



## Enhancing the Spectral Efficiency of an Uncorrelated Nakagami-M Fading Channel using a Modified Selection Combining Diversity Scheme

K. A. Ibrahim, A. D. Usman, S. M. Sani, H. Bello, E. E. Agbon  
Electronic and Telecommunication Engineering Department,  
Ahmadu Bello University, Zaria Kaduna State, Nigeria.

### ABSTRACT

Wireless communication system has found worldwide acceptability in providing acceptable signal level due to its portability, 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 fixed transmitting power used in the system. Hence, in this paper, an enhanced SC that adjust 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 transmitting signal over an uncorrelated Nakagami 0.5 fading channel are received using multiple antennas. The resultant signals at varying paths 'L' (2, 3, 4) were scanned by SC to choose a path with the highest Signal to 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 feedback algorithm. A mathematical expression for BER and SE were also derived. The proposed technique was simulated using Matrix Laboratory R2018a and evaluated using SE and BER by comparing with each of 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 show percentage reduction in BER of 33.33% and 66.67% when compared with ORA and CIFR, respectively. While, the proposed technique shows an increased in SE values by 32.14% and 54.17% when compared with ORA and CIFR, respectively. The study showed that the proposed technique gave lower BER values and high SE when compared with ARA and CIFR due to self-adjustment of the transmitting power. Therefore, the proposed technique can be deployed to improve the performance of wireless communication systems.

### ARTICLE INFO

#### Article History

Received: June, 2020

Received in revised form: July, 2021

Accepted: October, 2021

Published online: December, 2021

### KEYWORDS

Adaptive Power Control (APC), Selection Combiner (SC), Bit Error Rate (BER), Spectral Efficiency (SE), Nakagami 0.5 fading channel and diversity combiner.

### INTRODUCTION

Wireless communication which is a means of transmitting information over a distance without the use of electrical conductors or wire has become an important tool for fast and efficient means of data transmission. The term wireless is use to describe communications in which electromagnetic waves carries signal over part or the entire communication path [1]. Unlike wired

communication channel that 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 know as radio propagation. In the course of propagation, radio waves are mainly affected by three physical



phenomena includes diffraction, reflection and scattering resulting in signal fading [2]. Fading is a unique characteristic in wireless communication and it can be describing 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 degrade 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 signal propagates in multiple copies between the transmitter and receiver due obstructions along the propagation path, while, shadowing is the fluctuation in the power of received signal due to obstructions along the propagation path. The resulting 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 the techniques that mitigate the detrimental effect of fading in wireless communication. It is a technique that combines the multiple copies of 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 researches on DC technique reveals that, 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 SC technique, the SNR of all the diversity branches that are available in the system are evaluate 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 used out of the multiple available number of branches, fixed transmitting power and 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, receiver detects these changes directly from the received data without the need for explicit rate change control information [2]. Therefore, this paper proposes an enhanced SC technique that adjusts the transmitting power based on Channel State Information (CSI) known as Adaptive Power Controlled (APC). APC allows transmitter to adjust the signal power in compensating for channel condition thereby improving performance of SC. Signal propagation in wireless communication follows different fading distributions such as weibul, 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 SC technique that self-adjusting transmitting power based on the CSI at a particular time thereby improving the performance of the existing SC with ORA and CIFR.
- 2). Derive a mathematical expression of Bit Error Rate (BER) and Spectral Efficiency (SE) for the proposed technique over uncorrelated Nakagami- $m$  fading channel.

## RELATED WORKS

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 was 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 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 fixed transmitting power used. The performance analysis of hybrid MRC/EGC Diversity Combining Techniques over AWGN channel is carried out in [13]. In this paper, there was L number of MRC each having M number of input branches and each of the M branches received the signal and the individual antennas were kept sufficient 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 with hardware complexity. Also, in [14] presented a paper on 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 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 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 fixed power used for radio wave propagation. Furthermore, in [15], fading mitigation techniques in wireless mobile communication was carried out to solve the problem of multipath fading using Rake receiver. 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.

Previous works on DC show that, SC technique is often used in practice due to its low complexity but suffers from poor performance when compared with other diversity combining technique in a time varying channel due to only one paths and fixed transmitting power used. Therefore, in this paper SC with adaptive power controlled based on the CSI to improve the existing SC with adaptive transmission technique such as ORA and CIFR.

