A SWITCHED-BEAM ANTENNA FOR CELLULAR COMMUNICATION

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Special to my beloved mum and late daddy,

Dad,

You always have a special place in my heart forever and ever after.

(Al-Fatihah)

Mum,

Thanks for praying and wish for my success. Your love makes me strong and confident where ever I go, in what ever I do.

To my fiancé,

You meant everything to me,

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ABSTRACT

Wireless communication has created a continuing demand for increased bandwidth and better quality of services. Smart antenna arrays are one of the ways to accommodate this demand which can provide numerous benefits to service provider and the customer. Switched-beam antenna was chosen for this project due to its easier implementation and lower cost compared to adaptive array. Switched-beam antenna is one of smart antenna technique which comprises a number of predefined beams. The control system switches among the beams that provide the maximum signal response. Through the investigation and study on this system, found that, the 120° sectorization with three monopole antenna elements suited for prototype construction. The initial stage to design this system is by using MATLAB simulation to identify the antenna characteristic and the parameters involved. The second stage is about the construction of the prototype switched-beam antenna used to measure the antenna gain and relative power level which displayed using CASSY program.

ABSTRAK

Komunikasi tanpa wayar telah mencetuskan permintaan yang berterusan bagi meningkatkan lebar jalur serta perkhidmatan yang lebih berkualiti. Tatasusunan antena terbaik merupakan cara paling tepat untuk memenuhi permintaan ini kerana ianya menyediakan pelbagai faedah kepada pengeluar dan pengguna. Antena pensuisan alur telah dipilih untuk projek sarjana kerana senang dibina dan memerlukan kos yang rendah berbanding antena tatasusunan penyesuai. Antena pensuisan alur merupakan salah satu teknik antenna terbaik yang menggandingkan beberapa alur yang telah dikenalpasti. Suis sistem kawalan bertindak untuk memilih isyarat yang memberikan sambutan paling maksima. Berdasarkan kajian mengenai system ini, didapati bahawa, pensektoran 120° menggunakan tiga antena monopol adalah memenuhi kehendak binaan prototaip. Peringkat permulaan rekabentuk bagi sistem ini adalah menggunakan simulasi MATLAB untuk mengenalpasti ciri-ciri antena dan parameter-parameter yang terlibat. Peringkat kedua adalah mengenai binaan prototaip antena pensuisan alur untuk digunakan bagi mengukur gandaan dan aras kuasa yang boleh dipaparkan menerusi layar komputer menerusi aturcara CASSY.

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A_e		Effective aperture
C_s		Shunt capacitor
C/I		Channel to interference ratio
D		Directivity
D/R		Co-channel re-use ratio
G		Antenna gain
I		Interference
IF		Intermediate frequency
L		Length
L_p		Path loss
MU		Mobile unit
R		Cell radius
R_s		Source resistance
R_r		Loss resistance
RBS		Radio base station
RF		Radio frequency
SNR	-	Signal to noise ratio
X_A		Antenna reactance

ε	Relative permittivity
f	Frequency
J	Current density
λ	Wavelength
ρ	Charge density
μ	Relative permeability
σ	Conductivity
η	Radiation efficiency

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CHAPTER I

INTRODUCTION

1.1 Introduction

Initially, the ability to communicate with people on move has evolved remarkably since 1897. Started from that, the new wireless communications methods and services have been enthusiastically adopted by people throughout the world.

The wireless communications industry is growing at explosive rate and is projected to reach 100 billion dollars of annual activity by the end of the year 2000. Consumers are continuously pressing system providers to expand their suite of services and provide these services at ever-decreasing costs. This ever-growing demand for mobile communications is constantly increasing the need for better coverage, improved capacity and higher quality service.

Smart antenna is the solution for the demands, which can give the service to the higher number of users with the minimum of spectrum requirements. The basic principle behind smart antenna is to control or reduce interference.

Smart antenna is dividing into two types. The first one is switched-beam antenna systems and another one is adaptive antenna systems. Figure 1.1 shows both of the mentioned antenna systems.

