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# Simulation of Reflection Loss for Carbon and Nickel-Carbon Thin Films

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***Abstract*****—**Maximal radar wave absorbing cannot be achieved by shaping alone. We have to focus on the parameters of absorbing materials such as permittivity, permeability, and thickness so that best absorbing according to our necessity can happen. The real and imaginary parts of the relative complex permittivity ($\varepsilon_r'$ and $\varepsilon_r''$) and permeability ($\mu_r'$ and $\mu_r''$) were obtained by simulation. The microwave absorbing property of carbon and Ni(C) is simulated in this study by MATLAB software; the simulation was in the frequency range between 2 to 12 GHz for carbon black (C), and carbon coated nickel (Ni(C)) with different thicknesses. In fact, we draw reflection loss (RL) for C and Ni-C via frequency. We have compared their absorption for 3-mm thickness and predicted for other thicknesses by using of electromagnetic wave transmission theory. The results showed that reflection loss position changes in low frequency with increasing of thickness. We found out that, in all cases, using nanocomposites as absorbance cannot get better results relative to pure nanoparticles. The frequency where absorption is maximum can determine the best choice between nanocomposites and pure nanoparticles. Also, we could find an optimal thickness for long wavelength absorbing in order to utilize them in protecting shields and covering.

***Keywords*****—**Absorbing, carbon, carbon nickel, frequency, thicknesses.

## I. Introduction

RADAR waves are getting increasingly important with the evolution of communication bridges as wireless communications, and they are used for applications in special fields such as radar systems and military activities to detect the position, altitude, direction or speed of objects such as aircraft, ships, spacecraft, and so on [1]. On the contrary, radar absorbing material (RAM) is a material that has been mainly formed and shaped to capture incident longwave radiation in all of the incident directions or at least in the normal direction. RAM removes the effect of reflected waves to disguise a vehicle or structure from radar detection. A more effective RAM has been researched for quite a long time. The increase in electromagnetic pollution due to the rapid development of electronic systems, communication on construction sites and telecommunications has resulted in a growing and great interest in electromagnetic-absorber technology. Electromagnetic interference (EMI) can cause severe interruption and lose control of electronic systems. This factor makes a problem in device malfunctions and producing of false images, increase noise on the radar and reduce impressive performance because of system-to-system coupling. These are some of the reasons why the usage of self-generated electromagnetic radiation apparatuses, which include cellular telephones, wireless laptop, and pagers, are strictly banned in specific areas, for example, in hospitals, petrol stations and inside airplanes. Therefore, some protecting mechanisms must be prepared to eliminate messy noises of devices in these places. Electromagnetic wave absorbing materials are significant and practical for a wide range utilizing from minimizing radar reflecting of the incident wave through a target, protection of human eyes and human health, optical sensors from intense laser pulses, protective shielding of computers and consumer electronics [2].

Electromagnetic wave absorbers with the capability of absorbing unwanted electromagnetic signals are used to overcome the problems created by EMI, and research on their electromagnetic and absorption properties is still being carried out [3], [4].

Many measurements in the electromagnetic sketch of the proposed design are required to overcome spurious signals and to absorb all of them to avoid the risk of causing measurement errors and ambiguities. It is obviously a hard problem and cannot be achieved by shaping alone, and this situation requires a solution. One of the most effective solutions to this problem is manipulating of absorbing materials beside design shape of radar absorber.

