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Minimum and maximum Power Adaptation Methods using Haar Wavelet for Image Transmission using QPSK Modulation

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Abstract - This paper addresses power allocation methods for multimedia signals over wireless channels. The objective is to minimize total power allocated for image compression and transmission, while the power for each bit is kept at a predetermined value. Minimum and maximum power adaptation methods are proposed. In this work, an approach for minimizing the total power allocated of a multimedia like image due to source compression and transmission subject to a fixed bit source distortion. Simulations are performed using haar wavelet over AWGN channel using QPSK modulation.The numerical analysis shows that optimized power methods can reduce the total power allocated by a significant factor and the Bit error rate is reduced considerably compared to the Conventional equal power method.

***Keywords*— Minimum, Maximum, QPSK, Awgn, Haar, Modulation**

1. Introduction

By the advent of multimedia communications and the information superhighway has given rise to an enormous demand on high-performance communication systems. Multimedia transmission of signals over wireless links is considered as one of the prime applications of future mobile radio communication systems. However, such applications require the use of relatively high data rates (in the Mbps range) compared to voice applications. With such requirement, it is very challenging to provide acceptable quality of services as measured by the bit error rate (BER) due to the limitations imposed by the wireless communication channels such as fading and multipath propagation. Furthermore, the user mobility makes such a task more difficult because of the time varying nature of the channel. The main resources available to communications systems designers are power and bandwidth as well as system complexity. Thus, it is imperative to use techniques that are both power and bandwidth efficient for proper utilization of the communication resources.

Power Allocation has been an effective approach to mitigating the effect of fading channels in the quality of signal transmission over wireless channels. The system typically involves a mechanism of measuring the quality of the channel seen by the receiver and providing such information to the transmitter to adjust the amount of transmitted power. For instance, if the channel is good then less power is used while if the channel is bad then more power is used. Few modifications to this strategy have been proposed such as to send higher data rates rather than reducing the power if the channel is good or not to send at all if the channel is bad. These systems are considered as opportunistic systems since they take advantage of the information about the channel to optimize the communications process. The main issues for these systems are the need for a feedback link fast enough to track the time variation of the channel and not utilizing the message structure of the image or video signal to be transmitted in power allocation.

2. Problem Formulation

Efficient use of the multimedia limited battery power is one of the major challenges in information devices. The management of power becomes even more critical with devices integrating complex video signal processing techniques with communications. Some of the key technologies that affect the power in this respect are source signal compression, channel error control coding, and radio transmission. power consumption of base band processing should also be taken into account. On the other hand, the work on improving the power has focused on separate components such as algorithms and hardware design for specific video and channel coders and low power transmitter design [3], [4]. Joint optimization of source compression, channel coding, and transmission to balance the quality of service and power requirements of the multimedia has only recently attracted interest. The work by Appadwedula et al. [6], considers minimization of the total energy of a wireless image transmission system. By choosing the coded source bit rate for the image coder, redundancy for the Reed–Solomon (RS) coder, transmission power for the power amplifier and the number of fingers in the RAKE receiver, the total energy due to channel codec, transmission, and the RAKE receiver is optimized subject to end-to-end performance of the system. The proposed system is simulated for an indoor office environment subject to path loss and multipath. Significant energy saving is reported. In [7] and [8], by changing the accuracy of motion estimation different power and distortion levels for H.263 encoder are provided [9].The coded bits are packetized and unequally protected using RS codes and are transmitted over a code-division multiple-access system operating over a flat fading channel.

Depending on the execution location, power control algorithms can be categorized as either centralized or distributed. An optimum centralized power control algorithm which can achieve the minimum outage probability was studied in [3]. It is assumed that all the active link gains are available and remain constant during execution of the algorithm. This assumption, of course, is not realistic because of the high computational complexity required for the algorithm [9-12].

In the previous algorithms of power allocation methods only local information is used to adjust transmitting power. However, a normalization procedure is required in each iteration to determine transmitting power and, thus, these algorithms are not fully distributed. In this paper, a controlled power adaptation algorithm which does not need the normalization procedure is proposed. The excellent performance and the fully distributed property make our proposed algorithm a good choice for multimedia systems [13-16].

3. RMSE Optimization Using Power Allocation Methods

When there are N number of images and M number of bits in a multimedia system, then the powers transmitted by the bits be $p = [p_1, p_2, ...p_M]$ and the respective RMSEs at the bits be $RMSE = [RMSE_1, RMSE_2, ...RMSE_M]$. Let $RMSE^T$ be the target RMSE.

