INDOOR OUTDOOR EFFECT OF ANTENNA DIVERSITY ON CAPACITY AND PERFORMANCE

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ABSTRAK

Kepelbagaian antena semakin meluas digunakan untuk memperbaiki isyarat penghantaran komunikasi tanpa wayar. Di kawasan bandar, bangunan-bangunan adalah didirikan berdekatan dan kepelbagaian antena dalaman diperlukan untuk memperbaiki kualiti isyarat penerimaan. Di sebalik penggunaan satu antena semua arah (omnidirectional), kepelbagaian antena digunakan untuk meningkatkan dapatan (gain) dan halatuju antena. Terdapat beberapa teknik kepelbagaian antena yang digunakan dalam komunikasi tanpa wayar seperti kepelbagaian ruang, kepelbagaian pengutuban dan kepelbagaian corak. Kebiasaannya, teknik-teknik kepelbagaian digunakan bersama-sama untuk meningkatkan lagi prestasi penghantaran. Dengan mengambil kira kegunaan kepelbagaian antena yang luas dalam aplikasi dalaman dan luaran, kajian ini akan menjelaskan kesan kepelbagaian antena dalaman dan luaran terhadap kapasiti dan prestasi isyarat penerimaan. Prestasi kepelbagaian antena dalaman dikaji dengan membandingkan kelajuan sambungan dan julat liputan penghala tanpa wayar yang beroperasi tanpa penggunaan antena, satu antena, dan dua antena. Meter tinjauan radiasi elektromagnet, Narda digunakan untuk mengukur kekuatan isyarat pangkalan stesen antena bagi mengkaji prestasi kepelbagaian antena. Penyelidikan ini bertujuan mengenalpastikan bahawa kepelbagaian antena dalaman dan luaran dapat meningkatkan kapasiti dan prestasi sistem komunikasi tanpa wayar. Dengan menambahkan antena-antena pada jarak yang optimum, teknik-teknik kepelbagaian antena boleh digunakan bersama-sama untuk meningkatkan mutu bagi sistem telekomunikasi tanpa wayar.

ABSTRACT

Antenna diversity is widely used to improve the transmission signal of wireless communication. In urban area, buildings are built closely and indoor diversity antenna is needed in order to improve the signal reception quality. Instead of using only one omnidirectional antenna, diversity antenna is used to increase the gain and the directivity of antenna. There are antenna diversity techniques used in wireless communication such as spatial diversity, polarization diversity and pattern diversity. Most of the time these diversity techniques are used together to further improve the transmission performance. Considering the very wide usage of diversity antenna for indoor and outdoor applications, this project describes the effect of indoor and outdoor antenna diversity to capacity and performance on wireless communication systems. The performance of indoor diversity antenna is studied by comparing the connection speeds and the coverage range of the wireless router that operate using one antenna, two antennas and without antenna. Narda, the Electromagnetic Radiation Survey Meter is used to measure the field strength of base station antenna in order to study the outdoor performance of diversity antenna. From the results of this project, proven that antenna diversity improve the capacity and performance of wireless communication systems. With increase of number or diversity antennas place at optimum distance apart, antenna diversity techniques can be used together in wireless communications to improve the quality of the wireless communication systems.

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CHAPTER 1

INTRODUCTION

Since 1990s, the cellular communications system growth substantially and more than 600 million users are using cellular communication in late 2001 (Rappaport, 2002). The growth of the cellular communications led to the development of new wireless devices and standards for other types of telecommunication traffic besides mobile voice calls. For example, next generation of cellular networks enable high speed data communications in addition to voice calls. New technologies and standards implemented to allow data transmission up to several kilometers to be done without copper wire or fiber optic connections. Wireless networks also used within homes, buildings, and office to replace wires Local Area Network (LAN) through the development of Wireless LANs (WLANs).

WLANs were introduced in 1998 and had been widely used in office or home applications (Rappaport, 2002). WLANs make communications more simple and easy than conventional way that needs cable to link computers together. However, WLANs operation is affected by the destructive interference and noisy environment. The needs to operate at these conditions reduce the signal coverage inside a building and reduce the efficiency of the WLANs system. WLANs system experience three types of signal fading; path loss, large scale fading, and small scale fading (Alex, 2004).

Antenna diversity technique is an excellent way to reduce the effect of signal fading and thus improve signal coverage and transmission capacity. Development of wireless technologies in modernization century allows telecommunications to be more effective and reliable. Implementation of 802.11n standard into wireless devices in WLANs system such as router and Access Points (APs) with combination of suitable antenna diversity techniques increase the range of coverage and data transfer rate substantially (D-Link, 2008). This reduces the number of APs needed for indoor usage to provide coverage over a given area for example in an office and thus reduce the infrastructure costs. Other than that, antenna diversity techniques also use for outdoor applications. Antenna diversity techniques improve the capacity and performance of cellular base station, and allow operation in high interference environments (Winter et al., 1994).

