DESIGN AND DEVELOPMENT OF MICROWAVE ABSORBER USING WASTE MATERIALS

by

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LIST OF ABBREVIATIONS

2-D	Two Dimensional
BL	Back Layer
DUT	Device Under Test
EM	Electromagnetic
EMC	Electromagnetic compatibility
EMI	Electromagnetic Interferenc
FCC	Federal Communications Commission
FL	Front Layer
FSA	Free Space Arch
FSS	Frequency Selective Surfaces
GHz	Giga Hertz
GT	Geometrically Tapered
HARP	Halpern Anti Radar Paint
HFSS	High Frequency Structure Solver
HIS	High Impedance Surfaces
IFF	Identification of Friend or Foe
IL	Insertion Loss
MEKP	Methyl Ethyl Ketone Peroxide
MIL-STD	Military Standard
MUT	Material Under Test
NEMP	Nuclear Electromagnetic Pulse
NP	Null Point
OATS	Open Area Test Sites
PCB	Printed Circuit Board

PEC	Perfect Electric Conductor
PMA	Pyramidal Microwave Absorber
PVA	Poly Vinyl Acetate
RADAR	Ranging and Detection
RCS	Radar Cross Section
RH	Rice Husks
RTD	Rubber Tire Dust
RTDPMA	Rubber Tire Dust Pyramidal Microwave Absorber
SOLT	Short Open Load Thru
SCB	Sugarcane Bagasse
SCBRTD	Sugarcane bagasse rubber tire dust
TE	Transverse Elecetric
TM	Transverse Magnetic
TRL	Thru Reflect Load
UPR	Unsaturated Polyester Resin
VNA	Vector Network Analyzer
WLAN	Wireless Local Area Network

LIST OF SYMBOLS

$\varepsilon_r^{'}$	Real Part of Complex Permittivity
$\varepsilon_r^{''}$	Imaginary Part of Complex Permittivity
γ	Wave propagtion constant
α	Attenuation constant
β	Phase constant
t	Thickness
Z_{in}	Input impedance
f	Frequency
dB	Decibel
Γ	Reflection coefficient
T	Transmission coefficient
Γ_1	Reflection coefficient at first interface
λ	Wavelength
l	Length of single layer absorber
θ_i	Angle of incidence
θ_r	Angle of reflection
θ_t	Angle of transmission
ε_r	Relative Permittivity
Z_L	Load impedance
η	Charateristic impedance
η_0	Charateristic impedance of air
ω	Angular frequency
σ_{eff}	Effective conductivity
S_{21}	Transmission S-parameter

Merekabentuk dan Membangunkan Penyerap - Penyerap Gelombang Mikro Menggunakan Bahan Terbuang

ABSTRAK

Hampas tebu tebu ialah salah satu sisa pertanian yang berpotensi untuk mereka bentuk penyerap gelombang mikro berbentuk pyramid yang diguna pakai dalam frekuensi radio (RF) bilik tak bergema untuk tujuan pengujian. Bilik anekoik RF ialah sebuah bilik berperisai yang ditutup dengan penyerap untuk menghapuskan isyarat gambaran yang tidak dikehendaki. Dalam kerja ini, hampas tebu dari sisa industri gula dan tayar getah dari industri tayar telah digunakan. Kedua-dua bahan buangan ini telah mengandungi kandungan karbon, yang telah membuat mereka sesuai seperti bahan mentah untuk rekaan penyerap gelombang mikro. Pemalar dielektrik hampas tebu tebu telah diukur menggunakan perisian Agilent dielektrik teknik dan Agilent 85071E menggunakan teknik laluan penghantaran. Penyerap gelombang mikro diperbuat daripada dua komponen utama, satu bahan yang melakukan penyerapan, dan matriks bahan mengadakan pengisi. Dalam bahan dielektrik, ciri-ciri paling genting yang membolehkan mereka digunakan seperti penyerap gelombang mikro ialah pemalar dielektrik dan faktor kehilangan yang merupakan pelesapan tenaga pada bahan tersebut. Pada umumnya, penyerap bahan dielektrik dibina oleh gabungan pengisi dalam satu matriks polimer. Dalam kerja ini, pengisi ialah sisa pertanian yang merupakan hampas tebu (SCB) tebu dan debu (RTD) tayar getah dari industri tayar manakala matriks polimer ialah Polyester Resin RP9509 (UPR) tidak tepu yang mana tegar, fleksibel dan polimer telus dalam electromagnet. Dalam kerja ini, hampas tebu tebu juga telah bercampur dengan debu (RTD) tayar getah untuk menyiasat prestasi mereka. Penyerap gelombang mikro menggunakan hampas tebu tebu telah direka dan dibuat-buat dalam perisian studio CST gelombang mikro. Ukuran teknik pandu gelombang telah digunakan untuk menyemak kehilangan (S_{11}) gelombang dan pekali penghantaran (S_{21}). Penyerap gelombang mikro sedang disiasat dalam frekuensi mikrogelombang berkisar antara 1 GHz kepada 18 GHz. Keputusan menunjukkan bahawa hampas tebu tebu mempunyai potensi sebagai bahan asas dalam memajukan penyerap gelombang mikro dan boleh beroperasi dalam gelombang frekuensi tersebut. Menambah pengisi yang merupakan debu tayar getah menambah prestasi penyerap gelombang mikro. Penyerap ini telah direka bentuk berdasarkan pengecilan gelombang dan kedalaman data penembusan dan prestasi EMC mereka dinilaikan dalam soal prestasi kepantulan dwi statik. Prestasi penyerap didapati menjadi di bawah -10 dB. Kepekatan berbeza pengisi diukur dan kepantulan didapati untuk memperbaiki kemudian -20dB apabila nilai bertambah debu tayar getah telah ditambah.

