Comparing Probability of Error and Outage Probability of Different Channels

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***Abstract* – The objective of this study is to compare the various results in three different channel systems, namely the single channel system, the three-channel system, and the time-varying channel system. The aim is to determine the probability of error in the received signal and the outage probability, which checks if the received signal strength falls below a minimum threshold power. The comparative analysis of the three signal channels is aided by MATLAB software.**

Keywords – Error, Probability, Bit-Error-Rate(BER), Outage-Probability, Communication, Single-channel, Three-Channel, Fading, Performance

I. Introduction

Study of wireless communication starts from probability theory because wireless communications deal with uncertainty. If there are no channel impairments by nature, the transmitted messages can be received without distortion, and no need to care about probability theory. But in reality, channel fading, shadowing, and multipath loss are seen during the transmission and receiving of signals. Therefore, it may be necessary to use techniques such as channel coding, modulation schemes, and error correction to improve the system performance and reduce the error rates.

II. Theory

The probability of error, described in terms of either symbol or bit errors, and the outage probability, defined as the likelihood that the instantaneous signal-to-noise ratio will fall below a predetermined threshold, are the two performance parameters of interest.

A. Probability of Error

In wireless communication, the probability of error depends on various factors, such as the signal-to-noise ratio (SNR), the type of modulation used, the presence of interference, and the channel characteristics. Assuming a noise follows a Gaussian distribution and the channel is subject to Rayleigh fading, the probability of error for a given modulation scheme can be calculated using the Bit Error Rate (BER) formula:

$$Bit\ Error\ Rate\ (BER)\ =\ 0.5\ \times\ erfc(\sqrt{SNR})$$

where, $erfc$ is the complementary error function and SNR is the signal-to-noise ratio.

B. Outage Probability

The outage probability can be defined as the probability that the received signal-to-noise ratio (SNR) falls below a certain threshold, which is required to maintain a certain quality of service (QoS) at the receiver. The QoS can be defined as the bit error rate (BER), data rate, or other performance metrics. For example, suppose the outage threshold for a particular QoS level is SNRth. In that case, the outage probability can be calculated as

$$P_{out}\ =\ P(SNR\ <\ SNR_{th})$$

The outage probability can be estimated using various models, depending on the channel and propagation conditions, such as the log-normal model, the Rayleigh fading model, or the Nakagami-m model. The outage probability can be reduced using power control, adaptive modulation and coding, diversity techniques, and interference management. By reducing the outage probability, the overall system performance and reliability can be improved, especially in the presence of fading and interference.

III. Wireless Communication Channels

Wireless communication channels is the medium through which signal is transmitted from the sender to the receiver in a particular bandwidth.

A. *Single Channel*

A single-channel wireless communication system refers to a system that uses a single channel for both the transmission and reception of data. This means that the same frequency band is used to send and receive data. These systems often have low bandwidth requirements and low power consumption and may operate in environments with limited resources and infrastructure. One advantage of a single-channel system is that it is simple and cost-effective, requiring less hardware and power consumption than multi-channel systems. However, a single-channel system can be more susceptible to interference, noise, and other impairments, which can degrade the system's performance and reliability.

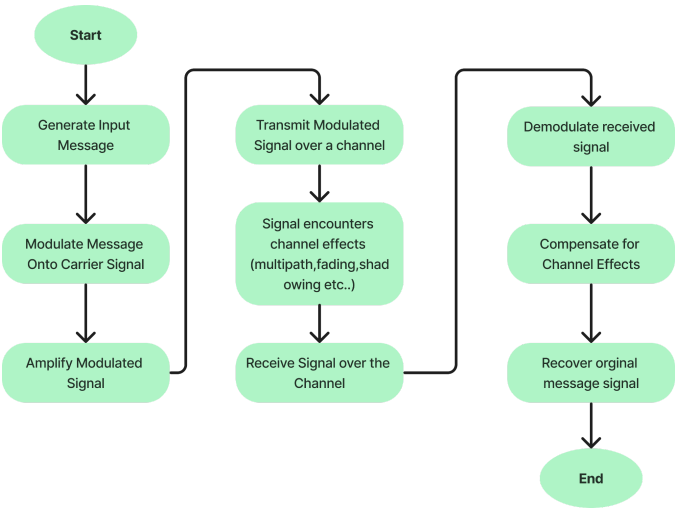
B. *Three Channels*

A three-channel system in wireless communication refers to a system that uses three separate channels for transmission and reception. One of the main advantages of a three-channel system is that it can provide more frequency diversity. By using three independent channels with different frequency characteristics, the system can further reduce the impact of frequency-selective fading and other frequency-dependent impairments. This can improve system performance and reliability, particularly in severe channel conditions. Another advantage of a three-channel system is that it allows more efficient use of the available frequency spectrum. However, using three channels can also increase the complexity and cost of the system, as well as the power consumption and bandwidth requirements.

C. *Time-Varying Channel*

A time-varying channel in wireless communication is a channel whose characteristics change over time due to various factors, such as the movement of the transmitter or receiver, changes in the environment, and interference from other sources. Time-varying channels can cause significant impairments to wireless communication systems, such as signal attenuation, dispersion, and fading. Fading is a significant effect of time-varying channels, which causes the received signal strength to fluctuate randomly over time, leading to temporary losses or errors in the received signal. Various techniques can be used to mitigate the effects of time-varying channels, such as diversity techniques, equalization, and adaptive modulation and coding. The ability to deal with the effects of time-varying channels is critical for ensuring these systems' performance, reliability, and quality of service.

IV. Flow Chart



V. Expected Results

An analysis of the three selected channels using the MATLAB software resulting in a detailed comparative study of the three channels on the important parameters like error probability, outage probability, bit error rate, signal to noise ratio, etc., and conclude on the plots of signal to noise ratio against outage probability and bit error rate against the probability of error in all three channels.

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