW) then (ACM is QAM64)
- 14. If (SNR is SNR__1718) and (BER is MEDIUM) then (ACM is QAM64)
- 15. If (SNR is SNR__1718) and (BER is HIGH) then (ACM is QAM32)
- 16. If (SNR is SNR__2122) and (BER is LOW) then (ACM is QAM128)
- 17. If (SNR is SNR__2122) and (BER is MEDIUM) then (ACM is QAM128)

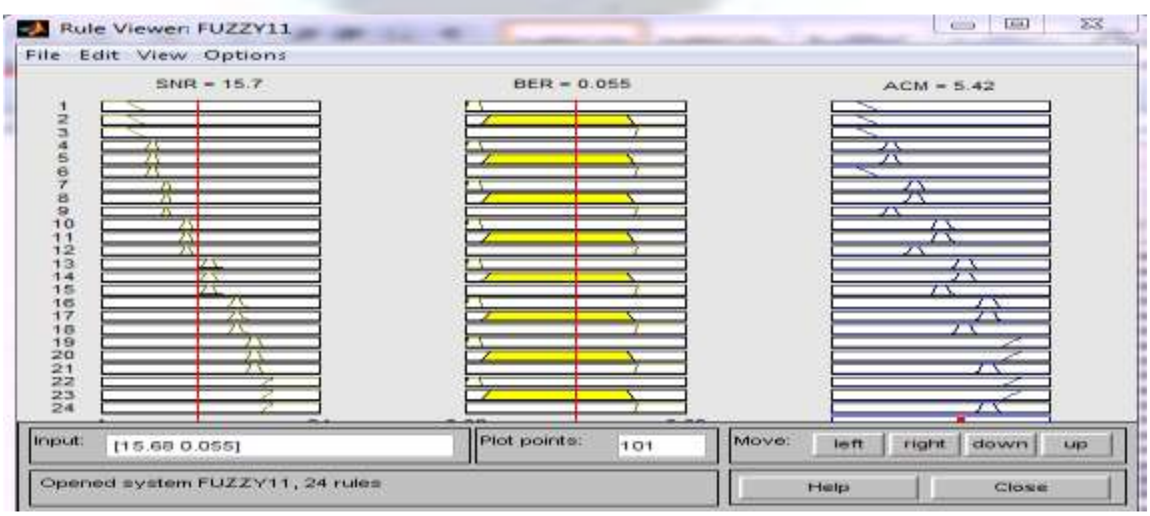
- 18. If (SNR is SNR__2122) and (BER is HIGH) then (ACM is QAM64)
- 19. If (SNR is SNR__2425) and (BER is LOW) then (ACM is QAM256)
- 20. If (SNR is SNR__2425) and (BER is MEDIUM) then (ACM is QAM256)
- 21. If (SNR is SNR__2425) and (BER is HIGH) then (ACM is QAM128)
- 22. If (SNR is SNR27) and (BER is LOW) then (ACM is QAM256)
- 23. If (SNR is SNR27) and (BER is MEDIUM) then (ACM is QAM256)
- 24. If (SNR is SNR27) and (BER is HIGH) then (ACM is QAM128)