Recent developments in microwave absorber technology have resulted in materials that can effectively reduce the reflection of electromagnetic. Application of micro and nano radar absorbers for military applications such as camouflaging ground against airborne microwave have some privileges as highly flexible, adaptive and lower production cost in comparison with the same bulk structure [5]-[8]. Microwave absorbers are generally classified into two categories: dielectric and magnetic absorbing materials. The dielectric absorbers, including carbon nano thin films, carbon nanoparticles, and SiC, depend on the electronic polarization, ion polarization, and intrinsic electric dipole polarization in their materials to realize microwave absorption [9]-[11]. Magnetic absorbers, such as Fe, Ni, and $Fe_3O_4$, depend on their magnetic properties to attenuate microwaves [12], [13]. However, in the microwave band of 2−18 GHz, both dielectric absorbers and magnetic absorbing materials have the deficiency of low attenuation ability when they are utilized alone. There are a variety of absorber materials that can be

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used to suppress EMI depending on whether they are suitable for narrow or broadband absorption and low or high-frequency applications. In the microwave region, dielectric materials are commonly used foams, plastics, rubbers, thermoplastics and natural rubbers. Absorbers often contain magnetic materials such as ferrites, iron or cobalt-nickel alloys as fillers. By incorporation of the magnetic fillers, the values of the dielectric permittivity and magnetic permeability of the materials can be altered to achieve maximal absorption of the electromagnetic energy. Hotta et al. and Zhang et al. have measured the real and imaginary parts of the relative complex permittivity and permeability for carbon and Ni(C) respectively, using a rectangular waveguide sample holder and a coaxial type sample holder, respectively [14], [15]. The measurement was in the frequency range between 2 to 12 GHz for carbon black (C), and carbon coated nickel (Ni(C)) by using experimental results obtained from Hotta et al. and Zhang et al., respectively [14], [15]. In order to improve electromagnetic parameters of RAM, in this paper, we have compared the difference between carbon thin film and Ni(C) nanocomposite with using of MATLAB simulation. So, we want to use the method to achieve the best thickness that provides zero specular reflection at normal incidence and improve microwave absorption. The obtained results are summarized as follows.

## II. Method

The difference in reflectivity between the samples can be proposed that it is due to differences in their physical properties as microstructures, dielectric and magnetic properties. The carbon has a high electric moment, whereas Ni(C) has both magnetic and electric moments in nature. The effects of microstructure, dielectric and magnetic properties of materials on microwave propagation was briefly discussed elsewhere [16]-[18]. The dependences of the absorption characteristics of the frequency, thickness and both the dielectric permittivity and magnetic permeability were obtained based on a model in which an incident wave is normal to the surface of the material backed by a perfect conductor. As shown in Fig. 1, when an electromagnetic wave passes through a medium, three different mechanisms could happen; namely reflection, absorption (multiple internal reflections) and transmission. If we try to trap incident wave inside of shielding layer, absorbing rate dramatically increases and object could be disappeared and vanished.

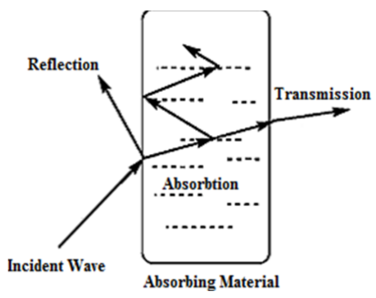


Fig. 1 The scheme of a RAM faced with incident wave

According to the electromagnetic wave transmission theory earned via Maxwell equations, reflectivity on the surface of monolayer RAM and the air is defined as:

$$RL(dB) = 20log\left|\frac{z_{in}-1}{z_{in}+1}\right| \quad (1)$$

where the input impedance at space is

$$z_{in} = z_0\sqrt{\frac{\mu_r}{\varepsilon_r}}\, tanh\left[j\frac{2\pi}{c}\sqrt{\mu_r\varepsilon_r}ft\right] \quad (2)$$

where $z_0$ is the characteristic impedance of free space, $\mu_r$ and $\varepsilon_r$ are respectively the complex relative permeability and permittivity of the material, c is the velocity of light, f is the frequency and t is the absorbing layer thickness. It is evidence that the reflectivity of RAM is substantially dependent on the impedance, magnetic permeability, dielectric permittivity, and thickness. Electromagnetic parameters of solid specimens had given in implicit papers.

