Research on a Communication Method Based on Spread Spectrum Technology

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Abstract. The arrival of the information age has made us rely on communication increasingly. However, in the current wireless communication, the signal is subjected to various interferences in the process of propagation due to the openness of the channel. In the conventional communication system, the bandwidth of the transmission signal is designed as a narrow band to achieve the purpose of suppressing interference, and the spread spectrum technology will spread the spectrum of the baseband signal to a wide frequency band for transmission to solve the problem in the wireless communication system. It is one of the best ways to solve multiple access, anti-interference and confidentiality in wireless communication systems.

1. Introduction
Transportation, energy and communication have become the three basic structures of modern society. Communication and interference are two aspects of interdependence, and all communications are accompanied by interference. In wireless communication, various interferences may be added in the process of information transmission due to the openness of the channel, such as atmospheric noise, multipath interference, industrial interference, co-channel interference of other communication equipment, and human interference. The interference environment for wireless communication is even worse. How to adopt anti-jamming technical measures to have a strong anti-interference performance in communication system? This is a problem that must be solved in modern communication systems, especially military communication systems.

2. Theoretical basis
The spread spectrum technology [1] mainly spreads the spectrum of the baseband signal to a wide frequency band (hundreds of thousands of times) for transmission, and the receiving end uses the principle of correlation reception to restore the extended spectrum to the spectrum of the baseband signal, thereby it can suppress the interference added during the transmission process. This method is different from the conventional anti-jamming communication. In the conventional processing mode, the transmitted signal bandwidth is designed to be narrowband as much as possible, so that the outband interference can be filtered out by the narrowband bandpass filter at the receiving end, finally the signal-to-noise ratio of received signal is improved and the interference is suppressed. The wider the bandwidth of the transmitted signal, the greater the interference energy added during the transmission process. The spread spectrum communication seems to be unreasonable. However, the Shannon Information Theory
proves that spread spectrum communication is an effective anti-interference communication method. It is one of the best ways to solve multiple access, anti-interference and confidentiality in wireless communication systems.

3. The basic principle of the spread spectrum system

3.1. Theoretical basis of spread spectrum

Spread Spectrum Communication [2] is an advanced information transmission method, in which the bandwidth occupied by the signal is much larger than the minimum bandwidth of the transmitted information, and the bandwidth of the frequency band is realized by the means of encoding and modulation, which belongs to broadband communication. It can establish high-quality wireless channels, and it has the advantages of high transmission quality, low cost, strong anti-interference ability, simple installation and easy to use.

The basic theory for spread spectrum communication is the Shannon formula in information theory, namely:

\[ C = B \log_2(1+S/N) \]  \hspace{1cm} (1)

In the formula, \( B \) is the signal bandwidth, \( S \) is the average power of the signal, and \( N \) is the noise power.

Performing a bottom transformation on equation (1), there is

\[ \frac{C}{B} = 1.44 \ln(1+S/N) \]  \hspace{1cm} (2)

Normally, \( S/N \ll 1 \), power-level expansion of equation (2), and omission of high-order terms, then

\[ \frac{C}{B} \approx 1.44 \frac{S}{N} \]  \hspace{1cm} (3)

If the power spectral density of white noise is \( n_0 \) and the noise power is \( N = n_0B \), the channel capacity can be expressed as

\[ C = B \log_2(1+S/n_0B) \]  \hspace{1cm} (4)

Shannon’s second theorem also states that if the information rate \( R \) of the source is smaller than the channel capacity \( C \), it can be transmitted through the channel with an arbitrarily small error probability by appropriate coding.

It can be seen from equations (1) and (3) that for any given signal-to-noise ratio, as long as the transmission bandwidth is increased and the channel capacity is kept unchanged, the transmission can be performed with an arbitrarily small error probability. Combining equations (1) to (3) leads to the following conclusions:

1. There are two ways to increase the channel capacity. One is to increase the bandwidth of the transmitted signal; the other is to increase the signal-to-noise ratio \( S/N \). Since \( C \) has a linear relationship with \( B \), and \( C \) has a logarithmic relationship with \( S/N \), it is more effective to increase \( B \) rather than \( S/N \).

2. When the channel capacity \( C \) is a constant, the bandwidth \( B \) and the signal-to-noise ratio \( S/N \) can be interchanged, that is, the signal-to-noise ratio \( S/N \) can be reduced by adding \( B \); or the signal bandwidth can be reduced by increasing the signal power \( S \).

3. It is obvious that the channel capacity cannot be increased indefinitely. It can be known from equation (1) that the channel capacity is proportional to the bandwidth of the signal, and the signal bandwidth is increased to increase the channel capacity. However, when \( B \) is increased to a certain extent, the increase of \( C \) is slow. It can be known from the equation (3) that the noise power is \( N = n_0B \),
the increase of $B$ tends to cause a decrease in the signal-to-noise ratio. We consider the situation when $B \to \infty$,

$$\lim C = \lim B \log_2(1+S/n0B) = \lim \left[ n0B/S \log_2(1+S/n0B) \right] (S/n0) = 1.44S/n0$$ (5)

It can be seen that when the signal power $S$ and the noise power spectral density are constant, the channel capacity is also a finite value.

When the bandwidth tends to infinity, the limit information rate, that is, the channel capacity is $R_{\text{max}} = C = 1.44S/n0$, and $Eb$ is the symbol energy, then $S = REb$, then when $B \to \infty$, there is

$$Eb/n0 = S/n0 R_{\text{max}} = 1/1.44$$ (6)

The resulting signal to noise ratio of the channel is

$$Eb/n0 = 1/1.44 = -1.6(\text{dB})$$ (7)

### 3.2. Main parameters of the spread spectrum system

The parameters of the spread spectrum system mainly include: band efficiency, processing gain, interference tolerance, frequency hopping rate etc. We mainly introduce processing gain and interference capacity.

