ELECTRICAL AND MECHANICAL PROPERTIES CHARACTERIZATION OF AGRICULTURAL WASTE / SAND COMPOSITES FOR WLAN ANTENNA DESIGN

by

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LIST OF ABBREVIATIONS

DRA	Dielectric Resonator Antenna
CST	Computer Simulation Technology
RF	Radio Frequency
PCB	Printed Circuit Board
MPA	Microstrip Patch Antenna
RDRA	Rectangular Dielectric Resonator Antenna
HDRA	Hemispherical Dielectric Resonator Antenna

LIST OF SYMBOLS

ε_r	Relative permittivity
K	Dielectric Constant
ε	Absolute Permittivity
ε_0	Free space of permittivity interaction of a material in the presence of an external electric field
$\tan\delta$	Loss tangent
ε'	Dielectric constant
ε''	Dielectric loss factor
c	Speed of light
fr	Frequency
W	Patch width
L	Patch length
Wg	Substrate/ground width
Lg	Substrate/ground length
Wf	Width feed line
Gpf	Gap between patch and feed line
Fi	Length of the feed line
Ht	Height patch

Pencirian Sifat Elektrikal dan Mekanikal Sisa Pertanian / Komposit Pasir untuk Reka Bentuk Antenna WLAN

ABSTRAK

Sekam padi, jerami padi, hampas tebu, daun pokok pisang yang kering adalah sebahagian daripada bahan buangan pertanian yang digunakan dalam kajian ini. Pada kebanyakan tempat, bahan buangan ini tidak mempunyai nilai komersil dan dilupuskan dengan pelbagai cara termasuk kaedah pembakaran terbuka yang boleh menyebabkan pemcemaran udara. Bagi menangani masalah ini, bahan ini boleh digunakan sebagai bahan dielektrik dalam antena resonator dielektrik. Harga bahan dielektrik sedia ada yang digunakan dalam antena resonator juga sangat mahal berbanding bahan buangan pertanian ini tadi. Selain itu, hal ini boleh mengurangkan penggunaan bahan bukan organik yang berbahaya sekaligus mengurangkan pencemaran udara disamping mengitar semula bahan-bahan buangan organik. Pada peringkat awal, bahan-bahan ini akan dicirikan dalam aspek sifat elektrikal dan mekanikal yang berpotensi untuk digunakan dalam aplikasi antena. Kajian bermula dengan mengisar semua bahan-bahan tadi menjadi serbuk halus yang kemudiannya akan dicampurkan dengan resin dan bahan pengeras. Kemudian, bahan campuran itu tadi akan dimasukkan kedalam bekas segi empat sama lalu dibiarkan selama dua hari dalam suhu bilik bagi memastikan campuran tadi menjadi keras. Seterusnya, sifat dielektrik juga dinilai bagi menentukan pencapaian pemalar dielektrik dan kehilangan tangen. Prestasi sifat dielektrik daripada sampel bahan ini dinilai dalam julat 1 GHz sehingga 3 GHz yang mana sampel ini dikaji dengan menggunakan probe sepaksi terbuka. Bacaan dielektrik pemalar yang tinggi dan kehilangan tangen yang rendah adalah sangat sesuai untuk digunakan dalam aplikasi antena. Selain daripada itu, sifat mekanikal daripada bahan ini akan menjalani 2 analisa iaitu ujian ketahanan yang menunjukkan keupayaan untuk menahan bebanan yang dikenakan dan analisa morfologi yang mengkaji struktur mikro bahan tersebut. Seterusnya, kajian ini diteruskan lagi dengan merekabentuk antena *patch* yang digunakan untuk rangkaian kawasan tempatan tanpa wayar (WLAN) pada frekuensi 2.45GHz dengan menggunakan perisian teknologi simulasi komputer (CST). Kemudian, kajian ini diteruskan lagi dengan merekabentuk antena *patch* dengan bahan dielektrik sebagai antena resonator dielektrik (DRA) pada frequency 2.45 GHz untuk tujuan pengecilan saiz antena. Kemudian, ketiga-tiga antena itu dihasilkan dan penilaian eksperimen dijalankan dengan menggunakan penganalisa rangkaian (PNA) dimana hasil penilaian eksperimen sejajar dengan penilaian simulasi. Hasil pekali pantulan, S_{11} dan perolehan dibandingkan antara antena *patch* dengan kehadiran dan ketidakhadiran bahan dielektrik selepas pengecilan saiz menunjukkan bacaan yang sama dengan antena patch microstrip yang asal. Oleh itu, objektif pengecilan saiz antena yang dilakukan tanpa mengganggu keberhasilan pekali pantulan dan perolehan adalah tercapai. Secara keseluruhan, daun pisang yang kering dan sampel pasir didapati menjadi bahan dielektrik yang terbaik untuk digunakan dalam aplikasi antena sebagai antena resonator dielektrik.

