DESIGN OF FIBERGLASS / ALUMINIUM COMPOSITE DIELECTRIC FEED FOR WIDEBAND PARABOLIC ANTENNA

By

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LIST OF ABBREVIATIONS

Abbreviation	**Meaning**
CDRA	Cylindrical Dielectric Resonator Antenna
CST	CST Microwave Studio Software
dB	Decibels
DR	Dielectric Resonator
DRA	Dielectric Resonator Antenna
E-field	Electric field
H-field	Magnetic field
GHz	Giga Hertz
RDRA	Rectangular Dielectric Resonator Antenna
RF	Radio Frequency
SIDRA	Substrates Integrated Waveguide Backed-Slot Antenna
VSWR	Voltage Standing Wave Ratio

LIST OF SYMBOLS

Symbol	**-**	**Meaning**
%	-	Percentage
e	-	Dielectric constant
E_{eff}	-	Effective dielectric constant
BW	-	Bandwidth
λ_0	-	Free space wavelength
h	-	Height of DR
r	-	Radius
a	-	Radius of DR
Ω	-	Ohm
Q	-	Q-factor
$J(x)$	-	Bessel function
$H(x)$	-	Hankel function
TE	-	Transverse electric mode
TM	-	Transverse magnetic mode
Re	-	Real
HEM	-	Hybrid mode
f_r	-	Resonant frequency
Z	-	Impedance
Z_0	-	System characteristic impedance
RL	-	Load impedance
T	-	Thickness
W	-	Width
K	-	Extension coefficient
HEM	-	Hybrid mode
fr	-	Resonant frequency
Z	-	Impedance
$Z0$	-	System characteristic impedance

REKA BENTUK GENTIAN KACA / ALUMINIUM KOMPOSIT PENYUAP DIELEKTRIK UNTUK JALUR LEBAR PARABOLA ANTENA

ABSTRAK

Dengan peningkatan teknologi, sistem tanpa wayar semasa yang sedia ada tidak cukup memuaskan. Sistem jalur lebar adalah sangat penting bagi memenuhi penghantaran tanpa wayar untuk kadar data tinggi dan sambungan tanpa wayar untuk pelbagai aplikasi. Dengan teknologi terkini, peranti penghubung radio menjadi lebih kecil dan lebih murah, oleh itu, ia memerlukan antena yang bukan sahaja kecil dari segi saiz tetapi juga mempunyai harga yang berpatutan. Ini hanya boleh dicapai dengan menggunakan antena parabola. Antena parabola biasanya menggunakan piring reflektor aluminium dan gandaan antenna ersebut bergantung kepada saiz reflektor. Berdasarkan kajian sebelum ini, beberapa teknik kepada peningkatan jalur lebar telah diadaptasi dalam tesis ini contohnya menggunakan penyusunan DRA bertingkat dengan penyuapan jalur mikrostrip. Tesis ini menerangkan cara rekaan silinder antena resonator dielektrik suapan untuk antena parabola. Susunan DRA, aperture gandingan dan DRA yang dilubangkan ditunjukkan dalam kajian ini. Simulasi ini dilakukan menggunakan CST microwave sebelum pengukuran mengambil dengan penganalisis rangkaian dan penganalisa isyarat. Hasil simulasi CDRA menunjukkan pelbagai frekuensi salunan dan menyediakan jalur lebar sebanyak 60.71% selepas teknik tersebut digunakan. Antena yang dicadangkan di dalam tesis ini telah beroperasi pada frekuensi dalam julat 11 GHz hingga 22GHz. Kemudian, pengukuran suapan CDRA untuk antena parabola telah dilakukan. Beberapa parameter telah diambil kira. Eksperimen ini dijalankan dengan membandingkan kerja yang dicadangkan dengan antena konvensional yang beroperasi pada 8.2GHz hingga 12.4GHz. Kedua-dua antenna dibandingkan dari segi gandaan dan mendapati bahawa antenna konvensional mempunyai nilai gandaan yang lebih baik. Sebagai contoh, pada 11.7GHz nilai gandaan antenna konvesional ialah 7.6dB manakala antenna yang dicadangkan ialah 9.2dB.

Design of Fiberglass / Aluminium Composite Dielectric Feed for Wideband Parabolic Antenna

ABSTRACT

In conjunction with future development of technologies, current wireless systems available have not kept pace. The great interest in wideband systems is because the needed of high data rate wireless transmission and a wireless connectivity for longer range applications. With the latest technology, the microwave radio link device become smaller and cheaper, therefore, require an antenna which is not only small in size and reasonable price. This can be only achieved by using parabolic antenna. The typical parabolic antenna are using solid aluminium dish reflector and the gain is depending on the size of the reflector. Based on previous research a few techniques on enhancing the bandwidth such as using stacked DRA with microstrip line feed are applied in this works. This thesis describes the development of cylindrical dielectric resonator antenna fed for parabolic antenna. The implementation of stacked DRA, aperture coupling and the perforated DRA are shown in this research. The simulation is being done in CST microwave at first before the measurement is taking with network analyzer and signal analyzer. The simulation result of CDRA shows multiple resonant frequencies and provides a wideband of 60.71% after the techniques mentioned above is applied. This proposed work has operating frequencies in the range of 11 GHz to 22GHz. Then, the measurement of this CDRA feed for parabolic antenna is being done. A few parameters are taken into consideration. The experiment is carried out by comparing the proposed work with existing antenna which operated at 8.2GHz to 12.4GHz.

The results show that the gain of conventional antenna is better than the proposed antenna. If they be compared at 11.7 GHz the gain of conventional antenna is reported to be 7.6dB while the proposed work is at 9.2dB.