1. Minimum Power Adaptation Algorithm (MPAA)

MPAA is one of the best- Controlled Power Adaptation algorithms, which achieves very good performance in Multimedia. As the name itself is self-explanatory, it is minimum because the algorithm uses only minimum power and does not depend on the large information for controlling the power.

The power-updating step of Minimum Controlled Power Adaptation is given by

$$P_i^{n+1} = R_i^n \times P_i^n \tag{1}$$

Where

$$R_i^n = \frac{\min(RMSE_i^n, RMSE^T)}{RMSE_i^n} \tag{2}$$

Where

$RMSE_i^n$ =Root mean square error of ith bit in nth iteration

$RMSE^T$ =Target Root Mean Square error

Here the new power level is calculated by the product of the previous power level and the ratio of RMSEs

2. Maximum Power Adaptation Algorithm (MaPAA)

MaPAA is an improved version of the previous MCPA algorithm proposed in [9]. The present algorithm differs from it in its consideration of the maximum value of the same. All the properties of MPAA are also satisfied by MaPAA. The power-updating step of Minimum Controlled Power Adaptation is given by equation (1), Where

$$R_i^n = \frac{Max(RMSE_i^n, RMSE^T)}{RMSE_i^n} \tag{3}$$

Where

$RMSE_i^n$ =Root mean square error of ith bit in nth iteration

$RMSE^T$ =Target Root Mean Square error

Here the new power level is calculated by the product of the previous power level and the ratio of RMSEs

4. BER of QPSK Modulation

Modulation is the process by which signal waveforms are transformed and enabled to better withstand the channel impairments.

In a BPSK system the received signal is given by

$$Y = x + n \qquad (4)$$

Where $x \varepsilon \{-A, A\}$ and $\sigma^2 = N_0$

The bit error probability is

$$P_b = \int_A^{\infty} \frac{1}{\sqrt{2\pi\sigma^2/2}} e^{-\frac{x^2}{2\frac{\sigma^2}{2}}} \qquad (5)$$

$$Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^{\infty} e^{-\frac{x^2}{2}} dx \qquad (6)$$

$$Q(x) \square \left[\frac{1}{(1-a)x + a(x^2+b)^{0.5}} \right] \frac{1}{(2\pi)^{0.5}} e^{-\frac{x^2}{2}} \qquad (7)$$

Equation (6) is widely used in Bit error rate calculation.

The Q-function can be described as a function of error function defined over $[0, \infty)$ and is given by

$$erf(x) = \frac{2}{\sqrt{\pi}} \int_0^x e^{-y^2} dy \qquad (8)$$

With erf (0) = 0 and $erf(\infty)$ =1

$$P_b = Q\left(\sqrt{2\gamma_b}\right) \qquad (9)$$

$$P_s = 1 - \left[1 - Q\left(\sqrt{2\gamma_b}\right)\right]^2 \qquad (10)$$

$$\gamma_s = 2\gamma_b = \frac{A^2}{N_o} \qquad (11)$$

$$P_s \le 2Q\left(\sqrt{\gamma_s}\right) + Q\left(\sqrt{2\gamma_s}\right) \le 3Q\left(\sqrt{\gamma_s}\right)$$

Where the Q function is defined as:

$$Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^{\infty} e^{-\frac{x^2}{2}} dx \qquad (12)$$

The Bit Error rate of QPSK involves two BPSK modulations on in-phase and quadrature components of the signal. The bit error probability is given by

$$P_b = Q\left(\sqrt{2\gamma_b}\right) \qquad (13)$$

The Probability of symbol error rate is given by

$$P_s = 1 - \left[1 - Q\left(\sqrt{2\gamma_b}\right)\right]^2 \qquad (14)$$

Since, equation (13) can be considered as

$$P_s \le 2Q\left(\sqrt{\gamma_s}\right) + Q\left(\sqrt{2\gamma_s}\right) \le 3Q\left(\sqrt{\gamma_s}\right)$$

Therefore, the Q-function can be expressed as

$$Q(z) \le \frac{1}{z\sqrt{2\pi}} e^{-\frac{z^2}{2}} \qquad (15)$$

and $$P_s \le \frac{3}{\sqrt{2\pi\gamma_s}} e^{-0.5\gamma_s} \qquad (16)$$

P_b can be approximated from P_s by P_b as

.
$$P_b = \frac{P_s}{2} \qquad (17)$$

The Bit Error Rate for QPSK signalling can be calculated by an approximation of symbol error rate using nearest neighbour approximation. The Symbol error probability can be approximated by

$$P_s = 2Q\left(\frac{2A\sin\frac{\pi}{M}}{\sqrt{2N_o}}\right) = 2Q\left(\sqrt{2\gamma_s}\sin\frac{\pi}{M}\right) \qquad (18)$$