Electrical and Mechanical Properties Characterization of Agricultural Waste / Sand Composites for WLAN Antenna Design

ABSTRACT

Rice husk, rice straw, sugarcane bagasse and dried banana leaves are the residues product used in this research. In most places, these residues possess no commercial value and are disposed in various ways, including illegal open burning, which causes pollution. To overcome this problem, these agricultural waste materials have potential to be used as a dielectric resonator material for dielectric resonator antenna. The existing dielectric material used for dielectric resonator antenna consume high price compared with agricultural waste material. Besides, this reduces the usage of hazardous inorganic materials, and at the same time minimizes pollution and recycles organic waste materials. These composites will be first characterized in term of their electrical and mechanical properties as potential to be used for antenna application. This starts with the preparation of the sample by grinding each of the materials into fine particle. Then, the residues powders were mixed together with the resin and hardener agent. After that, the mixture is then placed into a square mold and been left for two days in a room temperature to ensure the mixture become hardened. Next, the electrical parameter measurements like dielectric properties were studies to determine the performance of dielectric constant and loss tangent. The performance of the dielectric properties of the sample waste materials was studied in the range of 1 GHz until 3 GHz and the samples were measured by using the open ended coaxial probe techniques. The high reading of dielectric constant and low loss tangent of a material are suitable used for antenna application. Besides that, the mechanical properties of the agricultural waste sample undergo 2 analyses consist of tensile strength test and morphology analysis. Tensile strength indicates the ability withstand load or tension applied into the dielectric material and morphology analysis is used to analyze the composite microstructure. Furthermore, this research is proceeds by designing the microstrip patch antenna for Wireless Local Area Network (WLAN) application at frequency 2.45 GHz by using Computer Simulation Technology (CST) software. Then, this process is continued by designing microstrip patch antenna with single and double dielectric material as dielectric resonator antenna (DRA) at frequency 2.45GHz for antenna miniaturization purpose. Then, the three antennas were fabricated, and the experimental results were accomplished using PNA network analyzer where the measured results agree well with the simulated results. The results of reflection coefficients S_{11}, and results of gain for microstrip patch antenna with single and double dielectric resonator material after being miniaturized were same as the original microstrip patch antenna. Hence the objective to miniaturize the antenna without degrading the performance of reflection coefficient and gain is achieved. In overall, the dried banana leaves with sand sample found to be the best dielectric material to be used for antenna application as dielectric resonator antenna.

CHAPTER 1 : INTRODUCTION

1.1 Research Background

Nowadays, antennas using high-permittivity dielectric ceramic materials as radiation elements have received much attention due to several features like high radiation efficiency, low temperature coefficient, low profile and suitable scale in microwave band (Long & Connor, 2007). Since dielectric resonators have very low loss, higher efficiency without any conductor loss ensued (Rahim & Teknologi, 2013). Therefore, dielectric resonator antenna (DRA) owns much lower loss and become a very good candidate to design the antenna for microwave bands (Peng, Wang, & Yao, 2004). But, the current materials for (DRA) is expensive and contain a lot of chemical in it (Salame, Drai, Prakash, & Kulkarni, 2013). Then, to overcome this problem, the ceramic material was replaced by agricultural waste material is suggested. The analysis of several agricultural waste materials was evaluated in this research.

Agricultural wastes are made up of organic compounds from living plants. Rice husk (H Nornikman, Soh, Azremi, Wee, & Malek, 2009), rice straw, Sugarcane bagasse (Ho, 2006; Liyana et al., 2012; H Nornikman et al., 2009) and dried banana leaves (Kaur, Aul, & Chawla, 2015; Tock, Lai, Lee, Tan, & Bhatia, 2010) are the residues products used in this research. These materials have chance to be used as an alternative for microwave communication applications like antenna and microwave absorber. These agricultural waste materials also capable to replace the conventional printed circuit board (PCB) such as FR-4, Taconic, and roger (Hoon, Jack, Malek, & Hassan, 2012).

The measurements of dielectric properties of rice husk, rice straw, sugarcane bagasse and dried banana leaves are important to understand their physical and chemical properties which are related to the storage and loss energy in it (Kundu & Gupta, 2014; Wee, Soh, Suhaizal, Nornikman, & Ezanuddin, 2009). The high reading of dielectric constant and low reading of loss tangent of a material are suitable for antenna application while the low reading of dielectric constant and high reading of loss tangent is suitable for microwave absorber used in Radio Frequency (RF) anechoic chamber (H Nornikman et al., 2009).

