ENHANCEMENT OF GENERALISED SELECTIVE COMBINER USING COMBINED MODULATION SCHEMES OVER RAYLEIGH FADING CHANNEL

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Abstract: This research paper focused on the enhancement improvement of communication system using a combined modulation signal of Quadrature Amplitude Multiplexing and Orthogonal-frequency division multiplexing (OFDM) using a performance metrics of bit error rate (BER) and Signal to Noise Ratio (SNR) tested on a Rayleigh fading channel. The GSC is introduced at the receiving end to give a better received signal with in turn will result in better Quality of Service. The bit error rate (BER) performance of this type of systems are evaluated in the Rayleigh fading channel using Additive White Gaussian Noise (AWGN) channel as an ideal model.

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

1. INTRODUCTION

Due to a confluence of elements, wireless communication is a single significant sector in the present communication world [1]. Wireless communication can is used to convey data over near and long distances in telecommunication. Wireless operations enable facilities that would be hard or impractical to execute using cables, such as long-range communications. Wireless communication offers two different types of wireless transmission services: fixed wireless transmission and mobile wireless transmission. In fixed wireless transmission, the transmitter and receiver remain stationary, but in mobile wireless transmission, the transmitter and receiver move at different speeds. The channel refers to the physical medium that the signal moves from the transmitter to the receiver. In recent years, it's also been applied to a radio terminal connected to a high-speed mobile platform. A multitude of communication problems exist in the mobile wireless environment. Multipath transmission, signal attenuation due to big obstacle, relative transmitter-receiver movements, interference, electromagnetic radiation dispersion, and heat or underground noise are all possible sources of impairment [2]. Fading occurs when multipath propagation is combined with receiver and/or transmitter movement, resulting in significant and unpredictable fluctuations in the received signal [3]. Due to impediments impeding the line-of-sight path of the mobile radio communication, electromagnetic waves produced frequently do not eventually get to the receiving antenna, resulting in reflection, diffusion, and scattering.

The received signals are upper position of waves arriving from all angle. The available radio band for wireless communications is highly limited, yet request for mobile and individual communication is rapidly increasing [4]. Signals are sensitive to noise, interference, and many types of multipath disturbance, as well as the unpredictability

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with which user mobilities cause the received signal to vary or change. One of the major frequently used techniques for measuring a good QoS and a good signal at the receiving end is to employ BER, which is a widely used performance statistic in mobile wireless communication [5]. Communication systems engineers now have a collection of distributions at their discretion for forecasting the characteristics of various modulation and diversity techniques used in fading channel mobile communication systems [6].

In fixed wireless communication, more than a few academics have worked on some of the most relevant models for various settings. However, with respect to literature review on different author's research, little work has been done on the hybridization of modulation schemes in order to improve the performance of a variety of combining approaches over a Rayleigh fading channel in an ideal suburban environment [7]. QAM and OFDM are the modulation schemes that will be examined independently and then merged in the hopes that the one with the lowest BER over the model channel would be the ideal modulation scheme to employ in communication system design and prior to implementation, it will be applied to enhance the performance of diversity combining. With the QAM and OFDM signaling schemes, the generated data is changed to bits, rearranged, and modulated [8]. A square root raised cosine filter with a roll-off factor of 0.25 is employed to decrease spectral occupancy and convert the combined modulated signal to an analog signal appropriate for transmission across a time-varying channel.

Rayleigh fading distributions are used to convey filtered QAM and OFDM modulated signals. The demodulator demodulates the incoming signal envelope, which is then re-filtered to acquire the fading bits [9]. So, for comparison, the BER, which is employed as a symbol of performance metrics for evaluating each of the categories, is obtained.

2. SYSTEM MODEL

In this study, the transmitter, mitigation approaches, fading scenario, and receiver are all part of the system model employed. Before transmission, the randomly generated data of the information signal is received and processed by the transmitter. The signal received, $r(t)$, is given by:

$$r(t) = u(t) \times v(t) \times q(t) \tag{1}$$

where $u(t)$ is the fading distribution component, $v(t)$ is the QAM signal and $q(t)$ is the OFDM signal.

It can be noted that the fading distribution component $u(t)$ in the received signal $r(t)$, is an arbitrary data. Thus, the input data is transformed to bits, rearranged, then modulated using a signaling scheme (QAM & OFDM). The square root raised cosine filter is used to decrease spectral occupancy and convert modulated digital signals into analog signals appropriate for radio channel broadcast**.**

2.1. Doppler frequency shift

The arbitrary discrepancies in a channel triggered by a mobile user's movement are known as Doppler shift. As soon as there is a comparative motion amid the transmitter and receiver, it is the seeming modification in frequency of the received signals from that of the emitted signals.