The processing gain of the spread spectrum system is defined as the ratio of the signal-to-noise ratio at the output of the despread device to the signal-to-noise ratio at the input of the despread device [3-4], ie

$$Gp = (S/N)_{\text{out}}/(S/N)_{\text{in}}$$ (8)

The physical meaning of processing gain is the degree to which the surface-spreading system improves the signal-to-noise ratio, that is, the degree of suppression of interference. It can also be expressed as the ratio of the signal bandwidth after spectrum spreading to the signal bandwidth before spectrum spreading, ie

$$Gp = Bc/Bd = Rc/Rd = Td/Tc$$ (9)

From formula, $Bc$ is the pseudocode bandwidth, $Bd$ is the baseband information bandwidth, $Tc$ is the pseudocode symbol width, $Rc$ is the pseudocode rate, $Td$ is the baseband symbol width, and $Rd$ is the rate of the baseband symbol.

Usually the processing gain is expressed in dB.

For frequency hopping systems. Assuming that the frequency hopping range is $BR$, the entire frequency hopping frequency band is divided into $N$ channels, that is, the number of frequency hopping frequency bands is $N$. The frequency interval is $\Delta F$, and the information bandwidth is $Bd < \Delta F$, then the frequency hopping system processing gain is the frequency hopping bandwidth ratio of the upper baseband information bandwidth, ie

$$Gp = BR/Bd < N$$ (10)

It can be seen that the processing gain of the frequency hopping system is proportional to the number $N$ of available frequencies of the frequency hopping system. The larger the $N$, the wider the RF bandwidth and the stronger the anti-interference ability.
4. Establishment of system simulation model

4.1. Introduction of Simulink

Simulink is one of the most important components of MATLAB [8], providing an integrated environment for dynamic system modeling, simulation and comprehensive analysis. In this environment, a complex system can be constructed without a large number of writing programs, but with a simple and intuitive mouse operation. Simulink has the advantages of wide adaptability, clear structure and process, fine simulation, close to reality, high efficiency and flexibility. Based on the above advantages, Simulink has been widely used in complex simulation and design of control theory and digital signal processing. There are also a large number of third-party software and hardware available for or required to be applied to Simulink.

Simulink is a visual simulation tool in MATLAB [5-6]. It is a block diagram design environment based on MATLAB. It is a software package for dynamic system modeling, simulation and analysis. It is widely used in linear systems, nonlinear systems, digital control as well as the modeling and simulation of digital signal processing. Simulink can be modeled with continuous sampling time, discrete sampling time, or two mixed sampling times. It also supports multi-rate systems, where different parts of the system have different sampling rates. To create a dynamic system model, Simulink provides a graphical user interface (GUI) for building model block diagrams. This creation process can be done with just one click and drag mouse action, providing a faster, straightforward way. And the user can immediately see the simulation results of the system.

Simulink is a multi-domain simulation and model-based design tool for dynamic systems and embedded systems. For a variety of time-varying systems, including communications, control, signal processing, video processing and image processing systems, Simulink provides an interactive graphical environment and customizable library of modules to design, simulate, execute and test. Other products built on top of Simulink extend Simulink’s multi-domain modeling capabilities and provide tools for designing, executing, validating, and validating tasks. Simulink is tightly integrated with MATLAB® and provides direct access to MATLAB’s extensive tools for algorithm development, simulation analysis and visualization, batch script creation, modeling environment customization, and definition of signal parameters and test data.

4.2. Simulation results

We know that the spread spectrum technology spreads the spectrum of the baseband signal over a wide frequency band for transmission, in order to view the spectrum of the transmitted signal before and after frequency hopping in this simulation. I used the Spectrum Scope module in Simulink. The spectrum of the transmitted signal before and after frequency hopping is shown in Figure 1 and Figure 2.

![Figure 1. Signal spectrum before frequency hopping](image-url)
Figure 2. Signal spectrum after frequency hopping

It can be seen that the waveform of the frequency hopping signal is discontinuous, and the channel bandwidth occupied by the instantaneous time of each hopping signal is a narrowband spectrum, then the narrowband spectrum hops in a wide frequency band (In this simulation, the number of frequency hopping points is 64), in the end it forms a frequency hopping bandwidth. Due to the fast frequency hopping rate, the spectrum is expanded macroscopically. Due to the lower rate of the set hopping, the spectrum of the spectrum is lower. The most important part of frequency hopping communication is the number of hopping frequencies. In this simulation process, the effect of different hopping frequencies on the frequency hopping system is not studied, instead of the fixed value 64. According to theoretical knowledge, the more hopping frequencies, the stronger the anti-interference ability of the frequency hopping system. Therefore, it is an effective means to improve the anti-broadband noise interference of frequency hopping communication by extending the frequency hopping band.

5. Conclusion
This paper expounds the superiority and importance of spread spectrum communication technology, and introduces the theoretical basis of frequency hopping spread spectrum communication based on the theoretical basis of spread spectrum technology. Finally, the simulation model of frequency hopping spread spectrum communication system is established by using MATLAB's visualization tool Simulink. By setting the parameters of the simulation model, it is proved that the extended frequency hopping frequency band is an effective means to improve the anti-broadband noise interference of frequency hopping communication.

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