

THE EFFICIENT PERFORMANCE OF GENERALIZED SELECTIVE COMBINING TECHNIQUES ON RAYLEIGH FADING CHANNEL USING HYBRIDIZED MODULATION SCHEME

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Abstract This study concentrated on improving Generalized Selective Combining (GSC), one of the widely used diversity combining methods in telecommunications, by combining the modulation schemes of Quadrature Amplitude Modulation (QAM) and Orthogonal Frequency Division Multiplexing (OFDM) over a Rayleigh Fading channel. These were done with the intention of delivering strong Quality of Service (QoS) in mobile communication, particularly with the goal of lowering Bit Error Rate (BER) to improve reception on the receiving end. According to the findings, the communication system's performance efficiency was increased through the hybridization of the modulation schemes, with QAM (4 and 16 constellation being taken into consideration for this research) and OFDM, even though a Rayleigh Fading channel was used, preventing line of sight (LOS). Compared to the BER values obtained when the modulation schemes were not hybridized, GSC was considerably improved with a low BER. In light of the fact that the channel under consideration did not experience severe fading, which is what caused the low BER observed, this article indicates that GSC might be improved through the hybridization of modulation schemes to provide a good Quality of Services.

Keywords: Rayleigh fading, BER, SNR, multipath, QAM, and OFDM

I. INTRODUCTION

A convergence of circumstances has led to the emergence of wireless communication as a single major industry in the modern communication world [1]. In the field of telecommunication, wireless transmission is utilized to convey data across both short and long distances. Wireless operations enable the execution of long-range communications and other activities that would otherwise be challenging or unfeasible to do with wired systems. There are two distinct categories of wireless transmission services offered in the realm of wireless communication: fixed

transmission and mobile transmission. In the mobile wireless transmission, as distinguished from stationary/fixed transmission, the transmitter and receiver exhibit disparate velocities. The pathway over which the signal travels from the transmitter to the receiver is commonly known as channel. In recent years, the phrase has also been employed to denote a wireless communication device that is connected to a high-speed mobile platform. The mobile wireless environment is characterized by a multitude of communication challenges. Potential factors contributing to impairment in wireless communication systems encompass a range of phenomena, such as multipath transmission, signal attenuation caused by substantial obstructions, relative motion between the transmitter and receiver, interference, dispersion of electromagnetic

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radiation, thermal effects, and subterranean noise.[2]. The occurrence of fading can be attributed to the combination of receiver and/or transmitter movement with multipath propagation, ensuing in substantial and erratic swaying in the received signal.[3]. Obstructions frequently impede the Line-of-Sight trajectory of mobile radio communication, resulting in the obstruction of electromagnetic waves from reaching the receiving antenna within the expected timeframe. Consequently, this phenomenon gives rise to reflection, diffusion, and dispersion.

The optimal point of wave convergence, wherein signals are received from multiple directions, is the highest place in terms of signal reception. The availability of radio spectrum for wireless communications is severely restricted, yet the demand for mobile and personal communication is quickly growing [4]. Signals can be affected by interference, noise, multipath disturbances, and the unpredictable impact of user motions on the received signal. The utilization of Bit Error Rate (BER), a widely employed performance indicator in mobile wireless communication, is a prevalent strategy for assessing Quality of Service (QoS) and signal strength at the receiving terminal [5]. This paper examines the features of several modulation and diversity techniques employed in fading channels. Communication systems engineers now have the capability to predict mobile communications through the utilization of diverse distributions. [6].

Numerous researchers have made noteworthy involvement to the development of various models in the field of fixed wireless communication, which are highly relevant in diverse circumstances. However, there is a limited amount of research conducted on the

integration of modulation schemes to enhance the effectiveness of different combining methods in a Rayleigh fading channel inside an optimal residential environs, as indicated by literature evaluations conducted by multiple authors [7] [8]. The investigation will focus on the individual analysis of the modulation schemes QAM and OFDM. Subsequently, these schemes will be integrated to determine the modulation scheme that exhibits the lowest Bit Error Rate (BER) over the simulated channel. This selection will inform the design of the communication system. Before execution, it will be utilized to improve the performance of diversity combining. The data generated is transformed into binary digits, rearranged, and then modulated using QAM and OFDM signaling techniques [9]. The modulated signal, resulting from the combination of multiple signals, is converted into an analog signal that is suitable for transmission through a channel that varies over time. This conversion is achieved by employing a square root raised cosine filter with a roll-off factor of 0.25 [10]. This filter effectively reduces the spectrum occupancy of the signal.

