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Combining techniques graphical representation of bit error rate performance used in mitigating fading in global system for mobile communication (GSM)

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ABSTRACT

In wireless channels, fading has been viewed as a problem that must be combated in order to achieve reliable and effective information transfer. In this research, combining technique was applied to combating fading. The theory behind the chosen diversity combining technique, as well as appropriate algorithm to evaluating the system performance, is also presented. An application program was developed using MATLAB to model the communication system and the accompanying faded signal. Statistical analyses were performed on derived data to measure the performance improvement of the technique.

INTRODUCTION

Wireless communication channel suffers from many impairments such as the thermal noise often modeled as Additive White Gaussian Noise (AWGN), the path loss in power as the radio signal propagates, the shadowing due to the presence of fixed obstacles in the radio path, and the fading which combines the effect of multiple propagation paths, and the rapid movement of mobile units reflectors. Upon the signal transmission, different signal copies undergo different attenuation, distortion, delays and phase shifts. Due to this problem, the overall system performance can be severely degraded.

Fading is caused by certain terrain geometry and meteorological conditions that are not necessarily mutually exclusive. All radio transmission systems in the 0.3-300 GHz frequency range can suffer from the effect of fading including satellite earth terminals operating at low elevation angles and/or in heavy precipitation.

Fading problem is a major impairment of the wireless communication channel. Fading is caused by interference between multiple replicas of the same signal, which arrive at slightly different times at the receiver. It is the primary cause of performance degradation in wireless systems and the central among other challenges facing the radio engineers. Therefore, it demands a lot of attention from communication systems designers and researchers.

A method of mitigation used in GSM is slow frequency hopping. If the signal is undergoing severe fading, the carrier used to transmit the signal can be hopped to another frequency. This is done at a maximum rate of 217.6 hops per second (Falade et al., 2014).

Diversity technique had been a tool to mitigate fading effect by generating several samples of signal (Joydev et al., 2014). It is used when a signal arrive at a receiver's antenna from multiple paths. The antenna therefore receives the signals at different phases, some at peak and some at trough. This means that some signals will

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add together to form a strong signal, while others will subtract causing weak signal (Kuhn, 2006). Signal fading arises from multiple transmission paths at the receiver with different phase shift, delay spread which is the time spread between the arrival of the first and last multipath signal seen by the receiver (Falade et al., 2014).

In order to improve the reliability of transmissions on wireless radio channels, some measures have to be employed in order to reduce the degrading effects of multipath fading. Diversity techniques have been known to be effective in combating the extreme and rapid signal variations associated with the wireless radio transmission path (Dragan et al., 2015). In addition, diversity improves transmission performance by making use of more than one independently faded version of the transmitted signal (Prabhat and Manisha, 2014).

Diversity combining methods

The goal of a combiner is to improve the noise performance of the system (Rappaport, 1996; Brennan, 1959; Garg, 2007). After obtaining the uncorrelated signals, we need to consider the method of processing these signals to obtain the best results. The analysis of combiners is generally performed in terms of signal-to-noise ratio (SNR) (Joydev et al., 2014). The idea of diversity is to combine several copies of the transmitted signal, which undergo independent fading, to increase the overall received power. Different types of diversity call for different combining methods but in this study, the authors evaluated the bit error rate performance of three combining techniques which are: maximum ratio combining (MRC), equal gain combining (EGC) and selection combining (SC).

In MRC, the output of the diversity combiner is the weighted sum of the branched signals making the output optimum. The input signals are co-phased and proportionally weighted to the signal level, signal power or SNR. In EGC, the weights are normalized to unity. This implies that the individual strength of a branch signal is not taken into consideration. In SC, the combiner selects the input that has the highest or most desirable signal level. This selection process is based on some quality measurement, which can be signal level, signal power or SNR.

BIT ERROR RATE AND COMBINING TECHNIQUES

Bit error rate

The bit error rate or bit error ratio (BER) is the number of bit errors divided by the total number of transferred bits during a studied time interval. BER is a unitless performance measure, often expressed as a percentage.

