Université du Québec
Institut National de la Recherche Scientifique
Centre Énergie Matériaux Télécommunications

ULTRA WIDEBAND STACKED RECTANGULAR DIELECTRIC RESONATOR ANTENNA

Par

Mohamed Sedigh Bizan

Mémoire présenté pour l'obtention du grade de
Maître ès sciences (M.Sc.)

Jury d'évaluation

Président du jury et examinateur interne	Prof. Serioja Ovidiu Tatu INRS-Énergie Matériaux Télécommunications
Examinateur externe	Prof. Amari, Smain Génie électrique et informatique Collège militaire royal du Canada
Directeur de recherche	Prof. Tayeb A. Denidni INRS-Énergie Matériaux Télécommunications

ABSTRACT

This thesis is a presentation of a design and fabrication of ultra-wideband stacked rectangular dielectric resonator antenna (UWB-RDRA), where the effect of position perturbations on the bandwidth of an aperture coupled dielectric resonator antenna (DRA) is studied. The proposed antenna takes advantage of two low-Q modes which have overlapping bandwidths so as to achieve an ultra-wideband operation. This can be achieved by using two combinations of stacked DRAs for the analysis: larger over smaller (LOS), and smaller over larger (SOL). Different position perturbations on the transmission line (TL), LOS, and SOL are applied to widen the matching bandwidth of the antenna.

The performance of the proposed antenna is compared with the conventional antenna designed with no perturbations. The proposed antenna not only provides 5:1 ultra-wide matching bandwidth (from 2.7 GHz to 13.6 GHz), but also results in the highest gain of 9 dBi, which is 2 dBi more than the antenna designed with conventional method with no perturbation. The proposed antenna, therefore, consists of the dielectric constant of 6.15 and 9.8 that are stacked vertically in order to acquire a bandwidth that is more improved as compared to the conventional RDRA. A use of 50 Ω microstrip line is required in the proposed antenna to act as a feeding mechanism. The physical parameters of stacked RDRA are also optimized by extensive simulations using Computer Simulation Technology (CST) software.

The parameters of this antenna are 65x50x5 mm^3 and its grounded substrate size is 108x90 mm^2. The prototype is fabricated and measured. The measured results and simulated results show a good agreement. This prototype antenna is designed to cover the band from 2.7 GHz to 13.6 GHz. This proposed antenna is therefore suitable for wireless (Wi-MAX) and (WLAN) application bands.

Dedicated to

This thesis is dedicated to special people in my life:

my beloved parents, my teachers, my lovely wife who always inspires me, my wife's family for their encouragement and support, my son Mahmud, as well as my coming child.

ACKNOWLEDGMENT

In the name of Allah, Most Gracious, Most Merciful. Praise be to Allah, the Cherisher, and Sustainer of the Worlds. First and foremost, I am very grateful to my God for his blessings, graces. Who gave me the strength and will to complete this study that without his helps it would not have been accomplished.

Till this moment, this work is the higher achievement ever in my life and it would be impossible to go through it without acknowledging the people who supported me and as well as believing in me.

I acknowledge the support of my supervisor ***Prof. Tayeb A. Denidni*** *for his incomparable assistance and guidance all through the research. I have highly appreciated him for his subsequent and constant encouragement that he has always offered by giving his critics on my work bit by bit as I progress. I am therefore grateful for him for having given me the support and instilling confidence in me. His trust and support always gave me inspiration in many significant moments of arriving in the right decisions and I am glad to have worked with him in my entire course.*

I would also like to thank all my friends, and more so my classmates, every thought and mind stimulating discussions we had as a group, which consequentially prompted us to brainstorm and think beyond the normal reasoning. I have enjoyed their companionship so much during my stay at INRS. I would like to thank all those who made my stay in INRS a memorable and rewarding experience.

Last but not least, I would like to thank my parents who taught me the value of hard work by offering their own example. They gave me their gigantic support during the whole tenure of my stay at Quebec University.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES.

LIST OF ABBREVIATIONS AND SYMBOLS

UWB	Ultra-Wide Band
DRA	Dielectric Resonator Antenna
LOS	Larger Over Smaller
SOL	Smaller Over Larger
TL	Transmission Line
BW	Band-width
MMIC	Monolithic Microwave Integrated Circuit
ε_r	Relative Permittivity
λ_0	free space wavelength
f_0	frequency resonance
c	light velocity in free space
TE	Transverse Electric
TM	Transverse Magnetic
E	Electric field
H	Magnetic field
Z_{in}	Input Impedance
Z_0	Output Impedance
VSWR	Voltage Standing Wave Ratio
RF	Radio Frequency
MW	Microwave
RL	Return Loss
Q	Quality factor
CST	Computer Simulation Technology

CHAPTER ONE: INTRODUCTION

1.1 Introduction

In today communication world, antennas play an essential and important role in wireless communication systems whether in the transmitter or receiver circuit. The antenna becomes a basic part of all wireless communication systems such as cell phones, satellite, navigation systems for transportation, Wi-Fi networks etc.

Since the first successful transmission that was done by Galileo Marconi, the wireless communication systems have grabbed a great attention of many researchers. In some applications, a number of antennas are required to work in different frequencies, polarization, and radiation patterns to meet the need of these applications, therefore, various shapes, kinds, and techniques of antennas have been discovered and invented, one of those techniques uses a dielectric as a resonator in antenna design, this type of antennas is known later as a dielectric resonator antenna (DRA).

The DRAs have received considerable attention. They are inexpensive promising solutions that are able to change their characteristics in order to adapt to their environment and fulfill the operational requirements.

In 1983, S. Long, M. McAllister, and L. Shen have proposed a cylindrical dielectric as a resonator in the antenna. In [1, 2], it was the first generation of dielectric antenna technology. Today, more than 800 publications have been put forward alongside couple dozen issued patents that entail the dielectric resonator antenna (DRA) technology [3].

The main characteristic for the DRA with concept leading to extra work that improves the performance of the DRA technology have been discovered and published by the several researchers, which led to conclude that this technology offered a good alternative for the extra low gain antenna elements, as illustrated in Fig. 1.1.

The DRA initially used the dielectric resonator in place of a resonator device to store energy.

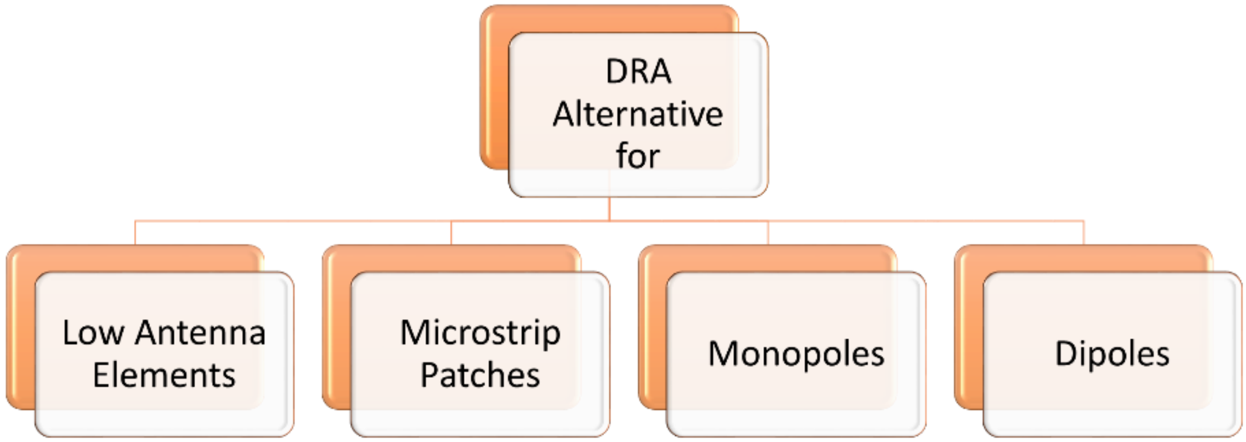

Fig. 1.1: DRA as an alternative to traditional low gain antenna elements [3].

Researchers who have directed much of their attention in the applications of using DRA technology to replace both the elements of the traditional low gain antenna, microstrip patches, monopoles, dipoles, since it offered a lot of advantages over the more traditional concepts of the antenna [3].

During the mid-late 1990s, DRA research advances covered from two-element arrays to more complex arrays of planar phased arrays consisting of over 300 elements containing advanced phased-steering capabilities [3]. It is also during this period that the performance of low profile and compact designs, mutual-coupling analysis array elements, and circular polarized DRAs, multi-band and wide design, active/ tunable DRAs and the cropping of the antenna designs have been proposed [3].

During the early years of the DRA concept development, it was only possible to achieve a narrow bandwidth which was wider than the microstrip antenna. This narrow bandwidth limitation, therefore, limited the applications of the DRA designs. Despite this phenomenon, subsequent research has led to the DRA offering a wider bandwidth, e.g. a technique used in increasing the wideband is that of a rectangular DRA stacked on a vertical ground plane edge. A parasitic ring was placed on the top of the DR, hence bandwidth improved from 96% to 105%, from 92% to 100%, and from 107% to 119% [40].

Besides, the excitation of two radiation bands at the same time improves the DRA bandwidth since the fields are added. One of the bands is from the DRA while the other remaining bandwidth is got from the feeding system like a hybrid design [4]. Multiple probes are a technique that is used in increasing the bandwidth [4].

The optimization of the impedance required the use of a crescent patch in feeding the DRA substantial bandwidth enhancement in the antenna design is provided by a parasitic cylindrical DRA [5, 6]. A natural control of a bandwidth behavior is therefore promoted by the rectangular DRA through adjustments of dimensional parameters like height, weight, and length [15]. Subsequent means of increasing the antenna bandwidth using stacked DRAs, embedded DRAs, or any other formations of DRA [1].

1.2 Project aim and objectives

The aim of this project is to investigate the DRA designs with improved performance in terms of bandwidth for wireless communications, sensing and energy harvesting at microwave frequencies. For this, we propose a stacked antenna concept. Techniques for increasing the performance of DRAs have been investigated during the project, by simulation with the CST Microwave Studio and then by experimentation, which is planned to lead to further more novel DRA designs.

1.3 Thesis organization

In Chapter one, a literature review about dielectric resonator antennas is presented. The stages of evolution of DRA techniques have been briefly reviewed. Chapter two introduces a general background of DRAs. As well known, the key point to design any antenna is well and wide understanding of its operational theory; therefore, antenna crucial parameters are presented as well. Since the main topic of this thesis is about designing an ultra-wide-band rectangular dielectric resonator antenna, several methods like stacked method, coplanar parasitic method, and embedded method, including their advantages and disadvantages, are discussed. Each bandwidth enhancement technique is supported by some examples.

The third chapter starts with a brief introduction to DRA. A method for designing an ultra-wideband rectangular dielectric resonator antennas is presented. The effect of position perturbations on the bandwidth of an aperture coupled dielectric resonator antenna (DRA) is studied and presented. Both simulation and experimental results are discussed and compared. Chapter four concludes the work of this thesis as well as the future work.

CHAPTER TWO: DIELECTRIC RESONATOR ANTENNAS REVIEW

2.1 Introduction

An antenna is a transitional structure that is able to change the received electromagnetic wave energy into an electrical current or vice versa. Antennas convert a guided electromagnet wave into a plane wave that propagates in free space [8]. IEEE defines an antenna as a part that is responsible for transmitting or receiving system that is designed with the purpose of radiating or receiving electromagnetic waves [9].

The antenna represents a necessary part when designing a wireless communication application due to its participation in the determination of the overall efficiency of any wireless communication system, and therefore, it is made from a good material that is conducive to enable it to radiate in a proper manner. Fig. 2.1 below shows how an antenna basically operates. The major function of transmitting antenna is changing transmitted power into the electromagnetic wave before radiating it in the space. The receiving antenna, however, is in charge of receiving a portion of the propagated waves before sending it to the receiver in form of power.

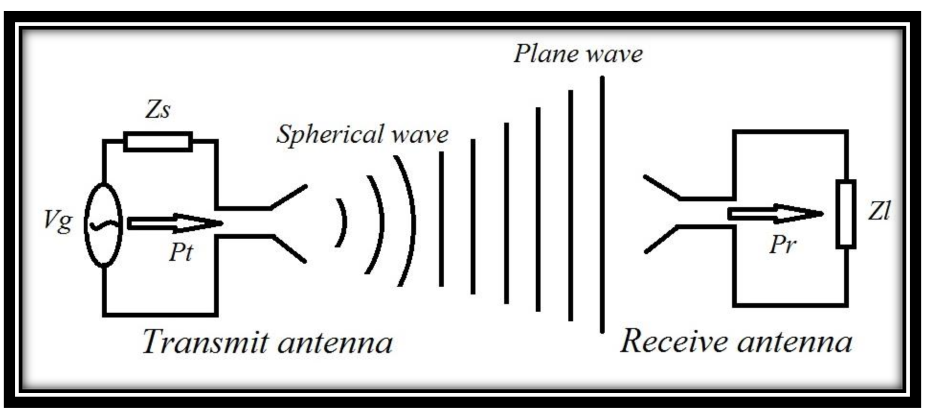

Fig. 2.1 Basic operation of transmitting and receive antennas [8].

The age of antenna began in the year 1901 when Guglielmo Marconi succeeded in transmitting a signal from England, UK, to Newfoundland, Canada, using 50 wires that were vertically arranged, and in the form of a fan that is connected to the ground in a form of a transmitting antenna, 200 m wire that were pulled and supported by a kite like a receiving antenna considered as the pioneer transatlantic transmission [10]. Marconi fan monopole is illustrated in the Fig. 2.2 below.

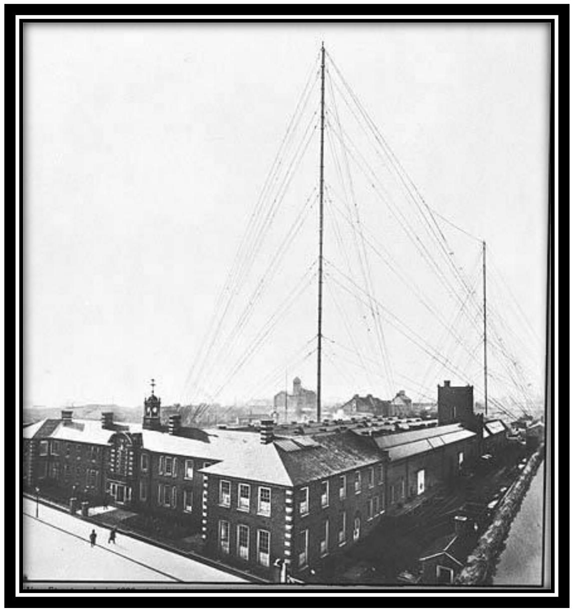

Fig. 2.2 Photography of Marconi's Fan Monopole antenna [10].

During the early nineteen-eighties, S.A Long proposed a dielectric resonator in a form of resonant antenna. The DRA which Long introduced has numerous advantageous features such as high radiation efficiency, compact size, light in weight and dexterity in shapes and feeding mechanism [46]. These advantageous characteristics that are fulfilled by DRA are important to many wireless applications that emerging and existing, hence, a lot of research is still done towards the improvement of BW and how to keep its size in the compact state.

2.2 Dielectric resonator antenna bandwidth and bandwidth enhancement

There are many methods of achieving DRA bandwidth enhancement, an area that researchers have put more concentration on so as to extend the number of applications that are found of the DRA. Due to the flexibility of the DRA design model, modification of its shape, size, feed, ground plane, and other parameters provides the possibility of improving the bandwidth. A portion of DRA can act as an antenna hence, placing the embedded DR in a plane vertically, and cropping some areas of the antenna, is enables the enhancement of the performance. When a slot is used at the same with optimizing some antenna parameters like position and ground plane dimensions, the resonant frequency of the antenna can be changed producing an increment in the antenna bandwidth [12].

As such, when combined with a monopole antenna to form a hybrid antenna, there is a possibility of improving the bandwidth to obtain Ultra-Wide Band (UWB) characteristic. To provide the needed wideband, high isolation and high gain, a DRA can take the resemblance of another antenna and work as a parasitic antenna. Researchers have also shown an enhanced performance hybrid DRA. This enhancement comes in terms of bandwidth.

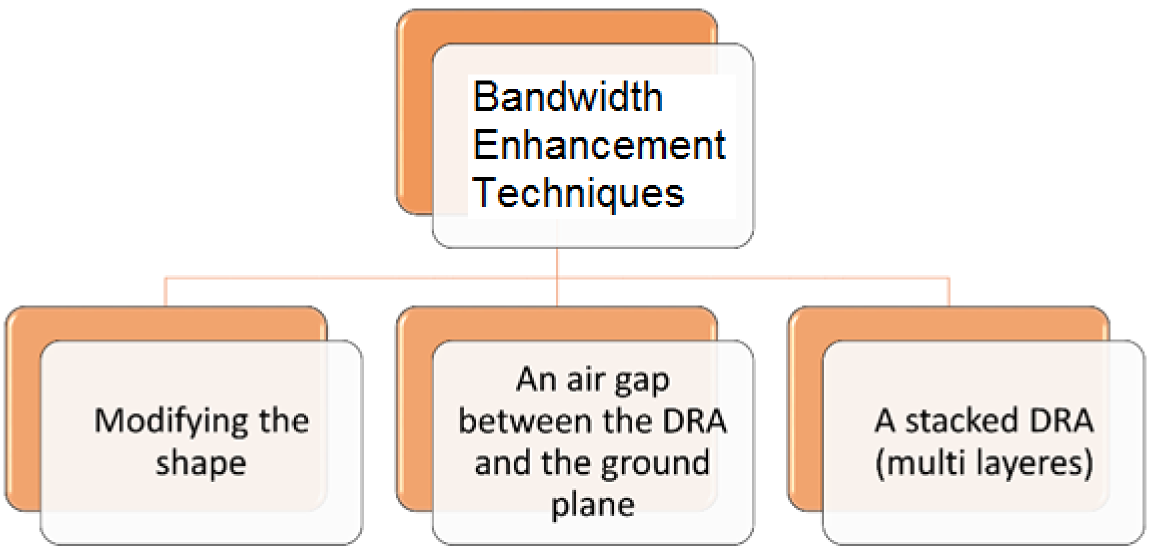

Fig. 2.3 Techniques for bandwidth enhancement [13].

A hybrid design antenna is made by combining two elements, mainly by inserting a quarter wavelength monopole in the DRA axis, where the excitation of the DR will be provided by the quarter wavelength monopole element. Research shows that these hybrid designs provide a wide bandwidth compared to other designs [14]. The presentation that was done by Zheng reveals that a hybrid antenna is made of three main elements, a monopole antenna that is inserted in the axis of two cylindrical DRAs with a cavity in its respective center [14]. With the optimization of the configuration parameters, this antenna attains its purpose of having a UWB of about 110% in the frequency that ranges from 3GHz to 11 GHz.

2.3 Ultra-wideband dielectric resonator antenna

The Ultra-wideband, (UWB) was approved by the US Federal Communications Commission in the year 2002 [1], permitting the unlicensed band that covers the 3.1 - 10.6 GHz for systems that able to transmit and receive high rate signals (nanoseconds) with the help of a very short energy pulse. Due to many advantages that were seen for the wireless world in the use of UWB communication systems like the rate of high-speed data, high precision, lower cost, and lower complexity have attracted the attention of most researchers alongside engineers [11]. The bandwidth and radiation pattern of a UWB DRA are a function of the shape and size of the ground plane [11].

2.4 Dielectric resonator antenna concept

A dielectric resonator antenna, (DRA) is a mode of antenna that is designed with a dielectric resonator serving as its main element. The design of DRA comprises of a piece of a dielectric resonator that is fed by a line of transmission. This has been explained in Fig. 2.4 below illustrates a design of DRA. It is a laboratory prototype rectangular DRA, (RDRA) that is connected in a position that measures its radiation pattern.

The DRA geometry, dielectric Permittivity, and its coupling mechanisms are factors that define its operational modes, resonant frequency, and radiation characteristics [15]. The modification of the DRA specifications and its feed mechanisms make it possible to modify and control the necessary antenna parameters like the input impedance, bandwidth, and the radiation pattern [16].

The possibility of many different types of feed mechanisms to feed a DRA enables the technology to be suitable for monolithic microwave integrated circuits

(MMIC) [17]. It is, therefore, possible to employ of available means of excitation for a DRA that cover a coaxial probe, a microstrip transmission line, a coplanar waveguide feed or aperture coupling [18].

The DRA revealed by an early research consists of a narrow bandwidth capability, even though it was wider compared to a microstrip system. Techniques have thereafter been developed to enhance a bandwidth [13].

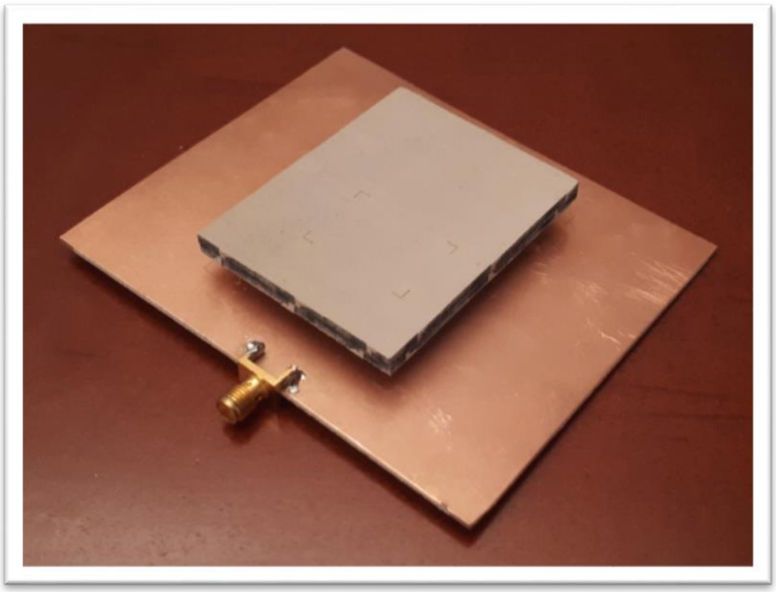

Fig. 2.4 An experimental laboratory prototype aperture coupled fed RDRA design.

DRA could be a candidate as a good concept for many applications that demand efficiency of high radiation, flexible feed arrangement, simple geometry, and a compact size. When compared to a microstrip, the DRA has a high-efficiency performance, higher degree of flexibility, wider bandwidth without excitation of surface waves [34]. Despite microstrip sharing common advantages such as lightweight, low cost and easy excitation [19], this concept gives DRA an upper hand over microstrip-patch antennas [12].

2.4.1 Dielectric resonator antenna characteristics

Numerous characteristics and advantages that DRA has over other wireless antennas like microstrip antennas have attracted many researchers to focus on studying the DRA concept. As mentioned earlier, some of these characteristics include lightweight, small size, low cost, low profile, and easy excitation [11,12,13] and has been illustrated in Fig. 2.5 below, which has also considered DRA's easy fabrication as another advantage [21,22,23].

The designs of DRA have the property of radiation all over its volume in a direction that is tri-dimensional [39]. When a material of high permittivity is used, DRA may be electrically small, meaning it is compact, albeit at the expense of bandwidth efficiency [25, 26].

