Quality Enhancement in MIMO based Wireless LAN

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Abstract – MIMO (Multi Input Multi Output) technology is widely used in current wireless communication standard. Compared with SISO (Single Input Single Output) technology, MIMO can provide higher data rate and better communication quality. This paper mainly focus on improving the communication quality of wireless local area network (WLAN) using wireless communication device with MIMO technology and Multi-polarized antenna

Index Terms – Wireless, MIMO, Multi-polarized antenna, WLAN

1. INTRODUCTION

Over the last decade there has been a dramatic growth in the use of wireless communication. Several wireless communication standards and devices have been developed. It is without doubt that wireless communication is playing a more and more important role in business and normal life. However, not like the wired communication style, the signal form of wireless communication is radio wave travel through open air which means interference can be a major problem. The interference caused by other RF signals causes the limitation of the communication performance, i.e. data rate, signal coverage area, etc. Many technologies have been developed to improve the performance of wireless communication. These technologies are mainly use special mechanism to avoid interference and collect as more signal power as possible. One of the most popular technologies is called MIMO (Multi Input Multi Output)[1]. Comparing with the regular SISO (Single Input Single Output) system, this technology utilizes multiple antennas on both transmitter and receiver which dramatically increase the transmission data rate and coverage without increase bandwidth and signal power [2]. Current application combines MIMO with other advanced technology (like Orthogonal frequency-division multiplexing technology, also called OFDM) to provide a much better communication service.

In this paper, on the other hand, the entire approach tries to improve the wireless communication quality based on MIMO device with new type of hardware, which refers to a new type of antenna called multi-polarized antenna (MP antenna)[3]. This paper work aims to improve the quality of received signal without increase the transmission power and bandwidth by using MP antenna on both transmitter and receiver. This performance improvement will also be implemented in an indoor WLAN (Wireless Local Area Network) plan.

The organization of this paper is as follows. In Section II, the fundamental of antenna will be introduced, some important parameters and feature of different kinds of antennas including MP antenna are discussed. In Section III, the WLAN based on MIMO technology is discussed. In Section IV, the simulation results are shown. Finally, Section V concludes the paper.

2. ANTENNA THEORY

Antenna is a very important element of radio equipment. Antennas are metallic structure that change radio signals in the air in to electricity wave or vice versa, depending on whether it is being used for receiving or for transmitting, respectively. In the other way to describe, they are designed for radiating and receiving electromagnetic energy [4]. Fig.2.1 can explain the radiation for an antenna which shows a voltage source connected to a two conductor transmission line. When the transmission line applies for sinusoidal voltage, an electric field is created which is sinusoidal in nature and this result in the creation of electric lines of force which are tangential to the electric field. The magnitude of the electric field is indicated by the bunching of the electric lines of force.

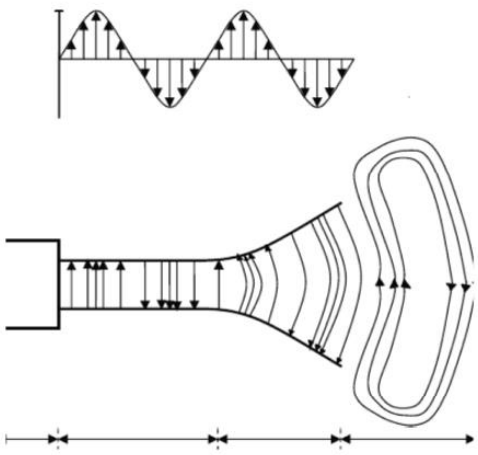

Fig 2.1: Antenna Radiation

2.1. Types of Antennas

- Directional Antenna

A direction antenna is an antenna which radiates greater power in one or more directions allowing for increased the performance on transmitter and receiver and reduce interference from unwanted radiation in a certain direction[4]. With directional antennas, you can divert the RF energy in a particular direction to farther distances. Then you can cover long ranges, but the effective beam width decrease. These antennas are suited for long range point to point solutions and the polarization for directional antenna is 90-180 degrees. The most common types are the yagi antenna, the log-periodic antenna, and the corner reector, which are frequently combined and commercially sold as residential TV antenna.

