

CHAPTER 1 INTRODUCTION

During the last decade, wireless communication is the fastest growing sector of communication field. Wireless communication networks will connect mobile phone, palmtop, laptop, and desktop computers anywhere within an office or campus. Wireless entertainment and business will diffuse the home and any place. As a result, the demand of wireless service and network has suddenly increased. However, design of wireless networks differs basically from wired network design because of the nature of wireless channel. The wireless channel is unpredictable and difficult communication medium as a signal propagates is change randomly as in Figure 1.1. The connection between two nodes can be very strong at some times and very weak at other times. Furthermore, in digital cellular radio systems, which are traveling near the boundary of the cell, can also suffer the interference from signal neighboring cells. To improve system quality and capacity in wireless communication systems, it is crucial to mitigate fading and co-channel interference.

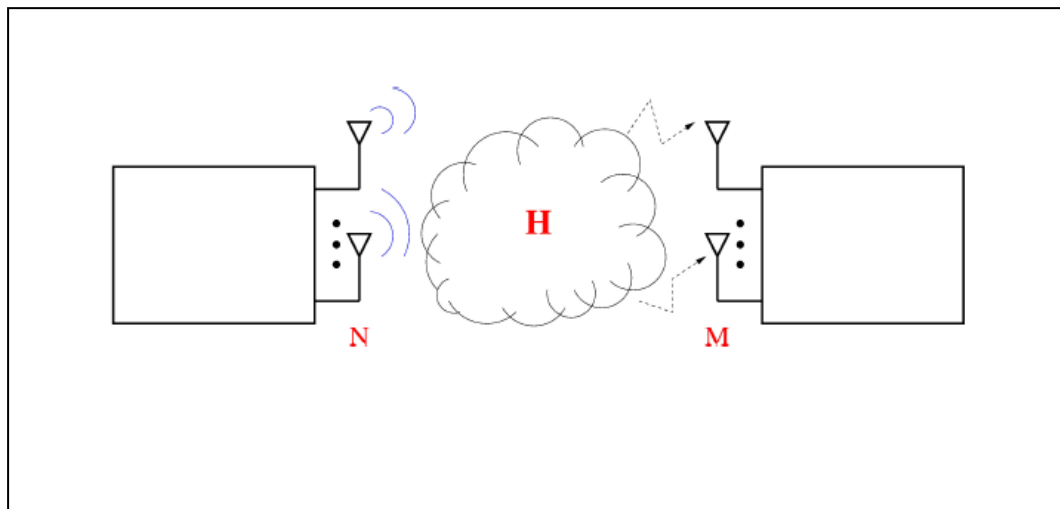


Figure 1.1 Features of Wireless Systems

1.1 Overview of Problem

Because of the randomness of the wireless propagation channels and limit radio spectrum, co-channel interference, and fading are major obstacle to high capacity transmission in bandwidth and power limited wireless systems. To achieve a better performance in wireless communication systems, it is necessary to reduce the effect of co-channel interference and multipath fading. Multipath fading is generally modeled as the sum of a large number of random sinusoids signal and behave as a Gaussian random process due to the central limit theorem (CLT). This Gaussian model is very widely studied in many researchers, since the mathematical analysis is simple and tractable. However, in practice, the CLT is not always valid in many environments. Therefore, the study of the propagation of signal in non-Gaussian channel is an important aspect.

Classical wireless research focused on the case where antenna diversity was employed exclusively at either the transmitter or receiver. When multiple antennas are only available at the receiver, combining schemes such as selection combining (SC) [1-2], equal gain combining (EGC) [3-4], maximal ratio combining (MRC) [5-7], and optimum combining (OC) [8-11] have been used to obtain diversity advantage from

corresponding single-input multiple-output (SIMO) wireless channel. When antennas diversity is employed at both transmitter and receiver, the multiple-input multiple-output (MIMO) channel encountered in the memoryless case is a matrix. MIMO wireless systems are of interest due to their ability to provide substantial gains in capacity and quality. We first need to characterize and analyze them in sufficient depth. Despite the importance of MIMO communication systems, the application of MMSE to these systems has not yet been addressed.