IV. Results and simulations

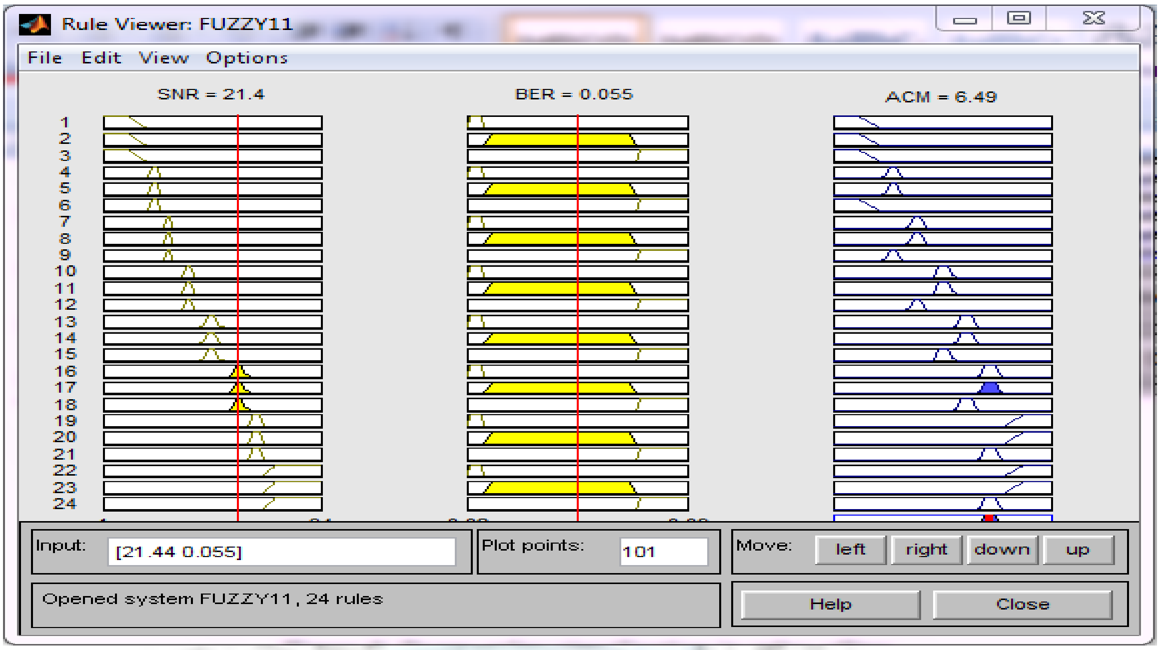


(a)

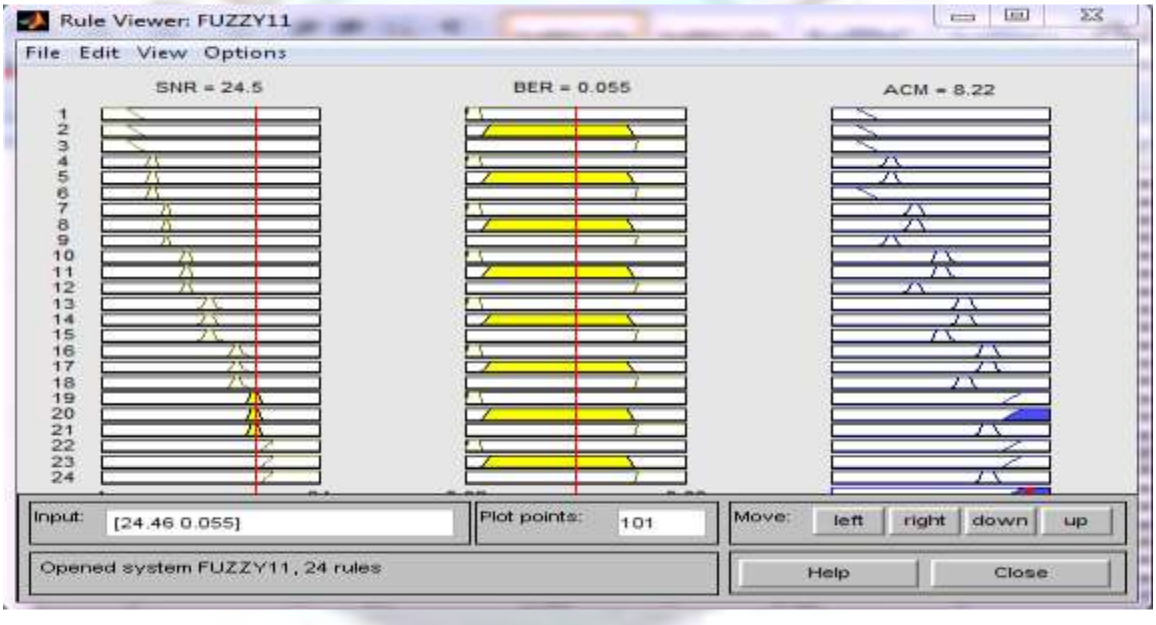
(b)



