COMPARATIVE STUDY OF RADIAL LINE SLOT ARRAY ANTENNA WITH DIFFERENT DIELECTRIC SUBSTRATES

WAN ASILAH BINTI WAN MUHAMAD

UNIVERSITI TEKNOLOGI MALAYSIA

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WAN ASILAH BINTI WAN MUHAMAD

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Specially dedicated to my beloved husband, parents, brothers and sisters

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ABSTRAK

Radial Line Slot Array Antena (RLSA) adalah salah satu alat komunikasi yang telah lama di gunakan di sebabkan oleh profil yang rendah, gandaan yang tinggi, dan tahan lasak untuk kegunaan dalam perhubungan titik ke titik. Daripada RLSA antena yang telah sedia ada, penyelidik mereka bentuk saiz antena dalam jejari yang besar secara tidak langsung membuatkan antena mereka menjadi berat. Oleh itu, tumpuan thesis ini adalah untuk meningkatkan prestasi antena dalam saiz yang lebih kecil atau padat dan pada masa yang sama mengekalkan operasi frekuensi pada 5.8 GHz. Dengan mengurangkan saiz antena, pertindihan slot akan berlaku dan seterusnya mengurangkan gain. Oleh yang sedemikian, teknik tambahan dengan substrat yang lain adalah salah satu cara untuk mengatasi masalah ini. Oleh itu, kajian ini membentangkan reka bentuk antena dengan tiga struktur yang berbeza: slot labah-labah-*Radial Line Array Slot* (SRLSA) antena yang berbeza iaitu lapisan tunggal SRLSA, satu jurang udara dan *Compact Sandwich Polypropylene* antena (CSPA). Pembinaan reka bentuk bermula dengan satu lapisan SRLSA antena dengan dimensi (100x100) mm. Bilangan slot dan sudut slot dari sinaran elemen secara ketara mempengaruhi prestasi keseluruhan SRLSA antena. Gandaan maksimum yang diperoleh daripada lapisan tunggal SRLSA antena hanya 3.42 dBi dan di anggap lemah untuk aplikasi titik ke titik. Oleh itu, struktur udara jurang disiasat. Bilangan yang sama untuk slot dan sudut digunakan. Selepas simulasi, gandaan 7.68 dBi dicapai. Peningkatan ini adalah disebabkan oleh perubahan ketelusan, ε antena. Nilai yang lebih rendah daripada 'ε' meningkatkan bidang pinggiran di pinggir dan secara tidak langsung memancarkan kuasa. Kajian lanjut telah dilakukan ke atas polypropylene (PP) substrat walaupun nilai gandaan antena jurang udara adalah lebih baik daripada lapisan tunggal SRLSA. Penggunaan PP dalam RLSA antenna telah berjaya meningkatkan keuntungan sehingga 10.52 dBi dalam julat frekuensi 5.49 GHz kepada 5.89 GHz. Hal ini kerana, substrat PP yang di gunakan sebagai pengisi dielektrik menambah baikkan nilai dielektrik dalam CSPA antena sekali gus menjana gandaan yang optimum. Dengan segala kemampuan yang disebut, antena CSPA ini adalah sangat berpotensi untuk digunakan dalam aplikasi perhubungan titik ke titik.

