Network for Research and Development in Africa
International Journal of Pure and Applied Science Research
ISSN: 2384-5918. Volume 12, Number 2
Pages 70-81 (June, 2021)
www.arcnjournals.org

EFFECT OF OPEFB-HDPE COMPOSITE RATIO ON THE MAGNITUDES OF TRANSMISSION AND REFLECTION COEFFICIENT AT 8 – 12 GHZ MICROWAVE FREQUENCY

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Abstract: *Oil palm empty fruit bunch fibre and high density polyethylene (OPEFB-HDPE) composites have been used in a variety of applications. To date, the application of biomaterials as fillers in composites for microwave applications has not been fully examined. The conventional solid-state method based on melt blend technique was used to prepared the composites. Five OPEFB-HDPE composites with different filler percentage were prepared. The rectangular waveguide (RWG) was used to evaluate the scattering parameters. The crystalline structure of the composites was analyzed using X-ray diffraction (XRD) machine. The permittivity of the composites was found to depend on the mixing ratio between OPEFB and HDPE. The dielectric constants of composites were found to be between 2.5 and 3.2 and the loss factor from 0.15 to 0.38 in the X-band frequency. Both the Ɛ' and Ɛ" of the OPEFB-HDPE composite increased with increasing percentages of OPEFB fillers. These, in turn, lead to higher values of the magnitude reflection coefficient $|S_{11}|$ and lower transmission coefficient $|S_{21}|$ by the impedance matching theory.*

Keywords: *XRD, Dielectric, Composite, Waveguide, Microwave*

Introduction

Composites are materials consisting of two or more different substance chemically and physically in phases separated by a distinct interface. The divergent frameworks are consolidated together so as to accomplish a framework with more beneficial structure or practical properties non-achievable by the individual constituent alone. Composites today are turning into an irreplaceable piece of materials because of the points of interest like low weight, imperviousness to erosion, high exhaustion quality, quicker to assemble and rigid

nature. They have extensively found application as materials in fabricating aircraft components, electronic packaging, medical equipment, space vehicle and home building (Shaw et al, 2010). Blends and composites differ in the sense that the two main elements in the composites are distinguishable, this is not so in blend, they might not be recognizable. Composites are blends of materials contrasting in structure, where the individual constituents hold their different behaviours. These different constituents act together to give the essential mechanical quality or firmness to the composite part. They are composed of distinct phases i.e. matrix phase and dispersed phase with significant bulk properties that are not similar to those of any of the constituents. Matrix phase is also referred to as primary phase, it has a constant character. Matrix is generally more ductile and soft phase. Dispersed phase grasps and shares a load with the matrix. Dispersed, otherwise known as reinforcing or secondary phase is embedded within the matrix in a discontinuous form. Usually it is tougher than the matrix, hence the name reinforcing phase.

Materials predominantly used every day are wood, concrete, ceramics, etc. Be that as it may, the most essential polymeric composites are found in nature and are alluded to as normal composites. In warm blooded animals, the connective tissues have a place with the most exceptional polymer composites in the world where the stringy protein, collagen is the support. It capacities both as delicate and hard connective tissue. According to (Mayer et al, 1998), composites for structural application possesses characteristics such as;

- Two or more physically distinct and mechanically distinguishable materials.
- Prepared by mixing the distinct materials so as to achieve controlled and even dispersion of the constituents.
- Having greater mechanical properties and may be uniquely distinct from the properties of their constituents

Typically, two goals are achieved in composite making. The first goal is to develop the strength, stiffness, toughness, or dimensional strength by embedding particles or fibers in a matrix or binding phase. Secondly, to use cost efficient, readily obtainable fillers than the reversed; this goal is important as petroleum product become expensive and unreliable. Other applications, fillers such as glass spheres are employ to improve processability. Incorporation of dry-lubricant particles such as molybdenum sulfide to make a self-lubricating bearing, and the use of fillers to reduce permeability have also been achieved.

A natural fiber composite with an exceptionally good combination of properties is not a dream today. Fiber-reinforced composites are known to be strong and light. This means that with proper processing techniques, fiber treatments, and compatibilizers/coupling agents, composites with optimum properties can be used to make automobiles lighter, and thus much more fuel efficient.

