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Attenuation of Electromagnetic Waves Us- Ing Nanocomposites

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Chapter 1

1.1. 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 im- portant topics in materials science due to the resulting common properties of insu- lation 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 con- ditions 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 mac- roscopic basis, to form a new and useful homogeneous material whose characteristics differ from those of its components [4]. Among these fea- tures 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 usu- ally affected by the properties of the materials included in their composi- tion, 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 rein- forcement materials and linking the parts together to form a coherent syn- thesis 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

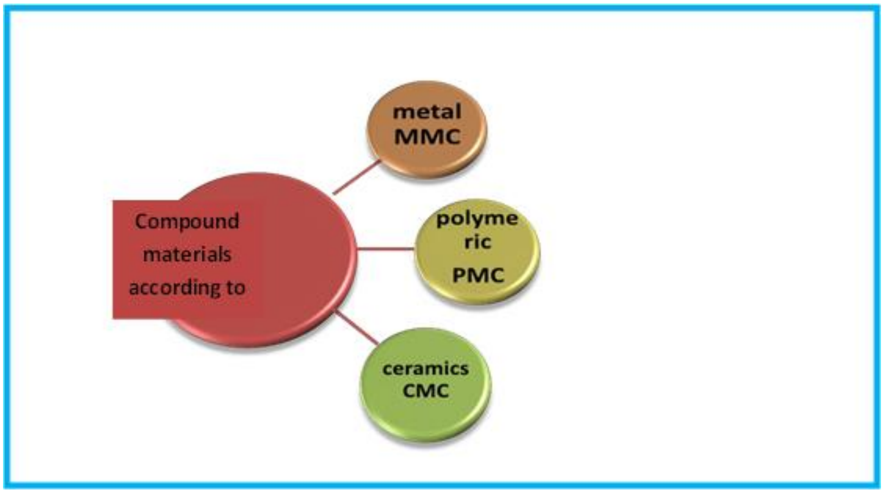


Figure (1-1) Classification of Compound Materials

These materials can be classified into several categories as follows:

A. Metal Matrix Composites

Metallic materials are a mixture of metal elements such as Fe, aluminum, Cu, and others. Such materials contain large numbers of free electrons, and these electrons are not affiliated with a particular atom, and the choice of these materials to be a base material depends on several factors such as values High for each of (re- sistance, density, thermal endurance, durability and thermal conductivity, in addi- tion to having a low coefficient of thermal expansion) [8] [2]

B. Polymer Matrix CComposites

Polymers consist of synthetic units called mer units or (monomers). Natural pol- ymers - those derived from plants and animals - have been used for centuries and include wood, rubber, cotton, wool, leather, silk, and others. Polymers also include familiar plastic and rubber materials, many polymers. They are organic com- pounds and hydrogen and carbon are the basic elements in their composition. These materials are usually of low density and may be very flexible [9].

There are four main types of polymers: [9] [3]

1. Linear Polymers
2. Crosslinked Polymers.
3. Branched Polymers.
4. Network Polymers.

C. Ceramic Matrix Composites (CMC)

Ceramic materials are compounds of metallic and non-metallic elements. They are mostly oxides, nitrates, and carbides. And that such materials are clay minerals, cement, and glass, which fall within the ceramic classification, and these materials are usually insulators for the passage of electricity and heat, and are more resistant to high temperatures and harsh environments than metals and polymers, and these materials are characterized by being solid, but very fragile and can withstand high stresses And high resistance to oxidation [10] [9].

2-2-1. Reinforcement Material

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 re- inforcing 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 $Fe2O3$, 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 ($Fe2O3$) or magnetite ($Fe3O4$), 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]:

1. Garnet.
2. Hard Ferrite.
3. Soft ferrite.

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 tempera- ture 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 conductive It chemical symbol is (Zn), its atomic number (30), its atomic mass (65.39 gm.mol-1), and its structural structure (sixth crystal sys- tem), 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 in- dustries for chemical and food sections as cans and sheets be- cause 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 phe- nomenon 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].

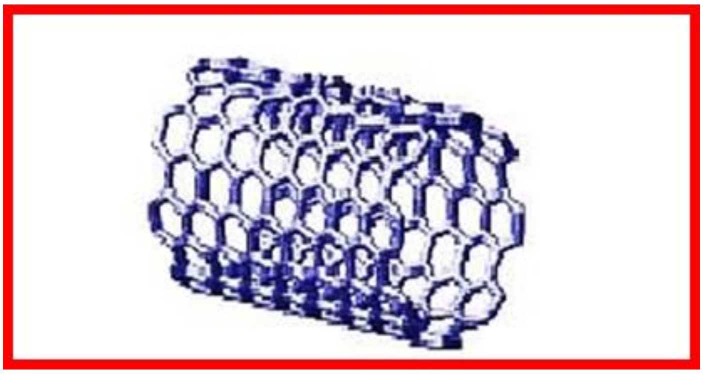


Figure (1-2) shows the shape of MCNT under the microscope SEM

- 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 liv- ing 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 ad- hesive 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 epchlo- rohydrin 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. Synap- tic linkage and the presence of integrated elevian chains.

1-3. Previous Studies

Many previous research and studies dealt with the processes of attenua- tion 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 fil- aments or needles, with average lengths of 10 micron or less and diame- ters 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 thickness It is (0.375 mm), and the material is thicker; As the researchers note; It gave absorption However, 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 Li0.5Ni0.75-x/2Cdx/2Fe2O4 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 tempera- ture, and he noticed a decrease in ( ) values with an increase in the amount of Cadmium in ferrite, which is accompanied by increased con- ductivity [29].

In the year 2012, the scientist (P.Bhattachrya eta.) presented an inten- sive study on microwave absorption within the X-band and it was in two steps, the first is by preparing titanium oxide and ferrites (Fe2O3 TiO2) 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 proper- ty for the compound (TiO2Fe2O3/CNT) and the maximum reflection loss was (8.4-10.99 dB) and at frequencies (12.4-15.6 GHz).), where the in- corporation 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 ra- diation absorption of the nanocomposite materials BaFe12O19 / ZnFe2O4 and by the method of preparing SOL-GEL), where the me- dium was developed by adding carbon nanotubes (CNT) because of its additional characteristic to enhance the And the radio wave absorp- tion 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 / NiZnFe2O4), where the compound was prepared by plumbing method and then thermally treated (sintering) at a tem- perature 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 fre- quency (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 pa- per on the study of the absorption and reflection of electromagnetic waves of the superparamagnetic compound (ZnNiFe2O4) 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% ap- peared to have a weak absorption capacity estimated at (67%), while the samples containing the nanocomposite had a high absorption capacity esti- mated at (99%) within the frequency (10GHz) and with a coating thickness of (2mm) [33].

1-4. The Aim Of This Research

This work aims to develop advanced nanocomposites prepared by powder technology and effective mechanical mixing. These compo- sites have been used in electromagnetic wave attenuation applica- tions and their resistance to harsh environmental conditions. There- fore, these materials are considered among the radio absorbent mate- rials (RAM).

Chapter2

2.1. Introduction

This chapter deals with some theoretical basics related to the topic of research. It begins with a quick look at electromagnetic waves, and moves on to talking about materials, their magnetic properties, and how microwaves propagate in them. It deals with the aspect of wave transmission from one material to another or the loss of its energy in it.

Finally, it presents the types of absorbent materials and their classifi- cation, as well as clarifying some of the advantages and disad- vantages of these absorbent materials, manufacturing methods and technical difficulties for these operations, as well as showing the magnetic and electrical properties of these materials, as well as talk- ing about wear and its types.

2.2. Electromagnetic Waves

Electromagnetic waves consist of the pairing of two fields, one elec- tric and the other magnetic, so that they are in the same phase and are perpendicular to each other and share the direction of propagation that is perpendicular to the direction of the two fields. These fields spread in the void and in the physical medium. The spectrum of elec- tromagnetic waves occupies a wide range of frequencies that includes a group of distinct regions. Microwaves are one of these regions, as their wavelengths extend from (1 cm) (34) GHz) up to (1 m) (300 MHz). [37] [38]] . It is customary to divide this frequency range into several frequency bands that can be summarized in the following ta- ble (2-1)

Table (2-1): Frequency bands of the electromagnetic spectrum in the microwave regiog

Frequency band	Microwave band
500 - 1000 MHz	VHF
1 - 2 GHz	L
2 – 4 GHz	S
4 - 8 GHz	C
8 - 12.4 GHz	X
12.4 - 18 GHz	Ku
18 - 26.5 GHz	K
26.5 - 40 GHz	Ka

Microwaves are of great importance as a result of their wide use. They are used in measuring distances and locations due to the fact that they travel even in cloudy and cloudy atmospheres. They are also used in the field of communications and satellite channels because they penetrate the ionosphere, which reflects lower frequency radio waves. It is also used in the field of cooking, for example, because it is absorbed by water [35].

2.3. EM Wave Propagation

When an electromagnetic wave falls on a material medium, it is sub- ject to one of three basic effects, which are either it is completely re- flected from it and it is said then that this medium is reflective, or it passes from it without affecting it, then it is said that that medium is transparent to this wave, or it is absorbed in that medium that is called then absorbent or attenuated medium for it.

This wave may fall under the influence of a compound of the pre- vious effects, so part of it is reflected and part is transmitted while the other part is absorbed. In this case, the wave will have spread in that medium and will be affected by its properties.

To describe the propagation of any electromagnetic wave in a medium, the four well-known Maxwell equations (2-4-2-7) are used, as well as the medium properties equations (2-1-2-3) [35][36] [29], and these equations are

Where:

$$B = \mu H \qquad (2-1)$$

$$D = \varepsilon E \qquad (2-2)$$

$$J = \sigma E \qquad (2-3)$$

$$\vec{\nabla} \times \vec{E} = -\frac{\partial B}{\partial t} \qquad (2-4)$$

$$\vec{\nabla} \times \vec{H} = \vec{J} + \frac{\partial D}{\partial t} \qquad (2-5)$$

$$\nabla \cdot D = \rho \qquad (2-6)$$

$$\nabla . B = 0 \qquad (2-7)$$

B: Magnetic flux density. H: Magnetic field strength

E: Electric field strength.

D: Electric displacement density.

J: Electric current density.

ρ: Volume charge density.

μ: Magnetic pearmeability.

ε: Electric susceptibility.

σ: Electrical Conductivity.

The first three equations define the relationship between the components of the electromagnetic field and the properties of the medium in which they propagate, and they are called equations of properties of the medium

It is usually expressed in terms of the space constants and where.[29]

$\mu = \mu_o \mu_r$ (2 – 8)

$\varepsilon = \varepsilon_o \varepsilon_r$ (2 – 9)

Where it represents the permeability of space and its value although it is the permittivity of the vacuum and its value. And that and are de- fined as relative permeability and relative permittivity, respectively, and they are unitless quantities.

As for equations (2-4) to (2-7), they are known as Maxwell's equa- tions. And each of these four equations has two formulas, one known as the differential formula and the other as the integrative formula, and these equations are of great importance in the field of electro- magnetic waves propagation [35]. Between the two, which we will ex- plain later .

2.4. Derivation of loss equations in the materia

An absorbing medium is a medium that dissipates the energy of an electromagnetic wave when it propagates through it. Returning to Maxwell's equation (2 - 5) and assuming the median is linearly con- ductive and taking advantage of equations (2 - 2) and (2 - 3), then:

$$\nabla \times \vec{H} = \frac{\partial(\varepsilon\ E)}{\partial\ t} + \sigma\,\vec{E} \qquad (2-10)$$

By taking the time dependence of the electromagnetic field in exponential form

The previous equation can be written in the following

.phase form [37][39]

$E = E_o\, e$

$$\nabla \times H = j\omega\,\varepsilon\,E + \sigma\,E \qquad (2-11)$$

What was it

$$\varepsilon = \varepsilon' - j\varepsilon' \qquad (2-12)$$

Substituting equation (2 - 12) into equation (2 - 11), we find that

$\nabla \times H = j\ \omega\ (\varepsilon' - j\ \varepsilon')\ E + \sigma\ E$

$\nabla \times H = \sigma\ E + \omega\ \varepsilon'\ E + j\ \omega\ \varepsilon'\ E \qquad (2-13)$

The first term in the last equation represents the conduction current, which is dissipative in nature, while the second and third terms repre- sent the components of the dissipative or lossy polarizing current and the non-dissipative or Stored, respectively [37]. So write this equation as follows

$\nabla \times H = (\sigma + \omega\ \varepsilon')\ E + j\ \omega\ \varepsilon'\ E$

The first term is the loss component, and the ratio between the loss component to the lossless component is called the electric loss tan- gent, and it is given as:

$$\tan\delta_e = \frac{\sigma + \omega\varepsilon'}{\omega\varepsilon'} \qquad (2-14)$$

When a part of the energy of the wave passing through the medium is lost, it is said that this energy has been absorbed by that medium, and for the medium to be a good absorber it must have tan δ_e. as much as possible

Now, assuming the medium is an insulator

$$\tan\delta_e = \frac{\varepsilon'}{\_'} \qquad (2-15)$$

$$\tan\delta_m = \frac{\mu'}{{}'} \qquad (2-16)$$

2.5. Radar Absorbing Materials

Radar Absorbing Materals (RAM) can be defined as composite materials that have the ability to absorb electromagnetic waves when passing through these materials, i.e. reducing the radar cross section (RCS) of the reflected waves. These materials can be used in maga- zines Many of them are medical, including military and scientific, so that (RAM) materials must be chemically stable materials, that is, they do not dissolve or char at different temperatures, and according to their use in that environment, RAM materials must bear the electrical risks arising from stable electricity and the danger of lightning And that they are anti-corrosion materials so as not to break the surfaces of the vehicles that these materials are used in their manufacture [38].

Also, RAM materials are included in microwave devices where a wide range of frequencies and a bandwidth that is wider for radar op- erations can be used. Also, these materials are effective at all angles of electromagnetic waves falling on them and ideal at the same time to reduce scattering in all directions. RAM) according to its engineer- ing design, there is a pyramid absorbent and foam absorbent or thin coatings with one or several layers, as well as they can be classified into magnetic and insulating materials, and thus we will mention the most important types of absorbent materials [39].

2.6. Absorber types

Radar absorbers (RAM) are classified according to their technical and design specifications into two main types, each of which has its uses and characteristics, and we will explain in this item these two types in a simplified manner [39][38].

2.6.1 Narrowband Absorber

These types of absorbent materials work to absorb a certain (nar- row) frequency band of electromagnetic waves, so they are known as Resonant RAM, and they usually consist of materials whose proper- ties are often dependent on frequency, making them variable proper- ties with frequency, so they absorb radiation falling on them when The fulfillment of a specific condition of its own, often called the zero re- flection condition, and these absorbents include the following types [40]:

a. Salisbury screen

b. Magnetic absorber

2.6.1.1. Salisbury Screen

$$R_s = \frac{1}{\sigma d} \qquad (2-17)$$

It is a thin film that has a certain surface resistance, and this surface resistance (Rs) is expressed in terms of the conductivity of the chip’s material ( ) by the relationship [39]:

where d is the thickness of the slice.

And this thin slice is separated from the metal surface by a material similar in properties to a vacuum known as a spacer, and its thick- ness, where d is the thickness of the slice.