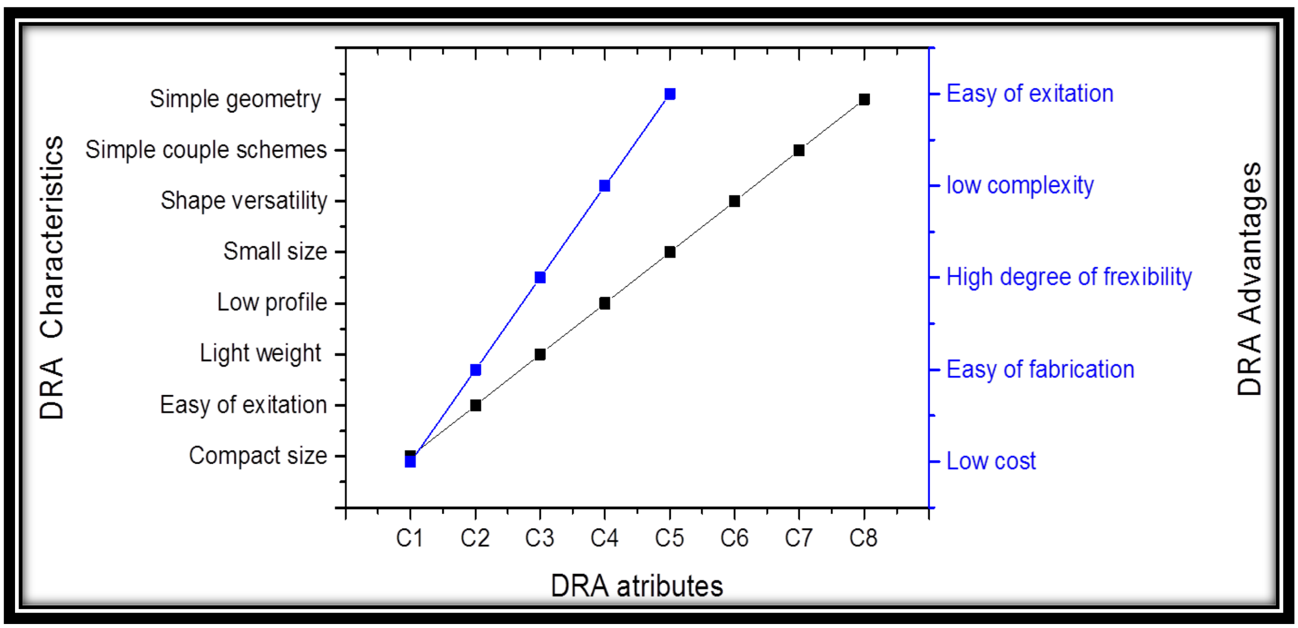

Fig. 2.5 Dielectric resonator antenna characteristics [11].

The DRA is able to provide efficiency that is of high radiation because of the absence of conductor or surface wave losses, and it also makes it less susceptible to tolerance errors, more so at millimeter wave frequencies with easy excitation [27].

2.4.2 Dielectric resonator antenna design

Designing DRA requires the inclusion of various elements some of which are having integrated substrate elements. Other designs will include stacked or embedded elements. Other elements that are commonly found in designs that are published are ground plane, substrate, dielectric resonator, and a feed mechanism. Other things to consider include elemental position and orientation like gaps, while others may be printed on the substrate.

The DRA design depends on the used application. Having known the application, the designer is required to analyze the needs of the electric that is required to perform and either develop a newer design or utilizes already published design that has necessary features. Upon completion of the design, the various elements are assembled followed by testing the antenna to ensure the consistency of the electrical performance with requirements of the designer. In case some parameters fail to meet the performance requirements, a review of the DRA must be done to identify the potential alterations to the design.

There is a certain size for each element, a variance of size will lead to performance change. Every millimeter change in the size of the antenna makes a significant difference. Various designs that include novel aspects to improve the capability of an antenna, such as a simple gap, stacked elements, embedded elements, cutting parts of the DRA, as well as hybrid designs are also available which they are made by combining a DRA with another for the antenna [3]. Each and every element in an antenna has a specific function.

2.4.3 Dielectric resonator antenna size

The dielectric constant is a function of electric resonator antenna size which is expressed in Equation (2-1). The maximum dimension (D_{DRA}) for a DRA is defined by the ratio existing between the wavelength and square root of the relative permittivity (ε_r). These relationships are both presented in the below equation, where "λ_0" is the free space wavelength (m), "ε_r" is the dielectric constant, "f_0" is the resonance frequency

(Hz) and “c” the light velocity in free space which is a constant value of $3x10^8$ m/s. Specifically for this thesis, the frequency range will be in terms of GHz, and the wavelength and speed of light will be expressed in millimeters (mm) which is $300x10^9$ mm/s.

The relationship is therefore written as:

$$D_{DRA} = \frac{\lambda_0}{\sqrt{\varepsilon_r}}; \lambda_0 = \frac{c}{f_0}$$ …………… (2-1) [28].

2.4.4 Dielectric resonator antenna shape

Various shapes of DRA have been put forward for study since it has been reported that shape variation can control the interior field in the DR [29]. Performing controlled modification to the shape also makes it possible to adjust the performance of the antenna by modifying the inner electric field. The shape of the DRA is directly correlated to its performance. The publications of the first papers on the DRA concept has undertaken much work on basic shapes of the DRA. The ability to assume various shapes is among the attractive features that are possessed by DRA. In addition, the operational mode and DRA performance vary when choosing DR with preferred structure. This is to say that numerous shapes have been experimentally tried, with the first experimental study being done on cylindrical disk DRA shape [47]. Various shapes have later been developed to split cylinder, sectored cylinder, cylindrical rings, metalized DRAs, triangular, rectangular, notched rectangular, chamfered DRA, conical, elliptical, spherical, hemispherical, spherical cup, tetrahedral, perforated DRA, stepped DRAs, and hybrid DRAs.

A DRAs in the fundamental modes have been said to be radiating like an electric or magnetic dipole, an incidence that relies on the excitation mode and shapes of dielectric material. Conical, stair, stacked triangular etc. are shapes that emanated from dual-band or wideband applications while others like elliptical, hexagonal, cylindrical-comb etc. emanated for circular polarization applications. Fig.2.6 shows shapes from which we are going to pick three as the basic shapes or the DRA for the purpose of discussion and presentation in this thesis. This is because despite many shapes being introduced, the basic and common ones still remain the cylindrical DRA, hemisphere DRA and rectangular DRA due to the simple nature of their design, fabrication, and analysis.

Fig. 2.6 Various shapes and types of DRs [29].

2.4.4.1 Famous shapes of Dielectric Resonator Antennas

The major common shapes of the DRA that are used are cylindrical, rectangular, and hemispherical. We are going to study these three shapes and their respective field mode configurations. This analysis may assist in predicting the radiation pattern resonant frequency, and Quality Factor (Q-factor) [31].

2.4.4.1.1 Cylindrical DRA

By comparing the three shapes, the cylindrical shape has advantages over all of them because of its ability to offer higher flexibility design with the radius/height are responsible in controlling the resonant frequency and the quality factor denoted as (Q). Various Q factor can be acquired by varying the dimensions of the DRA. A cylindrical DRA has a much easier fabrication with the excitability of the different modes resulting in either round side or omnidirectional radiation patterns. A cylindrical shaped DRA offers more degree freedom than hemispherical by one, with an aspect ratio (a/h) determining Q-factor for a specific dielectric consonant [31].

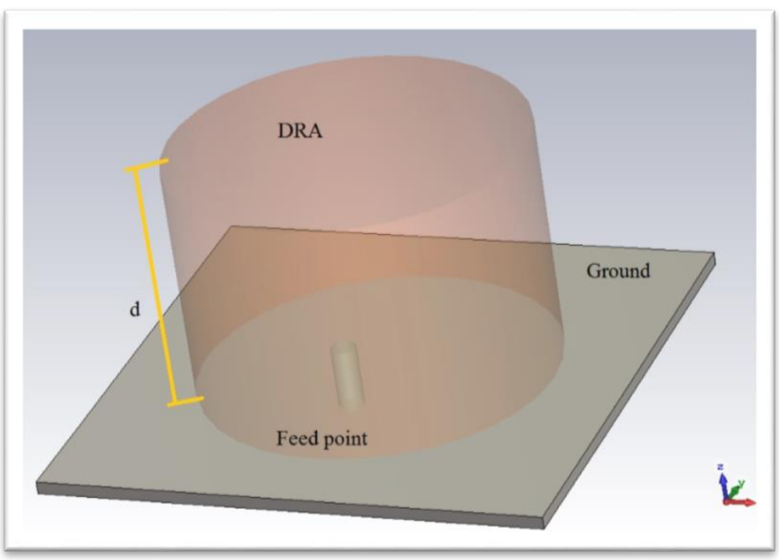

Fig. 2.7 The configuration of cylindrical DRA.

A cylindrical shaped DRA can provide various subclasses of DRA. These subclasses include cylindrical-ring DRA, split-cylindrical DRA, disk-cylindrical DRA, sectored-ring DRAs, sectored-cylindrical DRAs, elliptical shape DRA, and conical shape DRAs. A ring DRA offers an increase in impedance bandwidth performance. In circuit applications, filters, oscillators and more so in microstrip technology employ the use of cylindrical dielectric resonators, with low practicality in resonant waveguide cavities.

The geometry of cylindrical DRA as shown in Fig. 2.7 consists of materials with height h, radius a, and dielectric consonant (εr). The aspect ratio (a/h) determining k_0a and the Q factor for a specific dielectric consonant give this shape a disadvantage over a hemispherical DRA by one degree [31].

2.4.4.1.2 Hemisphere DRA

It was stated earlier that a model of the magnetic wall is not efficient to be used in calculating the input impedance of the DRA. (Long) conducted a pioneering analytical theory of the input impedance for the hemispherical DRA, whose shape is illustrated by the Fig. 2.8.

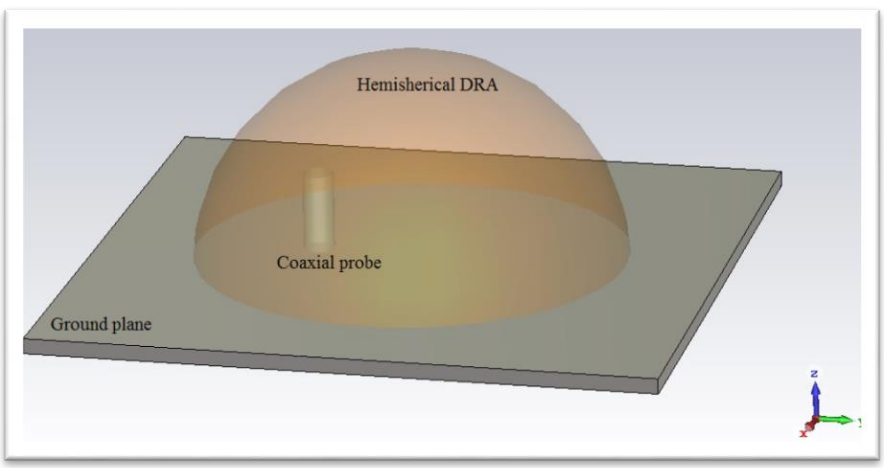

Fig. 2.8 Geometry of a probe feeding of hemispherical DRA.

The major characteristics of hemispherical DRA are radius (r) and a dielectric constant.

The hemispherical DRA is more advantageous over cylindrical and rectangular shaped DRAs because the simplicity of the interface between the dielectric and air, thus giving a closed form expression for the purpose of performing Green's function.

It is assumed that hemispherical DRA mounted on the ground plane has infinitive conductivity alongside infinite excitement. The theoretical picture is important in equating the hemispherical DRA of radius (r), to a dielectric sphere that is isolated, hence same radius. Transverse electric (TE) mode is a different mode from a transverse magnetic (TM) in a dielectric sphere with TE having radial electric field component whose value is zero, ($E_r = 0$), while the Traverse Magnetic mode having zero radial magnetic component field ($H_r = 0$) the two modes of hemispherical DRA that are fundamental are TE_{111}, with the similar radiation pattern to a short electric monopole.

2.4.4.1.3 Rectangular DRA

There are many advantages of rectangular DRA over than cylindrical and hemispherical shape since it offers a second-degree freedom that is one degree more over the cylindrical shape and two more degrees over the hemispherical shape. This DRA helps the designer to have a higher flexibility to acquire the desired profile and bandwidth features of a specific resonant frequency and dielectric permittivity. The various modes in an isolated rectangular dielectric guide can be split into TE and TM, even though the DRA mounted on the ground plane can only excite TE mode. The rectangular DRA maintains TE modes (TEx, TEy, and TEz) which radiate like a short magnetic dipole. The resonant frequency of every one of these modes performs is a function of DRA dimensions. When a designer chooses proper DRA dimensions he prevents unnecessary modes from appearing over the frequency band during the operation. By solving the transcendental equation, TE modes will be calculated [31].

The major characteristics of rectangular DRA are length (b), width (a), height (h), beside a dielectric constant. (See Fig. 2.9.).

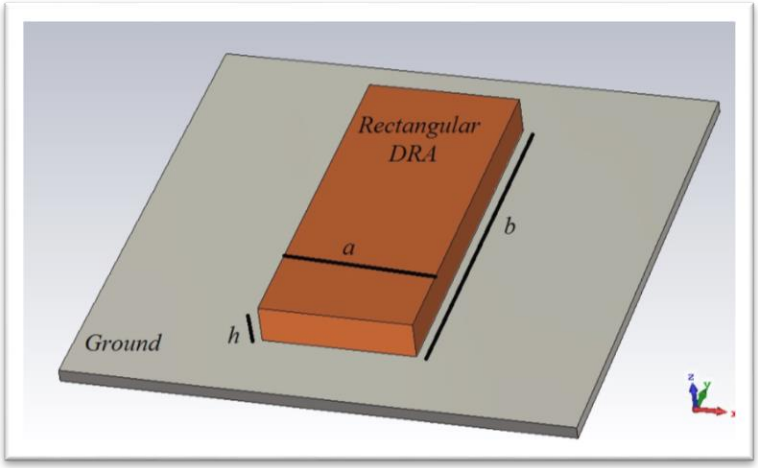

Fig. 2.9 Geometry of the rectangular DRA.

2.4.5 Resonant frequency

Any communication wireless application has a particular operating frequency; therefore, the designers should calculate the antenna resonant frequency and antenna bandwidth (frequency range of operation) before actually starting the antenna design process. The operation frequency and bandwidth are important parameters that have a significant impact on the antenna performance.

The antenna frequency response is defined as its input impedance over frequency [33]. The antenna is a circuit that has inductance and capacitance which are determined by its physical properties and its location environment. When the capacitance and inductance cancel each other, the antenna becomes pure resistance and said to be resonant. The input impedance Z_{in} is an important factor that determines the incident and reflected waves. Usually (Z_{in}) is kept as close to (Z_0) as possible to create matching state between the feeding and the antenna so the reflection coefficient (Γ) is zero, and the Voltage Standing Wave Ratio (VSWR) is 1, and the Return Loss (RL) of infinity [33].

$$\Gamma(\omega) = [Z_{in} - Z_0] / [Z_{in} + Z_0] \quad (2\text{-}2).$$

$$VSWR = V_{max}/V_{min} = (1+|\Gamma|) / (1-|\Gamma|) \quad (2\text{-}3).$$

$$RL = -20\ log|\Gamma|\ (dB) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2-4)}.$$

The effective length of any antenna determines its operating frequency. Usually, the first resonance frequency occurs at ½ λ, where λ is the wavelength at the operating frequency.

2.4.5.1 Stacked method

Stacking DRAs top one another is a method that is used in enhancing bandwidth in DRAs. With a single element DRA, it is not always easy to achieve the desired specifications, such as high gain, directional pattern, and wide bandwidth. The DRA that has suitable element matching and feed structure in these applications can be used in providing specifications that are desired. In the recent years, the stacked dielectric resonator antennas have been given more attention due to their many advantages. The radiation pattern of the dominant mode used in many probe feeding or slot fed configuration is based in broadside direction of the elements. The stacked technique is one of the high efficiency for enhancing bandwidth in the DRAs.

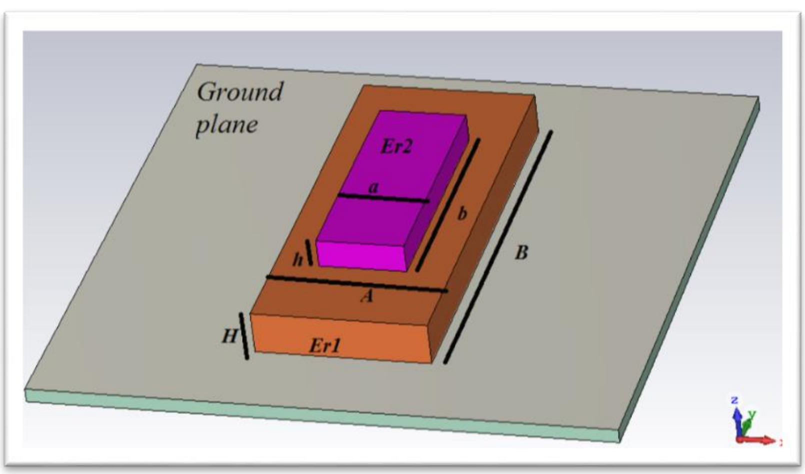

Fig. 2.10 Geometry of Stacked rectangular DRAs.

Fig. 2.10 explains a dielectric resonant antenna that is rectangular stacked. The stacked configuration of the DRA has two rectangular pieces made of different materials and dimensions vertically stacked, one over the other, and mounted on a grounded plane. A microstrip line feed is used to excite a lower DRA while the upper one coupled electromagnetically, with rectangular DRA possess length (a), width (b), height (h), and a relative dielectric permittivity (ε_r) [31].

It is also possible to introduce air gaps between the DRAs with the aim of enhancing the bandwidth. This method is associated with the disadvantage in that the geometry of the DRA does not have very low profile [31].

2.4.5.2 Coplanar parasitic method

In regards to the mechanical structures and fabrication, microstrip antennas are advantageous in that they have etching that is usable and a single process can be used to structure the feeding method and the antenna given an alignment that is of great accuracy. This advantage is given much appreciation in the array's configuration. A DRA should be sticky to hold the DR above the ground.

An array technique is another method that can be used in enhancing the input impedance bandwidth of DRA. The stack method leads that the increase to the total height of the antenna [31, 32], while some applications restrict the DRA design and the alternative method will be applied in enhancing the bandwidth of DRA known as a co-planner parasitic method where the same plane could also host the DRA. The center element here is excited through using any feeding mechanism whereas the neighboring elements are coupled electromagnetism. The major disadvantage here is the problem that becomes much pronounced in the array structure, with the individual alignment becoming increasingly critical. The deterioration can be caused by the possible misaligning the array elements in the antenna characteristic radiation. As a way of overcoming this problem, the suggestion was put forward that there is need to fabricate DRA using a single sheet where the area between the DRA has been perforated with a lattice of holes [32].

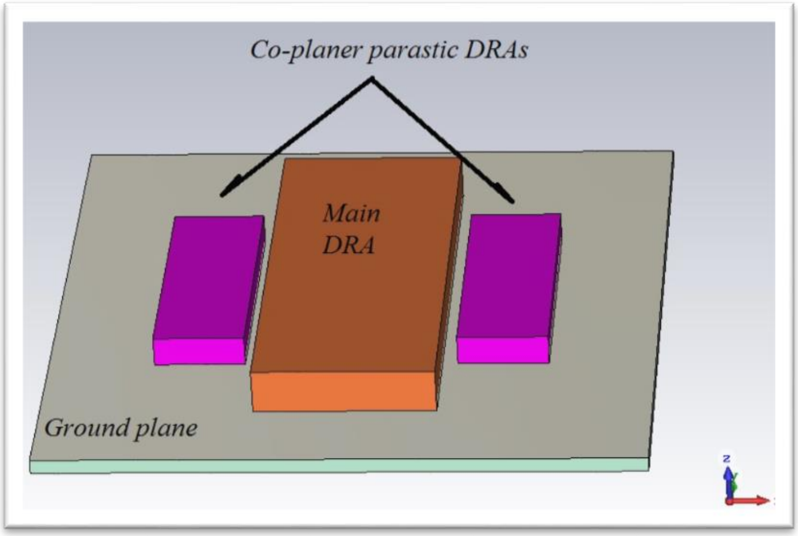

Fig. 2.11 Geometry of co-planar parasitic method.

A three width-band configuration of the DRAs has been pictured the above Fig. where there is a connection between the center DR and the microstrip feed line. The bottom and the above are ground and the substrate placed respectively, with the DR's appearing over the substrate material [31].

The stacked method is, however, more advantageous over co-planar method due to the following drawbacks faced by co-planar.

i. Comparing to a single feed stacked DR method, feeding process in co-planar is complex.

ii. DRA in co-planar needs much effort to align the DRA with the feeding structure.

iii. The requirements of the size are higher than the single substrate DR stacked method.

Considering the previous disadvantages, it is therefore recommended that Stacked Dielectric Resonators Bandwidth Enhancement must be given priority over co-planar.

2.4.5.3 Embedded method

The embedded technique can be used to enhance the bandwidth DRA where DRAs can also be embedded inside one another [31]. Despite its comparison with the stacked method, the co-planar parasitic method has a few shortcomings, such as the use of multiple dielectric constant DRAs, complicate this method as compared to the single dielectric consonant stacked method. Furthermore, the placement of the dielectric resonator of embedded is less flexible when compared to the stacked method. The above shortcomings make the stacked dielectric resonators preferable in term of bandwidth enhancement at millimeter-wave frequencies.

2.5 Dielectric resonator antenna performance

It is the required specifications which are directly related to antenna's application that determines its performance. These applications include frequency of operation, radiation pattern, gain and efficiency, beam-width (main lobes), minor lobes, radiation resistance and overall efficiency, input impedance, bandwidth and polarization (linearly elliptically or circularly)[34]. Besides, features that must be factored include size, structure, feed mechanism, conductors, insulators and weather protection [34].

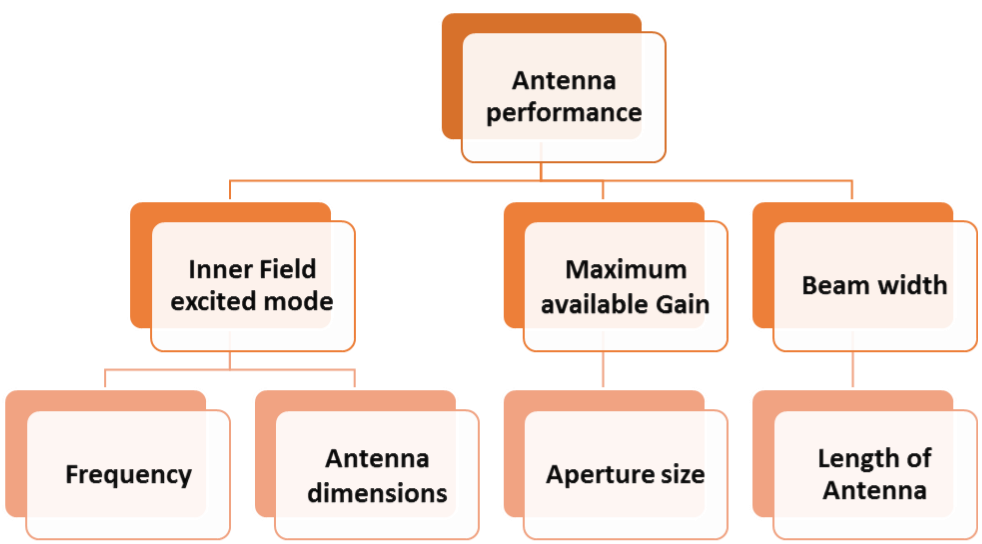

Fig. 2.12 Antenna characteristics that determine its performance [5].

