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Performance Comparison of FH-CDMA Scheme Using Chaotic Sequences over Fading Channels

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Abstract—*In this work, the performance analysis of FH-CDMA scheme in terms of bit error probability (BEP) Vs number of simultaneous users over three different channels i.e. AWGN, Rician and Rayleigh channels is presented. The prime and chaotic sequences were used in this work as spreading sequences to the FH-CDMA scheme resulting in prime/FH-CDMA and chaotic/FH-CDMA scheme respectively. Bit Error Probability against the number of simultaneous users over AWGN, Rician and Rayleigh fading channels are plotted for prime/FH-CDMA scheme and chaotic/FH-CDMA scheme and compared. Chaotic sequences have good correlation properties and then can be used as address sequences in spread spectrum communication. Simulation results showed that chaotic/FH-CDMA scheme can accommodate more number of simultaneous users with lower Bit Error Probability than compared to prime/FH-CDMA scheme.*

Index terms— *Bit Error Probability (BEP), Chaotic sequences, Code-Division Multiple-Access (CDMA), Frequency-Hopping (FH), Prime sequences.*

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I. Introduction

Frequency-Hopping Code-Division Multiple-Access (FH-CDMA) allows many simultaneous users to share the same transmission channel by assigning a unique FH pattern to each user. FH-CDMA provides frequency diversity and helps mitigate fading and diversity interference [1]. M-ary Frequency Shift Keying [2] was proposed to be added on top of the FH-CDMA to increase the data rate by transmitting symbols instead of data bits. Direct Sequence Code Division Multiple Access (DS-CDMA) is a method of multiplexing users by distinct codes and in this method all users use the same bandwidth. Spreading codes used in CDMA systems include Walsh-Hadamard sequences, Gold codes, Kasami codes, m-sequences etc. [3]. In any multiple access system, the main reason that affects the performance is the multiple access interference. It is found that, Multiple Access Interference (MAI) can be mitigated in Direct-Sequence CDMA (DS-CDMA) system when chaotic sequences are applied to a DS-CDMA system as spreading sequences. The selection of a good code is important, because auto-correlation properties and length of the code sets bound on the system capacity. Because of this reason, the selection of spreading codes to differentiate the users plays an important role in the system capacity.

In this work, the performance of FH-CDMA is evaluated when chaotic sequences were used as spreading sequences in terms of bit error probability (BEP) Vs number of simultaneous users over three different channels i.e. AWGN, Rician and Rayleigh channels is presented. Chaotic Sequences have good correlation properties and then can be used as address sequences in spread spectrum communication [4]. The generation of spreading sequences is described in section II. The structure and performance of FH-CDMA transmitter and receiver is presented in Section III. The results were discussed in Section IV, while the conclusions are drawn in Section V.

II. Spreading Sequence Generation

A. Chaotic Sequence Generation

A chaotic dynamical system is an unpredictable, deterministic and uncorrelated system that exhibits noise-like behavior through its sensitive dependence on its initial conditions, which generates sequences similar to PN sequences. Since the signals generated from chaotic dynamic systems are noise-like, super sensitive to initial conditions and have spread and flat spectrum in the frequency domain, it is advantageous to carry messages with this kind of signals that is wide band and has high communication security. This feature greatly enhances the low probability of intercept and low probability of error performance of the system. Chaotic sequences are created using discrete, chaotic maps.

One of the simplest and most widely studied non linear dynamical systems capable of exhibiting chaos is the logistic map [5]. The transformation mapping function of the logistic map is given by equation (1)

F(x,r) = rx(1-x) (1)

where F is the transformation mapping function and r is called the bifurcation parameter or written in its recursive form,

$x_n+1 = rx_n(1-x_n), 0 \le x_n \le 1, 0 \le r \le 4$ (2)

The dynamics of this system can change attractively depending on the values of r with $0 \le r \le 4$, exhibiting periodicity or chaos. In this work the initial parameters used to generate chaotic sequences are as follows: The initial parameter x_n is the initial value and varied from 0.2 to 0.5 to generate different sequences, the bifurcation parameter r is varies from 0.5 to 4 for all the sequences. Chaotic sequences are real valued sequences. Therefore chaotic sequences must be transformed into binary sequences. The block diagram generation of binary chaotic sequences is given in Fig.1. The chaotic sequences are generated by using Logistic map.