#### **Conventional Selection Combiner**

Conventional Selection Combiner (CSC) is a diversity combining technique that scans through the multiple paths of the received signal to selects the branch with the highest signal strength. Fig. 1 shows the block diagram of CSC in which the path is selected based on at a particular time based on signal strength. The output signal of CSC is the signal on only one path among the multiple copies of the received paths. Therefore, in the combiner, the coherent sum of the received paths is not required unlike EGC and MRC that requires coherent summation of the multiple copies of the received signal. [16, 17]. Also, in CSC, the co-phasing of the received signal is not required due to only one branch used as output signal at a time unlike MRC and EGC that require co-phasing of the received signal to avoid signal cancellation [18, 19]. However, the technique suffers from poor performance due to only one branch and fixed transmitting power used.

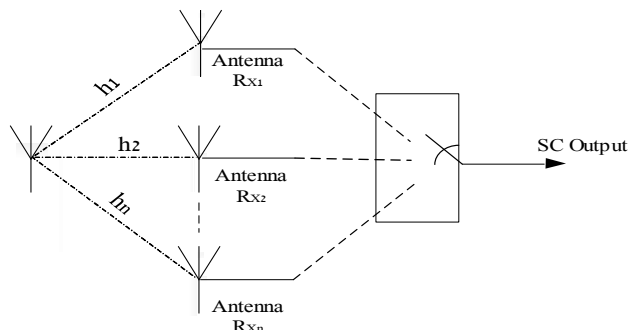


Fig. 1: Block diagram of CSC [19]

### Adaptive Power Controlled Technique

An Adaptive Power Control (APC) technique is used in time varying channel to solve the problem of fading by adaptively controlling the signal's transmitting power based on the channel conditions at a particular time. As a result, the interference observed by other users due to this user is less, which in turn reduces the average interference observed at the receivers. This consequently leads to a high-capacity system with improved battery life for the mobile terminals. Power control is used to adjust wireless station transmitting power so that the signal strength received at base station falls within an acceptable range [20]. APC technique provides adequate transmitting power for transmitting signal with respect to CSI [21]. The technique increases the signal power at the transmitter when the channel gain is low or the signal at the receiver falls below the specified threshold. The receiver sends a feedback through the feedback loop to the transmitter about the CSI in order to increase the signal power through a channel so as to increase

the signal strength to meet the required Quality of Service (QoS). APC is adopted in this work due to its ability to choose the power level based on the CSI thereby providing a reliable communication system even over a time varying channel.

### METHODOLOGY

Transmitting signal generated randomly is propagated through a Nakagami-m fading channel from transmitting antenna and Selection Combining (SC) scans through the multiple copies of the signals to choose the branch with 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 determine the SNR of the received signal. Output of CSI serves as input to the decision device to check the value of the SNR. If the channel gain is high, therefore, 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.

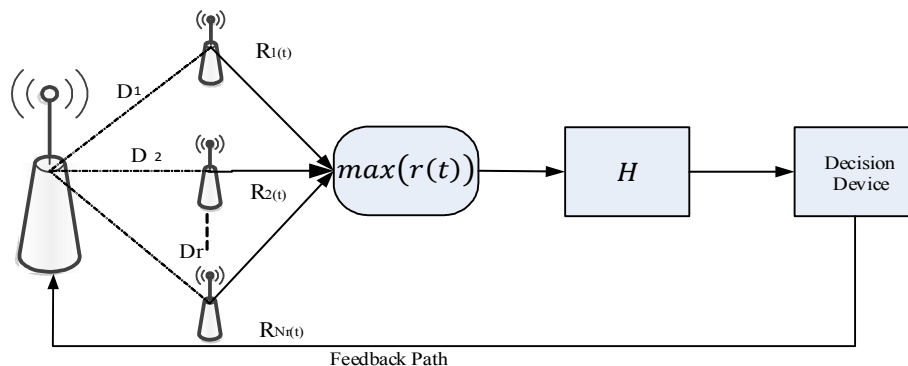


Fig. 2: Block diagram of an Adaptive Power Control System



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 Nakagami-m fading channel is given by [23] 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 transmit 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

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

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

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

Substituting equation 6 into equation 1 gives

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

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

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

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



$$P_r(r) = \frac{2}{\Gamma(0.5)} \left(\frac{0.5}{2\sigma^2}\right)^{0.5} \exp\left(\frac{-P_t \times (N \times 10^{R/B})^{-2}}{NB}\right) \quad (9)$$