The performance of the DRA involves a high efficiency, wide bandwidth, no excitation of surface waves, efficiency of high radiation, loss of low dissipation, zero inherent loss of conduction together with consistent radiation pattern, the capability of high power and a rate of high speed, as indicated in the Fig. 2.12.

2.5.1 Radiation Q factor

Some electronic devices have their operations based on resonance principles like resonators, filters, dielectric resonators, and dielectric resonator antennas [35]. The storage and release of the energy typify the resonance principle basis. It is during the object vibration/oscillation when receiving energy from an outside source when the resonance is observed. The type of the energy that is causing an object to oscillate is a function of the object nature with the tendency of freeing the energy that is being received. The relationship describing the release of energy from the object is known as the quality factor represented as Q.

In the device that is designed specifically for resonating or oscillating is assign a given value of Q factor. It is the Q factor that describes the amount of energy that is stored and that relates to the amount of energy emitted. Devices that have a high Q factor emit a little amount of energy, with a lower Q factor releasing much energy. As the Q factor decreases, the energy emitted multiplies.

$$Q = \frac{\sqrt{VSWR}-1}{VSWR\ (BW)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2-5) [36].}$$

The equation above can act as a good definition of Q factor in terms of the VSWR like VSWR ≤ 2.00, with the bandwidth being (BW). It is clear in this relationship that an increase in BW decreases the value of Q.

2.5.2 Radiation pattern

It is the radiation pattern that describes the signal that is radiated in the form of an electromagnetic field while the antenna gain is defined as a mathematical concept that describes the amount of energy radiated in a specific direction and it is also known as the main lobe as Fig. 2.13 indicates.

The part that best receives and transmits the electromagnetic signal measured on an angular scale is the antenna beam. The minor lobes which include side lobes and back lobes explain the amount of the electromagnetic signal radiated in various direction and propagated with levels that are less as compared to the main lobe [34].

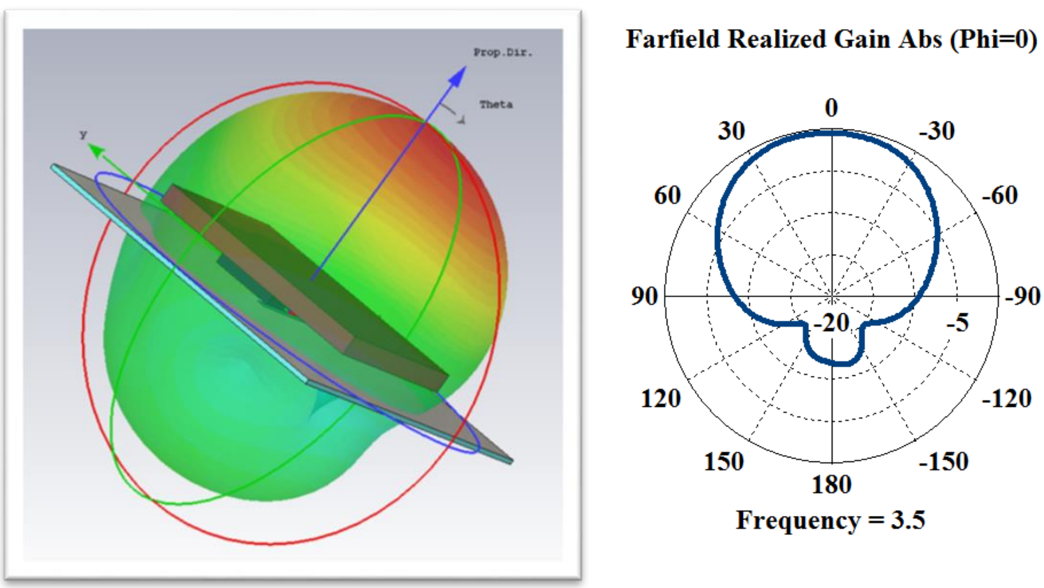

Fig. 2.13 Radiation pattern in 3D and 2D representation.

Radiation efficiency and input impedance are mathematical ideas that regard the signal transition among the -3 dB points, while the bandwidth is the desired frequency range over which the antenna will operate with satisfaction. Moreover, the antenna polarization describes the radiation of the antenna like shape and wave orientation according to its frequency operation [37].

A natural broad radiation pattern without introducing any performance enhancement is a characteristic that makes the DRA is classified as a low-gain antenna [16]. The radiation pattern is influenced by two components namely, the electric field (E) and the magnetic field (H). The E-field is oriented in elevation and the H-field has azimuth orientation [38, 39].

Research reported that a DRA possesses omnidirectional characteristics in the E-field and quasi-omnidirectional in the H component with half-power beam [38].

The cross polarization is one factor that affects radiation pattern and its introduction makes it possible to obtain an improvement in the radiation pattern. Research has shown that when a strip is used in place of feeding mechanism, the level of cross-polarization will decrease, improving the co-polarization radiation pattern [40]. Other shapes and exciting different modes for that shape can be used in changing the radiation pattern, hence, coming up with various types of radiation pattern since every mode will create a new kind of radiation pattern. A gap in the DRA design is therefore revealed to be having no effect on the radiation pattern [41]. Adding the effect of two different modes which are excited in the DRA helps in constructing the radiation pattern [41].

When an antenna design that is composed by a slot and a DRA is used to study the effect of the ground plane in the radiation pattern, the region of the radiation pattern that corresponds to the slot, there is much dramatically effect as a result of changes in the size of the ground plane, as compared to the part of radiation pattern that relates to the DRA [42]. The report revealed that the modification of the radiation pattern is done by making alterations in the slot, more so modification of the slot position and its shape [12]. According to the report, there is a reduced back radiation pattern of DRA when it is placed under the antenna ground plane which can also be referred to as the radial quarter-wavelength metallic annular disc [43]. The same report has also discussed that radiation relies on the mode of excitation together with the level of cross polarization increasing at higher frequencies [26].

The excitation of the $TM01^{\delta}$ mode within the DRA helps in obtaining an omnidirectional radiation pattern with ease [43], whose application in the WLAN mobile communication to be appropriate [44].

2.5.3 Input impedance and Bandwidth

The input impedance (Z_{in}) is defined as the impedance at the input of the antenna. It is also the ratio of the voltage and current at its terminal with no load connected [10]. The input impedance of an antenna is (r ± xj), and the antenna is said to be resonant if it has real input impedance. In other words, the antenna at the resonant frequency is seen as a resistance, while at other frequencies it is seen as a capacitive or inductive. In some cases, the incident waves that travel from the generator to the antenna, facing mismatching impedance creates some power reflection, which is propagating in the opposite direction.

This reflected value is determined by measuring the ratio between the incident and reflected waves, which is known as the Voltage Standing Wave Ratio (VSWR). If the VSWR = 1:1, which does not happen in practice, that means all incident waves are propagated by the antenna and no reflected waves. The accepted value of VSWR is a subjective value, which means it depends on the system. Some systems accept a VSWR value of 1.5:1 while the accepted standard value is 2:1. The characteristic impedance of the transmission line (Z_0) is usually 50Ω.

RF & MW testing and measuring equipment use this reference impedance. To ensure the maximum power transfer, increase the signal to noise ratio, and reduce the source power, the input impedance should be kept as close as possible to the characteristic impedance. If there is an impedance mismatch between the antenna and the transmission line, a part of the transmitted power will be reflected, which might damage the transmitter or the transmission line. Therefore, a matching network circuit has to be designed and connected between the transmission line and the antenna to compensate the mismatching state. A matching network could be a lumped element circuit when the operating frequency is less than 500 MHz, or a distributed element circuit for higher frequencies, more than 500 MHz.

The bandwidth of the antenna is described as the range of frequencies where the antenna shows the best performance. It is defined in the terms of its frequency limits like the lower and the higher frequencies. The BW attained and the DRA design boundaries are represented by the limit frequencies. It is in a relationship with the associated S_{11} like $|S_{11}| \leq -10$ dB that the lower and higher frequencies are chosen. The bandwidth is therefore defined in terms of the lower/higher and central frequencies such as f_1, f_2, and f_c respectively as equations (2-6) and (2-7).

$$BW = \frac{f2-f1}{fc} \quad \text{.....................................} \; (2\text{-}6).$$

$$fc = \frac{f2-f1}{2} \quad \text{.....................................} \; (2\text{-}7).$$

It is possible that the methods that are used in the assembling processes like the use of adhesive, environment, measurement equipment, and fabrication process can affect the characteristics of low frequency. The adhesive contains a dielectric constant that is capable of influencing the antenna in the electric field. In the case where the adhesive layer contains a different dielectric constant from that of DRA, the operation frequency can be modified up or down. Moreover, the influence of other radiation in the surrounding and the application of measuring equipment that is incorrectly calibrated can degrade the antenna performance.

2.5.4 Directivity and gain

The directivity can be described as the ratio between the radiated power of the antenna in the direction (θ, φ) to the total radiated power in all directions. In other words, the directivity is the ratio of the intensity of the radiation in a given direction to the intensity of the radiation of the reference antenna. The maximum directivity is the ability of the antenna to focus its radiated power in a given direction [46] and it is not affected by the loss of the antenna. The directivity of the isotropic antenna is unity (0 dB). The antenna directivity can be calculated by using the following formula:

$$D = \frac{4\,\pi\,Umax}{Prad} = \frac{4\,\pi\,Umax}{\int\int\; U(\theta,\emptyset)\,sin\theta\;d\theta\;d\emptyset} \text{ ………………………… (2-8).}$$

The antenna directivity has an inverse relationship with the beamwidth. Therefore, directional antennas that have less beamwidth are more directive

The gain of each RF component is the ratio between the input and output power. The antenna gain in a direction (θ, φ) is the ratio of radiated power in (θ, φ) direction to the total power. In other words, the gain is the ratio of the output power radiated by an antenna in a specific direction to the accepted power of a reference antenna. It does not include losses arising from impedance or polarization mismatching; therefore, it measures the performance of the antenna.

$$G = 4\pi\frac{radiation\;intensity}{total\;input\;accepted\;power} = 4\pi\frac{U(\theta,\emptyset)}{Pin} \text{ .... (2-9).}$$

It is important that not to be confused between the directivity and gain as in the reference used in directivity is total radiated power while in gain is the antenna total input power (accepted from the source). The gain is usually less than the directivity, it also could be equal directivity when the efficiency of the antenna is 100%.

$$G = e_{rad}\,.\,D \qquad \text{………………………… (2-10).}$$

We mostly transact with relative gain which is described as the ratio of power gain in a certain direction to the power to the reference antenna gain. It is required that the power input be equal in both antennas where the reference antenna always a horn, dipole or any other type of antennas with known gain. The reference antenna is, however, lossless isotropic in many cases, thus, the equation presented as

$$G = \frac{4\pi \cup(\theta,\emptyset)}{Pin\ (lossless\ isotropic\ source)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ \text{(2-11).}$$

Whenever a clear direction not stated, then the power gain will naturally follow the maximum radiation direction.

CHAPTER THREE: DESIGN OF NEW ULTRA-WIDEBAND DIELECTRIC RESONATOR ANTENNA

This chapter presents a bandwidth enhancement of an aperture coupled stacked dielectric resonator antenna using different position perturbations. The performance of the proposed antenna is compared with the conventional antenna designed without perturbations. The proposed antenna provides not only an ultra-wide matching bandwidth of 5:1 (covering entire C-band to X-Band) but also a higher gain of 9 dBi, which is 2 dBi more than the antenna designed with conventional methods.

3.1 Introduction

In communication systems, the dielectric resonator has more advantages than the microstrip antennas. Some of these advantages are a low loss, particularly at higher frequencies, and a wider bandwidth. The antenna properties of dielectric resonators were discovered by Long and Shen in 1983. By systematic analysis using the mode-merging technique, Young and Long have improved the bandwidth of DRA by varying geometrical parameters [46].

The bandwidth enhancement of the DRA can be achieved using multi-layers with different permittivity. This improved bandwidth of DRAs can increase the communication channels, where a single antenna can cover a large band, which provides a low cost of fabrication. In 1995, a stacked annular ring dielectric resonator (DR) antenna composed of commercially available dielectric resonators and excited by the axis-symmetric coaxial probe was studied computationally using the finite-difference-time-domain (FDTD) method [47]. The DRA bandwidth can also be improved by decreasing the Q factor of the excited DRA by stacking, a compact T-shaped DRA has been provided in 2006 [48]. By placing the dielectric layer of low permittivity below that of a high permittivity, an antenna with a low profile and wider impedance bandwidth has been designed [49]. A hybrid Z-shaped DRA design has been provided with (3.56 GHz-13.1

GHz) bandwidth [50], which is less than the bandwidth obtained from the proposed design.

This work presents a dielectric resonator antenna with ultra-wideband (UWB) characteristics by Position Perturbation in Stacked Dielectric Resonator. The proposed antenna is designed by improving an aperture coupled stacked DRA with the conventional method.

3.2 Ultra-wideband dielectric resonator antennas (two layers of DRs)

An ultra-wideband (UWB) technology was approved by the US Federal Communications Commission to allow an unlicensed band that covers 3.1-10.6 GHz for systems to be able to transmit and receive signals at a very high rate known as nano-seconds by using a very short energy pulse. This new technology has therefore attracted the attention of many researchers alongside engineers because it has wireless characteristics that have a lot of advantages in the UWB world of communication systems like a high-speed rate of data, high precision, lower cost, and lower complexity. A function of the shape and size of the ground plane is the bandwidth and radiation pattern of a UBD.

3.2.1 Aperture Coupled Stacked DRA with Conventional Method (with no offset)

Seeing the effectiveness of the proposed technique requires that the conventional aperture coupled without perturbations is used in designing an antenna, as shown in the figure below. There are two resonators in the stacked DRA; namely, D2 (larger size) and D1 (smaller size) that also consist of a relative permittivity of 6.15 and 9.8, respectively. A microstrip line feeds the antenna a rectangular made of GND coupling the energy to the radiator. Roger 5880 LZ substrate with permittivity of 1.96, and a thickness of 1.27 mm. is used in printing both TL and the aperture antenna. Various dimensions are used in the design, as shown in Fig. 3.1.

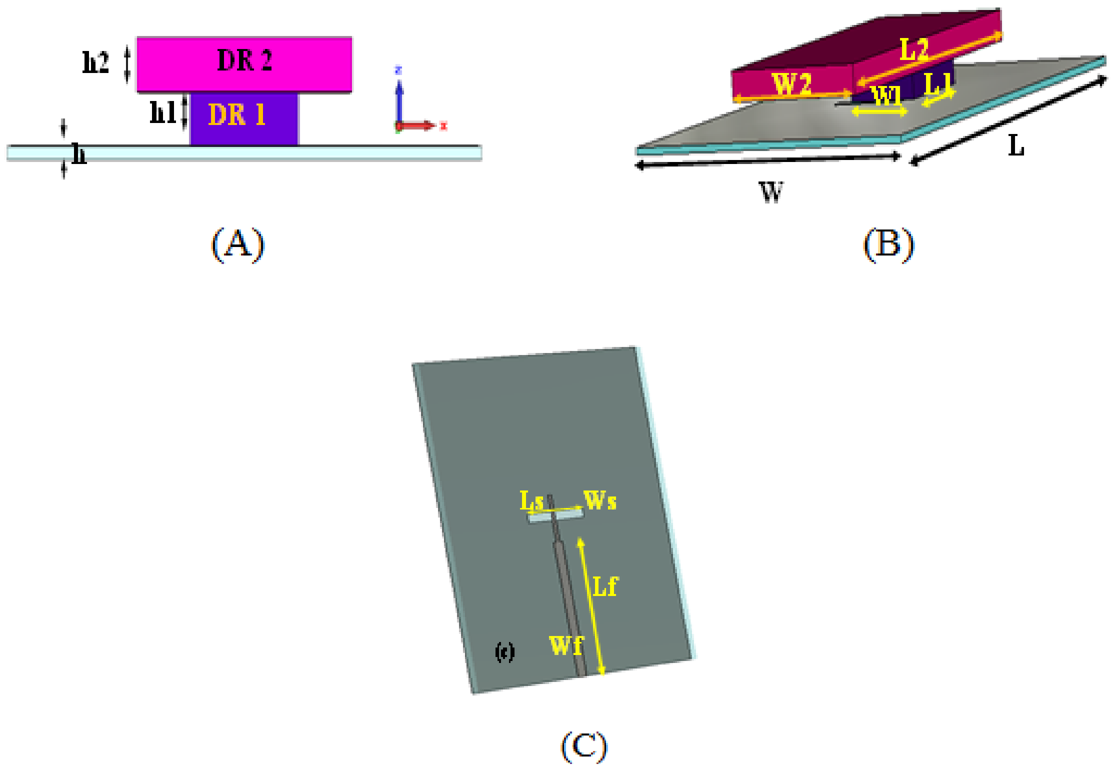

Fig. 3.1 The basic structure of an aperture coupled stacked DRA,

(a) side view, (b) a perspective view, (c) back view.

Table 3.1 shows the value of antenna parameters.

Table 3.1 The dimensions of the proposed antenna.

Parameter	**W**	**L**	**W1**	**L1**	**W2**	**L2**
Value (mm)	108	90	25	18	49.5	65
Parameter	**Wf**	**Lf**	**Ws**	**Ls**	**h**	**h1=h2**
Value (mm)	4.25	37	27	2.43	1.27	5.08

3.2.2 Proposed Aperture Coupled DRA with Improved Performance

This section illustrates how the proposed perturbation technique enhances the bandwidth of the conventional antenna. The effect of location offset and the rotation are considered in the perturbation. This perturbation technique is implemented in different steps and labeled “S_1 to S_6” as:

(1) TL shifted along X-axis 4 mm (S_1).

(2) D_1 4 mm offset along X-axis (S_2).

(3) The D_1 offset of 10 mm along Y-axis from its last position (S_3).

(4) D_1 clockwise rotation of 25 degrees (S_4).

(5) D_2 clockwise rotation of 25 degrees (S_5).

(6) Both D1&D2 clockwise rotation of 25 degrees (S_6).

The effect of the proposed technique on the antenna performance is discussed in Section 3.2.4.

3.2.3 Parametric study

The position of the small dielectric resonator has a big influence on the matching bandwidth as well as the dimensions of DR2 because it controls the physical length of the driven element. Therefore, the position of the DR1, as well as the length and width of the DR2, are precisely chosen to accomplish the required bandwidth.

Several parametric studies were carried out to determine the perfect position of the DR_1 and the dimensions of the DR_2, as shown in Figs. 3.2, 3.3, and 3.4, respectively. It can be observed that when the DR1 is shifted 4 mm along X-axis (xx), the proposed antenna bandwidth becomes continued. On the other hand, the proposed antenna has the best bandwidth when the length (dl_2) and width (dw_2) of DR2 are 65 *mm*, 50 *mm*, respectively.

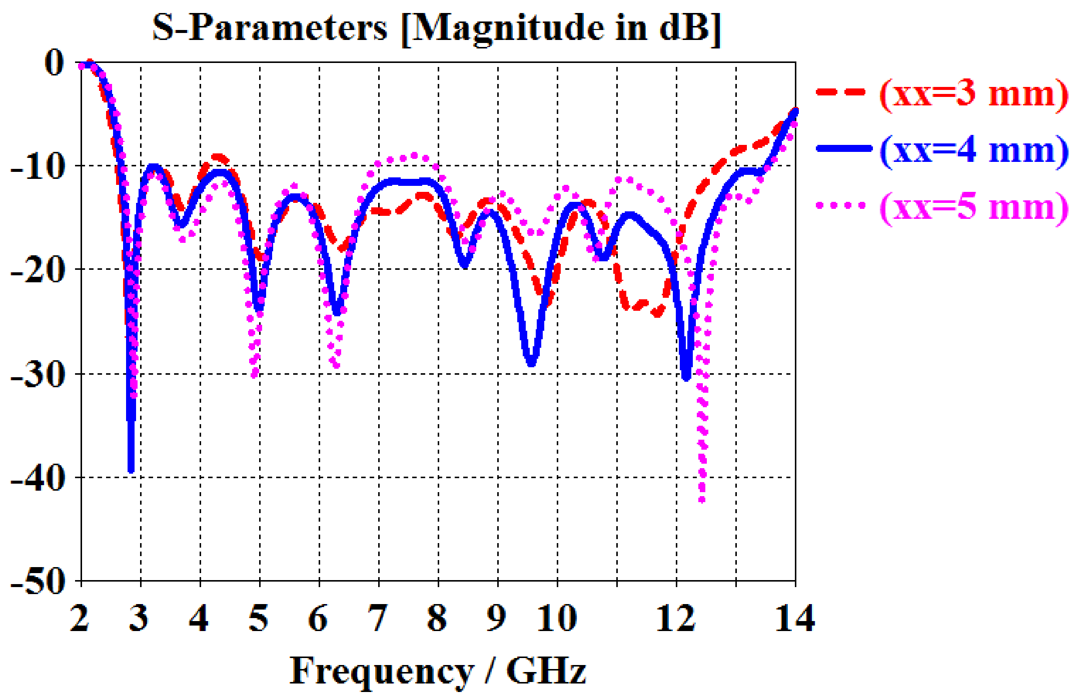

Fig. 3.2 The effect of DR_1 shifting along X-axis (xx).

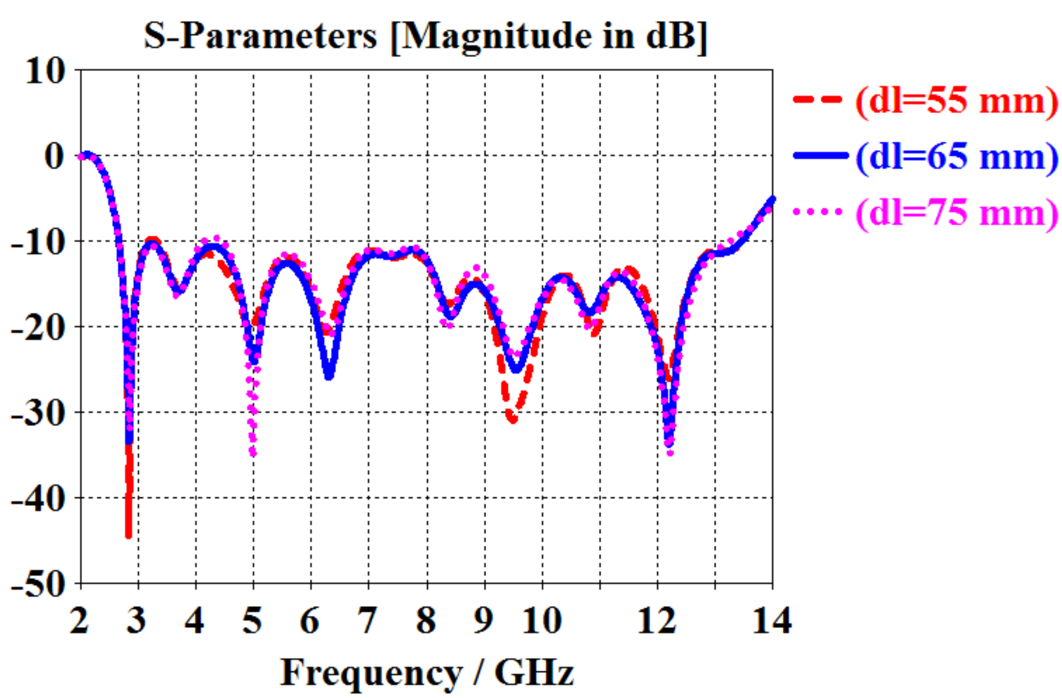

Fig. 3.3 The effect of the length of DR_2.

