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Original Article

Five Finger Rake Receiver Performance Analysis for Odd/Even Parity Maximal Spreading Code

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***Abstract* - *The main complication in wireless systems is multipath fading. There is substantial damage in the mobile unit that receives signals due to multipath fading. The received signal deterioration is very high if the multipath path delay is lower than the chip duration. Rake receiver mitigates multipath fading phenomenon. Rake receiver combines different incoming signals by a large quantity of 'sub receivers' called as 'fingers'. The multipath diversity principle is used in this receiver arrangement. Rake calculates the power from numerous transmitted signals. This paper presents the Bit error probability for Rake receiver using Odd parity or parity maximal codes for data spreading in the transmitter, considering mobile slow and flat fading channels. Performance Analysis of Rake receiver is publicized by applying MATLAB®.*

Keywords* - *Rake receiver, Multipath, Signal to Noise Ratio, Code matched filter, Parity bits.

1. Introduction

The rake receiver combines time delayed multipath signals by assigning a discrete correlator for each multipath component [1]. Maximal ratio combining is an optimizing signal combination technique. This spatial diversity method combines weighted locally received signals, i.e., signals carrying the same data, along with Time diversity, employed in rake receivers to improve SNR [2]. Multiple received signals at the receiver input are due to scattering, reflection and diffraction transmission path. The amplitude, phase and direction of arrival of each received signal differ. When all these signals are superimposed to form a single signal, it results in signal strength variations concerning time. [3]. Diverse paths and dissimilar time delays exist in multipath. Combining a delayed version of the received signal enriches the communication link SNR. More than chip delay in Multipath signals are uncorrelated to each other; hence, equalization is essential [4]. If the number of RAKE receiver's fingers increases, signal quality improves [5]. Each maximal sequence produces two codes, i.e., even parity sequence and odd parity sequence [6]. These sequences have better auto-correlation and improved cross correlation [7]. Increased autocorrelation and decreased cross correlation decreased the probability of e, reducing transmitting power and radiation levels [8, 9]. Variation of signal strength in a receiver input leads to fading.it is of two categories: (a) Large-scale fading, i.e., attenuation and shadowing and (b) small scale fading based on time delay spread, i.e., flat fading (Bandwidth of signal < Bandwidth of channel), frequency selective fading (Bandwidth of signal > Bandwidth of channel) and based on Doppler spread, i.e., fast fading (coherence interval < symbol duration) and slow fading (coherence interval > symbol Period) [10]. The existing work presented Rake receiver analysis for maximal sequences. The paper aims to evaluate and analyze the rake receiver for modified maximal sequences. The remaining part is structured as follows: The second Section describes the five finger rake receiver. The mathematical description of the system simulation model developed in MATLAB®, Results, and bit error rate performance curves are obtainable in Section 3. Section 4 completes this paper with a conclusion and future scope.

2. Five Finger RAKE Receiver Description

Rake receiver Five Finger Implementation is presented in Figure 1, which consists of three units, i.e., transmitter, channel, and receiver. In the Transmitter segment, input data is spread using spreading codes, which range the incoming data having *Tc* chip interval [11, 12]. The incoming chips are modulated and given as input to the transmitter. Due to obstacles in the medium, the propagated signal reaches the receiver in numerous paths, unlike time delays [13]. As the transmitted wave reaches the receiver in different directions, path delay and attenuation to each path are different [14]. The following assumptions are considered while developing the simulation model: (1) the time delay difference between each path is one chip duration, and each path is affected by channel impulse response coefficients (C). (2) Negligible propagation delay for Line of Sight (LOS). (3) Transmitting and Receiving antennas are assumed to be ideal. (4) No error detection and correcting mechanism at the receiver.

