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Research Article

Analysis of Receive Diversity in Rayleigh Fading for various Modulation Techniques

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ABSTRACT

Now-a-days the requirements of wireless communication are to have high voice quality, high data rates, multimedia features, lightweight communication devices etc. But the wireless communication channel suffers from several impairments .One of them is fading which is due to the effect of multiple propagation paths. One effective solution is proposed for wireless system named diversity, without the requirement of power or extra bandwidth. In this paper, we analyze the error performance of a wireless communication system employing receive diversity in a Rayleigh fading environment. The method is easily extended to obtain the BER for the coherent reception of M-ary modulation techniques.

Keywords: Fading, Diversity, Fading channels, combining techniques, Wireless Communication, MIMO.

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ELECTRONICS RESEARCH ARTICLE

Analysis of Receive Diversity in Rayleigh Fading for various Modulation Techniques

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ABSTRACT

Now-a-days the requirements of wireless communication are to have high voice quality, high data rates, multimedia features, lightweight communication devices etc. But the wireless communication channel suffers from several impairments .One of them is fading which is due to the effect of multiple propagation paths. One effective solution is proposed for wireless system named diversity, without the requirement of power or extra bandwidth. In this paper, we analyze the error performance of a wireless communication system employing receive diversity in a Rayleigh fading environment. The method is easily extended to obtain the BER for the coherent reception of M-ary modulation techniques.

Keywords: Fading, Diversity, Fading channels, combining techniques, Wireless Communication,MIMO.

I. INTRODUCTION

Wireless Communication has made a tremendous impact on the lifestyle of a human being. Wireless Network provides high speed mobility for voice as well as data traffic. The fundamental phenomenon makes which makes transmission unreliable is time varying fading [1]. The phenomenon is described as the constructive/destructive interference between signals arriving at the same antenna via different paths, and hence with different delays and phases, resulting in random fluctuations of the signal level at the receiver. When destructive interference occurs, the signal power can be significantly reduced and the phenomenon is called as Fading.

Deep fades that may occur at particular time or frequency or in space result in severe degradation of the quality of the signal at the receiver making it impossible to decode or detect. Multipath fading arises due to the non-Coherent combination of signals arriving at the receiver antenna.

Diversity is the technique used in wireless communications systems to improve the performance over a fading radio channel. Here 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.

II. DIVERSITY TECHNIQUES

In wireless mobile communications, diversity techniques are widely used to reduce the effects of multipath fading and improve the reliability of transmission without increasing the transmitted power or sacrificing the bandwidth [49] [48]. The diversity technique requires multiple replicas of the transmitted signals at the receiver, all carrying the same information but with small correlation in fading statistics. The basic idea of diversity is that, if two or more independent samples of a signal are taken, these samples will fade in an uncorrelated manner, e.g., some samples are severely faded while others are less attenuated. This means that the probability of all the samples being simultaneously below a given level is much lower than the probability of any individual sample being below that level. Thus, a proper combination of the various samples results in greatly reduced severity of fading, and correspondingly, improved reliability of transmission. In most wireless communication systems a number of diversity methods are used in order to get the required performance. According to the domain where diversity is introduced, diversity techniques are classified into time, frequency and space diversity.

Time diversity

Time diversity can be achieved by transmitting identical messages in different time slots, which results in uncorrelated fading signals at the receiver [4]. The required time separation is at least the coherence time of the channel, or the reciprocal of the fading rate 1/fd = c/vfc. The coherence time is a statistical measure of the period of time over which the channel fading process is correlated.

Frequency diversity

In frequency diversity, a number of different frequencies are used to transmit the same message. The frequencies need to be separated enough to ensure independent fading associated with each frequency. The frequency separation of the order of several times the channel coherence bandwidth will guarantee that the fading statistics for different frequencies are essentially uncorrelated.

Space diversity

Space diversity has been a popular technique in wireless microwave communications. Space diversity is also called antenna diversity. It is typically implemented using multiple antennas or antenna arrays arranged together in space for transmission and/or reception. The multiple antennas are separated physically by a proper distance so that the individual signals are uncorrelated. The separation requirements vary with antenna height, propagation environment and frequency. Typically a separation of a few wavelengths is enough to obtain uncorrelated signals.

