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Adaptive OFDM Modulation Used For SDR

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Abstract: Software defined radio (SDR) is the future trend for mobile communication. A SDR is supposed to facilitate high speed multimedia application for future mobile standards. Adaptive modulation forms an integral part of SDR system with robust and high data rate capability. Here we have analyzed adaptive modulation scheme with their performance in changing channel condition. The modulation scheme studied for adaptive modulation are BPSK, QPSK 16QAM , 32 QAM ,64 QAM . Different order modulations and different coding schemes, allow to send more bits per symbol, thus gaining higher throughputs and better spectral efficiencies. But it must also be noted that when using a modulation technique such as 64-QAM with less overhead bits, better signal-to-noise ratios (SNRs) are necessary to overcome any Intersymbol Interference (ISI) and also maintain a certain bit error ratio (BER). The use of adaptive modulation gains wireless technologies to yielding higher throughputs while also covering long distances. This paper focusing on the physical layer design (i.e. Modulation), here the various used modulation type will be implemented in a single Matlab function that can be called with the appropriate coefficients. A comparison will be made in terms of SNR and BER relation.

Index Terms: Software Defined radio, Adaptive modulation, Channel SNR, BER , OFDM.

I. Introduction

Orthogonal frequency-division multiplexing (OFDM) is widely used in wireless communication systems . But, drawback of OFDM signals is its high peak-to-average power ratio (PAPR) , which makes them very sensitive to nonlinear effects of power amplifier (PA). Orthogonal frequency-division multiplexing (OFDM) is a transmission technique that modulates multiple carriers simultaneously. Although their spectra overlap, the transmitted multiple carriers can be demodulated orthogonally, provided that correct time windowing is used at the receiver. Since the OFDM-based system has high spectral efficiency and is robust against intersymbol interference and frequency-selective fading channels, it has been widely chosen for Europea digital audio/video broadcasting and wireless local/ metropolitan area network standards, and now, it is used in most broadband wireless communication systems. However, one of the major problems of OFDM-based systems is the high peak-to-average-power ratio (PAPR) of a transmitted signal, which causes a distortion of a signal at the nonlinear high-power amplifier (HPA) of a transmitter. Thus, the power efficiency of the HPA is seriously limited to avoid nonlinear distortion; otherwise, the high PAPR results in significant performance degradation. Because of the practical importance of this problem, a number of algorithms for reducing the high PAPR have been developed, such as clipping and filtering (C&F) , coding , adaptive symbol selection, such as selected mapping; partial transmit sequence and interleaving , tone reservation/injection , active signal constellation extension , companding and others. Orthogonal Frequency Division Multiplexing (OFDM) is a popular modulation choice for wireless networks. Therefore, research involving such networks will benefit from software defined OFDM. Today most implementations of OFDM realize the IEEE 802.11a/g standards for local area networks. These transceivers are often based on application specific hardware and allow for little modification of modulation parameters. Application specific hardware is used because the computational requirements of OFDM are more than most general purpose systems can provide. For a software defined OFDM platform, a more programmable solution is needed. Because of the computational costs, some portion of OFDM must be moved to application specific hardware. By carefully designing both the hardware and the hardware/software interface, it is possible to retain the programmability of a purely software system while gaining hardware acceleration. Software defined radio have become more of reality than a buzz word in recent times.SDR are flexible, reconfigurable and multi-standard system which are capable of providing efficient communication. The multimode capability of SDR is the driving force for high data rate multimedia service for future mobile standards. Adaptive modulation is an important component of software radio . Adaptive modulation is a way to improve the tradeoff between spectral efficiency and bit error rate. We are able to make such optimizations in a Rayleigh channel by exploiting its fading dynamics. Periods of low fade and high gain, will improve instantaneous SNR, allows higher rate modulation schemes to be employed with low probability of error. Periods of high fade will lower the effective SNR and force us to use low rate modulation in order to make transmission more robust. Multimedia service requires high data rate and good QOS (Quality of Service) as well, therefore adaptive modulation suits well for fulfilling its requirement.

