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DEVELOPMENT OF AN ENHANCED SELECTION COMBINER IN AN UNCORRELATED NAKAGAMI 0.5 FADING CHANNEL USING ADAPTIVE POWER CONTROLLED

[1]Adedeji, Adebukola Ayoade [2]Hamzat Adewale Kazeem and Oladosu Jamiu A.
[1]Department of Mechatronics Engineering, Osun State College of Technology Esa-Oke, Nigeria
[2,3]Department of Electrical and Electronics Engineering,
Osun State College of Technology Esa-Oke
Corresponding author's email: -adedejibukky06@gmail.com-

Abstract
Wireless communication has found worldwide recognition in providing acceptable signal levels due to its flexibility and ease of usage. However, the system is characterized by severe multipath propagation effects that degrade its performance. Selection Combiner (SC), as one of the techniques being used to address this problem has a poor performance with low Spectral Efficiency (SE) and high Bit Error Rate (BER) due to the fixed transmitting power used in the system. Hence, in this paper, an enhanced SC that adjusts the transmitting power based on Channel State Information (CSI) with a closed-form expression over an uncorrelated Nakagami-0.5 fading channel is proposed. The proposed technique is developed using the conventional SC (CSC) and feedback algorithm. The multiple copies of the transmitting signal over an uncorrelated Nakagam 0.5 fading channel are received using multiple antennae. The resultant signals at varying paths 'L' (2, 3, 4) were scanned by SC to choose a path with the highest Signal Noise Ratio (SNR). The output of SC which is a function of Channel State Information (CSI) acquired was used to determine the channel gain. The transmitting power was then adjusted based on the value of channel gain through the feedback algorithm. A mathematical expression for BER and SE was also derived. The proposed technique was simulated using Matrix Laboratory R2018a and evaluated using SE and BER by comparing with each Optimal Rate Adaptation (ORA) and Channel Inversion Fixed Rate (CIFR) to determine the performance of the system. The results obtained revealed that the proposed technique shows a percentage reduction in BER of 33.33% and 66.67% when compared with ORA and CIFR, respectively. The study showed that the proposed technique gave lower BER values compared to ARA and CIFR and this is due to self-adjustment of the transmitting parameter.
Keywords—Diversity Combiner (DC), Adaptive Power Control (APC), Selection Combiner (SC), Bit Error Rate (BER), Spectral Efficiency (SE), Nakagami 0.5 fading channel

1 Introduction

Wireless communication system which involves the transmission of information across a distance without the use of wire has become an important tool for fast and efficient means of data transmission. The term wireless is used to describe communications in which electromagnetic waves carry signals over part or the entire communication path [1]. Unlike wired communication channel which is static and predictable, the wireless communication channel is dynamic and unpredictable and this makes an exact analysis of the wireless communication system often difficult. In wireless communication, the signal propagates from transmitter to receiver through an unbounded environment known as radio propagation. In the course of propagation, radio waves are mainly affected by three physical phenomena including diffraction, reflection, and scattering resulting in signal fading [2]. Fading is a unique characteristic in wireless communication and it can be described as variation of signal amplitude over time and frequency. Fading is a channel impairment that is characterized as a non-additive signal disturbance in the wireless channel and degrades the

transmitting signal. Fading is either due to multipath propagation, referred to as multipath fading, or as a result of blockage known as shadowing.