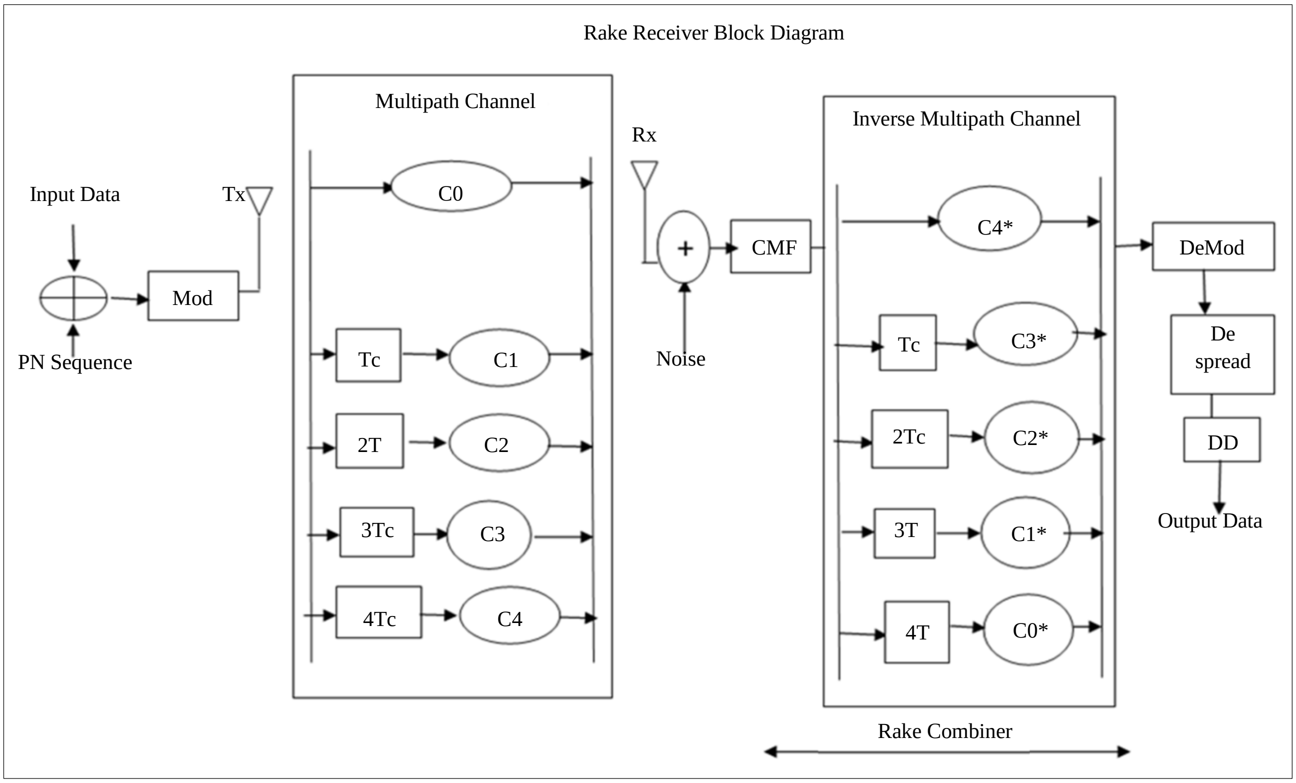

Fig. 1 Five finger RAKE receiver

(5) The Rake receiver has only five sub correlators. Additive White Gaussian Noise corrupts all multipath components, trailed by code matched filter. The receiver section consists of Code matched filter, channel inverse coefficients (C*) and succeeding demodulation, despreading, and decision device. $C_1, C_{2,} C_{3,} \dots\dots$ represent impulse coefficients of the channel. Γ = $\frac{E_b}{N_o} \times C^2{}_{avg}$; where Γ is the average SNR value. For $C^2{}_{avg} = 1$ resembles the mean Eb/No for the channel. The error probability for the Rayleigh channel using Binary Phase Shift Keying modulation is $P_{e,PSK} = 0.5 \times \{1 - \sqrt{\frac{\Gamma}{1+\Gamma}}\}$. A Rake combiner, in addition to code matched filter, is a rake receiver [15]. Figure 1 illustrates the block figure of five finger Rake receiver.

3. Results and Discussion

Twenty thousand bits that are binary phase shift modulated and transmitted through multipath channel with flat and slow fading characteristics are randomly generated. The bits are received in the rake receiver and analyzed to obtain error probability for different level signal to noise ratios. The Matlab program is written by considering the following parameters to obtain the error probability. Here, bits are binary phase shift modulated assuming two channels, i.e., first channel (Ch1) and second channel (Ch2). The relation between Signal power to Noise power Ratio (SNR) and Bit energy (E_b) to noise power spectral density (N_o) is given as,

$$\frac{S}{N} = \frac{E_b}{N_O} \frac{R_b}{BW}$$

Where, S = Signal power; N = Noise power; E_b = Bit energy; N_o = Noise power spectral density; R_b = Bit Rate; BW = Bandwidth of signal

In the simulation analysis, the bit rate to bandwidth ratio is assumed to be unity, and the obtained BER Vs SNR is the same as BER Vs E_b/N_o.