Few decades ago, polymers have replaced many of the conventional metals/materials in various applications. This was made conceivable because of the favourable circumstances polymers offer over regular materials. The absolute most essential points of interest are the simplicity of handling, efficiency and cost decrease. In a large portion of these applications, the

properties of polymers are modified utilizing fillers, for example, fibers to suit the high quality and modulus necessities. Fiber-fortified polymers give different preferences over regular materials when specific properties are analysed (Schneider et al, 1995). These composites are finding widespread applications in diverse fields from appliances to space crafts. Over the years, the attention of scientist and technologist have been drawn to the use of natural fibres instead of conventional reinforcement materials. These natural fibres are low-cost fibres with low density and high specific properties. They are biodegradable and nonabrasive, unlike other reinforcing fibers. Also, they are readily available and their specific properties are comparable to those of other fibers used for reinforcements (Colberg and Sauerbier, 1997). However, disadvantages such as incompatibility with the hydrophobic polymer matrix, the tendency to form aggregates during processing, and poor resistance to moisture serve as drawbacks to the potentials of natural fibers as reinforcement in polymers (Schloesser and Knothe, 1997).

OPEFB-HDPE composites has been used in a variety of applications. This work has been focus on developing the potentials of OPEFB-HDPE composite as a dielectric constant substrate which over the years has found application in the field of low temperature co-fired ceramic (LTCC) patch antenna in the microwave frequency range.
This work proposes to develop the potentials of OPEFB-HDPE composite as a dielectric constant substrate for electromagnetic shielding and antenna application.

Methodology

OPEFB preparation

For the purpose of this study materials used are, High Density Polyethylene granules (HDPE) 99.9% purity, with chemical formula $(CH_2CH_2)_n$, melting point at 150^0C and a density of 0.939 g/cm^3 (Alfa Aesar, a Johnson Matthey company). Oil palm empty fruit bunch (OPEFB) obtained from Okomu Oil Palm Company, Benin City, Edo State, Nigeria. Deionized water (DIW) (H_2O) with density 1.0 g/cm^3 and Acetone with chemical formula C_3H_6O, density 0.78998 g/ml at 20^0C and evaporating temperature above 53.0^0C at 1atm.

OPEFB-HDPE Composite Preparation

For the preparation of the OPEFB-HDPE composites, a total of 50.0g is to be prepare for each composition of the composites. The compositions for easy identification is 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 tabular form in table 1.

Table 1. Composition of raw materials used in composite preparation

HDPE Granules		OPEFB		
Mass (%)	Mass (g)	Mass (%)	Mass (g)	Total Mass (g)
70.0	35.0	30.0	15.0	50
60.0	30.0	40.0	20.0	50
50.0	25.0	50.0	25.0	50
40.0	20.0	60.0	30.0	50
30.0	15.0	70.0	35.0	50

The OPEFB-HDPE composites was prepared at Nigeria Leather Institute (NILEST) Zaria, Kaduna State. This was done 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 150^0C for heating, the rotation of the rotors set at 50 rpm. As the machine reached the required temperature (150^0 C), the high density polyethylene (HDPE) is pour into the vial of the Brabender heating block. After 5 minutes the OPEFB 100m grain size is introduced into the vial. The mixture will be left for another 15 minutes before taken out and fabricated into desired dimension using hot and cold press. Figure 3 present the flow chart for the sample preparation.
The composites was then be moulded according to desired shape and dimensions. In this research, rectangular shape of 0.22 cm x 0.11 cm, and 7cm thick as fabricated using a hydraulic press machine at 4 tonnes. The pellets fabricated was used in a rectangular waveguide setup to calculate the scattering parameters and vector network analyser (VNA).

Scattering-Parameters Measurements

In scattering-parameter measurement, rectangular waveguide technique was used. The set-up consists of a pair of rectangular waveguide (WR 90) shown in Figure (a) and (b), and an Agilent N5230A PNA-L network analyser. For calibration purposes, the LINE, REFLECT, LINE (LRL) calibration can be performed if the properly characterised 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.