The number of bit errors is the number of received bits of a data stream over a communication channel that has been altered due to noise, interference and distortion.

Mathematical model for signal transmission

For a slowly flat fading channel, the equivalent received signal of multiple branches, say the ith branch, can be written as:

$$r_i(t) = g_i s(t) + n_i(t), i = 1, 2, \ldots.., L \quad (1)$$

where:

$g_i = A_i e^{j\theta_i}$, is the ith branch fading attenuation with phase θ_i which is assumed uncorrelated;

$s(t)$, is the equivalent transmitted signal;

$n_i(t)$, is the Additive White Gaussian Noise;

L, is the total number of branches that lead to the receiver and the received signals.

MATERIALS AND METHODS

To be able to visualize the BER performance of MRC, EGC and SC techniques, some mathematical modelling and numerical simulations were performed and graphs plotted - collecting data from sufficient number of independent random realizations of the system's parameters.

Codes were written for each of the three combining techniques using four different paths from the transmitter to the receiver and the graphs of the BER against the SNR for the paths were plotted. Codes were also written for the three combining techniques on a graph for different paths.

System flow chart

The simulation flow chart presents a diagrammatic sketch of the step by step process of the operation carried out for each of the three diversity combining techniques. Figure 1 shows the flowchart for SC, for MRC, the received signals are weighted after addition of AWGN and the signals summed but for EGC, no weighting is required since the signals have an equal gain of unity.

Modelling parameters

The following parameters were used in the simulation:
Modulation scheme: BPSK

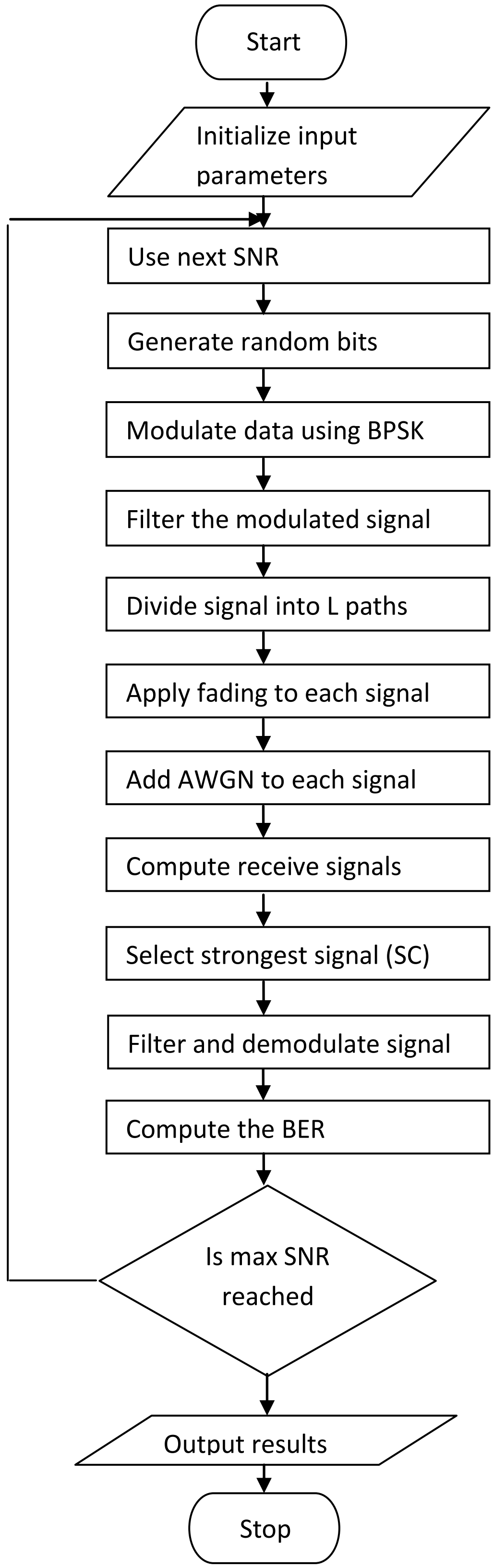

Figure 1. Simulation flow chart for selection combining (SC).

