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A Novel Fading Channels Using Two – Level FH – CDMA Method In Wireless Communication System

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Abstract

In This Work I Propose a Bi-level frequency hopping code-division multiple-access (FH-CDMA) scheme for wireless communication system has been proposed. A novel method provides flexibility in the range is in the range of modulation codes and FH models. By separating the modulation codes bi-level scheme can be modified to carry more possible users without increasing the number of FH models. The performance and spectral efficiency of the scheme are examined. The simulation results show that the divided bi-level FH-CDMA scheme supports higher data rate and greater spectral efficiency than frequency-shift-keying FH-CDMA scheme. The performance of our two-level FH-CDMA scheme over additive white Gaussian noise (AWGN), Rayleigh and Rican fading channels are analyzed algebraically. Therefore our two-level FH-CDMA scheme is more flexible in the selection of the modulation codes and FH patterns in order to meet different system operating requirements.

Index terms: code division multiple access, code modulation, frequency hopping, spectral efficiency.

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1. Introduction

Frequency Hopping Code Division Multiple Access (FH-CDMA) provides frequency range and helps ease multi-path fading and vary intervention. The advantages of FH-CDMA over Direct-Sequence DS-CDMA include better resistance to multiple access interfering. By conveying a unique FH models to each user a FH-CDMA system allows multiple users to share the same transmission channel concurrently. MAI occurs when more than one simultaneous user make use of the same carrier frequency in the same time slot.

M-ary frequency-shift-keying (MFSK) atop FH-CDMA scheme is used in order to enlarge data rate by transmitting symbols instead of data bits. In addition the uses of prime and Reed-Solution (RS) sequences as modulation codes atop FH-CDMA were represented by non-orthogonal sequences, rather than orthogonal MFSK. These prime FH-CDMA and RS FH-CDMA methods supported higher data rate than MFSK FH-CDMA scheme at the expense of the modulation codes and FH models needed to be the same in both methods confining the choice of suitable modulation codes and FH models to use.

The only condition is that the weight of the FH models is at least equal to the length of the modulation codes, which is usually true in modulation FH-CDMA methods because each element of the modulation codes needs to be conveyed by an element of the FH models. Therefore bi-level FH-CDMA method is more flexible in the selection of the modulation codes and FH models in order to meet different system operating requirements. The prime FH-CDMA and RS FH-CDMA methods are special case of the new method. Partitioning method on the modulation codes such that modulation codes with lower cross-correlation values are grouped together are proposed. The usage of different groups of modulation codes as an additional level of address signature to divide bi-level FH-CDMA method allows the assignment of the same FH model to multiple users, thus maximizing the number of possible users.

2. Related work

The performance of bi-level FH-CDMA method over additive white Gaussian noise (AWGN) and fading channels are analyzed algebraically. The new method with MFSK/FH-CDMA method in terms of performance and a more meaningful metric spectral efficiency (SE) has been compared. The numerical examples show that bi-level FH-CDMA method provides a trade-off between performance and data rate. In the comparison of SE the divided two-level FH-CDMA method displays better system efficiency than MFSK/FH-CDMA method under some constraints.

2.1 Description Of Two-Level Fh-Cdma Scheme

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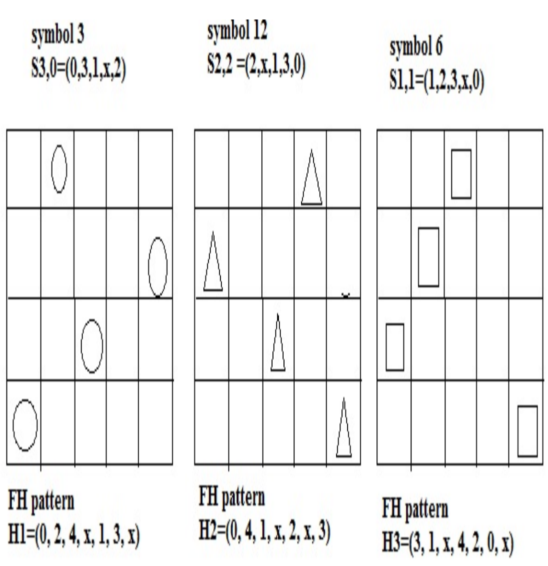
In two-level FH-CDMA scheme, the available transmission bandwidth is divided into M_h frequency bands with $M_{m,}$ carrier frequencies in each band giving a total of M_h M_m carrier frequencies. In the first level a number of serial data bits is grouped together and represented by a symbol. Each symbol is in turns represented by a modulation code of dimension $M_m \times L_m$ and weight $W_{m,}$ where M_m the number of data bits that can be represented by a symbol depends on the number of available modulation codes.

