Performance Evaluation of Code Division Multiple Access (CDMA) in terms of Power Measurement and Reduction

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Abstract— In this research paper the performance of the CDMA system has been analyzed with respect to PAPR (Peak to Average Power Ratio) measurement and its reduction. Simulation results verify that high peaks degrade the performance of CDMA, application of codes reduced high peaks and PAPR is a good measure for CDMA.

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***Index Terms*— CDMA, PAPR, Walsh Code**

I. INTRODUCTION

CDMA is a 3G Multiple Access technique. Its merits are: - high data rates, high tolerance to multi-path fading, orthogonality, security and no interference. In CDMA each user data is spread many times by multiplying its assigned Walsh code. Hence the power of the spread spectrum signal is spread over 100 – 1000 times the original bandwidth [1]. Consequently, the magnitude of the power exceeds the maximum amplitude of the PAPR [2]. These high peaks or amplitude tends to reduce the efficiency of the Power Amplifier (PA). Since the PA works properly in its linear region, so it is necessary to decrease the high peaks [6]-[8], [11]. Therefore, to lower the values of the high peaks, error correcting codes needs to be added to the message. There are codes available for the PAPR reduction [3], [4], [7]-[10] and measurement [2], [6] respectively.

II. CDMA SYSTEM

In CDMA multiple users share the same frequency band simultaneously. It uses spread spectrum technique, which provides high data rates to enhance the signal bandwidth far beyond the requirement for a given data rate. Each user has its own code words, which is approximately orthogonal to other code words. This feature makes the system bandwidth efficient and no interference among the users. Each user's data is secured, because of unique assigned code. Spread spectrum also resists to multi-path problem [4], [5]. Block diagram of CDMA system is shown in Fig. 1 [4]. Since the human speech is in the analog signal, so it has to be first converted into digital form. This function is performed by the source encoding module.

After the source information is coded into a digital form, redundancy needs to be added to this digital message or data. This is done to improve performance of the communication system by enabling the signal to better withstand the effects of channel impairments, such as noise and fading. The goal of channel coding is reliability or alternatively, given an achievable, to reduce the probability of error, but the trade off is more bandwidth. Redundancy is implemented in the form of bits, which are also called Error-correcting codes, when these codes applied to channel coding improve the error performance of the system. The purpose of the added bits to the message or data is that if the receiver found erroneous data, so it should be corrected [4]. After the message or data has been channel coded for error control, the signal is further transformed to allow access to multiple users. Multiple access by different users means to the sharing of a common resource i.e. RF spectrum.

III. GENERATION OF WALSH CODES

In order to avoid mutual interference on the uplink, Walsh codes are used to separate individual users while they simultaneously occupy the same RF band. Walsh codes as used in IS-95 are a set of 64 binary orthogonal sequences.

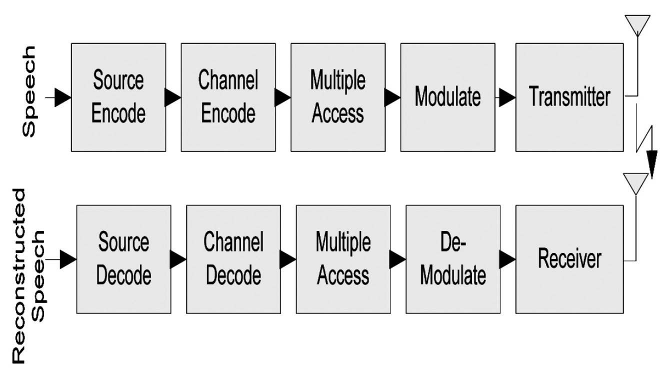

Fig.1. CDMA block diagram

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These sequences are orthogonal to each other, and they are generated by using the Hadamard matrix. Recursion is used to generate higher order matrices from lower order ones; that is [4].

$$H_{2N} = \begin{bmatrix} H_N & H_N \\ H_N & \overline{H_N} \end{bmatrix} \quad (1)$$

