

Improved Performance Evaluation of Frequency Hopped Spread Spectrum using QAM/FSK Modulation Techniques

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ABSTRACT

A brief theoretical foundation has been provided that expands upon QAM and FSK modulation in the application of Frequency Hopped spread spectrum systems. This paper mainly focuses on the Bit Error Estimation in Frequency Hop Spread Spectrum System using Quadrature Amplitude modulation and Frequency shift keying which are used in defense applications. The main aim here is to calculate the bit error performance of a frequency hopping spread spectrum model in the presence of AWGN channel. This paper provides a systematic approach for evaluating the performance of FHSS operating with coherent M -ary FSK demodulation. There have been investigations into the frequency hop spread spectrum systems employing different modulation schemes to decrease the bit error ratios. There has been much work done on computing BER of FHSS systems with error control coding using industry standard convolutional coding.

Keywords

Frequency Hopped spread spectrum, FSK, QAM.

1. INTRODUCTION AND LITERATURE REVIEW.

Spread spectrum techniques can be very useful to overcome the communication problems like security and efficient usage of power. In this technique, the information signal to be transmitted is multiplied by the PN code (This is the general case and it can be any kind of sequence), called spreading code signal. The signal which is obtained after the multiplication of PN code is called spread signal which is then transmitted. The receiving side acquires the transmitted signal, which is then multiplied by a same spreading code signal, so that the original signal is recovered. It can be seen that the required signal gets multiplied twice but the interference gets multiplied only once, which will reduce the interference and that will be a great protection against jamming. The main property of the spreading signal is the bandwidth expansion factor ($B_e = \text{Width}/\text{Data rate}$), which is much greater than unity, that means the redundancy involved in the spread signal can easily overcome the interference. The processing gain is used to measure the amount of the improvement of system with the use of spread spectrum system. Processing gain is the difference between the performance of the system using spread spectrum techniques and the performance of the system which is not using the

spread spectrum techniques processing gain also defined as the ratio of spread signal bandwidth (W_{SS}) to the information rate.

Spread Spectrum modulation techniques are defined as the technique in which the bandwidth of the transmitted signal is much greater than the bandwidth of the original message, and the bandwidth of the transmitted signal is determined by the message to be transmitted. Spread spectrum system has now come up as a promising digital technology for mobile systems, with the innovation of VLSI technology. In this technique, Linear Feedback Shift Register (LFSR) is the basic unit or element, which generates Maximal length PN sequence or m -sequence. Linear Feedback Shift Register represented by a primitive polynomial. In Spread Spectrum system each user is assigned a pseudo noise sequence (PN) for the purpose of spreading as well as de-spreading. Thus PN-sequence generation is considered to be the heart of SS system. The maximal length PN-sequence (m -sequence) is the best-known PN-sequence whose length is equal to its period. Various PN-codes can be generated using Linear Feedback Shift register (LFSR). The generator polynomial provides the necessary feedback taps for the LFSR circuit.

PN sequences are commonly used in wide variety of wireless application such as data encryption and decryption. The codes used in spread spectrum systems are longer than the codes used in other systems, as they are proposed for bandwidth spreading rather than transmitting the information. In order to alter the system's spreading capability it is necessary to alter the coding arrangement [1-2]. All spread spectrum communication systems employ a pseudo-noise (PN) code sequence to spread the data modulated carrier at the transmitter and de-spread the desired carrier at the receiver. Autocorrelation, cross correlation, and power spectrum of PN codes are the main functions which are used to measure the performance of spread spectrum communication systems [2, 3]. Spreading can be accomplished by multiplying the information symbols with a high rate pseudo-random sequence (so called pseudo-noise, PN) known to the receiver. The resulting signal is wideband and can be demodulated again by multiplying it with a synchronized replica of the PN sequence used by the transmitter. Spreading codes have good correlation properties so that each spread spectrum signal is uncorrelated with every other signal sharing the same bandwidth. The PN sequence is unique to each user, thus

allowing bandwidth sharing without any loss of information [4].

Spread Spectrum (SS) [6-10] is termed as a means of transmission in which the signal occupies bandwidth much in excess of the minimum necessary to send the information. It can be perfectly reconstructed for the intended receiver and it seems to be random-like for others. This randomness of the sequence should satisfy the properties like balance, run and autocorrelation. While the spread spectrum naturally means that each transmission utilizes a large amount of spectrum, so that a considerable number of users might share the same spectral band. A distinct code has been assigned for each transmitter. So there exists a possibility of high interference between the users when they are very close to each other. The interference may be intentional, as in military communications, or it may be no intentional as in a spectral overlay system [11]. In any case, the receiver achieves higher signal to noise ratios (SNR's) at the decision device input if an interference rejection filter is used before despreading [12]. The rejection filter is usually adaptive and relies on the pseudo-white properties of the spread spectrum signal [13]. Spread spectrum communication has advantages of strong anti-interference ability, good security, high-speed rate, being easy to realize CDMA and less interference to other narrowband systems in the same band[14]. The performance of wireless communication system is limited by fading and jamming, the former arises from signals multipath propagation, while the latter results from the reuse of frequencies.[15].It is widely used in military and civilian applications for its excellent performances and the spreading codes has high autocorrelation and low cross correlation properties.[16-18].

