SSRG International Journal of Electronics and Communication Engineering
ISSN: 2348-8549/ https://doi.org/10.14445/23488549/IJECE-V11I5P108

Volume 11 Issue 5, 78-83, May 2024

Original Article

Performance of DSSS-QPSK for Kasami Codes in Rayleigh Fading Channel

M. Dileep Reddy[1], G. Sreenivasulu[2]

[1,2]*Department of ECE, Sri Venkateswara University, Andhra Pradesh, India.*

[1]*Corresponding Author : mdileep21@gmail.com*

Received: 14 March 2024 Revised: 23 April 2024 Accepted: 10 May 2024 Published: 31 May 2024

***Abstract* - *Kasami sequences are derived from maximal sequences. This paper presents the auto correlation and cross correlation values of Kasami codes and their Comparison with the m sequence. The objective of this paper is to evaluate the effect of various length Kasami codes on the Bit Error Rate (BER) performance of multi-user spread spectrum Quadrature Phase Shift Keying (QPSK) in the fading channel, which exhibits a frequency selective nature and follows Rayleigh distribution, considering delayed exponential power profile with The Minimum Mean Squared Error (MSME) equalizer at receiver. Bit Error Rate Vs SNR (dB) for QPSK modulation in Kasami codes is shown using a graphical approach using MATLAB®.*

Keywords* - *Kasami sequences, QPSK, MMSE equalizer, Rayleigh fading channel, BER.

1. Introduction

Kasami sequences are generated with maximal codes [1]. The expression power 'm' is even, i.e., mp = twice that of q here the code span is Z=-1+2^p, which is a separated product of (2^q-1) and (2^q+1), where q = half of mp [2]. Initiating with maximal code m_0, relevant decimated code $_d$ was procured from m_0 for each dth chip. Where d = unity plus twice that of q, repeat these -1+2q chips for 1+2q times to obtain decimated sequence $k_{d,}$ which has the same length of maximal sequence $m_{0,}$ but with a periodicity of -1+ twice ^(q) [3, 4, 5].

Correlation tells the identical nature between the codes. The correlation value lies in between -1 (codes are mirror images to each other) to +1 (codes are perfectly similar) [6]. Zero Cross Correlation indicates perfectly orthogonal codes.

The below mentioned Table 1 represents the number of Kasami codes that can be generated from a particular maximal sequence with corresponding Kasami code auto correlation and cross correlation values [7].

The number of Kasami codes is much larger compared to the number of m sequences; hence, more users can be accommodated in the cellular system by assigning Kasami codes [8, 9].

The exact values of cross correlation and auto correlation are calculated in this paper so that in a multi-user environment, desired error probabilities are maintained, and proper communication is established between the transmitter and receiver [10, 11].

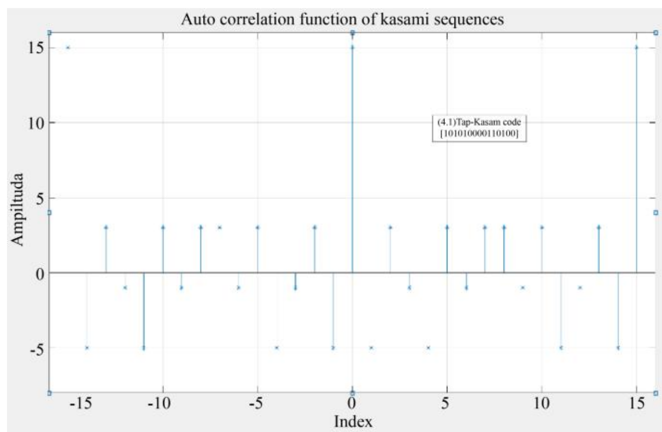

Fig. 1 Auto correlation- Kasami sequence generated (4,1) tap

Table 2 represents that Kasami codes exhibit four-valued auto correlation, i.e., $2^{(p-1)}$, (-1+20.5*p), -unity, - (unity + $2^{0.5*p}$) expect for two shift registers (mp=2) and three-valued cross correlation, i.e., ($2^{0.5*q}$-1),-unity, - ($2^{q/2}$+1) respectively. Below Table 3, receipts normalized CCF of Kasami codes in comparison to maximal codes.

