SDR Based Modulation Performance of RF Signal under Different Communication Channel

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Abstract **─** Hardware components are an integral part of Hardware Define Radio (HDR) for seamless operations and optimal performance. On the other hand, Software Define Radio (SDR) is a program that does not rely on any hardware components for its performance. Both of the latter radio programmers utilize modulation functions to make their core components from signal processing viewpoint. The following paper concentrates on SDR based modulation and their performance under different modulations. The bit error rate (BER) of modulations such as PSK, QAM, and PSAM were used as indicators to test channel quality estimation in planar Rayleigh fading. Though it is not commonly used for channel fading, the method of the adder determines the regionally segmented channel fading. Thus, the estimation error of the channel change substantially reduces the performance of the signal, hence, proving to be an effective option. Moreover, this paper also elaborates that BER is calculated as a function of the sample size (signal length) with an average of 20 decibels. Consequently, the size of the results for different modulation schemes has been explored. The analytical results through derivations have been verified through computer simulation. The results focused on parameters of amplitude estimation error for 1dB reduction in the average signal-to-noise ratio, while the combined amplitude deviation estimation error results are obtained for a 3.5 dB reduction.

Index Terms **─** Bit error rate, receiver operation, RF signal, signal noise ratio, transmitter, wireless channel.

I. INTRODUCTION

The domain of mobile communication continues to have a greater impact on our daily life as compared to other technological alterations. In fact, this field has been witnessing the fastest pace of changes since the dawn of the 21^{st} century with regard to design. At the same time, the services offered by mobile communication has revolutionized the current practices and systems in areas of health, finances, and education, across the world by accelerating transactions that would otherwise takes months to complete and completing them within a matter of a few hours. In more ways than one, mobile communication has extended the scope of business in unimaginable ways. One such transformative change has emerged as a significant reduction in costs made possible in the wake of modern tools used to design a wireless system [1]. Simulation is advantageous in that it can lower the cost associated with design testing, despite potentially necessitating investments in computing resources. Cognitive radio plays an important role in the reconfiguration of HDR in wireless communication. Based on the reconfiguration requirements antennas are designed. The designed antennas are used for cognition operation such as reconfiguration [2].

Channel modeling prepares any wireless communication system's core component to help determine whether packets are unable to reach the supposed destination, a phenomenon referred to as packet-loss. The wireless system's simulation could encompass channel coding, speech coding, as well as other issues pertaining to interleaving in modulation. It is possible to use different methods to estimate the wireless system's the overall performance by simulating the channel under different conditions [3]. Certain models leverage the simulation of bit-error-rate (BER) or signal-to-noise ratio (SNR), while others may concentrate on the as alterations occurring over a longer duration, including packet error rate or segmentation [4], [5].

The objective of this article is to provide radio frequency signals for various modulation modes in Rayleigh fading channels on the basis of data and pilot symbols. To that end, a number of modulation techniques are utilized for performance assessment by using the RF signal's BER. These simulation findings are found to be in alignment with our analytical results.

The remainder of this paper is organized in the following manner: Section II presents related work while the technique of the proposed work is explained in Section III. The channels using for SDR are discussed in Sections IV, V, VI and Section VII. Experimental results with associated discussions are given in Section VIII.

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Conclusion and future research directions are drawn in Section IX.

II. RELATED WORK

Wireless channel models are commonly used to study the performance of transmission or link-layer protocols using simulation. For example, the performance of transmission protocol (TCP) over the wireless link is studied by Chaskar et al. [6]. Analysis of TCP/ IP over wireless connections is presented by Cheyenne et al. [7]. Leibniz [8] studied the performance of error correction code on wireless connections. In all these cases, a frame loss model has been applied to the surface of the link layer. In addition, the performance of other communication protocols over wireless links (such as ATMs [9], [10]) is also studied by simulation. Channel detection has proven an effective technique in M-QAM demodulation as it accurately compensates for channel dimension and phase distortion [11]. Many authors have studied channels in the voice of PSAM [12], [13] and these relays have proven to be useful for fading channels. Previous studies on the performance of PSAM M-QAM were primarily based on computer simulation and experimental implementation. The only result of the analysis is that the upper limit of the 16-QAM [14] symbol error rate is strict. These results provide an efficient method to evaluate the performance of various system design parameters.