This thin slice is separated from the metal surface by a material similar in its properties to a vacuum known as a spacer, with a thick- ness of [44]. These materials include polystyrene or polyurethane foam (PUF), as these materials are characterized by having a low rel- ative permittivity (up to 1.1). . Figure (2-1) shows a schematic diagram of this type

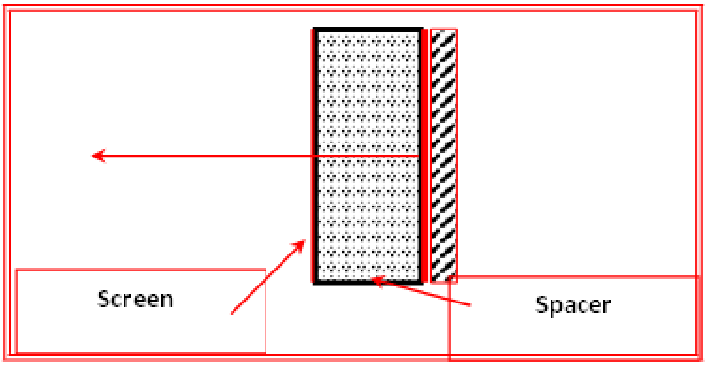


Figure (2-1): Schematic diagram of a Salisbury absorbent

When an electromagnetic wave falls vertically on the surface of Salisbury slice, its reflection coefficient is

$$\rho = \frac{Z_{in} - Z_o}{Z_{in} + Z_o} \qquad (2 - 18)$$

where Zo is the impedance of space (the first medium through which the wave travels) and is given by :[35] and surely:

$$Z_o \quad \sqrt{\frac{\mu_o}{\varepsilon_o}} \qquad (2 - 19)$$

$$Z_{in} = R_s \qquad (2 – 20)$$

Therefore, the zero-reflection condition for this thin film that covers the metal surface, we find it from equations (2-18) and (2-20) to

$$R_s = Z_o \qquad (2 – 21)$$

The absence of the reflected waves in this case is due to the completely destructive interference of the electromagnetic wave reflected from the metal surface with the wave falling on the boundary. (Space-slide)

The thickness of Salisbury membrane d can be found from

.equation (2 - 17) and (2 - 21)

$$d = \frac{1}{Z_o\ \sigma} \qquad (2 – 22)$$

Thus, d is inversely proportional to the conductivity of the membrane material, that material that must be selected such that it has a high electric or magnetic loss tangent [44], that is:

$$\varepsilon_r'' >> \varepsilon_r' \qquad (2 – 23)$$

$$\mu_r'' >> \mu_r' \qquad (2 – 24)$$

One of the disadvantages of the Salisbury absorber is that it is fast breaking and operates at a specific frequency [46], and it is also used in the case of vertical wave fall, and in order to use it at other angles of incidence, some modifications must be made in its design, as well as it needs to use a large thickness, especially at low frequencies, However, adding materials with magnetic or electrical properties or both to the spacer area leads to an increase in the permeability and permittivity of the medium, which increases the refractive index and this reduces the thickness by. [38]

$$,\ )1\ |\sqrt{\mu\varepsilon}\,(\qquad [38]$$

The last two equations represent the electrical and magnetic Salisbury membrane condition, respectively

2.6.1.2. Magnetic absorber

It is a magnetic strip made of a material similar to Salisbury's electric absorber, except that it is placed directly on the metal surface. Note Figure (2-2) and the reflection coefficient in this case is given by the relationship (2-25), [39]:

$$\rho = \frac{Z \tanh(\gamma\, d) - Z_O}{Z \tanh(\gamma\, d) + Z_O} \qquad (2\text{-}25)$$

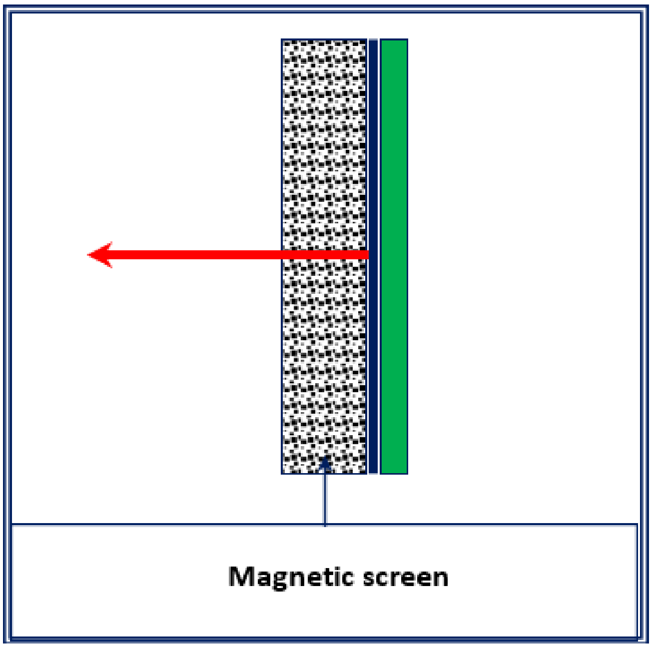


Figure 2-2: Diagram of a magnetic absorber

Where it represents the wave propagation constant in the conducting medium and is equal to [35][45]:

$$\gamma = \sqrt{-\omega^2 \mu \varepsilon + j\omega\mu\sigma} \qquad (2-26)$$

The zero reflection condition is:

$$Z_o = Z \tanh(\gamma d) \qquad (2-27)$$

Since this absorber is magnetic, the electrical loss in it is small, so the relationship (2 - 23) becomes as follows:

$$\varepsilon'_r >> \varepsilon''_r \qquad (2-28)$$

And by adopting the relationships (2-26) and (2-28), as well as (2- 19;), the thickness of the magnetic absorber will be in the following form, [39]:

$$d = \frac{\lambda}{2\pi\mu''_r} \qquad (2-29)$$

One of the characteristics of this absorbent is that it is thinner than its previous counterpart Salisbury absorbent, as the thickness of this magnetic absorbent (Magnetic RAM), which causes absorption (35 dB) in the ideal case, is about (0.21 cm), [39][47]. The thickness of the corresponding Salisbury absorbent is about (12 cm). In addition, it has stable absorption at a good frequency range, which makes it possible to be considered a broadband absorber. However, in practice, it is considered a narrowband absorber, due to the fact that the real and imaginary part of each of the permeability and permittivity of these materials changes with frequency[44] One of the materials used in the manufacture of magnetic absorbents are ferrite materials of various types after mixing with certain polymeric materials. Ferrite is unique in that it absorbs efficiently when prepared in two completely different thicknesses, reaching its thickness in some cases (8 mm), and it works at this thickness with good efficiency, but in this case it is not suitable from an applied point of view. Absorption in ferrite materials is attributed to their magnetization mechanisms, which are [48]

1. Relaxation magnetization
2. Resonance motion of magnetic domain

3. Spin resonance motion

Knowing that the greatest effect on the abnormal thickness of ferrite is due to the first mechanism, and we will explain these three mechanisms in a simplified manner in the following items, and the action of the magnetic absorber depends on the presence of steel (carbonyl iron) as well [47], as the small dipoles in these Materials try to orient themselves along the applied field. If the field suddenly changes, the diodes fail to keep pace with the change in the applied field and a torque is generated that dissipates energy in the material.

2.6.1.2.A magnetization relaxation

When a magnetic field is shed on a ferromagnetic piece, the intensity of the magnetic flux inside the material rises due to the process of its magnetization, and this rise continues until the flux reaches its maxi- mum value so that it does not increase after that, and the ferromagnetic piece here has reached a state of saturation. If the applied field were to be reduced, the magnetization of the material would begin to decrease, but it would not decrease at the same rate as its height. When the applied field reached zero, the flux would be

At a certain value, it is called remanence and is denoted by the symbol (Br) [48]. The behavior of the ferromagnetic material represented by the difference between the magnetic flux curve when the applied field is increased and decreased is called magnetic hysteresis. The amount of the inverse field needed to demagnetize the magnetic material, and the larger the area of the hysteresis ring, the more lost the material becomes, as it was found that the amount of losses is proportional to the area of the hysteresis ring [49]

2.6.1.2.B Magnetic walls move

We mentioned that ferromagnetic materials possess magnetic do- mains, and that each of these regions is magnetized until saturation, but they differ in the direction of their magnetization with neighboring regions, which makes the magnetization net zero.

We explained that shedding an external magnetic field on this mate- rial will increase its magnetization through the growth of fields parallel to the direction of the field or through the rotation of the direction of the magnetic fields moments, but the movement of the moments in these cases creates friction, and this friction will generate heat in the material and dissipate Impressed field energy, [49]

2.6.1.2.C Magnetic Resonance

When a piece of ferrite is magnetized until saturated, its electrons reach the state of equilibrium when its magnetic moments become parallel to the direction of the field. Until you finally reach a balanced precession orbit, at which the process of increasing movement stops due to certain losses mechanisms such as friction that prevents the orbit of the electron flood from continuing to increase. The energy in this case is in the form of heat generated in the substance [50].

Upon reaching this state, the field energy is converted by the electron into heat in the material and is dissipated in it.

This process occurs when the frequency of the applied field matches the precession frequency of the electron in the ferrite, so this process is called resonant absorption [2].

2.6.1.3. Dallebach layer

Instead of using a thin film with the spacer material in the Salisbury absorbent, a specific layer of insulating absorbent material can be used directly on the reflective surface without an additional layer, i.e. the spacer layer. This phenomenon was first observed by

[50].Therefore, this absorbent was called the Dallenbach absorbent.

In this case, the reflection coefficient and the zero-reflection condition are given in terms of the given relationship of the magnetic absorber itself, ie, equations (2 - 25) and (2 - 27) respectively. From the latter, we can write the thickness of the Dolenbach layer as follows

$$d = \frac{1}{\gamma}\tanh^{-1}\left(\frac{Z_o}{Z}\right) \qquad (2-30)$$

It is worth noting here that the impedance of the medium Z is a complex value because the absorbing medium has complex values, as well as a complex number, and thus (d) in equation (2-30) cannot be a real number for all values of Z and

.This absorbent turns into a magnetic absorbent; second type; When the . He gave [52] a mathematical solution for absorbent materials that have electrical and magnetic losses, and it is sufficient to say here that he concluded that materials with medium losses will have a wide absorption band.

2.6.1.4. Circuit analog RAM

An absorbent material that exploits the phenomenon of electrical losses (dielectric loses) in the design of a coating similar to the Salis- bury absorbent described previously, except that the thin outer layer in this case is not deposited on the entire spacer material, but rather it deposits in forms that change the surface impedance of the input im- pedance. This absorbent is known by the acronym

CA-RAM, and figure (3 - 2) shows a section of this absorbent, as we notice in Figure (4 - 2) some geometric shapes for the deposition of this absorben

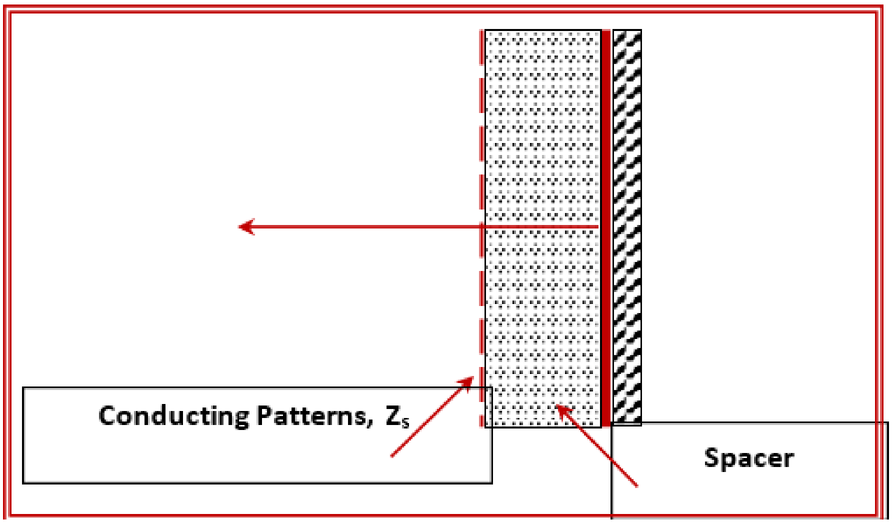


Figure2-3: Schematic diagram of a CA-RAM absorben

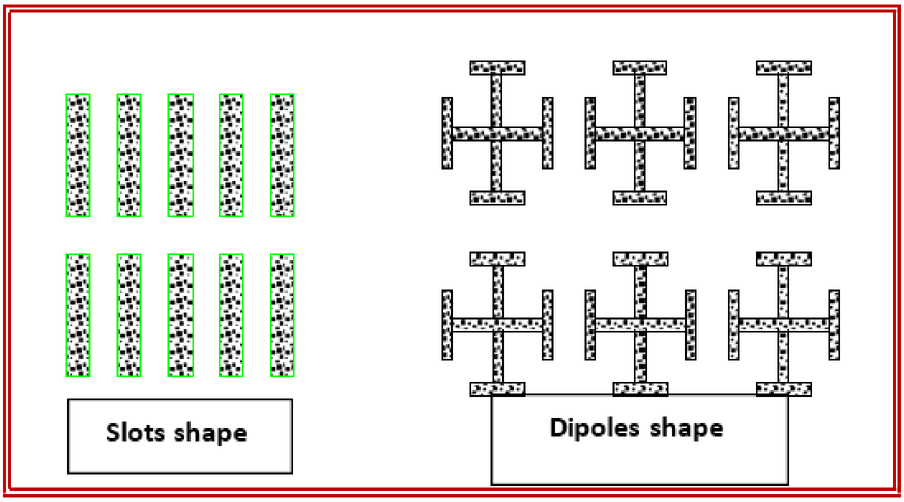


Figure 2-4: Some geometries of the CA-RAM absorber

The shape of this absorber has the property of resonance at a certain frequency, so it is considered a narrowband absorber, and the amount of absorption is affected by the direction of these precipitated shapes relative to the direction of the incident wave [53] [34].

2.6.2. Broadband Absorber

The absorbent materials in this case are characterized by hav- ing a wide absorption band that helps them in a wider absorption of the band falling on them. Among these absorbents are the following types [53]:

1. Jaumann absorber
2. Inhomogenous absorber .
3. Geometric transition layer .
4. Bulk absorber .
5. Chiral absorber.

2.6.2.A Jaumann absorber

The first way to obtain a broadband absorbent is by coating multiple layers of a narrow band absorbent. For example, multiple layers of the aforementioned Salisbury absorbent can be used, which gives resonant absorption at an independent set of frequencies and generates a broad band absorbent as a result. As shown in Figure (2-5) this absorbent is designed so that the impedance of the epitheli- al layers decreases as we advance towards the mineral background with spacer layers of uniform thickness between these layers [47].