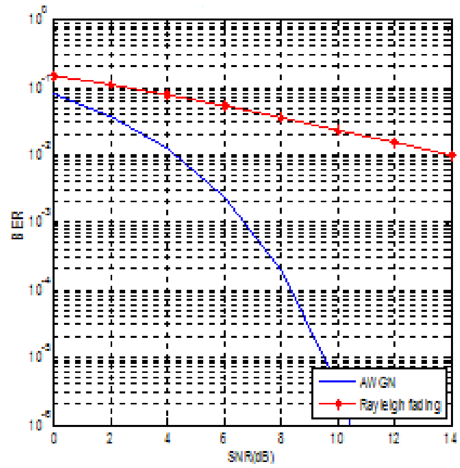

Figure 2. BER performance degradation due to fading-simulation results.

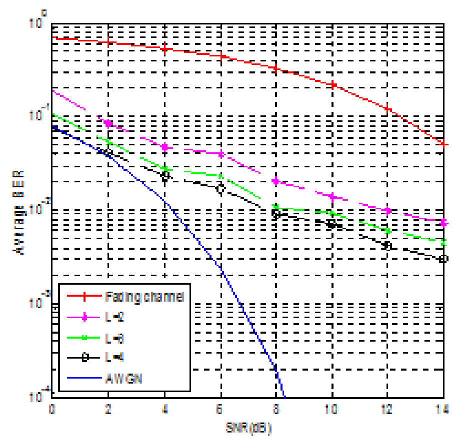

Figure 3. Simulation graph of BER performance of maximum ratio combining.

Data length: 10000
Number of samples per symbol: 16
Number of iterations, nIters: 20
Diversity paths, L: 2, 3, 4
Noise: Additive White Gaussian Noise
Fading: Rayleigh statistics with $E\{R^2\}$ =1

SIMULATION RESULTS

BER results - fading channel

Using the above mentioned parameters and assumptions, Monte-Carlo simulations were performed in both an AWGN channel and on a fading channel and the results are plotted in Figure 2.

BER performance of maximum ratio combining

The highest number of paths has the best BER performance because it is the one closest to the AWGN (non-fading) channel which is used in ideal situations and the highest number of paths is four. L is used to designate the number of paths, so we can deduce that L = 4 has the best BER performance.

BER performance of equal gain combining

The highest number of paths has the best BER performance because it is the one closest to the AWGN which is used in ideal situations. From the graph in Figure 3, we can deduce that path L = 4 having the best BER

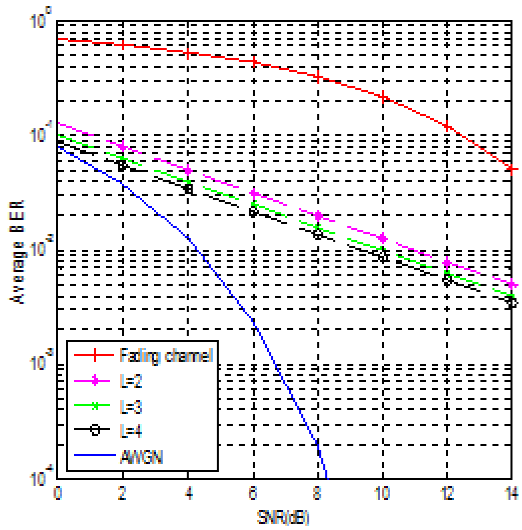

Figure 4. Simulation graph of BER performance of equal gain combining.

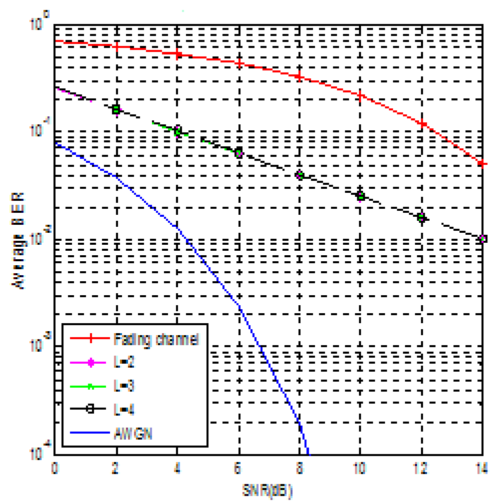

Figure 5. Simulation graph of BER performance of selection combining.

performance.

