Review: Fading Channels and its Mitigation Techniques

C. Padmaja and Dr.B.L. Malleswari

Abstract--- *MIMO systems have multiple antennas both at the transmitter and at the receiver. The input data from all elements are transmitted at once and the receiver solves a linear equation system to demodulate the data. MIMO systems have many advantages in terms of capacity improvement, higher bit rate, smaller bit error rate and reliability. Also provides good throughput and spectral efficiency with the same amount of transmit power and bandwidth as required in case of conventional single antenna system.*

The fundamental goal of this paper is analyze environmental factors that affect performance which include channel complexity, external interferences, and channel estimation errors.

Furthermore, this article provides a review of the diversity combining technique and explains how such benefits can be achieved using this technological breakthrough.

Keywords--- *Diversity, Fading Channels, Combining Techniques, Capacity*

I. Introduction

THE performance of wireless devices can be evaluated by considering the transmission characteristics, wireless channel parameters and device structure.

There are there basic propagation mechanisms such as reflection, diffraction and scattering, which impact the electromagnetic waves in realistic environment.

The received signal consists of multiple variations of transmitted signal with different time delays and phases. The superposition of these signals may cause interference between the signals, called Inter Symbol Interference (ISI). As the receiver moves, the surrounding environment also changes, which changes the received signal amplitude and phase.

The severe changes in amplitude variations over small distances are called fading. The fading is caused by number of following factors namely time variant Multipath characteristics of channel, relative motion between transmitter and receiver, turbulence of Ionosphere, Ionosphere height variations with time and atmospheric absorption and rain effects.

Fading is main problem in wireless communication but MIMO channels use the fading to increase the capacity. The manifestation of fading channels is shown below.

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The phenomenon is described as the constructive and /or 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 strength 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 sometimes impossible to decode or detect. Multipath fading arises due to the non-coherent combination of signals arriving at the receiver antenna.

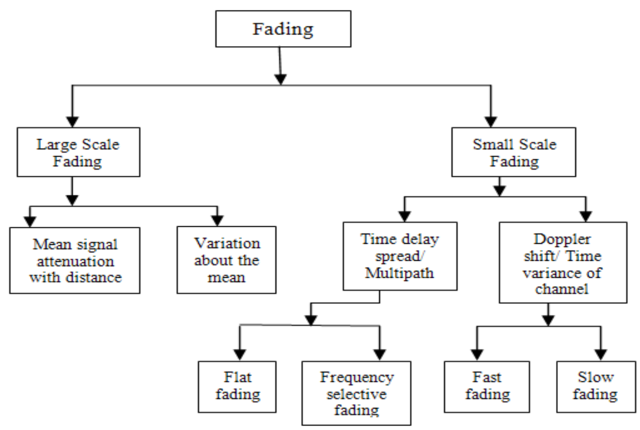


Fig. 1: Types of Fading

Large scale fading occur when the signal comes across large buildings, hills and trees results in path loss or attenuation in its power.

Small scale fading is due to nearby trees and buildings i.e., variation occurs due to short distance.

The channel fading distorts the received signal to an extent where the signal may become garbled.

There are several probability distributions that can be considered to model the statistical characteristics of the fading channel.

Table 1: Small Scale Fading

Frequency domain			
Flat fading	Coherence bandwidth >signal bandwidth(f_0>W)	Slow fading	Doppler shift< signal bandwidth
Frequency selective fading	Coherence bandwidth< signal bandwidth (f_0<W)	Fast fading	Doppler shift> signal bandwidth
Time Domain			
Flat fading	Maximum delay<	Slow fading	Coherence

	symbol duration		time > symbol duration
Frequency selective fading	Maximum delay> symbol duration	Fast fading	Coherence time < symbol duration

The rest of the paper is organized as follows. In section 2, statistical fading channels models are described. In section 3, the mitigation of fading is explained. In section 4, diversity and its combining techniques are discussed. In section 5, concluded the paper.

II. STATISTICAL FADING CHANNELS MODELS

A. Rayleigh Fading Channel: Rayleigh fading describes the received signal envelope distribution where all the components are non-line of sight[5],[6].

