Chipless RFID tag based on metamaterial absorbers

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***Abstract*— A metamaterial absorber (MA) used as RFID tag is proposed in this paper. Absorbers lead to small tags with absorption peaks as characteristic signatures. The designed structure is a metasurface with metallic frequency selective surfaces over a grounded dielectric slab. CST simulations have absorption peaks of 99.25% at 3.5 GHz and 99.4% at 5.9 GHz. Absorber unit cell on FR-4 is a square of dimensions of 0.201 times the wavelength at the low resonant frequency. Simulated radar cross section presents adequate beamwidth for the designed frequency bands.**

***Keywords*— metamaterial, RFID tag, absorber.**

I. Introduction

Radio Frequency Identification (RFID) uses a reader to send signals, then receives and identifies radio frequencies scattered back by tags [1]. RFID has applications[2] in healthcare activities[3] and farm management [4]. Frequency selective surface (FSS) is a periodic structure, which selectively reflects, or absorbs incident waves [5]. FSS with periodic loops, dielectric substrate and ground plane comprises a HIS (High-Impedance Surface), which controls RCS (Radar Cross Section). Absorbance quantifies the absorption of the incident wave[6]. Transmission is negligible due to the metallic layer on the back of the substrate, as shown in Fig. 1. In [7], metamaterial structure is proposed with improvement in directivity and gain of the tag. Absorption and frequency are controlled by parameters of the resonator and thickness of the substrate[8].

We propose here a dual band MA using square loop resonators, when absorber structure is a tag. Surface current analysis at absorption frequencies explains electric and magnetic excitations related to dielectric loss at those frequencies.

II. Design

Metamaterial loop resonators with ground plane are modeled as a tank circuit [9]. Reflection and transmission are analyzed by the interference theory and S-parameters of the resonator as in [10]. The matching layer does not cause any reflection. The absorption layer attenuates the wave [9]. One should consider the influence of dielectric thickness and the loop resonator pattern on absorption. The size of the resonator loop and the dielectric layer thickness control the frequency of the absorption peak, so the periodic arrangement are designed to obtain resonance in the desired range. The proposed RFID tag and its dimensions are presented in Fig. 1.

The designed structure is a dual band FSS. Frequencies are controlled by the square loops, whose length is the wavelength of a resonant frequency, with the parameters seen in Fig. 1. To reach the desired resonant frequency and band, a sweep of gap, D_1 and D_2 is performed on FR-4 using CST. Square loop and ground plane are made of copper. Absorption is studied for the substrate loss tangent tan(δ) variation while other parameters are kept constant. Bi-static RCS template is scanned from 1 GHz to 10 GHz. Boundary conditions for a simulation operate as a perfect electric conductor for the maximum and minimum of the x axis. The minimum of z axis operates as a perfect magnetic conductor for the maximum and minimum of the y axis. It operates as free space for the maximum of the z axis.

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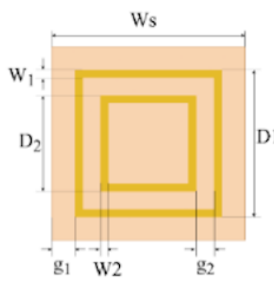
III. Numerical Results

Resonant frequencies are designed at 3.5 GHz with a band of 59 MHz, and, at 5.8 GHz, with a band of 75 MHz. Fig. 2 shows the reflection, absorption, and transmission of the proposed structure. Reflectance is large near the resonances, greater than 0.97 around 3.5 GHz and greater than 0.95 around 5.8 GHz. It reaches minima of 0.08 at ω_0 = 3.56 and 0.075 at ω_0 = 5.9 GHz. Due to the full ground plane, transmission is low near 3.5 GHz and 5.8 GHz. Absorbance is greater than 99% at 3.5 and 5.9 GHz, with FWHM of 5% and 4.4%, respectively. As seen in Figure 2, peaks are at the same frequencies for absorption for TE and TM modes with similar absorption. A parametric study of Im(δ) is performed to analyze impedance matching. Thus, tan(δ) is varied, and the absorbance is a function of the transmission and reflection parameters, as in Fig. 2. For 3.5 GHz, maximum absorption occurs for tan(δ) = 0.025 and 0.03. After reaching the maximum, absorption decreases to values below 20%. The same is seen at 5.8 GHz, where the peak is at tan(δ) = 0.02. For tan(δ) = 0.025, we have approximately 99.4% of absorption. With FR-4, it presents the best absorbance for these two frequencies. At maximum absorption frequencies, the effective impedance is Z_{eff} = 0.801 + 0.230j at 3.56 GHz and 1.128 - 0.192j at 5.9 GHz, which are close to the air impedance. The influence of the angle of polarization and incidence for TE and TM modes is shown in Fig. 4. The polarization angle and the incidence angle are varied with a step of 15^o, from 0^o to 45^o, where very small variations were detected independently of the angle of incidence and polarization.



Ws	W1	W2	D1	D2
17	0.3	0.3	12.73	8.28

g1	g2	t1	t2	ts
2.135	1.925	0.035	0.035	1.6

Fig. 1: Views of the proposed tag, with the size in millimeters.