Rayleigh fading distributions are employed for the transmission of filtered QAM and OFDM modulated signals. The demodulator processes the arriving signal packet, after which a re-filter is employed to catch the fading bits [11]. The BER, which serves as a metric for evaluating performance in each category, is acquired in order to facilitate a comparison.

II. MATERIALS AND METHODS

The approach model used in this work includes the transmitter, extenuation techniques, fading scenario, and receiver. The transmitter first receives and processes the information signal's randomly produced data before transmission. the received signal, $r(t)$, is determined by Eq. 1:

$$r(t) = u(t) \times v(t) \times q(t) \quad (1)$$

The fading spreading integral is denoted as $u(t)$, the QAM signal is represented by $v(t)$, and OFDM signal is denoted as $q(t)$.

It is imperative to highlight that the collective incoming signal $r(t)$ encompasses random data pertaining to fading distribution component $u(t)$. Consequently, the data that is received is transformed into binary digits, afterwards rearranged, and then modulated through the utilization of a signaling technique known as QAM and OFDM. The utilization of the square root raised cosine filter [12] enables the conversion of modulated digital signals into analog signals that are suitable for radio channel transmit, hence resulting in a reduction in spectrum occupancy.

A. Doppler frequency shift

Doppler shift describes the arbitrary variations in a channel caused by a mobile user's movement. When the transmitter and receiver move similarly, there appears to be a change in the frequency of the received signals compared to the produced signals.

The following is a given for the Doppler frequency shift, f_d by Eq.2:

$$f_d = \frac{v}{c} \cos\theta \quad (2)$$

Where, θ is the angle formed between the incident electromagnetic wave and the moving receiver, v is the mobile speed, λ is the wavelength of carrier and c is speed of light [12].

B. Rayleigh fading

The Rayleigh fading scenario is composed of various multipath elements, each exhibiting comparable signal magnitudes and equally dispersed phases [11]. The inclusion of Rayleigh

in this study was motivated by the absence of a direct line of sight (LOS) amid the transmitting and receiving entities. The transmission signal propagates over diverse paths to reach the receiver within the Rayleigh channel subsequent to undergoing reflection from numerous proximate objects. The received signal is formed by combining the source signal with the reflected signal at the receiver. The issue arises when the envelopes of many signals are superimposed, since signals in urban environments undergo diffraction or reflection due to structures, mobile objects, and other environmental factors. The Rayleigh fading environment is distinguished by a significant multitude of multipath components exhibiting comparable signal magnitudes and uniformly distributed phase variations. The user has provided a numerical reference without any accompanying text or context [13].

In the Rayleigh channel, the transmitted signal undergoes many reflections by various objects in the surrounding environment before reaching the receiver. The signal detected at the receiver is the result of combining the reflected signal with the primary signal.

In an urban environment, the summation of individual signal envelopes is subject to diffraction or reflection by various elements such as buildings, cars in motion, and other objects, hence presenting a significant obstacle. The Rayleigh fading channel model encompasses all constituent elements of the received signal, with no direct transmission line between the transmitter and receiver. Consequently, the acquired signal comprises the summation of all diffuse components. The probability density function (PDF) of Rayleigh distribution is expressed by Eq. 3 as:

$$P_R(r) = \frac{r}{\sigma^2} \exp\left[-\frac{r^2}{2\sigma^2}\right] \quad 0 < r \leq \infty \quad (3)$$

Where, r is the amplitude of the received signal, \bar{b} is the time average power of the received signal, $2\sigma^2$ is the prediction mean power of the received signal [9].

C. Quadrature amplitude modulation

Quadrature amplitude modulation (QAM) is a modulation technique that alters the amplitude of the carrier wave and introduces a quadrature carrier that is 90° degrees out of phase with the primary carrier wave. This modulation scheme relies on two input signals [1]. The amplitude and phase of the carrier wave concurrently adjust in accordance with the transmitted data. By employing a symbol rate that is one-fourth of the bit rate, QAM enables more efficient transmission in terms of spectral utilization. In comparison to binary phase shift keying (BPSK) and quadrature phase shift keying (QPSK), QAM exhibits superior effectiveness.

