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A Bi-Level FH-CDMA Scheme For Wireless Communication Over Fading Channels

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Abstract

In this project, we propose a "Bi-level" frequency hopping code-division multiple-access (FH-CDMA) scheme for wireless communication systems. The new scheme provides flexibility in the selection of modulation codes and FH patterns. By partitioning the modulation codes, our Bi -level scheme can be modified to support more possible users without increasing the number of FH patterns. The performance and spectral efficiency (SE) of the scheme are analyzed. Our results show that the partitioned Bi-level FH-CDMA scheme supports higher data rate and greater SE than Goodman's frequency-shift-keying FHCDMA scheme under some conditions.

1.Introduction

FREQUENCY-HOPPING code-division multiple access (FH-CDMA) provides frequency diversity and helps mitigate multi path fading and diversify interference. Major advantages of FH-CDMA over direct-sequence CDMA include better resistance to multiple access interference (MAI), less stringent power control, and reduced near-far problem and multi path interference. By assigning a unique FH pattern to each user, a FH-CDMA system allows multiple users to share the same transmission channel simultaneously. MAI occurs when more than one simultaneous users utilize the same carrier frequency in the same time slot. "One-hit" FH patterns have been designed in order to minimize MAI.

In addition, good man, proposed to add M-arry frequency shift keying(MFSK) atop FH-CDMA in order to increase data rate by transmitting symbols, instead of data bits.
we propose a partitioning method on the modulation codes, such that modulation codes with lower cross-correlation values are grouped together. Using different groups of modulation codes as an additional level of address signature, the partitioned Bi -level FH-CDMA scheme allows the assignment of the same FH pattern to multiple users, thus increasing the number of possible users. The performance of our Bi-level FH-CDMA scheme over additive white Gaussian noise (AWGN), and Rayleigh and Rician fading channels are analyzed algebraically.

2. ORTHOGONAL MC-CDMA

- MC-CDMA is a form of CDMA or spread spectrum, but we apply the spreading in the frequency domain (rather than in the time domain as in Direct Sequence CDMA).
- MC-CDMA is a form of Direct Sequence CDMA, but after spreading, a Fourier Transform (FFT) is performed.
- MC-CDMA is a form of Orthogonal Frequency Division Multiplexing (OFDM), but we first apply an orthogonal matrix operation to the user bits. Therefore, MC-CDMA is sometimes also called "CDMA-OFDM".
- MC-CDMA is a form of Direct Sequence CDMA, but our code sequence is the Fourier Transform of a Walsh Hadamard sequence.
- MC-CDMA is a form of frequency diversity. Each bit is transmitted simultaneously (in parallel) on many different sub carriers. Each subcarrier has a (constant) phase offset. The set of frequency offsets form a code to distinguish different users.

The MC-CDMA method described here is NOT the same as DS-CDMA using multiple carriers. In the latter system the spread factor per sub carrier can be smaller than with conventional DS-CDMA. Such a scheme is sometimes called MC-DS-CDMA. This does not use the special OFDM-like waveforms to ensure dense spacing of overlapping, yet orthogonal sub carriers. MC-DS-CDMA has advantages over DS-CDMA as it is easier to synchronize to this type of signals.

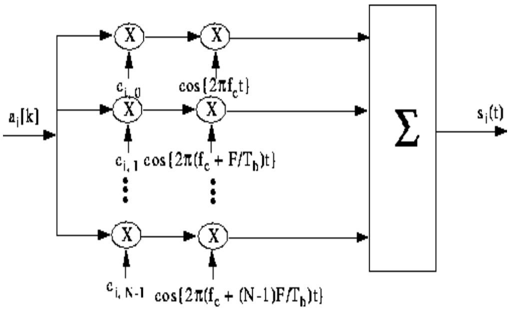


Fig 2.1: possible implementation of an Multi-Carrier spread-spectrum transmitter

MC-Code Division Multiple Access systems allow simultaneous transmission of several such user signals on the same set of subcarriers. In the downlink multiplexer, this can be implemented using an Inverse FFT and a Code Matrix.

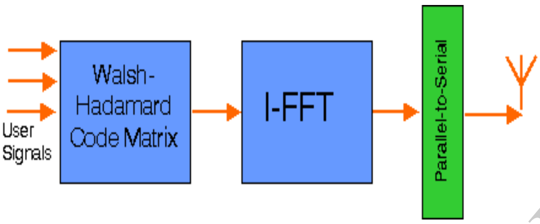


Fig 2.2 : FFT implementation of an MC-CDMA base station multiplexer and transmitter.

