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The Performance of Fast Frequency Hopping System in Additive White Gaussian Noise (AWGN)

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ABSTRACT

As in the present scenario, the progression technology is looming towards the challenges of the present and revolutionary requirements; the interest in faster frequency hopping rates to scrutinize the performance of channel in the presence of AWGN has been heightened. The focus of formulation of this manuscript is the analytical behavior of fast frequency hopping style in the occurrence of AWGN using two linear combination schemes, currently in practice in communication world. The frequency hopping (FH) constitutes a powerful spread spectrum technique, historically used for combating intention of jamming or interference. These linear combination schemes are equal gain combiner (ECG) and selective gain combiner (SC). The performance regarding to Bit Error Rate (BER) will be investigated in order to choose the best possible scheme from available ones.

1. INTRODUCTION

With the advancement of technology, communication is becoming better and better day by day. Frequencies hopping are one of the latest technologies used in the field of communication. Researchers are doing a lot of researches to get better performance in every respect of modern life. The theme of this paper is to know the performance of fast frequency hopping in AWGN channel. Frequency hopping (FH) comprise a controlling spread spectrum technique historically used for combating intention of jamming or interference. The carrier frequency is skipped in the current system in a special manner called pseudo-random .In which a large set of legitimate frequencies are under the control of a random manner designer. This eternal hopping of the transmitted frequency renders the system robust against interference and jamming. The motivation of this paper is to present a study of various performance enhancement techniques used for frequency hopping system.

To transfer signal we use different modulation techniques but frequency hopping is the most basic techniques used in transfering the information in the signal [2, 6, 24, 25]. The process used in frequency hopping is that the frequencies used are the repeatedly switching on and off during signal transmission, so to moderate the usefulness of the jamming,this process is called in communication system as frequency hopping code division multiple access (FH-CDMA) [2, 6, 24, 25]. In an FH-CDMA system a transmitter jumps between the frequencies which are available in a band which is design by the engineers, so transmitter must be coordinated with a receiver.In communication synchronization is done with the known center frequency transmited by the transmitter signal,so that we can receive our signal well with less error or error free.So the information transmitted on the band the signal transmited signal hoped to one frequency and than to other and process carried on like this. This process requires a bigger bandwidth to send the same data using only one carrier frequency. Therefore, FH is based on a distribution of the vacant channel bandwidth into various adjacent sub channels. Each sub-channel contains the same bandwidth, and is spread about a central frequency. The signal is transmitted over a one frequency during one period, and then at another frequency during the same period, the process continues like this. These frequencies used in a signal are obtained by a manner called pseudorandom sequence. The sudden changes in a frequency are called frequency hops. In the communication carrier frequency is always dependent upon the Q values of frequencies because carrier frequency hopped from one position to another and this process goes on and on. In FH systems, the carrier phases are difficult to guess when the duration of the hopping system is very small or very less. Therefore, we adopt non coherent data modulation schemes. In FH system most application used different linear combination schemes of M-ary frequency shift-keying (MFSK) where M is define by the researcher as the power of 2 and so we can write it as M=2^n where n is number of bit or the symbol transmitted, So symol transmited can be evaluated as $\log_2(M)$ where n = number of bits transmitted. The legimate signal set of non-coherent MFSK modulations consist of M sinusoids of separate frequencies, which is written as [6].

$$S_m(t) = \sqrt{2P}\cos[2\pi(f_c + f_m)t + \emptyset_m] \ ,$$

$$0 \le t \le T_s, 0 \le m \le (M-1) \ldots\ldots\ldots\ldots\ldots\ldots \ 1$$

Where the carrier frequency is denoted by fc and the power of the transmitted signal is expressed as P, the frequency of the mth signaling tone are denoted by fm and random phase is associated θm of the mth signaling tone. So correlation between two signaling tones can be expressed as [6]

$$\rho_{ij} = \frac{1}{E_s}\int_0^{Ts} \left(S_i\,(t)S_j\,(t)\right)$$

$$= \frac{1}{E_s}\int_0^{Ts} \cos[2\pi(f_i - f_j)t] + \emptyset_i - \emptyset_j]dt \text{ ....2}$$

Where Es = PTs expressed the energy of the symbol, the frequency disjointing between tones i and j are denoted by fi and fj, and the random carrier phases linked associated with them are expressed by θi and θj respectively. Let suppose we transmit two signals Si(t)and Sj(t) which are orthogonal two each other as we know that these are prependicular to each other or other words they are at 90 angle to each other. So power energy of the signal I and j will be zero when the values of I and j are equal to it $0 \leq i \neq j \leq (M - 1)$. We need to separate these values of i and j express it as

$$f_i - f_j = \frac{n}{T_s} \text{ ……………………..…..3}$$

Now suppose the least frequency division of 1/Ts between two adjacent signal, so the set of equation for the frequency can be expressed as

$$\frac{0}{Ts}, \frac{1}{Ts}, \dots\dots\dots\dots.. \frac{M-1}{T_s} \quad n = 1,2,3 \dots\dots.. \quad \text{……………4}$$

Where bandwidth can be expressed as

$W_{MFSK} = \frac{M+1}{Ts}$ .Where WMFSK is in Hertz (Hz). Figure1 explains the basic concept of an MFSK system. Each MFSK symbol interval is linked with a signal tone which is denoted by one of the valid signaling frequencies.