D. Orthogonal frequency division multiplexing

Orthogonal Frequency Division Multiplexing (OFDM) is a wireless communication technique that partitions a communication channel into multiple frequency bands of equal spacing. Each of these bands is assigned a sub-carrier that is responsible for transmitting a certain portion of the user's data [10]. Orthogonal Frequency Division Multiplexing (OFDM) is distinguished from the commonly employed Frequency Division Multiplexing (FDM) technology by the characteristic of orthogonality exhibited by each sub-carrier, ensuring their independence from one another [14]. The utilization of the modulation technology called Frequency Division Multiplexing (FDM) enables a solitary

transmission line to accommodate many signals simultaneously.

E. Generalized selection combiner

In this work, the diversity combining approach chosen is the generalized Selection Combiner (GSC), as it yields a decrease BER result than other diversity strategies similar to EGC [15]. Different digital modulation techniques can be used, and are best suited by, the SC and MRC combination. The expression for the PDF output is as follows by Eq.4:

$$\eta_i = \sqrt{E_s} \alpha_i \exp[j(\Phi_i + \Phi_m)] + \eta_i \quad (4)$$

Where θ_i is the desired phase modulation, Φ_i is the uniformly distributed random phase process, α_i is the random fading amplitude process, E_s is the Energy per information symbol and η_i is the Additive White Gaussian Noise (AWGN) component.

F. Transmit and receive filter

In order to fit the input signal in the analog band limited channel, the transmit and receive filters in this paper are identical square root raised cosine filters. This results in zero inter-symbol interference (ISI) at the pulse sampling time and trim down noise power outside of signal bandwidth at the receiver front end.

The square root raised cosine pulse shaping filter that is employed in mobile communication requires that the complete channel transfer function have a Nyquist frequency response in order to be considered filter-complete [16].

G. System simulation and modeling

i. Transmit and receive filter

In order to do this, the Rayleigh fading channels utilized in mobile communications must be

simulated and modelled. The combined application of the QAM signal and the OFDM transmission system signal enhances the GSC (H-SC/MRC), which selects two of the four strongest pathways. When transmitting modulated signals to the receiver, Rayleigh fading simulations generate and multiply the multiplicative distortion factor. The signal is defined for a Rayleigh fading channel according to equation (5). Equation (6), on the other hand, gives the expression for the total received signal.

$$r_i(t) = \sum_{i=1}^p h_i(t) s(t) + n_i(t) \quad (5)$$

$$r(t) = \sum_{i=1}^{n_i} r_i(t) \quad (6)$$

where; $r_i(t)$ is the received signal, p is the number of paths, $n_i(t)$ is the additive white Gaussian noise, $s(t)$ is the transmitted signal from QAM, $h_i(t)$ refers to a multiplicative distortion of the transmitted signal $s(t)$ along the i^{th} path, $r(t)$ is the total received signal.

ii. Simulation constraints

MATLAB Toolboxes for communication and signal processing are used to investigate how to improve GSC, as was previously indicated. Employed are the data that precisely specify the modulation and fading channels and Table 1 includes this information. The simulation used a arbitrary data basis that was transformed to binary using MATLAB's decimal to binary tool before being remodeled and modified using the QAM & OFDM technique for broadcast to the fading spreading. The aforementioned settings were used.

III. RESULTS AND DISCUSSION

The findings presented were acquired by running the developed algorithms through a computer simulation using the MATLAB software package. the worst-case scenario was

Table 1: System Simulation constraints and Description

	Constraints	Description
1.	Varying signal	QAM and OFDM
2.	Fading	Rayleigh
3.	Mitigation	GSC (H-SC/MRC)
4.	CSF	18×10^8 HZ
5.	Number of path	FOUR
6.	Noise	AWGN
7.	Data interval	10×10^3
8.	Filter	SRCF
9.	Signal-Noise-Ratio	0, 5,10,15, -----30
10.	Roll off parameter	$\frac{1}{4}$

represented by the Rayleigh fading channel used as the communication channel model. The bits of information were produced at random. It is suited for a mobile setting that is inherently unpredictable and erratic. effectiveness of the system was estimated using the Bit Error Rate (BER). The communication system operates more effectively when BER decreases. The worst-case scenario was represented by the Rayleigh fading channel used as the communication channel model. The bits of information were produced at random.

A. Performance comparison of standard diversity combining techniques

The study employed the method that produces the best results rather than focusing on just one because mobile communication provides multiple diverse merging avenues. Figure 1 and

2, respectively, display the BER values and performance efficiency for a number of diversity combining techniques across Rayleigh fading channels. SC, MRC, and GSC, which combines SC and MRC, are the three simulated diversity combining procedures. AWGN performance is the reference standard.