1.2 Problem Statement

The residues product or agricultural waste are made up from organic compounds from the living plants like sugarcane bagasse (Liyana et al., 2012), banana leaves (Kaur et al., 2015), coconut shell, oil palm empty fruit bunch, rice husk (Hassan Nornikman et al., 2010), rice straw (G.Sivakumar, K.Amutha, 2011), and others. Backyard burning had been a common trash disposal method in the agriculture area and the it has increase the environmental pollution (Farhany et al., 2012; Hoon et al., 2012; Islam, n.d, 2011). The usage of agricultural waste materials in this research is as one of the ways to overcome the open burning. The recent research shows that agricultural waste materials have a great potential of being used as a good microwave absorber in Radio Frequency (RF) anechoic chamber (H Nornikman et al., 2009). Microwave absorber application needs high loss tangent and low dielectric constant in order to increase the absorption properties of the basic material. Since the agricultural waste can be applied in Radio Frequency (RF) field as microwave absorber, and then the idea of agricultural waste to be used as dielectric resonator material was proposed in this research. But, the dielectric properties of agricultural waste do not achieve the standard performance for antenna application where the dielectric constant is low, and the loss tangent is high. Hence, to enhance the performance of dielectric properties of the agricultural waste, sand material was added into the agricultural waste mixture. Sand contain high silicon dioxide element that helps to improve the performance of dielectric material that is used in antenna application (Bala & Khan, 2013)(Soni & Shukla, 2021) . The composite of agricultural waste material with sand are suitable to be used as an alternative material for antenna application due to the high reading of dielectric constant and low loss tangent. Furthermore, recent research showed that dielectric resonator antenna was using ceramic as dielectric resonator material. Ceramic contains chemical that is not good for body (Wang, Luo, Li, Du, & Qiao, 2021)(Segal, Aea, Culham, & Ox, 1997). So, to overcome the problem, the agricultural waste with sand composites was used to replace the ceramic.

Besides that, dielectric resonator antenna with ceramic as resonant material is expensive and difficult to fabricate. The process to fabricate the ceramic material was exposed to the chemical contain and it is dangerous to human body (Wang et al., 2021). To overcome this problem, the fabrication of agricultural waste to be used as dielectric resonator material for dielectric resonator antenna was carried on in this research. Hence, the performance of WLAN antenna design with agricultural waste and sand composites was analyzed.

Furthermore, generally microstrip patch antenna is known to has a big size. But, this research needs a small antenna for WLAN application such as router. Thus, agricultural waste material was added as dielectric resonator material to miniaturize the size of the antenna with the performance of the antenna remain the same (Hoon, Fareq, & Seng, 2013) .

1.3 Objectives

There are three main objectives of this project

1. To characterize and enhance electrical (dielectric constant and loss tangent) and mechanical properties (tensile strength test and morphology analysis) of agricultural waste, sand, and composite of agricultural waste with sand.

2. To miniaturize WLAN antenna based on proposed agricultural waste with sand material.

3. To validate and analyze performance of reflection coefficient and gain of the proposed miniaturized WLAN antenna design.

1.4 Scope of Project

The scope of this project was to characterize electrical and mechanical properties of agricultural waste or sand composites for WLAN antenna design. To achieve the research objectives, the review of previous work was referred regarding the different agricultural waste material such as rice husk, rice straw, banana leaves and sugarcane bagasse to enhance the performance of antenna. Furthermore, the electrical properties (dielectric constant and loss tangent) and mechanical properties (tensile strength test and morphology analysis) of the agricultural wastes were characterized to determine the best agricultural waste among the four wastes to be used as dielectric resonator material. In addition, the fabrication of agricultural wastes samples has been done before measuring the dielectric properties of the agricultural waste materials. The mechanical part such as tensile strength testing and morphology analysis has been done to ensure the structures of the agricultural wastes are strong and durable. Open ended coaxial probe technique was used to measure the dielectric properties of the samples. Next, a simple microstrip patch antenna with frequency 2.45 GHz was designed by using Computer Simulation Tools (CST) software. This project is continued by designing others two microstrip patch antenna with agricultural waste sample as the resonant material. The first one was microstrip patch antenna with single dielectric resonator material and the second one was microstrip patch antenna with double dielectric resonator material. Then, the three antennas were fabricated and being tested by using network analyzer. Lastly, both simulation and prototype results was compared.

1.5 Report Organization

The research thesis was divided into five chapters as follows. In **chapter 1**, the project background, problem statement, objectives project, scope of project and report organization were presented.

This **chapter 2** was discussed about the literature review on the previous research on mechanical and electrical characterization of different agricultural waste material. Furthermore, the agricultural waste material was used to substitute ceramic material as Dielectric Resonator Antenna (DRA) also being discussed in this chapter. Besides that, dielectric properties, dielectric constants, and loss tangents of the sample also being highlighted in this chapter 2.

In **chapter 3**, methodology of this project was studied. This chapter contains of project overview, flow chart of this project, fabrication of agricultural waste sample, method of mechanical testing and antenna design of WLAN application.

Chapter 4 contains the results of dielectric constant and loss tangent of rice husk, rice straw, sugarcane bagasse, and dried banana leaves. Besides that, the result of tensile strength testing and morphology analysis was discussed in this chapter. Furthermore, this chapter explains the result of reflection coefficient, gain and directivity of three antennas design.

Chapter 5 presents the summary and future project recommendation on overall research presented. This conclusion was based on the performance of microstrip patch antenna, microstrip patch antenna with single dielectric resonator material and microstrip patch antenna with double dielectric resonator material. Therefore, this project research can be progressed in the future with enhancement of design and technique.