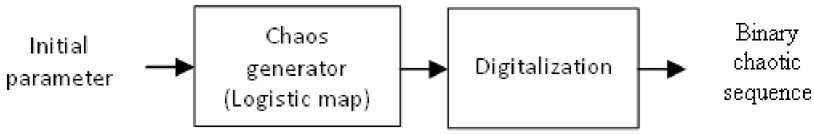

Fig 1: Generation of binary chaotic sequences

And then these chaotic sequences are transmitted into digitalization block. The process involved in digitalization block is as follows. Let w be the real valued chaotic sequence. For transforming this real valued sequence to binary sequence we define a threshold function $\theta_t(w)$ as

$$\theta_w(w) = 0, \quad w \le t \qquad (3)$$
$$= 1, \quad w > t$$

Where, t is the threshold value. Using this equation, we can obtain a binary sequence which is referred to as a chaotic threshold sequence.

A. Prime sequence generation

The prime sequences are constructed in Galois field GF (p) of a prime number p. Each prime sequence of weight wm [6] is as shown in equation (4)

$$S_{i_1,i_2} = \left(s_{i_1,i_2,1}, s_{i_1 i_2,2}, \ldots, s_{i_1,i_2,l}, \ldots, s_{i_1,i_2,p-1}\right) \qquad (4)$$

Where the lth element $s_{i_1,i_2,l} = i_2 \oplus_p (i_1 \otimes_p l)$ represents the frequency used in the lth position (i.e., time slot) of $S_{i_1,i_2,} \{i_1, i_2, l\} \in$ GF(p), "$\oplus_p$" denotes a modulo-p addition, and "$\otimes_p$" denotes a modulo-p multiplication. In this work p is taken as five. For example if we want add 4 with 3 in mod-5 then first we need to add 4+3=7. Then 7 is divided by 5. The remainder is 2.So the 4$\oplus$p 3=2. In the same way if we want multiply 2 with 3 in mod-5 then first we need to multiply 2×3=6. Then 6 is divided by 5. The remainder is 1.So the 2$\otimes$p 3=1. Using this process and equation (4) we generated prime sequences and used as modulation codes in MATLAB simulation tool.

III. Fh-Cdma Scheme

The prime/FH-CDMA scheme and chaotic/FH-CDMA scheme was simulated using MATLAB Communication Toolbox and Signal processing Toolbox. The block diagram of the transmitter and receiver of the FH-CDMA scheme used in this work are as shown below in Fig 2.

Three fading channels (i.e. AWGN channel, Rician and Rayleigh fading channels) were considered for the transmission of data. Total users considered are 45. The data for each user is generated in the MATLAB software using the randint() function available in MATLAB. The bit error probabilities versus the number of simultaneous users are plotted which is explained below.

At the transmitter side the user data is modulated using Qudrature Amplitude Modulation (QAM). The error margin for QAM is less than that of other modulation techniques. Then the spreading & hopping of data will be done by multiplying resultant data with modulation sequence. The modulation sequences used in this work are Prime sequences and chaotic sequences. The generations of these sequences have been discussed in Section II.

After spreading we will get serial data which is converted into parallel data to form symbols from the bit stream in order to perform Inverse Fast Fourier Transform (IFFT).After we have applied IFFT on symbols to remove Inter Symbol Interference (ISI) also to covert the symbols into signals with a certain frequency in order to transmit through channels. The output of IFFT is parallel data. Now it is converted to serial data and then it is transmitted through channel. In this work, three channels were considered to analyze the FH-CDMA system.

At the receiver end, the output of channel is again serial data. Now it is converted into parallel data in order to apply Fast Fourier Transform (FFT). The output of FFT block will be converted into serial data. After this de-spreading, de-hopping and demodulation will be performed to recover the information bits in its original form.

