Measured and Simulated Scattering Parameters Analysis of Oil Palm Empty Fruit Bunch fibre-High Density Polyethylene Composites, using Rectangular Waveguide and Finite Element Method for Shielding Application

Abubakar Dantani Meli[1*], CHE Azurahanim Che Abdullah[2], Usman Atiku Kende[3], Abubakar Samaila[4], Shehu Umar[5] Muhammad Aliyu Wara[6]

[1,4,5]*Department of Science Education, Waziri Umaru Federal Polytechnic Birnin Kebbi, Nigeria*
[2]*Material Synthesis and Characterization Lab, Institute of Advanced Technology, University Putra Malaysia 43400 Serdang Selangor*
[3]*Department Science Laboratory technology, Waziri Umaru Federal Polytechnic Birnin Kebbi, Nigeria*
[6]*Department of remedial studies, Waziri Umaru federal Polytechnic Birnin Kebbi, Nigeria*
**Corresponding Author*

Abstract: **A material description of oil palm empty fruit bunch fibre and high density polyethylene (OPEFB-HDPE) composites for microwave shielding applications was established by determining it reflection (S_{11}) and transmission (S_{21}) coefficient with respect to percentage and frequency. The proposed OPEFB-HDPE composites was studied at frequency from 8-12 GHz. The study was conducted using Waveguide Agilent N5230A PNA and Comsol software technique. The effect of different percentages (10%OPEFB-90%HDPE, 20%OPEFB-80%HDPE, 30%OPEFB-70%HDPE, 40% OPEFB-60%HDPE, 50%OPEFB -50%HDPE) and frequency (8-12 GHz) on S_{11} and S_{21} of OPEFB-HDPE composites were investigated. Results showed that the percentage of OPEFB significantly influenced the reflection S_{11} and transmission S_{21} coefficient of OPEFB-HDPE composites. Furthermore, the reflection S_{11} coefficient increased in magnitude with increased in OPEFB percentage and decreased with increased in frequency while the transmission S_{21} coefficient decreased in magnitude with increased in OPEFB percentage and increased with increased in frequency. The S_{11} and S_{21} of the smallest and largest percentage (10 and 50%) of OPEFB for RWG at smaller and bigger frequencies (8 and 12 GHz) were (0.6298 and 0.7912) and (0.7157 and 0.5699), the S_{11} of the smallest and largest percentage (10 and 50%) of OPEFB for FEM at smaller and bigger frequencies (8 and 12 GHz) were (0.6128 and 0.8217) and (0.8217 and 0.5673) respectively. The higher percentage of OPEFB filler the higher the reflection S_{11} coefficient, and the lower the transmission S_{21} coefficient. Also the higher percentage of HDPE host matrix the higher the transmission S_{21} coefficient and the lower the reflection S_{11} coefficient.**

Keywords **of Oil palm empty fruit bunch fibre; High density polyethylene; Waveguide; reflection (S_{11}) and transmission (S_{21}) coefficient.**

I. INTRODUCTION

The broad growth of electronic equipment and telecommunications has led to major concerns about electromagnetic pollution which has increased to a level never attained previously. This condition has obliged the continuous development of materials which are greatly efficient in the shielding or inhibition of this unwanted radiation. Electromagnetic shielding is defined as the prevention of the propagation of magnetic and electric waves from one medium to another by using magnetic or conducting materials (Mu et al., 2015). The shielding can be carried out by reducing the electromagnetic waves passing through a system either by absorbing or reflecting of the wave of the radiation power in the material. Theoretically, shielding decreases the coupling of electromagnetic fields, electromagnetic waves, and electrostatic fields and its efficiency depends on the type of the material used, its thickness, the size of the shielded size and operating frequency. In the field of aerospace, for instance, inventive solutions are required to shield efficiently sensitive electronic equipment such antennas from Electromagnetic interference (EMI) without adding much weight to aircraft. Previously, the problem of EMI was solved by isolating the electronic device through some metallic housing. Common metals like iron, silver and aluminum were seen in most of the shields composed of metals used at that time. The high conductivity and strength of metals and alloys like mu-metal made them an interesting excellent materials for shielding applications especially for shielding from low magnetic fields. The main parts of mu-metal were copper (5%), iron (14%), nickel (79.5%) and chromium (1.5%). It has sufficient ductility and could simply be made into sheets needed for magnetic shields. Similarly, high permeability in mu-metal provided an avenue for the magnetic line of flux around the shielded range. Nevertheless, the disadvantage was that the metals were easily inclined to oxidation or corrosion and so could not be utilized for outside applications. The heavyweight and price of the metal shields also limit the use of metals as shielding materials (Jagatheesan et al., 2015).

Currently, the most common method of shielding by reflection is the use of metallic plates or adsorption by conductive polymers. Polymeric materials have also attained attractiveness due to their flexibility, corrosion resistance, light weight and cost effective than metals. Recently, metallic materials and polymer composites are the most commonly used materials. researches have also been carried out on the applications of polymer composites re-enforced with conductive fillers, fibres, nanotubes and dispersing particles (Chen et al., 2015). Metals such as copper, gold, and silver have also been widely used in electromagnetic shielding. The problems of metal plates mainly focused on the uneasiness of poor mechanical flexibility owing to the high rigidity, high weight density, and high cost. For a typical EM shielding or absorbing material, low density, high conductivity, strong broadband absorption and excellent thermal stability are the key parameters. The mechanism of microwave shielding categorizes the materials into two major sections; dielectric loss materials and magnetically lossy materials (Arief et al., 2017).

