

BER of Fast Frequency Hopping Spread Spectrum Over Flat Rayleigh Fading Channel in Hostile Jammers

Abid Yahya¹ and Othman Sidek² and Prof. Farid Ghani³

Collaborative MicroElectronic Design Excellence Center

Universiti Sains Malaysia, Engineering Campus

³School of Computer and Communication Engineering

Universiti Malaysia Perlis,

Perlis, Malaysia

E-mail:¹abidusm@gmail.com,²othman@cedec.usm.my,³faridghani@rediffmail.com

Abstract: This paper demonstrates the execution and performance of frequency hopping spread spectrum system employing noncoherent frequency shift keyed (NCFSK) modulation. Fast frequency hopping is exploited as a diversity technique over flat Rayleigh fading channel with partial band noise jamming and additive white noise Gaussian (AWGN). The potentiality of the aforementioned system has then, ascertained by measuring the probability of error. The simulation results evince that the chance of getting 0 errors falls to about 1 percent. The overall fast frequency hopping (FFH) system has approximately 29 percent chance of producing 35 errors or less.

1. Introduction

Partial band noise interference is one of the cases of narrowband interference which can be either deliberately or unwittingly, has the capability to importantly put down the efficaciousness of frequency hopped spread spectrum system. In the worst condition of partial band noise interference, the performance of the system has almost the same effect as the signal transmitted over a Rayleigh-fading channel [1].

In early work most of the researchers have accentuated more on the effect of fading channels on the performance of FFH adaptive gain control receivers employing M-ary frequency shift keying (MFSK) and acquires that only the communications signal is transmitted over a fading channel. It aspects practical that, at large, in situations where channel fading overcomes the communications signal, channel fading will also affect the partial-band noise interference signal. The previous probes, that brush aside the hostile attack of fading on the partial band noise interference signal, at large, come out with erroneous results for fading channels.

The impression and effect of partial band noise interference on noncoherent orthogonal ideal FFH/MFSK adaptive gain control receivers has been examined in [2] and [3], but they have executed their work without channel fading. In [4] and [5] they have extended their work and present the performance of the ideal noncoherent FFH/MFSK adaptive gain control receiver for a signal transmitted over a Rician fading channel with partial-band noise interference. Their work is confined to line of sight due to the usance of Rician fading channel.

The aforementioned problem has been essayed in [6] for conventional noncoherent frequency hopped MFSK receivers where both the information signal and the partial-band noise interference signal are acquired to be

transmitted over a Rayleigh-fading channel but without any diversity technique.

This paper demonstrates the execution and performance of frequency hopping spread spectrum system, employing the non-coherent frequency shift keying modulation scheme, over flat Rayleigh fading channel with partial band noise is presented. Additionally, additive white Gaussian noise (AWGN) has been added to the channel, in order to establish the environment more hostile. We have carried out diversity in FHSS by employing fast frequency hopping with multiple hops per symbol being transmitted.

The second part of the paper demonstrates a method for the measurement of bit error rate (BER) of the aforementioned system. The method confere here caters prompt and precise measurement of the BER feature at a number of points with equal accuracy and employing minimum sample size. In hostile jamming environment, time-diversity techniques furnish high execution enhancement at the expense of a reduced data rate. This diversity is offered by transmitting an especial symbol L time, where L is the diversity level.

2. Rayleigh fading channel

In this part, the statistical model for flat Rayleigh fading channels is delineated. This channel model is used here to assess the dependability and performance of FFH system, which is assumed to be corrupted by PBN and AWGN.

The impulse response is a utile characterization of the channel, since it may be used to forecast and evaluate the performance of different mobile communication systems as well as the transmission bandwidths for a specific mobile channel condition [7].

The channel impulse response can be evinced as $h(d,t)$. Let the transmitted signal be set out by $x(t)$ and the received signal $y(d,t)$ at a position d is to be articulated as a convolution between (x) and $h(d,t)$.

$$y(d,t) = x(t) \otimes h(d,t) \\ = \int_{-\infty}^{\infty} x(\tau)h(d,t-\tau)d\tau \quad (1)$$

In case of a causal system the equation (2) turns into

$$y(d,t) = \int_{-\infty}^t x(\tau)h(d,t-\tau)d\tau \quad (2)$$

Where d represents the position of the receiver at constant velocity v is denotative as

$$d = vt \quad (3)$$

Substituting the value of d in equation (2)

$$y(vt, t) = \int_{-\infty}^t x(\tau)h(vt, t-\tau)d\tau \quad (4)$$

Given that v may be assumed as constant over a short time interval, therefore equation (4) can be stated as

$$y(t) = \int_{-\infty}^{\infty} x(\tau)h(t, \tau)d\tau \quad (5)$$

The impulse response $h(d, \tau)$ is a function of both t and τ which entirely characterizes the channel. The time variation and time delay of multipath channel is represented by t and τ respectively.