Tabel1.

	Group0	Group1	Group2	Group3	Group4
I2	I1=0	I1=1	I1=2	I1=3	I1=4
0	0000x	0123x	02x13	031x2	0x321
1	1111x	123x0	1302x	1x203	10x32
2	2222x	23x01	2x130	203x1	210x3
3	3333x	3x012	302x1	31x20	3210x
4	xxxxx	x0123	x01302	x2031	x3210

If there is ϕ_m available modulation codes, each symbol can be represent up to $[\log_2\phi_m]$ data bits, where [.] is the floor function. In the second (FH) level, each user is assigned a unique FH pattern of dimension $M_h \times L_h$ and weight W_h, where M_h is the number of frequencies and L_h is the number of time slots. The elements in the modulation codes and FH models conclude the carrier frequencies of the final FH-CDMA signals. While an element of modulation code define the carrier frequency used in a frequency band in a given time slot, an element of the FH pattern determines which frequency band to use. In proposed method families of ($M_m \times L_m$, $W_{h,}$ $\lambda_{a,m}$, $\lambda_{c,m}$) modulation codes are chosen and ($M_h \times L_h$, $W_{h,}$ $\lambda_{a,h}$, $\lambda_{c,h}$) FH models as long as $W_h \geq L_m$ prime sequences in Table I as the modulation codes. Fig.1 shows the encoding process of three simultaneous users. The data symbols of these users are $S_{1=}S_3$,0=(0,3,1,x,2), S_2= $S_{2,}$2=(2,x.1.3.0), S3=S1,1(1,2,3,x,0).



Elements of $S_{i1,i2}$ determines which carrier frequency of a frequency band in a given time slot to use. $S_{i1,\ i2}$,1=$i_2 \oplus_p (i_1 \odot_p l)$ [$\oplus$ - modulo p addition, $\odot$ -modulo p multiplication]. If the number of available carrier frequencies is restricted or the sequence weight needs to be varied in order to achieve certain method performance, the sequence weights are adjusted to be W_m $\prec$ P by dropping the largest p-W_m. elements in S_{i1},$i_{2.}$ As a result the construction algorithm gives ϕ_m=P^2 – P +W_m prime sequences of weight $W_m \leq$ P and length L_m = P with, $\lambda_{c,m}$ =1. Using these prime sequences as the modulation codes, at most twenty four symbols are supported and each symbol represents [$\log_2$24.]=4 data bits. FH models can be chosen for the second level of bi-level FH-CDMA method as long as $W_h \geq L_m$. To illustrate this ($M_h \times L_h$, $W_{h,}$ $\lambda_{a,h}$, $\lambda_{c,h}$) = (5 x 7, 5,0,1) prime sequences as the one-hit FH models are transmitting signal. Where $\lambda_{a,\ m}$, $\lambda_{a,\ h}$ and $\lambda_{c,\ m}$, $\lambda_{c,\ h}$ denotes the maximum autocorrelation and cross-correlation values of the modulation codes, respectively. To illustrate the main concept of bi-level FH-CDMA method, the prime sequences as the modulation codes are used, other codes, such as the RS sequences, quadratic congruence code (QCCs) and multilevel prime codes can also be used.