Ferrites have been used as shielding and absorbing materials in various forms for many years due to their huge magnetic loss and great resistivity. Since the imaginary part of the complex permittivity of ferrites is very small, the dielectric loss is almost insignificant and therefore their absorbing performance mainly depends on the magnetic loss (Li et al., 2017)

The design of an EMI shielding material with certain degree of attenuation while meeting a set of environmental criteria, maintaining economics and regulating shielding have been proposed. The main enthusiasm behind the proper design of the shield is to make a product that can conform to International Electromagnetic Interference Regulatory Standards. Investigation of new active materials applicable as microwave absorbers for electromagnetic interference (EMI) shielding of various electronic devices positions among significant present-day activities (Paligova et al., 2004). Several researches have also been carried out to develop new microwave shielding materials with respect to reflection (S_{11}) and transmission (S_{21}) coefficient (Luo et al., 2015).

Most conventional composites are reinforced by polymer as the matrix while fillers are the reinforcement's materials. The fillers are nominated according to their properties which are based on what is desirable from the composite. Many commercially produced composites utilize polymer matrix material often called a resin solution. There are a lot of diverse polymers with several broad categories and many variations available depending upon the preliminary raw ingredients. The most commonly used polymers are polyester, polylactic acid (PLA), high density polyethylene (HDPE), Polycaprolactone (PCL), ester, epoxy, phenol, polyimide, polyamide, polypropylene, and others (Pawar et al., 2016). Polymers have a very little concentricity of free charge carriers, and thus are non-conductive and transparent to electromagnetic radiation. Hence, they are not appropriate for use as shielding for electronic equipment because they cannot protect it from external radiation. Also, they cannot prevent the flight of radiation from the component. Various fillers can be added to the isolating polymeric matrix to obtain different conductivity ranges. As a result, the type or nature of fillers determines the dielectric characteristics of the polymer compound. A polymer that is conductive has advanced much interest in the recent past due to their excellent flexibility and easy preparation procedures as contrary to conventional inorganic semiconductors. They are applied in areas of electronics as flexibility conductors and shielding devices, especially from electromagnetic radiation. (Gupta et al., 2015).The ceramic microwave absorbers lack flexibility and moldability into any desired shape. These difficulties can be overcome by incorporating the opefb into the rubber matrix. Incorporation of opefb powders in natural or synthetic rubbers produces flexible Rubber opefb composites, which have many novel applications (Prema et al., 2008).

The ability of the material to interact with electromagnetic energy is related to the material reflection (S_{11}) and transmission (S_{21}) coefficient. A frequency characterizes this property in any homogeneous, isotropic and linear dielectric material. The reflection is a measure of how much energy from an external electric field is able to reflect in the material, while the transmission coefficient accounts for how material is able to transmit mechanisms in it (Lamberti, 2015). Therefore, the material with a higher reflection (S_{11}) and transmission (S_{21}) coefficient readily heated by microwave (Satish et al., 2006). On the other hand, any material that has a very low reflection (S_{11}) and transmission (S_{21}) coefficient is transparent to microwave effect. The microwave is only a small part of the electromagnetic spectrum (300 MHz to 300 GHz), which corresponds to wavelengths between 1m and 0.001m (Mudinepalli et al., 2013). However, their uses have become more and more important in the study of material properties. The material characterization is essential for the correct selection and conversion of a substance for industrial, scientific and medical applications. The scattering parameters over a wide temperature range are needed to assess their suitability for use in telecommunication, scattering waveguides, lenses, dielectric resonators, and microwave integrated circuits (MICs). The electromagnetic spectrum consists of various types of electromagnetic signals. Microwave behaves similarly to light wave, which travels in straight lines, reflect, refract, diffract, scatter, and interfere in the same physical length. However, they differ in the behavior due to the difference in wavelength. Microwave wavelengths are typically 10^5 greater than optical wavelengths. Thus microwaves tend to interact with materials and structures on a macroscopic scale. For instance, microwaves can penetrate most non-metallic materials, reflect and scatter from internal boundaries, and interact with molecules (Bahr, 1982). Microwaves do not change or heat in any way the material due to the very low energy emitted (Yahaya et al., 2015). The signals can infiltrate inside scattering (electrically insulating) material easily. The depth of penetration is dictated by the reflection coefficient of the transmission coefficient of the material (ability to transmit microwave energy), the frequency of operation and the dielectric or loss factor properties can then be related to the reflected or transmitted signal of the material (Zoughi & Ganchev, 1995). Many ideas have been tried to adapt this phenomena to microwave applications. The two key applications that deal with the use of microwave properties are EMI shielding and radar absorbing materials. The uses of microwave technology can be found in various fields such as communications, radio, military, environmental remote sensing, forecasting and weather monitoring, soil settlement system, astronomy and medical system. Much of the success of today's microwave technology is due to decades of unremitting efforts, hard work and careful research by Andre-Marie Ampere, Carl Friedrich Gauß, Michael Faraday, Oliver Heaviside, Heinrich Hertz and James Clerk Maxwell (Pozar, 2009).

