The Simulation Study of Multi-User Spread-Spectrum Wireless Communication System

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Abstract. Spread-spectrum technology is a promising and effective technique for multiple accessing, combating multi-user interference and rejecting unwanted radio jamming. In this paper, we explore the effect of Direct Sequence spread-spectrum (DSSS) which base on π/4-DPSK modulation and demodulation technique, we provide a multi-user spread-spectrum wireless communication system and the system performance was studied from simulation and comparison. Four users information are transmitting over Rayleigh fading channel to model the 5G communication environments. The performances of the system are expressed through comparisons of the bit-error rate (BER) and signal to noise ratio (SNR) for both original signals at transmitter and recovered signals at receiver. From the contrast results, the anti-multi-user interference ability of the system is provided.

Keywords: Multi-user; Direct Sequence spread-spectrum (DSSS); Frequency-hopping spread-spectrum (FHSS); Time-hopping spread-spectrum (THSS); Wireless communication.

1. Introduction

In telecommunication and radio communication, spread-spectrum techniques has attract the attention of scientists, researchers and industrialists due to the fact that these techniques can increase bandwidth efficiency, improve anti-jamming capability, enhance security of transmission and enable multiple-access. So, it is the preferred communication high-tech for military applications and popular used in ZigBee, Bluetooth, UWB communication systems.

Spread-spectrum techniques are the methods, which use pseudo-random sequences to spread narrowband signal bandwidth to thousands of times in frequency domain. At the receiver, the same pseudo-random sequences were generated to retrieve the spread-spectrum signal to the original narrowband wave-forms before detection.

Popular methods of spread-spectrum are: Direct Sequence spread-spectrum (DSSS), Frequency-hopping spread-spectrum (FHSS) and Time-hopping spread-spectrum (THSS). In DSSS communication system, the information signals are multiplied with pseudo-random sequences to spread-spectrum over a much wider frequency band. The information of other users are using different pseudo-random sequences to spread-spectrum to get non-interfering nature. Because of lower transmitted power density and non-interfering nature, other signals can occupy the same band. FHSS technology is using using pseudo-random sequences to control signal carrier frequency to rapidly hop among thousands of frequencies in very short time. And at macroscopic, the transmit FHSS signals occupied a large spectral band. FHSS and DSSS are used in IEEE 802.11 wireless standard. THSS technique, which usually realize from linearly sweeps the carrier frequency in time. Sweeps sequence also control by pseudo-random sequences. In order to get much wider spread frequency band, the hybrid spread-spectrum technique, for example FHSS with DSSS are offence used [1].
In this paper, the DSSS wireless communication system is studied by simulation method. The paper is organized as follows. Section 2 describe the fundamentals of spread-spectrum techniques. The designed DSSS multi-user spread-spectrum wireless communication system is given in Section 3, and we give simulation results in Section 4. Section 5 concludes the paper.

2. Fundamentals of Spread-Spectrum Techniques

The Spread-Spectrum techniques initiated encryption schemes for military applications in 1949 by Shannon [1]. And then, as a new high-tech developed by Scholtz [2][3]. In 1983, it’s ability of multiple accessing communications at a larger capacity was reveal [4].

The spread-spectrum concept in based on the principle of Shannon theorem. The Shannon-Hartley equation [1] is as following:

\[ C = B \cdot \log_2(1 + SNR) \]

(1)

where C is channel capacity, B is channel bandwidth, and SNR is signal-to-noise ratio. Supposing the signal is transmitting over a Gaussian channel, from equation (1), we can see:

- The same C value can be gotten from the trade-off between SNR and B.
- Keeping SNR not changing, we can increase C from increasing B.

This means from exchanging bandwidth can get high anti-jamming capability.