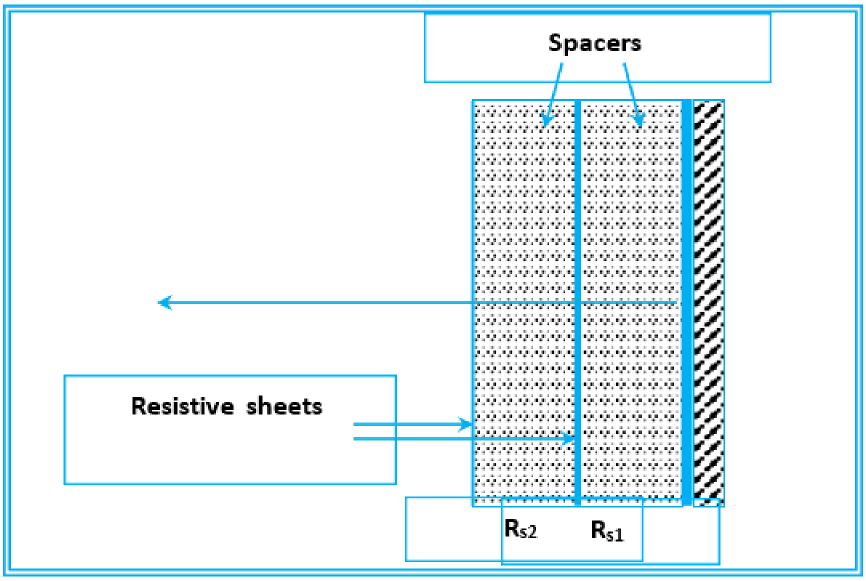


Figure 2-5: Diagram of a two-layered Juman absorben

The width of the absorbent beam in this absorbent depends on the number of layers used in the coating and the values of the absorbent layer. It is considered [35] that the permittivity affects the resonant frequency, while its effect is slight on the radar cross-section (RCS). The width of the absorption beam can be clearly increased by in- creasing the number of layers used in the coating, and Figure (2-6)

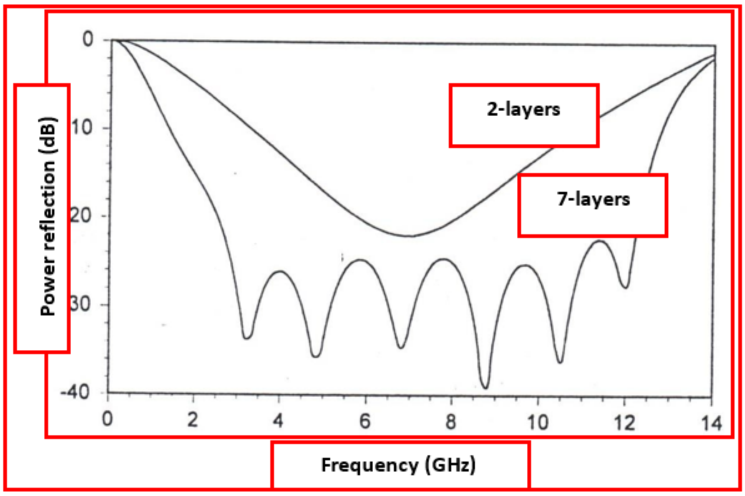


Figure 2-6: Comparison of the energies reflected from the Ju- man absorber at different numbers of layers

shows a comparison of an absorber of this type. Once using two lay- ers and once using seven layers [53].]

2.6.2.B Inhomogeneous absorber

The paint in this case is manufactured so that the metal surfaces are coated with an absorbent material with variable properties. If the coating material is considered to be composed of thin coating layers, then each of these layers has its properties different from the other- layers. The properties that must be changed between one epithelium layer and another in this field are the electromagnetic properties of the medium; That is, the permittivity and permeability, which makes these coating layers different from each other with the value of the loss tan- gent, and as a result they differ in the refraction coefficients of the wave they pass through.

These coatings are usually designed to increase the shade of loss; The refractive index increases; The more we advance from one layer to another towards the depth of the absorbent, i.e. towards the painted metal surface, and this increase is gradual, so this absorber is called a graded absorber as in Figure (7-2).

However, the most important difficulties that lie in obtaining this type of absorbent material is the necessity of changing the permittivity and permeability in a precise manner with the progress of the fish [53] [51].

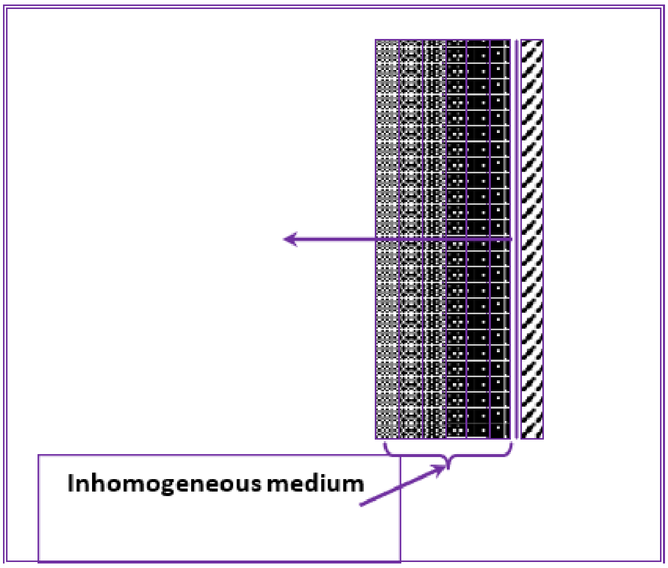


Figure2-7: Schematic diagram of a heterogeneous absorbent

2.6.2.C Geometric transition absorber

The difficulty of obtaining a heterogeneous absorbent in practice led to the design of another absorbent that depends in the gradation of its properties on the geometric shape instead of changing the properties of the medium. This absorbent is manufactured in homogeneous con- ical, pyramidal or wedge shapes. absorbent

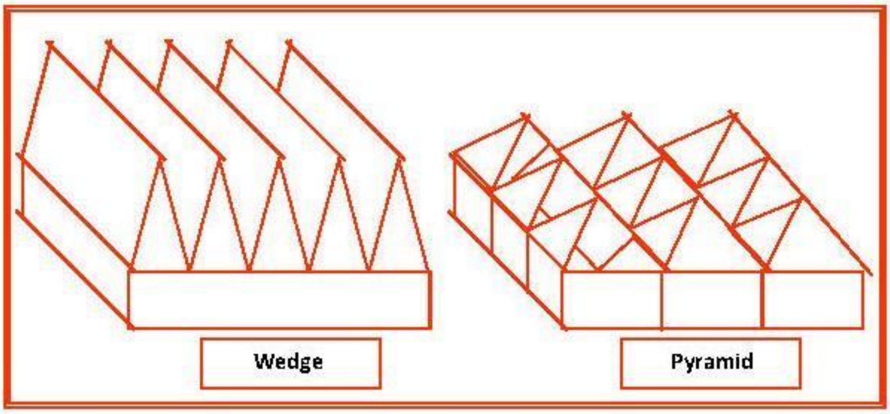


Figure 2-8: Some geometric shapes used in the manufacture of the geometric transformation absorbent

When an electromagnetic wave falls perpendicular to the surface, the area of the absorbent material it encounters will gradually in- crease as it approaches the metal. This gradation can be visualized as a gradual increase in the ratio between the area of matter to the area of space from its lowest value at the top of the pyramid or cone to its maximum value at its base. Thus, the wave will suffer from a gradient in the magnetic properties of the carrier medium, which generates the lowest rate of reflection of this wave.

It is mentioned [56] that with this type of absorbent material, a good level of absorption can be obtained (up to 20 dB) when manufacturing the absorbent surface with a thickness of about one-third of the wavelength, where in this case the many-hole foam (about 10 holes per inch) . One of the limitations of using this type of absorbent material is that it is weak in structure and prone to rapid wear, as well as being unsuitable for use at angles of fall far from vertical fall, and it is completely unsuitable for use in the airspace due to it affecting the geometric shape of the painted object [55].

2.6.2.D Bulk absorber

This type differs from the previous ones in that it works even if it is not made with the ideal thickness required for its work, as it works on absorption if its thickness is close to the ideal thickness. In other words, the absorption of electromagnetic wave energy in this type is proportional to the thickness of the material. This absorbent is classi- fied into two main categorie:

1. *Absorber $\mu = \varepsilon$:*

We mentioned earlier that the zero reflection condition is satisfied when:

Z = Zo

By using this condition and taking advantage of the relationships:

(2 - 8); (2 - 9) and (2 -19), we find that

$$\mu_r = \varepsilon_r \qquad (2 - 31)$$

This type is called an (absorber) where the electric and magnetic field of the passing wave attenuates exponentially as the wave advances towards the depth of the absorber bulk. [35] .

The basic condition in this type is that the absorbent material possesses large and equal values for the shade of electric and magnetic losses, as well as the relative permittivity and permeability, with these parameters not dependent on the frequency within the specified frequency range of work, but the difficulty of obtaining an absorbent material with these conditions makes the manufacture of this Absor- bent is a difficult process, so this substance is replaced by a mixture of substances (two or more substances) so that the properties of the resulting mixture meet the condition.

2. Low density absorber

It is a material that has a low relative permittivity, approximately equal to the value of the relative permittivity of space, as well as the case for relative permeability. Most of the materials that meet this condition are low-density materials, and there is little wave absorption with the dis- tance in the material, which makes the thickness of this type large to be able to absorb electromagnetic energy, which reduces the reflection when the wave reaches the surface of the coated metal [56].

2.6.2.E. Chiral absorber

When a polarized light beam passes through a certain medium, the plane of polarization suffers rotation during its transmission in that medium. The materials that have the ability to do that are called optically active materials, and these materials include quartz crystal, sodium chlorate, Rochelle salts and others.

When the light ray falls, it is divided into two parts (Right- and Left-circularly polarized) and they are called (RCP, LCP). Each ray when it travels in the crystal suffers from a different refractive index from the other, and when it reaches the end, the two beams unite after they have suffered from my two parameters. Two different refractions, which makes their meeting a waste of energy. This phenome- non can be taken advantage of when using other materials as they have this property when used in the microwave area, and one of these materials used in the application is the use of structures Minutes in different directions are immersed in a host medium as epoxy [55].

Examples of these structures are helical structures that may be skewed to the right right-handed helices) or left-handed helices with radii of the order half a wavelength or greater, [58]

2.7. Magnetic Moment

The magnetic field arises whenever there is a moving electric charge in a conducting wire, for example, and this was discovered in 1819 AD by the scientist (Orsted). While in permanent magnets, there is no traditional electric current that moves the charges, but from the atomic point of view of the matter, there are two types of movement of the electron as in Figure (9-2), which are [15]

1. The orbital motion of the electron is the movement of the electron around the nucleus, which results in a magnetic moment exactly simi- lar to the magnetic moment resulting from the passage of electric cur- rent in a circular conducting loop, where the resulting magnetic mo- ment is in a direction perpendicular to the plane of the ring.
2. The rotational motion (spin) within the permanent magnet means that each electron is considered a magnet being a small ball with a negative charge revolving around its axis, and as a result of this movement and according to the classical mechanics, a magnetic moment is generated, that this movement in itself can explain the magnetic properties of the material because the effect of the movement Tropical is considered a secondary effect.

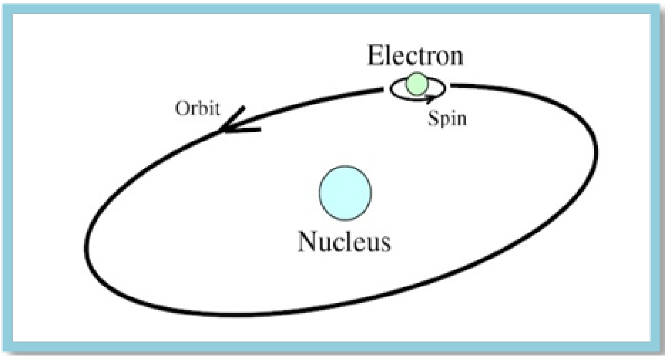


Figure (2-9): Electronic movement

The material is magnetized and a magnetic field is generated outside it because of these two types of electronic motion, with the exception of some nuclear magnetic effects, which are much smaller than that.

Atoms contain many electrons that rotate around their axis and move in their own orbit. The magnetic moment is associated with each type of movement. It is a vector quantity parallel to the axis of the electron's rotation around its axis and perpendicular to the level of the electronic orbit. The magnetic moment of the atom results from the directional summation of all the electronic moments. This results in two possibilities:

1. The magnetic moment of all electrons is directed in directions that cancel each other out where the net magnetic moment of the atom is equal to zero. This is a condition that generates diamagnetic materials.
2. The cancellation of the magnetic moments is only partial, and the atom has a net magnetic moment. This atom is often referred to as the magnetic atom, and the materials composed of such atoms are paramagnetic, ferromagnetic, antiferromagnetic, and ferromagnetic [61].

2.8. Magnetic Field

It is a force field similar to the gravitational field and the electric fields that surround the sources of voltage, and it represents magnetism by the quantities of the two fields (B and H). Where B is the magnetic flux density, measured by the force that affects a wire carrying an electric current, and it is measured in tesla. And that H represents the strength of the magnetic field and is calculated from the electric cur- rent that generates the magnetic field and is measured in units (A/m) in the magnetic material. The relationship between B and H is given by:

$$B = \mu H = \mu_{\circ} \mu r H \qquad (2-32)$$

$$B = \mu_{\circ} (H + M) \qquad (2-33)$$

Where ($\mu_{\circ}$) is the vacuum permeability and is equal to (4π x 10 – 7 H/m), and (μr) refers to the relative permeability, which is equal to:

$$\mu r = {}^{\mu}\mu^{\circ} \qquad (2-34)$$

And (M) is the magnetization of the material (it is the sum of the magnetic moments mj per unit volume of the magnetic material).

$$M = \sum v \, mj \qquad (2-35)$$

The magnetic properties of magnetic materials can be described in the way that the value of M differs with the value of H, and the ratio of these two quantities is called magnetic allotropy (X).

$$X = \frac{M}{H} \qquad (2-36)$$

From the above equations we get:

$$\mu = \mu_{\circ} (1 + X) \qquad (2-37)$$

It is the values of both permeability and magnetic susceptibility that characterize the magnetic properties of materials [64] [63]. Where the susceptibility represents the response of the physical medium to the applied magnetic field and it is closely related to the atoms and mole- cules of that medium, and the magnetic susceptibility depends on several factors, including the magnetic composition of the material and temperature, while it does not depend on the strength of the external magnetic field. for many magnetic materials [62]

2.9. Classification of Magnetic materials

The development of magnetic materials for technical applications began with the development of metallurgy and the study of materials in general, and in recent times many new applications have relied on began with the development of metallurgy and the study of materials in general, and in recent times many new applications have relied on magnetism and magnetic materials such as wireless communication tools [63]. Faraday) to magnetic induction, however, materials can be affected quite differently when they are in an external magnetic field.

This influence or interaction depends on a number of factors, such as the atomic and molecular structure of the material, and the net magnetic field arranged by the atoms [64]**.**

Magnetic materials can be classified into five groups:

Diamagnetic materials - paramagnetic materials - ferromagnetic materials - antiferromagnetic materials - ferromagnetic materials As in Figure (2-10).