CHAPTER ONE

INTRODUCTION

1.1 Background Studies

A microwave link is a communication system that uses a beam of radio waves in the microwave frequency range to transmit information between two fixed locations. With the speed of technology, the microwave radio link device becomes smaller and cheaper, therefore it required an antenna which is not only small in size and reasonable price(“Microwave Link Networks History Microwave Radio Link Planning Manufacturers of Microwave Link Equipment,” 2017). Microwave links are so adaptable due to their broadband which means they can pass large information at high speed. The installation of this kind of communication system is less costly and faster where it only needs two terminal points. In conjunction with future development of technologies, current wireless systems available have not kept pace. The great interest in wideband systems is because the needed of high data rate wireless transmission, a wireless connectivity for longer range applications, for low data rate applications and for radar and imaging system (Rusakov et al., 2017). The wireless spectrum that is below 6GHz will not be enough to fulfill future demands. Thus, many researches has been done to find a solution for this issues while taking a few matters on consideration for instance cost of developing, and simplicity in the design.

Within these past few years, dielectric resonator antennas (DRA) have been well known as possible radiators in communication systems. Since 1960s, DRs have been used as high –Q elements in oscillator design and microwave filter(Leung et al., 2012). The early research on practical application of dielectric resonator antenna has been introduced by (Long et al., 1983) where the capability of cylindrical dielectric antenna in providing an efficient radiation while retaining desired features necessary for future application is proved (Long et al., 1983). Since then, DRA has been realizes as the solution for enhancing wireless transmission due to the radiating elements DR. Various shapes and feeding mechanism are experimented to achieve desired radiation characteristics, for instances circular polarization or linear polarization is the recent one (Abedian et al., 2017). Choosing the right dielectric material played an important role as it can affect the size of antennas and the frequency required.

In this introductory chapter, it highlights the main reasons for the studies of dielectric feed for wideband parabolic antenna. The problems face that lead to this research and the objectives of research will be presented. For the studies of DRA characteristics, feeding technique, shape of DRAs and their affected resonant frequency, and the latest research on DRA will be seen throughout this research.

1.2 Problem Statements

Any dielectrics can be a radiator with the right excitation at specific frequencies. Dielectric antenna usage is now taking the leading in replacing the existing radiating elements at high frequencies especially for millimeter waves applications and beyond. This is due to their advantages of less conduction loss and high radiation efficiency.

In the past, these antennas are made of ceramics now it being innovative by making them with plastic material (Keyrouz et al., 2016). Many alternatives approach has been taken in recent papers to achieve large impedance bandwidth including combining different shape of DRA or different material, shaping the DRA, or use annular feeding slot (Keyrouz et al., 2016).

Thus, the focus of this research is to investigate and design an efficient dielectric feeding configuration technique for parabolic antenna which can cover wide operational bandwidth between 11 to 23 GHz band. Conventional antenna has a limited bandwidth due to the waveguide. In this dissertation, a solution for achieving wider bandwidth is shown by using DRA to excite the parabolic antenna. DRAs are practicable solution due to their features mentioned above. The simplicity in the design and type of dielectric material is chosen wisely for this research. The performance in terms of bandwidth, gain, and radiation pattern and return loss will be analyzed.

1.3 Research Objectives

1. To design and characterize a wideband dielectric feeder for fiberglass/ aluminium composite parabolic antenna.
2. To fabricate and measured the dielectric feeder for fiberglass/ aluminium composite parabolic antenna.
3. To compared the performance of the existing antenna and the proposed antenna.

1.4 Scope of Research

A systematic approach was employed to achieve the research objective of this dissertation work. The scope for this dissertation is focused on the bandwidth enhancement of parabolic antenna using DR feeding technique. The design will be more towards simplicity by choosing the type of material, the feeding structures, and radiating elements wisely. In this dissertation, the material use, the parameters of the design, and the feeding mechanism used by the antenna will be shown. The simulation of this work is done in CST Microwave studio. It is done earlier before the measurements are taking with the suitable equipment. The performance of the antenna can be seen in term of bandwidth, gain and radiation factor.

1.5 Thesis Outline

Literature review in chapter two presents the work done by other researcher related with DRAs. At the beginning of this chapter, is the introduction on DRA that stated the advantages of DRA and prove of DRA evolution. This followed by the next section that explain on the shape exist for DRA and how it affect resonant frequency. The techniques available for feeding the antenna are also mentioned in this chapter. Lastly the ways of enhancing the bandwidth of antenna proposed by previous researcher are presented.

Chapter three is mainly on how the research is carried out in order to achieve the objective of the research. The process of designing the dielectric feeder is done by using Computer Simulation Technology (CST) for microwave and radio frequency component applications. In this chapter the dimensions, and parameters use is presented.

At the beginning of this chapter a brief description on contents of chapter three is elaborated. In this section a general flowchart that concludes the whole process is shown followed with a flowchart which is more detailed on the designing of the parabolic antenna. Then, a description on subject of study is present with validity and reliability of measurement.

Next, in chapter four the main thrust of the research where findings of the study and interpretation of results presented. The results of this work are measure in term of their performance by observing the bandwidth, gain and radiation factor of the antenna. The result will be analyzed to identify the relationship between variable. Next, the result after testing the CDRA with parabolic dish will also be elaborated in this chapter. In this section, only a simulation result of CDRA and a measured result of parabolic antenna is presented due to time constraint and to simulate a parabolic in a CST software might not be suitable since it needs a bigger mesh size.