Fading channel usually follows the Rayleigh fading characteristics, when simulating the wireless channel for mobile and macro cellular communications. If we put on a mobile station with carrier frequency f_c moving at a velocity v , then the Doppler shift brought in the n^{th} incident wave is set by

$$f_{D,n}(t) = f_d \cos \theta_n(t) \quad (6)$$

where $f_d = v / \lambda_c$.

In [7-9] the complex baseband channel impulse response has been delivered which accompanying to this type of fading is

$$h_b(t, \tau) = \sum_{k=1}^N \alpha_k(t, \tau) e^{j[\omega_c \tau_k(t) + \phi_k(t, \tau)]} \delta[\tau - \tau_k(t)] \quad (7)$$

In equation (7), N is the total possible number of multipath components (bins), while the unit impulse function is represented by $\delta(\cdot)$ which ascertains the specific multipath bins that have components at time t and excess delays τ_k .

The terms $\alpha_k(t)$ and $\tau_k(t)$ are the amplitude and excess time delay, respectively for k_{th} path whereas $\omega_c \tau_k(t) + \phi_k(t, \tau)$ corresponds the randomly phases that are encountered in the channel.

where $\omega_c = 2\pi f_c$, and f_c represents the carrier frequency.

If we consider the channel impulse response as a time invariant then it may be modified as

$$h_b(\tau) = \sum_{k=1}^N \alpha_k e^{-j\phi_k} \delta[\tau - \tau_k] \quad (8)$$

Nonetheless, a large difference is observed in the received phases by a small divergence in the path delay as the carrier frequency is very high. Consequently, the received signal is still experiencing fading. The corresponding channel transfer function is incurred by taking the Fourier transform of equation (8) applying

$$T(t, f) = h(t) e^{-j2\pi f \tau_k} \quad (9)$$

Equation (9) depicts that received signal is said to demonstrate Flat Fading.

2. 1 FFH in Rayleigh Fading

This paper demonstrates, the performance of FFH/FSK signal transmits over Rayleigh fading channels and partial band noise interference as reveals in Figure.1. As a result, the dehopped information signal amplitude and the

dehopped instantaneous interference signal amplitude are modeled as Rayleigh random variables.

The FFH system model deliberates in this paper is characterized by flat Rayleigh fading channel with AWGN over PBN. The input binary data is coming at a rate R_b with a symbol rate R_s is presented as

$$R_s = \frac{R_b}{\log_2 M} \quad (10)$$

Fast frequency hopping is being employed as a diversity technique so that one of M -ary symbol is transmitted over L independent hops, where L is greater than or equal to one. In order to detect if a hop is jammed the presence of perfect side information is supposed, available to detect if a hop is jammed. The number L is sometimes addressed the order or level of diversity. The input and output periods and rate are correlated, repetitively by

$$L = \frac{R_h}{R_s} \quad (11)$$

where R_h is the hop rate.

The parameters in the system are separation frequency and sampling frequency at 1MHz and 2MHz respectively with a signal length of 40,000 bits. The system employs Pseudonoise code generator for spreading the bandwidth of the modulated signal to the larger extent of transmission bandwidth and identifying between the unlike user signals employing the same transmission bandwidth in a multiple-access scheme. The preferred baseband signal is broken into the L hops, by mixing it with the output of a synthesizer which is ascertained by a pseudorandom sequence generator. The synthesizer picks out a new frequency every seconds and the output of the mixer is communicated through a filter, transforms to RF, amplifier and radiates from the transmit antenna.

The transmitted signals are noncoherent frequency shift keyed (NCFSK) orthogonal signals that hop over a total spread spectrum bandwidth of W_{ss} . The M -ary transmitted symbol rate, is $R_s = R_b / (r k)$ where $k = \log_2 M$. Each symbol is repeated on L hops where $L = R_h / R_s$ is the diversity level and R_h is the hop rate. The presence of matched filters at the receiver, establish the dehopped and demodulated signal.