The received data will be in matrix form because we have considered 45 users to transmit data in this work. The available transmission bandwidth is divided into M_h frequency bands with M_m carrier frequencies in each band, giving a total of M_mM_h carrier frequencies.
The probability of having interfere occupying the same frequency in the same frequency band as the desired user [8] is shown in equation (5).

$$q = \frac{w_m^2}{M_m M_h L_h} \qquad (5)$$

The probability that there are 'n' entries in an undesired row of the decoded matrix [6], [7], [8] is shown in equation (6).

$$P(n) = \binom{w_m}{n} \sum_{i=0}^{n} (-1)^i \binom{n}{i} \left[1 - q + \frac{(n-i)q}{w_m} \right]^{K-1} \qquad (6)$$

Including noise and fading effect of channels, the probability that the de-hopped matrix contains 'n' entries in an undesired row [6], [7], [8] is shown in equation (7)

$$\begin{aligned} P_S(n) = & \sum_{j=0}^{n} \sum_{r=0}^{\min[n-j, w_m-n]} [P(n-j) \binom{n-j}{r} \\ & \times p_{dl}^{r} (1-p_{dl})^{n-j-r} \binom{w_m-n+j}{r-j} \times p_{fa}^{r+j} (1-p_{fa})^{w_m-n-r} \\ & + \sum_{j=1}^{w_m-n} \sum_{r=j}^{\min[n+j, w_m-n]} [P(n+j) \binom{n+j}{r} \\ & \times p_{dl}^{r} (1-p_{dl})^{n+j-r} \binom{w_m-n-j}{r-j} \times p_{dl}^{r-j} (1-p_{fa})^{w_m-n-r} \end{aligned} \qquad (7)$$

where p_{fa} and p_{dl} are probability of false-alarm and probability of deletion of channels used in this work. In order to analyze the performance of FH-CDMA scheme over different fading channels in terms of Bit Error Probability a false-alarm probability and a deletion probability were included in finding the probability of bit errors against number of simultaneous users. A false-alarm probability, p_{fa} is the probability that a tone is detected in a receiver when none has actually been transmitted.

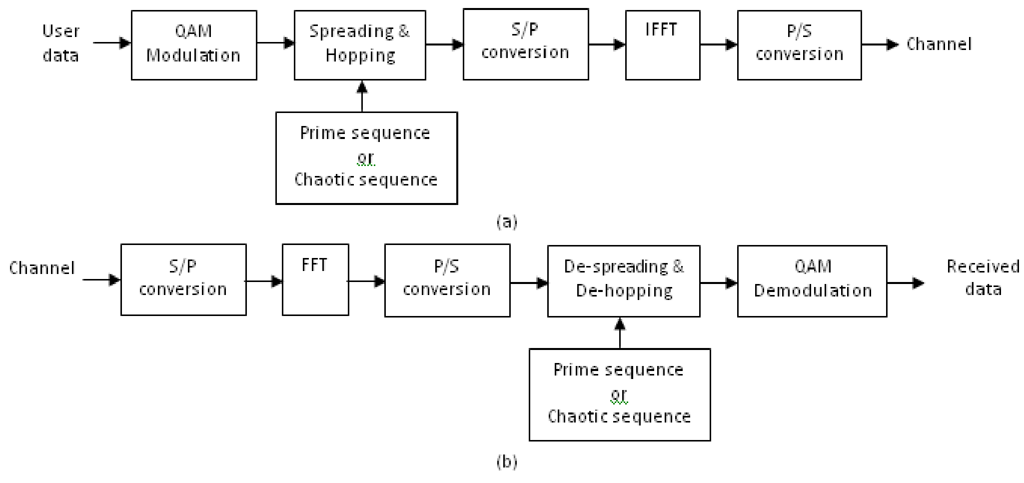

Fig 2: Block diagram representation of (a) Transmitter and (b) Receiver

A deletion probability, p_{dl} is the probability that a receiver missed a transmission tone. For the three types of fading channels, the false-alarm probability [2] is shown in equation (8).

$$p_{fa} = \exp\left(-\beta_0^2/2\right) \tag{8}$$

The deletion probability is different for each of the fading channels. For an AWGN channel, the deletion probability [6], [7], [8] is shown in equation (9)

$$p_{dl} = 1 - Q\left(\sqrt{2\left(\overline{E_b}/N_0\right)\left(k_b/w_m\right)}, \beta_0\right) \tag{9}$$