The basic model of Rayleigh fading assumes a received multipath signal with (theoretically infinitely) large number of reflected waves with independent and identically distributed (i.i.d) in phase and quadrature amplitudes [8]. The mobile or indoor radio channel is characterized by multipath reception. The signal offered to the receiver contains not only a direct line-of-sight (LOS) radio wave, but also a large number of reflected radio waves. In urban centers, the LOS is often blocked by obstacles, and a collection of differently delayed waves is received by a mobile antenna. These reflected waves interfere with the direct wave, which causes significant degradation of the performance of the link. Additionally, if the antenna moves, the channel varies with location and time, because the relative phases of the reflected waves change.

A wireless system has to be designed in such way that the adverse effect of multipath fading is minimized [8].The random variable R following Rayleigh fading has the probability density function (PDF) is given by,

$$f_R(r) = \frac{r}{\sigma^2} e^{-\left(\frac{r^2}{2\sigma^2}\right)}$$

B. Ricean Fading Channel:

The Ricean model fading is similar to that for Rayleigh fading, except that in Ricean fading a strong dominant LOS component is present. A refined Ricean model also considers the following:

•The dominant wave can be a phasor sum of two or more dominant signals, e.g. the line-of-sight, plus a ground reflection. This combined signal is then mostly treated as a deterministic (fully predictable) process, and

•The dominant wave can also be subject to shadow attenuation. This is a popular assumption in the modeling of satellite channels. Besides the dominant component, the mobile antenna receives a large number of reflected and scattered waves as well. As stated, the Ricean distribution results when, in addition to the multipath components, there exists a direct path between the transmitter and the receiver.

The envelope in this case has a Ricean density function is given by,

$$f_R(r) = \frac{r}{\sigma^2} \exp\left(-\frac{r^2 + k_d^2}{2\sigma^2}\right) I_0\left(\frac{r k_d}{\sigma^2}\right), r \geq 0$$

Where $I_0(.)$ is the 0^{th} order Bessel function of the first kind, constant K_d determines the strength of the direct component.

The factor K is usually expressed in decibel units as

$$K(dB) = 10 \log_{10}\left(\frac{k_d^2}{2\sigma^2}\right)$$

C. Nakagami Fading Channel: Nakagami fading occurs for multipath scattering with relatively large delay-time spreads, with different clusters of reflected waves.

Within any one cluster, the phases of individual reflected waves are random, but the delay times are approximately equal for all waves. As a result the envelope of each cumulated cluster signal is Rayleigh distributed.

The average time delay is assumed to differ significantly between clusters. When the delay times also significantly exceed the bit duration of a digital link, the different clusters produce serious inter-symbol interference (ISI), and thus the multipath self-interference then approximates the case of co-channel interference by multiple incoherent Rayleigh-fading signals.

•If the envelope is Nakagami distributed, the corresponding instantaneous power is Gamma distributed.

•The parameter 'm' is called the 'shape factor' of the Nakagami or the Gamma distribution.

$$f_R(r) = \frac{2m^m r^{2m-1}}{\Gamma(m)\Omega^m} \exp\left(-\frac{mr^2}{\Omega}\right), r \geq 0$$

III. TECHNIQUES TO MITIGATE FADING EFFECTS

The channel impairments of wireless mobile communication systems can be improved by mitigating the fading using the following techniques.

- Equalization,
- diversity and
- channel coding

An equalizer is a filter at the mobile receiver whose impulse response is the reciprocal (inverse) of the channel impulse response. As such equalizers find their use in frequency selective fading channels. If the channel impulse response be H_c (f), the equalizer should have the transfer function given by

$$H_{eq}(f) = \frac{1}{H_c(f)}$$

Channel coding improves the performance of mobile communication link by adding redundant data bits in transmitted message. Channel Coding is used to correct deep fading or spectral null [11].

Diversity is another technique used to compensate fast fading and is usually implemented using two or more receiving antennas. It is based on the fact that individual channels experience different levels of fading and interference. Multiple versions (or replicas) of the same signal may be transmitted and/or received and combined in the receiver. It is usually employed to reduce the depths and duration of the fades experienced by a receiver in a fading channel [3].

