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# Utilization of Oil Palm Empty Fruit Bunch Fiber Waste for Microwaves Application

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***Abstract:*** *The dielectric properties of high density polyethylene (HDPE) filled with oil palm empty fruit bunch (OPEFB) fiber has been investigated at filler loading 30, 40, 50, 60 and 70 % fiber. Five different composites with dimensions 3.5cm × 6.1cm and thickness 0.62cm were prepared for open ended coaxial probe technique. Also, another five different composites with dimensions 0.228 × 0.114cm and thickness 0.5cm were prepared for rectangular waveguide technique. The HDPE-OPEFB compounding was carried out in a Brabender blending machine and the pellets were made in a mold using hydraulic hot pressed machine. Results shows that for both techniques the permittivity increased with increase in percentage of OPEFB filler contents. Results also shows that the permittivity value is higher at lower frequencies and decreased as the frequency increases. However, the dielectric loss factor for the waveguide show a slight increase with frequency for the 70% and 100% composites which may be attributed to software malfunction.*

***Keywords:*** Oil palm fiber, *High Density Polytechnic, Dielectric Constant, Loss Factor*

## INTRODUCTION

Material scientist, researchers and industries in the past decades have been attracted to natural fibers because of their specific advantages as compared to the conventional or synthetic fibers. It is environmentally friendly, and the issue of environment is top at the national and international agenda. Hence, the natural fibers because of its biodegradable nature unlike synthetic fibers has become center of attraction. This is in addition to low cost and low density. (Mohanty, 2002) and (Singha, 2008).

Polymers eg. Polyethylene has been found to be applicable in many field of research in the world today. They are frequently compounded with natural minerals so as to improve their properties. Glass fiber is used to improve the stiffness and strength of thermoplastic material (Sanadi, 1995). Polymer-fiber composites are mostly cheap to produce because the natural fiber is readily available, also it possess improved mechanical and electrical properties (Ibrahim, 2011). This research work is aim finding out the electrical properties of the composites prepared with different ratio of environmentally friendly high density polyethylene (HDPE) and oil palm empty fruit bunch fiber (OPEFB) from 8GHz to 12GHz (X band) in the microwave frequency band. OPEFB is a solid waste and was chosen for this research so that excess waste will be reduced from the environment. The composite product from this research can be used as a substrate in various microwave applications such as microstrip antenna and transmission lines components which can be found in mobile communication, aerospace and defense industry.

In his work (Boudenneb, 2006), reported that the value of dielectric constant decreased as frequency increases. This means that at higher frequency the value of the dielectric constant is low which may be attributed to space charge polarization and likewise the loss factor.

## THEORY

A dielectric material simply put, is a capacitor and a resistor in parallel. The current passing through any of such sample would have the real and imaginary part. By so doing, the complex permittivity or relative permittivity, $\varepsilon^*$ relates to material's ability to respond to the electric field by its polarization.

Relative permittivity can be defined as the measure of the amount of polarization (Kochetov, 2013). The imaginary part represents the loss factor which is a measure of the losses involved in the polarization processes. Permittivity behavior with respect to frequency is very sensitive to material properties influenced by addition of fillers. Any change of the molecular structure of a dielectric will show up if the related polarization phenomena are occurring in the measured frequency range (Andritsch, 2010). The loss tangent tan (δ) is the ratio of the loss factor to the dielectric constant.

The permittivity of materials is related to a variety of physical phenomena. Ionic conduction, dipolar relaxation, atomic polarization, and electronic polarization which are the main mechanisms that contribute to the permittivity of a dielectric material. Typical behavior of permittivity ($\varepsilon' and\ \varepsilon''$) as a function of frequency are shown in Figure 1. At Low frequency range, imaginary permittivity, $\varepsilon''$ is dominated by the influence of ion conductivity by free ions. In dielectric spectroscopy, measurement of dielectric and electrical properties of materials are as a function of frequency in time domain. Their measurement is based on the interaction of external electric field with the electric dipole moment and charges of the materials. Three important properties are associated with the properties of dielectric. These properties are as follows (Haj. Lakhdar *et al,* 2014); complex permittivity, complex conductivity and complex electric modulus.

