Frequency-Selective Rasorber with Tri-resonant Absorption Band

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***Abstract*—In this paper, a rasorber with broadband absorption response is presented. The absorption band is located below the transmission window, and a good absorptivity is achieved. Cross-frame and cross-slot FSSs are employed to fulfill the desired rasorber performance. Tri-resonant behavior is obtained by the lossy cross-frame array and used to consume the wide-band incident power. Furthermore, a stable absorption performance is achieved until 50° incident angle. The current distribution and simulated results are given to illustrate the operating mechanism of the presented design.**

Keywords—frequency-selective rasorber, wide-band absorption, transmission window, tri-resonant

I. Introduction

In the past, frequency-selective surface (FSS) were widely applied in the radome applications due to its outstanding band-pass response [1]. A radome cover could protect the antennas from the physical environment and transmit the in-band power [2]. For some stealth applications, such as stealth aircraft, the power reflected by FSS radome may lead to a high radar cross section. Therefore, an absorptive FSS named frequency-selective rasorber (FSR) has been proposed and extensively studied in [3]. Different from lossless FSSs radome, the out-of-band could be absorbed by covering rasorber radome, and the transmission performance is limited by the lossy layer.

Various methods have been studied to realize the transmission behavior of the rasorber [4]. By employing the low-pass behavior of the strip-type FSS, a transmission window could be achieved at the lower frequencies of the absorption band [5]. Furthermore, lumped and distributed *LC* elements have been employed to obtain the pass-band above the absorption band in [6], [7], and the wide-band reflection reduction performance has been provided. To further reduce the structure complexity, rasorbers with hybrid *LC* resonator have been studied in [8]. The lossy FSS arrays with multi-resonant response have been employed in these works, and a pass-band could be realized without using extra *LC* elements. Most of works mentioned above fulfill the transmission window by employing the parallel resonance generated by the lossy FFS. However, the absorption performance plays an important role in the field of the stealth facilities. Most of the above-mentioned literatures are focus on the wide-band reflection reduction performance instead of the good absorption performance.

To improve the absorptivity and bandwidth, a rasorber with tri-resonant absorption band is presented in this paper. The parallel resonance is employed to achieve the absorption response instead of the transmission behavior. Therefore, the absorption performance is greatly improved. The transmission pole between the basic and high-order series resonances is employed to realize the transmission. Additionally, the dual-polarized behavior is obtained by the presented structure.

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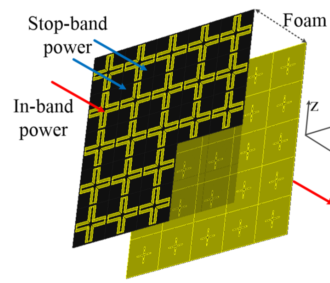
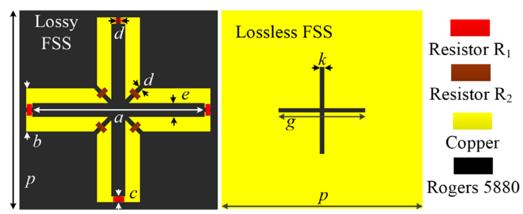


(a)



(b) (c)

Fig. 1. Unit cells of the proposed rasorber. (a) Perspective view of the proposed rasorber. (b) Top view of the lossy layer. (c) Top view of the lossless layer.

II. Rasorber Design

Lossy cross-frame and lossless cross-slot FSSs are employed to complete the represented rasorber, and the geometrical details are shown in Fig. 1. The lossy layer locates above the lossless layer, and the two layers are connected by the 10 mm foam spacer to achieve the absorption behavior. Both the cross-frame and cross-slot FSSs are periodic along the x- (TM) and y- (TE) axes, and the -z-axis is the direction of the incident wave. The substrate Rogers 5880 is used to support lossy and lossless arrays. The resistors of 110 Ω and 30 Ω are loaded at the edge and the junction of the cross-frame arm, respectively, to realize the wide absorption band. The planner symmetrical loss and lossy arrays could lead to the identical response under TM- and TE-polarized incident wave. Thus, only the response under the TE-polarized wave is represented in this paper. The geometric dimensions of the presented are: a = 18.3 mm,

b = 4.5 mm, c = 0.6 mm, d = 0.5 mm, e = 1.5 mm, g = 9.1 mm, k = 0.5 mm, p = 21 mm, R_1 = 110 Ω, R_2 = 30 Ω.

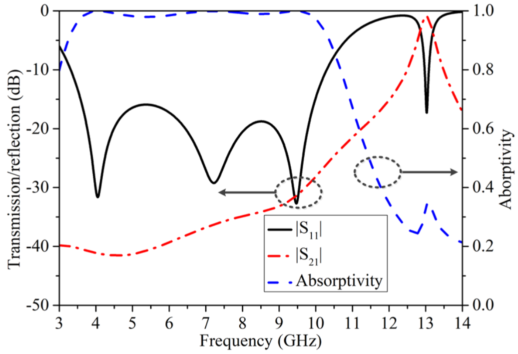


Fig. 2. Simulated results of the proposed rasorber.

