Transactions of
The Nigerian Association of
Mathematical Physics
Journal homepage: https://nampjournals.org.ng

TRANSACTIONS OF THE NIGERIAN ASSOCIATION OF MATHEMATICAL PHYSICS
Published by Nigerian Association of Mathematical Physics

PERFORMANCE ANALYSIS OF ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING SYSTEM IN TRANSIT ANTENNA DIVERSITY TECHNIQUES

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ARTICLE INFO

Article history:
Received xxxxx
Revised xxxxx
Accepted xxxxx
Available online xxxxx

Keywords:
Antenna,
Selection,
Equal gain,
Maximum ratio
.

ABSTRACT

The fourth generation and fifth generation mobile communication systems make use of orthogonal frequency division multiplexing technique. Orthogonal frequency division multiplexing technique is a multi-access scheme which aids information splitting among several scarcely spaced sub-channel frequencies in the process of data transmission.Orthogonal frequency-division multiplexing technique can also convert a single wideband signal channels into multiple narrowband channels and then transmits them to the receiver while ensuring no inter-symbol interference. But this technique is sensitive to multipath fading and signal strength can be lost due to shadowing in different radio frequency propagation terrains during practical applications. One way of mitigating this multipath fading problem is by utilizing antenna diversity combining techniques. In this work, MATLAB Simulink software is employed to analytically simulate three antenna diversity techniques, viz; the selection, equal gain and maximum ratio techniques. Emphasis is laid on Rayleigh fading channels and quadrature phase shift key carrier modulation technique. Symbol error rate and bit error rate are used as performance indicators, the result shows that the MRC having bit error rate performance value of $\mathbf{2.0x^{-6}}$ ***and symbol error rate performance value of*** $\mathbf{1.3x^{-7}}$***. The results indicate that the performance of the three diversity techniques increases as the antenna grows in quantity.***

1.0 Introduction

Free space transmission of radio wave is plagued with deep loss in signal strength. As waves propagate through space, there is interaction with layers of the atmosphere in the propagating environment which result in a large number replicas of sent signal having different attenuations, phase shift, and delay arriving to the receiver antenna input. As these replicas superpose at the user side, the motion of receivers/transmitters, causes time-variation of the signal amplitude received [1], this process is known as fading [2]. Because of the impact of fading on radio communications, there has been several scientific techniques, such as, modulation schemes, channel models employed to reduce the effects of fading and to have performance of transmitted signal improved upon. In recent time, wireless transmission techniques used is Transit Antenna Diversity Technique. Some distribution channelsused in mitigating fading in radio propagation include, the Rayleigh, Rician, Nakagami channels and Additive White Gaussian Noise channel (AWGN) [1][3].

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https://www.doi.org/10.60787/tnamp-19-147-154

These channels are modeled and used depending on the specific nature of the environment. For instance, the Rayleigh channel model is employed in cases whereby direct line-of-sight (LOS) between the transmitting and the receiving antennas does not exist. The Rayleigh channel model is suitable for urban environments. The Rician model is employed in the inter-city and suburban environment, where there is LOS [3]. Nakagami model describes the variations in the signal strength received in urban environment [4]. Average signal power fluctuations level is a propagation characteristics of frequency broadband through a large communication system having multiusers. The fluctuations are generally demonstrated by Additive white Gaussian Noise(AWGN) channel [2]. In enhancing or improving system performance with regards to s fading, different approaches are involved, but the most frequently applied technique is the diversity techniques [3][6]. This technique involves making use of multiple replicas of signals transmitted, which are independent statistically. Frequently employed combining signals techniques after application of diversity techniques includes: Selection Combining (SC), Maximum Ratio Combining (MRC), Equal Gain Combining (EGC), Switch and Stay Combining (SSC) [1]. In combating fading in the telecommunication industries, so as to create a limitless future. As the demand for wireless communication increases, it is expected that spectral efficiency and higher data rates would be handy. There is need for more bandwidth efficient scheme. Attaining high data rates entails carefully selecting from the available multicarrier modulation schemes. Orthogonal frequency division multiplexing (OFDM) is the much needed multi-carrier transmission technique that can improve signal transmission. OFDM may be regarded as a modulation technique, transmitting data at higher rates thereby, also improving spectral efficiency [7]. This technique separates the available spectrum into several subcarriers, and these subcarriers in turn transmit data in a single stream, with each subcarrier modulated at a very low symbol rate, which result in a signal having high interference resistance.

