Designing and Comparative Analysis for BER of Selection, Equal Gain and Maximal Ratio Combining Diversity Techniques

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Abstract

This paper provides a brief introduction to the various types of Diversity systems in wireless systems. Stepping into the new generation of mobile communication it is of concern to increase the performance of the mobile terminals and their antennas to be able to answer to the demand of faster and more various communicational services. Still, the issue of signal fading in a multi-path environment stands as an obstacle today. The purpose of this work is to introduce diversity techniques as a promising way of improving the performance at the mobile terminals. The goal is more profound, dealing with analysis of the correlation between received signals and the propagation environments that diversity improvement depends on, and putting together a repeatable method for measuring the improvement. The work resulted in simulated and measured diversity performance for three different, antenna diversity concepts created for the purpose of this work. The results confirmed by using Rayleigh fading in AWGN noisy channel and with the BPSK modulation, presented the best diversity technique out of three and also provide a comparison between all. An analytical expression for the signal-to-bit-error-rate (BER) at the output of a three-diversity technique is given. The three branches are assumed to be Rayleigh fading, correlated with the BPSK modulation. Measurements of the bit-error-rate with the Eb/N0 after selection, equal gain combining and maximal ratio combining were made in Rayleigh fading channels and compared with the analytical results.

Keywords: Diversity, fading, selection diversity, maximal ratio combining, equal gain diversity, bit error rate, signal to noise ratio.

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I. Introduction

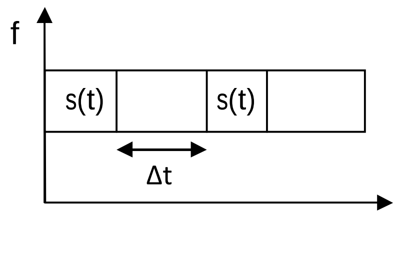
Modern communication systems have become an important part of day-to-day life. The demand for higher data-speed in wireless networks calls for innovative efficient Communications technologies which are not only spectrally-efficient but also energy efficient. Diversity techniques is to be effective to overcome the channel fading and exploit broadcast nature of transmission to provide reliable and better links. Diversity is a powerful communication receiver technique that Provides wireless link improvement at a relatively low cost. Diversity techniques are used in wireless communications systems to improve performance over a fading radio channel.

In such a system, the receiver is provided with multiple copies of the same information signal which are transmitted over two or more real or virtual communication channels. Thus the basic idea of diversity is repetition or redundancy of information. In virtually all the applications, the diversity decisions are made by the receiver and are unknown to the transmitter. As the use of multimedia applications grows, there is an increasing demand for higher data rate and access to such services. The diversity techniques have been proven to be effective for such purpose.

II. Types of diversity

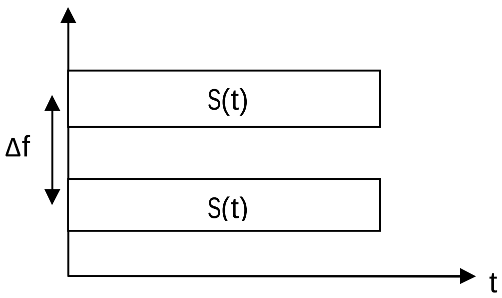
Fading can be classified into small scale and large scale fading. Small-scale fades are characterized by deep and rapid amplitude fluctuations which occur as the mobile moves over distances of just a few wavelengths. For narrow-band signals, this typically results in a Rayleigh faded envelope.

A. Time Diversity: In this, multiple versions of the same signal are transmitted at different time instants this information signal is transmitted at regular intervals of time. The separation between the transmit times should be greater than the coherence time period. In order to transmit the desired signal in M different periods of time, i.e., each symbol is transmitted M times. The time interval depends on the fading rate, and increases with the decrease in the rate of fading.



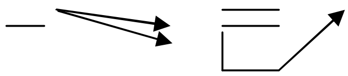
"Figure 1: Time Diversity Scheme"

B. Frequency Diversity: The signal is transmitted using several frequency channels spread over a wide spectrum. The same information signal is transmitted on different carriers, each carrier should be separated from the others by at least the coherence bandwidth so that different copies of the signal undergo independent fading. To achieve this, modulate the information signal through M different carriers.



