Review on Effect of Electric Permittivity and Magnetic Permeability over Microwave Absorbing Materials at Low Frequencies

Sameer Duggal, Gagan Deep Aul

Abstract- ***The dielectric properties of any material is the most important parameters to judge its microwave absorptive properties. This paper reviews the sufficient conditions for absorption of electromagnetic waves by a material by taking electric permittivity and magnetic permeability of materials into consideration. At the end of this paper the electric permittivity and magnetic permeability of different materials having single layer (composite structures) and multilayer structure is compared to see the effect of electric permittivity and magnetic permeability.***

Keywords- ***Real permittivity, imaginary permittivity, real permeability, Imaginary permeability, dielectric losses, impedance matching.***

I.INTRODUCTION

Microwave absorbing materials are extensively used nowadays in various fields, whether in defense as radar absorbing materials for aircrafts or for commercial use as television image interference for high rise buildings [1]. These all applications are because of unique property of absorption of electromagnetic waves by the material. There are number of parameters over which absorption of microwave materials depends upon like impedance matching of absorbing material with free space, specific resistance of the material, frequency response and flexibility of material to get operated over different ranges of frequency, dielectric losses, magnetic losses and so on. In the same manner different materials show different response to above define parameters. There is wide variety of microwave absorbing materials available in present scenario but each material show its optimum absorbing characteristics in certain frequency range and under certain control parameters. Out of all the parameters, there are two most important parameters upon which absorption property of material is dependent. First is dielectric losses and the second one is magnetic losses. The dielectric losses are defined by the electric permeability and magnetic losses are defined by the magnetic permeability which are explained ahead. Microwave absorbers are formed in different shape like conical, spinal, pyramidal etc. and they are fabricated from semiconductors of high resistivity. But these structures have one drawback which is large thickness.

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Because of this drawback, these materials are not used for shielding purpose for moving objects like aircrafts which require smooth surfaces due to which there are absorbers which are formed in the form of paint or spray so that they can be coated over the surface of moving objects.
Thickness is in inverse correlation with magnetic permeability that is more is magnetic permeability; less is the thickness of material. Microwave absorbers are of two types, one with magnetic permeability having value unity i.e. $\mu=1$ .These absorbers are called purely dielectric absorbers and another one with magnetic permeability and electric permittivity different to one [2].
Absorbing materials runs on two primary conditions, first one is impedance matching and another one is maximum attenuation at finite thickness [3]. These two conditions are purely dependent upon electric permittivity and magnetic permeability. By determining the electric permittivity and magnetic permeability, the response of material over different frequency range can be determined easily [4].
Existing Electromagnetic materials are very heavy; less durable show heavy reflection characteristics for certain frequency rage, now to improve these characteristics of Electromagnetic materials composite materials are used. Composite materials exploit one characteristic of material to cover another characteristic. This cause formation of core shell structure with novel physiochemical properties. The formations of composite materials are generally by reinforcing some particles in the base structure of some other particle for example. In case of magnetic nano particles when used as fillers, they effect straightly on the conductivity of the material. As conductivity got affected, it lowers down effective permeability at high frequency because of eddy current losses by electromagnetic waves [6]. But sometimes the thickness of these composite materials becomes so large which cannot be placed over moving objects as it may hamper the speed of them. In case of multilayered structures, two layers of different materials are used which give same effect as composite material of single layer does but it have some more added advantages like reduced thickness are more effective absorption and attenuation.

II.FERRITES AS MICROWAVE ABSORBERS

It has been seen that ferrites have better electromagnetic interference suppression properties. There are numerous electric and magnetic properties exhibited by ferrites and among those properties, the permittivity (ε) and permeability (μ) are most important.

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The permeability and permittivity are further classified into real and imaginary part. The real and imaginary part forming complex permittivity and permeability. These complex permittivity and permeability are very important in determining high frequency characteristics of the material [5].Complex part of electric permittivity corresponds to dielectric losses and complex part on magnetic permeability corresponds to magnetic losses. The magnetic losses of spinal ferrites (ferrites individually used as absorbers) are quite less but these materials do not show high absorbing characteristics in high frequency ranges. So large amount of research is carried on to form composite ferrites so that one limitation is compensated by other. Research in ferrite technology is done to get hold over gyromegnetic resonance characteristics over a certain frequency range. Ferrites (mixture of magnetic ferrite) are used as a material which is applied as a very thin layer and is applied as a past or ink over the surface of aircrafts. Now as explained earlier, magnetic permeability (μ) and electric permittivity (ε) exist in their most complex form as (ε=ε'-jε") and (μ=μ'-jμ") where ε' and μ ' represents real part and ε" and μ" represents imaginary part. One relation to thickness with magnetic permeability μ is saw which is already discussed above that magnetic permeability is in inverse relation with thickness. But this relation also determine the relation of thickness with magnetic permeability that greater is μ, lesser is thickness and greater is absorption as given by this formula thickness = $\lambda / (\varepsilon'' \mu'')^{1/2}$) [2]. The actual significance of ε" and μ" is discussed ahead.

