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Performance Analysis of Conventional Diversity Combining Schemes in Rayleigh Fading Channel

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Abstract - **Diversity is a powerful technique to combat the wireless fading impairment. In this paper, types of diversity along with different diversity combining techniques –Selection Diversity, Equal Gain Combining and Maximal Ratio combining are being proposed. An analytical expression for the signal-to-noise ratio (SNR) and bit-error-rate at the output of a three-branch maximal ratio combining, equal gain combining and selection diversity system is given. The three branches are assumed to be Rayleigh fading, correlated with the BPSK modulation. Measurements of the signal-to-noise ratio and bit-error-rate 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, Equal Gain Diversity, Maximal Ratio Combining.**

I. Introduction

The Next generation wireless systems are required to have high voice quality and high bit rate data services as compared to current wireless system. In other words, the next generation systems are supposed to have better quality, coverage and must be bandwidth efficient. Also the system must be reliable in different types of environment. When the signal is transmitted, different signal copies undergo different attenuation, distortion, delays and phase shifts and also the wireless communication channel suffers from much impairment such as

i. Thermal noise often modeled as Additive White Gaussian Noise (AWGN)
ii. The path loss in power as the radio signal propagates
iii. The shadowing due to the presence of fixed obstacles in the radio path
iv. The fading which combines the effect of multiple propagation paths.

If these impairments are not overcome, the performance of the system is slowly degraded and hence the efficiency. The major problem in all these which makes reliable wireless transmission difficult is multipath fading. There are two techniques proposed to combat the effect of fading.

i. Transmitter Power control
ii. Diversity technique

In power control method, there are two major drawbacks- First, the transmitter requires a dynamic range. Second, channel information has to be fed back from the receiver to the transmitter. So, Diversity technique is being employed. Diversity refers to transmitting and/or receiving the same information via different independent ways. In such a system, multiple copies of the same information signal are being transmitted to the receiver over two or more real or virtual communication channels. Thus the basic idea of diversity is repetition or redundancy of information. The diversity decisions are made by the receiver and are unknown to the transmitter. Thus, it provides wireless link improvement at a relatively low cost, power savings and increased system capacity. If diversity is not employed; the resulting efficiency would be very low.

II. Diversity Schemes

1. ***Time Diversity***: In this, multiple versions of the same signal are transmitted at different time instants or the information signal is transmitted at regular intervals of time. The separation between the transmit times should be greater than the coherence time. In order to transmit the desired signal in M different periods of time, i.e., each symbol is transmitted M times.
2. ***Frequency Diversity***: The signal is transmitted using several frequency channels or spread over a wide spectrum. The same information signal is transmitted on different carriers, the frequency separation between them being at least the coherence bandwidth. To achieve this, modulate the information signal through M different carriers. Each carrier should be separated from the others by at least the coherence bandwidth.

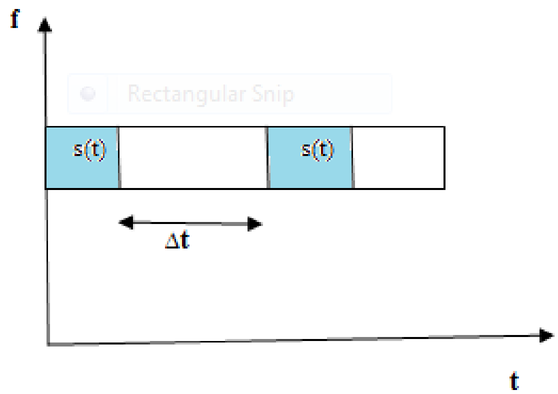


Fig 1: Time diversity scheme

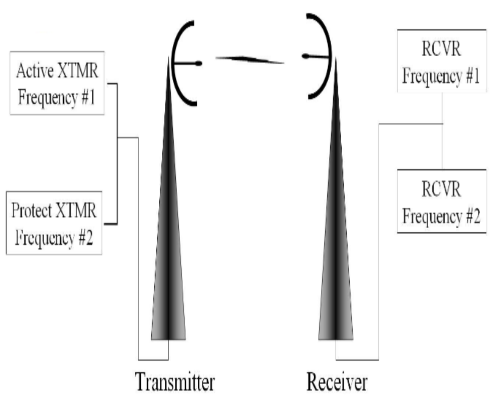


Fig 2: Frequency diversity scheme

3. Space Diversity: In Space diversity, there are multiple receiving antennas placed at different spatial locations, resulting in different (possibly independent) received signals, M antennas are used to receive M copies of the transmitted signal. The antennae should be spaced far enough apart.