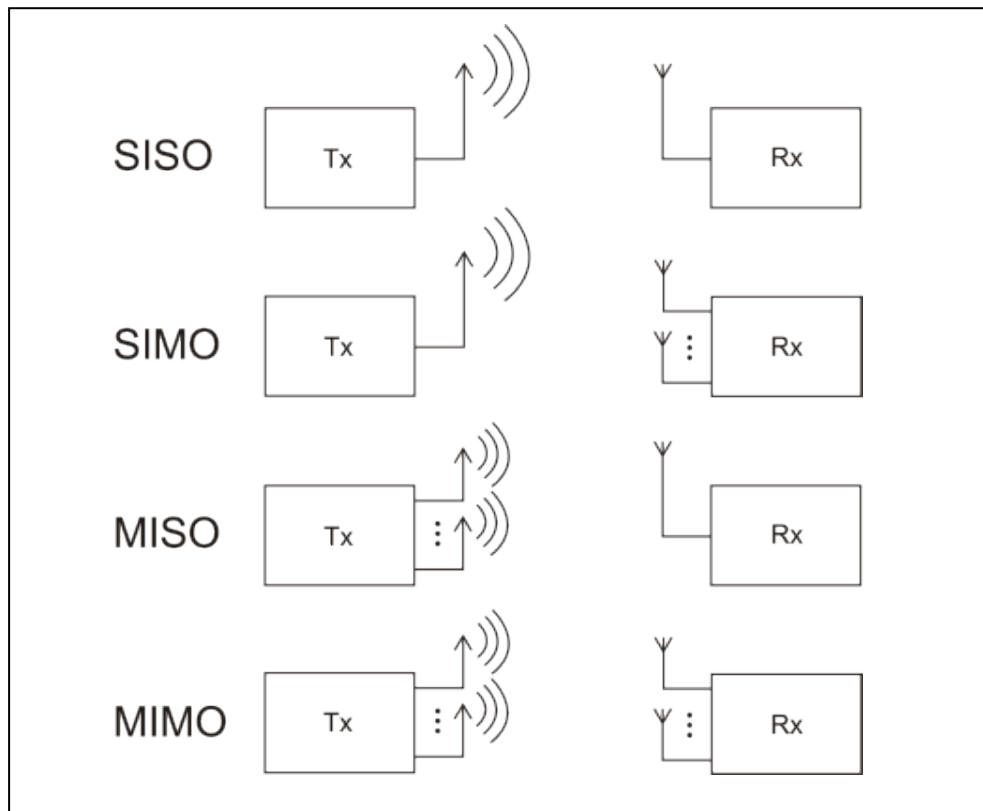


Figure 1.2 Difference between SISO, SIMO, MISO and MIMO systems

In other direction, the appearing demand for high spectral efficiency and wireless multimedia applications are the key drives for the evolution in wireless architectures. Recently, several advancements have been introduced for 3G wireless communications to further improve the data rate and the system performance. However, due to the increase of wireless applications and services, it is clear that 3G wireless systems will not be able to comply with is ever increasing demand. The next generation wireless communications are expected to sustain much higher data rate services compared to evolving 3G systems. Radio spectrum resource is one of fundamental importance in wireless communications. Hence it has become to find suitable spectrum bands to meet the demand of future services. The most promising way to significantly improve spectral efficiency is to give opportunistic access of frequency bands to a group of users for whom the band has not been licensed, which is referred to cognitive radio [24]. The term cognitive radio describes the evolution of radios to highly adaptive systems. Since most of the spectrum is already assigned, the important challenge is to share the licensed spectrum without interfering with the transmission of other licensed users. To make this possible, smart radios have also to be aware about interference reduction and

must have powerful capability of sensing its spectrum environment. Due to the progress in digital signal processing, strategies for interference mitigation become applicable.