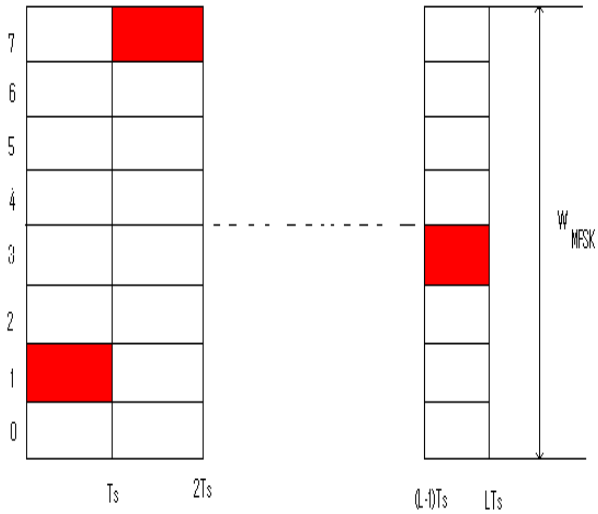

Figure1: Shows the representation of MFSK system

Assuming the mth tone is transmitted without noise in the signal so the output at the receiver can be expressed as

$$r(t) = \sqrt{2P}\cos[2\pi(f_c + f_m)t + \emptyset_m], \quad 0 \leq t \leq T_s \text{ ………………………………………….5}$$

For the non coherent signals the scientist preferred the maximum likelihood (ML) receiver because the receiver decided that which branch of the transmitted signal contain maximum energy in MFSK signals. As explain in the figure. It is important to have the carrier frequencies information, while the carrier phase is not important. Therefore we need to have non-coherent receiver.

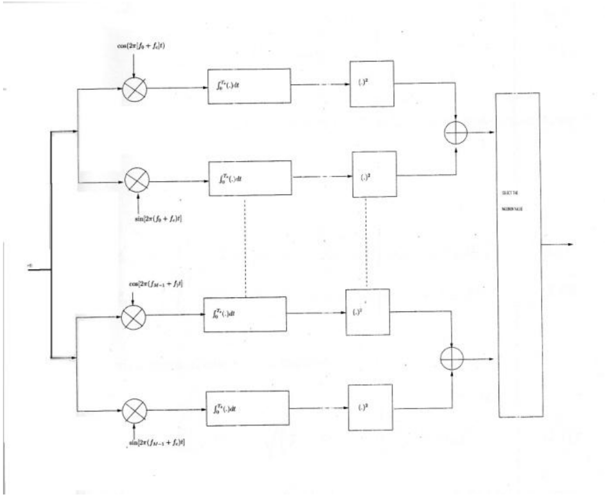

Figure2: shows the behaviour of the non coherent receiver

M number of decision variables which are estimated by the receiver on the basis of calculating the energy of the output signal according to the equation

$$Z_i = Z_{c,i}^2 + Z_{s,i}^2, \quad i = 0,1 \dots\dots (M-1) \text{………….6}$$

Where, $Z_{c,i}$ and $Z_{s,i}$ are given as

$$Z_{c,i} = \int_0^{Ts} r(t)\cos[2\pi(f_c + f_i)t] \text{………………..7}$$

$$Z_{s,i} = \int_0^{Ts} r(t)\sin[2\pi(f_c + f_i)t] \text{………………..8}$$

Putting the value of r(t) from 4 in the above equation, we get

$$Z_m = Z_{c,m}^2 + Z_{s,m}^2$$

$$= \left(\sqrt{\frac{\rho}{2}}T_s\cos\emptyset_m\right)^2 + \left(\sqrt{\frac{\rho}{2}}T_s\sin\emptyset_m\right)^2 \text{ ……9}$$

Where Es = PTs denotes the energy of the signal. So we can simply above equation as

$$Z_m = \begin{cases} \frac{E_s T_s}{2}, & i = m \\ 0, & otherwise \end{cases} \text{ …………………………10}$$

After getting all the desire results of the information we can expressed M as the variables of Z.So the final values can be expressed as Z_0, Z_1, ………, $Z_{(M-1)}$, so the largest among them is selected according to their energy level and then it is mapped to an M-ary symbol which is liked transmitted symbol. So, if there is any channel behavior it will not affects the signal because receiver will decided on the maximum energy power, so the estimated symbol might have small errors.

1.1 Frequency Hopping (FH) Systems

The number of times a FH system changes its frequency in a second is referred to as the hop rate [6,9]. On the basis of the relation between the hop rate and symbol rate, FH systems may be classified into two basic types [2,6,9]. Slow frequency hopping is one of the types, in which one or more data symbols are transmitted per frequency hop, therefore, if Th is the hop duration and defined by the scientist as the time for which one of the many possible frequencies is transmitted in a single channel, and Ts is the symbol duration, then in SFH systems, we have Ts = LTh and Rh= LRs, where Rh = 1/Th and Rs = 1/Ts which is the hop rate or the symbol rate respectively and L ≤ 1.

The second type of FH systems is constituted by the family of fast frequency hopping (FFH) [6]. In FFH, in contrast to SFH, a single data symbol is transmitted using several frequencies [2,9]. Hence, in FFH, the relationship between the hop duration Th and symbol duration Ts may still be represented by the same equation of Ts = LTh, but with L > 1. Therefore, in FFH, the frequency is hopped L times within one data symbol duration. This process may be viewed as the repetition of each symbol L number of times for a total duration of Ts [6].

1.2 FFH Assisted Non Coherent MFSK

We commence our discourse by outlining the basic philosophy of FFH assisted non-coherent MFSK systems in this section. A brief introduction to the principles of FFH-MFSK transmitter is presented followed by generating the orthogonal tones. Finally, the FFH-MFSK receiver is discussed in detail.