1.1 Antenna history

Antenna plays important roles in wireless communications and has existed since million years ago, as one of the sensing organ of animals or insects and has been applied into radio system and all wireless communication system. In the history of communications, wireless is actually the oldest form when considered shouts and jungle drums that did not require any wires or cable in the information transmission. The first radio antenna was built by Heinrich Hertz in 1886 and until now, this antenna system linked the whole world together using many types of wireless devices such as Global Positioning Satellite (GPS), cellular phone, television, radio, and so forth (Kraus & Marhefka, 2002).

After Heinrich Hertz demonstrated the radiation of antenna for the first time, this antenna communication system was called wireless and broadcasting began about 1920 and by that time, the word radio was introduced (Kraus & Marhefka, 2002). Nowadays, wireless means many systems operate and linked together without wires.

Wide area network of wireless transmission though unidirectional propagation was introduced by late 1930s and at the same time, the bi-directional mobile communication comes into study (Molisch, 2005).

In 1946, the first mobile telephone system was installed in USA and provided interface to the Public Switched Telephone Network (PSTN). After the Second World War, Claude Shannon comes with his "A mathematical theory of communications" by 1948 (Molisch, 2005). The phenomena he included in his theories are the possibility of error-free transmission under limited data rate and the signal-to-noise ratio.

In 1970s, in order to develop analog cellular system, research has been done and pathloss, Doppler spectra, fading statistics, and other quantities are taking into consideration to determine the performance of the analog telephone systems (Molisch, 2005).

Global System for Mobile Communications (GSM) was developed in 1980s and has overtook the use of analog communication system in USA early 1990s and this bring the country into digital world it has become a starting of Second Generation

(2G) cellular system. By that time, many regular home telephones was replace by cordless 2G phone that are much more convenient (Molisch, 2005).

After a short period of time, the Third Generation (3G) was introduced with higher speed and supports more information transmission such as video file, or other complex file types compared to 2G communication systems that can only support Short Message Service (SMS) and voice transmission only.

1.2 Basic technology of antenna

Antenna is a transition or transducer device which interface the circuit and space. Radio antenna is said to be a device that convert electrons to photon, or vice versa between a guided wave and a free-space wave.

Antenna is considered as radiation resistance, *Rr* in transmitter circuit and this resistance is not resistance of the antenna but the resistance between the space and antenna terminals. In transmitting signal, the radiated power is absorbed by obstacle such as trees, buildings, and other antennas. When receiving signal, passive radiation from obstacles and active radiation other antenna will raise the temperature of *Rr* (Siwiak, 1998). In order to make sure that the Signal to Noise Ratio (SNR) is very low, diversity is used. The principle of diversity is to ensure that all the information that received by the receiver will be the same as the information transmitted on independent channels (Molisch, 2005).

1.3 Antenna diversity

Antenna diversity is one of wireless diversity schemes that use two or more antennas to improve the quality and reliability of a wireless communication system. Quality of signal reception can be improved by various transmitting and receiving diversity techniques such as repeated transmission, or simultaneous transmission from multiple antennas (Siwiak, 1998).

Antenna diversity technique can be in form of adaptive array or spatial, temporal, frequency, angle, and polarization diversity depending on which technique is most suitable for corresponding environment.

1.4 Project overview

Antenna diversity is used to improve the signal quality of wireless communication. Indoor diversity antenna is used in large building in order to enhance the signal reception. In additions, the outdoor diversity antenna is widely used for cellular telecommunication system. Hence, this project is mainly study the effect of indoor and outdoor antenna diversity to capacity and performance of signal reception as the usage of antenna diversity techniques is very important in providing better performance of signal transmission and reception.

In this project, activities such as measurements of base station electrical field strength for different period of times will be carried out by using the Electromagnetic

Radiation Survey Meter. Other than that, to determine the indoor antenna diversity effect on capacity and coverage, wireless router with diversity antennas is used.

1.5 Objectives

The objectives of this study are as following:

i. Analyze and measure the electrical field strength of the base station corresponding to different distance using Electromagnetic Radiation Survey Meter.

ii. Determine the effect of antenna diversity on indoor wireless application by using wireless router equipped with two diversity antennas. The connection speed and the coverage area are to be determined.

1.6 Project outline

Chapter 1 briefly introduces the history of antenna, basic technology of antenna, antenna diversity, objective and project outline.