#### Derivation of Bit Error Rate for the proposed technique

The performance of the proposed technique is evaluated using BER which is the ratio of 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

$$P_b(E) = \int_0^\infty P_b(E/\gamma) P_r(\gamma) d\gamma \quad (10)$$

where:  $P_b(E/\gamma)$  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

$$P_b(E) = \int_0^\infty P_b(E/\gamma) \frac{2}{\Gamma(0.5)} \left(\frac{0.5}{2\sigma^2}\right)^{0.5} \exp\left(\frac{-P_t \times (N \times 10^{R/B})^{-2}}{NB}\right) d\gamma \quad (11)$$

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

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

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

For non-coherent modulation, equation 12 becomes

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

By substituting equation 13 into 10 gives

$$P_b(E) = \int_0^\infty 1/2 \exp(0.5\gamma) \frac{2}{\Gamma(0.5)} \left(\frac{0.5}{2\sigma^2}\right)^{0.5} \exp\left(\frac{-P_t \times (N \times 10^{R/B})^{-2}}{NB}\right) d\gamma \quad (14)$$

#### Derivation of Spectral Efficiency (SE) for the proposed technique

Spectral efficiency (SE) is also a performance used to measure the performance of the proposed technique and it describe the rate at which information is transmitted over a given bandwidth. According to [24], spectral efficiency 'SE' is given as

$$SE = \frac{c}{B} \quad (15)$$

where:  $c$  is the channel capacity

$B$  is the channel bandwidth

But channel capacity 'c' is given as

$$C = B \log_2(1 + SNR) \quad (16)$$

Substituting equation 16 into 15 gives

$$SE = \frac{B \log_2(1+SNR)}{B} \quad (17)$$

### SIMULATION 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. Comparison was done using the results obtained by comparing with ORA and CIFR proposed in [12]. The proposed technique is named as Adaptive Power (AP) and this was used in presenting the results for ease of comparison.

#### Bit Error Rate (BER) Results at Different Propagation Paths

Fig. 3 presents 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 Nakagami m fading channel. At SNR of -6, -4, 2, 4 dB, the BER values of  $1.69 \times 10^{-5}$ ,  $1.14 \times 10^{-5}$ ,  $1.59 \times 10^{-7}$  and  $8.54 \times 10^{-8}$  were obtained respectively for AP as against  $1.13 \times 10^{-2}$ ,  $1.68 \times 10^{-3}$ ,  $1.61 \times 10^{-4}$  and  $8.51 \times 10^{-5}$  obtained for ORA at the

same value of SNR. CIFR showed a poor performance when compared with AP and ORA with BER values  $1.69 \times 10^{-1}$ ,  $4.18 \times 10^{-2}$ ,  $4.17 \times 10^{-3}$  and  $2.69 \times 10^{-3}$  at SNR of -6, -4, 2, and 6 dB, respectively. From Fig. 3, the AP showed better performance with lower BER when compared with ORA and CIFR. The improved performance of the proposed AP technique is due to adjusting the transmitting power based on the channel gain at any time. Fig. 4 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  $9.84 \times 10^{-8}$ ,  $9.67 \times 10^{-9}$ ,  $8.82 \times 10^{-11}$  and  $9.35 \times 10^{-12}$  were obtained, respectively for AP. The BER values obtained for ORA at the same SNR were  $9.84 \times 10^{-5}$ ,  $9.67 \times 10^{-6}$ ,  $8.01 \times 10^{-7}$  and  $9.67 \times 10^{-8}$  as against  $2.79 \times 10^{-2}$ ,  $9.84 \times 10^{-3}$ ,  $4.37 \times 10^{-4}$  and  $2.53 \times 10^{-4}$  for CIFR. The results obtained showed that, BER decreases as SNR increases and this demonstrate the effect of transmitting power on the transmitting signal.