However, the BER values of the AWGN, SC, MRC, GSC, and No Diversity Combining (NDC) are, respectively, 0.0391, 0.3512, 0.2798, 0.2453, and 0.7839, based on the results at SNR of 2dB. The relative BER values for the AWGN, SC, MRC, GSC, and NDC at 4dB SNR are 0.0129, 0.2107, 0.1636, 0.1302, and

0.7358, correspondingly. ABER values of 0.0169, 0.1957, 0.1544, and 0.1275 are obtained for AWGN, SC, MRC, GSC, and NDC, respectively, based on the average BER of the diversity approaches. The outcome of NDC is 0.7030. Because the GSC delivers the lowest BER and ABER values, it was chosen for this investigation based on the findings. The GSC approach outperforms SC and MRC taken separately in terms of AWGN. The NDC situation also shows the worst BER performance since the communication system cannot function with no diversity combining at the receiver.

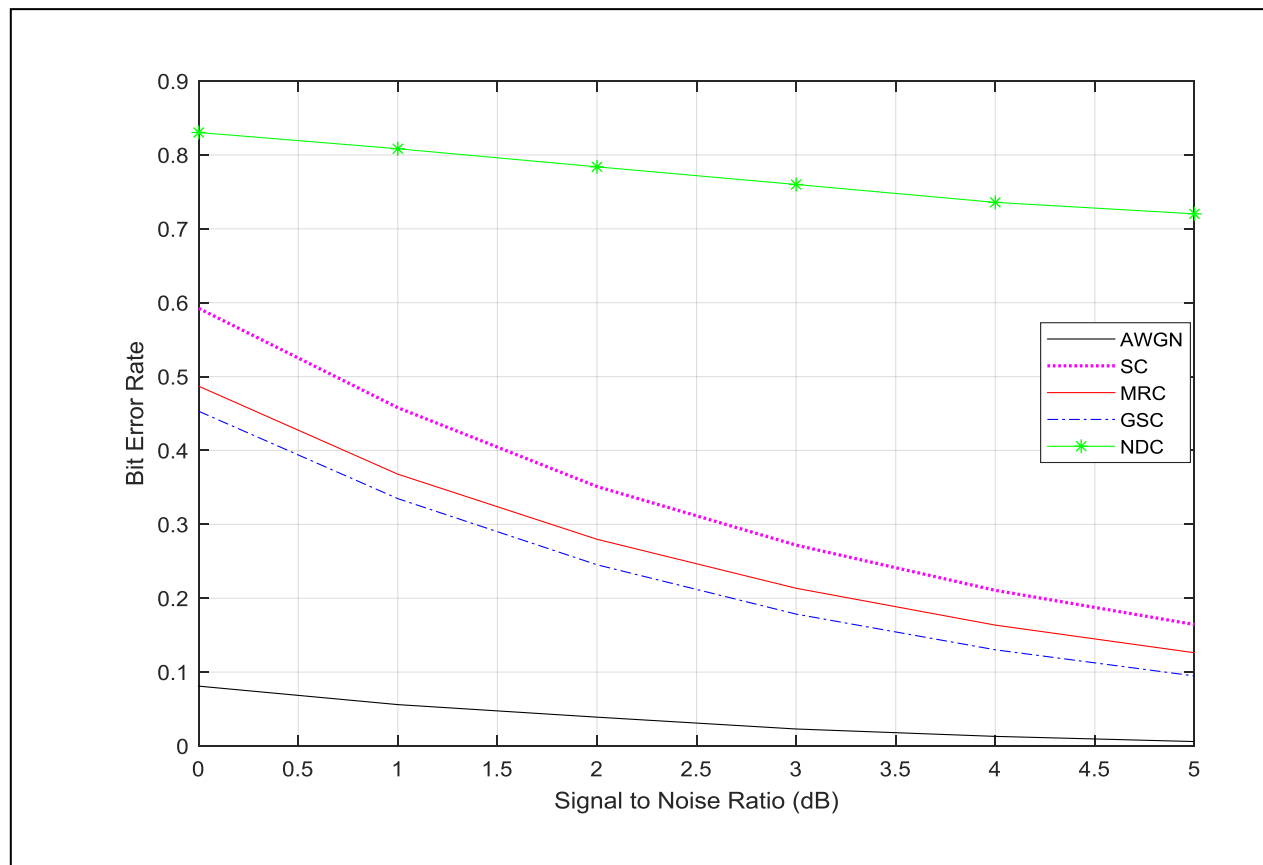


Figure 1: BER Analysis Results For Different Diversity Combining Techniques Over Rayleigh Fading Channel