The main interest of this work is in the interaction of microwaves with materials. These include parameters of absorption in materials, scattering, reflection, and transmission. These effects are utilized in various test setups to allow quantitative measurements in materials.

Natural fibres offer several advantages such as low density, cost effective, biodegradability, acceptable specific properties, better thermal and insulating properties and low energy consumption during processing (Faizi et al., 2017).

The oil palm industries produce an abundant amount of biomass in millions of tons per year (Mohanty et al., 2005) which, if properly utilized, can bring an end to the problem of disposal and build value-added products as well. OPEFB fibre is among the biomass that is currently utilized as fuel in the oil palm mills for energy production. There are ongoing attempts to transform OPEFB fibres into fertilizers by burning them into ash, which is abundant in potassium. However, this raises the issue of environmental pollution created by the unrestrained burning of OPEFB fibres. The researches on OPEFB fibre properties, such as their mechanical and physical characteristics, has resulted in their diverse applications in the field of composite materials.

Oil palm fibres are obtained from two parts of the oil palm tree, which are, the OPEFB and mesocarp. Among these two, OPEFB fibre is the most frequently used in composite materials and several other applications, because OPEFB is comprised of a cluster of fibres which is easily available and cheap. OPEFB fibres are extracted from the empty fruit bunch through the retting process while the mesocarp fibres are waste materials that remain after the oil extraction and requires cleaning before it is finally used (Hassan et al., 2010).

Biodegradable polymers are defined as those that undergo microbially induced chain scission leading to the mineralization. Biodegradable polymers may not be produced from bio source only, but it can be derived from the petroleum source. Polymers are also being produced from bio sources such as poly-hydroxybutyrate (PHB) and polyhydroxy valerate (PHV). On the other hand, the biodegradable polymer which is produced from the petroleum source is polylactic acid (Ray & Bousmina, 2005). HDPE production has grown annually, and currently, it is estimated that worldwide production will reach at least 800,000 tons by 2020 with Japan and the USA the two major producers. HDPE has gained importance due to its mechanical properties which are similar to the petrochemical-based plastics polyethylene terephthalate (PET) and polystyrene (PS). It has some favourable properties including ease of fabrication, zero toxicity, biocompatibility, high mechanical strength and thermal plasticity and is compostable. Most importantly its raw material, lactic acid, can be obtained from renewable resources, principally starch. As HDPE is a polymer synthesized from renewable resources, it has been suggested that its use could help to reduce greenhouse gas emissions and decrease fossil energy consumption compared to conventional petrochemical-based polymers. Though, the ever-increasing diversion of starch feed-stocks such as maize to HDPE production also brings pressures on land use and agriculture (Karamanlioglu et al., 2017). Polymers are usually used as housings or assemblies in the electronic and electrical industries. The desirable combination of characteristics like the low cost, a simplicity of fabrication, lightweight, and superior insulation characteristic make plastics one of the most useful materials for electronics and electrical applications. The function of plastics in the electronic and electrical applications was limited to general applications with no-load bearing uses. Plastic materials reinforced with fibre serve as effective insulators which enhance the mechanical properties of the field - carrying conductors (Jayamani et al., 2014). However, different applications such as cable and wire sheathing and shielding from electromagnetic interference require the polymers be made conductive for the dispersal of electrostatic charges. This is achieved by incorporating conductive reinforcements in them. Combining fibrous reinforcements into polymer matrices results into high-performance matrix materials having excellent mechanical characteristics suitable for electronics and electrical applications. They can be utilized as terminals, connectors, household and industrial plugs, printed circuit boards and switches.

II. METHODOLOGY

For the OPEFB grain sizes preparation, the raw fiber was grinded using grinding machine to reduce the surface area. The process was repeated three more times to obtain fine powdered grain size of the fiber. Next, the grinded fiber was soaked in water and allowed for 24 hours to remove the dirty inside. After that the fiber was washed using acetone to remove impurities and then dried in an oven at temperature of 60 ^{o}C for 5 hours, for acetone to evaporate and also the excess water. The fiber was sieve to grain sizes of 100µm

The grain size of the dried OPEFB sample were re-enforced with HDPE host matrix and molded into rectangular shape using 0.22 cm x 0.11 cm, mold in a hydraulic hot and cold press machine at 4 tonnes and a temperature of 170 ^{o}C. The five fabricated samples were used to study the reflection (S_{11}) and transmission (S_{21}) coefficient of the different percentage using rectangular waveguide method.

For the preparation of the OPEFB-HDPE composites, a total of 25.0 g was prepared for each composition of the composites. The compositions for easy identification are named 30% HDPE, 40% HDPE, 50% HDPE, 60% HDPE and 70% HDPE. The summary of the masses and percentages for each element is presented in a tabula form in table 1.