III.EFFECT OF ELECTRIC PERMITTIVITY AND MAGNETIC PERMIABILITY ON ABSORTION

As discussed above, absorption in MA are characterized by (μ) and (ε). (ε) is measure of material effect on the electric field in EM waves and (μ) is measure of material effect on the magnetic component in the EM wave. ε and μ are represented by their real and imaginary counter parts as (ε=ε'-jε") and (μ=μ'-jμ"). ε' is real part of electric permittivity and it varies significantly with the frequency, ε" is the imaginary part of electric permittivity and it represents measure of attenuation of electric field caused by medium. It is also called dielectric heating loss, the EM wave fall over the material got dissipated in the form of heat. Combining these two factors, they for electric loss tangent tanδe which is equal to the ratio of imaginary part to the real part i.e. tanδe =ε"/ε'Greater is the electric loss tangent; greater is the attenuation as wave travel through medium. in case of magnetic permeability, μ' is real part of permeability and it again varies significantly with frequency. μ" is imaginary part and it represents magnetic losses. Together they form magnetic loss tangent tanδm which is given as tanδm=μ"/μ'. Both μ and ε compress wavelength inside material. Loss in either electric or magnetic field attenuate energy in wave.ε is measured in farad/m and of μ in hennery/m.

The complex permittivity and permeability of microwave absorbers play very important part in determining the reflection or attenuation property. To achieve low reflection, there are two methods. Firstly, to make EM waves get attenuated entirely. But this method very difficult to achieve so another method has to choose. Another method is to let EM waves enter into the absorbing material at greater extent. This is achievable when impedance of free space and impedance of material got matched.

The condition for complete impedance matching is μ'/ε' to be equal to 1 i.e. μ'/ε'=1. For most of the magnetic materials, μ' is smaller than ε' at microwave band. Now as by impedance matching, we can let EM waves enter into the material, but then the next step is to attenuate them as much as possible. To satisfy condition of attenuation characteristics, certain requirements must be satisfied for microwave EM parameters. Attenuation constant is given by

$$\alpha \frac{\sqrt{2\pi f}}{c} \left\{ \sqrt{\mu''\varepsilon'' - \mu'\varepsilon'} \left(\sqrt{(\mu''\varepsilon' - \mu'\varepsilon')^2 + (\varepsilon'\mu'' + \varepsilon''\mu')^2} \right) \right\}$$

Equation 1[7]

Now higher will be ε" and μ", greater will be attenuation constant and greater will be attenuation. But higher value of ε" leads to greater dielectric heating, which is not desirable.

So, by combining requirement of impedance matching with attenuation, the magnetic material should have lower values of ε" and higher values of μ" and appropriate values of ε' and μ' for μ'/ε'=1. [7]

IV.COMPARISON OF PERMITTIVITY AND PERMIABILITY OF MICROWAVE ABSORBING MATERIALS

Microwave absorbing materials exist either in single layer structure or multi layer structure.

In single Layer structure, the function of impedance matching and attenuation is performed by single material only. Generally ferrites are used but ferrites are not self-sufficient to perform these two operations. So to do this work, another material is added into ferrites to improve absorption characteristic of the material. These materials are then called composite materials. In composite materials, impedance matching is controlled by one material and attenuation is looked after by another one. There is problem of thickness associated with single layer structures and sometimes it is not possible to fabricate material with another one to compensate the losses of other. So in this case multilayer materials are used. Multilayer materials have been proven to be a very efficient way to cover losses. Following is a comparison of different microwave absorbers based on dielectric losses and impedance matching.

M.N Afsar et Al. [8] have researched that magnetic powders are very useful in electromagnetic shielding interferences in wireless system and use of nano- magnetic particles are found very helpful in fuel cell applications. So, by understanding electromagnetic parameters like permittivity and permeability, certain microwave applications can be concluded. Microwave permittivity and permeability of solid substances have been calculated by numerous researchers and is completely known but when their nano composition is measured precisely, their characteristic comes out to be different from that of solid ones which are represented further by taking materials $Ba_2Co_2Fe_{12}O_{22}$ (99% pure phase hexa ferrites). The average powdered size of these microns was between 3 and 6 micron. The other 6 different nano ferrites (average particle size less than 40 nm) have also been used. To carry out measurement ferrite powder is loaded in 5 calibrated waveguide shims {G (4 to 6 GHz), C (4 to 8 GHz), X (8 to 12.4 GHz), Ku (12.4 to 18 GHz)} and measured with Agilent's 8510C Vector Network Analyzer used to record scattering parameters.

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The result of work over micron sized powdered planar hexaferrite of Co2Y ($Ba_2Co_2Fe_{12}O_{22}$) and powdered nano M-type hexaferrite of Ba_2M ($BaFe_{12}O_{19}$) and SrM ($SrFe_{12}O_{19}$) (shown in Figure 1 and Figure 2) reflects the electric permittivity and magnetic permeability of nano and micron size ferrites over 0 to18 MHz range. In case of Imaginary Permittivity or Dielectric losses, Increase in value of $BaFe_{12}O_{19}$ and $SrFe_{12}O_{19}$ is observed but value for $BaFe_{12}O_{19}$ is much higher than that of $SrFe_{12}O_{19}$ and it increase up to 12 GHz and then it decreased. On the other hand value for $Ba_2Co_2Fe_{12}O_{22}$ decrease up to 12 GHz and then it increase up to 18 GHz. In case of imaginary permeability or magnetic loss, for Ba2Co2Fe12O22 value remains constant up to 9 GHz but from then it start increasing. For SrFe12 O_{19} Value decrease up to 12 GHz and then it start increasing and converse effect seen on BaFe12O19. For Impedance matching from]

Table 1 Impedance matching table (approximate values) [8], it can be observed that value of μ'/ε' for $Ba_2Co_2Fe_{12}O_{22}$ keep on decreasing with increase in frequency. The value for $BaFe_{12}O_{19}$ First decrease up to 12GHz and then it start increasing showing best results on the other hand value for $SrFe_{12}O_{19}$ remains constant throughout.