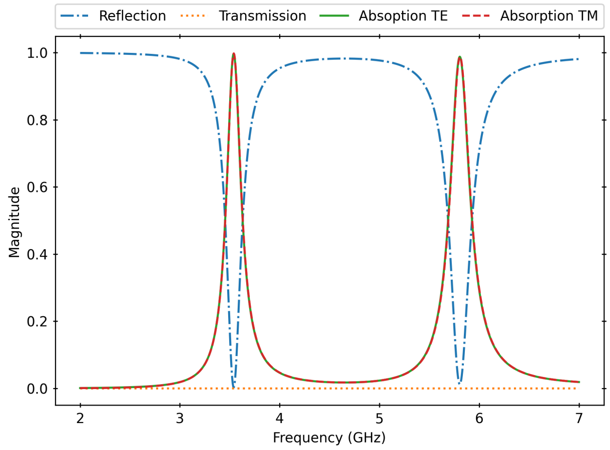


Fig. 2: Simulated transmission, reflection and absorption.

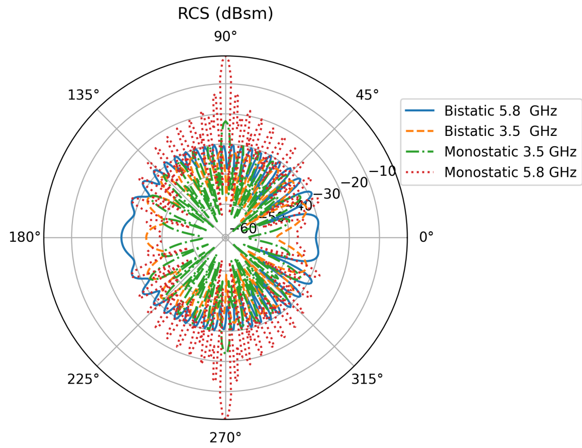


Fig. 4: Monostatic and Bistatic RCS for resonant frequency.

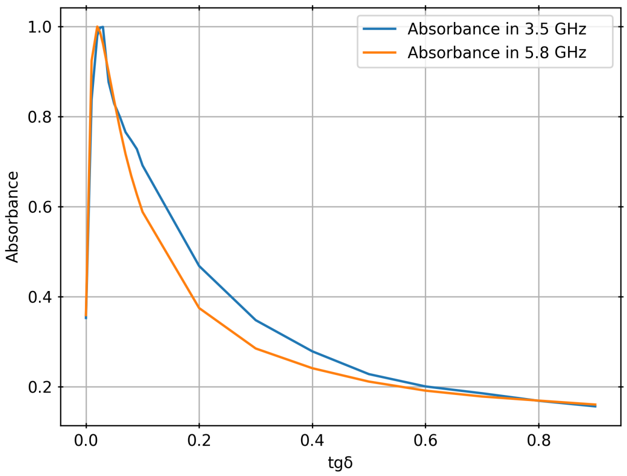


Fig. 3: Absorbance for each variation of tan(δ).

To analyze the tag signature, monostatic and bistatic RCS are simulated for the resonant frequencies. In bistatic mode, at θ = 137º, a peak occurs in -37.9 dBsm at 3.5 GHz and, at θ = 180º, the peak is -26.5 dBsm, at 5.8 GHz. In monostatic mode, -22.42 dBsm with θ = 90º and another with -22.425 dBsm with θ = -90º for 3.5 GHz. This pattern is observed for 5.8 GHz, with one peak at -0.767 dBsm with θ = 90º and another peak at -0.767 dBsm with θ = -90º. Monostatic RCS presents two peaks of θ = 90º and -90º with less scattering in other directions. In bistatic mode, scattering of the RCS is larger in all directions without a significant peak. Simulations are performed with an infinite number of unit cells. Simulations show that the proposed absorber can be used as a tag in identification systems, given its specific signature. The larger the panel dimension, the larger is the RCS. To verify this hypothesis, we simulate structures comprising patterns of 2×2, with total dimension of 34 mm, and 3×3 unit cells with total dimension of 51 mm. The overall thickness of the unit cell represents $0.018\lambda_0$. We also simulate monostatic RCS of the two analyzed structures, along with a flat metallic plate used as a reference. The structure has a well-defined signature in the desired bands. Moreover, reflection response is maintained to show that the projected unit cells have peaks coincident with an infinite size panel. The structure is now under fabrication.

IV. Conclusion

A metamaterial absorber based on HIS is proposed here to be used as an RFID tag. Design of the square loop FSS gives us control of the reflection coefficient, making it simple to set the resonant frequencies 3.5 GHz and 5.8 GHz. Simulation results show that absorption presents a good response for the band in which it was designed. RCS simulation allows to characterize the tag for different incidence angles in the material. Moreover, we have a tag with good detection, both in bistatic systems and in monostatic systems. Based on the current state of the project, we can consider that our tag indicates the presence of the object. The structure is now under fabrication.

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