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Diversity: A Fading Mitigation Technique

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Abstract— **Now-a-days, the users of wireless communication demand for higher data rates, good voice quality, light weight communication devices, etc. But the wireless communication channel suffers from much impairment which leads to the degradation of the overall system performance. Fading is a major impairment problem in wireless communication. Thus, it is necessary to nullify its effect to transmit the signal successfully. So, we employ the diversity technique along with its different types to combat the effect of fading. In this paper, different types of fading and different diversity techniques are being proposed.**

Keywords— **AWGN, Diversity, Fading.**

I. INTRODUCTION

The wireless communication channel suffers from much impairment due to Additive White Gaussian Noise (AWGN), shadowing, path loss and fading. Fading is a major problem and it being addressed in this paper. In order to reduce the effect of fading, we employ the diversity technique. Diversity is a powerful communication receiver technique that is used to improve the performance over a fading radio channel at a relatively low cost. In the diversity technique, multiple copies of the same information is transmitted to the receiver on statistically independent paths or channels. As a result, the probability that all replicas of signals will fade simultaneously is reduced considerably. The final decision is made by the receiver , and this decision is unknown to the transmitter.

II. FADING

In a typical wireless communication environment, multiple propagation paths exist between transmitter and receiver due to scattering by different objects. Constructive and destructive interference between the copies of the signal following different paths, and hence with different attenuations, delays and phase shifts, can occur at the receiver. When destructive interference occurs, the signal power can be significantly diminished.
This phenomenon is called **fading.**

Parameters of Fading

Multipath Spread (Tm): It tells us the maximum delay between paths of significant power in the channel.

Coherence Bandwidth ($(\Delta f)c$): The coherence bandwidth of a wireless channel is the range of frequencies that are allowed to pass through the channel without distortion.

Doppler Spread (Bd): It gives the maximum range of Doppler shifts.

Coherence Time ($(\Delta t)c$): It is the reciprocal of Doppler spread. The coherence time is the time over which a propagating wave may be considered to be coherent (predictable).

Types of fading

Frequency Selective fading:

If the bandwidth of the transmitted signal is larger than the coherence bandwidth $(\Delta f)c$, then the different frequency components of the signal that differ by more than $(\Delta f)c$ would undergo different degrees of fading. The channel is then classified as frequency selective.
The symbol duration is small compared with $(\Delta t)c$ (due to reciprocal relationships). Delays between different paths can be relatively large with respect to the symbol duration. We then assume that we would receive multiple copies of the signal.

Frequency Non-Selective fading:

If the bandwidth of the transmitted signal is smaller than the coherence bandwidth $(\Delta f)c$, then all frequency components of the signal would roughly undergo the same degree of fading. The channel is then classified as frequency non-selective (also called **flat fading**). The symbol duration is large compared with $(\Delta t)c$. Delays between different paths are relatively small with respect to the symbol duration. We can assume that we would receive only one copy of the signal, whose gain and phase are actually determined by the superposition of all those copies that come within $(\Delta t)c$.

Slow fading:

When the signaling interval T is much smaller than the coherence time $(\Delta t)c$, i.e. $T \ll (\Delta t)c$, the channel is said to be under slow fading.
Slow fading is a long-term fading effect changing the mean value of the received signal. Slow fading can be caused by events such as shadowing, where a large obstruction such as a hill or large building obscures the main signal path between the transmitter and the receiver.

Fast fading:

When the signaling interval T is much greater than the coherence time $(\Delta t)c$, i.e. $T \gg (\Delta t)c$, the channel is said to be under fast fading.
Fast fading is the short term component associated with multipath propagation. It is influenced by the speed of the mobile terminal and the transmission bandwidth of the signal.
In general, it is difficult to estimate the channel parameters in a fast fading channel.