Multipath fading occurs when the signal propagates in multiple copies between the transmitter and receiver due to obstructions along the propagation path, while, shadowing is the fluctuation in the power of the received signal due to obstructions along the propagation path. The effect of multipath fading and shadowing is degradation in the quality of the received signal causing poor reception. Thus, fading compensation is typically required to mitigate the effect of fading [1]. Diversity Combiner (DC) is one of the techniques that mitigate the detrimental effect of fading in wireless communication. It is a technique that combines multiple copies of the transmitted signal at the receiver to improve the signal strength of the received signal [8]. DC technique consists of Equal Gain Combiner (EGC), Maximal Ratio Combiner (MRC), and Selection Combiner (SC). The results of the past research on the DC technique reveal that the SC technique is often used in practice due to its low complexity but suffers from poor performance when compared with MRC and EGC [9]. In the SC technique, the SNR of all the diversity branches that are available in the system is evaluated to select the best path. The diversity output path from the combiner has a signal-to-noise ratio that is equal to the maximum SNR of all the diversity branches [10, 11, 12]. The poor performance of SC is due to only one signal branch being used out of the multiple available branches, fixed transmitting power, and the time-varying nature of the channel [1, 8]. As a result of the varying nature of the channel, modern wireless devices are equipped with channel measurement and rate adaptive capabilities that allow the transmitter-receiver pair to measure the fade state using a pre-determined pilot signal and rate control capability that allows the transmitter to adjust the reliable transmission rate over time. Such a control is achieved in various ways such as adjusting the power level, symbol rate, coding scheme, constellation size, and any combination of these approaches. Then, the receiver detects these changes directly from the received data without the need for explicit rate change control information [2]. Therefore, this paper proposed an enhanced SC technique that adjusts the transmitting power based on Channel State Information (CSI) known as Adaptive Power Controlled (APC).

Several works have been carried out on diversity combiners to improve the performance of wireless communication systems**.** In [12], closed-form expressions for the spectral efficiency of dual branch Selection Combiner (SC) with no diversity under Optimum Rate Adaptation (ORA) and Channel Inversion with Fixed Rate (CIFR) schemes were proposed. Error bounds were derived for truncated infinite series under ORA. The results illustrated that bounds can be used effectively to determine the number of terms needed to achieve a desirable level of accuracy. The results obtained in the paper revealed that the SC with ORA and CIFR gave a lower BER when compare with conventional SC. However, the technique suffers from poor performance in a time-varying channel due to the fixed transmitting power used. The performance analysis of hybrid MRC/EGC Diversity Combining Techniques over the AWGN channel is carried out in **[13]**. In this paper, there was an L number of MRC each having an M number of input branches and each of the M branches received the signal and the individual antennas were kept sufficiently apart to have negligible correlation among the received branch signals. The output of each of the L Maximum Ratio Combining was used as input to Equal Gain Combiner.

The results obtained from the paper showed that the hybrid technique gave better performance by providing a maximum benefit compared to other techniques. However, the technique is characterized by hardware complexity. Also, **[14]** presented a paper on the Spectral efficiency of dual diversity selection combining schemes under correlated Nakagami-0.5 fading with unequal average received SNR**.** The authors derived expressions for the spectral efficiency over correlated Nakagami-0.5 fading channels with unequal average received SNR. The spectral efficiency was

evaluated under different adaptive transmission schemes using a dual-branch SC diversity scheme. The result obtained from the paper revealed the spectral efficiency degradation due to channel correlation and unequal average received SNR between the different combined branches under different adaptive transmission schemes. The authors stated that the truncated channel inversion with fixed rate (TIFR) scheme is a better choice over the ORA scheme under correlated Nakagami-0.5 fading channels with unequal average received SNR. However, the techniques suffer from poor performance in a time-varying channel due to the fixed power used for radio wave propagation. Furthermore, in [15], fading mitigation techniques in wireless mobile communication were carried out to solve the problem of multipath fading using a Rake receiver. The rake receiver combined the time-shifted versions of the original signal by providing a separate correlation receiver for each of the multipath signals. The design of a rake receiver can be visualized as a series of time-delayed correlator taps fed from a common antenna. The system has a better performance but it requires a dedicated receiver for each path which led to total dependence of the entire transmission process on a single receiver. As such, the failure of the dedicated receiver would imply total system shutdown.

