# A Review Based on Effects of Change in Thickness and Number of Layers on Microwave Absorbing Materials

**Harsroop Kaur[1], Gagan Deep Aul[2]**

[1]Electronics and Communication Department, DAV University, India

[2]Assistant Professor, Electronics and Communication, Department, DAV University, India

**Abstract:** ***This review is essentially based on the results of microwave absorbing materials which are increasing in demand due to their unique absorbing microwave energy and promising applications in the stealth technology of aircraft, television image interference of high-rise buildings, and microwave dark-room and protection. Extensive study has been carried out to develop new microwave absorbing materials with a high magnetic and electric loss. Electromagnetic absorbers are specifically chosen or designed materials that can inhibit the reflection or transmission of electromagnetic radiation. This can be accomplished with materials such as dielectrics combined with metal plates spaced at prescribed intervals or wavelengths. Various parameters such as particular absorption frequencies, thickness, component arrangement and configuration of the materials determine the capabilities and uses of these materials. In this review the effect of single and multilayer types of materials as well as effect of variation in thickness of materials on microwave absorption properties is examined and concluded.***

**Keywords:** Microwave absorbing materials, MAMs, RAMs, Layers, Thickness

## 1. Introduction

Absorbers in the RF/microwave realm are the materials that attenuate the energy in an electromagnetic wave. Absorbers are used in a wide range of applications to eliminate stray or unwanted radiation that could interfere with a system's operation. Absorbers can be used externally to reduce the reflection from or transmission to particular objects. They can also be used to recreate a free space environment by eliminating reflection in an anechoic chamber. It is possible to describe the interaction of an electromagnetic wave with microwave absorbing materials (RAM's) as a phenomenon where the electromagnetic energy is transformed into thermal energy. According to the principle of energy conservation, the electromagnetic wave impinging on a material can be reflected, attenuated or transmitted through the material. The response of the material to the wave depends on its intrinsic characteristics [6]. Absorbing material can be of different types, shapes and forms such as:

- Microwave Absorbing Materials (Foam)
- Microwave Absorbing Materials (Rubber)
- Microwave Absorbing Materials (Coating)
- Ferrite Absorbing Block
- Absorbing PuttySingle and multilayer materials

Here the last category is taken into account, evaluated and concluded. RAM'S are broadly divided into two types [8]:

a) Narrowband or "tuned" RAM is one in which its peak performance is focused to a specific, narrow frequency or frequency band. This type of RAM is more likely used for attenuating the undesired output from radar or other type of system that transmits a narrow frequency spectrum.
b) Broadband RAM has its performance spread out over a wide frequency range. This type of RAM is more likely used for simultaneously attenuating the undesired emissions from
c) an EW system or several narrowband systems, where attenuation of signal energy across a wide band of frequencies is required. In general, greater attenuation performance (25–30 dB) can be achieved with a tuned RAM, but the performance is available only over a narrow frequency range. A broadband RAM will provide somewhat less attenuation performance (15–20 dB) but will do so over a much wider frequency range [13].

Absorber theory: Absorbers generally consist of a filler material inside a material matrix. Absorbers are characterized by their electric permittivity and magnetic permeability. The permittivity is a measure of the material's effect on the electric field in the electromagnetic wave and the permeability is a measure of the material's effect on the magnetic component of the wave. The permittivity is complex and is generally written as:

$$\boldsymbol{\varepsilon * = \varepsilon' - j\,\varepsilon''} \qquad \text{Eq 1 [6]}$$

The permittivity arises from the dielectric polarization of the material. The quantity ε' is sometimes called the dielectric constant which is something of a misnomer when applied to absorbers as ε' can vary significantly with frequency. The quantity ε" is a measure of attenuation of the electric field cause by the material.