1.3 FH-MFSK Transmitter

In this technique, the carrier frequency is hopped across explicit values of legitimate frequencies under the behavior and response of a pseudo-noise (PN) series producer [2]. In FH systems normally non-coherent data modulation techniques are incorporated for the reason a times, it is hard and intricate to perceive carrier phase, so to estimate within the hop length, which is typically a small portion of the symbol period [2,6,9].

Therefore a non-coherent modulation phenomenon, in FH systems is MFSK [6]. Let us first consider a SFH transmitter using MFSK modulation.

1.1.1 SFH-MFSK Transmitter:

The operation of a SFH-MFSK transmitter may be understood by referring to figure below. The MFSK modulated signal **s**$\mathbf{s_m}(t)$ is modulated by a carrier $\cos(2\pi f_l t)$ having a frequency f_l, which is generated by a frequency synthesizer working under the influence of sequence called PN sequence.

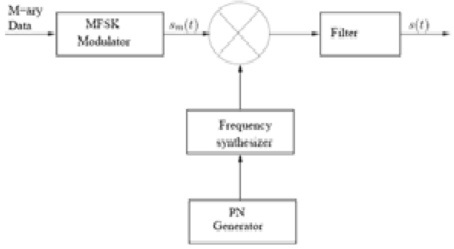

Figure 3 shows the MFSK Transmitter which works with PN Generator

The signal which is transmitted during one symbol duration may be expressed as

$$s(t) = \sqrt{2P}P_{Ts}(t - iT_s - lT_h)\cos\pi[f_m + f_l]t + \emptyset_m + \emptyset_l \text{..} 11$$

Where the power of the transmitted signal is denoted by P, the MFSK tone's frequency is fm, fl is the lth frequency in the FH sequence during the time interval lTh ≤ t ≤ (l+ 1) Th and Th explains the FH stay interval or the hop duration. PTs denotes a rectangular signaling waveform associated with one symbol duration and θ_m and θ_l represents the phase associated with lth hopping tone and mth MFSK respectively. In this treatise, we will refer to the transmitted or activated MFSK tone as the signal tone and all other (M−1) tones as non-signal tones.

In figure under discussion highlights the MFSK modulation incorporated in a SFH-SS system. In this form modulation is undertaken in the shape of diagrammatic form, in which various slots represents the hopping and Octal-FSK data modulation.

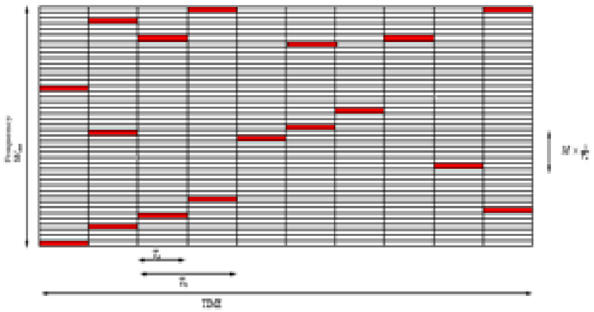

Figure 4:shows the graphical representation of SFH-SS signals using six frequency slots and 8-FSK data modulation signal,where two 8 FSK symbols are transmitted within one slot,i.e T_h=2T_s.The transmitted symbols are given by{0,3,7,6,1,7,4,4,5,7,2,5,4,7,4,4,7,3} assuming they take on values from{0,….7}.

Furthermore, it is implicit that the FH settle time Th is double the MFSK symbol duration Ts, i.e. we have Th = 2Ts, this equation shows that two Ts symbols are transmitted within each FH settle time. The above figure explains the manner how data is periodic sequenced in the set values which are shown in given set {0,4,7,6,1,7,4,4,5,7,2,5,4,7,4,4,7,3}.

1.1.2 1.3.2 FFH-MFSK Transmitter:

Now let us consider an FFH system where a particular MFSK symbol is transmitted with the assist of numerous FH frequencies. The system has the identical transmitter plan as the SFH system of figure above. However, in this kind of systems, we have L = Tf Tk < 1,where L denotes the value of an integer number and call as the diversity order of the system. So the L determines the number of times the symbol transmission is repeated.In the context of the FFH-MFSK, the transmitted signal during the ith symbol is written

$$s(t) = \sum_{l=0}^{L-1} \sqrt{2P}P_{th}(t - iTs - lTh)\cos[(2\pi(f_m + f_l)t) + \emptyset_m + \emptyset_l] \text{...} 12$$

Where all parameters are the same as defined by (11), but PTh(t) denotes a rectangular signaling waveform associated with one hop duration. The corresponding transmitted signal during the lth hops duration.

$$s(t) = \sqrt{2P}P_{Th}(t - iT_s lT_h)\cos[(2\pi(f_m + f_l)t) + \emptyset_m + \emptyset_l] \ldots\ldots\ldots\ldots\ldots\ldots\ldots 13$$

Note that in this paper we explain that FFH system L legimated values should be greater than one if not we are dealing with SFH system. The data modulation is used as shown in Figure. 2.7, where we assume that one 8-FSK symbol is transmitted using two FH slots, i.e. we assume that Ts = 2Th. The FH model used in figure below is the same as that used in figure SFH

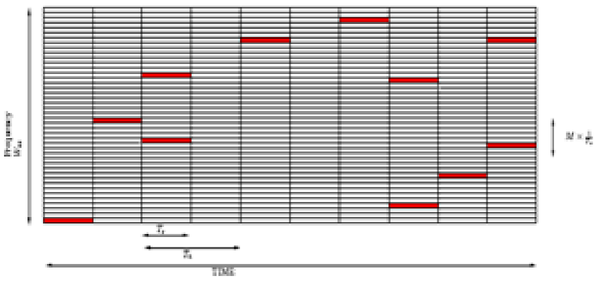

Figure 4 shows the Graphical representation of FFH-SS signals using 6 frequency slots and 8-FSK data modulated signal,where one 8-FSK symbols are transmitted within two slot i.e Th=2Ts.The transmitted symbols are given by {0,3,1,5,1,0,7,6,1,5,1} assuming they take on values from{0,…..7}