MC-CDMA as a special case of DS-CDMA

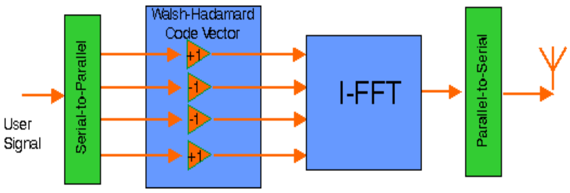


Fig 2.3 : possible implementation of a Multi-Carrier spread-spectrum transmitter.

The above transmitter can also be implemented as a Direct-Sequence CDMA transmitter, i.e., one in which the user signal is multiplied by a fast code sequence. However, the new code sequence is the Discrete Fourier Transform of a binary, say, Walsh Hadamard code sequence, so it has complex values.

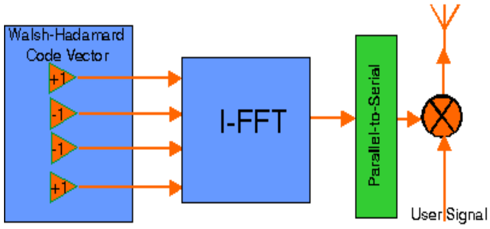
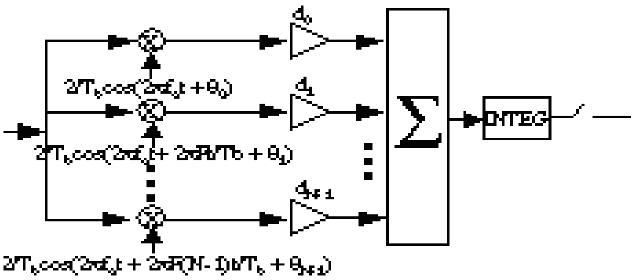


Fig2.4 : Alternative implementation of a Multi-Carrier spread-spectrum transmitter, using the Direct sequence principle.

2.1 RECEIVER DESIGN



Because of delay spread and frequency dispersion due to multipath fading, subcarriers are received with different amplitudes. An importance aspect of the receiver design is how to treat the individual subcarriers, depending on their amplitude r_i. Options are

- Linear combining, by weighting the ith subcarrier by a factor d_i according to
  - Maximum Ratio Combining: $d_i = r_i$. This optimally combats noise, but does not exploit interference nulling. (See also MRC diversity)
  - Equal Gain: $d_i = 1$. The simplest solution. (See also EGC diversity)
  - Equalization: $d_i = 1/r_i$. This perfectly restores orthogonality and nulls interference, but excessively boosts noise.
  - Wiener filtering: $d_i = r_i/(r_i^2 + c)$. This gives the best post-combiner signal-to-noise-plus-interference ratio.
- Maximum likelihood detection

2.2 ADVANTAGES OF MC-CDMA

Compared to Direct Sequence (DS) CDMA. DS-CDMA is a method to share spectrum among multiple simultaneous users. Moreover, it can exploit frequency diversity, using a RAKE receiver. However, in a dispersive multipath channel, DS-CDMA with a spread factor *N* can accommodate *N* simultaneous users only if highly complex interference cancellation techniques are used. In practice this is difficult to implement. MC-CDMA can handle *N* simultaneous users with good BER, using standard receiver techniques.

Compared to OFDM. To avoid excessive bit errors on subcarriers that are in a deep fade, OFDM typically applies coding. Hence, the number of subcarriers needed is larger than the number of bits or symbols transmitted simultaneously. MC-CDMA replaces this encoder by an *N x N* matrix operation. Our initial results reveal an improved BER

3.Multiple Access Techniques

Multiple access schemes are used to allow many simultaneous users to use the same fixed bandwidth radio spectrum. In any radio system, the bandwidth, which is allocated to it, is always limited. For mobile phone systems the total bandwidth is typically 50 MHz, which is split in half to provide the forward and reverse links of the system.

3.1 Frequency Division Multiple Access (FDMA):

In Frequency Division Multiple Access (FDMA), the available bandwidth is subdivided into a number of narrower band channels. Each user is allocated a unique frequency band in which to transmit and receive on. During a call, no other user can use the same frequency band.

Each user is allocated a forward link channel (from the base station to the mobile phone) and a reverse channel (back to the base station), each being a single way link. The transmitted signal on each of the channels is continuous allowing analog transmissions. The bandwidths of FDMA channels are generally low (30 kHz) as each channel only supports one user. FDMA is used as the primary breakup of large allocated frequency bands and is used as part of most multi-channel systems.