Figure 1 represents the auto correlation plots of Kasami spreading code generated from four shift registers with (4,1) valid tap has four values, i.e., 15 (Peak value),3,-1,-5

Figure 2 represents the cross correlation plot of Kasami spreading code generated from four shift registers with (4,1) valid tap has three values, i.e.,3 (Peak value),-1,-5 that has normalized magnitude of 0.20.

Table 1. Kasami codes their ACF and CCF

#Register	Taps	No. of Kasami Codes	ACF Kasami Sequences	CCF of Kasami Sequences
2	(1,2)	1	3,-1	1,-3
4	(4,1)	3 K_1 K_2 K_3	K_1=15,3,-1,-5 K_2=15,3,-1,-5 K_3=15,3,-1,-5	K_1,K_2=3,-1,-5 K_1,K_3=3,-1,-5 K_2,K_3=3,-1,-5
	(4,3)	3 K_1 K_2 ,k3	K_1=15,3,-1,-5 K_2=15,3,-1,-5 K_3=15,3,-1,-5	K_1,K_2=3,-1,-5 K_1,K_3=3,-1,-5 K_2,K_3=3,-1,-5
		Total =6		
6	(6,1)	7	K_1=63,7,-1,-9 K_2=63,7,-1,-9 K_3=63,7,-1,-9 K_4=63,7,-1,-9 K_5=63,7,-1,-9 K_6=63,7,-1,-9 K_7=63,7,-1,-9	K_1,K_2=7,-1,-9 K_1,K_3=7,-1,-9 K_1,K_4=7,-1,-9 K_1,K_5=7,-1,-9 K_1,K_6=7,-1,-9 K_1,K_7=7,-1,-9 K_2,K_3=7,-1,-9
	(6,5) (6,5,4,1) (6,5,3,2) (6,5,2,1) (6,4,3,1)	7 7 7 7 7	Same as above	Same as above
		Total= 42	all combinations of CCF are the Same	
8	Taps 13	Each has 15 Kseq, Total 195	255.15,-1,-17 for All 195 Codes	15.-1,-17 for All 195 Codes