The carrier frequency used in each frequency band in a time slot is determined by superimposing all W_m=4 elements of S_1 on top of this first W_m non-X elements of H_k and the X elements of S_i produce empty frequency bands in the final two level FH-CDMA signal, where K={1,2,3} the shaded columns in the transmitting signal, T_k of Fig 1 represent the frequency bands specified by the corresponding FH models, Hk for K={1,2,3}. In review two level frequency hopping CDMA can be represented by Tk=(Tk,0,Tk,1…….Tkj,…..TkL,h-1=Sk), where Tk,j represents frequency used in ith time slot and Δ denotes super impose operation for example two level FH CDMA signal of first user is found to be T_1=(0+, 0*4, 3+2*4, 1+4*4,x,x,2+3*4,x)=(0, 11, 17, x, x, 14, x) after super imposition similarly other two simultaneous users have T_2=(2,x,5,x,11,x,12) and T_3=(13,6,x,19,x,0,x). in receiver , received two level FH CDMA signal of all users and effects of MAI, fading and noise are hard limited, dehooped and finally decoded in order to recover transmitted data symbol. Fig 2 illustrates decoding and detection process of user 1. Received signal is first hard limited and then dehopped by user 1's FH pattern to give a dehopped signal R_1 of dimesions 4*5. The role of the dehopping process simply brings the frequency bands in each time slot of back to the base band, according to the frequency bands specified by H1. Although the prime sequences can only support up to $\lfloor \log_2(p2 - p + wm) \rfloor$ bit/symbol, it is important to point out that our two-level FH-CDMA scheme allows the use of other codes, such as the RS sequences ,QCCs ,and MPCs ,as the modulation codes. For example, the MPCs have pn+1 sequences of weight $wm = p$ and length $L_m = p$ with $\lambda c, = n$ (i.e., symbol interference), where n is a natural number. If the MPCs are used as the modulation codes, the date rate can be increased because the MPCs can support up to $\lfloor \log_2 P^{n+1} \rfloor$ bit/symbol at the expense of worsened symbol interference.

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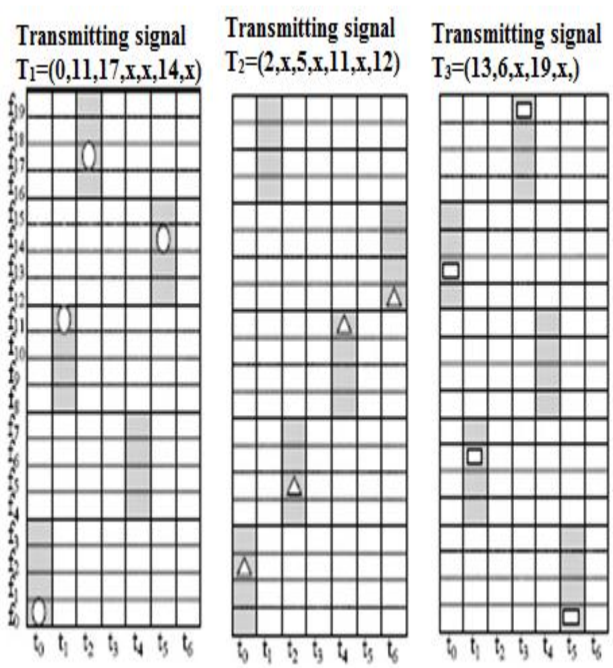

Fig.2.1.1 Example of the encoding process of the two-level FH-CDMA scheme with three simultaneous users.