1.2 Literature Review

One of the key technologies to mitigate fading and CCI is to implement antenna arrays in the system [25, 26, 27, 28, 29]. Antenna arrays can be employed at the transmitter, or receiver, or both ends. With an antenna array at the receiver, fading can be reduced by diversity techniques, i.e., combining independently faded signals on different antennas that are separated sufficiently apart. If antennas receive independently faded signals, it is unlikely that all signals undergo deep fades, hence, at least one good signal can be received. Three common diversity schemes are SC, EGC and MRC. To reduce strong interference, appropriate combining weights can be chosen to maximize the signal-to-interference-plus-noise ratio (SINR), i.e., enhance the desired signal and suppress the interfering signals, as well as reduce fading. If the desired and interfering signals are highly directional, the array radiation pattern may form a beam, i.e., beam-forming, to the desired user and null the interfering signals.

Within ten years, MIMO system has made its way from purely theoretical analysis. However, numerous MIMO techniques still have not been sufficiently tested under realistic propagation condition. Initially, MIMO MRC have already been considered and shown to provide Rician fading and Rayleigh fading channels [13-14]. The Khatri distribution of the largest eigenvalue of central complex Wishart matrices is investigated. Model of indoor and outdoor MIMO channel have been reported in [16-17], respectively. In a MIMO system employing OC scheme in presence of co-channel interference studied in [17], the system performance in term of outage probability in Rayleigh fading scenarios. In [18] the authors derived a closed form expression for the MIMO-OC in correlated Rayleigh fading channels. Based on Gaussian random matrices and signal to interference ratio (SIR) are investigated in interference limited environment.

1.3 Purpose and Contributions

The purpose of this proposal is to analyze the performance of wireless systems with MIMO systems in a non-Gaussian multipath fading channel. The main focus of this research is to use the non-Gaussian fading to model. The following are the specific objectives of this thesis.

1. To review the properties and study the generation of MIMO systems.
2. To study the performance of MIMO employing MMSE diversity in a non-Gaussian fading environment.
3. To model a new term non-Gaussian multipath fading channel and study its characteristics.
4. To model a new term, is defined to measure the diversity performance of different diversity methods under identical conditions.
5. To model a new term spectrum sensing for wireless communication systems. The detection performance gain using multiple antenna processing is obtained by exploiting the micro-diversity offered by the wireless channel.

1.4 Research Method

The performance of wireless communication systems has been extensively analyzed. For voice systems, performance measures used include outage probability, and output signal to interference plus noise ratio (SINR). On the other hand, a measure of how much information that can be transmitted and received with a negligible probability of error is called the channel capacity. In this thesis, therefore, we will use outage probability and the information-theoretic capacity to represent the system performance.

1.4.1 Outage Probability

The outage probability is the probability of failing to achieve adequate reception of wanted signal, is a useful statistical parameter for assessing the quality of service (QoS) in digital mobile communication systems. Its can be described mathematically by

$$P_{out} = \Pr(0 \leq \gamma \leq t) = \int_0^t f_\gamma(\gamma) d\gamma \quad (1.1)$$

where $p_\gamma(\gamma)$ is the pdf of the desired and interfering signals power.

1.4.2 Channel Capacity

For fixed linear $n \times n$ matrix channel with additive white Gaussian noise and when the transmitted signal vector is composed of statistically independent equal power components each with a Gaussian distribution and the receiver knows the channel capacity is

$$C = \log_2 \det(\mathbf{I} + \frac{\rho}{n} \mathbf{H} \cdot \mathbf{H}^\dagger) \quad (1.2)$$

where n is number of transmit/ receive antennas, ρ is the average signal to noise ratio, \mathbf{I} is $n \times n$ identity matrix, \mathbf{H} is the normalized channel matrix, which is considered to be frequency independent over the signal bandwidth and \dagger means transpose conjugate.

