Analysis of the Coding Performance and Performance of Anti-jamming of JTIDS

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***Abstract*—JTIDS (Joint Tactical Information Distribution System) is a kind of anti jamming information distribution system. In order to analyze the performance of each part of JTIDS, this paper firstly analyzes the technical principles of each part, and then calculates the ber, building simulation platform based on Simulink, respectively through channel coding, CCSK soft spread spectrum, and frequency hopping system when signal is transmitted in JTIDS and gets the corresponding ber comparison figure. As the coding gain is mainly provided by RS code and CCSK code, comparisons on the coding performance of JTIDS in gauss channel, rayleigh channel and rice channel are conducted. It turns out that the channel characteristics can be described well when Rician factor is five in rice channel. In the end, by analyzing and comparing JTIDS's effects to anti-broad band noise and anti-comb interference, it finds out that the latter is more effective than the former.**

Keywords- JTIDS; Simulink；CCSK Soft Spread Spectrum; Frequency Hopping System.

I. INTRODUCTION

The JTIDS of U.S. army, a kind of high capacity digital information distribution system of communication, navigation and identification, can distinguish between friends and enemies and guarantee the army to interact real-time information of the battlefield under the harsh radio environment by providing antijamming and secretive digital voice information and its data interactive function, which greatly improves the flexibility and viability of the army. By taking advantage of CRC(237,225) error-detecting code, RS(31,15)Forward Error Correction, Interleaving, CCSK Soft Spread Spectrum and High-Speed Frequency Fast Hopping, JTIDS tremendously enhances its antijamming capability, even when lots of errors occur in the transmission process, it can restore the correct information.

In reference 3, the anti-noise of JTIDS in AWGN Channel had been carried out, showing that JTIDS owns great anti-white noise ability with RS code and CCSK code. On this basis, this paper compares the coding performance of JTIDS respectively in gauss channel, rayleigh channel and rice channel. From the analysis on reference 4, when the number of suppression information is 20, it can effectively affect the JTIDS. Reference 5 dissects the anti-jamming performance of JTIDS in different interference signals with SystemView5.0. But this paper, based on the previous research results, analyzes the anti-broadband noise and anti-dressing interference of JTIDS with Simulink. At the same time, by using Simulink to design the simulation model of JTIDS, it also analyzes the JTIDS's coding performance and anti-jamming performance, which provides a platform and reference for researches and interfering JTIDS.

II. MODEL ANALYSIS

Supposing that the system is synchronized and considerations only taken to the ber performance of JTIDS, not to error detection and CCSK baseband encryption process, the ber performance analysis of JTIDS can be built according to signal transmission process. As it is shown in figure one.

Data transfer process can be divided into three parts: coding including CRC calibration, RS coding and interleaving; frequency-hopping spread spectrum; decoding, namely, reverse transformation of coding.

It is obviously in the figure that processing procedure of masthead is similar to that of message, only different in RS coding rate [6]. The receiving model is denoted with the dotted box in the figure, including MSK demodulation and CCSK decoding.

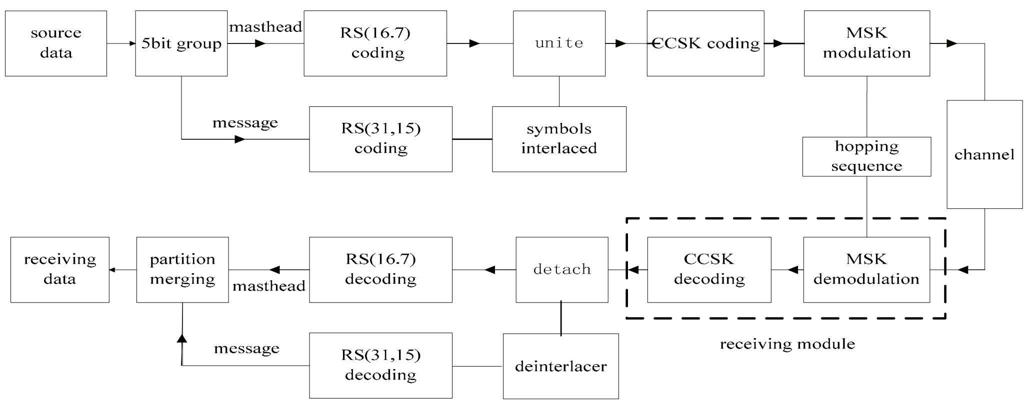

Figure 1. Model frame of JTIDS ber performance analysis

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A. Compiler Theory of CRC check Code