1.2 Performance of FFH in AWGN Channel

In this section we will be dealing with the effect of AWGN channel in FFH. AWGN channel model is the one in which the input signal is altered by the linear addition of white noise [9]. White noise has a flat power spectral density which covers all frequency components [9]. Amplitude of the white noise follows a guassian or normal guassian distribution which seems to be like a bell shaped continuous probability distribution defined by the first and second moments, mean and variance respectively [9]. So the transmitted signal is degraded by AWGN noise, and the final signal received at receiver can be given as

$$r_1(t) = \sqrt{2P}\cos[2\pi(f_m + f_l)(t - \tau) + \emptyset_m] \ldots\ldots 14$$

.

Where $n_m(t)$ is zero mean AWGN having a power $\boldsymbol{\sigma_N}^2$ = BNO, NO is the power spectral density of the AWGN, FH tone bandwidth is given by B = 1/Th. The signal noise ratio may be expressed as Eb/NO where Eb = Es/b is the energy per bit, b = log2(M). M is the modulation index. While Es = PTs is the energy per transmitted symbol. Similarly Eh = Es/L = PTh may be defined as the energy per symbol per hop

$$E_s = E_b \log_2(M)$$

$$E_s = LE_h$$

$$E_b = \frac{LE_h}{\log_2(M)}$$

Let us now investigate the no coherent detection of the signal contaminated by AWGN .In the square law detector of Figure below, the received signal is multiplied in parallel by both the sine and cosine of the MFSK tone.

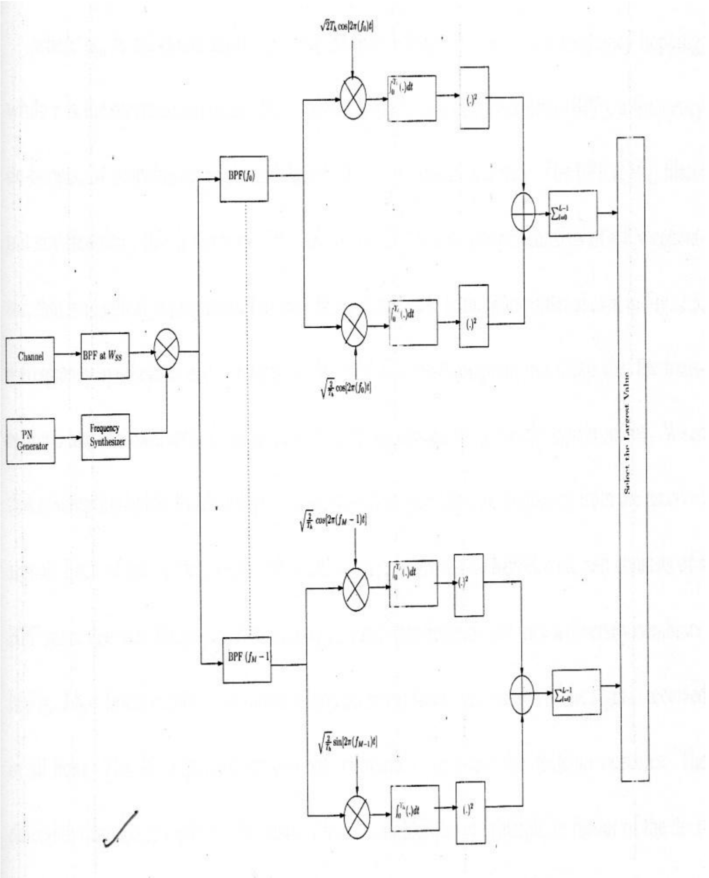

Figure 5 shows the block diagram of FFH Assisted Non-Coherent MFSK Receiver using Linear Combining schemes

More precisely, the square law detector consists of two branches, one where the input signal is multiplied by p2/Th cos(2_fmt) and the other where it is multiplied p2/Th sin(2_fmt). The products are integrated over the duration of one hop in the two separate correlators. Thus, assuming that the first tone m = 0 is the transmitted one and using the expression for the de hopped signal from (10), we can yield of the cosine based correlator as

$$r_{o,c} = \int_0^{T_h} r_o(t)\sqrt{\frac{2}{T_h}}\cos(2\pi f_0 t) = \sqrt{PT_h}\cos\theta_o + n_{o,c} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 15$$

Where n_{0c} represents the outputs of the cosine based correlator corresponding to the first tone, when AWGN n(t) is present at its input. Similarly, the output of the correlator corresponding to the sine branch is given by

$$r_{o,s} = \int_0^{T_h} r_o(t)\sqrt{\frac{2}{T_h}}\sin(2\pi f_0 t) = \sqrt{PT_h}\sin\theta_o + n_{o,s} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 16$$

Where $n_{o,s}$ represent the outputs of the sine based correlator corresponding to the first tone, when AWGN n(t) is present at its input. The sine and cosine components are squared and added to yield a variable corresponding to the m tone during the lth hop, which denoted here by Uml, can be expressed as

$$U_{o,l} = (r_{o,c})^2 + (r_{o,s})^2 = PT_h + n_o = E_h + n_o \ldots 17$$

Where $\mathbf{n_0} = \mathbf{n_{oc}}^2 + \mathbf{n_{os}}^2$ are the AWGN components respectively and this output is at the square law detectors. So it corresponds to the transmitted signal tone. For the remaining (M−1) square law detectors that correspond to non-signal tones, it can be justified that the output consists of superposition of thermal noise. Thus we have

$$U_{m,l} = U_m \qquad ,m > 0 \text{.................................} 18$$

If the noise is present in the signal it will effect the signal energy also

$$U_{o,l} = E_h + n_o \text{..} 19$$

So in the context of FFH systems, the probability of all hops experience noise and jamming. But jamming is low. Therefore in comparison to SFH, FFH is more robust against AWGN [28,29]. Nevertheless, AWGN can still degrade the performance of the FFH receiver employing linear combining.