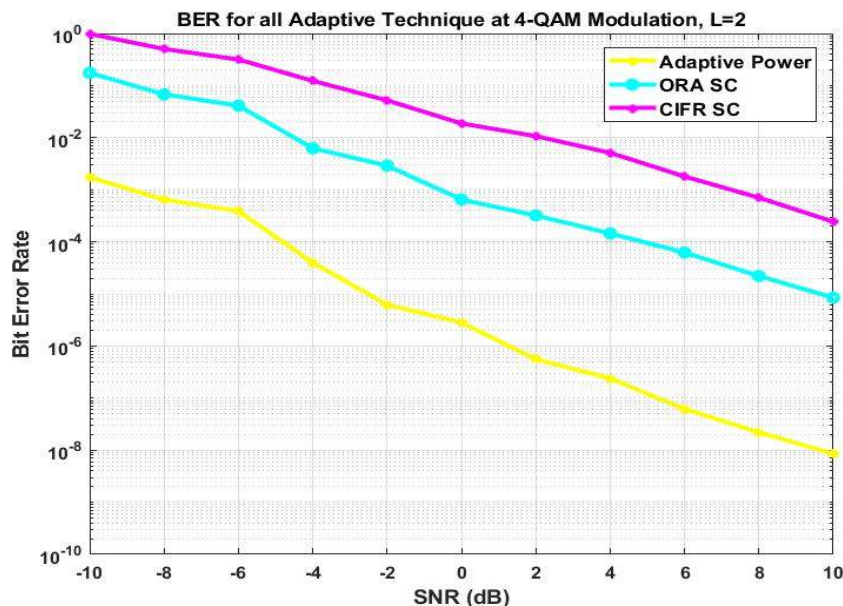
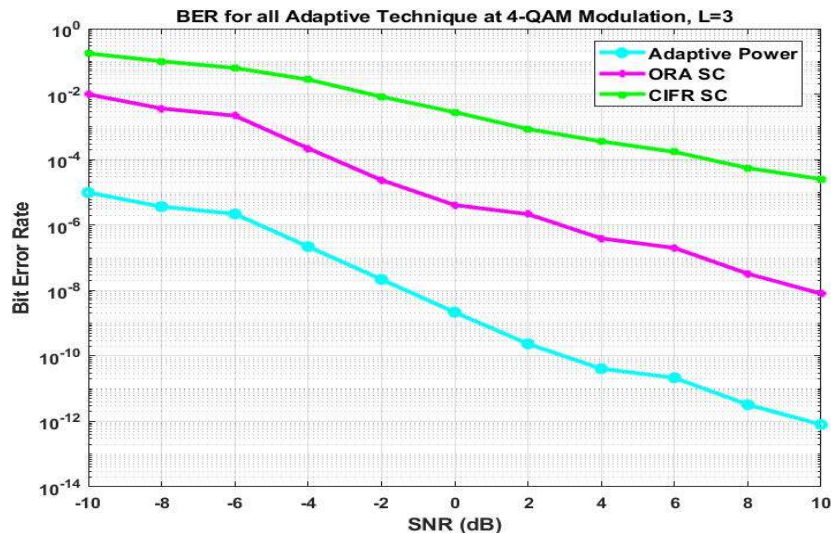


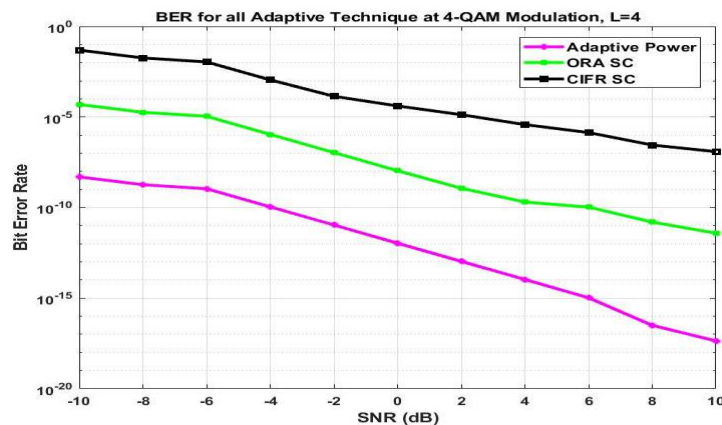
Fig. 3: Bit Error Rate versus SNR for Adaptive Power, ORA and CIFR at  $L = 2$  using over Nakagami 0.5 Fading Channel.



**Fig. 4:** Bit Error Rate versus SNR for Adaptive Power, ORA and CIFR at  $L = 3$  using over Nakagami 0.5 Fading Channel.