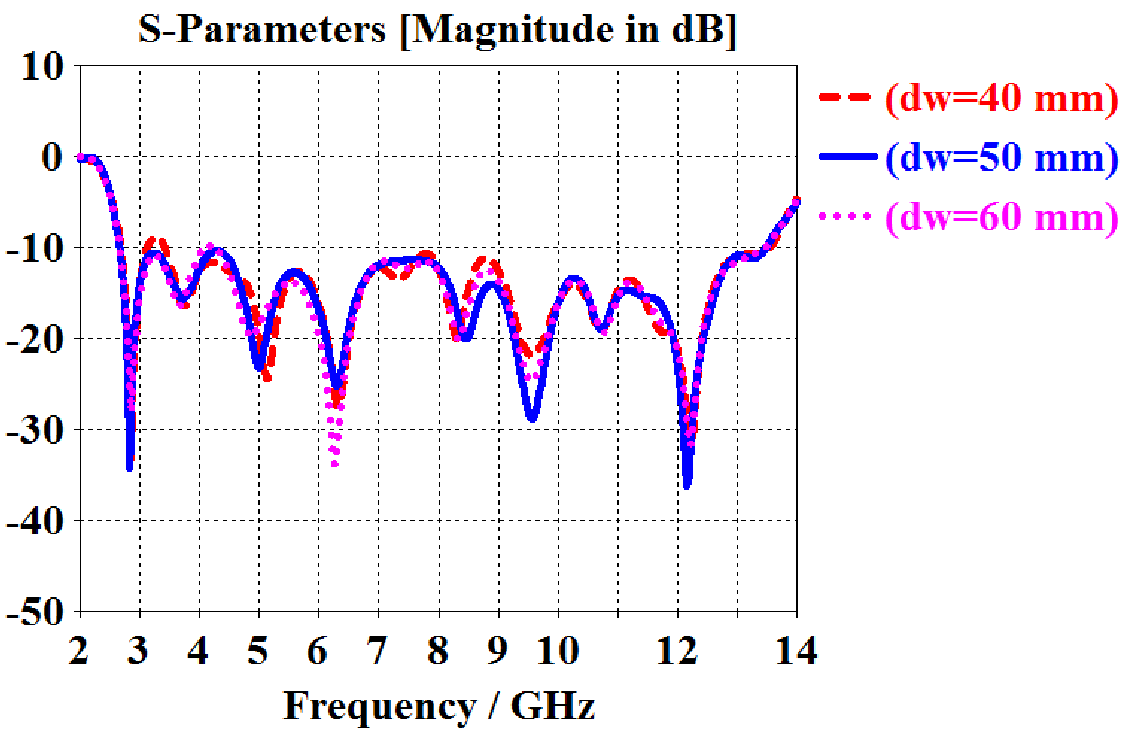

Fig. 3.4 The effect of the width of DR_2.

3.2.4 Simulation results and discussion

The performance of the conventional antenna is analyzed in terms of the reflection coefficient, realized gain, and the radiation pattern in both E-and H-planes. Figs. (3.5, 3.6, 3.7 and 3.8) show the performance of a stacked DRA antenna designed with the conventional aperture coupled method without perturbation (referenced performance). It is clear from these results shown in Fig. 3.2 that in both LOS and SOL environment of the resonators, the accumulative matching bandwidth is less than 2 GHz in the whole band, while the average gain almost remains between 7 to 8 dBi.

Fig. 3.6 shows the simulation results of the conventional antenna frequency vs gain.

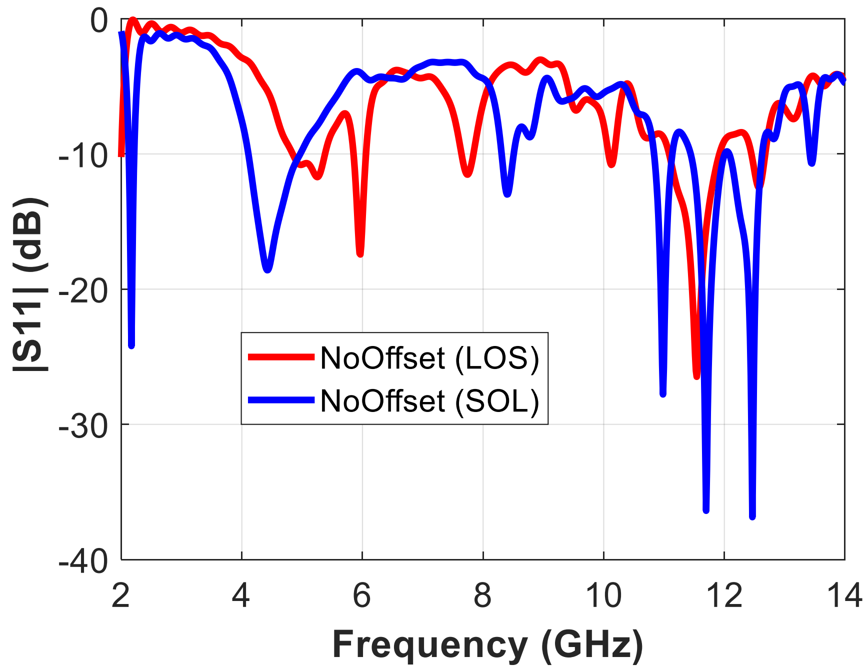

Fig. 3.5 The simulation results of the conventional antenna, frequency vs. reflection coefficient magnitude.

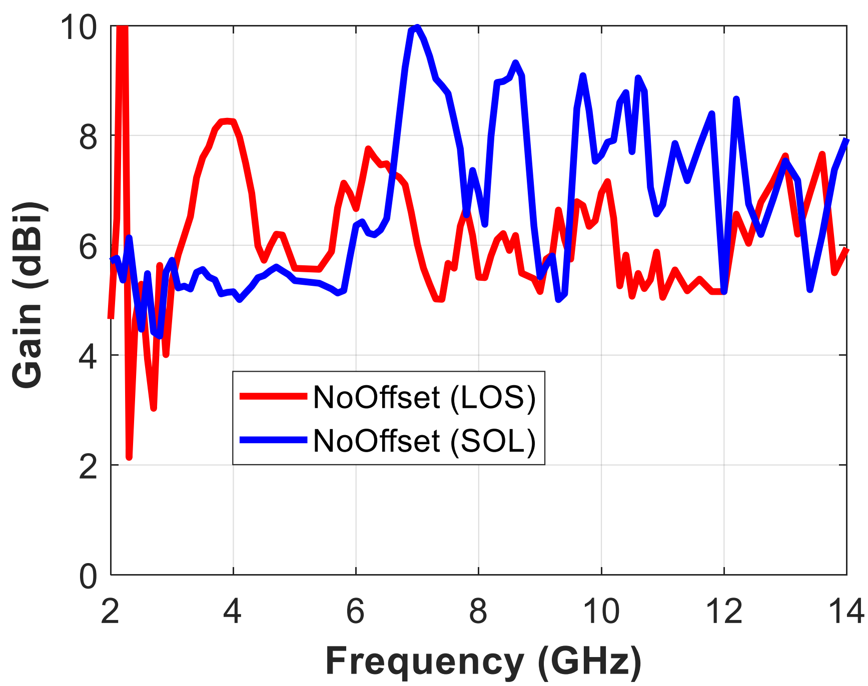

Fig. 3.6 The simulation results of the conventional antenna, frequency vs. gain.

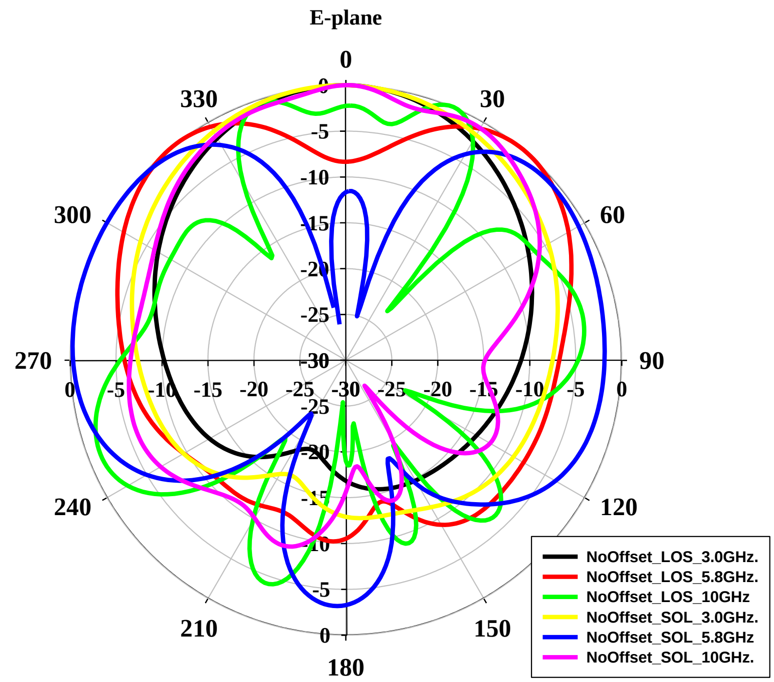

Fig. 3.7 The simulation results of the conventional antenna E-plane radiation patterns vs. frequency.

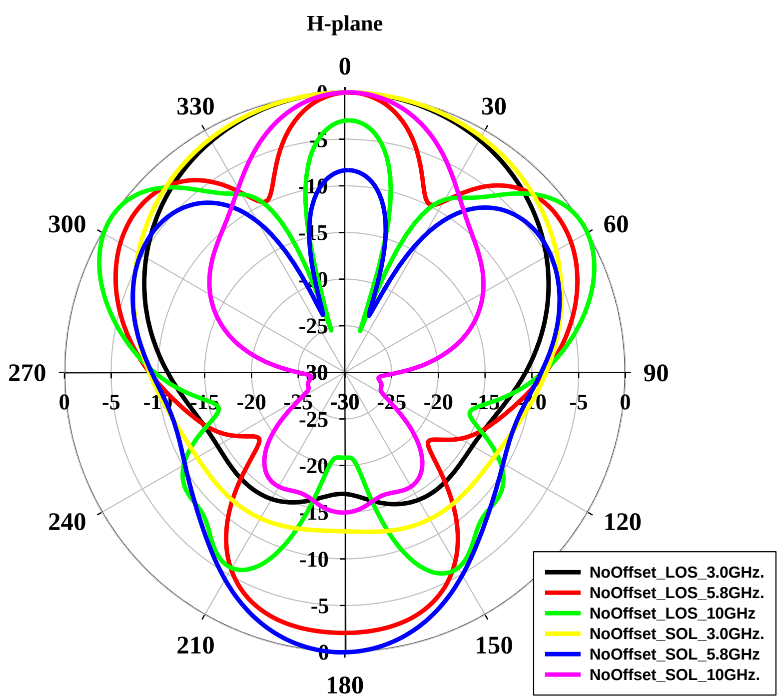

Fig. 3.8 The simulation results of the conventional antenna H-plane radiation patterns vs. frequency.

Figs. 3.7 and 3.8 show the radiation patterns in both E- and H-planes at different frequencies (3.0 GHz, 5.8 GHz, and 10.0 GHz), respectively, which exhibit that the antenna radiation is good at the lower frequency, while as the frequency increases, the radiation is heading for the worst. The pattern degrades in both E- and H- planes.

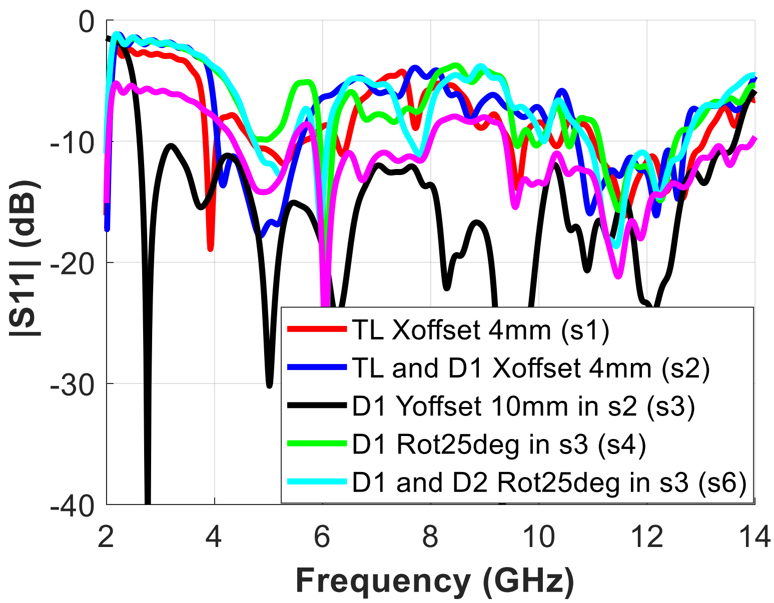

Fig. 3.9 The simulation results of the proposed antenna with Perturbations, frequency vs. reflection coefficient magnitude.

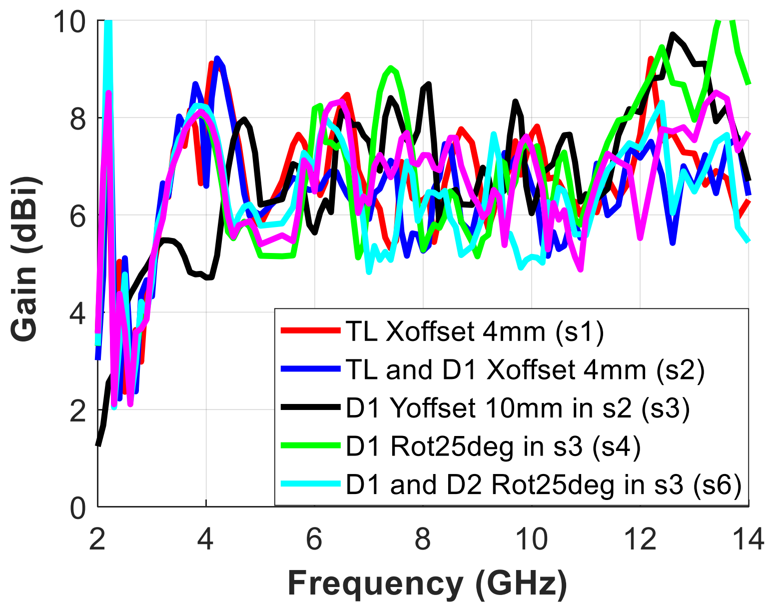

Fig. 3.10 The simulation results of the proposed antenna with perturbations vs. frequency for gain.

Similarly, Figs. (3.9, 3.10, 3.11 and 3.12) show the performance of the proposed antenna in terms of same steps discussed in Section (2). It is clear from these results that using the proposed perturbation technique results in more than 5:1 matching bandwidth ratio, while the highest gain is 9 dBi, the average gain remains little higher than the conventional case. The radiation pattern in both E- and H-planes are improved as shown in Figs. 3.11 and 3.12 show.

To reduce a crowdedness of curves in the radiation patterns, the radiation patterns at 3 GHz is shown in both planes. The performance of the proposed antenna versus the conventional is summarized in Table 3.2.

Table 3.2 Performance Comparison between two cases, conventional stacked DRA, and the proposed stacked DRA.

	Techniques	$\lvert S_{11}\rvert$ Avg. BW	Max. Gain
Proposed	Perturbations (with offsets and rotations)	2.7-13.6 GHz	9 dBi
Conventional	No perturbations (without offset and rotations)	<2 GHz	7 dBi

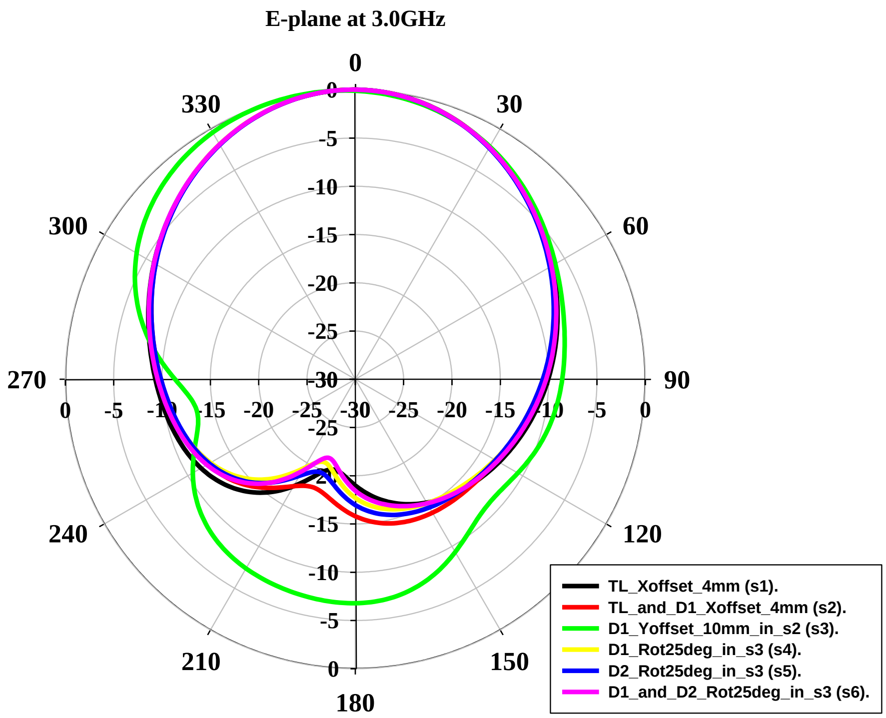

Fig. 3.11 The simulation results of the proposed antenna with perturbations for E-plane radiation patterns at 3 GHz.

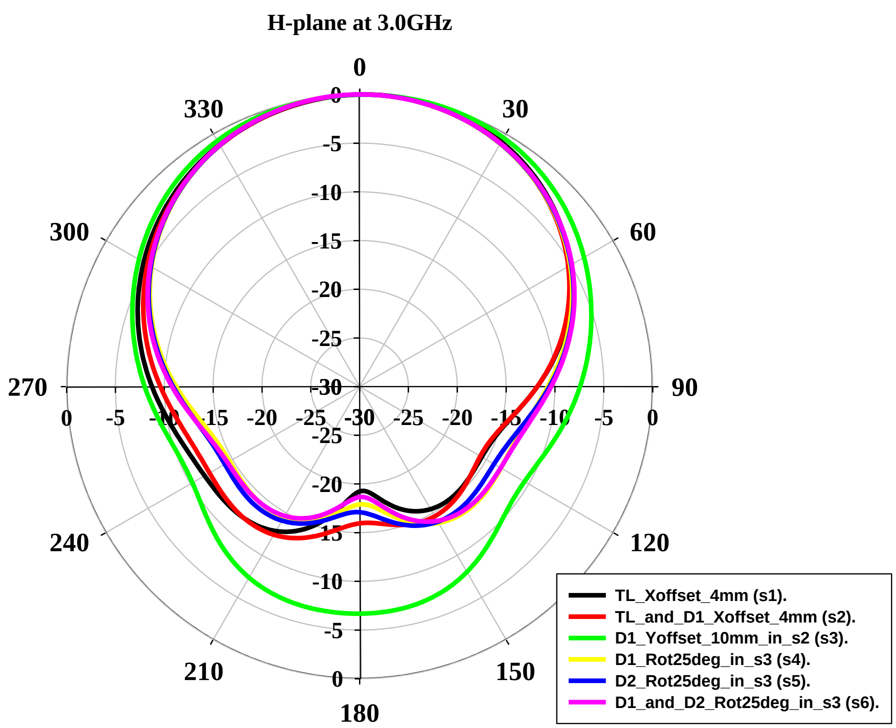

Fig. 3.12 The simulation results of the proposed antenna with perturbations for H-plane radiation patterns at 3 GHz.

3.3 Aperture Coupled Stacked DRA (three layers of DRs)

3.3.1 Structure and design

In this design, a stacked square of three dielectric resonators is used. All three dielectric resonators (d_1, d_2, and d_3) are stacked vertically, which have a permittivity of 12.85, 9.8, and 6.15, respectively. The big top resonator has an edge length (d_1) of 62 *mm* with higher of 2.54 *mm*. The middle resonator has an edge length (d_2) of 48 *mm* with higher of 2.54 *mm*, while the bottom small resonator has an edge length (d_3) of 19 *mm* with higher of 5 *mm*. The substrate of this design has the same dimensions of the design in Section 3.3.1, which is illustrated in Table 3.1.

To obtain a wide continue bandwidth, the stacked dielectric resonators are shifted tow times, the first one is along X-axis by 4.5 *mm*, and the second move is along Y-axis by 10.7 *mm*. Fig. 3.13 shows the structure in both front and side views of the designed antenna.

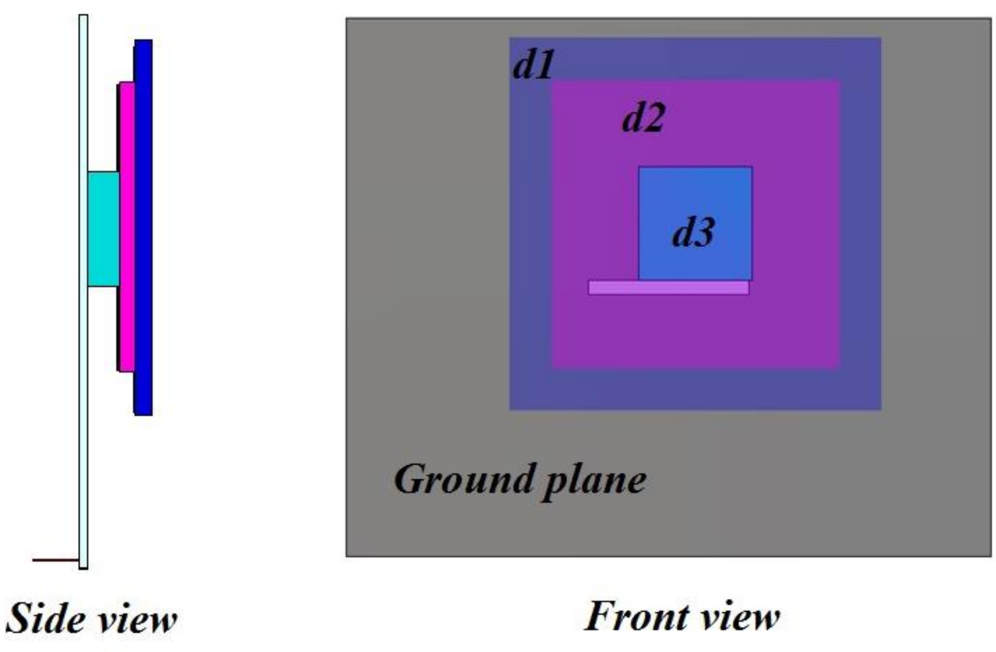

Fig. 3.13 The structure of the three layers stacked DRA.

3.3.2 Simulation results and discussion

As can be observed in Fig. 3.14, the antenna has a matching bandwidth of 2.66 GHz to 13.6 GHz, which is the same ultra-wide band of the antenna designed in Section 3.2.2.

