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FUZZY ACM IN WIRELESS COMMUNICATION

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ABSTRACT

Spectrally efficient transmission schemes are becoming a more common requirement for digital communication systems. Especially in wireless communication since the bandwidth of available frequencies is a shared resource. Adaptive coded modulation (ACM) has been suggested as a bandwidth-efficient transmission technique in wireless fading environments. The use of ACM is motivated by its ability to improve spectral efficiency (SE) by adapting the transmission rates to the variations in channel signal-to-noise ratio. Any ACM scheme relies on being able to predict future states of the transmission medium. Under idealized conditions, such as the prediction being perfect, an ACM scheme can be configured to maximize the SE under the condition of the bit error rate (BER) being below a specified target BER. In this paper, a simulation considering an example system shows that such systems in some cases fail to achieve the target BER, since the idealized conditions used in the design process do not hold in a realistic setup. By limiting the number of transmission modes, introducing imperfect prediction, and other practical conditions such as delay in the communication system and probability of outage, a more practical ACM scheme can be considered. We show that it is still possible to optimize the performance of such schemes.

Keywords: Transmission; Adaptive; BER.

I. NTRODUCTION

Any new electronic device which includes sufficiently new or improved technology is often adopted by a high number of users. To become popular, electronic devices must process larger amounts of information at higher information rates to satisfy new and “greedier” applications. The increased mobility among user’s results in an increased popularity for wireless applications where the information processed by the device can be updated (downloaded) on the fly. Popular devices are also usually very small and with a low weight, and it is commonly required that the battery life-time (between recharging) is long. Examples of popular portable devices are personal computers, game consoles, music players, and mobile (cellular or satellite) phones. As a result, the radio spectrum is being used by an increasing number of systems and users. The available radio spectrum is a finite resource that is shared between all users. In order to avoid in-band interference, the power consumption should be kept to a minimum (allowing the use of small long-life batteries). Keeping both the bandwidth and power used by communication systems low limits the amount of information that can be communicated. The increasing use of wireless transmission media therefore calls for more spectrally efficient transmission schemes, where spectral efficiency (SE) can be defined as the amount of information bits transmitted per time unit per Hertz available bandwidth. Evidently, SE or information throughput is a measurement of the performance of a wireless transmission scheme. In addition, the amount of information that is received in error may reduce the quality of the communication. For applications such as voice communication relatively large amounts of errors can be tolerated. For some pure data communication applications, such as downloading a text document to a computer, no errors can be tolerated since one error may affect the entire amount of information transmitted. However, voice communication and other applications, such as streaming media, often require constant transmission of information, thus putting a very strong demand on the so called outage probability, which is the probability that no reliable communication is possible. Thus, outage probability is another performance measure for a wireless communication system. A technique commonly referred to as rate-adaptive modulation or adaptive coding and modulation (ACM) can be used to improve the SE in wireless communications. In traditional investigation of ACM schemes an idealized channel model is assumed and the technique promises the user the highest possible average spectral efficiency (ASE). In this thesis the practical limitations and possibilities of ACM schemes are investigated by removing some of the idealized assumptions.\

OFDM is a multicarrier transmission technique, which divides the bandwidth into many subcarriers; each one sub-carrier is modulated by a low rate data stream. It is very similar to the well known and used technique of Frequency Division Multiplexing (FDM). OFDM uses the principles of FDM to allow multiple messages to be sent over a single radio channel. It is, however, in a much more controlled manner, allowing an improved spectral efficiency [11]. In FDM transmission the signals need to have a large guard-band between channels to prevent interference. For instance, in Frequency Division Multiple Access (FDMA) each user is typically allocated a single channel, which is used to transmit all the user information. The bandwidth of each channel is typically 10 kHz-30 kHz for voice communications. However, the minimum required bandwidth for speech is only 3 kHz. This extra bandwidth is to allow for signals from neighboring channels to be filtered out, and to allow for any drift in the center frequency of the transmitter or receiver. In a typical system, up to 50% of the total spectrum is wasted due to the extra spacing between channels. This lowers the overall spectral efficiency. Time Division Multiple Access (TDMA) partly overcomes this problem by using wider bandwidth channels, which are used by several users. Multiple users access the same channel by transmitting their data in time slots. Thus, many low data rate users can be combined together to transmit in a single channel which has a bandwidth sufficient so that the spectrum can be used efficiently

