



Power Optimization Using Efficient Codes

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Abstract: Power control and low error rate is the basic requirement of wireless communication system. The principle subject of this paper is to investigate the fact that the said objective is achievable through Codes. For this purpose Hamming, E.Golay (Extended Golay) and BCH (Bos-Chdhuri-Hocquenghem) are considered. Simulation results show that E .Golay (24, 12) and BCH (127, 64) can improve the performance of communication system with optimize power or Ec / N0 (Ratio of the signal code bit energy to noise power density) and low error rate.
Keywords- CDMA, Codes, MC-CDMA, OFDM

INTRODUCTION

Advantages of Digital communication are many compare to Analog communication: like resistance to channel noise and distortion, use of regenerative repeaters to maintain the strength of transmitted signal over a distance, use of microprocessor, signal coding or channel coding to detect and correct errors etc...(B. P. Lathi, 3rd Edition).

Our basic communication model is shown in (Fig.1), which is simple, but enough to achieve our objective i.e. reduced power. The first block is the Data, which is converted to bits using vocoder. The second one is the Channel Encoder; its purpose is to add redundancy for low error rate and power reduction. The third block represents Modulation; BPSK (Binary Phase Shift Keying), the purpose of it is to shift the frequency of the base band signal to carrier frequency.

The fourth block is concerned with the Multiple-Access technique, where the each user is assigned a unique channel in the form of Walsh Code, while they simultaneously occupy the same frequency band. These codes are generated by Hadamard matrix. Cross-correlation of between two rows (except W0) is zero. This isolates interference of one user's data from another. Here the data is also spreaded many times depends on the length of the Walsh Code. In the last one we have reduced power Pc to be transmitted. At the receiver end reverse process is performed i.e... Demodulation, channel decoding etc...

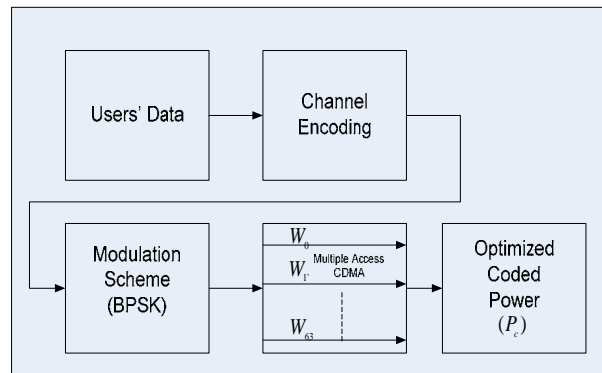


Fig.1. Basic Communication model

Using codes for power reduction and low error rate in communication system is an active research area (Kenneth et al., 2004) Tony Ottosson, 1997; Braithwaite, 2000). The ability of different codes to detect and correct data at receiving side improves the quality of communication and also minimizes the chances of re-transmissions. The importance of error rate is also realized in (Kenneth et al., 2004; Ottosson, 1997; Yang, 1998; Schulze, et al., 2005).

Apart from the ability of using codes to minimize the error rate the possibility of reducing PAPR (Peak to Average Power ratio) using specific codes is now under consideration in OFDM (Orthogonal Frequency Division Multiplexing) and MC-CDMA (Multi-Code Code Division Multiple Access) (Kenneth et al., 2004; Ottosson, 1997; Braithwaite, 2000; Schmidt, Sep 2009; Schmidt, April

2009; Schmidt, 2008; Schmidt, 2007; Nieswand, *et al.*, 1998). Use of codes to reduce power will help in building robust and stable systems with better quality of voice and data.

With the preference of wireless devices for the communication purpose the focus of research has now mainly shifted to wireless communication system design and also takes the channel coding aspect with it. The battery power is a big constraint for the long duration communication and adjustment of power during calls cause a lot of power usage. This problem gives a clear motivation for investigating such codes that can reduce the power transmission while keeping the same or low bit error rate (Kenneth *et al.*, 2004; Schmidt, Sep 2009; Schmidt, April 2009; Schmidt, 2008; Schmidt, 2007; Nieswand, *et al.*, 1998).

This paper presents an investigative study of using popular codes to minimize the transmission power. Effect of using codes on transmitted power is investigated in detail and observations are noted about the effect on bit error rate, which remains the main quality standard.

Rest of the paper is divided into 5 sections. Section II provides details about the well known codes like Hamming, Golay and BCH that are used in simulations. Section III presents details about simulation setup. Section IV provides results and discussion on them. Finally section V gives conclusion and future directives.

CODES TYPES

A. Background

Digital communication systems mostly implements channel coding to protect information bits from noise and interference. Channel coding provides better bit error control and thus provides better quality communication. The basic idea of channel coding is to introduce some additional bits in transmitted information bit sequence, so these bits can be used to detect and sometimes correct errors at the receiving end. Thus these additional bits improve the reliability of information transmission. There are two main types of channel codes Block codes and Convolution codes.