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CHAPTER 2 : LITERATURE REVIEW

2.1 Introduction

This section contains 8 main parts with several subdivisions in each of them. Initially, this chapter presented the basic concept of dielectric resonator antenna (DRA) in section 2.2 and the description about agricultural waste materials (section 2.3). Besides that, dielectric properties (dielectric constant and loss tangent) concept also being interprets in this chapter through section 2.4. Sand material and microstrip patch antenna also discussed in this chapter at section 2.5 and 2.6 respectively. Review of previous research is elaborated in section 2.7 and section 2.8 is the summary for the whole chapter 2.

2.2 Dielectric Resonator Antenna (DRA)

Dielectric resonator antenna (DRA) is a radio antenna mostly used at microwave frequencies and higher (Peng et al., 2004). DRA consists of a block of ceramic material of various shapes, and mounted on a metal surface at ground plane (Long & Connor, 2007). The first DRA was proposed by long et. Al in 1980s, showed that the dielectric resonators, well known from the microwave circuits, can in fact become very efficient antennas if properly excited(Long & Connor, 2016; M. Singh, 2016). In the past two decades, dielectric resonator antennas (DRAs) have been increasingly considered as possible radiators in communication systems due to their attractive features including high degree of design flexibility, high radiation efficiency, nearly constant gain over a wide frequency band, various excitation mechanisms and compact antenna size (Peng et al., 2004).

Dielectric resonator antennas (DRAs) were developed for use in the microwave and millimetre frequency bands due to their attractive radiation characteristics. They offer several potential advantages such as small size, light weight, high radiation efficiency, wide bandwidth, low loss, and no excitation of surface waves (Al-zoubi, Kishk, & Glisson, 2009; Eshrah et al., 2005; A. Kishk, 2003; Shin & Ahmed, n.d.). Usually DRAs are made of high dielectric constant materials with very low loss tangent. The low conduction loss makes them attractive for high frequency applications. In contrast, the conductor loss of metallic antennas at high frequencies becomes severe and the radiation efficiency of the antenna is reduced significantly (Al-zoubi et al., 2009) .

Dielectric resonator antenna (DRA) can be in any three-dimension shape such as rectangular, hemispherical (Pimpalgaonkar, Chaurasia, Raval, Upadhyaya, & Pandya, 2016), circular (Khoo, Member, Guo, & Member, 2007), cylindrical (Xie et al., 2016), triangular shape (Kishk, n.d., 2002; The et al., 1999) , P-shaped (Rahim & Teknologi, 2013) and H-shaped (Xu, Zhu, Wang, & Xie, 2016) . Figure 2.1 shows the image of rectangular dielectric resonator antenna (RDRA). The relative permittivity used for this dielectric resonator is 4. The information of RDRA can be seen from the Table 2.1 below. Figure 2.2 shows the image of hemispherical dielectric resonator antenna (HDRA).

Table 2.1: Dimension of RDRA (Pimpalgaonkar et al., 2016)

parameter	Dimension of dielectric resonator	Dimension of substrate
Length (mm)	30	90
Width (mm)	40	100
Height (mm)	1.56	2.2
Relative permittivity	4	3.2

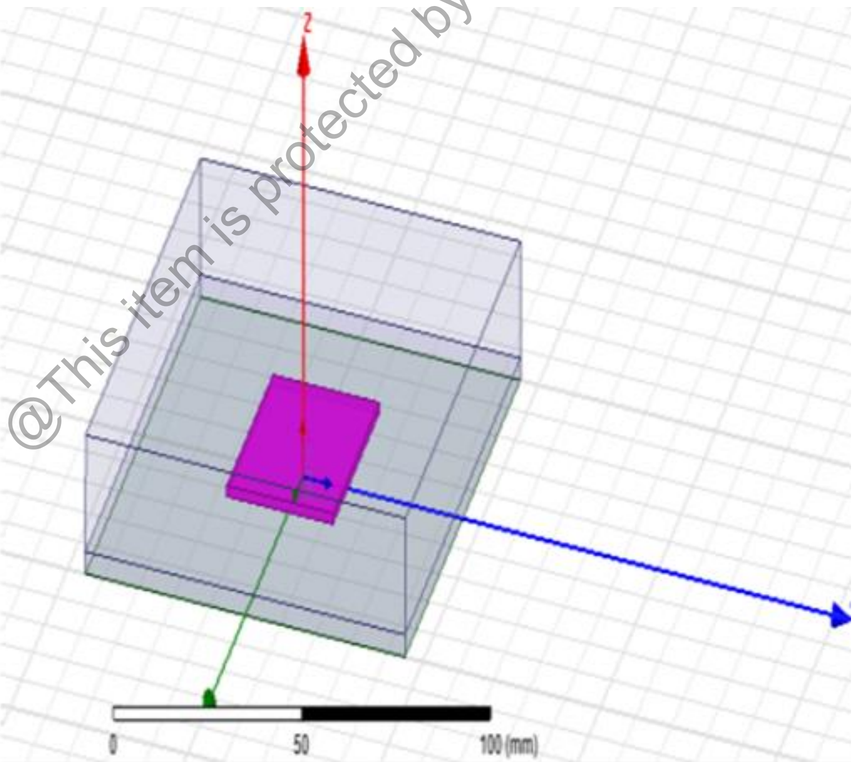


Figure 2.1: Rectangular Dielectric Resonator Antenna (RDRA) with Rectangular Substrate (Pimpalgaonkar et al., 2016)

Different shapes of DRAs such as cylindrical, hemispherical, elliptical, pyramidal, rectangular, and triangular have been presented in the literature. It was found that DRAs operating at their fundamental modes radiate like a magnetic dipole, independent of their shapes. The rectangular-shaped DRAs offer practical advantages over cylindrical and hemispherical ones in that they are easier to fabricate and have more design flexibility (Al-zoubi et al., 2009).