2. FREQUENCY HOPPED TRANSRECEIVER

In a Frequency- hopped (FH) spread spectrum communication system the available channel bandwidth is subdivided into a large number of contiguous frequency slots. In any signalling interval, the transmitted signal occupies one or more of the available frequency slots. The selection of frequency slot(s) in each signalling interval is made according to the output from a PN generator. The modulation technique which is used in FHSS is M-ary FSK and QAM along with convolution coder . The resulting FSK signal is translated in frequency by an amount that is determined by the output sequence from the PN generator, which, in turn is used to select a frequency that is synthesized by the frequency synthesizer. This frequency is mixed with the output of the modulator and the resultant frequency-translated signal is transmitted over the channel. The m bits from the PN generator may be used to specify 2^m-1 possible frequency translations. The modulated signal is transmitted over the AWGN channel. At the receiver, we have an identical PN generator, synchronized, with the receiver signal, which is used to control the output of the frequency synthesizer. Thus, the pseudorandom frequency translation introduced at the transmitter is removed at the receiver by mixing the synthesizer output with the received signal. The resultant signal is demodulated by means of an M- FSK demodulator. A signal for maintaining synchronism of the PN generator with the frequency –translated received signal is usually extracted from the received signal.The improvement of FHSS/QAM along with viterbi decoder reduces the Bit error rate.

2.1 Mathematical Interpretation

Transmitting two signals by modulating them with QAM, the transmitted signal will be of the form

$$s(t) = I(t) \cos(2\pi f_0 t) + Q(t) \sin(2\pi f_0 t)$$

where $I(t)$ and $Q(t)$ are the modulating signals and f_0 is the carrier frequency. At the receiver, these two modulating signals can be demodulated using a coherent demodulator. Such a receiver multiplies the received signal separately with both a cosine and sine signal to produce the received estimates of $I(t)$ and $Q(t)$ respectively. Because of the orthogonality property of the carrier signals, it is possible to detect the modulating signals independently.

In the ideal case $I(t)$ is demodulated by multiplying the transmitted signal with a cosine signal:

$$r_i(t) = s(t) \cos(2\pi f_0 t)$$

Using standard trigonometric identities, we can write it as:

$$r_i(t) = \frac{1}{2}I(t) + \frac{1}{2}[I(t) \cos(4\pi f_0 t) + Q(t) \sin(4\pi f_0 t)]$$

Low-pass filtering $r_i(t)$ removes the high frequency terms (containing $4\pi f_0 t$), leaving only the $I(t)$ term. This filtered signal is unaffected by $Q(t)$, showing that the in-phase component can be received independently of the quadrature component. Similarly, we may multiply $s(t)$ by a sine wave and then low-pass filter to extract $Q(t)$.

Frequency hopping systems change the carrier frequency at a rate comparable with (or slower than) the information rate which used to transmit .frequency hopping can be done coherently or non -coherently. For a coherent FH system the output of the frequency's written as [5]

$$h_T(t) = \sum_{n=-\infty}^{\infty} 2p(t - nT_c) \cos(\omega_n t + \phi_n)$$

where $p(t)$ represents pulse of duration T_c , with unit amplitude starting at time zero, ω_n and ϕ_n are the radian frequency and phase during the n th frequency hop interval .The frequency ω_n is taken from a set of 2^k frequencies. In FH system k -bits of the spreading code is used . Transmitted signal is the data modulated carrier whose frequency changes to a new carrier frequency ie ($\omega_{n+} \omega_0$) for each FH chip [5]

$$s_t(t) = \left[s_d(t) \sum_{n=-\infty}^{\infty} 2p(t - nT_c) \cos(\omega_n t + \phi_n) \right]_{\text{sumfreq components}}$$

Power spectrum of the transmitted signal is sum frequency term of the convolution of $S_d(f)$ and $S_h(f)$, where $S_d(f)$ is the power spectral density of the data modulated carrier $S_h(f)$ be the power spectral density of the carrier hop $h_T(t)$, these two are independent . The signal $h_T(t)$ may or may not be periodic. If it is periodic, its period would be sufficiently long that little error would be made in considering the period infinite. .Fig 1 shows the improvement of FHSS/QAM along with viterbi decoder which reduces the Bit error rate.