3. The Design of DSSS Multi-user Spread-Spectrum Wireless Communication System

In this section, we set up a DSSS multi-user spread-spectrum wireless communication system. The system block graph is show in figure.1.

\[ C = B \cdot \log_2(1 + SNR) \]

Figure 1. Block Diagram of DSSS Multi-user Spread-Spectrum Wireless Communication System

The designed DSSS multi-user spread-spectrum wireless communication system consists of three main parts: a transmitter, Rayleigh fading channel and a receiver. The transmitter composed from Signal generator, Polarity converter, π/4-DPSK modulator, Interpolator, Spread-spectrum modulator and Filter. The channel is time- and frequency-selective fading channel, which obeys to Rayleigh distribution. The receiver composed from Spread-spectrum demodulator, Filter, Sampler, π/4-DPSK demodulator, and Polarity converter.

3.2. Programming Description

In this section, we discuss simulation process to clarify the working principle of our system.

At receiver, Signal generator generates single-polar binary bits and then convert input bits to bipolar bits for four users. Using Matlab software to plot base band information in bipolar none return zero format for user 1, user2, user3 and user4, separately. Four users signal then π/4-DPSK modulated. The sampling rate of sinusoidal carrier matches the sampling rate per bit. Here we take 200 samples per carrier and plot the π/4-DPSK signals for four users and plot the π/4-DPSK signals. Next, realtime curve interpolators are used, and then DSSS spread-spectrum modulators 20 times the signals at frequency domain and also modulated spread-spectrum signals are plotted. Four users’ spread signals go through base band filters, and the noise outside the filters are filtered. Then filtered signals transmits over wireless channels.
DSSS spread-spectrum processes are modulated from multiply the $\pi/4$-DPSK modulated signals with PN codes. The channel is flat Rayleigh fading channel with SNR 5 db to simulate the 5G wireless communication environments. In our simulation, four users signals are transmitted on fading channel at the same frequency band and time.

At receiver, received four users’ signals are multiples with PN codes, separately. Then $\pi/4$-DPSK demodulated by multiplying with the carrier signals. Then four users samples over 1 bit interval are summed to determine 0 or 1 of the recovered signals. At last, the received signals comparison with the original signals to estimate the system capability.

4. Simulation
In this section, we give the simulation graphs.

Figure 2. The Original Binary Sequences
Figure 3. $\pi/4$-DPSK Modulated Signals

Figure 4. Modulated spread-spectrum Signals
Figure 5. FFT of Modulated spread-spectrum Signals
5. Results and Comparison
In this section, the simulation results and comparison analysis are given. Figure 2 is four users original binary signals produced from signal generator. After convert to bipolar bits, signals modulate in $\pi/4$-DPSK modulator. Figure 3 shows the $\pi/4$-DPSK modulated signals. Then, the modulated signals go through interpolate and DSSS spread-spectrum process. Figure 4 is the spread-spectrum signals for 4 users. Figure 5 shows Fourier transformation of the modulated spread signals in frequency domain.
At the receiver, received signals recovered to original signals from despreding, filtering, sampling, $\pi/4$-DPSK demodulation and polarity conversion. Figure 6 shows the recovered sequences. Compare Figure 2 with Figure 6 we can see that the received signals have the same waveform with the original sequences, which means as long as SNR is over some reasonable threshold value, there are no bit errors. Figure 7 shows the comparison figure of BER vs. SNR for original signals and received signals.

6. Conclusion
Spread-spectrum technique is a wide-band technology, which was realized from exchanging bandwidth. It has many benefits, such as avoiding interception, resistance to fading, accurate low power position finding and providing improved multiple access schemes. In this paper, we set up a multi-user spread-spectrum wireless communication system which base on $\pi/4$-DPSK modulation and demodulation technique, and using simulation method to study the effective of the provided system. Firstly we described in detail the concept and principle of the spread-spectrum technique, and then, discussed and constructed a four users’ pseudo-noise spread-spectrum system. At receiver, four users’ signal are conducted from polarity conversion, $\pi/4$-DPSK modulation, interpolation, spread-spectrum modulation and filtered. Then four users’ signal transmitted over a Rayleigh time-variable fading channel to simulate 5G wireless communication environments. Four users transmit signals at the same time and the same frequency, and at the receiver recovered signals separately for each user. We simulate graphs of signal wave in time-domain and the spectrum graphics in spectrum-domain. The validity and accuracy of the model are confirmed by comparison figure of BER vs. SNR for original signals and received signals.

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