

Single-layer performance of sugarcane bagasse-and rubber tire dust microwave absorber in narrow band frequency of 3.85 GHz to 8.2 GHz

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ABSTRACT

In this paper, the single and flat layer of microwave absorber has been fabricated with different weight percentage of sugarcane bagasse (SCB) and rubber tire dust (RTD). The dielectric properties and wave propagation have been investigated in this work. There are two different designs in developing this layer of microwave absorber. In this work, the targeted frequency is within 3.85 GHz to 8.2 GHz. The preference was based on the fact that our goal was to achieve minimum backward reflections, and the sugarcane bagasse material, with its low dielectric constant, high loss factor, large attenuation per unit length, and ease of fabrication, provided a better opportunity to achieve that goal which is better than -10dB (90 % of absorption).

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1. INTRODUCTION

The requirement of the electromagnetic compatibility (EMC) applications such as microwave absorbing material in the range of frequencies from kilohertz (kHz) to gigahertz (GHz) of microwave signals have incredibly extended the applications in GHz range for mobile phone, local area network, radar system and others [1, 2]. Absorbers in the RF/microwave realm are materials that attenuate the energy in an electromagnetic wave. The electromagnetic interference is the degradation in the performance of a 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 [3]. The effects of EMI include the malfunction, or even the permanent damage to the electronic devices which can lead to the failure [4-10]. Absorbers are used in a wide range of applications to eliminate stray or unwanted radiations that could interfere with a system's operation. Absorbers can be used externally to reduce the reflection and transmission to particular objects and can also be used internally to reduce oscillations caused by cavity resonance [11]. They can also be used to recreate a free space environment by eliminating reflections in an anechoic chamber. A single layer of lossy rice husk (RH) or scrap rubber (SR) with any of the adhesives (Glue or UPR) is efficient in suppressing EM echoes only at multiple discrete frequencies in multiple bands. However, this single layer design is impractical to solve the broadband EMC problems. Many of the communication devices uses the L, S and C frequency bands, hence a lot of EMI noises can be expected in the shared frequency spectrum of 1 to 10 GHz. That's why the need of a single

broadband absorber is evident to suppress the EM noise in a broad range of frequencies. One of the earliest absorber type which is inherently narrowband is known as the Salisbury screen [12,13]. The impedance at a metal surface is equal to zero. At one quarter wavelength in front of the surface the impedance will be infinite and the admittance will be zero. If a resistive sheet with surface resistivity equal to 377 ohms is placed here, the impedance will be equal to 377 ohms.

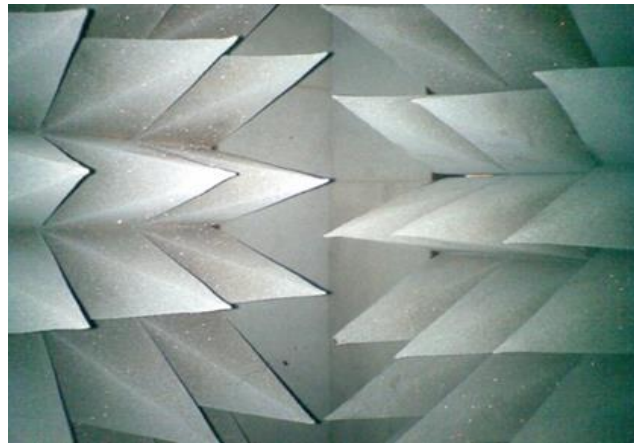


Figure 1. Flat absorbers installed in an anechoic chamber

The selection of the broadband absorbers and their performance is very crucial. The thickness of these absorbers depends upon the dimensions of their neighboring geometric transition absorbers. Figure 1 shows the flat absorbers installed in an anechoic chamber to reduce the corner reflections.

The required performance limits for EMC test facilities in GHz frequency range are -10 dB and -20dB according to MIL-STD-461-F and CISPR-20 [14] standards, respectively. In the case of flat absorbing structures, broadband performance can be achieved by using multiple lossy layers. These layers may be of different materials or same material with different loadings.

Previous research has identified several potential materials for the use in designing and developing of the microwave absorber. They included carbon loaded plaster, carbon black, iron powder, aluminum flakes, copper and many others [15]. The principle element in the dielectric absorber is the carbon itself. The carbon is being used as the dielectric loss adder in the lossless polymer matrix materials. This process is also known as carbon consumption and is being used in the microwave industry, especially in the production of foam based absorbers. In humid surroundings, the carbon is chosen due to its corrosion resistance [16]. Besides, carbon has less density as compared to the metal and due to this reason, carbon is preferred to fabricate the absorbers [17].