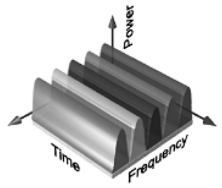


Fig.1.2 FDMA showing that the each narrow band channel is allocated to a single user.

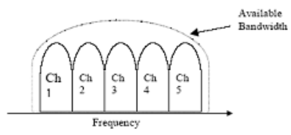


Fig.1.3 FDMA spectrum, where the available band width is sub-divided into narrow band channels.

Fig. 5 TDMA/FDMA hybrid, showing that the bandwidth is split into frequency channels and time slots.

3.2 Code Division Multiple Access:

Code Division Multiple Access (CDMA) is a spread spectrum technique that uses neither frequency channels nor time slots. In CDMA, the narrow band message (typically digitized voice data) is multiplied by a large bandwidth signal, which is a pseudo random noise code (PN code). All users in a CDMA system use the same frequency band and transmit simultaneously. The transmitted signal is recovered by correlating the received signal with the PN code used by the transmitter. **Fig. 1.6** shows the general use of the spectrum using CDMA.

3.2.1 CDMA Generation:

CDMA is achieved by modulating the data signal by a pseudo random noise sequence (PN code), which has a chip rate higher then the bit rate of the data. The PN code sequence is a sequence of ones and zeros (called chips), which alternate in a random fashion. The data is modulated by modular-2 adding the data with the PN code sequence. This can also be done by multiplying the signals, provided the data and PN code is represented by 1 and -1 instead of 1 and 0. **Fig.8** shows a basic CDMA transmitter.

3.2.2 CDMA SYSTEM :

The rapid worldwide growth in cellular telephone subscribers over the past decade has evidently showed that the wireless communication is an effective means for transferring information in today’s society. Time Division Multiple Access (TDMA) and Frequency Division Multiple Access (FDMA) are two approaches that have contributed to this advancement in the telecommunications industry.

However, the widespread success of these communications systems has led to the development for newer and higher technology techniques and standards in order to facilitate high-speed communication for multimedia, data and video in addition to voice transmissions . Code Division

Multiple Access (CDMA) is today's dominant technology for the evolution of third generation (3G) mobile communications systems with the development of two major schemes: Wideband CDMA (W-CDMA) and CDMA2000.

The W-CDMA technology otherwise known as the Universal Mobile Telecommunications System (UMTS) is designed with the intention of providing an upgrade path for the existing Global System for Mobile Communications (GSM) while CDMA2000 is based on the fundamental technologies of IS-95, IS-95A (cdmaOne) as well as the 2.5G IS-95B systems . These two schemes are similar for their ability to provide high data rates and the efficient use of bandwidth but are incompatible as they use different chip rates. The following sections of this chapter will describe and explain the basic concepts behind the CDMA technology.

3.3 Spread Spectrum Multiple Access

The spread spectrum modulation techniques are originally developed for use in the military and intelligence communications systems due to their resistance against jamming signals and low probability of interception (LPI). They are immune to various kinds of noise and multipath distortion.

A number of modulation techniques have been developed to generate spread spectrum signals. These can be generally classified as direct-sequence spread spectrum (DS-SS), frequency-hopping spread spectrum (FH-SS), time-hopping spread spectrum (TH-SS), chirp modulation and the hybrid combination modulation . We will look into the functionality of the DS-SS and how this modulation technique is incorporated to the CDMA system.

3.3.1 Direct-Sequence Spread Spectrum (DS-SS):

The DS-SS technique is one of the most popular forms of spread spectrum. This is probably due to the simplicity with which direct sequencing can be implemented. Figure 1 shows the basic model and the key characteristics that make up the DS-SS communications system. In this form of modulation, a pseudo-random noise generator creates a spreading code or better known as the pseudo-noise (PN) code sequence. Each bit of the original input data is directly modulated with this PN sequence and is represented by multiple bits in the transmitted signal. On the receiving end, only the same PN sequence is capable of Demodulating the spread spectrum signal to successfully recover the input data .