II. ADAPTATION MECHANISM

We focus on two significant performance metrics: BER and Spectral efficiency. Spectral efficiency is defined as the expected value of log2M (number of bits per symbol) , where M is the modulation level. The modulation schemes chosen for adaptive modulation are BPSK, QPSK, 16-QAM , 32QAM and 64-QAM offering 1, 2, 4 , 5 and 6 bits per symbol respectively . We are going to examine a threshold based adaptation scheme which switches between the different modulations schemes depending upon the estimated channel SNR (signal-to-noise ratio) during each frame. The Channel SNR is estimated at the receiver and is reported to the transmitter through a feedback channel. This information is used to select a modulation scheme for the next transmission frame thereby maintaining the BER below a desired performance threshold level . To have a constant estimated channel SNR for all the symbols in the frame we require a slow and flat fading channel. This condition is necessary to insure that channel conditions do not change drastically in the course of a frame. In such a case, the modulation scheme based upon the estimated channel SNR would no longer be optimal for the active frame. Figure 1 gives an overview of the adaptive modulation[1].

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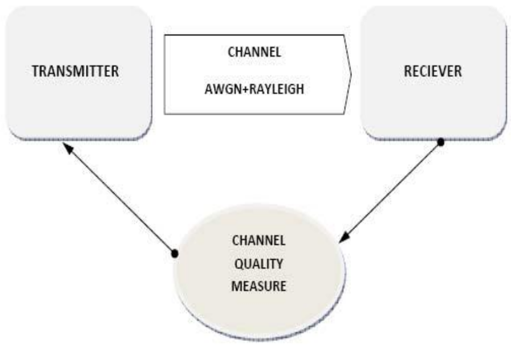

Figure 1 gives an overview of the adaptive modulation.

As mentioned earlier, modulation is adapted on the basis of the channel SNR estimated from the received signal. The three sets of switching levels for the modulation were assumed and correspond to the SNR at which QPSK, 16-QAM and 64-QAM achieve 0.1%, 1% and 10% BER in a Gaussian channel[3]. The reason that we use AWGN performance to choose the thresholds is that during the frame we assume constant SNR, i.e., AWGN conditions. The SNR ranges corresponding to the three different BER targets are described in Table 1[1]. In this simulation, the performance of adaptive modulation is investigated in terms of BER performance. To highlight the advantages of adaptive modulation comparison is made with fixed modulation system under various IFFT size. BER is calculated using following formula

$$BER = \frac{\text{Number of error bits per transmission}}{\text{Number of bits per transmission}}$$

III. OFDM

The functions of the OFDM transmitter can be divided into two categories; channel coding and modulation. Cource coding refers to all processing that occurs before individual subcarriers are modulated. This includes actions such as data framing, forward error correction coding and data scrambling. OFDM Modulation refers to the modulation of individual subcarriers, the inverse fast fourier transform operation and guard interval insertion. While channel coding can vary significantly between standards, OFDM modulation generally includes the same 3 components. In adaptive OFDM transmission, all subcarriers in an AOFDM symbol are split into blocks of adjacent subcarriers. The same modulation is employed for all subcarriers of the same block [1][2]. The choice of the modulations to be used by the transmitter for its next OFDM symbol is determined by the channel quality estimate of the receiver based on the current OFDM symbol. In this simulation the instantaneous SNR of the subcarriers is measured at the receiver. The channels quality varies across the different subcarriers for frequency selective channels. The received signal at any subcarrier can be expressed as:

$$R_n = H_n X_n + W_n$$

Where H_n is the channel coefficient at any subcarrier, X_n is the transmitted symbol and W_n is the Gaussian noise sample. So the instantaneous SNR can be calculated using :

$$SNR = \frac{H_n^2}{N_0}$$

Where N_0 is the noise variance For a real signal, x(n), sampled at fs Hz, the noise bandwidth will be half the sampling rate. Therefore, we find the average power of the noise by multiplying the power spectral density of the noise by the noise bandwidth:

$$N_0 = \frac{n_0 f_s}{2}$$

n_0 One sided power spectral density of noise in **W/Hz.**

IV. Modulation

The first step in OFDM modulation is subcarrier modulation. One or more bits from the channel coding step are assigned to each subcarrier then modulated using a simple technique such as phase shift keying (PSK) or quadrature amplitude modulation (QAM). The number of bits used for each subcarrier depends on the modulation tech nique being used. For example, QPSK requires two bits per subcarrier. The number of subcarriers and the modulation to use for each subcarrier is defined by the protocol or standard being used. At the heart of an OFDM modulator is the Discrete Fourier Transform (DFT) in its common implementation the Fast Fourier Transform (FFT) algorithm. The DFT is a function that takes time series data as its input and returns a set of coefficients representing frequencies found in that data. The OFDM modulator performs the inverse DFT operation using the inverse FFT (IFFT) algorithm. As its name implies, this operation is the opposite of the DFT, transforming frequency information into time This is the amount of input and output produced by one execution of the algorithm and is an important design parameter for OFDM systems. The sample rate of the system and Nfft determine the spacing of the subcarriers. IFFT is ideal for OFDM because it is has efficient hardware and software implementations and because it produces subcarriers that are ideally spaced. Subcarriers are in fact orthogonal in that they are spaced so that they do not interfere with each other. The IFFT found in OFDM takes modulated subcarrier data as input and produces time series data as output. This time domain signal will contain the sum of each of the Nfft subcarrier signals. One OFDM Symbol consists of the output of one IFFT execution representing Nfft subcarriers. Since the OFDM symbol contains many subcarriers representing many bits, the duration of the OFDM symbol can be relatively long. This reduces the effect of intersymbol interference (ISI) caused by multipath reflections at the OFDM receiver. Multipath reflections occur when a signal reffects of different surfaces along multiple paths from the transmitter to the receiver. Since any of these reffected paths will be longer than the direct path from transmitter to receiver, the multipath signals will be delayed relative to the direct path signal and will overlap with the next OFDM symbol. Since the OFDM symbol period is long, the amount of overlap can be small when compared with a serial modulation scheme where the amount of overlap can span several short symbols. To completely eliminate ISI, a guard interval can be inserted at the start of each OFDM symbol. During the guard interval, the receiver might still be receiving delayed copies of the previous symbol caused. The receiver then ignores the guard interval portion of the transmission. In many OFDM systems the guard interval is a cyclic extension of the OFDM

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symbol. A cyclic extension is a copy of the last portion of the OFDM symbol appended to the start of the same symbol. Multipath reflections also cause attenuation or nulls to occur at different frequencies within an OFDM symbol.

V. BLOCK DIAGRAM

The block diagram of this system is shown in Fig 2. Here the channel estimation and modulation selection are done at the receiver side . The information is sent to the transmitter using a feedback channel . In this modulation the adaptation is done frame by frame. The channel estimator estimates the instantaneous SNR of the received signal. Depending on the instantaneous SNR calculated, the best modulation scheme will be chosen for the next transmission frame. This task is done by the modulation selector . At the transmitter the adaptive modulator block consists of different modulators which are used to provide different modulations schemes. The switching between these modulators will depend on the instantaneous SNR provided.

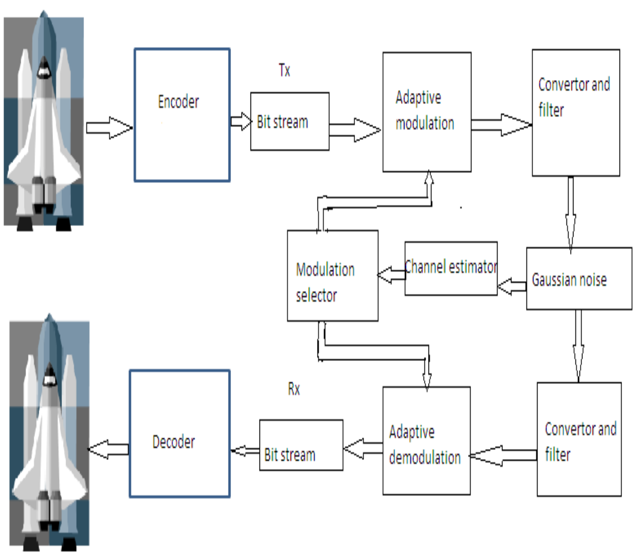

Figure 2. Block Diagram of Adaptive Modulation System

VI. FLOWCHART

Following figure shows flowchart of Adpative Modulation. It takes OFDM symbol as an input to AWGN Channel receiver. This adds White Guassian noise into OFDM symbol. Then, the instantaneous SNR of received symbol is calculated. This instantaneous SNR is compared with the switching threshold values , where it checks the each threshold value against respective modulation scheme. Once appropriate switching threshold range is found , it selects respective modulation scheme for next OFDM symbol. This selected modulation scheme information goes simultaneously to transmitter and receiver. In this way, flow-chart defines selection of modulation scheme based upon instantaneous SNR of received symbol.