Chapter 2 reviews some literature about electromagnetic wave, various types of antennas, base station characteristics, and environment effect on capacity and performance.

Chapter 3 outlined the methodology in completing this study. These included Electromagnetic Radiation Survey Meter, Narda and the wireless router.

Chapter 4 shows the results and analysis of this study. Results will include outdoor electrical field strength measurement for base station and measurement of indoor Wireless Local Area Networks (WLANs) connection speed and coverage of wireless router.

Chapter 5 concludes the results of this study and lists some recommendations for future improvement of wireless communications research.

CHAPTER 2

LITERATURE REVIEW

Transmission and reception of signal is carried by electromagnetic wave. Radio frequencies are divided into various type of frequency range for different wireless communication systems. Various antenna diversity techniques are used to improve the capacity and performance of wireless communication systems.

2.1 Electromagnetic fundamental

Maxwell law is used in the fundamental of electromagnetic to solve the radio communication problems and the Maxwell equation is used to solve all problems involving the motion of charge that raise the electromagnetic waves under normal temperature (Siwiak, 1998). The relationship between electric and magnetic field that provided by Maxwell equations allow the determination of the radio wave interact with the environment.

The Maxwell equations convey of four vector field quantities namely, electric field E (V/m), displacement field D (C/m^2), magnetic field intensity H (A/m), magnetic flux B (tesla) (Siwiak, 1998).

The law of induction discovered by Michael Faraday (1792-1867) stated that the curl of electric field is given by time rate of change of magnetic flux is given by Equation [2.1].

$$\nabla \times E = -\frac{\partial \boldsymbol{B}}{\partial t} \tag{2.1}$$

The law of André Marie Ampere that generalized by Maxwell (1775-1836) has included the current density *J*, stated that the curl of magnetic field density *H* (A/m) is given by time rate of change of electric displacement field *D* (C/m^2) plus current density *J* (A/m^2) as show as Equation (2.2).

$$\nabla \times D = -\frac{\partial D}{\partial t} + J \tag{2.2}$$

2.2 Electromagnetic radiation

Electromagnetic (EM) radiation is a self-propagating wave in space or through matter. EM radiation has an electric and magnetic field component which oscillate in phase perpendicular to each other and to the direction of energy propagation (Siwiak, 1998). Electromagnetic radiation is classified into types according to the frequency of the wave. These types included radio waves, microwaves, terahertz radiation, infrared radiation, visible light, ultraviolet radiation, X-rays and gamma rays.

Radio waves have the longest wavelengths and Gamma rays have the shortest. A small window of frequencies, called visible spectrum or light, is sensed by the eye of various organisms, with variations of the limits of this narrow spectrum. EM

radiation carries energy and momentum, which may be transmitted when interacts between transmitter and receiver.

The electromagnetic (EM) spectrum is the range of all possible electromagnetic radiation. The electromagnetic spectrum of an object is the characteristic distribution of electromagnetic radiation from that particular object. Figure 2.1 shows the electromagnetic spectrum.

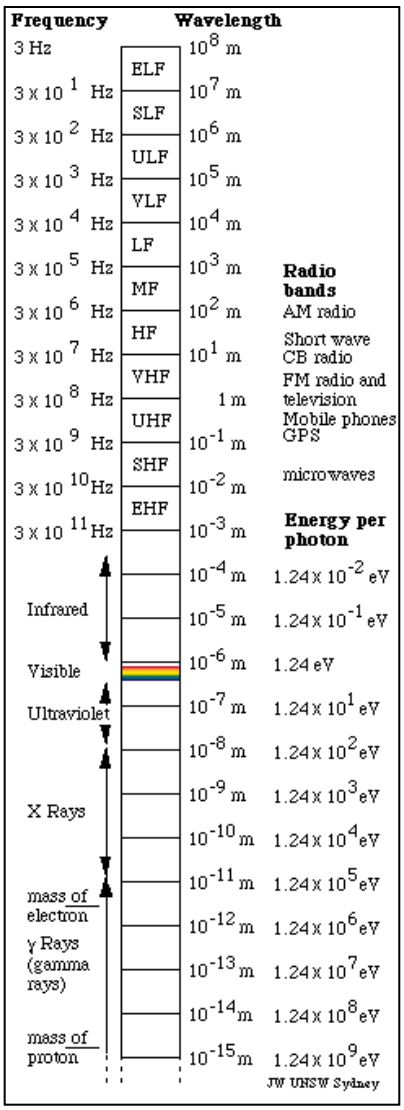

Figure 2.1 Electromagnetic spectrum (Wolfe, 2002)