Lastly is chapter five, for conclusion and future works. In this chapter, it discusses the achievements of this works and a recommendation for future works based on limitations founds in this research. The summary of the findings based on research objectives are presented throughout this chapter.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

With rapid development of wireless communication, a broadband operation is high in demand. After decades of research done on DRA, it is finally realize as one of the solution for wideband (Cicchetti et al.,2016). This chapter discusses a variety research subjects related to DRA. At the beginning of this chapter, the most common shapes of DRA are presented and how it affects the resonance frequency. From these common shapes many researchers come up with new idea for instance hemisphere, cross-shaped and supershaped DRA such as in (Simeoni et al., 2011). DRA become tremendously popular for variety of communication system, as they are light in weight, high radiation efficiency, and made up from low loss dielectric material. DRA can replaced the conventional microstrip- antennas due to their features of lower power loss and can offer a wider bandwidth (Solomon et al., 2015). In antenna engineering, enhancement techniques are very important. This can be done by taking other parameters into consideration. For instance by choosing the suitable coupling method and feeding mechanism. In this chapter previous work done on DRA will be presented. These include feeding mechanism and coupling method and also the ways on enhancing antenna bandwidth.

2.2 Various Shape of DRA Affect Resonant Frequencies

To achieve a compact wireless communication the antenna structure has to be miniaturized. One of the way could be done is by minimize the dimensions of the antenna, its performance in term of radiation pattern, gain or shape (Messaoudene et al., 2017). This shows shape of DRA does played an important role. Nowadays, DRA can be found in many shapes and size but hemispherical, cylindrical, and rectangular are the popular and common shapes of DRA (Keyrouz et al., 2016). Different shapes gives out different field mode configurations. Through these analyses, it can be used to calculate the Q-factor, resonance frequency and radiation pattern of the DRA.

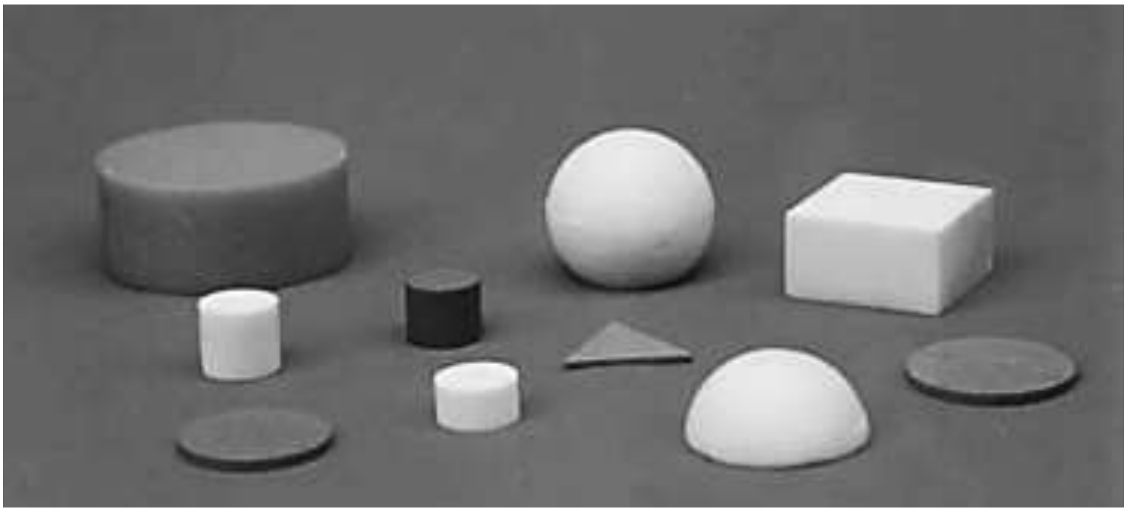

Figure2.1: Various Basic Shapes of DRAs (Luk et al., 2003)

What makes DRA interesting is, it can be designed in any 3D shaped for instance a basic shape like cylindrical, rectangular or hemispherical. After the first experimental of DRA carried by (Long et al., 1983), many research have been done on different shapes such as stair annular shape (Das et al., 2016), concentric truncates cones (Cicchetti et al., 2016), T-shaped f DRA (Trivedi et al., 2016) and another example is a tree shaped fractal DRA (Trivedi et al., 2017). Figure 2.1 shows various shapes of DRA and they are the basic shapes that lead to super shaped nowadays.

2.2.1 Hemispherical DR

An example of hemispherical DRA is as shown in Figure 2.2. It offers advantages compare to rectangular and cylindrical shapes because of the simpler interface between dielectric and air. However, hemisphere always supports degenerate resonant modes due to the existence of certain symmetry. These modes will increase the cross polarization ratio that is undesirable for linear polarizations but may be needed for dual or circular polarizations designs (Luk et al., 2003).

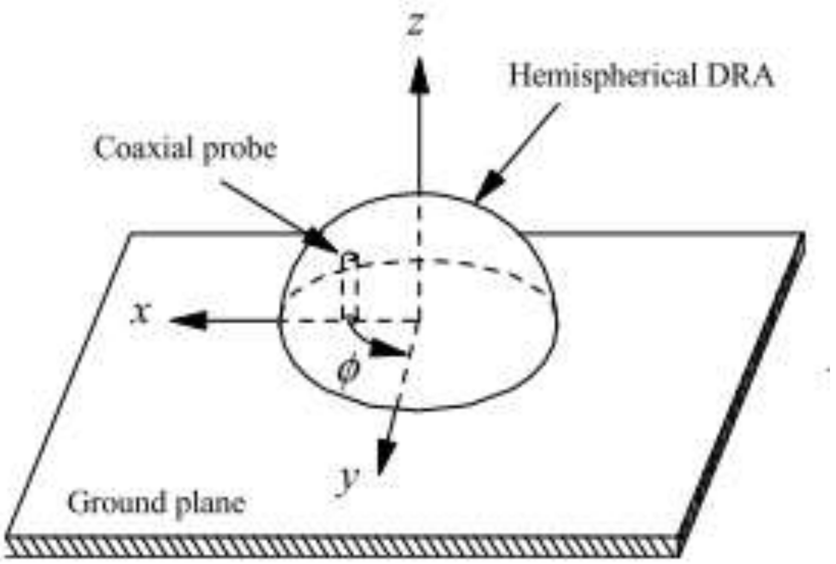

Figure2.2: Three dimensional view of cylindrical DRA with an air gap for bandwidth enhancement (Luk et al., 2003)