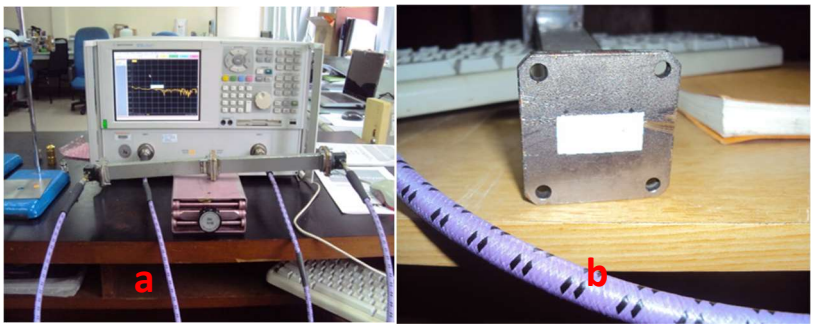


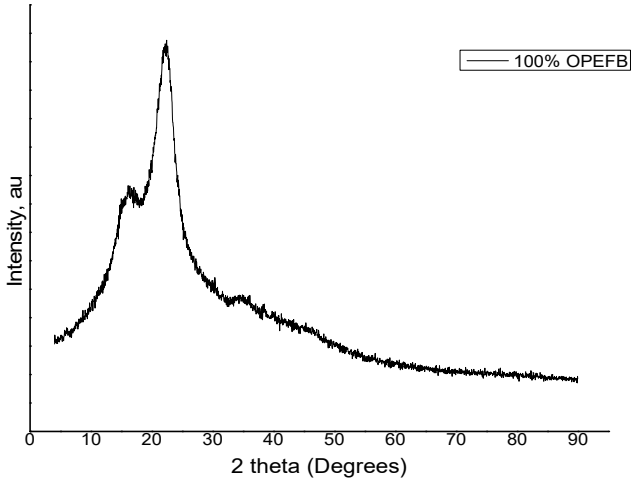
Fig. 1 (a) T/R measurement using a PNA set-up (b) Sample fitting in RWG

Results and Discussion

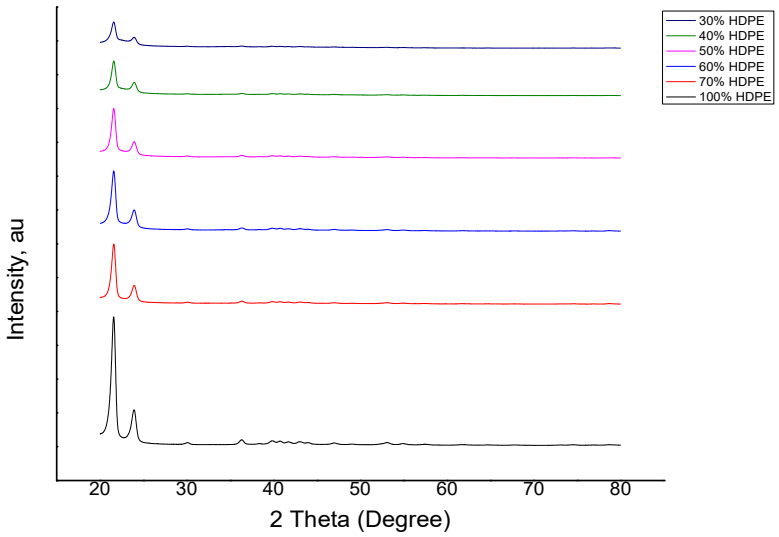
XRD profile

X-ray diffractogram for OPEFB and OPEFB-HDPE composites are presented in figures 2 (a) and (b) respectively. From fig. (a), the spectrum showed a broad diffraction peak indicating that at angle 2θ range from 4 to 90 degrees OPEFB is amorphous. In fig. 5.1 (b) the two main diffraction peaks in the HDPE were observed at 21.0° and 24.1° 2θ, which correspond to110 and 200 planes this is in agreement with result obtained by (Patwary & Mittal, 2015). The addition of OPEFB did not lead to any shift in the position of the diffraction peaks of pure PE, but the intensity of the peaks gradually showed a decrease in the diffraction signals as more OPEFB fillers are added.

In the composites, no filler peaks were observed indicating the shear mixing with polymer resulted in disturbing the ordering between the filler particles, thus, interposing the polymer chains in the interlayers of filler particles. The diffraction pattern revealed a slight crystalline form at between 20^0 and 25^0 whereas from 25^0 to 80^0 is completely amorphous due to absence of diffraction peak.