1.1 Spectrally Efficient Transmission Techniques

In this subsection a selection of established techniques that can be used in the design of spectrally efficient communication systems are described. The “classical” transmission system in Figure 1.1 shows how (possibly nonredundant) information is coded into a redundant bit stream. The coded information is subsequently modulated onto the (communication) channel by performing a mapping of coded information and filtering the resulting symbols. The receive filter is usually built as a matched filter taking into account the stationary characteristics of the channel. After filtering the received information carrying signal, the information is detected (or sliced) into a set of symbols such that all symbols are elements in the alphabet used at the transmitter. Subsequently, the demapper produces a detected version of the coded information bits which is then decoded producing the decoded source bits. The system in Figure 1.1 outlines the use of a so called “hard” decoder, i.e. decisions are made before decoding. If a “soft” decoder is used the received information from the channel is employed directly in the decoding process.

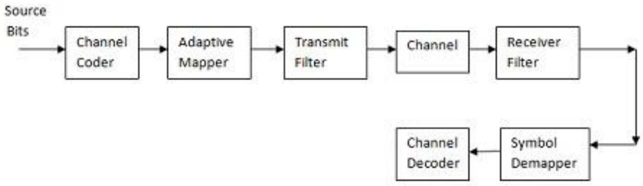

Figure1. A classic transmission system with coding and decoding of binary information, symbol mapping and demapping, and transmit and receive filters.

1.2 Non-Adaptive Techniques

Spectrally efficient transmission techniques, using modulation constellations with a high number, S, of different channel symbols, and thus many information bits per symbol ($\log_2 S$ in the uncoded case), can be shown to be very effective as long as the *channel signal-to-noise ratio* (CSNR) is sufficiently high and constant. Also, employing error correcting codes may help reduce the amount of errors introduced by the communication channel by adding redundant information to the information signal to be transmitted. The expenses paid using an error correcting code are reduced SE and increased processing delay, complexity, and power consumption in both transmitter and receiver. The error correcting properties of such codes are also dependent on the CSNR. However, fluctuations in the CSNR are among the most severe restrictions in wireless communication systems.

II. LITERATURE SURVEY

[1] Geir Egil øien et al. in 2004 had investigated the effects of predicting the CSI using a linear fading-envelope predictor in order to enhance the performance of an ACM system.[2] 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. . Simulation result also show the flexibility of the adaptive system to operate with different desired BER. [3]Faezah et al. in 2009 first investigated the OFDM system performanceThe 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.[4] Sharma et al. in 2012 discussed various digital modulation techniques such as BPSK (2bits), QPSK (4 bits), QAM, 16 QAM and 64 QAM. Authors have studied existing configurations with analog and digital modulation techniques and compared the results. [10],[11] Sohaib et al. in 2006 simulated single-channel transmission through long-haul fiber systems with or without inline chromatic dispersion compensation, incorporating numerous optical switches, evaluating the impact of fiber nonlinearity and bandwidth narrowing. With zero SNR margin, we achieve bit rates of 200/100/50 Gb/s over distances of transmission, showing that interchannel nonlinearities decrease achievable distances by about 10% and 7% for dispersion-compensated. Harivikram et al. in 2013 provided a background of the High Speed Downlink Packet Access (HSDPA) concept;

III. OBJECTIVE FUNCTION

Traditional theoretical analysis of adaptive communication systems assumes perfect knowledge of the CSI and a return channel that is error-free and with a zero delay. Previously an adaptive coding scheme using outdated fading estimates was considered, and it was shown that information on the fading process should be included in the system design since variations in the channel characteristics highly affects the BER performance of an ACM scheme. The combined power and bandwidth requirements suggest that the adaptive modulation schemes can provide reliability when deployed in a real time channel, resulting in improved system performance & Focus on the modulation aspects of the optical wireless communication, this thesis try to improve the channel immunity by utilising optimised modulation to the channel. Modulation schemes such as all types of phase shift keying modulation have been validated.

