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Comment on "Design of a Quad-Band Wide-Angle Microwave Metamaterial Absorber"

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In recent days, we read a paper called "Design of a Quad-Band Wide-Angle Microwave Metamaterial Absorber", which was written by Ren et al. In such report, Ren et al. proposed a quad-band wide-angle absorber based on a metallic hexagonal patch layer. The absorption peaks are located at 6.8 GHz, 8.24 GHz, 11.24 GHz, and 12.7 GHz, whose absorptivity values are 97.2%, 95.2%, 97.7%, and 98.5%, respectively. However, we verified that the results which were given by Ren et al. are wrong because they ignored the polarization conversion. The proposed quad-band metamaterial absorber (QBMA) is not an absorber.

Key words: Metamaterial, polarization converter, absorber

INTRODUCTION

Since Landy et al. proposed the first metamaterial absorber in 2008,[1] the metamaterial absorbers have been attracting more and more researchers. For the absorbers, the angular stability is one of the most important parameters. Tao et al. proposed a wide-angle absorber in a THz regime with a highly flexible material,[2] and they found that such a metamaterial absorber can realize a stable absorption when the incident angle is less than 40°. Shen et al. presented a wide-angle and polarization-independent metamaterial absorber,[3] which has three absorption peaks. Those absorption peaks are located at 4.06 GHz, 6.73 GHz, and 9.22 GHz whose absorptivity values are 99%, 0.93%, and 0.95%, respectively. Besides, the metamaterial also can be used to realize other applications. For instance, polarization converters.[4–6] Recently, we read a paper called "Design of a Quad-Band Wide-Angle Microwave Metamaterial Absorber". In such paper, Ren et al. designed a wide-angle absorber which has four absorption peaks whose absorptivity values are larger than 90%.[7] And these absorption peaks are situated at 6.8 GHz, 8.24 GHz, 11.24 GHz, and 12.7 GHz whose values are 97.2%, 95.2%, 97.7%, and 98.5%, respectively, when the incident angle is less than 40°. In this comment, we recalculate the absorption spectra of such a quad-band metamaterial absorber (QBMA), which is mentioned by Ren et al., and we found that the proposed QBMA is not an absorber, but a polarization converter.

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MODELING AND SIMULATION

The schematic configuration of the proposed QBMA is plotted in Fig. 1. The parameters of such a QBMA are listed in Table I. A transverse electric (TE) wave assumes that the electric field is parallel to the y axis and the magnetic field is parallel to the x axis. A transverse magnetic (TM) wave describes that the electric field is parallel to the x axis and the magnetic field is parallel to the y axis. The following results are calculated under a TE wave.

The absorption of the proposed QBMA can be described as $A(\omega) = 1 - R(\omega) - T(\omega)$. In this formula, $A(\omega)$ is the absorption, and $R(\omega)$ and $T(\omega)$ stand for the reflection and transmission, respectively. The transmission is zero because the backboard is a whole metal plate. Therefore, such an expression can be simplified as $A(\omega) = 1 - R(\omega) = 1 - |S_{11}(\omega)|^2$. It is noticed that $|S_{11}(\omega)|^2 = |S_{\mathrm{TMTE}}(\omega)|^2 + |S_{\mathrm{TETE}}(\omega)|^2$. $|S_{\mathrm{TMTE}}(\omega)|^2$ means the cross-polarization reflectivity, and $|S_{\mathrm{TETE}}(\omega)|^2$ refers to the co-polarization reflectivity. Both of them cannot be ignored. Otherwise, the calculated results will be wrong. The computed reflection and absorption of the proposed QBMA are given in Fig. 2. We can see from Fig. 2a that the co-polarization is almost less than 0.3 in the frequency region 8.12–12.20 GHz, but its value is larger in other frequencies. However, a different trend can be found in the cross-polarization. The cross-polarization is large in the frequency region 8.12–12.20 GHz, but its value is smaller in other frequencies. The reported absorption spectra in Ref. 7 and the actual absorption spectra are displayed in Fig. 2b. Ren et al. claimed that such a QBMA has four absorption peaks, which are located at 6.8 GHz, 8.24 GHz, 11.24 GHz, and 12.7 GHz. The absorptivity values of those peaks are 97.2%, 95.2%, 97.7%, and 98.5%, respectively. However, one can see from Fig. 2b that the absorption peaks only appear at 8.91 GHz and 11.43 GHz, and their corresponding absorption are 48.7% and 50.9%, respectively. Therefore, we can conclude that the results which were proposed by Ren et al. are wrong because they ignored the reflection of the cross-polarization.