CRC (Cyclic Redunandy Check), with the basic idea of using linear coding theory and according to k binary code sequence to be transmitted at the transmitting terminal generates a calibration r check code to be attached to the back of information bit, constructing a new $n = k + r$ binary code sequence. This code is named (n, k) code. For a given (n, k) code, there is a polynomial $G(x)$ with r being its highest power. Based on $G(x)$, k information check code can be produced and $G(x)$ is the generator polynomials of this CRC code. After receiving the signal, the receiver will isolate check node from information code, then re-calculate the check node with isolated information code and compare with the received check. If the results are the same, it means no problems, otherwise, transmission error. When the error happens, receiving terminal will ask transmitting terminal to retransmit information code so as to realize signal error correction.

The check code in JTIDS is generated from CRC(237,225), and its generator polynomials is $g(x) = x^{12} + x^{11} + x^3 + x^2 + 1$.

B. Principle of RS Encoding and Decoding

RS code, a kind of m-ary BCH code of powerful error correction capability, tries to realize the code word polynomial of each multiple of $g(x)$ with the basic idea of choosing a proper generator polynomial $g(x)$. That is, to divide code word polynomial by $g(x)$, we will get 0. When the result is not 0, there must be some errors in receiving code word. At most

RS (n, k) code can be represented by three parameters: m, n and 3, of which m means code element is derived from $GF(2^m)$; n is the length of code element; and k represents the information field size. In JTIDS, message with RS(31,15) coding and masthead with RS(16,7) can respectively correct 8 errors and 4 errors at most.

C. Principle of Interlace Code & Decode

Interlacing means that the data sequence conducts data location rearrangement on the condition of one-to-one correspondence. Its inverse process is de-interlacing. If a set of information $X = (x_1, x_2, \cdots, x_{15})$ is to be transmitted, firstly transmits X into interleaver, then writes interleaver in lines and outputs it in line of 5×3, the outcome is:

$$X = \begin{bmatrix} x_1 & x_6 & x_{11} \\ x_2 & x_7 & x_{12} \\ x_3 & x_8 & x_{13} \\ x_4 & x_9 & x_{14} \\ x_5 & x_{10} & x_{15} \end{bmatrix}$$

After clearing away the interwoven matrices, the result is: $X = (x_1, x_6, x_{11,} x_2, x_7, x_{12} \cdots, x_{15})$. When two burst errors occur in burst channel: 1~4 and 10~13 in a row, the outcome will be

$$X = (\overline{x}_1, \overline{x}_6, \overline{x}_{11,} \overline{x}_2, x_7, x_{12}, x_3, x_8, x_{13}, \overline{x}_4, \overline{x}_9, \overline{x}_{14}, x_5, x_{10}, x_{15})$$

after de-interlacing. It is obviously that undergoing the decoding of interlacer, the burst errors of the previous channel will become memoryless and independent random errors and few consecutive errors.

D. Principle of CCSK soft Spread Spectrum Encoding and Decoding

CCSK coding, a M32 encoding, firstly divides sequence into 5bit group and then makes each 5bit correspond with M32 code in the way of bit value shift and the corresponding circular shifted code; that is, the 5bit of each code element is mapped into 32bit transmission code word which then will modulate carrier by means of MSK to form RF as so to send the wave form. The CCSK spread spectrum code is shown in table one.

After receiving the 32 bit transmission code word modulated by MSK, when CCSK is decoding, the receiver will do relevant calculations between the received sequence and the local 32 route CCSK code word and then choose the route with maximum correlation as the decoded signal.