Table 1. Variables for numerical used in Matlab programming

parameter	Value
SNR(dB)	0 to 34 (DB)
Modulation	Binary Phase Shift Keying
Channel impulse coefficients	Ch1 [0.15 0.335 0.2644 0.18 0.873] Ch2 [0.35 0.435 0.764 0.28 0.16]
channel	Multipath channel with AWGN
Fading type	Flat and slow fading channel
No. of Multipath	5paths.

coding	No Channel coding / Source coding technique used
No. of bits	20,000 bits
Spreading code used and code length	Maximal Sequence with even/odd parity & 11 (3,1) Tap - Even Parity sequence [0 1 0 1 0 1 0 1 1 1 1] (3,1) Tap - Odd Parity sequence [1 1 1 0 0 1 0 0 0 0 1] (3,2) Tap - Even Parity sequence [1 1 1 1 0 0 1 1 0 0 1] (3,2) Tap – Odd Parity sequence [1 1 1 0 0 0 1 0 0 1 0]
Maximal sequence	(3,1) Tap Sequence [1 1 1 0 1 0 0] (3,2) Tap Sequence [1 1 1 0 0 1 0]

Table 2. Probability of error for channel 1 (3-bit SR)

Ch1	**Practical Error Probability-Maximal Sequence**				
E_b_N_o (dB)	**(3,2) Tap**	**(3,1) Tap**	**(3,1) Tap even parity**	**(3,2) Tap even parity**	**(3,2) and (3,1) Tap odd parity**
0	0.2881	0.2570	0.0434	0.0406	0.5043
3	0.2508	0.2040	0.0108	0.0107	0.5043
6	0.2320	0.1643	0.0013	0.0006	0.5043
9	0.2182	0.1422	0.0005	0.0003	0.5043
12	0.2055	0.1169	0.0002	0.00005	0.5043
15	0.2060	0.0994	0.00001	0	0.5043
18	0.2127	0.0843	0	0	0.5043
21	0.2100	0.0751	0	0	0.5043
24	0.200	0.0552	0	0	0.5043

3.1. Result 1

The comparison of error probabilities for different tap 3-bit Linear Feedback Shift Register maximal sequences and even and odd parity sequences are presented numerically for diverse values of SNR in Table 2. Also, it was clear that the probability of error performance for even parity maximal code obtained from three stages (LFSR) is better than the original M sequence. The same is depicted in Figure 2. The probability of error Vs E_b/N_o depicted below is the same as that of error Vs signal to Noise Ratio.

