A Numerical Study with Various Intersecting Twin Structures on Tuning the Absorption Spectra in S-Band

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Özet: *Bu çalışma ikiz levha ve ikiz halka yapıları için nümerik analiz çıktılarını sunar. Burada ikiz levha yapıları; ikiz dairesel levha, ikiz sekizgen levha ve ikiz kare levhadır bununla birlikte ikiz halka yapıları; ikiz dairesel halka, ikiz sekizgen halka ve ikiz kare halkadır. Analizlerde soğurma seviyesi, rezonans frekansı ve yarı güç hüzme genişliği (YGHG) gözlemlenmiştir. Sonuçlar göstermektedir ki levha tipi yapılar, halka tipi türevlerine göre daha yüksek soğurma seviyesi, daha yüksek rezonans frekansı ve daha yüksek YGHG sunarlar. Buna ek olarak, merkezden merkeze mesafenin değiştirilmesi hem rezonans frekansını hem de YGHG seviyesini azaltır.*

Abstract: *This study presents numerical analyses outputs for twin sheet and twin ring type absorber structures. Herein the twin sheet structures are twin circular sheet, twin octagonal sheet and twin square sheet on the other hand the twin ring structures are twin circular ring, twin octagonal ring and twin square ring. In the analyses, the absorption level, resonance frequency, and half power beam width (HPBW) are observed. It is reported that sheet type structures promise higher absorption levels, higher resonance frequencies and higher HPBW levels as compared to their ring type derivatives. Moreover, increasing the center-to-center distance decreases both resonance frequency and HPBW level.*

1. Introduction

The interest on the design of metamaterial based electromagnetic absorbers has increased, recently which frequently aim a perfect absorption [1]. In 2008, thin perfect metamaterial based absorber experimentally demonstrated by Landy et al. [1]. They used three stacked layers, which are an electric resonator layer, a dielectric layer and a cut-wire layer. Nowadays, metamaterial based absorbers take places in many applications such as radar cross section [2], cloaking [3], energy harvesting [4], switching [5], and sensing [6].

There various geometries reported in literature on the absorber design [1, 2, 4, 5, 7, 8]. Among them, square and circular shaped structures are very popular [6, 7, 8]. Specifically, Yoo et al. made comparisons between circular sheet, and circular ring. They found that the resonance frequencies of the sheet type structures were higher than that of the ring type structures. On the other hand the absorption peaks of the sheet types were observed to be lower than the absorber peaks of the ring type structures [7]. Additionally, Wang et al. studied on metallic square, circular and cross type absorbers and investigated the effects of temperature on the absorption spectra and demonstrated frequency tunable absorber structures [8].

As the contribution to the literature, this work presents numerical analyses for the comparison of two groups of intersecting metallic absorber structures, which are twin sheet and twin ring type absorbers, in S-band regime. As the outputs, the resonance frequency, absorption level, and half power beam width (HPBW) are investigated.

2. Design

The schematic views and the design parameters of the proposed structures are presented in Fig. 1. All the structures are constructed by three stacking layers, which are; intersecting twin metallic resonators, 1.48 mm thick FR4 substrate with loss tangent 0.025, dielectric constant 4.3 at 10 GHz and finally, entire metallic ground layer. The all-metallic layers are made of 0.035 mm thick copper with conductivity value 5.8×10^{7} S/m. The geometrical parameters of group-1 (i.e. twin sheet structures) and group-2 (i.e. twin ring structures) are shown in Fig. 1.b-d, and 1.e-g, respectively with dimensions: L_x = 72.136 mm, L_y = 34.036 mm, r = 10 mm, w = 3.5 mm and s is a variable distance which is measured from center to center. In simulations, it ranges from 0 to 8 mm with a 2 mm step size. The numerical analyses are performed by CST Microwave Studio with frequency domain solver. The structures are placed in an S-band hollow waveguide setup and excited by fundamental TE_{10} mode, where the propagation vector *k*, *E*-field and *H*-field are in –*z*, *y* and *x* directions, respectively. In the simulation setup, the boundaries that are perpendicular to *x*, and *y* axes are specified as $E_t = 0$ boundary (i.e. perfect electrical conductor (PEC)) [5] (see Fig. 1.a). This setup is used to obtain complex S-parameters related to the absorber structures placed in the waveguide. Following, the absorption spectra are obtained for each structure by using $absorption = 1 - |S_{11}|^2 - |S_{21}|^2$ formula [1, 4, 5]. Using a full ground plane thicker than the skin depth results $|S_{21}|^2 = 0$, which means absorption only depends on reflectance i.e. $|S_{11}|^2$ [4].