- Omni-directional Antenna

An omni-directional antenna is an antenna which radiates power uniformly in all directions in one plane, with the radiated power decreasing with elevation angle above or below the plane, dropping to zero on the antenna's axis. The 3-D radiation pattern can be considered as a shape of donut. Omni-directional antennas are vertically oriented and widely used for non-directional communication (e.g. Mobile phone system radio broadcasting) on the surface of the earth because they radiate equally in all horizontal directions. There will be little radio energy which is aimed in to the sky or down toward the earth wasted. Due to the structure of the antenna, it is very easy to install. Due to the 360 degrees horizontal pattern, it can even be mounted upside down from a ceiling in the indoor environment. Omni-directional antennas are widely used for radio broadcasting antennas, and in mobile devices that use radio such as cell phones, FM radio, Wi-Fi, GPS as well as for base stations that communicate with mobile radio such as police and taxi dispatchers and aircraft communications.

- Microstrip Antenna

Microstrip or patch antenna is a kind of antenna which can be printed directly onto a circuit board. Because of this property, microstrip antennas are becoming very widespread within the mobile communication market, especially mobile phone. Patch antennas are low cost, have a low profile and are easily fabricated [5]. Microstrip Antenna can be considered as one kind of directional antenna with linear polarization.

- Multi-polarized antenna

Multi-polarized antenna (MP antenna) use different kind of technology to make the antenna radiates and receives radio wave with different polarization [3]. In this paper, Trident MP Antenna is used for evaluation. Trident MP Antenna has six build-in linear polarized omni-directional sub-antennas. These sub-antennas has cover almost all different polarization direction. This type of antenna also has build-in spatial diversity to improve the communication quality.

3. WLAN AND MIMO

Current requirement for WLAN is to perform satisfactory data exchange speed and signal coverage area under limited bandwidth and transmit power. In this case , WLAN should has a satisfactory data rate and signal quality, i.e. signal strength or signal to noise ratio (SNR) and interference resistance ability. Meanwhile, the WLAN should handle multiple user in the same time while still provide satisfactory communication performance. Since WLAN transmit signal through open air space, the signal can be easily interfered and changed by both natural and artificial matter. Signal power can reduce due to penetration through an obstacle, i.e. shadowing. The most interesting problems in WLAN which are under concern in this paper are multi-path propagation and polarization mismatch. When one signal come across different objects and cause multi-path reflection, causing multi-path propagation. Multi signals will be received at the receiver. Multi-path signals have different phase due to different length of propagation path. These signals will merge at the receiver and cause the power reduction, i.e. fading. However, it is also possible that one signal's positive peak meets others positive peak at a specific point which makes this point has a very high signal strength called hot spot. The worst case, one signal's positive peak meets another one's negative peak which causes a null point with no signal power, see Fig.3.1.

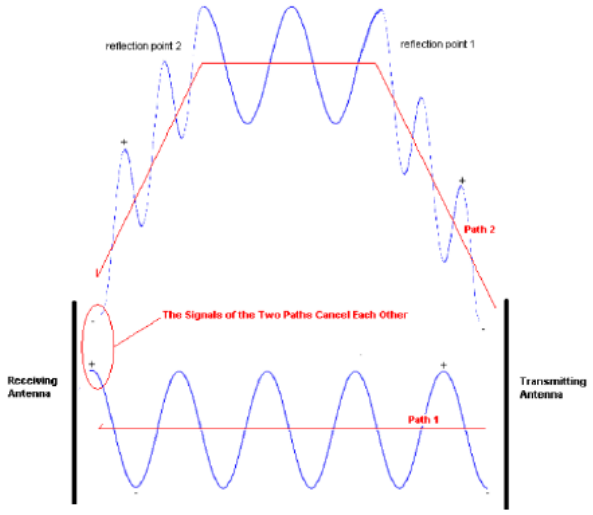

Fig 3.1: Multipath propagation of radio waves

Polarization mismatch is caused by reflection, in this case, scattering and multi-path propagation. Due to the reflection, the signal polarization will be shifted which may be different from the polarization of the receivers antenna. In general, for