(a)



(b)

Figure 2: XRD spectrum of (a) OPEFB and (b) OPEFB-HDPE composites

The effects of OPEFB-HDPE composite ratio on S_{11} and S_{21} magnitudes

This section investigates the effects of OPEFB percentage on the S_{11} and S_{21} magnitudes of the OPEFB-HDPE composite. The S-Parameters on the Y axis are the linear magnitude of S_{11} and S_{21} whilst the operating frequency represents the x axis. The S-parameter results for the hollow waveguide and waveguide loaded with OPEFB-HDPE composite are shown in figures 3, 4 and 5.

Rectangular waveguide method

Figure 3 illustrates the effect of frequency on the S_{11} and S_{21} of a hollow 6mm thick waveguide sample holder. As expected S_{11} and S_{21} values were closed to theoretical values 0 and 1.

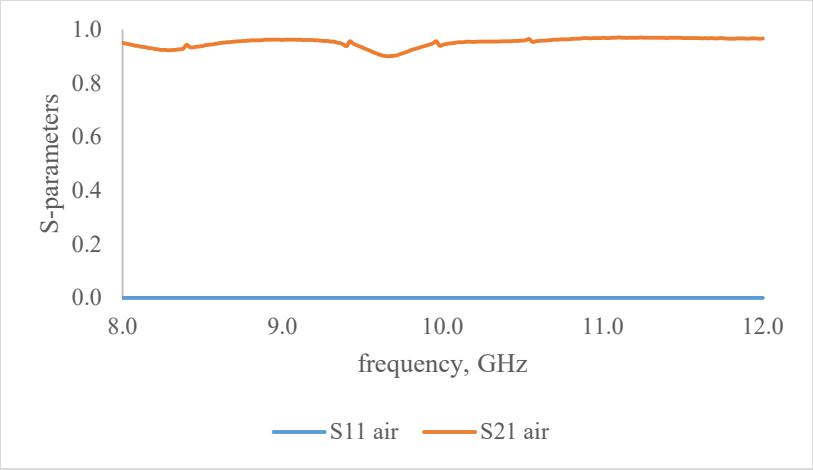


Figure 3: Variation in S_{11} and S_{21} for a hollow waveguide

Evidently from figures 4 and 5, the ripples nature of the $|S_{11}|$ and $|S_{21}|$ could be due to the internal surface roughness of the rectangular waveguide, air gab between the samples and the internal walls of the rectangular waveguide, sample imperfections and voids within the sample and the ripple nature is due to half wavelength effects and might also be attributed to the impedance mismatched between input impedance of the waveguide, the surface impedance of the sample and the characteristics impedance of the coaxial cable (Pozar, 2009). The result reveals multiple reflection for both S_{21} and S_{11}. This effect is attributed to the sample thickness being relatively small about 6mm. However, if samples are sufficiently thick, there will be no multiple reflection and S_{21} will decrease with frequency (Abbas, 2001). The spikes or half wavelength effect in the graph is repeated every $\lambda/2$ due to multiple reflection effect in the sample (Nicholson Ross-Weir, 1970).

Table 2 list the magnitudes of S_{21} and S_{11} for all composites at 8 GHz and 12 GHz. The result reveals that the higher the HDPE the higher the S_{21}, whist the higher the HDPE the lower the S_{11}. This is attributed to increase in loss factor as the % HDPE is decreased and the % OPEFB filler increased. The higher the ε'', the higher is the reflection and lower transmission is observed as the % of OPEFB filler is increased.

Table 2: Magnitudes of S_{21} and S_{11} at 8 GHz and 12 GHz

HDPE (%)	S_{21}		S_{11}	
	8 GHz	12 GHz	8 GHz	12 GHz
30	0.5066	0.7876	0.7966	0.3905
40	0.5498	0.7553	0.7435	0.4512
50	0.5913	0.7943	0.7098	0.4684
60	0.6353	0.8486	0.6614	0.4016
70	0.6778	0.8786	0.6102	0.3705