The Doppler frequency shift, f_d, is given as follows:

$$f_d = \frac{v}{c} cos\theta \tag{2}$$

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 [10].

2.2. Rayleigh fading

The Rayleigh fading scenario is defined by several multipath components, each having quite similar signal magnitude, and consistently distributed phase. One of the reasons Rayleigh was considered for this study is that there is no line of sight (LOS) path between transmitter and receiver. After being reflected by numerous objects in the surroundings, the signal takes various pathways to reach the receiver in the Rayleigh channel. The reflected signal and the main signal are added together to form the received signal at the receiver. Signals in the urban environment are diffracted or reflected by buildings, moving vehicles, and other objects, resulting in a problem when the envelopes of the individual signals are added together The Rayleigh fading environment is characterized by a large number of multipath components with similar signal sizes and regularly scattered phase [11].

The signal in the Rayleigh channel takes a multitude of paths to reach the receiver after being reflected by several objects in the environment. The signal received at the receiver is the summation of the reflected and main signals When the envelope of each individual signal is added up in an urban setting, the signal is diffracted or reflected by buildings, moving vehicles, and other objects, posing a challenge. All components that make up the final received signal are reflected in the Rayleigh fading channel model, and there is no direct path from the transmitter to the receiver. As a result, the received signal is made up of all diffuse components added together. Rayleigh's PDF is given as:

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

where, r is the amplitude of the received signal, σ is the time average power of the received signal, $2\sigma^2$ is the prediction mean power of the received signal [12].

2.3. Quadrature amplitude modulation

In accordance with the two input signals, quadrature amplitude modulation (QAM) modifies the amplitude of the carrier wave and a quadrature carrier that is 90º out of phase with the main carrier wave. In reaction to the data to be transmitted, the carrier wave's amplitude and phase are both changed at the same time. This modulation strategy enables more spectrally efficient transmission because the symbol rate is a quarter of the bit rate. It is more efficient than both BPSK and QPSK.

2.4. Orthogonal frequency division multiplexing

Orthogonal Frequency Division Multiplexing (OFDM) is a wireless communications technique in which a communications channel is divided into a number of evenly spaced frequency bands, with each band receiving a sub-carrier conveying a piece of the user's information. The fact that each sub-carrier is orthogonal (that is, independent of the others) distinguishes OFDM from the frequently used frequency division multiplexing (FDM) technology [13]. FDM is a modulation technology that simultaneously sends many signals through a single transmission line.

2.5. Generalized selection combiner

The generalized Selection Combiner (GSC) is the diversity combining technique selected in this study since it produces a lower BER result than the other diversity techniques like EGC [14]. It is the combination of SC and MRC that allows for and suits various digital modulation schemes. The PDF output expression is given as:

$$r_i = \sqrt{E_s}\alpha_i exp[j(\emptyset_i + \emptyset_m)] + \eta_i \tag{4}$$

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.

2.6. Transmit and receive filter

An identical square root raised cosine pulse shaping filter is used at the transmit and receive filters in this paper so that the input signal can fit in the analog band limited channel, resulting in zero inter-symbol interference (ISI) at the pulse sampling time and reduced noise power outside of signal bandwidth at the receiver front end. Filtering is completed by confirming that the entire channel transfer function has a Nyguist frequency response, which is a feature of the square root raised cosine pulse shaping filter used in mobile communication [15].

3. SYSTEM SIMULATION AND MODELLING

3.1. Transmit and receive filter

This entails the modelling and simulation of Rayleigh fading channels that are used in mobile communications. The OFDM transmission system signal is used with the QAM signal to improve the GSC (H-SC/MRC), which selects two of the four strongest pathways. The multiplicative distortion factor is generated and multiplied with the modulated signals for onward transmission to the receiver in Rayleigh fading simulation. In a Rayleigh fading channel, the signal is described as given in equation (5). The total received signal, on the other hand, is expressed as given in equation (6):

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

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

where $ri(t)$ 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 ith path, $r(t)$ is the total received signal.

3.2. Simulation parameters

The investigation of the enhancement of GSC as earlier stated is carried out using MATLAB Toolboxes for communication and signal processing. The data that closely define the fading channel and modulation signals are used. These data are listed in Table 1. The simulation was carried out with Random data source which was changed to binary using MATLAB's decimal to binary function, reshaped and modulated with QAM & OFDM scheme for transmission to the fading distributions. The following parameters limit were used.

Table 1. System simulation parameters specifications.

