STUDY SPREAD SPECTRUM IN MATLAB

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Abstract

In this paper, various techniques involved like DS, FH, PN sequences in Spread Spectrum Communication system are discussed using MATLAB.

1. Introduction

The first intentional use of Spread Spectrum backs to 1920-1930 by Armstrong with wideband FM. The real impetus for Spread Spectrum came with World War II. However, the first public patent for Spread Spectrum was from Hedy Lamarr, the Hollywood movie actress, and George Antheil, an avant-garde composer. The patent was granted in 1942.

At the beginning, Spread spectrum signals for digital communications were developed and used for military communications either to provide resistance to hostile jamming; to hide the signal by transmitting it at low power; or to make it possible for multiple users to communicate through the same channel.

Spread Spectrum was first used for commercial purpose in the 1980s. Today, it is being used to provide reliable communications in a variety of commercial applications, including mobile communications and interoffice wireless communications.

2. DS Spread Spectrum

It is also known as direct sequence code division multiple access (DS-CDMA), is one of two approaches to spread spectrum modulation for digital signal transmission over the airwaves. In direct sequence spread spectrum, the stream of information to be transmitted is divided into small pieces, each of which is allocated across to a frequency channel across the spectrum. A data signal at the point of transmission is combined with a higher data-rate bit sequence (also known as a chipping code) that divides the data according to a spreading ratio. The redundant chipping code helps the signal resist interference and also enables the original data to be recovered if data bits are damaged during transmission.

A m-file program simulation is done to demonstrate the effect of a DS spread spectrum signal in suppressing sinusoidal interference.

$$Pb = Q^*\left(\sqrt{(2\text{£}/(N+J))}\right) \qquad (1)$$

Pb is the error probability, N stands for the noise, J=P/W, is the power-spectral density.

The simulation result is shown below:

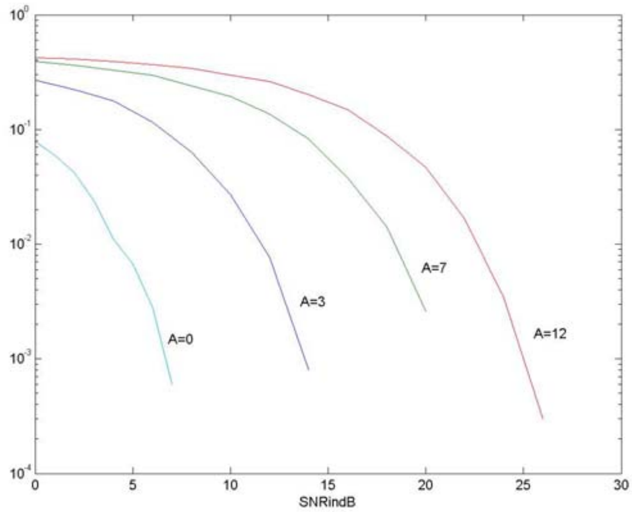

Figure 1: DS with different interferences

X axis refers to Signal to Noise ratio, **Y** axis measures the error rate with certain interference. **A**s stand for the amplitudes of the sinusoidal interferences.

From the graph, we can see that with a certain signal to noise ratio, the increase of the interference will lead to a larger error rate. For a certain interference level, the larger SNR, the smaller error rate.

3. Frequency Hopping

FH is one of the two basic modulation techniques used in spread spectrum signal transmission. In an FH-CDMA system, a transmitter 'hops' between available frequencies according to a specified algorithm, which can be either random or pre-planned. Frequency hopping requires a much wider bandwidth than is needed to transmit the same information using only one carrier frequency.

Here is a program simulation of the performance of an FH communication system that employs binary FSK and is corrupted by worst-case partial-band interference.

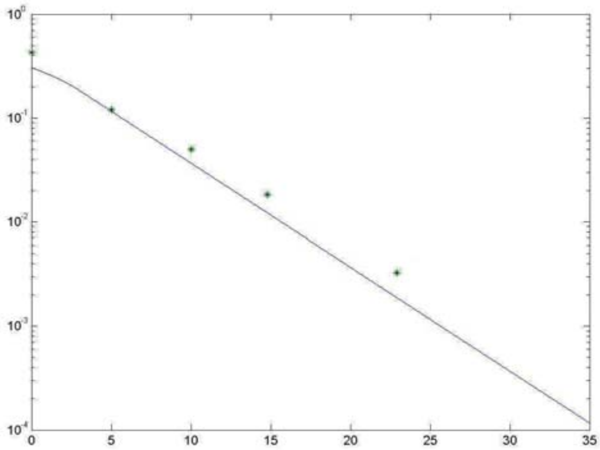

Figure 2: Error rate performance

X axis stands for Signal-to-Noise Ratio in dB, **Y** axis refers to the error rate.

The theoretical value is the continuous line, and the error rate that results from the Monte Carlo simulation is the stars.