Table 1: Composition of raw materials used in composite preparation

(OPEFB)		(HDPE)		Total
Percentage (%)	Mass (g)	Percentage (%)	Mass (g)	Mass (g)
10.0	2.50	90.0	22.50	25
20.0	5.00	80.0	20.00	25
30.0	7.50	70.0	17.50	25
40.0	10.0	60.0	15.00	25
50.0	12.5	50.0	12.50	25

The OPEFB-HDPE composites was prepared via the melt blend technique using the Brabender poly-drive three-phase motor with a drive of 1.5 kW, 3x230 V, 40 A and speed range of 0-120 rpm. In this method, the machine is set to 170 ^{o}C for heating, the rotation of the rotors was set to 50 rpm. After the machine has reached the required temperature (170 ^{o}C), the high density polyethylene (HDPE) is introduced into the vial of the Brabender heating block. After 5 minutes the OPEFB 100m grain size is poured into the vial. The mixture is left for another 10 minutes before taken out and processed into desired dimension using hot and cold press. The composites are then moulded according to desired shape and dimensions. In this study, rectangular shape of 0.22 cm x 0.11 cm, were fabricated using a hydraulic press machine at 4 tonnes. The pellets are used in a rectangular waveguide setup to calculate the scattering parameters, determine the reflection (S_{11}) and transmission (S_{21}) coefficient of the samples using rectangular waveguide technique.

In measurement of scattering-parameter, rectangular waveguide technique was used. The set-up consists of a pair of rectangular waveguide (WR 90) and an Agilent N5230A PNA-L network analyser. For calibration purposes, the LINE, REFLECT, LINE (LRL) calibration can be performed if the properly characterized standards are available. However, the reflection only calibration produces errors due to the source match and directivity. It is assumed that the directivity value is very small compared to the size of the reflected signal from the short. For the correction and handling of all errors within the measurement, a full 2 port calibration is best considered.

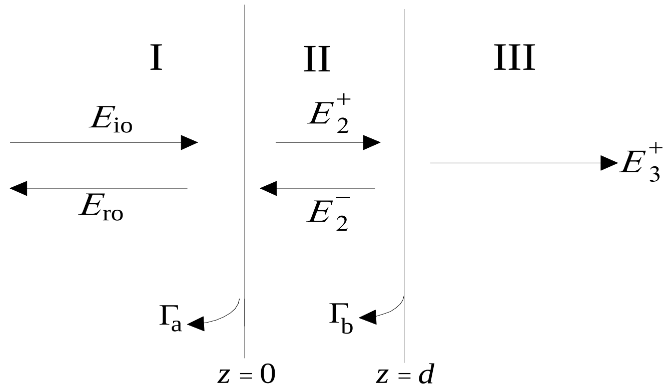
In this research, calibration of the vector network analyser was done using the standard full two-port calibration technique of THRU, REFLECT, LINE (TRL) technique.

In trying to avoid air gaps between the inner walls of the waveguide and edges of the sample, samples were carefully fabricated so as to fit the port of the rectangular waveguide. The uniformity in cross section of the sample and waveguide would produce a dominant mode analysis for material constant accuracy. For this study, the material used were HDPE and OPEFB-HDPE composites which are placed inside the rectangular waveguide for scattering parameter measurement.

Due to its relative convenience and simplicity, the transmission and reflection (TR) method is widely used in broad-band measurement technique by placing a sample in a section of a coaxial line, the two-port complex scattering parameters can be measured with the TR method (Zhou et al, 2009). Nicolson (1970) introduced transmission and reflection method in frequency domain whilst Nicolson and Ross (1970) introduced transmission reflection method in time domain.

Weir (1974) found that the imaginary part of propagation coefficient of a complex quantity is equal to the angle of the complex value plus $2\pi n$, where n is equal to the integer of length of the sample divided by the transmission line wavelength (Jing and Jiang, 2005). The phase ambiguity is resolved by finding a solution for permittivity and permeability from which a value of group delay is computed that corresponds to the value determined from measured data at two or more frequencies.

Abbas (2000), gave a detail explanation on the reflection and transmission coefficients of a dielectric slab placed between two planar boundaries unbounded homogenous medium. In his work, σ and α, are considered as the complex propagation constant in media I and III respectively. Suppose the complex propagation constants in the dielectric slab of thickness d represented by medium II in Figure 1 is represented by β



Reflection and transmission for a dielectric slab

The electric and magnetic fields in each media take the following form, (Abbas, 2001):

For Medium I,

$$E_I = \dot{x}(E_{io}e^{-\sigma z} + E_{ro}e^{\sigma z}) \quad (1)$$

$$H_I = \frac{\dot{y}}{z}(E_{io}e^{-\sigma z} - E_{ro}e^{\sigma z}) \quad (2)$$

For Medium II,

$$E_{II} = \dot{x}\left(E_2^+e^{-\beta z} - E_{ro}^-e^{\beta z}\right) \quad (3)$$

$$H_{II} = \frac{\dot{y}}{z}\left(E_2^+e^{-\beta z} - E_2^-e^{\beta z}\right) \quad (4)$$