	Parameters	Specification
1.	Modulation scheme	QAM and OFDM
2.	Fading channel	Rayleigh
3.	Diversity technique	GSC (H-SC/MRC)
4.	Carrier frequency	1800 MHZ
5.	Number of path	4
6.	Noise	AWGN
7.	Data length	10000
8.	Filter	Square raised cosine filter
9.	SNR	0, 2, --------30
10.	Roll off factor	0.25

4. RESULTS AND DISCUSION

With the aim of enhancing the performances of GSC, QAM (4 and 16 constellation) was used with OFDM, a multicarrier modulation scheme, was introduced to help mitigate further fading problem.

BER and SNR are used as performance metrics in this paper to check the performance obtained from QAM with GSC along with when the combined modulations of QAM and OFDM with GSC is used over the same fading channel (Rayleigh). The results are deductions from MATLAB simulations.

Figure 1 presents results for 4-QAM and 4-QAM-OFDM with GSC. The BER result at SNR of 2dB for example with respect to AWGN value of 0.1147, 4-QAM with GSC gives a value 0.3874 while 4-QAM-OFDM combined with GSC gives 0.2288. It is evident from the result that the value of BER when a combined modulation was used with GSC outperform the value of BER when only QAM was used with GSC. Scientifically the lesser the value of BER the better the performance of the communication system which invariably means that the system experienced little or no fading, which in turns give a good QoS at the receiving end.

Figure 2 presents results for 16-QAM-OFDM with GSC. The BER value of 16QAM- OFDM with GSC is 0.2109, at SNR of 2 dB while 16-QAM with GSC has a BER value of 0.5870 at AWGN of 0.1147 respectively on the same fading channel. From the values of BER recorded for the two cases it can be deduced that at a given SNR value the performance of combined modulation schemes with GSC gives a better result of low BER value compared with when a single modulation scheme is used with GSC. A system gives a better signal output at the receiving end when low BER value is recorded with the implication that fading is greatly controlled to the bearable standard.

Considering the graph with respect to AWGN which serves as an ideal model communication system, it can be deduced form Figures 1 and 2 that on each case the curve of QAM-OFDM with GSC is closer to the curve of AWGN which implies that the closer the curve to AWGN the better the performance of the system, showing that the system is tending to ideal.

The simulation results obtained from the hybridization showed that GSC with 4-QAM-OFDM outperforms GSC with only 4-QAM. Similarly, GSC with 16-QAM-OFDM outperforms GSC with only 16-QAM. The use of OFDM with the primary modulation schemes of (4-QAM and 16-QAM) has helped to enhance the GSC and system performance since a low BER value was recorded at different categories of the hybridization in comparison with when a modulation scheme was used. Figure 3 represent the combined graph of Figures 1 and 2 which gives a better graphical presentation.

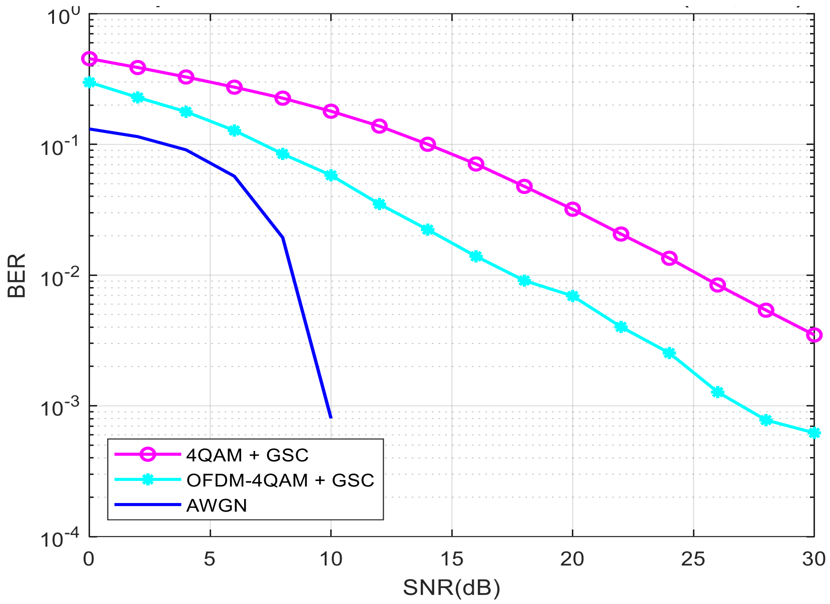

Fig. 1. Graphs of performance of 4-QAM and 4-QAM-OFDM with GSC.

