Adaptive Modulation Using Neuro-Fuzzy (N-F) Controller for OFDM System

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***Abstract*—As demand for high quality transmission increases, improving spectrum efficiency and error performance in wireless communication systems are important. OFDM is a multi-carrier modulation technique with densely spaced sub-carriers that has gained a lot of popularity among the broadband community in the last few years. One of the promising approaches to next generation communication systems are adaptive OFDM (AOFDM). Fixed modulation systems uses only one type of modulation scheme (or order), so that either performance or capacity should be compromised but in adaptive modulated systems change modulation scheme (or order) depending on instantaneous Signal to Noise Ratio (SNR) to attain superior performance and capacity compared to fixed modulated systems. Neuro-fuzzy controller combines advantages of fuzzy logic and neural networks. Neuro-fuzzy controller provides automatic adaption procedure to fuzzy logic controller. Neural networks requires sufficient prior knowledge to be initialized but neuro-fuzzy systems doesn't requires any prior knowledge to be initialized and is efficient compared to fuzzy logic and neural networks. In this paper we propose an adaptive modulated OFDM system using neuro-fuzzy controller. The proposed system is simulated in MATLAB and compared with existing systems, simulation results shown significant improvement in systems performance.**

***Index Terms*—Adaptive modulation, OFDM, Neuro-Fuzzy controller**

I. Introduction

Orthogonal Frequency Division Multiplexing (OFDM) is a special form of multi-carrier transmission technique in which a single high rate data stream is divided into multiple low rate data streams. These data streams are then modulated using sub carriers which are orthogonal to each other to reduce symbol rate on each sub channel, and hence the effect of inter symbol interference (ISI) due to channel dispersion in time which is due to multipath delay spread is reduced. Guard interval is also be inserted between OFDM symbols to reduce ISI further. In [1] and [2] K.Seshadri Sastry and M.S. Prasad Babu proposed adaptive modulated system using fuzzy logic interface which performed better than fixed modulation systems**.** The channel performance may be highly fluctuating across the sub carriers and varies from symbol to symbol [3]. If the same fixed transmission scheme is used for all OFDM sub carriers, the error probability is dominated by the OFDM sub carriers with highest attenuation resulting in a poor performance. Therefore, in case of frequency selective fading the error probability decreases very slowly with increasing average signal-to-noise ratio (SNR) [4]. The combination of adaptive modulation with OFDM was proposed as early as 1989 by Kalet which was further developed by Chow [5] and Czylwik [4]. Specifically the results obtained by Czylwik showed that the required SNR for the BER target 10-3 can be reduced by 5dBto 15dB compared to fixed OFDM depending on the scenario of radio propagation. In [6] K.Seshadri Sastry and M.S. Prasad Babu proposed Non Data Aided SNR Estimation for OFDM Signals in Frequency Selective Fading Channels. In [7] K.Seshadri Sastry and M.S. Prasad Babu proposed SNR Estimation for QAM Signals Using Fuzzy Logic Interface.

The performances of turbo-coded adaptive modulation are investigated in [8]. Three different modulation mode allocation algorithms were discussed and compared. Further studies on the application of turbo code in adaptive modulation and coding is conducted in [9]. This paper proposed an approach based on prediction of the average BER over all sub carriers. In [10], an adaptive OFDM system with changeable pilot spacing has been proposed. The results showed that a significant improvement in the BER performance is achieved with sacrificing a small value of the total throughput of the system. A work is done on several strategies on bit and power allocation for multi-antenna assisted OFDM systems in [11]. They found out that sometimes power and bit adaptation is required for efficient exploitation of wireless channels in some system conditions. The performance analysis of OFDM systems with adaptive sub carrier bandwidth is investigated by [12]. Further investigations on sub carrier adaptive modulation scheme of pre coded OFDM is presented in [13] under multipath channels. In [14] adaptive modulation for OFDM system using fuzzy logic interface was illustrated. In [15] efficient methods for high speed data transmission are proposed. In [16] AI based companding scheme to increase speed of OFDM system was proposed. In [17] SNR Mismatch and Online Estimation in Turbo Decoding were proposed. In [18] SNR estimation in generalized fading channels and their application are proposed. In [19] AI Based Digital Companding Scheme for Software Defined Radio is presented. In [20] SNR estimation method for QPSK modulated short bursts is

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presented. In [21]-[22] comparison of various SNR Estimation Techniques is presented. In this paper we propose an adaptive modulated OFDM system using neuro-fuzzy controller to achieve optimum bit error rate performance and channel capacity.