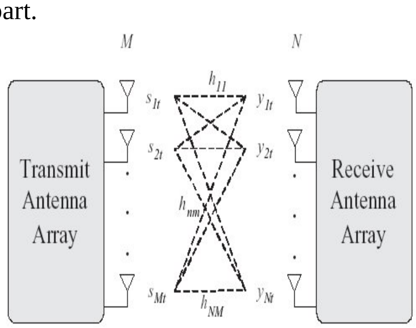
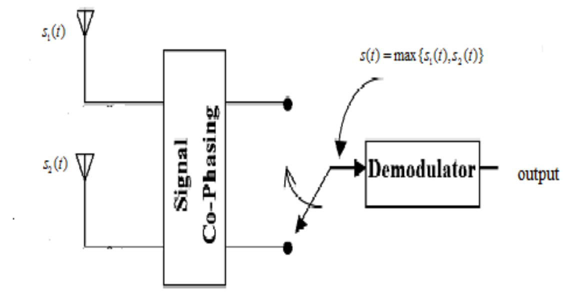


Fig 3: Space diversity scheme

III. Diversity Combining Techniques

i. Selection Diversity

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 (SNR) at the output.



Fi

g 4: Block diagram of selection diversity scheme.

The combined output is given by:

$$y(t) = Ae^{j\theta_i} s(t) + z(t)$$

$$A = \max\{A_0, A_1, ..., A_{M-1}\}$$

The received SNR is

$$\Gamma = \frac{A^2 E_b}{N_O} = \max\{\Gamma_0, \Gamma_1, ..., \Gamma_{M-1}\}$$

The CDF of Γ is

$$P_\Gamma(\gamma) = \prod_{i=0}^{M-1} P_{\Gamma i}(\gamma)$$

The bit-error rate probability

$$P_e = \frac{1}{2}\sum_{k=0}^{N}(-1)^k\binom{N}{k}\left(1+\frac{k}{(E_b/N_0)}\right)^{-1/2}$$

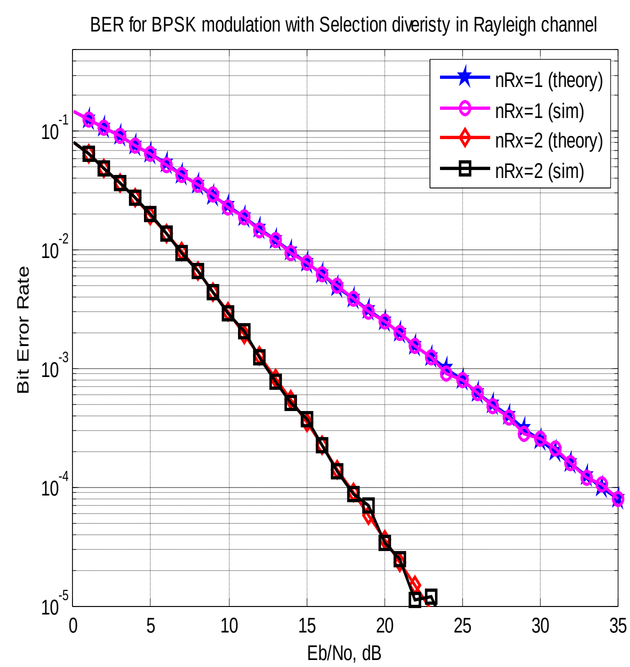


Fig 5: BER Vs E_b / N_0 for selection diversity

ii. Maximal Ratio Combining

Both branches are weighted by their respective instantaneous voltage-to-noise ratios.The branches are then co-phased prior to summing 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.

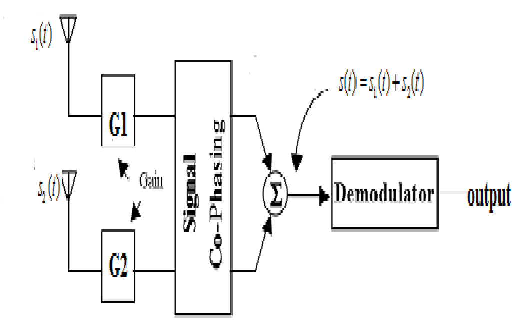


Fig 6: Block diagram of maximal ratio combining diversity scheme.

The combined output is given by:

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

The received SNR is

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

The bit-error rate probability

$$P_e=\int_0^{\infty}\frac{1}{2}erfc(\sqrt{\gamma})p(\gamma)d\gamma$$

$$=\int_0^{\infty}\frac{1}{2}erfc(\Gamma)\frac{1}{(N-1)!(\mathrm{E}_b/\mathrm{N}_0)^N}\gamma^{N-1}e^{\frac{-\gamma}{(E_b/N_0)}}d\gamma$$

iii. 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.