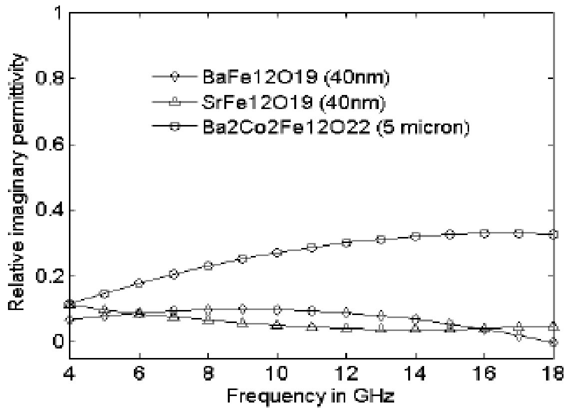

Figure 1 Imaginary permittivity V/S Frequency *[8]*

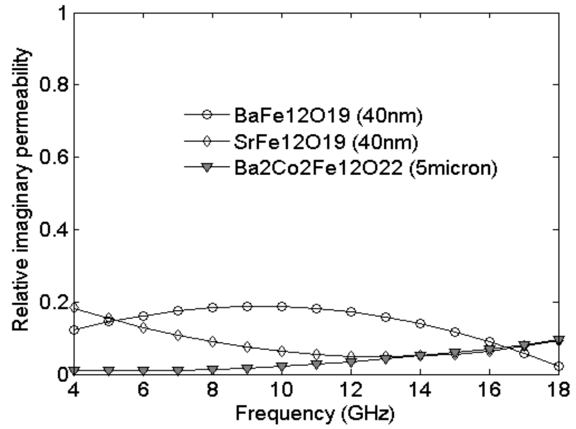

Figure 2 Imaginary permeability V/S. Frequency [8]

Table 1 Impedance matching table (approximate values) [8].

Frequency(GHz)	$Ba_2Co_2Fe_{12}O_{22}$	$BaFe_{12}O_{19}$	$SrFe_{12}O_{19}$
4	0.483	0.75	0.7
8	0.443	072	0.7
12	0.403	.072	0.7
16	0.362	0.863	0.7

Work over nano sized available powdered spinal ferrites $CuFe_2O_4$, $NiFe_2O_3Zn$, $CuFe_2O_3Zn$ and magnetite Fe_3O_4. In case of Measurement of imaginary permittivity Value for Fe_3O_4 is exceptionally high at 4GHz but it drops down to approximately 0.5 from 4 to 18 GHz. While the value of $NiFe_2O_3Zn$ raise a little from 0 in the given frequency range and values of $CuFe_2O_4$ and $CuFe_2O_3Zn$ start from 0.25(approx) to 0 up to 18GHz. In case of Measurement of imaginary permeability, the Decrease in the value for $CuFe_2O_4$ and $CuFe_2O_3Zn$ decrease in the same order but value of former material is still higher than that of later, on the other hand $NiFe_2O_3Zn$ and Fe_3O_4 show same decrease in values but here value for former is higher than that of latter as shown in Figure 3 and Figure 4. From

Table 2 it can be observed that Value of μ'/ε' of $CuFe_2O_3Zn$ and $CuFe_2O_4$ is increasing with increase in frequency and the value of $NiFe_2O_3Zn$ is decreasing but still it shows best result.

The measured data showed that powdered nano spinal ferrites show exceptional properties then other powdered nano ferrites. This may be because of the aggregate properties of magnetite or because of semiconductor properties of magnetite between Fe^{2+} or Fe^{3+}. Other nano ferrites show approximately similar behavior. Microwave permittivity of above materials is similar to that of air which is a remarkable property as for microwave absorption. Microwave permittivity of above materials is similar to that of air which is a remarkable property as for microwave absorption.

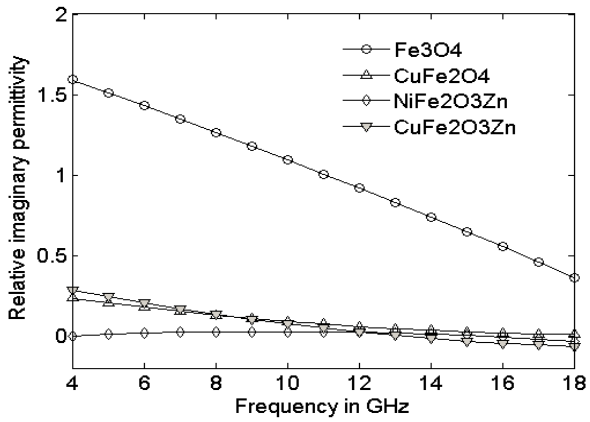

Figure 3 Imaginary permittivity V/S frequency [8]

Table 2 Impedance matching table (approximate values) [8].