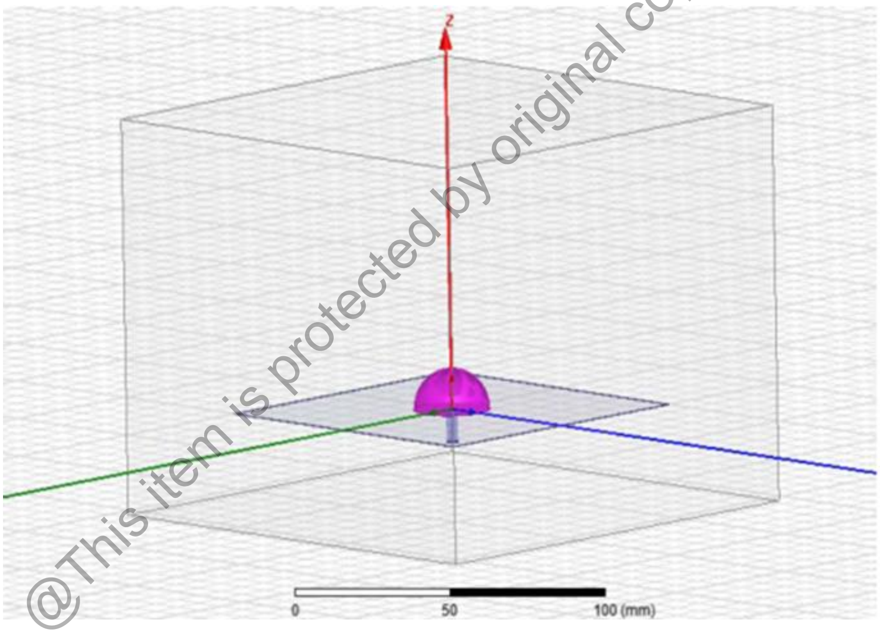


Figure 2.2: Hemispherical Dielectric Resonator Antenna (HDRA) with Rectangular Substrate. (Pimpalgaonkar et al., 2016)

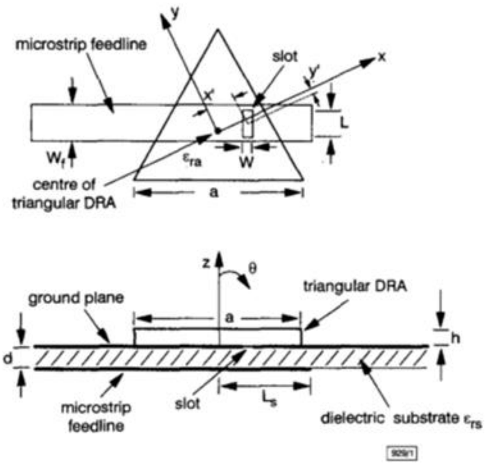


Figure 2.3: Triangular Dielectric Resonator Antenna (The et al., 1999)

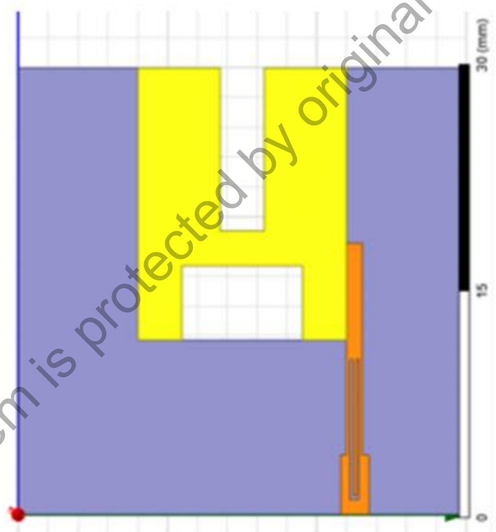


Figure 2.4: H-shaped Dielectric Resonator Antenna (Xu et al., 2016)

2.3 Agricultural Waste Material

Agricultural waste material is made up of organic compounds from living plants, trees, or organic sources such as rice husk, rice straw, sugarcane bagasse, and dried banana leaves. These agricultural waste material has the potential to be used as an alternative material for antenna application and microwave absorber application (H Nornikman et al., 2009), (H Nornikman, Malek, Soh, & Azremi, 2010).