1.3 FFH Transmitter

In this section we will deal with the explanation and example of FFH in transmitting and receiving the signal according to my project. The main theme to use FH and MFSK modulation schemes is to obtain and consume better available frequency bandwidth.let consider that we have the transmitted sde like this as shown in figure below

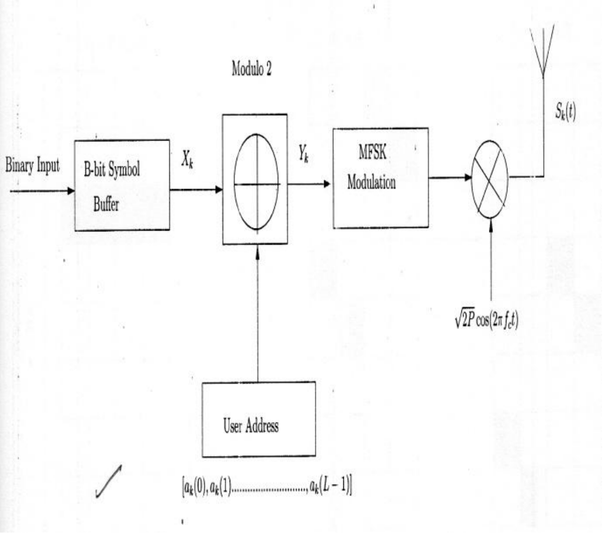

Figure 6 shows the transmitter schematic of FFH, which works with unique address expressed as User address.

In FFH systems, every user is allogated by a unique plain mark. This pattern in FH is referred as an address code, this code differ from every different users which are present in that bandwidth. So this is the possibilities that interference among each user is different and there is very less chance of interference between two users. In MFSK signaling period is denoted by Ts seconds, let suppose we have 'b' message bits to send by k-th user so the given date rate can be expressed by Rb. Now these bits are encumbered into a n-bit symbol represented by Xk, where all values belongs to the set of Xk and all elements present in Xk have the values between the [0,M till 2n]. Where the output bit n can be expressed by the symbol rate Rs=Rb/n.This shows how much data is send. In the site of communication FH frequencies have same values of MFSK modulation, so we can say that Q = M = $2^{\mathbf{n}}$ where n = 1, 2, 3, and so on. Let suppose that n = 2 so Q = M = 4. Besides that L = Tf/Tk and L = 4, than the user's address code is this [4,3,7,6] which shows that address code is unique for each user and the signal which is send and symbol values taken for the given condition is 5.Symbol values are denoted by Xk in majority books. Let suppose we have k-th user and it starts from 1 till K, so we can expressed it as their address code as $1 \leq k \leq K$ and address code can be written as ak =[ak(0), ak(1), ak(2).....ak(L − 1)], Where ak(l) ε GF(M) and l =0, 1,……… , L − 1 this can be seen by the study of math's sets and GF(M) denotes Galois field having a finte number of elements of M =2^n. Then the output of each user can be written as yk(0),yk(1) and so on. Total output can be written as Yk =yk(0), yk(1), yk(2)……y(L-1).Therefore kth user transmission bits can be expressed by

$$Y_k = [y_k(0), y_k(1), \dots \dots, y_k(L-1)] = X_k l \oplus a_k \text{..} 20$$

Furthermore $\oplus$ denotes the addition operation in GF(M).Let suppose we have user address is [4, 3, 7, 6] and Xk is our input signal so Yk will be [9,812,11] so mode 2 will do it as [1,0,4,3] which is shown in figure below.

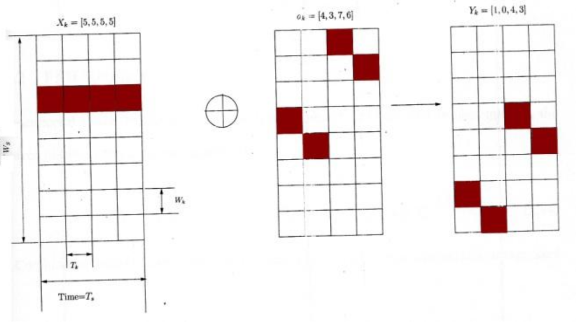

Figure7 shows the graphical representation of FFH system,where Xk denotes transmitted bits and ak denotes user address

He $Y_k = X_k l \oplus a_k$nce. These values are just assumed in practical X_k and a_k can be changed as they are randomly generated. Finally the modulated signal is transmitted using carrier frequency fc. So the kth user's transmitted signal with M-ary symbol of Xk during a symbol time interval as

$$s(t) = \sqrt{2P} P_{Th}(t - iT_s - lT_h) \cos\left[2\pi\left(f_c + f_I^{(k)}\right)t\right] + \quad \theta_I^{(k)} \text{..} 21$$

Where the transmitted power is denoted by P, PTh(t) is the rectangular pulse-shaped signal waveform with respect to chip time interval and $\theta_l^{(k)}$ denoted the phase which occur due to MFSK and by a carrier signal.