In 1960s the resonant modes of dielectric sphere in free space is studied. Hemispherical DRA is in a perfect electric conductor, thus image theory can be used to compare its radius to an isolated dielectric sphere having the same radius (Petosa, 2007). The results obtained can be directly applied to hemispherical DRA. For this shape of DRA two modes can be seen, TE_{111} and TM_{101}. TE_{111} mode is the lowest order mode for hemispherical DRA. In far-field radiation pattern, it produces a pattern similar like short horizontal magnetic dipole. Equation 2.1 is the Bessel function, J(x) and Hankel function, H(x) while k_0 is the free-space wave number (Petosa, 2007). In Equation 2.2, a represent the radius. While for Q-factor can be calculated by using Equation 2.4 (Petosa, 2007).

$$\frac{J_{1/2}(\sqrt{(\varepsilon_r k_0 a})}{J_{3/2}(\sqrt{(\varepsilon_r k_0 a})} = \frac{H^2{}_{1/2}(k_0 a)}{\sqrt{\varepsilon_r}\, H^2{}_{1/2}(k_0 a)} \tag{2.1}$$

Once k_0 is obtained, resonance frequency can be determined by

$$f_{GHz} = \frac{4.7713\, Re(k_0 a)}{a_{cm}} \tag{2.2}$$

Q-factor can be calculated by deriving from curve-fitting traces

$$Re(k_0 a) = 2.8316 {\varepsilon_r}^{-0.47829} \tag{2.3}$$

$$Q = 0.08 + 0.796\varepsilon_r + 0.01226{\varepsilon_r}^2 - 3.10^{-5}{\varepsilon_r}^3 \tag{2.4}$$

2.2.2 Cylindrical DR

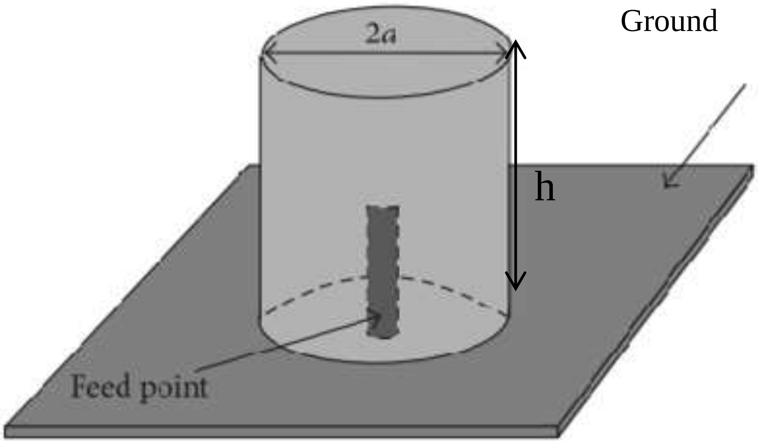

Figure2.3: Three dimensional view of cylindrical DRA (Keyrouz et al., 2016)

For cylindrical shown in Figure 2.3, it offers great design flexibility where the ratio of radius over height controls the resonant frequency and the Q-factor. In other words, different Q-factor can be obtained for a given dielectric constant and resonant frequency by varying the DRA's sizes. Various mode transverse magnetic TM, transverse electric TE, and hybrid mode HEM can be easily excited within cylindrical DRA which then result in either omnidirectional or broadside radiation pattern (Petosa, 2007).