$$\left.\begin{matrix} \varepsilon^* & & \varepsilon' - j\varepsilon'' \\ \sigma^* & = & \sigma' + j\sigma'' \\ M^* & & M' + jM'' \end{matrix}\right\}$$

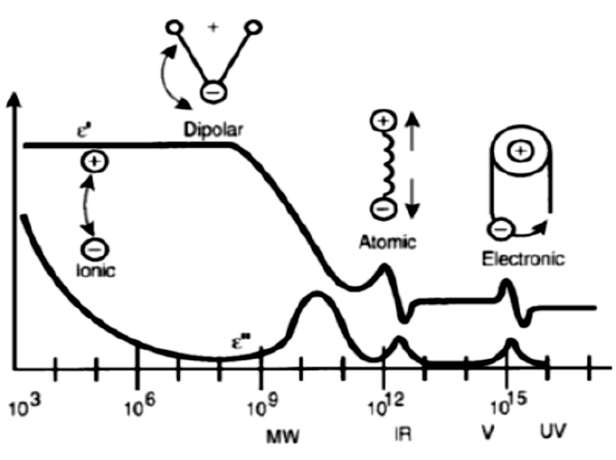

**Fig.1: Frequency dependence of permittivity for a hypothetical dielectric material**

## MATERIALS AND METHODS

### Materials


**(a) (b) (c)**

**Fig. 2: Photos (a) brand of HDPE (b) HDPE (c) OPEFB**

### Methods

The oil palm empty fruit bunch (OPEFB) was soaked in distilled water for 24 hours. Then the mixture was heated at about 100$^{o}$C and removed from the oven. This process was repeated twice. Later, the fiber was filtered and washed with acetone and dried in an oven at 100$^{o}$C to remove the wax layer of the fibers. The long chains of small molecules of the fiber were then grinded and sieved to the size of 200μm for use in the next step. The compounding of OPEFB and HDPE was carried out in a Brabender blending machine at 150$^{o}$C with rotor speed at 50 rpm in 15 min of blending. The substrates were prepared by placing 22g of the blends into a mold with the dimension of 3.5x6.1 cm and thickness of 0.8 cm, and for the smaller pellets 6g of the blend was placed into a mold of dimension 0.228 by 0.114cm and thickness 0.5cm. Using a hydraulic hot press machine, the OPEFB-HDPE composites were preheated for 10 minutes with upper and lower platen temperature at 150$^{0}$C. Breathing time of 8 minutes was allowed to release bubble sand to reduce void. The OPEFB-HDPE composites were then pressed at the same temperature for another 7 minutes at a pressure of 110 k/bar and left to cool at a pressure of around 110 k/bar for 10 minutes.

**Table 1: Composition of raw materials used composite preparation**

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

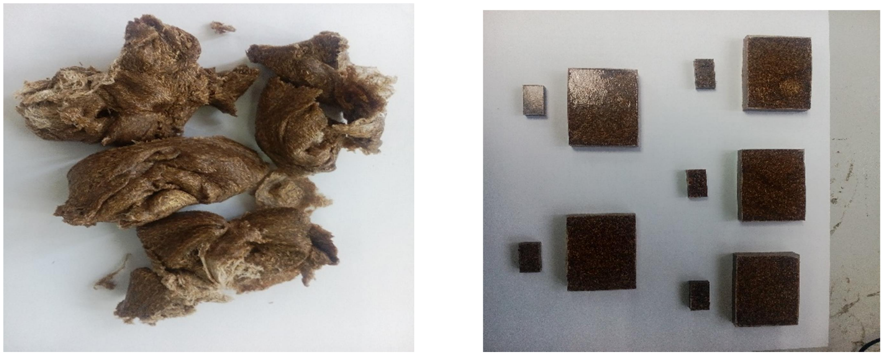

**Fig. 3: HDPE-OPEFB composite and pellets**

## Measurement of dielectric properties

Permittivity measurements were performed using two different techniques. First is using open ended coaxial probe (OEC) technique fig. 4a. Secondly, is using rectangular waveguide (RWG) technique based on the Agilent N5230A PNA-L network analyzer fig. 4b.

