Role of Diversity in Wireless Communication Enhancement- A Review

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Abstract – In wireless communication, a diversity scheme refers to a method for improving the reliability of a message signal by using two or more communication channels with different characteristics. Diversity is mainly used in communication and is a common technique for combatting fading and co-channel interference and avoiding error bursts. It is based on the fact that individual channels experience different levels of fading and interference. Multiple versions of the same signal may be transmitted and/or received and combined in the receiver. Alternatively, a redundant forward error correction code may be added and different parts of the message transmitted over different channels. It is the technique used to compensate for fading channel impairments. Diversity is usually employed to reduce the depth and duration of the fades experienced by a receiver in a flat fading channel. These techniques can be employed at both base station and mobile receivers.

Index Terms – Communication, Fading, Diversity, Fading channels, Wireless Communications.

1. INTRODUCTION

There is a great role of wireless communication on our life the first example which changes our life-style is the mobile phone. Mobile phones have evolved from the simple phones for voice-calling in 1970s to present smart-phones with computer-like functionality. The second example is wireless local area networks (WLAN), the so-called Wi-Fi. Equipped with a WLAN device, a laptop or desktop computer can connect easily to the Internet without the use of wires. As WLAN devices have been installed in many personal computers, video game consoles, mobile phones, printers, and other peripherals, and virtually all laptop or palm-sized computers. The third example is the Global Positioning System (GPS), a space-based global navigation satellite system which provides reliable location and time information in all weather and at all times and anywhere on or near the Earth. With the navigation of GPS, we can drive easily in any cities. GPS has become a useful tool for map-making, land surveying, commerce, scientific uses, tracking and surveillance, and hobbies such as geo-caching and way-marking.During the last decades, wireless communications have advanced at an incredible pace.

The basic concept of a wireless communication system is almost deceptively easy to understand. An electromagnetic signal is created, modulated, amplified, and broadcast to one or more receivers that can be fixed or mobile. The data in that signal is received and demodulated in order to recover the original information that was sent. A basic system will normally consist of a transmitter, receiver, and a channel (i.e. radio frequency) that utilizes different carrier frequencies for each baseband (information signal) that is transmitted. The basic issues that one must address in the design of wireless systems are common to all of telecommunications, namely the effective use of the available frequency spectrum and power to provide high-quality communications. Some wireless systems often involve mobile services; this implies a constantly changing environment with rapidly changing interference conditions and dynamically variable multi-path reflections. This condition, plus the potential of conflicting demands for the use of radio frequencies in a free-space medium, means difficult challenges for creating high-quality signals.

2. DIGITAL WIRELESS SYSTEMS

Digital wireless systems have been growing in popularity, complexity and capabilities over the last decade, and there are now mobile as well as fixed wireless networks, proprietary as well as standardized systems, personal area networks as well as metropolitan area networks. Each of these systems has unique requirements and constraints, but they share at least one key feature: Digital signals should be transmitted over physical channels, which are usually subject to fading. Multi-path fading is one of the most common phenomena in wireless systems. It is due to the constructive and destructive combination a number of multi-paths received at the receiver with random attenuations and delays. This type of fading affects the signals transmitted through wireless channels and causes the short-term signal variations. There are various models to describe statistical behavior of this phenomenon. Two common models are Rayleigh and Rician fading channels.

The Rayleigh distribution models multi-path fading with no line-of-sight (LOS) while Rician distribution models fading channel in the presence of LOS. The fading channels that information is transmitted over may change over time, or the bandwidth occupied by these channels may be large enough that the frequency response of the channel varies over that range. We call the former class of channels time-selective fading channels, while the latter is called frequency-selective or inter-symbol-interference (ISI) channels. Channels can be both time- and frequency-selective. In this thesis, we consider flat (non-frequency-selective) fading channels, also known as multiplicative fading, and hence ISI is not present.

There has been great interest in the structure of optimum receivers for detection of digital signals transmitted over a flat fading in the presence of additive white Gaussian noise (AWGN) for last decades. To detect transmitted symbols, two types of receivers, coherent and noncoherent, are conventionally considered.

Coherent Receiver: It attempts to estimate the channel and use this estimate as if it is the true channel. In other words, the design of coherent receivers is based on the assumption that the channel estimate is error-free.

Non-Coherent Receiver: For this type of receiver no attempt is made to estimate the channel, and hence, the receiver does not use any channel estimate.

