Performance Comparison of QAM and ASK with Minimum Energy Coding in Phase Coded SSMA for Wireless Sensor Network

*O. P. Chaudhary
Lecturer
Department of Electrical Engineering Government Polytechnic Faizabad, (UP), India
Email: op_chaudhary77@yahoo.com

*Prof. (Col.) Gurmit Singh
Head of Department
Department of computer science and information technology, AAI-Deemed University Allahabad, (UP), India
E-mail: gurmitsingh3@rediffmail.com

Abstract: Source coding with spread spectrum technique for reducing multiple access interference (MAI) in phase coded SSMA for ASK and QAM in wireless sensor network has been presented in this paper. The source symbol is represented by modified minimum energy coding (MME) for both ASK and QAM. When each channel uses MME coding combined with phase coded SSMA the probability of error of multiple channels sending signals at the same time is lowered in QAM as compared to ASK, this implies that the MAI is reduced. It has been analysed that with the new low MAI with MME coding, signal to noise ratio significantly increases while error probability decreases in both ASK and QAM and no another differences is founded. Finally, a sensor network system is designed and simulated to verify the theoretical results and demonstrate the low MAI and low energy features of wireless sensor network.

Key words: amplitude modulation, amplitude shift keying, low complexity, modified minimum energy coding, phase coded SSMA, power control, quadrature.

I. INTRODUCTION

There is an increasing need for short range low power multiple access wireless communication. Today, the wireless devices are tiny and can be placed in the human body and micro machines, places where traditional RF and IR devices cannot be used. This will open up new possibilities for wireless local area networks. Low power wireless networking is still a challenging problem, however, Bluetooth is an ambitious technology, but its power consumption of around 30 mW is too high to power the device with a small cell battery. A regular size battery limits its form factor. Furthermore Bluetooth still has a major difficulty in MAI, causing a serious delay of delivery. MAI reduction has been studied extensively in the academia in conjunction with phase coded SSMA for ASK. Theoretical analysis revealed that the average bit error probability sharply increases as the channel number increases in DS-CDMA system with BPSK modulation [9]. In the past decade, numerous methods for MAI cancellations and reduction have been developed [2], [5]-[6], [9], [13], [16], most of which focus on the design of effective correlation receivers [16].

II. SYSTEM MODEL

The sensor node architecture and phase coded SSMA for communication are considered in this section. Energy consumption model and signal model are also discussed for system analysis in [16].

A. Architecture of a Sensor Node

A tiny sensor node has typically four components as in [16] a sensing module, processing (computing) module, a communication module and a power module. It may have application specific components such as a location finding module, solar power generator. The sensing module is composed of two subunits: analog sensor and analog-to-digital converter (ADC). It detects analog signal, and feeds digitally converted data to processing module. The processing module controls all the other components in a node and contains microprocessor or microcontroller and storage subunit(s). The communication module connects the node to network and performs physical, MAC layer operations. In [9] we assume this module has transceiver only. Thus, MME coding takes place at the processing module, and communication module deals with phase coded SSMA. The last and may be the most important one is a
power module. It contains battery and DC-DC converter and supplies power to the rest of the node [4].

During the operation of a tiny sensor node, most of power is consumed in communication. The average energy consumption of radio communication can be modelled as

$$E_{\text{radio}} = E_{\text{tx}} + E_{\text{rx}}$$

$$= [P_{\text{tx}} + T_{\text{on-tx}} + P_{\text{T}}] + P_{\text{rx-ckt}} (T_{\text{on-rx}} + T_{\text{startup}})$$

(1)

Where, $E_{\text{tx/rx}}$ is average energy consumption of a sensor node while transmitting/receiving, $P_{\text{tx/tx-ckt}}$ is the power consumption of the electronic circuits while transmitting/receiving, $P_{\text{tx}}$ is the output transmitter power, $T_{\text{on-tx}}$ is the transmitter/receiver on-time, and $T_{\text{startup}}$ is the startup time of the transceiver [18]. Since $P_{\text{tx-ckt}}$ and $T_{\text{startup}}$ are determined by hardware characteristics equation (1) can be further simplified as

$$E_{\text{tx}} = P_{\text{tx-ckt}} T_{\text{on-tx}} + P_{\text{T}}$$

(2)

$$E_{\text{rx}} = P_{\text{rx-ckt}} T_{\text{on-rx}}$$

(3)

Where, $E_{\text{tx/tx}}$ denotes the average energy consumption which is manageable by MME coding and phase coded SSMA scheme.

B. Signal Model

We consider an asynchronous phase coded SSMA system with MME coding of $K$ users in local area as shown in fig. (1). The local area can be a cluster as proposed in [3] and the system model and analysis follow reference [9], [10], [16].