Therefore, previous works on diversity combiner showed that the **S**C technique is often used in practice due to its low complexity but suffers from poor performance when compared with other diversity combining techniques in a time-varying channel due to only one path and fixed transmitting power used. Therefore, in this paper SC with adaptive power control based on the CSI to improve the existing SC with adaptive transmission techniques such as ORA and CIFR is proposed. Signal propagation in wireless communication follows different fading distributions such as Weibull, Nakagami-*m,* and Rician fading distributions. Uncorrelated Nakagami-*m* distribution in which that signal propagated does not encounter overlapping is adopted in this paper due to its capability to model both the indoor and outdoor mobile radio environment[13, 14, 15]. The proposed technique will be compared with the commonly used adaptive SC technique, that is, Optimal Rate Adaptation (ORA) and Channel Inversion with Fixed Rate (CIFR) to measure the performance. The contribution of this paper is as follows

1). Proposes an adaptive SC technique that adjusts its transmitting power based on the channel gain at an instant thereby enhancing the performance of the existing SC.

2). Derivation of Bit Error Rate (BER) expression for the proposed adaptive SC technique over uncorrelated Nakagami 0.5 fading distribution.

The remaining part of this paper is organized as follows; section 2 designed the proposed adaptive SC, while, the simulation results that analyzed the performance of the proposed SC technique are presented in section 3. The conclusion of the paper is presented in section 4.

2. METHODOLOGY

2.1 Designed of the Proposed Adaptive SC Technique

The transmitting signal generated randomly is propagated through a Nakagami-m fading channel from the transmitting antenna and Selection Combining (SC) scans through the multiple copies of the signals to choose the branch with the highest SNR*(max R (t))*as shown in Fig 2. The selected signal passes through Channel State Information (CSI) to obtain the channel gain thereby determining the SNR of the received signal. The output of CSI serves as input to the decision device to check the value of the SNR. If the channel gain is high, therefore, the decision device instructs the transmitter through a feedback path to increase or reduce transmitting power based on the value of SNR of the received signal.

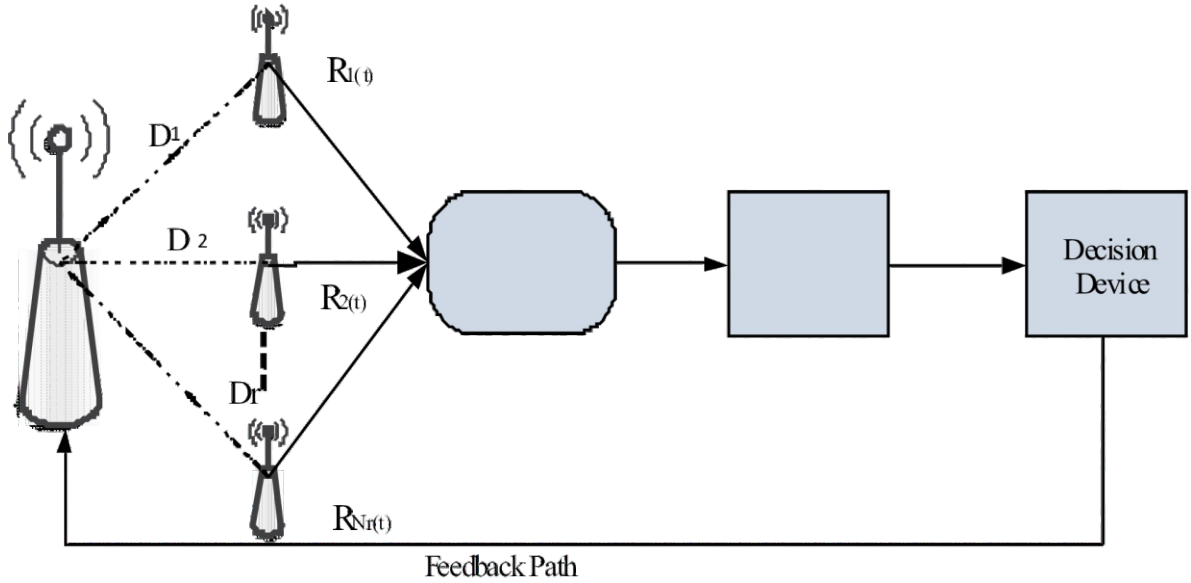


Fig. 1: Block diagram of an Adaptive Power Control System

The instantaneous Signal-to-Noise ratio (SNR) of the received signal is the product of channel gain $'H'$ at a particular time and the constant $P_t/_{NB}$. Therefore, the instantaneous SNR of the received signal $'\gamma'$ is given by [22] as

$$\gamma = \frac{P_t H}{NB} \quad (1)$$

Where: P_t is the transmit power
$B$is the channel bandwidth
$H$is the channel gain
$N$is the noise spectral density which is equal to $10^{-9} W/Hz$