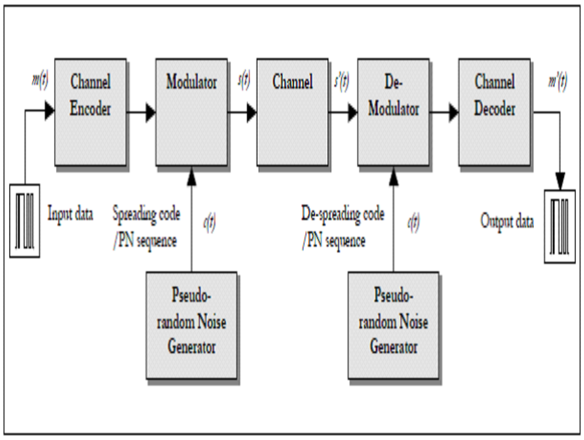


Fig:3.1 Basic model of the direct-sequence spread spectrum communications system

The bandwidth of the transmitted signal is directly proportional to the number of bits used for the PN sequence. A 7-bit code sequence spreads the signal across a wider frequency band that is seven times greater than a 1-bit code sequence, otherwise termed as having a processing gain of seven. Figure 2.2 illustrates the generation of a DS-SS signal using an exclusive-OR (XOR) operation. The XOR obeys the following rules:

$0 \oplus 0 = 0$ $0 \oplus 1 = 1$ $1 \oplus 0 = 1$ $1 \oplus 1 = 0$

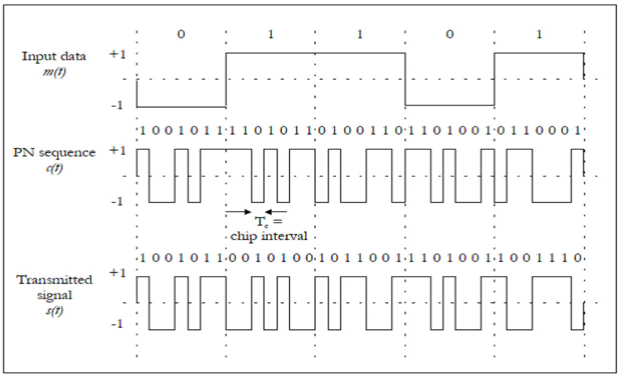


Fig:3.2 Generation of a DS-SS signal with processing gain = 7

Note that an input data bit of zero causes the PN sequence coding bits to be transmitted without inversion, while an input data bit of one inverts the coding bits. Rather than to represent the binary data with bits 0's and 1's, the input data and PN sequence are converted into a bipolar waveform with amplitude values of ±1. This is further illustrated in figure 3.

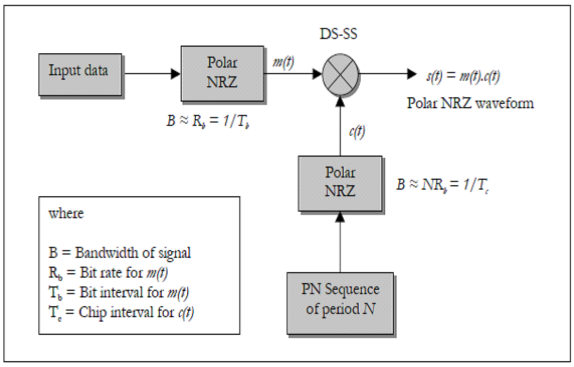


Fig: 3.3 Transmitter of the DS-SS system

we are also able to identify two criteria that need to be met in order to be considered as a DS-SS system. The bandwidth of the transmitted signal s(t) is much wider as compared to the input data m(t); and This wide bandwidth is caused by the modulation of the spreading signal c(t) and the intended receiver requires this identical signal for retrieving the message signal m(t). In the next few sections, we will look into the functionality of the various components for a Direct-Sequence Code Division Multiple Access (DS-CDMA) system.

4 . New Bi-Level FH-CDMA Scheme Description

In our Bi-level FH-CDMA scheme, the available transmission bandwidth is divided into Mh frequency bands with Mm. carrier frequencies in each band, giving a total of MmMh carrier frequencies. In the first first level, a number of serial data bits is grouped together and represented by a symbol.

	Group 0	Group 1	Group 2	Group 3	Group 4
i_2	$i_1 = 0$	$i_1 = 1$	$i_1 = 2$	$i_1 = 3$	$i_1 = 4$
0	0000x	0123x	02x13	031x2	0x321
1	1111x	123x0	1302x	1x203	10x32
2	2222x	23x01	2x130	203x1	210x3
3	3333x	3x012	302x1	31x20	3210x
4	xxxxx	x0123	x1302	x2031	x3210

Table slots (i.e., pattern length). The elements in the modulation codes and FH patterns determine the carrier While an element of a modulation code defines the carrier frequency used in a frequency band in a given time slot, an element of the FH pattern determines which frequency band to use.

4.1 Partitioned Bi-level FH-CDMA Scheme

In general, the number of possible users in a FH-CDMA system is limited by the number of available FH patterns. However, our Bi-level FH-CDMA scheme can flexibly increase the number of possible users by trading for lower data rate through a reduction of symbol size. It is done by partitioning the modulation codes into several groups and each group contains reduced number of modulation codes.