III. Numerical Simulation Analysis

The proposed rasorber was simulated by a full-wave electromagnetic (EM) simulation software CST microwave studio. The simulated results are plotted in Fig. 2. It is seen that a rasorber response is achieved by the proposed strcuture. From 3.3 GHz to 10.3 GHz, an absorption band of 90% absorption rate is achieved with a fractional bandwidth of 103%. By combining with resistors, three resonances are employed to achieve the wide-band absorption. The transmission window with 0.9 dB insertion loss is obtained around 13 GHz. Based on the theory in [9], a transmission pole (modal interaction pole) could be obtained between two transmission zeroes which are generated by the basic and high-order resonances of the strip-type FSS, respectively. Within the frequencies of modal interaction pole, an FSS should be transparent to the incident wave. Therefore, the modal interaction pole locates around 13 GHz is employed to fulfill the transmission window in this work. The rasorber response under oblique is plotted in Fig. 3. It is seen that the transmission at high frequency is vulnerable to the oblique incidence. However, the wide-band absorption of 80% absorptivity could be obtained up to 50°, which could be deemed as a good performance under the oblique incidence.

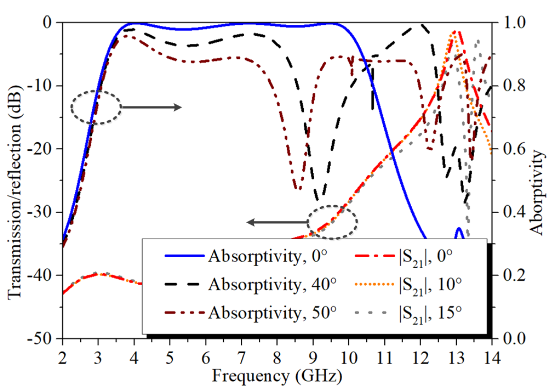
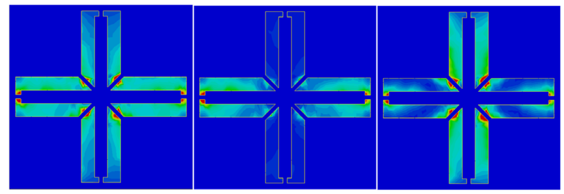


Fig. 3. Simulated results of the proposed rasorber.

Furthermore, the current distributions on the cross-frame FSS are plotted in Fig. 3. It is shown that the cross-frame FSS resonates at 4 GHz, 7GHz and 9.5 GHz. At 4 GHz and 7 GHz, series and parallel resonances are generated, respectively. The current passes through the loaded resistors, and two absorption bands are realized. For the series resonance around 9.5 GHz, two current paths flow through the horizontal and vertical arms respectively. Therefore, the resistors need to be located at the edge and joint part of the arms to achieve the absorption performance.



(a) (b) (c)

Fig. 4. Current distributions on the cross-frame FSS. (a) 4GHz. (b) 7 GHz (c) 9.5 GHz

IV. Conclusion

A dual-polarized rasorber with wide-band absorption performance has been proposed and discussed in this paper. Three resonances generated by the lossy cross-frame FSS have been employed to absorb the incident wave. Meanwhile, the modal interaction pole has been used to achieve the pass-band. In this design, the parallel resonance has been employed to obtain the absorption behavior instead of the transmission window. Therefore, the absorption band has significantly been broaden, and an excellent stealth performance is realized. The proposed rasorber could be widely applied in the radome system while providing an excellent stealth performance.

References

[1] B. Lin, F. Li, Q. Zheng, and Y. Zen, "Design and simulation of a miniature thick-screen frequency selective surface radome," IEEE Antennas Wirel. Propag. Lett., vol. 8, pp. 1065-1068, Sep. 2009.

[2] N. Liu, X. Sheng, C. Zhang, and D. Guo, "Design of frequency selective surface structure with high angular stability for radome application," IEEE Antennas Wirel. Propag. Lett., vol. 17, no. 1, pp. 138-141, Nov. 2018.

[3] F. Costa and A. Monorchio, "A Frequency selective radome with wideband absorbing properties," IEEE Trans. Antennas Propag., vol. 60, no. 6, pp. 2740-2747, Jun. 2012.

[4] Z. Wang, Q. Zeng, J. Fu, W. Chen, B. Lv, M. Song, and T. A. Denidni, "A high-transmittance frequency-selective rasorber based on dipole arrays," IEEE Access, vol. 6, pp. 31367-31374, Jun. 2018.

[5] Q. Chen, J. Bai, L. Chen, and Y. Fu, "A miniaturized absorptive frequency selective surface," IEEE Antennas Wirel. Propag. Lett., vol. 14, pp. 80-83, Sep. 2015.

[6] Y. Shang, Z. Shen and S. Xiao, "Frequency-selective rasorber based on square-loop and cross-dipole arrays," IEEE Transactions on Antennas and Propagation, vol. 62, no. 11, pp. 5581-5589, Nov. 2014.

[7] Q. Chen, L. Liu, L. Chen, J. Bai, and Y. Fu, "Absorptive frequency selective surface using parallel LC resonance," Electronics Letters, vol. 52, no. 6, pp. 418-419, Mar. 2016.

[8] H. Huang and Z. Shen, "Absorptive frequency-selective transmission structure with square-loop hybrid resonator," IEEE Antennas and Wireless Propagation Letters, vol. 16, pp. 3212-3215, Oct. 2017.

[9] B. A. Munk, Frequency Selective Surfaces: Theory and Design. New York, NY, USA: Wiley, 2000.