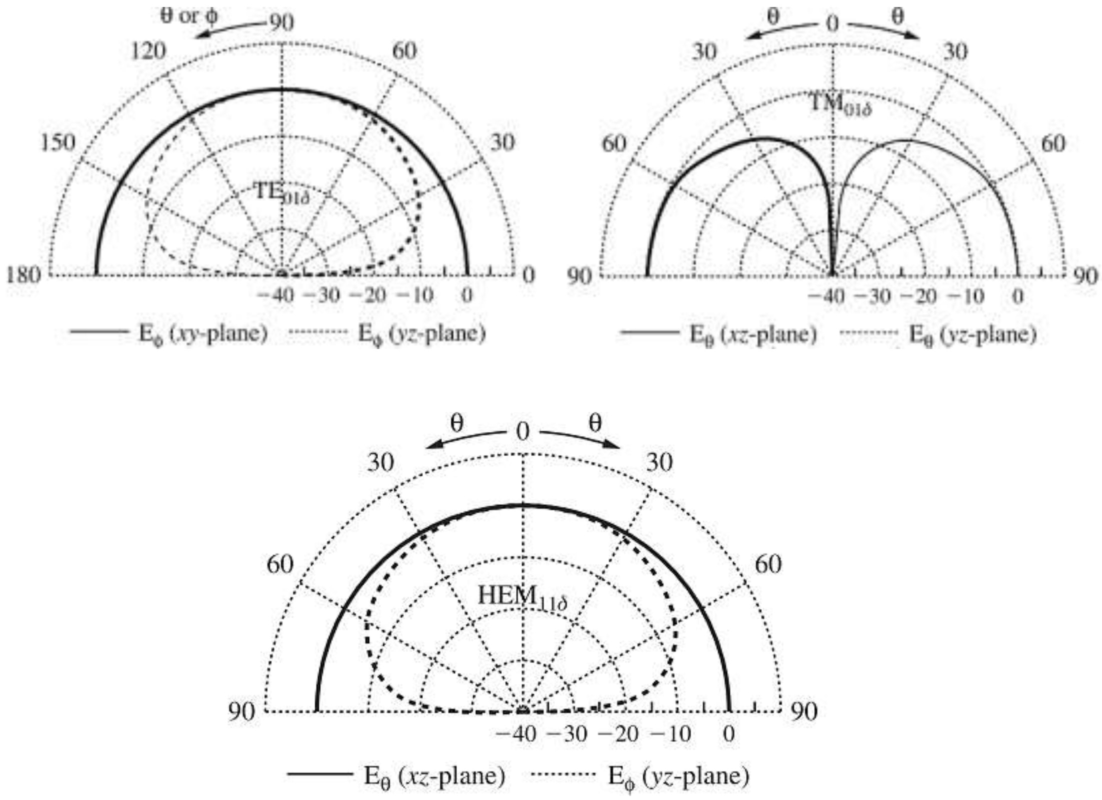

Figure 2.4: Radiation Pattern for Modes of CDRA (L., Warren et al., 2012)

The radiation patterns for these modes are shown in Figure 2.4. For TE and TM modes, they are axially symmetric which means no azimuthal dependence while hybrid modes do depends on the azimuth. In (L., Warren et al., 2012) it stated the limitations for each mode based on the radius to height ratio where TE and TM mode is $0.33 \leq \frac{a}{h} \leq 5$, while for HE mode is $0.4 \leq \frac{a}{h} \leq 6$.

The resonance frequency, f_0 is affected by the ratio radius to height and the value of dielectric constant ε_r. It is inversely proportional to the value of ε_r, where the resonance frequency increases as the ε_r decrease and vice versa. Equation (2.5), and (2.7) shown below is the approximate calculation for conventional cylindrical DRA. The resonance frequency for TM01δ mode and HE11δ can be calculate by expression bellow in Equation 2.5 to 2.8 (Chaudhary et al., 2010) where a and h are the radius and height of DR. In practical applications, TM_{110} mode is always chosen as it is the dominant mode. It has the lowest resonance frequency (Long et al., 1983). Equation (2.5) can be used to determine the bandwidth of antenna based on the calculation of Q-factor.

Resonant Frequency for TM01δ

$$f_r = \frac{c}{2\pi a\sqrt{(\varepsilon_r+2)}}\sqrt{3.83^2 + (\frac{\pi a}{2h})} \tag{2.5}$$

Q-factor can be calculated by

$$Q_{rad=}0.008721\varepsilon_r{}^{0.888413}e^{0.0397447}$$

$$\times\left\{1-\left(0.3-0.2\frac{a}{h}\right)\left(\frac{38-\varepsilon_r}{28}\right)\right\} \tag{2.6}$$

$$\times\left\{9.498186\frac{a}{h}+2058.33\left(\frac{a}{h}\right)^{4.32226}e^{-3.5(\frac{a}{h})}\right\}$$

Resonant frequency for HE11δ mode

$$f_r = \frac{6.324}{a\sqrt{(\varepsilon_r+2)}}\left\{0.27+0.36\left(\frac{a}{2h}\right)+0.02\left(\frac{a}{2h}\right)^2\right\} \tag{2.7}$$

Q-factor can be calculated by

$$Q_{rad=}0.01007{\varepsilon_r}^{1.3}\left(\frac{a}{h}\right)\left\{1+100e^{-205(\frac{a}{2h}-\frac{1}{80}(\frac{a}{2h})^2}\right\} \tag{2.8}$$

Q-factor is then be used to estimates the fractional bandwidth of DRA

$$Bandwidth\ (BW) = \frac{VSWR-1}{Q-factor\ \sqrt{VSWR}} \tag{2.9}$$

From equation 2.8 we know that, the low value of Q-factor could lead to a larger fractional bandwidth for low dielectric constant material. For multilayer DRA, the section with lower dielectric values helps in improves the bandwidth while the one with higher dielectric constant can lower the resonant frequency and vice versa.

2.2.2 Rectangular DR

On the other hand, rectangular DRA offer the greatest design flexibility since it has three independent geometrical dimensions which is the height, length, and width. It can be seen in Figure 2.5 as compared to cylindrical DRA (Keyrouz et al., 2016).Besides that, it is also characterized by low cross-polarization level compared to cylindrical DR(Ali et al., 2015). Cross polarization is the negative dB power level which indicates on how many decibels below the desired polarization's power level the cross polarization power level is.

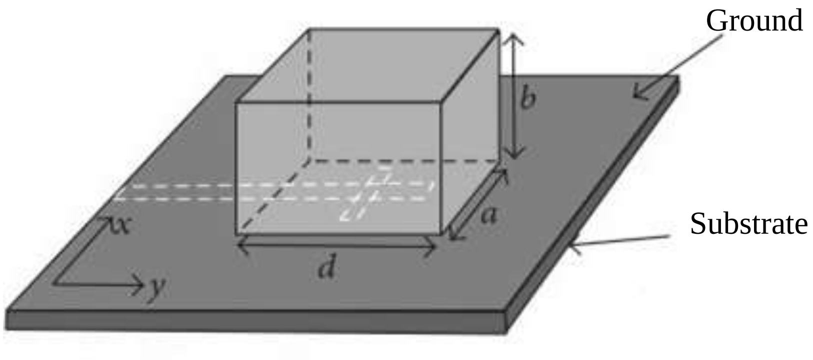

Figure 2.5: Three dimensional view of rectangular DRA (Keyrouz et al., 2016).