III. PROPOSED FRAMEWORK

In an attempt to transmit information from one point to another, the signal has to be sent through the medium to reach the recipient. The path from the transmitter to the receiver is referred to as a channel. Some examples of channels include copper cable, fiber optic cable, or space. The channel characterizing features may include.

A. Additive white Gaussian noise channel

The channel model commonly used in communication system analysis is that of the Additive White Gaussian Noise (AWGN) channel, and it is longer and easier than the Gaussian Noise Channel.

The term "additive" refers to the superposition or addition of noise to a signal, thus limiting the receiver's ability to make decisions about the correct signal and the rate of information. Therefore, AWGN is the effect of thermal noise generated through the movement of electrons in all electronic components (Resistors, wires, etc.) featuring dissipation property [15].

For wireless channels, their properties are usually determined by specific locations, atmospheric effects, transmission objects, multi-pathing effects, and so on. Transmitter and receiver in this study are assumed to be fixed as a state of default and for the line of sight (LOS). In other words, the transmitter and receiver are not moving, and the theory between each other is very intuitive.

The rationale for a fixed LOS wireless channel is the AWGN channel, which has frequency selectivity in the case of matte channels, rather than frequency selectivity. Given that, both, the frequency converter and the receiver are default, this study does not take into account signal delay and the use of AWGN to terminate the signal in such a mobile communication channel.

Assume that the AWGN channel bandwidth has a constant power spectral density (PSD) and Gaussian amplitude probability density. As depicted in Fig. 1, this Gaussian noise is incorporated into the transmitted signal before it is received by the receiver. Mathematically, thermal noise is expressed by the zero-mean Gaussian random process, where the signal is a random variable of Gaussian noise, and the DC signal as (1):

$$\boldsymbol{r(t)} = \boldsymbol{s(t)} + \boldsymbol{n(t)}. \quad (1)$$

In the formula defined in equation (1), r(t) is the received signal, s(t) is the transmitted signal and n(t) is the noise signal between the transmitted input and the received output signal.

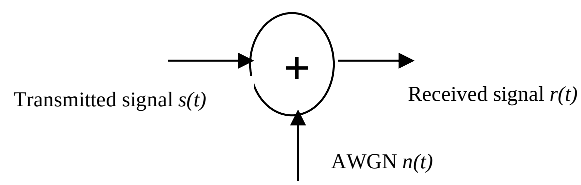

Fig. 1. The Gaussian channel diagram

In this model, the noise power (white noise) of uniform spectral density is incorporated into the actual signal. The result of the distribution of sound is the Gaussian process at zero average. Although not always realistic, this assumption simplifies the mathematical process associated with estimating the performance of a given communication system. In fact, most of the BER curves are generated by analyzing Gaussian noise channels.

B. Rayleigh fading channel

Since the signal is propagated in the air and near the ground, in addition to the influence of the freeway loss Ls, the most important effect of signal attenuation is the multipath propagation effect. This effect will cause the amplitude, phase and angle to fluctuate in the received signal due to multipath blur.

In general, mobile communication has two blurring effects: large-scale blurring and small-scale blurring. Large-scale blurring, when moving over a large area, represents an increase in average signal strength or damage along the way due to the effects of shadows. On the other hand, small-scale fading refers to sharp changes in signal amplitude and phase, caused by minute changes in the spatial separation between the receiver and the transmitter (as small as a half-wavelength). Small-scale fading is also called Rician fading because the signal envelope received can be expressed by the Rician Probability Density function (PDF).

IV. MULTIPATH CHANNEL

The most destructive feature of the mobile radio in the communication system is its gradual disappearance of path. The author focused on multipath characteristics of the channel with high and low waves travelling in different directions before reaching to the receiver antenna. The experimental test were taking in the daytime with fixed transmitter antenna and moved the receiver antenna. This radio signal can reach the receiver after various delays, in amplitudes and phases due to multiple interferences of multi-fading in the channel. The receiver antenna is installed in a vehicle to measure the received signal with different disappearances shown in Fig. 2.

