Determining of Threshold Levels of Burst by Burst AQAM/CDMA in Slow Rayleigh Fading Environments

F. Nejadebrahimi, and M. ArdebiliPour

***Abstract*—**In this paper, we are going to determine the threshold levels of adaptive modulation in a burst by burst CDMA system by a suboptimum method so that the above method attempts to increase the average bit per symbol (BPS) rate of transceiver system by switching between the different modulation modes in variable channel condition. In this method, we choose the minimum values of average bit error rate (BER) and maximum values of average BPS on different values of average channel signal to noise ratio (SNR) and then calculate the relative threshold levels of them, so that when the instantaneous SNR increases, a higher order modulation be employed for increasing throughput and vise-versa when the instantaneous SNR decreases, a lower order modulation be employed for improvement of BER. In transmission step, by this adaptive modulation method, in according to comparison between obtained estimation of pilot symbols and a set of above suboptimum threshold levels, above system chooses one of states no transmission, BPSK, 4QAM and square 16QAM for modulation of data. The expected channel in this paper is a slow Rayleigh fading.

***Keywords*—**AQAM, burst, BER, BPS, CDMA, threshold.

I. Introduction

WE know the mobile transmission channels have time variant characteristics. Although most of mobile radio systems, except cordless phones, use automatic gain control (AGC) in order to decrease the fluctuations of the incoming signal power [1]. But fast fluctuations of transmission quality in wireless channels with Raleigh fading that is even over than 40 dB [2] cannot be compensate by using power control methods. Also using power control methods have some disadvantages such as common and adjacent channel interference, more consumption of power, distortion of signal figure and making unwanted harmonics. Optimization criteria which changes with time for a flexible transceiver system are only possible when adaptive methods such as adaptive modulation are used [1]. On the other hand, a successful adaptive modulation needs to precise prediction and estimation of channel and the optimization of levels which determine modulation order [3]. In steel and webb's [4] research paper, a differential adaptive method is presented considering the signal to noise ratio (SNR). Although in code division multi access systems, if there is much inter symbol interference (ISI) due to multi-paths and incomplete orthogonal codes, signal to interference plus noise ratio (SINR) must be used for recognize these threshold levels.

An adaptive modulation method with using time division duplex (TDD) technique and transmission of pilot symbol is possible with estimation of instantaneous power of incoming symbols (s) which can give us some information about the condition of channel according to the coherency between uplink and downlink channels, when Doppler frequency is small enough.

The resulting estimation of instantaneous received signal power (s) is then compared to n different levels L_i , i = 1,2,…, n to be switched to one of the degrees of the modulation.

If we consider the adaptive modulation in triple mode, then we'll have 3 levels that if (M_s) is the chosen modulation and (s) is the incoming power then [5]:

$$M_S = \begin{cases} NoTransmission.....If & s \langle L_1 \\ BPSK.....................If & L_1 \le s \langle L_2 \\ 4-QAM...............If & L_2 \le s \langle L_3 \\ Square\ 16-QAM..If & L_3 \le s \end{cases} \quad (1)$$

In CDMA systems with ISI and incomplete orthogonal of codes, will be harmful factors in obtained estimation. These problems can be reduced by using pilot symbols witch have advantages such as: low delay of estimation, no error propagation, instantaneous information of channel and Convergence in invariant channels. Orthogonal codes can even be used to transmit these symbols. In equation (1) decrease in values of threshold levels causes increase of average bit per symbol (BPS) rate and vise-versa with the increase in these values average bit error rate (BER) decreases, so we need a compromise between desired BER and needed BPS according to type of incoming information and also source and channel coding. As we know, information of audio and video in live transmission is much more sensible of latency than the transmission of computer data. In contrast, computer data are more fragile with channel error. The mentioned latency is caused by saving information in transmitter registers in adverse channel condition. Using a suitable source coding in this condition will decrease transmission rate and improve error performance of system.

Manuscript submitted November 26, 2006. This work was supported by the telecommunication research center of Iran.

Dr. M. Ardebilipour and F. Nejadebrahimi are with the Electrical Engineering Department of K.N. Toosi University of Technology of Tehran, Iran (phone: +98-21-33293250; fax: +98-21-88032809; e-mail: Mehrdad@eetd.kntu.ac.ir and nezhadebrahimi@yahoo.com).