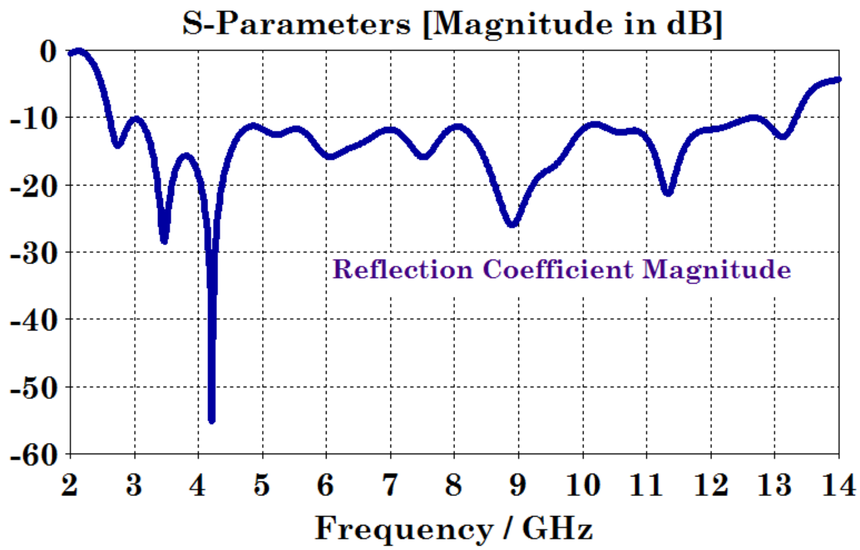

Fig. 3.14 S_{11} vs. frequency of the three layers stacked DRA.

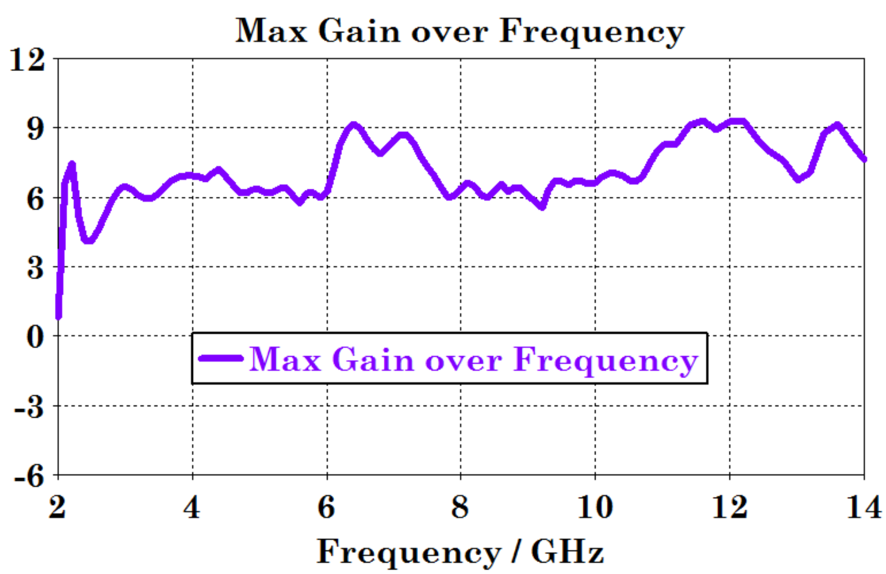

Fig. 3.15 Gain vs. frequency of the three layers stacked DRA.

Fig. 3.16 shows the radiation pattern in both E- and H-planes at different frequencies (3.5 GHz, 5.4 GHz, and 10.0 GHz), respectively, which exhibit that the antenna radiation is good at the lower frequency, while as the frequency increases, the radiation is heading for the worst. The pattern degrades in both E- and H- planes.

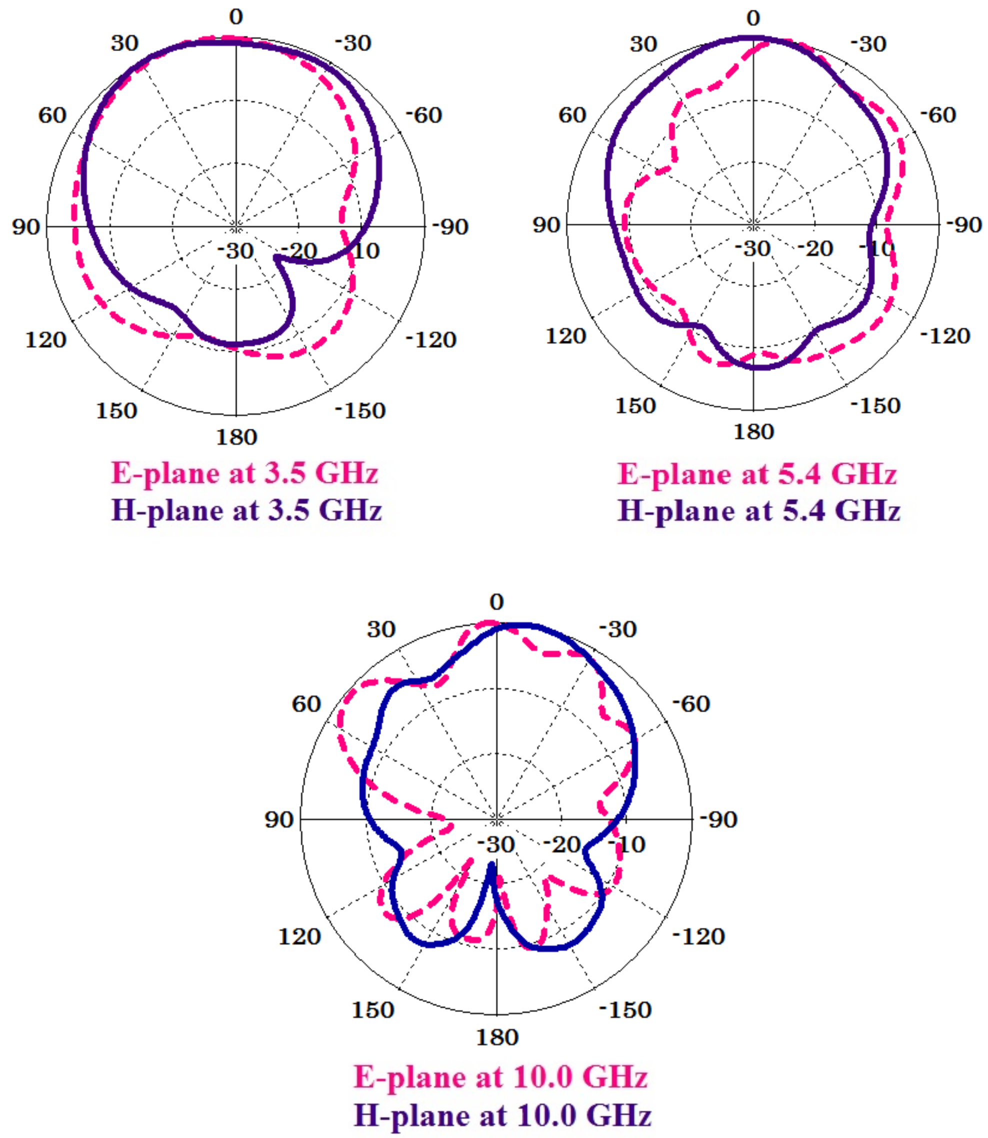

Fig. 3.16 The radiation pattern for E and H-plane of the proposed antenna at frequencies 3.5, 5.4, and 10.0 GHz.

3.4 Aperture Coupled Stacked DRA

3.4.1 Antenna fabrication

In this part of the thesis, the proposed antenna case (S_3) in Section 3.2.2 is chosen to be fabricated due to the best results in all other cases. As mentioned earlier, the case (S_3) can be obtained starting from the conventional case by shifting the transmission line feeding 4 mm along X-axis, offset the small bottom dielectric 4 mm along X-axis, and then 10 mm along Y-axis.

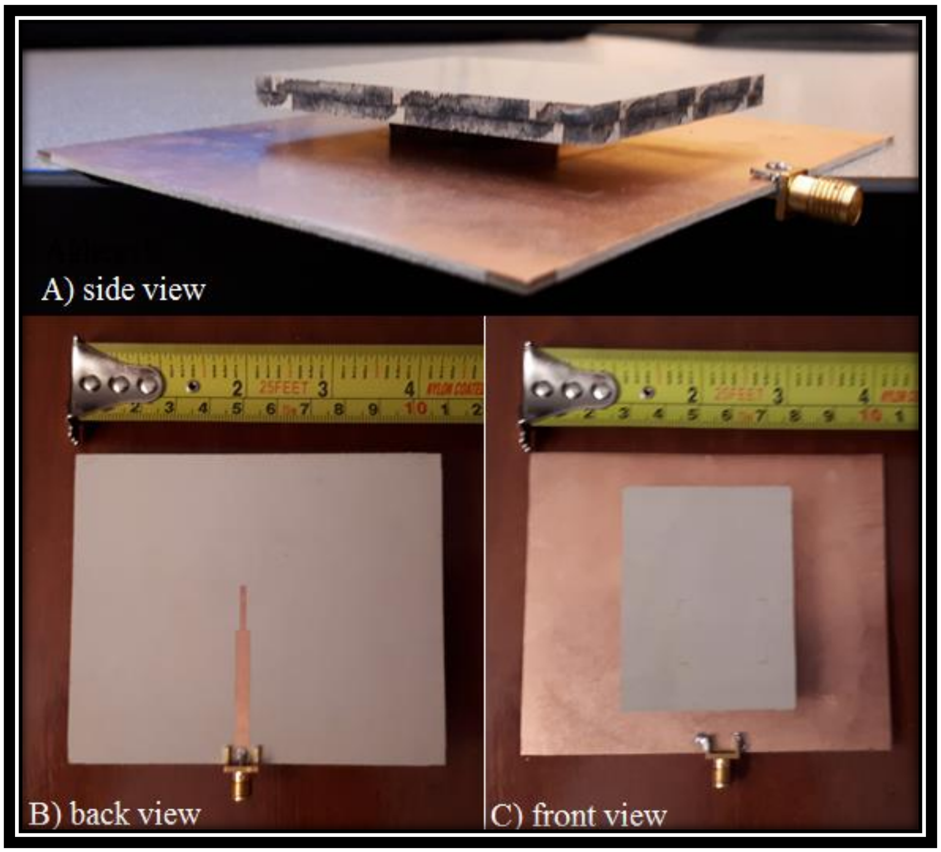

Fig. 3.17 Fabricated Antenna.

Fig. 3.17 shows the proposed fabricated antenna in three different positions, front, back, and side views, while Fig. 3.18 shows the antenna under test. The antenna is tested and measured in RF. laboratory (INRS). The network analyzer used to measure reflection coefficient is illustrated in Fig. (3.19).

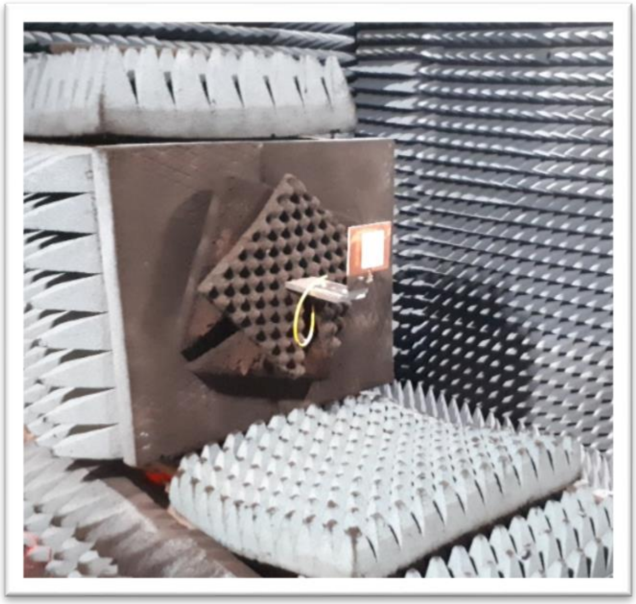

Fig. 3.18 The antenna under test in the measurement room.

Fig. 3.19 Network Analyzer Agilent 8722ES.

3.3.2 Simulation and measured results.

Experimental measurements result on the fabricated prototype were carried out, the measured results are presented and compared to the simulation ones. According to the graphs, the measured results are in a good agreement with the simulated results. Figs. (3.20, 3.21, 3.22, and 3.23) illustrate that the reflection coefficient, the gain, and the radiation pattern. The minor difference between the measured and simulated results could be due to fabrication inaccuracy or measurement errors, whether they are human errors or devices errors.

As illustrated in Fig. 3.20, there is a good agreement between simulation and measured result in terms of match bandwidth, just a slight difference appearance which can be neglected.

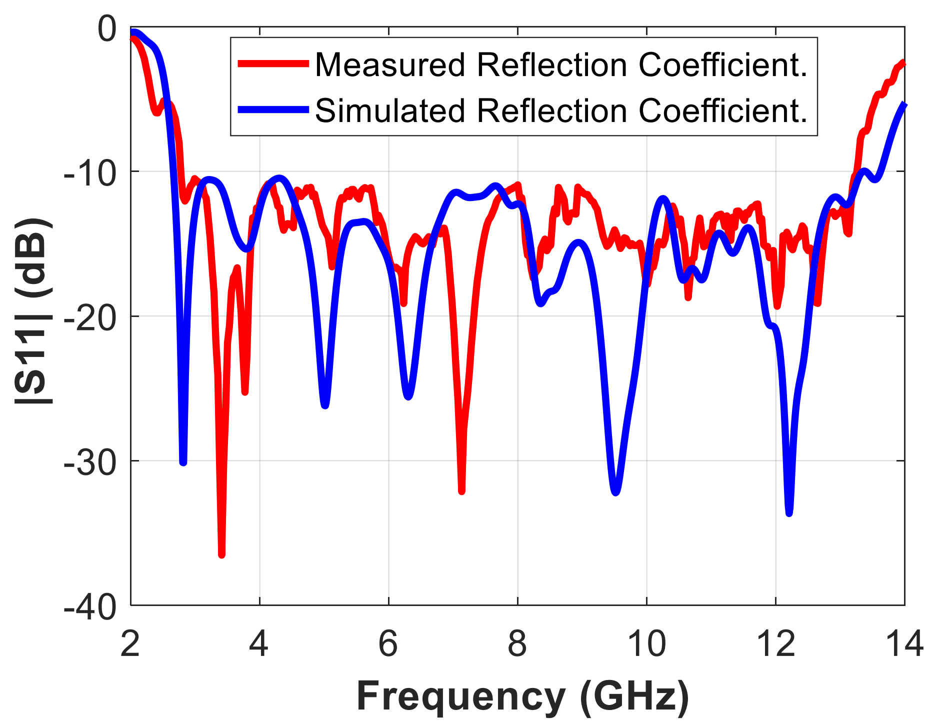

Fig. 3.20 Amplitude of reflection coefficient of the proposed antenna.

The proposed antenna propagates in the Z direction. There are three different simulated and measured radiation patterns of the proposed antenna at 3.5GHz, 5.0 GHz, and 10.0 GHz are plotted in Figs 3.21, 3.22, and 3.23, respectively. The radiation pattern results in H- plane indicate that the antenna radiates in the directional pattern and omnidirectional behavior in the E- plane. The Figs. show a reasonable agreement between the simulations and measurements results.

According to the measured result illustrated in Fig. 3.24, the proposed antenna has its best performance at which its maximum measured achieved gain values are 8.3 dB, and 9.6 dB at 6.6 GHz, and 12.6 GHz, respectively. The proposed antenna provides more than 87% efficiency. Both measured and simulation results conclude that this antenna has better performance at low frequencies.

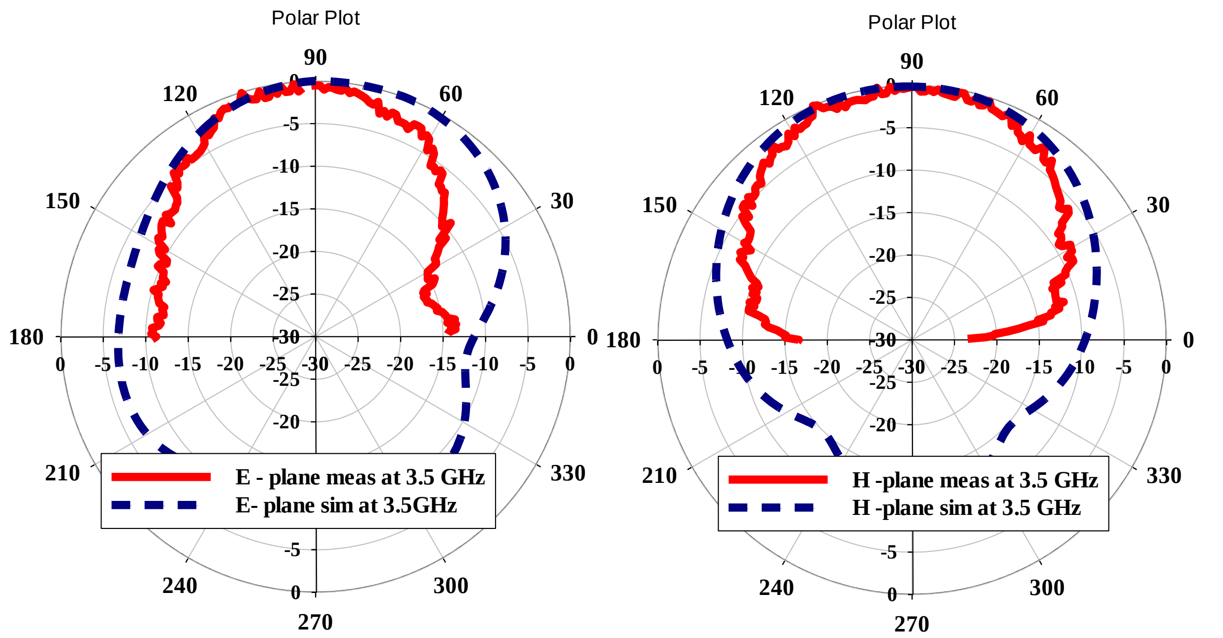

Fig. 3.21 Normalized radiation pattern of the proposed antenna at 3.5 GHz.

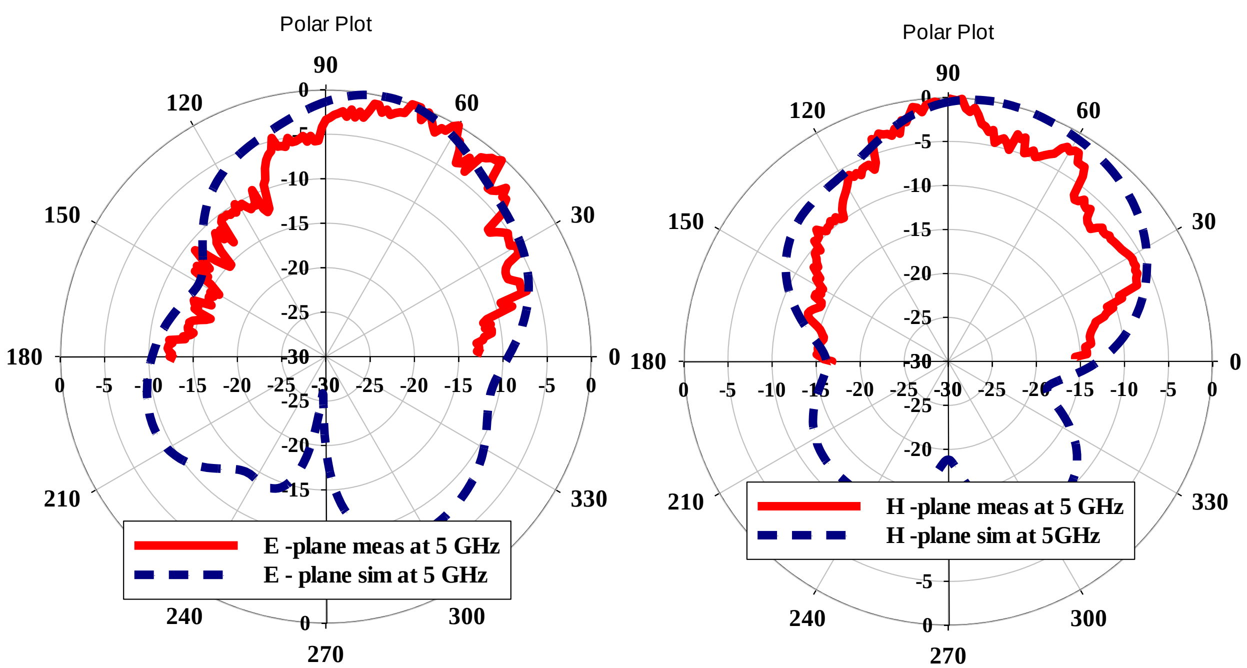

Fig. 3.22 Normalized radiation pattern of the proposed antenna at 5.0 GHz.

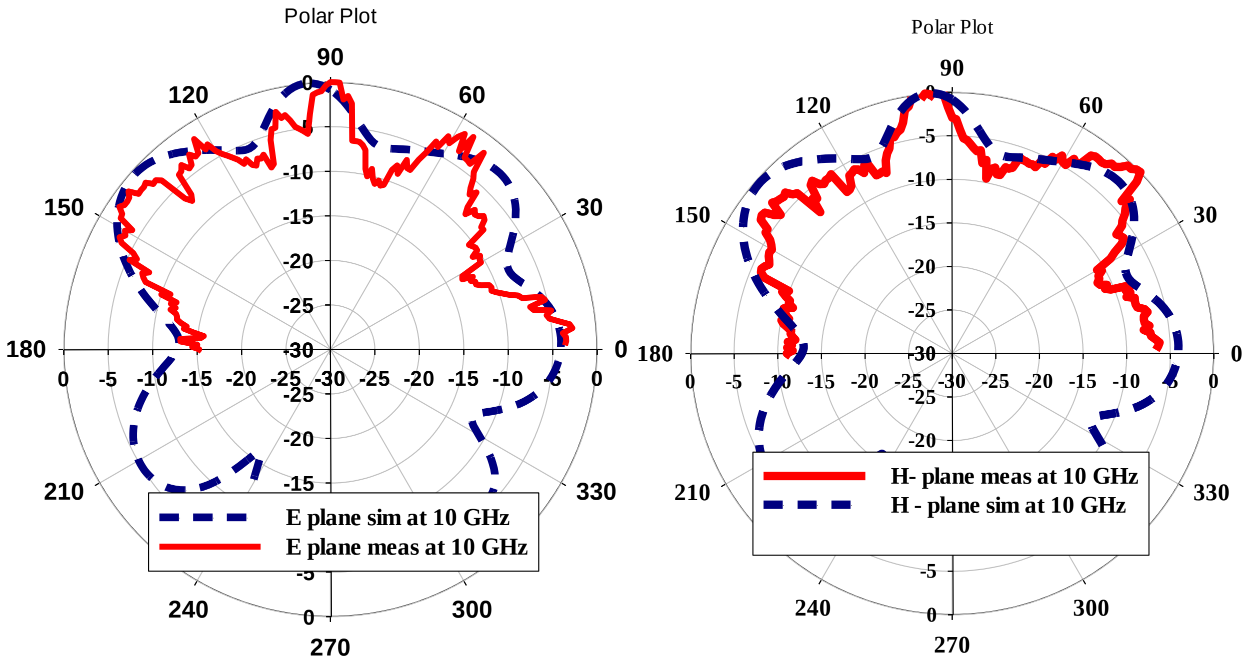

Fig. 3.23 Normalized radiation pattern of the proposed antenna at 10.0 GHz.

