Attenuation of Electromagnetic Waves Using Nano Composites

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ABSTRACT

Through all the prepared samples, it was found that they have a varying ability to attenuate microwaves within the (X) band (X-band) and at different ranges of frequency. Regarding the electrical properties, it is noted that there is a similarity in the behavior of the dielectric constant with the capacitance of the capacitance and for all the samples that were prepared, which indicates the similarity between the electrical conduction and polarization in ferrite materials

Keywords: Attenuation, Electromagnetic Waves, Nano composites

Introduction

Radar Absorbing Materials are composite materials that have the ability to absorb the energy of electromagnetic fields passing through them and thus reduce the waves reflected from the target. M) is one or more of the divalent ions such as (Ni, Mn, Cu, Cobalt, Co, Cd, Zn) [1]. This topic is considered one of the current important topics in materials science due to the resulting common properties of insulation and conductivity and their entry into important technology applications [2]

The radio-absorbing materials (RAM) have a high efficiency in the technique of infiltration or disguise, especially in the military fields. The conditions of these materials are to be as light as possible, as well as to withstand harsh weather conditions and high stresses imposed on them, and their resistance to scratching and shocks, and they cannot be easily eaten [3] and this is what it aims at We searche.

Composite materials, which can be defined as a combination of two or more different materials, in specific volume or weight ratios, and on a macroscopic basis, to form a new and useful homogeneous material whose characteristics differ from those of its components [4]. Among these features and characteristics that can be improved through the production and formation of a new composite material, we mention (durability - light weight - corrosion resistance - external design and shape - sound insulation - thermal insulation - electrical insulation) [5]. Compound materials are usually affected by the properties of the materials included in their composition, which include the base material (Matrix) and the reinforcing phase (Reinforcing), as the base material usually represents the continuous phase in the composite material, as the cohesion of the elements and reinforcement materials and linking the parts together to form a coherent synthesis system that can produce performance Good new [6].

As for the reinforcing materials, they are used to strengthen the base material. These materials may be ceramic, metallic or polymeric, and they are different things, they may be in the form of powders, fibers, or peels [6] [2]

1-2 Types of composite material

The overlapping materials can be classified according to the type of the base material (Matrix) and others according to the reinforcing

material (Reinforcement Material), as shown below:

1-2-1 Types of overlapping materials according to the type of the base material (Matrix)

.The crystalline fibers and filaments are usually of little use when they are collected to take the form of a construction material that can withstand high and low loads. The bonding material is usually called the base material (Matrix), and the purpose of the base material is to strengthen and protect the materials from weather conditions and stress distribution. Among other materials ... etc. [7], and the description of these materials can be represented as in

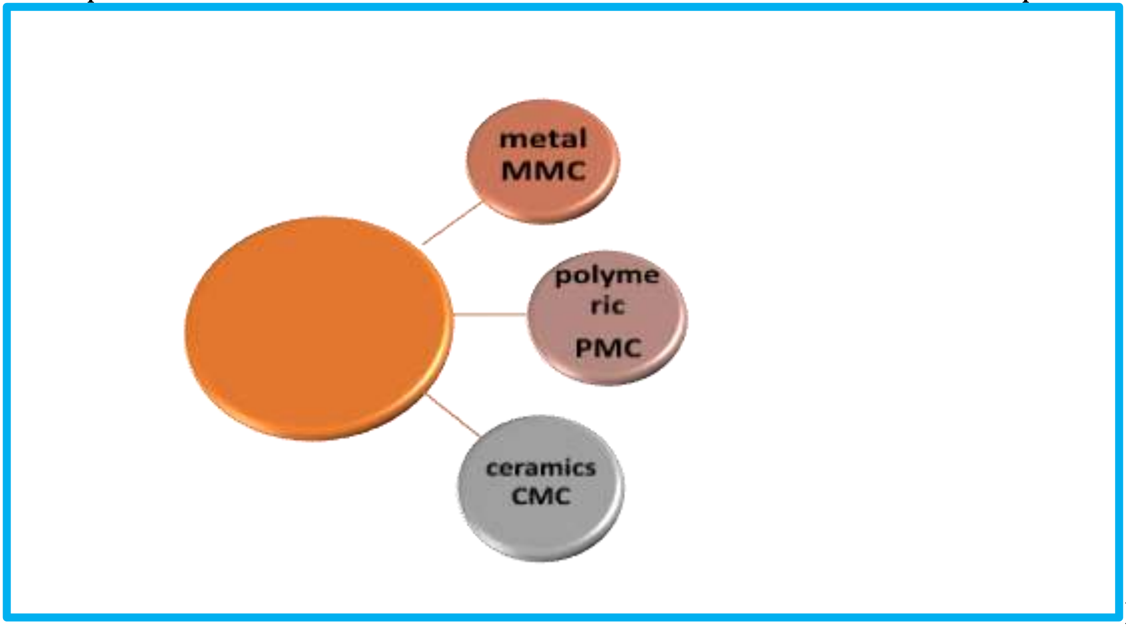


Figure (1-1

Figure (1-1) Classification of Compound Materials

Reinforcement Material 2-2-1

Many materials with which the base material is strengthened for the purpose of forming a composite material with developed and improved properties, one of the most important features of the reinforcement materials are (metallic, ceramic or plastic materials) due to their high strength [11].

The overlapping materials can be divided according to the type of the reinforcing material into several sections and according to the form of the[9]reinforcement used and according to the scheme.

In our work, we dealt with the use of a new, important and easy-to-prepare technology method for composite materials (ceramic + metal + polymer) represented by ferrite Fe_2O_3, Zn, MCNT and UPE in different proportions, and that the most important physical and structural properties of these powders are as follows:

1 Ferrites

It is an important class of magnetic oxides of semiconductor nature and has great technological importance thanks to its interesting properties. Ferrite materials are usually ferrimagnetic ceramic compounds derived from iron oxides such as hematite (Fe_2O_3) or magnetite (Fe_3O_4), as well as other metal oxides in fixed proportions according to their types [12].] [13] [14], ferrite has been used for many centuries past due to its high importance, and like most ceramics, it is brittle and hard, it was used in the early twelfth century in the manufacture of compasses and through it the scientific use of ferrite was studied by studying the structural, electrical and magnetic properties in 1930 Since then, many researchers have studied ferrites on a large scale [15]

Ferrites can be classified into three types based on their crystal structure, which are [16][15]:

.Garnet.1

.Hard Ferrite.2

.Soft ferrite.3

2 Zinc

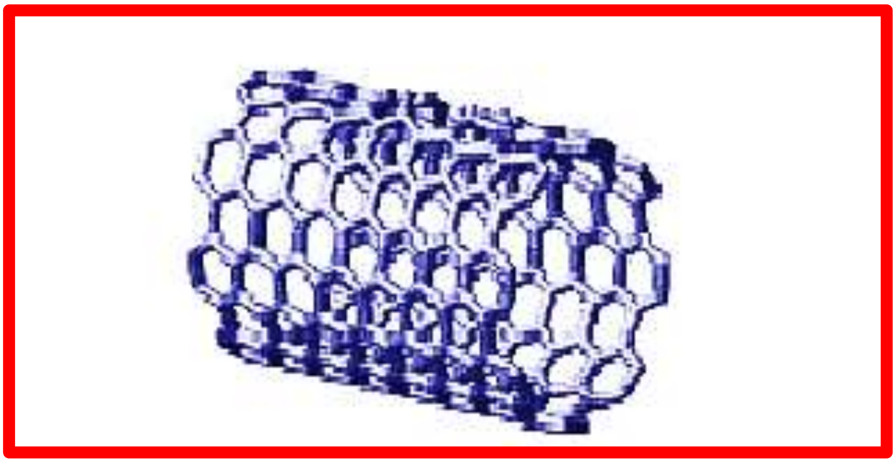
Zinc is one of the important minerals in the composition and engineering design, and it is a bluish-white metal that is brittle at the boiling temperature of water, and it is one of the twenty-four most abundant elements in the earth's crust. China and India at the end of the fourteenth century .Zinc is characterized by being hard, not malleable, ductile at normal temperatures, rust-resistant,

and electrically conductiveIt

chemical symbol is (Zn), its atomic number (30), its atomic mass (65.39 $gm.mol^{-1}$), and its structural structure (sixth crystal system), and zinc is a diamagnetic element [17]. Zinc is used a lot in the manufacture of alloys used in the processes of welding and coating and the manufacture of coins for its good resistance to corrosion. It is also used in the manufacture of ship hulls and industries for chemical and food sections as cans and sheets because it is a non-toxic substance [18]

3. Multi Carbon Nanotubes (MCNT)

The (MCNT) can be defined as empty cylinders in the form of nanometer-sized tubes and consisting of a huge group of hexagonal structures that in turn consist of carbon atoms [19], and carbon nanotubes are a physical phenomenon that was first observed in 1991 at the NEC Company in Japan by the scientist Sumio ligima, as it was examined under an electron microscope and it was found that the carbon position is abnormal, as shown in the figure below[20].



•Figure (1-2) shows the shape of MCNT under the microscope SEM

- Carbon nanotubes have the following properties: [21]

  It is so strong that it is 100 times stronger than iron and 6 times lighter in weight
- A very good conductor of electricity.
- It can be semi-conductor, and this depends on the method of its manufacture and on the arrangement of the atoms within the atomic structure.
- It has good thermal conductivity, higher than that of diamond

Carbon molecules can be prepared for the purpose of incorporating it into the CNT in several ways, namely: [22][21]

1) Conducting electrolysis using graphite electrodes in molten salts.
2) Catalytic thermal analysis of hydrocarbons.
3) Fumigation of graphite using a laser.

The (MCNT) has several applications in important fields, such as the manufacture of automobile fuel tanks, tennis and golf rackets, and the coating of military materials that are not detected by radar, as it is considered an absorbent material for radar waves. Binaries and keys [21][23].

Carbon nanotubes have many uses as mentioned above, but one of the most important of these uses and applications is its use in the medical field, as it is considered a revolution in the world of medicine, such as its use in imaging living membranes such as blood vessels and the stomach, and it is also used in the treatment of dead or infected cells such as cancer cells by injecting it The human body as a protein conductor [24].

4 Epoxy or epoxy resin

is a chemical substance that is one of the types of thermoplastic solids[25][26][27] It has two components: a base (resin) and a hardener (hardener), which is highly adhesive and resistant to friction and chemicals, whether acids, bases or solvents, as an insulating layer is formed when dry. Use as a coating, mortar or adhesive. The most common type of epoxy resin produced by the reaction between the chemicals epchlorohydrin and bisphenol A.

The first attempt to produce it from this substance was in 1927 in the United States through the Swiss company Ciba for chemical production.

Epoxy resin belongs to the group of thermosetting resins, as these resins are not able to be reformed by heat after turning into a solid material due to the formation of long polymeric chains intertwined with each other, which is called crosslinking. Epoxy resin contains two or more epoxide groups consisting of one oxygen atom bonded with two carbon atoms and the epoxy group chemically bonded with other molecules to form a three-dimensional crosslinked network in the curing process. Epoxy resin is characterized by relatively high hardness and chemical resistance. In addition, this resin has a high specific adhesion due to the chemical composition of this resin, which is represented by the ethers, hydroxyl groups and polar groups that give durability and high adhesion and give the material hardness and strength, so it is used in applications that require high functional performance. These resins react with hardeners during curing and the reaction is not accompanied by the emission of water or the release of any by-products, which makes the volume shrinkage very small (less than 2%) and thus the resin acquires strength and high mechanical properties. Synaptic linkage and the presence of integrated elevian chains.

1-3 Previous Studies

Many previous research and studies dealt with the processes of attenuation of electromagnetic waves in several ways, such as changing the preparation methods or materials or even changing the granular size of the materials used.

In 1993 (Johnson eta) and others invented microwave absorbing materials consisting of thermoplastic polymer materials, adhesive and insulating such as polyamides, polypropylene and epoxy, so that these materials used have the property of not being able to be re-dissolved for re-forming after manufacture. These materials are loaded with magnetic materials including ferric oxide or ferric oxide adsorbing cobalt, iron, nickel or cobalt and their alloys. These materials or oxides are in the form of metallic filaments or needles, with average lengths of 10 micron or less and diameters of 0.1 micron, where the ratio of length to diameter is from (10: 1) to (50: 1). The researchers state that for this material to absorb well, the thickness must be 2.5% of the wavelength. In the frequency region (2-20GHz), for example, the minimum thicknessIt is (0.375 mm), and the material is thicker; As the researchers note; It gave absorptionHowever, the increase in thickness is accompanied by an increase in weight and limited in the possibility of practical application,Therefore, the researchers considered that the ideal thickness of such materials is about (2 mm) or less, although the upper limit of the thickness in the microwave area, as they mentioned, reaches (37.5 mm) [28]

The scientist also attended (Kharabe eta.) in the year (2006) ferrites with the formula $Li_{0.5}Ni_{0.75-x/2}Cd_{x/2}Fe_2O_4$ with a value (x=0, 0.1, 0.3, 0.5, 0.7 & 0.9), which was intended to study some of its properties. The X-ray diffraction examination of all the prepared models showed that they are single-phase. Then he used those models to study the nature of the change of saturation magnetization Ms with the amount of cadmium in the sample. He also studied the dielectric constant and the electrical loss remained in the frequency range (100 Hz - 1 MHz) and at room temperature, and he noticed a decrease in ( ) values with an increase in the amount of Cadmium in ferrite, which is accompanied by increased conductivity [29].

In the year 2012, the scientist (P.Bhattachrya eta.) presented an intensive study on microwave absorption within the X-band and it was in two steps, the first is by preparing titanium oxide and ferrites (Fe_2O_3 TiO_2) and adding carbon nanotubes (CNT) and the method of preparing SOL-GEL, and the second step They added polyurethane to the compound in the preparation and treated it thermally, and after several tests, including XRD, SEM, TEM, EM, the results showed an excellent absorption property for the compound ($TiO_2Fe_2O_3$/CNT) and the maximum reflection loss was (8.4-10.99 dB) and at frequencies (12.4-15.6 GHz).), where the incorporation of CNT) enhanced the thermal stability and absorption of the prepared compound [30]

In the year 2017, the researcher (S.Tyagi, eta.) studied the radar radiation absorption of the nanocomposite materials $BaFe_{12}O_{19}$ / $ZnFe_2O_4$ and by the method of preparing SOL-GEL), where the medium was developed by adding carbon nanotubes (CNT) because of its additional characteristic to enhance the And the radio wave absorption was improved by adding 20% to the compound and it was found that the maximum reflection reaches (43.22 dB) at the frequency (10.30 GHz) and the minimum is (10 dB) at the frequency (2.95 GHz) [31]

In the year 2019, the researcher (MSMustaffa) and others presented a paper on the study of the absorption and magnetic properties of the compound (CNT / $NiZnFe_2O_4$), where the compound was prepared by plumbing method and then thermally treated (sintering) at a temperature of (1200 C∘) and then added MWCNT to the compound by chemical precipitation method (CVD) , then annealed with epoxy .The results showed that the reflectance is at (-19.34 Db) at a frequency (8.46 GHz) and with a thickness of (3 mm) for the sample [32].