ABSTRACT

Radial Line Slot Array Antenna (RLSA) is the legendary types of communication device due to its low profile, high gain, and durable antenna for point to point. From the existing RLSA antenna, most researcher designed their antenna with a huge size indirectly make antenna become weight. Hence, this dissertation focus on enhancement performance of antenna in compact size and at the same time retain a frequency operation which is at 5.8 GHz. By reducing the size of antenna, the overlapping of slots will be occurred and subsequently decrease the gain. Thus, the attachment technique with another substrate is one of the options to overcome this problem. Hence, the research presents the antenna designed with three different structures: Spider-Radial Line Slot Array (SRLSA) antennas which are Single Layer of RLSA, an Air-Gap RLSA and Compact Sandwich Polypropylene Antenna (CSPA). The design construction is started with a single layer of SRLSA antenna with a dimension of (100x100) mm. The number of slots and degree angles of radiating element are significantly affected the overall performance of SRLSA antenna. Parameter sweeps study on the number of slots and degree angles are executed to obtain an optimum gain of SRLSA antenna. The maximum gain obtained of single layer SRLSA antenna is only 3.42 dBi which is consider average for point to point application. Thus, air-gap structure is investigated. The similar number of slots and degree angles is used. After simulation, the gain of 7.68 dBi is achieved. This improvement gain is due to the changes of permittivity, ε. The lower value of ε increased the fringing field at the patch periphery and thus radiated power. Further research has been done on polypropylene (PP) substrate even though the gain of air gap antenna is better than single layer of SRLSA. The deployment of PP has successfully boost the gain up to 10.52 dB within the frequency range of 5.49 GHz to 5.89 GHz. It is found that the incorporation of PP filler improved the dielectric constant and inclined the dielectric loss of the CSPA antenna thus generating an optimum gain. With all capabilities mentioned, this CSPA antenna is highly potential to be deployed for point to point application.

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LIST OF ABBREVIATIONS

RLSA	-	Radial Line Slot Array Antenna
P2P	-	Point to point
CSPA	-	Compact Sandwich Polypropylene Antenna
CST	-	Computer Simulation Technology
WCC	-	Wireless Communication Centre
SRLSA	-	Spider-Radial Line Slot Array
TEM	-	Transverse Electromagnetic Wave
VSWR	-	Voltage Standing Wave Ratio
LP-BSRLSA	-	Linear Polarized Beam Squinted RLSA
PP	-	Polypropylene
CPW	-	Coplanar Waveguide
RFID	-	Radio Frequency Identification
CP	-	Co-Polarization
XP	-	Cross Polarization
HPBW	-	Half Power Beamwidth
IEEE	-	Institute of Electrical and Electronic Engineers
PCB	-	Printed Circuit Board
NiZn	-	Ferrite Tiles

LIST OF SYMBOLS

dBi	-	Decibels isotropic
%	-	Percentage
λ	-	Semi-lambda
dB	-	Decibel
θ	-	Theta
φ	-	Phase
r	-	Constant radius
φ_i	-	Inner termination angles
φ_o	-	Outer termination angles
f_o	-	Frequency of operation
ε_r	-	Dielectric constant
Ω	-	Ohm
Γ	-	Reflection coefficient
c	-	Speed of light
λ_g	-	Wavelength in cavity
λ_0	-	Wavelength in air
mm	-	Milimeter
m	-	Meter
°	-	Degree Angle
3D	-	Three Dimension
S_{11}	-	Return Loss
η	-	Antenna Efficiency
tan δ	-	Lost Tangent
G	-	Gain
D	--	Directivity
Q_T	-	Total quality

Q_D	-	Dielectric Loss
Q_{Rad}	-	Radiation loss
d	-	Air gap distance
P_{rad}	-	Radiating power
P_i	-	Input power
R_r	-	Radiation resistance
R_L	-	Dielectric resistance
Q_s	-	Surface waves loss
Q_c	-	Ohmic loss
$\approx$	-	Approach

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CHAPTER 1

INTRODUCTION

1.0 Introduction

Presently, the radial line slot array (RLSA) antenna has achieved a large attention among researchers and industry players. This is due to the capability of low profile, attractive, high gain and durable antenna for point to point, point to multipoint and satellite broadcasting applications. Low cost feature of RLSA has inspired some researchers to investigate more design for lower frequency applications such as researcher Imran Ibrahim et al [1] . Based on the IEEE 802.1ln standard, the operating frequency of wireless bridging is in range of 5.725-5.875 GHz.