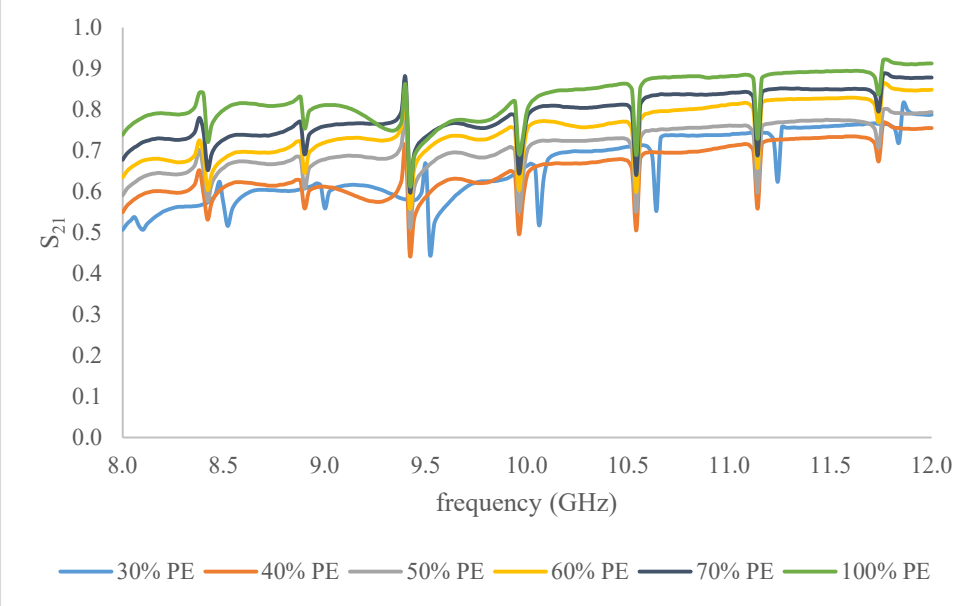


Figure 4: Variation in S_{21} OPEFB-HDPE for different % ratio of composites

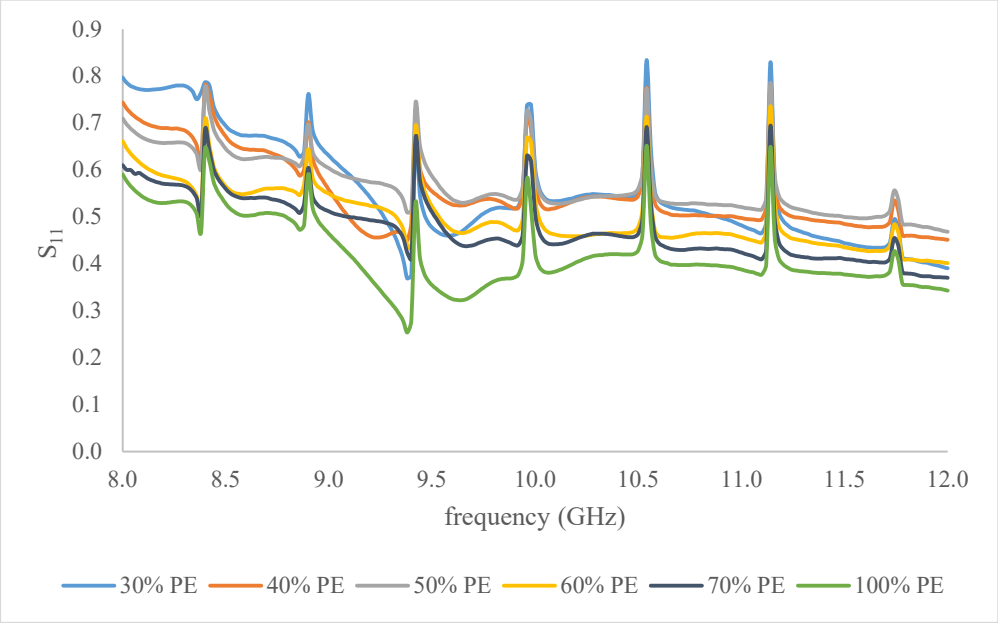


Figure 1: Variation in S_{11} OPEFB-HDPE for different % ratio of composites

Effects of % OPEFB on S_{11} and S_{21}

The variation in S_{11} and S_{21} with respect to % OPEFB filler content are presented in figures 6 and 7 respectively. From the result, it can be deduced that the change in S_{11} and S_{21} with % OPEFB are proportional and inversely proportional respectively. The increase in S_{11} with % OPEFB is because OPEFB has higher ε' than HDPE, also attributed to impedance matching. The S_{21} decrease with % OPEFB because OPEFB has higher ε'' than HDPE and also due to absorption within the composite which is attributed to the cellulose present in the OPEFB.