Therefore, in a multipath fading channel, the pulse transmitted signal at the receiver end receives multiple pulses due to multiple fading in the channel. These fading can blur the amplitude and phases of the received signal, can lead to careful fluctuations, which effect the transmitting information and reliability. This problem causes very small destructive interventions in recipients [16] where many textbooks have extensively introduced multidimensional minerals for optimal results. The main features of the multipath fading channel with frequency non-selective fading are introduced in the following subsections.

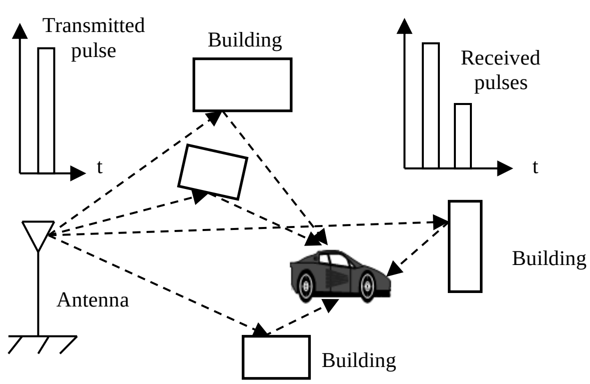

Fig. 2. The Gaussian channel diagram.

V. FADING CHANNEL CHARACTERIZATION

As mentioned earlier, the delay and destructive feature will reflect to the transmitting behaviour of the signal. Therefore, multiple pulses received by recipients cannot solve the problem arise by multiple path. The problem can be reduced, if the transmitting signal can transmit a very short signal (pulses in an ideal case). These transmitting signals can be transmitted to different fading channels at different times and on the receiver side, it can be received in the form of a series of pulses as shown in Fig. 3.

For the use of multipath channel, the signal received at different time slot in order to receive the transmitting signal seems random and unpredicted. Therefore, it is important to characterize the channel from a statistical point of view. Thus, first check the channel influence on the transmission signal, usually as (2):

$$\boldsymbol{S_P(t) = Re\{s(t)e^{j2\pi f_c t}\}}, \quad (2)$$

Where;

Re - the real part;

$S_P(t)$ - band-pass transmission pulse;

s(t) - baseband input signal whose bandwidth is limited by the filter in the transmitter with a carrier frequency f_c.

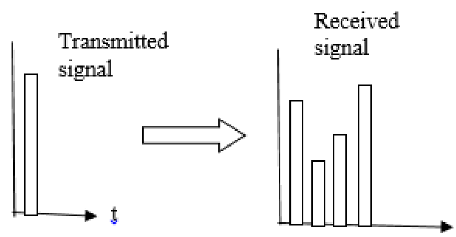

Fig. 3. The Gaussian channel diagram.

The multiple propagation paths associated with each path has propagation delay τ(t) and attenuation factor $a_n(t)$. Due to the change of the medium structure in the wireless communication system, the propagation delay and the amplitude attenuation factor have all shown to be time-varying. Therefore, the bandpass signal received after multipath propagation can be derived as (3):

$$\boldsymbol{x(t) = \sum_n a_n(t) s_p\{t - \tau_n(t)\}}, \quad (3)$$

Where;

$\boldsymbol{a_n(t)}$ - amplitude attenuation factor of the received signal in the nth path;

$\boldsymbol{\tau_n(t)}$ - propagation time delay of the nth path.

Substituting, $\boldsymbol{S_P(t)}$ from equation (4) into equation (5) gives the result:

$$\boldsymbol{x(t) = Re\left[\sum_n a_n\, s[t - \tau_n(t)] e^{j2\pi f_c [t - \tau_n]}\right]}, \quad (4)$$

and the baseband filter received the signal at the receiver side as (5):

$$\boldsymbol{x(t) = Re\left[\sum_n a_n(t) e^{-j2\pi f_c \tau_n(t)} s[t - \tau_n(t)]\right]}. \quad (5)$$

Since $\boldsymbol{x(t)}$ is the filter response to the input signal, $\boldsymbol{s(t)}$, it can be expressed as h(τ,t) by using the time-varying impulse response as (6):

$$\boldsymbol{h(\tau, t) = \sum_n a_n(t) e^{-j2\pi f_c \tau_n(t)} s[t - \tau_n(t)]}. \quad (6)$$