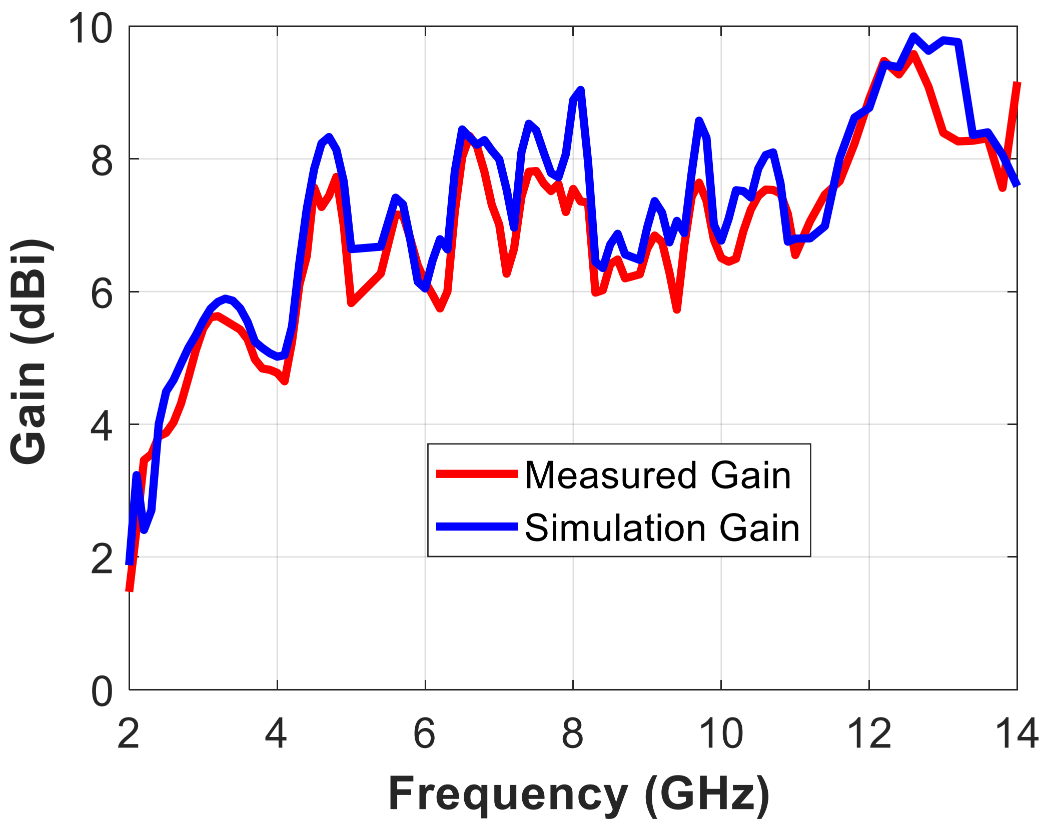

Fig. 3.24 Simulation and measured gain vs. frequency of the proposed antenna.

CHAPTER FOUR: CONCLUSION

4.1 Conclusions

In this thesis, Ultra-Wide Band Dielectric Resonator Antennas have been designed, fabricated and measured. In the first part of the thesis, an introduction of DRAs, a brief view of the history of DRAs has been reviewed; the applications, characteristics, pro and cons, and bandwidth range have been discussed. Several of bandwidth enhancement techniques have been studied. Since the parameters of the antenna have a great role in antenna performance, adjustments and optimizations on the antenna parameters have been made and also extended.

A new Ultra-Wide Band Stacked Rectangular DRA has been proposed and fabricated by using Roger materials. The resonance of an aperture coupled feeding slot has been designed to obtain a desirable bandwidth covering entire C-band to X-Band.

The effect of the position perturbations on the bandwidth of an aperture coupled dielectric resonator antenna (DRA), has been presented. Two and three combinations of stacked DRA's have been considered for the analysis: larger over smaller (LOS), and smaller over larger (SOL). Different position perturbations on the transmission line (TL), LOS, and SOL have been applied to widen the matching bandwidth of the antenna. The performance of the proposed antenna has been compared with the conventional antenna designed with no perturbations. The proposed antenna not only provides 5:1 ultra-wide matching bandwidth (from 2.7 GHz to 13.6 GHz), but also result in the highest gain of 9 dBi, which is 2 dBi more than the antenna designed with the conventional method without perturbation.

The simulated and measured results show that the designed antenna provides the desired matching bandwidth (from 2.7 GHz to 13.6 GHz), that involves all (Wi-MAX) and (WLAN) applications. The antenna provides a maximum gain of 9 dBi. This design is overall appropriate for wireless local area networks (WLAN).

4.2 Future work

Based on the observations of this work, some points are specified that could help for future investigation. Since the operation frequency of most applications heading to higher frequencies, the dielectric resonator antennas become considerably beneficial. Furthermore, there is a need to develop integration techniques of fabrication. The fabrication and measurements of stacked DRAs and other DRA designs will be carried out in future.

From point-view of researchers, there is no limit in the antenna research domain. By choosing a different substrate material with higher dielectric constant and lower losses and using different feeding methods would enhance the performance of the proposed antennas. Designing an array could be investigated to increase the gain. Since the small size and light weight are substantial in the antenna design, a miniaturization technique could be implemented to further to reduce the size of the proposed antennas. In addition, an air gap between the ground plane and the dielectric resonator can be enhancement the bandwidth. Studies predict that someday the DRAs will become as common use as microstrip antennas.

CHAPITRE CINQ: SOMMAIRE

5.1.1 Résumé

Cette thèse présente la conception et la fabrication d'une antenne à résonateur diélectrique rectangulaire (UWB-RDRA) empilée à ultra large bande, où l'effet des perturbations de position sur la bande passante d'une antenne à résonateur diélectrique (DRA) est étudié. L'antenne proposée tire parti de deux modes Q bas qui ont des largeurs de bande qui se chevauchent de manière à réaliser une opération à bande ultra large. Cela peut être réalisé en utilisant deux combinaisons de DRA empilés pour l'analyse: plus grand que plus petit (LOS), et plus petit plus grand (SOL). Différentes perturbations de position sur la ligne de transmission (TL), LOS et SOL sont optimisées pour élargir la bande passante correspondante de l'antenne.

La performance de l'antenne proposée est comparée à l'antenne conventionnelle conçue sans perturbation. L'antenne proposée offre non seulement une bande passante 5: 1 ultra large (de 2,7 GHz à 13,6 GHz), mais aussi un gain élevé de 9 dBi, soit 2 dBi de plus que celui de l'antenne conçue avec la méthode conventionnelle sans perturbation. L'antenne proposée est donc constituée de deux substrats ayant une constante diélectrique de 6.15 et 9.8 qui sont empilés verticalement afin d'acquérir une largeur de bande qui est plus améliorée par rapport à la RDRA conventionnelle. Une ligne microruban de 50 Ω est nécessaire dans l'antenne proposée pour agir comme un mécanisme d'alimentation. Les paramètres physiques du RDRA empilé sont également optimisés par des simulations extensives à l'aide du logiciel Computer Simulation Technology (CST).

Les dimensions de cette antenne sont de 65x50x5 mm3 et sa taille de substrat mise à la terre est de 108x90 mm2. Le prototype est fabriqué et mesuré. Les résultats mesurés et les résultats simulés montrent un bon accord. Ce prototype d'antenne est conçu pour couvrir la bande de 2.7 à 13.6. Cette antenne proposée est donc adaptée aux bandes d'application sans fil (Wi-MAX) et (WLAN).

5.1.2 Introduction

Depuis la première transmission réussie réalisée par Galileo Marconi, les systèmes de communication sans fil ont attiré l'attention de nombreux chercheurs. Dans certaines applications, un certain nombre d'antennes sont nécessaires pour travailler dans différentes fréquences, polarisation et diagrammes de rayonnement pour répondre aux besoins de ces applications, par conséquent, différentes formes, sortes et techniques d'antennes ont été découvertes et inventées. Une de ces approches utilise un diélectrique comme un résonateur dans la conception de l'antenne fonctionne, ce type d'antennes est connu plus tard comme une antenne à résonateur diélectrique (DRA).

En 1983, S. Long, M. McAllister et L. Shen ont proposé un diélectrique cylindrique comme résonateur dans l'antenne. En [1,2], c'était la première génération de technologie d'antenne diélectrique. Aujourd'hui, plus de 800 publications ont été mises en avant aux côtés de quelques douzaines de brevets d'émission qui impliquent la technologie de l'antenne à résonateur diélectrique (DRA) [3].

La principale caractéristique de la DRA avec un concept conduisant à un travail supplémentaire qui améliore les performances de la technologie DRA ont été découvertes et publiées par plusieurs chercheurs, ce qui a conduit à conclure que cette technologie offrait une bonne alternative aux éléments d'antenne à faible gain, illustré à la Fig. 5.1.

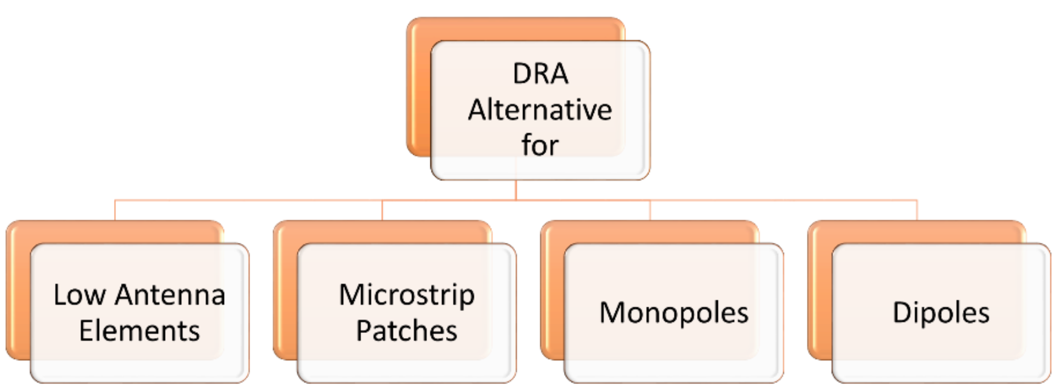

Fig. 5.1: DRA comme alternative pour les éléments d'antenne traditionnels à faible gain [3].

Au milieu des années 1990, les travaux de recherche du DRA ont couvert des réseaux de deux éléments et des réseaux plus complexes de réseaux planaires à déphasage comprenant plus de 300 éléments de balayage électronique [3].

L'optimisation de l'impédance a nécessité l'utilisation d'un patch croissant pour alimenter le DRA. L'amélioration substantielle de la bande passante dans la conception de l'antenne est assurée par un DRA cylindrique parasite [5,6]. Un contrôle naturel du comportement de la bande passante est donc favorisé par les ajustements rectangulaires des paramètres dimensionnels tels que la hauteur, le poids et la longueur [15].

5.1.3 But et objectifs du projet

Le but de ce projet est d'étudier les conceptions DRA avec une performance améliorée en termes de bande passante pour les communications sans fil, la détection et la récupération d'énergie aux fréquences micro-ondes. Pour cela, nous proposons un concept d'antenne empilée. Des techniques pour augmenter la performance des DRA ont été étudiées pendant le projet, par simulation avec le CST Microwave Studio et ensuite par expérimentation, ce qui devrait mener à d'autres conceptions de DRA plus originales.

5.1.4 Organisation de la thèse

Dans le premier chapitre, une revue de la littérature sur les antennes à résonateur diélectrique est présentée. Les étapes de l'évolution des techniques DRA ont été brièvement passées en revue. Le chapitre deux présente un contexte général sur les DRA. Comme on le sait, le point clé pour concevoir une antenne est de comprendre sa théorie opérationnelle; par conséquent, les paramètres cruciaux de l'antenne sont également présentés. Comme le sujet principal de cette thèse porte sur la conception d'une antenne à résonateur diélectrique rectangulaire à bande ultra large, plusieurs méthodes comme la méthode empilée, la méthode parasite coplanaire et la méthode intégrée, y compris leurs avantages et leurs inconvénients, sont discutées. Le troisième chapitre commence par une brève introduction sur le DRA. L'invention concerne un procédé de conception d'antennes à résonateur diélectrique rectangulaire à ultra large bande. L'effet des perturbations de position sur la bande passante d'une antenne à résonateur diélectrique à couplage d'ouverture (DRA) est étudié et présenté. Les résultats de simulation et les résultats expérimentaux sont discutés et comparés. Le chapitre quatre conclut le travail de cette thèse et présente les travaux futurs

5.2 Antennes à résonateur diélectrique

5.2.1 Introduction

L'antenne représente une partie nécessaire lors de la conception d'une application de communication sans fil en raison de sa participation à la dictée de l'efficacité globale de tout système de communication sans fil, et donc elle est faite d'un bon matériau qui lui permet de rayonner correctement. La Fig. 5.2 montre comment une antenne fonctionne. La principale fonction de l'antenne émettrice est de changer la puissance transmise de l'onde électromagnétique avant de l'irradier dans l'espace. L'antenne de réception est cependant chargée de recevoir une partie des ondes propagées avant de les envoyer au récepteur sous forme d'énergie.

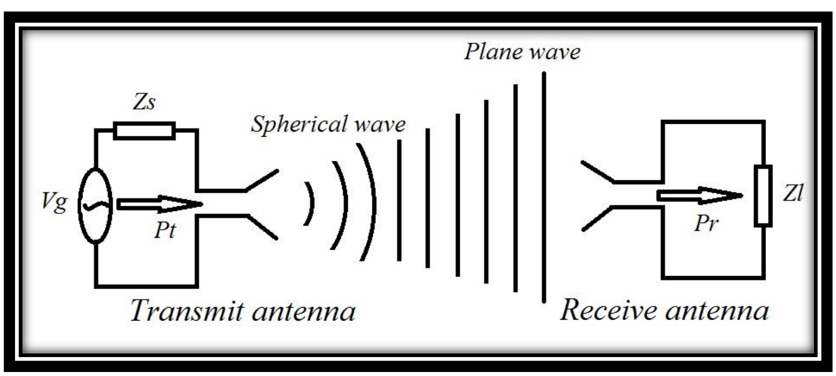

Fig. 5.2 Fonctionnement de base des antennes d'émission et de réception [8].

5.2.2 Bande passante de l'antenne à résonateur diélectrique et amélioration de la bande passante

Il existe de nombreuses méthodes pour améliorer la bande passante DRA, un domaine que les chercheurs ont mis plus de concentration afin d'étendre le nombre d'applications qui se trouvent dans la DRA. En raison de la flexibilité du modèle de conception DRA, la modification de sa forme, taille, alimentation, plan de masse et d'autres paramètres offre la possibilité d'améliorer la bande passante. Une partie de DRA peut donc agir comme une antenne, plaçant le DR incorporé dans un plan placé verticalement, et recadrer certaines zones de l'antenne permet d'améliorer les performances.

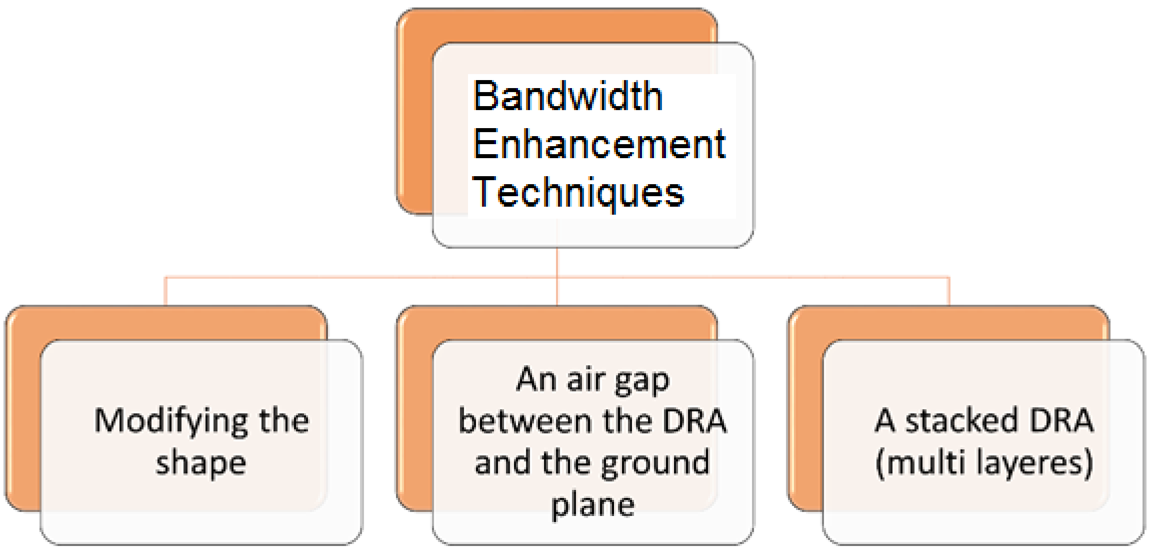

Fig. 5.3 Techniques d'amélioration de la bande passante [13].

Une antenne de conception hybride est réalisée en composant deux éléments, principalement en insérant un quart de longueur d'onde unipolaire dans l'axe DRA, où l'excitation de la DR sera assurée par l'élément monopôle quart d'onde. La recherche montre que ces conceptions hybrides contiennent une bande passante plus large par rapport à d'autres conceptions [14].

5.2.3 Antenne à résonateur diélectrique ultra large bande

La bande ultra-large (UWB) a été approuvée par la Federal Communications Commission des États-Unis en 2002 [1], autorisant la bande sans licence couvrant la bande 3.1 -10.6 GHz pour les systèmes capables de transmettre et de recevoir des signaux à haut débit (nanosecondes) à l'aide d'une impulsion d'énergie très courte. En raison des nombreux avantages qui ont été observés pour le monde sans fil dans l'utilisation des systèmes de communication UWB comme le taux de données haute vitesse, haute précision, coût réduit et complexité moindre ont attiré l'attention de plusieurs chercheurs [11].

5.2.4 Concept d'antenne à résonateur diélectrique

Une antenne à résonateur diélectrique (DRA) est un mode d'antenne conçu avec un résonateur diélectrique servant d'élément principal. La conception de DRA comprend un pièce d'un résonateur diélectrique alimenté par une ligne de transmission. Ceci a été expliqué à la Fig. 5.4 qui illustre un type de conception de DRA. C'est un prototype de laboratoire rectangulaire DRA, (RDRA) qui est connecté dans une position qui mesure son diagramme de rayonnement.

La géométrie DRA, la consonne diélectrique et ses mécanismes de couplage sont des facteurs qui définissent ses modes de fonctionnement, sa fréquence de résonance et ses caractéristiques de rayonnement [15].

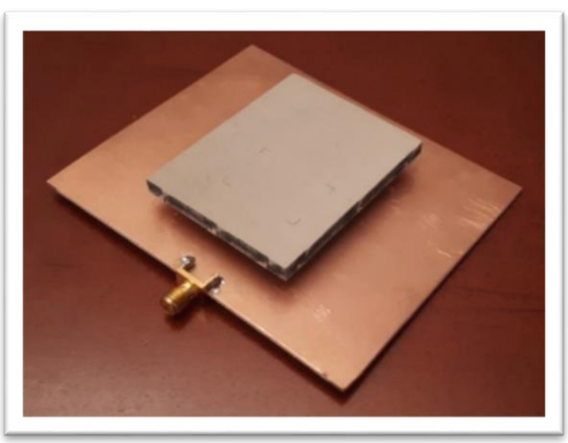

Fig. 5.4 Une ouverture de prototype de laboratoire expérimental couplée à un modèle RDRA.

5.2.4.1 Caractéristiques de l'antenne du résonateur diélectrique

De nombreuses caractéristiques et avantages que DRA a sur d'autres antennes, comme les antennes microruban, ont attiré de nombreux chercheurs à se concentrer sur l'étude du concept DRA. Les conceptions de DRA ont la propriété du rayonnement dans tout son volume dans une direction tridimensionnelle [39]. Quand un matériau de haute permittivité est utilisé, une DRA peut être électriquement petite, ce qui signifie qu'elle est compacte, mais au détriment de l'efficacité de la bande passante [25,26]. La DRA est capable de fournir un rendement de rayonnement élevé en raison de l'absence de pertes de conducteurs ou d'ondes de surface [27].

5.2.4.2 Conception de l'antenne à résonateur diélectrique

La conception de DRA nécessite l'inclusion de divers éléments dont certains ont des éléments de substrat intégrés. D'autres conceptions incluront des éléments empilés ou incorporés. D'autres éléments qui sont couramment trouvés dans les conceptions publiées sont le plan de masse, le substrat, le résonateur diélectrique et un mécanisme d'alimentation. D'autres éléments à prendre en compte comprennent la position et l'orientation des éléments tels que les espaces, tandis que d'autres peuvent être imprimés sur le substrat.

5.2.4.3 Taille de l'antenne du résonateur diélectrique

La fonction du constant diélectrique affecte directement la taille d'antenne à résonateur diélectrique. La dimension maximale (DDRA) est définie par le rapport existant entre la longueur d'onde et la racine carrée de la permittivité relative (ε_r).

5.2.4.4 Forme de l'antenne à résonateur diélectrique

Différentes formes de DRA ont été proposées pour étude car il a été rapporté que la variation de forme peut contrôler le champ intérieur dans la DR [29]. Effectuer une modification contrôlée de la forme permet également d'ajuster les performances de l'antenne en modifiant le champ électrique interne. Diverses formes ont ensuite été développées telles que cylindre, cylindre sectorisé, anneaux cylindriques, DRA métallisés, triangulaire, rectangulaire, rectangulaire entaillé, DRA chanfreiné, conique, elliptique, sphérique, hémisphérique, coupe sphérique, tétraédrique, DRA perforé, DRA étagés, et DRAs hybride.

5.2.4.4.1 Formes célèbres d'antennes à résonateur diélectrique

5.2.4.4.1.1 DRA cylindrique

En comparant les trois formes, la forme cylindrique présente des avantages sur l'ensemble d'entre elles en raison de sa capacité à offrir une plus grande flexibilité de conception avec le rayon / hauteur responsable de la fréquence de résonance et du facteur de qualité noté (Q).

Un DRA de forme cylindrique peut fournir diverses sous-classes de DRA. Ces sous-classes comprennent DRA à anneau cylindrique, DRA à cylindre cylindrique, DRA cylindrique à disque, DRA à anneau sectorisé, DRA cylindrique sectorisé, DRA de forme elliptique et DRA de forme conique. Un anneau DRA offre une augmentation des performances de la bande passante d'impédance.

5.2.4.4.1.2 DRA hémisphérique

Il a été indiqué précédemment qu'un modèle de paroi magnétique n'est pas efficace pour calculer l'impédance d'entrée de la DRA. (Long) a conduit une théorie analytique pionnière de l'entrée d'impédance pour le DRA hémisphérique. Les principales caractéristiques de le DRA hémisphérique sont le rayon (r) et une constante diélectrique. La DRA hémisphérique est plus avantageuse sur les DRA de forme cylindrique et rectangulaire parce que la simplicité de l'interface entre le diélectrique et l'air, donnant ainsi une expression de forme fermée dans le but d'exécuter la fonction de Green.

5.2.4.4.1.3 DRA rectangulaire

La DRA aide le concepteur à avoir une plus grande flexibilité pour acquérir les caractéristiques de profil et de bande passante souhaitées à une fréquence de résonance spécifique. La DRA rectangulaire maintient les modes TE (TE_x, TE_y et TE_z) qui rayonnent comme un dipôle magnétique court. Lorsqu'un concepteur choisit des dimensions DRA appropriées, il empêche l'apparition de modes inutiles sur la bande de fréquence pendant l'opération.

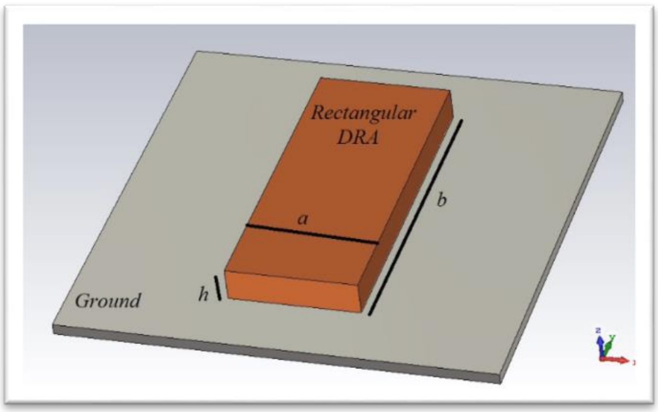

Fig. 5.5 Géométrie du DRA rectangulaire.