II. Investigation of Performance

With the assumption of sufficient low Doppler frequency in order to maintain near-constant fading envelope and also with using of pilot symbols, there will be Gaussian condition along the transmission of modulated symbols. So, upper bound of error function for adaptive modulation in fading channel will be available. For example in triple mode, error function related to coherent modulation methods of transmission rate of 1, 2, 4 bit per symbol and with the assumption of synchronization in Gaussian channel will be followed as [5]:

$$P_b(\gamma) = Q(\sqrt{2\gamma}) \tag{2}$$

$$P_q(\gamma) = Q(\sqrt{\gamma}) \tag{3}$$

$$P_{16}(\gamma) = \frac{1}{4}\left[Q(\sqrt{\frac{\gamma}{5}}) + Q(3\sqrt{\frac{\gamma}{5}})\right] + \frac{1}{2}Q(\sqrt{\frac{\gamma}{5}}) \tag{4}$$

Where $Q(x) = \frac{1}{\sqrt{2\pi}}\int_x^{\infty} e^{\frac{-x^2}{2}} dx$, γ is the signal to noise ratio, while $P_b(\gamma)$, $P_q(\gamma)$, $P_{16}(\gamma)$ are the mean BERs of BPSK, QPSK, Square 16QAM respectively. Probability density function for variable incoming power (s) and average signal power (S) over Rayleigh fading environments are given by [5]:

$$F(s,S) = \frac{2s}{S} e^{\frac{-s^2}{S}} \tag{5}$$

If $X_g(\gamma)$ represents Gaussian error function (as was shown in 2, 3 and 4 equation) then the following $X_\delta(\gamma)$ will refer to upper bound of error function in Rayleigh channel:

$$X_\delta(\gamma) = \int_0^{\infty} X_g(\gamma).F(s,S)ds \tag{6}$$

Therefore upper bound of error function of narrow bound channel for adaptive modulation and in triple mode will be calculated as:

$$P_a(S/N) = B^{-1}.\begin{bmatrix} \int_{L_1}^{L_2} P_b(s/N).F(s,S)ds \\ + \int_{L_2}^{L_3} P_q(s/N).F(s,S)ds \\ + \int_{L_3}^{\infty} P_{16}(s/N).F(s,S)ds \end{bmatrix} \tag{7}$$

In a way that L_1, L_2, L_3 are threshold levels for choosing the cases of no-transmission, BPSK, 4QAM and square 16QAM and B is average bit per symbol and will be as follows:

$$B = \int_{L_1}^{L_2} F(s,S)ds + 2.\int_{L_2}^{L_3} F(s,S)ds + 4.\int_{L_3}^{\infty} F(s,S)ds \tag{8}$$

In order to investigation of BER and BPS performance in the above adaptive modulation, L_i, i=1, 2, 3 must be determined that will be calculated and discussed in the next section.

III. Determining of Suboptimum the Threshold Levels

As we can see in the equations of the previous section, changing in average of received signal power (S) in equation of Rayleigh probability function will change the BER and rate of BPS in above system. So it is possible to average the BER and BPS rate on S and in this averaging, a part of range of S witch is more possible enters into calculation with higher weight and will determine the threshold levels by optimum values of average BER or BPS. If the average signal Power (S) changes from 0^{dB}-50^{dB}, the average operation of BER and BPS with the same weight for magnitude of above range is as the Figs. 1 and 2 respectively. As we can see in Figs. 1 and 2, the average BER and BPS have shown according to threshold levels of L_2 and L_3, which switch operation to higher degree modulation, is done according to them. Level L_1 has determined according to L_2 and L_3 to minimize average BER and average BPS. In Table I, also the optimum values of average BER and BPS which are optimized according to definite values of L_1 and L_2 and changes of L_3 are shown. As it is shown, the values of Table I are according to Figs. 1, 2. To continue the study, we choose the average BER 10^{-2} which the