(c)



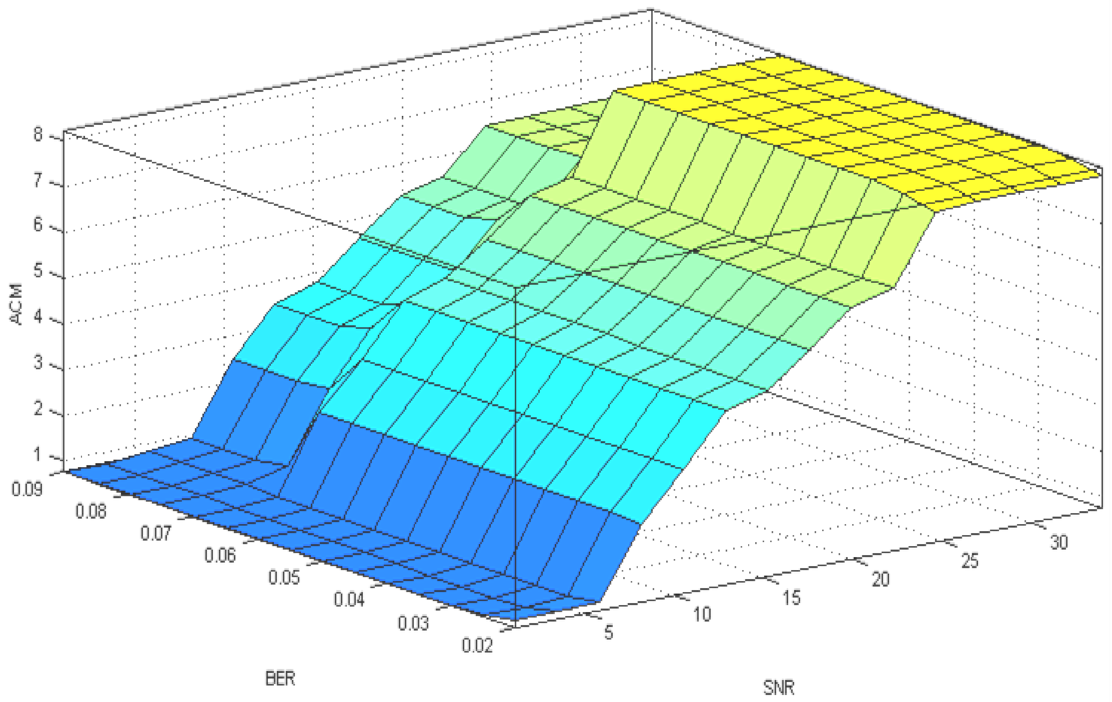
(d)



(e)