II. Proposed Scheme

Adaptive modulation system proposed by [1] K.Seshadri Sastry and Dr .M.S.Prasad Babu was modified in proposed scheme .In this Section, we explain OFDM system with adaptive modulation using Neuro-Fuzzy (N-F) controller. The proposed scheme is depicted in Fig. 1. The proposed system was simulated in MATLAB, Parameters of the system are as follows , IFFT Size is 512 , Number of sub carriers are 512 , Number of sub bands are 32 , Number of sub carriers per sub band are 16 , Guard Time Duration is 128 , frame size is 6 , SNR 1-35 dB, modulation schemes used are MPSK, and MQAM , convolutional coder with code rate 2/3 , bandwidth 5MHz, carrier Frequency 2 GHz, sampling frequency 5.4MHz .The transmit signals of the base station are created through convolutional encoder, modulated, Inverse Fast Fourier transform (IFFT), guard interval (GI) was injected and transmitted. The proposed scheme uses Adaptive Modulation that use 6 modulation orders. Signal to Noise Ratio (SNR) estimation and change of modulation order are carried by FIS (Fuzzy Interface System). Non Data Aided (NDA) SNR estimator proposed in [6] was employed to estimate channel.

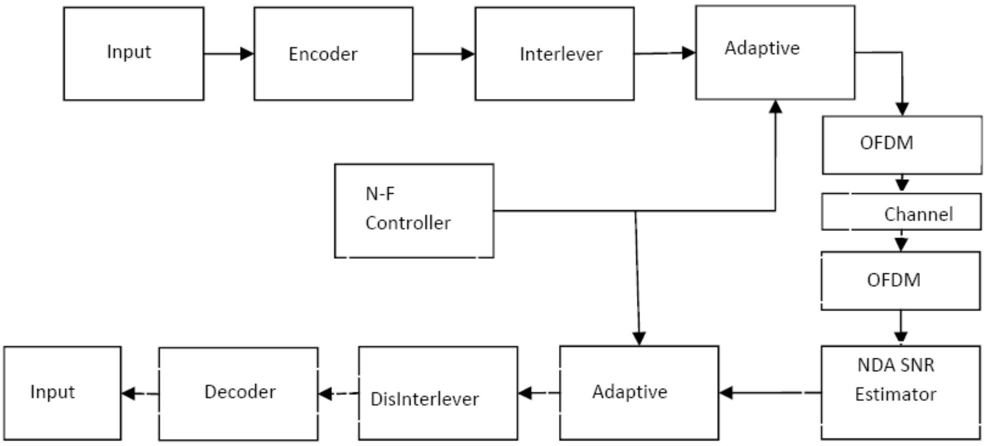

Figure 1. Block Diagram of Proposed System

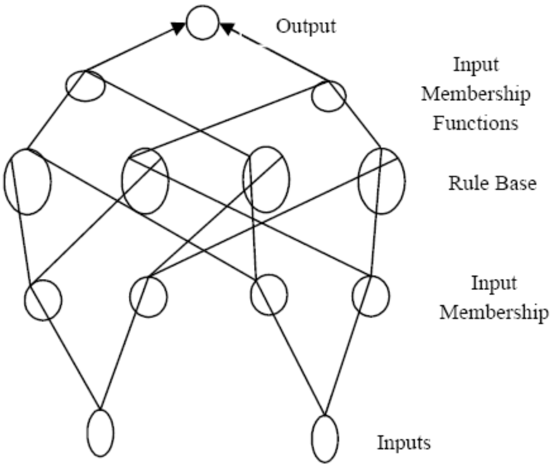

Figure 1. Architecture of Neuro-Fuzzy controller

Fig. 2 explains the architecture of N-F controller. N-F controller uses Sugeno-type Fuzzy Inference System (FIS), with the parameters of FIS decided by the neural-network back propagation method.

The proposed controller was simulated in MATLAB using Fuzzy interface System (FIS) editor. In a conventional fuzzy logic controller approach the membership functions and the consequent models are fixed by the designer based on prior knowledge. If this set is not available but when a set of input and output data is observed from a process, the components of a fuzzy system (membership functions) can be represented in a parametric form and the parameters are tuned by neural networks (which is called as Neuro-Fuzzy system). A fuzzy system can explain the knowledge it encodes but can't learn or adapt its knowledge from training examples, while a neural network can learn from training examples but cannot explain what it has learned. Fuzzy systems and neural networks have complementary strengths and weaknesses. In this paper hybrid model that can take advantage of strong points of both fuzzy logic and neural networks is utilized to change modulation order in adaptive modulation.

Adaptive modulation involves measuring the SNR (Signal to Noise Ratio) of each subcarrier in the transmission, then selecting a modulation scheme that will maximize the spectral efficiency, while maintaining an acceptable BER Adaptive modulation is advantageous than fixed modulation scheme since it responds to channel condition and maintains good performance (Bit Error Rate) and speed (capacity). But if the decision making system is not efficient then response of the system to changing conditions of channel is not good (that is either BER or capacity of the system is compromised) In this case the advantages of using adaptive modulation over fixed modulation is very less.

By employing Fuzzy logic in decision making system modulation levels can be changed very efficiently with changing conditions of channel [1], [2] and [14]. But ordinary fuzzy logic controller doesn't have learning capacity; adding learning capacity to fuzzy logic controller will further enhance the performance of fuzzy logic controller proposed in [1] and [2]. In this paper learning capacity is added to fuzzy logic controller by implementing Neuro-Fuzzy controller to change modulation order or control adaptive modulation (in decision making). The proposed system is simulated in MATLAB and compared with fixed modulation system and fuzzy logic based adaptive modulation system.