The challenge of spectrum sharing is sensing. The model is to detect which part of the spectrum is currently unused, and then do the transmission at that frequency band. Users are classified as licensed users and unlicensed users. Unlicensed users can access and share the spectrum only if they cause limited interference to licensed users or when licensed users are inactive as illustrated in figure 1.3. One of the problems in spectrum sensing is the delay between sensing and decision. Energy sensing is more general but waveform sensing is outperforms in short measurement time and reliability.

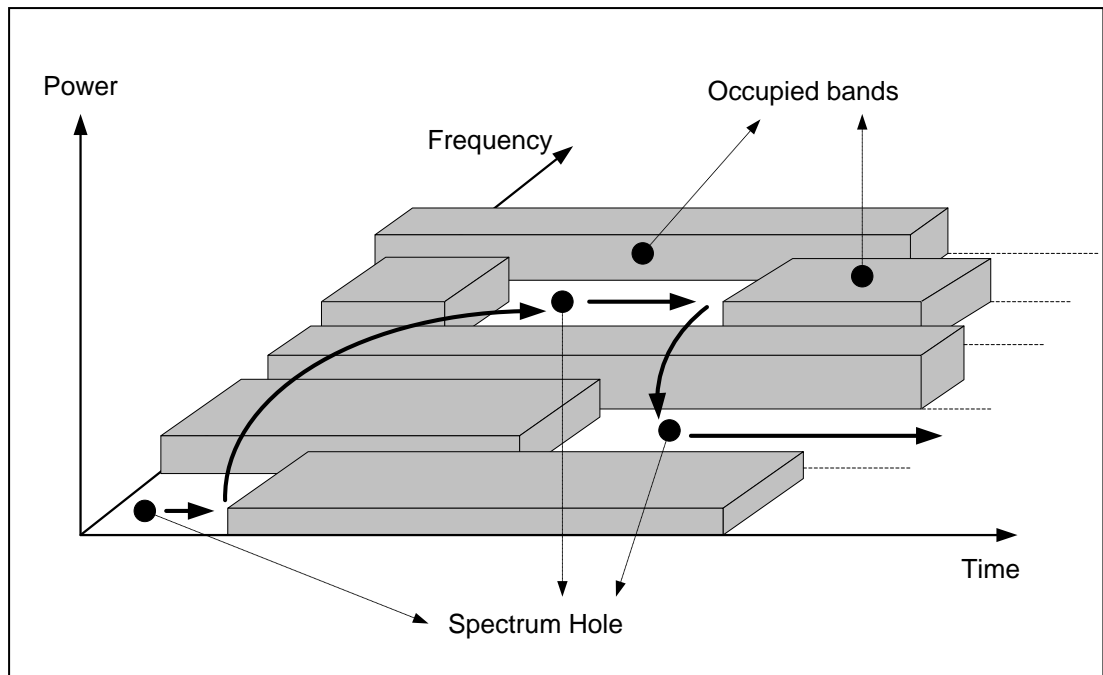


Figure 1.3 Schematic description of the process spectrum holes concept with respect to the 3 dimensions of time, frequency and power

Communicating over a wireless channel is highly challenging due to the complex propagation medium. The major impairments of the wireless channel are fading and co-channel interference. Due to ground irregularities and typical wave propagation phenomena such as diffraction, scattering, and reflection, when a signal is launched into the wireless environment, it arrives at the receiver along a number of distinct paths, referred to as multipath. Each of these paths has a distinct and time-varying amplitude, phase and angle of arrival. These multipaths add up constructively or destructively at the receiver. Hence, the received signal can vary over frequency, time, and space. These variations are collectively referred to as fading and deteriorate the link quality. Moreover, in cellular systems, to maximize the spectral efficiency and accommodate more users while maintaining the minimum quality of service, frequencies have to be reused in different cells that are separated sufficiently apart. Therefore, the desired user's signal may be corrupted by the interference generated by other users operating at the same frequency. This kind of interference is called co-channel interference (CCI). As a result, to increase capacity and spectral efficiency of wireless communication systems, it is crucial to mitigate fading and CCI.