2.3.1 Rice Husk

Rice husks are the by-product of paddy *(Oryza sativa)*. Rice husks or rice hulls are the hard covering of grains of rice. Within the period from 2010 until 2011, there are about 577 Million tons of paddy (Oryza sativa) was produced around the world. While, in Malaysia, it is around 350,000 tons of rice husk being produced annually (H Nornikman, Malek, Soh, Azremi, & Ghani, 2010), (Hoon et al., 2012). Due to the large quantity of paddy residues, this by-product of rice cultivation has been traditionally burnt in the field or trucked out and dumped. This may cause pollution to the environment (Hassan Nornikman et al., 2010). Nowadays, rice husk has the potential to be used in building construction area by mixed with the cement to increase the strength. In addition, rice husk can be used as the base material for microwave absorber fabrication. Lastly in this project, the rice husk was used as the resonant material for antenna application. Table 2.2 shows the element percentage of rice husk material. Figure 2.5 below shows the image of rice husk.

Table 2.2: Elements Percentages of Rice Husk Material (Hassan Nornikman et al., 2010).

Element in rice husk material	Percentage % of element
Silicon dioxide	22.24
Carbon	35.77
Hydrogen	5.06
Oxygen	36.59
Nitrogen	0.32
Sulphur	0.02

Figure 2.5: Rice Husk (Hoon et al., 2012; Seng et al., 2015)

2.3.2 Sugarcane Bagasse

Sugarcane bagasse is the waste product of sugarcane industry obtained after the extraction of juice for the production of sugar. In the year of 2005, about 54 million dry ton of sugarcane bagasse had been produced whole world (Garg & Sud, 2005). This waste material can be used in many industries and application. Sugarcane bagasse is one of a suitable resources for the preparation of activated carbon (Liyana et al., 2012). This material also had been providing for sustainable electricity industry (Ã & Jr, 2007; Garg & Sud, 2005; Hemmasi, Samariha, Tabei, Nemati, & Khakifirooz, 2011). Table 2.3 below shows the element percentage of raw sugarcane bagasse. Figure 2.6 shows the image of grinded sugarcane bagasse.

Figure 2.6: Image of Grinded Sugarcane Bagasse (Liyana et al., 2012)

Table 2.3: Elements Percentage of Sugarcane Bagasse Material (Liyana et al., 2012)

Element	Percentage element %
Oxygen	75.6%
Carbon	17.89%
Aluminum	1.47%
Silica	2.67%
Phosphorus	0.75%
Sulfur	0.07%
Potassium	0.04%
Calcium	0.58%
Iron	0.4%

2.3.3 Dried banana Leaves

Dried banana leaves used for pyramidal microwave absorbers application has been states detailed in paper (Srinivasan & Vijayalakshmi, 2011), (Farhany et al., 2012) and (Kaur et al., 2015). These papers describe that banana leaves have many usages such as for traditional wrappings, plate mat, and as employed in cooking techniques. Banana plant has an origin from Asian region such as Malaysia, India, and Japan. Due to the excessing harvest of banana leaves in those countries, many researchers are trying to innovate new techniques by using dried banana leaves such as pyramidal microwave absorber application. Table 2.4 shows the elemental percentage analysis of banana leaves material. Figure 2.7 shows the image of banana leaves start from collecting the raw material, then dried it under direct sun for a week, and lastly grinded the dried banana leaves material into powder by using grinder (Kaur et al., 2015).

Table 2.4: Elements Percentage of Dried Banana Leaves Material (Kaur et al., 2015)

Element	Percentage element %
Carbon	43.5%
Hydrogen	6.28%
Nitrogen	1.31%
Sulphur	0.36%
Oxygen	41.3%

Figure 2.7: Drying and blending of banana leaves (Kaur et al., 2015)

2.4 Dielectric Properties

Dielectric properties measurement is a chemical properties and physical properties characterization related to the storage and loss of energy in various type of material. (Kundu & Gupta, 2014; Tereshchenko, Buesink, & Leferink, 2011) The definition of dielectric properties is a measure of the polarizability of a material when subjected to an electric field. To analyze the material, the dielectric properties are represented by the relative complex permittivity, ε_r (Kundu & Gupta, 2014).

$$\varepsilon_r = \varepsilon' - j\varepsilon'' \tag{2.1}$$

Where ε' is the dielectric constant which describes the ability of the material to store energy. While ε'' is the dielectric loss factor, which reflects the ability of a material to dissipate the electric field energy.