(a) (b)

**Fig. 4: (a) OEC (b) network analyzer and waveguide**

## RESULT AND DISCUSSION

### Permittivity result using open-ended coaxial probe (OEC)

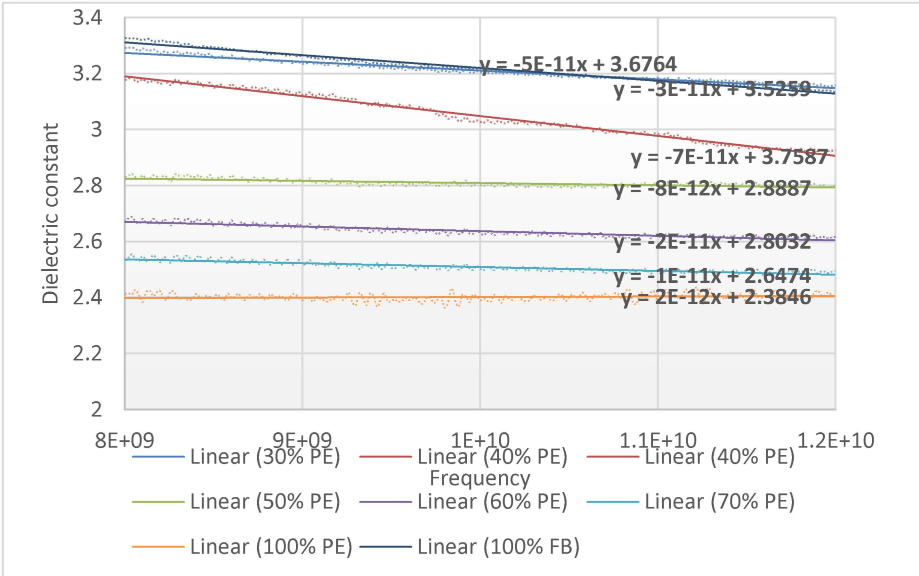


**Fig. 5: Variation of dielectric constant with frequency using OEC**

**Table 2: Trendline equations**

| Samples | Equations |
|---|---|
| 30% PE | y = -3E-11x + 3.5259 |
| 40% PE | y = -7E-11x + 3.7587 |
| 50% PE | y = -8E-12x + 2.8887 |
| 60% PE | y = -2E-11x + 2.8032 |
| 70% PE | y = -1E-11x + 2.6474 |
| 100% PE | y = 2E-12x + 2.3846 |
| 100% FB | y = -5E-11x + 3.6764 |

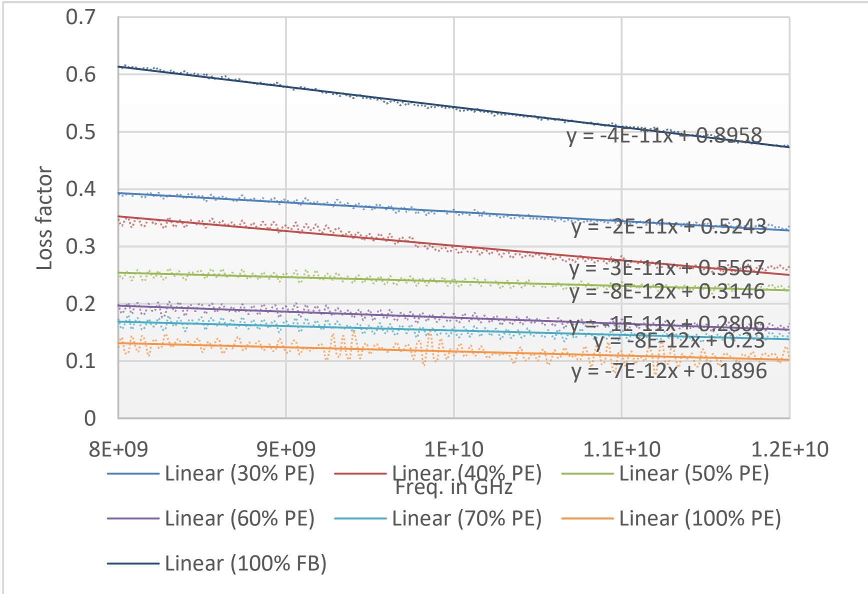


**Fig. 6: Variation of loss factor with frequency using OEC**

**Table 3: Trendline equations**

| Samples | Equations |
|---|---|
| 30% PE | y = -2E-11x + 0.5243 |
| 40% PE | y = -3E-11x + 0.5567 |
| 50% PE | y = -8E-12x + 0.3146 |
| 60% PE | y = -1E-11x + 0.2806 |
| 70% PE | y = -8E-12x + 0.23 |
| 100% PE | y = -7E-12x + 0.1896 |
| 100% FB | y = -4E-11x + 0.8958 |

