

Research on Interference of Conventional Communication Signals

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Abstract. This paper, presents the effect of jamming strategies on communication signal by using BPSK and MSK. Jammer can use different strategies and each one of them has advantages and disadvantages. Whoever these two modulations are considered as the most robust digital modulation technique. They have been widely used, therefore it is very important to choose the best jamming strategy for this modulation. In this purpose, it is tested under different kind of jamming namely: single-tone, multi-tone, broad band noise (BBN) and partial band noise (PBN) interference channel for its bit error rate performance. Performance of jamming strategies in this system is analysed and simulated by using MATLAB program.

Keywords: Communication signals · Jamming effect · Spot jamming
Full band jamming

1 Introduction

The notion says that the electronic warfare (EW) can play big role in military field back many years ago. Recently, awareness of using EW in communication field increases dramatically. Nowadays, we are living in time where everything is directly related to technology. Communication involves our daily life in different ways that, it is very easy to overlook the multitude of its facets. In the past methods that used to transmit and receive information between a source and a user destination took long time. The methods used were analog and digital. As a result of this delay and by time that analog way is switched rapidly by using digital communication. In purpose of achieving transmission of this information, signal is modified into a suitable form before transmitting it over the channel by a process which known under a name of modulation [1, 2].

In this paper, BPSK modulation is used, which is a digital technique. It has a basic concept on phase shift keying. In addition, the transmitted signal of BPSK is a sinusoid of fixed amplitude. It has one fixed phase when the data is at one level and when the data is at the other level the phase is different by 180° . Due to widely use of BPSK, it is significant and necessary to find the effective jamming for the BPSK signal [3].

Minimum shift keying (MSK) is a special type of continuous phase-frequency shift keying with $h=0.5$ that is used in a number of applications, sometimes called fast frequency shift keying (FFSK). The name minimum refers to the minimum modulation index that allows two FSK signals to be coherently orthogonal, the fast refers to the same given frequency band.

Interference is the sum of all signal contributions that are neither noise nor the wanted signal. The interference in communication systems has its effects that can be decisive. It may cause degradation of signal quality and so on. The concept of avoiding interference and increasing range resolution was a familiar concept at the end of the Second World War. Now many anti jamming technologies are in a wide range of applications. In other hand, there is little tendencies on the analysis of BPSK signal jamming pattern. Therefore, this problem is discussed and optimal jamming is analyzed [4].

2 The Principle of BPSK and MSK Signal

A continuous message signal is transformed into a corresponding sequence of binary symbols by passing three steps: sampling, quantizing and encoding. These binary symbols can be used to modulate a carrier signal. The modulator modifies the carrier by changing its frequency, amplitude and phase. In BPSK, binary symbol 1 and 0 modulation the phase of the carrier. BPSK is a type of digital modulation technique in which we are sending one bit per symbol 0 or a 1 [6].

For example, we can have the following transmitted band-pass symbols:

$$S_1 = \sqrt{\frac{2E}{T}} \cos(2\pi ft) \rightarrow \text{represent '1'} \quad (1)$$

$$S_2 = \sqrt{\frac{2E}{T}} \cos(2\pi ft + \pi) \rightarrow \text{represent '0'} \quad (2)$$

Among them, E is the symbol energy; T represents the symbol time period; f represents the frequency of the carrier; By using orthogonalization, we get signal orthonormal basis function, given as:

$$\psi_1 = \sqrt{\frac{2}{T}} \cos(2\pi ft) \quad (3)$$

Hence, the resulting constellation diagram can be given as follows.

We can notice that there are just two in-phase components, and the two waveform of S_1 and S_2 are inverted with respect to one another. Hence, we can use following scheme to design a BPSK modulator:

First of all, digital bits are converted into impulse to add notion of time to them by using NRZ encoder. After that, up-sampling these impulses generate NRZ waveform. Afterwards, the result of NRZ encoder multiple with the carrier (orthonormal basic function) then is carried out to generate the modulated BPSK waveform [7].