Where β_0 denotes the actual threshold divided by the root-mean-squared receiver noise, k_b is the number of bits per symbol, $\overline{E_b}/N_0$ is the average bit-to-noise density ratio, Q is Marcum's Q-function. To minimize the error probability, the optimal β_0 of an AWGN channel should be a function of the signal-to-noise ratio (SNR), $\left(\overline{E_b}/N_0\right)\left(k_b/w_m\right)$ and can be written as equation (9A). [8]

$$\beta_0 = \sqrt{2 + \frac{\left(\overline{E_b}/N_0\right)\left(k_b/N_0\right)}{2}} \tag{9A}$$

For a Rician fading channel, the detection probability [6], [7], [8] is given by equation (10)

$$p_{dl} = \left[1 - Q\left(\sqrt{\frac{2\rho\left(\overline{E_b}/N_0\right)\left(k_b/w_m\right)}{1+\rho+\left(\overline{E_b}/N_0\right)\left(k_b/w_m\right)}}, \beta_1\right)\right] \tag{10}$$

Where, the Rician factor ρ is given as the ratio of the power in reflected components to the power in multipath components. Similarly, β_0 and β_1 can be written [8] as below

$$\beta_0 = \sqrt{2 + \frac{\left(\overline{E_b}/N_0\right)\left(k_b/w_m\right)}{2}} \tag{10A}$$

$$\beta_1 = \frac{\beta_0}{\sqrt{1+\left(\overline{E_b}/N_o\right)\left(k_b/w_m\right)/\left(1+\rho\right)}} \tag{10B}$$

Finally, for a Rayleigh fading channel, the deletion probability is given by [6], [7], [8] equation (11)

$$p_{dl} = 1 - \exp\left\{\frac{-\beta_0^2}{2+2\left(\overline{E_b}/N_0\right)\left(k_b/w_m\right)}\right\} \tag{11}$$

Similarly, the optimal β_0 of a Rayleigh fading channel can be written as below equation (11A). [8]

$$\beta_0 = \sqrt{2 + \frac{2}{\left(\overline{E_b}/N_0\right)\left(k_b/w_m\right)}} \times \sqrt{\log\left[1+\left(\overline{E_b}/N_0\right)\left(k_b/w_m\right)\right]} \tag{11A}$$

Let 'n' be the maximum number of entries in a row of the decoded matrix. The probability that there are exactly't' incorrect rows containing 'n' entries [6], [7], [8] is shown in equation (12).

$$P_r(n,t) = \binom{2^{k_b}-1}{t}\left[P_s(n)\right]^t\left[\sum_{i=0}^{n} P_s(n)\right]^{2^{k_b-1-t}} \tag{12}$$

For Prime/FH-CDMA scheme, it adds extra errors because the non-zero cross correlation values of modulation codes add extra errors, to account for this Ps(n) is replaced with $P_s^{|}(n)$ in P_r (n, t). [8]

$$P_s^{|}(n) = \frac{p-1}{p^2}P_s(n-1) + \left(1 - \frac{p-1}{p^2}\right)P_s(n) \tag{13}$$

where p is prime number for prime codes. This equation is only used in prime/FH-CDMA scheme to plot bit error probability versus number of simultaneous users. Equation (12) is not used in chaotic/FH-CDMA scheme because chaotic sequences have zero cross correlation values as its property. The desired symbol is detected when the maximum number of entries in the't' incorrect rows is less than 'n' and it is the final bit error probability [7] is shown in equation (14).

$$P_e(K) = \frac{2^{k_b}}{2\left(2^{k_b}-1\right)} \times \left\{1 - \sum_{n=1}^{W_m}\left[\binom{W_m}{n}\left(1-p_{dl}\right)^n \times \left(p_{dl}\right)^{W_m-n}\sum_{t=0}^{2^{k_b-1}}\frac{1}{t+1}P_r(n,t)\right]\right\} \tag{14}$$

The received data is analyzed trough the equation (5) to (14) one by one and by using simulation parameter in Table I. All the 45 users bit error probabilities are plotted as bit error probability versus number of simultaneous uses. Number of simultaneous users on x-axis and bit error probabilities on
y-axis.