The electric loss tangent of a material is defined as:

$$tan\,\delta e = \varepsilon''/\,\varepsilon' \qquad \text{Eq 2 [6]}$$

The greater the loss tangent of the material, the greater the attenuation as the wave travels through the material. Analogous to the electric permittivity is the magnetic permeability which is written as:

$$\mu * = \mu' - j\mu'' \qquad \text{Eq 3 [6]}$$

With magnetic loss tangent defined as:

$$tan\ \delta m = \mu''/\mu' \qquad \text{Eq 4 [6]}$$

The permeability is a measure of the material's effect on the magnetic field. Both components contribute to wavelength compression inside the material. Additionally, due to the coupled EM wave, loss in either the magnetic or electric field will attenuate the energy in the wave. In most absorbers, both permittivity and permeability are functions of frequency and can vary significantly over even a small frequency range. If the complex permittivity and permeability are known over a frequency range then the material's effect on the wave is completely known. The units of permittivity are farads/meter and the permeability units are henrys/meter. The actual values for most materials can be cumbersome in calculation. For this reason they are usually compared to the permittivity and permeability of a vacuum. These values are

$\varepsilon o$ = 8.854x10$^{12}$ farads /meter and
$\mu o$ = 4 $\pi$x10$^{-7}$henrys /meter [6]

The values ε* and μ* then become dimensionless. Since ε is dependent on the dielectric polarization which always opposes the electric field, ε for all materials is greater than that of free space and hence is always greater than 1.

*L. C. Folgueras et al [1]* produced RAM's in the form of single and multi-layer lightweight thin flexible sheets containing the conducting polymer polyaniline dispersed in a polyurethane matrix. The sheets consisted of 1 to 4 layers of absorbing materials, each having the same electromagnetic properties. Bulk electromagnetic properties of these RAMs were analyzed using the waveguide technique in the frequency range of 8 to 12 GHz (X-Band). Conducting polyaniline was prepared and obtained as a powder. The polyaniline powder was mixed with polyurethane at the proportion of 15% w/w. The attenuation of the incident radiation by the RAMs was obtained from the difference between the reflectivity of an aluminium plate (reference material) and the same aluminium plate coated with the RAMs. The prepared mixture of polyaniline and polyurethane was applied to a substrate as layers. Measurements were carried out considering only the bulk properties of the layered material. Therefore the measured values of permittivity and permeability refer to 1, 2, 3and 4layer materials; the thickness of these layers were 2.2, 2.6, 2.8, and 3.2 mm, respectively.

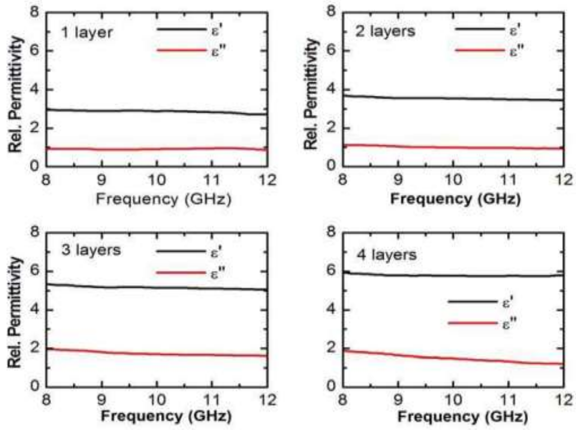


**Figure 1:** Relative permittivity of layered materials [1]

From Figure 1, it can be observed that although only one type of material (polyaniline dispersed in polyurethane) was used, the effect of using layers is to change the bulk property of the RAM, with an average change of about 100% in **ε**' and **ε** ".The bulk real permittivity increased with the number of layers, whereas the imaginary permittivity showed significant changes when the number of layer used increased from 2 to 3.

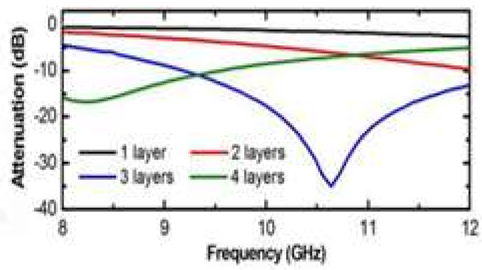


**Figure 2:** Attenuation of the electromagnetic radiation by the layered RAMs [1]

Figure 2 shows, that the material consisting of 3 layers, presented good absorption characteristics about 10.6 GHz. The resonance peaks of the other RAMs consisting of 1 and 2 layers are outside the range of frequencies studied. The 4-layer RAM has a weaker resonance peak at about 8.2 GHz. The 4 RAMs behaved as narrowband absorbers [11].