2.4.1 Dielectric Constant

Dielectric constant also known as permittivity in definition, is a quantity that measure the ability of a substance to store electrical energy in an electric field (Kundu & Gupta, 2014), (Wee et al., 2009), (Venkatesh & Engineering, 2005). Equation 2.2 shows the formula for dielectric constant.

$$K = \frac{\varepsilon}{\varepsilon_0} = \varepsilon_r = \varepsilon'_r - j\varepsilon''_r \tag{2.2}$$

Where;

K= dielectric constant

ε_r = relative permittivity

ε = absolute permittivity

ε_0 = free space of permittivity interaction of a material in the presence of an external electric field

2.4.2 Loss Tangent

Loss tangent is a criterion of a dielectric material that quantifies its inherent dissipation of electromagnetic energy (Hoon et al., 2012). Equation 2.3 shows the equation of loss tangent. The relative loss of a material is the ratio of the energy lost (ε''_r) to the energy stored (ε'_r).

$$\tan\delta = \frac{\varepsilon''}{\varepsilon'} \tag{2.3}$$

Where;

$\tan\delta$ = loss tangent

ε' = dielectric constant

ε'' = dielectric loss factor

2.5 Sand

Sand is a common contaminant for outdoor application as is the main component of soil and it is also used in road construction/repair. Small particle sizes of sand are more likely to be airborne for a finite period of time before falling down to ground permanently or temporarily before becoming involved in “road spray” activity (Du et al., 2017). Sand also can be used for antenna application. From the analysis of results shown in paper (Bala & Khan, 2013) and (Du et al., 2017), it is shown that sand composites contain silicon material that is used in this research to enhance the performance of dielectric properties materials in the agricultural waste sample. Table 2.5 shows the chemical composition of sand samples from different places. Table 2.5 below shows that all sand has the highest silicon dioxide compared with others elements. This shows that sand material has the potential to increase the dielectric constant and lower the loss tangent of agricultural waste material.

Table 2.5 Chemical Composition of Sand Samples (Bala & Khan, 2013)

Constituent	Chelford (%)	Warri River Sand (%)	Ethiope River Sand (%)	Ughelli River Sand (%)	Lagos Bar Beach Sand (%)
SiO_2	97.91	96.18	98.12	97.01	53.16
Al_2O_3	1.13	2.76	0.91	1.96	19.40
Fe_2O_3	0.50	0.06	0.16	0.13	4.70
CaO	-	-	-	-	2.66
MgO	-	-	-	-	2.08
K_2O	0.25	-	-	-	-
Loss on ignitation	0.21	1.00	0.72	0.90	18.0
Total	100.00	100.00	100.00	100.00	100.00

2.6 Microstrip Patch Antenna

Microstrip Patch Antenna (MPA) can be used in various wireless communication applications such as satellite, Radar, missile and aircraft. MPAs are called low profile antenna because these can be flush mounted on curved surface and they only require space for the feed line. Microstrip patch antenna are popular with the application over than frequency 100 MHz(S. Singh & Singh, 2016). Microstrip patch antennas have a wide variety of application as they are lightweight, low profile, cheap to manufacture and easy to feed (Abdullah & Bhardwaj, 2017; Mitha & Pour, 2017; S. Singh & Singh, 2016). Improper impedance matching and narrow bandwidth are two main disadvantages of MPA's. There are two techniques to enhance the bandwidth, one is by using thick dielectric substrate and the second is by using slotted (S. Singh & Singh, 2016).

Frequency, thickness and material of the substrate are the three necessary parameters for designing the MPA. The resonant frequency of 1.5 GHz suitable for satellite application is chosen for this research. The patch width of microstrip patch antenna (MPA) is determined using the equation (2.4) as given below (R. Singh & Singh, 2014; S. Singh & Singh, 2016; Sivia, Singh, Rani, & Kamal, 2012)

$$W = \frac{c}{2f_r\sqrt{\frac{\varepsilon_r+1}{2}}} \tag{2.4}$$

An effective dielectric constant is introduced due to fringing effect because some waves travel in the air and some in the substrate as follows (2.5).

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2} \left[1 + 12\frac{h}{w}\right]^{\frac{-1}{2}} \tag{2.5}$$

Due to the fringing effect, the dimension of the patch are extended by ΔL on both sides according to equation (2.6)

$$\Delta L = 0.412h \frac{(\varepsilon_{eff}+0.3)(\frac{w}{h}+0.264)}{(\varepsilon_{eff}-0.258)(\frac{w}{h}+0.8)} \tag{2.6}$$

The final or actual length of the patch is calculated by the equation (2.7) as follows:

$$L = \frac{c}{2f_r\sqrt{\varepsilon_{eff}}} - 2\Delta L \tag{2.7}$$

The transmission line model can be applied to infinite ground plane only, but infinite ground plane is not possible for practical use (Shrestha et al., 2013; S. Singh & Singh, 2016). So, the dimensions of the ground plane are calculated by the following formula (2.8) and (2.9):