2. MATERIALS AND METHODOLOGY

In this work, sugarcane (*Saccharum 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 generates 280 kg of bagasse, the fibrous by-product remaining after sugar extraction from the sugarcane [18]. Sugarcane bagasse is also the potential material for the pyramidal microwave absorbers used in anechoic chamber to eliminate reflected signal[19]. The large percentage of carbon that occurs naturally in sugarcane bagasse can provide good reflectivity performance[20]. The first stage of this study is to prepare the samples for the dielectric measurement. The dielectric properties of the materials in a broad frequency ranges from 1.0 GHz to 18 GHz were investigated. The samples were fabricated in composite form. There are two methods of measuring the dielectric properties namely, coaxial probe technique and the transmission line method. Figure 2 shows the steps in fabricating and measuring the microwave absorber in flat layer.

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 [21], [22]. 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 the sugarcane bagasse (SCB) and rubber tire dust (RTD) from tire wear. The polymer matrix that has been used is unsaturated Polyester Resin RP9509 (UPR)

which is rigid, flexible and electromagnetically transparent polymer. UPR is a type of the thermosetting polymer and it needed to be added with a binder to start the cross linking process. So, methyl ethyl ketone peroxide (MEKPO) which is in the liquid state was used as the binder with UPR. In the composites with more filler, the composites seem to be more compact and have less air gap. The compactness and the interaction between those particles in the composites will affect the dielectric properties of the materials. The first step is to find the sugarcane bagasse from its natural sources. Before fabricating the samples, the sugarcane bagasses needed to be processed first. First of all, the sugarcane bagasses needed to be fully dried to ensure that they can be easily grinded and mixed with unsaturated polyester resin (UPR) and hardener agent which is the methyl ethyl ketone peroxide (MEKP). The samples were first dried under the sunlight. Manually, the sugarcane bagasse needed to be separated first from its thick stems to get the sugarcane bagasse only. Next, the sugarcane bagasse needed to be cut into very small pieces to make it easier when the sugarcane bagasse is being grinded.

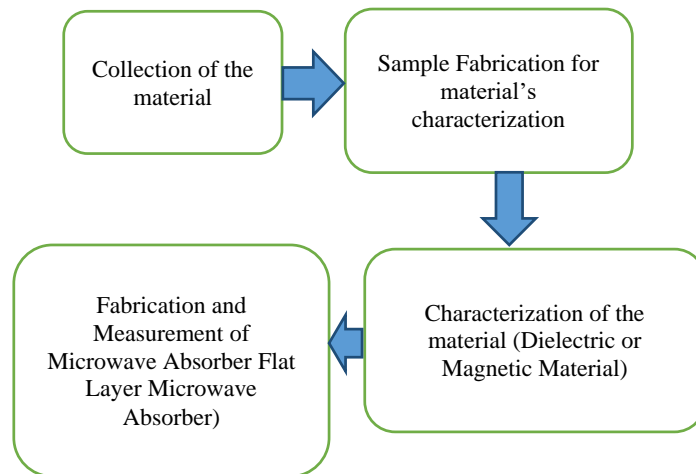


Figure 2. Steps in fabricating and measuring the microwave absorber in flat layer shape



Figure 3. The high temperature probe with the shunting block for the dielectric measurement setup

The open ended coaxial probe method was being used to measure the dielectric properties of the samples composed of different weight fractions of the lossy (SCB and RTD) fillers. It is very important to have a good contact between the sample and the end of the probe to minimize the air gap. The air gap will affect the accuracy of the measurement. The apparatus that have been used in this study includes the Agilent 85070B High Temperature Dielectric Probe, Agilent Network Analyzer, Agilent 85070 software, a cylindrical open ended probe, and a calibration load as shown in the Figure 3. The end of the probe is needed to be in contacted with the flat surface of the sample, so that the reflected signal from the sample can be detected by the probe's sensor. The reflected signal is displayed on the network analyzer's interfaces as S11 in dB. By using the software, the reflected signal is converted into real (ϵ'_{r}) and imaginary part (ϵ''_{r}) of the

complex permittivity. Figure 4 shows the complex permittivity of sugarcane bagasse and rubber tire dust in the frequencies range of 2 GHz to 8 GHz. Table 1 shows the measured range of dielectric properties of the two raw materials which are the sugarcane bagasse and rubber tire dust in the frequency range between 2 GHz to 8 GHz.