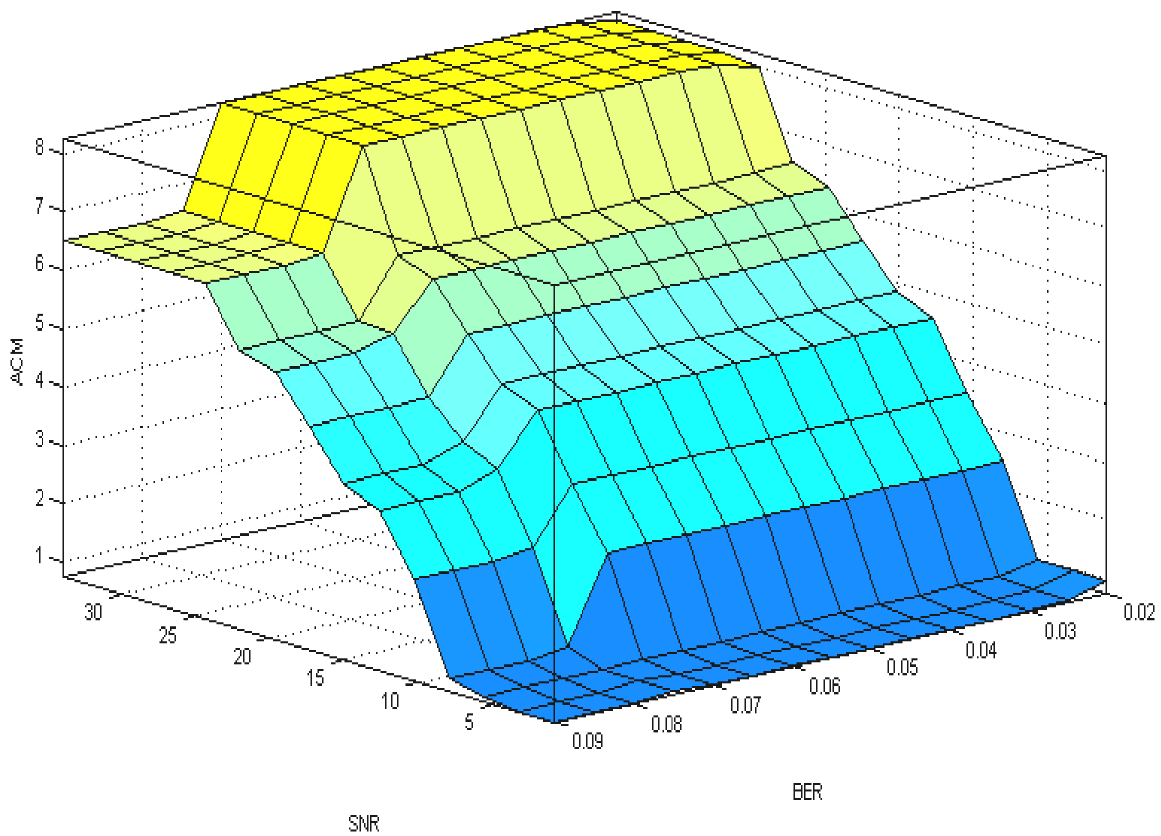
Figure 6(a , b ,c ,d ,e): Fuzzy rules visualization in rules editor

The rule editor of fuzzy toolbox also facilitates to visualize the rules in the editor as shown in above figure 6(a,b,c,d,e) . The first two columns in the figure plot the input membership functions and third column plotting is for output membership function. The last row in the third column shows the aggregated weighted decision for the given inference system. This decision will depend on the input values for the system. The defuzzified output is displayed as a bold vertical line on this plot. The three dimensional plot of rules can be checked form the surface plot which is also a part of fuzzy rule editor. From the table 4 as we seen that as the SNR is increase modulation are switch on the higher modulation technique like as the SNR up to 7db than modulation technique is 4QAM, and as the SNR is increases from 7db than modulation technique switch on higher modulation technique 8QAM an .If the SNR is decreases than it switch back on the lower modulation technique.



(a)

The smoothness of surface guarantees the correctness of rules set. The 3-D surface view of our rules set is shown in figure 7(a, b). it is having three axis each for one variable defined. Output is mapped along vertical axis while inputs are mapped along horizontal axis. How surface plot helps in understanding the rule based output is more clearly visible in figure 7 (a , b) in which figure 7(b) is rotated by 90^o. for example figure shows that upto SNR =5, whatever be value of BER in the range, modulation will be ACM2 as shown by dark blue region.