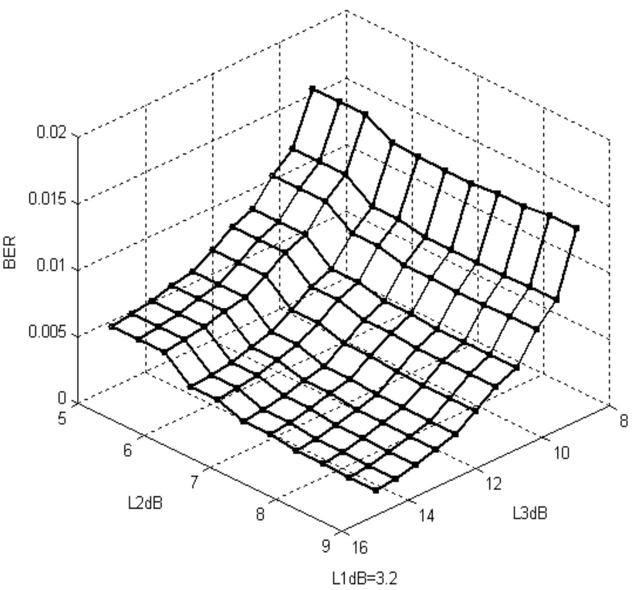

Fig. 1 BER performance versus L2dB and L3dB in triple-mode

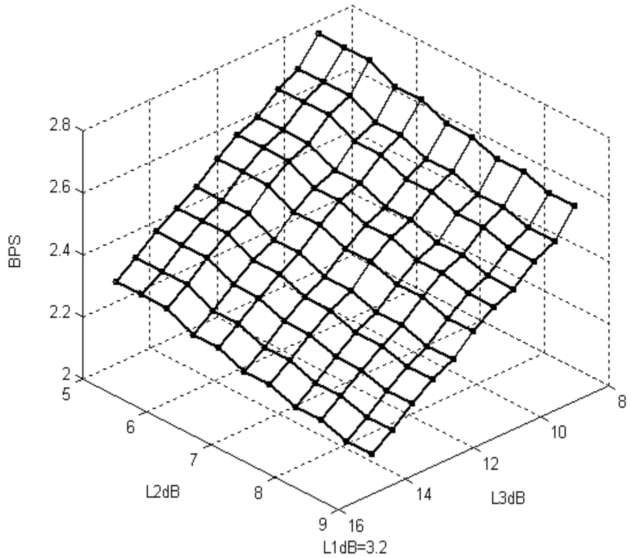

Fig. 2 BPS performance versus L2dB and L3dB in triple-mode

L_1=3.2[dB], L_2=7.8[dB] and L_3=9.6[dB] for threshold levels and $2.55\,\frac{bit}{Symbol}$ for average BPS are obtained according to Table I. The above result has obtained without channel coding.

Figs. 3 and 4 show the exact operation of BER and BPS of above adaptive modulation system according to above parameters. As it observed from Fig. 3 the above system satisfies the BER 10^{-2} during all above range except from 15^{dB}-32^{dB}. In Fig. 4, also we can see that in the average channel SNR more than 18dB, BPS exceeds from $2\,\frac{bit}{Symbol}$ that clears the expected operation of above adaptive system.

TABLE I
SUBOPTIMUM VALUES OF AVERAGE BER AND BPS VERSUS L1DB, L2DB, L3DB

L_3^{dB}	L_2^{dB}	L_1^{dB}	<BER>	<BPS>
9	7	3.2	1.4×10^{-2}	2.62
9.6	7.8	3.2	1×10^{-2}	2.55
10.8	8.6	3.2	6.2×10^{-3}	2.45
11.4	8.6	3.2	5.4×10^{-3}	2.42
12.6	8.6	3.2	3.3×10^{-3}	2.31
13.2	8.6	3.2	2.8×10^{-3}	2.28
14.4	8.6	3.2	2.1×10^{-3}	2.18
15	8.6	3.2	1.9×10^{-3}	2.13

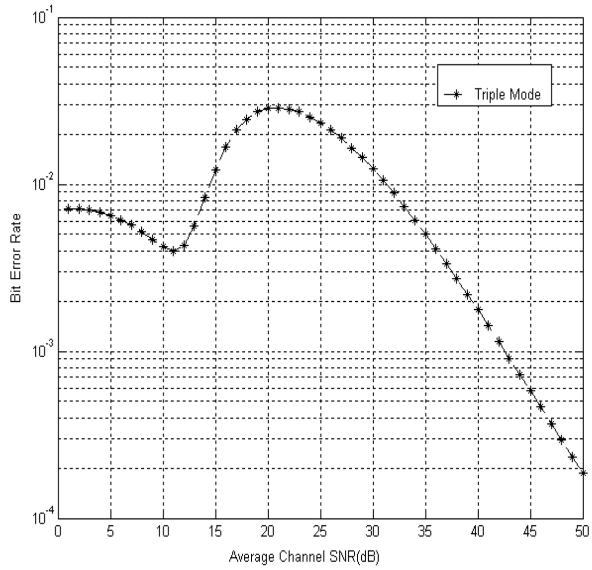

Fig. 3 BER performance versus average channel SNR in triple-mode

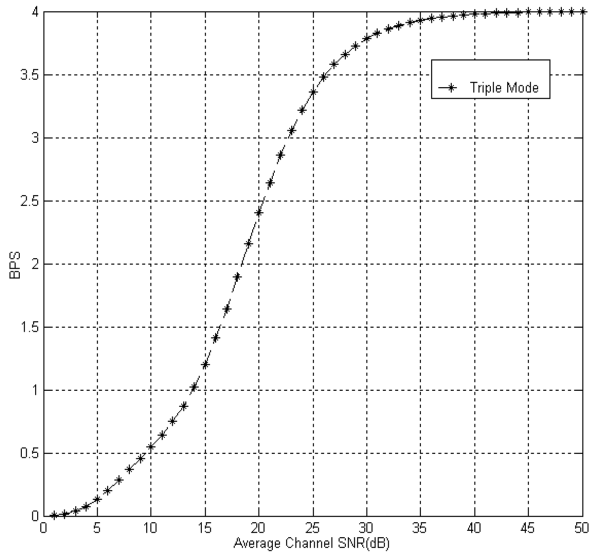

Fig. 4 BPS performance versus average channel SNR in triple-mode

But according to the CDMA technique, we can use the variable spread factor (VSF) to keep BER in a constant rate and adaptation of BPS according to the conditions of channel. In a sort that by increasing the chosen modulation degree, the VSF technique increases too that causes to keep BER constant when the BPS increases. But it spreads the frequency bound.

