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M-FSK in Multi Coding and Channel Environments

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Abstract— ***Frequency-shift keying (FSK) is a frequency modulation scheme in which digital information is transmitted through discrete frequency changes of a carrier wave currently used by manufacturers of low power low data rate data transmission equipment. The power efficiency of this modulation increases as the signal alphabet increases at the expense of increased complexity and reduced bandwidth efficiency. Most early telephone-line modems used frequency-shift keying (FSK) to send and receive data at rates up to about 1200 bits per second. In this paper M-FSK have been tested under multi-channel environments AWGN, Rayliegh fading and Risian fading channels in term of BER with coherent and non- coherent demodulation and deferent Size of modulation constellation, Improving techniques used to enhanced the performance of the system under AWGN where convolutional code with hard and soft decision, extended Golay code and Reed-Solomon code, the ratio of energy in the specular component to the energy in the diffuse component (linear scale) and diversity used to improve the performance under Rayliegh and Risian fading channels.***

Index Terms- M-FSK, FSK with matlab, M-FSK coding, multi-channel.

I. INTRODUCTION

M-ary frequency shift keying (FSK) is a power efficient modulation scheme whose efficiency improves as the number of frequencies employed (M) increases at the expense of additional complexity and smaller bandwidth efficiency[1,2]. This scheme has been found advantageous in low rate low power applications, low noise,since amplitude is constant, operates in virtually any wires available , used in long distance communication , easy to decode and good sensitivity[1,2]. The major disadvantage is its high bandwidth requirement Therefore FSK is extensively used in low speed modems having bit rates below 1200 bits/sec. The FSK is not preferred for the high speed modems because with increase in speed, the bit rate increases. This increases the channel bandwidth required to transmit the FSK signal. As the telephone lines have a very low bandwidth, it is not possible to satisfy the bandwidth requirement of FSK at higher speed. Therefore FSK is preferred only for the low speed modems[1].

II. M-FSK MODEL (TRANSMITTER)

The model built by matlab simulink 2015, figure (1) shows the transmitter of FSK modulation where two carrier frequencies used, carrier for 1's and other for 0's.

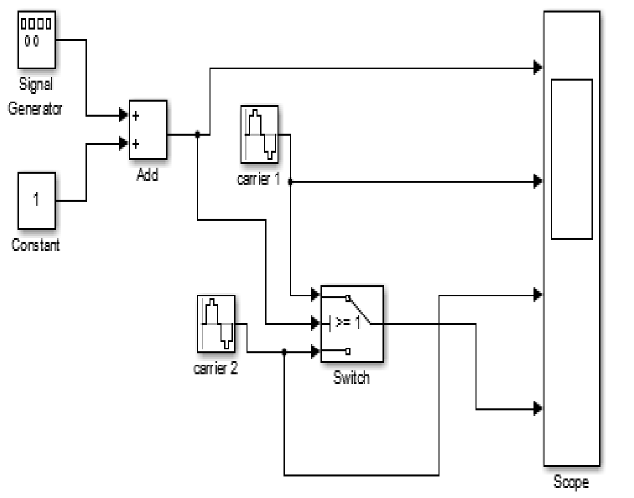

Figure (1): FSK transmitter.

Information, carriers and FSK signal is shown in figure (2) that taken from scope in figure.

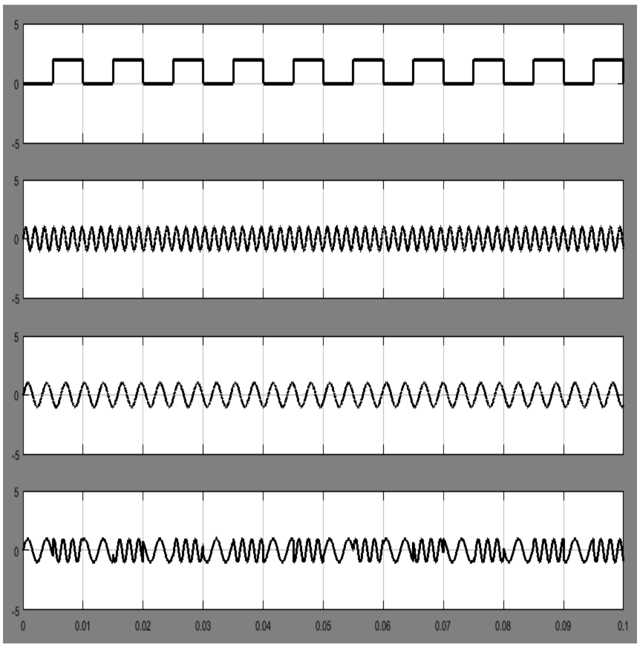

Figure (2): information, carrier of 1's, carrier 0's and FSK signal

FSK system transmitter and receiver shown in figure (3) , where FSK signal multiplied by the two carriers, amplified by gain and passed throw integrator to recovered the original signal as shown in figure (4).