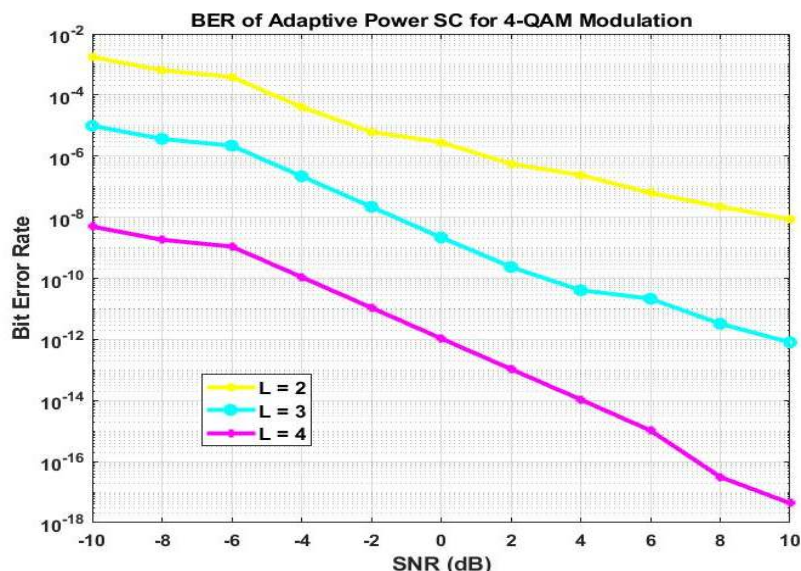
Fig. 5 depicts the BER values obtained versus SNR at  $L$  of 4 over Nakagami 0.5 Fading Channel. The BER values obtained at SNR of -6, -4, 2 and 6 dB are  $4.92 \times 10^{-11}$ ,  $4.83 \times 10^{-12}$ ,  $4.65 \times 10^{-15}$ ,  $4.65 \times 10^{-16}$  for AP as against  $4.92 \times 10^{-7}$ ,  $4.83 \times 10^{-8}$ ,  $4.34 \times 10^{-10}$  and  $4.65 \times 10^{-11}$  for ORA. CIFR showed a poor performance when compared with APC and ORA with BER values of  $4.92 \times 10^{-4}$ ,  $1.37 \times 10^{-4}$ ,  $4.83 \times 10^{-6}$  and  $1.22 \times 10^{-6}$

at SNR of -6, -4, 2, and 4 dB, respectively. The results obtained shows that, BER values decrease with increase in the number of paths. Figure 4.4 depicts the BER values obtained for AP at different propagation path ( $L = 2, 3, 4$ ) over Nakagami 0.5 fading distribution. At SNR of 6 dB, BER values of  $4.18 \times 10^{-8}$ ,  $8.01 \times 10^{-12}$  and  $4.65 \times 10^{-17}$  were obtained for  $L$  of 2, 3, 4, respectively. The results obtained showed that, BER value decreases as number of path increases.



**Fig. 5:** Bit Error Rate versus SNR for Adaptive Power, ORA and CIFR at  $L = 4$  over Nakagami 0.5 Fading Channel





**Fig. 6:** Bit Error Rate versus SNR for Adaptive Power at L of 2, 3, 4, over Nakagami 0.5 Fading Channel.

### Spectral Efficiency (SE) Results at Different Propagation Paths

Figs. 7, 8 and 9 depict the SE results obtained at  $L = 2, 3$  and  $4$ , respectively. Fig. 7 present the SE values obtained versus SNR with  $L$  of 2 over Nakagami 0.5 fading channel for AP, ORA and CIFR technique. At SNR of  $-6, -4, 2, 4$  dB, the SE values of 1, 1.3, 2, and 2.3 were obtained, respectively for AP as against 0.9, 1.2, 1.9, and 2.2 obtained for ORA at the same value of SNR. CIFR gave a poor performance when compared with AP and ORA with SE values of 0.8, 1.1, 1.8 and 2.1 at SNR of  $-6, -4, 2$  and  $4$  dB, respectively. Fig. 8 shows the SE results obtained with  $L$  of 3 for AP, ORA and CIFR technique. The SE obtained for AP are 1.3, 1.5, 2.3 and 2.5 at SNR of  $-6, -4, 2$  and  $4$  dB, respectively. ORA and CIFR gave a poor performance when compared with AP at the same value of SNR with SE values

of 1, 1.3, 2, 2.3 and 0.9, 1.1, 1.9, 2.1 for ORA and CIFR, respectively. The results obtained show that, SE increases as SNR increases and this is due to increase in signal strength as SNR increases. Fig. 9 depicts the SE results with  $L$  of 4 over Nakagami 0.5 fading channel for APC, ORA and CIFR technique. At SNR of  $-6, -4, 2, 4$  dB, the SE values of 1.5, 1.8, 2.5 and 2.8 were obtained, respectively for AP as against 1.1, 1.4, 2.2, and 2.4 obtained for ORA at the same value of SNR. CIFR gave a poor performance when compared with AP and ORA with SE values of 0.9, 1.2, 1.9 and 2.2 at SNR of  $-6, -4, 2$  and  $4$  dB, respectively. The values obtained shows that, SE increases as number of paths increases thereby justify the benefit of diversity in enhancing performance of wireless communication.