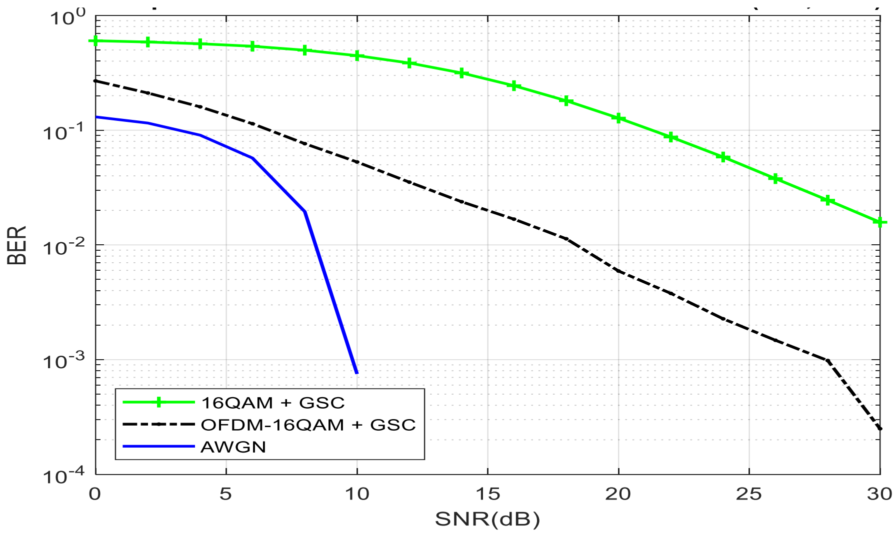

Fig. 2. Graphs of performance of 16-QAM and 16-QAM-OFDM with GSC.

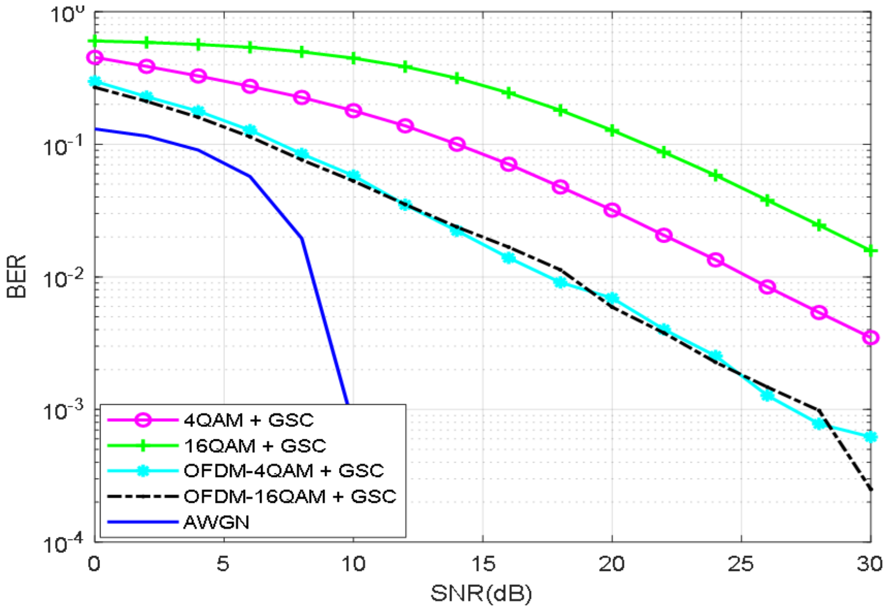

Fig. 3. Graphs of M-QAM-OFDM.

5. CONCLUSIONS

This research work has investigated the problem caused by fading channel on communication systems, and has proffered a solution using OFDM multicarrier to mitigate the fading. The system model was first developed for the received signal through multipath propagation over Rayleigh fading channel. The received signal was processed by SC, MRC and GSC diversity combining techniques to reduce the impairment caused by the multipath propagation. The system model was simulated using MATLAB application package and numerical results were obtained in terms of BER. The results showed that with GSC, the effect of high BER was reduced indicating improvement on the signal performance compared to without diversity combining. The GSC showed a better immunity to signal fading compared to the MRC technique.

Furthermore, the GSC diversity combining technique was used with the combination of MQAM and OFDM modulation schemes with the aim of enhancing the system. The simulation results obtained showed that GSC with OFDM-4QAM outperforms GSC with only 4QAM. Similarly, GSC with OFDM-16QAM outperforms GSC with only 16QAM. The use of OFDM with the primary modulation schemes (4QAM and 16QAM) has helped to improve the GSC system. Based on the deduced simulation result values in this research work, it gives an insight for the mobile wireless communication engineer to know which combined modulation schemes and diversity combining techniques can be used for a particular fading channel in the physical realization of this theoretical modeled values.

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