CDMA MODEM USING DIRECT SEQUENCE SPREAD SPECTRUM

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ABSTRACT

Spread spectrum is a type of modulation that spreads data transmission across available frequency band, in excess of minimum bandwidth available. Because of its advantages, it is used in Code Division Multiple Access systems to assign a unique code to every user. Our project aims to simulate the CDMA modem using Direct Sequence Spread spectrum. The paper includes real time processing of signal, BPSK modulation, and multiplication with a pseudo random code to generate Spread Spectrum, transmitting it over a common frequency band and descrambling the signal using the same pseudo-random code at the receiver.

KEY WORDS

Code Division Multiple Access (CDMA), Binary Phase Shift Keying (BPSK), Direct Sequence Spread Spectrum (DSSS), Direct Sequence – Code Division Multiple Access (DS – CDMA)

1. INTRODUCTION

Spread Spectrum is a type of modulation that spreads data transmission across available frequency band, in excess of minimum bandwidth required to send the information. Spreading makes signal resistant to noise, interference and eavesdropping. Spread Spectrum is commonly used with personal communication devices such as cell phones and LAN's [1].Spread Spectrum has many unique properties that cannot be found in other techniques like the ability to eliminate or alleviate multi-path interference, privacy of due to unknown random codes, multi-user handling capacity over a single frequency, low power spectral density since signal is spread over a large frequency band. There are two techniques to achieve spread spectrum. The most common methods are Direct Sequence Spread Spectrum and Frequency Hopping Spread Spectrum [12]. A DSSS transmitter converts an incoming data (bit) stream into a symbol stream. Using a digital modulation technique like BPSK or QPSK, a transmitter multiplies symbols with a pseudo random noise code. This multiplication operation artificially increases used bandwidth based on length of chip sequence. A CDMA system is implemented via these coding. Each user over a CDMA system is assigned a unique PN code sequence. Hence, more than one signal can be transmitted at same time on same frequency.

2. TECHNICAL WORK PREPARATION

The following are the important stages of DS- CDMA system used for transmission and reception of audio signals:

2.1 Spread Spectrum

The main principle of Spread Spectrum communication is that the bandwidth occupancy is much higher than usual. Because of this much larger bandwidth the power spectral density is lower, in the channel the signal just looks like noise [10]. The Spreading is done by combining the data signal with a code (code division multiple access) which is independent of the transmitted data message [2]. The advantages of the method are:

- As the signal is spread over a large frequency-band, the Power Spectral Density is getting very small, so other communications systems do not suffer from this kind of communications. However the Gaussian Noise level is increasing.
- Random Access can be dealt with, as a large number of codes can be generated a large number of users can be permitted
- Security: without knowing the spreading code, it is (nearly) impossible to recover the transmitted data

There are a couple of Spread Spectrum Techniques which can be used. The most famous one is Direct Sequence (DS).

2.2 Direct Sequence Spread Spectrum

In a DS-SS system, each user is assigned a unique code sequence [3] 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 [4]. This multiple access method is CDMA, which is a form of a DSSS system. 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 ***Gp*** of the DS-SS system: ***Gp*** = ***Bt/Bi,*** where *Bt* is the transmission bandwidth and ***Bi*** 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. They are used to implement synchronization and uniquely code individual user signals across the transmission interface. PN generators are based on Linear Feedback Shift Registers (LFSR) [4].

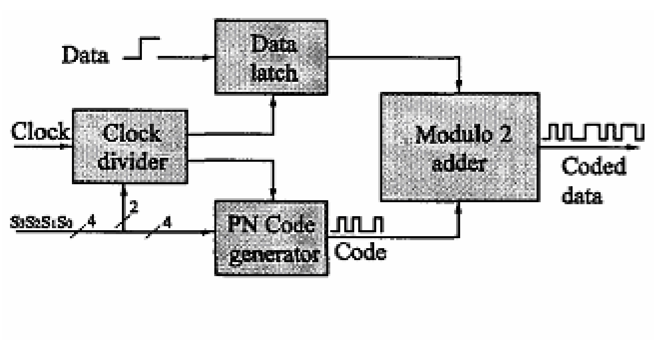

Fig.1. DS-CDMA Transmitter Block Diagram

A DS-SS receiver is based on a correlator, which utilizes correlation properties of the PN codes [4]. The correlators attempt to match the incoming received signal with each of the candidate prototype waveforms (PN sequences) known *a priori* to the receiver. Since we deal with the discrete signals in practice, the discrete form of the correlation of two discrete signals is given as