Frequency(GHz)	Fe_3O_4	$CuFe_2O_4$	$NiFe_2O_3Zn$	$CuFe_2O_3Zn$
4	0.178	0.66	1.11	.067
8	0.160	0.69	1	.068
12	0.18	0.72	.95	0.72
16	0.20.	0.77	.9.0	.078

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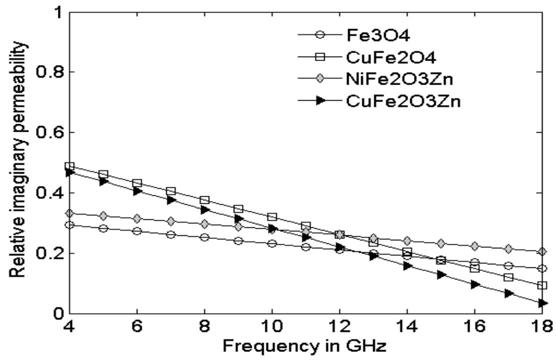

Figure 4 Imaginary permeability Vs frequency [8]

Author has found that ferrite powder is capable to generate more reflectivity and show high magnetic losses and low dielectric losses. Powdered nanohexa ferrites have smaller microwave losses as compared to powdered spinal ferrites and permittivity of spinal nano ferrites are higher than that of hexaferrite. Nano ferrite of magnetite is much different from that of other spinal nano ferrites. It can be concluded that nano magnetite powder can be used for MRI measurement that has very high permittivity as compared to other nano powders, and several other nano ferrites have permittivity and permeability comparable to air causing high impedance matching hence increasing absorption of em waves.

XinweiJi, et Al. [9] have researched that Silicon dioxide particles can be directly added into solvent. The mixing of silicon dioxide can effectively change iron based particle electromagnetic parameters, which can further be used to regulate impedance matching and magnetic losses. By taking material Carbonyl Iron Particles (2 to 5 µm in diameter) and Silicon dioxide (in fumed form). YXE=CIP and 0 wt% fumed silicon dioxide, YXE1=CIP and 2.5 wt% fumed silicon dioxide and YXE2=CIP and 5 wt% fumed silicon dioxide. And using technique SEM, EDS and voter network analyzer. The result was that the real part of permittivity of uncoated CIP decreases with increase in frequency range 4GHz to 18GHz .With increase in silicon content, value of real part of permittivity decrease around 20 to 17. For YXE1, value of real part of permittivity decrease slightly but for YXE2 it remains almost same as shown in Figure 5

For Imaginary part Figure 6, with addition of fumed silicon, permittivity of YXE1 increase at low frequency and then decrease with frequency increasing .The reason for this is scattering of EM waves due to silica particles result in dielectric loss increase at low frequency. For YXE2 imaginary part of permittivity decreases sharply at low frequency and then fluctuates with increasing frequency. With the increasing content of fumed silicon coated CIP, the formation possibility of conducting network decreased, resulting in reducing the conductivity of the mixture, thereby leading to the imaginary part of the dielectric constant decreased. In general, real part of permittivity drop down to average of 3 and imaginary part drop down to average of about 2. The dielectric loss of coated CIP is smaller than that of uncoated, Dielectric loss tangent of YXE1 increase initially an then decrease and fluctuating with frequency increase but for YXE2 it decrease sharply at low frequency and then increase with increasing frequency.

In case of permeability For YXE, YXE 1 and YXE2 the value of real part decrease from 2 GHZ to 7 GHz, as shown in table. But values for YXE1 is lower than that of YXE2 and YXE2 is lesser than YXE as shown in Figure 7

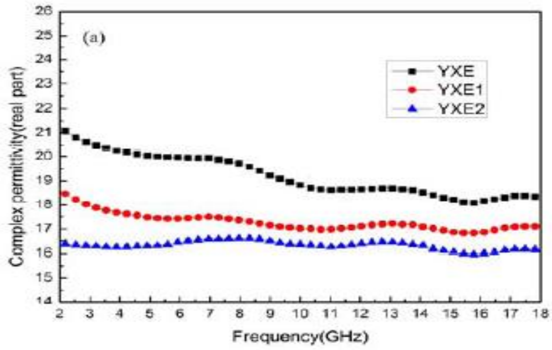

Figure 5Comparison of complex permittivity(real part)[9]

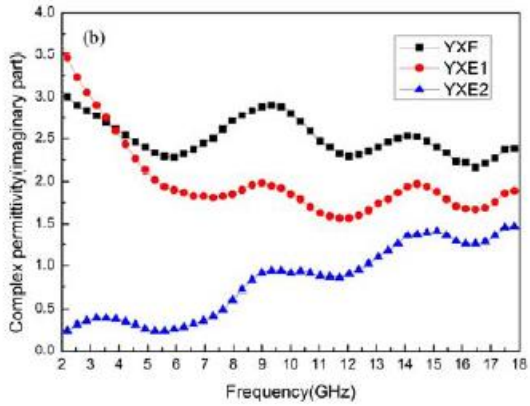

Figure 6 Comparison of complex permittivity (imaginary Part) [9]