This work employed BER, SER and quadrature phase shift key in analyzing the performance of the selected antenna diversity techniques. The binary scheme of a digital data consists of only two symbols i.e. 1 and 0. The pulse/ waveform is assign to 0 and 1symbols and it is then transmitted over a channel and identified at the receiving end. In quadrature phase shift key scheme, a symbol may consists of either 0 and 1 or both. Quadrature phase shift key and Rayleigh fading channel are used in analyzing BER and SER. Also considered is the density function for each of the diversity combiners in order to determine the best diversity technique for orthogonal frequency division multiplexing system performance. The simulation is done using MATLAB.

2.0 Materials and method

The simulation work was done by using simulink in MATLAB. The OFDM parameters used in the performance analysis include; a 20MHZ bandwidth with a subcarrier frequency spacing of 312.5KHZ. Quadrature phase shift key modulation technique was employed along with the Rayleigh fading channel. The distance between the transmitting and receiving antenna was the transit diversity (Multiple-Input Multiple-Output). The Doppler shift was 10Hz.

Since the focus is evaluating each scheme by comparing the BER, SER to the SNR, the results obtained in the simulation is then used to produce the Matlab code for the analysis of each modulation schemes under consideration. The first step in the simulation process was to use the integer calculator to generate a stream of bits, these bits were imputed into the OFDM and modulation was done subject to quadrature phase shift key modulation, Rayleigh channel along with selection combiner to produce signal to noise ratio values and there after the system was simulated. The BER calculator displayed the simulated BER for selection combiner, equal gain combiner and the maximum ratio combiner. In each of these combiners, the corresponding values of SNR and SER were obtained.

2.1 Rayleigh fading model

The Rayleigh model is applied in an environment where the receiver and transmitter are far apart, in such case, a direct line of sight is not attainable. Hence, the signal makes use of multipath, in this situation, central limit theorem is applied to each path and modeled as Gaussian complex random variable having time as variable.

The Rayleigh model is applicable in an area having large deflectors and blockades. The input signal received $r(t)$by the receiver is represented by equation (1).

$$r(t) = S(t)\ x\ h(t) + n(t) \qquad (1)$$

Where $n(t)$ is the AWGN, $h(t)$ is the Rayleigh distribution matrix of the random channel and $S(t)$ is the transmitted signal.

Usually, the magnitude x, is the Rayleigh distribution of the summation of two independent orthogonal Gaussian random variables that are equal. The density function is

$$f(X) = \frac{x}{\sigma^2} e^{\frac{x^2}{2\sigma^2}},\ \ X \geq 0 \qquad (2)$$

The mean value$E(x)$, and the variance of Rayleigh distribution is obtained by using equation (3).

$$E(x) = \sigma\sqrt{\frac{k}{2}} \qquad Variance\ Var(x) = \sigma^2\,\frac{4-n}{2} \qquad (3)$$

Where σ is the mode.

Hence, the Rayleigh fading model is given by equation (4) for K diversity branches. Therefore the signal received at the ith branch is;

$$r_i(t) = g_i S(t) + n_i, \quad i = 1,2, \dots k \qquad (4)$$

Where g_i is the channel gain and n_i is the additive white Gaussian noise variable with zero mean and variance $\sigma_n^2 = \frac{N_0}{2}$

Calculating the signal power for a symbol period T_s, we use equation (5)

$$p_s = \frac{1}{T_s}\int_0^{T_s} |g_i|^2\, |S(t)|^2 dt = |g_i|^2 \frac{1}{T_s}\int_0^{T_s} |S(t)|^2\, dt = |g_i|^2 \qquad (5)$$

Removing the term $|g_i|^2$ out of the integral and assuming that it is constant over T_s, we have a slow fading situation and if $S(t)$ possess a unit power, then, the SNR of the ith path will be,

$$\gamma_i = \frac{|g_i|^2}{\sigma_n^2} = \frac{2|g_i|^2}{N_0} \qquad (6)$$

The average SNR at each branch Γ is evaluated using equation (7);

$$\Gamma = \mathrm{E}(\gamma_i) = \frac{2|g_i|^2}{\sigma_n^2} = \frac{2E|g_i|^2}{N_0} \qquad (7)$$