5. Wavelets

Wavelets are mathematical functions that cut up data into different frequency components, and then study each component with a resolution matched to its scale. The wavelet transform has the ability to decorrelate an image both in space and frequency there by distributing energy compactly into a few low frequency and a high frequency coefficients.The efficiency of a wavelet based image compression scheme depends both on the wavelet filters chosen as well as on the coefficient quantization scheme. In the discrete wavelet transform, an image signal can be analyzed by passing it through an analysis filter bank followed by decimation operation. The analysis filter bank consists of a low pass and high pass filter at each decomposition stage.when the signal passes through these filters it splits into two bands [17-18].

The low pass filter corresponds to an averaging operation, extracts the coarse information of the signal, The high pass filter corresponds to a differencing operation that extracts the detail information of the signal. The output of the filtering operation is then decimated by two.A two dimensional transform is accomplished by performing two separate one dimensional transforms. First the image is filtered along the row and decimated by two. It is then followed by filtering the sub image along the column and decimated by two. This operation splits the image into four bands, namely LL, LH, HL and HH respectively. The LL band is transmitted along the channel by allocating power allocation and one level of decomposition was taken into consideration. The four bands are transmitted over wireless channel and the coefficients are reconstructed using inverse transform. Minimum and maximum power algorithms are applied and the corresponding vectors are transmitted over the channel.

The approximation coefficients are reconstructed using inverse discrete transform process and various parameters are studied in the Minimum and Maximum Power adaptation methods for one level of sub band decomposition.

6. Numerical results and conclusions

Bit Error Rate (BER) values are obtained for Equal Power Adaptation Algorithm, Minimun Power Adaptation Algorithm and Maximum Controlled Power Adaptation Algorithms. The results obtained via equations (6), (13) and (16) are presented for AWGN channel in Fig. 1,2 and 3.The improvement in performance obtained by the Minimum Power Adaptation Algorithm (MPAA) with low power as compared to the Maximum Power Adaptation Algorithm (MaPAA) with maximum power and the value of E_b/ N_o at which the system is operating as shown in Fig. 2.A better Performance is observed in Maximum Power Adaptation Algorithm (MaPAA) compared with Equal Power Adaptation Algorithm as shown in Fig.3

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Fig.4 shows the plots of BER performance of BPSK modulation using haar wavelet at level 1, level 2 and level 3 using Equal Power Adaptation Algorithm (EPAA), Minimum Power Adaptation Algorithm (MPAA) and Maximum Power Adaptation Algorithm (MaPAA) Ihe plot proves that better Performance is observed in Maximum Power Adaptation Algorithm compared with Equal Power Adaptation Algorithm as the power controlled is maximum. If the minimum power is considered, then Minimun Power Adaptation Algorithm exhibits better performance than the other two algorithms. Ihe plots shows that better Performance are observed in Maximum Power Adaptation Algorithm (MaPAA) compared with Equal Power Adaptation Algorithm (EPAA) as the power is maximum. If the minimum power is considered, then Minimun Power Adaptation Algorithm exhibits better performance than the other two algorithms, since it uses minimum power. Ihe plot proves that better Performance is observed in Maximum Power Adaptation Algorithm compared with Equal Power Adaptation Algorithm as the power is maximum. If the minimum power is considered, then Minimun Power Adaptation Algorithm exhibits better performance than the other two algorithms. Both minimum power Adaptation Algorithm and Maximum Power Adaptation Algorithms show better BER performance in image transmission using three levels of haar wavelet compared with Equal Power Adaptation Algorithm.

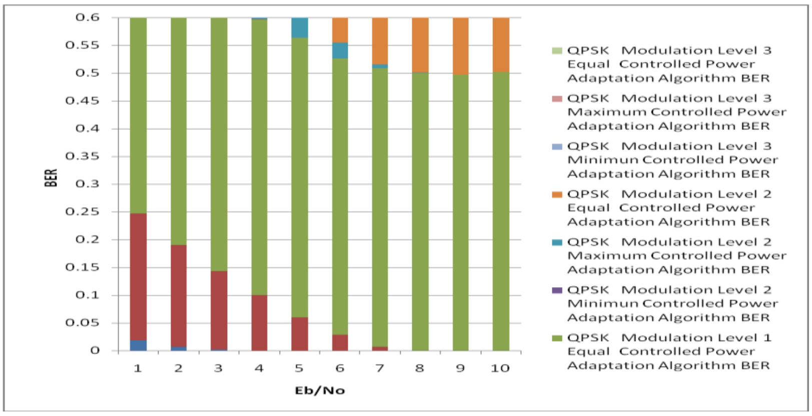

Fig.1 BER Performance for Image Transmission in AWGN for QPSK Modulations using Equal, Minimum and Maximum Power Adaptation Algorithms