For a number of years, a standard parabolic dish antenna was implanted for point to point communications systems. However, such antenna has some disadvantages of aperture blockage. For this concern, the RLSA antenna might be favorable.

A unique type of slot's orientation and variable in degree angle will be focused on this dissertation. It is believed that both technique can give a solid result in order to achieve a high gain antenna's performance. The combination of polypropylene material with FR-4 is a novelty in this research. The proposed antenna

will be compared with the common type of antenna such as one layer RLSA antenna and air-gap antenna.

1.1 Problem statement

Point to point (P2P) communication has tremendous growth nowadays. Various types of appropriate antennas, including parabolic reflectors, microstrip arrays and radial line slot arrays (RLSA) have been proposed. Parabolic reflectors are the most widely used. Unfortunately, this type of antenna have disadvantage of aperture blockage in a primary fed design.

Instead of patch array, a radial line slot array (RLSA) antenna might be another option. An RLSA antenna has as much as 50% higher gain than the patch array antenna [2]. Nonetheless, the size of that RLSA is as big as 200 mm from Imran Ibrahim et al [1]. Such big diameter needs to be optimized. Reducing its dimension will lead towards efficiency degradation. Subsequently the same reduction goes to the gain parameter. Moreover, overlapping slot is likely going to happen by minimizing the dimension of the RLSA antenna. Additional reflection-cancelling slot and attachment of another substrate is considered as one of the option to solve the problems.

1.2 Objectives

The objectives of this dissertation are as follows:

1. To enhance gain of RLSA antenna by integrating additional polypropylene substrate.

2. To compare three prototypes of spider-RLSA antenna; single layer of RLSA, Air-Gap RLSA and Compact Sandwich Polypropylene Antenna

(CSPA) in terms of radiation pattern, return loss and half-power beamwidth.

1.3 Scope of works

This research focuses on enhancement performance of antenna in compact size and at the same time retain a frequency operation which is at 5.8 GHz. The proposed antenna is designed using Computer Simulation Technology (CST) software and fabricated in etching room at Wireless Communication Centre (WCC), UTM. The fabricated prototypes are tested and measured in the anechoic chamber and their results are compared with the simulated results. The measured return losses and radiation patterns are compared with simulations.

1.4 Contributions

1. Introducing a novel spider-Radial Line Slot Array (SRLSA) of common air-gap antenna with a small size but good in performanced.

2. Finding of polymer material (polyproplyene) with permittivity of 2.33 as a potential replacement for an air-gap layer.

3. The compact polyproplyene spider-RLSA antenna is capable to produce a broadside return loss, single sided broadside radiation pattern and enhanced the antenna performanced.

1.5 Thesis outline

This thesis is organized into five chapters. Chapter 1 consists of the introduction, problem statements, objectives, scopes of works, contributions and thesis outlined. In Chapter 2, literature review of several different antenna geometries which form the basis for the radial line slot array (RLSA) antenna designs and theory of antenna issues are included. Moreover, it also provides history and analysis of RLSA antenna likes designs antenna, polarization antenna, and radiation pattern antenna. Other than that, theory of basic antenna such as gain, radiation pattern, return loss, bandwidth and beamwidth is also explained.

In Chapter 3 contains of three different types of antennas; single layer of spider-Radial Line Slot Array (SRLSA) antenna, air-gap antenna SRLSA and Compact Sandwich Polypropylene antenna (CSPA). It provides an expanded and detailed analysis of dissimilar antenna concept for those antennas. This part also presents the technique in designing of proposed antenna which are number of slots and slot's degree angle.

Meanwhile, a results of specific investigations using simulations and experimental methods would be described in details in Chapter 4. The investigation of these SRLSA types of antenna is carried out by Computer Simulation Technology (CST) software with an analysis of the measured fabrication antennas. Assessment of those antennas which are single layer of SRLSA antenna, common air gap antenna and CSPA antenna also written in this chapter. Lastly, the conclusion will be obtained in Chapter 5.

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