The Rayleigh fading for bit error rate is given by equation (8);

$$BER = \int_0^{\infty} \frac{2|g_i|}{p_0} e^{-\frac{|g_i|^2}{P_0}} ercf\left(\sqrt{2\,\frac{|g_i|}{\sigma_n}}\right) d(|g_i|) \qquad (8)$$

Where the error function $ercf(x) = \frac{2}{\sqrt{\pi}}\int_x^{\infty} e^{-t^2}\, dt$

In selection combiner, received signal with the highest SNR is used in computing the BER. (9)

$$\omega_i = \begin{cases} 1 & \gamma_i = Max \\ 0 & otherwise \end{cases} \qquad (9)$$

In equal gain combining, the combiner sets all the received signals to a level gain by multiplying the gains by the signal attenuation equation (10).

$$g_i * e^{j<g_i} = G^T e^{j<g_i}, \qquad G = [g_1, g_2, \dots, g_N] \qquad (10)$$

Where $e^{j<g_i}$ is the signal attenuation gain.

In maximum ratio combining, the received signal r_i(t) is linearly combined with the signal having high SNR with the weighing coefficient ω_i and then sum the entire combination of ith branches. The result is given by equation (11).

$$r_i(\mathrm{t}) = \sum_{i=1}^{M} \omega_i r_i(\mathrm{t}) = \mathrm{S}\ (\mathrm{t}) \sum_{i=1}^{M} \omega_i g_i\ +\ \sum_{i=1}^{M} \omega_i\, n_i \qquad (11)$$

Equation (12) is used for calculating the SER for the diversity combiners

$$BER = SERLOG2(M) \qquad (12)$$

Where M= Modulation techniques used, M = 4 for QPSK

3.0 Results and Discussion

The values below are calculated based on the OFDM parameters presented in chapter three. The SNR is set within the range of 0 and 25dB, the BERs of each diversity combining technique SC, EGC, and MRC are calculated accordingly. The SERs for corresponding BERs are also calculated.

After simulation, the results obtained are presented as performance graphs shown in figure (1) for selection combining BER against SNR.

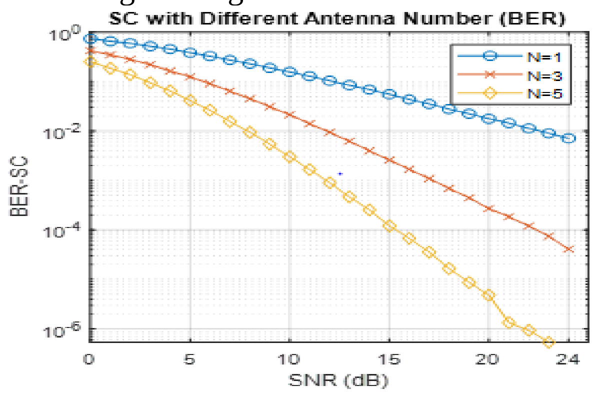

Figure1: BER vs. SNR plot for Selection combining with 1, 3 and 5 numbers of antenna.

From figure 1 above, the plot shows that, for N=1 antenna, SNR = 24dB having bit error of 10^{-2}. For SNR value of 24dB, N=3 antennas gives a lower bit error of 10^{-4}. The N=5 antennas shows the best performance of all the three plots, with SNR of less than 24dB, and bit error of exactly 10^{-6} received.

For equal gain combining, the simulation result, is shown in figure (2).

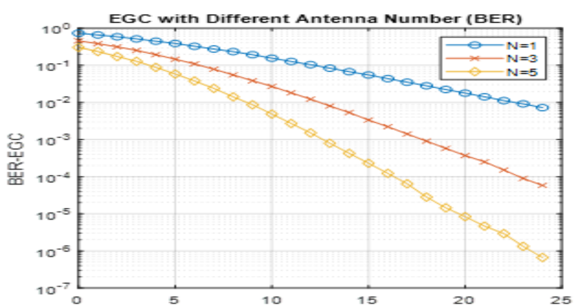

Figure 2: BER vs SNR plot for equal gain combining.

figure 2 shows SNR value of 24dB for the three plots, N=1 antenna shows the least performance with bit error of 10^{-2}, the N=3 antennas although of slightly better performance than N=1 having bit error of 10^{-4} didn't show a tangible improvement as expected, however, the N=5 antennas here shows a noticeable improvement than in figure1, with the least received bit error slightly less than 10^{-6}.