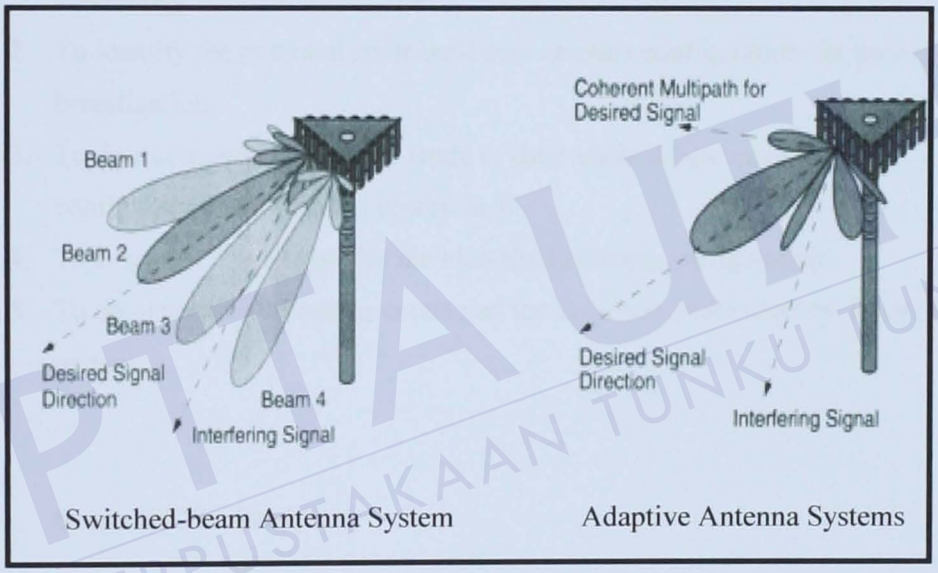

Figure 1.1: Types of antenna systems

Switched-beam system can select one of several beams to enhance receive signal. Adaptive antenna can adjust its antenna pattern to enhance the desired signal, null or reduce interference and collect correlated multipath power.

1.2 Aim Of Project

The aim of this project is to investigate a potential switched-beam antenna configuration for use in mobile communications.

The project objectives are as follows: -

1. To be familiar with the current state of the art in switched-beam antenna technology.
2. To identify the potential switched-beam antenna configuration for further investigation.
3. To do a computer simulation study of the switched-beam antenna configuration identified in objective 2.
4. To construct a prototype for the identified antenna configuration.
5. To do experimental measurements on the switched-beam antenna radiation pattern.

1.3 Scope Of The Study

This project will only be concerned with the design, construction and testing of the identified switched-beam antenna configuration. It will not be concerned with other potential structures. A three beams smart antenna system is proposed for this project with the 120° sectorization.

This project used three monopole antennas in the experiment based on its characteristics. The most important things are to be familiar with the switching techniques by using the simple switches.

CHAPTER II

THEORETICAL BACKGROUND

2.1 Antenna Definitions

Antennas are basic components of any electronic system which depends on free space as a propagation medium. It is a device which provides a means for radiating or receiving radio waves. It is a transducer between a guided electromagnetic wave and electromagnetic wave propagating in free space (Martin S.Smith, 1988)

Antenna is an RF component used to transform an RF signal, traveling on a conductor, into an air-borne wave and vice versa. Antennas can be active or passive components (Carl J. Weisman, 1999).

An antenna is a way of converting the guided waves present in a waveguide, micro strip or transmission line into radiating waves traveling in free space or vice versa (Simon R. sounders, 1999)

An antenna is defined as means of coupling radio frequencies from transmissions line into free space. It also acts as a receiver to capture incident electromagnetic power which can then be processed to retrieve the information contained in the captured electromagnetic waves (Saleh Al-Jazzar and R.Rajesh, 2000).