As for the year 2020, the scientist (L.T.Quynh) and others presented a paper on the study of the absorption and reflection of electromagnetic waves of the superparamagnetic compound ($ZnNiFe_2O_4$) as a nanocomposite and the addition of black carbon within the frequency range (8-12GHz). Where the samples were prepared as a solid coating with epoxy on pre-prepared steel bases, the samples containing carbon black 20% and epoxy 80% appeared to have a weak absorption capacity estimated at (67%), while the samples containing the nanocomposite had a high absorption capacity estimated at (99%) within the frequency (10GHz) and with a coating thickness of (2mm) [33].

2-2 Calculation of theoretical and scientific density

Table (1-4) and Figure (1-4) show that there is a small difference in the density values between the practical and the theoretical, and this small difference may be due to my manufacturing of the prepared samples. The results of the practical density show an increase in their values with an increase in the percentage of the powder added to the polymer, and the fact that the density of the powder is four times greater than the density of the polymer led as a result to an increase in the density of polymeric nanocomposites compared to the base material (EP polymer). The high level of the powder within the polymer matrix, which led to closing the pores and gaps that are always formed when forming and pouring samples.

Table (1-4): shows the theoretical and practical density.

Theor.Density	Exper.Density	Sample
1.12	1.1	0% $ZnFe_2O_3$/MWCNT
1.15	1.14	1% $ZnFe_2O_3$/MWCNT
1.2	1.19	2% $ZnFe_2O_3$/MWCNT
1.25	1.23	3% $ZnFe_2O_3$/MWCNT
1.29	1.27	4% $ZnFe_2O_3$/MWCNT

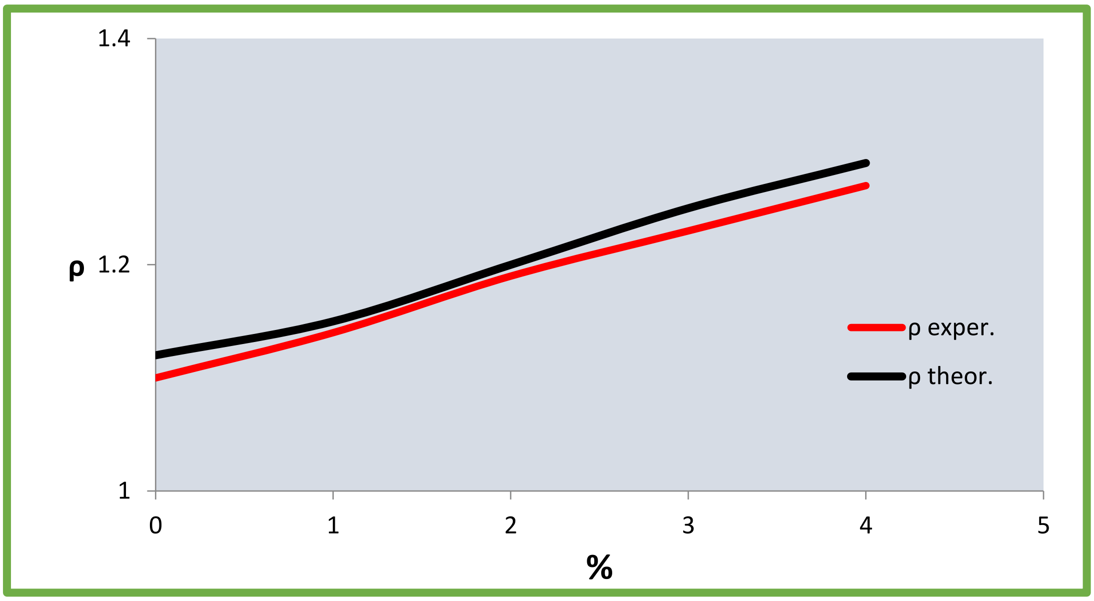


Figure (4-1): Diagram showing the theoretical and practical density with the percentage of the substance

Results of a device check (VNA)

The reflectance, transmittance and reflection coefficient as well as the impedance of microwave waves within the (X) beam were measured for the prepared samples.

Reflection Loss

When an electromagnetic beam falls or shines on the surface of a sample that has an electrical conductivity, inductive currents will be generated by the transport electrons, which in turn return secondary electromagnetic radiation that overlaps each other, forming a reflected wave, and a portion of this energy absorbed by the transport electrons will be given to the crystal lattice ions.

The induced currents generate magnetic fields that oppose the magnetic field causing them (the incident radiation), that is, they block the external magnetic field (the incident) and this leads to the decay of the penetrating wave inside the surface of the sample, that is, it reduces or limits the penetration of the incident wave into the prepared sample.

The loss in reflection energy versus frequency can be calculated using the following

formula :[100]

) 4-1 ($R\,(dB) = 20 \,Log\, |(Zin-1)/(Zin+1)|$

Whereas:

Zin represents the internal impedance at the absorbing surface (sample) / air, and the internal impedance can be expressed by the following equation:

$$Z_{in} = \sqrt{\mu_r/\varepsilon_r}\ \tanh\left[\left(\frac{2\pi}{c}\sqrt{\varepsilon_r \mu_r}\right) f.d\right] \quad (4\text{-}2)$$

Whereas

C: the speed of light in a vacuum. r μ: magnetic permeability.

d: thickness of the prepared sample. ϵr: electrical permittivity.

f: the frequency of the microwave signal.

Figure(4-17) shows the amount of reflection energy loss within the band (X - Band), where it is noted that the largest amount of reflection energy loss was (-22.82 Db) and at the frequency (11.52 GHz) for the sample (3). There is a wide band of loss in reflection energy for all the prepared samples and its amount ranges between (-14dB / -19dB) within the frequency range (10.35GHz / 9.5GHz) as shown in Figure (4-17).