two linearly polarized antennas that are rotated from each other by an angle Phi, the power loss due\ to this polarization mismatch will be described by the Polarization Loss Factor (PLF) in Eq. 3.1

$$PLF(\text{dB}) = 20\log(\cos\phi) \quad (3.1)$$

Hence, if both antennas have the same polarization, the angle between their radiated E-fields is zero and there is no power loss due to polarization mismatch. If the polarizations of transmission and receiving antenna are perpendicular to each other, then no power will be transferred. In current days, WLAN devices require more and more mobility. It is hard to configure the antennas polarization in WLAN device to be matched with the transmitter antenna's polarization. However, that not means the signal will be poor due to polarization mismatch. Since in most of the cases these device are used indoorly, the mixed, scattered multi-propagation signals contains many different polarizations which make it possible to receive signal energy. The variety of signal polarization is called polarization diversity.

MIMO, also known as Multi-input Multi-output, is a wireless communication technology. MIMO uses multiple antennas on both transmitter and receiver, which dramatically increases the spectral efficiency, i.e. improves the performance of wireless communication. The channel capacity is increased proportionally in the number of antennas; meanwhile, no additional power or bandwidth will be applied [7]. As the paper mentioned in the former section, one of the most significant problems in wireless communication is fading caused by multi-path propagation. The power of the transmitted signal will decrease at the receiver side because of fading. MIMO, however, takes advantages of multi-path propagation. The received multi-path signals can be considered as in independent fading channel (also called independent spatial signature), i.e. possible to be distinguished from each other, if the antennas of receiver are placed far enough compared with signal wave length. MIMO utilizes the independent fading channel to transmit different signals via multiple antennas in same frequency. By using sophisticated signal process technology, it is possible to separate and collect different signals. In general, this technology is called spatial multiplexing, a high speed data stream can be divided into several low speed data stream and send out in the same time over same frequency. In this way, the data rate of the wireless communication is significantly increased. The most popular wireless communication standard (IEEE 802.11g) can support data rate up to 54Mbps, which cannot meet modern data rate for special service like high definition video stream, data traffic with large number of users at the same time, etc. By adopting MIMO technology, the new wireless communication standard IEEE 802.11n[8] can perform a raw data rate up to 600Mbps with four with the use of four spatial streams (e.g. four antennas) with a channel bandwidth of 40 MHz.

Another technology inside MIMO is called spatial diversity [9]. The aim of spatial diversity is to collect different multi-path signal with independent fading properties (if the receivers antennas are positioned far enough from each other, then the received signal on each antenna can be considered as independent fading channel). This is also called receive diversity. Several independent observations of the signal (one data bit) are combined at the receiver by combining techniques in order to get a better signal quality. There are three different combination technology, selection combining (SC),equal gain combining (EGC),maximum ratio combining (MRC) [10]. The detail of these technologies will not be discussed in this paper. In general, take MRC as an example; different multi-path signals are combined after putting different weight and extra phase shifting individually in order to maximize the SNR of the combined signal. By doing this, the received signal can has a quite high SNR, i.e. better quality. On the other hand, since MIMO utilizes multiple antennas, it is very unlikely that all antennas will be positioned at a null point, which means the received signal are very likely to be better than the signal received in SISO system.

4. SIMULATION RESULTS

The results are plotted by MATLAB and shown below. Fig.4.5,Fig.4.6 and Fig.4.7 shows the data rate and SNR at different distance with three different antenna configuration. Fig.4.5 shows the result with vertically polarized omni-directional antenna on both routers,Fig.4.6 shows result with omni-directional antenna mutually perpendicular to each other, Fig.4.7 shows results with MP antenna on both routers.

