DESIGN AND ANALYSIS OF WIDEBAND CIRCULARLY POLARIZED DIELECTRIC RESONATOR ANTENNA FOR WIRELESS COMMUNICATION APPLICATIONS

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Dedication to my beloved parents and family for their everness support and care

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ABSTRACT

Recent advancements in antenna structures have gathered lots of attention toward dielectric resonator antennas (DRAs). Wide impedance bandwidth, low dispersion loss, and high efficiency are the highlighted characteristics that caused DRAs to be the focus point of scholars and industry. Besides, there is a need to have a circular polarized antenna to alleviate the problem of having the same transmitter and receiver orientation. For circular polarization, several designs have been proposed. In order to have a higher axial ratio bandwidth, most of the proposed structures suggest having a two feed mechanism. Although they have a higher CP bandwidth rather than single feeding structures, the complexity in fabrication is a problem. Thus, there is a great need to have structures with a single feeding method and high axial ratio bandwidth. This thesis represents a novel DRA configuration that is excited with a simple micro strip feed line with a truncated ground plane. Thus, the fabrication is simplified via one feeding mechanism. Besides, a square shape notch is created inside the DRA patch and is rotated 45 degrees to create a low axial ratio. Since the whole structure is mounted vertically on the edge of its substrate, the high radiation resulted in a wide matching band width. The proposed compact DRA antenna showed a good radiation characteristic with an impedance bandwidth of 5.9GHz between 3.9GHz and 9.8GHz and axial ratio of 1.25GHz between 3.9GHz and 5.15GHz and axial ratio of 900MHz between 7GHz and 7.9GHz.

ABSTRAK

Kemajuan terkini dalam struktur antena telah berkumpul banyak perhatianke arah antena resonator (DRAs) yang dielektrik. Galangan lebar jalur yang luas, rendahpenyebaran, kerugian dan kecekapan yang tinggi adalah ciri-ciri penting yang menyebabkanDRAs menjadi titik tumpuan ulama dan industri. Selain itu, terdapat keperluan untuk mempunyaipekeliling antena polarisasi untuk mengurangkan masalah yang mempunyai pemancar yang sama danorientasi penerima. Bagi polarisasi pekeliling, reka bentuk telah dicadangkan. dalamuntuk mempunyai jalur lebar nisbah paksi yang lebih tinggi, kebanyakan struktur yang dicadangkan mencadangkanmempunyai mekanisme dua suapan. Walaupun mereka mempunyai CP jalur lebar yang lebih tinggi dan bukandaripada struktur pemakanan tunggal, kerumitan dalam fabrikasi adalah masalah. Oleh itu, terdapatadalah suatu keperluan yang hebat untuk mempunyai struktur dengan kaedah suapan satu dan nisbah paksi tinggijalur lebar. Tesis ini mewakili tatarajah DRA novel yang teruja denganmudah jalur mikro suapan selaras dengan satah tanah yang terpotong. Oleh itu, fabrikasidipermudahkan melalui mekanisme setiap kali penyusuan. Selain itu, satu takuk bentuk persegi diwujudkan di dalampatch DRA dan berputar 45 darjah untuk mewujudkan nisbah paksi yang rendah. Sejak keseluruhanstruktur bagi memastikan ia dipasang secara menegak di pinggir substrat, radiasi yang tinggi menyebabkandalam pemadanan lebar jalur lebar. DRA antena padat yang dicadangkan menunjukkan baikciri-ciri radiasi dengan lebar jalur galangan 5.9GHz antara 3.9GHz danNisbah 9.8GHz dan paksi 1.25GHz antara nisbah 3.9GHz dan 5.15GHz dan paksi900MHz antara 7GHz dan 7.9GHz.

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LIST OF ABBREVIATIONS

FCC	–	Federal Communication Commission
UWB	–	Ultra-wideband
DR	–	Dielectric Resonator
DRA	–	Dielectric Resonator Antenna
RDRA	–	Rectangular Dielectric Resonator Antenna
TSDRA	–	Two Segments Dielectric Resonator Antenna
DWM	–	Dielectric Waveguide Model
dB	–	Decibel
CST	–	Computer Simulation Software
ACIS	–	Alan, Charles, Ian and Spatial
BW	–	Bandwidth
BW%	–	Bandwidth percentage
PCB	–	Printed Circuit Boards
Hz	–	Hertz
GHz	–	Giga Hertz
mm	–	Millimeter
RF	–	Radio Frequency
IEEE	–	Institute of Electrical and Electronic Engineers
VSWR	–	Voltage Standing Wave Ratio
RL	–	Return Loss
EM	–	Electromagnetic
AR	–	Axial Ratio
	–	