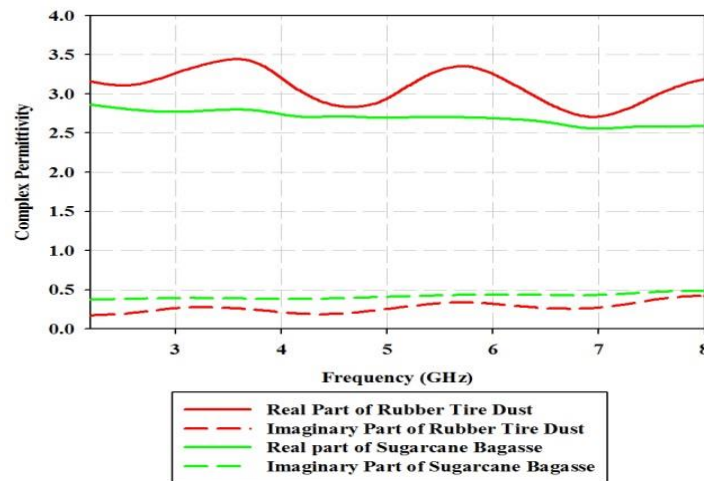


Figure 4. Complex permittivity of sugarcane bagasse and rubber tire dust in the range frequency of 2-8 GHz

Table 1. Measured Range of Dielectric Properties of the Two Raw Materials Which Are Sugarcane Bagasse and Rubber Tire Dust in Range Frequency between 2- 8 GHz

Sample	Dielectric Constant, ϵ'	Loss Factor, ϵ''
Sugarcane Bagasse	2.00 – 2.80	0.30 – 0.50
Rubber Tire Dust	3.00 – 3.20	0.10 – 0.40

Table 2. Different Designation of Flat Layer Absorber

Sample	Fillers Loading
SCB 1	25 wt % SCB:75 wt % RTD
SCB 2	75 wt % SCB:25 wt % RTD

3. RESULTS AND DISCUSSIONS

To identify the use of those composite materials in microwave application, their electromagnetic properties need to be defined first. In dielectric absorbers, there is no magnetic loss component involved so the absorption of the dielectric absorber depends on dielectric properties of the absorber. The characteristic impedance (η_m) of a dielectric material will match with the free space impedance (η_0) only when the $\mu_r = 1 + j0$, $\epsilon'_r = 1$ and $\epsilon''_r = 0$. Under these conditions, there will be no partial reflection of the wave at the air-dielectric interface and the entire wave will be transmitted in the dielectric medium. As the sugarcane bagasse and rubber tire dust-based absorbers are non-magnetic lossy materials with $\epsilon'_r > 1$ and $\epsilon''_r > 0$, hence their characteristic impedances will never match with the free space impedance. However, their input impedance (Z_{in}) that would be experienced by the incoming wave at the interface can be matched to the free space wave impedance.

The input impedance is a function of absorber's geometry, dielectric properties, and also the frequency of the incident wave. Therefore, the impedance will be matched only at certain frequencies and the resonance behavior will be observed at those (resonant) frequencies. Figure 5 shows the reflectivity of the single layer-sugarcane bagasse flat absorber. The flat layer absorber has been designed in two samples according to the analysis of characteristic impedance in the previous section. Table 2 shows the different designation of different filler for the sample of flat layer absorber.

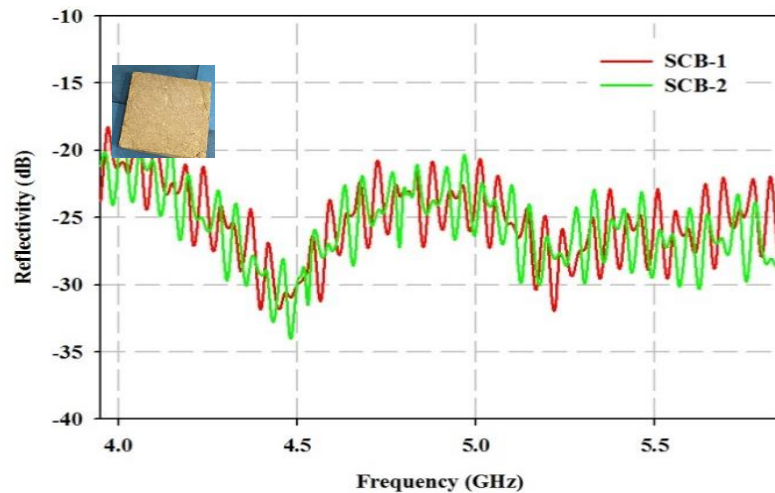


Figure 5. Reflectivity of flat layer absorber for SCB 1 and SCB 2 in frequency range of 3.85 GHz to 5.85 GHz