Resonance frequency for rectangular DR can be calculated from the following transcendental equation in Equation (2.2) (Mongia et al, 1997). Where fr is the resonant frequency and other parameters are as shown in Figure 2.2.

$$fr = \frac{c}{2\pi a\sqrt{\varepsilon r}}\sqrt{k^2x + k^2y + k^2z} \qquad (2.10)$$

$$kx = \frac{\pi}{a} \qquad (2.11)$$

$$kz = \frac{\pi}{2b} \tag{2.12}$$

$$d = \frac{2}{ky}\tanh\left(\frac{ky0}{ky}\right),\ ky0 = \sqrt{k^2x + k^2z} \tag{2.13}$$

2.3 Coupling Method and Feeding Mechanism for DRA

When DR is mounted on top of a metallic ground plane, they radiate energy thus it can act as antennas. The critical part in designing a DRA is in choosing the suitable coupling method and feeding mechanism where this affects the resonance frequency and the Q-factor. The most common methods to excite a DRA are probe coupling, microstrip line coupling and aperture coupling. By deciding the position or location, method of coupling and the dimension, the mode that will be excited can be determined.

In (Kumar Vasa et al., 2016), the antenna is excited by using coaxial probe feed which is located nearly 5mm from the center of the CDRA. There is an existence of air gap that increase the efficiency of radiating. (Yasin et al., 2016) also use a probe as feeding mechanism but it applied it from its bottom. Another example is by using microstrip to fed the stacked CDRA which has been proposed in (Sharma & Gangwar, 2016).

2.3.1 Probe Coupling

Among various excitation method, probe is the first method to be experimented to radiated the DRA. It has a center pin of a coaxial transmission line extends through the ground plane. Another way is by having a probe that perfectly fits the hole size. With this method, usually an air gap will exist and the results will differ from predicted value (Luk et al., 2003) .

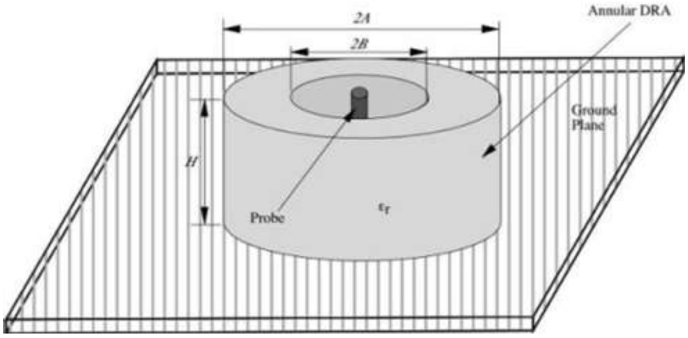

Figure 2.6: Probe-fed annular DRA (Luk et al. 2003)

For this type of coupling there are no specific equations to design it but practically the probe is located adjacent to DRA so no drilling of DRA is needed.

By positioned it adjacently to rectangular DRA, TE mode can be excited same goes to cylindrical DRA, HE mode will be excite or TE mode will be excited if it is for spilt cylinder (Petosa, 2007).

The probe can also be connected to the metal strip that is positioned adjacent to the DRA or it can be a microstrip line. Probe-fed annular Figure 2.6 is one of the examples to position the probe coupling. The height of the probe can be adjusted to achieve the desired matching. An advantage by using probe coupling is it does not need matching impedance. It can be directly coupling to 50Ω feed. However it only useful for lower frequency applications where aperture-coupling is not practical because of larger slot size required (Petosa, 2007).

2.3.2 Microstrip Line Coupling

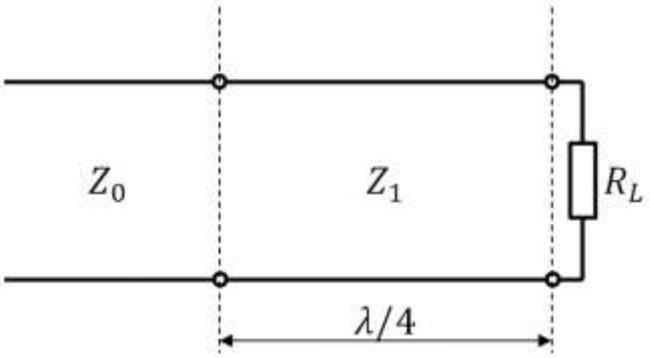

Figure 2.7: Schematic of quarter wave transformer (D.M Pozar, 2017)

Figure 2.7 is the schematic of quarter-wave transformer, a simple impedance transformer which is usually used in impedance matching. It can reduce the energy that reflects when a transmission line is connected to a load. The quarter-wave transformer uses a transmission line with different characteristic impedance. The length of the guide wavelength is one-quarter so that it can match to a load which is shorter than free-space wavelength because of the presence of dielectric substrate (D.M Pozar, 2017). Equation 2.7 shows how to calculate the impedance Z1.