Fig. 1. Phase coded SSMA combined with MME coding

As shown in fig. (1) the transmitted signal for $K$ users is given

$$S_k(t) = \sqrt{2P_k d_k(t) a_k(t) \cos(\omega_c t + \theta_k)}$$

(4)

Where

$$d_k(t) = \sum_{j=-\infty}^{\infty} d_j^{(k)} p \tau_k (t - jT_k)$$

(5)

Where, $d_j^{(k)}$ is the data bit, $d_j^{(k)} \in \{0,1\}, T_k$ is the bit duration, and $p \tau_k(t)$ is a rectangular pulse which are $p \tau_k(t) = 1$ for $0 \leq t < \tau$ and $p \tau_k(t) = 0$ otherwise.

In the above expressions $\theta_k$ represents the phase of the $k$-th carrier, $\omega_c$ represents the common centre frequency, and $P_k$ represents the common signal power. The results that follow can easily be modified for unequal centre frequencies and power levels.

If the SSMA system is completely synchronized, then the time delays $\tau_k$ shown in the model of Eq. (1) can be ignored (i.e., $\tau_k = 0$ for $k = 1, 2, \ldots, K$). This would require a common timing reference for the $K$ transmitters and it would necessitate compensation for delays in the various transmission paths. This is generally not feasible and hence the transmitters are not time-synchronous. For asynchronous systems the received signal $r(t)$ in Fig. (1) is given by

$$r(t) = \sum_{k=1}^{K} \left[2P_k a_k(t - \tau_k) \cos(\omega_c t + \phi_k) + n(t)\right]$$

(6)

Where, $\phi_k = \theta_k - \omega_c \tau_k$ and $n(t)$ is the channel noise process which we assume to be a white Gaussian process with two sided spectral density $N_0/2$. Since we are concerned with relative phase shifts modulo $2\pi$ and relative time delays modulo $T$, there is no loss in generality in assuming $\theta_0 = 0$ and $\tau_0 = 0$ and considering only $0 < \tau_k < T$ and $0 < \phi_k < 2\pi$ for $k \neq i$.

If the received signal $r(t)$ is the input to a correlation receiver matched to $s_i(t)$, the output of user $i$ is

$$Z_i = \int_0^T r(t) a_i(t) \cos \omega_c t dt$$

(7)

$$Z_i = D_1 + I_i + \eta_i$$

D_1 = \text{desired signal for user } i$$

I_i = \text{Interferences from other users}$$

$\eta_i = \text{AWGN with variance } N_0 T_0 / 4.$

$$D_1 = \sqrt{\frac{P_i}{2}} T d_0^{(1)}$$

(8)

$$I_i = \sum_{k \neq i} \sqrt{\frac{P_k}{2}} \left[ d_k \cos(\omega_c t + \phi_k) + \hat{R}_{k,i}(\tau_k) \right]$$

(9)

$$\eta = \int_0^T n(t) a_i(t) \cos \omega_c t dt$$

(10)

Where, $R_{k,i}$ and $\hat{R}_{k,i}(\tau)$ are the continuous-time partial cross correlation functions defined by
\[
R_{k,i}(\tau) = \int_{0}^{\tau} c_k(t-\tau)c_i(t)dt \quad (11)
\]

\[
\hat{R}_{k,i}(\tau) = \int_{\tau}^{T} c_k(t-\tau)c_i(t)dt \quad (12)
\]

The ME coding and MME coding reduce the interference term in (9) thus improve the performance shown in section 4.0

**III. SYSTEM PERFORMANCE EVALUATION**

The system performance in the sense of probability of bit error and power consumption is analysed in this section. In order to do the required analysis, SNR of the MME Phase Coded SSMA system is derived first.

**A. Signals-To-Noise Ratio (SNR)**

Signal-To-Noise ratio is defined as the ratio of signal power to the variance of noise \(Z_i\).

\[
\text{SNR} = \frac{P_{d_1}}{\text{var}\ Z_1} \quad (13)
\]

\[
P_{d_1} = \left( \frac{P_s}{2 T_0} \right)^2 dt = \frac{\alpha P_s}{2} \quad (14)
\]

Where, \(\alpha_i\) is the rate of high bits for \(d_i(t)\) during the MME symbol period \(T = L T_b\). The noise power consists of MAI term and Gaussian noise term as defined in (5). The interference term \(I_i\) are random and are treated as additional noise as in [10]. Thus the variance of the noise component of \(Z_i\) can be expressed as:

\[
\text{var}(Z_i) = \sum_{k=2}^{K} \frac{P_s}{4 T_0} \int_{0}^{T} \left( R_{k,i}(\tau) + \hat{R}_{k,i}(\tau) \right) d\tau + \frac{\alpha_i^2 N_0 T}{4} = \frac{T^2}{12 N} \sum_{k=2}^{K} \alpha_k \left(P_{d_1} + \frac{\alpha_k^2 N_0 T}{4} \right) \quad (15)
\]

