Overview of Electromagnetic Interference and Absorption

Abstract—Electromagnetic interference has become a major issue now a days due to increase in use of high frequency devices. Now this has lead to move the interest of the globe towards microwave absorption techniques and its ultimate solution is to develop materials which can absorb these electromagnetic waves. These materials should have high reflection loss, wide bandwidth of absorption, should be economical and light weight. The same should possess properties of permittivity and permeability. It should be with a large value of Curie temperature and have suitable saturation magnetization.

Conclusively, techniques of absorption are also presented below.

Keywords—Electromagnetic absorption, electromagnetic properties, impedance matching.

There is continuous rise in electromagnetic pollution due to today’s wireless communication. This has now become threat to the whole world. The electromagnetic pollution has not only affected human health but also has become a concern to a National security and defense.

To deal with same problem, electromagnetic material came into existence. As displayed in figure 1, an efficient absorbing material should have strong absorption, low density and wide absorption bandwidth. Now if we want to maximize the absorption, incident wave must enter absorberat its largest (impedance matching) and the em wave arriving at the material must be absorbed within the precise absorber thickness (attenuation characteristic). Electromagnetic absorbing material has a capacity to absorb electromagnetic energy and convert it into heat. Along with above given properties it should have Curie temperature at its higher side, should possess the properties of permittivity-permeability, should have excellent saturation magnetization and should be economical.

When electromagnetic wave falls on shielding material it undergoes reflection, transmission and absorption.

Now when the electromagnetic energy of wave deals with materials’ electronic and molecular structure, heat energy is generated within the material due to dissipation of energy. This newly generated energy can be heat or any other form of energy.

Figure 1. Desired properties of good absorbers

These absorbers work on different mechanisms, namely 1. Shielding effectiveness 2. Impedence matching Mechanism 3. Quarter wavelength mechanism.

1. Shielding Effectiveness:

In figure 2, when the electromagnetic waves fall on the absorbing material, some of its energy is reflected back while some is absorbed, and the remanent of the waves are encountered at other side of material, this is termed as Shielding.

Now, Shielding Effectiveness (X) is given by

$$X = 10 \log \left( \frac{Y_1}{Y_2} \right)$$

Where,

- $Y_1$-Signal received in the presence of shielding material
- $Y_2$-Signal received in the absence of shielding material

Now the Mechanism of Shielding Effectiveness has $S_R, S_A, S_M$ i.e $S_T=S_R+S_A+S_M$

Where,

- $S_R$-Reflection
- $S_A$-Absorption
- $S_M$-Multiple internal reflection

The phenomenon that takes place since the impedance of the electromagnetic waves falling on the material does not match with the impedance of absorber (material), is termed as Reflection.

Mathematically this equation is given by
\[ SE_{R} = -10 \log(\sigma/16f) \]

\( \epsilon \) is permittivity & \( \mu \) is permeability,

\( \sigma_T \) is total electrical conductivity of material.

From the above equation, we can say that those materials are good reflectors of electromagnetic waves which own the property of immense electrical conductivity.

Internal reflections may occur within the material when some electromagnetic waves penetrate the surface of material. The materials with good specific internal surfaces possess the characteristic of multiple reflections. Composites having large number of fillers in them possess multiple reflection mechanism. This is because of the fillers having different dielectric properties. These dielectric properties of material are responsible for absorption of electromagnetic waves within the material, also giving rise to heat energy due to these internal reflections.

There are many techniques of shielding effectiveness of a material. Many of the techniques used a VNA (Vector Network Analyzer) in which a radio frequency signal is developed and then an Antenna transmits it. Now shielding effectiveness of material can be calculated by knowing energy within the reflected signal and the transmitted one.

2. Impedance Matching Mechanism:

Suppose electromagnetic wave incidents on a lossy dispersive material then incident signal

\[ S_I = S_R + S_T + S_T \]

Here, \( P_I \) incident signal

- \( P_R \) is reflected signal
- \( P_A \) is absorbed signal
- \( P_T \) is transmitted signal

Now the reflection of electromagnetic wave is given by surface reflection plus multiple reflections

This multiple reflections give rise to extended transmitted routes of electromagnetic waves which further enhance absorbing ability of absorbents. Now the incident signal leads to the creation of heat energy in the absorber majority due to interactions of materials molecular and electronic structure with the given electromagnetic field. This causes energy dissipation as a result of thermal energy generation.

We have two techniques to enhance the absorption of electromagnetic waves in the material, 1-by increasing transmitted routes of electromagnetic waves by managing the nanostructure (pores, multilayer, etc) 2-by manipulating the electromagnetic parameters (permittivity & permeability)

Relative complex permittivity,

\[ \epsilon_r = \epsilon' - j\epsilon'' \]

Relative complex permeability,

\[ \mu_r = \mu' - j\mu'' \]

Here, \( \epsilon' \) and \( \mu' \) are the real parts of \( \epsilon_r \) & \( \mu_r \) respectively and are responsible for energy storage.

While \( \epsilon'' \) and \( \mu'' \) are imaginary parts and deal with the energy dissipation, that could be from conduction, resonance or relaxation mechanisms.

By transmission line theory,

The input impedance \( Z_{in} \) of single layer absorber

\[ Z_{in} = Z_0 (\mu/\epsilon)^{1/2} \tanh \left( j2\pi f t \right) / \left( \epsilon (\mu \epsilon)^{1/2} \right) \]

Where \( Z_0 \) = characteristics impedance of free space
- \( t \) - Thickness
- \( f \) - Frequency
- \( \epsilon \) - Complex permittivity
- \( \mu \) - Complex permeability
- \( c \) - Velocity of light

Reflection loss is given by

\[ RL = 20 \log \left( \frac{|Z_{in} - Z_0|}{|Z_{in} + Z_0|} \right) \]

If the values of \( \epsilon_r \) and \( \mu_r \) are close, the reflection is less & RL is more. The phenomenon of Dielectric loss is mainly the result of conductivity loss and polarization loss, whereas polarization loss is given by addition of ionic polarization, electronic polarization, dipole orientation polarization & interfacial polarization. But Ionic and Electronic polarization can be overlooked here, since its occurrence takes place at high frequency region (10^3 to 10^6 GHz).

Figure 2. Flow of EM wave through absorptive material
Quarter Wavelength Mechanism

From the figure 3, we can see that there is a ferrite absorber layer over a metal plate, now when the microwave signal (R1,R2,R3,R4 here) is incident on the absorber having thickness(d) of 1/4\textsuperscript{th} wavelength of signal, some of the waves will be reflected from the front surface of absorber(R1,R4 here) itself while some will be transmitted through it (R2,R3).

The transmitted waves which went through the absorber layer, gets reflected after reaching the metal surface and reaches the front surface of the absorber again. Now these reflected waves which have arrived from the front face of the absorber are equal in magnitude but 180° out of phase with those waves which have reflected from the metal plate. In this way there is cancellation of each wave here and total reflection is zero.

This mechanism is termed as Quarter Wavelength Mechanism.

![Quarter Wavelength Mechanism Diagram](image)

**Figure 3. Quarter wavelength mechanism**

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Thus with the help of mentioned mechanisms, electromagnetic interference can be controlled by absorber/shield.