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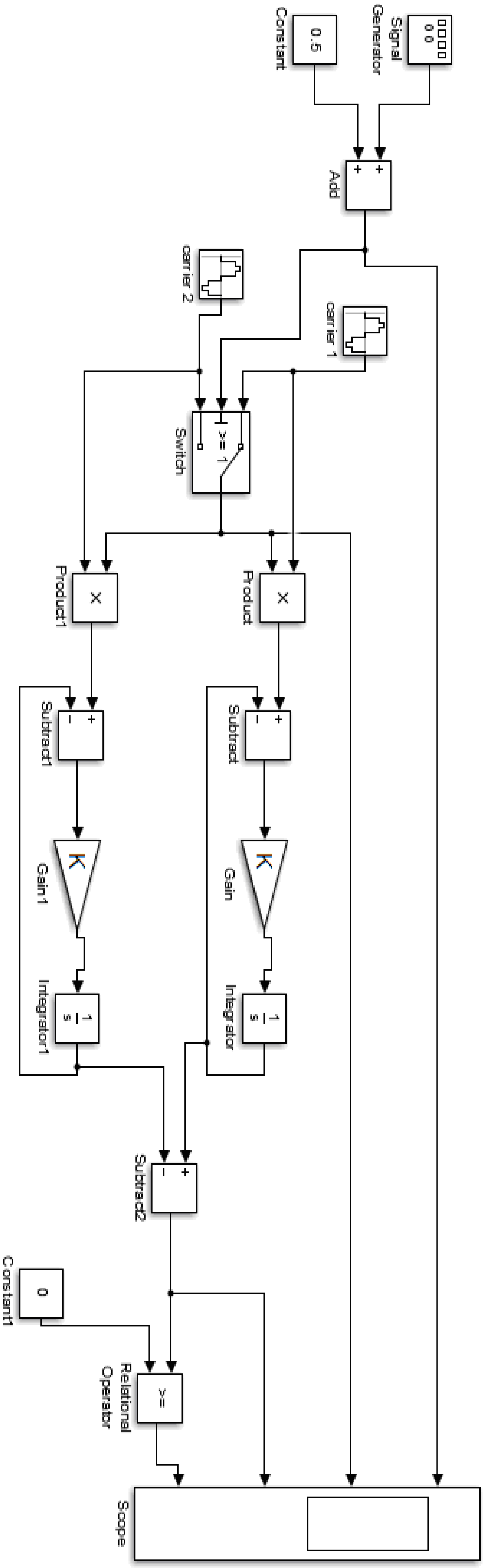

Figure (3): FSK system, transmitter and reciever

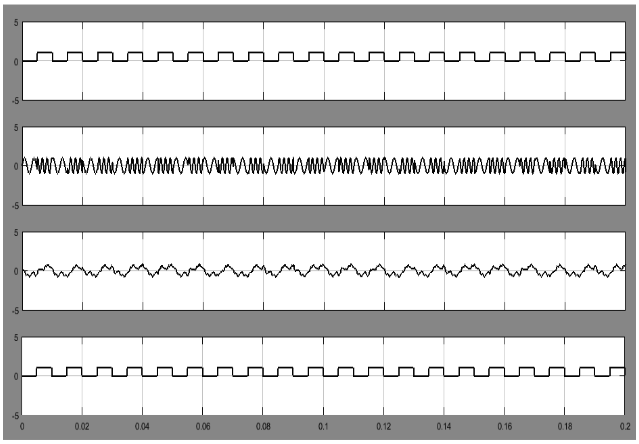

Figure (4): Information, FSK signal, Integrator signal, Recovered information signal