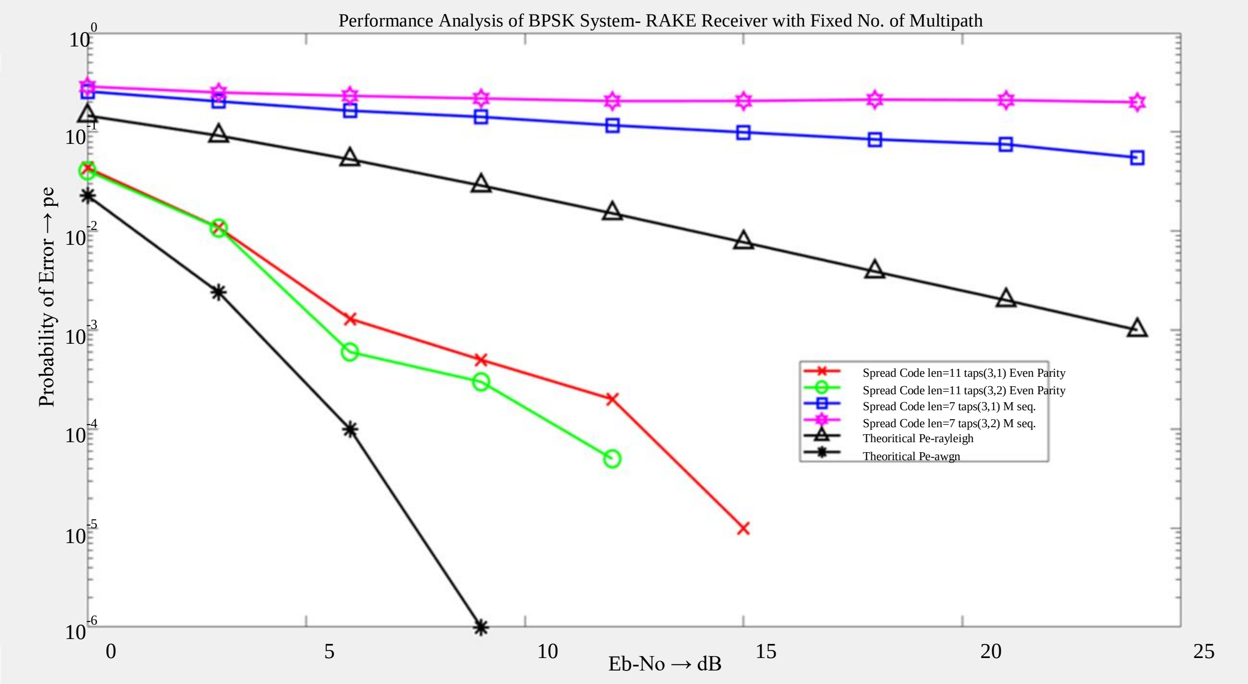

Fig. 2 Performance plots for channel 1 (3-bit SR)

Table 3. Probability of error for channel 2 (3-bit SR)

Ch2	**Practical Error Probability-Maximal Sequence**				
$E_b\_N_o$ (dB)	**(3,2) Tap**	**(3,1) Tap**	**(3,2) Tap Even Parity**	**(3,1) Tap Even Parity**	**(3,2)& (3,1) Odd Parity**
0	0.1794	0.1069	0.0297	0.0238	0.503
3	0.1319	0.0659	0.0045	0.0034	0.503
6	0.0959	0.0396	0.0003	0.0001	0.503
9	0.0534	0.0163	.00001	.00002	0.503
12	0.0194	0.0041	0	0	0.503
15	0.0037	0.0007	0	0	0.503
18	0.0002	0	0	0	0.503
21	0	0	0	0	0.503

3.2. Result 2

If the channel conditions are altered due to a dynamically changing environment, i.e., considering the second channel (Ch2) in simulation again, the maximal even parity sequence performance is better than the maximal sequence. The probability of error vs Signal to Noise Ratio for channel 2 is shown in Table 3. The corresponding plot for the mentioned second channel conditions is shown in Figure 3. From Figure 3, it was concluded that an even parity sequence has more ones than zeros; hence, its probability of error performance is better than an odd parity sequence, which has more zeros than ones. Also, a sequence of the same length produces different error probabilities for a fixed E_b/N_o (or) for a fixed Signal to Noise Ratio in different wireless channel conditions.