The Probability Density Function (PDF) of the received signal over the Nakagami-m fading channel is given by [23] as
as

$$P_r(r) = \frac{2}{\Gamma(m)} \left(\frac{m}{2\sigma^2}\right)^m r^{2m-1} \exp\left(\frac{-mr^2}{2\sigma^2}\right) \quad r \geq 0 \quad (2)$$

But Bit Rate 'R' is given by [19] as

$$R = Bx log_{10}\left(\frac{1+(PxH)}{N}\right) \quad (3)$$

where: B is the Bandwidth of transmitted data
P is the transmit power in watts
H is the channel gain
N is the noise.

From equation 3, channel gain 'H' was obtained as

$$\frac{R}{B} = log_{10}\left(\frac{1+(PxH)}{N}\right) \quad (4)$$

$$10^{\frac{R}{B}} = \frac{1+(PxH)}{N} \quad (5)$$

$$H = \frac{\left(Nx10^{R/B}\right)-1}{P} \quad (6)$$

Substituting equation 6 into equation1 gives

$$\gamma = \frac{P_t\frac{\left(Nx10^{R/B}\right)-1}{P}}{NB} \quad (7)$$

Therefore, a PDF of the received signal for the proposed technique is obtained by substituting equation 7 into equation 2, yield

$$P_r(r) = \frac{2}{\Gamma(m)}\left(\frac{m}{2\sigma^2}\right)^m \left(\frac{P_t\frac{\left(Nx10^{R/B}\right)-1}{P}}{NB}\right)^{2m-1} \exp\left(\frac{-m\times\frac{P_t\frac{\left(Nx10^{R/B}\right)-1}{P}}{NB}}{2\sigma^2}\right)^2 \quad (8)$$

By solving equation 8 and substituting m = 0.5, equation 8 becomes

$$P_r(r) = \frac{2}{\Gamma(0.5)}\left(\frac{0.5}{2\sigma^2}\right)^{0.5} \exp\left(\frac{-P_t\times\left(N\times10^{R/B}\right)^{-2}}{NB}\right) \quad (9)$$

2.2 Derivation of Bit Error Rate for the proposed technique

The performance of the proposed technique is evaluated using BER which is the ratio of the erroneous bit to the transmitted bit and the lower the value of BER, the better the performance of the technique. The expression for Bit Error Rate ($P_b(E)$) is given by [19] as

$$P_b(E) = \int_o^\infty P_b\left(E/\gamma\right) P_r(\gamma)d\gamma \quad (10)$$

where: $P_b\left(E/\gamma\right)$ is the conditional error probability

$E$is signal per bit or signal per symbol

$\gamma$is the received SNR

$P_r(\gamma)$is the PDF of the output SNR.

Substituting equation 9 into equation 10 gives

$$P_b(E) = \int_o^\infty P_b\left(E/\gamma\right)\frac{2}{\Gamma(0.5)}\left(\frac{0.5}{2\sigma^2}\right)^{0.5} \exp\left(\frac{-P_t\times\left(N\times10^{R/B}\right)^{-2}}{NB}\right)d\gamma \quad (11)$$