IV. Diversity Techniques

Diversity is a powerful communication receiver technique to transfer different samples of same signal (that is replica of same signal) over essentially independent channels. There are several approaches to implement diversity in wireless transmission.

Diversity exploits the random nature of radio propagation by finding independent signal paths for communication. As there is more than one path to select, both the instantaneous and average SNRs at receiver may be optimized significantly.

Diversity decisions are usually made by receiver. Unlike equalization, diversity requires no training overhead as a training sequence. Note that if the distance between two receivers is a multiple of λ/2, there might be a destructive interference between the two signals, where λ is the wavelength of the carrier.

The receivers in diversity technique are used in such a way that the signal received by one is independent of other.

The antenna diversity techniques are used to convert an unstable time-varying wireless fading channel into a Stable AWGN-like channel without significant instantaneous fading, thereby steepening the BER versus SNR curve.

Among many different types of antenna diversity techniques, transmit diversity techniques have been used to reduce the processing complexity of the receiver. Furthermore, it requires multiple antennas only on the transmitter side. The space-time coding techniques that are used for achieving the antenna diversity gain.

There are various ways of realizing diversity gain. Time frequency and spatial diversity techniques. In time diversity, data is transmitted over multiple time slots. In frequency diversity, the same data is transmitted at multiple spectral bands to achieve diversity gain.

Space diversity is a method of transmission or reception, or both, in which the effects of fading are minimized by the simultaneous use of two or more physically separated antennas, ideally separated by one half or more wavelengths. Signals received from spatially separated antennas have uncorrelated envelopes.

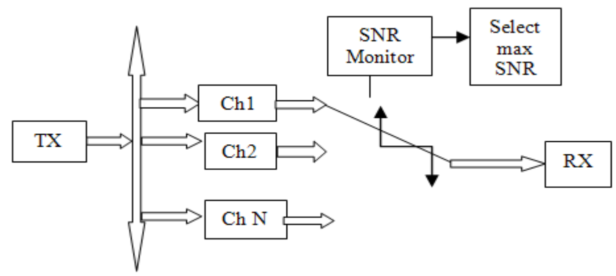
Modulation diversity (MD) is also known as signal space diversity (SSD); this scheme can improve system performance without requiring additional bandwidth and power [24]. The principle underlying the modulation diversity is based on the rotation of multi-dimensional signal constellation in which the components of the signal constellation points are sent over independent fading channels. In2D signal constellation, the components are sent as in phase and quadrature phase for baseband transmission.

SSD scheme combined with receiver MRC in order to achieve more diversity gain in fading environments. Rotation diversity makes use of an interleaver and de-interleaver pair with in-phase and quadrature components of the received signals being affected by independent channel fading coefficients. These fading coefficients called channel state information (CSI) are assumed known at the receiver. Error performance has been studied by many researchers for rotated signal constellation [24]-[29].

Several copies of the transmitted signal undergo independent fading and are combined at the receiver in a way to increase overall received power.

Different types of diversity call for different combining methods. Here, we review several common diversity combining methods.

Selection Combining (SC):



$$Y_C = \begin{cases} y_1.\,if\ y_1 > y_2 \\ y_2\ if\ y_2 > y_1 \end{cases}$$

The algorithm for selective diversity combining is based on the principle that at the receiver end, one selects the best signal among all of the signals received from different branches.

Maximum Ratio Combining:

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 [34].

$$y_c = \frac{Y_2 + Y_2}{2}$$

Equal Gain Combining:

It is a co-phase combining that brings all phases to a common point and combines them. The combined signal is the sum of the instantaneous fading envelopes of the individual branches.

Thus co-phasing and summing is done on the branches which are received directly i.e. $g\ s_i$' of the MRC scheme are made equal to 1, for all $i = 1, 2, 3, \ldots\ldots M$. The performance of the Equal Gain Combining is worse than the MRC [39].

The combined signal envelop is given by

$$a = \sum_{i=1}^{M} a_i \circ$$

V. Conclusion

The survey has provided a comprehensive idea on fading effects and its mitigation techniques.

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