1.4 FFH Receiver

As mentioned above that the symbol interval mth tone is transmitted and the received signal without noise can be expressed as

$$r(t) = \sqrt{2P} cos[2\pi(f_c + f_m)t + \emptyset_m], 0 \leq t \leq T_s \quad \text{…} 22$$

Combination with kth user's transmitted signal the received signal can be expressed as

$$r(t) = \sum_{l=0}^{L-1} \sqrt{2P} P_{Th}(t - iT_s - lT_h - \tau_k) \cos\left[2\pi\left(f_c + f_l^{(k)}\right) t + \emptyset_l^{(k)}\right] \text{……………………………………23}$$

Where τk denotes the time delay of the kth user. Now if the noise is introduced, now the signal is distorted by the unwanted or undesirable signals which are random and unpredictable..External noise are generated by channels which are nearby like faults in connected switches or by the sources which are present near the equipment which are present in the labs at that time such as fluorescent lights or natural noise from lightning as well as electrical storms and solar and intergalactic radiation. We can reduce or even minimized the external noise. Internal noise is generated by thermal motion of electrons in conduction or diffusion process, so if proper attention is given we can minimize its effect. Noise is one of the basic factors that set limits on the rate of communication. So, the result of AWGN is to directly add the noise to the signal. When noise has uniform psd (Power Spectral Density) than the noise is called "white" noise. Therefore, due to the relationship between the autocorrelation and psd, it can be seen that any two diverse samples of a white noise is uncorrelated. So the received signal after the noise will be

$$r(t) = \sum_{l=0}^{L-1} \sqrt{2P} P_{Th}\,(t - iT_s - lT_h - \tau_k) \cos\left(2\pi\left[f_c + f_l^{(k)}\right] t + \emptyset_l^{(k)}\right) + n(t) \text{……………………………24}$$

Where n(t) represents the additive white guassian noise. The corresponding structure of the receiver for FFH signal, will be the inverse of the transmitted side like in other communication system as shown in figure below

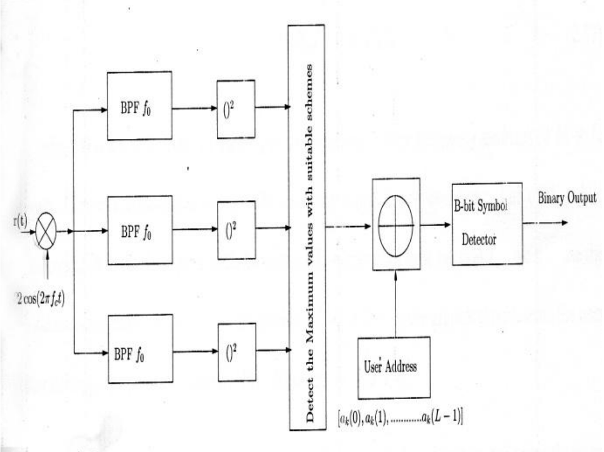

Figure 8 shows the receiver schematic of FFH, which works with maximum values with suitable schemes

From the above figure the received signal first multiple by the carrier frequency for a down conversion to the FH band. Next step is to detect the energy of a signal through energy detectors and matched to the M-frequency tones of the MFSK stage which can help to convert the signal back which is term as down converted signal. The detection interval is matched with the chips of FH desired user. The M energy detectors will provide a M ×L output when there are L chips each symbol time interval will corresponding to M-ary symbol interval of Ts seconds. So if we can do energy detection in all L chips than the sequence of Y_k can be detected properly. In order to get our original signal we perform modulus two operation in which we subtracts from the user addresses a_k of the k user from Y_k chip. This is expressed by this equation

$$Y_k - a_k = X_k l + 0 = X_k l \text{………………………………25}$$

Where 0 is null vector of the length L. By means of time frequency matrices of M × L,where M rows correspond to the M-FSK frequency stages during each bandwidth of W_h while L correspond to the L chips in each duration of Th per symbol time interval Ts. We still use the same user-address as used at transmitted side.For all elements of time frequency matrix received signal should be detected correctly when there is no noise or we have noiseless channel. The matrix Y_k are activated by Y_k = [1, 0, 4, 3] and the corresponding address signal is given by a_k = [4, 3, 7, 6] the transmitted symbol X_k can be given as

$$X\_k = Y\_k - a\_k = [1,0,4,3] - [4,3,7,6] = [-3,-3,-3,-3] = [5,5,5,5] \text{……………………………26}$$

2. LINEAR DIVERSITY COMBINING TECHNIQUES

This section discusses the basic principles of the diversity combiner referred to as the linear diversity combiner that forms part of the FFH assisted MFSK receiver. As mentioned earlier, this scheme used outputs of the square-law detectors so each received hops have the values of the previous hops values. Thus for each of the receiver branch corresponding to an MFSK tone, a decision variable can be given as [6]
Upon completing L hops where the output of the square-law detector is denoted by Uml which shows that how the lth hop in a time period. As mentioned above, the outputs Zm, m = 0, 1… , (M−1) of all the M combiners constitute the detection decision variables.

2.1 Optimum Combining Or Maximum Ratio Combining

In the context of the first category, referred to as the optimum combining (OC) or maximum ratio combining (MRC), the signals received in various diverse paths are weighed in proportion to the gains of the individual paths before they are combined [36]. This scheme is considered to be the optimum, since it caters for the channel impairments imposed on the signal in each individual path [37]. However, it requires the knowledge of the channel gains [6]. Another category is referred to as the selection or switched combining (SC), in the context of which the Receiver chooses the path yielding the maximum SNR [38]. This scheme gives reasonably good performance but results in poor performance under low SNR conditions. Finally, in the context of EGC, the signals in all the diverse paths are merely summed without any weightage [39, 40]. We can see that EGC is another name for linear combining discussed above. In fact, majority of the non-linear diversity combining schemes we will consider in this section may be deemed as sub-classes of the EGC scheme, since they operate without applying any weights to the various received signals. Indeed, some of them do apply various de-emphasis mechanisms but they are not based on the knowledge of the channel gains. This is attractive from the viewpoint of implementation in non-coherent FFH-MFSK receiver where channel estimation may not be feasible.