Comparing between MSK and BPSK, we find that the MSK signal decreases more rapidly than in BPSK spectral components out of band and BPSK data transmission rate is lower than the MSK data transmission rate [8].

$$S_{MSK} = A_S \cos(2\pi f_c + \frac{\pi a_k t}{2T_b} + \theta_k) \quad (4)$$

f_c represents the carrier frequency, T_b represents the bit width binary baseband signal, θ_k represents the Carrier phase constant symbols.

The minimum frequency difference should be $\Delta f = f_2 - f_1 = 1/2T_b$ to achieve orthogonality condition 2FSK signal (f_1 and f_2 are the carrier frequency for 2FSK signal). The MSK signal can be denoting as $S_{MSK} = \cos[\phi_k(t)]$. Convert it as follows:

$$\frac{d\phi_k(t)}{dt} = \omega_c \pm \frac{\pi}{2T_b} \quad (5)$$

According to this equation the integer times of MSK signal in each symbol period should contain 1/4 carrier cycles. MSK, in particular, has a significant advantage which is known as a continuous phase. No phase discontinuities are a result of changing the frequency of the signal by modulating data signal. This arises as a consequence of the unique factor of MSK that the frequency difference between the logical one and logical zero states is always equal to half the data rate. Whats more, MSK signal has a constant envelope characteristic. MSK modulations wide frequency band and high effectiveness of channel can increase in the frequency hopping spread spectrum communication.

3 Jamming Strategies

Jamming makes use of intentional radio interferences to interrupt wireless communications by adding unwanted signal. Jamming mostly targets attacks at the physical layer but sometimes cross-layer attacks are possible too. In this section, we are going to talk about various types of jamming techniques—each has its own advantages and disadvantages. So this paper makes a detailed analysis of these jamming patterns and considers the broad band jamming, the partial band jamming and the tone jamming. The analysis of the jamming effect needs to rely on JSR. Usually, the jamming-to-signal ratio (JSR) of the receiver determines the impact of the jamming. The main purpose of jamming is to improve the receiver side of the JSR, and then improve the receiver's bit error rate. In the field of military, the jamming effect achieves the requirements when the error rate is bigger than 0.2.

In addition to the above jamming patterns, there are other jamming patterns, such as pulse type jamming, sweep frequency jamming and the smart jamming. These patterns need high technology to achieve and many other factors to consider. For example, the smart jamming technology just interferes a part of the communication to interfere the signal, it can send the false messages to damage communication. So this paper makes a detailed analysis of these jamming patterns and considers the broad band jamming, the partial band jamming and the tone jamming.

3.1 The Broad Band Noise Jamming

Broad band noise jamming is the whole frequency band which is applied to the target station. It is also called full band jamming and it is sometimes called barrage jamming. This kind of jamming is effective against all kinds of anti-jamming communication. This type of jamming increases the background noise level at the receiver, creates a higher noise environment, attacks the Channel capacity of the communication system directly. if we improve the noise emission power that we can get better jamming effect. On other hand, the efficiency of this mode of jamming is very low, and the cost is very high. The jamming is placed between friendly and enemy communication. If this method is used correctly, we can prevent interception of our communication for a period of time.

Since broad band noise jamming generates signals that are similar to broad-band noise, the level of jamming power and is measured in watts/hertz just as background noise is specified. Full band jamming is the best a jammer can do in the absence of any knowledge of the target signal. But, it has also weakness. In the jamming, all the communication in the bandwidth cannot work correctly. Furthermore, it is indispensable to use a large power to interfere communication in a wide frequency band, and it is also bounded by its application to a certain extent.

3.2 The Partial Band Noise Jamming

When the signal is jammed on a single carrier, this gain may be shown by the interference that can be achieved by jamming with the part of the signal rather than by jamming the entire signal in the frequency domain. This is known as partial-band jamming. This strategy is considered more effective than BBN because the jammer uses less bandwidth and more power for the given bandwidth. In this case of jamming, we can set up K as a disturbance coefficient, which indicates that the frequency band of the jamming signal and the frequency band of the whole communication signal are proportional. Hence, the bit error rate can be presented in the following equation:

$$P_e = KP_{e1} + (1 - K)P_{e2} \quad (6)$$

P_{e1} means the bit error rate of the band which has the partial band noise and P_{e2} means the bit error rate of the band which only has the Gauss White Noise. This kind of jamming is very similar to the broad band noise jamming, so we don't discuss it in the paper.