For Maximum Ratio Combining, the simulation result, is shown in figure (3).

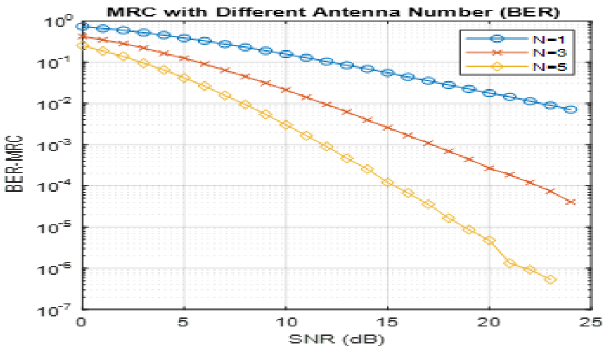

Figure 3: BER vs. SNR plot for Maximum Ratio Combining.

In figure 3, the N=1 antenna shows same performance as in the figure1 and figure 2, while the N=3 antennas shows a better performance. Here, the N=5 antennas shows the best performance than the N=1 and N=3 antennas, with a lower SNR of 23dB and the least bit error of less than 10^{-6}.

In general, it is important to note that, a BER of 10^{0} means that all the transmitted bits were received with errors; that is, a 100% received error. In the three plotted graphs, it is observed that, the BERs for N=1, 3 and 5 antennas between 0dB to 5dB SNR values fall within 10^{0} and 10^{-1}, this means that at lower SNR values, the performance is generally poor irrespective of the number of antennas. It is noted from the graph that there was no improvement in the results of the N=1 antenna, the BER values for both the SC, EGC and MRC remains the same for all three graphs. This implies that even at high SNR values; there will still be relatively more errors received with a single transmitting antenna. However, fewer errors will be received with 3 to 5 antennas, and an approximately zero errors with multiple antennas.

The performance graphs of SER against SNR for selection combining is shown in figure 4

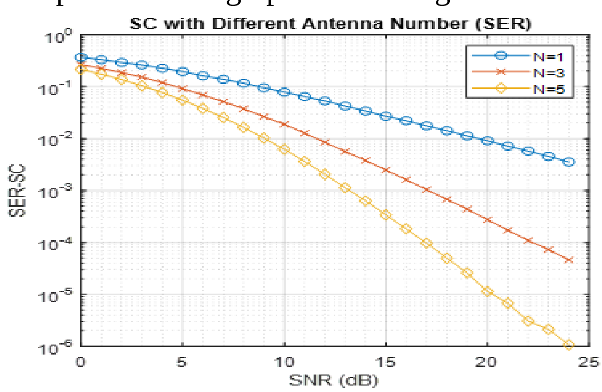

Figure 4: SER vs. SNR plot for Selection Combining

The performance of data transmission in symbol for SER against SNR values from 0dB to 25dB with Selection Combining (figure 4), shows that for SNR at 0dB, SER is below zero for all three plots. for SNR at 24dB, N=1 antenna have SER value of 10^{-2}, N=3 antennas have SER value of 10^{-4} and N=5 antennas have SER value of 10^{-6}. Hence, it is observed that N=3 antennas shows a better performance compare to N=1 antenna. N=5 antennas shows the best performance of all three plots with as low as only one symbol error out of every one million bits transmitted (i.e. SER = 10^{-6}).

For equal gain combining, the simulation result, is shown in figure (5).