Fig. 5 shows the probability of using of any above modulation in fixed mode and according to variation of average channel SNR. As it is observing, by increasing the average of received SNR, probability of non-transmission or choice of modulation with low degree decreases.

Fig. 6 shows BER performance for any of above modulations in fixed mode. The remarkable point is that the modulation square 16QAM has wide variation of

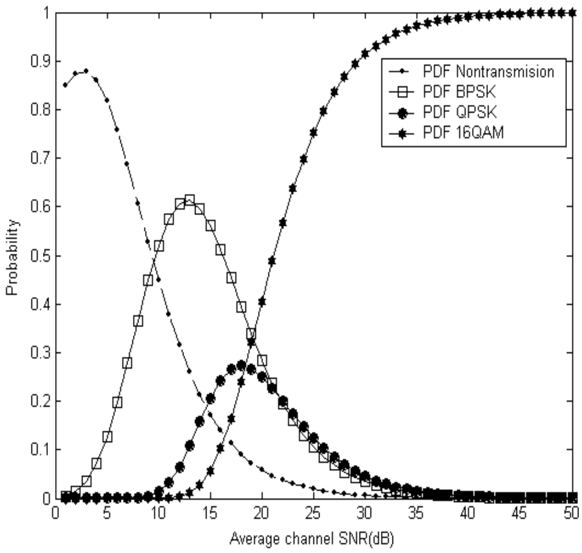

Fig. 5 Probability distribution of no-transmission, BPSK, 4QAM, 16QAM in fixed mode

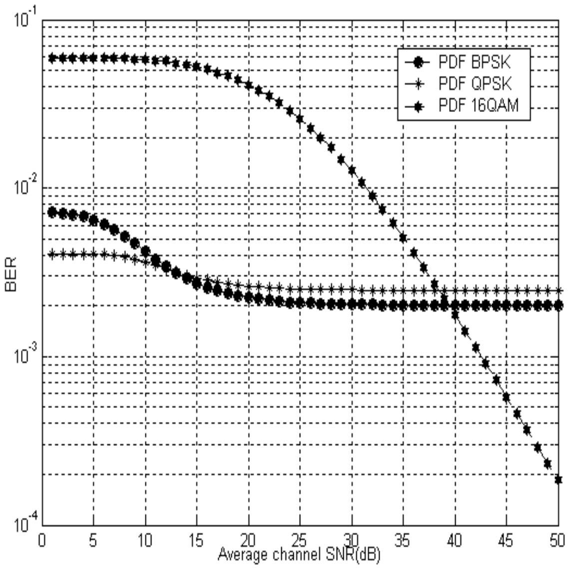

Fig. 6 BER performance of BPSK, 4QAM, 16QAM in fixed mod

magnitude rather than the other modulations. But modulation BPSK and 4QAM has asymptotic shape that is because of fading probability distribution function.

IV. Conclusion

As it viewed, suboptimum threshold levels of Burst by Burst AQAM/CDMA system calculated and investigated and it is viewed that by these suboptimum levels, we can make a compromise between the desired BER and needed BPS. Also ,VSF methods is suggested as a proper technique in CDMA systems to increase the degree of freedom in the above compromise and to fix one of BER or BPS parameters in a certain rate along the variations of other parameters.

Acknowledgment

The financial support of Iran Telecommunication Research Center is gratefully acknowledged.

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Farhad Nejadebrahimi was born in Iran in 1979. He received B.Eng. degree in electrical and telecommunication engineering from Iran Telecommunication University, Tehran, Iran in 2002. Recently He studied MSc. Degree in electrical engineering in K.N. Toosi University of Technology, Tehran, Iran. His research interest include CDMA systems, Channel modeling.

Mehrdad Ardebilipour was born in Iran in 1954. He received Bsc. and Msc. Degrees in electrical engineering from K.N. Toosi University of Technology, Tehran, Iran. in 1977 and Tarbiat Modarres University, Tehran, Iran in 1989, respectively. He has also been awarded the degree of Ph.D by the University of Surrey, Guildford, England in 2001.

Since 2001, he has been assistant professor at K.N. Toosi University of Technology with major interests in spread spectrum and multi user detection.