2.2 Partitioned Two-level FH-CDMA Scheme

In general the number of possible users in a FH-CDMA system is limited by the number of available FH patterns. However our two level FH-CDMA scheme can flexibly increase the number of possible users by tracking for lower data rate through a reduction of symbol size. It is done by partitioning the modulation code into several groups and each group contains reduced number of modulation codes with lower $\lambda_{c,m}$ each user can now only use one group of modulation codes for symbol representation. The same FH pattern can now be reused by multiple users as long as they have different groups of modulation codes. Let say there are The same FH pattern can now be reused by multiple users as long as they have different groups of modulation codes. Let say there are ϕ_h FH patterns and ϕ_m modulation codes with $\lambda_{c,m}$. If the modulation codes are partitioned into t groups of codes with $\lambda'_{c,m}$. (results in $\lambda'_{c,m} = \lambda_{c,m} - 1$.) We can then assign each user with one FH pattern and one of these t groups of modulation codes, thus supporting a total of $t.\ \phi_h$ possible users. The tradeoff is that each group now has at most ϕ_m/t modulation codes and thus the number of bits per symbol is lowered from $\lfloor \log_2 \phi_m \rfloor$ to $\lfloor \log_2(\phi_m/t) \rfloor$.

For example, the twenty-four $\lambda_c, = 1$ prime sequences in Table 4.1 can be partitioned into five groups of prime sequences of $\lambda'_c, = 0$ and assigned to five different users with the same FH pattern. Although the number of bits represented by each symbol decreases from $\lfloor \log 2\ 24 \rfloor$ to $\lfloor \log_2 5 \rfloor$, the number of possible users is now increased from ϕ_h to $5\phi_h$. We can also choose the MPCs of length p and $\lambda_c, = n$ as the modulation codes. As shown, the MPCs can be partitioned into $pn{-}n'$ groups and each group has $\lambda'_c, = n'$ and $\phi_m = p^{n'}{+}1$, where $n > n'$. The number of possible users is increased to $\phi_h\ pn{-}n'$, but the number of bits per symbol is reduced to $\lfloor \log_2 p^{n'}{+}1 \rfloor$.

3. Methodology

3.1 performance analysis

In this FH-CDMA system MAI depends on the cross correlation values of FH patterns. For our two level FHCDMA scheme, the cross-correlation values of the modulation codes impose additional interference and need to be considered. Assume that one-hit FH patterns of dimension $M_h * L_h$ are used and the transmission band is divided into $M_m * M_h$ frequencies, in which M_m frequencies are used to carry the modulation codes of weight W_m the probability that a frequency of an interferer hits with one of the frequencies of the desired user is given by $q = \dfrac{w_m^2}{M_m M_h L_h}$

(1)

Assume that there are K simultaneous users the probability row is given by

$$P(n) = \binom{w_m}{n} \sum_{i=0}^{n} (-1)^n \binom{n}{i} \left[1 - q + \frac{(n-1)q}{w_m} \right]^{K-1} \quad \textbf{(2)}$$

That the dehopped signal contains n entries in an undesired over AWGN, and Rayleigh and Rician fading channels, false alarms and deletions may introduce detection errors to the received FH-CDMA signal. A false alarm probability P_d is the probability that a receiver missed a transmission tone. For these three types of channels the false alarm probability is generally given by

$$P_f = \exp\left({-\beta_o^2}/{2} \right) \quad (3)$$

For an AWGN channel, the deletion probability is given by

$$P_d = 1 - Q\ \sqrt{2(\bar{E}_b / N_o).(K_b / w_m)}, \beta_o \quad (4)$$

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Where β_0 denotes the actual threshold divided by the root mean-squared receiver noise, is the number of bits per symbol, E_b/N_0 is the average bit-to-noise density radio

$Q(a,b)= \int_b^\infty x.*.\ \exp[-(a^2 + x^2)/2] I_0(ax)*dx$ is Marcum's Q function and $I_0(.)$ is the modified Bessel function of the first kind and zeros order. To minimize the error probability the optimal β_0 of an AWGN channel should be a function of the signal to noise ratio (SNR) E_b/N_0 and K_b/W_m can be more accurately written as

$$\beta_o = \sqrt{2 + \frac{(\bar{E}_b / N_o).(K_b / w_m)}{2}} \tag{5}$$

Rather than an inaccurate constant value i.e. $\beta_0=3$, used in equations (5, 9, 10).