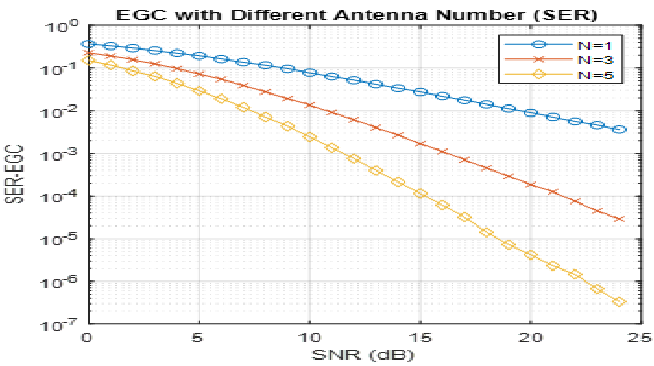

Figure 5: SER vs SNR plot for equal gain combining.

In Figure 5, the SER for N=5 antennas is 10^{-1} and corresponding to a value of SNR close to 0dB. This shows a slight improvement in SER compare to figure 4 for the EGC plots. Also, looking across the graph, we observe a clearer improvement with the N=5 antennas, as we see that, at SNR = 24dB, SER is now closer to 10^{-7} than the previous results, while the N=1 and N= 3 antennas didn't perform badly either for the same SNR value.

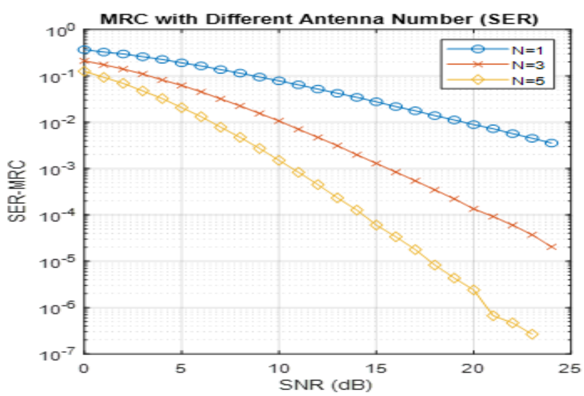

Figure 6: SER vs SNR plot for maximum ration combining.

A more conspicuous improvement in performance is seen in figure 6 above. Here for the same SNR = 24dB, N=3 antennas appears more close to 10^{-5} than in figure 4 and figure 5 and performs better than N=1 antenna. The N=5 antennas with most improved performance shows a SER more close to 10^{-7} than in figure 5 at the same value of SNR = 24dB. And so, again the N=5 antennas shows a noticeable performance than the N=1 and N=3 antennas in this plot.

Again, Going through the graphs of SER against SNR for SC, EGC and MRC, we can observe that, unlike the graphs for BER against SNR, they is a significant improvement in the SER values as antenna number increases with increasing SNR value across the graph. The common behavior one can clearly derive from the three graphs is that, for lower SNR values within 1dB and 5dB only a small variation in SER is observed between the three plots. But as the SNR increases, we can admit a significant improvement of performance is observe with each of the three plots which makes it easier to distinguish which plot has the best results.

The analysis of performance using three SNRs 23dB, 24dB and 25dB is presented in figure 7. Plotting the data in bars actually provides pictorial and understandable information on the data, making it easy to see even small variations in the results of SC, EGC and MRC.

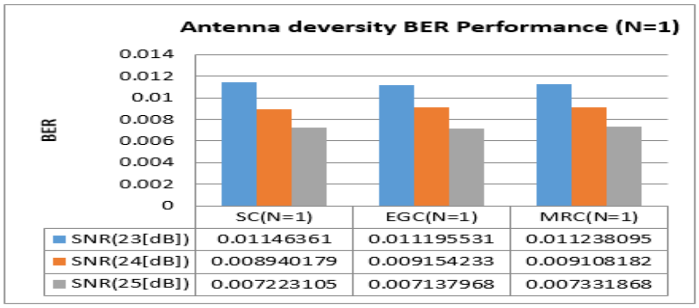

Figure 7: BER performance for SC, EGC and MRC.

Figure 7 shows the plotted BER results for SC, EGC and MRC with N=1 antenna. With the information on the graph we can see that an SNR of 23dB (Blue) has the least performance with BER values 0.0114, 0.0111 and 0.0112. It is obvious from the heights of the bars that the SNR of 24dB (Gray) pulled the lowest BER values 0.00722 on SC, 0.00712 on EGC and 0.00733 on MRC.