"Figure 2 : Frequency Diversity"

C. Space Diversity: In Space diversity, there are multiple receiving antennas placed at different spatial locations, resulting in different independent received signals, M antennas are used to receive M copies of the transmitted signal. The antennae should be spaced far enough apart. Different from frequency diversity, no additional work is required on the transmission end, and no additional bandwidth or transmission time is required.



"Figure 3: Space Diversity"

III. Diversity Combining Techniques

The aim of diversity is to combine several copies of the transmitted signal, which undergo independent fading, to increase the overall received power. There are different types of diversity combining methods.

A. Selection Diversity: In this method, the strongest signal branch is selected. From the number of antennas, the branch that receives the signal with the largest signal-to-noise ratio is selected and connected to the demodulator. Larger the number of available branches, the higher the probability of having a larger signal-to-noise ratio at the output.

r(t)= $Ae^{j\theta}$s(t) + Z(t)-

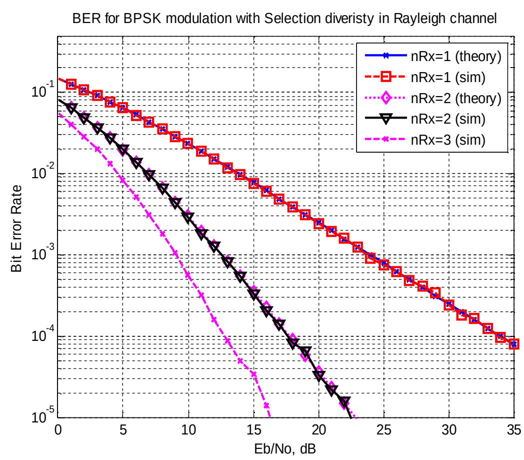
s(t) = is the equivalent lowpass of the transmitted signal,

$Ae^{j\theta}$ = is the fading attenuation of branch

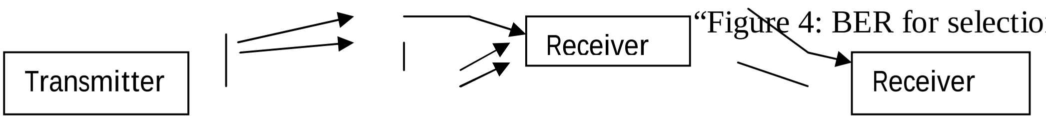
where A= max{ $A_\circ, A_1, \ldots, A_{M-1}$}

received signal to noise ratio is given as:

$$\Gamma = \frac{A^2 E_b}{N_\circ} = \max\{\Gamma_\circ, \Gamma_1, \ldots\ldots, \Gamma_{M-}\}$$



"Figure 4: BER for selection diversity"



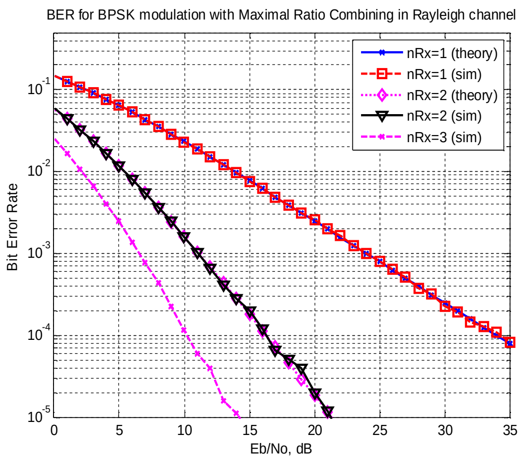
B. Maximal Ratio Combining

Both branches are weighted by their instantaneous voltage-to-noise ratios. Each of the branch signals is weighted with a gain factor proportional to its own SNR. The branches are then co-phased and summed in order to insure that all branches are added in phase for maximum diversity gain. The summed signals are then used as the received signal and connected to the demodulator. The advantage is that improvements can be achieved with this configuration even when both branches are completely correlated. The disadvantage of maximal ratio is that it is complicated and requires accurate estimates of the instantaneous signal level and average noise power to achieve optimum performance with this combining scheme. Maximal ratio combining will always perform better than either selection diversity or equal gain combining because it is an optimum combiner. The information on all channels is used with this technique to get a more reliable received signal.