For Medium III,

$$E_{III} = \dot{x}E_3^+e^{-\alpha z} \quad (5)$$

$$H_{III} = \frac{\dot{y}}{z}E_3^+e^{-\alpha z} \quad (6)$$

Assuming Z_I, Z_s and Z_{III} are the complex impedances in media I, II and III respectively. If all the media has the free space permeability ($\mu_r'' = \mu_r' = 1$) then the complex impedance of each medium is related to its complex permittivity by;

$$Z_{I,s,III} = \frac{Z_o}{\sqrt{E_{I,s,III}^*}} \quad (7)$$

Where $Z_o = \sqrt{\frac{\mu_o}{\varepsilon_o}}$ is the free space impedance, In calculating the reflection coefficient R and transmission coefficient T of the slab, the boundary conditions at $z = 0$ and $z = d$ will give;

$$R = \frac{E_{ro}}{E_{io}} = \frac{(Z_{III}+Z_s)(Z_s-Z_I)e^{-\beta d} + (Z_{III}-Z_s)(Z_s+Z_I)e^{\beta d}}{(Z_{III}+Z_s)(Z_s+Z_I)e^{-\beta d} + (Z_{III}-Z_s)(Z_s+Z_I)e^{-\beta d}} \quad (8)$$

$$T = \frac{E_3^+}{E_o} = \frac{4Z_sZ_{III}}{(Z_{III}+Z_s)(Z_s+Z_I)e^{-\beta d} + (Z_{III}-Z_s)(Z_s-Z_I)e^{-\beta d}} \quad (9)$$

A more general form of R and T are given as (Baker-Javis, 1990; Abbas, 2001);

$$R = \frac{\Gamma_A + \Gamma_B p^2}{1 + \Gamma_A\Gamma_B p^2} \quad (10)$$

$$T = \frac{(1 + \Gamma_A\Gamma_B)p}{1 + \Gamma_A\Gamma_B p^2} \quad (11)$$

Where

$$\Gamma_A = \frac{Z_s - Z_I}{Z_s + Z_s} = \frac{\sqrt{E_I^*} - \sqrt{E_s^*}}{\sqrt{E_1^*} + \sqrt{E_s^*}} \quad (12)$$

$$\Gamma_B = \frac{Z_{III} - Z_s}{Z_{III} + Z_s} = \frac{\sqrt{E_s^*} - \sqrt{E_{III}^*}}{\sqrt{E_s^*} + \sqrt{E_{III}^*}} \quad (13)$$

$$p = e^{-\beta d} \quad (14)$$

At the interface of Z = 0 and Z = d the reflection coefficients are Γ_A *and* Γ_B respectively. If media I and II are free space media then $Z_I = Z_{II}$ hence (10) and (11) will be reduced to;

$$R = \frac{(1-p^2)\Gamma}{1-\Gamma^2p^2} \quad (15)$$

$$T = \frac{(1-\Gamma^2)p}{1-\Gamma^2p^2} \quad (16)$$

It is assumed that $\Gamma = \Gamma_A$ *and* $\Gamma = -\Gamma_B$ at boundary Z = 0 and Z = d respectively. This analysis can be used to determine the complex permittivity of a material sample by matching the measured reflection/transmission coefficients with calculated method (Abbas, 2001).

FEM was first employed by Courant (1943) to solve problems of equilibrium and vibration. Subsequent works by Mei (1974), Marin (1982), Bossavit and Verite (1982) and Barton and Cendes (1987) provided significant contributions to the improvement of FEM as cited by (Faiz, 2013). FEM has since become a very useful tool in computational electromagnetic (CEM) with the development of vector elements and boundary integral equations to deal with open region scattering problems (Jin, 2010). This method was used to validate S parameter measurement of PTFE and inorganic samples. Barkanov, (2001) in his work stated that the three basic FEM procedures are formulation of the problem, discretization of the formulation and solution for the resulting finite element equations. FEM can be categorised into three electromagnetic domains, namely the electric intensity, E, magnetic intencity, H and potential, V. In solving the potential V domain, the scalar or vector finite element routines may be used. Whereas solving of electric intensity, E and magnetic intensity, H domains are effectively solved using vector finite element routine. Scalar routine cases are readily and easily obtained than vector routine. However, many electromagnetic problems reduction of unknown quantity to scalar potential is completely impossible. The solution to it is to find a two or three component vector field. FEM has the flexibility to solve many engineering problems delving down to microwave heating and high power transmitter design. The popularity of FEM also leads to development of many commercial FEM solver packages which are commercially available as HFSS and COMSOL Multiphysics®. FEM is used in this study to model the rectangular waveguide and calculate the S parameters, S_{11} and S_{21} of material sample placed inside the waveguide

In this research, FEM is used to model a rectangular waveguide for microwaves characterisation. The transverse electric (TE) wave having no electric field component in the direction of propagation was examined using the FEM model in this study. The frequency and waveguide dimension used in this study was specifically chosen so as to have a single TE10 wave propagating through the waveguide. A sinusoidal wave with two nodes with non-zero component is assumed to be the electric field. The simulation run time depends highly on the number of refined mesh as well as computer properties. The simulation is implemented using The COMSOL Multiphysics software package, version 3.5, 2012, on a Hewlett Packard (PC) with a 2.10 GHz dual core processor (AMD Athlon™) 64 bit operating system.

The procedure of implementing FEM (COMSOL Multiphysics) in the evaluation the magnitude of transmission and reflection coefficients is highlighted in a flow chart shown in Figure 2 whilst the comprehensive procedure for using FEM COMSOL Multiphysics is followed immediately.