Luiza de Castro Folgueras et al [2] produced sheets of microwave absorbing materials using conductive polyaniline dispersed in a silicone rubber matrix and to characterize the electromagnetic properties like absorption, transmission and reflection of electromagnetic energy; and electric permittivity and magnetic permeability of these sheets in the X-band (8 – 12 GHz). Variation of the thickness and number of layers leads to alteration of electromagnetic properties of RAM'S. Small samples (about 2 cm) were cut from the sheets and inserted into the waveguide. The complex electromagnetic parameters, (permittivity and permeability) were obtained from the measured values of the S-parameters using commercial software specifically designed for this task. The attenuation of the incident radiation by the RAM's was obtained from the difference between the reflectivity of an aluminium plate and that of the same aluminium plate covered with the RAM.

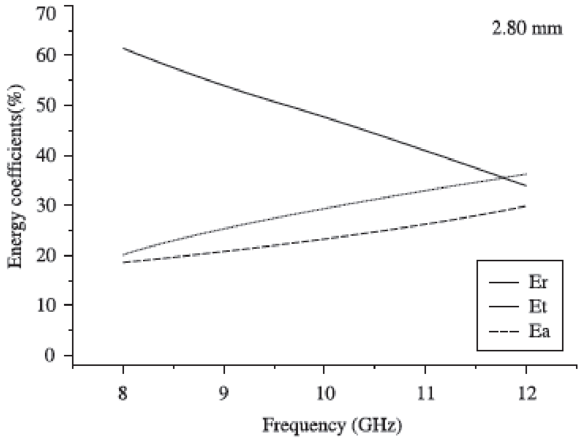


**Figure 3:** Curves of coefficients (in percentages) absorbed (Ea), transmitted (Et) and reflected (Er) energies: RAM thickness, 2.80 mm, silicone matrix L9000 [2]

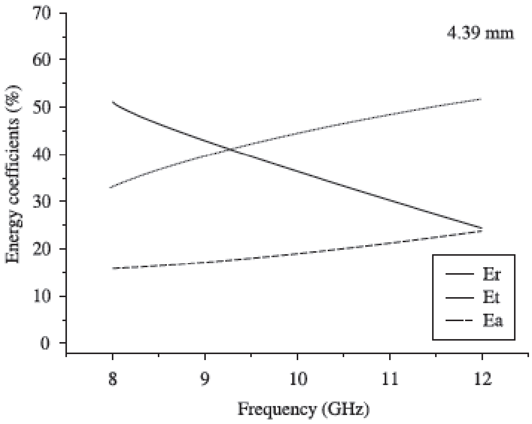


**Figure 4:** Curves of coefficients (in percentages) absorbed (Ea), transmitted (Et) and reflected (Er) energies: RAM thickness 4.39 mm, silicone matrix RTV630 [2]

**Table 1**: Observation from **Error! Reference source not found.** Figure 3 and Figure 4 [2]

| S. no | Substrate | Thickness (mm) | Max Energy Absorption (%) |
|---|---|---|---|
| 1 | Metal Plate | 2.80 | 18.5 |
| 2 | Metal Plate | 4.39 | 16.2 |
| 3 | Aluminium Plate | 2.80 | 88 |
| 4 | Aluminium Plate | 4.39 | 71 |

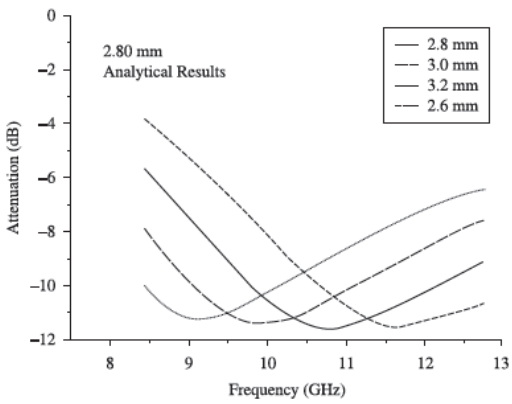


**Figure 5:** Energy absorption of single-layer RAMs as a function of frequency and different layer thicknesses: RAM produced with silicone rubber L9000 [2]