$$r_{xy}(k) = \sum_{n=0}^{N-1} x(n)y(k+n) \quad (1)$$

Equation (1) is the fundamental equation implemented in software and hardware. The hardware implication is that the implementation of a correlator is based on a multiplier accumulator circuit (MAC) [11]. At the receiver, the same PN sequence used in the transmitter is correlated with incoming signal. Block diagram of the receiver is shown

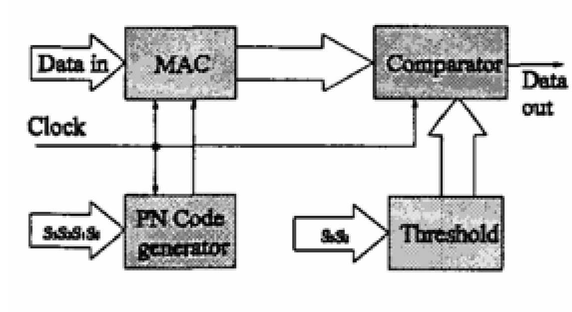

Fig. 3. DS-CDMA Receiver Block Diagram.

2.3 Analysis of DS-CDMA system

The following signals at several important points along a DS-CDMA system will help understand the technique of transmission and reception.

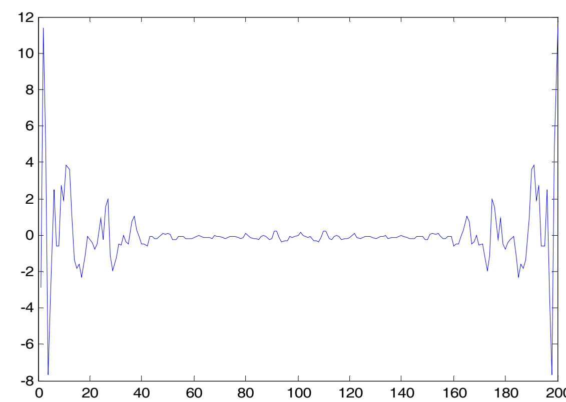

Fig.3. Audio Signal 1 User 1

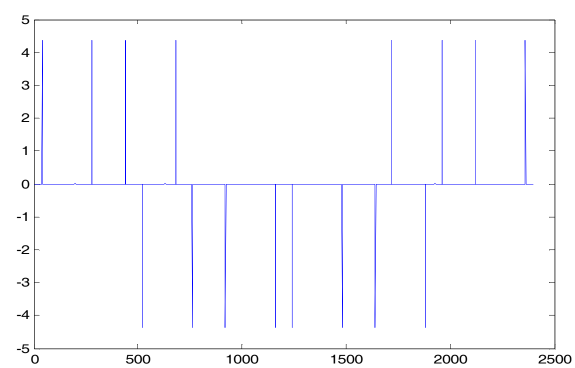

Fig.4. User 1 Spread Spectrum

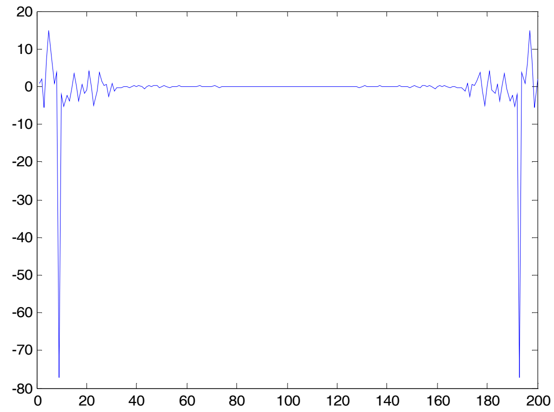

Fig.5. User 2 Audio Signal 2

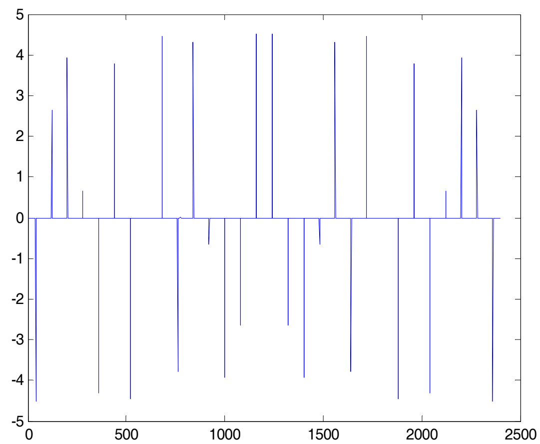

Fig.6. User 2 Spread Spectrum

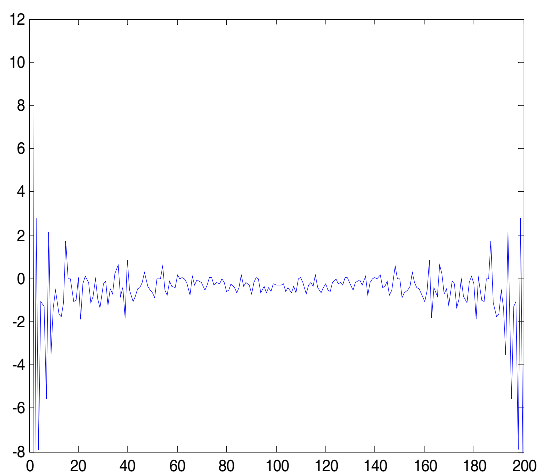

Fig.7. User 1 Received Signal

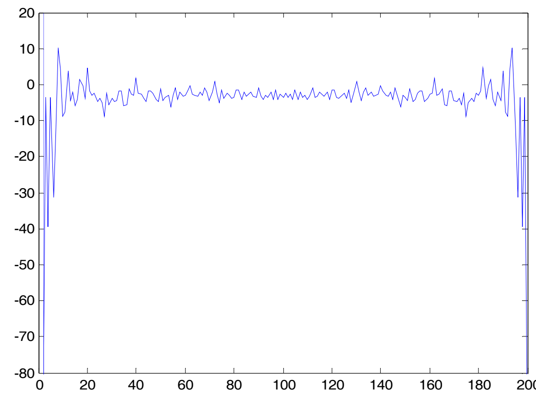

Fig.8. User 2 Received Signal

2.4 Limitations of a DS-CDMA system

The main problem with DS-CDMA systems is the Near-Far effect. If there are more then one users active, the transmitted power of non-reference users is suppressed by a factor dependent on the (partial) cross correlation between the code of the reference user and the code of a non-reference user [8]. However when a non-reference user is closer to the receiver then the reference-user, it is possible that the interference caused by this non-reference user (however suppressed) has more power the reference user. Now only the non-reference user will be received, this nasty property is called the near-far effect. One way to