III. BER MATHEMATICAL CALCULATION OF M- FSK SYSTEM

1. M- FSK with Coherent Detection in AWGN channel. From equation in [1] and equation in [2]:

$$P_S = 1 - \int_{-\infty}^{\infty} \left[Q\left(-q - \sqrt{\frac{2kE_b}{N_o}}\right)\right]^{M-1} \frac{1}{\sqrt{2\pi}} exp\left(-\frac{q^2}{2}\right) dq \quad (1)$$

$$P_b = \frac{2^{k-1}}{2^k - 1} P_S \quad (2)$$

Where

P_s :Symbol error rate (SER)

P_b :Bit error rate (BER)

M : Size of modulation constellation

K :Number of bits per symbol → k= $\log_2$ M

$\frac{E_b}{E_0}$: Energy per bit-to-noise power-spectral-density ratio.

2. M-FSK with Noncoherent Detection in AWGN channel. From equation in [1] and equation in [2]:

$$P_S = \sum_{m=1}^{M-1} (-1)^{m+1} \binom{M-1}{m} \frac{1}{m+1} exp\left[-\frac{m}{m+1}\frac{kE_b}{N_o}\right] \quad (3)$$

$$P_b = \frac{1}{2}\frac{M}{M-1} P_S \quad (4)$$

3. M-FSK with convolution code:
   - Soft Decision. From equations and in [1], and equations in [3]:
   -

$$P_b < \sum_{d=d_{free}}^{\infty} a_d f(d) P_2(d) \quad (5)$$

With transfer function

$$T(D,N) = \sum_{d=d_{free}}^{\infty} a_d D^d N^{f(d)} \quad (6)$$

$$\left.\frac{dT(D,N)}{dN}\right|_{N=1} = \sum_{d=d_{free}}^{\infty} a_d f(d) D^d \quad (7)$$

Where *f(d)* is the exponent of *N* as a function of *d*.

$$P_2(d) = P_b|_{\frac{E_b}{N_o} = \gamma_d R_c d} \quad (8)$$

Where:

d :distance

p: is the bit error rate (BER) in an uncoded AWGN channel

γ_d : Energy-per-information bit-to-noise power- spectral-density Ratio.

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R_c : code rate → $R_c = \frac{k}{N}$, k is message length, N is code length

- Hard Decision. From equations in [1], and equations in [3]:

  $P_b < \sum_{d=d_{free}}^{\infty} a_d f(d) P_2(d)$ (9)

  where

  $P_2(d) = \sum_{k=(d+1)/2}^{d} \binom{d}{k} P^k (1-p)^{d-k}$ (10)

  When d is odd, and

  $P_2(d) = \sum_{k=(d+1)/2}^{d} \binom{d}{k} P^k (1-p)^{d-k} + \frac{1}{2}\binom{d}{d/2} P^{d/2}(1-P)^{d/2}$ (11)

  When d is even (p) is the bit error rate (BER) in an uncoded AWGN channel.

- AWGN with hamming code Hamming code in [4], and in [5]:

  $P_b = \frac{1}{N}\sum_{m=2}^{N} m \binom{N}{M} p^m (1-p)^{N-m} = p - p1-pN-1$ (12)

- Extended Golay code in [4],[3]:

$P_b \le \frac{1}{24}\sum_{m=4}^{24} \beta_m \binom{24}{m} p^m (1-p)^{24-m}$ (13)

  Where βm is the average number of channel symbol errors that remain in corrected N-tuple when the channel caused m symbol errors [4].

- Reed-Solomon code with $N = Q - 1 = 2^q$ [4],[1],[5],[3]

  $P_b = \frac{1}{q}\frac{1}{N}\sum_{m=t+1}^{N} m \binom{N}{M} (P_s)^m (1-P_s)^{N-m}$

  (14)

  Otherwise,

  If $\log_2 Q / \log_2 M = q/k = h$ where h is an integer (equation in [6])

  $P_s = 1 - (1-s)^h$ (15)

  Where s is the symbol error rate (SER) in uncoded AWGN channel.