Where this classification was based on the value of the magnetic susceptibility and the behavior of the magnetic material under the in- fluence of an external magnetic field and we will allow it in the expla- nation below [65]

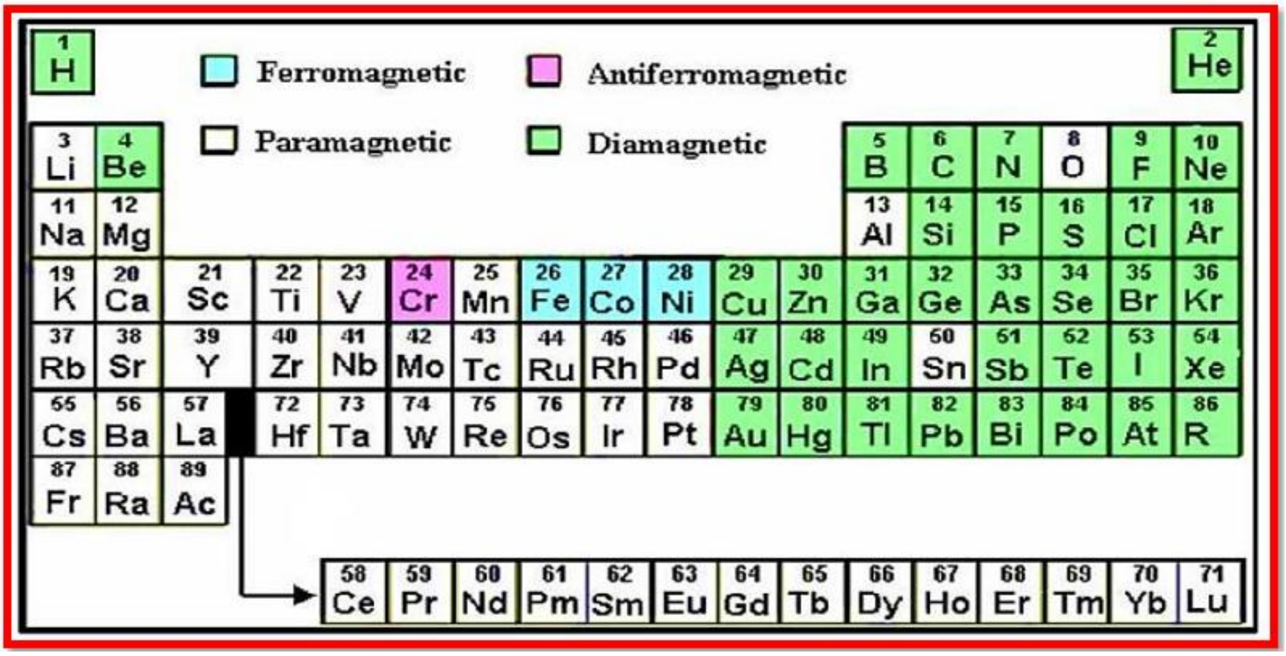


Figure (2-10) shows the types of magnetic elements in the periodic table

2.9.1. Diamagnetic materials

These materials do not contain a non-double electron and do not have a net magnetic moment. When an external magnetic field is ap- plied, small spin currents produce a magnetic effect that opposes the external magnetic field applied to the material and thus is repelled as in Figure (11-2). These materials are characterized by that the magnetic archaeological value is negative as it is about (10-6) and does not depend on the temperature and the permeability coefficient less than one. Examples of this type of materials are (quartz, inert gases, water, hydrogen, organic compounds, bismuth and silicon) [65].

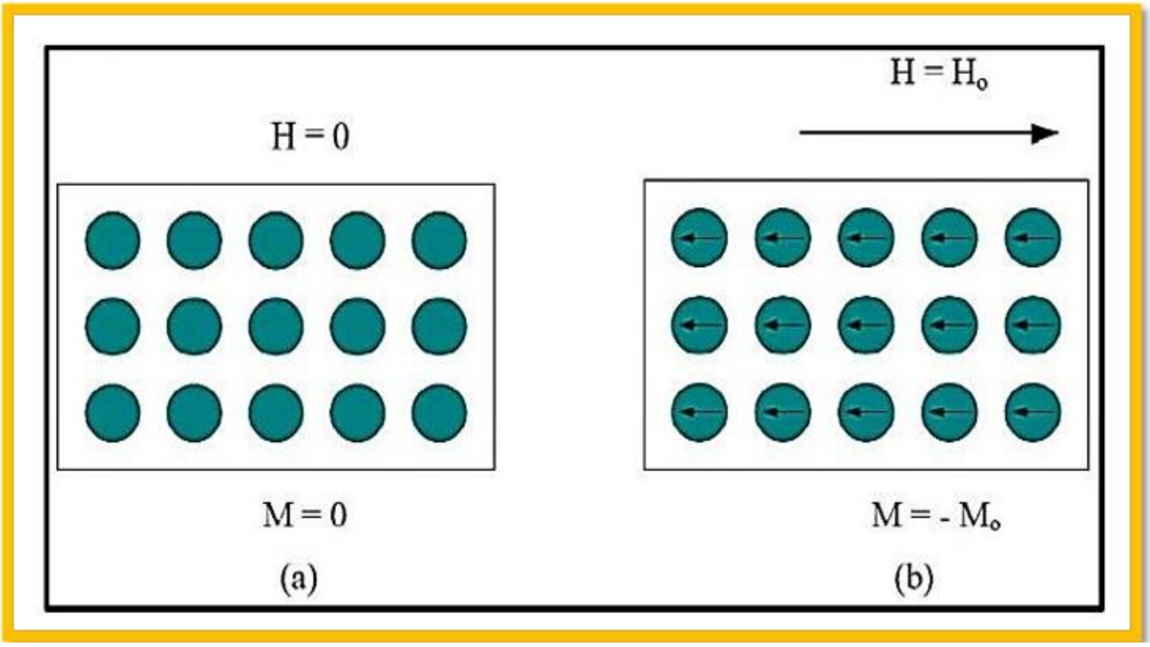


Figure (2-11): The material is magnetic a) in the absence of a magnetic field b) in the presence of a field.

2.9.2. Paramagnetic materials

These materials are subject to the Curie-Weiss law, meaning that the magnetic effect is inversely proportional to temperature and rang- es between 10-10 and the permeability of these materials is positive and less than one. These materials possess a permanent magnetic moment that arises from the spinning of the electron and according to the (Lingevin) model every An atom that has a magnetic moment, which is randomly directed as a result of thermal induction, and when the external magnetic field is applied, produces a slight alignment of these moments, which generates low magnetization towards the ap- plied field, as in Figure (2-12). Examples of these materials are (oxy- gen, aluminum, tin, titanium, potassium, lithium and cesium). [66] [65]

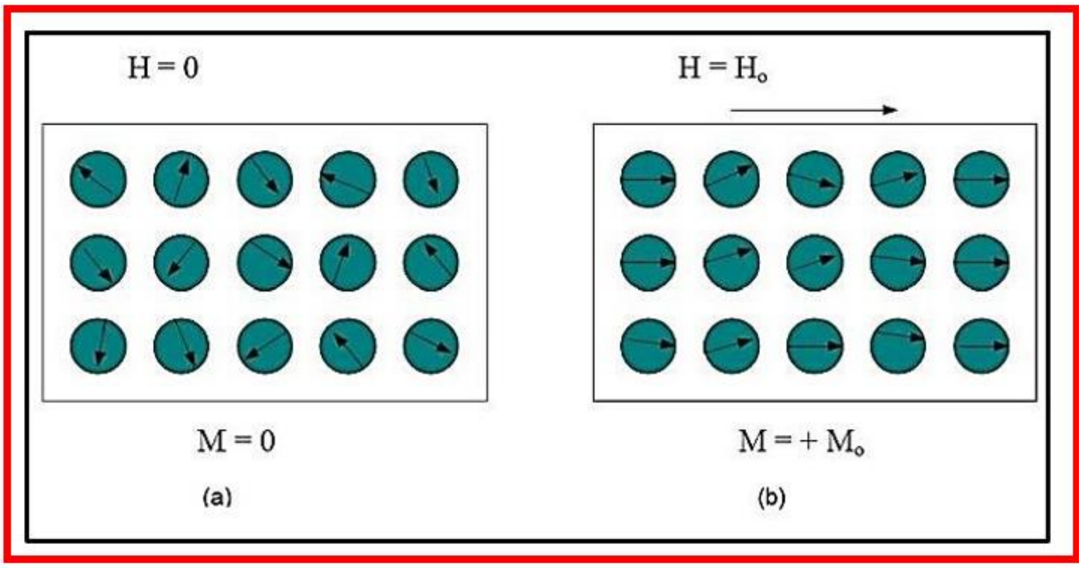


Figure (2-12): Para material. magnetism a) in the absence of a magnetic field b) in the presence of a field

2.9.3. Ferromagnetic materials

These materials have permanent magnetism because the electrons of all atoms rotate together to form the resultant unit cell magnetic moment or magnetic domins and it occurs when the magnetic moments of the atoms in the lattice are arranged in the same direction as in Figure (2-13). In these materials spontaneous magnetization occurs only below the Curie temperature, they behave like paramagnetic materials. Examples of these materials are iron, nickel, cobalt and barium, and they have a very high magnetic permeability around 105). The effect of these materials follows the Curie-Weiss law and is known as $m = C / (T--)^{\chi})$.

So, C is a curie constant θ: Curie temperature. [67]

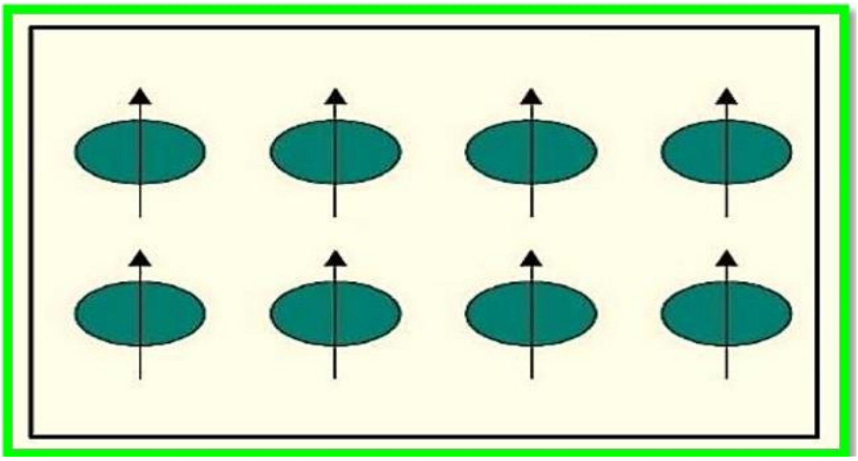


Figure (2-13): Ferromagnetic materials

2.9.4. Antiferromanetic materials

In these compounds, the metal ions rotate in parallel and opposite pairs and in the direction in one basic lattice, so the net magnetic moments in the basic lattice become zero, where in the absence of the external field, no magnetization is produced, as in Figure (2-14), and the effect of these materials depends on the temperature, when the temperature is raised The temperature of the material is higher than the temperature of Neil, the material is subject to (Curie - Weiss) law and becomes paramagnetic, some of these materials can be made ferromagnetic materials by applying a high (sufficiently) external magnetic field parallel to the axis of rotation and examples of these materials are many metal oxides Transition, manganese and chromium [66] [67]

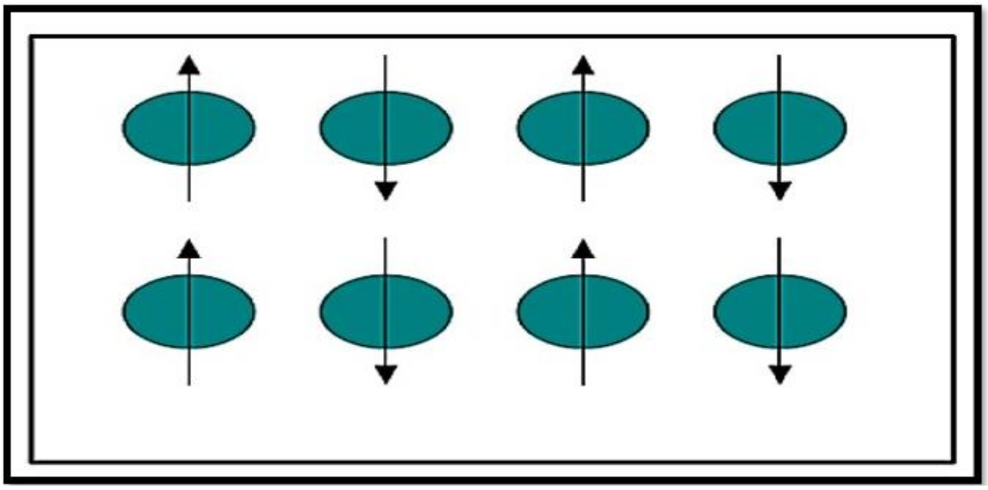


Figure (2-14): Antiferromagnetic materials

2.9.5. Ferrimagnetic materials

In fact, these materials are a special case of antiferromagnetic mate- rials whose magnetization is not equal to zero, that is, they contain net magnetization due to the unequal parallel and opposite torques in the direction, i.e. unlike antiferromagnetic materials, they do not can- cel each other out and thus produce permanent magnetic moments. And as in Figure(2-15). It is characterized by having high magnetic permeability and impact, but less than that of ferromagnetic materials, and its specific resistance is much higher than that of ferromagnetic materials. It also depends on the temperature. When the temperature is raised above absolute zero, the magnetism will decrease to zero at the Curie temperature and turn into ferromagnetic materials or similar in behavior, the best example of these materials is iron oxide [68].

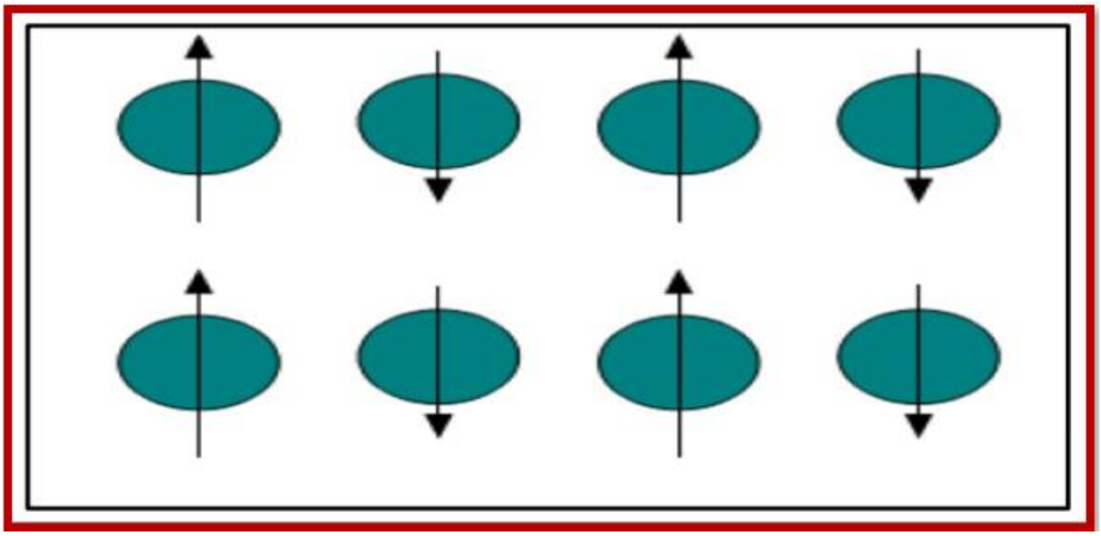


Figure (2-15): ferromagnetic materials

2.9.10. Magnetic properties

2.9.10.1. Permeability

It is a measure of the ease of permeability of magnetic flux through matter and for ferromagnetic materials it is a function of magnetic field strength [68]. Magnetic permeability is used over a wide range of frequency, at low frequencies, permeability is a real number and therefore vectors H and B are parallel to each other and as in Figure:(2-16) . At higher frequencies, the transmittance is a complex value

(2 - 38)

μr) the real part of permeability, ′(μr′ - μr= (,μr) the imaginary part of permeability , (i) a constant of √(-1iμr

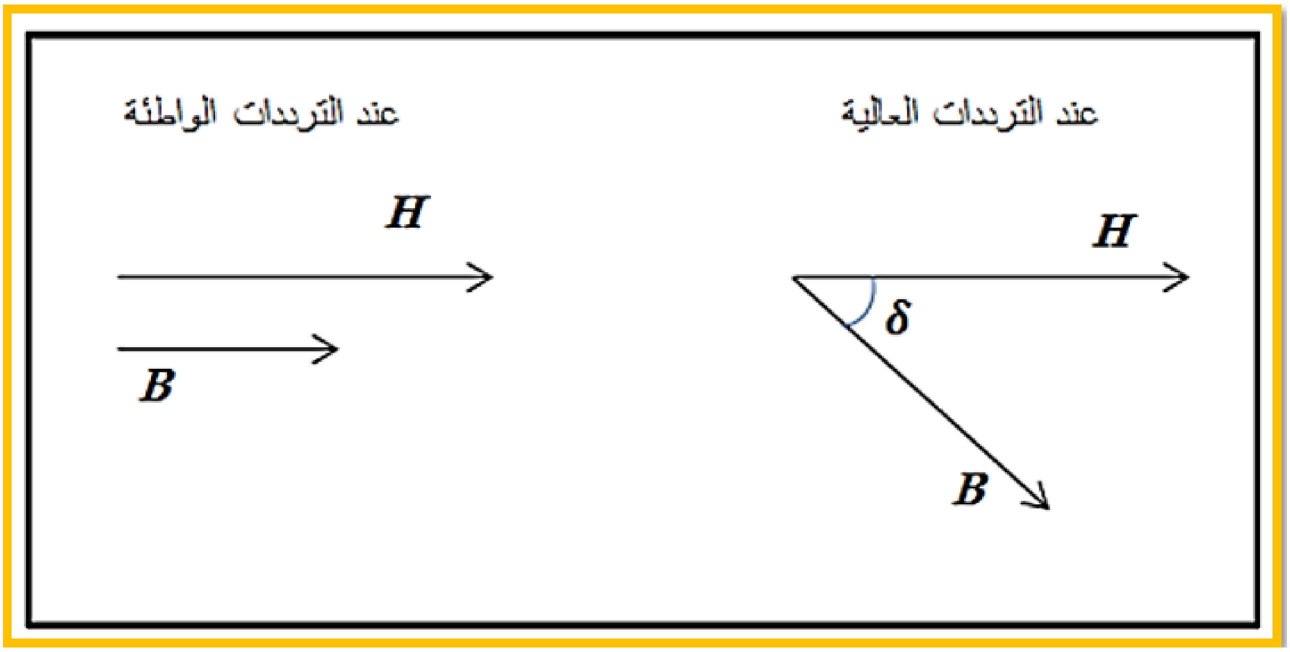


Figure (2-16): The change in the direction of the magnetic flux from the applied field strength with frequency

That is, the vectors H and B are not parallel to each other and have a phase difference angle $^{\delta}$, which is the angle of loss in the material.