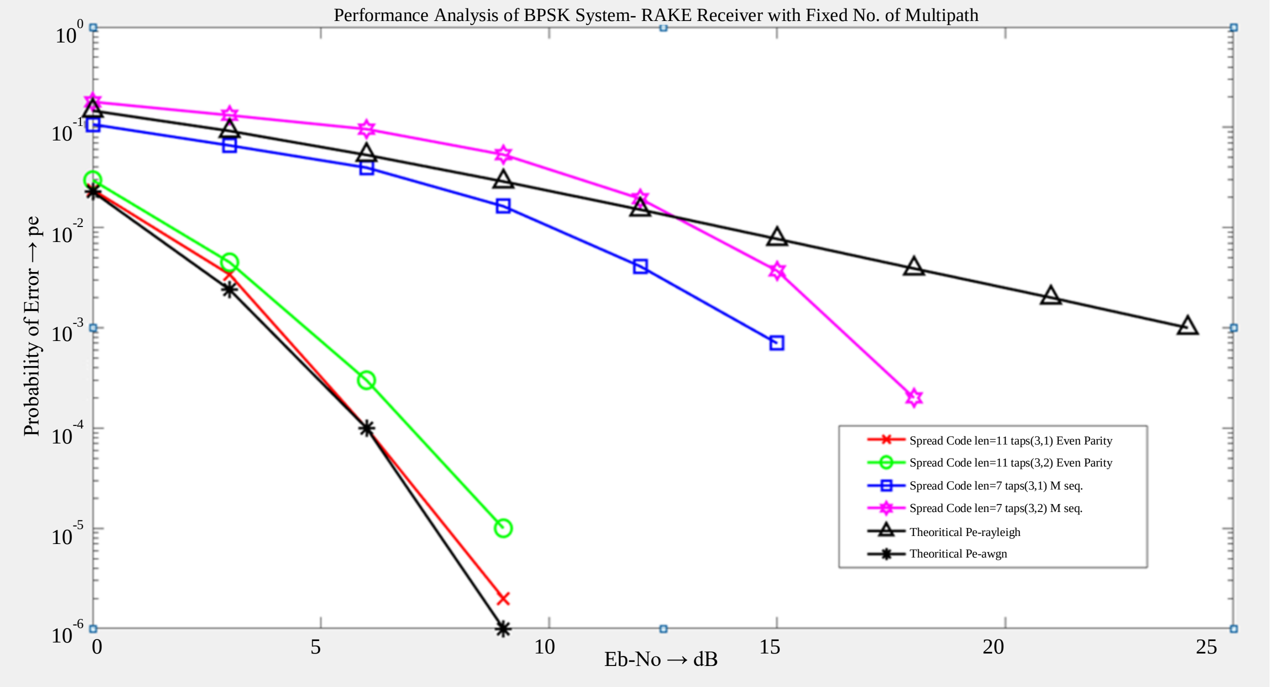

Fig. 3 Performance plots for channel 2 (3-bit SR)

Table 4. Probability of error for channel 2 (4-bit SR)

Ch2	**Practical Error Probability**		
$E_b\_N_o$ (dB)	**(4,1)Tap**	**(4,1) Tap even parity**	**(4,1) Tap odd parity**
0	0.9104	0.5030	0.0569
3	0.9605	0.5030	0.0138
6	0.9876	0.5030	0.0014
9	0.9982	0.5030	0.0001
12	1.0000	0.5030	0
15	1.0000	0.5030	0
18	1.0000	0.5030	0
21	1.0000	0.5030	0
24	1.0000	0.5030	0

Consider four flip-flop linear feedback shift registers with (4,1) tap combination maximal sequence generated with (i) even parity is :[1 1 1 1 0 0 1 0 1 1 0 0 1 1 0 0 0 0 1 0] and (ii) odd parity is:[1 1 1 1 1 0 1 0 1 1 0 0 0 1 0 0 1 0 0 1]. The simulation results for 20k bits using a rake receiver are presented in Table 4. Therefore, in four four-stage LFSRs, (4,1)Tap odd parity sequence has more ones; hence, it performs better than even parity. Next, consider Five shift registers with (5,4,3,2) Tap combinations, then (i) even parity maximal sequence of length 37 is :[1 1 1 1 1 1 0 0 1 0 0 1 1 0 0 0 0 1 0 1 1 0 0 1 0 1 0 0 0 1 1 1 1 1 0 1 0] & (ii) Odd parity sequence is [1 1 1 1 1 0 0 0 1 0 0 1 1 0 0 0 0 1 0 1 11 0 1 0 1 0 0 0 0 1 1 1 0 0 0 1]. The following results were obtained for 20 K-bit transmission with Ch2 coefficients using a rake receiver. Similarly, for five five-stage LFSRs (5,4,3,2), tap even parity results in less error probability.

Table 5. Probability of error for channel 2 (5-bit SR)

Ch2	**Practical Error Probability-Maximal Sequence**		
$E_b\_N_o$ (dB)	**(5,4,3,2) Tap**	**(5,4,3,2) Tap Even parity**	**(5,4,3,2) Tap Odd**
0	0.2157	0.0206	0.5040
3	0.1348	0.0021	0.5040
6	0.0643	0	0.5040
9	0.0201	0	0.5040
12	0.0033	0	0.5040
15	0.0002	0	0.5040
18	0	0	0.5040
21	0	0	0.5040
24	0	0	0.5040

3.3. Result 3

From Figure 4, the probability of error comparison of five multipath coefficients CH2 for various maximal codes of even parity or odd parity of length 11, 20, 37 generated with (3,1) (3,2) (4,1) (5,4,3,2) valid taps respectively. In the Ch2 multipath channel (5,4,3,2), the tap of the even parity maximal sequence performs better. In Figure Three, the stage shift register performance is better than that of the four stages shift register. Hence, it is concluded that increasing the maximal sequence length does not guarantee performance improvement.