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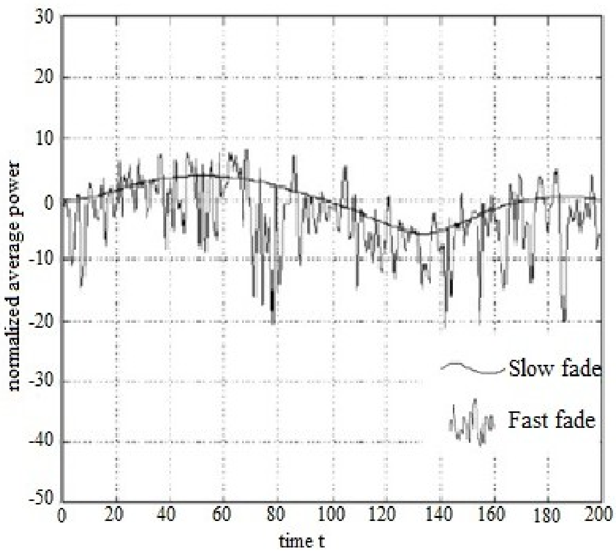

Fig.1 Slow fading versus fast fading

III. TYPES OF DIVERSITY

Micro-diversity and macro-diversity:

According to the two different types of fading; small-scale fading and large-scale fading, the two corresponding diversity techniques are implemented.

In order to prevent deep fades from occurring, **microscopic diversity techniques** is applied to mitigate ***small-scale fading*** effects by selecting the optimized signal all the time.

On the other hand, **macroscopic diversity techniques** is applied in the case of ***large-scale fading*** to improve the average SNR on the forward link by selecting a base station which is not shadowed when others are.

In this paper, micro-diversity techniques will be addressed.
Space diversity, frequency diversity, time diversity, polarization diversity and angle diversity techniques are discussed below.

Space Diversity:

Spatial diversity is the oldest and simplest form of diversity. It is achieved by using multiple antennas at the base station or at the mobile station or at both ends, which are physically separated (ideally separated by one half or more wavelengths), so that the different received copies of the signal undergo independent fading.

Space diversity, which has been widely exploited in wireless communications to combat channel fading, promises higher data rates and larger network coverage.

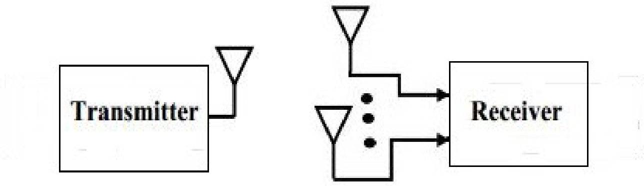

Fig.2a Space Diversity: One Transmitter – N Receiver Antennas

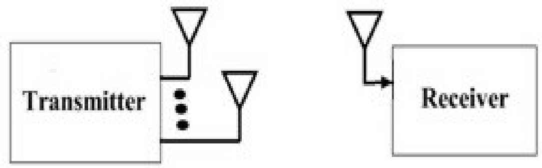

Fig.2b Space Diversity: N Transmitters – 1 Receiver Antenna

Frequency Diversity:

In this diversity technique, the same information signal is transmitted on different well-spaced frequency carriers, the frequency separation between them being at least the coherence bandwidth, $(\Delta f)c$, so that different copies of the signal undergo independent fading.

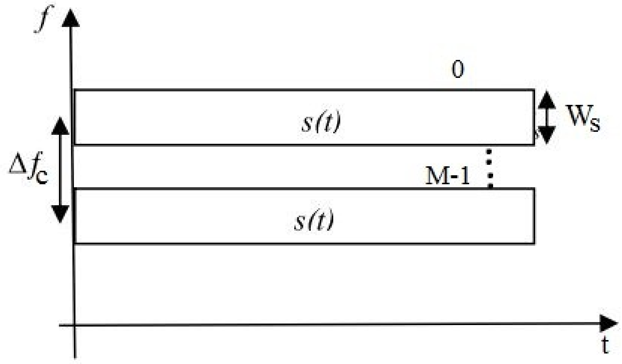

Fig.3 Frequency diversity

As shown in Fig.3, the signal s(t) is modulated through M different carriers in the frequency interval Ws. The separation between the carriers should be at least the coherence bandwidth, $(\Delta f)c$, as it represents the frequency separation of uncorrelated signals.

Time Diversity:

Time diversity is achieved by transmitting the same bit of information repetitively at short time intervals. The separation between the transmit times should be greater than the coherence time, so that different copies of the same symbol undergo independent fading. The time interval depends on the fading rate, and increases with the decrease in the rate of fading.