For this work, the particle size of the OPEFB chosen is combination of 200µm and 300µm which gives a higher permittivity values. Dielectric constant of 3.5667 and loss factor of 0.4683.

It is observed from the result that, the value of dielectric constant is smaller for the composite with lower content of OPEFB. However, the value of the dielectric constant increase as the percentage of the OPEFB increase. The composite with high percentage of OPEFB has the highest value of dielectric constant. This result is in agreement with the findings by (Chen *et al*, 2003).

Effective Medium Theory reported that the permittivity of polymer-based composite can be increase by adding fillers with higher permittivity values.

The result shows that the permittivity decrease with frequency for all samples. At higher frequencies the movement of charge cannot keep up with the alternating field, and the polarisation mechanism ceases to contribute to the polarisation of the dielectric. Hence as the frequency increase the material net polarisation drops since each polarisation mechanism ceases to contribute and this give rise to drops in dielectric constant. This decrease in dielectric constant as filler decreases in a composite as frequency increase is supported by works of (Syeds and Ambika, 2014).

**Table 4: Real and Imaginary parts of permittivity for all samples at 8GHz (OEC)**

| Samples | Dielectric constant | Loss factor | Ɛr= Ɛ'-j*Ɛ" |
|---|---|---|---|
| HDPE | 2.4124 | 0.1226 | 2.4124-j*0.1226 |
| OPEFB | 3.5667 | 0.4683 | 3.5667-j*0.4683 |
| HDPE-OPEFB-30%PE | 3.2907 | 0.3917 | 3.2907-j*0.3917 |
| HDPE-OPEFB-40%PE | 3.1773 | 0.3479 | 3.1773-j*0.3479 |
| HDPE-OPEFB-50%PE | 2.8302 | 0.2553 | 2.8302-j*0.2553 |
| HDPE-OPEFB-60%PE | 2.6704 | 0.1995 | 2.6704-j*0.1995 |
| HDPE-OPEFB-70%PE | 2.5327 | 0.1737 | 2.5327-j*0.1737 |