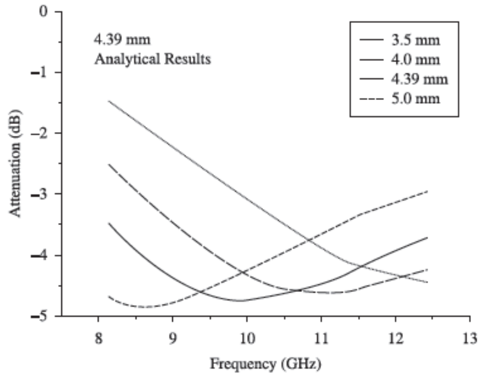


**Figure 6:** Energy absorption of single-layer RAMs as a function of frequency and different layer thicknesses: RAM produced with silicone rubber RTV6300 [2]

From Figure 5 and Figure 6, it can be seen that there is displacement of resonance peak (maximum absorption) as a function of the thickness. Also, the RAM produced with the silicone rubber L9000 absorbs electromagnetic energy more efficiently.

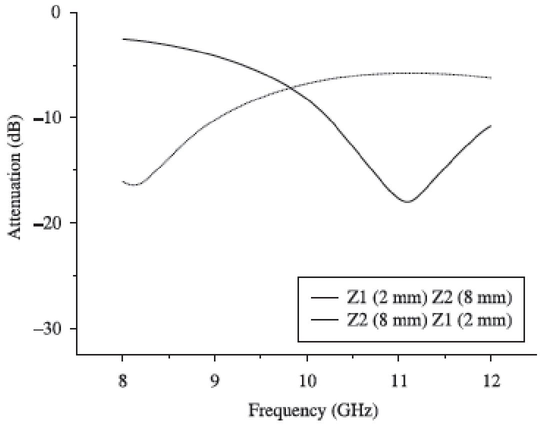


**Fig 7**

Fig 7 Simulations of two-layer RAM's attenuation of electromagnetic radiation as a function of frequency, thickness and stacking order of the absorbing materials. Z1, RAM produce with L9000 silicone rubber; Z2, RAM produce with RTC6300 silicone rubber: a) layers 2 and 8 mm thick [2]

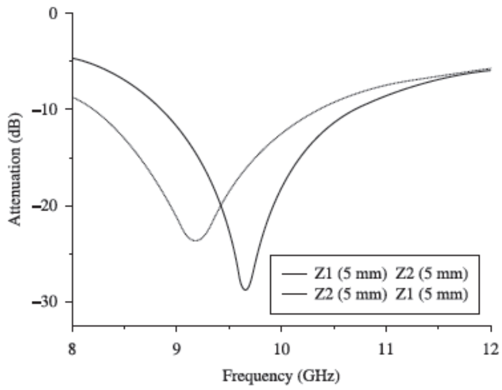


**Figure 8:** Simulations of two-layer RAM's attenuation of electromagnetic radiation as a function of frequency, thickness and stacking order of the absorbing materials. Z1, RAM produce with L9000 silicone rubber; Z2, RAM produce with RTC6300 silicone rubber: both layers are 5mm thick [2]

Fig 7 and Figure 8 shows that the order in which these materials are stacked plays an important role in determining the final properties of the RAM, affecting the amplitude and the position of the resonance peak. [9] [15]

It can be concluded that the attenuation pattern of electromagnetic energy by the absorbing materials suggests that the electrical conductivity of these materials is related to the quantity of absorbing centres (conducting polyaniline) and type of polymer matrix (silicone rubber), which modify the impedance of absorbing materials. In absorbing materials, a large fraction of the incident energy must be attenuated, which is a consequence of the equilibrium between electric conductivity and electric losses [14].

Mingxia Chen et al [3**]** Multilayered carbon nanotubes/silicon dioxide (CNTs/SiO2) electromagnetic wave absorbing ceramic matrix composite material was fabricated by hot-pressed sintering. The gradient layer structure was designed to improve its absorbing properties. The multilayered CNTs/SiO2 composite was shaped by adding five kinds of mixed powders with different CNTs content to the graphite die in turn, and its average CNTs content was 5 wt%. Meanwhile, a single layered composite with the same content of CNTs (5 wt %) was fabricated as a contrast sample. The electromagnetic interference (EMI) shielding effectiveness (SE) and reflecting effectiveness (RE) were studied with insertion loss (IL) and return loss (RL) measurements in the range of 8–12 GHz.