This shows that presence of silicon dioxide reduces the value of real part of permeability. For 7 GHz to 12 GHz, value for YXE increase, YXE1 remains same and YXE2 decrease. For 12 GHz to 18 GHz values of YXE, YXE1 and YXE2 reduce. For imaginary part as shown in Figure 8, Value of YXE is higher than that of both YXE1 and YXE2 and sharp decrease is observe in both YXE1 and YXE in frequency range 2GHz to 7GHz. But value for YXE2 remains almost same. For Higher Frequency region (7 to 18 GHz), Value for YXE and YXE1 increase but for YXE2 remains same. It can be observed from data that with increase in silicon content, the effect over imaginary permeability reduces.

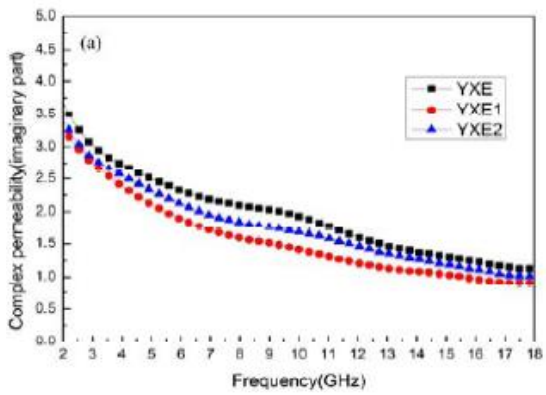

Figure 7 Comparison of complex permeability (real part) [9]

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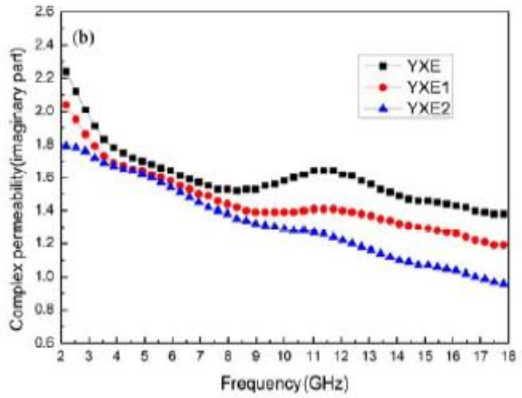

Figure 8 Comparison of complex permeability (imaginary Part) [9]

Author came to conclusion that Modification in the CIP by fumed silicon dioxide improves the electromagnetic parameters. Addition of silicon dioxide adjusts the impedance matching. CIP and silicon dioxide combine form network structure causing more electromagnetic scattering and multiple loss mechanism resulting in greater absorbing ability.

Yuping Duan, et Al. [10] has worked on the complex permittivity, permeability and microwave absorbing properties of rubber composite filled with carbonyl iron over 2-18GHz. Result indicate shift in reflection peak toward low frequency with increase in weight concentration. The result represents good absorbing capability of composites. By using material Carbonyl iron powder (3.4 micrometer) and Elastomer used –silicon rubber (density 0.93 g/cm^{3}). Applying SEM, It is found that Maximum value of permeability found at 2GHz The dispersion effect of real and imaginary part of permeability varies very less in whole frequency range hence thickness is reduced The real and imaginary part of permittivity decrease with increase in frequency as dielectric dipoles polarized in phase with TEM waves. This reflects carbonyl iron as magnetic loss materials. Due to ferromagnetic property of carbonyl iron, when EM waves fall on them, the atoms of particle starts vibrating and by absorbing energy they transit to another level. Therefore carbonyl iron particles have strong ability to absorb EM waves. For single layer electromagnetic absorber, input impedance normalized with impedance of free space is given as

$$Z = \frac{Zin}{Zo} = \sqrt{\frac{\mu r}{\varepsilon r}} \tanh\left(\frac{j2\pi d}{\lambda 0} . \sqrt{\mu r \varepsilon r}\right) \quad \textit{Equation 2 [10]}$$

Where $\lambda 0$ is wavelength and d is thickness.
Reflection coefficient is given as

$$R = 20\log \left|(Z-1)/(Z+1)\right| \quad \textit{Equation 3 [10]}$$

SEM figure show that carbonyl iron powder has huge specific area, so interaction between carbonyl iron particle and incident wave is large and wave is attenuated effectively increasing absorption property of carbonyl iron.

Figure 9 shows the electromagnetic properties of carbonyl iron from which it can be concluded that carbonyl iron powder enhance absorbency of composite and Figure 10 and Figure 11 shows complex permeability and permittivity of carbonyl iron.