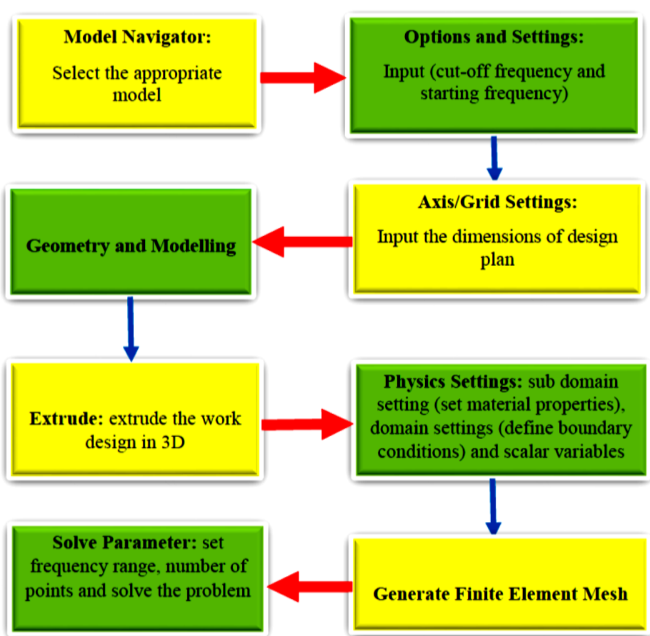


Fig. 2: shows the procedure of implementing FEM (COMSOL Multiphysics) in the evaluation the magnitude of transmission and reflection coefficients

III. RESULT AND DISCUSSIONS

As explained earlier, the reflection (S_{11}) and transmission (S_{21}) coefficient obtained from the rectangular waveguide method were used as initial input to FEM to compare the |*S11*| and |*S21*| of the samples.

The graphs in Figures 3 and 4 are the comparison between the measured and simulated (FEM) values of the |*S21*| and |*S11*| OPEFB- HDPE composites respectively.

Generally, the magnitude of |*S21*| increased with decreasing % OPEFB filler content, where the 90% HDPE sample was found to have the highest |*S21*| with corresponding lowest |S11|. The change in |*S21*| and |*S11*| with frequency are proportional and inversely proportional respectively. The results are in agreement with each other. Tabulated in table 2 is the relative errors analysis of the rectangular waveguide with respect to simulated results for S21. Based on the analysis, the FEM has confirmed the measurement results. The relative errors are in the range between 0.0748 and 0.0519, far less than 1.

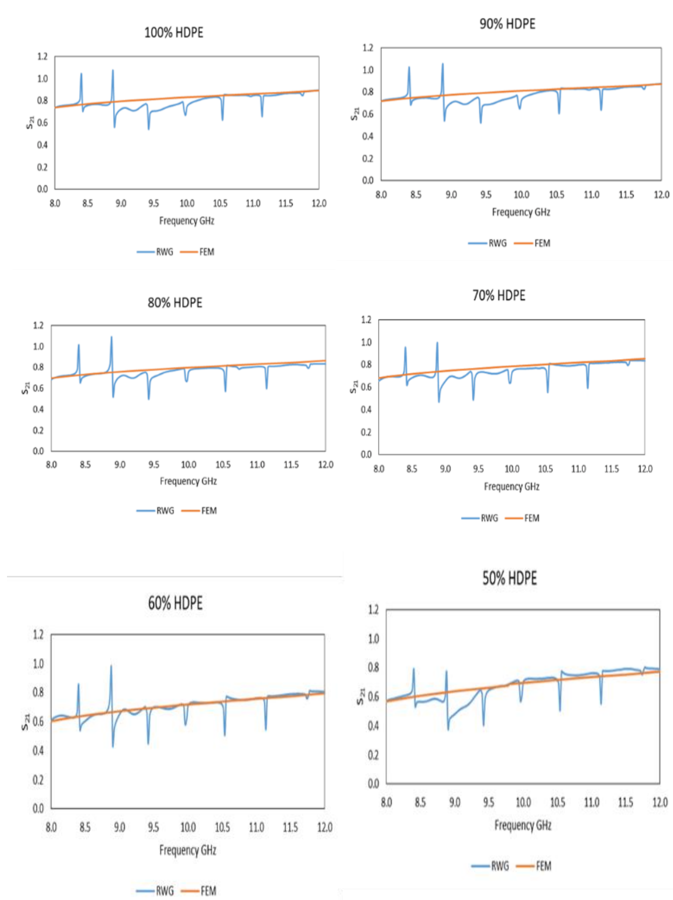


Fig. 3: Measured and simulated S21 for all samples

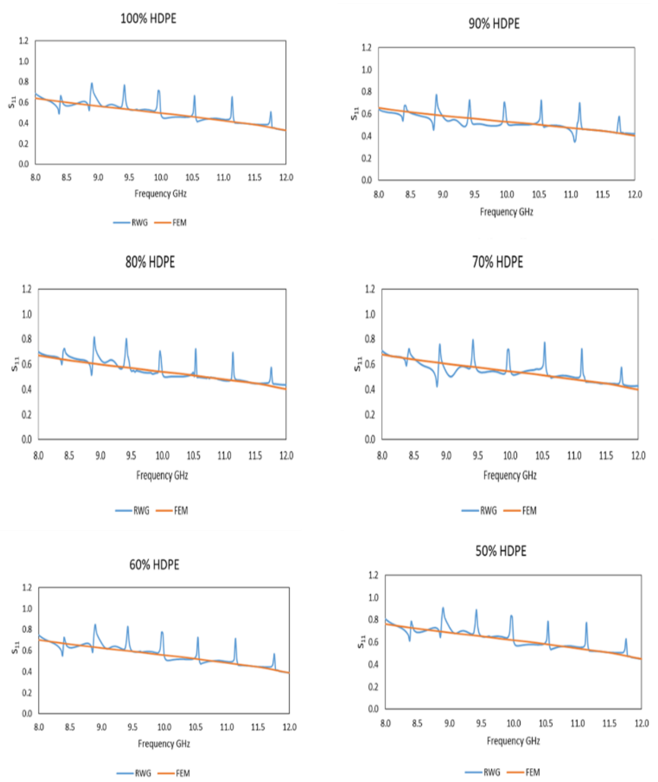


Fig. 4: Measured and simulated S11 for all samples

Table 2: Relative error of FEM with respect to RWG (S21)