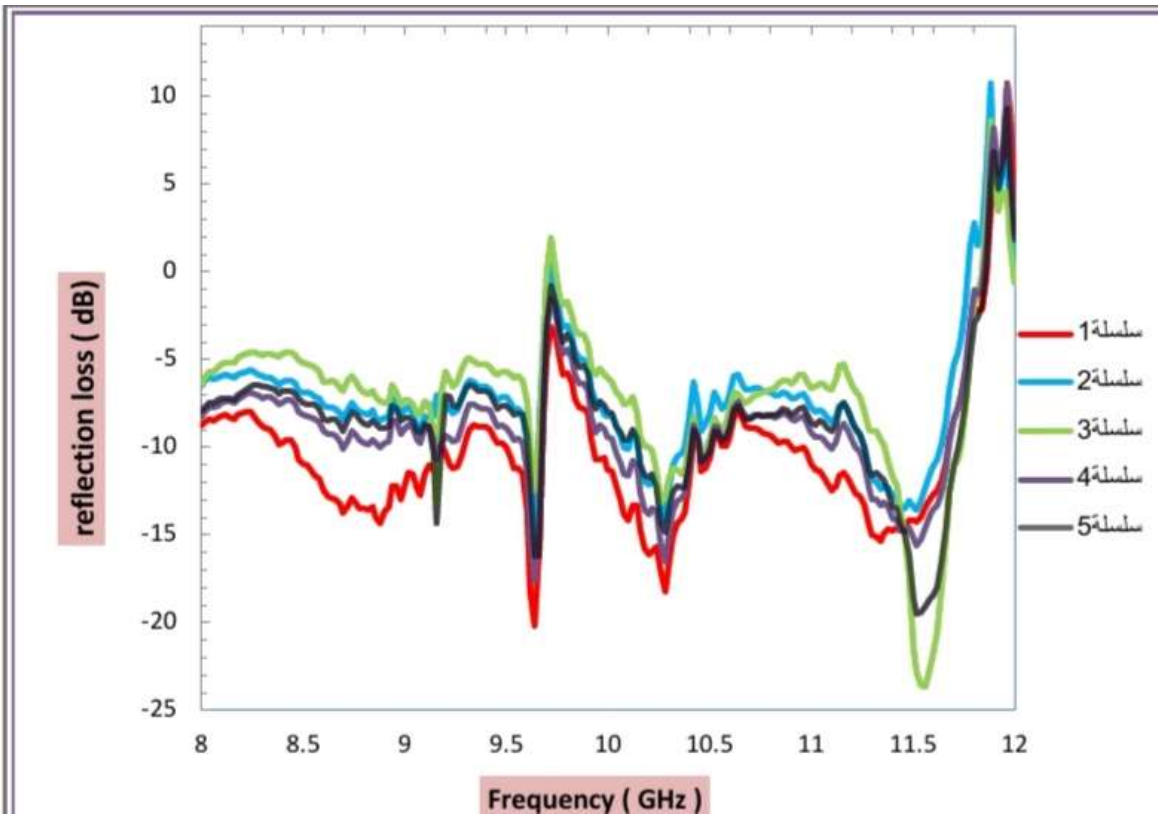


Figure (4-2): The loss in reflection energy as a function of frequency.

Reflection Coefficient

The reflection coefficient (Γ) was determined for the prepared samples as a function of frequency, which can be calculated through the following relationship [15

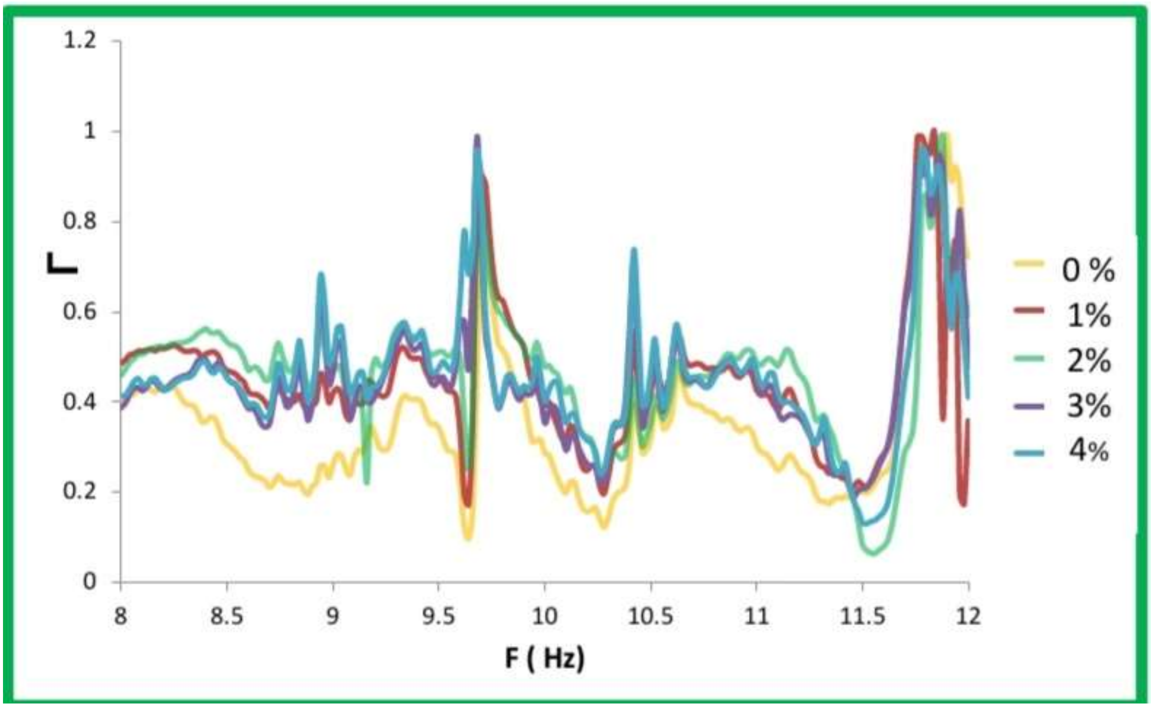
$$\Gamma = \frac{Z - Z^{\circ}}{Z + Z^{\circ}} \quad (4\text{-}3)$$

Where: Zo: the vacuum impedance and Z: the sample impedance.

Figure(4-18) shows the change of the reflection coefficient with frequency and shows the lowest reflectivity of the sample (S3) amounting to (0.084) at the frequency (11.54 GHz) and the lowest reflectivity of the sample (S1) which reached (0.1) at the frequency (9.62 GHz).

Figure (4-3): The reflection coefficient as a function of frequency.

Permeability



In general, the transmittance is the value of the extent of the possibility of rushing electromagnetic radiation through a medium, where the transmittance of the prepared samples was determined based on the scattering coefficients (S-parameters) obtained from the (VNA) device, and Figure (4-19) shows the change of transmittance As a function of frequency within the band (X - Band)