3.3 The Tone Jamming

Tone jamming is one of the main kinds of spot jamming. In this mode of jamming, one or more jammer tones are strategically placed in the spectrum. Where they are placed and their number affects the jamming performance. Depending on the tones transmitted the technique is called single-tone or multi-tone jamming (MTJ).

Single-tone jamming consists of transmitting an unmodulated carrier with an average power J within the spreading bandwidth. In general tone jamming against direct sequence spread spectrum system is very effective because it can offset the receiver end processing gain, which will cause jamming to the spreading process.

The jammer can emit more than one tone, which can be randomly distributed, or at a particular frequency. When these tones are located on adjacent channels, they are called comb like interference. No matter which tone interference is adopted, as long as it can filter through the receiver, it can produce effective interference to the communication signal [5,9].

4 Jamming in BPSK System

The baseband carrier frequency of BPSK in the paper is 1×10^4 Hz, the sampling frequency is 5×10^4 , the rate of bits is 1×10^4 . The frequency after digital up conversion is 15 MHz with the White Gaussian Noise of 5 dB. In the discussion of the interference of BPSK system, we first interfere the system with the Broad Band Jamming. Figure 1 shows the jamming effect.

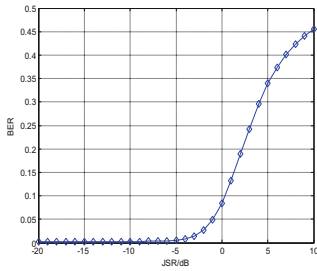


Fig. 1. Broad band noise jamming in BPSK system.

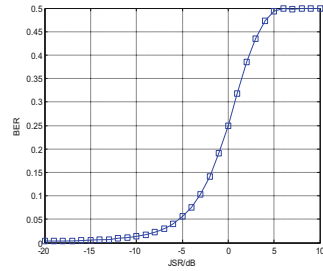


Fig. 2. Single-tone jamming in BPSK system.

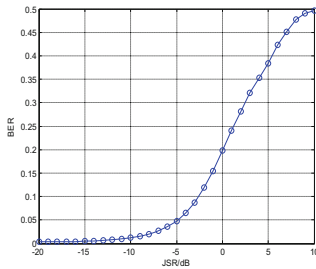


Fig. 3. Multi-tone jamming in BPSK system.

Then, we add a single-tone jamming signal with the same frequency as the BPSK signal, The curve of the error rate changes as the Fig. 2 shows. From Fig. 4 we can get that the jamming effect of single-tone is very good and when the JSR is 0 dB, the BER of communication system can be 0.25.

In the case of multi-tone, the number of tones used is 2 with same power size, and the distance from the center frequency of the communication signal is also the same. The jamming effects are shown in Fig. 3. As a result, we can say that the jamming effect is almost the same with the single tone jamming but the single tone is a little better than multi tone from -5 dB to 5 dB clearly. The transmission of multi tone jamming needs to have higher requirements for the system. Hence we can assume that the selection of single tone jamming efficiency is higher.

5 Jamming in MSK System

The simulation is made under the conditions below. The baseband carrier frequencies of the MSK systems are 9×10^4 Hz and 10.2×10^4 Hz. The rate of bits is 2.4×10^4 . The sampling frequency is 1.92×10^5 Hz. The frequency after digital up conversion is 15 MHz with the White Gaussian Noise of 5 dB.

In the discussion of the interference of MSK system, we first interfere the system with the Broad Band Jamming. The Fig. 4 below shows the jamming effect.

Then we will discuss how the different power affects the jamming effect. We first examine the case of single-tone jamming in this section, with fixed frequency attacks the midfrequency. The BER increases as JSR increases. The selected range for SNR was from -20 dB to 10 dB. We notice that BER reaches the highest value which is 0.4836 (Fig. 5).