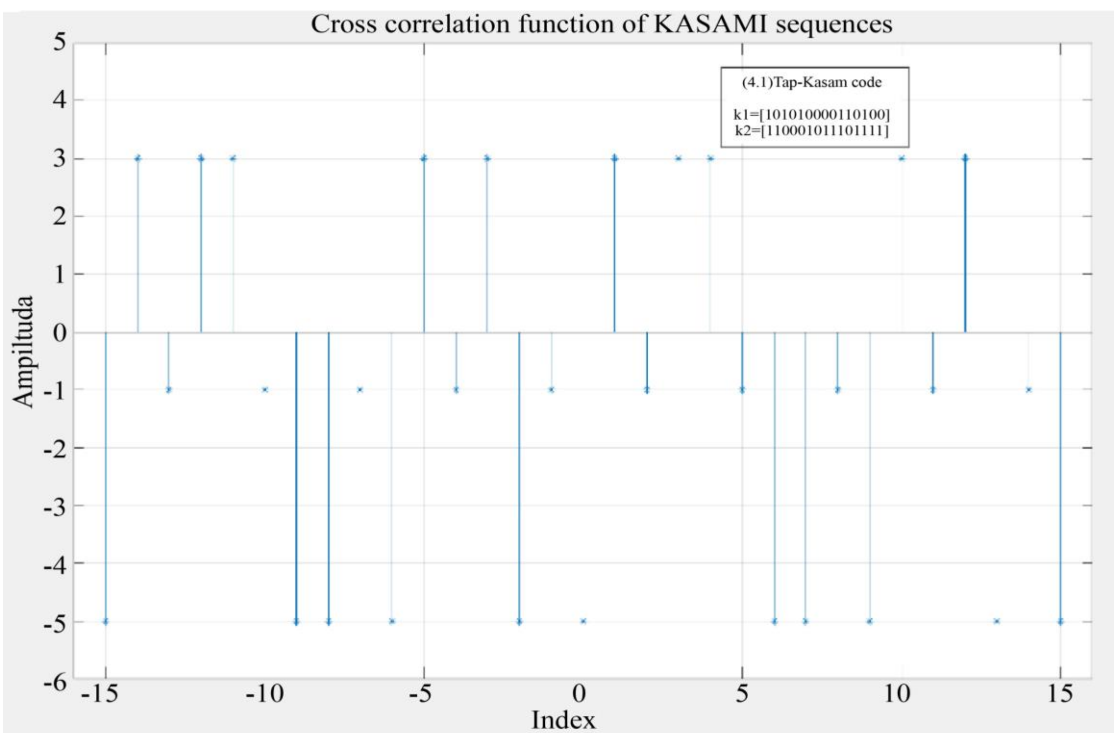

Fig. 2 Cross correlation of kasami codes with (4, 1) tap

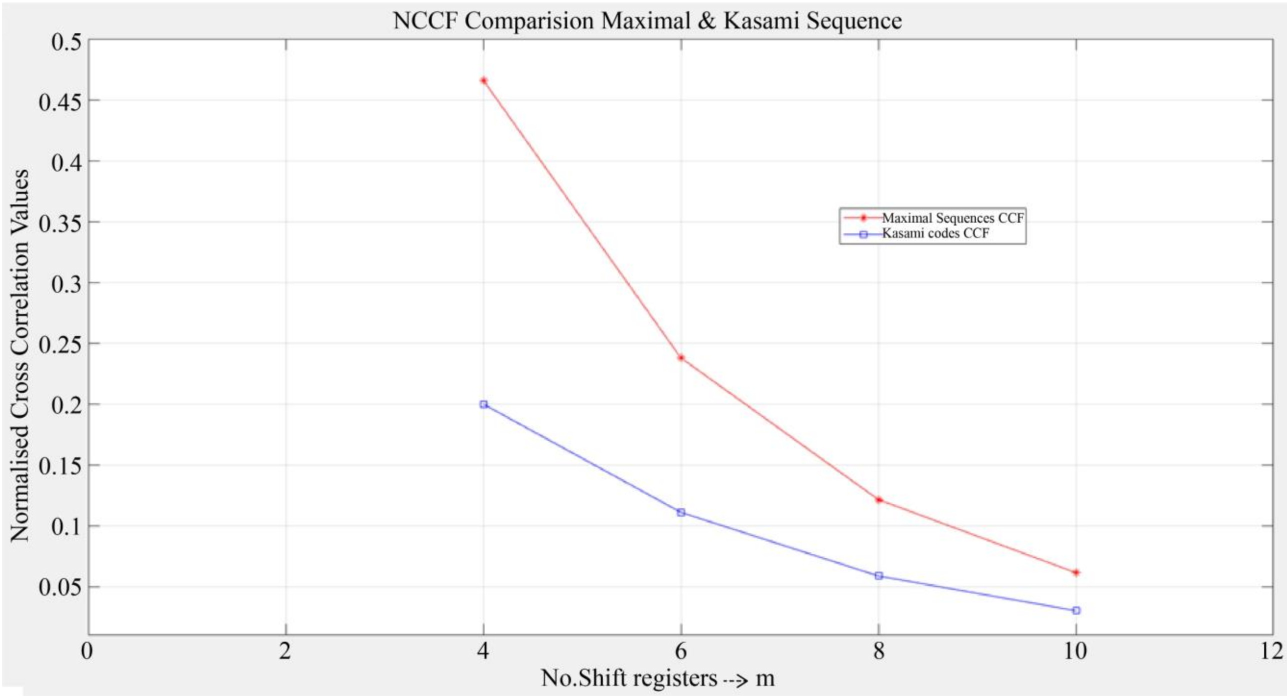

Fig. 3 Plot of normalized Cross Correlation Function (CCF)