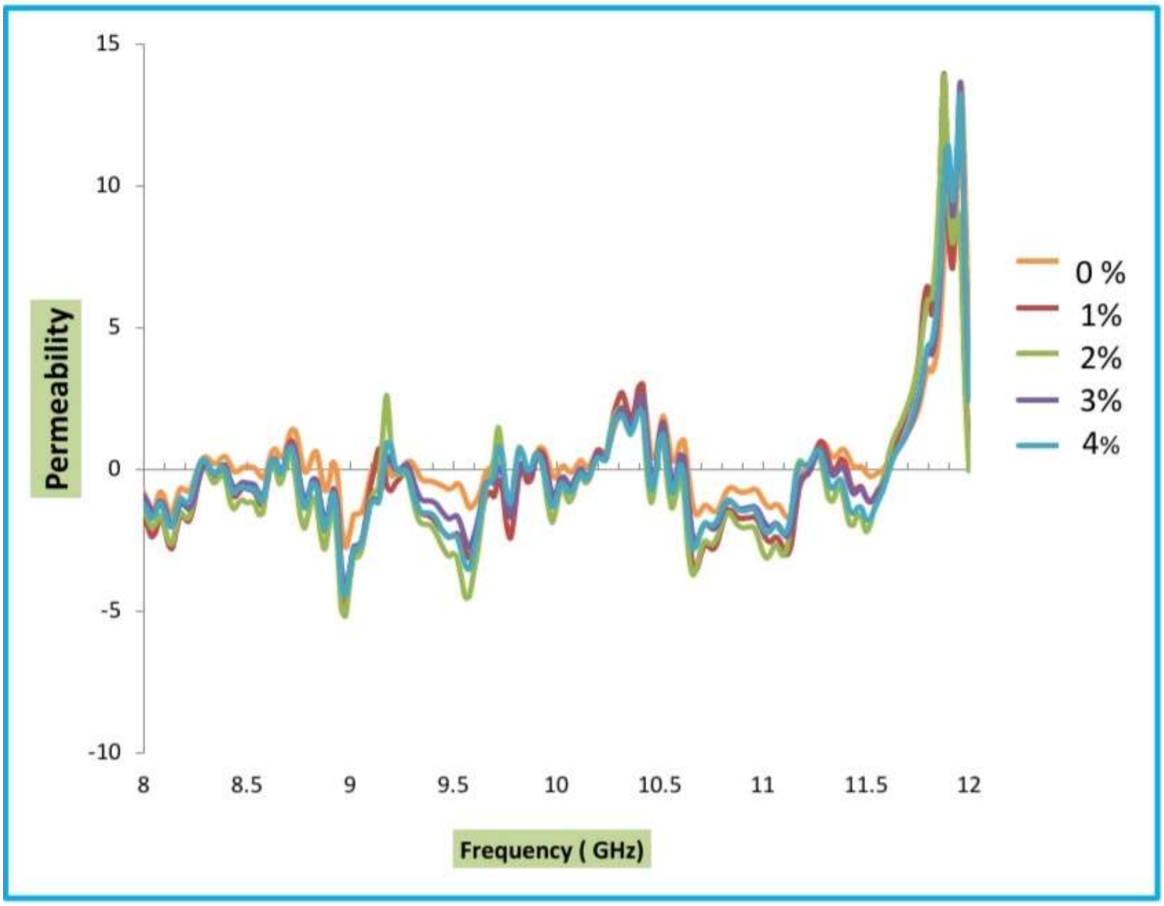


Figure (4-4): The change of transmittance as a function of frequenc

Absorbency

Absorption is one of the important topics in our study in this research and it was obtained based on the scattering coefficients in the (VNA) device according to the following equation [130]:

R2 + A2 + T2 = 1 (4- 4)

Whereas:

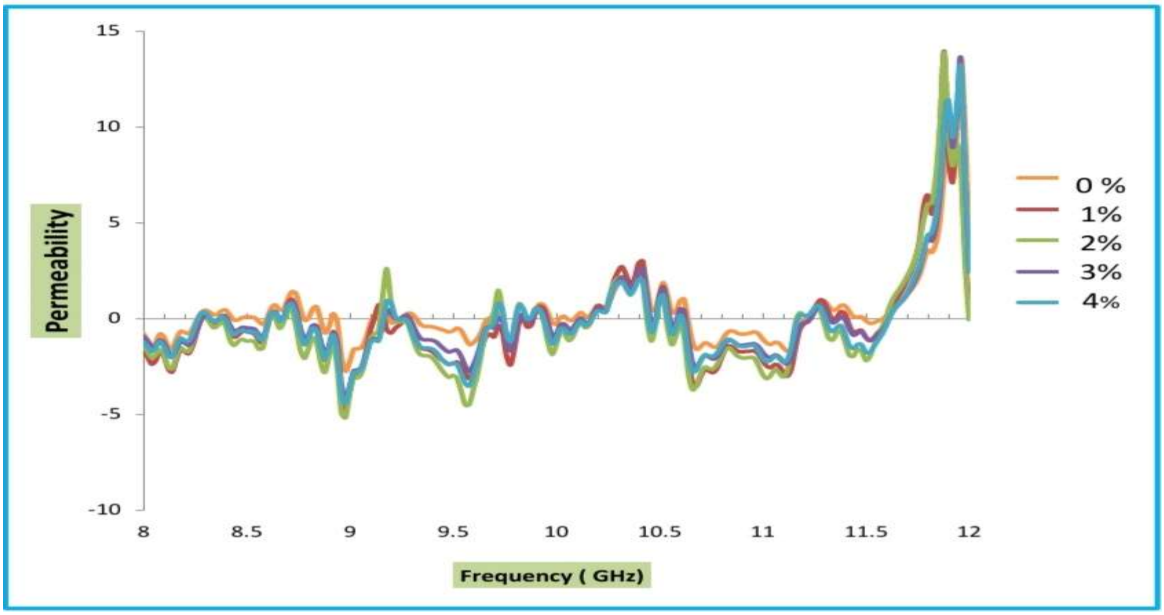
R: Reflectivity. A: absorbency T: permeability

. Figure (4-20), which shows the extent of the absorbance of all the prepared samples, where it is noted that the greater the percentage of MCNT ZnFe2O3 in the sample, the greater the material's absorption of electromagnetic waves**.**

Figure (4-5): Absorbance as a function of frequency

Impedances

The graphics and information about the impedance and its real and imaginary parts, which were as a



function of frequency, were included within the (X-Band) package to confirm the validity and accuracy of the information on reflectivity, transmittance and absorbance, as shown in Figure (4-4).