$$L_g = 6h + L \tag{2.8}$$

$$W_g = 6h + W \tag{2.9}$$

2.7 Review Previous Research

As depicted in Table 2.6 below shows the review paper of the previous research. The table below shows a few approaches by the previous researchers study about agricultural wastes used for microwave communication application such as rice husk, rice straw, and banana leaves (H Nornikman, Malek, Soh, & Azremi, 2010; H Nornikman et al., 2009). These two papers used the same method to measure the dielectric properties of the sample by using free space measurement method. This paper applied the agricultural wastes sample for microwave absorber design where the results of the loss tangent of agricultural waste need to be high to store the energy. Based on these papers, the results of the dielectric constant were acceptable to be used for antenna application. But the results of loss tangent value were high. So, the loss tangent results were not suitable to be used for antenna application. Hence, to overcome this problem, sand is used in this research. Sand contains high silica that able to reduce the value of the loss tangent. Besides that, the others researchers (Farhany et al., 2012; Liyana et al., 2012; Malek, Nornikman, & Nadiah, 2014) were using dielectric probe technique to measure the dielectric properties. Since the agricultural waste samples used in this research were small in size, so the dielectric probe technique is suitable to be used to measure the dielectric constant and loss tangent of the samples. Moreover, in (Pimpalgaonkar et al., 2016) shows the study of dielectric resonator antenna using the dielectric constant of 4.0 as its dielectric resonator material. Although this paper used ceramic as dielectric resonator material, but the dielectric constant was almost the same as needed in this research. The dielectric constant of 4.0 is sufficient to be used as dielectric resonator material for dielectric resonator antenna at frequency 2.45 GHz.

Table 2.6: Table of review previous research

<table>
<tr><th>References</th><th>Description</th><th>Results</th></tr>
<tr>
<td>H. Nornikman et al, (2009)</td>
<td>Frequency range (0.1GHz – 20GHz)

Material used: rice husk

Resin: Urea Formaldehyde (UF) and Phenol Formaldehyde (PF)

Method used to measure: Free Space Measurement Method</td>
<td>Different resin mix will give different dielectric constant and reflectivity of a microwave absorber

<table>
<tr><th>Resin</th><th>Resin %</th><th>ε_r</th></tr>
<tr><td>Urea Formaldehyde (UF)</td><td>10%</td><td>3.2355</td></tr>
<tr><td></td><td>20%</td><td>3.2745</td></tr>
<tr><td></td><td>30%</td><td>3.5813</td></tr>
<tr><td>Phenol Formaldehyde (PF)</td><td>10%</td><td>2.8907</td></tr>
<tr><td></td><td>20%</td><td>3.4054</td></tr>
<tr><td></td><td>30%</td><td>3.6808</td></tr>
</table>
</td>
</tr>
<tr>
<td>H. Nornikman et al. (2010)</td>
<td>Frequency range: (1 GHz – 20 GHz)

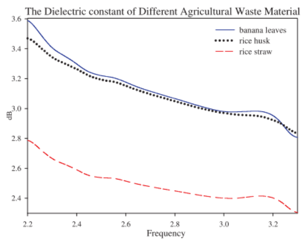
Material used: rice husk, rice straw, banana leaves

Resin: polyester resin

Hardener agent: methyl ethyl ketone peroxide (MEKP)

Method used to measure: free space</td>
<td>TABLE I
DIELECTRIC PROPERTIES OF AGRICULTURAL WASTE

<table>
<tr><th>Agricultural Waste</th><th>Dielectric Constant, ε_r</th><th>Loss Tangent, tan δ</th></tr>
<tr><td>Banana leaves, BL</td><td>3.218</td><td>1.014</td></tr>
<tr><td>Rice husk, RH</td><td>3.100</td><td>0.827</td></tr>
<tr><td>Rice Straw, RS</td><td>2.492</td><td>0.956</td></tr>
</table>



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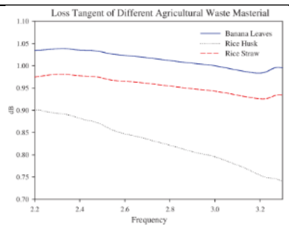
<table>
<tr>
<td></td>
<td>measurement technique</td>
<td>
</td>
</tr>
<tr>
<td>Z. Liyana et al,.

(2012)</td>
<td>Frequency range (0.1GHz – 20GHz)

Material used: sugarcane bagasse

Resin: polyester

Hardener agent: Methyl Ethyl Ketone Peroxide (MEKP)

Method used to measure: dielectric probe technique</td>
<td>Sugarcane bagasse shows better reflection loss compared to the rice husk

<table>
<tr><th>Material</th><th>Average Dielectric constant</th><th>Average Tangent Loss</th></tr>
<tr><td>Rice husk</td><td>2.03</td><td>0.132</td></tr>
<tr><td>Sugar cane bagasse</td><td>1.44</td><td>0.161</td></tr>
</table>
</td>
</tr>
<tr>
<td>Z. S. Farhany et al., (2012)</td>
<td>Frequency range (0.1GHz – 20GHz)

Material used: banana leaves

Resin: polyester

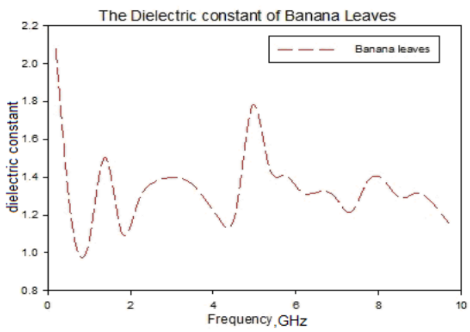
Hardener agent: Methyl Ethyl Ketone Peroxide (MEKP)</td>
<td>

Fig. 9. Dielectric constant of for dried banana leaves</td>
</tr>
</table>