A uniform random number generator (RNG) is used to generate a binary information sequence, which is the input. The output is corrupted by AWGN. Another RNG is used to determine when the AWGN corrupts the signal and when it does not.

$$R1 = (\sqrt{\mathcal{E}b} * \cos\Phi + n_c)^2 + (\sqrt{\mathcal{E}b} * \sin\Phi + n_s)^2 \quad (2)$$

$$R2 = n_{2c}^2 + n_{2s}^2 \quad (3)$$

Where Φ is the channel phase shift and n2c, n2s, nc, ns represent the additive noise components.

From figure 2, it shows the simulated result is very similar to the theoretical result.

4. M-Sequence & Gold-Sequence

A Pseudo-random Noise Sequence is a sequence of binary numbers, e.g. ±1, which appears to be random, but is in fact perfectly deterministic.

The most widely known binary PN sequences are the maximum-length shift-register sequences, or m-sequence for short.

Autocorrelation $R_c(m) = \sum C_n C_{n+m}$, $0 \leq m \leq L-1$

L is the period of the sequence, {C} is the bipolar sequence.

In case of m-sequence,

$$R_c(m) = L, \ m=0$$
$$\text{or } -1, \ 1 \leq m \leq L-1 \quad (4)$$

Gold sequences are constructed by taking a pair of specially selected m-sequences, called preferred m-sequences, and forming the modulo-2 sum of the two sequences for each of L cyclically shifted versions of one sequence relative to the other one.

$$R_{max} = \sqrt{(2*L)} \ \text{m is odd,}$$
$$R_{max} = \sqrt{L} \quad \text{m is even.} \quad (5)$$

Both m-sequence and Gold-sequence are generated. And used for the FH/DPSK m-file program. The simulation results are shown
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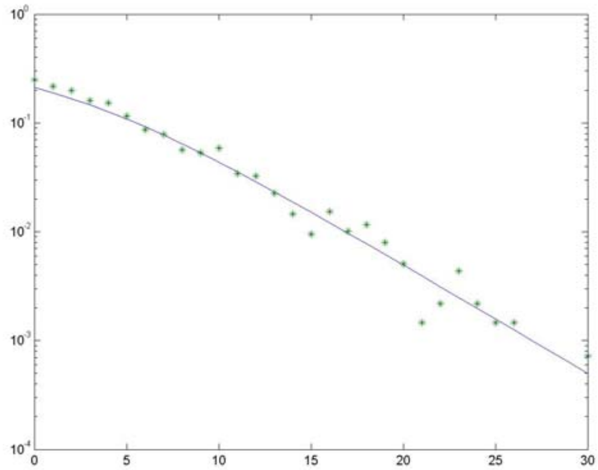

Figure 3: Rayleigh Channel with m-sequence

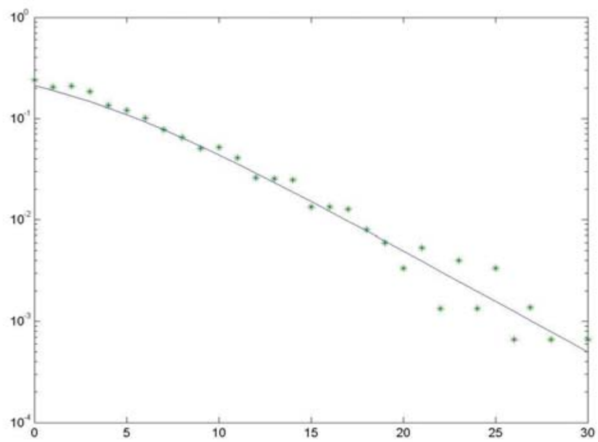

Figure 4: Rayleigh Channel with Gold-sequence

It is shown that there is no difference with the results between Gold sequence and m-sequence. This is because of the generated signal has no interference disturbance.

The improvement of Gold sequence compare to m-sequence is the control of Rmax, which stands for cross-correlation. It is known that the number of m-sequences of the length L increase rapidly with m. Rmax is a large percentage of the peak value of the autocorrelation function. Consequently, m-sequences are not suitable for CDMA communication systems. However, Gold sequences are able to control Rmax within a small area. Therefore, Gold sequences are more preferred for CDMA.

Nevertheless, the further programming of multiple user has not been done yet during this project. The simulation result cannot be viewed here.

5. AWGN & Rayleigh Fading

During a time interval of length less than the coherence time the channel can be well approximated by an AWGN channel.

Wireless communication channel, however, exhibit time-varying channel-signal-to-noise ratio, usually caused by multi-path reflections, shadowing and the relative movement between transmitter and receiver. Therefore, flat-fading channel will be the choice. One of the easiest is Rayleigh Fading.

A program simulates the FH/DPSK with AWGN & Rayleigh is done to show the difference between AWGN and Rayleigh.