In N-F controller Input and output membership function adjustments are generated by back- propagating the error through the "neural-like" architecture of the fuzzy controller. The back propagation algorithm would encourage rules which contribute towards taking the actual control action towards the desired control action and discourage rules which tend to take the control action away from the desired goal. The error is assumed to be due to the bad choice of membership functions. Membership functions can be adjusted by laterally moving the domain or by bending the segments of the function. The error may be due to combination of errors due to wrong lateral placement of the domains and specification of function shapes. In N-F controller the when an error due to lateral placement of domain results, output membership function is modified and when error due to function shapes occurs, input membership function is modified. In the proposed N-F controller two inputs namely *pres_mod* and *est_SNR* are taken. The input *Pre-mod* is having six membership functions namely *qpsk, 8-qam, 16-qam, 32-qam, 64-qam, 128-qam.*Input *est_SNR* is having six membership functions namely *poor, very_low, low, medium, high, ver-high*. Proposed N-F controller consists of one output membership function namely *new_mod,* back propogation algorithm is used to modify input and output membership functions based on knowledge acquired due to training.

III. Results

The proposed scheme using N-F controller based adaptive modulation was simulated in MATLAB using fuzzy editor and compared with existing fuzzy based adaptive modulation scheme[1] and fixed modulation schemes. Fixed modulation systems uses only one type of modulation scheme (or order), so that either performance or capacity should be compromised but in adaptive modulated systems change modulation scheme (or order) depending on instantaneous Signal to Noise Ratio (SNR) to attain superior performance and capacity compared to fixed modulated systems. It was already shown in [1] and [2] that fuzzy based adaptive modulation scheme outperforms fixed modulation schemes and adaptive modulation scheme using ordinary control (using only if and else statements to change modulation). Using fuzzy logic in decision making is a good choice because ordinary (non fuzzy) system is controlled by plain if and else , for example if for *poor SNR* range is declared as 0 to 3 , if input is 3.1 then the input is not considered as *poor SNR* (But it is poor). If we use fuzzy logic in above case 3.1 is also considered as *poor SNR*. So using Fuzzy logic based control increases the performance adaptive modulation system. Neuro-fuzzy (N-F) controller combines advantages of fuzzy logic and neural networks. N-F controller provides automatic adaption procedure to fuzzy logic controller. Neural networks requires sufficient prior knowledge to be initialized but N-F systems doesn't requires any prior knowledge to be initialized and is efficient compared to fuzzy logic and neural networks. In the proposed N-F controller back propagation algorithm is used to adjust the values of input and output membership functions of fuzzy logic so that the performance of fuzzy logic is further improved based on training samples. The performance of fuzzy controller proposed in [1] is improved in this paper using back propagation algorithm. Figure 3 shows Bit Error Rate comparison of proposed N-F controller based adaptive modulation scheme with existing fuzzy based adaptive modulation schemes and fixed modulation schemes. Simulation results confirmed that N-F based adaptive modulator outperforms fixed modulation systems and N-F based adaptive modulator shows improved performance compared to fuzzy based adaptive modulator [1].

IV. Conclusion

In this paper N-F based adaptive modulator was proposed and simulated using MATLAB and compared with existing fuzzy based adaptive modulation scheme [1] and fixed modulation schemes. Fixed modulation systems uses only one type of modulation scheme (or order), so that either performance or capacity should be compromised but in adaptive modulated systems change modulation scheme (or order) depending on instantaneous Signal to Noise Ratio (SNR) to attain superior performance and capacity compared to fixed modulated systems.

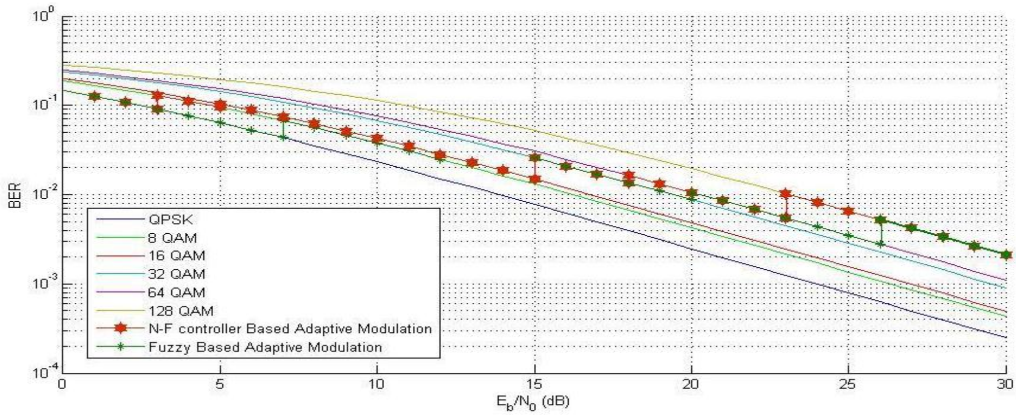

Figure 2. Bit Error Rate comparison of proposed N-F controller based adaptive modulation scheme with existing fuzzy based adaptive modulation schemes and fixed modulation schemes

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