Table 2. Normalized Cross Correlation Function (CCF) values

# Shift Reg.	Total Kasami Codes	Kasami Codes Auto Correlation Function	Cross Correlation (CCF)	Normalized CCF
2	1	3,-1	-1,-3,0	0.333
4	6	15,3,-1,-5	3,-1,-5	0.20
6	42	63,7,-1,-9	7,-1,-9	0.111
8	195	255.15,-1,-17	15.-1,-17	0.058
10	1860	1023,31,-1,-33	31,-1,-33	0.030

Table 3. Normalized CCF comparision (optimum value)

No. of Shift Registers	Maximal Sequences	Kasami Sequence
3	0.428	-
4	0.466	0.20
5	0.2258	-
6	0.238	0.1111
7	0.118	-
8	0.12156	0.0588
9	0.0606	-
10	0.0615	0.0303

From the above Figure 3, Kasami codes have lesser value cross correlation and are hence best suited in multi-user environments.

2. Numerical Simulation

Matlab software code is used to evaluate the probability of error with the following parameters taken into consideration [12, 13].

Table 4. Probability of error

Parameter	Value
Total bits	10,0000 (one Lakh)
No of iterations on averaging BER	10 iterations
SNR(dB)	0 to 15dB
Channel	Frequency selective Rayleigh fading channel
Equalizer	Minimum Mean Squared Error (MMSE)
No of multipath	7
Modulation	QPSK
Power delay profile	exponential
Spreading codes	Kasami codes
Spread spectrum Technique	Direct sequence Spread spectrum

For four Shift registers with tap (4, 1) combinations, three Kasami codes are obtained that are assigned to three different users in a multi-user system.

User 1 spreading code K_1 = [1 0 1 0 1 0 0 0 0 1 1 0 1 0 0]
User 2 spreading code K_2 = [1 1 0 0 0 1 0 1 1 1 0 1 1 1 1]
User 3 spreading code K_3 = [0 1 1 1 0 0 1 1 0 0 0 0 0 1 0].