BER performance of selection combining

The highest number of paths has the best BER performance because it is the one closest to the AWGN which is used in ideal situations. From the graph in Figure 4, we can deduce that path L = 4 has the best BER performance.

BER results - Diversity combining using simulation graphs

The results for diversity combining using simulation are shown in the Figures 5, 6, 7 and 8 for three different paths: L = 2, L = 3 and L = 4. Further, the BER plots illustrate through simulation, the effectiveness of diversity combining techniques over fading channels.

Comparing the simulation graphs for L = 2, L = 3 and L = 4, it can be clearly seen that the MRC provides the best

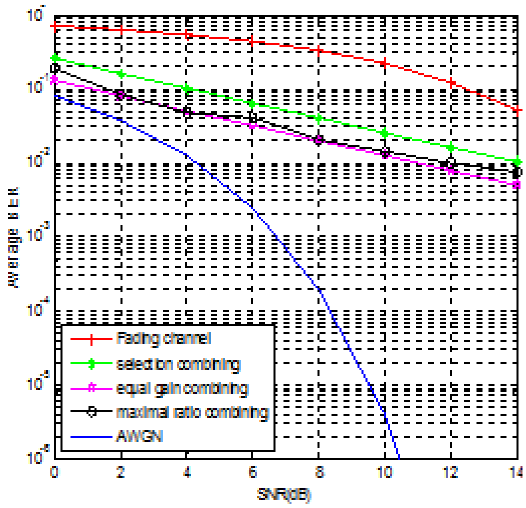

Figure 6. Simulation graph of MRC, EGC and SC for path L = 2.

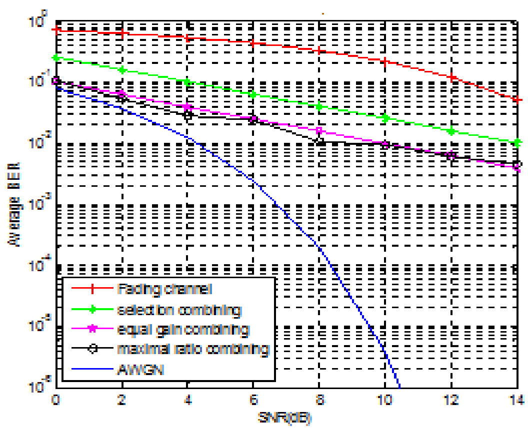

Figure 7. Simulation graph of MRC, EGC and SC for path L = 3.

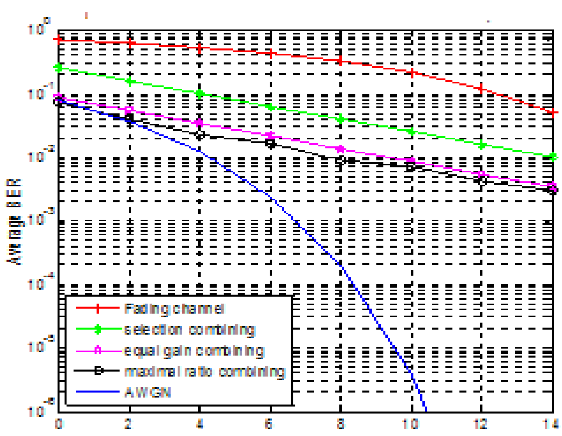

Figure 8. Simulation graph of MRC, EGC and SC for path L = 4.

performance, while EGC and SC provide marginally inferior performances.

Conclusion

The results of this research work has determined the bit error rate performance of selection combining, equal gain combining and maximum ratio combining. It has shown and proved that the maximum ratio combining has the beast performance with the highest number of paths L = 4.

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