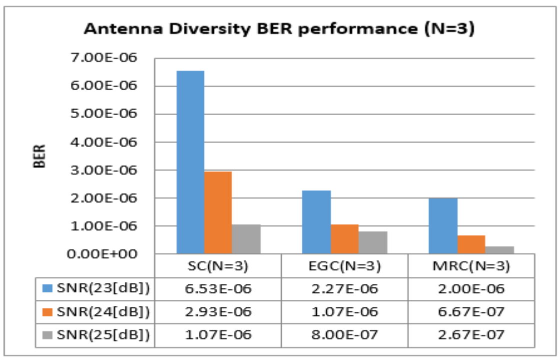

Figure 8: BER performance for SC, EGC and MRC.

Figure 8 is a graph for N=3 antennas showing BER values comparing SC, EGC and MRC for three values of SNR 23dB (Blue), 24dB (Orange), and 25dB (Gray) respectively. Here we can see an interestingly drastic improvement in BER values as SNR increases. This is a dramatic performance even for just three antennas. It's interesting to see that the SC which shows the least performance on this graph with SNR = 23dB has a BER of 0.000006 which is by far a better performance compared to the MRC in figure 7 above for N=2 antennas with a BER of 0.0000468 and SNR = 25dB. Again in this graph, MRC shows a BER of 0.000000267 for SNR = 25dB, which literally means an amount of insignificant error, is received. For SNRs of 23dB, 24dB and 25dB, we can notice clear variations in BERs on the graph, looking through the three SNR rows; it is observed that the column for MRC has the least BER values followed by that of EGC, and then the SC. Considering SNR =25dB, SC shows BER=0.00000107, EGC shows BER=0.0000008 and MRC shows BER=0.000000267. The MRC has the least received error of all three combiners as observed in figure 8.

CONCLUSION

A thorough simulation study on transit antenna diversity techniques using OFDM system has been carried out; three diversity combining techniques which include Selection Combining (SC), Equal Gain Combining (EGC) and Maximum Ratio Combining (MRC) techniques were comparatively investigated in the study. Due to the uniqueness of the non-LOS propagation environment which is the particular environment of interest in the study, the Rayleigh fading channel was considered, along with the Quadrature Phase Shift Keying (QPSK) modulation scheme. MATLAB communication tool box was used to simulate the required OFDM block with the intended OFDM parameters. There is strong consistencies in performance between the SC and EGC, and even stronger consistencies from the results with MRC. Increasing the antenna number in the diversity technique drastically reduces the magnitude of bit error of the received signal and improves its performance. Fewer antennas would probably not give a significant improvement on the transmitted signal strength. However, with fewer antennas, improved performance is only achieved at the expense of high SNR. Maximum Ratio Combining (MRC) technique from the analysis is a better diversity combining technique than the Equal Gain Combining (EGC) and the Selection Combining (SC) techniques in a non-LOS environment.

REFERENCES

[1] Aleksandar LEBL and Žarko MARKOV (2014), An Overview and Analysis of BER for three Diversity Techniques in Wireless Communication Systems, Yugoslav Journal of Operations Research 25 (2015) Number 2, 251-269 DOI: 10.2298/YJOR131120007M

[2] Proakis J., Digital Communications, Third Edition, McGraw-Hill, 1999

[3] Lee W.Y.C., Mobile Cellular Communications, McGraw-Hill Book Co., New York, 1989

[4] Thomas M. Cover, and Joy A. Thomas, Elements of Information Theory, 2nd Edition, WileyInterscience, 2006

[5] Simon M.K., and Alouini M.S., Digital Communications over Fading Channels, 2nd ed., John Wiley& Sons, New York, NY, USA, 2005

[6] Stuber G.L., Principles of Mobile Communications, 2nd Ed, Kluwer Academic Publishers, 2001.

[7] John, S. N., Akinola, E., Ibikunle, F., Ndujiuba, C. U., and Akinaade, B. Modeling of orthogonal frequency division multiplexing (OFDM) for transmission in broadband wireless communications. J o u r n a l o f E m e r g i n g T r e n d s i n C o m p u t i n g a n d I n f o r m a t i o n S c i e n c e s , 3 (4), 534539, 2012.