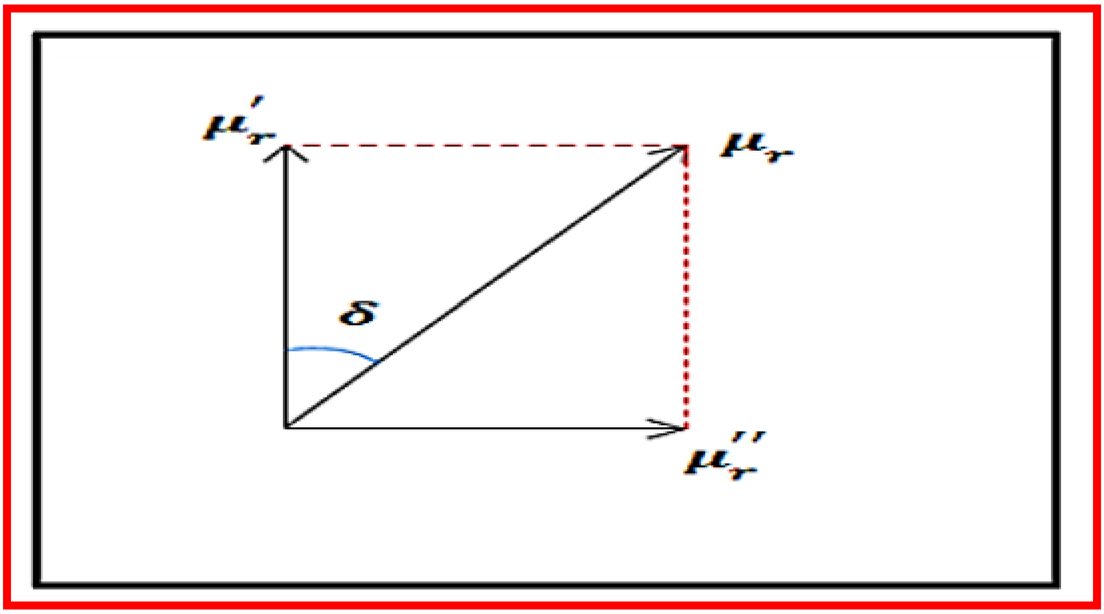


Figure (2-17): Angle of loss in the material

Where the complex permeability with its real parts ′μr and imaginary ″μr is the frequency function where the real part of the permeability expresses the magnetic energy stored in the material.

The imaginary part expresses the energy lost in the material, and through Figure (2-17) it is possible to calculate the loss angle δ and is equal to [70]:

$\mu r'' \tan\delta = (\mu r')$

Ferrite materials are characterized by having a high magnetic permeability that is 1000 times greater than the permeability of vacuum, but the magnetic properties of ferrite materials have lower values than the properties of magnetic metals. It is the energy loss much less than the energy loss in magnetic minerals because the resistance of ferrite materials is very large [71].

2.10. Magnetization

Ferromagnetic and ferrimagnetic materials are the most common be- cause they are attracted to the magnet by a perceptible force, be- cause they contain unbound electrons in their applied atomic struc- ture. Some are automatically [72], when a magnetic field (H) is ap- plied to the material, and the fields gradually align with that, as in Fig- ure (2-18) [73].

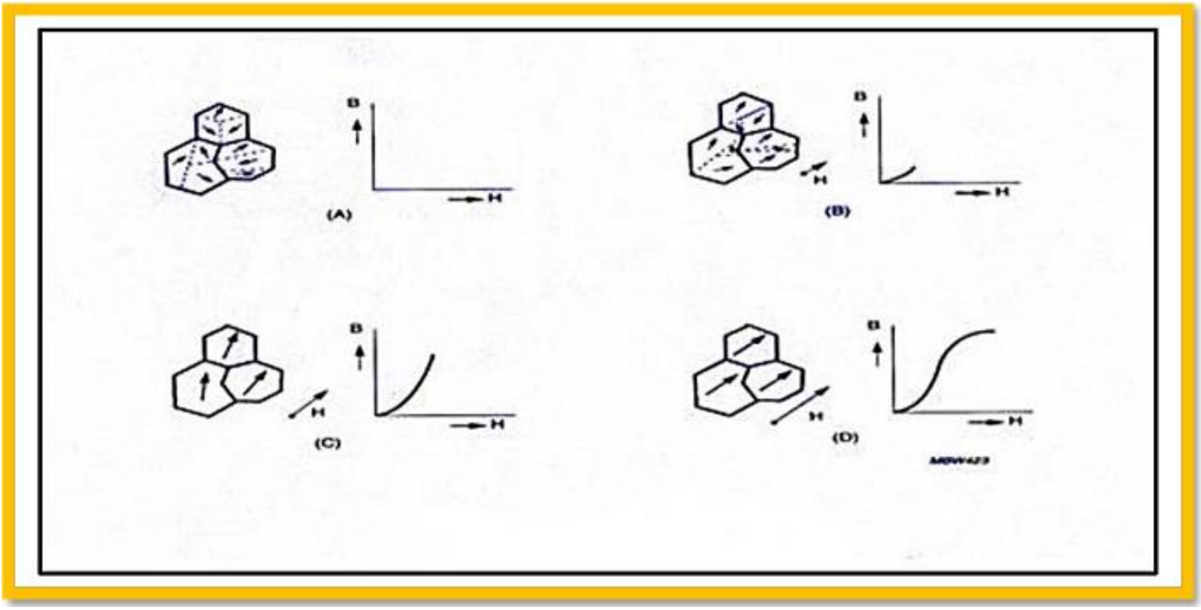


Figure (2-18): The magnetization of the material with increasing field strength

2.11. Electric Properties

2.11.1. Electric Polarization

Insulating materials are characterized by containing a very small number of free electrons to contribute to electrical conductivity. Such materials have interesting electrical properties due to the ability of the electric field to polarize them to form an electric dipole, and thus the molecules of these materials are called (non-polar molecules) [15][74]. In some materials, dipoles exist as a permanent feature even in the absence of an electric field. These dipoles are called permanent dipoles, in which the center of the positive charge does not coincide with the center of the negative charge, such as the molecules of these materials are called (polar molecules) and the induction of these mole- cules is called electric polarization.[83] Polarization (P) is defined as the surface charge density in the insulator and is equal to the dipole moment per unit volume of the material and as follows:

$$P = Nm \qquad (2-41)$$

Where N is the number of dipoles per unit volume. m: average dipole moment.

The electric dipole moment depends on two opposite electric charges with polarity separated by a distance of d [73].

$$m = qd \qquad (2-42)$$

2.11.2. Dielectric constant

Assuming that we have two parallel metal plates, each with an area

(A) separated by a space (d) in space and connecting the two plates to an electrical circuit, the capacitance of the parallel plates Co is given by the following relationship:

$$Co = \varepsilon o A\ d \qquad (2-45)$$

Since εo represents the space permittivity, which is (8.85 x 10- 12 F/m).

But when an insulating material is inserted between the parallel plates instead of the space, as in Figure (2-19)

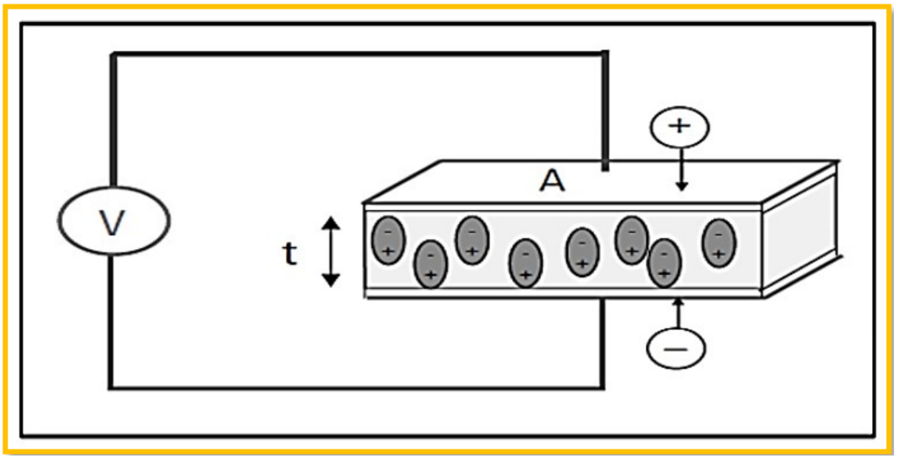


Figure (2-19): the dilated in case of an insulator

The capacitance of the parallel plates C is given by the following relationship:

$$C = \varepsilon\ A / d \qquad (2-46)$$

where ε is the permittivity of the insulator, and the ratio between the permittivity of the insulator ε to the permittivity of the vacuum εo is called the dielectric constant εr

$$\varepsilon r = \varepsilon/\varepsilon o \qquad (2-47)$$

Since ε is always greater than εo, the minimum value of the dielectric constant εr is (1). By substituting equation (2 - 47) into equation (2 - 46), we get the capacitance of the plates with the presence of the insulator and in terms of the dielectric constant, as in the following equation:

$$C = \varepsilon r \, \varepsilon o A / d = \varepsilon r \, Co \quad (2 – 48)$$

The dielectric constant is a quantity without units because it is a relative value and the dielectric constant depends on the frequency of the applied field as well as on the temperature [74][75][76].

2.11.3. Dielectric Loss

When an insulator opposes alternating current, it absorbs electrical en- ergy and dissipates it in the form of heat. This dissipation of energy is called insulator loss. The dissipation of electrical energy during a speci- fied period of time, if a metal conductor is connected first to the con- stant voltage and then to the alternating voltage equal to it in value to the constant voltage, then the loss of electrical energy will be the same in both cases according to the law (Joule - Lenz)[77] [78]

$$P = V^2/R \qquad (2\text{-}49)$$

Where: P is the electrical power in watts.

V: the electric potential difference in units of volts. R: electrical resistance in ohms.

Where the dielectric loss can easily be found easily through the relationship (2 - 49), suppose we have an electrical circuit that contains a capacitor, the air being the insulating medium between its plates, and we connect the capacitor to an alternating voltage ($V = Vm\ e^{i\omega t}$), the current (I) passing through dilated according to Ohm's law:

$$I = V/X_C \qquad (2\text{-}50)$$

Where: XC: the capacitive will of the capacitive is equal to $XC= 1/iwc$ (2-51)

ω : angular frequency equal to ($2\pi f$) , $i = \sqrt{(-1)}$

Thus, the capacitive current can be calculated by substituting equations (2 - 48) and (2 - 51) into equation (2 - 50), so we have:

$$I = i\omega \epsilon r C o V \qquad (2 - 52)$$

By observing Figure (2-23), the current in the capacitor advances with a phase difference angle from the voltage of (90o), but when an insulating material is inserted between the plates of the capacitor, the phase difference angle between the voltage and the total current is slightly less than (90o) by (θ).) This indicates that the insulator caused the generation of a resistance current (Ir), which is in the same phase with the voltage, and through what was presented, the insulator can be represented by an equivalent parallel-connected electrical circuit containing a capacitor and a drain resistance [75].

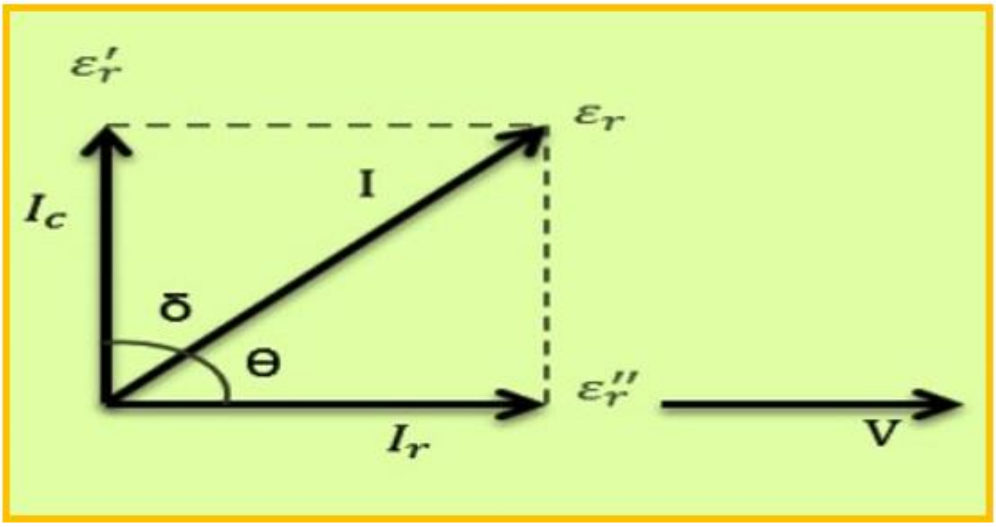


Figure (2-20): The phase diagram of voltage and current.

The angle (δ) is called the dielectric loss angle or the dissipation factor. If it is small, then ($\tan\delta \approx \sin\delta$) and the tangent of the angle δ is equal to the ratio between the two currents as in the following equation:

$$\tan\delta = I_r/I_c \qquad (2\text{-}53)$$

We can briefly describe the response of the dielectric solid by formulating the dielectric constant (ϵr) with a complex value:

$$\varepsilon r = \varepsilon r` - i\varepsilon r`` \text{ whereas:} \qquad (2\text{-}54)$$

$\varepsilon r`$: the real component of the dielectric constant of the capacitance and it can be calculated through equation (2 - 48), then:

$$\varepsilon r` = (C\,d)/(A\,\epsilon_o) \qquad (2\text{-}55)$$

and surely:

$\varepsilon r``$: the imaginary part of the dielectric constant, which represents the dielectric loss factor.

