Enhanced radar absorption with soft magnetic layer composites for stealth applications

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This work reports recent advancements in the development of novel magnetic composites for enhanced radar absorbing systems. These systems are based on the fabrication of multi-layered structures composed of magnetodielectric composites. Various multi-layer configurations were tested under real radar far-field conditions inside an anechoic chamber. The experimental data show excellent agreement with theoretical predictions.

Keywords: magnetic composites; multilayer systems; electromagnetic properties; radar absorption; stealth technology

1. Introduction

The design of microwave and radar absorbing systems has traditionally focused primarily on the dielectric response of materials. However, enhancing and optimizing these systems by leveraging their magnetic properties offers significant advantages. In this context, composite magnetodielectric materials are at the forefront of the field. These materials are often used as coatings or layered structures to electromagnetically shield objects, spaces, or vehicles. Recently, multilayer systems have been explored both theoretically and experimentally due to their superior performance [1, 2].

2. Results and discussion

A material's absorption is typically quantified through reflection loss (R_L), which measures the amount of power absorbed under reflection conditions. This can be related to the medium's impedance (Z), which, for a monolayer system is:

$$Z = Z_0 \sqrt{\frac{\mu_r}{\varepsilon_r}} tanh\left[\left(j\frac{2\pi f d}{c}\right)\sqrt{\mu_r \varepsilon_r}\right]$$

, being μ_r and ε_r the complex relative permeability and permittivity, respectively, d the layer thickness, f the frequency and c the speed of the light in vacuum. The theory for a bi-layer system was recently published [3]:

$$Z = Z_0 \frac{\sqrt{\frac{\mu_1}{\varepsilon_1}} tanh\left[\left(j\frac{2\pi f d_1}{c}\right)\sqrt{\mu_1\varepsilon_1}\right] + \sqrt{\frac{\mu_2}{\varepsilon_2}} tanh\left[\left(j\frac{2\pi f d_2}{c}\right)\sqrt{\mu_2\varepsilon_2}\right]}{1 + \sqrt{\frac{\mu_1\varepsilon_2}{\mu_2\varepsilon_1}} tanh\left[\left(j\frac{2\pi f d_1}{c}\right)\sqrt{\mu_1\varepsilon_1}\right] tanh\left[\left(j\frac{2\pi f d_2}{c}\right)\sqrt{\mu_2\varepsilon_2}\right]}$$

This expression describes a more complex scenario where R_L depends on the electromagnetic and geometrical properties of each layer.

We studied mono and bilayer composite systems using far-field radar measurements to simulate real radar conditions inside an anechoic chamber. Figure 1.a shows a 40 dB absorption achieved by a bilayer system containing ceramic nanocomposites with random magnetic properties [4], combined with another layer of soft magnetic metallic particles. This subplot also provides a comparison with the bilayer model. Figure 1.b demonstrates our capacity to modulate the absorption by the adequate design of the bilayer structure [2].

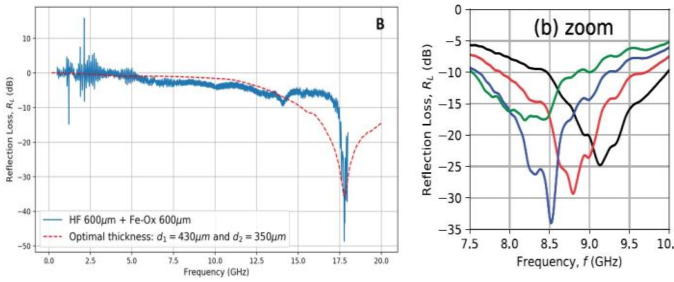

Figure 1: R_L spectra with (a) a 50 dB absorption at 17.5 GHz [3] and (b) modulation of the absorption spectra by different bilayer designs [2].

References

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