FREQUENCY RECONFIGURABLE ARCHIMEDEAN SPIRAL ANTENNA

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Specially dedicated to my beloved mother and sisters…

Norsiah, Mastura *and* ***Siti Roselina***

for their endless love that keeps me going.

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ABSTRACT

The latest evolution of communication technology system has observed an emerging of new multi-functional devices and new applications operating in different frequencies. As the technology advances, it becomes apparent that a transceiver which could operate at multi-frequency is in need to support the system. Hence in this thesis, a frequency reconfigurable switchable between wideband and narrowband has been proposed and investigated. The idea was to support a wide frequency of operation and at the same time could be switched to operate at a single frequency in order to reduce the interference level at the receiver. This antenna is potentially useful for UWB and future cognitive radio systems. The proposed antenna utilized an Archimedean spiral antenna as the wideband antenna, and it was reconfigured by adding a slot resonator to the structure to enable narrowband operation. Two ideal switches in the form of metal pads are used for the studies to enable the reconfiguration capability. Performance results from the measurements and simulations results shows a good agreement in terms of return loss and radiation pattern which shows a broad bandwidth operation at wideband operation and 16% bandwidth for the narrowband operation with a maximum gain of 3dBi at the frequency of operation.

ABSTRAK

Evolusi terbaru sistem teknologi komunikasi dapat diperhatikan dengan kemunculan peranti pelbagai fungsi dan juga kemunculan aplikasi baru yang beroperasi dalam frekuensi yang berlainan. Dengan ini jelas sekali bahawa alat pemancar dan penerima signal yang dapat berfungsi dalam pelbagai frekuensi diperlukan untuk menyokong sistem komunikasi. Oleh itu, di dalam tesis ini, antenna yang berkemampuan untuk mengubah frekuensi operasinya dari jalur lebar (2GHz - 8GHz) kepada jalur sempit pada frequensi 5.8GHz telah dicadangkan dan dikaji. Antenna ini direka supaya ianya dapat beroperasi dalam pada jalur lebar dan dalam masa yag sama boleh ditukarkan supaya berfungsi pada jalur sempit hanya dengan menggunakan satu antenna sahaja untuk mengurangkan tahap gangguan signal pada alat penerima. Antenna ini berpotensi untuk digunakan untuk aplikasi radio kognitif sistem pada masa depan. Antenna yang dicadangkan menggunakan struktur antenna lingkar Archimedean dan ditambah dengan slot resonator untuk membolehkan ianya direkonfigurasi. Keputusan prestasi dari simulasi dan pengukuran menunjukkan satu persamaan antara satu sama lain dari segi kehilangan balikan dan pola radiasi yang menunjukkan respon frekuensi jalur lebar apabila beroperasi pada jalur lebar, dan menghasilkan 16% lebar jalur untuk operasi pada jalur sempit

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LIST OF ABBREVIATIONS

mm	-	Millimeter
GHz	-	Gigahertz
MHz	-	Megahertz
UWB	-	Ultra Wideband
ASA	-	Archimedean Spiral Antenna
CPW	-	Coplanar Waveguide
WiFi	-	Wireless Fidelity
WLAN	-	Wireless Local Area Network
WiMAX	-	Worldwide Interoperability for Microwave Access
WPAN	-	Wireless Personal Area Network
Gbps	-	Gigabits per second
Mbps	-	Megabits per second
SDR	-	Software Define Radio
IEEE	-	Institute of Electrical & Electronics Engineers
MIMO	-	Multiple Input Multiple Output
FM	-	Frequency Modulated
GPS	-	Geostationary Position System
FET	-	Field Effect Transistor
RF-MEMS	-	Radio Frequency – M
CST MWS	-	CST Microwave Studio
FR4	-	Fire Retardant 4
PB	-	Passband

LP	-	Low Pass
GSM	-	Global System for Mobile Communications
DCS	-	Digital Communication System
PCS	-	Personal Communication System
UMTS	-	Universal Mobile Telecommunications System
LAN	-	Local Area Network
PIFA	-	Proportional-Integral
WCC	-	Wireless Communication Center
H-plane	-	Magnetic field plane
E-plane	-	Electric field plane

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LIST OF SYMBOLS

dB	-	Decibel
dBi	-	Decibel isotropic
Q	-	Quality Factor
α	-	Spiral Growth Rate
ϕ	-	Angle
r_{max}	-	Maximum radius of spiral

CHAPTER 1

INTRODUCTION

1.1 Introduction

In today's fast paced communication technology changes, new applications are rapidly emerging. UWB system, multimode radio and future cognitive radio have become the hot topics amongst researchers nowadays. The rapid developments of communication system have driven the invention of wireless terminal that is capable of operating in multimode, multiband and do handover between multiple standards [1]. These technologies combine several applications and services that we use nowadays including Bluetooth, WiFi, WLAN, WiMAX, UWB and many others.