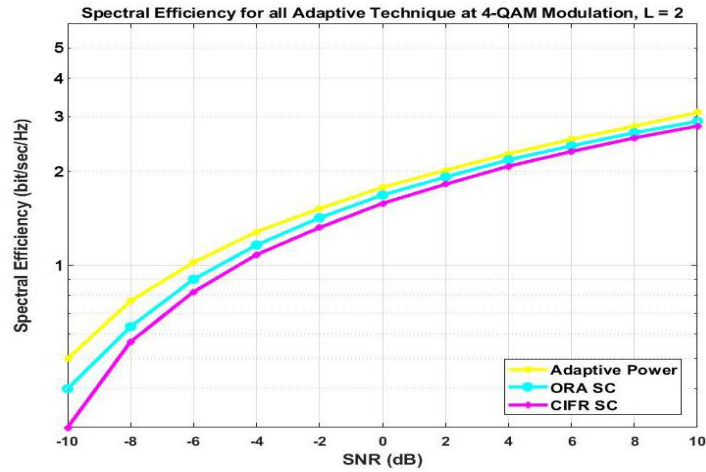


Fig. 7: Spectral Efficiency versus SNR for AP, ORA and CIFR at L of 2 over Nakagami 0.5 Fading Channel.

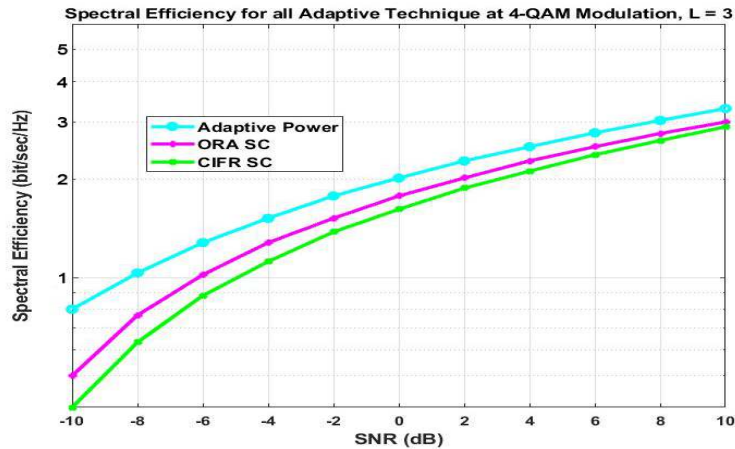


Fig. 8: Spectral Efficiency versus SNR for AP, ORA and CIFR at L of 3 over Nakagami 0.5 Fading Channel.

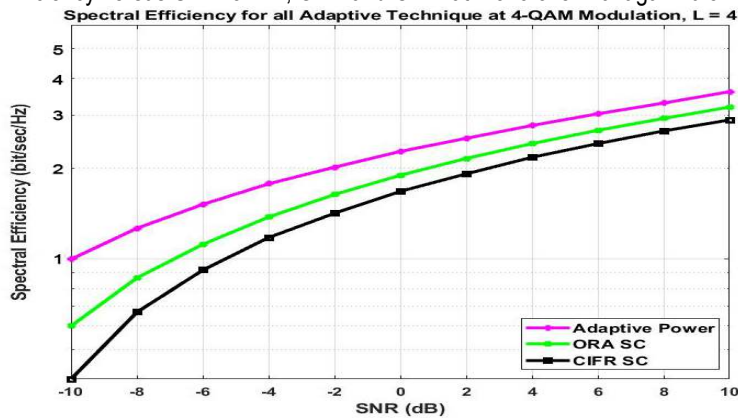


Fig. 9: Spectral Efficiency versus SNR for AP, ORA and CIFR at L of 4 over Nakagami 0.5 Fading Channel.

Fig. 10 depicts the SE values obtained for AP at different propagation path ( $L = 2, 3, 4$ ) at a fixed SNR. At SNR of 4 dB, SE values of 2.3, 2.5 and 2.8 were obtained for  $L$  of 2, 3, and 4,

respectively. The results obtained showed that, SE value increases as number of paths increases as against BER that decrease as number of path increases.