According to [19], conditional error probability $P_b\left(E/\gamma\right)$ is given as

$$P_b\left(E/\gamma\right) = 1/2 \exp(a\gamma) \quad (12)$$

where: $a = 0.5$ for non-coherent modulation

For non-coherent modulation, equation 12 becomes

$$P_b\left(E/\gamma\right) = 1/2 \exp(0.5\gamma) \quad (13)$$

Substituting equation 13 into10 gives

$$P_b(E) = \int_o^\infty 1/2 \exp(0.5\gamma)\frac{2}{\Gamma(0.5)}\left(\frac{0.5}{2\sigma^2}\right)^{0.5} \exp\left(\frac{-P_t\times\left(N\times10^{R/B}\right)^{-2}}{NB}\right)d\gamma \quad (14)$$

3 RESULTS AND DISCUSSION

Results for BER and SE presented in equations (14) and (17), respectively were obtained and used to evaluate the performance of the proposed technique. The comparison was done using the results obtained by comparing with ORA and CIFR proposed in [12]. The proposed technique is named Adaptive Power (AP) and this was used in presenting the results for ease of comparison.

Fig. 2presents the Bit Error Rate (BER) versus SNR at propagation path 'L' of 2, for the proposed Adaptive Power (AP), Optimal Rate Adaptation (ORA), and Channel Inversion Fixed Rate (CIFR) over the Nakagamim fading channel. At SNR of -6, -4, 2, and 4 dB, the BER values of 1.69×10^{-5}, 1.14×10^{-5}, 1.59×10^{-7} and 8.54×10^{-8} were obtained for AP, respectively, as against 1.13×10^{-2}, 1.68×10^{-3}, 1.61×10^{-4} and 8.51×10^{-5} obtained for ORA at the same value of SNR. CIFR showed poor performance when compared with AP and ORA with BER values 1.69×10^{-1}, 4.18×10^{-2}, $4.17\times10^{-3}$and 2.69×10^{-3} at SNR of -6, -4, 2, and 6 dB, respectively. From Fi.3, the AP showed better performance with lower BER when compared with ORA and CIFR. The better performance of the proposed AP technique is due to adjusting the transmitting power based on the channel gain at any time.

Fig.3 depicts the BER values obtained for AP, ORA, and CIFR at L of 3. At SNR of -6, -4, 2, and 4 dB the BER values of 9.84×10^{-8}, 9.67×10^{-9}, 8.82×10^{-11} and 9.35×10^{-12} were obtained, respectively for AP. The BER values obtained for ORA at the same SNR were 9.84×10^{-5}, 9.67×10^{-6}, 8.01×10^{-7} and 9.67×10^{-8} as against 2.79×10^{-2}, 9.84×10^{-3}, 4.37×10^{-4} and 2.53×10^{-4} for CIFR. The results obtained showed that BER decreases as SNR increases and this demonstrates the effect of transmitting power on the transmitting signal. Fig. 4 depicts the BER values obtained versus SNR at L of 4 over the Nakagami 0.5 Fading Channel.

The BER values obtained at SNR of -6, -4, 2, and 6 dB are 4.92×10^{-11}, 4.83×10^{-12}, 4.65×10^{-15},4.65×10^{-16} for AP as against 4.92×10^{-7}, 4.83×10^{-8}, 4.34×10^{-10} and 4.65×10^{-11} for ORA. CIFR showed poor performance when compared with APC and ORA with BER values of 4.92×10^{-4}, 1.37×10^{-4}, 4.83×10^{-6} and 1.22×10^{-6} at SNR of -6, -4, 2, and 4 dB, respectively. The results obtained show that, BER values decrease with an increase in the number of paths.