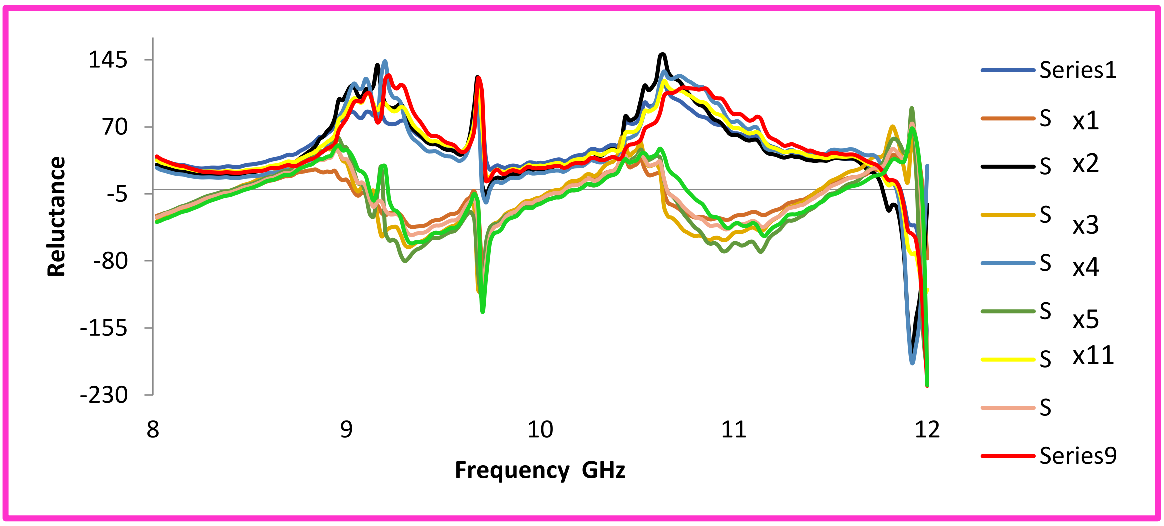
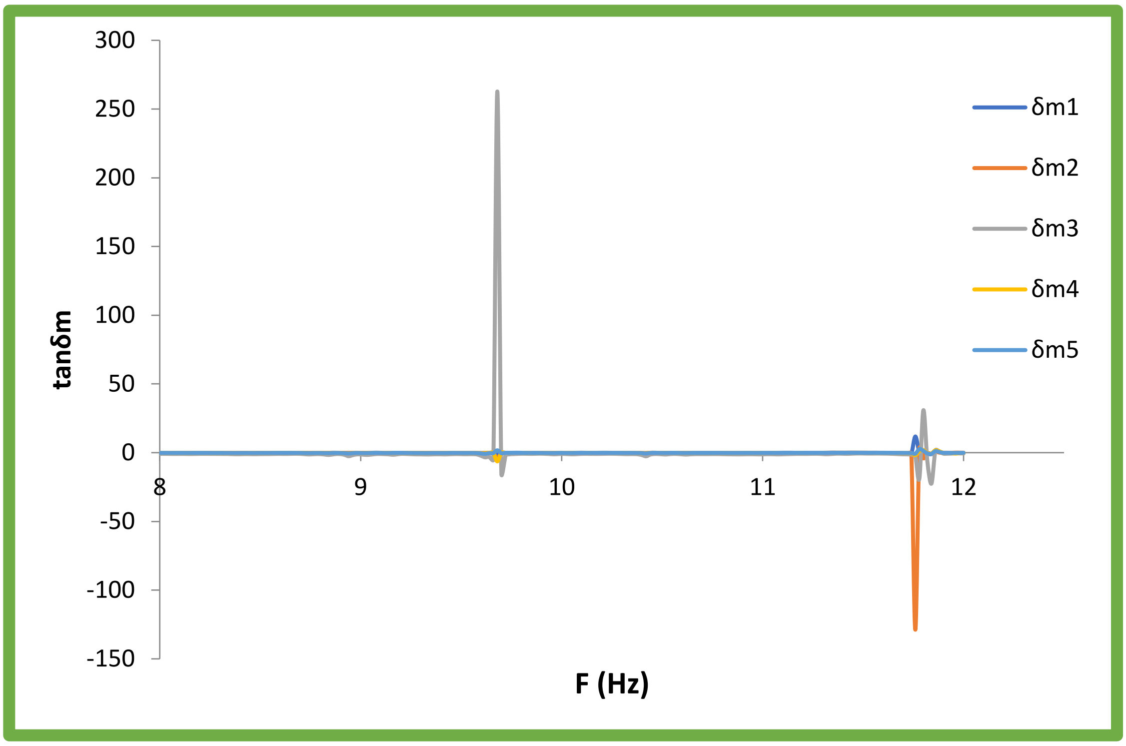


Figure (4-6): Impedance in its real and imaginary parts as a function of frequency.

Magnetic Loss Tangent

The magnetic loss angle was determined as a function of frequency within the beam (X) for all samples and according to equation (2-39) and as shown in Figure (4-7) which shows the magnetic loss angle.

Figure (4-7) shows that all the samples that were prepared have a small magnetic loss angle, except for some losses at some specific frequencies, which indicates that they have small magnetic losses



Figure(4-7): The angle of magnetic loss as a function of frequency

Electric Loss tangent

Through equation (2-58), the angle of electrical loss was calculated as a function of frequency within the range (8-12 GHz), as shown in Figure(4-8).

It is noticed from Figure(4-23) that all the samples that were prepared have a very small loss angle (insulation losses) for all ratios, with the exception of some high losses at specific frequencies or periods, and this indicates that the prepared samples have small insulation losses in general**.**

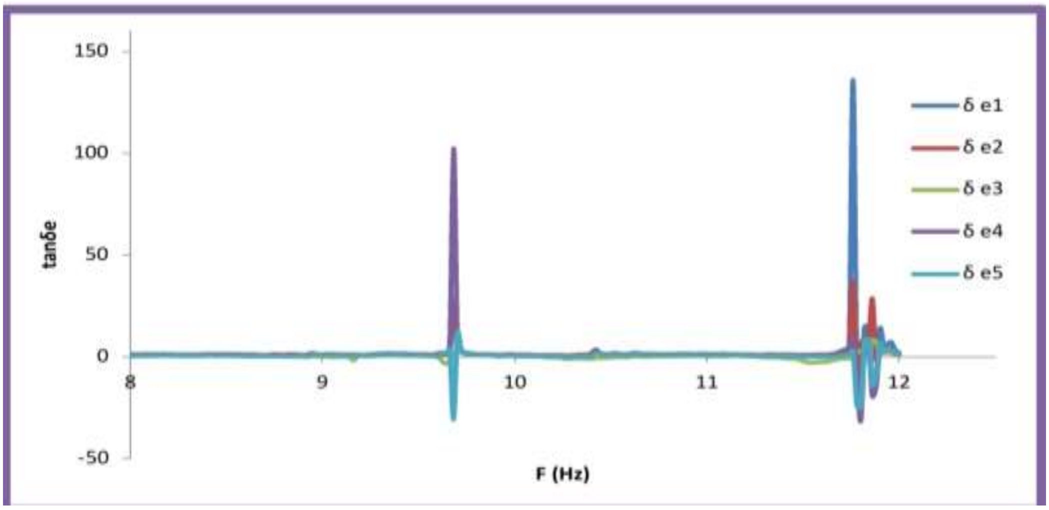


Figure (4-8): The angle of electrical loss as a function of frequencies

Electrical Properties

The alternating electrical properties change with the frequency of the electric field within the frequency range (50 Hz - 5 MHz) was studied for all samples prepared using (LCR meter), and through it the dielectric properties of the real dielectric constant (ϵ1) and the imaginary dielectric constant (ϵ2) were studied, in addition to conductivity (σ), capacitance, and loss factor.

Real dielectric constant . (ϵ1)

The real dielectric constant was determined using the relationship (2 - 55) and as shown in Figure (4 - 9), where a decrease in the values of the dielectric constant is observed with an increase in the angular frequency for all ratios of the samples, and the reason for this decrease is the ferrite element, which is characterized by this behavior, which was agreed upon by the researchers [100]. This is due to the inability of dipoles and charges to change the direction of their movement and to adjust the rapid change in the direction of the effective electric field, which results in a decrease in electric polarization, which causes a decrease in the dielectric constant.