TABLE I. CCSK SPREAD SPECTRUM CODE

Code Element	32bit CCSK chip sequence
00000	S_0 = 01111100111010010000101011101100
00001	S_1 = 11111001110100100001010111011000
00010	S_2 = 11110011101001000010101110110001
	…
11111	S_{31} = 00111110011101001000010101110110

E. Frequency Hopping

Frequency hopping system refers to use PRBS to constitute frequency hopping instructions so as to control frequency synthesizer and choose frequency shift keying in several frequencies. JTIDS, by making use of frequency hopping transmission, divides the frequency band of 960MHz~1215MHz into three frequency hopping sections: 969~1008MHz、1053~1065MHz and 1113~1206. In this way, it keeps away from the tactical navigation system in the same frequency section and the frequency band that is occupied by identification friend-or-foe system. The frequency hopping space of JTIDS is 3MHz with 51 frequencies in total. According to the fh pattern, it chooses a frequency from the 51 as MSK modulated carrier frequency and the frequency space of each frequency hopping between the current frequency and the last one is greater than 30MHz.

III. REALIZATION OF MODEL

The Simulink is employed to design Link-16 system. In this paper, 210b message data and 15b track number are generated from binary sequence generator firstly. As the transmission modes of masthead data and data information are the same, only different in RS code rate, this paper only studies the message part. Then, after 12b check code is produced by CRC (237,225), the data will be appended to the back of 225b data, thus, 237b code word is formed. Later, the first 210b message data of 225b is divided into three groups, each group of 70b, and meanwhile, 12b check bit falls into three groups, with each of 4b. And each group turns into 5b with zero-padding in front of check bit, and then 75b data will generated after respectively they are respectively added to the back of message data. As RS code is the BCH code of duotricemary notation, the every 5b of 75b should be regarded as a character and RS (31,15) coding will be conducted on 15 characters in total. After three groups of RS (31,15) coding undergo matrix interlacing with the length of three, each character will be restored to 5b binary sequence, the encoding process is completed. CCSK soft spread spectrum will be carried out on the finished coding, to map 5b information into 32b. At last, the information will be modulated by MSK, and then hopping frequency will be sent out. Demodulation decoding is the reverse transformation of modulation coding.

The coding process of JTIDS is shown in figure two.