- M-FSK in rayliegh fading channel [1,2,7,8]

  $P_s = P_b = \frac{1}{2^L}\left(1 - \sqrt{\frac{\bar{\gamma}}{2+\bar{\gamma}}}\right)^L \sum_{k=0}^{L-1} \binom{L-1+k}{k} \frac{1}{2^k}\left(1 + \sqrt{\frac{\bar{\gamma}}{2+\bar{\gamma}}}\right)^k$

  (16)

  Where

  L : diversity branch

  M_{γ_l} : Moment generating functions for each diversity branch

  For Rayleigh fading:

  $M_{\gamma_l}(s) = \frac{1}{1 - s\,\overline{\gamma_l}}$ (17)

4. M-FSK in rician fading channel [1,2,7,8]

$$P_s = \sum_{r=1}^{M-1} \frac{(-1)^{r+1} e^{-\frac{LK\bar{\gamma}_r}{(1+\bar{\gamma}_r)}}}{(r(1+\bar{\gamma}_r)+1)^L} \binom{M-1}{r}^r$$

$\sum_{n=0}^{L-1} \frac{\Gamma(L+n)}{\Gamma(L)} \left[\frac{1+\bar{\gamma}_r}{r+1+r\bar{\gamma}_r}\right]^n F_1 \Big(L + n,L;LK\gamma r/1+\gamma rr1+\gamma r+1$

(18)

$P_b = \frac{1}{2}\frac{M}{M-1} P_s$ (19)

$\bar{\gamma}_r = \frac{1}{1+K}\bar{\gamma}$ (20)

$\beta_{nr} = \sum_{i=n-(L-1)}^{n} \frac{\beta_{i(r-1)}}{(n-i)!} I_{[0,(r-1)(L-1)]}(i)$ (21)

$\beta_{00} = \beta_{r0} = 1$

$\beta_{n1} = \frac{1}{n!}$

$\beta_{1r} = r$

And $I_{[a,b]}(i) = 1$ if $a \le i \le b$ and 0 otherwise.

Where K is the ratio of energy in the specular component to the energy in the diffuse component (linear scale).

For identically-distributed diversity branches:

$M_{\gamma_l}(s) = M_{\gamma}(s)$ for all l.

IV. M-FSK IN AWGN RESULTS

1. Multi order in FSK coherent demodulation.

Figure (5) shows BER of Multi order FSK in AWGN with coherent demodulation. It is clear from the results that as order of modulation increased BER will decrees, as increased order from 2-32 BER 10^{-8} and the gain Eb/Eo reached to 5.8 dB.

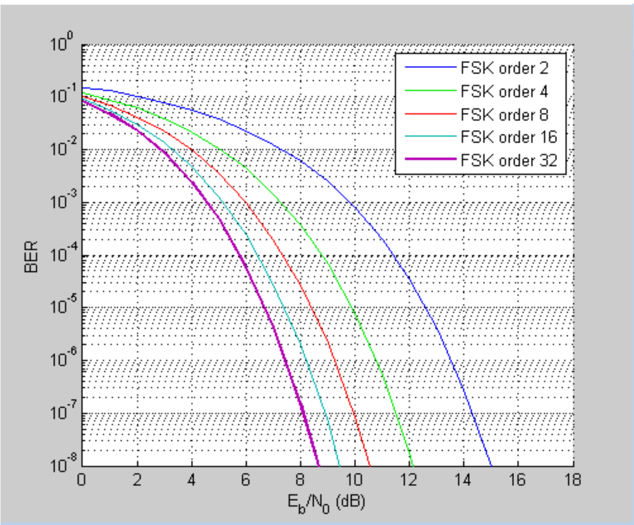

Figure (5): BER of Multi order FSK in AWGN with coherent demodulation.

2. Figure 6 shows BER results of FSK in AWGN with multi order coherent and non-coherent demodulation, from the figure non coherent demodulation increases BER as compared with coherent modulation at the same order and Eb/Eo. As order increased in non-coherent demodulation BER decreased as in coherent demodulation, the gain in Eb/Eo 0.5 dB with coherent over non coherent demodulation with BER 10^{-8}.

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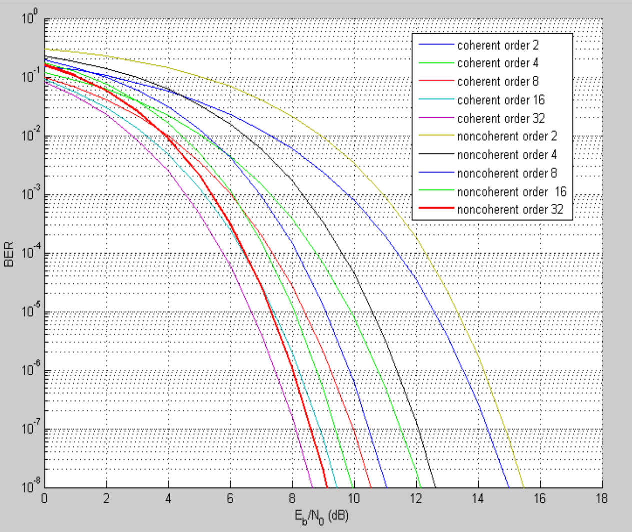

Figure (6) Multi order FSK in AWGN with coherent and non- coherent demodulation.