By interchanging x and y axis, we can always predict % of HDPE or OPEFB in the composite for a given frequency by applying the regression equations in both cases. For example, using the S_{11} value of 0.8 at 8 GHz, the prediction for the OPEFB filler is 70% using the equation. The result can be confirmed by using the equation at different frequency range.

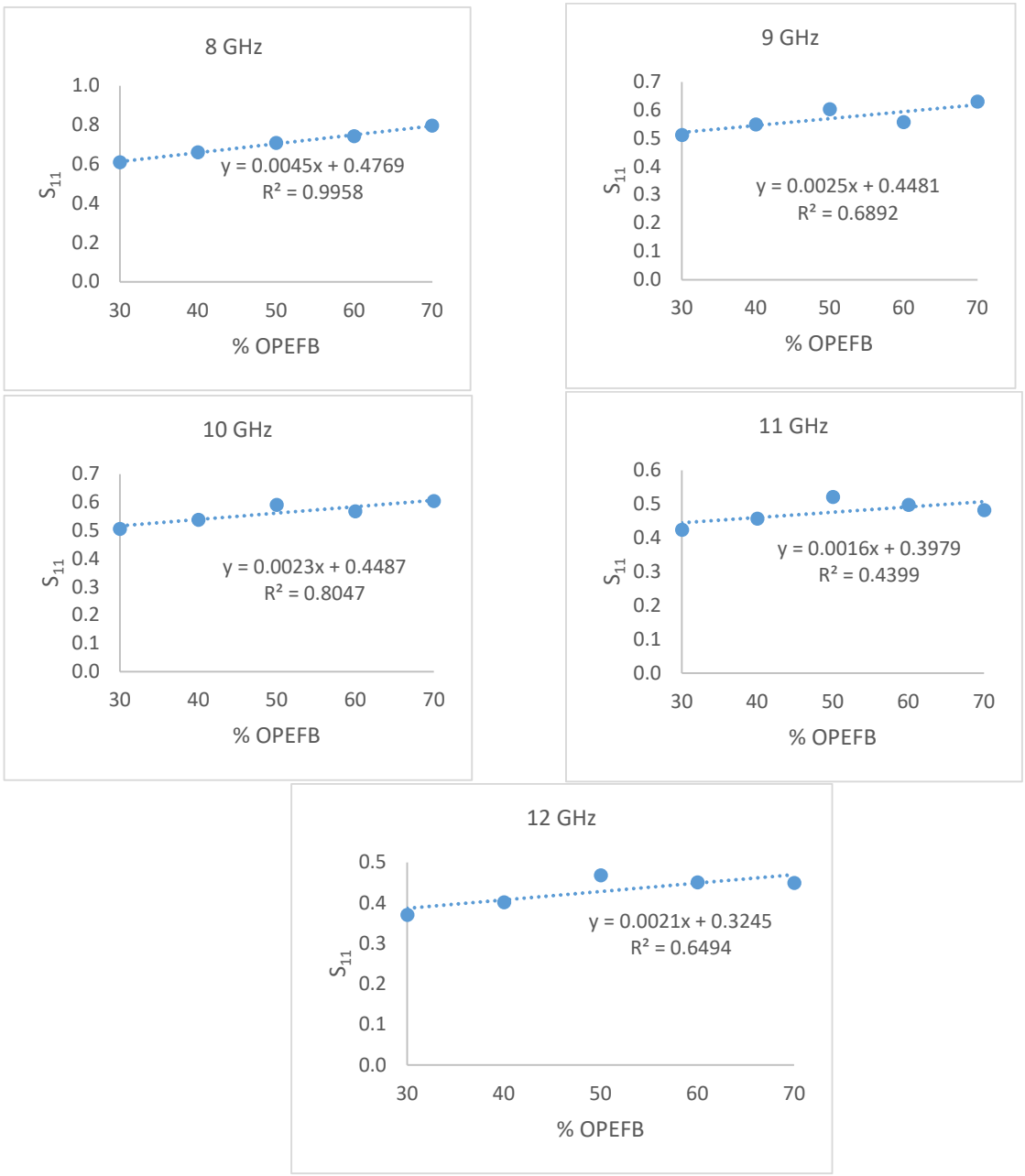