Where $\overline{H_N}$ contains the same but inverted elements of H_N. The seed matrix is

$$H_2 = \begin{bmatrix} 0 & 0 \\ 0 & 1 \end{bmatrix} \quad (2)$$

IV. MODULATOR

BPSK is the simplest type of PSK (phase shift keying) as shown in Fig. 2 [4]. It uses two phases of difference 180° (0° and 180°). It is, however, only able to modulate at 1 bit/ symbol. Let's examine its performance in a Gaussian noise environment. The concept is simple. Whenever the transmitter wants to send a + 1, it will transmit a positive co-sinusoid; whenever the transmitter wants to send a -1, it will transmit a negative co-sinusoid [4]. The analytic expression for BPSK is

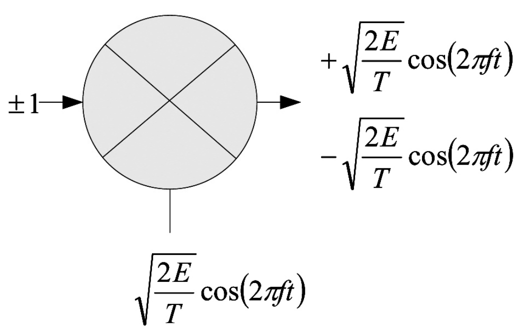

Fig.2. BPSK Modulator

$$+1; s_{+1}(t) = \sqrt{2E/T}\cos(2\pi ft) \quad 0 < t < T$$

$$-1; s_{-1}(t) = \sqrt{2E/T}\cos(2\pi ft + \pi) \quad 0 < t < T$$

$$= \sqrt{2E/T}\cos(2\pi ft) \quad (3)$$

V. DEMODULATOR

The purpose of the BPSK demodulator is to recover the original signal. The demodulator procedure is based on the matched-filter approach. In this approach the buried signal is extracted from the noise. The received signal r(t) has two components: the originally transmitted signal $s_i(t)$ where i could be either +1 or -1; and noise n(t), which has been introduced by the channel. The received signal r(t) is multiplied by the reference signals $s_{+1}(t)$. The multiplied result is then integrated over one bit interval T [4]. If the transmitter sent a +1 (that is., $s_i(t) = s_{+1}(t)$), then the integrated result is

$$y = \frac{2E}{T}\int_0^T \cos^2(2\pi ft)dt + \sqrt{\frac{2E}{T}}\int_0^T \cos(2\pi ft)n(t)dt \quad (4)$$

Where the first term is the signal term that is utilized by the decision threshold to make the decision and the second term is the noise contribution. In the absence of noise, we see that the first term reduces to [4]

$$\frac{2E}{T}\int_0^T \cos^2(2\pi ft)dt = 2\frac{E}{T}\left(\frac{1}{2}\right) = \frac{E}{T} \qquad for +1 \quad (5)$$

VI. PAPR AS MEASURE FOR CDMA

As mentioned in earlier discussion that the high peaks degrades the performance of the CDMA. Therefore, a measure should be available in evaluating the performance of the CDMA system. One such measure is called PAPR, which can be formulated as follows [12]

$$PAPR = \frac{|x_P|}{\sqrt{\frac{x_1^2 + x_2^2 + \ldots\ldots x_n^2}{n}}} \quad (6)$$

Where x_p is the peak power and RMS value is $\sqrt{\frac{x_1^2 + x_2^2 + \ldots\ldots\ldots x_n^2}{n}}$.

VII. USING CODES TO REDUCE PAPR

As discussed in section 1 that codes are used in the form of redundant bits which when are added to the message, provide reliability with lower power level. The objective of PAPR reduction can be obtained from the following formula:

$$PAPR(Coded) = \frac{M - Ary/rms}{Code * DataRate} \quad (7)$$

VIII. SIMULATION RESULTS

In this section some results are presented, which showed the performance of CDMA system. In simulation, we have used MAT Lab and assumed some parameters, which are shown in the table 1. fig. 3 shows correlation coefficient between time and probability of error versus coded PAPR. Graph reflects that optimized values of coded PAPR and Correlation Coefficient (i.e., 4, 16) respectively at high coded PAPR there is a less value of correlation coefficient, which means PAPR is a measure for CDMA system [11]. Simulation result of graph shown in Fig. 4 also reflects that using hamming code (15,11) PAPR is reduced from 35dB to 4dB. There is a separate graph of PAPR coded versus error rate as shown in fig. 5.