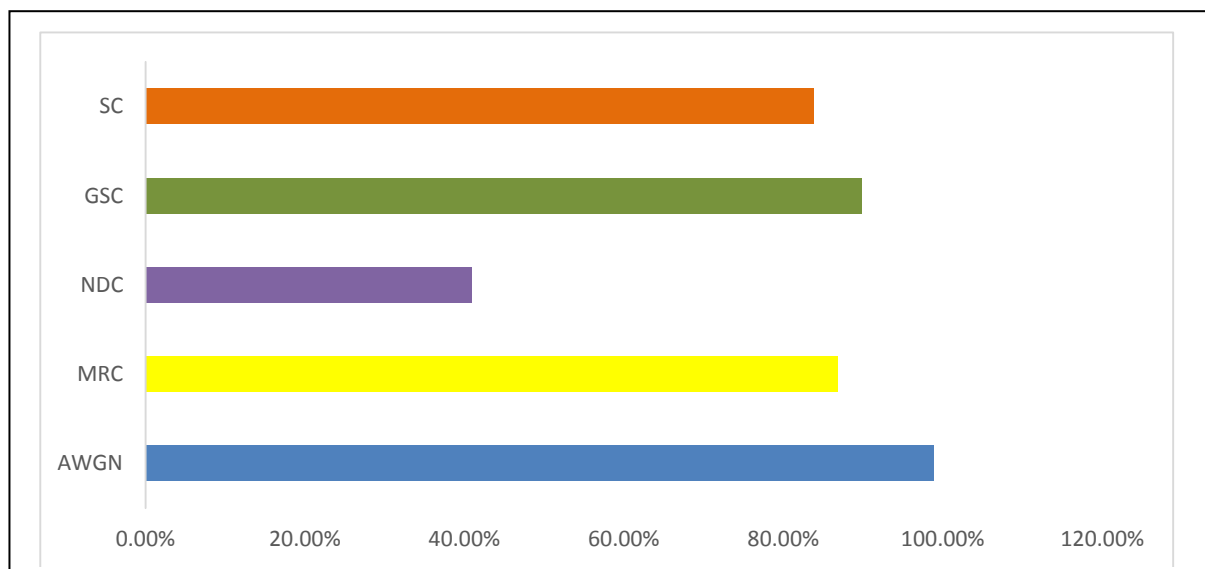


Figure 2: Performances comparison chart of diversity combining techniques with respect to system efficiency

B. Comparison evaluation of diversity combining techniques with respect to system efficiency.

4-QAM modulation with GSC over a Rayleigh fading channel was used to estimate the BER performance of the communication channel, and the results are displayed. As demonstrated in Figure 3, AWGN provides 99% efficiency for the communication system when measured as a percentage, however 4-QAM with GSC provides 76% efficiency for similar communication system over Rayleigh fading channel. Figure 3 shows the BER outcomes for GSC over a Rayleigh fading channel using a 16-QAM modulation technique. To determine in what way will this constellation mitigates contrary to noise when GSC is used on similar system and fading channel, the communication system must be examined due to the change in QAM constellation

As indicated in Figure 3, the communication system's efficiency has a percentage of 99% at ideal AWGN and 50% over Rayleigh fading channel while using 16-QAM with GSC. The

results show that as the size of the QAM constellation rises, the BER performances for 16-QAM with GSC deteriorate. In other words, over Rayleigh fading channels, 4-QAM modulation technique performs efficiently than 16-QAM modulation scheme.

C. The efficiency performance evaluation of GSC with OFDM-M-QAM

A multicarrier modulation strategy was designed to additionally reduce the fading issue and improve the efficiency presentations of GSC 4-QAM with OFDM. For OFDM-4-QAM with GSC, the results are shown in Figure 4. These findings demonstrate that OFDM significantly boosted GSC with respect to AWGN, as shown in the graph, and assisted in increasing the efficiency of the GSC using 4-QAM. OFDM-16-QAM with GSC yields 90% in investigation of the system performance efficiency. These findings demonstrate how OFDM enhanced the 16QAM with GSC efficiency as shown in Figure 5. When comparing the figures from the graphs presented previously in this research shows clearly that GSC performs far better when OFDM and QAM are combined than

when QAM is used alone. A graphical simulation study of OFDM-M-QAM and M-

QAM using all the settings from the prior discussion is shown in Figure 6.