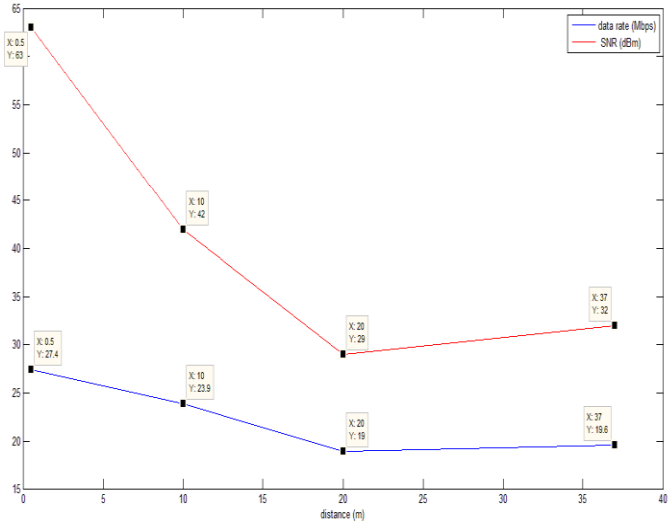

Fig 4.5: Vertically polarized omni-directional antenna on both routers

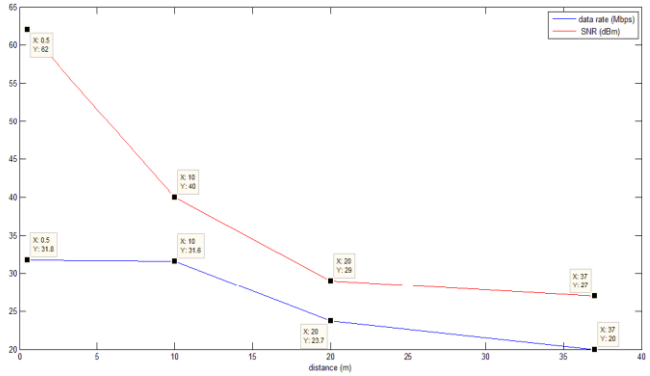

Fig 4.6: omni-directional antenna mutually perpendicular to each other

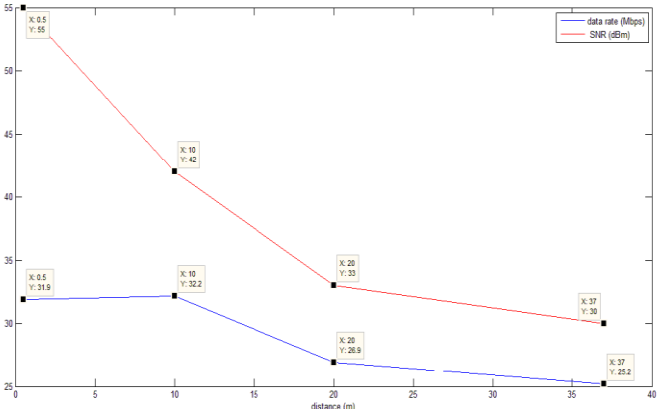

Fig 4.7: Multi polarized Antenna

It can be seen from the result that as the transmission distance became longer, the data rate and SNR became lower. However, it also can be seen that in some result, as the transmission distance became longer, the data rate, on the other hand, became higher. That may because the structure of the building causing multipath propagation and make the signal strength higher at some specific area than others. From an overview of the whole picture, it is still very obvious that as the transmission distance became longer, the data rate and SNR became lower. Compared with different kind of antenna, under same transmission procedure, MP antenna performs higher data rate in certain transmission distance which also means wireless communication device with MP antenna has larger coverage area under same data rate.

5. CONCLUSION

In this paper, the MIMO-MP system is compared with IEEE 802.11g device, MIMO-MP system has higher data rate and larger signal coverage area. It can be a sufficient substitution of IEEE 802.11g device to perform better communication quality with rather low cost. It will become a trend to use this kind of device for future WLAN systems.

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