beat the near-far effect can be exploited in cellular systems. In such systems the base station takes care that all users have such a power that the received power at the base station is equal for all users. In non-cellular systems the influence of the near-far effect can be reduced by using the *frequency-hopping spread spectrum technique*. [9]

3. RESULT

The simulation of the entire CDMA system has been implemented using MATLAB, which provides for input of real time audio signals. The evaluation of signal values at different points along the system was performed using a program written in MATLAB. The sampling rate was selected to be 8000Hz for reasonably accurate analysis. The transmitted signal was seen to be successfully reproduced at the receiver, error being within permissible range. Coherent demodulation was used to demodulate the CDMA signal and the physical channel was simulated by adding additive white Gaussian noise (AWGN). It was found that the mean square error for a S/N ratio of -50 dB gave a BER of 0.167 and anything in excess of -5 dB for a two user system gave 100% accuracy.

4. Conclusion

We have implemented a DS-SS based two user communication system incorporating principles of CDMA system. The simulation involves use of a GUI environment, providing user convenient access to signals at different points along the system. The system functions as intended provided the signal to noise ratio is set sufficiently high. The described communication system provides a reliable data transmission in a noisy environment by spreading available data over a wide frequency range, in excess of minimum bandwidth. Hence, the power spectral density is considerably low.

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