For a good absorbing material, there are two requirements: first, the intrinsic impedance of material is made equal to the impedance of free space. Second, the incident electromagnetic wave must enter and be attenuated rapidly through the material layer. However the CNTs/SiO2 composite materials cannot fulfil these two conditions at the same time. So some changes such as structure designs are needed. Some researchers found that double layered or multilayered structure with matching layer and absorption layers can lower the reflection loss.

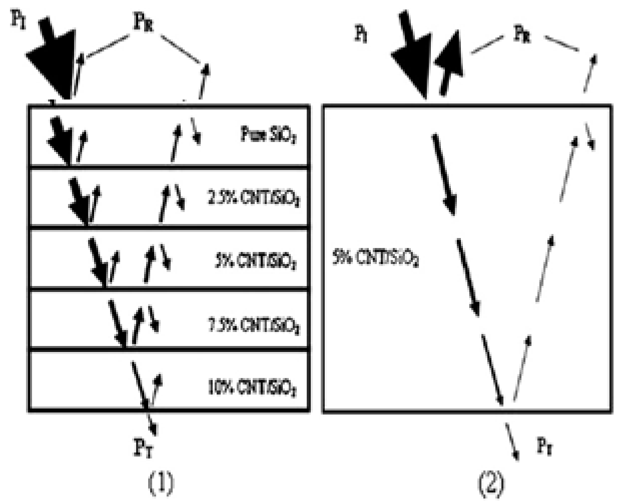


**Figure 9:** Schematic diagram of the incidence, reflecting and transmitting of the electromagnetic wave through the CNTs/SiO2 composite materials: (1) multilayered sample (2) single layered sample [3]

The absorbance of the 5 wt% CNTs/SiO2 is 49.83%. The multilayered sample's is 74.83% which is 1.5 times as high as the 5 wt% CNTs/SiO2 sample's. This means the multilayered structural design can improve the absorbance and reduce the reflection.. From Figure 9 it can be observed that the topside layer is made of pure SiO2 and bottom side layer is made of 10%CNT/SiO2. And from top to down the content of the CNTs is increased layer by layer. Due to the good conductivity of the CNTs, the conductivity of the composite material will increase layer by layer. The reflection loss of the materials for the electromagnetic wave will increase with relative conductivity and relative permeability of the materials. So the reflectance of the layers goes higher as the content of the CNTs increases from topside to bottom side, due to this reason the electromagnetic wave can go deeper in the multilayered sample than the single layered sample. As the average contents of the CNTs in the two samples are the same, the electromagnetic wave that goes into the material can be absorbed by the CNTs. The absorbing effect can be enhanced with this kind of gradient multilayer structural design.[10]

Y.S. Lee et al [4] took the different thickness of rice husk microwave absorber and showed its effects on microwave absorption performance. The sample microwave absorber was fabricated using rice husk material. The complex permittivity will be measured using an Agilent dielectric probe. The reflection loss and absorption performance of rice husk microwave absorbers will be investigated. This rice husk microwave absorber was simulated using the CST Microwave Studio simulation software. The ability of absorption microwave frequency between different thicknesses of the rice husk microwave absorber was compared.

| Thickness of Rice husk sample(mm) | Absorption | |
|---|---|---|
| | Best point, % | Average point, % (12 - 18 GHz) |
| 1 | 2.75 | 1.68 |
| 2 | 18.06 | 11.89 |
| 3 | 44.99 | 33.50 |
| 4 | 65.56 | 54.76 |
| 5 | 75.08 | 69.13 |

Table 2 Comparison of absorption in different thickness of rice husk sample [4]. Error! Reference source not found. shows that the highest percentage absorption is the sample with thickness 5 mm which its best point 75.08% at 18 GHz and an average point in 12- 18 GHz is 69.13 %. The lowest percentage absorption is the 1mm thickness sample where the best point of absorption is only 2.75 % and the average point is 1.68 %. The difference average absorption point between 1 mm and 5 mm of thickness sample are 67.45 %.It can be concluded that absorption increase with increase in thickness of material [12].