5.2.4.5 Fréquence de résonance

Toute application sans fil de communication a une fréquence de fonctionnement particulière; par conséquent, les concepteurs devraient calculer la fréquence de résonance de l'antenne et la largeur de bande de l'antenne (gamme de fréquences de fonctionnement) avant de lancer réellement le processus de conception de l'antenne. La réponse en fréquence de l'antenne est définie comme son impédance d'entrée en fonction de fréquence [33]. L'antenne est un circuit qui a une inductance et une capacitance qui sont déterminées par ses propriétés physiques et son environnement de localisation. Lorsque la capacité et l'inductance s'annulent, l'antenne devient purement résistive.

$$\Gamma(\omega) = [Z_{in} - Z_0] / [Z_{in} + Z_0] \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(5-1).}$$

$$VSWR = V_{max}/V_{min} = (1+|\Gamma|) / (1-|\Gamma|) \ldots\ldots (5\text{-}2).$$

$$RL = -20 \log |\Gamma| (dB) \ldots\ldots (5\text{-}3).$$

5.2.4.5.1 Méthode empilée

Empiler les DRAs les unes sur les autres est une méthode utilisée pour améliorer la bande passante dans les DRA. Avec un seul élément DRA, il n'est pas toujours facile d'obtenir les spécifications souhaitées, telles qu'un gain élevé, un diagramme directionnel et une large bande passante.

Le diagramme de rayonnement du mode dominant utilisé dans de nombreuses configurations d'alimentation de sondes ou de fentes est basé dans le sens large des éléments. La technique empilée est l'une des plus efficaces pour améliorer la bande passante dans les DRAs.

La Fig. 5.6 explique une antenne résonante diélectrique qui est empilée de manière rectangulaire. La configuration empilée de la DRA comporte deux pièces rectangulaires constituées de matériaux différents et de dimensions empilées verticalement, de façon que l'une sur l'autre, et montées sur un plan mis à la terre. Il est également possible d'introduire des entrefers entre les DRA dans le but d'améliorer la bande passante. Cette méthode présente un inconvénient en ce que la géométrie de la DRA n'a pas un profil très bas [31].

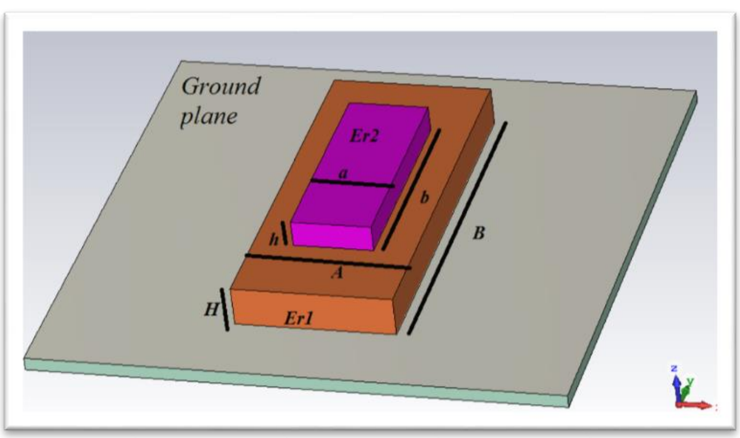

Fig. 5.6 Géométrie des DRA rectangulaires empilées.

5.2.4.5.2 Méthode incorporée

La technique intégrée peut être utilisée pour améliorer la bande passante DRA où les DRA peuvent également être intégrés les unes dans les autres [31]. En dépit de sa comparaison avec la méthode empilée, la méthode parasitique coplanaire présente quelques inconvénients, tels que l'utilisation de plusieurs constantes diélectriques DRA, compliquent cette méthode par rapport à un seul substrat diélectrique. En outre, la mise en place d'un résonateur diélectrique intégré est moins flexible par rapport à la méthode empilée.

5.2.5 Performance de l'antenne du résonateur diélectrique

5.2.5.1 Diagramme de rayonnement

C'est le diagramme de rayonnement qui décrit l’énergie rayonnée sous la forme d'un champ électromagnétique tandis que le gain d'antenne est défini comme un concept mathématique qui décrit la quantité d'énergie rayonnée dans une direction comme l’indique Fig. 5.7.

La région qui reçoit et transmet le mieux le signal électromagnétique mesuré sur une échelle angulaire est le faisceau d'antenne. Les lobes mineurs qui comprennent les lobes latéraux et les lobes arrière expliquent la quantité de signal électromagnétique rayonnée dans diverses directions et propagée avec des niveaux moins élevés que ceux du lobe principal [34].

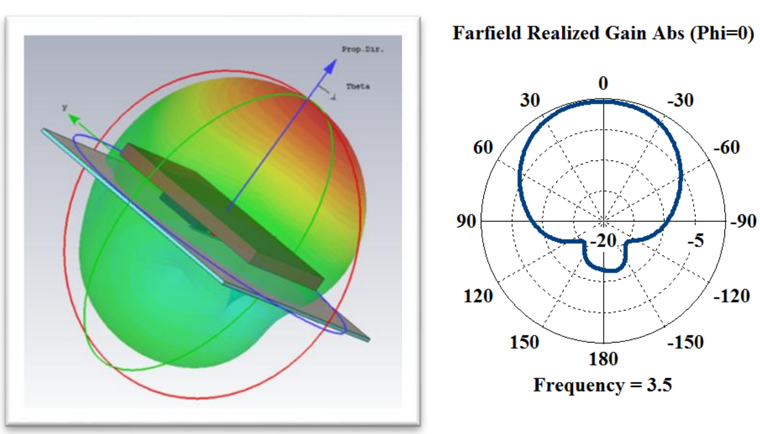

Fig. 5.7 Schéma de rayonnement en représentation 3D et 2D.

5.2.5.2 Impédance d'entrée et bande passante

L'impédance d'entrée (Z_{in}) est définie comme l'impédance à l'entrée de l'antenne. C'est aussi le rapport de la tension et du courant à sa borne sans charge connectée [10]. L'impédance d'entrée d'une antenne est ($r \pm x_j$), et on dit que l'antenne est résonnante si elle a une impédance d'entrée réelle. En d'autres termes, l'antenne à la fréquence de résonance est considérée comme une résistance, tandis qu'à d'autres fréquences, elle est considérée comme capacitive ou inductive.

Les équipements de test et de mesure RF et MW utilisent cette impédance de référence. Pour assurer le transfert de puissance maximum et augmenter le rapport signal à bruit, et réduire la puissance de la source, l'impédance d'entrée doit être maintenue aussi proche que possible de l'impédance caractéristique.

5.2.5.3 Directivité et gain

La directivité peut être décrite comme le rapport entre la puissance rayonnée de l'antenne dans la direction (θ, φ) et la puissance rayonnée totale dans toutes les directions. En d'autres termes, la directivité est le rapport entre l'intensité du rayonnement dans une direction donnée et l'intensité du rayonnement de l'antenne de référence. La directivité maximale est la capacité de l'antenne à focaliser sa puissance rayonnée dans une direction donnée [46] et elle n'est pas affectée par la perte de l'antenne. La directivité de l'antenne peut être calculée en utilisant la formule suivante:

$$D = \frac{4\,\pi\,Umax}{Prad} = \frac{4\,\pi\,Umax}{\int\int\ U(\theta,\emptyset)\,sin\theta\;d\theta\;d\emptyset} \quad \text{.................................... (5-4).}$$

Le gain de toute composante RF est le rapport de la puissance de sortie rayonnée par une antenne dans une direction spécifique à la puissance acceptée d'une antenne de référence. Il n'inclut pas les pertes résultant de l'impédance ou de la désadaptation de polarisation; par conséquent, il mesure la performance de l'antenne.

$$G = 4\pi \frac{intensité\ du\ rayonnement}{puissance\ totale\ acceptée\ en\ entrée} = 4\pi \frac{U(\theta,\emptyset)}{Pin} \text{.................... (5-5).}$$

Il est important de ne pas confondre la directivité et le gain car dans la référence utilisée en directivité, c'est la puissance totale rayonnée alors qu'en gain c'est la puissance d'entrée totale de l'antenne (acceptée de la source). Le gain est généralement inférieur à la directivité, il pourrait également être égal à la directivité lorsque l'efficacité de l'antenne est de 100%.

$$G = e_{rad} \, . \, D \text{ .... (5-6).}$$

5.3 Conception d'une nouvelle antenne à résonateur diélectrique ultra-large bande

Cette partie de la thèse présente une amélioration de la bande passante d'une antenne à résonateur diélectrique empilée couplée à une ouverture en utilisant différentes perturbations de position. La performance de l'antenne proposée est comparée à l'antenne conventionnelle conçue sans perturbations. L'antenne proposée offre non seulement une bande passante ultra-large de 5:1 (couvrant toute la bande C vers la bande X), mais aussi un gain plus élevé de 9 dBi, soit 2 dBi de plus que l'antenne conçue avec les méthodes conventionnelles.

5.3.1.1 DRA empilée couplée à l'ouverture avec méthode conventionnelle (sans décalage)

Il y a deux résonateurs dans la DRA empilé; à savoir, D2 (taille plus grande) et D1 (taille plus petite) qui se composent également d'une permittivité relative de 6.15 et 9.8, respectivement. Roger 5880 LZ substrat avec une permittivité de 1.96, et une épaisseur de 1.27 mm est utilisé pour imprimer à la fois TL et l'antenne à ouverture. Différentes dimensions sont utilisées dans la conception, comme le montre la Fig. 5.8.

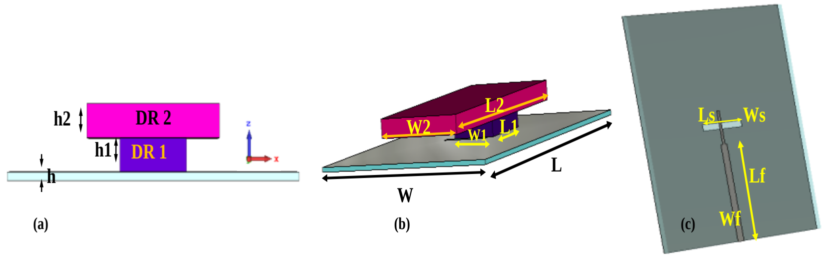

Fig. 5.8 La structure de base du DRA empilé, (a) vue de côté, (b) vue en perspective. , (c) vue arrière.

Tableau 5.1 Les dimensions de l'antenne proposée.

Paramètre	**W**	**L**	**W1**	**L1**	**W2**	**L2**
Valeur (mm)	108	90	25	18	49.5	65
Paramètre	**Wf**	**Lf**	**Ws**	**Ls**	**h**	**h1=h2**
Valeur (mm)	4.25	37	27	2.43	1.27	5.08

5.3.1.2 DRA couplée à l'ouverture proposée avec performance améliorée

Cette section illustre comment la technique de perturbation proposée améliore la bande passante de l'antenne conventionnelle. Cette technique de perturbation est implémentée en différentes étapes et étiquetée "s1 à s6" comme: (1) TL décalée le long de l'axe X 4 mm (s1), (2) D1 4 mm décalé sur l'axe X (s2), (3) Décalage D1 de 10 mm suivant l'axe Y depuis sa dernière position (s3), (4) D1 rotation horaire de 25 degrés (s4), (5) D2 rotation horaire de 25 degrés (s5), (6) rotation D1 et D2 dans le sens horaire de 25 degrés (s6). L'effet de la technique proposée sur la performance de l'antenne est discuté dans la prochaine section.

5.3.1.3 Résultats de la simulation et discussion

Figs. (5.9, 5.10, 5.11 et 5.12) montrent les performances d'une antenne DRA empilée conçue avec la méthode couplée par ouverture conventionnelle sans perturbation (performance référencée). Il ressort de ces résultats présentés à la Fig. 5.9

que dans les deux environnements LOS et SOL des résonateurs, la bande passante d'adaptation cumulée est inférieure à 2 GHz dans toute la bande, alors que le gain moyen reste presque entre 7 et 8 dBi. Fig. 5.10 montre les résultats de la simulation de la fréquence d'antenne conventionnelle par rapport au gain.

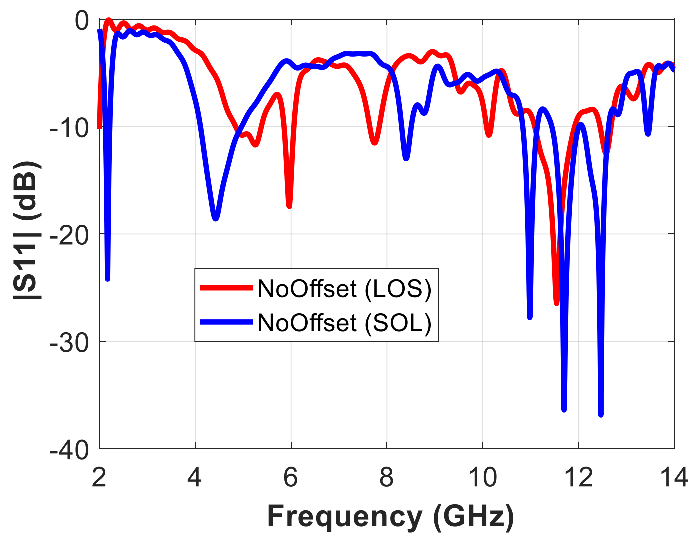

Fig. 5.9 Résultats de la simulation de l'antenne conventionnelle, fréquence vs. S11

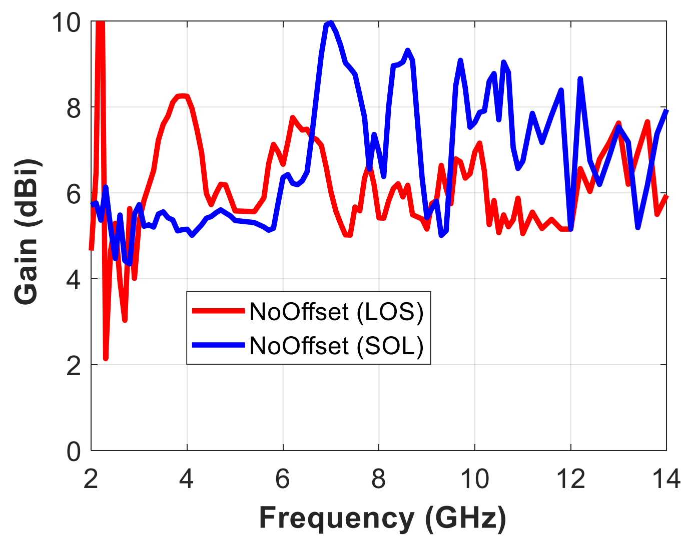

Fig. 5.10 Les résultats de la simulation de l'antenne conventionnelle, fréquence vs gain.

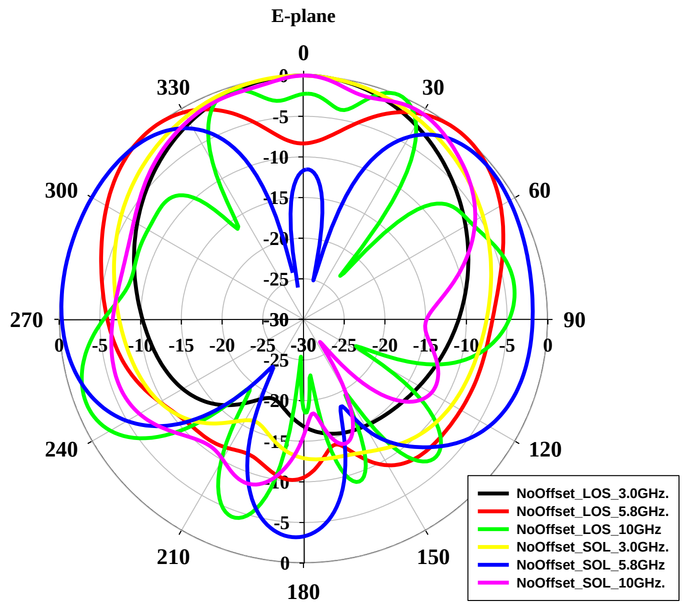

Fig. 5.11 Résultats des diagrammes de rayonnement du plan E de l'antenne conventionnelle en fonction de la fréquence.

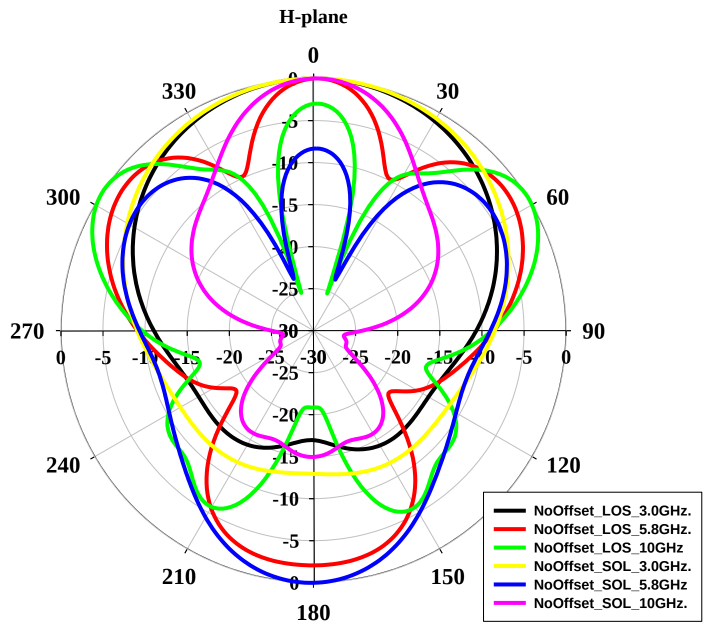

Fig. 5.12 Résultats des diagrammes de rayonnement du plan H de l'antenne conventionnelle en fonction de la fréquence.

Figs. 5.11 et 5.12 montrent les diagrammes de rayonnement dans les deux plans E et H à différentes fréquences (3,0 GHz, 6,8 GHz et 10,0 GHz), respectivement, qui montrent que le rayonnement de l'antenne est bon à la fréquence inférieure, tandis que la fréquence augmente, le rayonnement se dirige vers le pire. Le modèle se dégrade dans les deux plans E et H.

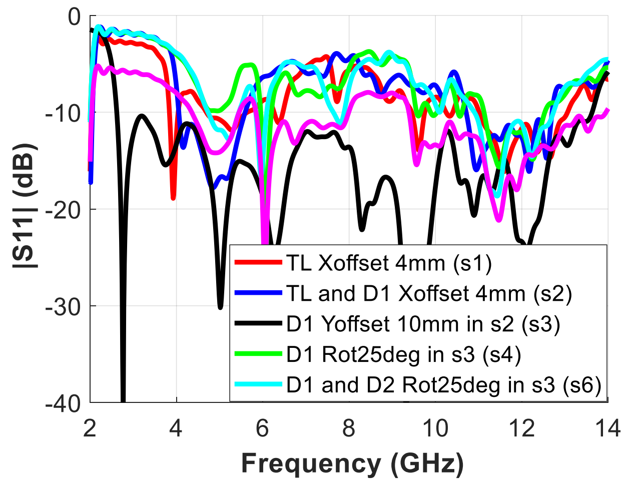

Fig. 5.13 Résultats de la simulation de l'antenne proposée avec Perturbations, fréquence vs S11

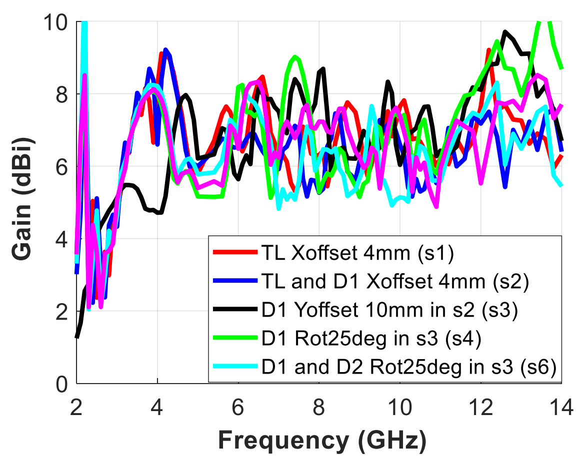

Fig. 5.14 Les résultats de la simulation de l'antenne proposée avec des perturbations par rapport à la fréquence pour le gain.

De même, les Figs. (5.13, 5.14, 5.15 et 5.16) montrent les performances de l'antenne proposée en termes de mêmes étapes que celles décrites dans la section (2). Il ressort clairement de ces résultats que l'utilisation de la technique de perturbation proposée conduit à un rapport de bande passante correspondant supérieur à 5: 1, alors que le gain le plus élevé est de 9 dBi, le gain moyen reste peu supérieur au cas conventionnel. Le diagramme de rayonnement dans les deux plans E et H est amélioré comme le montrent les Fig. 5.9 et 5.10.

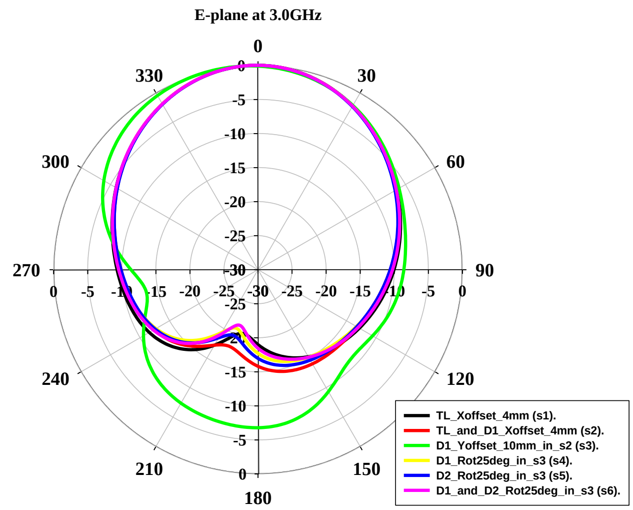

Fig. 5.15 Résultats de la simulation de l'antenne proposée avec perturbations pour les diagrammes de rayonnement du plan E à 3 GHz.

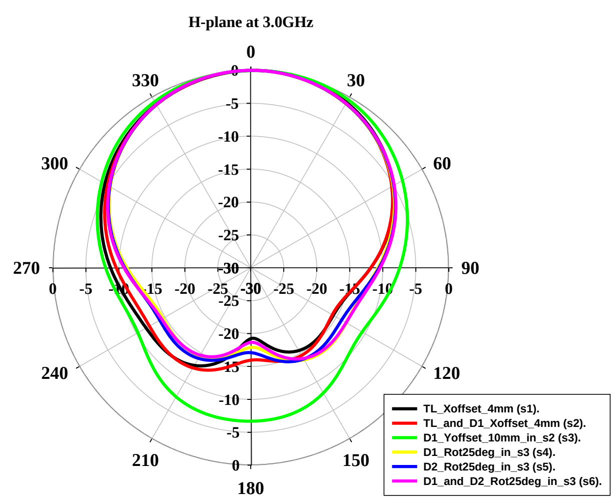

Fig. 5.16 Résultats de la simulation de l'antenne proposée avec perturbations pour les diagrammes de rayonnement du plan H à 3 GHz.