In practical wireless systems, the channels cannot be estimated exactly. Several channel estimation techniques such as minimum mean-square error (MMSE) estimation or pilot-symbol assisted modulation (PSAM) are prevalent. In the presence of complex Gaussian fading channels (Rayleigh and Rician fading channels), these channel estimation techniques have been shown to result in complex Gaussian channel estimate and channel estimation error. In PSAM, pilot symbols are inserted periodically into the data sequence at the transmitter. Then, the receiver extracts the received signals due to pilot symbols and interpolates them to estimate the channel state. Several interpolation filters have been studied in the literature. In MMSE estimation, the channel estimate is derived from the received signal due to pilot symbols such that the mean square of estimation error is minimized.

In wireless communication systems, in addition to fading, interference from other users is another major reason for performance degradation. In urban area, interference is more severe due the large number of base stations and mobile users. Co-channel interference (CCI) is one of the major types of interference which is generated in a cellular system due to frequency re-use, i.e. from the cells that use the same frequencies. Number of receive antennas is usually only two or at most four, so in a wireless system the number of interferers most probably exceeds the number of antennas.

3. PERFORMANCE MEASURE OF COMMUNICATION SYSTEM

Some key measures of performance related to practical communication system design are as follows:

Signal to noise Ratio (SNR) It is a vital performance measure of a communication system. This performance measure is usually measured at the output of the receiver and indicates the overall quality of the system. For wireless communication system due to the presence of fading, the instantaneous SNR is a random variable.

Outage Probability: It is another important measure of performance to calculate the quality of service provided by wireless systems over fading channels and is defined as the probability that SINR falls below a certain threshold.

Average Bit Error Probability (BEP): It is one of the most informative indicators about the performance of the system. This measure can be obtained by averaging the conditional (on the fading) BEP over fading statistics.

Bit Error Rate (BER): In digital modulation techniques, due to some noise, interference, and distortion the received bits are altered .So bit error rate is defined as the no of error bits divided by total no of transmitted.

$$\text{Bit Error Rate (BER)} = \frac{\text{No of bits in error}}{\text{Total no of transferred bits}}$$

The performance of modulation is calculated measuring BER with assumption that system is operating with Additive white Gaussian noise. Modulation schemes which are capable of delivering more bits per symbol are more immune to errors caused by noise and interference in the channel. Moreover, errors can be easily produced as the number of users is increased and the mobile terminal is subjected to mobility. Thus, it has driven many researches into the application of higher order modulations.

4. DIGITAL COMMUNICATION SYSTEMS

Figure 1 illustrates a general block diagram for a digital communication system. In this diagram, digital data from a source are encoded and modulated for transmission over a channel. At the other side, the data are extracted by demodulation, decoding, and then sent to a sink. The encoder can be divided into two blocks, namely the source encoder and the channel encoder.

In some digital communication systems, channel coding and modulation are combined together; this is called coded modulation. In general, there are two main constraints in communication systems, the available spectrum (or bandwidth) and the power required for data transmission. The bandwidth is becoming a rare commodity with the demand of high speed and high quality of service (QoS) for wireless communications. In this paper M-ary phase shift keying (M-PSK) used for improving BER performances.

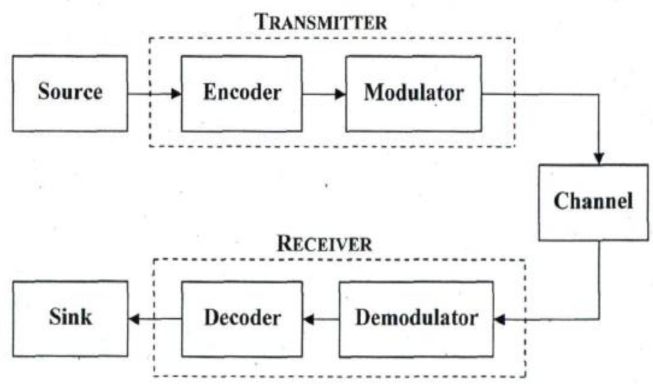

Figure 1: Block diagram of a digital communication system.