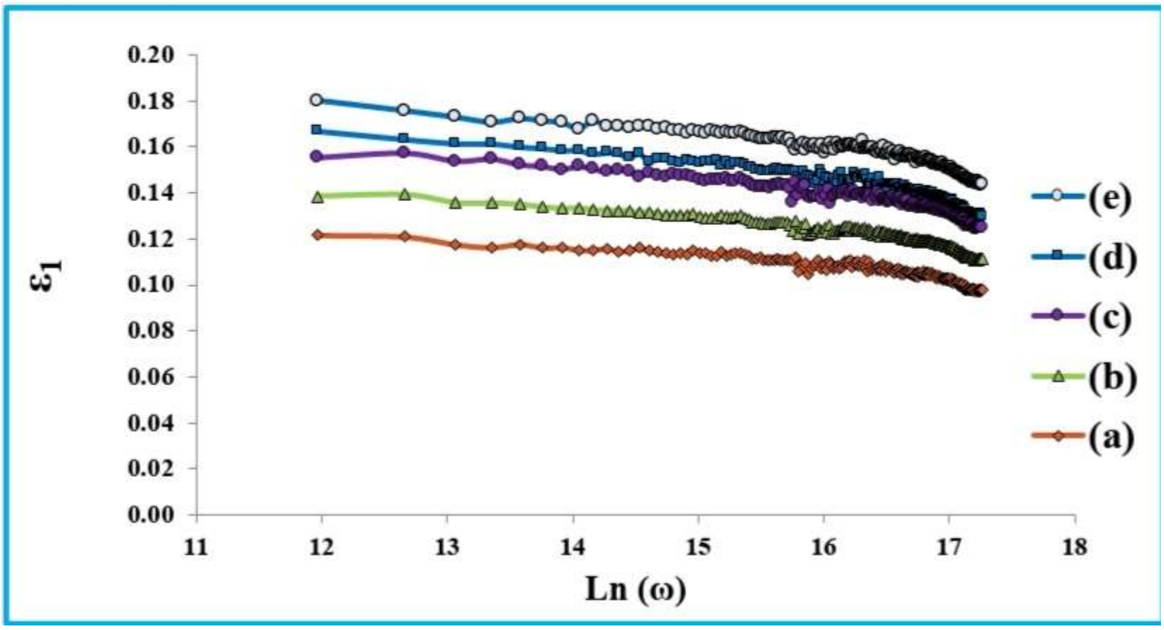
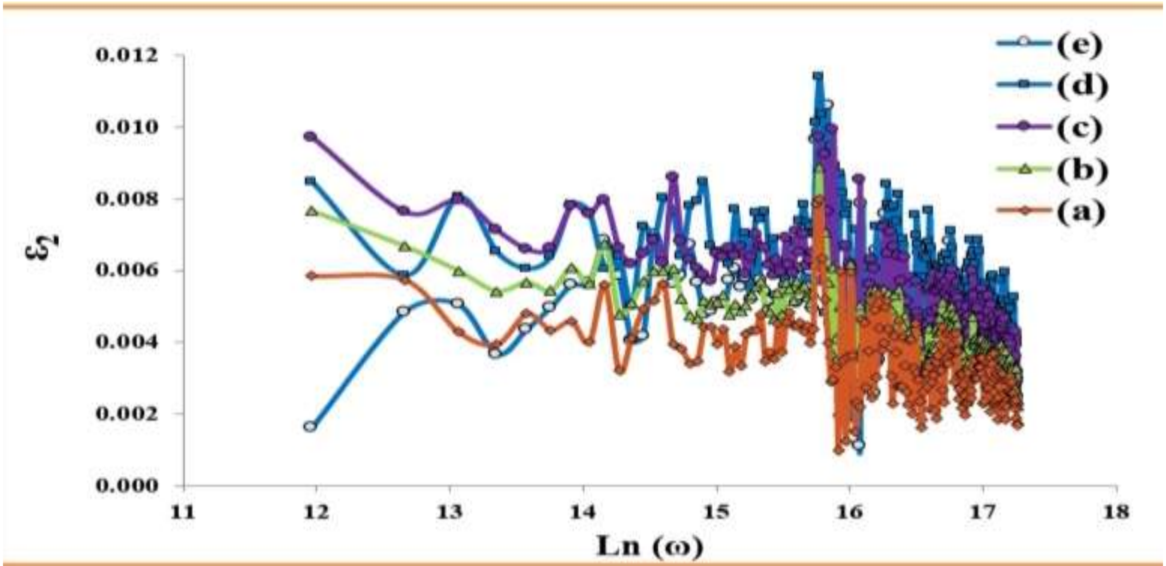


Figure (4-9) an increase in the real dielectric constant with an increase in the ratio of (ZnFe2O3), as the (Zn) increases the real dielectric constant.

2Imaginary dielectric constant (ε2)

It is also known as the electrical loss coefficient, and it has an important cognitive value and a great benefit in many applications, where the energy dissipated in the insulator is directly proportional to



it. The imaginary dielectric constant can be calculated using the relationship (2-58), as Figure (4-10) shows.

Figure (4-10): The change of the imaginary dielectric constant as a function with the angular frequency

Conductivity

The conductivity value was obtained through the relationship (2-63) and by deducing from Figure(4-10), where it is noted that there is a slight difference in the conductivity of the prepared materials as they are nanomaterials. A lot in explaining the behavior of conductivity (σ) versus frequency [100]. When the frequency is low, the granular boundaries behave actively and electrons are transferred between ions (Fe+2, Fe+3) located in octahedral sites [99]. This transition is slow at low frequencies, which makes the conductivity low as well, and when the frequency increases towards high frequencies, the electrons will jump between the ferrous and ferric ions and thus the conductivity will increase. From Figure (4-11) it is also noticed that the conductivity increases with the addition of the zinc ion and increases with its increase. Thus, the zinc ion enhances the transmission of electrons. Also, all the prepared samples have an increase in the electronic mobility at high frequencies and the reason for this is due to the granular boundaries, which are more active

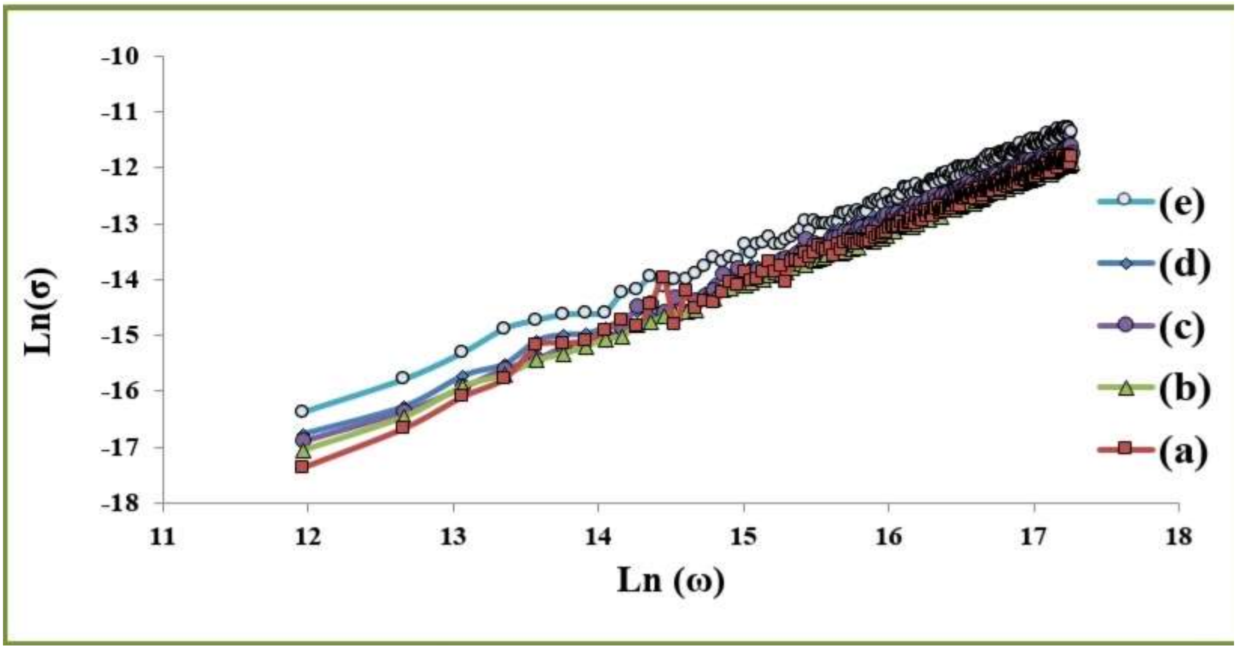


Figure (4-11): The change of the imaginary dielectric constant as a function with the angular frequency

Vast Capacitor

Through Figure (4-12), which shows the results of the examination of the prepared nanocomposite, which represents the capacitance as a function of frequencies, the capacitance of the diode increases with the increase of the reinforced material (ZnFe2O3 - MWCNT), where the capacitance of the diffuse showed a high increase and a significant improvement through the increases and abundance of the charge carriers represented by zinc (Zn) and iron oxide in addition to carbon nanoparticles. As all the supported models are semiconductor materials when compared with the base material (EP), so the increase in capacitance results from the movement and transfer of positive and negative charges.