LIST OF SYMBOLS

f_0	–	Resonant Frequency
ε_s	–	Dielectric Constant of the Substrate
ε_r	–	Dielectric Constant of the Upper Segment
H_{eff}	–	Effective Height
ε_i	–	Dielectric Constant of the Inserted Segment
Z_0	–	Characteristic Impedance
η_0	–	Intrinsic Impedance of Free Space
k_0	–	Free Space Wave Number
k_x	–	The Wave Number in the x Direction
k_y	–	The Wave Number in the y Direction
k_z	–	The Wave Number in the z Direction
Ω	–	Ohm
λ_0	–	Free Space Wavelength
δ	–	Dielectric Loss Tangent
W_1	–	Substrate Width for A-Shape Antenna
W_2	–	A-shape Width
W_3	–	Microstrip transformer Width in A-shape Antenna
W_4	–	Microstrip Width in A-shape Antenna
W_5	–	P-shape Strip Width in A-shape Antenna
W_7	–	Notch Width in A-shape Antenna
L_1	–	Substrate Length without Ground in A-shape Antenna
L_2	–	Ground Length in A-shape Antenna
L_3	–	Micro Strip Feed Line Length in A-shape Antenna

L_4	–	Feed Line Transformer Length in A-shape Antenna
L_5	–	Top Notch Length in A-shape Antenna
L_6	–	Bottom Notch Length in A-shape Antenna
a	–	Width of Rectangular DRA
b	–	Length of Rectangular DRA
c	–	Height of Rectangular DRA
s_1	–	Front Chamfer ength in L-Shape DRA
s_2	–	Back Chamfer ength in L-Shape DRA
g_1	–	Spiral Strip Air gap in L-Shape DRA
g_1	–	Front Strip Air gap in L-Shape DRA
h_1	–	L-shape Antenna Height
F_{1l}	–	Strip Feed Length in L-shape DRA
F_{1l}	–	Stub Length in L-shape DRA
s	–	Substrate Thickness
S_{11}	–	S Parameters from Port1 to Port1
c	–	Speed of Light 3x 10^8 m/s
G	–	Gain
π	–	Pi
η	–	Efficiency
	–	

CHAPTER 1

INTRODUCTION

1.1 Introduction

In the current world, recent technology demands growth in the spectrum of RF and Microwave fields to enhance the capability of mediums for a variety of applications in wireless communications, medical instruments and etc. In wireless Communications there is a great need in the development of antennas [1]. Thus, lots of attempts were derived towards designing of antennas for specific applications. Amongst them, micro strip patch antennas and Dielectric Resonator antennas are investigated for modern applications. Dielectric resonator antennas have been targeted in the past two decades as a potential solution for wideband antennas. Although they provide larger band and smaller size than patch antennas, they are usually designed for linearly polarized radiation, their performances in circular polarization is still limited [2], [3].

DRAs are Open resonating structures which are made from low loss microwave dielectric materials like ceramic, powder, liquid, and etc. They have a wide range of dielectric constant, ϵ_r(4-140). Efficient radiating modes are the low order modes because they have a low radiation Q-factor. Dielectric resonators have been used as high Q-factor elements in microwave-circuit applications since the development of low-loss ceramics in the late 1960s. A systematic study of dielectric resonators as radiating elements was first carried out in the 1980s by Long, McAllister, and Shen, who examined the characteristics of dielectric resonator antennas (DRAs) of hemispherical, cylindrical, and rectangular shapes. Dielectric resonators offer a more-compact alternative to waveguide-cavity resonators, and are more amenable to printed-circuit integration. For these applications, cylindrically shaped (puck) dielectrics resonators are typically used, fabricated from materials with relatively high dielectric constants for compactness. The dielectric resonators are also often enclosed in metal cavities to prevent radiation and to maintain a high Q factor, important for filter or oscillator designs. By removing the shielding and with the proper feeding to excite the appropriate mode, it was found that these same dielectric resonators could actually become efficient radiators. In addition, by reducing the dielectric constant, this radiation could be maintained over a relatively wide range of frequencies. Usually, DRAs are mounted on a ground plane.