(b)

Figure 7: (a, b) Surface view plots of ACM in Fuzzy Logic System

Table 4: Fuzzy Rules Based Values of SNR, BER and Modulation Used

SNR	BER	MODULATION
4.54	0.0023	QAM4
4.54	0.0259	QAM4
4.54	0.0288	QAM4
4.54	0.0498	QAM4
4.54	0.0744	QAM4
6.15	0.023	QAM4
6.15	0.0262	QAM4
6.15	0.0288	QAM4
6.15	0.0498	QAM4
6.15	0.0744	QAM4
7.89	0.023	QAM8
7.89	0.0264	QAM8
7.89	0.0288	QAM8
7.89	0.0498	QAM8
7.89	0.0744	QAM4
7.89	0.023	QAM8
7.89	0.0264	QAM8
7.89	0.0288	QAM8
7.89	0.0498	QAM8
7.89	0.0747	QAM4
8.68	0.023	QAM8
8.68	0.0264	QAM8
8.68	0.0288	QAM8
8.68	0.0498	QAM8
8.68	0.744	QAM4
9.87	0.023	QAM8
9.87	0.0264	QAM8
9.87	0.0288	QAM 8
9.87	0.0498	QAM8
9.87	0.0744	QAM4
9.87	0.023	QAM8
9.87	0.0264	QAM8
9.87	0.0288	QAM8
9.87	0.0498	QAM8
9.87	0.0744	QAM4
11	0.023	QAM16
11	0.0264	QAM16
11	0.0288	QAM16
11	0.0498	QAM16
11	0.0744	QAM8
12	0.023	QAM16
12	0.0264	QAM16
12	0.0288	QAM16
12	0.0498	QAM16
12	0.0744	QAM16
12.6	0.023	QAM32
12.6	0.0264	QAM32
12.6	0.0288	QAM32
12.6	0.0498	QAM32
12.6	0.0744	QAM16
14.1	0.023	QAM32
14.1	0.0264	QAM32
14.1	0.0288	QAM32
14.1	0.0498	QAM32
14.1	0.0744	QAM16
15.5	0.023	QAM64
15.5	0.0264	QAM64

SNR	BER	MODULATION
15.5	0.0288	QAM64
15.5	0.0498	QAM64
15.5	0.0744	QAM32
17.4	0.023	QAM64
17.4	0.0264	QAM64
17.4	0.0288	QAM64
17.4	0.0498	QAM64
17.4	0.0744	QAM32
19.5	0.023	QAM128
19.5	0.0264	QAM128
19.5	0.0288	QAM128
19.5	0.0498	QAM128
19.5	0.023	QAM128
19.5	0.0264	QAM128
19.5	0.0288	QAM128
19.5	0.0498	QAM128
21.8	0.023	QAM128
21.8	0.0264	QAM128
21.8	0.0288	QAM128
21.8	0.0498	QAM128
23.5	0.023	QAM256
23.5	0.0264	QAM256
23.5	0.0288	QAM256
23.5	0.0498	QAM256

From the above table we conclude that as the value of SNR and BER is increases than it switches according to the rules. Hence from the fuzzy logic we can design our rules and system is working according to it .Fuzzy logic gives the value in between 0 and 1.

V. Conclusion

A fuzzy logic model is purposed from fuzzy for ACM. The designing of fuzzy rules set in MATLAB is quite user friendly. We have taken bit error rate and signal to noise ratio of receiver as input to fuzzy logic inference system and switching modulation as the output. The decision levels in form of membership functions are assigned for SNR input and ACM output. A total of 24 fuzzy rules are defined, on the basis of which switching will be done. Linguistic variables defined in fuzzy logic makes it close to human point as defining rules in words is easier than mathematical forms. It defines rules in the form of 'if and then'. To check the correct designing of decision levels, surface view of rules is checked. The smoothness of 3D surface proves that rules are set very precisely and switching of ACM will be done at various levels very effectively.

References

[1]. Kalet I., "The multitone channel," IEEE Tran. Commun., vol. 37, pp.119–124, Feb. 1989.

[2]. Chow P.S., Cioffi J.M and Bingham J.A.C., "A practical discrete multi tone transceiver loading lgorithm for data transmission over spectrally shaped channels", IEEE Transactions Communications, vol 38, pp. 772-775, 1995

[3]. A.Cyzlwik, "Adaptive OFDM for wideband radio channels", Global Telecommunications Conference, vol 1, pp713-718, Nov 1996.