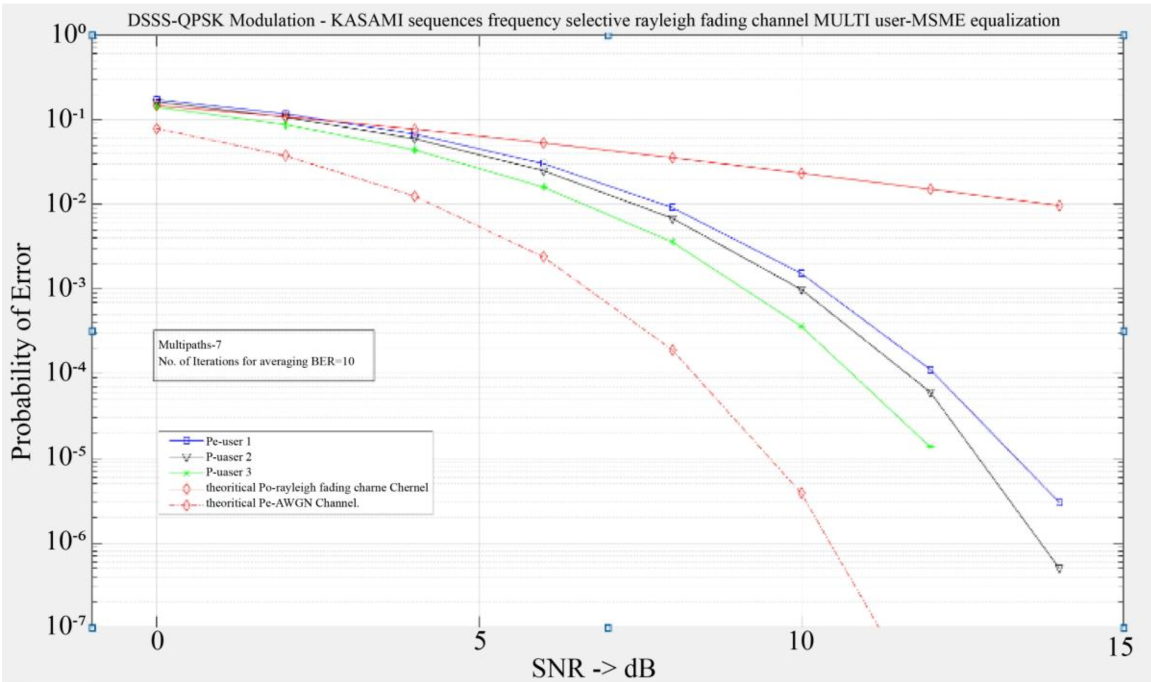

Fig. 4 P_e Vs SNR for K_1, K_2, and K_3 Kasami codes of length 15

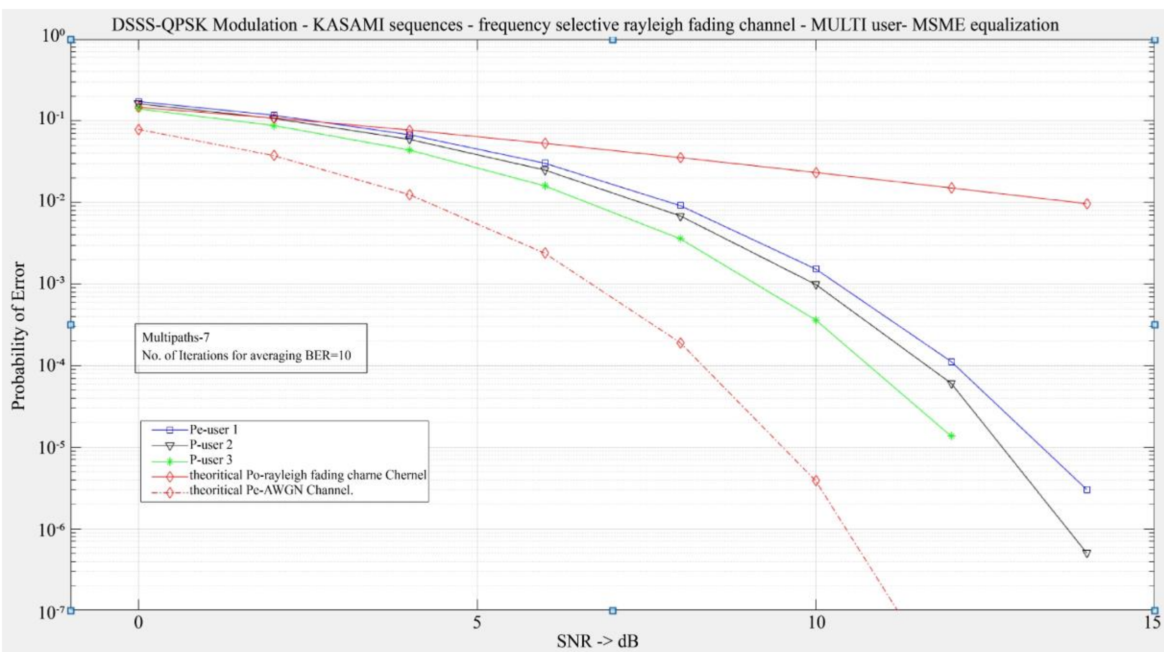

Fig. 5 P_e vs SNR for 63 length K_1, K_2, K_3, and K_4 kasami

For 6 Shift registers with (6, 1) tap combinations, four Kasami codes of length 63 are obtained, and the codes are assigned to different users in a multi-user cellular environment. i^{th} user uses Kasami code K_i for spreading the data signal at the transmitter before modulation.

