PERFORMANCE EVALUATION OF PSEUDO-RANDOM NOISE AND HADAMARD-WALSH SEQUENCES FOR HAMMING CODED WCDMA SYSTEM OVER AWGN AND FAADING CHANNELS

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Abstract
In this paper, the impact of pseudorandom noise (PN) sequence code and Hadamard–Walsh sequence code on the performance of a Wideband Direct Sequence Code Division Multiple Access (WCDMA) system with Hamming coding or without error correction and detection coding under quadrature phase-shift keying (QPSK) modulation over an Additive White Gaussian Noise (AWGN) channel and fading channel is investigated. The study is made with the development of a computer program written in MATLAB source code and its application on the processing of a simulated digital signal. The simulation results of estimated Bit error rate (BER) show the performance of WCDMA system with Hamming coding is highly effective for AWGN channel but less effective to combat inherent interference in the communication system. It is anticipated that the performance of the communication system degrades with the increasing of noise power.

Keyword: Pseudo-random noise (PN) sequence, Hadamard-Walsh sequence, Bit error rate (BER), Hamming coding, Wideband Code Division Multiple Access (WCDMA)

Introduction
In a multiple access system, a large number of users share a common channel to transmit information to a receiver. The system has to manage resources appropriately in order to cover and support all the users that want to access the system. More than one user is allowed to share a channel by use of direct sequence spread spectrum (DS-SS) signals (Scholtz, 1982, Pickholtz et all. 1982). In a DS-SS system, each user is assigned a unique code sequence (Dinan, et all.1998) that allows the user to spread the information signal across the assigned frequency band. Signals from the various users are separated at the receiver by cross-correlation of the received signal with each of the possible user code sequences. Possible narrow band interference is also suppressed in this process. By designing these code sequences to have relatively small cross-correlation, the cross-talk inherent in the demodulation of the signals received from multiple transmitters is minimized. This multiple access method is CDMA, which is a form of a DSSS system (Raitola, 1996, Prasad, et all. 1998). The Wideband Direct-Sequence CDMA (WCDMA) is 3G-system operation in 5MHz

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bandwidth to support both high-rate packet data and circuit-switched data (Rappaport, 2006, Wang, et al. 2002). This modulation transforms an information-bearing signal into a transmission signal with a much larger bandwidth. This transformation is achieved by encoding the information signal with a code signal that is independent of the data and has much larger spectral width than the data signal. This spreads the original signal power over a much broader bandwidth, resulting in a lower power density. The ratio of transmitted bandwidth to information bandwidth is called the processing gain, \( G_p \) of the DS-SS system: \( G_p = B_t/B_i \), where \( B_t \) is the transmission bandwidth and \( B_i \) is the bandwidth of the information bearing signal.

In DS-SS transmitter the data is spread by multiplying with a pseudo-random noise (PN) sequence. A PN sequence is a binary sequence that exhibits randomness properties but has a finite length and is therefore deterministic. A single pulse or symbol of the PN waveform is called chip. They are used to implement synchronization and uniquely code individual user signals across the transmission interface. The PN sequence is usually generated using sequential logic circuits i.e. feedback shift register (Dixon, 1994).

A DS-SS receiver is based on a correlator, which utilizes correlation properties of the PN codes (Dixon, 1994). The correlators attempt to match the incoming received signal with each of the candidate prototype waveforms (PN sequences) known a priori to the receiver. The received DS-SS signal for a single user can be represented as

\[
S_{ss}(t) = \sqrt{\frac{2E_s}{T_s}} m(t)p(t) \cos(2\pi f_c t + \theta)
\]

where \( m(t) \) is the data sequence, \( p(t) \) is the PN spreading sequence, \( f_c \) is the carrier frequency and \( \theta \) is the carrier phase angle at \( t = 0 \).

However, popular code sequences that can be found in practical DSSS-systems are: Hadamard-Walsh codes, M-sequences, Gold codes and Kasami-codes. In this paper, we used also Hadamard-Walsh code instead of PN sequence code under same condition. Walsh-sequences have the advantage to be orthogonal, in this way we should get rid of any multi-access interference under a perfect synchronization. In particular, the Hadamard-Walsh codes of length \( N; N = 2^n, n = 1,2, ..., \) can be often generated using Hadamard matrices \( H_N \) (Harmuth, 1970) with

\[
H_N = \begin{pmatrix}
H_{N/2} & H_{N/2}\\
H_{N/2} & -H_{N/2}
\end{pmatrix}
\]

with \( H_0 = [1] \)

The rows (or columns) of the matrix \( H_N \) are the Hadamard-Walsh codes.