5. DIVERSITY CONCEPT

The reception of a signal in a channel transmitted through any type of fading channel degrades in quality if the signal level attenuation is below the expected operation region of the receiver. In this situation, the received signal power is not expectedly enough comparing with signal noise and interference power for reliable reception. The solution to overcome the channel attenuation because of fading problem in channel is to increase the transmitted power adjusted to the attenuation which is called power control (PC). On the other hand, there are two primary problems with this power control (PC) system. One of these problems is that the dynamic range of the transmitter and the required transmitting power is extremely high if it's intended to fully compensate the fading. This is impossible because of the radiation power limitations, the cost and the size of the amplifiers, and the limited battery power in the portable unit. Moreover, excess transmitted power increases the interference level at the other channels and users in the system unit. Another problem in power control (PC) approach that a feedback link is needed for the channel unless the operation of the radio channel is in time division duplex (TDD) mode. In a TDD system, the same frequency band is used for the downlink transmission from the base station to mobile unit and for the uplink transmission from the mobile unit to the base station. As a result, the transmitted signal undergoes the fading channel as the received signal due to its reciprocal characteristic of the channel, the transmitted power of transmitter is adjusted according to the received signal power. The feedback information usage decreases throughout the channel and increases the complexity in the system. Even an appropriate feedback link may not available in some application.

Using PC the fading can't be overcome completely but the attenuation may compensate considerably. It can mention that large-scale fading can be compensated as well in the uplink of a system, for example CDMA. But stringent power control is required in prevention near-far problem in the system. The rate of large-scale fading is simply slow, as a result it can be tracked well and the delay in the feedback of the power control commands can be neglected comparing with the rapid fading. On the other hand, small-scale fading can result in such rapid variations in the signal power that even the power control can't follow them.

Another approach to minimize fading effect in a system is to supply multiple replicas of the transmitted signal to the receiver which already have passed through different fading channels. The result of this approach is that the probability that all replicas of the signal will fade simultaneously is reduced, this is called diversity and it is effectively and commonly used to overcome degradation in performance due to interference and fading. If there is D number of fading channels and the probability of any one channel may fade under some threshold is P, then the probability of all D signals which fade below the threshold is P^D. The number of diversity channel D is called diversity order in the system.

6. DIVERSITY TECHNIQUES

Diversity technique is used to decreased the fading effect and improve system performance in fading channels. In this method, we obtain L copies of desired signal through M different channels instead of transmitting and receiving the desired signal through one channel. The main idea here is that some the signal may undergo fading channel but some other signal may not. While some signal might undergo deep fade, we may still be able to obtain enough energy to make right decision on the transmitted symbol from other signals. There is a number of different diversity which is commonly employed in wireless communication systems. Some of them are following:

1. Multipath/frequency diversity.
2. Spatial/space diversity.
3. Temporal/time diversity.
4. Polarization diversity.
5. Angle diversity.
6. Antenna diversity.

7. CONCEPTS OF DIVERSITY COMBINING TECHNIQUES

It is important to combine the uncorrelated faded signals which were obtained from the diversity branches to get proper diversity benefit. The combing system should be in such a manner that improves the performance of the communication system. Diversity combing also increases the signal-to-noise ratio (SNR) or the power of received signal. Mainly, the combining should be applied in reception; however it is also possible to apply in transmission. There are many diversity combining methods available but only three of them are prevalent.

1. Maximal ratio combining (MRC)
2. Equal gain combining (EGC)
3. Selection combining (SC)

The combining processes which use to combine multiple diversity branches in the reception, has two classes such as post-detection combing and pre-detection combining. The signals from diversity branches are combined coherently before detection in pre-detection combining. However, signals are detected individually before combining in post-detection. The performance of communication system is the same for both combining techniques for coherent detection. However, the performance of communication system is better by using pre-detection combining for non-coherent detection. It does mean that there is no effect in performance by the type of combining procedure for the coherent modulation case. The post-detection combining is not complex in non-coherent detection, results very common in use. There is a difference in system performance when used pre-detection combining and post-detection combining for non-coherent detection such as frequency modulation (FM) discriminator or differential detection schemes. Moreover, the terms pre-detection and post-detection are also indicates the time of combining means when the combining is performed, before or after the hard decision.

8. CONCLUSION

Diversity technique is used to decreased the fading effect and improve system performance in fading channels. Diversity improves reliability of a message signal by using two or more communication channel with different characteristics. Diversity plays vital role in combating fading and co-channel interference and avoiding error bursts. It is based on the fact that individual channels experience different levels of fading and interference. Among different combining techniques MRC has the best performance and the highest complexity. Spatial Diversity is the most widely used diversity technique.

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