3. FSK in AWGN with convolutional code.

BER of FSK system in AWGN channel shown in figure 7, convolution code used with hard and soft decision in order to reduce BER performance of the system. The results shows that BER will be reduced from $6*10^{-3}$ to 10^{-3} at hard decision and to $3*10^{-6}$ at soft decision when Eb/Eo equal to 8 dB, the gain in Eb/Eo when BER 10^{-8} equal to 6 dB.

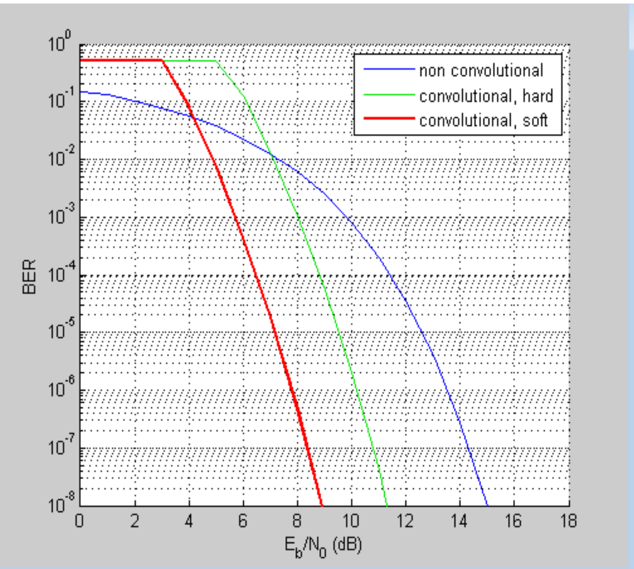

Figure (7) FSK in AWGN with convolutional code (Hard and soft decision)

4. FSK in AWGN with Hamming, Golay and reed Solomon code.

Three type of codes used to reduced BER in AWGN, figure 8 shows BER of Hamming, Golay and reed Solomon in FSK with AWGN channel, Reed Solomon code was the best code among the three types reduces BER from 3*10^-5 to 5*10^-8 at 12 dB Eb/Eo.

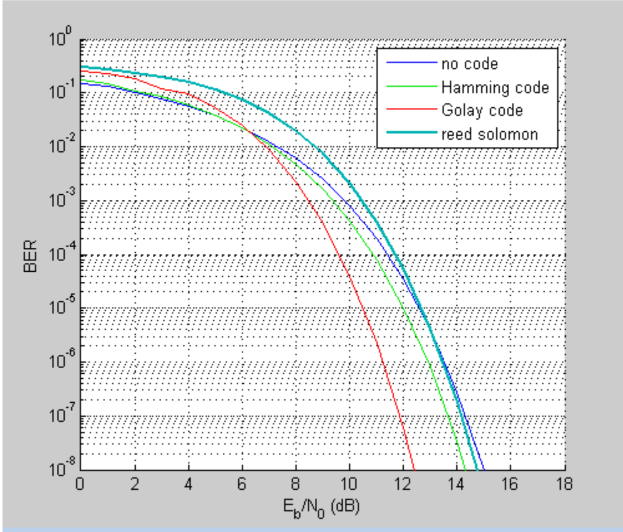

Figure (8): FSK in AWGN with Hamming, Golay and reed Solomon code.

5. FSK in Rayleigh with multi diversity order.

By increasing diversity order BER of FSK system in Rayleigh channel will be increased, as diversity increased from 1 to 4 BER decreased from $0.5*10^{-3}$ to $4*10^{-8}$ at 25 dB of Eb/Eo, the gain in Eb/Eo will be 14 dB as shown in figure 9 and 10.