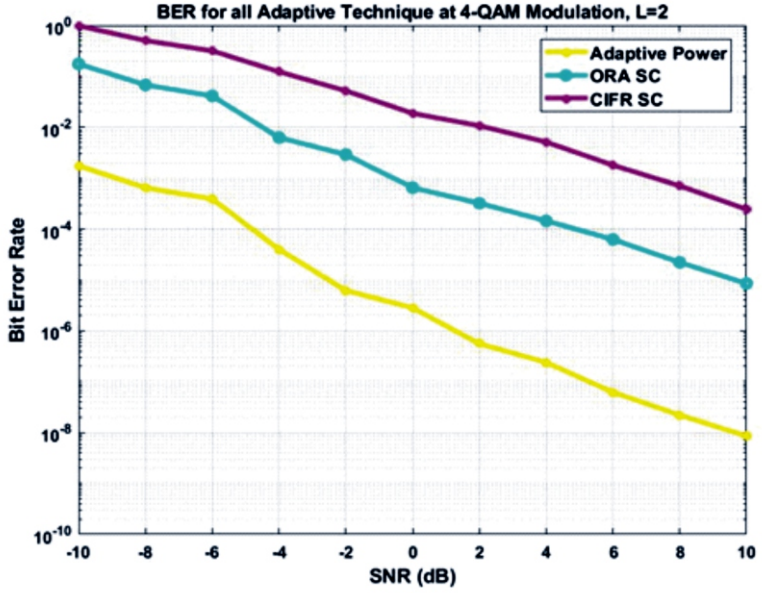


Fig. 2: BER versus SNR for Adaptive Power, ORA, and CIFR at L of 2 over Nakagami 0.5 Fading distribution.

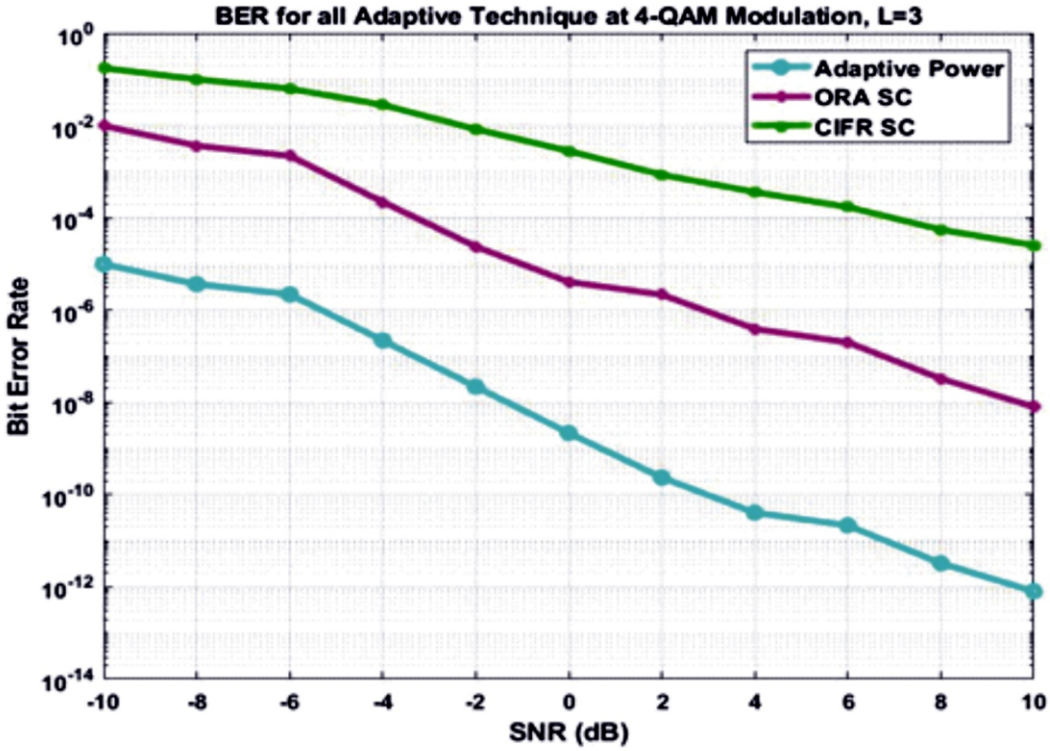


Fig.3: BER versus SNR for Adaptive Power, ORA, and CIFR at L of 3 over Nakagami 0.5 Fading distribution.