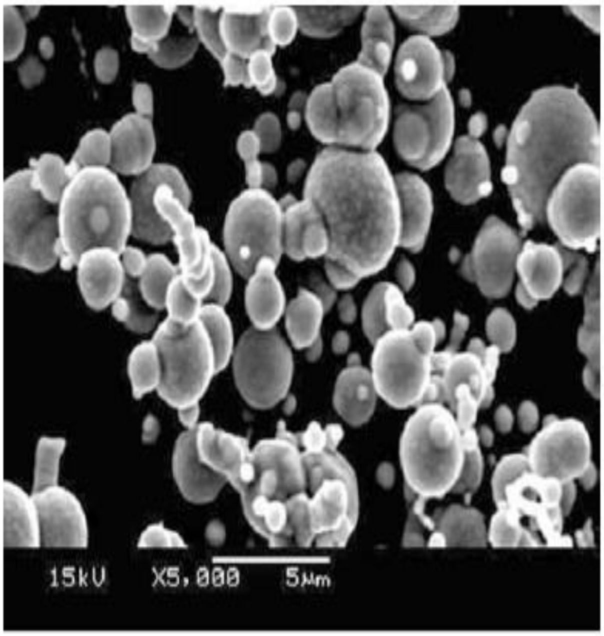

Figure 9 SEM of carbonyl iron powder [10].

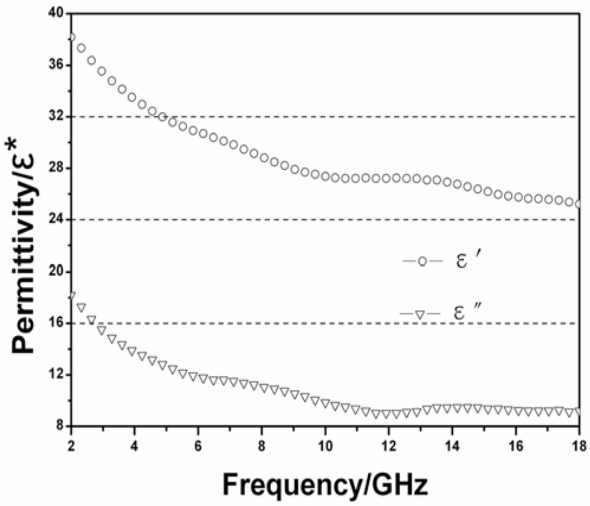

Figure 10 Complex permittivity of carbonyl iron [10].

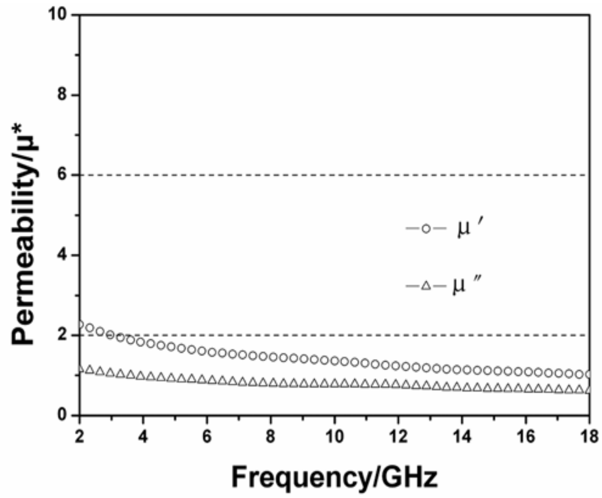

Figure 11 Complex permeability of carbonyl iron [10].

Four samples with carbonyl iron weight fraction 50%wt, 60%wt, 70%wt and 80%wt are taken. With thickness 4mm multiple absorption peaks are monitored at different frequency regions. With increase in carbonyl iron filling ratio, reflectivity increase and absorption peak shift to lower frequency band. Imaginary part and loss tangent of composite also increase so absorbency increase. With 2 mm thickness, only one absorption peak is monitored at high frequency.

Table 3 Values of Dielectric parameters of carbonyl iron (approximate values) [10].

Frequency (GHz)	μ'/ε'	ε''	μ''
2	0.056	18	1
6	0.050	12	1
12	0.046	9	0.9
16	0.042	9	0.9

From Table 3, it can be observed that carbonyl iron show very good characteristics in case of magnetic and dielectric losses but impedance matching decreases with increase in frequency.

So, according to the research of author Effective absorption shows high values at low frequency but with increase in frequency, absorption decreases because of lower values of impedance matching and decrease in magnetic losses.Yougquin Yang et Al. [11] have suggested that Magnetoplumbite ferrite is new type of microwave absorbent which include M type (BaFe12O19) and W type (BaM2Fe16O27). They are having properties like large anisotropy, large coercively and low symmetry of crystal structure. But individually (BaFe12O19) cannot be used because of high thickness and heavy weight so they are combined with some conductive material.

By using material BaFe12O19 combined with NanoG and applying technique Scanning Electron Microscopy (SEM), Energy Dispersive Electroscopy (EDS), X-Ray Diffraction (XRD) and Transmission Electron Microscope (TEM), Lake Shore7307 Vibrating Sample Magnetometer, HP8753D Vector Network Analyzer and Matlab, the results comes out as BaFe12O19 belongs to hexagonal crystal system ferrites and to improve dispersity, layered NanoG is used as a hard template. BaFe12O19 is hard ferrite with high remnant magnetization(Mr=34.80emu/g), high saturation magnetization (Ms=51.00 emu/g) and high coercive forces(H=4001.45) resulting in high absorption, The non Magnetic NanoG composition with BaFe12O19 lead to decrease magnetic properties but conductivity of composite increase and electromagnetic parameters are anticipated to match well.