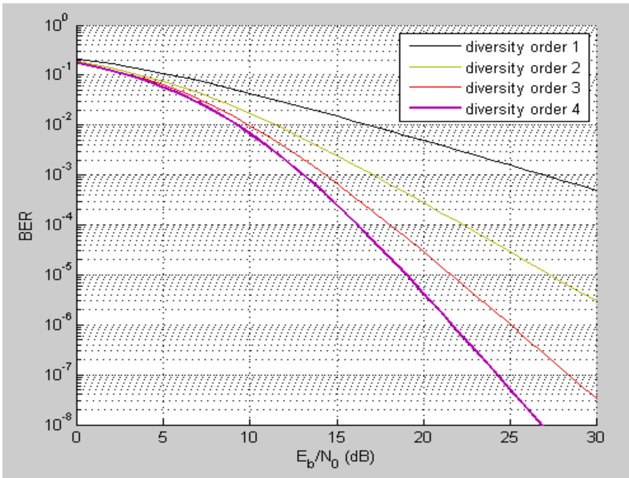

Figure (9): FSK in Rayleigh with multi diversity order

6. FSK in rician channel with multi diversity order.

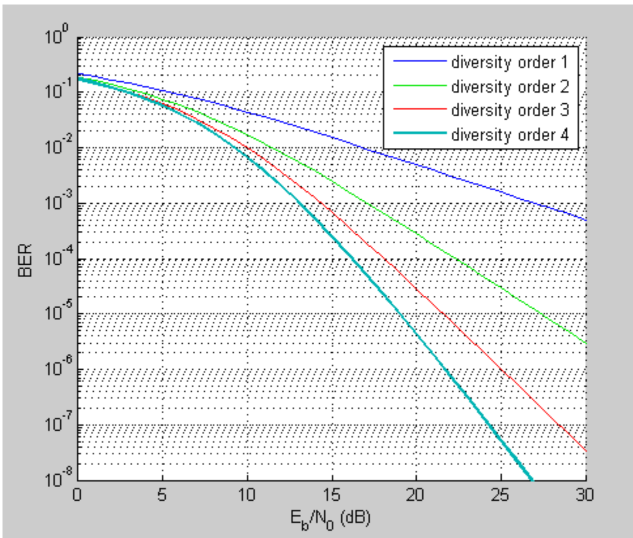

Figure (10): FSK in rician channel with multi diversity order.

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7. FSK in Rician channel with deferent diversity order and k factor.

By increasing diversity order and K factor BER of the system will be decreased as shown in figure 11, the gain in Eb/Eo as k- factor increased from 0 to 3 is 7dB.

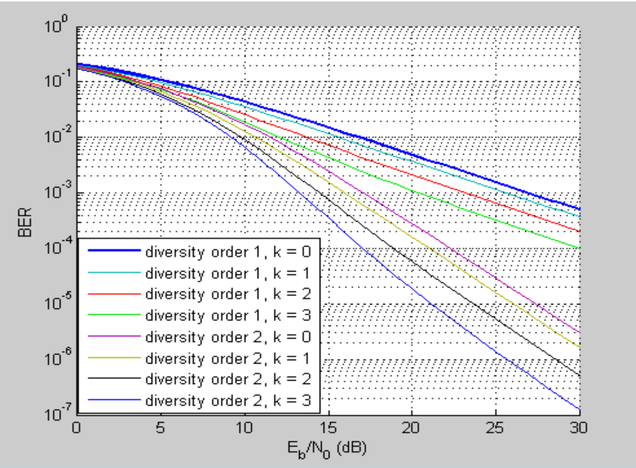

Figure (11): FSK in Rician channel with deferent diversity order and k factor.

V. CONCLUSION

This paper focus on M-FSK modulation and demodulation, where the system design and implemented using Matlab Simulink and then tested under AWGN, rayeigh and rician fading channel, M-FSK in AWGN can be improved by increasing modulation order where the gain in Eb/Eo will be 5.8 dB ,by inserting convolution code where the gain in Eb/Eo 6dB, coherent and non coherent demodulation tested on system under AWGN where coherent demodulation shows butter performance with gain in Eb/Eo 0.5 dB, Hamming, Golay and reed Solomon applied to reduce BER of the system, Reed Solomon shows best results with gain in Eb/Eo reached to 12 dB. M-FSK with Rayleigh and Rician channel performance improving by increasing diversity order where BER BER decreased from 0.5 *10^-3 to 4*10^-8, system with rician channel further more improved by increasing K-factor where the gain in Eb/Eo 7dB. M-FSK system is generally have good performance improving with the above techniques in term of BER and the gain in Eb/Eo.

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