Figure 6: Variation in S_{11} with % OPEFB at selected frequencies

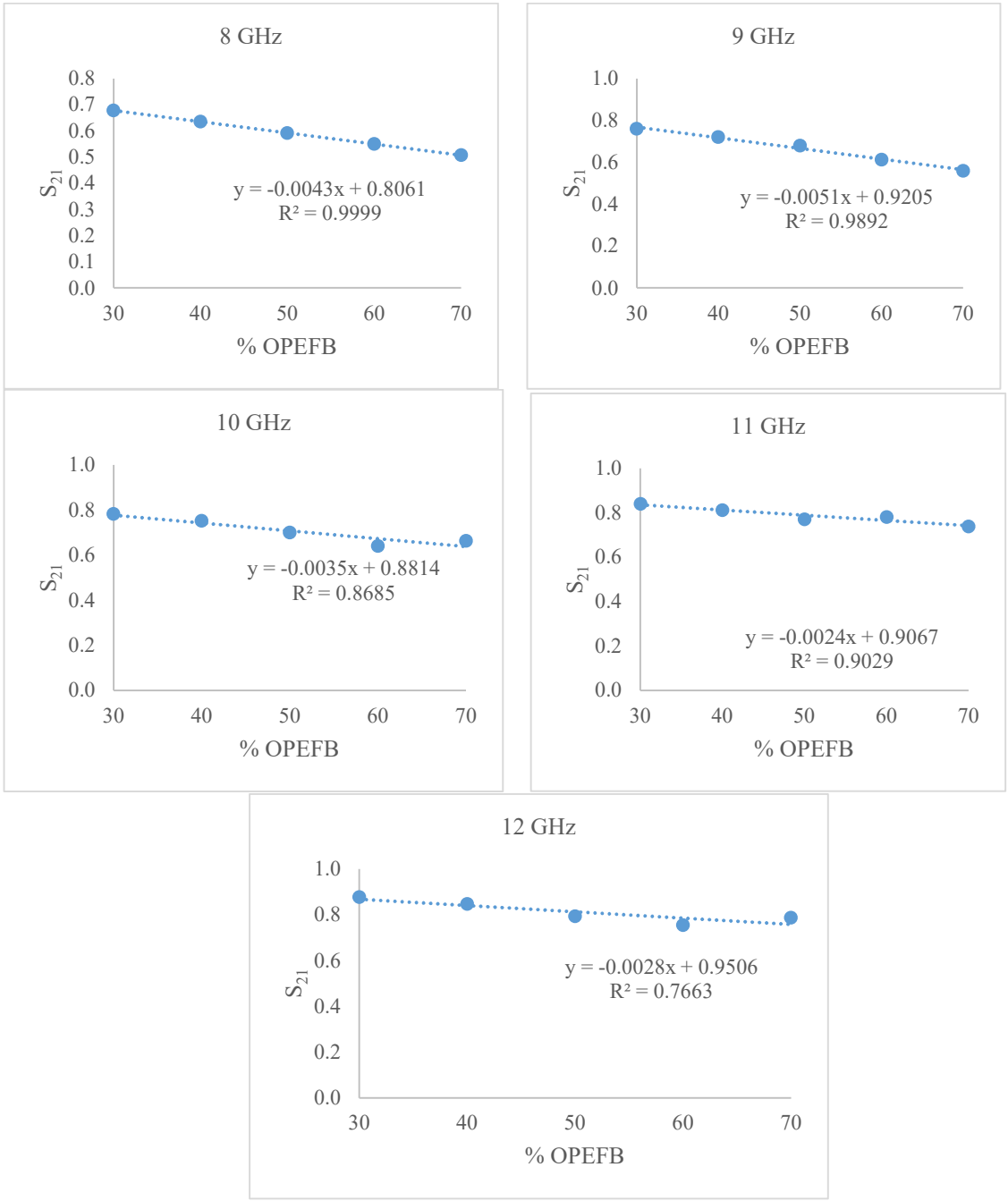


Figure 7: Variation in S_{21} with % OPEFB at selected frequency

Conclusion

The transmission and reflection coefficients and absorption of the different OPEFB-HDPE composites were determined using the closed waveguide technique. 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.

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