**Permittivity result using rectangular waveguide technique (RWG)**

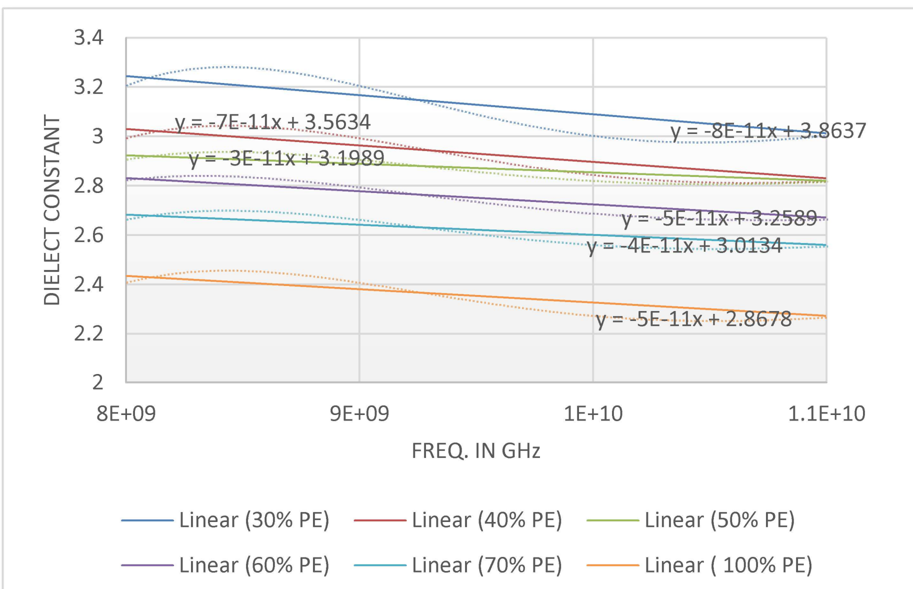


**Fig. 7: Variation of dielectric constant with frequency using RWG**

**Table 5: Trendline equations**

| Samples | Equations |
|---|---|
| 30% PE | y = -8E-11x + 3.8637 |
| 40% PE | y = -7E-11x + 3.5634 |
| 50%PE | y = -3E-11x + 3.1989 |
| 60% PE | y = -5E-11x + 3.2589 |
| 70% PE | y = -4E-11x + 3.0134 |
| 100% PE | y = -5E-11x + 2.8678 |