2.2 Antenna Terminology

a. Bandwidth

An antenna's bandwidth refers to the usable frequency range over which the gain is within 3dB of a nominal value.

b. Radiation impedance

A lumped circuit element description of an antenna, relates the power through an antenna to some reactance seen by equivalent current and voltage.

c. Beam width

The angular separation between the two half power points (-3dB) on the major lobe of an antenna's plane radiation pattern, usually taken in one of the principle planes. An antenna's main lobe radiation pattern can be thought as the energy traveling in the primary direction of propagation.

d. Radiation pattern

A polar diagram representing field strengths at various angular positions relative to an antenna. The front to back ratio is the front lobe power to the back lobe power. The line bisecting the major lobe or pointing from the center of the antenna in the direction of maximum radiation is called the line of shoot.

e. Directive gain

Directive gain is the ratio of the power density radiated in a particular direction to the power density radiated to the same point by a reference antenna assuming both antennas are radiating the same power

f. Power gain

Power gain is the same as directive gain except that the total power fed to the antenna is used (take into account antenna efficiency). The power radiated from an antenna can never exceed the input power. An antenna simply concentrates its radiated power in a particular direction.

g. Antenna polarization

The polarization of an antenna is the orientation of the electric field radiated from it. Polarization is the sense of the antenna's E field motion relative to the earth. Vertical polarization is when the E field is perpendicular to the earth. Horizontal polarization is when the E field is parallel to the surface of the earth.

2.3 Basic Concept

Antennas radiate and/or receive electromagnetic waves. Maxwell's equations allow us to derive the relations for plane electromagnetic waves. Maxwell's equations are

$$\text{div } \boldsymbol{D} = \rho \tag{2.1}$$

$$\text{div } \boldsymbol{B} = 0 \tag{2.2}$$

$$\text{curl } \boldsymbol{E} = -\partial \boldsymbol{B} / \partial t \tag{2.3}$$

$$\text{curl } \boldsymbol{H} = \boldsymbol{J} + \partial \boldsymbol{D} / \partial t \tag{2.4}$$

where ρ is charge density and $\boldsymbol{J}$ is current density.

Consider a particular value of frequency and assume a time factor exp ($j\omega t$), where $f = \omega/2\pi$ is the frequency in Hertz.

Equations (2.3) and (2.4) then become

$$\text{curl } \boldsymbol{E} = -j\omega \boldsymbol{B} \tag{2.5}$$

$$\text{curl } \mathbf{H} = \boldsymbol{J} + j\omega \boldsymbol{D} \tag{2.6}$$

The constitutive relations for linear, isotropic media are

$$\boldsymbol{B} = \mu_r \mu_o \boldsymbol{H}, \quad \boldsymbol{D} = \varepsilon_r \varepsilon_o \boldsymbol{E}, \quad \boldsymbol{J} = \sigma \boldsymbol{E} \tag{2.7}$$

where $\mu_o = 4\pi$ X 10 exp (-7) H/m, $\varepsilon_o = (1/36\pi)$ X 10 exp (-9) F/m,

μ_r is relative permeability, ε_r is relative permittivity, σ is conductivity.

In free space

$$\mu_r = \varepsilon_r = 1, \quad \sigma = 0 \tag{2.8}$$

Two important quantities are

$C = 1 / \sqrt{(\mu_o \varepsilon_o)} = 3 \times 10 \exp(8)$ m/s , the velocity of light in vacuum

$Z_o = \sqrt{(\mu_o / \varepsilon_o)} = 377\ \Omega$, impedance of free space (2.9)

Total power $P = G.\ P_t.\ A / 4\pi r^2$

Gain $G = \eta.D$ (2.10)

where P_t is transmitted power, $G(\theta,\Phi)$, A is area, r is the distance and D is directivity.

The average power density $U_{avg} = U(\theta,\Phi)$

The maximum power density $U\max = \max_{(\theta,\Phi)} \{U(\theta,\Phi)\}$ (2.11)

2.4 Concepts In Radio Wave Propagation

Figure 2.1 illustrated the basic concept in radio wave propagation. A transmitter produces an RF signal with time average-power P_t, using an antenna with gain G_t. At the receiver, which is a distance d from the transmitter, an antenna with gain G_r is used.

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