Block codes are very famous codes used for both error detection and correction. They have their roots in abstract algebra and finite field arithmetic. Block codes takes as input k information bits and produces a block of n coded bits by using predefined rules. Thus an addition of $n-k$ redundant bits occurs and these redundant bits are responsible for error control. Generally, these codes are called (n,k) block

codes. Among the block codes mostly used block codes are Hamming codes, Golay codes, Extended Golay, BCH codes, and Reed Solomon codes (Sklar, 2006). Convolutional code not only depends on present but also on past i.e.... $T-1$ time units (B.P. Lathi, 3rd Edition). We will use block codes because these codes full filled our objective i.e. to achieve optimal power and reduced probability of error. This research work has utilized three of the well know block code namely Hamming, Extended Golay and BCH. Brief description is given as below.

B. Hamming

Extension of hamming codes that can correct one and detect more than one error is widely used in different applications. The main principal behind working of Hamming codes is "parity". Parity is used to detect and correct errors. These parity bits are the resultant of applying parity check on different combination of data bits. Structural representation of Hamming codes can be given as (Bernard Sklar, 2006)

$$(n, k) = (2^x - 1, 2^x - 1 - x) \quad (1)$$

Where $x = 2, 3, \dots$. For hamming codes Syndrome decoding is well suited. It is possible to use syndrome to act as a binary pointer to identify location of error.

If hard decision decoding is assumed then the probability of bit error (P_B) can be given as follows (Sklar, 2006):

$$P_B \approx \frac{1}{n} \sum_{m=2}^n m \binom{n}{m} p^m (1-p)^{n-m} \quad (2)$$

Where p is the channel symbol error probability, $m=e+1$ is the probability of errors in a block of n symbols, and e is the error correcting capabilities.

C. Extended Golay

The Extended Golay code uses 12 bits of data and coded it in 24-bit word. This (24,12) extended Golay is derived by adding parity bit to (23, 12) Golay code. This added parity bit increases the minimum distance d_{\min} from 7 to 8 and produces a rate $1/2$, which is easier to implement than the rate $12/23$ that is original Golay code (Sklar, 2006) Though the advantages of using extended Golay is much more to that of ordinary Golay but at the same time the complexity of decoder increases and with the increase

in code word size the bandwidth is also utilized more. Extended Golay is also considered more reliable and powerful as compared to Hamming code. Its probability of bit error, assuming hard decision decoding is given in equ. 2, which is same as equ. 3 except $n=24$ and $m=4$.

$$P_B \approx \frac{1}{24} \sum_{m=4}^{24} m \binom{24}{m} p^m (1-p)^{24-m} \quad (3)$$

Extended Golay provides better bit error detection even in higher channels symbol error rate as compare to hamming code (Bernard Sklar, 2006)

D. BCH Codes

BCH belongs to powerful class of cyclic codes. BCH codes are powerful enough to detect multiple errors. The most commonly used BCH (Bernard Skalar, 2006) codes employs a binary alphabet and a codeword block length of $n = 2^x - 1$, where $x = 3, 4, \dots$

E. Trade off using codes

As explained in the earlier sections that use of codes reduces the power and lowers the possibility of error rates. However, to do this we have to pay the price for it in terms of more bandwidth. For example if we use the Extended Golay (24,12), we need twice the bandwidth of the message signal.

MATERIAL AND METHODS

Experiment

We have used MatLab for Simulation purpose and parameters assumed are shown in given below (Table I).

Table I. Simulation parameters

Multiple Access technique: CDMA, because codes commonly used in CDMA and OFDM to provide reliability (Henrik Schulze, *et al.*, 2005, chapter 3, p.92).

Frequency re-use factor: 100%

Error correcting codes: Block codes

Data rate: 9600bits per second

Area: 5Sq.km

Model: Two Ray Ground

ERP (Effective Radiated Power of Transmitter): 44000 or 46.435dB

Modulation Scheme: BPSK (Binary Phase Shift Keying)

Walsh code = 64, out of which W0 is used as a pilot channel, W1 to W7, only one for paging, W32 for sync purpose, remaining 61 for traffic channel.