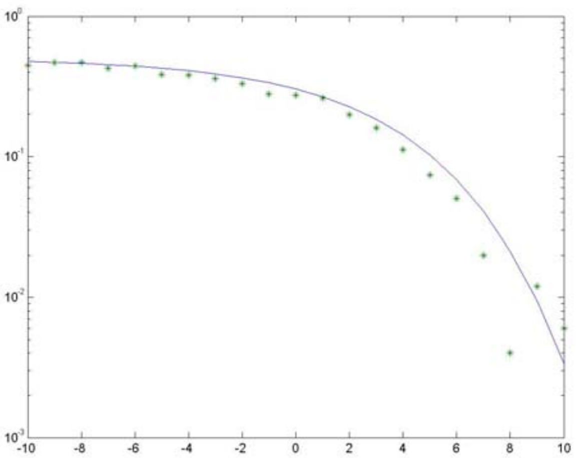

Figure 5: With only AWGN

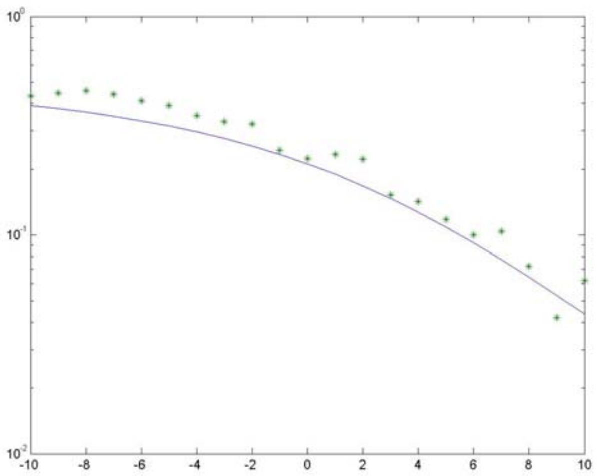

Figure 6: With Rayleigh Fading

X axis is Signal-to-Noise Ratio; **Y** axis refers to the Error Rate.

It is obviously that with the same signal to noise ratio, Rayleigh Fading channel leads to a poor error rate. This is due to the interference, shadowing, and so on. Rayleigh Fading presents wireless communication situation more accurately.

6. DS vs. FH

Direct-sequence spectrum spreading combines the information signal with a spreading signal having much wider bandwidth. The net modulation signal effectively handles the wide bandwidth of the spreading signal. This wide modulation is then applied to a fixed frequency carrier signal for transmission. The spreading code directly spreads the information, ahead and independent of the RF modulator.

Frequency hopping takes the opposite approach. Rather than spreading the modulation about a fixed carrier, the information is left unchanged and directly modulates a carrier of varying frequency.

DS: For a shorter (length 15) spreading code that might be used for high-speed data applications, the jamming margin is smaller and throughput begins to fail at lower interference power levels.

FH: The frequency hopping receiver has bandwidth matched to the data modulation, and follows the transmitter as it jumps around the band. If one of those jumps encounters a narrowband interferer, then the communications on that channel can be jammed if all three interference conditions described earlier are met. On the next jump, the narrowband interferer will be moved away from (avoided). This allows the receiver's selectivity filters to reject the narrowband interferer, essentially independent of its power.

From figure 1 and figure 2, it shows that DS has better error rate when both of them under the same signal to noise ratio.

Base on figure 1 & 2, and the theory of DS & FH, some comparison results are made as below:

1. FH is more secure than DS.
2. DS has fine resolution, rapid switching and rapid settling a practical reality at reasonable cost.
3. Interference rejection:

   a). DS systems accept levels of interference a little bit higher that those accepted by FS systems;

   b). However if the interference is higher than the limit the DS stop to work but the FS try to use unaffected frq. and continue to work.

   c). For signals lower than the jamming margin, the DSSS system throughput is unity, which means that every packet sent can be accurately received.

   d). DS systems are affected by high levels of interference created by other DS systems using the same band but different codes.

4. Throughput

a) DS systems transmit continuously (PSK). FS spend some time to re-synchronize and for hopping (FSK);

b) DS systems may have a better throughput for same data rate over the air.

5. If the interferer is within the spreading band, then the DSSS system can tolerate and completely reject it while the FHSS system can be completely jammed on that channel. For a large out-of-band interferer, the opposite is true. The DSSS process is sensitive to such interferers, where the FHSS system is not.

6. FH has to be placed far away before there interference with the other group is minimized. DS, on the other hand can be placed much closer to other DS on the same channel due to the interference resistant nature of the DS waveform.

7. Power density: DS achieve very low power spectral density, therefore minimizes interference. FH has higher power spectral density which is not as good as DS since more transmit power is needed.

8. Hardware requirement: FH can be handled with a simple analog limiter receiver while DS requires complex base band processing. DS requires higher logic speeds and more complex processing.

Conclusion: The proper choice of direct sequence or frequency hopping as a spread spectrum technique depends on the actual environment in which the system will be deployed. If there are narrowband interferers of moderate level, then a DSSS system that will completely reject them may be designable. Should there be any large interfering signals, then a DSSS link may completely fail while FHSS is likely to continue operating, even though the interference is not completely rejected.

7. Conclusion

Digital Communication is very important today. Spread Spectrum becomes more and more popular. DS and FH are the two major method of SS. They have different strongpoint and are equally important. M-sequence and Gold-sequence have almost the same performance with single information transmission. However, the multi-user situation has to be considered in the further work. AWGN is usually used as the noise channel during simulation. But for wireless communication, Rayleigh Fading Flat Channel should be used instead to represent the communication channel.

More discussion between DS and FH is expected as further research. Better binary sequences are also necessary to block multi-user communication interference.

8. References

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