4. Significant Limitations

Channel coding improves communication link performance by withstanding channel impairments such as noise, interference and fading. Automatic Repeat Request (ARQ) and forward error correction (i.e., error detection & and correction) are two methods to control errors. In ARQ, the receiver does not attempt to correct the errors but requests the source to resend the data where a way link is required. In the forward error correction method, parity or redundant bits are added to reduce the errors. Two major categories of error control codes are Block codes and convolutional codes. Block coding involves binary (linear and cyclic codes) and non-binary codes. The analysis of the rake receiver for all the above-mentioned coding schemes will be tabulated and presented in the future scope of the work, as channel coding is a limitation of this paper. Performance evaluation of rake receivers with different modulation techniques like Quadrature Phase Shift Keying (QPSK) and Quadrature Amplitude Modulation (QAM) will be presented.

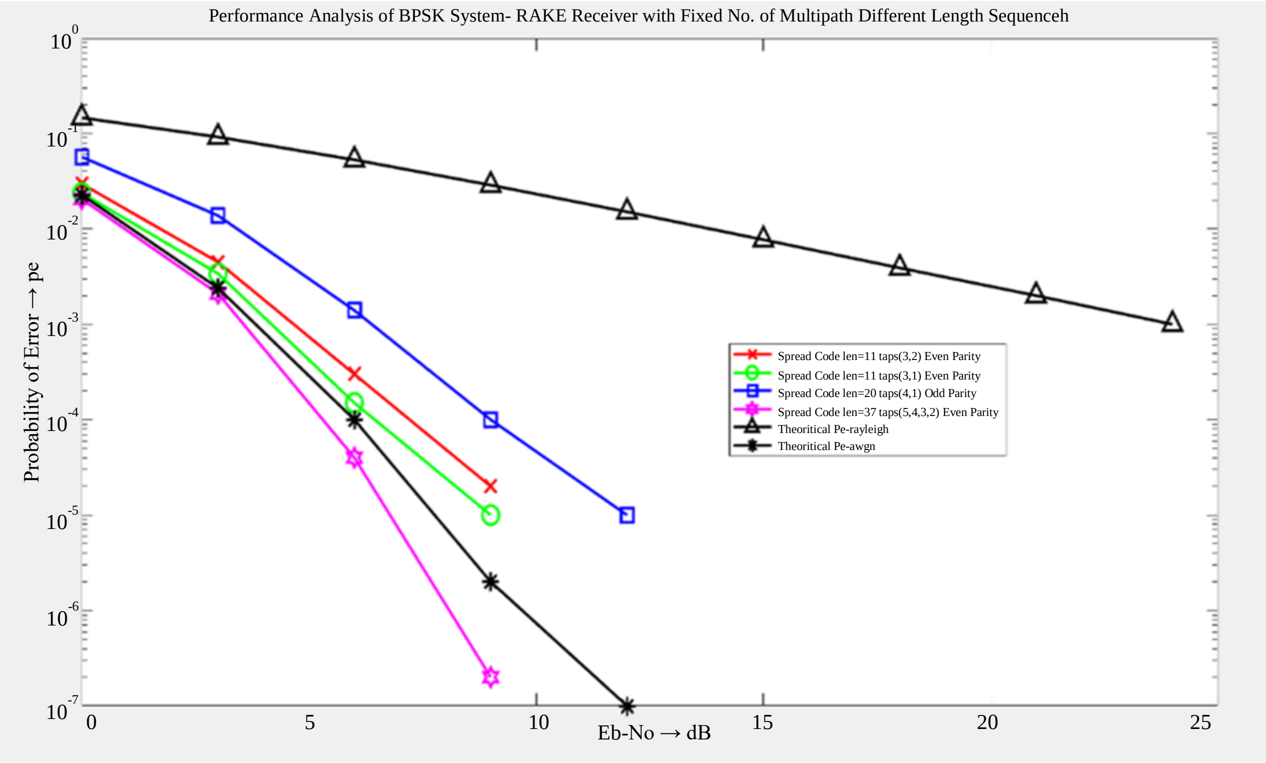

Fig 4. Performance plots for channel 1 (3, 4,5-bit SR)

5. Conclusion

Simulation results show that, without channel coding techniques, using even parity maximal sequence or odd parity maximal sequence as spreading code results in less probability of error compared to the original Maximal sequence generated from any tap combination with the expense of a slight increase in bandwidth. The probability of error performance for even parity maximal code obtained from three stages (LFSR) is better compared to the original M sequence, and even parity sequence has more number of ones than zeros; hence, its probability of error performance is better in contrast to odd parity sequence has more zeros than ones. From all the curves, the performance of the rake receiver is proved to be better for modified maximal codes than maximal codes.Due to dynamically changing wireless channels, the increased maximal sequence length does not assure performance improvement. The future scope of work includes Racian channel conditions with other diversity techniques to evaluate its performance. The rake receiver technique is applied to indoor multipath channels in 5G systems and 5G TDD cellular based on multipath division multiple access systems to compare error probability with existing work.