In this simulation we used BW exp (Bandwidth Expansion) of codes such as Hamming, Golay and BCH. E_b/N_0 (ratio of bit energy per noise power spectral density) is taken as a power comparison parameter for coded and uncoded signal. The E_b/N_0 parameter is calculated using formula

$$E_b/N_0 = P_r/N_0 (1/R_d) \quad (4)$$

Where R_d is the data rate in bits per second. P_r/N_0 is ratio of the received power to the noise. Please note that for coded scheme $R_c = n/k * 1/R_d$ and we substitute this R_c for R_d in equ. 4 and E_b/N_0 will become E_c/N_0 or reduced power. Apart from E_b/N_0 comparison, the value of bit error rate is also compared for un-coded and coded bit stream which is calculated by the $Q\left(\sqrt{\frac{2E_b}{N_0}}\right)$ formula given in equ. 5 and 6 respectively

$$P_u = Q\left(\sqrt{\frac{2E_b}{N_0}}\right) \quad (5)$$

$$P_c = Q\left(\sqrt{\frac{2E_c}{N_0}}\right) \quad (6)$$

Where $Q(x)$ is called complementary error function or co-error function, it is commonly used symbol for probability under the tail of Gaussian pdf. Where P_u is probability of error in un-coded bit sequence and P_c is the probability of error in coded bit sequence.

Finally the most important parameter that shows the edge of using codes with the data is calculated which is the probability of bit detected correctly for coded and un-coded bit sequence which is given by equations 7 and 8 respectively:-

$$P_d^c \approx \binom{n}{m} (p_c)^m (1 - p_c)^{n-m} \quad (7)$$

$$P_d^u = 1 - (1 - p_u)^k \quad (8)$$

where, P_d^c and P_d^u are probability of coded data block received in error and probability of un-coded block received in error respectively. Using Hamming code (15, 11) we can compute probability of data error for coded and un-coded data using last two equations, which gives data error for coded is 1.94×10^{-6} and 1.12×10^{-4} for un-coded. It is concluded that using code data error has improved (Sklar, 2006).

RESULTS AND DISCUSSION

This section presents graphs that are obtained through simulation. The parameter of investigation is E_c/N_0 of coded and E_b/N_0 un-coded sequences, Correlation Coefficient (coded power, BW exp and error) and bit error probability at receiving end.

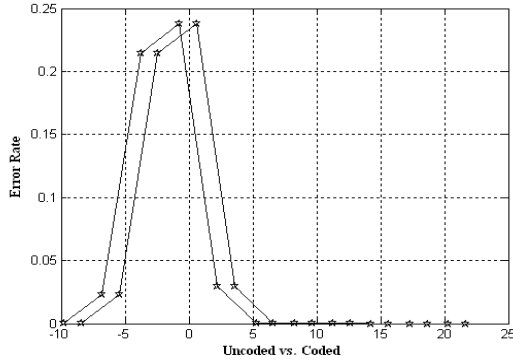


Fig.2. Power reduction using codes

Graph of (Fig.2) represents un-coded and coded power on X-axis and error probability on the Y-axis. Graph shows that (left curve) using code we have acquired reduction in power from 4 to 2 dB with same low probability of error i.e. 3×10^{-2} . Thus with the help of codes it is shown that more reliable transmission with the reduced power is possible. Thus the power can be efficiently used and will help to improve the up time for the mobile devices with better quality of data transmission.

Graph of (Fig.3) shows correlation coefficient (Coded Power & BW exp.), vs. Error this graph is based of three attributes of signal. One is Coded power, second is BW exp. and third is Error. Interesting part to be noted from the graph is that from 12 dB(coded power) onwards we have almost '0' probability of error. This proves that coding may significantly reduces the error rate.

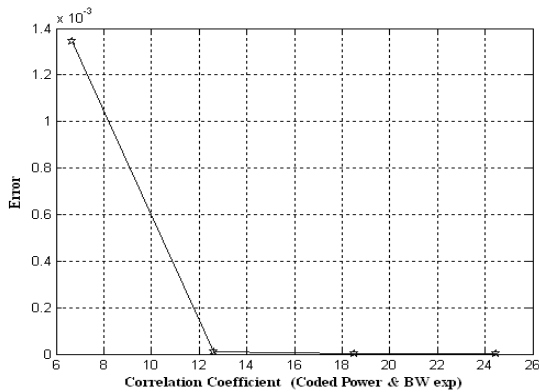


Fig.3. Correl. Coeff. b/w coded power and BW exp vs. Error

Graph of (Fig.4) represents power vs. probability of error. It shows that the use of E. Golay (24,12) and BCH(127,64) gives power of 3.6dB and 3.65dB respectively. The said power is achieved with minimum probability of error with average 1.33×10^{-3} . Though the graph shows further reduction in error probability i.e... (1.3×10^{-3}) can be can obtained by using BCH(127,36), but at the cost of very high BW