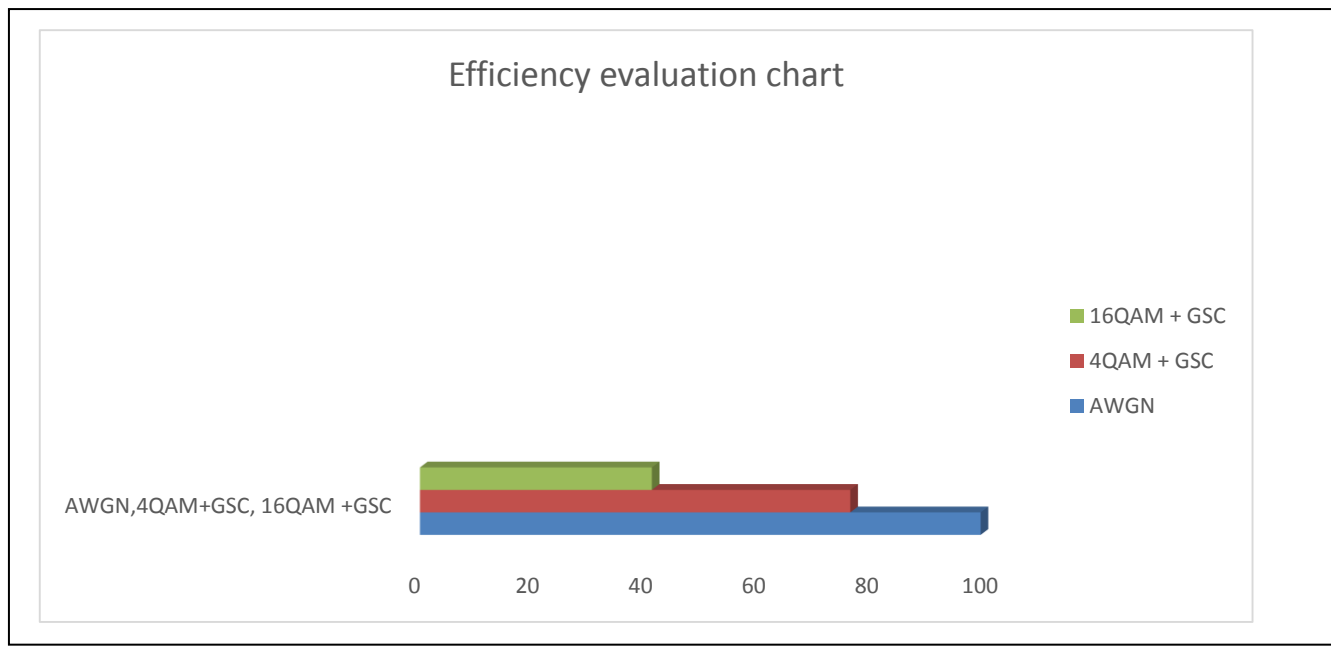


Figure 3: System performances efficiency evaluation chart of M-QAM with GSC using AWGN over Rayleigh Fading Channel