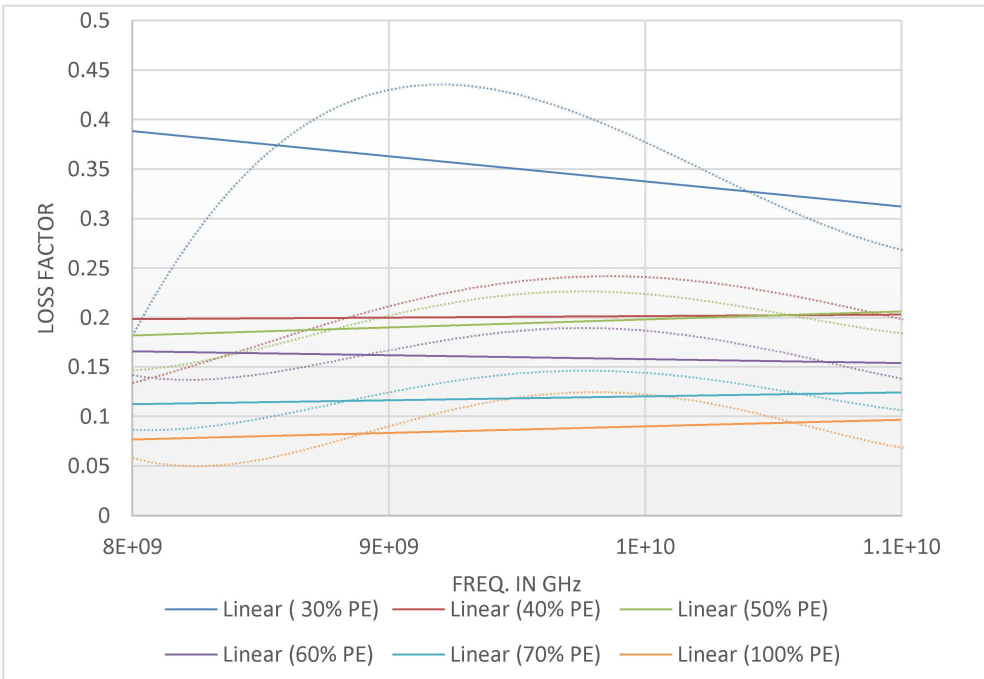


**Fig. 8: Variation of loss factor with frequency using RWG**

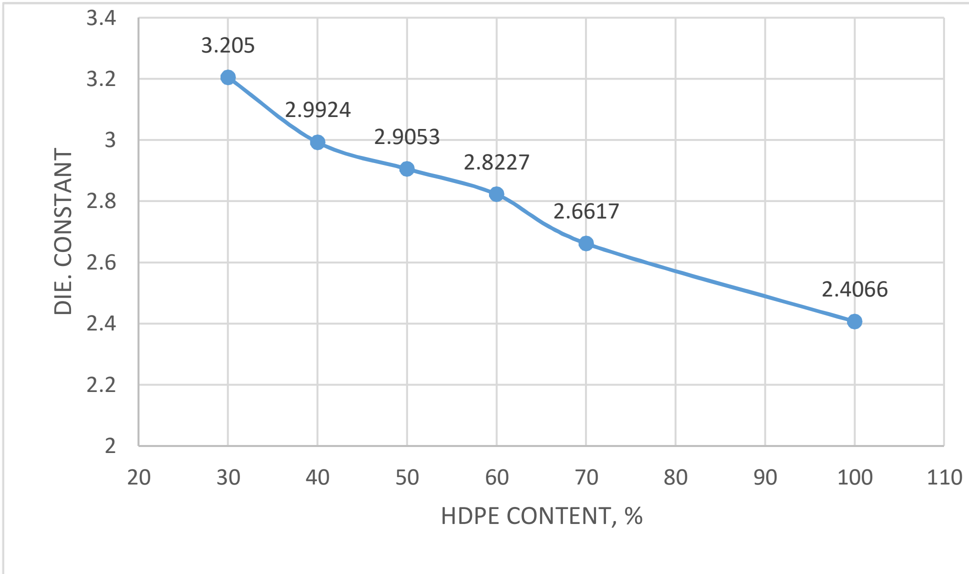


**Fig. 9: Variation of dielectric constant with HDPE % content**

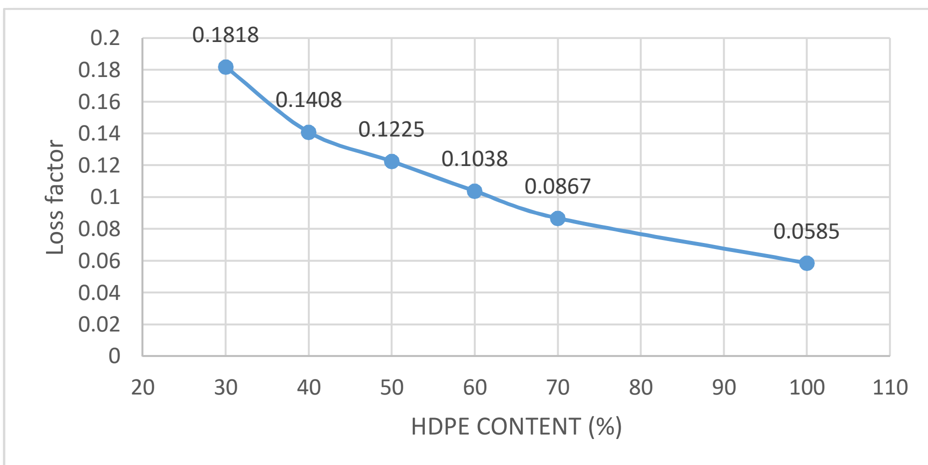


**Fig. 10: Variation of loss factor with HDPE % content**

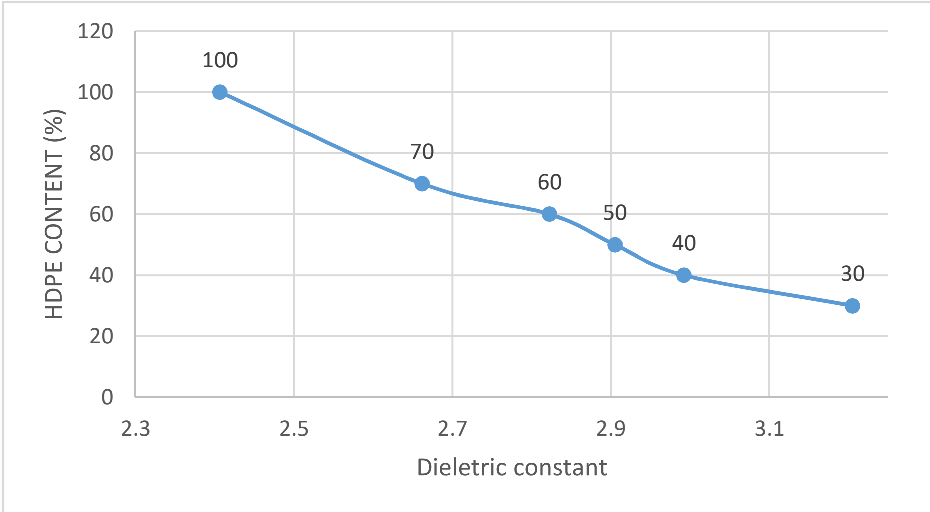


**Fig. 11: Variation of HDPE % content with dielectric constant**

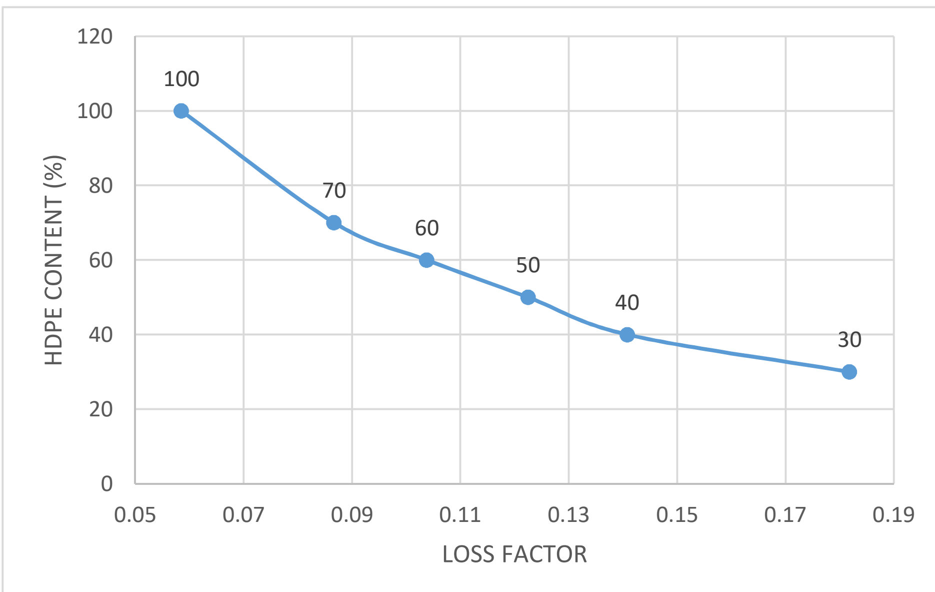


**Fig. 12: Variation of HDPE % content with loss factor**

From figures 5 and 7 it can be seen that the composite with least % of HDPE (30% HDPE and 70% OPEFB) has the highest permittivity value of 3.205 and this trend decrease as the % of HDPE increases. This trend was reported by (Chen *et al*, 2003). This is because increase in effective dipole moment of the composites due to the polar groups in the filler material. (Faiz, 2013) observed the same trend for coconut fibre-polypropylene composites. The dielectric loss also follows the same trend. Further, high dielectric constant is observed at lower frequencies and is due to the heterogeneous conduction in the multiphase of the composites as reported by (Wang, and Chen, 2012).

**Table 6: Real and imaginary parts of permittivity for all samples at 8GHz (RWG)**

| Samples | Dielectric constant | Loss factor | Ɛr=Ɛ'-j*Ɛ" |