3.1 Time-Domain Orthogonality

Signals are orthogonal if they are mutually independent of each other. Orthogonality is a property that allows multiple information signals to be transmitted over a common channel and detected, without interference. Loss of orthogonality results in blurring between these information signals and degradation in communications. TDM allows transmission of multiple information signals over a single channel by assigning unique time slots to each separate information signal. During each time slot only the signal from a single source is transmitted preventing any interference between the multiple information sources. Because of this TDM is orthogonal in nature. In the frequency-domain most FDM systems are orthogonal as each of the separate transmission signals are well spaced out in frequency preventing interference. Although these methods are orthogonal, the term OFDM has been reserved for a special form of FDM. OFDM signals are made up from a sum of sinusoids, with each corresponding to a subcarrier. The baseband frequency of each subcarrier is chosen to be an integer multiple of the inverse of the symbol time, resulting in all subcarriers having an integer number of cycles per symbol. As a consequence the subcarriers are orthogonal to each other. Two continuous and discrete time periodic signals are orthogonal to each other if they match the conditions in Equations (2.1) and (2.2), respectively.

$$\int_0^T \cos(2\pi n f_0 t)\cos(2\pi nmt)\,dt = 0\,(n \neq m) \qquad (2.1)$$

$$\sum_{n=0}^{N-1} \cos\left(\frac{2\pi kn}{N}\right)\cos\left(\frac{2\pi km}{N}\right)=0 \qquad (2.2)$$

3.2 Frequency-Domain Orthogonality

Another way to view the orthogonality property of OFDM signal is to look at its spectrum. In the frequency-domain each OFDM subcarrier has a sinc function frequency response, as shown in Figure 2.1. This is a result of the symbol time corresponding to the inverse of the carrier spacing. As far as the receiver is concerned, each OFDM symbol transmitted for a fixed time TFFT with no reduction at the ends of the symbol. This symbol time corresponds to the inverse of the subcarrier spacing of $1/T_{FFT}$Hz. The sinc shape has a narrow main lobe, with many side-lobes that decay slowly with the magnitude of the frequency difference away from the center. Each carrier has a peak at the center frequency and nulls evenly spaced with a frequency gap equal to the carrier spacing [11].

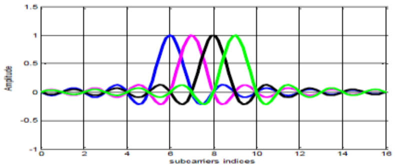

Figure 2.1 Frequency-Domain Representation of a Multicarrier Signal.

3.3 Generation of OFDM Symbols

A baseband OFDM symbol can be generated in the digital domain before modulating on a carrier for transmission. To generate a baseband OFDM symbol, a serial of digitized data stream is first modulated using common modulation schemes such as the phase shift keying (PSK) or Quadrature amplitude modulation (QAM). These data symbols are then converted from serial-to parallel (S/P) before modulating subcarriers. Subcarriers are

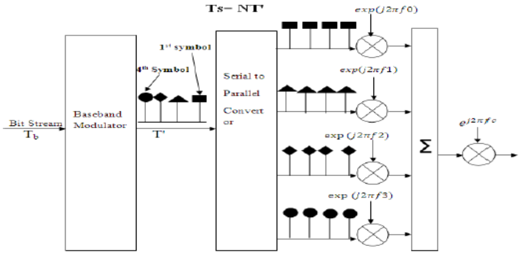

Figure 2.2 a 4-Subcarrier OFDM Transmitter.

Sampled with sampling rate N/Ts, where N is the number of subcarriers and Ts is the OFDM symbol duration. Finally, samples on each subcarrier are summed together to form an OFDM symbol. An OFDM symbol generated by an N-subcarrier OFDM system consists of N samples and the mth sample of an OFDM symbol is given as

$$X_m = \sum_{n=0}^{N-1} X_n \exp\left(\frac{j2\pi mn}{N}\right) \quad 0 \le m \le N-1 \qquad (2.3)$$