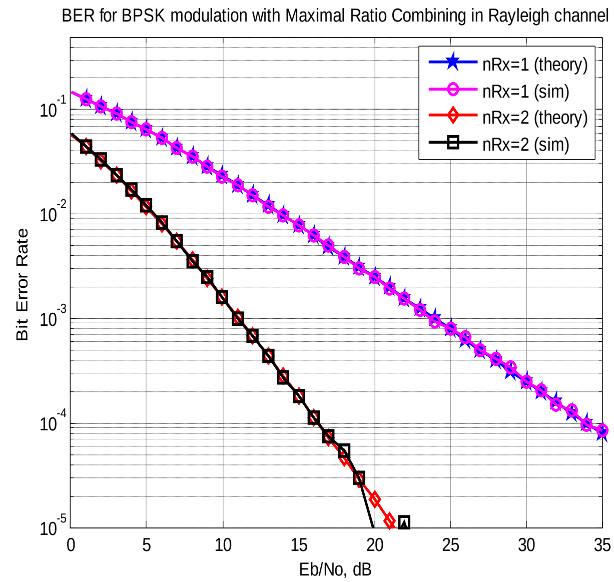


Fig 7: BER Vs E_b/N_0 for Maximal Ratio Combining.

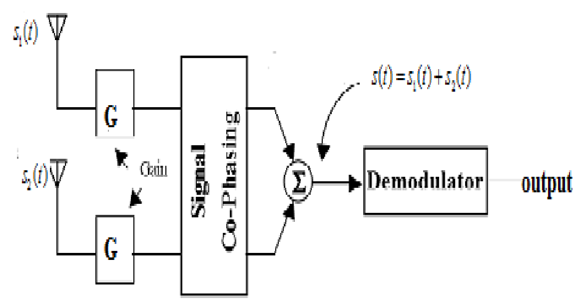


Fig 8: Block diagram of equal gain combining diversity scheme

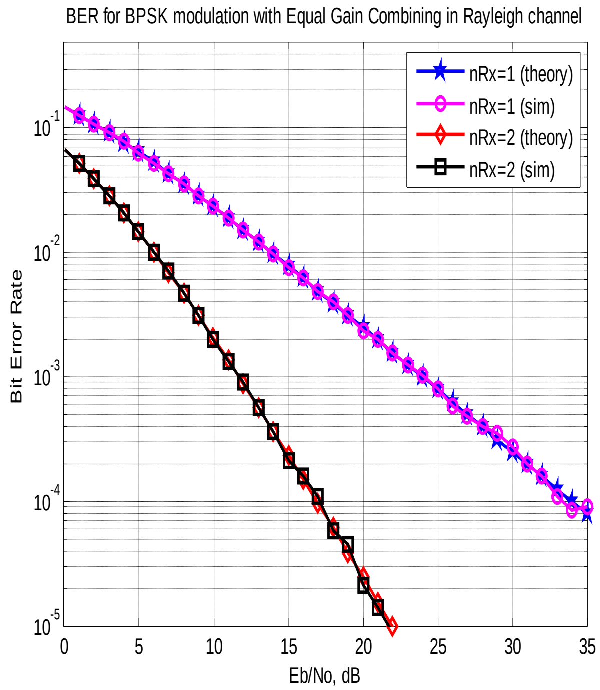
The combined output is given by:

$$y(t)=\sum_{i=1}^{M} e^{-j\theta_i} r_i(t)=(\sum_{i=0}^{M} A_i)s(t)+\sum_{i=0}^{M} e^{-j\theta_i} z_i(t)$$

The received SNR is

$$\Gamma=\left(\sum_{i=0}^{M-1} A_i\right)^2\frac{E_b}{MN_0}$$

It can be observed from the figure 10 the value of bit error rate is lesser for Maximal Ratio Combining diversity technique as compare to Equal Gain Combining and Selection diversity technique and BER value for Equal Gain Combining is more than the Selection diversity technique



iv. 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 when we calculated the value of SNR with different no. of antenna for these three techniques, maximal ratio combining diversity technique gives the best result as compare to the equal gain combining and selection diversity. 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.

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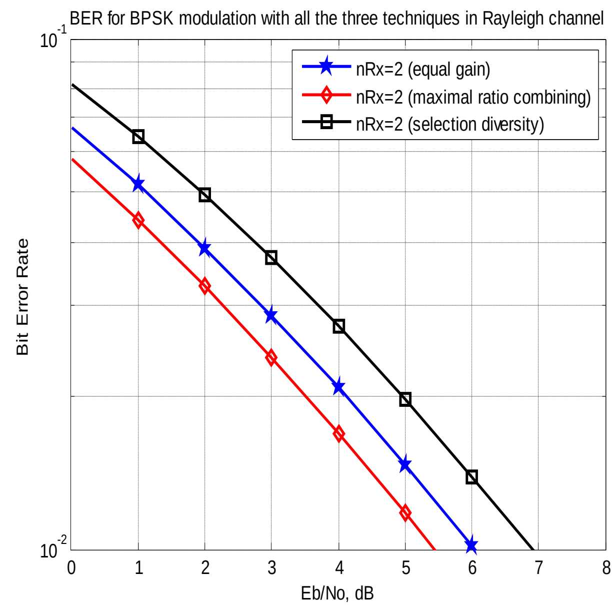

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