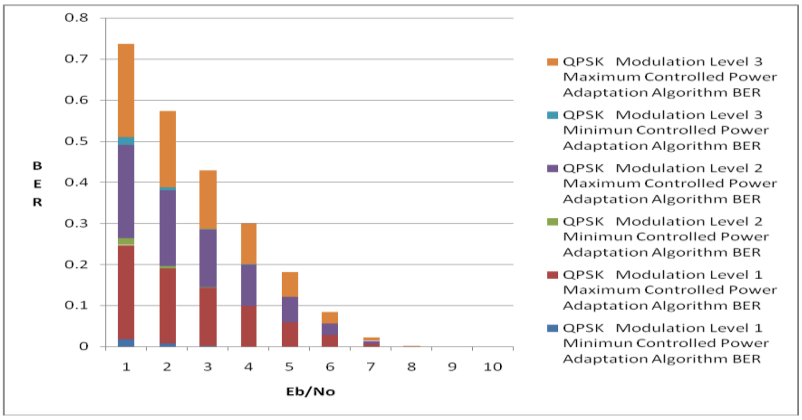

Fig.2 BER Performance for Image Transmission in AWGN for QPSK Modulations using Minimum and Maximum Power Adaptation Algorithms

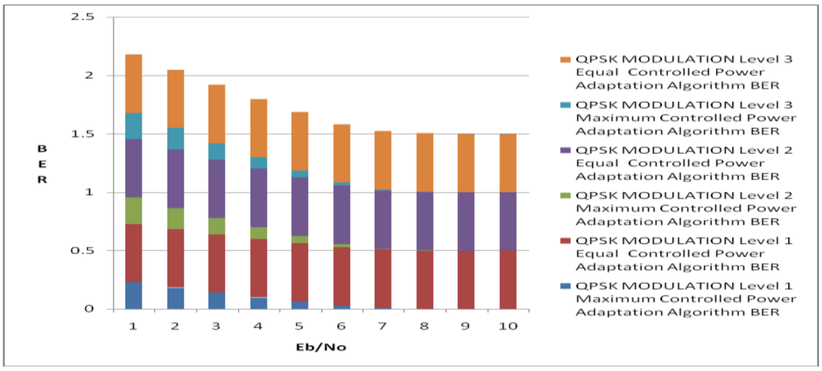

Fig.3 BER Performance for Image Transmission in AWGN for QPSK Modulations using Equal and Maximum Power Adaptation Algorithms

Table 1: BER values of Image Transmission in AWGN using QPSK Modulation at different levels using Haar wavelet

Modulation Type	**QPSK Modulation**								
LEVEL	**Level 1**			**level 2**			**Level 3**		
Power Allocation Method	**Minimun Controlled Power Adaptation Algorithm**	**Maximum Controlled Power Adaptation Algorithm**	**Equal Controlled Power Adaptation Algorithm**	**Minimun Controlled Power Adaptation Algorithm**	**Maximum Controlled Power Adaptation Algorithm**	**Equal Controlled Power Adaptation Algorithm**	**Minimun Controlled Power Adaptation Algorithm**	**Maximum Controlled Power Adaptation Algorithm**	**Equal Controlled Power Adaptation Algorithm**
Eb/No	**BER**	**BER**	**BER**	**BER**	**BER**	**BER**	**BER**	**BER**	**BER**
0	0.0166	0.2273	0.495	0.0183	0.2288	0.4992	0.0182	0.2274	0.4995
1	0.0063	0.1835	0.4993	0.0073	0.183	0.4978	0.0075	0.1849	0.4999
2	0.0019	0.1398	0.4987	0.0023	0.1404	0.4977	0.0018	0.1424	0.5008
3	0.0003	0.1002	0.5042	0.0003	0.0993	0.4984	0.0004	0.0984	0.4973
4	0	0.0608	0.5011	0.0001	0.06	0.504	0	0.0598	0.5009
5	0	0.0284	0.4997	0	0.0283	0.4987	0	0.0278	0.4967
6	0	0.0073	0.4985	0	0.0072	0.5015	0	0.0075	0.4988
7	0	0.0004	0.502	0	0.0005	0.5002	0	0.0006	0.501
8	0	0	0.501	0	0	0.4972	0	0	0.5003
9	0	0	0.4963	0	0	0.5025	0	0	0.4996

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