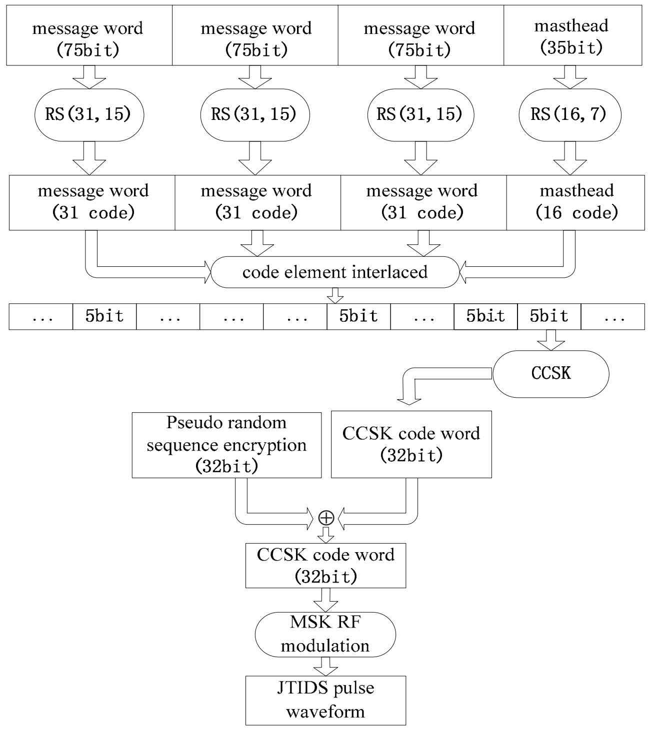

Figure 2. Coding process of JTIDS

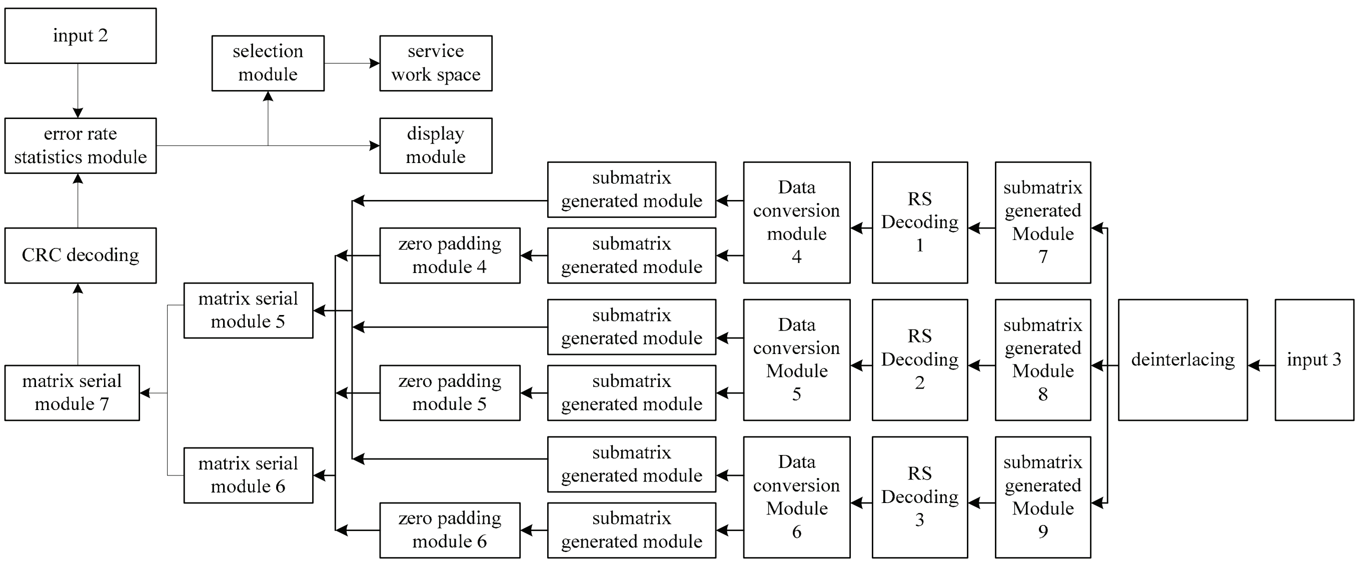

Figure 3. Partial model of JITDS coding

A. Coding

The coding model is shown in the following figure:

Information source adopts binary Bernoulli Binary Generator which produces 210bit information frame and 15bit track number per 0.04s. The 12bit check code will be produced after Matrix Concatenation sends it into CRC (225,237) General CRC Generator, and 237bit code word will be obtained after adding the check code to the back of 225bit data. The generator polynomials of CRC coder is set as [1 1 0 0 0 0 0 0 0 1 1 0]. After that, 210 information bit is divided into three groups by submatrix, with each group of 70 bit, and meanwhile 12bit check bit into four, each of 4bit. And each group turns into 5b with zero-padding in front of check bit. In order to form 75bit word, , information bit of three 70bit and three 5bit check bit respectively cascaded by Matrix Concatenation. As RS code is the BCH code of duotricemary notation, the every 5b of 75b should be regarded as a character and RS Integer-Input RS Encoder will be conducted on 15 characters in total by binary Bit to Integer Converter. The GF of RS coding model is [1 0 0 1 0 1]. In the end, Matrix Converter will carry out interlacing coding on three groups of RS code with the depth of three. Then burst errors will be transformed to random error. Decoding part is the reverse transformation of the coding part.

B. *Frequency-Hopping Spread Spectrum*

The data after coding is 93 character each frame. In order to fit S function, the data will be cascaded and transformed by buffer. In Simulink, users can compile the definition module with S function, while the input and output of S function cannot be matrix.