Cognitive radio is one of the potential use of reconfigurable antenna employing wideband-narrowband mode. It is a smart technology that soon predicted would replace the current technology by enabling a single device serving for many communication applications. Cognitive radio definition as approved by IEEE and Software Define Radio (SDR) Forum as a system that is aware of its surrounding and can make decision about their operating behavior upon the current situation [2].

1.2 Background of Study

Reconfigurable antenna has been implemented in a system whereby multiple radiation properties are required from a single element. Reconfigurable antenna has been applied in various applications including cellular system, Multiple Input Multiple Output (MIMO) communication [3], cognitive radio, military applications and plug and play reconfigurable satellites. The antenna has been incorporated in mobile devices [4,5] in response to high demand for multiple services being incorporated in one device such as for WiFi/WLAN connectivity, Bluetooth, FM Radio, Global Positioning System (GPS), and pentaband cellular services. A five band reconfigurable antenna has been developed in [6] to cover 5 cellular radio frequency bands for global operation. It also has been applied to laptops [7] and base station [8] whereas it has to operate at different frequencies for different services.

Reconfigurable antenna can be classified into four categories based on previous work and is categorized based on its reconfigurable properties. The first one is frequency reconfigurable antenna [9, 10, and 11], the second one is reconfigurable radiation pattern antenna [12], the third one is reconfigurable polarization antenna and the last one is any combination of the mentioned properties [13].

Many techniques have been employed in order to control the antenna reconfiguration ability. However, fixed reconfiguration and tunable reconfiguration are the most popular techniques used. In fixed configuration, the frequency, polarization or beam is changed at fix value using switches like PIN diode, RF-MEMS or Field Effect Transistor (FET). As for tunable configuration, the frequency, polarization or beam is smoothly changed from specific range. It is implemented using lumped elements integrated into microstrip for example, varactor diodes.

1.3 Problem Statement

For the multimode terminal to be realized, it needs to be able to operate in multi frequency. However, a receiver in this system may be susceptible to interference from other devices in range that operates in the same or neighboring frequencies; thus the efficiency of the receiver could be compromised. In addition, the impedance bandwidth of UWB system span from the range of 3GHz to 10.6GHz. This wide bandwidth includes the operating frequency of WLAN and WiMAX which may interfere with the UWB system at the receiver.

Moreover, fast growing in telecommunication market with increasing users and services has led to the congestion in the available bandwidth. Even with today's existing users and application, almost all the available spectrum has already been occupied, thus the allocation for new users and applications would pose a major problem to the already congested spectrum. Hence, a frequency agile antenna such as wideband antenna that can be reconfigured to operate at a specific frequency is desirable to reduce the interference level [2].

1.4 Objectives

The objectives of this project are:

1. To design a reconfigurable Archimedean spiral antenna that can be switched between wideband-narrowband configurations at wide bandwidth of 2GHz to 8GHz and narrow bandwidth at 5.8GHz for WiMAX applications.

1.5 Scopes of Project

The scopes of this project include the design of slot resonator that forms a filter to be implemented to Archimedean spiral antenna as a wideband antenna. The design of the antenna with a reconfigure capability is simulated with CST Microwave Studio 2010 and is fabricated on FR4 photo resist board by chemical etching technique. The antenna characteristics and performance such as its operating bandwidth, gain, axial ratio and radiation pattern are justified through the simulation results and measurements from the fabricated antenna.

1.6 Thesis Organization

This thesis is organized into five chapters:

Chapter I briefly describes the introduction of the thesis. It covers topics such as the context, problem statement, objectives and scope of the project.

Chapter II explains the literature review of the topics related to this research work. Three main topics have been highlighted which are types of available reconfigurable antenna, filter theory and design structure, and Archimedean spiral antenna.

Chapter III explains the methodology of the project. This chapter will briefly explicate the design process of slot resonator to filter the antenna from broad impedance bandwidth to narrow bandwidth. The fabrication and measurements process and techniques are presented in this chapter.

Chapter IV presents the results obtained from the simulation. These results are analyzed and discussed in detail. Here the results before and after implementation of slot resonator are explained in detailed.

Chapter V presents the conclusion and recommendations or suggestions for future work.

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