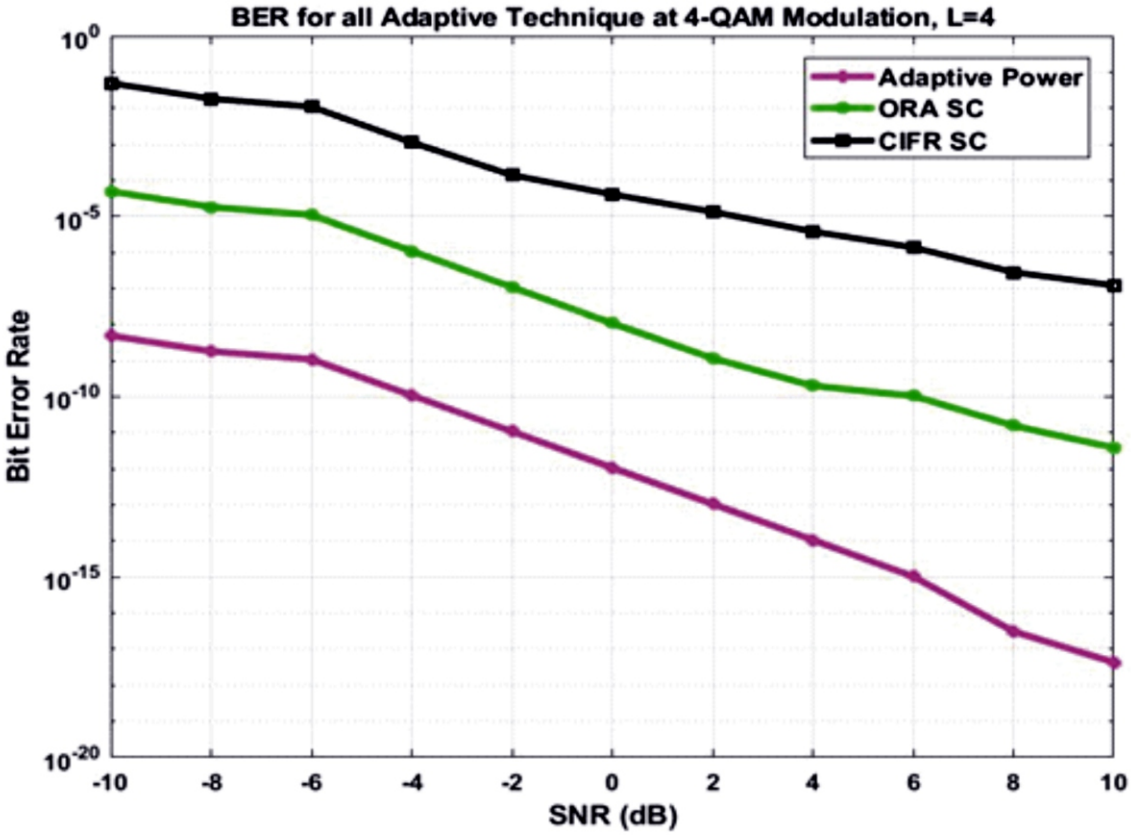


Fig. 4: BER versus SNR for Adaptive Power, ORA and CIFR at L of 4overNakagami 0.5 Fading distribution

3 CONCLUSION

This paper enhanced the performance of SC using Adaptive Power Controlled (APC) system over a time-varying Nakagami 0.5 fading distribution. The closed-form expression of the Bit Error Rate (BER) for the proposed technique was derived using the Probability Density Function (PDF) of the received signal. The proposed technique is evaluated using BER as performance metrics by comparing it with each of the ORA and CIFR techniques. BER values for the proposed adaptive SC technique, ORA, and CIFR are obtained at different SNRs using different numbers of paths.

The results obtained revealed that the proposed adaptive SC technique gives better performance with a reduction in BERcompared to the other two existing techniques, that is, ORA and CIFR, and this is due to self-adjustment of transmitting power of the proposed technique, which happened to be a function of channel gain at an instant. The percentage reduction in BER is 33.33% and 66.67% when compared with ORA and CIFR, respectively. The better performance of the proposed SC technique is a result of the self-adjustment of the transmitting power based on channel gain at an instant, which allocates an appropriate transmitting power to the transmitting signal based on channel gain at an instant.

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