References:

[1] D. Sri Kavya, and P. Siddaiah, “Implementation of Seven Finger RAKE Receiver Using MRC Technique,” *International Journal of Recent Technology and Engineering (IJRTE)*, vol. 8, no. 3, pp. 1689-1693, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[2] I.A. Alimi, J.J. Popoola, and K.F. Akingbade, “A Power Efficient Rake Receiver for Interference Reduction in the Mobile Communication Systems,” *International Journal of Electronics and Electrical Engineering*, vol. 3, no. 6, pp. 501-505, 2015. [CrossRef] [Google Scholar] [Publisher Link]

[3] Vaibhav Khairanr, Jitendra Mathur, and Hema Singh et al., “Bit Error Rate Performance Analysis of CDMA Rake Receiver,” *International Journal of Engineering Science Invention*, vol. 3, no. 6, pp. 52-58, 2014. [Google Scholar] [Publisher Link]

[4] Busim Ananta Lakshmi et al., “Design and Analysis of Rake Receiver,” *2023 International Conference on Sustainable Computing and Data Communication Systems (ICSCDS)*, Erode, India, pp. 1020-1027, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[5] 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]

[6] U. Grob et al., “Microcellular Direct-Sequence Spread-Spectrum Radio System Using N-Path RAKE Receiver,” *IEEE Journal of Selected Areas in Communications*, vol 8, no. 5, pp. 772-780, 1990. [CrossRef] [Google Scholar] [Publisher Link]

[7] Babak Hossein Khalaj, Arogyaswami Paulraj, and Thomas Kailath, “2D Rake Receivers for CDMA Cellular Systems,” *1994 IEEE GLOBECOM. Communications: The Global Bridge*, San Francisco, CA, USA, 1994. [CrossRef] [Google Scholar] [Publisher Link]

[8] Xinyue Li, Yajie Yan, and Deyue Zou “A Master-Slave Rake Receiver for Integrated Navigation/ Communication Signal,” *2021 International Wireless Communications and Mobile Computing (IWCMC)*, Harbin City, China, pp. 1070-1074, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[9] V. Umadevi, and P. Easwaran “ A Study on Rake Receivers,” *2017 IEEE International Conference on Electrical, Instrumentation and Communication Engineering (ICEICE)*, Karur, India, pp. 1-5, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[10] S. Popa, N. Draghiciu, and R. Reiz, “Fading Types in a Wireless Communication System,” *Journal of Electrical and Electronics Engineering*, pp. 232-237, 2008.

[11] James S. Lehnert, and Michael B. Pursley, “Multipath Diversity Reception of Spread-Spectrum Multiple-Access Communications,” *IEEE Transactions on Communications*, vol. 35, no. 11, pp. 1189-1198, 1987. [CrossRef] [Google Scholar] [Publisher Link]

[12] Tengku Azita Tengku Aziz, and Abdul Halim Ali, “A New Rake Receiver Design for Long Term Evolution - Advance Wireless System,” *2011 IEEE Symposium on Wireless Technology and Applications (ISWTA)*, pp. 52-55, Langkawi, Malaysia, 2011. [CrossRef] [Google Scholar] [Publisher Link]

[13] Gregory E. Bottomley, “A Generalized Rake Receiver for Interference Suppression,” *IEEE Journal on Selected Areas of Communication*, vol. 18, no. 8, pp.1536-1545, 2000. [CrossRef] [Google Scholar] [Publisher Link]

[14] Ahmed Faraz, “Performance Metrics of Rake Receivers,” *2023 IEEE International Multi-disciplinary Conference in Emerging Research Trends (IMCERT)*, Karachi, Pakistan, pp. 1-4, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[15] P. Nilsson, and T. Maseng, “RAKE Receiver CDMA performance,” *5th IEEE International Symposium on Personal, Indoor and Mobile Radio Communications, Wireless Networks - Catching the Mobile Future*, The Hague, Netherlands, pp. 696-699, 2002. [CrossRef] [Google Scholar] [Publisher Link]