Hoa Zou et al [5] prepared silicone rubber microwave absorbing materials (RMAMs) based on ferrite as the major absorbent by the mechanical blending method. The effects of thickness of ferrites on the mechanical properties, processing performance, and absorbing property of RMAM were estimated. With increase in thickness of RMAM and as the amount of absorbents increases, the absorption peak moves toward low frequency, the absorption frequency bandwidth is narrowed and the reflectivity first decreases and then increases. The optimum thickness is 1.5-1.7mm and the amount of ferrite is 450 parts per hundreds of rubber [7].

## 2. Conclusion

It can be concluded that as the number of layers of microwave absorbing materials increases, absorption also increases. This means absorption property of a multilayered structure is more than that of a single layered structure and by varying number of layers ,amount of absorption can be enhanced which further implies that amount of reflection can be reduced simultaneously. In case of multilayer materials, amount of absorption also depends upon the order of stack that is which composition of RAM is placed at which number layer because absorption for different composition of materials is distinct. The change in absorbing property of a microwave absorbing materials with thickness alters from material to material. Some materials require more thickness whereas some needs less thickness for the same amount of absorption but we aim at getting high absorption with least thickness. It is observed that absorbing properties of thinner conducting aniline are better than thicker material which is our aim. In case of rice husk, thicker material gives more absorption but its advantage is that it is cheap and easily available.

## References

[1] L.C.Folgueras, M. a. (2009). Single and Multi-layer Microwave Absorbing Material Based on Conducting Polyaniline and Polyurethane Polymers for Operation in the X-band. *Progress In Electromagnetics Research Symposium,Beijing, China* .

[2] Luiza de Castro Folgueras, M. A. (2010). Dielectric Properties of Microwave Absorbing Sheets. *Materials Research* .

[3] Mingxia Chen, Y. Z. (2011). Gradient multilayer structural design of CNTs/SiO2 composites for improving. *Materials and Design,ELSEVIER* .

*[4]* Y.S. Lee, F. M. (2013). An Experimental Thickness of Microwave Absorber. *IEEE Symposium on Wireless Technology And Applications*

[5] Hua Zou, S. L. (2011). Determining factors for high performance silicone rubber microwave absorbing materials. *Journal of Magnetism and Magnetic Materials* .

[6] Dixon, P. (n.d.. Theory and Application of RF/Microwave Absorbers. Retrieved from http://www.ecnmag.com/: http://www.ecnmag.com/sites/ecnmag.com/files/legacyfiles/ECN/Absorbers_White_Paper.pdf

[7] (n.d.). Retrieved April Tuesday, 2014, from www.researchgate.net: https://www.researchgate.net/application.Login.html

[8] Marker, B. (n.d.). *Use of Radar-Absorbing Material to Resolve U.S. Navy Electromagnetic Interference Problems.* Retrieved April Monday, 2014, from http://www.navsea.navy.mil: http://www.navsea.navy.mil/nswc/dahlgren/Leading%20Edge/E3/05_Solving_the_E3_Challenge_continued.pdf

[9] *SAO/NASA ADS Physics Abstract Service.* (n.d.). Retrieved April Monday, 2014, from http://adsabs.harvard.edu/: http://adsabs.harvard.edu/abs/2010JAP...108h3113A

[10] (n.d.). Retrieved April Tuesday, 2014, from http://www.sciencedirect.com/.

[11] (n.d.). Retrieved April Wednesday, 2014, from http://www.elsevier.com/.

[12] (n.d.). Retrieved April Thursday, 2014, from http://www.ieee.org/.

[13] Claire M. Watts, X. L. (n.d.). *Metamaterial Electromagnetic Wave Absorbers.* Retrieved April Monday, 2014, from http://onlinelibrary.wiley.com/: http://onlinelibrary.wiley.com/doi/10.1002/adma.201200674/pdf

[14] (n.d.). Retrieved April Monday, 2014, from http://www.scielo.org/.

[15] *Directory of Open Access Journals.* (n.d.). Retrieved April Tuesday, 2014, from http://doaj.org/.