For a Rayleigh fading channel the deletion probability is given in eq. (14)

$$P_d = 1 - \exp\left\{ \frac{-\beta_o^2}{2 + 2(\bar{E}_b / N_o).(K_b / w_m)} \right\} \tag{6}$$

Similarly the optimal β_0 of a Rayleigh fading channel can be more accurately written as

$$\beta_o = \sqrt{2 + \frac{2}{(\bar{E}_b / N_o).(K_b / w_m)}} \times \sqrt{\log\left[1 + (\bar{E}_b / N_o).(K_b / w_m)\right]} \tag{7}$$

Finally for a Rician fading channel the deletion probability is given in e.q (14)

$$P_d = \left[1 - Q\left(\sqrt{\frac{2\rho(\bar{E}_b / N_o).(K_b / w_m)}{1 + \rho + (\bar{E}_b / N_o).(K_b / w_m)}}, \beta_1 \right) \right] \tag{8}$$

Where the Rician factor P is given as the ratio of the power in the seculars components to the power in multipath components. Similarly β_0 and β_1 can be more accurately written as

$$\beta_o = \sqrt{2 + \frac{(\bar{E}_b / N_o).(K_b / w_m)}{2}} \tag{9}$$

$$\beta_1 = \frac{\beta_o}{\sqrt{1 + (\bar{E}_b / N_o).(K_b / w_m) / (1 + \rho)}} \tag{10}$$

Including the noise or fading effect, the probability that the dehopped signal contains. Entries in an undesired row is given by e.q (5, 8, 15)

$$P_s(n) = \sum_{j=0}^{n} \sum_{r=0}^{\min[n-j, w_m - n]} \left[P(n-j) \binom{n-j}{r} \times P_d^r (1-P_d)^{n-j-r} \binom{w_m - n + j}{r + j} \times P_f^{r+j} (1-P_f)^{w_m - n - r} \right]$$
$$+ \sum_{j=1}^{w_m - n} \sum_{r=j}^{\min[n+j, w_m - n]} \left[P(n+j) \binom{n+j}{r} \times P_d^r (1-P_d)^{n+j-r} \binom{w_m - n - j}{r - j} \times P_f^{r-j} (1-P_f)^{w_m - n - r} \right]$$

(11)

The FH-CDMA system, an error occurs when interference causes undesired rows in the dehoppes signal to have equal or more entries than the desired rows. In addition an error may still occur in our two-level FH-CDMA scheme even when the undesired rows have fewer entries than the desired rows. Because the nonzero cross-correlation values of the modulation codes add extra undesired entries. To account for this, let A_i^z denote the conditional probability of the number of hits being increased from Z to Z+i where $i \in [1, \lambda_{c,m}]$. To account for the effect of $\lambda_{c,m} \neq 0$, we derive a new probability of having a peak of Z as

$$P_s^1(z) = A^z_{\lambda_{c,m}} P_s(z - \lambda_{c,m}) + A^z_{\lambda_{c,m} - 1} * P_s(z - (\lambda_{c,m} - 1)) + \ldots + A_1^z P_s(z - 1) \quad (12)$$

Where $A_t^{z+t} = 0$ when $z + i > W_m$. The computation of A_i^z is exampled in Appendix. If there are $2kb - 1$ incorrect rows, the probability that n is the maximum number of entries and that exactly t unwanted rows contain n entries is given by

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$$P_r(n,t)=\binom{2^{k_b-1}}{t}\left[P_s'(n)\right]^t\left[\sum_{m=0}^{n-1}P_s'(m)\right]^{2^{k_b}-1-t} \qquad (13)$$

Over a noisy or fading channel, the probability of having an entry in a desired row is $1-P_d$. Therefore, the probability that there exist n entries in a desired row is given by

$$P_c(n)=\binom{w_m}{n}(1-P_d)^n(P_d)^{w_m-n} \qquad (14)$$

The desired symbol is detected wherever the maximum number of entries in the t incorrect rows is less than n. As the receiver decides which symbol (out of $2kb$ symbols) is recovered by searching for the modulation code with the largest matching entries, the bit error probability (BEP) is finally given by

$$P_b(K)=\frac{2^{k_b}}{2(2^{k_b}-1)} \times\left\{1-\sum_{n=1}^{w}\left[P_c(n)\sum_{t=0}^{2^{k_b-1}}\frac{1}{t+1}P_r(n,t)\right]\right\} \qquad (15)$$