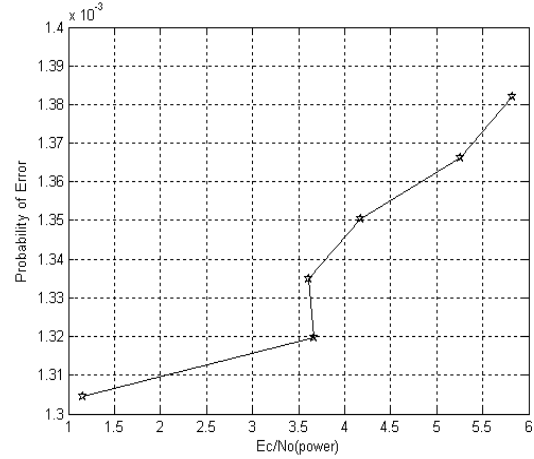


Fig.4. Ec/No (power) using different codes vs. error

Finally (Fig.5) shows another important result. Here the graph is plotted between BW exp vs. power. Different values of BW exp with its corresponding power values are shown in Table II. This graph proves that at BW exp of 2 and 1.98; optimal power is 3.6dB & 3.65dB using E. Golay (24, 12) and BCH (127, 64) respectively. Please also note that the redundancy of the said codes is 100%, which helps to achieve optimal power in addition to redundancy.

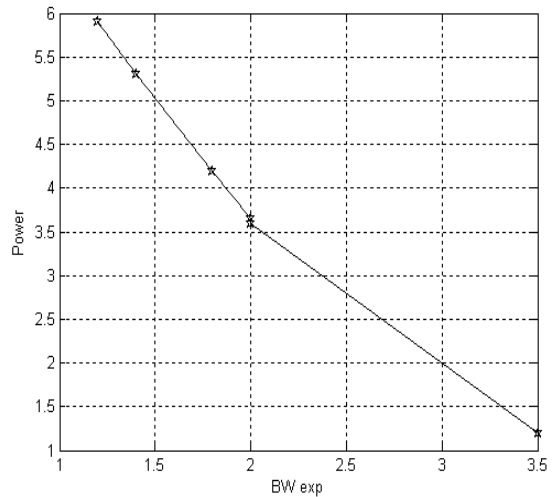


Fig.5. Optimal Power of 3.6 & 3.65 dB of E.Golay and BCH

Table 2. Code Comparison

CODE TYPE	CODE (n, k)	(n, k) BW EXP	Ec/N _o	DATA RATE
HAMMING	(7,4)	1.75	4.2	9600
“	(15,11)	1.36	5.3	“
“	(31,26)	1.19	5.9	“
E. GOLAY	(24,12)	2	3.6	“
BCH	(127,64)	1.98	3.65	“
“	(127,36)	3.52	1.15	“

CONCLUSIONS

In this research we verified that using E. Golay or BCH, provides optimal power with low probability of error (figure 4 and 5). But, at the expense of higher BW. Another Interesting part to be noted is that correlation coefficient between coded power and BW exp vs. error showed that error is almost zero as the coded power increases from 12 (Fig. 3). For future work, new codes from the existing one or algorithm may be designed to implement on multi-carrier systems such as OFDM and MC-CDMA, which may provides high data rates, but at very high PAPR, which is undesirable.

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REFERENCES

Braithwaite, R. N. (2000) “Using Walsh Code Selection to Reduce the Power Variance of Band-Limited Forward-Link CDMA Waveforms” IEEE Journal on Selected Areas on Communications, VOL. 18, NO. (11) 23-26.

Katherine M.N. and K. N. Wagner. (1998) Octary Codewords with Power Envelopes $3 * 2^m$.

Kenneth G. P. (2004) Member, IEEE “On Codes with Low Peak-to-Average Power Ratio for Multi-Code CDMA” IEEE Transactions on Information Theory, VOL 50 (3):550-559.

Lathi. B.P. Modern digital and Analog Communication systems, 3rd. edition.

Ottosson T. (1997) “Precoding in Multicode DS-CDMA Systems” 1997 IEEE.

Sklar, B. (2006) Digital Communications: Fundamentals and Applications, 2nd Edition, Pearson education.

Schulze H. and Luders, C. (2005) “Theory and application of OFDM and CDMA” Wideband Wireless Communication, John Wiley and Sons, Ltd, .

Schmidt. K.U. (2009) Bounds on the PMEPR of translates of Binary Codes. IEEE Transactions on Communications, submitted September,.

Schmidt. K.U. (2008) On the peak to Mean Envelope Power Ratio of Phase –Shifted Binary Codes. IEEE Transactions on Communications, vol. 56, No. (11): 1816-1823.

Schmidt. K.U. (2007) On Spectrally Bounded Codes for Multi-Carrier Communications, Vogt Verlag, Dresden, Germany.

Schmidt. K.U. (2009) Quaternary Constant Amplitude Codes formulti-Code CDMA. IEEE Transaction on Information Theory, Vol. 55, No. (4): 1824-1832.



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Yang, S. C. (1998) "CDMA RF SYSTEM ENGINEERING", Artech House, INC, 685 Canton Street Norwood, MA 02062.