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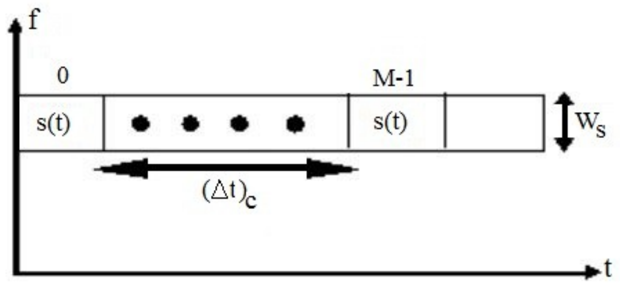

Fig.4 Time diversity

As shown in Fig.4, the desired signal s(t) is transmitted in M different periods of time i.e., each symbol is transmitted M times in the frequency interval Ws. The interval between transmissions of same symbol should be at least the coherence time (Δt)c, so that different copies of the same symbol undergo independent fading.

Polarization Diversity:

In polarization diversity, multiple versions of a signal are transmitted and received via antennas with different polarizations, i.e., the electric and magnetic fields of the signal carrying the information are modified and many such signals are used to send the same information. Thus, orthogonal type of Polarization is obtained. This diversity mechanism is very practical because of the very small size of antennas that can be used.

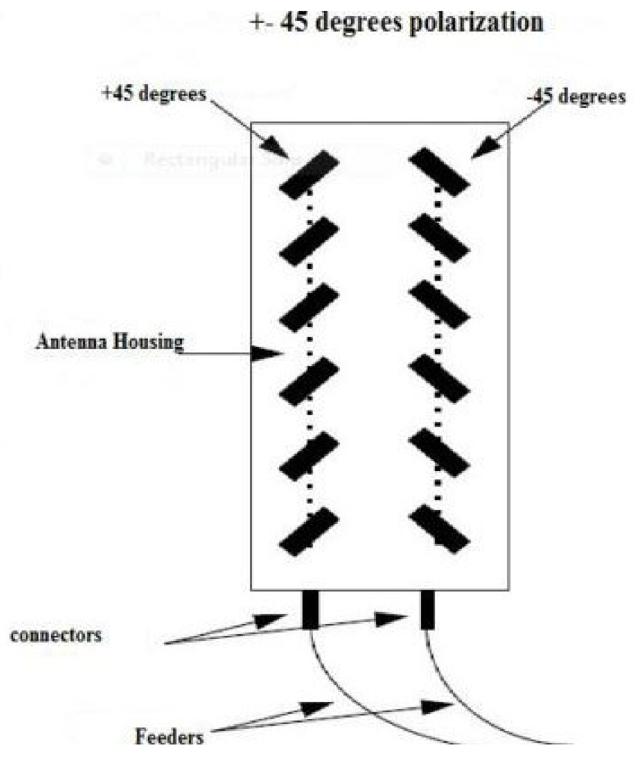

Fig.5 Polarization diversity

As shown in Fig.5, two antennas are employed with different polarization and then they are connected to receiver through feeders and connectors.

Angle Diversity:

This diversity system needs a number of directional antennas those which respond independently to wave propagation. At a mobile terminal, angle diversity can be achieved by using two Omni directional antennas acting as parasitic elements to each other changing their patterns to manage the reception of signals at different angles. As shown in Fig.6, two orthogonal antennas are employed on a single base at different angles.

Fig.6 Angle diversity

IV. DIVERSITY PROCESSING TECHNIQUES

Selection diversity:

Selection processing presents only one antenna's signal to the receiver at any given time. In this technique, the diversity branch having the highest signal level is selected and processed, while all the other copies of the signal in the other branches are discarded.

The selection diversity technique is shown in Fig.7, where the signal having maximum signal-to-noise ratio (i.e. the signal from channel 1) is taken by the receiver.

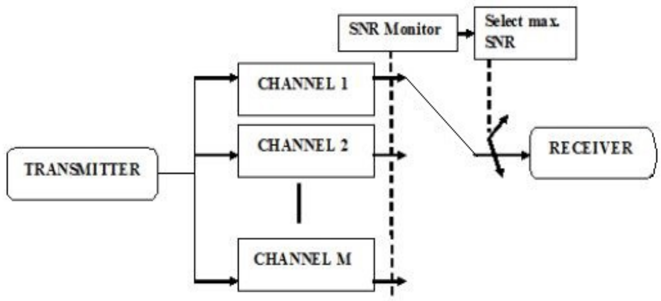

Fig.7 Selection diversity

Switched diversity:

The main drawback of Selection diversity is that we have to monitor all the diversity branches. In addition, if we want to monitor the signals continuously, we need the same number of receivers and branches. This increases the hardware effort. An alternate solution to this is Switched diversity, where just the active diversity branch is monitored.