Given that $\boldsymbol{f_c}$ is the transmitted unmodulated carrier frequency and $\boldsymbol{s(t) = 1}$ for all $\boldsymbol{t}$, then the received signal reduces as depicted in (7):

$$\boldsymbol{r(t) = \sum_n a_n(t) e^{-j2\pi f_c \tau_n(t)} = \sum_n a_n(t) e^{-j\theta_n(t)}}, \quad (7)$$

where $\boldsymbol{\theta_n(t) = j2\pi f_c \tau_n(t)}$.

Thus, it is concluded that the received signal is a summary of the amplitude and phase with varying vectors of different times. Since the changes of $\boldsymbol{a_n(t)}$ and $\boldsymbol{\theta_n(t)}$ occur on different scales, when the randomly changing vector is added catastrophically, the multipath propagation model in equation (9) disappears with a strong signal. When this happens, the input signal received is too small or almost zero. Due to the effect of $\boldsymbol{a_n(t)}$ and $\boldsymbol{\theta_n(t)}$, the received signal r (t) can also be changed as a random operation. Therefore, rewriting the fading response as in equation (8):

$$\boldsymbol{h(\tau, t) = \sum_n a_n (t) e^{-j\theta_n(t)} s[t - \tau_n(t)]}, \qquad (8)$$

where $\boldsymbol{h(\tau, t)}$ the modulated process with varying time $(\boldsymbol{t})$. Central limit theorem in [16] explains the complex value of Gaussian filters with a different number of paths. When there are a large number of paths, r(t) can be simplified to a complex-valued Gaussian stochastic process. Therefore, $\boldsymbol{r(t)}$ can be simplified as channel fading response by Gaussian filter process based with variable time $(\boldsymbol{t})$.

VI. DOPPLER SHIFT

The Doppler Effect leads to having different signals shift at one time which when combined at some other time cancel the effect of fading due to multiple paths staying as time-dependent parameters. Therefore, fast and slow fading normalize the maximum effect of the fading rate as described in [17] and are reproduced as in (9):

$$\boldsymbol{f_d = \frac{f_m}{B} = \frac{f_c\, v\cos\propto}{B}}, \qquad (9)$$

Where;

$\boldsymbol{f_m}$- maximum Doppler shift frequency;

$\boldsymbol{B}$ - bandwidth of the baseband signal;

$\boldsymbol{v}$- speed of the wireless signal;

$\boldsymbol{f_c}$ - carrier frequency;

$\propto$ - arrival angle of the path with the maximum Doppler shift frequency;

c - speed of light constant.

VII. FREQUENCY OF SLOW RALEIGH FADING CHANNEL

Channel fading can also be classified as frequency selective fading or frequency non-selective repetitive fading as given in [18] by $\Delta\boldsymbol{f_{coh}}$ as:

$$\Delta\boldsymbol{f_{coh} = \frac{1}{T_m}}. \qquad (10)$$

If the bandwidth of the blurred channel is less than the bandwidth (Δfcoh) of the transmission signal, the channel is said to be the frequency selection attenuation. In this case, the channel will severely distort the signal and may cause inter-signal interference. In frequency non-selective fading channels, all frequency components present in the transmission signal experience almost the same focus and phase shift.

According to [16] and [18], in the frequency non-selective fading channel, the received signal reaches the receiver through the fading path. Therefore, the signal can be simplified as the product of the transmitted signal and α, showing time-varying features of fading multipath channels.

To make the analysis simpler, it has been omitted. Also, unlike signals, noise does not necessarily attenuate the number of multipath channels that come into the channel. In this communication system, it is assumed that AWGN has a connected power spectrum, and that the deviation of its centre frequency will not change its statistical properties. It is generally assumed that the band Gaussian has got a circular symmetry in complex Gaussian noise.

By itself, the real and imaginary parts of random variables are free, and so is the Gaussian distribution. Carrier frequency and phase offset will not change its statistical characteristics. Therefore, noise can be expressed as an additional term in the received signal expression.