2.2 Results of FFH in AWGN Channel

In this section we will discuss the results of diversity schemes which depends on EGC and SC scheme. Let us look into them in detail.

2.2.1 Increasing the M in both schemes

In this part of the paper we will explain our results regarding the effect of M when using EGC and SC. Figure 10 and figure. 11 show the effect of increasing M when employing EGC and SC receiver. From figure 10 and figure 11 it can be concluded that as value of M increases the BER performance of the FFH system improves. Furthermore, it can be concluded that performance of both the receivers are equivalent.

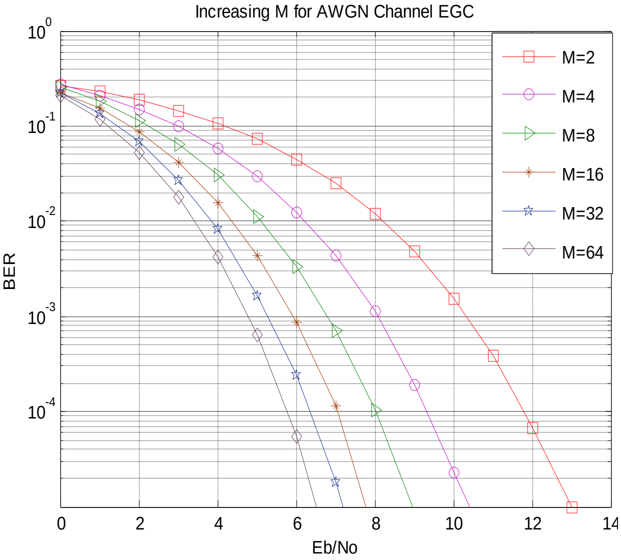

Figure 10 :This figure shows that increasing M the performance become better

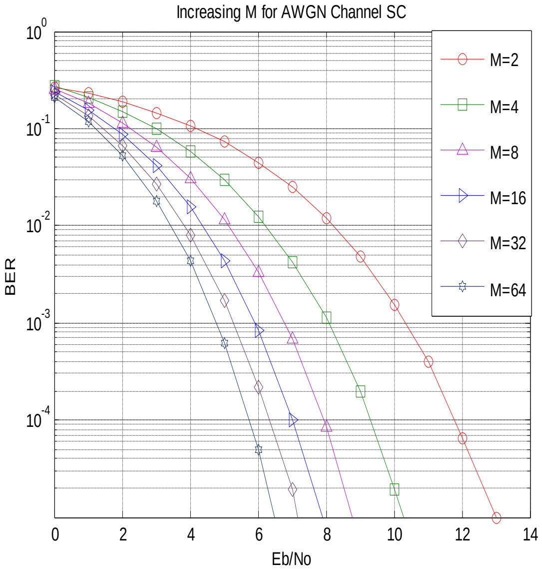

Figure 11:This figure shows that increasing M shows that performance in SC when M increases the performances of BER becomes better.

2.2.2 Increasing the L in both schemes

In this section we will discuss the effect of L using EGC and SC. Figure 12 and figure. 14 shows the effect of employing EGC receiver when the value of M = 2 and M = 4, respectively. From figure. 12 and figure. 14 it can be observed that the BER performance of the EGC receiver degrades as the value of L increases. Figure 13 and figure 15 shows the effect of employing SC receiver when the value of M =2 and M = 4, respectively. From figure. 2.18 and Figure. 2.20 it can be observed that the BER performance of the SC receiver degrades as the value of L increases.

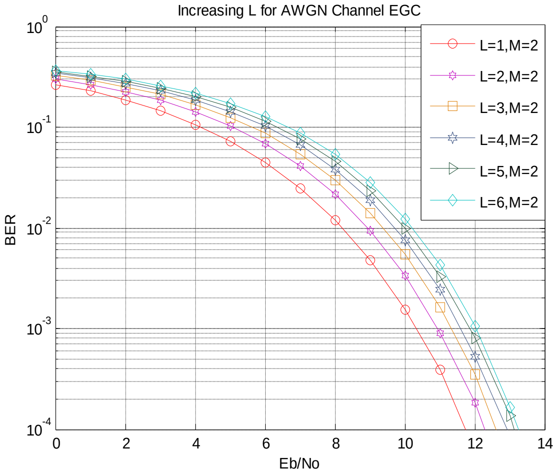

Figure 12: BER versus SNR per bit performance of EGC scheme when using FFH-MFSK system.

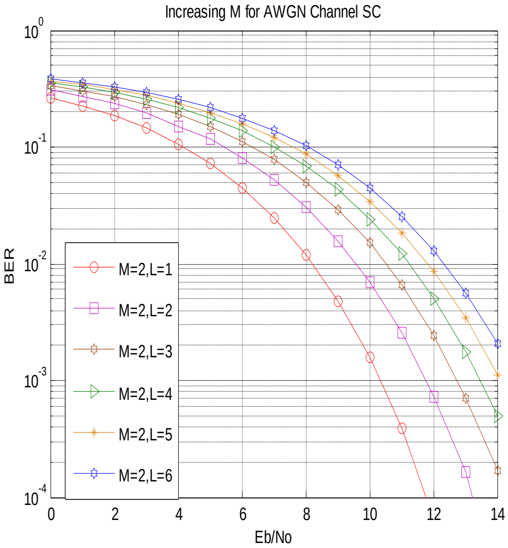

Figure 13: BER versus SNR per bit performance of SC scheme when using FFH-MFSK system.This sernio looks bad as compared with EGC.