[4]. KellerT., and Hanzo L., "Adaptive modulation techniques for duplex OFDM transmission," IEEE Transactions on Vehicular Technology, vol.49, no.5, pp.1893-1906, Sep 2000.

[5]. Albertazzi G., Cioni S., Corazza G. E., Laurentiis N. De, Neri M., Salmi P. and A. Vanelli-Coralli, "Part II: Reverse Link," Proc. of 10^{th} Ka and Broadband Communications Conference, Vicenza (Italy), vol. I, pp. 399-404, 2004.

[6]. Birla V. and Rupesh D., "Capacity Enhancement of WiMAX System Using Adaptive Modulation and Code Rate," International Journal of Emerging Technology and Advanced Engineering ,ISSN 2250-2459, Vol. 2, pp.1-8, 2012.

[7]. Bello O. and Fsasi A. A., "Simulation of Wimax 802.16E Physical Layermodel," Iosr Journal of Electrical and Electronics Engineering, Volume 5,pp.8- 12,2013.

[8]. Chatzidiamantis N. D., Lioumpas A.S., Karagiannidis G.K., and Arnon S., "Optical Wireless Communications with Adaptive Subcarrier PSK Intensity Modulation," Journal of Lightwave Technology, Vol. 30, No. 12, pp.118-128, 2012.

[9] Deepa and Singh S., " An adaptive approach to switching coded modulation in OFDM system under AWGN channel", International Journals of Scientific research & Development, ISSN(online) 2321-0613,Vol.2,pp. 457-462,2014.

[10]. Faezah J. and Sabira K., " Adaptive Modulation for OFDM Systems," International Journal of Communication Network and Information, Vol. 1, pp. 1-8,2009.

[11]. Harivikram T.S., Dr. Harikum R., Dr. C.G.B. and P. M , "Adaptive Modulation and Coding Rate for OFDM Systems," International Journal of Emerging Technology and Advanced Engineering, Volume 3, Issue 2, pp. 28-41, 2013

[12]. Islam M.A., Mondal R.U. and Hasan M.Z., " Performance Evaluation of Wimax Physical Layer under Adaptive Modulation Techniques and Communication Channels," (IJCSIS) International Journal of Computer Science and Information Security, Vol. 5,pp.111-114, 2009.

[13]. Mohamed M. A., Zaki1 F.W. and Mosbeh R. H.," Simulation of Wimax Physical Layer," Ieee International journals of computer science and Technology and Network system,Vol.10,pp. 49-55,2010.

[14]. Nagar K.K., and Sharma K., " Adaptive OFDM Implementation Using Fuzzy Inference System", International Journal of Advanced Research in Computer Science and Software Engineering, Vol. 3, pp. 193-1906,July 2013.

[15]. Rao A. and Alouini M. S., "Multiuser Diversity with Adaptive Modulation in Non Identically Distributed Nkagami Fading Environment," IEEE Transaction on vehicular Techonology, Vol.61, pp.1439-1444, 2012.

[16]. Sastry K.S. and Dr. Babu M.S.P., " Fuzzy logic based Adaptive Modulation Using Non Data Aided SNR Estimation for OFDM system," International Journal of Engineering Science and Technology Vol. 2,pp. 2384-2392,2010.

[17]. Sharma U., "Comparative Study of Digital Modulation Techniques in WIMAX," International Journal of Engineering and Innovative Technology (IJEIT) Volume 2, Issue 2, pp. 38-41, 2012.

[18]. Sharma A. and De S., "Exploiting Fading Dynamics along with AMC for Energy-Efficient Transmission over Fading Channels," IEEE Communications Letters, Vol.15, pp.1218-1220,2011.

[19]. Sharma A. and Garhwal A.," Performance Analysis Physical Layer of Wimax System Using Simulink," International Journals of Computer Science and Research,Vol.2, pp.203-207,2013.