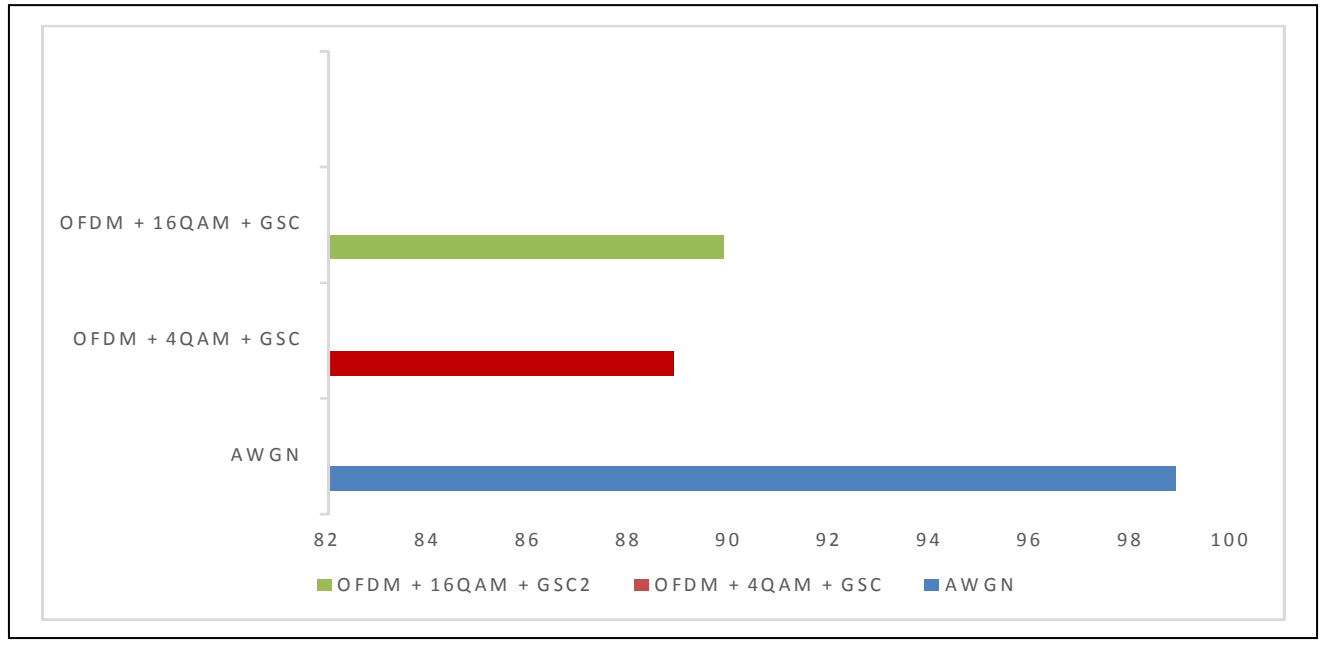


Figure 4: System performances efficiency chart of OFDM-M-QAM with GSC using AWGN over Rayleigh Fading Channel

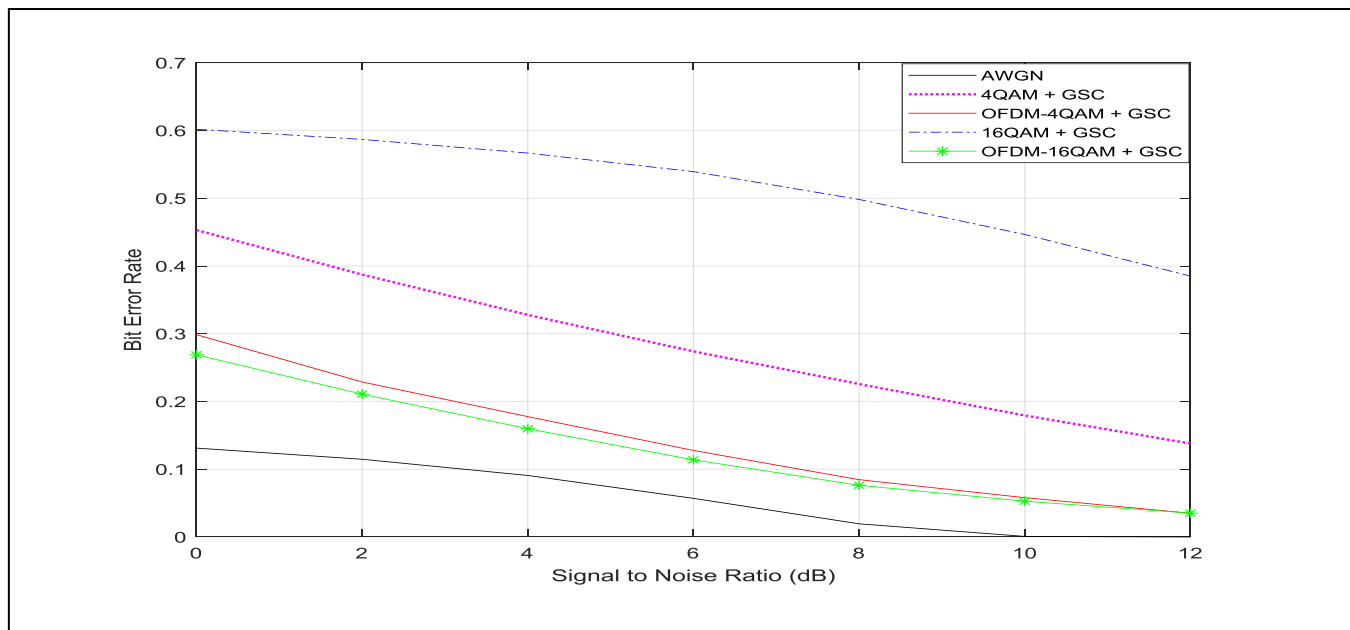


Figure 5: BER evaluation analysis with combined modulation schemes of QAM and OFDM ,using GSC on Rayleigh Fading Channel