Considering the above discussion, the frequency non-selective and dim Rayleigh fading channel can be approximated as a multiplication factor of the transmission signal. Therefore, for noise, the received signal can be expressed in the same way:

$$\boldsymbol{r(t)} = \mathbf{c(t)} \times \boldsymbol{s(t)} + \boldsymbol{n(t)}, \qquad (11)$$

Where;

$\boldsymbol{r(t)}$ - received signal;

$\boldsymbol{c(t)}$- Fading distortion, its envelope has a Rayleigh distribution;

$\boldsymbol{s(t)}$- Transmitted signal;

n(t) - average of zero additive white Gaussian noise and the power spectral density N_0

The systematic convolution code (SCC) model is used for transmitted signal where Fading and AWGN signal appears as the part of received signal. The SCC model is shown in Fig. 4 encoded the representation of signal. The SCC decision is used for soft decision with the configurable frequency factor.

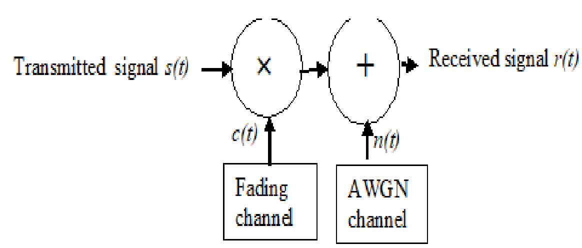

Fig. 4. Transmission channel model.

VIII. EXPERIMENTAL RESULTS AND DISCUSSION

Antenna plays an important role in the reconfigurable procedure of wireless communication. The adaptation reconfigurable antennas is used to maximize the performance by operation during communication. The common factor that is used for SDR algorithms are used as RF reconfiguration. The Matlab program has been used for SDR simulation to evaluate the efficiency of RF signal transmission. Transmitted and received signals of Fig. 5 show the BER and SNR, and the acquisition performance of the proposed system to indicate the transmitted and received signals using the proposed SDR system. It can be concluded that the nature and shape of the sent and received signals are the same. However, due to the noise and filtering effect of the synchronization in the transmission, the signal size will vary but the overall transmission remains accurate.

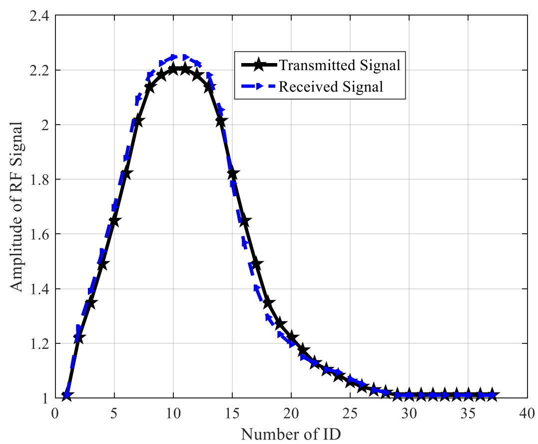

Fig. 5. Transmitted and received signal using proposed SDR system.

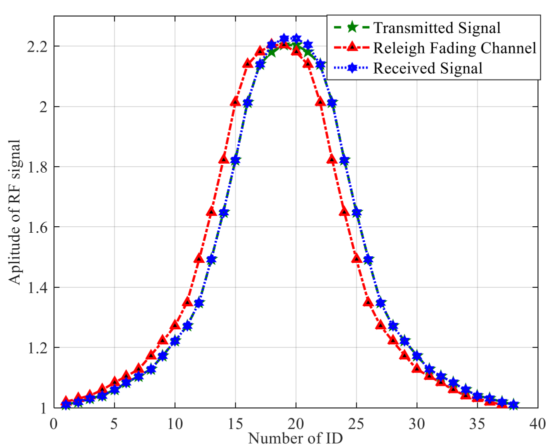

Fig. 6. BER degradation using SDR system.