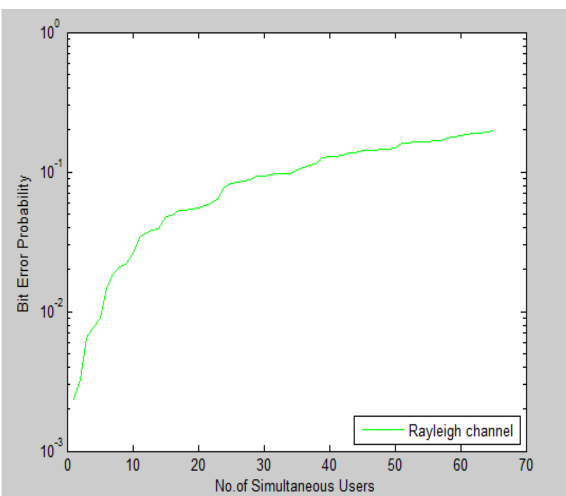

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Fig 3.1.1 BEP of Rayleigh Channel using Bi-level FH-CDMA for No. Of simultaneous users.

4. Experiment and analysis

In this section we compare the performances of the new two-level FH-CDMA and Goodman's MFSK/FH-CDMA schemes under the condition of same transmission parameters: $M_g = M_m M_h$, $L_g = L_h$, and $W_g = W_m$, where M_g, L_g, and W_g are the number of frequencies, number of time slots, and weight of FH patterns utilized by Goodman's MFSK/FHCDMA scheme, respectively. As illustrated, the prime sequences may give at most two hits in Goodman's MFSK/FHCDMA scheme under a symbol-asynchronous assumption. The main difference is that Goodman's MFSK/FH-CDMA scheme supports M_g modulation symbols (represented by the orthogonal frequencies), while the two-level FH-CDMA scheme supports

$P^2 - P + W_m$ symbols with the symbol interference level λ_c, = 1 if the prime sequences in section are used as the modulation codes. This symbol interference is accounted for by the probability term $P_s'(z)$

The BEPs of both schemes are plotted against the number of simultaneous users K over a Rayleigh fading channel, based on the condition of same transmission parameters, where $M_g \times L_g = 44\times47$, $W_g = W_m = 4$, $M_m \times L_m = 4\times11$, $M_h \times L_h = 11\times47$, and $E_b/N_0 = 25$ dB. Using p = 11, our two-level FH-CDMA scheme supports Kb = 6 bits/symbol, while Goodman's MFSK/FH-CDMA scheme supports K*b* = 5 bits/symbol. Based on (7) and K*b* = {5, 6}, we more accurately calculate β_0 = {3.4633, 3.5148}, respectively, instead of the constant $\beta_0 = 3$. In general, the performance of our scheme is worse than that of Goodman's scheme because of the additional symbol interference created by the prime sequences.

Also shown in the figure is the computer-simulation result for validating our theoretical analysis. The computer simulation of our two-level FH-CDMA scheme is performed as follows.

However, the number of data bits per symbol in Goodman's scheme is decreased to $kb = [\log_2 (M_g/p)]$. In figure the BEPs of both schemes over a Rayleigh fading channel are plotted against the number of simultaneous users K, based on the conditions of same number of possible users and same transmission parameters, where $M_g \times L_g = 44 \times 47$, $W_g = W_m = 4$, $M_m \times L_m = 4\times 11$, $M_h \times L_h = 11 \times 47$, and $E_b/N_0 = 25$ dB. Our partitioned scheme supports K*b* = 3 bits/symbol, while Goodman's scheme supports K*b* = 2 bits/symbol.