ABSTRACT

Sugarcane bagasse is a potential agricultural waste to design the pyramidal microwave absorber to be used in radio frequency (RF) anechoic chamber for testing application. An RF anechoic chamber is a shielded room covered with absorbers to eliminate unwanted reflection signal. In this work, sugarcane bagasse from the sugar industry and rubber tire dust from tire wear have been used. Both of the wastes have lossy carbon contents naturally, which has made them suitable as the raw materials for the fabrication of the low cost microwave absorbers. The dielectric constant of the sugarcane bagasse had been measured using the Dielectric Probe Technique and Software of Agilent 85071E using Transmission Line Technique. Microwave absorbers are made of two main components, a filler material that does the absorption, and a material matrix to hold the filler. In dielectric materials, the most crucial properties that enable them to be applicable as microwave absorbers are the dielectric constant and the loss factor which is the dissipation of energy in the material. Generally, dielectric material absorbers are fabricated by the combination of fillers in a polymer matrix. In this work, the fillers are the agricultural waste which is sugarcane bagasse (SCB) and rubber tire dust (RTD) from tire wear whereas the polymer matrix is unsaturated Polyester Resin RP9509 (UPR) which is rigid, flexible and electromagnetically transparent polymer. In this work, the sugarcane bagasse also has been mixed with rubber tire dust (RTD) to investigate their performance. The microwave absorber using sugarcane bagasse had been designed and simulated in the CST Microwave studio software. The measurement of waveguide technique has been used to check the reflectivity performance. The microwave absorber has been investigated in microwave frequency range between 1 GHz to 18 GHz. The results show that the sugarcane bagasse has the potential used as the base material in developing the microwave absorber and can operate in that range of frequency successfully. The adding of the filler which is rubber tire dust increased the performance of the microwave absorber. These absorbers were designed on the basis of the wave attenuation and depth of penetration data and their EMC performance was evaluated in terms of bi-static reflectivity performance. The performance of the absorbers was found to be below -10 dB. The different concentration of the filler were being measured and the reflectivity was found to be better then -20 dB when the increasing value of rubber tire dust were added.

CHAPTER 1

INTRODUCTION

1.1 Background

In recent years, the applications of electromagnetic compatibility (EMC) for electronic devices and equipment with different electromagnetic environments have incredibly extended the applications in GHz range for mobile phone, local area network, radar system and others (Feng, Y. B., Qiu, T., & Shen, 2007; M. S. Kim, Min, & Koh, 2009). This requires the electromagnetic compatibility (EMC) application such as microwave absorbing material in the range of frequencies from kilohertz (kHz) to gigahertz (GHz) of microwave signals. Electromagnetic interference is the degradation in the performance of device, or equipment, or a system caused by an electromagnetic disturbance. The electromagnetic disturbance can be in the nature of an electromagnetic noise, or an unwanted signal, or a change in the propagation medium itself (Kodali, 2001). At high frequency ranges, the commercialized and conventional conductive shielding materials become less effective to its function. The absorber has been used in military standard, immunity and emission test chamber (Holloway et al., 1997). The conventional conductive shielding materials include conductive foams, metal in the form of sheeting, metal flakes and stainless steel fibers in order to harness, capture and ground the EMI energy. Therefore, the EMI absorbing materials are designed. The absorber materials are created to attenuate electromagnetic wave and there is conversion from the electromagnetic wave into heat (Ch, T E, n.d.). This design has been integrated with different loss mechanism over the broader range of bandwidths with different structures from the large thickness pyramidal structures to single layer coatings and multilayer materials. There are two categories of microwave absorber which are those that absorb incident and reflected wave energy in free space which is the empty space or vacuum. The other one is absorbers that called load, cavity and bulk loss absorbers. They absorb the waves inside waveguides and coaxial lines. Dielectric absorbers used the dielectric materials to be used as absorber application (Wang et al., 2014). Agricultural wastes such as rice husk, rice straw, coconut shells and sugarcane bagasse have their own dielectric properties and behavior. This residue agricultural waste material has potential to be used as an alternative material for pyramidal microwave absorber in Radio Frequency (RF) anechoic chamber.