\[
H_2 = \begin{pmatrix}
1 & 1 \\
1 & -1
\end{pmatrix}
\]

\[
H_4 = \begin{pmatrix}
1 & 1 & 1 & 1 \\
1 & -1 & 1 & -1 \\
1 & 1 & -1 & -1 \\
1 & -1 & -1 & 1
\end{pmatrix}
\]
In each case the first row (row 0) of the matrix consists entirely of 1s and each of the other rows contains N/2 0s and N/2 1s. Row N/2 starts with N/2 1s and ends with N/2 0s. The Hadamard–Walsh code can be used as a block code in a channel encoder: each sequence of n bits identifies one row of the matrix (there are N =2^n possible rows). The cross-correlation between any two Hadamard-Walsh codes of the same matrix is zero, when perfectly synchronized. In a synchronous CDMA this ensures that there is no interference among signals transmitted by the same station. Only when synchronized, these codes have good orthogonal properties (Dinan, et all.1998).

In order to reduce the BER level, one channel coding scheme could be used. Channel coding is required for wireless communications to protect data from the errors that may result from noise and interference. In this work we used Hamming coding which have the ability of making error detection and correction at the receiver. By applying this channel coding technique very low BER value was obtained at relatively small SNR.

**Materials and Methods**

There are many features of WCDMA system that are more easily manipulated in a software situation using Matlab, a software package, to allow various parameters of the system to be varied and tested. The model is shown in Figure :1. The original data/ information is generated randomly. The source outputs a sequence of binary digits, processed by the source encoder to remove any redundancy in the data so that the information is represented by the minimum number of binary digits. The data stream is processed next by the channel encoder, which adds a certain redundancy to the information the can be used by the receiver to detect or correct error which occur due to signal corruption by the channel additive noise and interference. The encoded data signal are added with a unique high-speed PN code to obtain high-speed spread spectrum data and then modulated by a high-speed Quadrature phase-shift keying (QPSK) modulator to generate the IF signal. The signal is then upconverted by a mixer to suitable RF signal. After amplification, digitally modulated information symbols are transmitted. The transmitted symbols are corrupted by Gaussian distributed additive noise, interference from other transmitters operating within the frequency spectrum and Inter Symbol Interference (ISI) causing received signal fading. At the receiver, spread-spectrum demodulator performs the inverse of the modulator. The spread-spectrum IF signal is demodulated to the composite spread-spectrum data and added then with the same PN code. Sequentially in the reverse order to that in the transmitter, reconstructing a recognizable version of original message data (Faruque, 2008, Abu-Rgheff, 2007). The model parameters used in the simulation study are the number of users=12, the desired users=12, the chips length=7, coding technique is used either none of error correction and detection code or Hamming code, transmission channel is either Additive White Gaussian channel (AWGN) or fading channel.
Simulation Results

We present results of our computer simulation on the BER performance of either the PN sequence coded or the Hadamard–Walsh coded WCDMA system with no error correction and detection code or with Hamming code on both Additive White Gaussian channel (AWGN) and fading channels. When the signal with PN sequence code passes away through the AWGN channel without error correction and detection code (Fig.2a), the signal-noise ratio (SNR) increases then the bit error rate (BER) is slightly decreased. But with error correction and detection Hamming code (Fig.2b), BER linearly decreases when the SNR increases. For SNR=10dB, a remarkable change on BER and that is nearly zero. Using the Hadamard–Walsh code instead of PN sequence code under same condition, the BER is non-linearly decreased when the SNR is increasing with none error correction and detection coding environment (Fig.3a). But with the using of Hamming code, the BER linearly decreases with increasing of SNR (Fig.3b). It is negligible at SNR=10dB in both cases. So it is found that system performance is improved for AWGN channel by using Hamming-coding technique.
Fig. 4 and Fig. 5 show the BER performance by using the same parameters under same condition, used in AWGN channel, of WCDMA system on a fading channel. When the signal with PN sequence code passes away through the fading channel with none error correction and detection code (Fig. 4a), the SNR increases then BER randomly decreases. At SNR=10dB, then BER is too much high. But using the Hamming coding technique (Fig. 4b), linearity is just found on BER that is decreases when the SNR increases and no remarkable change on it at 10dB SNR level. Applying the Hadamard–Walsh code in lieu of PN sequence code under same environment, the relation between BER and SNR is same as seen of using PN sequence with using either none error correction and detection coding or Hamming coding technique (Fig. 5). In comparison of the fading channel with
AWGN channel, it is found that due to fading channel effect, system performance degrades and its performance slightly improves with Hamming coding technique.
Conclusions

In this paper, we evaluated the performance of the WCDMA system by using hamming coding under PN sequence and Hadamard-Walsh codes. We showed that the system achieves good error rate performance on an AWGN channel. But no significant performance improves on fading channel. On the basis of results obtained in the present study, it can be concluded that the system with hamming coding is very much effective on AWGN channel than fading channel.

References