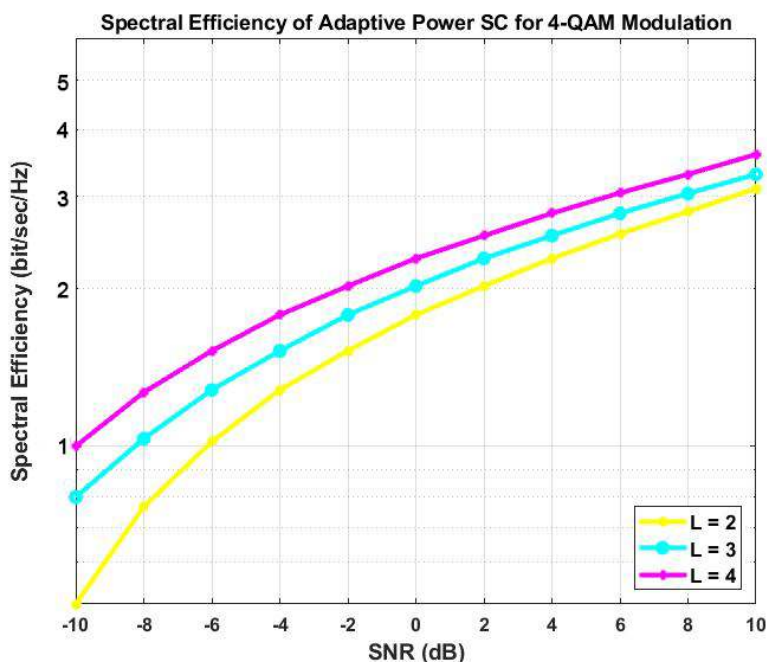


Fig. 10: Spectral Efficiency versus SNR for Adaptive Power at  $L$  of 2, 3, 4, over Nakagami 0.5 Fading Channel.

## CONCLUSION

In this paper, an Enhanced Selection Combiner (ESC) has been proposed using Adaptive Power Controlled (APC) system over Nakagami 0.5 fading channel. Closed form expression for Probability Density Function (PDF) of the received signal was derived for the enhanced technique and used to derive the Bit Error Rate (BER). The Spectral Efficiency (SE) was also derived for the proposed technique using SNR of the received signal and channel bandwidth. The proposed technique is evaluated using BER and SE as performance metrics by comparing with each of ORA and CIFR technique. BER and SE values for proposed technique and ORA as well as CIFR are obtained at different SNRs using different paths. The results obtained revealed that the proposed technique gave a better performance than the other two existing techniques, that is, ORA and CIFR due to

reduction in BER and increase in SE values. The percentage reduction in BER are 33.33% and 66.67% when compared with ORA and CIFR, respectively. The proposed technique also increased SE by 32.14% and 54.17% when compared with ORA and CIFR, respectively. The improved performance of the proposed technique is as a result of self-adjusting of the transmitting power based on channel state information, that allocate an adequate transmitting power to the transmitting signal based on channel status at a particular time.

## REFERENCES

- [1] Adeyemo, Z.K, and Ojedokun, I.A., EGC Receiver using Single Radio Frequency Chain and Single Matched Filter over Combined Rayleigh and Rician Fading Channels, *ARPN Journal of Engineering and Applied Sciences*, 9(7): 992-994, 2014.