1.2 RF/ Microwave Absorber

Absorbers in the RF/Microwave field are the materials to debilitate the energy in electromagnetic wave. Absorbers are used in a broad range of applications to eradicate stray or unwanted radiation that could intermeddle with a system's operation (D. Il Kim, Kim, & Choi, 2007). Absorbers can be used externally to diminish the reflection from or transmission to particular objects and can also be used internally to reduce oscillations caused by cavity resonance. They can also be used to stimulate a free space environment by eliminating reflections and bounces in an anechoic chamber. Absorbers can take many different physical forms including flexible elastomers or foam or rigid epoxy or plastics. They can be made to resist weather and temperature extremes. Absorbers have become a critical element in some systems to reduce interference between circuit components. The interior surfaces of RF anechoic chamber are sometimes similar with acoustic anechoic chamber but there are different between these two chambers. The first absorber fabrication is 2 GHz quarter-wave resonant investigated at the Naamlooze Vennootschap Machinerieen (Naamlooze, 1936). Two materials that had been widely used for the measurement of microwave absorber are polyurethane and polystyrene. The example of microwave absorber design by using urethane foam as it based material with carbon loaded at the top of the pyramid is *VHP-8-NRL* absorber from Eccosorb (Emerson, 2008). *TDK ICT-030* absorber (TDK, 2008) is also the microwave absorber in the current market that used carbon as the material. There are two types of tests which are performed within the EMC test facilities for the compatibility of the electronic equipment and these are known as conducted and radiated EMC tests. These tests are performed in accordance with the internationally well-known standards in military and civil domains such as MIL-STD-461 and CISPR series standards (Holloway et al., 1997; Trautnitz, 2007). Active electronic components and devices in electrical, electronics and communications systems can be evaluated for their levels of emissions, radiations and sensitivity. However, microwave absorbers are passive components and are used to increase the EMC performance of the electronic systems. There are many other techniques to enhance the EMC performance such as filtering, grounding and shielding the radiated EMI.

The EMC performance of a device, system or even anechoic chamber strongly depends on the performance of the microwave absorbers which are depends on many factors, including frequency, angle of incidence, the geometry and dimension of the absorber, and the absorber reflectivity (B. Chung & Chuah, 2003). Therefore the EMC-oriented study of the microwave absorbers involves the study of all those factors that can affect its ability to control radiated EMI. The knowledge of the properties of the absorbing material exposed to high frequency EM radiations is very important at different weight fractions of the lossy filler.

In this work, sugarcane (*Saccarhum officinarum*) bagasse has been used as the main material in designing the microwave absorber. Sugarcane bagasse is a residue produced in large quantities by sugar industries. In general, 1 ton of sugarcane bagasse generates 280 kg of bagasse, the fibrous by-product remaining after sugar extraction from sugarcane (Hasnain *et al*., 2007). Sugarcane bagasse is also the potential materials for the pyramidal microwave absorbers used in anechoic chamber to eliminate reflected signal. The large percentage of carbon that occurs naturally in sugarcane bagasse can provide good reflectivity performance (L. Huang and H. Chen, 2011). The content of carbon is the main element that helps to absorb the microwave signal.

1.3 Problem Statement

In anechoic chamber, there are four possible bounce paths, which are ceiling, floor and walls. The multipath problem at anechoic chamber is potentially much worse than an outdoor ground-plane range. Electromagnetic wave is being used in wireless communication applications and other communication equipment. This could cause the performance degradation of a device, inaccuracy of signal measurement cause by electromagnetic interference (EMI) and even can damage the component or a device. Thus, a system must be compatible within the EMI environment to control the EMI disturbance to any other device. This problem can be solved by installing the RF microwave absorbers to reduce the effect of chamber reflection to a manageable level and eliminate the interference problem of a device. Currently, most of microwave range absorbers in the market, seen in the anechoic chamber are made of carbon impregnating polyurethane foam or polystyrene with carbon.

The pyramidal absorber is investigated but for general purpose of EMC application, it includes the suppression of electromagnetic echoes from the flat reflecting surfaces other than chamber walls. To date, no study has been conducted to investigate the effectiveness of flat planar of sugarcane bagasse (SCB) and rubber tire dust (RTD) based microwave absorber as it has robust design and wide electromagnetic application. The absorber material that configures line inside the floor of the shielded room is magnetic loss ferrite tile which is suitable for low frequencies within the range of 30MHz to 1000MHz. The drawback of this material is that it is not suitable for high frequencies (R. Walker, F. Leuterer, D. Wagner & Hailer, 2002).

The most important point in the optimization of designing the EMC absorber is the information regarding the behavior of the dielectric properties of the materials. To date, no detailed data are available for the sugarcane bagasse and rubber tire dust in a broad frequency range of 1GHz to 20 GHz especially in the composition between those two materials. So, in this thesis the thorough information of the dielectric behavior of the materials are investigated and explained. The electromagnetic wave absorbed by a material is related to the dielectric properties of the material and the design of the absorber. Dielectric properties are functions of frequency and consequently the absorbing properties vary significantly as the frequency varied.