3D Printed Absorbing Frequency Selective Surface in the S-Band

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Abstract—This work presents the design and experimental characterization of a 3D printed absorbing frequency selective surface (FSS) working in the S-band. Conductive polylactic acid (PLA) is used to manufacture the unit cells composing the high impedance surface.

Keywords- additive manufacturing, absorbing FSS, resistive surface

I. INTRODUCTION

The study and development of frequency selective surfaces (FSS) to implement high impedance surfaces (HIS) have been a well-reported topic in the past years [1]. A HIS is implemented by placing an FSS on top of a grounded dielectric slab. These structures are designed to exhibit a perfect magnetic conductor (PMC) behavior over a certain frequency range. Applications include surface current suppression, radar cross section reduction, and microwave thin absorbers. Numerous techniques can be used to implement a microwave thin FSS-absorber, such as photo etching from conductive layers and printing of conductive inks [2]. Additive manufacturing using conductive material is an alternative for quick prototyping of FSSs. In this work, a 3D-printed wideband absorbent FSS in the S-band is designed and implemented. Experimental results of the absorption level and the characterization of the PLA material are presented.

II. ABSORBING FSS DESIGN

The surface impedance of the absorbing-FSS can be computed as the parallel connection of the FSS impedance and the grounded substrate impedance:

$$Z_{abs} = \frac{Z_{FSS} Z_d}{Z_{FSS} + Z_d}. \qquad (1)$$

When the reactance of Z_{FSS} cancels the inductance of Z_d, the parallel circuit resonates, and Z_{abs} becomes real-valued [1]. The real part of Z_{abs} must match the free-space impedance to effectively absorb the incoming wave. Under this condition, an optimum value R_{FSS} = Re{Z_{FSS}} can be extracted [1].

$$R_{FSS} = \left(\frac{\beta}{\omega \varepsilon_r \varepsilon_0 \eta_0} \right) \tan^2(\beta d) \approx R_s \left(\frac{P^2}{A} \right) \qquad (2)$$

where d is the dielectric thickness, η_0 and ε_0 are the free-space impedance and permittivity, respectively, P is the FSS periodicity, and A is the area covered with PLA per unit cell. β is the propagation constant and ω is the angular frequency. The FSS sheet resistance, R_s (Ω/sq), is related to the PLA conductivity σ, and thickness h_t, as [1]

$$R_s = \frac{1}{\omega h_t j \cdot (\varepsilon_0 \varepsilon_r - j\sigma / \omega)} \approx \frac{1}{h_t \sigma} \qquad (3)$$

The dielectric parameters of the conductive PLA material were characterized using an open-ended coaxial probe, and the results are plotted in Fig. 1.

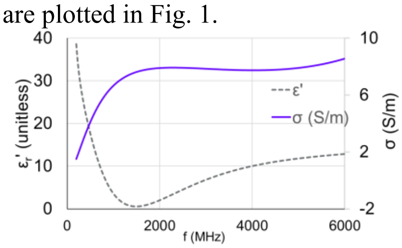
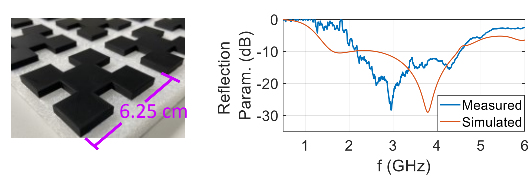


Figure 1. Conductive PLA measured characteristics.

A crisscross geometry is selected as the FSS unit cell due to its simplicity and wideband response [2]. The thickness of the unit cell is optimized via full-wave simulation, using the PLA material characteristics. An array of 6 x 7 squared unit cells with a 6.25 cm side was 3D-printed with a 100% density. Fig. 2a shows the prototyped unit cell. The FSS is glued on one side of a 12 mm thick Styrofoam layer (ε_r=1.1), 38x44 cm^2. A layer of aluminum foil acts as the ground plane.

III. RADIATION TEST RESULTS

A two antenna, quasi-monostatic setup was used to characterize the FSS in an anechoic environment. The transmission parameter (S_{21}) from an aluminum plate of the same dimensions as the FSS is used as the reference. A comparison of the measurement and simulation results is presented in Fig. 2b. Discrepancies are observed at low frequency. However, almost the complete S-band is covered with the presented design for absorbance levels better than -10 dB.



(a) (b)

Figure 2. 3D-printed absorbing FSS prototype. (b) Measured reflection coefficient on boresight.

REFERENCES

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