Figure 6 shows a typical SNR value of 4dB. Iterative decoding algorithms have been used to obtain transmitted RF signals using Rayleigh fading channels. The number of repetitions affects the bit error rate. In Fig. 8, it can be seen that the performance of the system is well estimated in a large number of numbers. Further, the decline in the performance of the SDR-based BER modulation scheme provides an approximate value with slight fluctuations compared to the input value. The performance index can be estimated by plotting the relationship between BER and SNR as EB / No. It can be seen that this fluctuation will cause BER to drop and reduce efficiency due to the influence of probability error on the detection process as compared to the input probability error. It has also been observed that BER decreases with increasing SNR. In the PSAM modulation scheme, the BER degradation is almost parallel to the input degradation curve.

Figure 7 shows the BER performance of RF data communication via the SDR-type digital modulation scheme on the fading channel. In all cases, the performance of the proposed system in PSAM and QAM will be low, and the performance in PSK modulation will be satisfactory. For the typical 4 dB SNR value, the BER values of the PSK, QAM and PSAM modules are 0.002035, 0.5086 and 0.7586, respectively. The system performance is better from 10 to 18 dB. From ambient SNR (4-16 dB) values, the system shows almost flat degradation performance. For PSK, when SNR is greater than 12 dB, BER is close to zero. It can be seen from Figure 7 that the performance of QAM and PSAM system is poor compared to PSK using the receiver.

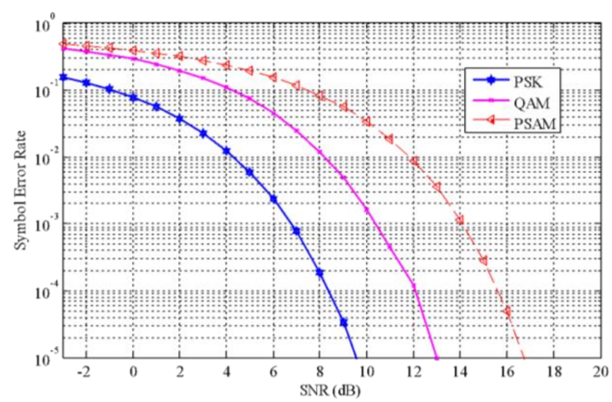

Fig. 7. SDR performance under different modulation schemes.

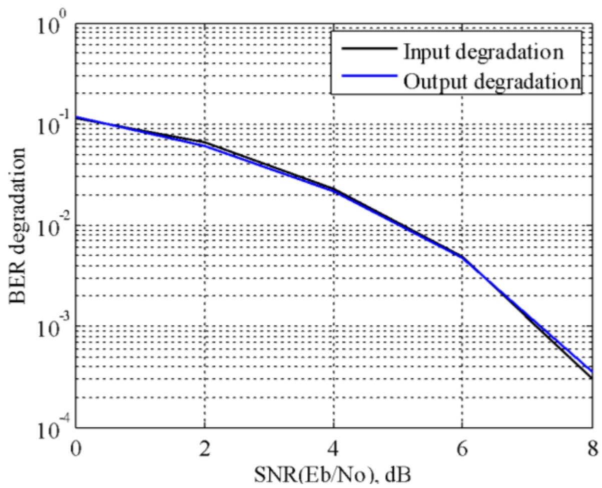

Fig. 8. BER performance of RF transceiver in Rayleigh fading channel.

As illustrated in Fig. 8, the performance of the system is thoroughly examined in a large number of iterations. It shows that the decline in performance of the SDR-based BER modulation scheme provides an estimate with a slight change compared to the input value. Measure performance indicators can be found due to the detection process and the probability error impact on the input probability error index. These changes tamper with the efficiency of the BER and, hence, the performance. In the PSAM modulation scheme, the BER degradation curve is almost parallel to the input degradation curve.

IX. CONCLUSION

This paper designs the SDR system based on RF simulation. The SNR of 10 dB has been used to test the degradation of the performance of the synthetic softening channel. The results obtained indicate PSAM with the optimal performance in terms of BER under various roll-off coefficients, thus, reflecting the performance of the proposed SDR. It can be seen that a fixed SNR with a higher roll-off factor will reflect lower results. Consequently, the RF transmission capacity is improved. Therefore, it can be concluded that in case of high bit transmission rate requirements, the PSAM used as a modulation scheme stands a chance of achieving better transmission efficiency.

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