Samples (%HDPE)	S_{21}		Relative error
	RWG	FEM	
50	0.5699	0.5673	0.0026
60	0.6082	0.6034	0.0048
70	0.6551	0.6817	0.0266
80	0.6845	0.6973	0.0128
90	0.7157	0.7179	0.0022
100	0.7912	0.8217	0.0212

IV. CONCLUSION

The OPEFB-HDPE composites was prepared using melt blend technique. Five different percentages of OPEFB of 100μm were analyzed based on their scattering parameters. The 50% OPEFB was found to have optimal properties of S_{11} and leased properties of S_{22} as such is best the composite to be used for shielding application. It been established that, the higher the OPEFB the higher the S_{11} and the lesser the S_{22}, also the higher HDPE the higher S_{22} and the lesser S_{11}.

The scattering parameters of the materials were measured by using both the rectangular waveguide and finite element method. The effect of the different percentages of OPEFB fillers on the scattering parameters of OPEFB-HDPE composites were analyzed for the whole frequency range between 8 GHz and 12 GHz (X-band). The scattering parameters OPEFB-HDPE composites varied from 0.5699 and 0.7912 for measured to 0.5673 and 0.8217 for FEM respectively in the X-band frequency. It was found that both transmission and reflection coefficient values of OPEFB-HDPE composites increased with increasing % of the OPEFB.

The transmission and reflection coefficients and absorption of the different OPEFB-HDPE composites were determined using the waveguide technique and finite element method. The effect of the different % of OPEFB filler on the scattering parameters were also investigated. The higher operating frequencies were found to give lower values of the amplitude of the reflection coefficients. The FEM was implemented using COMSOL software allowing visualization of the computation of its transmission and reflection properties of the OPEFB-HDPE composites. The calculated and measured scattering parameter of the OPEFB-HDPE composites were found to be in good agreement.

REFERENCES

[1] Abbas, Z. (2000). Determination of Dielectric Properties of the Material at Microwave Frequencies Using Rectangular Dielectric Waveguide, PhD Thesis, University of Leeds

[2] Abbas, Z. Pollard, R. D. and Kelsall, R.W. (2001). Complex Permittivity Measurements at Ka Band Using Rectangular Dielectric Waveguide. IEEE Transaction on Instrumentation and Measurement, vol. 50. No. 5, pp 1334-1342.

[3] Arief, I., Biswas, S., & Bose, S. (2017). FeCo-Anchored Reduced Graphene Oxide Framework-Based Soft Composites containing Carbon Nanotubes as Highly Efficient Microwave Absorbers with Excellent Heat Dissipation Ability. ACS Applied Materials & Interfaces.

[4] Baker-Jarvis, J. (1990). Transmission/Reflection and Short-circuit Line Permittivity Measurements, Electromagnetic Field Division, National Institute of Standards and Technology (NIST), Colorado, USA.

[5] Barkanov, E. (2001). Introduction to Finite Element Method, Institute of Materials and Structures, Riga Technical University, Latvia.

[6] Barton, M. L. and Cendes, Z. J. (1987). New vector finite elements for three dimensional magnetic field computation. Journal of Applied Physics. 61: 3919-3921

[7] Bossavit, A. and Verrite, J. C. (1982). A mixed FEM and BIEM methods to solve 3-D edge current problems. IEEE Transaction on Magnetics. 18(2): 431-435.

[8] Courant, R. L. (1943). Variational methods for the solution of equilibrium and vibration, Bulletin of American Mathematical Society. 49(1): 1-23.

[9] Chen, X., Liu, L., Liu, J., & Pan, F. (2015). Microstructure, electromagnetic shielding effectiveness and mechanical properties of Mg–Zn–Y–Zr alloys. Materials & Design (1980-2015), 65, 360-369.

[10] Faiz, M. Z. (2013). Design and analysis of monopole sensor for the determination of moisture content in dioscoreahispida tuber, PhD Thesis, Universiti Putra Malaysia.

[11] Faizi, M., Shahriman, A., Majid, M. A., Shamsul, B., Ng, Y., Basah, S., . . . Wan, K. (2017). An verview of the Oil Palm Empty Fruit Bunch (OPEFB) potential as reinforcing fibre in polymer composite for energy absorption applications. Paper presented at the MATEC Web of Conferences.

[12] Gupta, V., Rama, S., Jha, M. K., & Qureshi, M. (2015). ANFIS Prediction of the Polymer and Polymer Composite Properties and Its Optimization Technique: IJIRSET.