For user 1 spreading code is K_1= [1 1 0 0 1 1 0 0 0 1 1 1 1 1 0 1 1 1 1 0 0 0 1 1 1 0 0 0 0 1 1 0 1 1 1 1 0 1 1 1 0 1 0 1 1 1 0 1 1 1 0 0 1 1 0 1 0 0 0 0 1 0 0]

For user 2 spreading code is K_2 = [1 1 1 0 0 0 1 0 0 0 1 0 0 0 0 1 0 1 0 1 1 0 1 0 1 1 1 1 0 1 0 0 0 0 0 1 0 0 1 0 1 0 0 1 0 1 1 0 0 1 0 1 1 0 1 0 0 0 1 0 0 1 1]

For user 3 spreading code is K_3 = [1 0 1 1 1 1 1 0 1 0 0 1 1 0 0 0 0 0 1 0 1 0 0 0 0 0 0 1 0 0 0 1 1 1 0 1 1 0 0 1 0 0 0 0 0 0 0 1 0 1 1 1 0 1 0 0 0 1 1 1 1 0 1]

For user 4 spreading code is K_4 = [0 1 0 1 1 0 1 1 0 1 0 1 0 0 1 1 1 0 1 1 1 1 1 1 0 0 1 1 1 1 1 1 1 0 0 0 0 1 0 1 1 0 1 1 1 0 0 0 0 0 0 0 0 1 1 0 1 0 0 1 1 1 1]

From Figures 4 and 5, the bit error curves for different Kasami codes of the same length produced from the single tap combination are dissimilar.

The probability of error Vs SNR curves for different length codes generated from different length shift Registers is shown in Figure 6. Various kami codes assigned to multiple users are mentioned below.

- For two shift registers with (1, 2) tap combination, the selected Kasami sequence is K_1 of length 3, i.e., [1 0 0]
- For four shift registers with (4,3) tap combination, the selected Kasami sequence is K_2 of length 15 [1 1 0 0 1 0 0 0 0 0 1 1 0 0 1]
- For six shift registers with (6, 5) tap combination, the selected Kasami sequence is K_3 of length 63, i.e., [1 1 0 1 0 1 1 1 1 0 0 1 0 1 1 0 0 0 0 0 0 0 0 1 1 1 0 1 1 0 1 0 0 0 0 1 1 1 1 1 1 1 0 0 1 1 1 1 1 1 0 1 1 1 0 0 1 0 1 0 1 1 0]
- For eight shift registers with (8, 6, 5, 1) tap combination, selected Kasami sequence is K_4 of length 255 [1 0 1 0 1 1 0 1 0 1 1 1 1 1 1 0 0 1 1 1 0 0 0 1 1 0 0 1 0 1 0 1 1 1 1 0 0 1 0 1 0 0 0 1 1 1 1 0 0 1 0 0 0 0 0 0 1 0 0 1 1 0 1 0 1 0 0 0 1 0 1 0 1 0 0 1 1 0 1 0 1 0 1 0 0 0 1 0 0 1 0 1 0 1 0 0 0 0 0 0 1 1 1 1 0 1 11 1 0 1 1 1 1 1 0 0 0 1 1 1 0 1 1 0 1 0 0 0 1 0 1 1 0 0 1 0 11 1 0 0 1 1 1 0 0 0 0 1 1 0 1 0 0 1 1 1 0 0 1 0 0 0 0 0 1 1 10 1 1 1 0 0 1 1 1 1 1 1 1 1 1 1 1 1 0 0 1 1 1 1 0 1 1 1 0 1 0 0 1 1 0 0 1 0 0 1 1 1 0 0 1 0 1 0 1 0 1 1 0 1 1 1 0 1 1 1 0 1 0 1 0 0 1 0 1 1 0 0 1 0 0 0 0 10 1 0 1 1 0 1 0]. The four users in a multicellular environment are assigned different Kasami codes with unlike cross correlation and auto correlation values.