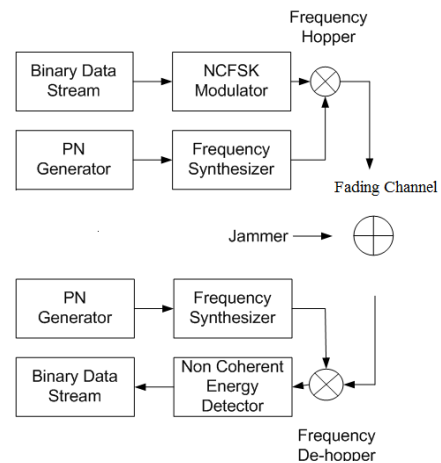


Figure.1. Block diagram of FFH system over Flat Rayleigh Fading with PBN

4. BER Measurement of the System

In FHSS systems, the bandwidth of usable channel is subdivided into a large number of adjacent frequency slots. For a fixed hop rate, the necessary unit of energy is the energy per hop $E_h = P_s T_h$ where P_s and T_h represent the signal power and hop period respectively. Every signal transmission is corrupted by AWGN and PBJ. Since, Gaussian noise jamming, the effective single-sided jamming noise power spectral density is $J_o = J_t / W_{ss}$ which illustrates the power density, which would be established only if the total jamming power, J_t were evenly spread across the entire hop bandwidth. The effective SJR is then $SJR = E_h / J_o$. Likewise, the signal-to-system-noise ratio is $SNR = E_h / N_o$, whereas N_o reveals the noise power density, which is the thermal noise power normalized to a 1Hz bandwidth. Mathematical representation of noise power density is

$$N_o = \frac{N}{B} \text{ (W / Hz)} \quad (12)$$

N = thermal noise power (watts), B = bandwidth (hertz)

The binomial distribution is commonly employed to characterize the probability of an event. The signaling-error rate can be encountered from the binomial distribution. If bit errors are statistically independent, then the random variable k , corresponding a number of errors in a sample of n bits, has binomial distribution as exposes in equation (13) with the variance $\sigma^2 = npq$ [10-11].

$$P_{tot} = C_{(n,k)} * [p^k * (q)^{(n-k)}] \quad (13)$$

where p is the bit error probability and $q = 1 - p$, whereas,

$C_{(n,k)}$ is the binomial coefficient as depicted in equation (14).

$$C_{(n,k)} = \frac{n!}{k! * (n-k)!} \quad (14)$$

where n = number of bits to be processed and k = number of errors.

4. Results and Discussion

GSM profile has been used in the aforementioned system for simulation with 1.8 GHz transmission frequency and bandwidth of 200 KHz on each channel. We have applied the Nyquist pulse shaping to construct the transmitted signal to accommodate the communication channel by restraining the effective bandwidth of the transmission. By filtering the transmitted pulses in this way, the intersymbol interference stimulated by the channel, can be easily contained. The $T_s = 5$ microseconds, where T_s is the symbol period, incurred from the reciprocal of bandwidth. It is acquired that user is moving at a velocity of 100 Km/hr with a coherence time $T_c = 1.1$ milliseconds, which interprets the condition of slow flat fading channel. From the study it is acknowledged that an actual signal ought to have a transform magnitude that is proportioned for positive and negative frequencies. So instead of bearing a spectrum that goes from 0 to (f_s) , it would be more

suitable to illustrate the spectrum from $-\frac{f_s}{2}$ to $\frac{f_s}{2}$. This is

accomplished by using the Matlab's `fftshift` function. In the simulation, baseband signal has been employed from the next to 0Hz up to the highest frequency in the signal with noteworthy power. The two independent Gaussian low pass noise roots are employed to generate in-phase and quadrature fading branches. Each Gaussian source is shaped by adding up two independent Gaussian random variables. The RF signal spectral shape acquires after Doppler spread by the result incurs from the product of amplitude of complex Gaussian random variable and square root of Doppler power spectrum. To correspond to the RF signal spectral shape by product of amplitude of complex Gaussian random variable and square root of Doppler power spectrum, a diagonal matrix is employed with each component in the main diagonal approach from amplitude Gaussian random variable, which is formed with the help of Matlab's function as portrays in Figure. 2.

