OPTIMAL DESIGN OF MICROWAVE ABSORBERS BASED ON HIGH-IMPEDANCE SURFACES

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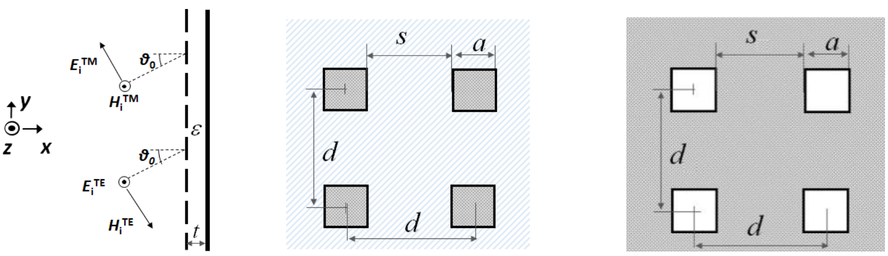
Electrically thin microwave absorbers based on high-impedance surfaces (HISs) use capacitive metallic patch arrays over metal-backed dielectric slabs, creating a resonant LC circuit. Ideally, this circuit provides infinite impedance, resulting in total reflection with continuously varying reflection phase [1]. In real scenarios, losses introduced by lossy patches, substrate permittivity, or metallic vias yield a finite conductance, influencing the reflection coefficient [2].

In the following, an innovative analytical method for the optimal design of microwave absorbers based on High-Impedance Surfaces (HISs) is introduced. The absorbers consist of periodic arrays of metallic patches deposited on a dielectric substrate, which is backed by a perfectly conductive (PEC) ground plane. A novel analytical formulation for the effective admittance of the metallic patch array is derived, incorporating assumptions regarding both substrate thickness and the intrinsic capacitance of the patch grid without the substrate. Building upon these assumptions, explicit analytical expressions for determining the real and imaginary components of the substrate's complex permittivity are provided [3]-[4]. This approach allows precise tuning of the absorber characteristics to achieve specific target reflection coefficients at designated resonance frequencies. Consequently, this analytical methodology facilitates rapid, accurate, and customizable absorber design, significantly streamlining the development of advanced electromagnetic absorption solutions.

The proposed absorber structure is excited by a Transverse Magnetic (TM) or Transverse Electric (TE) plane wave with an incidence angle ϑ_0, as shown in Fig. 1(a). The pattern configuration of the periodic thin metal patches over a dielectric substrate is represented in Fig.1 (b) alongside the complementary inductive grid with square apertures in the metal plate shown in Fig.1 (c). In both configurations, *d* is the pattern period, *s* the gap distance between adjacent patches/apertures and *a* = *d*-*s* the size of patches/apertures [4].



(a) (b) (c)

Fig.1. Schematic configuration of the excited absorber (a) and pattern configuration of periodic grids made by square (b) patches on dielectric substrate and (c) apertures on metal plate. The metal and dielectric parts are grey and in light blue respectively [4].

The absorber input admittance is modeled analytically, combining the effective admittance of the patch array Y_g and the substrate admittance Y_s. Closed-form expressions are derived under the short-line hypothesis of the substrate, enabling rapid design optimization. Specifically, the complex permittivity components ε' and ε'' are formulated as functions of absorber parameters, allowing direct computation to meet predefined absorption specifications [4].

For instance, Figs. 2(a) and (b) illustrate, respectively, the frequency spectra of the real part ε' of the substrate permittivity for various substrate thicknesses t, and of the imaginary part ε'' for different target reflection coefficients R. Using these permittivity spectra, the reflection coefficients were computed at a resonance frequency of 4 GHz. The resulting reflection coefficients are presented in Fig. 2(c), assuming a target reflection coefficient R=−30 dB, with ε' values of 20.96 (for t=1 mm) and 6.32 (for t=3 mm), and a constant ε'' value of 1.96 [4].

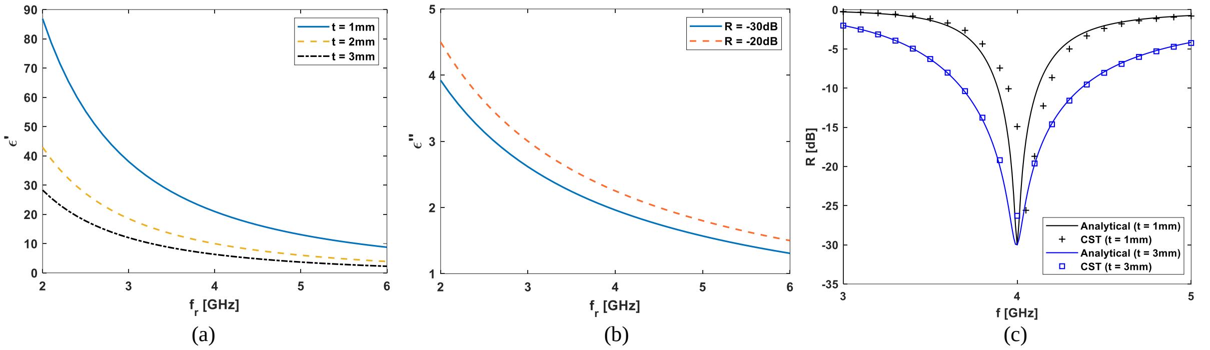


Fig.2. Frequency spectra of (a) real and (b) imaginary parts of the complex permittivity as function of the resonance frequency for d=5mm and s=0.1 mm. Frequency spectra of the reflection coefficients for R=-30 dB and t=1mm and t=3mm [4].

Simulations and analyses performed for normal and oblique incidence plane waves reveal excellent agreement between analytical predictions and numerical results obtained with CST software.

For oblique incidence, the model precisely predicts variations in resonance frequency and reflection performance for both TM and TE polarizations. Results highlight an optimal trade-off between bandwidth, absorption stability, and angular robustness. For instance, Figs. 3(a) and (b) present the reflection coefficient spectra for obliquely incident TM- or TE polarized plane waves, respectively. These results were computed assuming a target reflection coefficient R=−30dB at a resonance frequency of 4 GHz, with geometric parameters set to d=5mm, s=0.1mm, and substrate thickness t=3mm. The spectra are shown for incidence angles ϑ_0 equal to 0°, 30°, and 40°. Also in these cases, the frequency spectra computed with the analytical model are in good agreement with those given by the CST code used for validation.

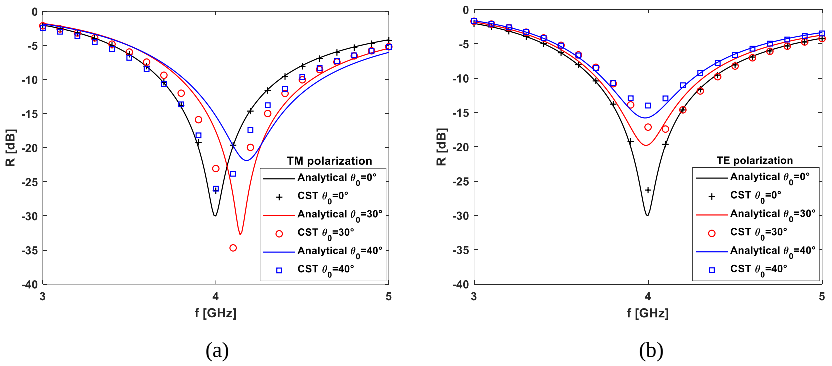


Fig.3. Frequency spectra of the reflection coefficient for (a) TM and (b) TE polarization with t = 3mm and different values of the incidence angle ϑ_0 [4].

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