The frequency dependences of the real and complex parameters in the range of 2-12 GHz, for both samples, are shown in Fig. 2.

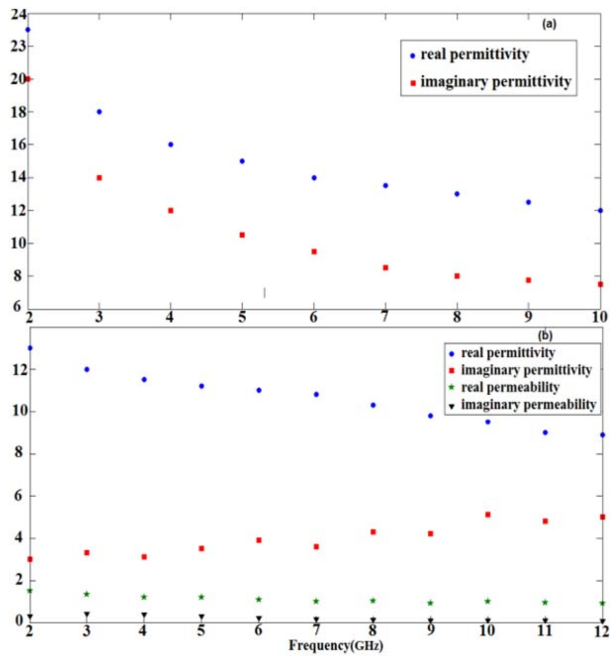


Fig. 2 The relative complex permittivity and permeability of (a) Carbon and (b) Ni-C

It can be clearly seen that $\varepsilon_r''$ for the Ni(C) increased, but for the carbon, it decreased by frequency. The real and imaginary parts of the relative complex permeability ($\mu_r'$ and $\mu_r''$) for pure carbon were almost one and zero, respectively.

## III. Results and Discussion

The RAM is designed by using (1) and (2), and the thickness of the sample with the absorbing coating is 3 mm.

RL is calculated from a MATLAB simulation by using the values of relatively complex permittivity and permeability shown in Fig. 2.

Fig. 3 shows the obtained reflection loss of carbon and nickel-carbon composite samples with a thickness of 3 mm.

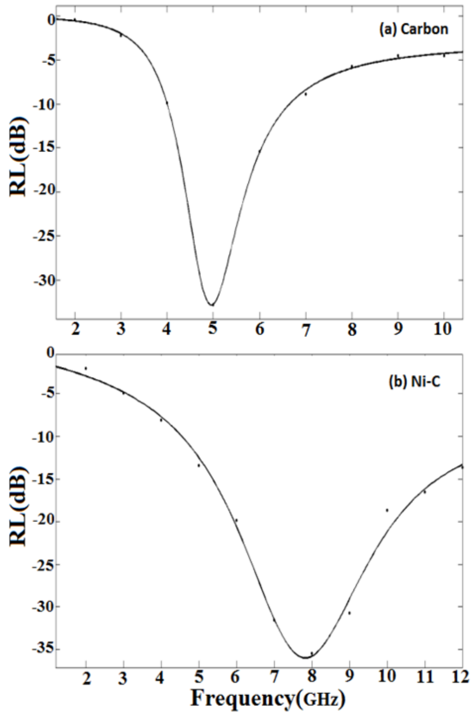


Fig. 3 The reflection loss of (a) Carbon and (b) Ni-C for 3 mm thickness

The depth of RL shifts to a higher frequency with wider full width at half maximum (FWHM). Our results show that adding the Ni nanoparticles to carbon is the reason of the shift of reflection loss. Core/shell microstructure of Ni(C) has a better magnetic loss than pure nano carbon. Due to the dielectric shells (carbon) and ferromagnetic cores (nickel), the Ni(C) nanoparticles can establish a better electromagnetic absorption which can obtain a storage microwave absorption.

We have predicted reflection loss of carbon and Ni(C) with different thicknesses and observed different behaviors of both matters. We observed unsteady behavior in absorbing with the change of frequencies.