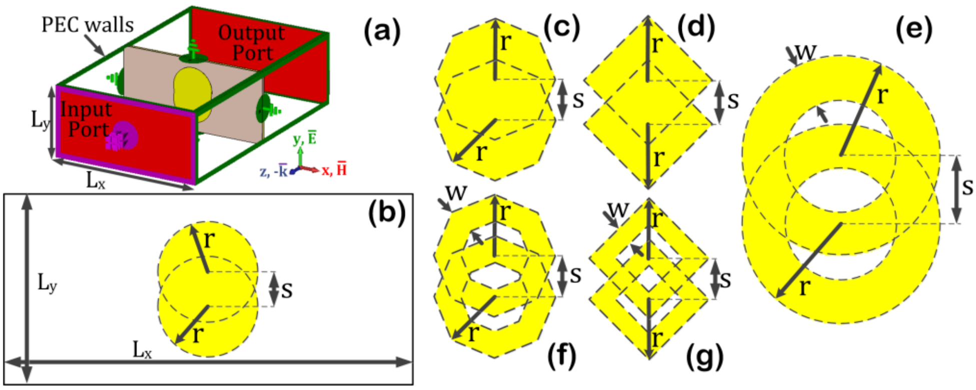


Figure 1. Schematic view and design parameters for **a)** simulation setup, **b)** twin circular sheet, **c)** twin octagonal sheet, **d)** twin square sheet, **e)** twin circular ring, **f)** twin octagonal ring and **g)** twin square ring.

2. Results and Discussion

For an easier explanation, the structures are discussed in two separate groups, which are twin sheet structures and twin ring structures (see Fig. 1).

Twin sheet structures: Fig. 2.a and b include the simulation results of three different twin sheet structures (labeled with filled markers) that are presented in Fig.1.b-d. Herein center to center distance is set as s = 6 mm. The results show that all three structures have absorption peak near unity. In addition, the twin circular sheet has absorption peak at 3.079 GHz with 155 MHz HPBW, the twin octagonal sheet has absorption peak at 3.174 GHz with 159 MHz HPBW and finally the twin square sheet has absorption peak at 3.554 GHz with 179 MHz HPBW.

Twin ring structures: Fig. 2.a and b include the simulation results of three different twin ring structures (labeled with empty markers) that are presented in Fig.1.e -g. Herein again center to center distance is set to s = 6 mm. In the ring cases, the absorption peaks decrease and show values around 0.9. In addition, the twin circular ring has absorption peak at 2.623 GHz with 85.7 MHz HPBW, the twin octagonal ring has absorption peak at 2.742 GHz with 92 MHz HPBW and finally the twin square ring has absorption peak at 2.969 GHz with 89.1 MHz HPBW.

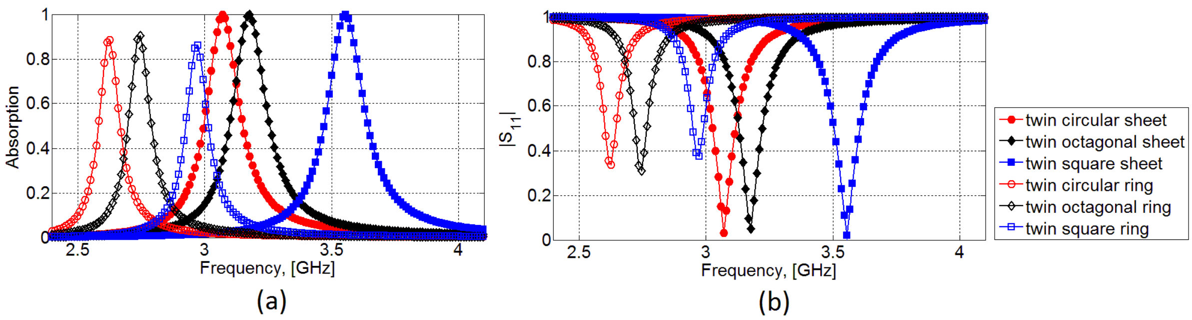
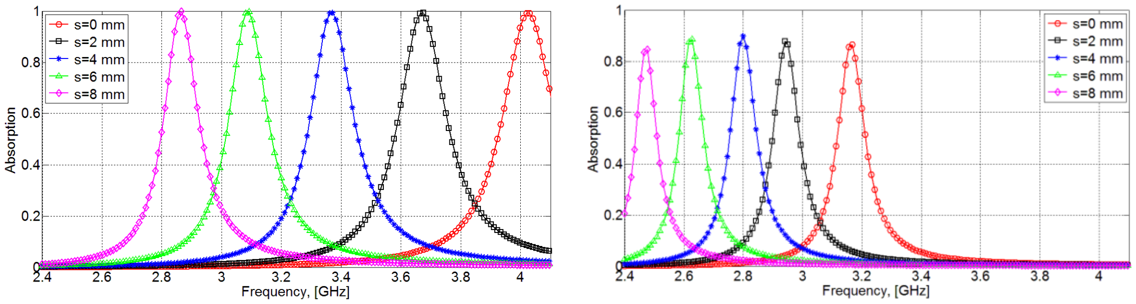


Figure 2. Numerically obtained **a)** absorption and **b)** reflection plots of the proposed structures for s = 6 mm.