We can find both the value of (Ic) and (Ir) by substituting equation (2 - 54) into equation (2 - 52), resulting in:

$$I = \omega\,\varepsilon r``CoV + i\omega\,\varepsilon r`CoV \qquad (2\text{-}56)$$

The total current is equal to the sum of the two currents (Ic and Ir:)

$$I = Ir + Ic \qquad (2\text{-}57)$$

By comparing equations (2-56) and (2-57), we get:

$$\tan\delta = (\varepsilon r``)/(\varepsilon r)` \qquad (2\text{-}58)$$

It is possible to determine the quality factor Q for any insulating material through the reciprocal of the value of the tangent of the angle of loss in the insulator [93.]

$$Q = 1/\tan\delta \qquad (2\text{-}59)$$

The value of the insulator losses in watts is expressed as follows [94]

$$P = VIc = VIr\tan\delta \qquad (2 - 60)$$

2.11.4. Conductivity

The conductivity of a sample to alternating current σAC can be calculated by applying the loss angle and using the following relationship:

$$\sigma AC = \omega\,\varepsilon o\varepsilon r \qquad (2 - 61)$$

Where ω: represents the angular frequency and is equal to ($2\pi f$) and since the quality factor Q for any dielectric material is the reciprocal of the value of the loss tangent of the insulator [79].

$Q = 1/\tan\delta$

Substituting the value of the imaginary dielectric constant from equation (2 - 62) into equation (2 - 61), we get:

$$\sigma AC = 2\pi f\,\varepsilon o\varepsilon r\tan\delta \qquad (2 - 63)$$

Also, the conductivity of this sample to DC can be calculated if we determine its cross-sectional area A and thickness d through the following equation:

$$\sigma DC = 1/\rho = d/RA \qquad (2 - 64)$$

where ρ is the resistivity and is equal to the reciprocal of conductivity and R is the material's resistance in ohms. The total conductivity of the material can be determined as follows [78]:

$$\sigma = \sigma AC + \sigma DC \qquad (2 - 65)$$

The resistance of the material ρ depends on the temperature as in the following relationship [79]:

$$\rho = \rho o \exp(Ea / KT) \qquad (2 - 66)$$

Ea is the activation energy, T is the temperature, K is the Boltzmann constant (8.62 x 10-5 ev/K), and ρo is a constant.

3. Introduction

This chapter includes a comprehensive review of the preparatory as- pects of the selection of materials and the interchangeable ratios between them, in addition to conducting a series of operations to reach the final form of the models. Figure (1-3) illustrates the practical steps and technological path of this research. Structural and microscopic properties such as X-ray dif- fraction (XRD), scanning electron microscopy (FeSEM) measurements (Field Emission Scanning Microscopy) and Atomic force microscope (AFM) measurements to identify the crystal structure and grain size and observe the extent of homogeneity in Materials . Also, this chapter included important tests and measurements, which included all of the magnetic tests and measurements, which included magnetic hysteresis. Finally, this chapter dealt with the most important practical techniques that were used in the research, such as finding the mechanical properties represented by Vickers Hardnees, as well as checking wear (Wear) and observing changes in the physical and mechanical properties after changing several parameters such as time, as well as conducting electrical tests (LCR).

The practical part of this research has been divided into three stage:

A. Prepare raw materials.
B. Preparation of forms.
C. Conducting tests and measurements.

Figure (1-3) illustrates the technological process of the model manufacturing stag

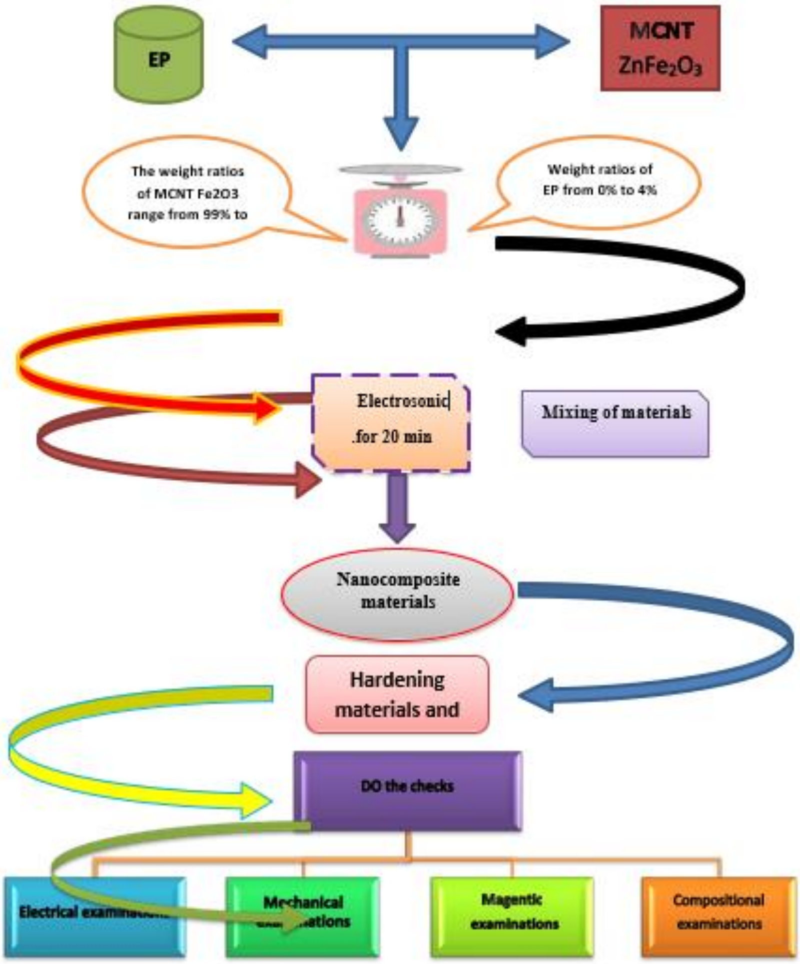
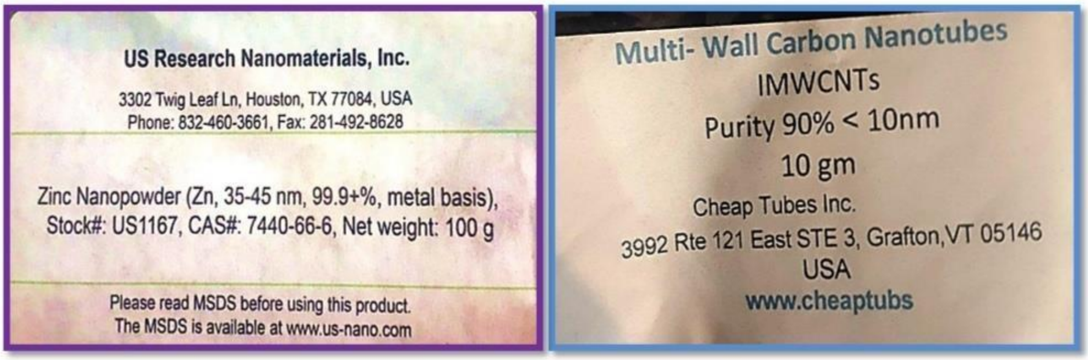


Figure (1-3) is a diagram showing the stages of preparation and measurements in this research

3.1. Nitialization of raw materials

The materials were prepared in the form of nanopowders (Zn), (Fe_2O_3) and (MCNT) with high purity approaching 99.98% and 90%, respectively, and of global origin according to the international standard measurements (ASTM) and as shown in Figure (3-2). Which represents the specifications of the materials in terms of material purity, particle size and use (100g for 1g of hardener)



US Research Nanomaterials, Inc.

3302 Twig Leaf Ln, Houston, TX 77084, USA
Phone: 832-460-3661, Fax: 281-492-8628

Zinc Nanopowder (Zn, 35-45 nm, 99.9+%, metal basis),
Stock#: US1167, CAS#: 7440-66-6, Net weight: 100 g

Please read MSDS before using this product.
The MSDS is available at www.us-nano.com

Multi- Wall Carbon Nanotubes
IMWCNTs
Purity 90% < 10nm
10 gm
Cheap Tubes Inc.
3992 Rte 121 East STE 3, Grafton,VT 05146
USA
www.cheaptubs

Figure (3-2): It represents the type of materials used, their purity and particle size

3.2. Calculation of relative density and process

The practical and theoretical results were calculated to calculate the volumetric density, where the density values were measured by two methods, the first by dimensionality and the other method by the Archimedes method, where there was a great convergence in the values. To calculate the mass, in addition to using the digital micrometer to calculate the dimensions (thick- ness and diameter), the method of calculating the theoretical density was done using the method of mixing rules according to the following equation:

Density of the first substance x its percentage + density of the second sub- stance x its percentage = density of theoretical nanocomposites

By knowing the theoretical density of the base material (polymer 1.12 grams per cubic centimeter) as well as the density of the nano-reinforced compound ($ZnFe_2O_3$ / MWCNT) (5.4 grams per cubic centimeter) and through the percentages used in the work, the density of the theoretical nanocomposites was calculated.

3.3. Samples Preparation

The method of liquid mixing and ultrasonic technology was used to preparethe nanocomposites, where the UPE polyester was reinforced by weight ratios of zinc nanometal powder $ZnFe_2O_3$ (4-1)%, where the powder was mixed first by adding it to the polymer resin and then the hardener was added to it and then the The mixture was in the electrosonic device for a period of (20 min.) for the purpose of distributing and spreading the powder, and then the mixture was poured into pre-prepared molds for the purpose of preparing the models, both according to the standard conditions for examination, including cylindrical, circular

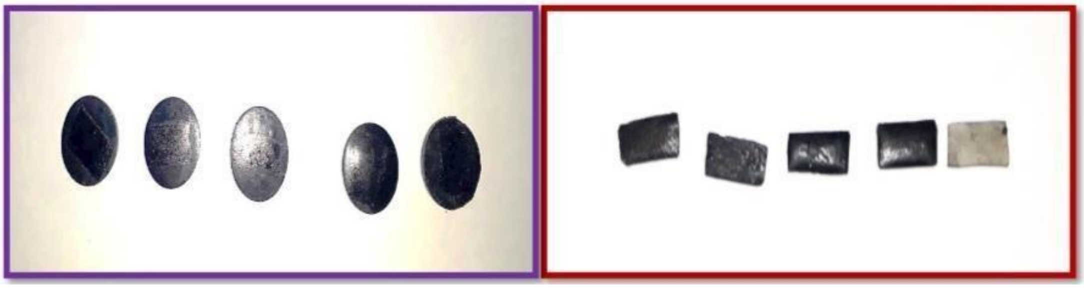


Figure (3-3): The shape of the samples that were manufactur and rectangular ones, and as in Figure (3-3) which shows the shape of the samples that were Manufactured for testing purposes

3.4. Magnetic Measurements:

A number of important magnetic examinations were carried out as they represent the main part of the research, namely**:**

3.4.1. Magnetic Vibrating Device

The magnetic properties were measured using the Vibrating Sample Mag- nometer (VSM) model (10 EZ VSM).

It is shown in Figure (3-7), located at the University of Tehran, and it has the ability to measure the magnetic properties of materials, whether they are in the form of rings or powders. In our research, this was measured

Magnetic properties in the form of discs [124]. Figure (3-4) shows the method of fixing the sample by a special material. If a material is placed in an external magnetic field, the magnetization intensity M depends on the magnetic field (H) and temperature as well as the type of material. Figure (3-4 :) shows the magnetic examination device with the sample holders diagram material.

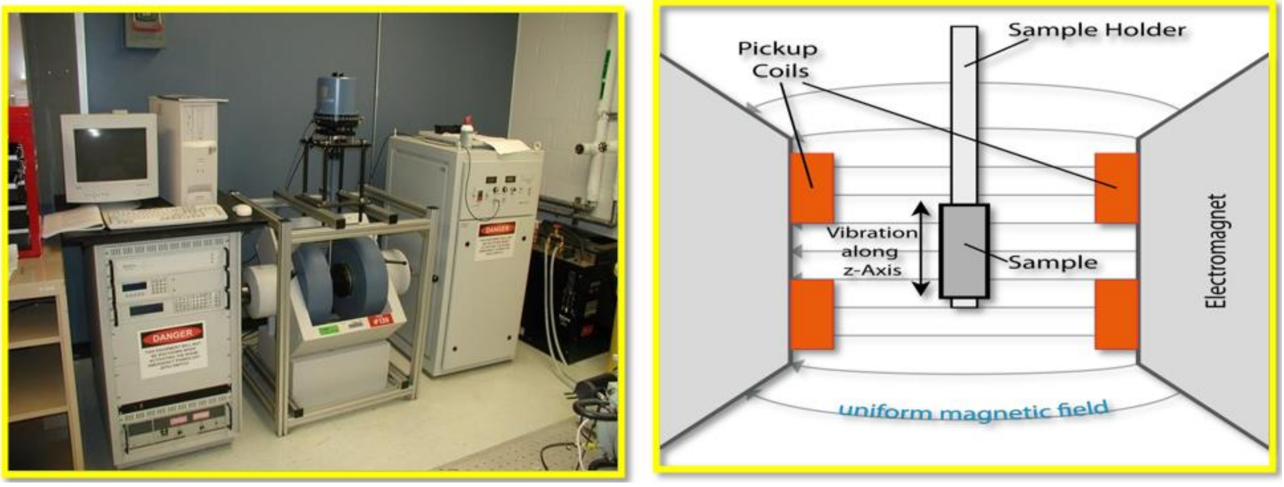


Figure (3-4) shows the method of fixing the sampl

3.4.2. Vector Network analyzer

This device was used to analyze the attenuation, absorption and resistance vectors of the magnetic materials to be examined. This examination was car- ried out at the Ministry of Science and Technology / Research Department and industrial development, and the device type and model was (Anritsu MS4642A-20GHz) of American origin, as shown in Figure (3-4)

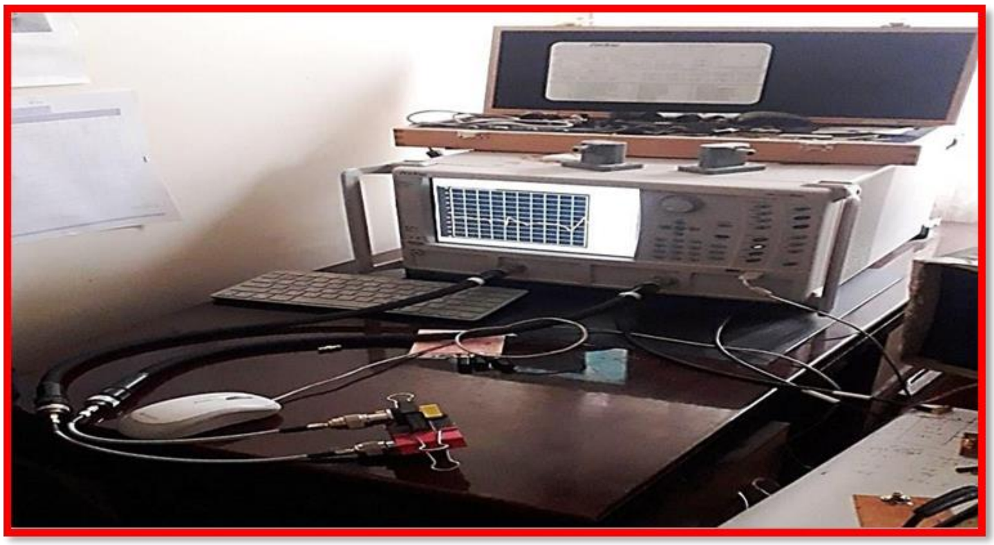


Figure (3-5): The Vector Network Analyze

The (VNA) device measures each of the scattering coefficients (S11, S21, S12, S22) of electromagnetic waves, through which it is possible to obtain the transmittance, reflectivity, impedance and resistance at specific or different frequencies.