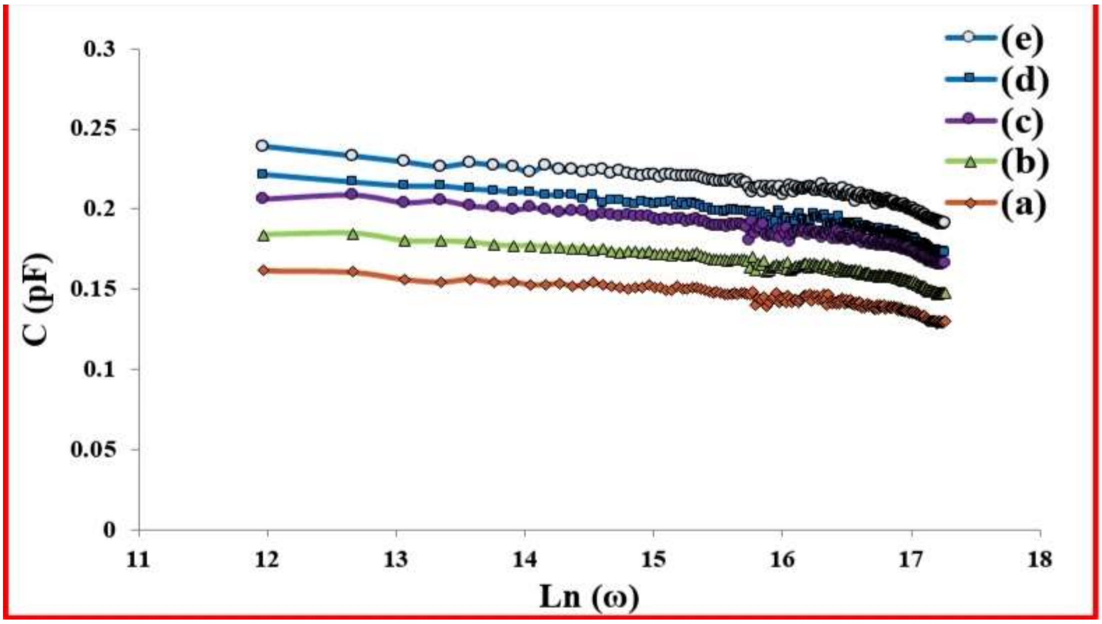


Figure (4-12): The amplitude of the amplitude changes as a function with the angular frequency

Exponent facto

Figure (4-13) represents the loss factor as a function of the percentage of nanocomposites, and it is noticed in the figure a sharp decline at the percentage (4%) and the percentage (3%), while at the percentage (0%) the loss factor starts and continues to rise to the value (1%) and 2% (respectively of the fortified material (ZnFe2O3 MCNT). This indicates that increasing the percentage to more than (3%) leads to a decrease in the loss factor resulting from eddy currents.

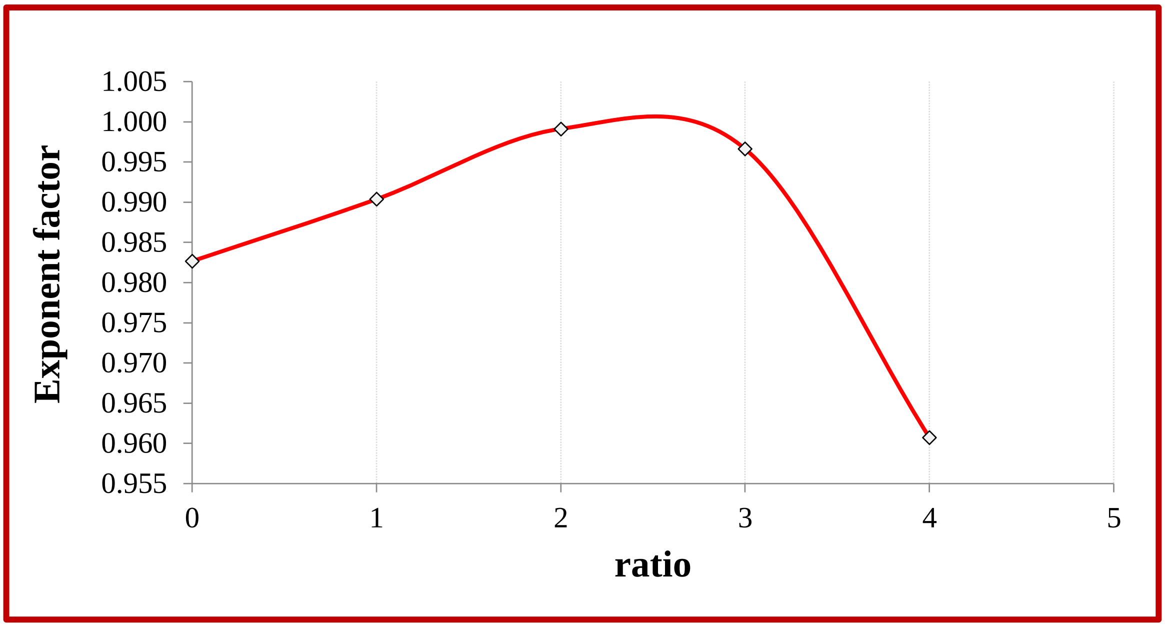


Figure (4-13) represents the loss factor as a function of the percentage of nanocomposites

2-3 Conclusions

.1-Through all the prepared samples, it was found that they have a varying ability to attenuate microwaves within the (X) band (X-band) and at different ranges of frequency.

.2-Regarding the electrical properties, it is noted that there is a similarity in the behavior of the dielectric constant with the capacitance of the capacitance and for all the samples that were prepared, which indicates the similarity between the electrical conduction and polarization in ferrite materials.

2-4 Recommendation & Suggestion

To complement the work of the current research and for the purpose of obtaining other experimental results that may be better, we include the following some recommendations and suggestions:

.1-Improving the mechanical and physical properties by adding some polymeric improvers such as (plasticizers, antioxidants, ...) and others.

.2-Adding more divalent ions such as manganese, copper or nickel and studying their electrical and magnetic properties.

.3-Studying the electromagnetic properties of the samples at microwave frequencies within the Ku band.

.4-Studying the effect of the thickness of the samples on the attenuation of microwaves within the X-beam.

.5-Using other methods of preparation instead of the liquid mixing method to determine the difference resulting from the difference in the preparation technique

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