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Since the bandwidth of the dielectric resonator antenna is inversely related to its dielectric constant, wideband performance is best achieved by dielectric resonator antennas with low values of ϵ_r. By using simple analytical models to predict the radiation quality factor of cylindrical and rectangular dielectric resonators it was estimated that for $\epsilon_r = 10$, a rectangular shape could achieve a bandwidth of about 20%, and cylindrical dielectric resonator antennas could achieve a bandwidth between 30-40% for the lowest mode orders.

Why DRAs are the focus point of attentions. In order to answer this question, advantages of DRAs should be mentioned. As has been recently demonstrated, DRAs offer a high degree of flexibility and versatility over a wide frequency range, allowing for designers to suit many requirements. DRAs have the following advantages:

- DRAs have a low dissipation loss which enhances their radiation efficiency.
- One of the main aspects in the flexibility of DRAs, which is of a great

importance, is their resonant frequency. The designer can manipulate the size and shape of the structure to achieve its desired results in resonant frequency for a given application.

- Since the DRA size is proportional to $\frac{\lambda_0}{\sqrt{\epsilon_r}}$, where λ_0 is the wavelength at resonant frequency and ϵ_r is the dielectric constant of the dielectric resonator. Thus for the same frequency, there is a natural reduction in size, compared with micro strip antennas. Also, different values of ϵ_r , ranging from 4 to 100, can be used, thus allowing the designer the flexibility in controlling the size and bandwidth.
- Compared to other antennas structure, DRAs have a low radiation Q-factor. Since the relation between the bandwidth (BW) and quality factor (Q) of a DRA antenna is $BW \propto \frac{1}{Q}$, it means with a lower quality factor there is a wider bandwidth for dielectric antennas.
- One of the main concerns in array antennas is the high amount of coupling between two antennas due to small distance between them. The amount of coupling is proportional to the amount of surface waves of the structures. In DRAs there is no surface current and hence no surface wave exists. The result is the low mutual coupling between two resonators. This matter has ranked DRAs as the best candidate for array antennas.
- The different pattern shape for various applications is affordable via excitation of different modes within the DRA element. Also, the Q-factor of some of these modes will depend on the aspect ratio of the DRA, thus allowing one more degree of flexibility in the design.
- DRA antennas have a high dielectric strength, more than 200V/mil and high power capability. In addition, one of the main factors that is a demanding concern of technology, especially in space antennas, is the stability of materials against the wide temperature variation. DRA materials are stable in the range of -65 to 110 degrees.

1.2 Problem Statement

One of the basic problems associated with the design of a dielectric resonator antenna is that most of the proposed structures are linearly polarized antennas that are sensitive to the transmitter and receiver orientation. Circular polarization is achieved through a narrow band of the antenna impedance bandwidth. Certain mode excitation is applicable by a special complex circuitry or probe position to provide quadrature signals. Besides, there is an incongruity between size and impedance bandwidth.

1.3 Objective

The objective of this research is divided into two categories:

- To design and characterize a new wideband dielectric resonator antenna that is workable for wireless applications.
- To make the structure circular polarized in the resonant frequency to achieve a wide axial ratio.The new structure of DRA will be designed, characterized, simulated, fabricated, and measured.

The behavior and properties of wideband circular polarized DRA will be investigated by simulation and measurement. Finally, this new structure will be modeled based on analytical methods to more understanding of behavior of the antenna.

1.4 Scope of Project

The main scope of this research is:

- To study and understand the techniques of designing wideband dielectric Antennas.
- To study and understand the circular polarized dielectric designs.
- To design a new wideband circular polarized dielectric resonator antenna.
- Enhance and optimize the performance using simulation and experimental techniques.
- Finalize the design, compile reports and write a conference or journal paper.

1.5 Thesis Organization

This thesis consists of five chapters, which is organized based on the following categories: Chapter 1 addresses a a general definition and overview of the project , introduction, problem statement, objective and scope of the project.

In chapter2, dielectric resonator antennas are reviewed and their advantages and disadvantages are discussed. Different types of polarization, feeding mechanisms for linear and circular polarization are introduced.

Chapter 3 addresses the antenna design methodology and design procedure. It presents different DR antenna configurations designed as well as their specifications.

Chapter 4 presents design verification and simulated and measured results for different features of the antenna such as reflection coefficient, axial ratio, gain and radiation patterns. Furthermore, a detailed analysis of parametric study is conducted. Finally, a comparison is made between measured results and simulation results using CST Microwave Studio Software.

Chapter 5 finishes the book with the theoretical and experimental works as well as several comments for future studies.

1.6 Summary

This chapter discussed the project introduction followed by problem statement, objective of the project, as well as scope of work. Finally, a short description of each chapter is briefly presented.

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