Where, Xn is the transmitted data symbol on the nth subcarrier. Equation 2.3 is equivalent to the N-point IDFT operation on the data sequence with the omission of a scaling factor. It is well known that IDFT can be implemented efficiently using IFFT. Therefore, in practice, the IFFT is performed on the data sequence at an OFDM transmitter for baseband modulation and the FFT is performed at an OFDM receiver for baseband demodulation. Finally, a baseband OFDM symbol is modulated by a carrier to become a bandpass signal and transmitted to the receiverFigure 2.2 shows a 4-subcarrier OFDM transmitter and the process of generating one OFDM symbol. In the figure the sub carrier frequency is given as

$$f_k = \frac{k}{T_s} = \frac{k}{NT'}$$

Where and are the subcarrier frequency and spacing respectively and are the signal and OFDM symbol period respectively.

3.4 OFDM System Model

In this section, we look at the basic OFDM system model components. Since our objective is to investigate the OFDM system performance in terms of BER and spectral efficiency and to enhance the system throughput using AMTW over doubly selective fading channel.

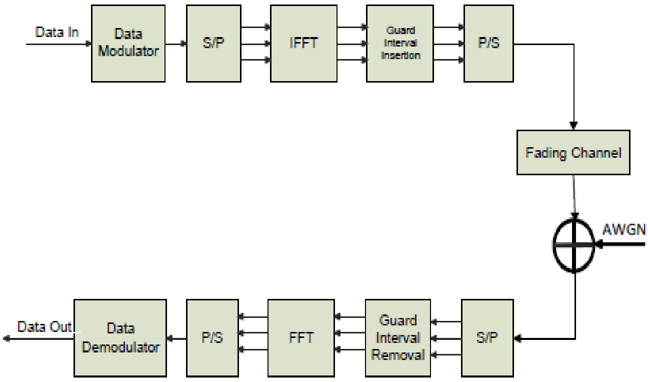

Figure 2.3 Basic OFDM System Model.

IV. RESULTS

Our work uses MATLAB as a tool as it provides a wide range of toolboxes which avoids us to develop the simulation from the scratch level. In this work MATLAB's communication and signal processing toolbox is used. We have developed a graphical user interface (GUI) using MATLAB which makes user easy to interact with the adaptive ACM simulation. A comparison with simple conditions based ACM and fuzzy adaptive ACM is shown in the further results. The GUI so developed is show in figure 4.1 below.

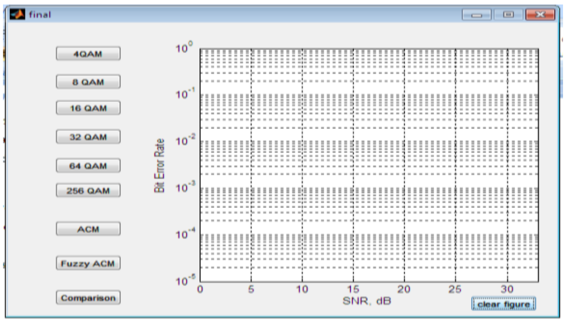

Figure 4.1: GUI Constructed for the Proposed Work

We have used 1-256 QAM modulation and results have been shown in graphical form between bit error rate and SNR. Parameters used for the simulation of quadrature amplitude modulation (QAM) are shown in table 4.1.

Table 4.1: Input Parameters for Simulation of QAM

FFT size	64
Number of data subcarriers	512
OFDM symbols	10^4
number of bits per OFDM symbol	52
Signal to noise ratio	0-33
Modulation scheme	QPSK, 16QAM, 64QAM, 256QAM
Channel	AWGN

We have tested results of every BER-SNR graph with theoretical results too. It has been noticed that simulation results overlapped with the theoretical results as shown in figure 4.2 for 4 QAM. Graph is in logarithmic scale. The bit error rate is continuously decreasing with increase in signal to noise ratio. Signal to noise ration increases due to decrease in noise. If noise decreases then bit error rate also decreases as it represents the ratio of wrong bits received.