Based on (7) and K*b* = {2, 3}, we more accurately calculate β_0 = {3.1943, 3.3154}, respectively, instead of the constant $\beta_0 = 3$ .The performance of our partitioned scheme is very comparable to that of Goodman's scheme.

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In fig.3 , the BEPs of our two-level FH-CDMA scheme under AWGN, and Rayleigh and Rician fading channels are plotted against the number of simultaneous users K, where $W_m = 4$, $M_m \times L_m = 4\times 11$, $M_h \times L_h = 11 \times 47$, $\rho = 13$, $kb = 6$, and $E_b/N_0 = 25$ dB. Based on (5), (7), (9), and (10), we more accurately calculate β_0 and β_1, which are given in fig.3. As expected, the AWGN curve always performs the best and the Rayleigh curve performs the worse, while the Rician curve is in between. Also shown in the figure is the computer-simulation result for validating our theoretical analysis.

Table.2 SE Comparison of both schemes with P_e={10-2,10-3}

Bit error probability	$P_e=10^{-2}$	$P_e=10^{-3}$
Goodman's FH-CDMA (k_b=2)	K=144 SE=13.93%	K=56 SE=5.42%
Two-level FH-CDMA (k_b=3)	K=126 SE=18.29%	K=53 SE=7.69%

To compare our partitioned two-level FH-CDMA and Goodman's MFSK/FH-CDMA schemes,

$$SE = \frac{k_b K}{ML} \qquad \textbf{(16)}$$

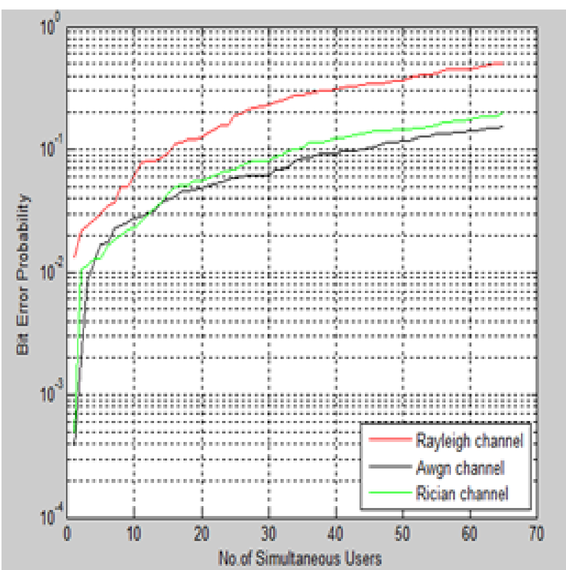

Fig.4.1 BEPS of our Two_level FH-CDMA scheme under AWGN, Rayleigh and Rician Fading channels.

BEPs of the two-level FH-CDMA scheme versus the number of simultaneous users K over AWGN, and Rayleigh and Rician fading channels,

where $W_m = 4$, $M_m \times L_m = 4 \times 11$, $M_h \times L_h = 11 \times 47$, $\rho = 13$, $kb = 6$, and $E_b/N_o = 25$ dB.

As expected, the AWGN curve always performs the best and the Rayleigh curve performs the worse, while the Rician curve is in between. The new two level FH-CDMA in the AWGN fading channel performs the best i.e. it supports more number of user with less bit error probability and the performance of this system is worse in the Rayleigh fading channel and the performance in Rician fading channel is in between additive white Gaussian noise and Rayleigh fading channels.

5. Conclusion

In this project, a new two-level FH-CDMA scheme is proposed. The prime/FH-CDMA and RS/FH-CDMA schemes were special cases of our scheme. The performance analyses showed that the two-level FH-CDMA scheme provided a trade-off between performance and data rate. The partitioned two-level FH-CDMA scheme increased the number of possible users and exhibited higher data rate and greater SE than Goodman's MFSK/FH-CDMA scheme. In summary, the new scheme offered more flexibility in the design of FH-CDMA systems to meet different operating requirements.

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