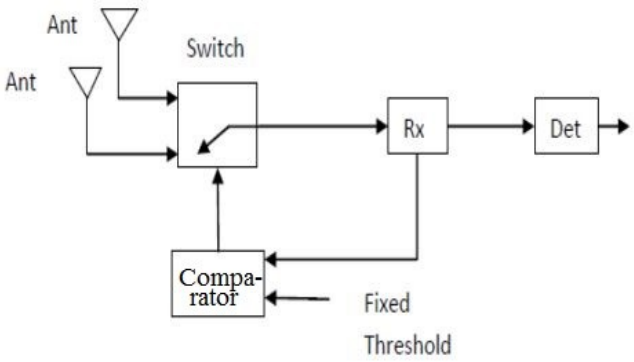

Fig.8 Switched diversity

In a switching receiver, the signal from only one antenna is fed to the receiver for as long as the quality of that signal remains above some prescribed threshold. If and when the signal degrades, another antenna is switched in.

It is very important to determine the optimal switching threshold in this method. If the value of threshold is very high, then the rate of undesirable switching transient increases. However, if the threshold is very low then the diversity gain is also very low.

Combining Diversity:

In combining diversity, all copies of the signal are combined and the combined signal is decoded. Depending on the sophistication of the system, the signals can be added directly (**equal gain combining**) or weighted and added coherently (**maximal-ratio combining**). Such a system provides the greatest resistance to fading but since all the receive paths must remain energized, it is also consumes the most power.

Maximal Ratio Combining(MRC)

In MRC, all the branches are taken into consideration simultaneously. Each of the branch signals is weighted with a gain factor proportional to its own SNR. The MRC scheme requires that the signals be added up after bringing them to the same phase (i.e. after co-phasing).

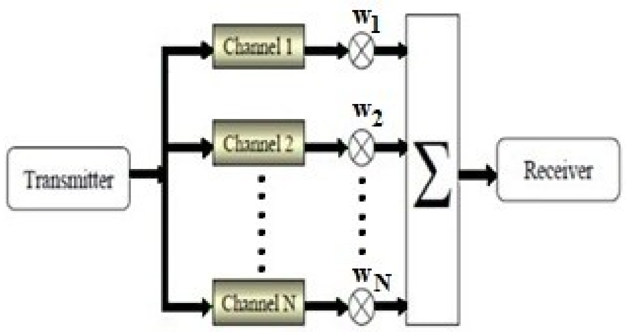

Fig.9 Maximal Ratio Combining

Equal Gain Combining:

It is also a co-phase combining technique that brings all phases to a common point and then combines them. Here, all the amplitude weights are taken to be the same. The performance of the Equal Gain Combining is worse than the MRC.

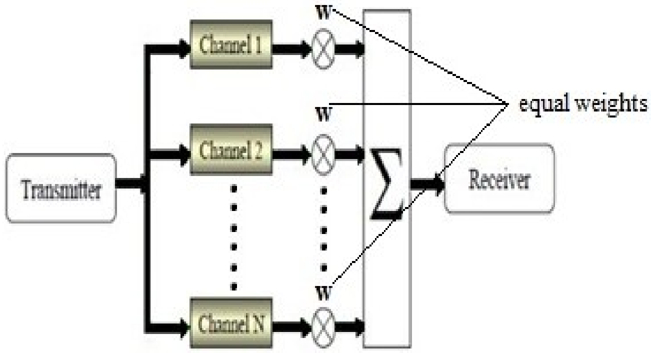

Fig.10 Equal Gain Combining

V. CONCLUSION

The diversity technique is used to provide the receiver with several copies of the same signal. Diversity techniques are used to improve the performance of the radio channel without increasing the transmitted power. Different types of diversity schemes have been discussed above, which have their own merits and demerits. Depending on the application and working environment, the most suitable diversity scheme is selected. Also, we have seen the various Diversity Combining techniques that are used in order to reduce the impact of fading on the signal. Combining schemes are also application and environment dependent. Among different combining techniques, MRC has the best performance and the highest complexity, EGC is easier to implement compared to MRC, but its performance is about 1 dB worse than MRC, and Selection technique has poorer performance but the least complexity.

Thus by employing multiple transmit and receive antenna, the diversity can be achieved to improve the performance of radio wireless communication channel, mitigating fading.

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