In order to figure out the mechanism of polarization conversion for the proposed QBMA, the surface currents at different frequencies are plotted in Fig. 3. As shown in Fig. 3a, at 9.3 GHz, the directions of the surface currents on the top copper patch and the bottom copper plate are described by the black arrows (marked by "1" and "2"). The anti-parallel surface currents "1" and "2" form a cycle, which can generate a magnetic dipole m_1. As a result, an induced magnetic field $\mathbf{H_1}$ is produced by m_1 (as shown in Fig. 3a). Along the direction of surface current "1", the induced electric field $\mathbf{E}$ emerges. The combined action of $\mathbf{E}$ and $\mathbf{H_1}$ generates the reflection of a TM wave. The directions of the surface currents at 10.8 GHz on the top copper patch (marked by "3") and bottom copper reflector (marked by "4") are shown in in Fig. 3b, which are described by the black arrows. As mentioned above, a circulation also can be caused by the anti-parallel surface currents "3" and "4", which also can produce a magnetic dipole m_2. Obviously, an induced field $\mathbf{H_2}$ is produced, and the induced electric field $\mathbf{E}$ is arisen along the current "3". The reflection of the TM wave is produced by the combined action of $\mathbf{E}$

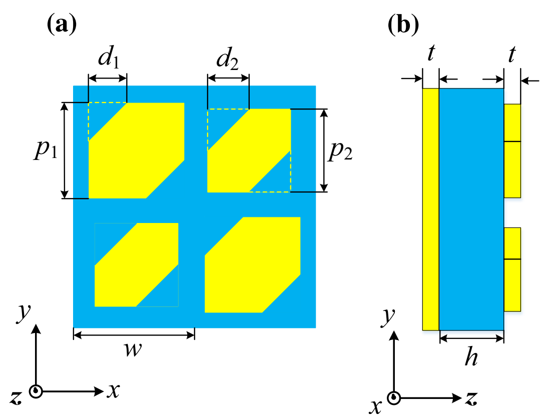

Fig. 1. The schematic configuration of the proposed QBMA: (a) the top view of the proposed QBMA, (b) the side view of the proposed QBMA.

Table I. The parameters of the proposed QBMA

Parameter	d_1	d_2	h	p_1	p_2	t	w
Value (mm)	3.42	2.56	1.5	7.1	6.8	0.05	11.4

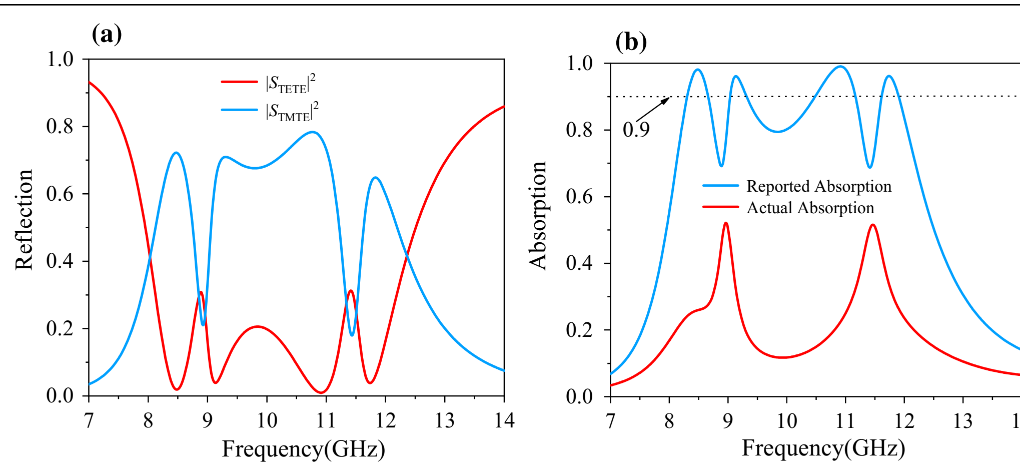

Fig. 2. The calculated reflection and absorption of the proposed QBMA: (a) the calculated reflection spectra of $|S_{\mathrm{TETE}}(\omega)|^2$ and $|S_{\mathrm{TMTE}}(\omega)|^2$, and (b) the reported and actual absorption spectra.