III. DIVERSITY COMBINING METHODS

In the previous section, diversity techniques were classified according to the domain where the diversity is introduced. The key feature of all diversity techniques is a low probability of simultaneous deep fades in various diversity sub channels. In general, the performance of communication systems with diversity techniques depends on how multiple signal replicas are combined at the receiver to increase the overall received SNR [2]. Therefore, diversity schemes can also be classified according to the type of combining methods employed at the receiver. According to the implementation complexity and the level of channel state information required by the combining method at the receiver, there are four main types of combining techniques, including selective combining, and maximal ratio combining (MRC) and equal-gain combining (EGC).

Selective Combining

The algorithm for selective diversity combining is based on the principle of selecting the best signal among all of the signals received from different branches, at the receiver end. [7]

Limitation: The main handicap of selection diversity is that the signals must be monitored at a rate faster than that of the fading process if the largest of them all is to be selected.

Maximal Ratio Combining

Maximum ratio combining is a linear combining method. In a general linear combining process, various signal inputs are individually weighted and added together to get an output signal.

Figure 1. Shows a block diagram of a maximum ratio combining diversity. The output signal is a

linear combination of a weighted replica of all of the received signals. It is given by

$$r = \sum_{i=1}^{n_R} \alpha_i . r_i \qquad (1)$$

Where r_i is the received signal at receive antenna i, and α_i is the weighting factor for receive antenna i. In maximum ratio combining, the weighting factor of each receive antenna is chosen to be in proportion to its own signal voltage to noise power ratio.

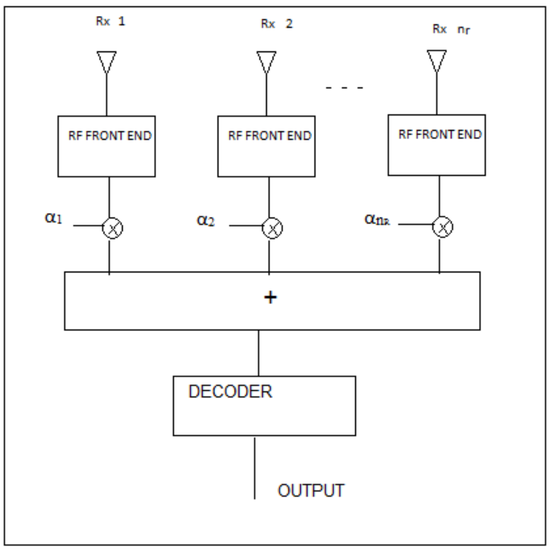

Fig.1 Maximum ratio combining method

Let A_i and φ_i be the amplitude and phase of the received signal r_i, respectively. Assuming that each receive antenna has the same average noise power, the weighting factor α_i can be represented as

$$\alpha_i = A_i e^{-j\varphi_i} \qquad (2)$$

This method is called optimum combining since it can maximize the output SNR. It is shown that the maximum output SNR is equal to the sum of the instantaneous SNRs of the individual signals. In this scheme, each individual signal must be co-phased, weighted with its corresponding amplitude and then summed. This scheme requires the knowledge of channel fading amplitude and signal phases. So, it can be used in conjunction with coherent detection, but it is not practical for non coherent detection.

IV. SIMULATION RESULTS

Consider a receive diversity system with NR receiver antennas. Assuming a single transmit antenna as in the single input multiple output (SIMO) channel, the channel is expressed as

$$h = [h_1\, h_2 \ldots\ldots h_{N_2}]^T \qquad (3)$$

for NR independent Rayleigh fading channels. Let x denote the transmitted signal with the unit variance in the SIMO channel. The received signal $y \varepsilon^{NR\times2}$ is expressed as

$$y = \sqrt{\frac{E_x}{N_o}} hx + z \qquad (4)$$

The received signals in the different antennas can be combined by various techniques. These combining techniques include selection combining (SC), maximal ratio combining (MRC), and equal gain combing (EGC). In SC, the received signal with the highest SNR among NR branches is selected for decoding. Let Υ_i be the instantaneous SNR for the ith branch, which is given as

$$\Upsilon_i = |h_i|^2 \frac{E_x}{N_o}, \quad i=1, 2\ldots N_R \qquad (5)$$

In MRC, all NR branches are combined by the following weighted sum:

$$Y_{MRC} = \left[w_1^{(MRC)} w_2^{(MRC)} \ldots\ldots W_{N_R}^{(MRC)}\right] Y = \sum_{I=1}^{N_R} W_I^{(MRC)} y_I \qquad (6)$$

Where y is the received signal and WMRC is the weight vector.

$$Y_{MRC} = W_{MRC}^T \left(\sqrt{\frac{E_x}{N_o}} hx + z \right) = \sqrt{\frac{E_X}{N_O}} W_{MRC}^T hx + W_{MRC}^T z \qquad (7)$$

Maximal Ratio Combining performance is verified for different modulation techniques. In fact, MRC achieves the best performance, maximizing the post-combining SNR. The various outputs show that the performance improves with the number of receiving antennas.