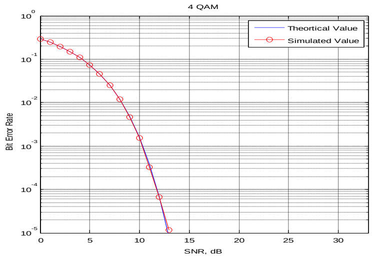

Figure 4.2: BER vs SNR for 4 QAM

Fuzzy logic rules target the decrease of BER even in condition when SNR increases. A comparative curve is shown in figure 4.3. Magenta color graph line shows the BER vs SNR curve for fuzzy ACM. It shows that where simple ACM switches to multiple modulation techniques with SNR condition, fuzzy ACM manage that decrease in BER at low modulation switching technique. The decrease in bit error rate in case of fuzzy ACM is more than simple conditions based ACM. Table 4.3 shows the BER values for both cases with corresponding SNR. Table shows that fuzzy based ACM decreases the BER to zero at 18 dB SNR whereas conditions based ACM reduces to BER upto minimum error value but not to zero. This proves proposed work reduces the BER at high SNR to zero whereas simple conditions based ACM.

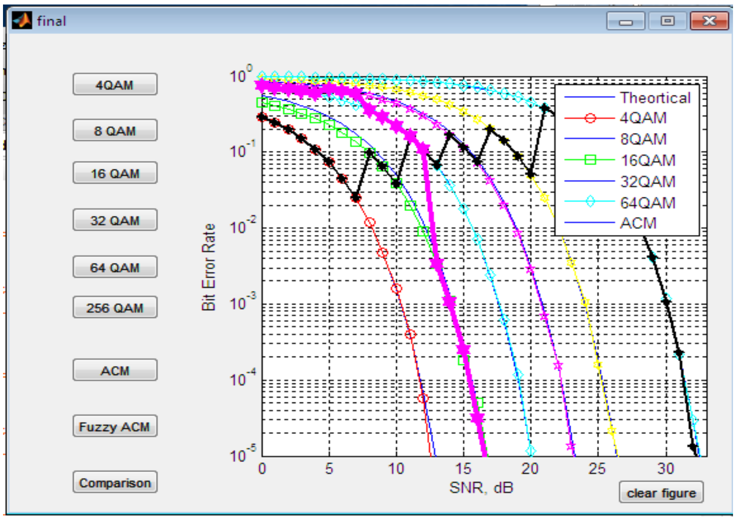

Figure 4.3: Comparison of Fuzzy ACM and Conditions Based ACM

Table 4.3: BER Comparison of fuzzy ACM and Conditions Based ACM

SNR	Conditions based ACM	Fuzzy rules based ACM
0	0.292815384615385	0.742425000000000
1	0.244390384615385	0.710198076923077
2	0.196728846153846	0.675805769230769
3	0.151523076923077	0.634598076923077
4	0.109969230769231	0.589432692307692
5	0.0745692307692308	0.680878846153846
6	0.0449884615384615	0.641473076923077
7	0.0252557692307692	0.595915384615385
8	0.0974788461538462	0.353544230769231
9	0.0639538461538462	0.287613461538462
10	0.0379961538461538	0.222473076923077
11	0.162178846153846	0.161682692307692
12	0.109521153846154	0.109682692307692
13	0.0677480769230769	0.00347115384615385
14	0.168998076923077	0.00101346153846154
15	0.116588461538462	0.000242307692307692
16	0.0733038461538462	1.34615384615385e-05
17	0.202498076923077	1.92307692307692e-06
18	0.139690384615385	0
19	0.0890538461538462	0
20	0.0505269230769231	0
21	0.374348076923077	0
22	0.296869230769231	0
23	0.221496153846154	0
24	0.153303846153846	0
25	0.0985538461538462	0
26	0.0564019230769231	0
27	0.0281538461538462	0
28	0.0120134615384615	0
29	0.00414423076923077	0
30	0.00108269230769231	0
31	0.000230769230769231	0
32	1.34615384615385e-05	0
33	3.84615384615385e-06	0

V. CONCLUSION

The possibility of the adaptive modulation can indeed be further explored. As the discussions were based on utilizing the QAM in the modulation scheme. Yet using the same analytical model, other modulation schemes, such as the PAPM and throughput improving DAPPM can also be investigated in terms of adaptability under channel uncertainty. The fuzzy logic control algorithm developed in this thesis can be further investigated. As the efficient control mechanism will provide the communication system with more accurate instructions for adapting system parameters.

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