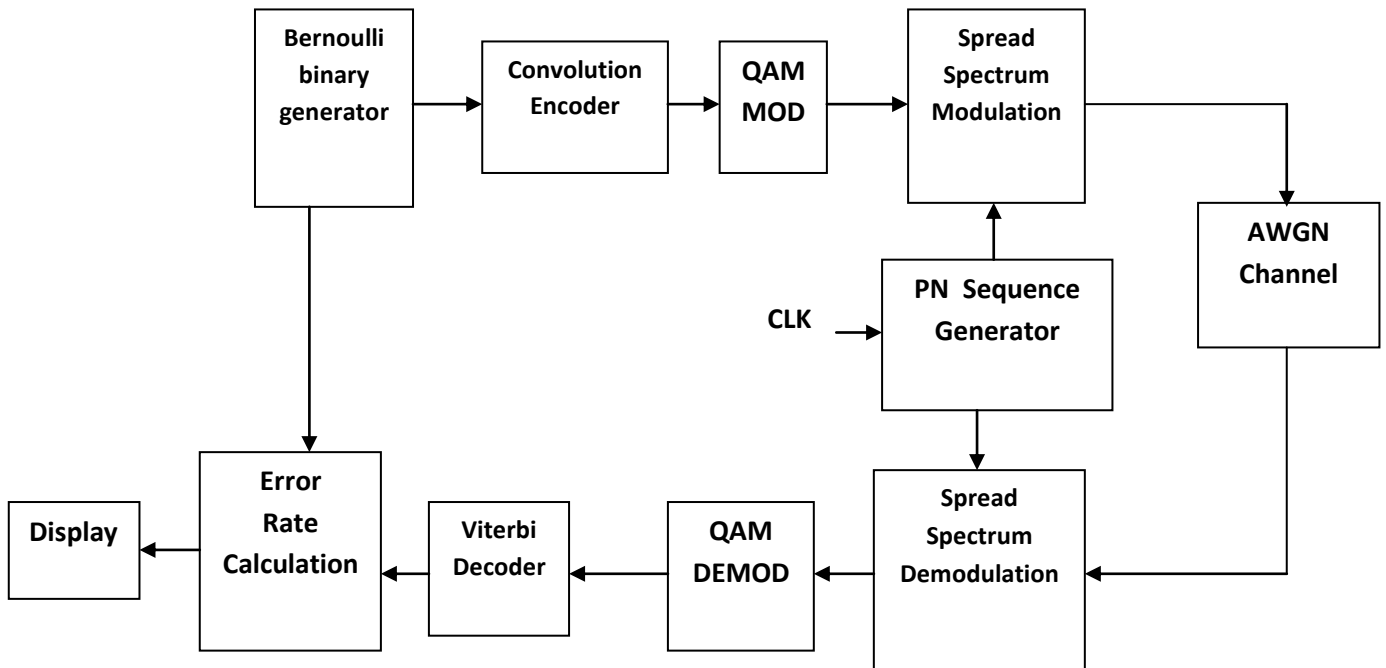


Fig 1. FHSS / QAM with Viterbi decoder

3. RESULTS AND DISCUSSIONS

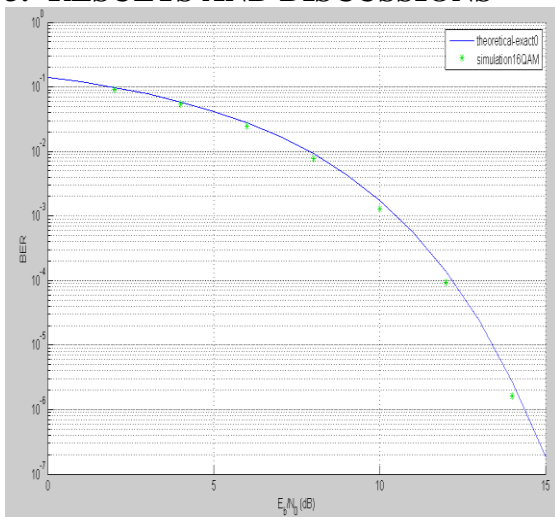


Fig 2. QAM with AWGN

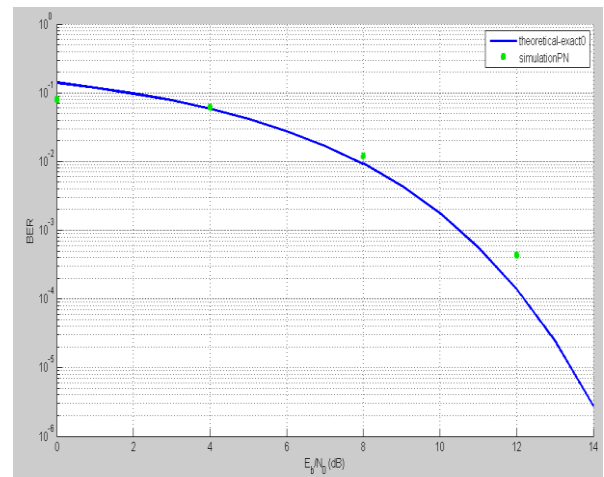


Fig 3. QAM with FHSS without FEC using PN sequence generator

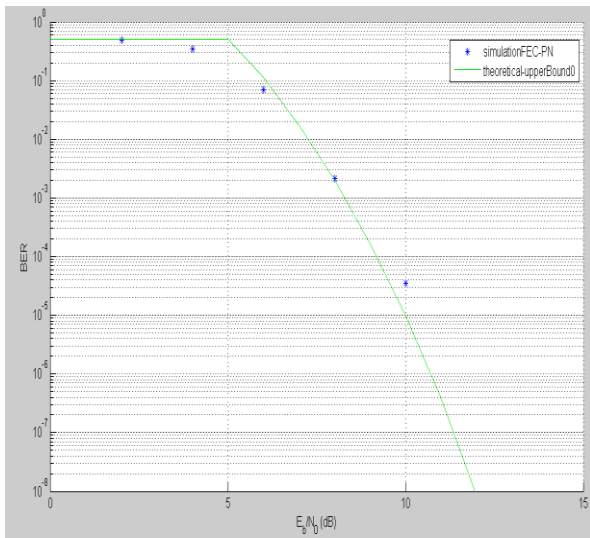


Fig 4. QAM with FHSS using PN sequence generator with FEC

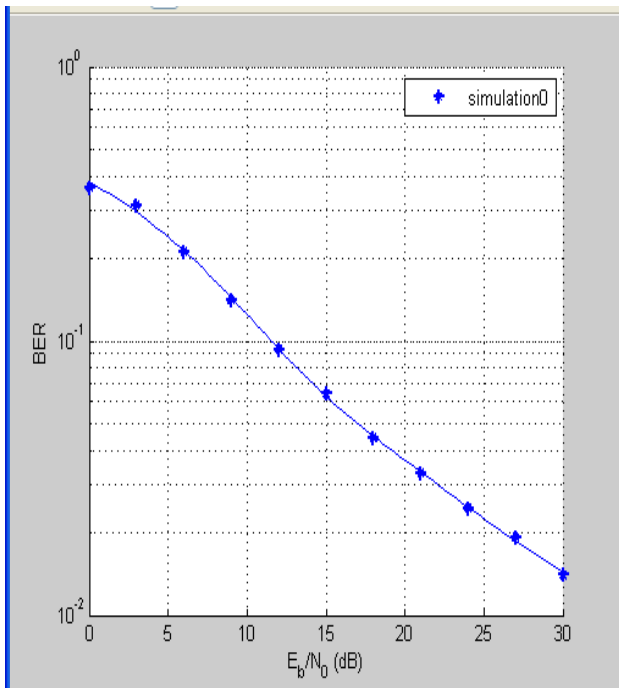


Fig 5. BER of FHSS/FSK with PN sequence in AWGN channel

A model of gray coded 16-QAM with AWGN Channel has been designed and the BER curve for this has been simulated as shown in Fig2. The result is close to the theoretically expected plot of BER vs. E_b/N_0 of an ideal 16-QAM system without error coding. Fig 3. demonstrates the BER performance using frequency hopping modulation without Forward error correction using QAM respectively. Using FHSS systems with FEC as shown in Fig 4. decreases the BER per E_b/N_0 and hence improves the BER performance further than what was achieved when FHSS without FEC was used. The bit error rate calculation for FHSS using FSK modulation is achieved with perfect synchronisation. The

analysis data for the Maximal length code is plotted in Fig.5. From the simulation results it can be observed that as the Signal to noise ratio increases the Bit error rate attains a negligible value .

4. CONCLUSION

The objective of this investigation was met successfully and various plots generated supported the conclusion that the generated models were close to and in cases better than the ideal performance expected. The spread spectrum process as evident is an effective way of transmission with lesser bit error ratio and the FEC employed as a Convolution/Viterbi coding is also productive in obtaining a lowered BER of the FHSS/QAM system. Forward Error correction helps in reducing the inherent disadvantage of a QAM system that is high signal to noise ratio requirement for a small change in BER. This paper also demonstrates the development and analysis of Frequency- Hopped Spread Spectrum (FH/SS) transceiver using M-FSK works under the influence of an Additive White Gaussian Noise (AWGN) channel were simulated.

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