From Figure 5, the SCB-2 flat layer absorber shows the better reflectivity compared to SCB-1 within the range frequency of 4.5 GHz. The result shows a bit resonance in the frequency. The best reflectivity shows at frequency 4.5 GHz which both design has a better performance at -30 dB to -35 dB. At frequency 5.2 GHz, for SCB 1, the reflectivity is -32dB. Figure 6 shows reflectivity of flat layer absorber for SCB 1 and SCB 2 in frequency range of 5.85 GHz to 8.2 GHz.

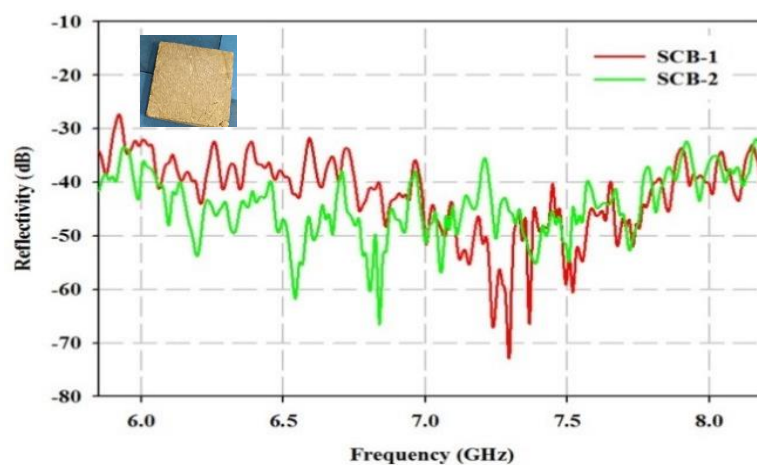


Figure 6. Reflectivity of flat layer absorber for SCB 1 and SCB 2 in frequency range of 5.85 GHz to 8.2 GHz

There are two different samples fabricated in the flat geometry. These two flat samples have different dielectric properties. Within the range frequency of 5.85 GHz to 7.2 GHz, SCB -2 shows better reflectivity compared to SCB-1. This SCB single layer absorber shows narrowband absorption with more than -10dB reflectivity (~90% absorption) in specific frequency. The incident and reflected waves contain of quarter wavelength reflection which allows absorber to obtain the minimum reflected energy.

4. CONCLUSION

The study of the EMC-oriented microwave absorbers composed of sugarcane bagasse (SCB) and lossy rubber tire dust (RTD) was performed numerically using CST Microwave studio and measured with the aid of pairs of horn antennas and network analyzer (PNA), within the anechoic chamber. From the results,

these two waste materials have strong potential to be used in the fabrication of the value-added EMC absorbers for the suppression of EM echoes. These two waste materials were dielectric materials as the relative magnetic properties are nearly equal to free space, $\mu=1-j0$.

The EMC performances of single layer microwave absorber by using SCB and RTD were below than -20 dB in term of reflectivity. This indicates that the absorber can absorb ~90 % of the incident signals. The dielectric properties of the material have been investigated as well. The rubber tire dust has the highest dielectric constant as compared to sugarcane bagasse. The SCB-2 flat layer absorber shows the better reflectivity as compared to SCB-1 within the frequency range of 4.5 GHz. The best reflectivity shows at frequency 4.5 GHz which is both design has a better performance at -30 dB to -35 dB. At frequency 5.2 GHz, for SCB 1, the reflectivity is -32dB. Within the frequency range of 5.85 GHz to 7.2 GHz, SCB -2 shows better reflectivity as compared to SCB-1. This SCB single layer absorber shows narrowband absorption with more than -10dB reflectivity (~90% absorption) at specific frequency.

The cost of the pyramidal microwave absorber can be reduced by using sugarcane bagasse (SCB) as the main material. This SCB base material is an environmental friendly absorber. The results of this study proves that waste materials such as SCB and rubber tire dust (RTD) can give a good performance up to -20 dB of reflectivity (~99.99%) of absorption in single layer design.

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