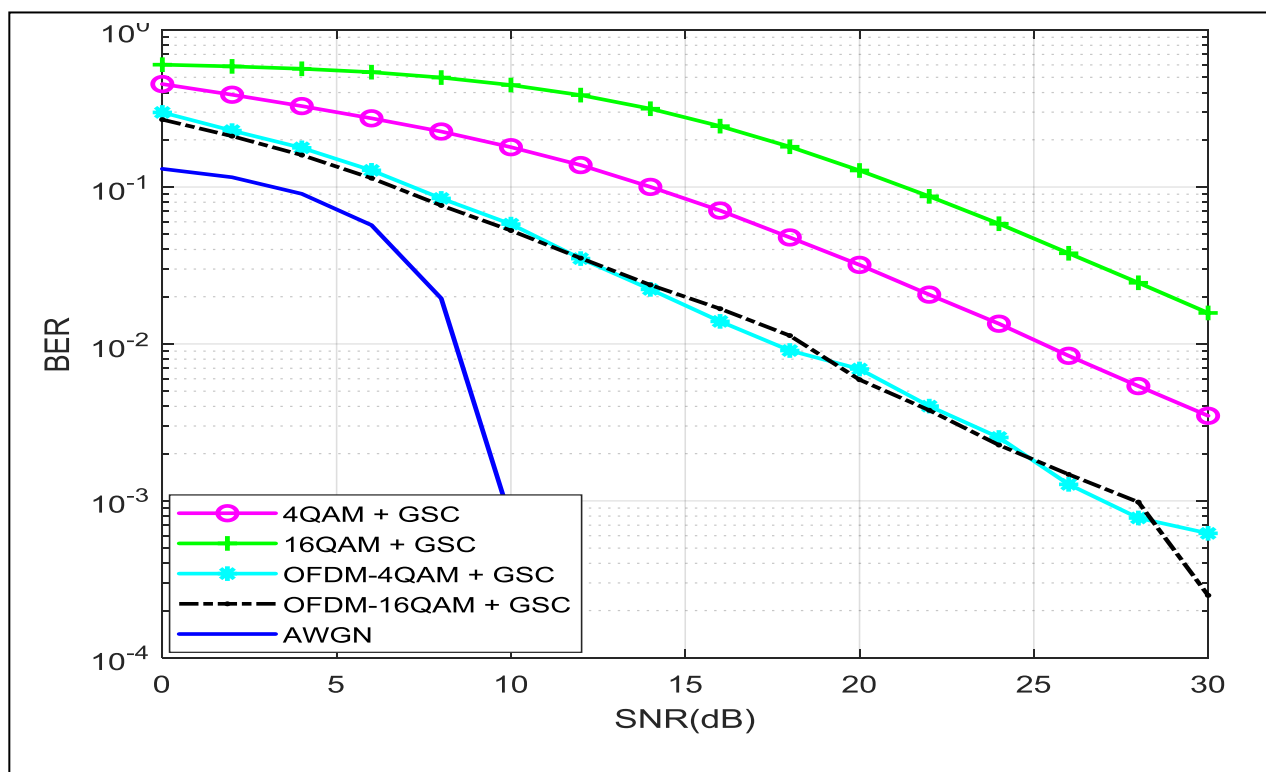


Figure 6: Graph of BER performance of OFDM-M-QAM and M-QAM with GSC

IV. CONCLUSION

The current study examined the issue of fading channels in communication systems and proposed an OFDM multicarrier technique to reduce fading. Initially, the signal was modelled for the system's multipath propagation through a Rayleigh channel that was fading. To mitigate the degradation resulting from multipath propagation, the received signal was modified using techniques from the SC, MRC, and GSC diversity combining families. BER-expressed numerical results were obtained by simulating the system model with the MATLAB application program. The results demonstrated that using GSC improved signal performance in comparison to not using diversity combining by reducing the effects of high BER. When compared to the MRC method, the GSC demonstrated greater resistance to signal fading. Furthermore, by combining the MQAM and OFDM modulation techniques with the GSC diversity combining method, the system was improved. According to the simulation results, GSC that uses OFDM-4QAM performs better than GSC that only uses 4QAM. Compared to GSC using 16QAM alone, GSC using OFDM-16QAM performs better. The two main modulation methods used with OFDM, 4QAM and 16QAM, have improved the GSC system. In the physical achievement of these theoretically presented figure, the mobile wireless communication engineer can learn on how modulation schemes can be combined to give an optimum result and also will be able to know which diversity combining techniques can be used for a specific fading channel from the inferred simulation result figures of this research work.

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