Subsequently FHSS signal is brought forth by employing NCFSSK modulation by utilizing the diversity technique of fast frequency hopping with multiple hops per symbol being transmitted is exposed in Figure. 3, which is then communicated over the flat Rayleigh fading channel with partial band noise jamming and despread at the receiver end as exemplifies in Figure.4.

In order to recover the entropy at the receiver, the received signal is dehopped by combining it with the hopped carrier frequency. This operation takes away the hopping pattern and fetches the received signal in all subintervals to an ordinary frequency band that comprehends the likely transmitted frequencies, which are sampled at the end of each subinterval and communicated to the detector. The consequent dehopped signal is displayed in Figure.5.

The probability of error of 5000 bits out of 40,000 bits is illustrated in Figure. 9. The results incur from Figure.9 clearly depicts that when BER is 0.0006 and 5000 bits are being transmitted, we are about likely to make out 14 percent chance of acquiring 3 errors in the system. The likelihood of getting 0 errors falls to about 1 percent. The overall FFH system has around 29 percent possibility of generating 35 errors or less. At large, the factual BER increases and the 'peak' of the distribution move further and further to the right. In other words, distribution will be transferred further and further to the right. The larger the existent BER, the smaller the area under the errors will be which constitutes the probability of receiving up to 35 bit errors.

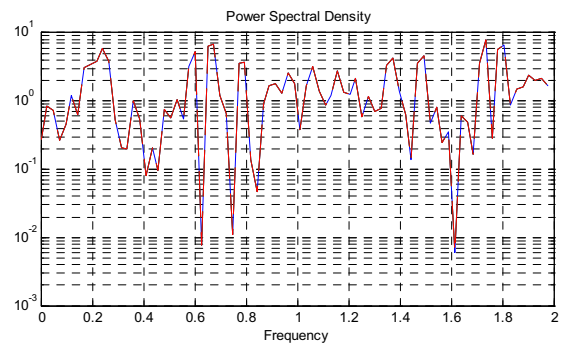


Figure.2 Doppler power spectrum

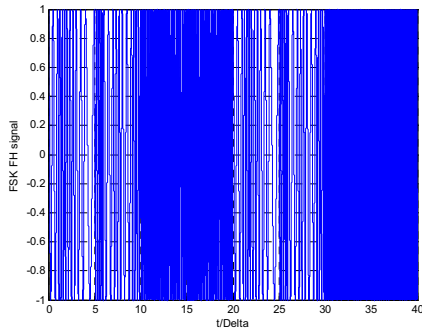


Figure.3 Frequency hopping with 10 signature using FSK modulation

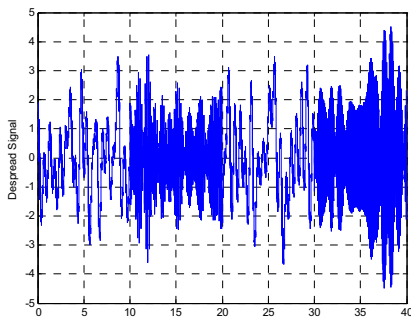


Figure.4 Despreading signal after passing through flat Rayleigh fading channel in noisy environment with PBN

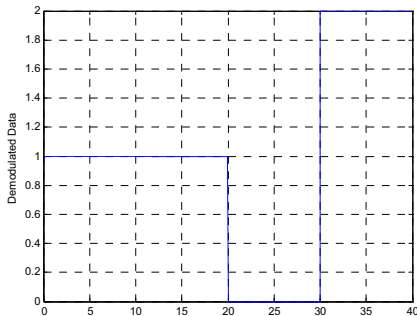


Figure.5 Resultant demodulated data signal

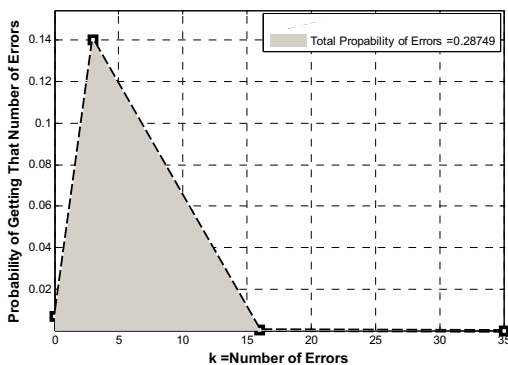


Figure.6 Binomial Distribution for Probability of Error

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