3.5. Electrical Tests

The insulating properties were measured by using impedance using a device (LCR - Meter) with specifications (6500 Series, UK) and for a frequency range (50 HZ - 5MHZ) and at room temperature, which is located in the Materials Research Department / Ministry of Science and Technology, The examination was to as shown in Figure (3 - 11) was done through this obtain the real and imaginary dielectric constant, and to calculate the AC electrical conductivity and resistance for all the prepared samples.

Figure (3-6): (LCR) device

4. Introduction

This chapter includes the presentation and discussion of the results obtained through the tests conducted on the research samples, such as the presentation of the results of the analysis of the results of X-ray diffraction (XRD) and (EDX), as well as the study of surface morphology in terms of technical (FE - SEM) in addition to the use of force microscopy As well as conducting magnetic tests (VSM) and deducing from them the magnitude of the coercive force, residual magnetism and critical magnetic moment, and measuring some electrical properties (LCR) and attenuation properties of radar waves such as (reflection, transmittance, absorption, impedance and reflection coefficient).

This chapter also dealt with conducting some mechanical tests such as examining the wear during different times and treating it thermally, finding the wear coefficient and volumetric wear, as well as the wear rate, and observing the extent of wear resistance of the prepared samples, as well as the hardness test of the prepared samples.

4.1. 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% ZnFe2O3/MWCNT
1.15	1.14	1% ZnFe2O3/MWCNT
1.2	1.19	2% ZnFe2O3/MWCNT
1.25	1.23	3% ZnFe2O3/MWCNT
1.29	1.27	4% ZnFe2O3/MWCNT

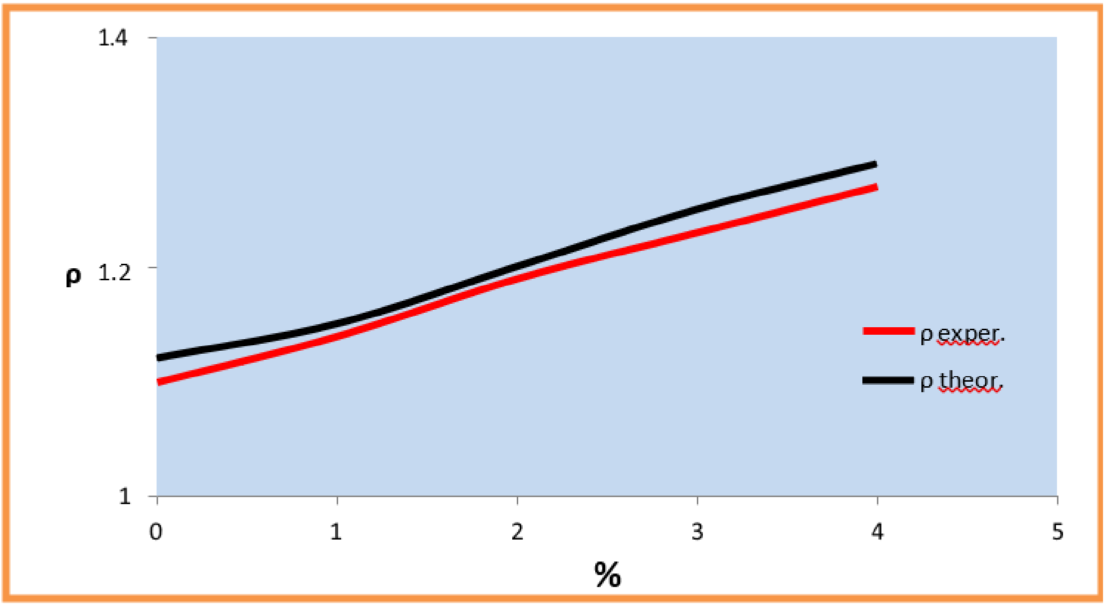


Figure (4-1): Diagram showing the theoretical and practical density with the percentage of the substance

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 sam- ple 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 crys- tal 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]

$$|R\ (dB) = 20\ \mathrm{Log}\ |(Zin-1)/(Zin+1)\ ) \qquad (4\text{-}1)$$

Whereas:

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

$$\tanh\ [(2\pi/c\ \sqrt{(\ 〖\varepsilon\_r\ \mu〗\ \_r\ )})f.d]\ Zin = \sqrt{(\mu\_r/\varepsilon\_r\ )} \qquad (4\text{-}2)$$

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).

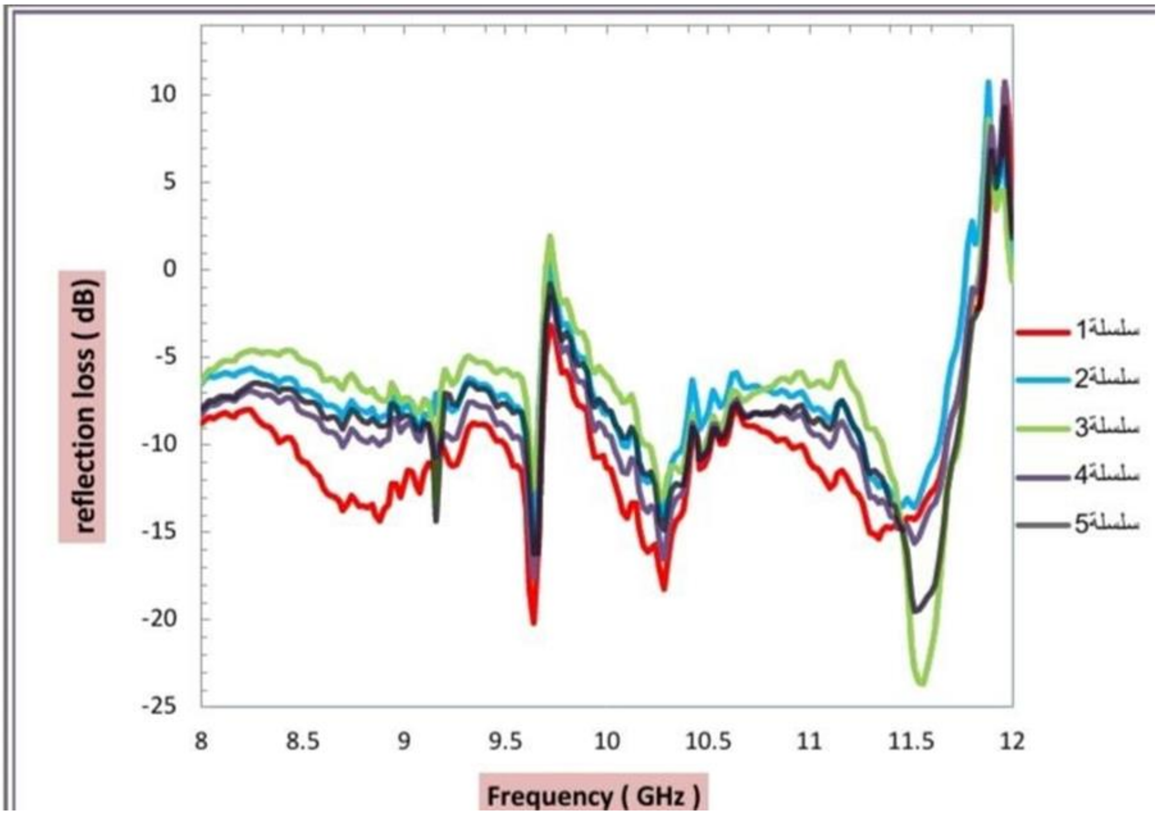


Figure (4-2): The loss in reflection energy as a function of frequency

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

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

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).

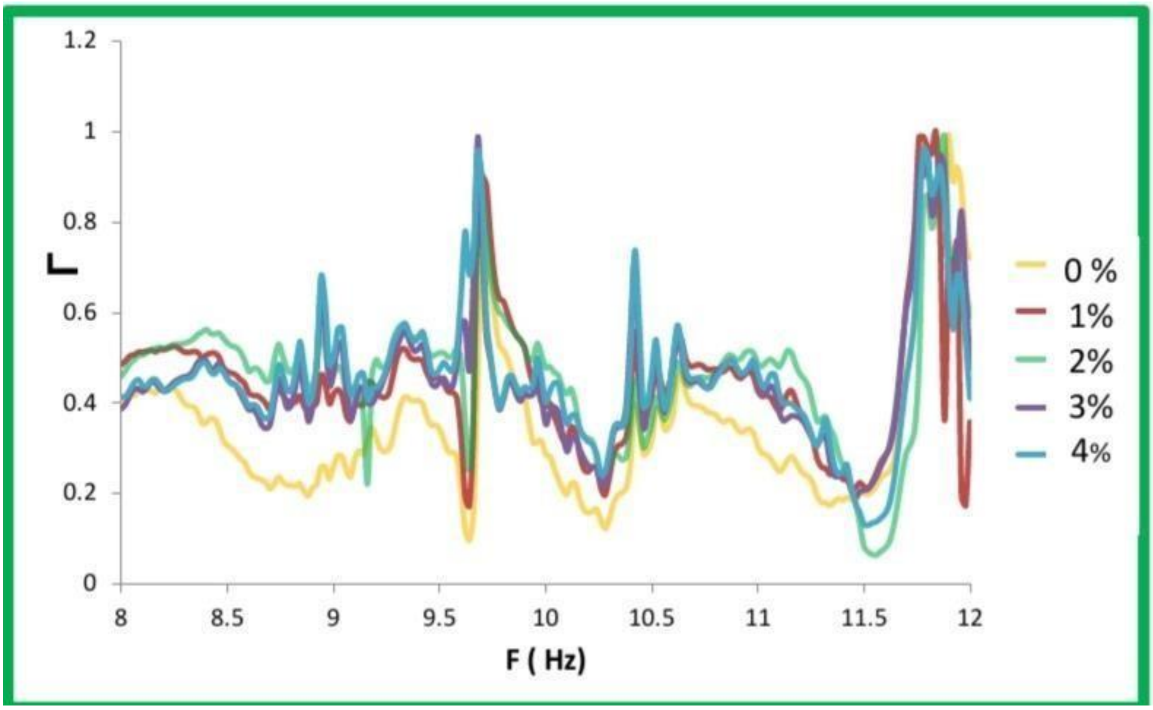


Figure (4-3): The reflection coefficient as a function of frequency

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)

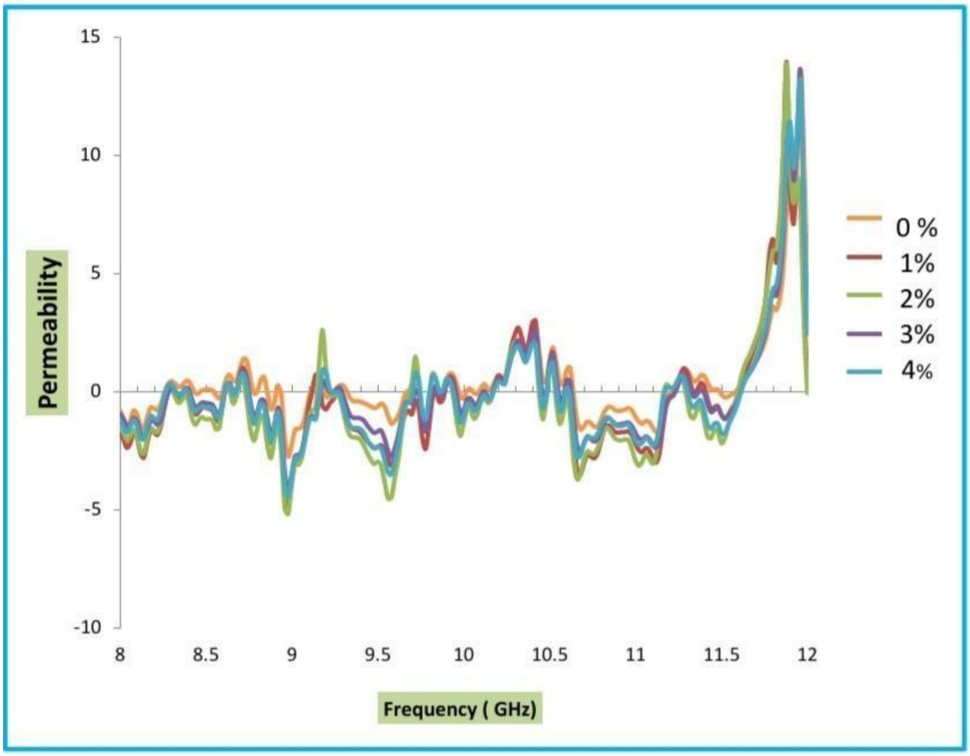


Figure (4-4): The change of transmittance as a function of frequenc Absorbency

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 ac- cording to the following equation [130]:

$$R2 + A2 + T2 = 1 \qquad (4-4)$$

Whereas:

R: Reflectivity. A: absorbency T: permeability

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

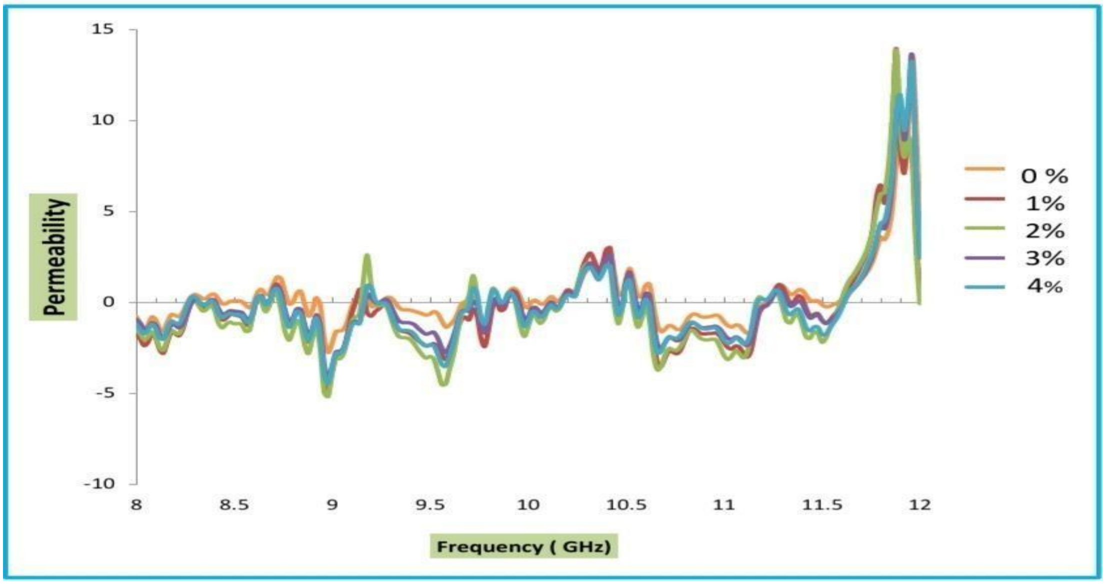


Figure (4-5): Absorbance as a function of frequency Impedances

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)

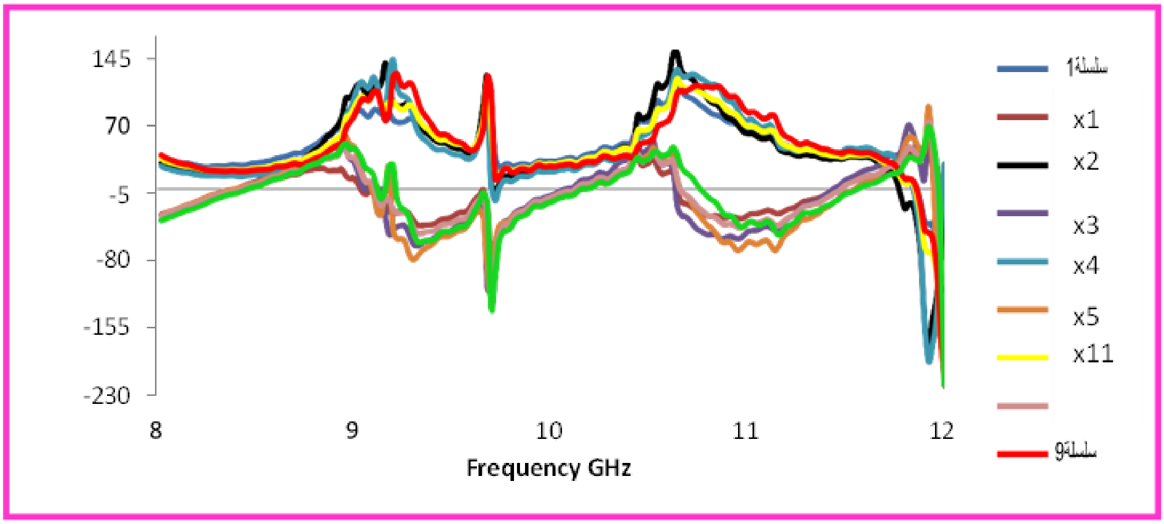


Figure (4-6): Impedance in its real and imaginary parts as a function of frequency

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.