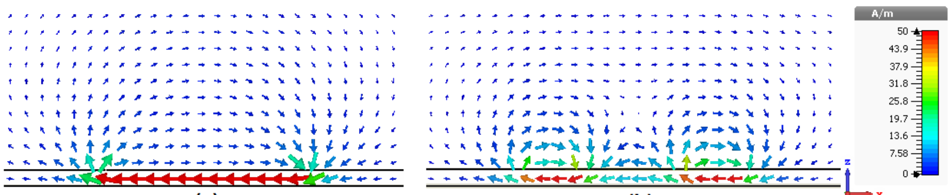
In addition, the effects of changing center to center distance 's' on absorption spectra have also been examined for only twin circular sheet and twin circular ring structures for five steps from s = 0 mm to 8 mm. The results are demonstrated in Fig. 3. It is clear that increasing s, decreased both the resonance frequency and HPBW for both structures. Nevertheless, the resonance frequency of twin circular sheet is more sensitive to s distance than the twin circular ring structure.



(a) **(b)**

Figure 3. Numerically obtained absorption results of the proposed structures for variable s distance. **a)** Twin circular sheet and **b)** twin circular ring structures.

Moreover, Fig. 4.a, and b show the induced *H*-field at resonance frequencies for twin circular sheet and twin circular ring structures having both s = 6 mm, respectively. Herein it is clear that the circulating magnetic field in twin circular sheet is higher than the circulating current in the twin circular ring which may be associated with the stronger absorption levels in the twin sheet structures than the twin ring structures.



(a) **(b)**

Figure 4. *H*-field monitors where normal cut plane at center. **a)** Twin circular sheet at resonance frequency 3.079 GHz and **b)** twin circular ring at resonance frequency 2.623 GHz.

3. Conclusion

In this study, numerical analyses results for twin intersecting sheet resonator and twin intersecting ring resonator type absorber structures are reported. The analyses show that the sheet type structures promise higher absorption levels, higher resonance frequencies and higher HPBW levels as compared to their ring type derivatives. In addition, increasing the center to center distance is observed to decrease both resonance frequency and HPBW levels.

References

[1]. Landy, N. I., Sajuyigbe, S., Mock, J. J., Smith, D. R., and Padilla, W. J., "Perfect metamaterial absorber", Phys. Rev. Lett., vol. 100 no. 20, 207402, 2008.
[2]. Liu, T., Cao, X., Gao, J., Zheng, Q., Li, W., and Yang, H., "RCS reduction of waveguide slot antenna with metamaterial absorber", IEEE Trans. Antennas Propag., vol. 61 no. 3, pp. 1479-1484, 2013.
[3]. Schuring, D., Mock, J. J., Justice, B. J., Cummer, S. A., Pendry, J. B., Starr, A. F., and Smith, D. R., "Metamaterial Electromagnetic Cloak at Microwave Frequencies", Science, vol. 314 no. 5801, pp. 977-980, 2006.
[4]. Dincer, F., "Electromagnetic energy harvesting application based on tunable perfect metamaterial absorber", J. Electromagn. Waves Appl., vol. 29, no. 18, pp. 2444-2453, 2015.
[5]. Ekmekci, E., and Demir, E., "On/Off Switching of Absorption Spectra by Layer Shifting for Double Layer Metamaterial Based Absorber", IEEE Antennas Wirel. Propag. Lett., vol. 15, pp. 532-535, 2016.
[6]. Liu, N., Mesch, M., Weiss, T., Hentschel, M., and Giessen, H., "Infrared perfect absorber and its application as plasmonic sensor", Nano Lett., vol. 10, pp. 2342-2348, 2010.
[7]. Yoo, Y. J., Kim, Y. J., Tuong, P. V., Rhee, J. Y., Kim, K. W., Jang, W. H., Kim, Y. H., Cheong, H., and Lee, Y., "Polarization-independent dual-band perfect absorber utilizing multiple magnetic resonances", Opt. Express, vol. 21 no. 26, pp. 32484-32490, 2013.
[8]. Wang, B. X., Zhai, X., Wang, G. Z., Huang, W. Q., & Wang, L. L., "Frequency tunable metamaterial absorber at deep-subwavelength scale", Opt. Mater. Express, vol. 5 no. 2, pp. 227-235, 2015.