Table 1. Simulation parameters

Assumptions
Multiple Access Technique : CDMA
Channels 64 per cell
Frequency reuse factor 100%
Walsh code = 64, out of which W0 is used as pilot channel, W1 to W7, only one for paging and W32 for sync. Remaining 61 for traffic channels
Modulation : QPSK
CDMA (because codes commonly used in CDMA and OFDM, to reduce high peaks and provide reliability)
Error correcting code (15,11) Linear block code
Data rate : 9.6kbps
Area : 5 Sq.km
Model : Two ray ground model
ERP (Effective Radiated Power, of transmitter) = 48.76dB for 8 dB power of mobile
Pr = 75162

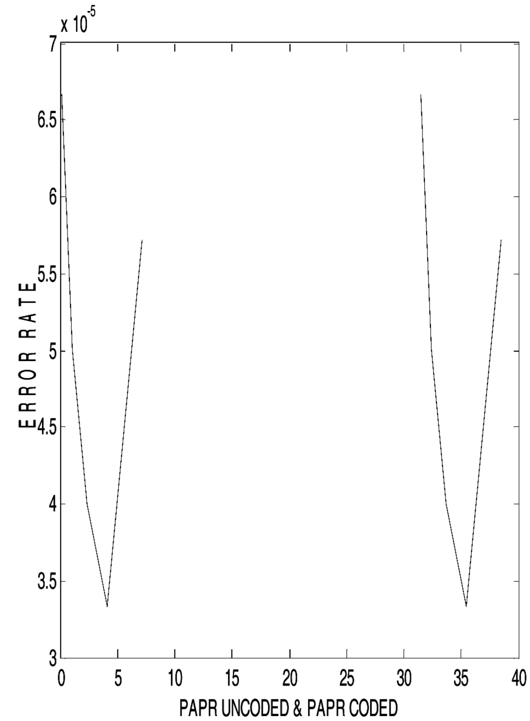

Fig.4. PAPR uncoded and coded versus error rate

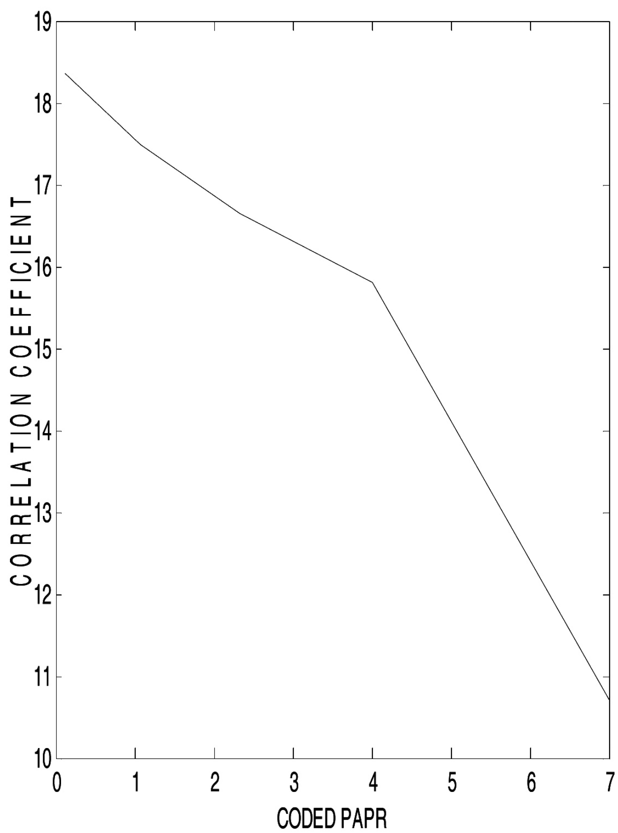

Fig.3. correlation coefficient between time and error versus coded PAPR

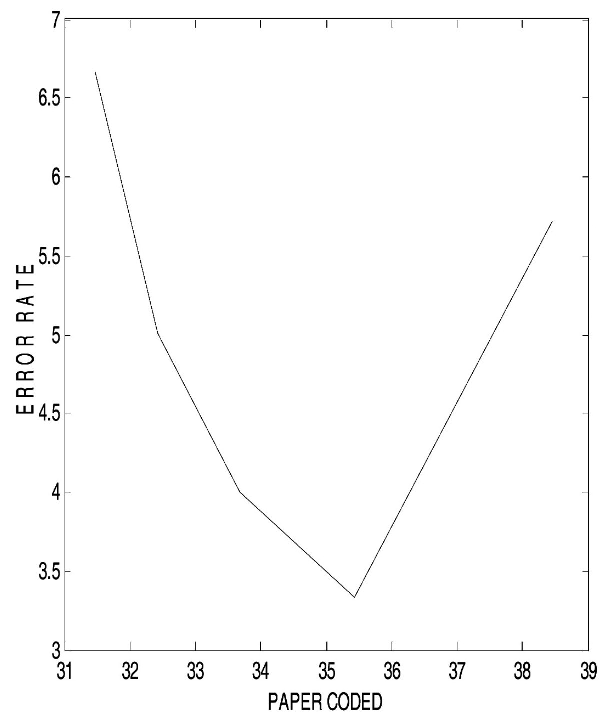

Fig.5. PAPR coded vs error rate

IX. CONCLUSION

Our results reveal that high peaks degrade the CDMA efficiency. Walsh code selection is a way to reduce power and it is easy to implement, because Walsh codes are available and (no need to design a code) used in forward link (from base station to mobile unit) in CDMA. There are two ways to measure peak power one is power Variance and the other one is PAPR. We have opted PAPR. We have also shown that PAPR is a good measure of high peaks. Codes like hamming (15, 11) may be used to reduce the power. To reduce PAPR further, we may design new codes or drive codes from the existing codes such as BCH (multiple error correcting property), Reed Muller, Golay and bent function.

REFERENCES