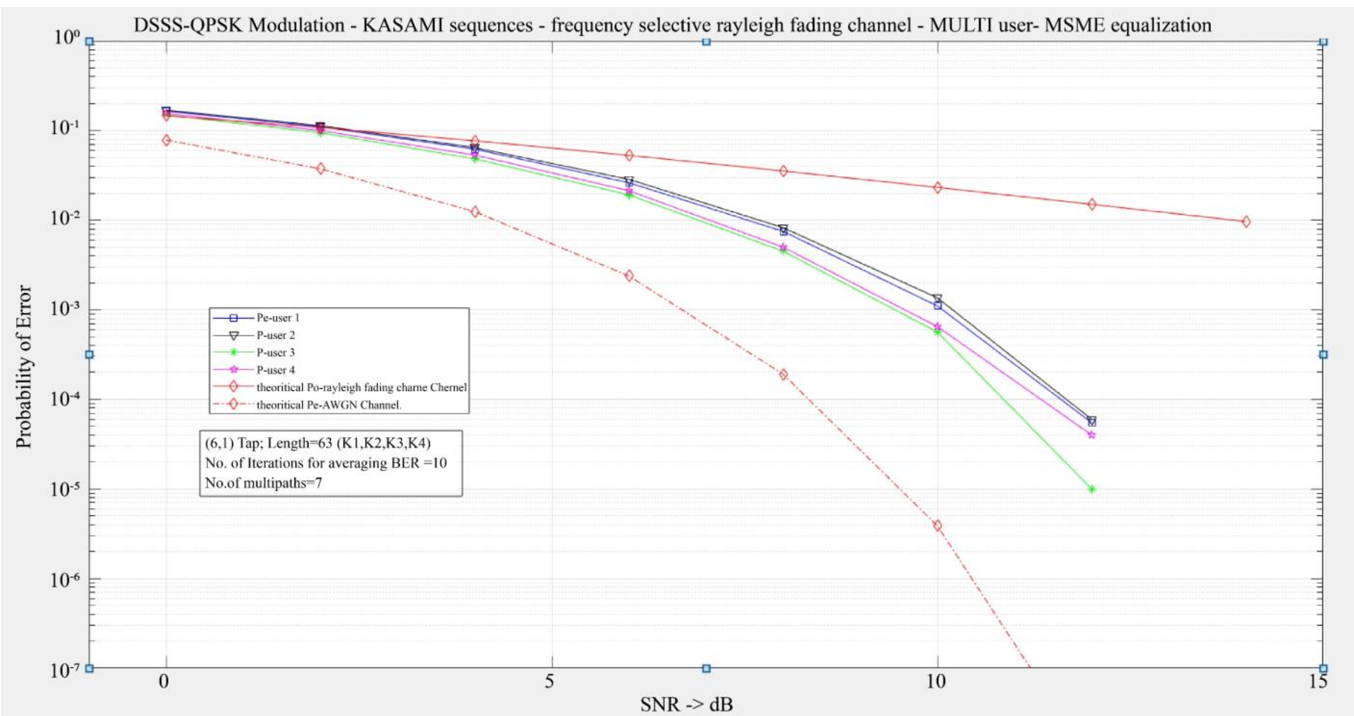

Fig. 6 Pe Vs SNR for 3, 15, 63, 255 length kasami code

From Figure 6, if the length of Kasami codes increases, the probability of error decreases for a particular signal-to-noise ratio, or a particular probability of error SNR requirement is reduced as the spreading code length increases.

3. Conclusion

- For a fixed Signal to Noise Ratio, increasing the length of Kasami codes decreases the probability of error.
- The probability error Vs SNR graph for diverse Kasami codes of equal length produced from the same tap is unrelated.
- Kasami codes exhibit better cross correlation than maximal sequences, maintaining the same peak auto correlation value.