We assume that power control is used and the probability of transmitting high bits for each transmitter is the same as in [9] i.e. \(P_1 = P_2 = \ldots = P_K = P\) and \(\alpha_1 = \alpha_2 = \ldots = \alpha_K = \alpha\). Under these conditions, the SNR can be expressed by the equation (13) is:

\[
\text{SNR} = \left[ \frac{\alpha (K-1)}{3N} + \frac{N_0}{2E_s} \right]^{1/2} \quad (17)
\]

**B. Probability of Error**

The error probability of MME codeword is analysed in this subsection. Since the decoding process is performed on a sub frame basis, the decoding of the indicator bit is very important. The symbol error rate can be expressed as:

\[
P_{\varepsilon} (\varepsilon) = 1 - P_{\varepsilon}(\varepsilon) = 1 - \prod_{j=0}^{N-1} \bar{P}_j(\varepsilon) \quad (18)
\]

Where, \(\bar{P}_j(\varepsilon) = 1 - P_j(\varepsilon)\) is the probability of correct decoding of \(j\)th sub frame.

**IV. BER PERFORMANCE**

**A. Amplitude Shift Keying**

As discussed earlier that the bit error rate (BER) can be deliberately reduced by using minimum energy (ME) and modified minimum energy coding (MME) coding using on off keying (OOK). By analyzing the graph shown in fig.(2) we can say that the minimum energy (ME) and modified minimum energy coding (MME) using on off keying (OOK) have better bit error rate (BER) performance than the conventional DS-CDMA system that uses BPSK. The conventional DS-CDMA system using BPSK means rate of high bits \((\alpha) = 1\) which is shown in fig. (2). Another discussion which has been done is better performance of modified minimum energy coding (MME) over minimum energy (ME) coding and the results are shown in fig. (2) that bit error rate (BER) in modified minimum energy coding (MME) coding is lesser than minimum energy (ME) coding for all \(\alpha\). Also as discussed earlier that as the rate of high bits \((\alpha)\) decreases the bit error rate (BER) both in modified minimum energy coding (MME) coding and minimum energy (ME) coding decreases [16].
B. Quadrature Amplitude Modulation  
By analyzing In [18] the graph of QAM as the gain increases for different value of alpha the probability of error increases that means as alpha is increased the probability of error also increases ,otherwise if we decrease the value of alpha or number of high bite probability of error decreases but for the value of alpha =0.3 the probability of error in QAM is less than as compared to probability of error in ASK as shown in fig. (2)

\[
\frac{E_{\text{rx}}^{\text{MME}}}{E_{\text{rx}}^{\text{ME}}} = \frac{T_{\text{rx-ME}}}{T_{\text{rx-MME}}} = \frac{L}{N_0 \left[ L_s (1-(1-\alpha)^{-1}) + (1-\alpha)^{-1} \right]} 
= \left( 1 + \frac{1-L_s}{L_s} (1-\alpha)^{-1} \right)^{-1} 
\]

V. POWER CONSUMPTION

MME coding reduces energy consumption for receiving data. The energy gain of MME to ME coding is shown in fig. (4) and it can be represented as:

\[
\rho = \frac{E_{\text{rx-MME}}}{E_{\text{rx-ME}}} = \frac{T_{\text{rx-ME}}}{T_{\text{rx-MME}}} 
= \frac{L}{N_0 \left[ L_s (1-(1-\alpha)^{-1}) + (1-\alpha)^{-1} \right]} 
= \left( 1 + \frac{1-L_s}{L_s} (1-\alpha)^{-1} \right)^{-1} 
\]

VI. CONCLUSION

In this paper, phase coded SSMA with modified minimum energy coding has been proposed for ASK and QAM and analysed using MATLAB. Results indicate that MME coding greatly reduce both multiple access interference and transmit
energy of phase coded SSMA system for ASK and QAM modulation, their results are compared as shown in fig. (2) and fig. (3) for the different value of alpha at gain=2db, it has been seen that the value probability of bit error of QAM is less as compared to ASK with low MAI, it means as increasing the value of gain the probability of bit error is less for QAM as compared to ASK using MME coding as compared to the previously proposed system without MME coding scheme [5], [10]-[11], [19].

Finally, it is concluded that when MME coding is combined with each modulation schemes i.e. QAM and ASK it achieves more energy saving at both the transmitter and receiver by partitioning the code word into several sub frame using indicator bits. The MME coding also improves BER performance due to the reduced MAI and achieves power gain at the expense of codeword length i.e. bandwidth. However, the bandwidth increased can be justified because the power constraints are much more important than bandwidth constraints in wireless tiny sensor network. In other words, combining MME and phase coded SSMA is an attractive choice for wireless tiny sensor networks, in the context of total system energy saving and improved BER performance.