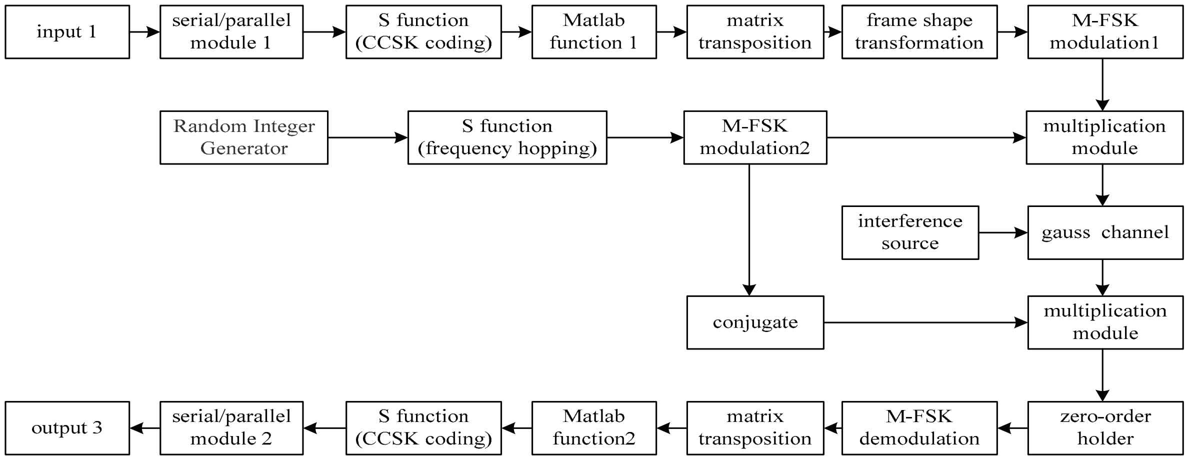

Figure 4. Partial model of Frequency-Hopping Spread Spectrum

This model writes CCSK encoding and decoding module with S function, with the main purpose of representing decimal character with 5bit binary. According to figure one, 5bit binary sequence will be mapped into related 32bit binary sequence, and then it is input in decimal format. Since the decimal data is quite big, it is the time to call de2bi (u,32) to restore it into 32bit CCSK code word with MATLAB Fcn module. Then, the spread spectrum part is accomplished.

Choosing a range of the three JTIDS frequency hopping in the frequency hopping part, pseudorandom integer sequences will be generated with Random Integer Generator, map each integer into corresponding hopping sequence through writing S function and then modulate it into relevant hopping carrier with M-FSK. Last, the frequency hopping part is completed when multiplying carrier by MSK modulation signal. With the aim of delaying one circle, the Traceback in MSK modulation model is set as 2796. AWGN Channel is used for channel transmission, and interferences can be added to the channel for the realization of anti-interference analysis. In modulation, the Math Function of the original frequency carrier be multiplies by the received signal. Dispreading S function is similar to SPSP S function and not explained here.

IV. RESULT ANALYSIS

Research is conducted on the system performance at the aforesaid platform. Error statistics model is shown in figure 5.

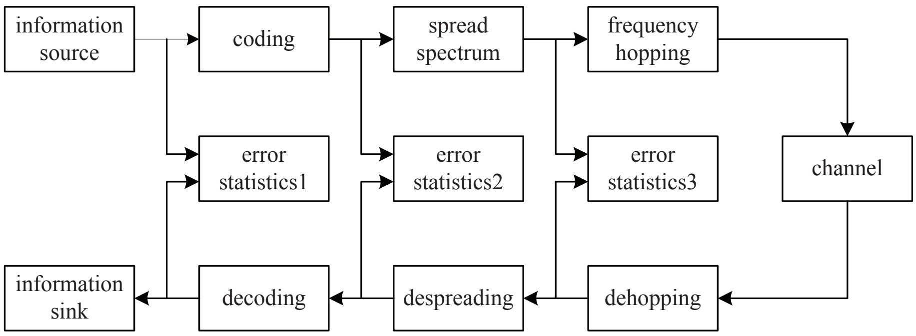

Figure 5. Error statistics of JTIDS simulation system

A. *Coding Perfromance Comparison of JTIDS in Different Channel*

The coding gain is mainly provided by RS code and CCSK code. Comparisons on the coding performance of JTIDS in gauss channel, rayleigh channel and rice channel are conducted, of which the Rician factor in rice channel is respectively K=0, K=5, K=10. The simulation coding performance in difference channels is shown in fig.6:

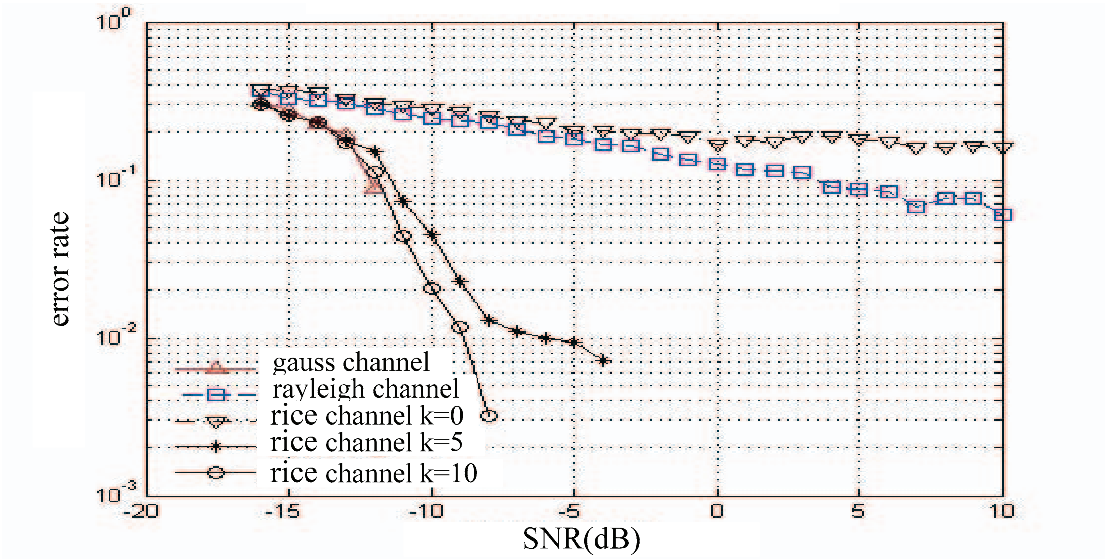

Figure 6. Coding performance comparison of JTIDS in different channels

In the fig. above, the curve of error rate of rayleigh fading channel is close to that of rice fading channel when K=0. It manifests that rice channel will become rayleigh channel when K=0. Then, the coding performance is the worst and this difficulty can't be well overcome by mere coding. With the increase of K, the coding performance will become better, which proves that the greater rician factor is, the better the channel is. Therefore, channel characteristics can be described well when Rician factor is five in rice channel.

B. Anti-jamming Performance Analysis of JTIDS

Broad band noise jam is kind of jamming mode in which the total jamming power is fixed and gauss band-limited white noise evenly distributes on the whole transmission band. Thus, it is also called barrage jamming. In general, the frequency spectrum is assumed to have the same frequency range with spread spectrum signals.

Without using any other information except the system total bandwidth, broad band noise jam can cover the whole signal spectrum so that signals can be interfered no matter how they jump. It, in essence, enhances the noise power spectrum density of the whole signal spectrum as well as directly reduces bit SNR, which for the interference party, is at the cost of sacrificing the jamming power.

As some frequency hopping systems have large bandwidth, a huge power will be taken for broad band noise jam. At this moment, jamming power can be gathered in a certain subset of signal total bandwidth according to a proper ratio to improve the jamming efficiency, which is called partial band jamming (comb jamming). When frequency hopping is in jamming bandwidth, signals will be heavily affected.