References

[1] N. Abdul Haq, Rajani Katiyar, and K.V. Padmaja, "BER Performance of BPSK and QPSK Over Rayleigh Channel and AWGN Channel," *International Journal of Electrical Electronics Engineering & Telecommunication*, vol. 3, no. 2, pp. 12-16, 2014. [Google Scholar] [Publisher Link]

[2] Neha Mukul, Shailendra Singh Pawar, and Mohd. Sarwar Raeen, "BER and SER Based Performance Analysis of BPSK and QPSK Modulation Schemes with OFDM in Rayleigh Fading Channel," *International Journal of Emerging Trends in Science and Technology*, vol. 1, no. 8, pp. 1242-1250, 2014. [Google Scholar] [Publisher Link]

[3] Yihong Gao, "The Analysis on the Direct Sequence Spread Spectrum Communication System," *International Conference on Network Communication and Information Security*, Beijing, China, vol. 12175, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[4] P. RatnaKamala et al., "Performance Evaluation of Modulation Schemes in AWGN and Rayleigh Fading Channel," *International Journal of Scientific Research in Science and Technology*, vol. 11, no. 11, pp. 857-862, 2024. [Publisher Link]

[5] A. Md. Anamul Islam, C. Md. Julkarnain, and B. Md. Abdul Kader, "BER Performance Analysis of a Real Data Communication through WiMAX-PHY Layer Over an AWGN and Fading Channels," *International Journal of Electrical and Computer Science*, vol. 10, no. 4, pp. 13-16, 2010. [Google Scholar] [Publisher Link]

[6] Meenakshi, and Paras Chawla, "A Review Comparison of Different Spreading Codes for DS CDMA," *International Journal for Scientific Research & Development*, vol. 2, no. 2, pp. 995-999, 2014. [Google Scholar] [Publisher Link]

[7] Kyungwhoon Cheun, "Performance of Direct-Sequence Spread-Spectrum RAKE Receivers with Random Spreading Sequences," *IEEE Transactions on Communications*, vol. 45, no. 9, pp. 1130-1143, 1997. [CrossRef] [Google Scholar] [Publisher Link]

[8] Khalid Hamid Bilal, Ibrahim Khider Eltahir, and Amin Babiker, "Performance Evaluation of DS-WCDMA," *2013 International Conference on Computing, Electrical and Electronic Engineering*, Khartoum, Sudan, pp. 316-318, 2013. [CrossRef] [Google Scholar] [Publisher Link]

[9] E.H. Dinan, and B. Jabbari, "Spreading Codes for Direct Sequence CDMA and Wideband CDMA Cellular Networks," *IEEE Communications Magazine*, vol. 36, no. 9, pp. 48-54, 1998. [CrossRef] [Google Scholar] [Publisher Link]

[10] Abhijit Mitra, "On Pseudo-Random and Orthogonal Binary Spreading Sequences," *International Journal of Electronics and Communication Engineering*, vol. 2, no. 12, pp. 2836-2843, 2008. [Google Scholar] [Publisher Link]

[11] Shibashis Pradhan et al., "Generation of Spreading Codes with Minimum Correlation Using Sorting Genetic Algorithm-II," *International Journal of Innovative Technology and Exploring Engineering*, vol. 9, no. 1, pp. 1744-1749, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[12] T.P. Surekha et al., "Modeling and Simulation Analysis of QPSK System with Channel Coding," *Recent Trends in Wireless and Mobile Networks*, Ankara, Turkey, vol. 162, pp. 57-64, 2011. [CrossRef] [Google Scholar] [Publisher Link]

[13] Abhijit Chandra, and Sudipta Chattopadhyay, "Small Set Orthogonal Kasami Codes for CDMA system," *2009 4th International Conference on Computers and Devices for Communication*, Kolkata, India, pp. 1-4, 2009. [Google Scholar] [Publisher Link]