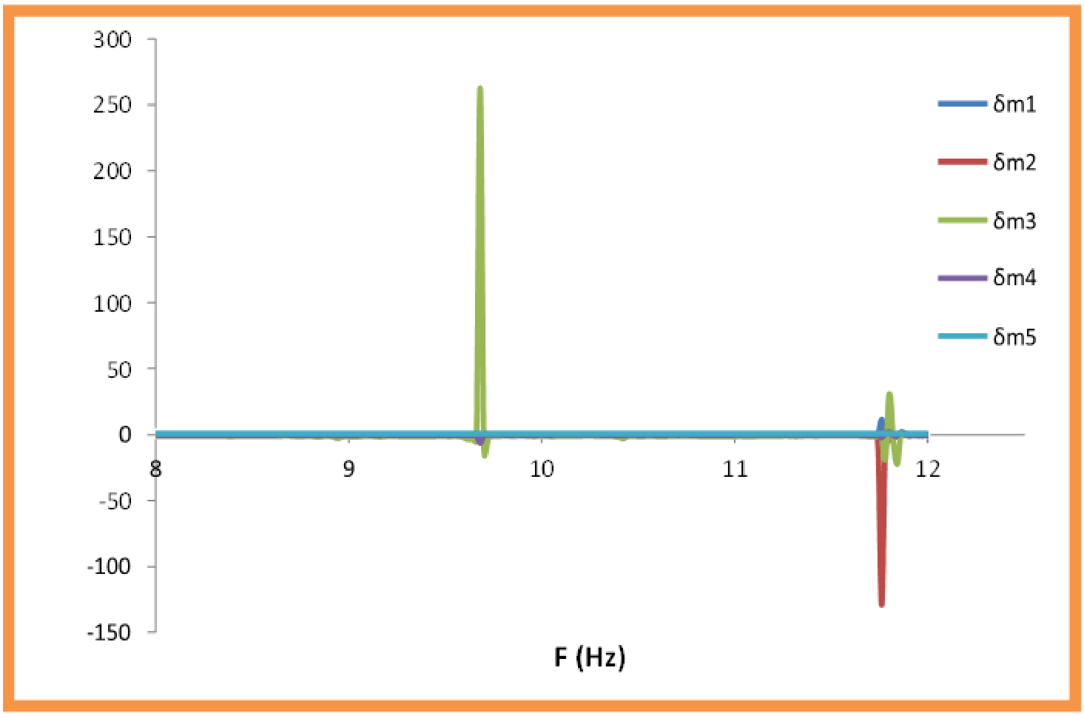


Figure (4-7): The angle of magnetic loss as a function of frequency

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.

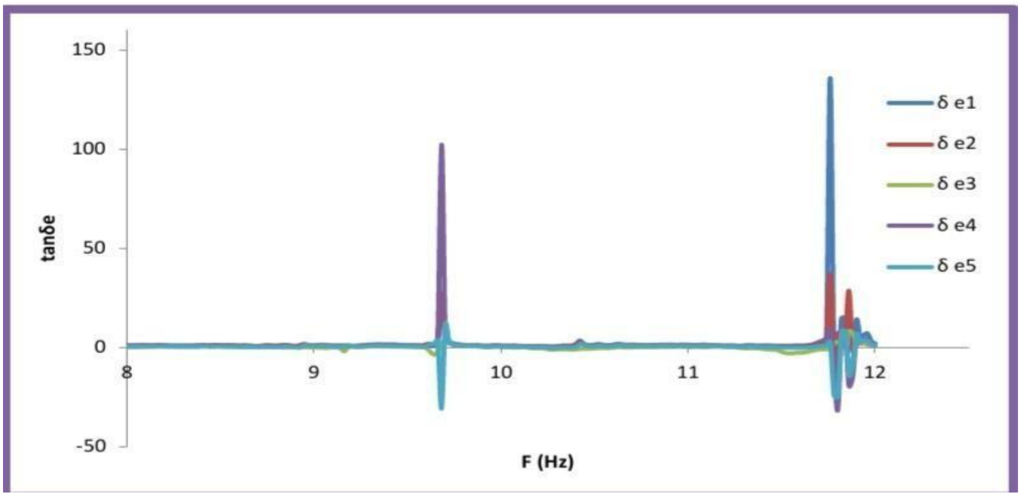


Figure (4-8): The angle of electrical loss as a function of frequencies Electrical Properties

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 ($\epsilon 1$) and the imaginary dielectric constant ($\epsilon 2$) were studied, in addition to conductivity (σ), capacitance, and loss factor.

Real dielectric constant . ($\epsilon 1$)

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.

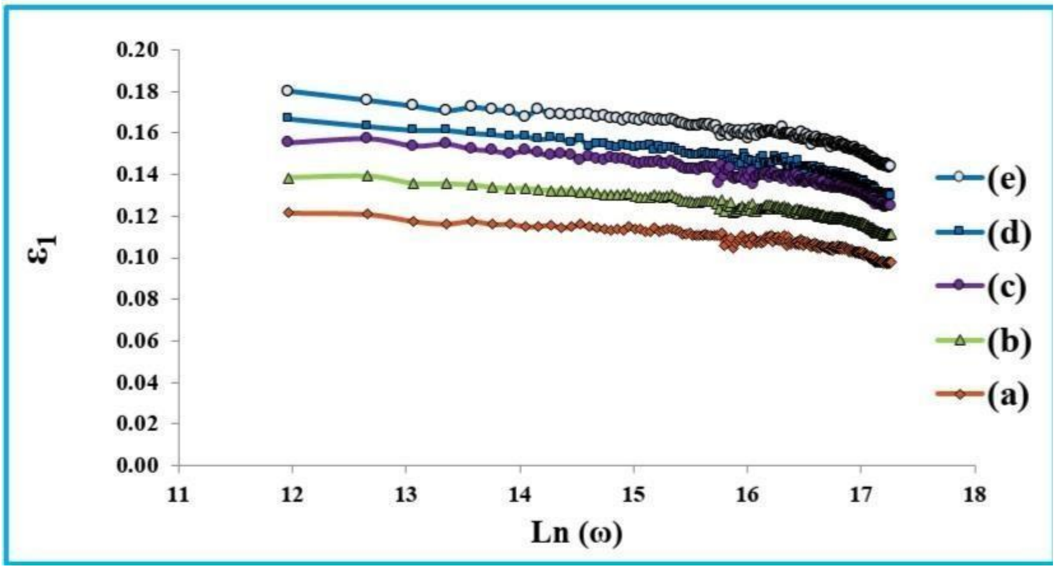


Figure (4-9) an increase in the real dielectric constant with an increase in the ratio of (ZnFe2O3), as the (Zn) increases the real dielectric constant

Imaginary 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

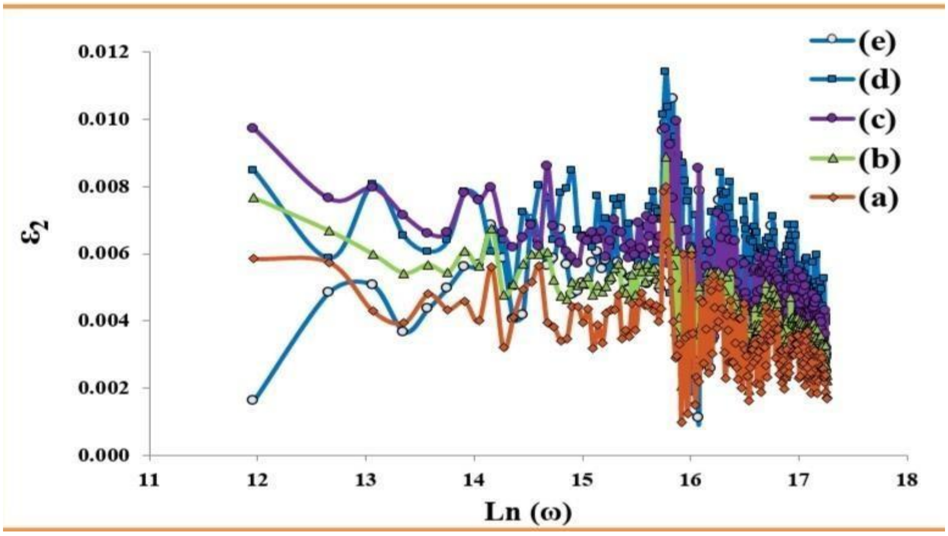


Figure (4-10): The change of the imaginary dielectric constant as a function with the angular frequency

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

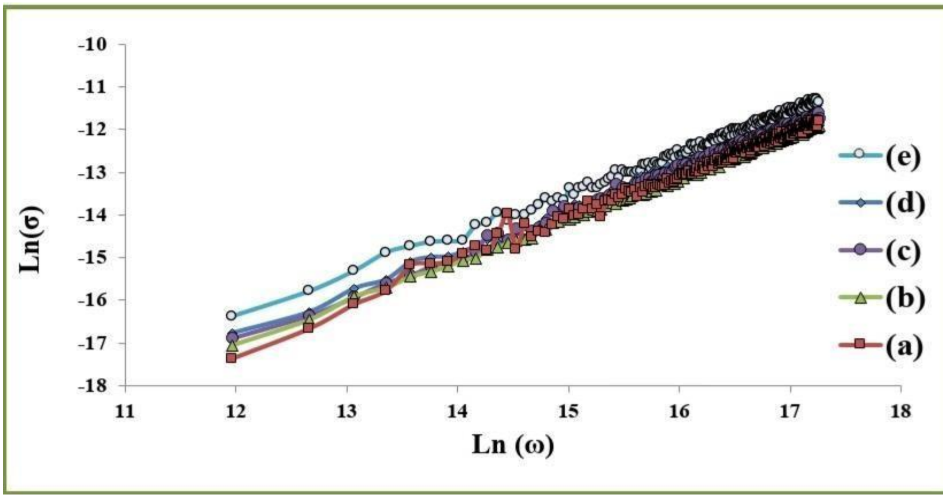


Figure (4-11): The change of the imaginary dielectric constant as a function with the angular frequency

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 in- creases 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.

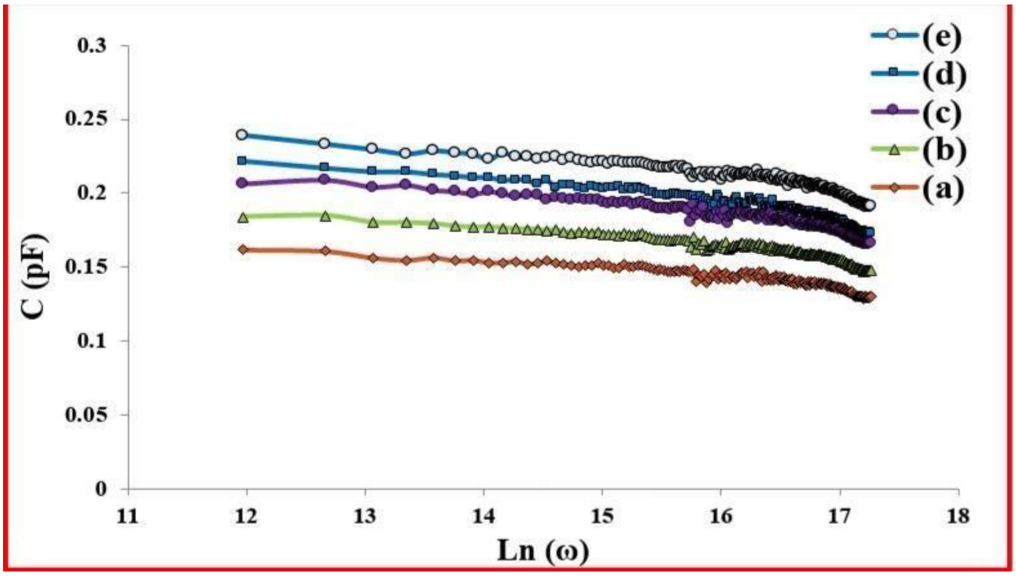


Figure (4-12): The amplitude of the amplitude changes as a function with the angular frequency

Exponent facto

(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

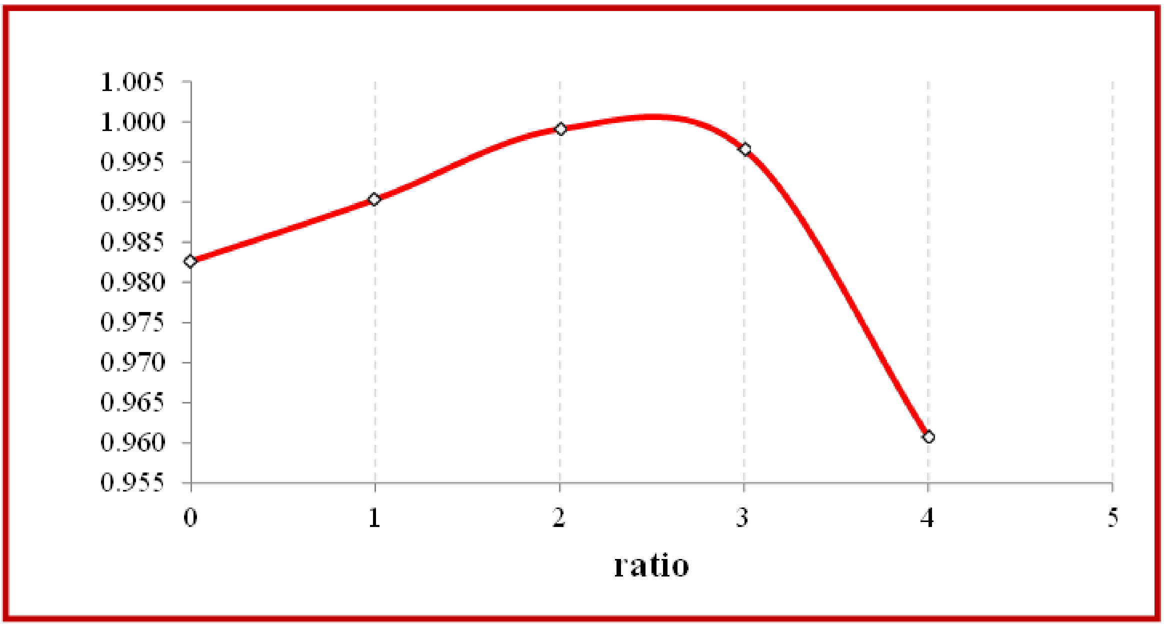


Figure (4-13) represents the loss factor as a function of the percentage of nanocomposites

4.2. Conclusions

.1-Through all the prepared samples, it was found that they have a vary- ing 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 similari- ty 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.

4.3. 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 attenua- tion 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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