Table – Comparison of different modulations and error control codes

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Modulation</th>
<th>Codes</th>
<th>Performance parameters</th>
<th>Overall system performance</th>
<th>Channels</th>
<th>Simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BPSK QPSK 16QAM 64QAM</td>
<td>Convolutional</td>
<td>SE BLER</td>
<td>Good system performance</td>
<td>AWGN Rayleigh</td>
<td>MAT LAB</td>
</tr>
<tr>
<td>2</td>
<td>BPSK QPSK 16QAM 64QAM</td>
<td>RS</td>
<td>BER</td>
<td>Efficient physical layer design</td>
<td></td>
<td>MAT LAB</td>
</tr>
<tr>
<td>3</td>
<td>BPSK QPSK 16QAM 64QAM</td>
<td>RS BCH</td>
<td>BER Power</td>
<td>Better, energy efficiency</td>
<td></td>
<td>MAT LAB</td>
</tr>
<tr>
<td>4</td>
<td>BPSK QPSK</td>
<td>RS FEC</td>
<td>Energy Frame loss</td>
<td>Suitable for mobile Sensor</td>
<td></td>
<td>MAT LAB</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th></th>
<th>Modulation</th>
<th>ARQ</th>
<th>Code Rate</th>
<th>BER</th>
<th>Efficiency Error Control Mechanism</th>
<th>MAT LAB</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>QPSK 16QAM</td>
<td>HARQ</td>
<td>SINR gain</td>
<td>BCH</td>
<td>Code rate comparatively better than other codes</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>QPSK 16QAM</td>
<td>BCH RS Convolution</td>
<td>BER</td>
<td>BCH code</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>MPSK MQAM MFSK</td>
<td>BCH RS Convolutional</td>
<td>BER Energy Lifetime</td>
<td>Suitable for short distance communication</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>16QAM 8PSK BPSK</td>
<td>Turbo</td>
<td>Avg throughput FER SNR</td>
<td>The maximum Avg throughput achieved</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>8PSK 16QAM</td>
<td>Extended BCH</td>
<td>BER</td>
<td>Multistage decoding and modulation used</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>ASK or OOK</td>
<td>ME coding</td>
<td>BER SNR</td>
<td>Reduced transmit power &amp; increased receiver power consumption</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>ASK or OOK</td>
<td>MME coding</td>
<td>BER SNR</td>
<td>Reduced transmit power &amp; decreased receiver power consumption</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>QAM ASK</td>
<td>MME coding</td>
<td>BER SNR</td>
<td>Decreased BER in QAM Total system energy saving &amp; improved BER performance</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**ACKNOWLEDGEMENTS**

We the authors are grateful to god, their parents and institutions for providing research facilities to complete this work in its present shape.
REFERENCES


[12] Mohsen kaveh and wsund berg ETSEIO,E NS NO. CO VMO-3L5..4, APRIL 1987


[16] O. P. Chaudhary1, R. K. Saket2, Lokendra Kumar Sharma3* & Manish Gupta" PROBABILISTIC APPROACH FOR MODIFIED MINIMUM ENERGY CODING WITH PHASE CODED SSMA" IJRRAS6(4)●March2011,


[18] Pavan Kumar Vitthaladevuni IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS, Vol. 4, No. 6, NOVEMBER 2005


About Authors:

**O. P. Chaudhary** received his B. E Degree in Electrical Engineering from Madan Mohan Malviya Engineering College, Gorakhpur (UP) India in 1998, M.Tech. in Electronics Engineering (Digital System) from Motilal Nehru National Institute of Technology, Allahabad (UP) India in 2003. He is pursuing Ph. D. Degree Shephered School of Engineering and Technology, SHIATS-Deemed University, Allahabad (UP) India and presently he is Lecturer in Department of Electrical Engineering Government Polytechnic Faizabad, Technical Education Kanpur (UP) India since 2010. His area of interest includes Electrical & Electronics, Digital communication and Digital signal processing.

**Col. Gurmit Singh** obtained B. Tech. Degree in Electronics from College of Military Engineering; Pune (Maharastra); India and Military College of Telecommunication Engineering; MHOW (MP); India, in 1976; and M.Tech. Degree in Electrical Engineering from Indian Institute of Technology; Kanpur (UP); India in 1979. He has authored / Co-authored many papers in the national / international journals / conference proceedings. His research interests include Reliability Engineering, Software Reliability and Computer Technology. He has served in the Corps of Signals, Indian Army, from 1968 to 1998 and developed a Network Management System for communication grid and worked extensively in RTDS Systems for Defence Forces.