$$y(t) = \sum_{i=0}^{M-1} w_i r_i\,(t)$$

received signal to noise ratio is given as:

$$\Gamma = \frac{\sum_{i=0}^{M-1} A_i^2 E_b}{N_0} = \sum_{i=0}^{M-1} \Gamma_i$$



"Figure 5: BER for Maximal Ratio Combining"

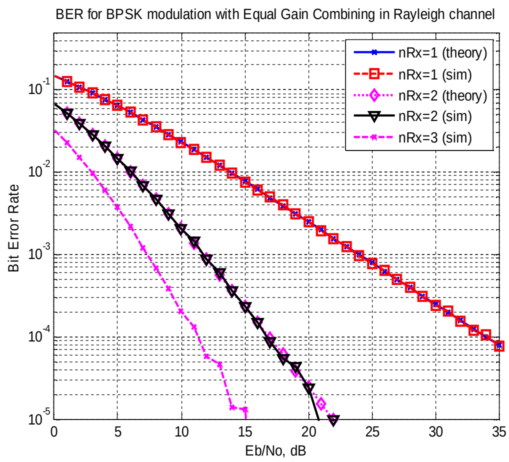
C. Equal Gain Combining

It is same as that of maximal ratio combining except that of equal gains. In this scheme the gains of the branches are all set to a single value and are not changed. Both the branch signals are multiplied by the same branch gain (G) and the resulting signals are co-phased and summed. The resultant output signal is connected to the demodulator.

$$y(t) = \sum_{i=1}^{M} e^{-j\theta}\, r_i(t) = \left(\sum_{i=0}^{M} A_i\right) s(t) + \sum_{i=0}^{M} e^{-j\theta}\, Z_i(t)$$

SNR is given by

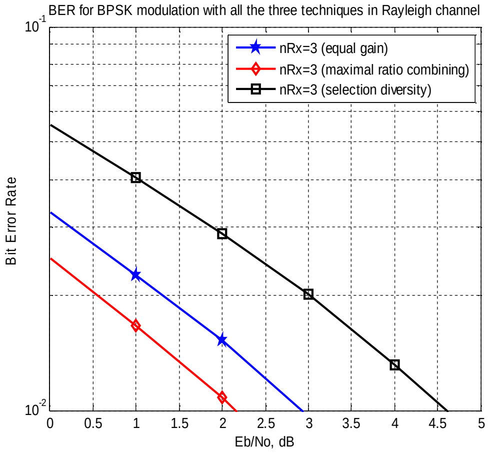
$$\Gamma = \left(\sum_{i=0}^{M-1} A_i\right)^2 \frac{E_b}{M\,N_0}$$



"Figure 6: BER for Equal Ratio Combining"

IV. Result Comparison

In the figure below, plots for the SNR with the different no. of antenna for all the three techniques have been shown. This clearly shows that SNR in case of MRC is much than that of Equal Gain and selection diversity. It is also observed that as the number of receiver increases SNR increases gradually. If the no. of antenna is 4 then it can be observed from the below figure the value of signal to noise ratio is more for Maximal Ratio Combining diversity technique as compare to Equal Gain Combining and Selection diversity technique and SNR value for Equal Gain Combining is more than the Selection diversity technique.



"Figure 7: BER Comparison"

V. Conclusion

For the receiver diversity we have different diversity technique, out of which we used three techniques-selection diversity, maximal ratio combining and equal gain combining for our work. BPSK modulation technique and Rayleigh fading is used for checking the performance of these techniques. We observed that for the calculation the bit error rate with respect to the E_b/N_0 then again maximal ratio combining have lesser value as compare to the equal gain combining and selection diversity. So, we can say that the performance of the maximal ratio combining is better as compare to the equal gain combining and selection diversity. Other effective techniques are time and frequency diversity. Time interleaving, together with error correction coding, can provide diversity improvement.

VI. References

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