In this section we examine the case of multi-tone jamming. The number of tones used is 2 with same power size, and the distance from the center frequency of the communication signal is also the same. Due to two picks of MSK frequency we have 3 cases depending on the position of jamming comparing to frequency of MSK.

This Fig. 6 represents change of BER by using multi-tone jamming, with fixed frequencies which is the same as the the frequencies of MSK system. The BER increases as JSR increases. The selected range for SNR was from -20 dB to 10 dB. We see that BER reaches the highest value which is 0.4945.

In the second case when the frequencies of double-tone (low frequency and high frequency) which is off carrier frequency 4×10^3 Hz. We can notice that BER increases when JSR increases and the highest value of BER is 0.4635. This curves in Fig. 7 is lower than the first curve.

The third case this figure represents change of BER by using multi tone jamming, with fixed frequencies which is off the carrier frequency 4×10^3 Hz in the opposite direction above. The BER increases as JSR increases. The selected range for SNR was from -20 dB to 10 dB. We note that BER reaches the highest value which is 0.4703 in Fig. 8.

According to those three figures we notice that the first curve is much higher than the other two curves. According to BER value We can see that the first case is better than the other two when the position of two frequencies of double-tone are between frequencies of MSK modulation. From my point of view multi-tone is the best jamming strategies for MSK modulation when the frequency of jamming signal and MSK signal is the same.

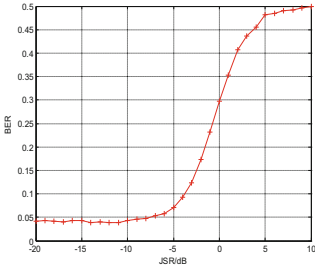


Fig. 4. Broad band noise jamming in MSK system.

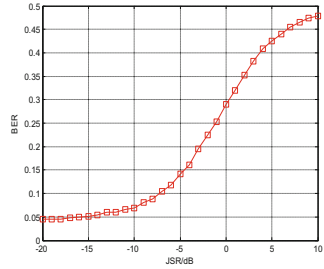


Fig. 5. Single-tone jamming in MSK system.

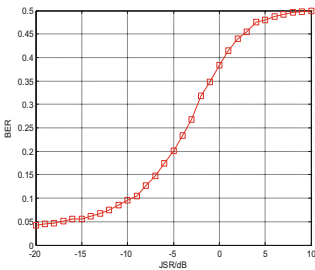


Fig. 6. Multi-tone jamming with spot frequency.

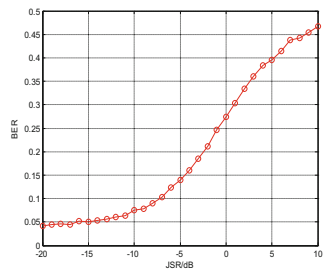


Fig. 7. Multi-tone jamming with the first group of frequency.

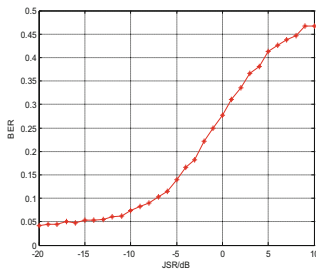


Fig. 8. Multi-tone jamming with the second group of frequency.

6 Conclusion

According to the results of jamming patterns of the ratio of the JSR and the error rate curve diagram above we can assume that the single tone jamming is the most jamming efficiency in BPSK system, and the multi-tone is the most efficiency in MSK system when the frequency of jamming signal and MSK signal is the same, compared with the two methods above the broad band noise jamming is the worst efficient way. In summary, the spot jamming is more efficiency than the full band jamming and if we can get priori information about the communication, we can interfere the system better.

Acknowledgment. This work is supported by the Key Development Program of Basic Research of China (JCKY2013604B001), the National Natural Science Foundation of China (61301095), the Fundamental Research Funds for the Central Universities (GK2080260148 and HEUCF1508).

This paper is funded by the International Exchange Program of Harbin Engineering University for Innovation-oriented Talents Cultivation.

Meantime, all the authors declare that there is no conflict of interests regarding the publication of this article.

We gratefully thank of very useful discussions of reviewers.

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