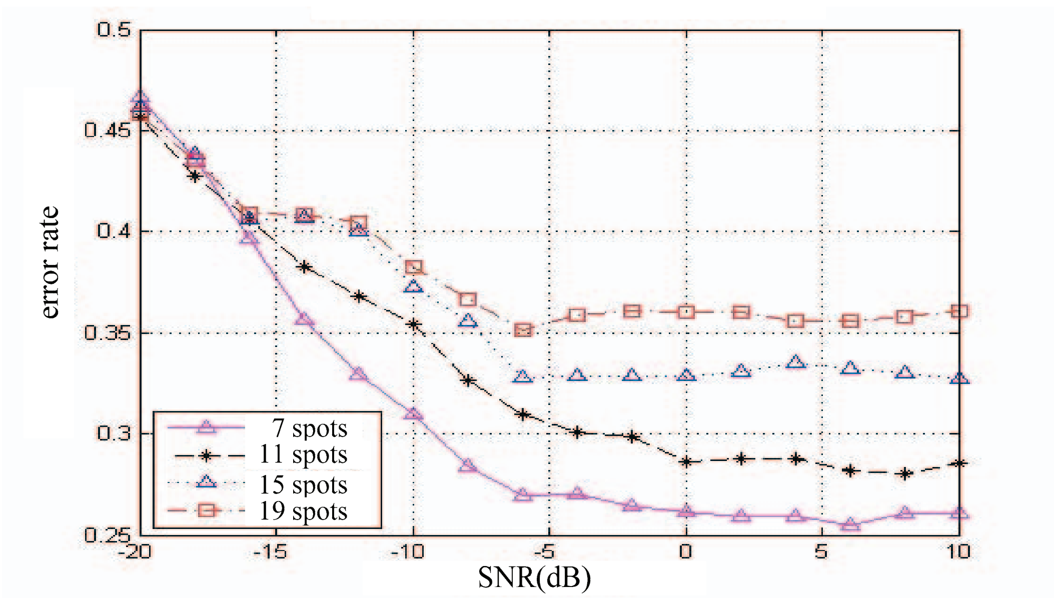

Figure 7. Anti- comb jamming analysis of JTIDS

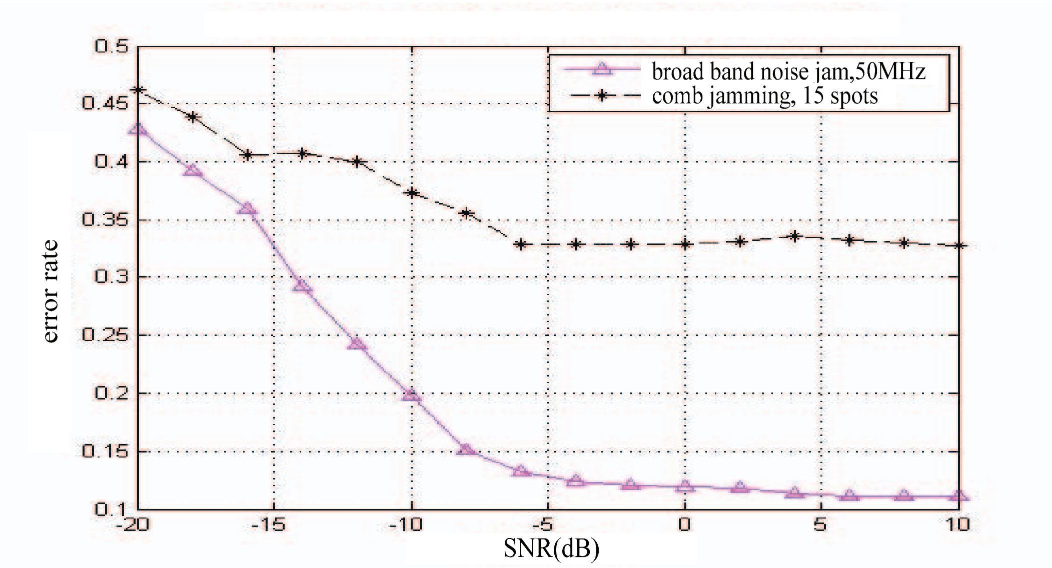

Figure 8. Effect contrast of broad band noise and comb jamming of JTIDS

From the fig.7 and fig. 8, with the increase of jamming spots, the comb jamming will be wider and jamming effect will be more obvious; the effect of comb jamming is apparently better than that of broad band noise jam, for the power of the latter is much more dispersive than that of the former in the same jamming broad band situation.

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