$$Z_1 = \sqrt{Z_o R_L} \tag{2.7}$$

2.3.3 Slot or Aperture Coupling

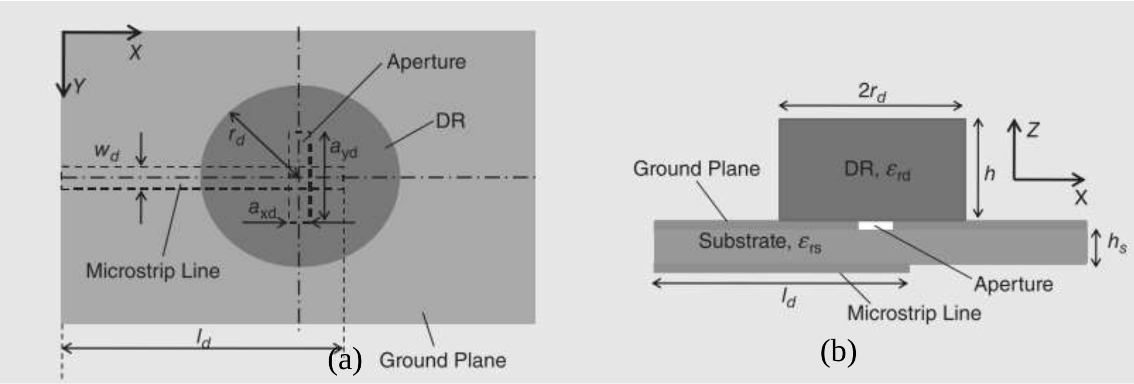

Figure 2.8: Aperture-coupled (a) top view.(b)side view (Guha et al., 2016)

Microstrip feed line and probe feed, both have inherent asymmetries in which will generate higher order mode that can cause cross-polarized radiation. Thus, a noncontacting aperture coupling like in Figure 2.8(b) could overcome this issue. It has a microstrip line that cross with a slot on it. The position of feeder is under the ground plane which an advantage as it can isolate the unwanted coupling. The aperture can be fed by a waveguide, microstrip or coaxial line. This kind of feeds is easier to model, eventhough it has a narrow bandwidth.

The dimensions of this microstrip line, slot aperture and the shape of the stub will determined the impedance matching. Aperture coupling act like a magnetic current flow parallel to the aperture that excited the DRA. Usually to use this type of feeding mechanism is by excited the DRA through an aperture in the ground plane where it in contact with DRA. Rectangular slot is frequently being used as it has the widest aperture (Petosa, 2007).

2.4 Bandwidth Enhancement Techniques

Surface wave and spurious feed radiation will increase as the substrate thickness increases which can limited the bandwidth in practical designs (Constantine A., 2005). However that can only be achieved if the dielectric constant is more than 20, if it is low and required for wideband operation it might be problematic (Gangwar et al., 2010). Theoretically, bandwidth of DRA can be increased through the reduction of dielectric permittivity and vice versa. However, by reducing the permittivity of dielectric material will results in increasing DRA dimensions (Luk et al., 2003). This is the challenge face in designing a DRA. In this section various techniques can be seen to enhance the bandwidth of the DRA. These include the impedance matching done with matching stubs, or quarter wave transformer, and the usage of multiple DRA.

Since the first fabrication of CDRA in 1983 (Long et al., 1983) many research have been carried out and various techniques are introduced to increase the bandwidth of the antenna. In (Kumar et al., 2016) the proposed antenna is excited using a coplanar waveguide feed that results as a wideband antenna with frequency of 3.265GHz to 15.0GHz. This antenna is combining two rectangular slots in the ground plane to improve the return loss at higher frequency. The corresponding impedance bandwidth to this antenna is 128.498%. (Lin et al., 2017) Introduce a new enhancement technique by introducing a feeding a ring under the DRA and the slot windows are etched on the ground plane. With this technique the bandwidth achieved is 38.1% from 6.72GHz to 9.88GHz.

Other example is by (Gupta et al., 2017) that shows the usage of copper strip connected to the microstrip line. The copper strip has the similar advantage as coaxial probe but the energy coupling between DRA and copper strip are better since it is placed on the DRA surface. The proposed rectangular dielectric resonator antenna (RDRA) array offers a high gain of 10.50dB and a bandwidth of 512MHz from a 3.44GHz to 3.95GHz. For impedance matching by using aperture slot, (Belazzoug et al., 2016) introduce a two ways aperture excitation with one etched on the ground and the other is at the center of CDRA. The proposed antenna implements a diode since they are functioning for WiMax band at 3.77GHz and the WLAN band at 5.48GHz. It is called reconfigurable techniques that can improve the spectral effectiveness of the transmission.

Another approached is by using plus shaped aperture slot for a dielectric resonator loaded substrate integrated waveguide backed slot antenna (SIDRA) (Thilagam et al., 2016). 8.80% of bandwidth is achieved by using plus shape aperture. This paper compared a rectangular slot with plus shaped slot and the result shows that plus shaped has the widest bandwidth.

Multiple DRA is also one of the methods to enhance the bandwidth of antenna. This is an alternative to attain a wideband or dual-band operation (Luk et al., 2003). Multiple DRA can either stack on each other or can be arranged in a co-planar. In (Messaoudene et al., 2017) the antenna is stacked with two different dielectric material with different permittivity. The lower DR permittivity is lower than the upper DR and is excited using microstrip line. It results with a 32MHz impedance bandwidth from 8GHz to 10.77GHz. This antenna achieves 67% reduction of size compare to conventional DRA with the same resonance frequency of 7.99GHz.

The proposed antenna in this paper (Hu et al., 2017) used the low profile stacked DRA and microstrip metasurface. In order to achieve a broad bandwidth, four resonant modes are excited HEM11δ, HEM12δ, HEM31δ and HEM13δ modes of cylindrical DRA. It is results in a wider bandwidth which is 61.4% that shows that cylindrical stacked DRA has greater impedance and gain bandwidth, thus preferable to the design for broadband filtering DRA. The author also compared the work with rectangular stacked DRA. The findings conclude that stacked CDRA has a better matching. Table 2.1 summarizes previous mentioned method. Next example by using stacked DRA is by (Mishra et al., 2015) where three cylindrical is stacked with each other. They are in equal thickness but different material, different permittivity. In this paper a CDRA having a diameter of 6mm and thickness of 3mm are fed with coaxial probes. By varying the height of probe from 4.05mm to 4.85mm, the result shows that at the height of 4.45mm the bandwidth achieve is 2.5GHz with impedance bandwidth of 22.94%.