It has been found experimentally that NanoG has high electric permittivity (ε_r) as shown in Figure 12 and electric tangent losses and low for BaFe12O19. But on the other hand BaFe12O19 has high magnetic permeability (μ) as shown in Figure 12and magnetic tangent losses shown in Figure 13which is low for NanoG as shown in

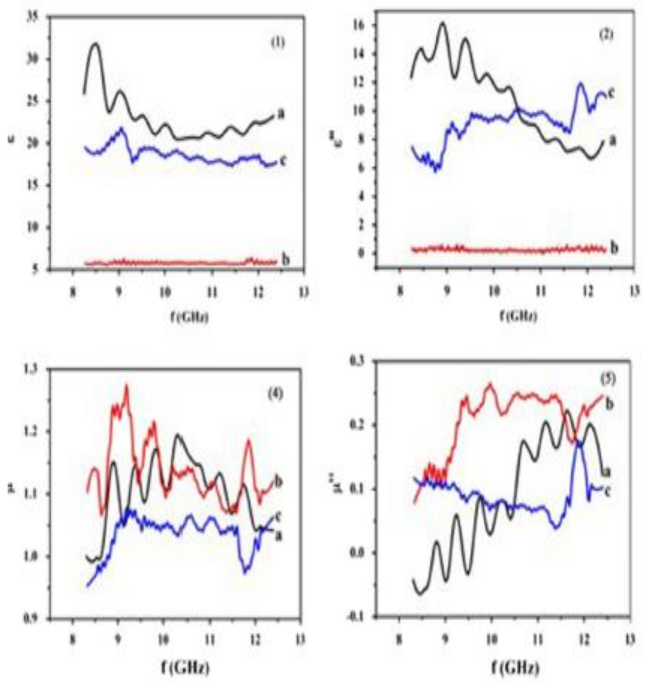

Figure 12 Electric permittivity and magnetic permeability [11].

. After combining BaFe12O19 with NanoG, The magnetic properties of BaFe12O19/NanoG lay midway between BaFe12O19 and that of NanoG. So by chemically coating BaFe12O19 on the NanoG surface, the magnetic losses and dielectric losses can be matched well.

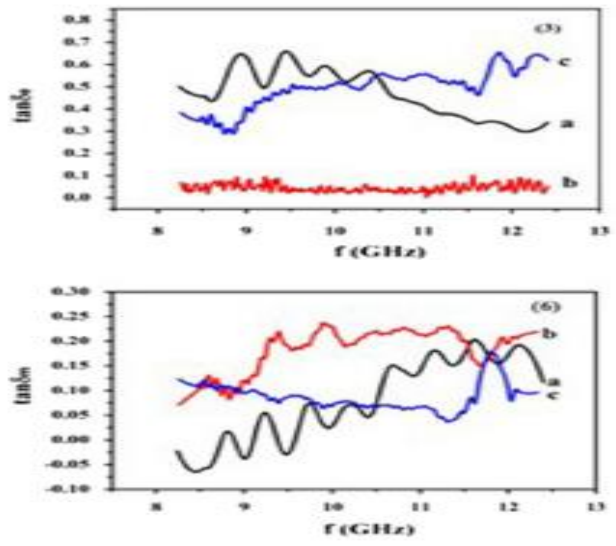

Figure 13 Electric and magnetic loss tangent [11].

SO, author have researched that Fabrication of BaFe12O19 on the Surface of NanoG leads to decrease in conductivity of BaFe12O19/NanoG with increase in BaFe12O19 content while magnetic properties rises causing reflection losses up to 17 dB up to 9.27 GHz, which is still higher than those of traditional ferrites.

Baharudin et Al. [12].Have shown that Agricultural waste can be used as microwave absorbers by keenly observing their dielectric properties.

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It is observed that material density and air-particle permittivity have effect on the wave absorption. Dielectric properties of all pulverized materials are measured and calculated using different techniques to see relation between them. SO, when material Empty fruit bunch (dielectric constant. =3.49), oil palm frond (dielectric constant =4.06) and rise husk (dielectric constant=3.31) used as materials and Coaxial probe technique, material density measurement and dielectric mixture model were applied and EFB, OPF and RH is measured, it is observed that permittivity's of all MUTs are much lesser than calculated.

Table 4 Measured and calculated values of real and imaginary permittivity of EFB and OPH (approximated values) [11]

Frequency (GHz)	EFB				OPF			
	M ε'	C ε'	M ε''	C ε''	M ε'	C ε'	M ε''	C ε''
10	2	4	-0.2	-0.8	2.1	4.9	-0.1	-1
12	1.85	3.2	0.1	0.5	1.9	3.6	0.1	0.5
14	1.9	3.5	0	0.2	2	4	0	0.2
16	2	3.7	0.05	0.4	2	4.2	0	0.5
18	1.8	3	0.1	0.5	1.8	3.4	0.1	0.6
20	1.69	3.5	0.1	0.4	2	4	0.1	0.5

Table 5 measured and calculated values of real and imaginary permittivity of RH (approximate values).