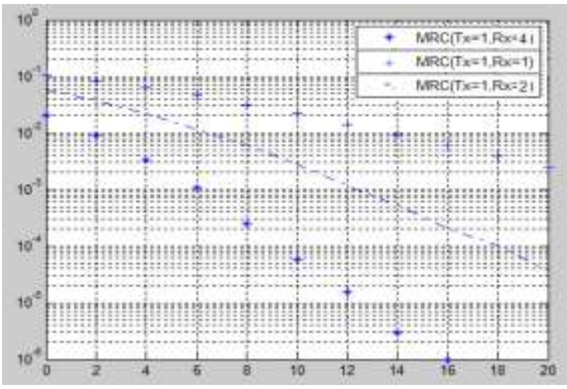

Fig.2 Performance of MRC in Rayleigh fading channel for QPSK modulation (X-axis SNR(dB) Vs Y-axis BER).

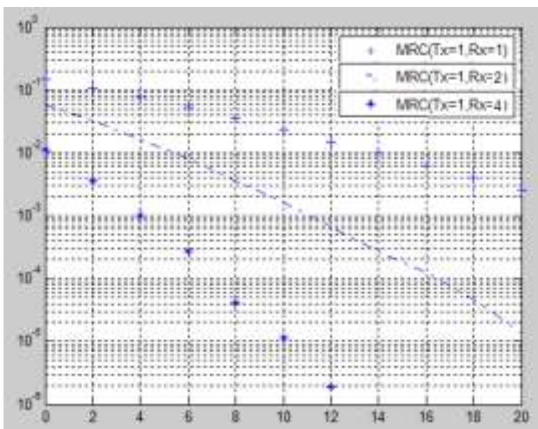

Fig.3 Performance of MRC in Rayleigh fading channel for BPSK modulation (X-axis SNR(dB) Vs Y-axis BER).

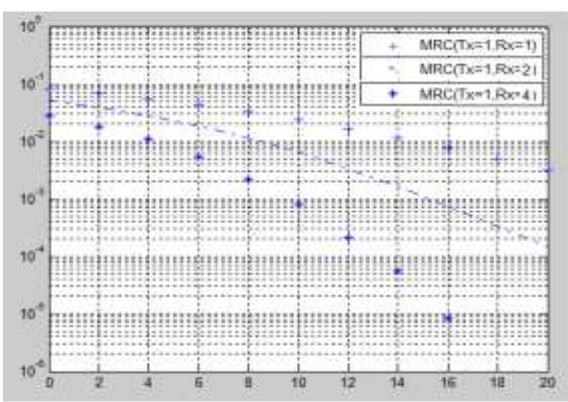

Fig.4 Performance of MRC in Rayleigh fading channel for 8-PSK modulation (X-axis SNR(dB) Vs Y-axis BER).

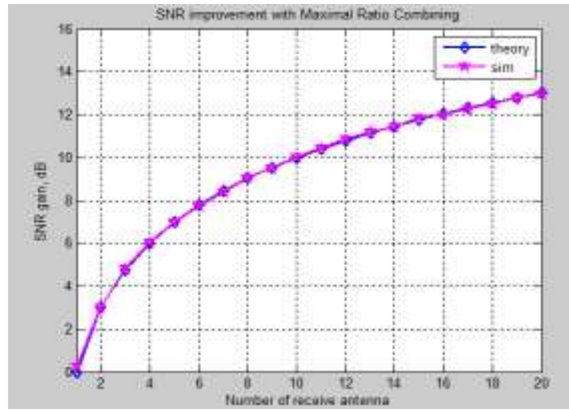

Fig.5 SNR improvement with MRC

V. CONCLUSION

The diversity is used to provide the receiver with several replicas of the same signal. Diversity techniques are used to improve the performance of the radio channel without any increase in the transmitted power. As higher as the received signal replicas are de-correlated, as much as the diversity gain can be achieved. Different types of Diversity schemes have their own merits and demerits. So in different environment different diversity schemes are selected. Combining schemes is also application and environment dependent. The performance of receive diversity in Rayleigh fading for various modulation techniques is verified.

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