|---|---|---|---|
| HDPE | 2.4066 | 0.0585 | 2.4066-j*0.0585 |
| OPEFB | 3.6000 | 0.7171 | 3.6000-j*0.7171 |
| 30% HDPE | 3.2050 | 0.1818 | 3.2050-j*0.1818 |
| 40% HDPE | 2.9924 | 0.1338 | 2.9924-j*0.1338 |
| 50% HDPE | 2.9053 | 0.1465 | 2.9053-j*0.1465 |
| 60% HDPE | 2.8227 | 0.1418 | 2.8227-j*0.1418 |
| 70% HDPE | 2.4066 | 0.0867 | 2.4066-j*0.0867 |

There is a gradual decrease in loss factor of the composites at frequency of 11GHz which may be in agreement with measurement carried out by (Abdullah et al, 2008). This decrease values of dielectric loss at high frequency of 11GHz for the composites suggests that they are lossless materials at microwave frequencies. (Syeda and Ambika, 2014). The dielectric loss arises due to the localized motion of charge carriers.

**Conclusions**

In this article, the dielectric properties of HDPE-OPEFB were investigated at frequency range of 8-12GHz (X-band). The result show that the dielectric constant and the loss factor depends on the fiber content loading. The dielectric properties increased with increased percentage of fiber.

Further, the dielectric constant and loss factor are frequency dependent. At lower frequency the values are high and gradually decrease as frequency increase.

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