[13] Hassan, A., Salema, A. A., Ani, F. N., & Bakar, A. A. (2010). A review on oil palm empty fruit bunch fiber-reinforced polymer composite materials. Polymer Composites, 31(12), 2079-2101.
[14] Jagatheesan, K., Ramasamy, A., Das, A., & Basu, A. (2015). Fabrics and their composites for electromagnetic shielding applications. Textile Progress, 47(2), 87-161.
[15] Jayamani, E., Hamdan, S., Rahman, M. R., & Bakri, M. K. B. (2014). Comparative study of dielectric properties of hybrid natural fiber composites. Procedia Engineering, 97, 536-544.
[16] Jin, J. M, (2010). The Finite Element Method, in Theory and Computation of Electromagnetic Field, John Wiley & Sons, USA.
[17] Jing, H. and Jiang, Q. (2005). Transmission/Reflection method based on coaxial line for RF materials characterization measurement. Journal of Astronautics, Vol. 26, No. 5.
[18] Karamanlioglu, M., Preziosi, R., & Robson, G. D. (2017). Abiotic and biotic environmental degradation of the bioplastic polymer poly (lactic acid): A review. Polymer Degradation and Stability.
[19] Lamberti, G. (2015). Microwave technology applied in post-harvest treatments of cereals and legumes. Chemical engineering transactions, 44, 13-18. doi: 10.3303/CET1544003
[20] Li, L., Liu, S., & Lu, L. (2017). Synthesis and significantly enhanced microwave absorption properties of cobalt ferrite hollow microspheres with protrusions/polythiophene composites. Journal of Alloys and Compounds.
[21] Luo, H., Gong, R., Wang, X., Nie, Y., Chen, Y., & Harris, V. G. (2015). Fe 3 O 4 cladding enhanced magnetic natural resonance and microwave absorption properties of Fe 0.65 Co 0.35 alloy flakes. Journal of Alloys and Compounds, 646, 345-350.
[22] Marin, S. P. (1982). Computing scattering amplitudes for arbitrary cylinders under incident plane waves. IEEE Transaction on Antennas and Propagation, 30(6): 1045-1049.
[23] Mei, K. K. (1974). Unimoment method of solving antenna and scattering problems. EEE Transaction on Antennas and Propagations. 22(6): 760-766.
[24] Mohanty, A. K., Misra, M., & Drzal, L. T. (2005). Natural fibers, biopolymers, and biocomposites: CRC press.
[25] Mu, S., Xie, H., Wang, W., & Yu, D. (2015). Electroless silver plating on PET fabric initiated by in situ reduction of polyaniline. Applied Surface Science, 353, 608-614.
[26] Mudinepalli, V. R., Song, S., Li, J., & Murty, B. (2013). A comparative study of structural and electrical properties of Ba 0.8 Pb 0.2 TiO 3 nanocrystalline ceramics prepared by microwave and spark plasma sintering. Materials Chemistry and Physics, 142(2), 686-691.
[27] Nicolson, A. M and Ross, G. F, (1970). Measurement of Intrinsic Properties of Materials by Time Domain Techniques, IEEE Transaction on Instrumentation and Measurement, Vol. IM-19, pp. 395-402.
[28] Pawar, R., Pawar, G., & Mahale, P. (2016). A Review on Effect of Variation in Material Composition and Structural Dimensions on Vibrational Behavior of Composite Materials. International Journal of Current Engineering and Technology.
[29] Prema, K., Kurian, P., Anantharaman, M., Suma, M., & Joseph, M. (2008). Permittivity characteristics in the X-and S-band frequencies of microwave absorbers based on rubber ferrite composites. Journal of Elastomers & Plastics, 40(4), 331-346.
[30] Paligova, M., Vilčákova, J., Sáha, P., Křesálek, V., Stejskal, J., & Quadrat, O. (2004). Electromagnetic shielding of epoxy resin composites containing carbon fibers coated with polyaniline base. Physica A: Statistical Mechanics and its Applications, 335(3), 421-429.
[31] Pozar, D. M. (2009). Microwave engineering: John Wiley & Sons.
[32] Ray, S. S., & Bousmina, M. (2005). Biodegradable polymers and their layered silicate nanocomposites: in greening the 21st century materials world. Progress in materials science, 50(8), 962-1079.
[33] Satish, H., Ouellet, J., Raghavan, V., & Radziszewski, P. (2006). Investigating microwave assisted rock breakage for possible space mining applications. Mining technology, 115(1), 34-40.
[34] Weir, W. B., (1974). Automatic measurement of complex dielectric constant and permeability at microwave frequencies. Proceedings of the IEEE, Vol. 62. Pp. 33-36.
[35] Yahaya, N. Z., Abbas, Z., Yahaya, M. Z., Norimi, A., Ashikin, N. N., Razak, A., & Mustafa, I. S. 2015). Development of Calibration Equation Based on Complex Permittivity of Hevea Rubber Latex. Asian Journal of Applied Sciences (ISSN: 2321–0893), 3(03).
[36] Zhou, H. Lu, G. Li, Y. Wang, Y. (2009). An Improved Method of Determining Permittivity and Permeability by S-Parameters, Progress in Electromagnetic Research Symposium Proceedings, Beijing, China.
[37] Zoughi, R., & Ganchev, S. (1995). Microwave Nondestructive Evaluation: State-of-the-Art Review: DTIC Document.