The absorption of electromagnetic waves decreases with increasing of carbon's thickness and shift to lower frequencies which are shown in Fig. 4, and the reflection loss reaches approximately from 25 to 44 dB for carbon with the thickness of 2 mm.

Contrary to what we said about carbon thin film, absorption of electromagnetic waves increases by increasing of Ni(C) thickness and shift to lower frequencies and the reflection loss reaches approximately from 26 to 43 dB for Ni(C) with the thickness of 4 mm. We have to look for an optimal thickness, permittivity, and permeability so that thin absorbing layer can absorb all normal incident waves.

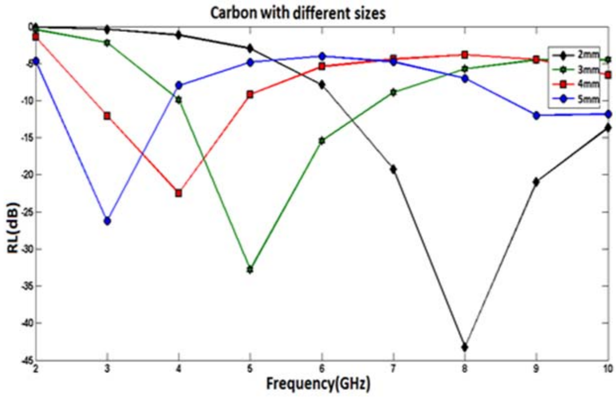


Fig. 4 The reflection loss of carbon with different thicknesses

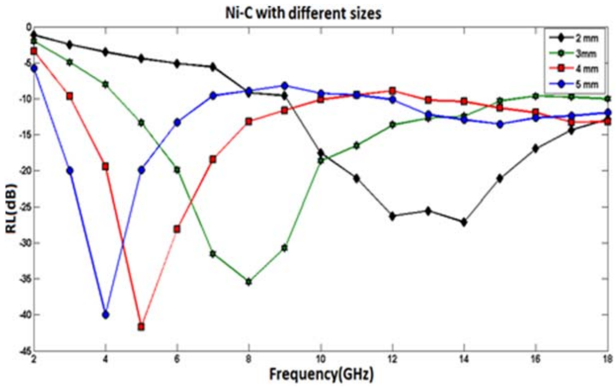


Fig. 5 The reflection loss of Ni-C with different thicknesses

## IV. Conclusion

More recently, it is deducted that the shape of absorbing device does not suffice to design for absorbing of incident destructing noises and needs coated absorbing layers. The first step in the design process is to pick the permeability and permittivity values precisely from the universal design charts in order to obtain effective radar cross-section reduction. Since the frequency dependency of the absorbing material in nanoscale, one should choose the related material properties to have a small thickness in order to reduce the total additional weight of the coated sample. Due to loss of energy and disturbing of incident waves by excessive noises, some shielding mechanism must be protected incident waves by devices in the presence of external electromagnetic waves (EMW). The effects of this method as well as choosing of complex permittivity and permeability were investigated in order to the matching of optimal thickness. The universal design chart gives combinations of μ and ε that provide zero reflection at normal incidence. Nanomaterials have some benefits and privileges such as low cost and low weight in the utilization of shielding layers.

In this paper, we could compare long wave reflection loss of pure nanocarbon with its composite and predict absorbing rate with thickness. The results showed microwave absorption values above 10 dB in wide frequency ranges of 2-10 and 2-18 GHz, with maximum reflection loss peaks between 44 and 43 dB for carbon (thickness about 2 mm) and nickel-carbon (thickness about 4 mm), respectively. These values are the considerably comparable absorbing performance of the samples with other thickness. Figs. 4 and 5 are used to choose the proper thickness for the RAM before the experiment. We could find an optimal thickness for both C and Ni(C). Then, we could just choose our thickness of shield layer in order to have the best performance.

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