Relation with figure. 14 and figure 15 which shows that the EGC receiver out performs better than SC receiver for the same value of L. So in an environment where the value of M is constant and the value of L is increased it might be useful to employ EGC receiver. Furthermore, a gain of 2-dB’s can be observed for M = 4, L = 6 when employing EGC receiver as compared to SC receiver.

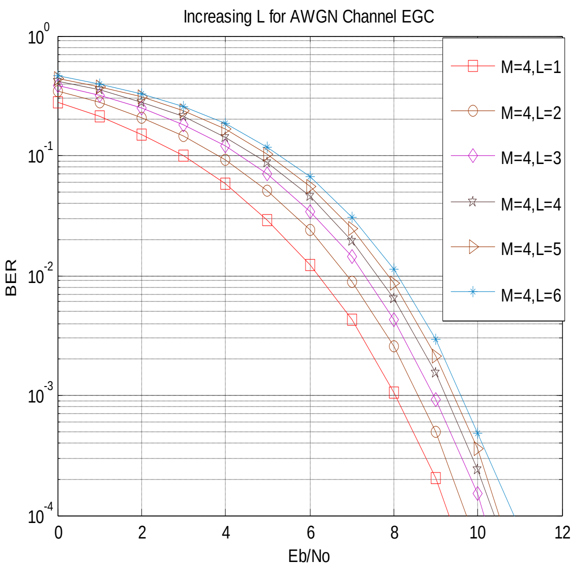

Figure 14: BER versus SNR per bit performance of EGC scheme when using FFH-MFSK system.

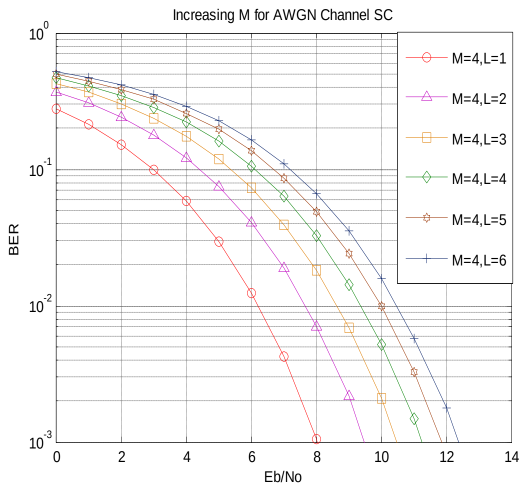

Figure 15: BER versus SNR per bit performance of SC scheme when using FFH-MFSK system.

2.2.3 Increasing the K in both schemes

In this part we will explain the effect of K in EGC and SC schemes. Figure 16 and figure 17 show the effect of increasing K when employing EGC and SC receiver. From the figure 16 and figure 17 it can be accomplished that as value of K changes in ascending order the BER output of the FFH system decreases as the receivers does not have the capability to remove multiuser interference.

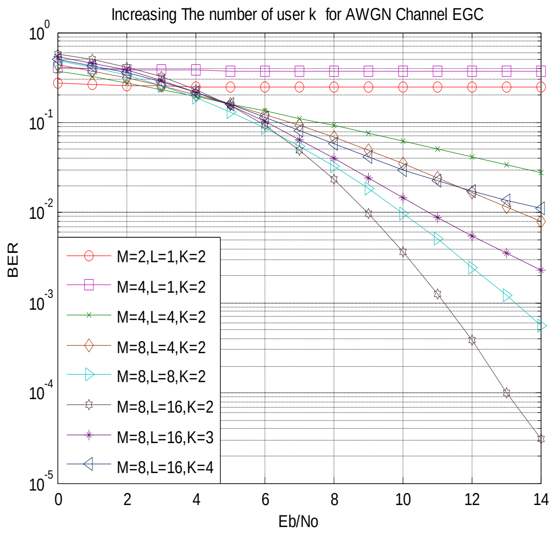

Figure 16: BER versus SNR per bit performance of EGC scheme when using FFH-MFSK system.

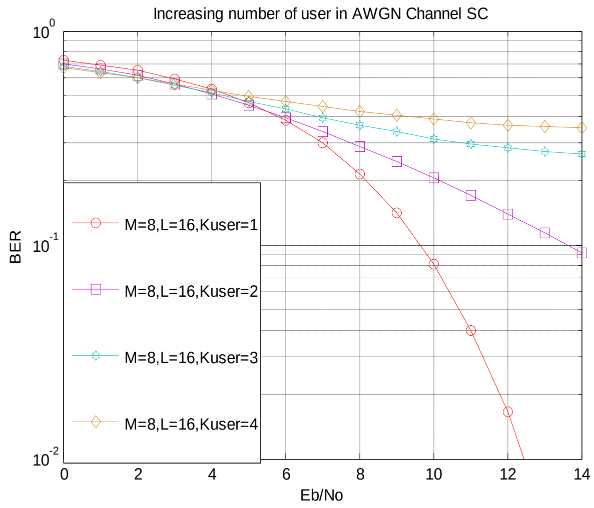

Figure17 : BER versus SNR per bit performance of SC scheme when using FFH-MFSK system

2.3 Conclusion

This paper begins by explaining in detail of the fast frequency hopping system and scheme, the difference between slow frequencies hopping. The paper investigates the performance of the linear combination schemes in AWGN channel and the effect of M,L and k-user between EGC and SC. It seems that these schemes have the same performance in AWGN channel.

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