5.3.3 DRA empilée couplée à l'ouverture

5.3.3.1 Fabrication d'antennes

Dans cette partie de la thèse, le boîtier d'antenne proposé (S3) est choisi pour être fabriqué en raison des meilleurs résultats dans tous les autres cas.

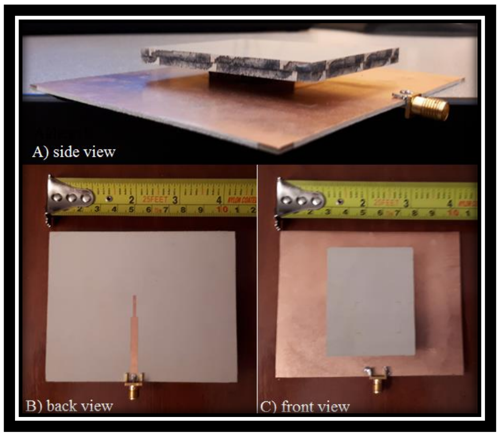

Fig. 5.17 Antenne fabriquée.

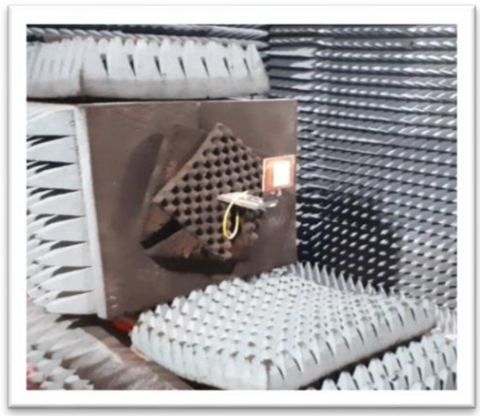

Fig. 5.18 L'antenne sous test dans la salle de mesure.

Fig. 5.17 montre l'antenne fabriquée proposée dans trois positions différentes, les vues avant, arrière et latérale, tandis que Fig. 5.18 montre l'antenne testée. L'antenne est testée et mesurée en RF. laboratoire (INRS).

5.3.3.2 Simulation et résultats mesurés.

Des résultats de mesures expérimentales sur le prototype fabriqué ont été réalisés, les résultats mesurés sont présentés et comparés aux résultats de simulation. Figs. (5.19, 5.20, 5.21 et 5.22) illustrent le coefficient de réflexion, le gain et le diagramme de rayonnement. La différence mineure entre les résultats mesurés et simulés pourrait être due à une imprécision de fabrication ou à des erreurs de mesure.

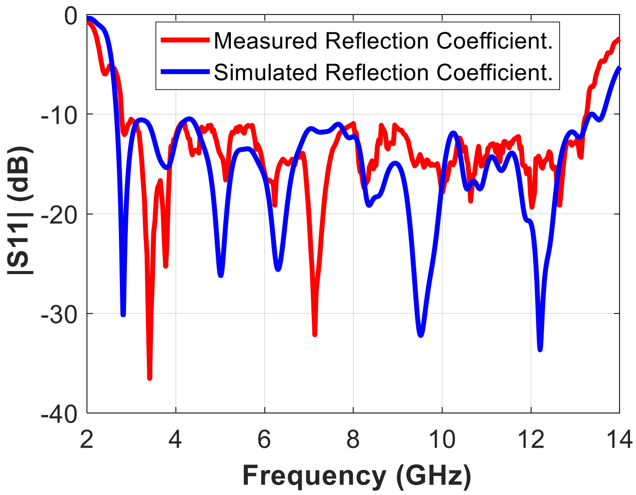

Fig. 5.19 Amplitude du coefficient de réflexion de l'antenne proposée.

L'antenne proposée rayonne dans la direction Z. Trois diagrammes de rayonnement simulés et mesurés différents de l'antenne proposée à 3,5 GHz, 5,0 GHz et 10,0 GHz sont représentés aux Figs. 5.20, 5.21 et 5.22, respectivement.

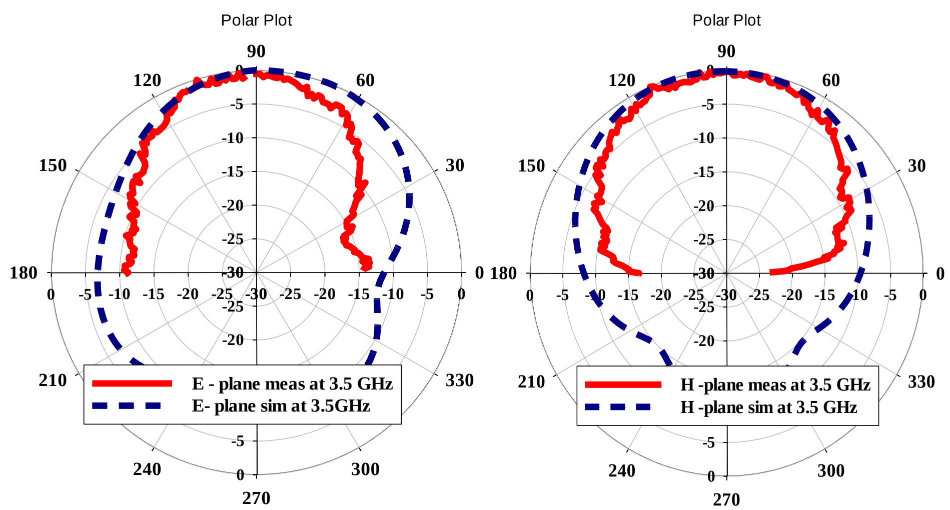

Fig. 5.20 Diagramme de rayonnement normalisé de l'antenne proposée à 3,5 GHz.

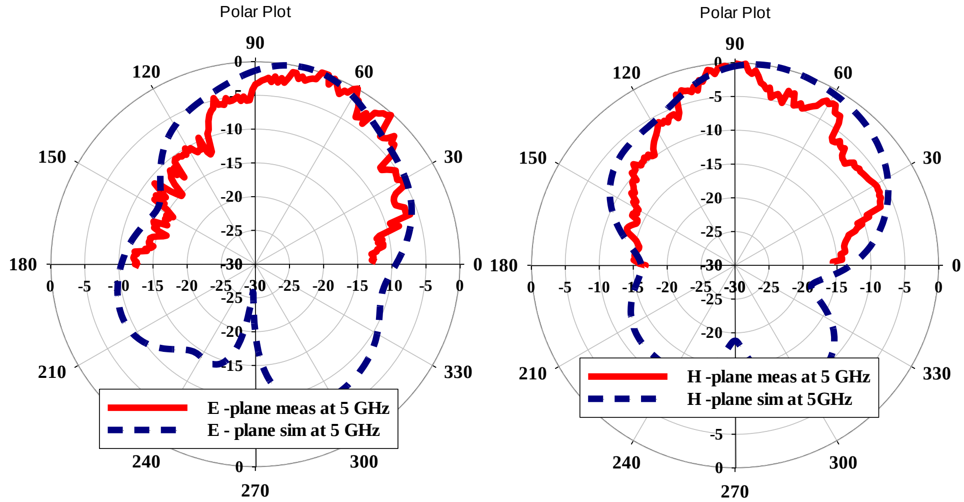

Fig. 5.21 Diagramme de rayonnement normalisé de l'antenne proposée à 5,0 GHz.

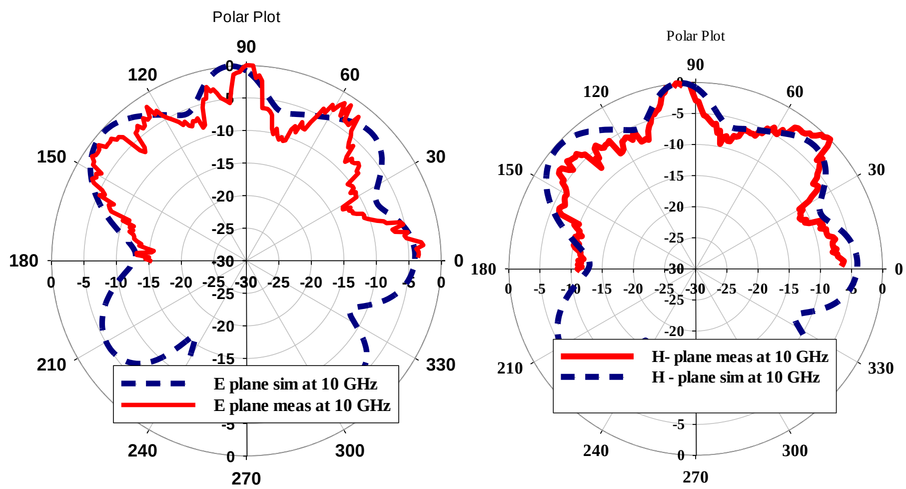

Fig. 5.22 Diagramme de rayonnement normalisé de l'antenne proposée à 10,0 GHz.

5.4.1 Conclusions

Dans cette thèse, les antennes à résonateur diélectrique à ultra large bande ont été conçues, fabriquées et mesurées. Dans la première partie de la thèse, une introduction des DRAs, un bref aperçu de l'histoire des DRAs a été examinée; les applications, les caractéristiques, les avantages et inconvénients, et la gamme de bande passante ont été discutés. Plusieurs techniques d'amélioration de la bande passante ont été étudiées. Puisque les paramètres de l'antenne ont un grand rôle de la performance de l'antenne, des ajustements et des optimisations sur les paramètres de l'antenne ont été faites et également étendues.

Une nouvelle DRA rectangulaire empilée ultra large bande a été proposée et fabriquée en utilisant des matériaux Roger. La résonance d'une fente d'alimentation couplée à l'ouverture a été conçue pour obtenir une largeur de bande souhaitable couvrant la totalité de la bande C vers la bande X.

L'effet des perturbations de position sur la bande passante d'une antenne à résonateur diélectrique (DRA) couplée à l'ouverture a été présenté. Deux et trois combinaisons de DRA empilées ont été prises en compte pour l'analyse: plus grand que plus petit (LOS), et plus petit plus grand (SOL). Différentes perturbations de position sur la ligne de transmission (TL), LOS et SOL ont été appliquées pour élargir la bande passante correspondante de l'antenne. La performance de l'antenne proposée a été comparée à celle de l'antenne conventionnelle conçue sans perturbation. L'antenne proposée offre non seulement une bande passante 5: 1 ultra large (de 2,7 GHz à 13,6 GHz), mais aussi le gain le plus élevé de 9 dBi, soit 2 dBi de plus que l'antenne conçue avec la méthode conventionnelle sans perturbation.

Les résultats simulés et mesurés montrent que l'antenne conçue fournit la bande passante correspondante (de 2,7 GHz à 13,6 GHz), ce qui implique toutes les applications (Wi-MAX) et (WLAN). L'antenne fournit un gain maximum de 9 dBi. Cette conception est globalement appropriée pour les réseaux locaux sans fil (WLAN).

5.4.2 Travaux futurs

Basé sur les observations de ce travail, certains points sont spécifiés qui pourraient aider les futurs travaux de recherche. Depuis la fréquence de fonctionnement de la plupart des applications se dirigeant vers des fréquences plus élevées, les antennes à résonateur diélectrique deviennent considérablement bénéfiques. De plus, il est nécessaire de développer des techniques d'intégration de la fabrication. La fabrication et les mesures de DRA empilées et d'autres conceptions DRA seront effectuées à l'avenir.

Du point de vue des chercheurs, il n'y a pas de limite dans le domaine de la recherche sur les antennes. En choisissant un matériau de substrat différent avec un constant diélectrique plus élevée et des pertes plus faibles et en utilisant différentes méthodes d'alimentation, on améliorerait les performances des antennes proposées. La conception d'un réseau pourrait être étudiée pour augmenter le gain. Étant donné que la petite taille et le poids léger sont importants dans la conception de l'antenne, une technique de miniaturisation pourrait être mise en œuvre afin de réduire davantage la taille des antennes proposées. De plus, un entrefer entre le plan de masse et le résonateur diélectrique peut améliorer la bande passante. Des études prédisent qu'un jour, les DRAs deviendront aussi courantes que les antennes à microruban.

REFERENCES

[1] Al-askalani R., Hammad H. F., and Leib M., [2010], “Investigation on a UWB Antenna combining a Caped-Monopole and a Dielectric Resonator,” IEEE International Conference Wireless Information Technology and Systems (ICWITS), pp. 1 – 4.

[2] Zainud-Deen S. H., Malhat H. A., and Awadalla K. H., [2010], “Dielectric Resonator Antenna Mounted On A Circular Cylindrical Ground Plane,” Progress In Electromagnetics Research B, Vol. 19, pp. 427-444

[3] Petosa A. and Ittipiboon A., [2010], “Dielectric Resonator Antennas: A Historical Review and the Current State of the Art” IEEE Antennas and Propagation Magazine, Vol. 52, Issue: 5, pp. 91 – 116.

[4] Massie G., Caillet M., Clenet M., and Antar Y. M. M., [2010], “A New Wideband Circularly Polarized Hybrid Dielectric Resonator Antenna,” IEEE Antennas and Wireless Propagation Letters, Vol. 9, pp. 347 – 350.

[5] Othman A., Ain M.F., Sulaiman A.A., Othman M.A., [2010], “A Ka-Band Horn Antenna Excited with Parasitic Dielectric Resonator Antenna,” IEEE 17th International Conference Telecommunications (ICT), pp. 446 – 448.

[6] Weng Z.-B., Wang X.-M., Jiao Y.-C., and Zhang F.-S., [2010], “CPW-Fed Dielectric Resonator Antenna for Ultra-Wideband Applications,” Microwave and Optical Technology Letters, Vol. 52, Issue: 12, pp. 2709 – 2712.

[7] Gürel Ç. S., Coşar H., Akalın Ö., [2010], “Accurate Resonant Frequency Computation Of Multisegment Rectangular Dielectric Resonator Antennas,” Journal of Electromagnetic Waves and Applications Vol. 24, Numbers 5-6, pp. 839-847(9)

[8] David Pozar, ”Microwave and RF design of wireless system”, John Wiley & Sons, Inc, 2001. Print.

[9] V. Kumar, D. R. Jahagirdar, A. Basu and S. K. Koul, "Intra-band frequency reconfigurable antenna using RF MEMS technology," IEEE MTT-S International Microwave and RF Conference, New Delhi, 2013.

[10] Antenna polarization, [Online]. Available: http://www.air-stream.org.au/technical-references/antenna-polarisation

[11] S. V Shynu, G. Augustin, C. K. Aanandan, P. Mohanan, and K. Vasudevan, "Design Of Compact Reconfigurable Dual-Frequency Microstrip Antennas Using Varactor Diodes," PIER, pp. 197–205, 2006.

[12] Gopakumar C. and Mathew K. T., [2010], "A Wideband Microstrip-Line-Fed Isosceles Trapezoidal Dielectric Resonator Antenna with Modified Ground Plane," Progress In Electromagnetics Research C, Vol. 16, pp. 127-136.

[13] Ryu K. S. and Kishk A. A., [2010], "Ultrawideband Dielectric Resonator Antenna with Broadside Patterns Mounted on a Vertical Ground Plane Edge," IEEE Transactions on Antennas and Propagation, Vol. 58, Issue: 4, pp. 1047 – 1053.

[14] Zheng K. H. R., Chua H. O., and Li L.-W., [2010], "Analysis and Design of UWB Monopole-Dielectric Resonator Antenna", IEEE International Conference on Ultra-Wideband (ICUWB2010), pp.

[15] Almpanis G., Fumeaux C., Fröhlich J., and Vahldieck R., [2009], "A Truncated Conical Dielectric Resonator Antenna for Body-Area Network Applications," IEEE Antennas and Wireless Propagation Letters, Vol. 8, pp. 279 - 282

[16] Ain M. F., Qasaymeh Y. M., Ahmad Z. A., Zakariya M. A., Othman M. A., Sulaiman A. A., Othman A., Hutagalung S. D. and Abdullah M. Z., [2010], "A Novel 5.8GHz Array Dielectric Resonator Antenna," Progress In Electromagnetics Research C, Vol. 15, pp. pp. 201-210.

[17] Ee L., Chuen M. O. L., [2009], "Aperture Coupled, Differentially fed DRAs," Asia Pacific Microwave Conference, 2009. APMC 2009, pp. 2781 – 2784.

[18] Pereira F. M. M., Sohn R. S. T. M., Rodrigues H. O., Júnior G. F. M. P., Theophilo K. R. B., Rocha M. J. S., Silva M. A. S., and Sombra A. S. B., [2010], "Experimental And Numerical Investigation Of A Magnetic Resonator Antenna Based On The M-Type Hexaferrite (BaxSr12xFe12O19)," Microwave And Optical Technology Letters, Vol. 52, Issue: 2, pp. 249–496.

[19] Massie G., Caillet M., Clenet M., Antar Y.M.M., [2010], “A Wideband Circularly Polarized Rectangular Dielectric Resonator Antenna,” Proceedings of the Fourth European Conference on Antennas and Propagation (EuCAP), pp. 1 – 5.

[20] Ryu K. S. and Kishk A. A., [2010], “Ultra-Wideband Dielectric Resonator Antennas,” International Workshop on Antenna Technology (iWAT), pp. 1 – 4.

[21] Madhuri R. G., Hadalgi P. M., Mallikarjun S. L., and Hunagund P. V., [2010], “A Wideband-Stacked Rectangular Dielectric Resonator Antenna,” Microwave And Optical Technology Letters, Vol. 52, Issue 11, pp. 2432–2434.

[22] Wahab, W.M.A., Safavi-Naeini, S., Busuioc, D., [2009], "SIW-series fed RDRA array system for millimeter-wave applications", 3rd European Conf. on Antennas and Prop. (EuCAP), Berlin, Germany, pp. 979 – 981.

[23] Madhuri R. G., Hadalgi P. M., Mallikarjun S. L., and Malipatil S. A., [2010], “Bandwidth Enhancement of Slot-Fed Dielectric Resonator Antenna,” Microwave and Optical Technology Letters, Vol. 52, Issue 2, pp. 316 – 318.

[24] Almpanis G., Fumeaux C., and Vahldieck R., [2010], “Dual-Mode Bridge-Shaped Dielectric Resonator Antennas,” IEEE Antennas and Wireless Propagation Letters, Vol. 9, pp. 103 – 106.

[25] Tian R., Plicanic V., Lau B. K., and Ying Z., [2010], “A Compact Six-Port Dielectric Resonator Antenna Array: MIMO Channel Measurements and Performance Analysis,” IEEE Transactions on Antennas and Propagation, Vol. 58, Issue: 4, pp. 1369 – 1379.

[26] Jazi M. N. and Denidni T. A., [2010], “Ultra-Wideband Dielectric Resonator Antenna with Band Rejection,” Antennas and Propagation Society International Symposium (APSURSI), IEEE, pp. 1 – 4.

[27] Li-Na Z., Zhong S.-S., and Liang X.-L., [2010], “Wideband U-Shaped Dielectric Resonator Antenna Fed By Triangle Patch,” Microwave And Optical Technology Letters, Vol. 52, Issue 11, pp. 2435–2438.

[28] Chen T.L. and Hsieh C-W., [2005], "Com-Shaped Dipole antenna on Transparent Substrate," Antennas and Propagation Society International Symposium, 2005 IEEE, Vol. 3A, pp. 610 – 612.

[29] Denidni T. A., Weng Z., and Niroo-Jazi M., [2010], "Z-Shaped Dielectric Resonator Antenna for Ultrawideband Applications," IEEE Transactions on Antennas and Propagation, Vol. 58, Issued 12, pp. 4059 – 4062.

[30] A. Petosa, A. Ittipiboon, Y.M.M. Antar, D. Roscoe, and M. Cuhaci, —Recent advances in dielectric resonator antenna technology, IEEE Antennas Propag. Mag., vol. 40, No. 3, pp. 35-48, Jun 1998.

[31] A. Petosa, "Dielectric Resonator Antenna Handbook", Artech House Publishers, 2007.

[32] C. A. Balanis, "Antenna Theory, Analysis and Design" 2nd Edition, John Wiley & Sons, Inc., New York 1982.

[33] Jeniffer Bernard, Reconfigurable Antennas, Morgan &Claypoolpublishers, 2004.

[34] Blake L.V., [1966], "Antennas", Wiley Series in Electronic Engineering Technology. Ed. John Wiley and Sons, LTD.

[35] Pozar D.M., [2012], "Microwave engineering," 4th Edition; Wiley; pp. 306 – 312.

[36] Robertson I. D., and Lucyszyn S., [2001], "RFCI and MMIC design and technology," IEE circuits, devices and systems series 13, the institution of electrical engineers.

[37] Rudge A.W., Milne K., Olver A.D., Knight P., [1982], "The Handbook of Antenna Design, Volume I", Published by Peter Peregrinus Ltd., London, UK.

[38] Abumazwed A. A., and Sebak A., [2009], "Compact DRA for Broadband Wireless Applications," Antennas and Propagation Society International Symposium, 2009, APSURSI '09. IEEE, pp. 1 - 4

[39] Abumazwed A., Ahmed O., and Sebak A.R., [2009], "Broadband Half-Cylindrical DRA for Future WLAN Applications," 3rd European Conference on Antennas and Propagation, EuCAP 2009, pp. 389 – 392.

[40] Morsy M. M., Khan M. R., and Harackiewicz F. J., [2010], "Ultra-Wideband Hybrid Dielectric Resonator Antenna (DRA) with Parasitic Ring," IEEE International Conference on Wireless Information Technology and Systems (ICWITS), pp. 1 – 4.

[41] Chang T. H. and Kiang J. F., [2009], "Bandwidth Broadening of Dielectric Resonator Antenna by Merging Adjacent Bands," IEEE Transactions On Antennas And Propagation, Vol. 57, No. 10, pp. 3316 - 3320

[42] Ding Y., and Leung K. W., [2009], "On the Dual-Band DRA-Slot Hybrid Antenna," IEEE Transactions On Antennas And Propagation, Vol. 57, No. 3, pp. 624 – 630

[43] Hady L. K., Kishk A. A., and Kajfez D., [2008], "Dual Band Dielectric Resonator Antenna for GPS and WLAN Applications," Asia-Pacific Microwave Conference, APMC 2008, pp. 1 - 4

[44] Ain M.F., Hassan S.I.S., Ismail M.N., Othman M.A., Jaffar M.R., Othman A., Sulaiman A. A., Zakariyya M.A., Sreekantan S., Hutagalung S.D., Ahmad Z.A., [2008], "3.5 GHz Rectangular Dielectric Resonator Antenna," IEEE International RF And Microwave Conference Proceedings pp. 189 – 191.

[45] R. E. Collin, Antennas and Radiowave Propagation, Mc Graw Hill, New York, 1985.

[46] S. Long, M. McAllister, and L. Shen, "The resonant cylindrical dielectric cavity antenna", IEEE Transactions on Antennas and Propagation, vol. 31, 1983.

[47] S. M. Shum and K. M. Luk, "Stacked annular ring dielectric resonator antenna excited by axis-symmetric coaxial probe," IEEE Transactions on Antennas and Propagation, vol. 43, no. 8, pp. 889–892, Aug 1995.

[48] Q. Rao, T. A. Denidni, and A. R. Sebak, "Broadband compact stacked T-shaped DRA with equilateral-triangle cross sections," IEEE Microwave and Wireless Components Letters, vol. 16, no. 1, pp. 7–9, Jan 2006.

[49] Y. M. Pan, and S. Y. Zheng, "A Low-Profile Stacked Dielectric Resonator Antenna With High-Gain and Wide Bandwidth ", IEEE Antennas and Wireless Propagation Letters,Vol.15,20