- [2] Suvarna P.J and Vaibhav S.H., Performance of Maximum Ratio Combining (MRC) MIMO Systems for Rayleigh Fading Channel, *International Journal of Scientific and Research Publications*, 3(2):1-3, 2013.
- [3] Nirmal, C., *Diversity Techniques in Wireless Communication Systems*, Rutgers University, Piscataway, pp 1-7, 2005.
- [4] Khoa, N., A review of selection combining receivers over correlated Rician fading, School of Computing, Engineering and Mathematics, Western Sydney University Australia *Elsevier Inc.* vol. 1, no. 2, pp 1-22, 2019.
- [5] Aleksandra, D. G., Nikola, M. S., Mihajlo, C. S., Dejan, N. M., Zorica, B. N., Performance Analysis of Selection Combining System that uses the Minimal Interference Algorithm, *IETE Journal of Research*, vol. 10, no. 10, pp 8-10, 2019.
- [6] Niruddha, C., Chanika, B. and Manas, K., Performance of non-coherent MFSK with selection and switched diversity combiner over Hoyt fading channel, *springer science and Business media journal*, vol. 12, no. 9, pp 386-389, 2011.
- [7] Shukla, C.A., Vaibhav, S.H. and Fazal, N., Performance Evaluation of Maximal Ratio Combining Diversity with Prime Interleaves for Iterative IDMA Receiver, *International Journal of Information Engineering and Applications*, vol. 1, no. 3, pp 29-39, 2011.
- [8] Rajanna, A., & Dettmann, C. P., Adaptive Transmission in Cellular Networks: Fixed-Rate Codes with Power Control Physical Layer Rateless Codes. *IEEE Transactions on Wireless Communications*. Pp 1-14, 2019.
- [9] Karagiannidis, G.K., Sagias, N.C., Zogas D.A., Error analysis of M-QAM with equal-gain diversity over generalized fading channels, *IEE Proceedings Communications Online* vol. 152, no. 1, pp. 69-70, 2005.
- [10] Ray, E. S., Hu, Y. F., *Mobile Satellite Communication Networks*, John Wiley and Sons, Canada, pp 168-169, 2001.
- [11] Jayanthi, K., Arunachalam, V., Vasanthanayaki, C., Recovering Weak Signal using Nakagami Fading Wireless Channel with Multiuser Diversity, *WSEAS Transactions on Communications*, vol. 12, no. 12, pp. 609-614, 2013.
- [12] Hasan, M. I., & Kumar, S., Spectral efficiency evaluation for selection combining diversity schemes under worst case of fading scenario. *International Journal of Communication Networks and Information Security*, 7(3), 123-130, 2015.
- [13] Pradeep, V. H., & Padmarajan, S., Performance Analysis of Hybrid MRC/EGC Diversity Combining Technique over AWGN channel, *IOSR Journal of Electronics and Communication Engineering* 42(2):25-26, 2016.
- [14] Hasan, M. I., & Kumar, S. Spectral efficiency of dual diversity selection combining schemes under correlated Nakagami-0.5 fading with unequal average received SNR. *Telecommunication Systems*, 64(1), 3-16, 2017
- [15] Murt-Sarma N.S. and Thrimurthulu V., Fading Mitigation Technique in wireless mobile communication system, *International Journal of Engineering Technology science and research* 4(5), 782-791, 2017.
- [16] Abolade R.O. and Adeyemo Z.K., Adaptive modulation performance in MIMO - STBC over Rayleigh fading channel, *International Journal of Engineering and Computer Science IJECS –IJENS* vol. 12 no. 6, pp 1-4, 2012.
- [17] Hafeth, H., Overview of Diversity Techniques in Wireless Communication Systems, *Postgraduate Course in Radio Communications*, vol.7 no. 5, pp. 5–46, 2005.
- [18] Adeyemo, Z.K., Badrudeen and Abolade, R.O., Inter-symbol Interference Distortion Cancellation Using a Modified Maximal Ratio Combiner in Mobile Wireless Communication; *Journal of Information Engineering and Application*, vol. 3, no. 8, pp 16-17, 2013.
- [19] Adeyemo Z. K., Ojo S. I., Omowaiye R. O., Bamikefa I. A., Adaptive Selection Combiner over Log-normal Fading Channel in Wireless Communication System, *Universal Journal of Electrical and Electronic Engineering* 7(5): 263-272, 2020.



- [20] Pabst, R., Walke, B. H., Schultz, D. C., Herhold, P., Yanikomeroglu, H., Mukherjee, S., & Aghvami, H. Relay-based deployment concepts for wireless and mobile broadband radio. *IEEE Communications Magazine*, 42(9), 80-89, 2004.
- [21] Olawuyi, O. K., & Abolade, E. R., Adaptive Power Allocation in MIMO Spatial Multiplexing Over Frequency-Selective Rayleigh Fading Channel. Pp 63-72, 2016.
- [22] Simon, M. K., & Alouini, M. S., Digital Communication over Fading Channels, John Wiley & Sons. Inc., Hoboken, New Jersey, USA. pp 4-9, 2005.
- [23] Taruna, T. and Bhumika P., Multiple Detectors Based Analytical Performance of Spectrum Sensing, *International Journal of Advanced Computer Research* 4 (1): 1-12, 2014.
- [24] Ekpenyong, M. and Isabona, J., Improving Spectral Efficiency of Spread Spectrum Systems Under Peak Load Network Conditions, the Sixth International Conference on Systems and Networks Communications, pp 1-8, 2011.