IV. Simulation Results And Discussions

The simulation results in terms of bit error probability (BEP) Vs number of simultaneous users over three different channels i.e. AWGN, Rician and Rayleigh channels of FH-CDMA scheme is presented. The prime and chaotic sequences were used in this work as spreading sequences and the performances of the new chaotic/FH-CDMA scheme and prime/FH-CDMA schemes were compared. Simulations were carried out under the conditions of same transmission parameters except the weight of the sequence wm. The parameters used in the simulations are as shown in table. I. Bit Error Probability against the number of simultaneous users K over AWGN, Rician and Rayleigh fading channels are plotted for prime/FH-CDMA scheme and chaotic/FH-CDMA scheme as shown in fig. 3 and fig. 4 respectively. The Bit Error Probability of prime/FH-CDMA scheme and chaotic/FH-CDMA schemes over AWGN channel is found to be less when compared to Rician and Rayleigh channels as shown in fig. 3 and fig. 4 respectively. It is observed better BER performance of prime/FH-CDMA and chaotic/FH- CDMA schemes with AWGN channel instead of Rician and Rayleigh channels.

Bit Error Probability of both prime/FH-CDMA and chaotic/FH-CDMA schemes are plotted against the number of simultaneous users K over AWGN channel, Rician fading channel and Rayleigh fading channel as shown in fig. 5, fig. 6 and fig. 7 respectively. It is observed that chaotic/FH-CDMA scheme showed lesser Bit Error Probability than compared to prime/FH-CDMA irrespective of the type of fading channel. The Bit Error Probability of both schemes for 45 simultaneous users is tabulated and is shown in table.II. The bit error probabilities get worse as K (the number of simultaneous users) increases due to strong mutual interference.

TABLE 1: Simulation Parameters

Parameter	**Description of parameter**	**Specification**	**Scheme**
$M_m \times L_m$	dimension of the modulation code	4×5	Same for both
$M_h \times L_h$	dimension of the FH pattern	5×7	Same for both
$\overline{Eb}/N0$	bit energy to noise power spectral density	25*db*	Same for both
k_b	number of bits per symbol	4	Same for both
w_m	weight of the modulation sequence	4	prime/FH-CDMA
		10	chaotic/FH-CDMA

Table. 2: Bit Error Probability of Prime/FH-CDMA and chaotic/FH-CDMA schemes for 45 simultaneous users over different channels

Channel	**Bit Error Probability when simultaneous users,45**	
	prime/FH-CDMA	**chaotic/FH-CDMA**
AWGN	25 X 10-4	4x10-4
Rician	500 X 10-4	100x10-4
Rayleigh	5000 X 10-4	800x10-4

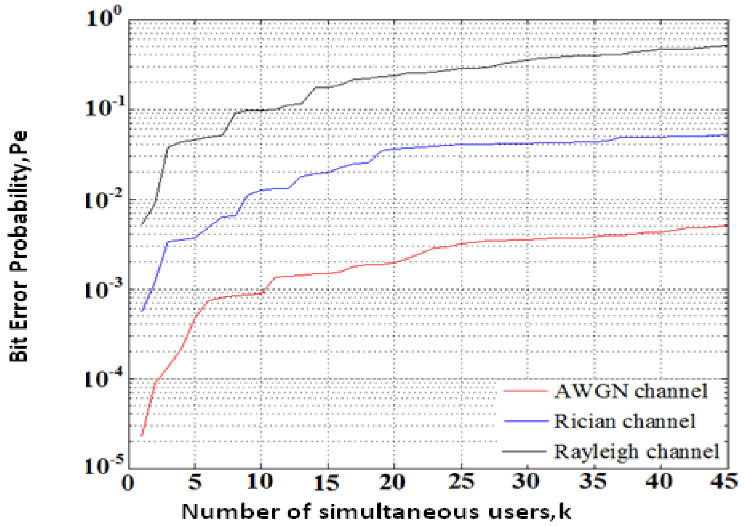

Fig. 3. BEPs of the prime/FH-CDMA scheme versus the number of simultaneous users K over AWGN, Rician and Rayleigh fading channels.

