5. Microwave studies

5.1. Introduction

The wave pollution on the atmosphere is increasing due to the increase in the communication technology and wireless technology. The wireless technology produces the waves which are hardness some times to the human being and animals. It is very important for the human being to control the wave pollution in the atmosphere. Thus the microwave absorbers place very important in the reduction of the wave pollution in the atmosphere [1-4]. Some of the electronics devices produces excessive self emission of the electromagnetic waves which disturb the functioning of the equipment. Then the microwave absorbing materials are used in the in electronic equipment to controls the excessive self-emission of electromagnetic waves. The EMC (Electro-Magnetic Compatibility) can be achieved when the wave condition at the same time.

The EMC is an essential for developing technology of the field information and communication, particularly in the field of with high packing density of circuits in the electronic devices. EMC became very crucial concern due the rapid growth of the use of the cellular phones and other wireless devices and the increase in the wireless technology, the further problem is added to the EMI technology[5-6].

5.2 Conducting Polymers in Microwave Absorption Applications

The polymers in conducting form have very important properties of good electrical conductivity. Also it has flexible properties like light weight, flexibility and reasonably facile processability. Thus conducting polymers have potential application in the field of EMI, shielding, coating for flexible conductor due to these properties and as broad band microwave absorbers.

The term microwave is utilized to know the EM waves in spectrum of frequency approximately ranging from 1GHz to 30GHz. Thus it is usually the study of frequency in the range of GHz. The approximate range 1GHz-30GHz corresponds to wavelengths
from 30cm to 1cm. The existence of the EM waves was discovered or identified first time in the year 1888 by Heinrich Hertz through building an apparatus that produced and detected microwaves in the UHF region. Study and research in microwaves has not only been an interesting and challenging academic endeavor but it has led to several useful applications which are as follows.

1. Telephone networks
2. Broadcast and Television Systems
3. In RADAR to detect the aircraft
4. To measure the pollutants in polluted areas
5. They can be used for heating
6. In cooking microwave oven
7. For printing, textiles industries, dryers

When it is placed in the periodic electromagnetic fields, microwaves exhibit very important feature in atomic, molecular and nuclear systems. This may due to the rotational transitions in the molecules. By this we get the information on the molecular structure and intramolecular energies by absorption spectra. Hence, to study the some basic properties of the material, the microwaves is powerful experimental tool[7-9].

The magnetic dipole moments associated with the polarons are responsible for the Magnetic permeability of a polymer. When the external magnetic field is applied, then all the dipole moments which are randomly arranged are aligned in the direction of applied magnetic field. Then, in the absence of the magnetic field, the dipole moments are randomly arranged. Hence, when the magnetic field is applied, the dipoles will align in the direction of applied magnetic field. This leads to the permeability of these materials.
Microwaves in many frequency bands (30 MHz–30 GHz) are used extensively in radar, transmission of television programmes, wireless communication, astronomic research, radio spectroscopy and many other things. High packing density of circuits places a very important role in electronic devices/system. Due to this technology, there is drastic development in information and communication technology. Hence, devices have made electromagnetic compatibility (EMC) as an essential requirement to be fulfilled by the electronic devices/systems. In the present day, the use of wireless technology have increased drastically. Thus the electromagnetic Interference (EMI) has therefore, become a matter of crucial concern. EMI is a cause of disturbances on electronically controlled systems for medical, industrial, commercial and military applications[10].

Polymers in conducting state have very important properties such as electrical conductivity along with this it is very light in weight and it is very flexible. Due this properties of conducting polymers, it has increased the interest in microwave applications. Conducting polymers also has very important application in the field of military. Also it has very important property and application in aero space point. In particular, it very useful in the absorption characteristics such as stealth and where CPs appear to be one of the few materials capable of dynamic microwave absorption.

The CPs is also have very vital application in the field of civil and defense development technology for long time due to their ability to eliminate electromagnetic wave pollution and to reduce radar signature. PANI and conducting carbon in polyurethane binder are used to for absorber formulations.

Bulk properties in the Organic/inorganic composite materials which can be improved and compared with those of the base polymers are observed in the present study, Microwave absorption, permittivity, permeability and successful utilization of Polyaniline – WO3, Polyaniline – CdO and Polyaniline – CoO composites as microwave absorbers has been reported.