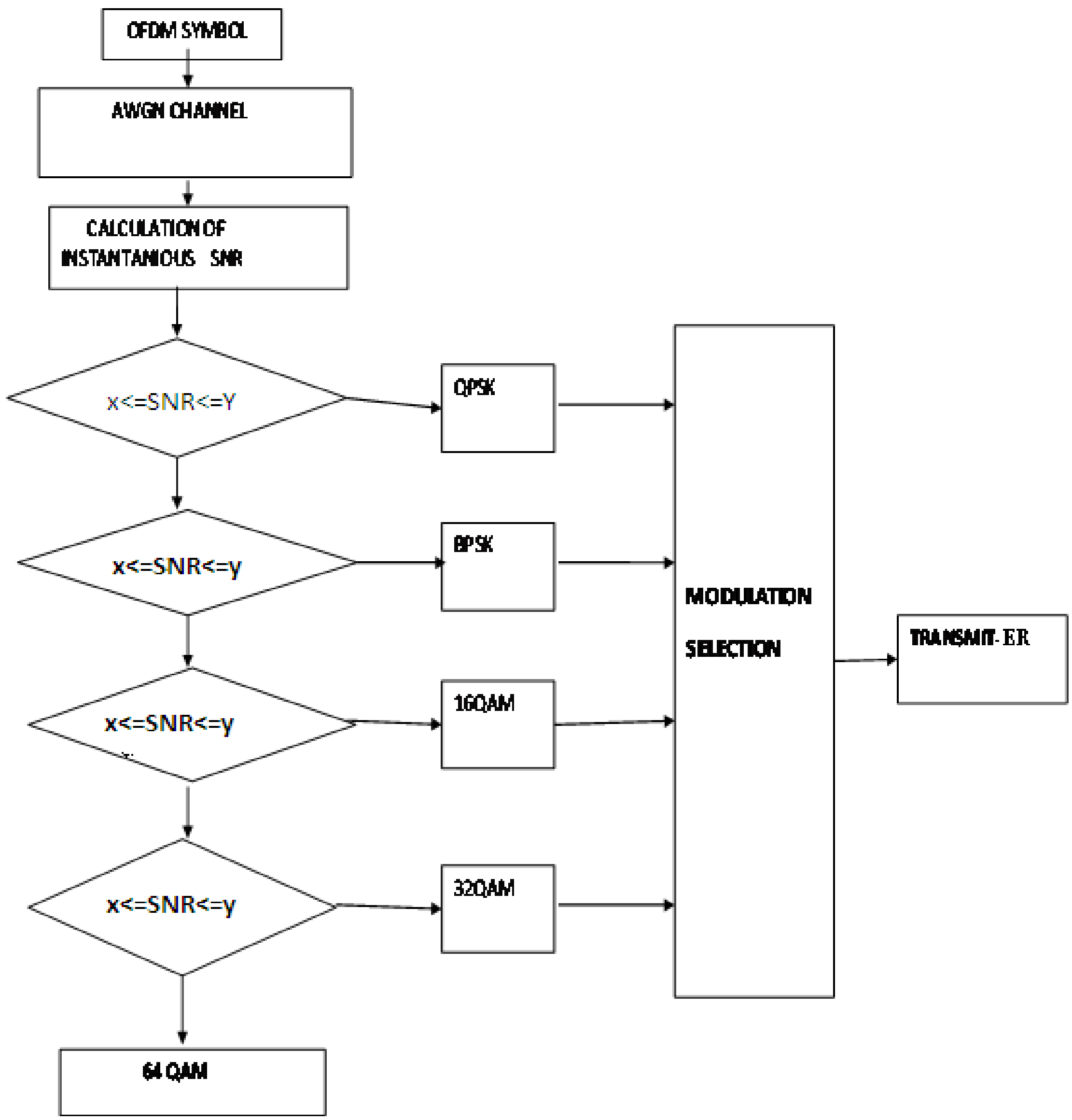

Figure 3. Adaptive Modulation flow-char

VII. CONCLUSION

In this paper, we can infer that our adaptive modulation gives better results when compared to higher order fixed modulation scheme as BER and PAPR is improved . In adaptive modulation, modulation rate changes depending upon value of an instantaneous SNR. The BER performance comparison between fixed and adaptive modulation shows that BER performance for all modulation techniques is better..Hence, it concludes that BER performance of adaptive modulation is better than fixed modulation with the cost of more execution time.

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