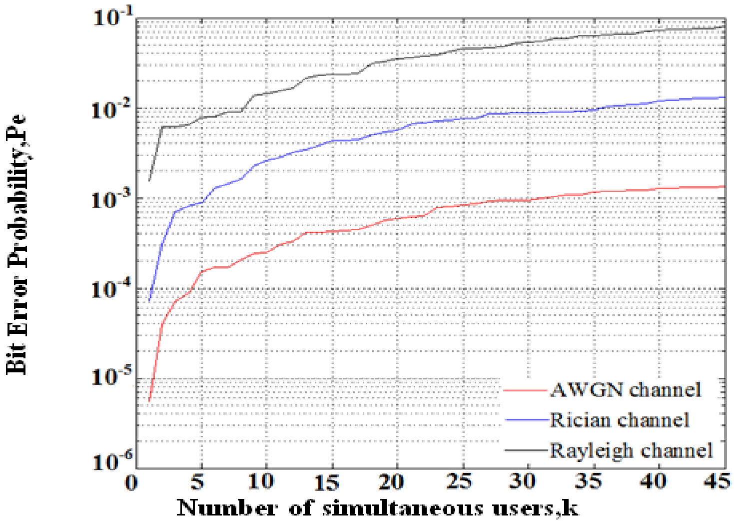

Fig. 4. BEPs of the chaotic/FH-CDMA scheme versus the number of simultaneous users K over AWGN, Rician and Rayleigh fading channels

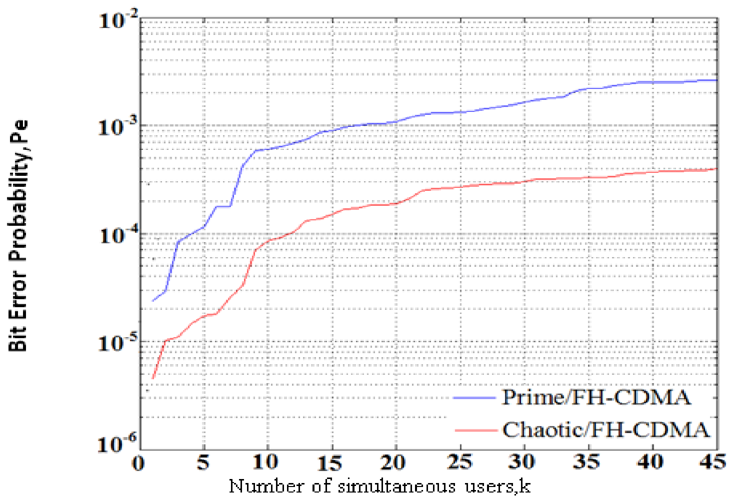

Fig. 5. BEPs comparison of chaotic/FH-CDMA and prime/FH-CDMA schemes versus number of simultaneous users K over AWGN channel.

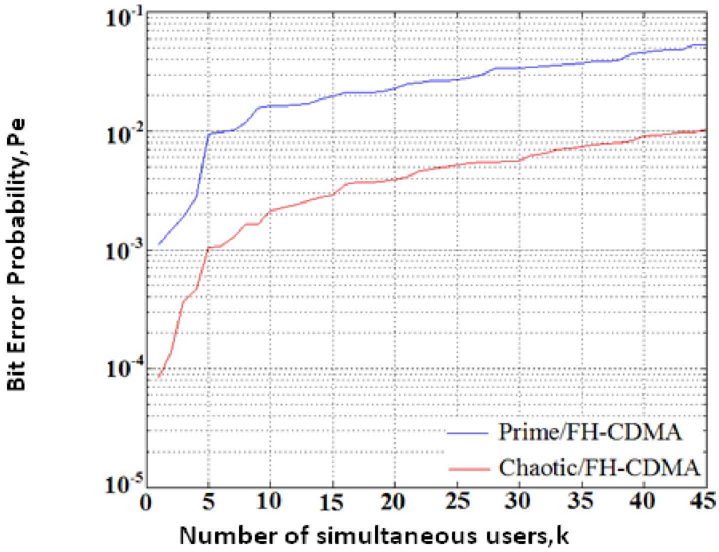

Fig. 6. BEPs comparison of chaotic/ FH-CDMA and prime/FH-CDMA schemes versus number of simultaneous users K over Rician fading channel.