5.3. Experimental techniques
The prepared samples were shaped to fit exactly in to rectangular X band wave guide (WR 90) for Microwave measurements .The complex scattering parameters corresponds
to the reflection ($S_{11}$ or $S_{22}$) and transmission ($S_{21}$ or $S_{12}$) in the composites samples using a vector network analyzer (HPES6719). Full to port calibrations were initially done on the test setup in order to remove errors due to directivity, source match, load match, isolation etc, in both the forward and reverse direction. By the measurement of scattering parameter, the complex permittivity, permeability can be determined. Then, the EM – Wave absorption (return loss) properties of all the prepared PANI and composites are measured. The polymer composite plate with thickness are placed in the highly conductive metal sheet in the single-layer observers, the input impedance ($Z_{in}$) at the air material interface is given by [10-18]

$$Z_{in}=Z_o \left( \mu^*/\varepsilon^* \right)^{1/2} \tanh \left[j(\omega/c) \left( \mu^*/\varepsilon^* \right)^{1/2} d \right]$$

Where $Z_o$ is the characteristic impedance of the free space

$\mu^*$ is Complex relative permeability

$\varepsilon^*$ is Permittivity of the free space

$\omega$ is the angular frequency and

c is the velocity of light.

The input impedance $Z_{in}$ can be calculated with the equation given below

$$Z_{in}=j Z_o \left( \mu^*/\varepsilon^* \right) \omega d/c$$

The return loss RL (in decibel dB) is given by

$$R_L=20 \log \left( Z_{in} - Z_o \right) \left( Z_{in} + Z_o \right)$$

5.4. Results and Discussions

5.4.1. Polyaniline / WO$_3$ composites

Variation of Return loss $R_L$ of the PANI- WO$_3$ composites with different wt% of WO$_3$ at X-band frequencies is given in Fig.5.1. From this Fig.5.1, it is clear that the Return loss $R_L$ decreases with the increase in wt% of WO$_3$. The multi band spectra in the return loss is mainly due to the resonance between the material and the applied frequency.

The behavior of electromagnetic absorption on the dielectric and magnetic properties of the materials are represented by complex permittivity and permeability. These composites can have both dielectric as well as magnetic properties due to the presence of
WO₃. So the observed Return loss $R_L$ characteristics can be attributed to the combined effect of dielectric and magnetic properties of these composites. It is observed that the return loss of the composites decreases as the volume fraction increases. Therefore the Return loss $R_L$ properties of PANI/WO₃ composites has shown strong dependence of WO₃ volume in PANI. The present work shows that the PANI/ WO₃ based Return loss $R_L$ exhibit better in of 10.5 – 11.5 GHz which is good among all the reported reports.

![Graph showing Return loss of PANI/WO₃ composites](image)

**Fig.5.1.** Return loss of PANI/ WO₃ composites

### 5.4.2. Polyaniline / CdO composites

**Fig.5.2** is the variation of return loss with frequency for the composites 10-50 weight percent in PANI at 8 to 12 GHz frequency range. It is observed that, as the frequency was increased, the return loss of all the composites also decreases in multiple bands. Compared to the return loss of the composites, the composite 10 weight percentage of CdO shows the maximum return loss. As the content of cadmium oxide is increased in the Polyaniline matrix, the return loss of the composite decreases which may be due to
the resonance [6-7]. The multi band spectra in the return loss is mainly due to the resonance between the material and the applied frequency.

Return loss $R_L$ (in decibel, dB) is obtained by [20-27]

$$R_L = 20 \log \left[ \left( Z_{in} - Z_0 \right) \left( Z_{in} + Z_0 \right) \right]$$

**Fig.5.2.** Return loss of PANI/ CdO composite

### 5.4.3. Polyaniline / CoO composites

**Fig.5.3** shows the variation of return loss spectra at X-band frequency for the composites samples 10wt%-50wt% in polyaniline in the frequency range 8 to 12 GHz. It is observed, that the decrease in the $R_L$ value in multiple band form as frequency increased from 8 to 12 GHz. Also, it is observed there is the decrease in the return loss as the content of the cobolt oxide increases in the polyaniline matrix. Thus the return loss decreases as the composition increases. Among all the composites, the composite with 10wt% of Cobolt oxide in PANI matrix showing the maximum return loss and also observed that the return loss increases with the decrease of Cobolt oxide in PANI this
may be due to resonance [9-10]. The multi band spectra in the return loss is mainly due to the resonance between the material and the applied frequency. Return loss RL (in decibel, dB) is obtained by

$$R_L = 20 \log \left( \frac{(Z_{in} - Z_o) (Z_{in} + Z_o)}{Z_o^2} \right)$$

**Fig.5.3.** Return loss of PANI/CoO composite
5.5 References