5. Performance Analyses and Comparisons

In FH-CDMA systems, MAI depends on the cross correlation values of FH patterns. For our two-level FHCDMA scheme, the cross-correlation values of the modulation codes impose additional (symbol) interference and need to be considered. Assume that one-hit FH patterns of dimensions MhXLh and the transmission band is divided into MmMh frequencies.

The probability that a frequency of an interferer its with one of the wmfreuencies of the desired user is given by

$$q = \frac{w_m^2}{M_m M_h L_h}. \qquad (1)$$

the probability that the dehopped signal contains n entries an undesired row is given by

$$P(n) = \binom{w_m}{n} \sum_{i=0}^{n} (-1)^i \binom{n}{i} \left[1 - q + \frac{(n-i)q}{w_m}\right]^{K-1}. \quad (2)$$

Over AWGN, and Rayleigh and Rician fading channels, false alarms and deletions may introduce detection errors to the received FH-CDMA signals. A false-alarm probability, ,is the probability that a tone is detected in a receiver when none has actually been transmitted. The False Alarm probability is generally by

$$p_f = \exp\left(-\beta_0^2/2\right). \qquad (3)$$

In this section, we compare the performances of the new Bi-level FH-CDMA and Goodman's MFSK/FH-CDMA schemes under the condition of same transmission parameters.

Also shown in the figure is the computer-simulation result for validating our theoretical analysis. The computer simulation of our two-level FH-CDMA scheme is performed as follows. The FH pattern assigned to each user is arbitrarily selected from all 472 possible(11 × 47, 11, 0, 1) prime sequences constructed from GF(47)and then all 112 possible (4 × 11, 4, 0, 1) prime sequences constructed from GF(11) are used as the modulation codes for each user. For each simulation point in the figure, the total number of data bits involved in the simulation ranges from104 to 106, depending on the targeted error probability.

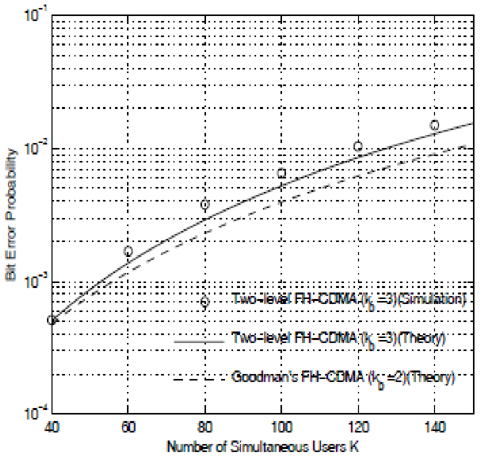


Fig: 5.1 BEPs of the partitioned Bi-level FH-CDMA and Goodman's FH-CDMAschemes versus the number of simultaneous users K over a Rayleighfading chanel , where MgxLg=44x47,wg=wm=4, MmxLm=4x11,MhxLh=11x47**.**

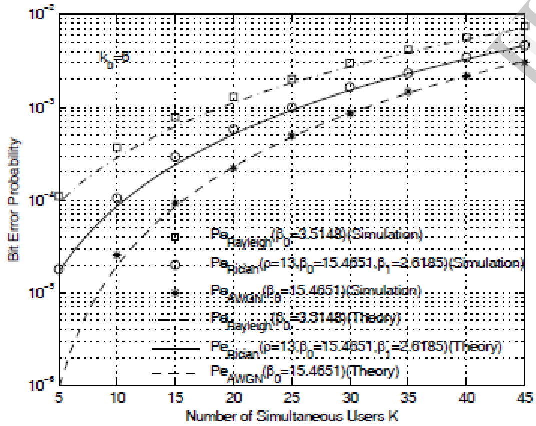


Fig. 5. BEPs of the Bi-level FH-CDMA scheme versus the number of simultaneous users K over AWGN, and Rayleigh and racial fading channels, where wm=4,Mm=4x11,MhxLh=11x47

6. Conclusion

In this project, we proposed a new Bi-level FH-CDMA scheme. The prime/FH-CDMA and RS/FH-CDMA schemeswere special cases of our scheme. The performance analysesshowed that the Bi-level FH-CDMA scheme provided atrade-off between performance and data rate. The partitioned Bi-level FH-CDMA scheme increased the number of possible users and exhibited higher data rate and greater SE than Goodman's MFSK/FH-CDMA scheme. In summary, the new scheme offered more flexibility in the design of FH-CDMA systems to meet different operating requirements.

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