Frequency (GHz)	RH			
	M ε'	C ε'	M ε''	C ε''
10	2.1	3.8	-0.1	-0.5
12	2	3	0.2	0.5
14	2	3.2	0	0.2
16	2	3.5	0.1	0.2
18	1.9	2.9	0.2	0.5
20	2	3.2	0.1	0.4

The values in Table 4 and Table 5 have been approximated from Figure 14, Figure 15 and Figure 16

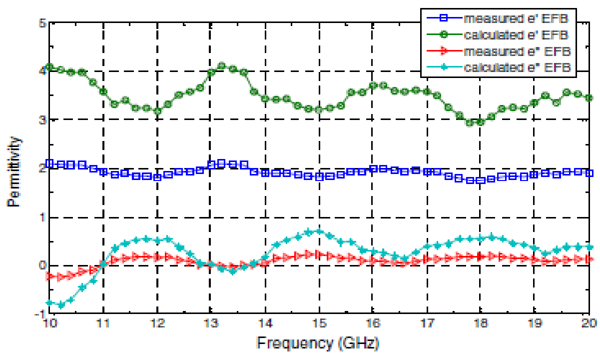

*Figure 14 M*easured and calculated complex permittivity of EFB [12]

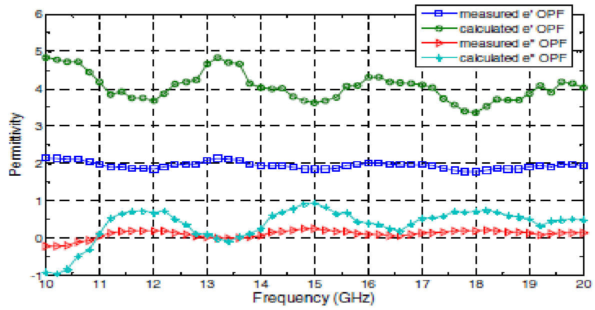

Figure 15 Measured and calculated complex permittivity of OPF [12].

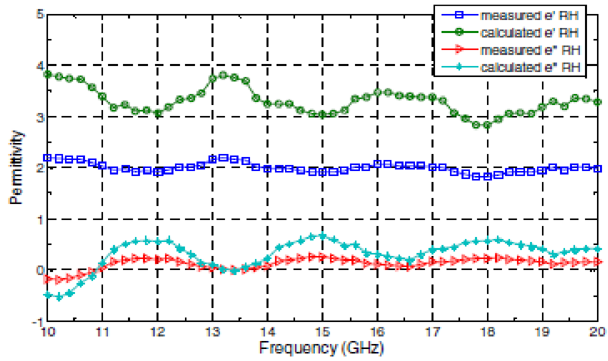

Figure 16 Measured and calculated complex permittivity of RH [12].

Table 6 Calculated loss tangent values of EFB, OPF and RH [12]

Frequency	Loss Tangent, ε''/ε'		
	MUT	*Measured*	*Calculated*
11.8 GHz	EFB	0.0940	0.1672
	OPF	0.1010	0.1928
	RH	0.1150	0.1858
15.0 GHz	EFB	0.1231	0.2201
	OPF	0.1332	0.2579
	RH	0.1366	0.2218
18.2 GHz	EFB	0.1074	0.1930
	OPF	0.1090	0.2112
	RH	0.1247	0.2032

This is for a reason that solid pulverized materials have gap filled with air which drop down values of permittivity. OPF has highest dielectric constant and loss factor because of lowest fractional volume reflecting highest potential in absorbing microwaves. OPF has highest loss tangent calculated because of high imaginary part of permittivity but RH shows highest loss tangent when measured by coaxial probe method. Calculated loss tangent values are shown in Table 6 On measuring EFB, OPF and RH, it is observed that permittivity's of all MUTs are much lesser than calculated. This is for a reason that solid pulverized materials have gap filled with air which drop down values of permittivity. OPF has highest dielectric constant and loss factor because of lowest fractional volume reflecting highest potential in absorbing microwaves. OPF has highest loss tangent calculated because of high imaginary part of permittivity but RH shows highest loss tangent when measured by coaxial probe method.

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The author have researched that the coaxial technique is best suitable to determine dielectric properties of pulverized materials. LLL equation method support for calculation of dielectric properties. Solid material permittivity is extracted from air particle permittivity, which is responsible for material to act as absorber. Among all, oil palm fond is best microwave absorber because of high loss tangent, high loss factor and its fibrous structure

V. CONCLUSION

It has been observed that electric permittivity and magnetic permeability are the most important factors to calculate the microwave absorption of any material. Among all the materials, ferrite has shown remarkable response toward absorption. Along with some regular microwave material, exceptional materials like agricultural waste have also been covered under study and they have also shown very good impedance matching value and magnetic losses, although they were not good as ferrites but they overpower ferrites when cost is to be considered. Almost every material from spinal ferrites to multi-layer structure and pulverized material have tried to maintained the condition for impedance matching as we have already discussed above but every material lags at one point or other. For example Carbonyl iron powder shows exceptionally good magnetic losses from 0-10GHz range on the other hand MnFe2O3Zn allow almost every part of EM wave to absorb near 8GHz range while SrFe2O19 was remain unaffected at whole frequency range (0 – 18 GHz) and Fe3O4 has shown weakest impedance matching but highest magnetic losses. There is still more research needed to be done in order to find a material with perfect dielectric characteristics and super microwave absorbing power.

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