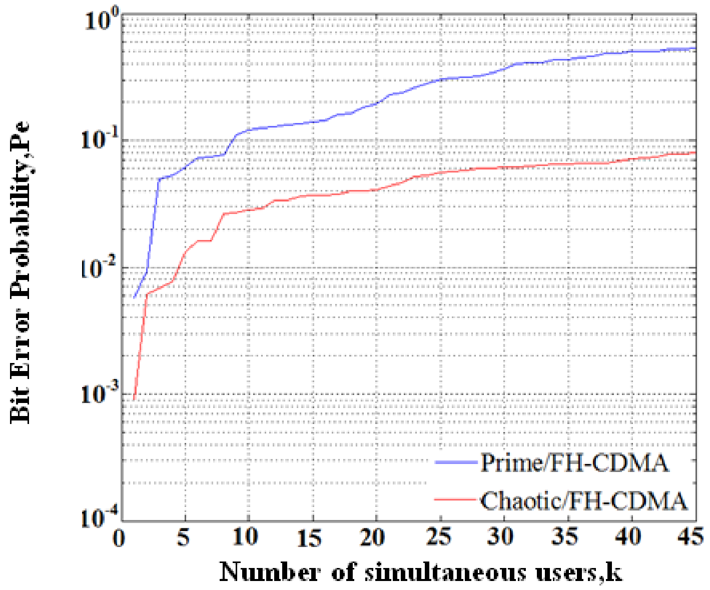

Fig. 7. BEPs comparison of chaotic/ FH-CDMA and prime/FH-CDMA

V. Conclusion

Chaotic sequences were used as spreading sequences for FH-CDMA scheme. The performance chaotic/FH-CDMA is analyzed and compared with prime/FH-CDMA in terms of Bit Error Probability (BEP) against the number of simultaneous users over AWGN channel, Rician fading channel and Rayleigh fading channel. From the simulation results it is observed that chaotic/FH-CDMA scheme can accommodate more number of simultaneous users with lower bit error rate probability than compared to prime/FH-CDMA scheme. Also the performance of system is found to be better when the channel is AWGN than compared to that of either Rician fading channel or Rayleigh fading channel.

References

[1]. J.-Z. Wang and L. B. Milstein, "CDMA overlay situations for micro-cellular mobile communications," *IEEE Trans. Commun.*, vol. 43, no. 2/3/4, pp. 603-614, Feb./Mar./Apr. 1995.

[2]. D. J. Goodman, P. S. Henry, and V. K. Prabhu, "Frequency-hopping multilevel FSK for mobile radio," *Bell Syst. Tech. J.*, vol. 59, no. 7, pp. 1257-1275, Sep. 1980.

[3]. M. Schwartz, W. R. Bennett, and S. Stein, *Communication Systems and Techniques*. McGraw-Hill, 1996.

[4]. Laxmi Bhat and Dr. K. L. Sudha "Performance Analysis of Chaotic DS-CDMA with CSK modulation" International Journal of Mobile Network Communications & Telematics (IJMNCT) Vol.2, No.2, April 2012.
[5]. Wang Hai, Hu Jiandong. "Logistic-Map chaotic spreadspectrum sequence "ACTA ELECTRONICA SINICA 1997 Vo1.25 No.1 19-23.
[6]. C.-Y. Chang, C.-C. Wang, G.-C. Yang, M.-F. Lin, Y.-S. Liu, and W. C. Kwong, "Frequency-hopping CDMA wireless communication systems using prime codes," in *Proc. IEEE 63rd Veh. Technol. Conf.*, pp. 1753-1757, May 2006.
[7]. M.-F. Lin, G.-C. Yang, C.-Y. Chang, Y.-S. Liu, and W. C. Kwong, "Frequency-hopping CDMA with Reed-Solomon code squences in wireless communications," *IEEE Trans. Commun.*, vol. 55, no. 11, pp. 2052-2055, Nov. 2007.
[8]. Sung-Ming Wu, Guu-Chang Yang, Cheng-Yuan Chang, "A Two-Level FH-CDMA scheme for wireless communication systems over fading channels" IEEE Transactions on Communication, volume:59, Issue 1, 2011.

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