Table2.1: Summary of Measured DRAs In Terms of Bandwidth Enhancement

Description	Excitation	BW %	References
CDRA with Annular Shaped Microstrip	Microstrip	27	(Das et al., 2016)
Series-Fed Linear DRA Array	Microstrip	38.1	(Lin et al., 2017)
RDRA Array	Aperture	13.8	(Gupta et al., 2017)
SIDRA	Aperture	8.80	(Thilagam et al., 2016)
Compact RDRA	Stacked DRA	29.51	(Messaoudene et al., 2017)
Filtering DRA with Wide Stopband	Stacked DRA	61.4	(Hu et al., 2017)
CDRA for Wideband	Stacked DRA Coaxial Feeding	22.94	(Mishra et al., 2015)
Perforated DRA	Coaxial Probe	26.7	(Chair, Kishk, & Lee, 2006)
DRA Array	Aperture Coupled	5.76	(Movahedinia, Chaharmir, Sebak, Ranjbar Nikkhah, & Kishk, 2017)

Based on the summarization in the table above, this dissertation is taking the work by (Hu et al., 2017) as an example. The implementation of microstrip and stacked DRA are also in shown in this paper and proved that cylindrical stacked DRA has greater impedance and gain bandwidth and a better matching.

Perforated antenna was first done by (Kishk et al., 1989), to altered the dielectric constant of a material. The author use perforation techniques to improve radiation pattern and efficiency of microstrip patches. In (R Chair et al., 2006), this techniques is used and proves that the DRA with air-filled holes can enhance the impedance bandwidth to 26.7%.

Perforated technique altered the effective permittivity depending on the space between hole and its diameter. Another implementation of this technique is done by (Movahedinia et al., 2017) for DRA subarrays which help in eliminating the needs for bonding an aligning each DRAs. The DRA array is fed by aperture coupled lines at the back of antenna. This works achieve about 5.76% of bandwidth.

Figure 2.9 is the hole configuration and Equation (2.8) and (2.9) as shown is to calculate the efective dielectric permittvity(Petosa et al., 2002) where A_0 is the area of the hole, A is the area of cell unit,d is the hole diameter and s is the spacing.

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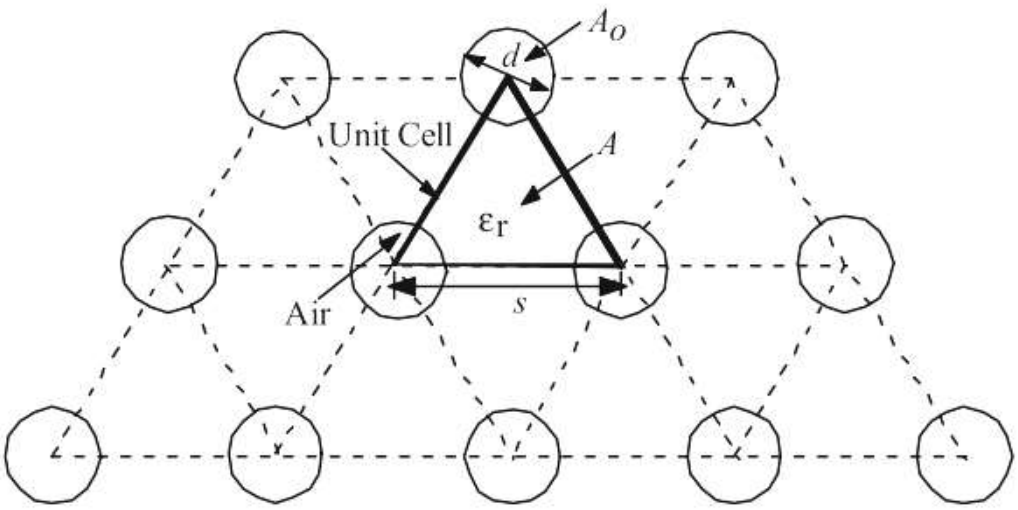

Figure 2.9: Hole configuration (Petosa et al., 2002)

$$\varepsilon_{eff} = \varepsilon_r(1-a)+a \tag{2.8}$$

Where a is the filling factor

$$a = \frac{A_0}{2A} = \frac{\pi d^2/4}{2\left(\frac{\sqrt{3}}{4}\right)s^2} = \frac{\pi}{2\sqrt{3}}\left(\frac{d}{s}\right)^2 \tag{2.9}$$

2.5 CDRA Fed for Reflector Antenna

With current development in communication, wideband antenna is one of the ways to provide a wide frequency usage. They are in charge for receive, decodes and converts electromagnetic waves into electric current or vice-versa. Conventionally, coaxial probe is use as feeding mechanism. However due to their limited bandwidth, it is not suitable to be used in wideband applications. DRA as mentioned previously is a suitable candidates since it comes in small sizes, light weight, low loss and easy to fabricate. Moreover it has more than 98% of high radiation efficiency.

In (Ricky Chair et al., 2006) a rectangular slot is excited with a microstrip line feed with a U-shape tuning stub at the center of the slot results in an impedance bandwidth of 110%. The ultra-wideband antenna proposed by the author has a reflector at the back of the antenna. The distance between reflector and the antenna is about 8mm. The experiment is tested with different size of reflector, which is 150mm by 150mm and 100mm by 100mm and prove that the antenna matching is achieving with larger size of antenna.