[1] R. L. Picoltz, L.B Milstein and D. L Schilling, "Spread Spectrum for Mobile Communications" *IEEE Transactions on Vehicular Technology*, vol. 40, no. 2, pp. 313-322, May 1991

[2] R.N.Braithwaite "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, November, 2000.

[3] T. Ottosson, "Precoding in Multicode DS-CDMA Systems" 1997 IEEE, pp. 351-351

[4] S.C. Yang, "CDMA RF System Engineering", Artech House, INC, 685 Canton Street Norwood, MA 02062, 1998

[5] T. S. Rappaport, "Wireless Communication, Principles & Practices", *2nd Edition*, Pearson Education, 2002

[6] A.Behravan. and T. Erikson., "PAPR and other measures for OFDM systems with nonlinearity" The 5th International Symposium on Wireless Personal Multimedia Communications, Vol.1, October 2002, pp.149-153

[7] H. Schulze and C.Luders, Theory and application of OFDM and CDMA, Wideband Wireless Communication, John Wiley and Sons, Ltd, 2005.

[8] B. Skalar, Digital Communications Fundamentals and Applications, *2nd Edition*, Pearson Education, 2006.

[9] K.G. Paterson, "On Codes with Low Peak-to-Average Power Ratio for Multi-Code CDMA" *IEEE Transactions on Information Theory*, vol.50 (3), pp.550-559, 2004.

[10] I.A. Tasadduq "Novel OFDM-CPM Signals for Wireless Communications: Properties, Receivers & Performance", Ph.D. dissertation, the University of Western Ontario, London, Ontario, 2002

[11] S.R. Hasan, S.Ahmed. and M. Imam, "PAPR as measure for OFDM with non-linearity" Proc. 7th. CIIT Workshop on Research – Computing, Lahore, June 23rd 2008. pp.114-117

[12] Wikipedia,"Crest Factor" http://en.wikipedia.org/wiki/Crest_factor