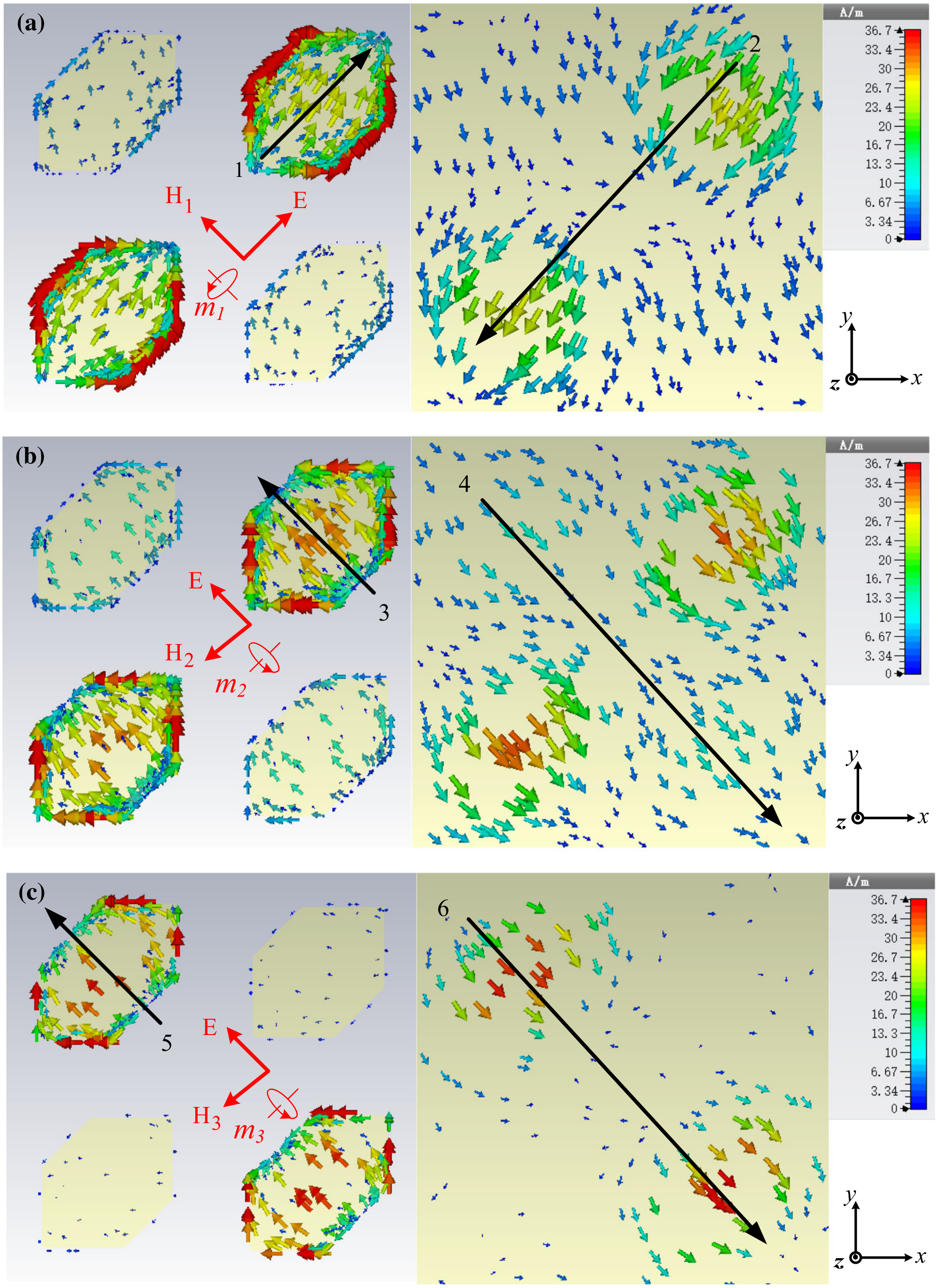

Fig. 3. The surface current distributions of the proposed QBMA on the upper copper patch and bottom copper reflector at different frequencies: (a) the surface current distributions at 9.3 GHz, (b) the surface current distributions at 10.8 GHz, and (c) the surface current distributions at 12 GHz.

and $\mathbf{H_2}$. In Fig. 3c, the surface currents at 12 GHz are depicted. As shown in Fig. 3c, a circulation is caused by the anti-parallel surface currents "5" and "6", which leads to the production of a magnetic dipole m_3. Similarly, an induced field $\mathbf{H_3}$ is produced, and the induced electric field $\mathbf{E}$ is generated along the current "5". Thus, the reflection of the TM wave is caused by the combined action of $\mathbf{E}$ and $\mathbf{H_3}$. Obviously, the reflection of the incident electromagnetic wave is composed of the TM wave and the TE wave. The TM wave gives rise to absorption, and the TE wave leads to polarization conversion. The performance of the absorber as mentioned in Ref. 7 is very poor since there is a strong polarization conversion, which is ignored by Ren et al. Therefore, we do not need to repeat the discussion of the surface currents distribution at 9.3 GHz and 10.8 GHz.

CONCLUSIONS

In conclusion, the QBMA as mentioned in Ref. 7 cannot act as an absorber because Ren et al. did not consider the cross-polarization. Obviously, such a QBMA only has two absorption peaks which are located at 8.91 GHz and 11.43 GHz, and the absorptivity values for those two peaks are 48.7% and 50.9%, respectively. In a word, if we want to design an absorber, both of the co-polarization and cross-polarization should be considered to ensure the accuracy.

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REFERENCES

1. N.I. Landy, S. Sajuyigbe, J.J. Mock, D.R. Smith, and W.J. Padilla, *Phys. Rev. Lett.* 100, 207402 (2008).
2. H. Tao, C.M. Bingham, A.C. Strikwerda, D. Pilon, D. Shrekenhamer, N.I. Landy, K. Fan, X. Zhang, W.J. Padilla, and R.D. Averitt, *Phys. Rev. B* 78, 1879 (2008).
3. X.P. Shen, T.J. Cui, J.M. Zhao, H.F. Ma, W.X. Jiang, and H. Li, *Opt. Express* 19, 9401 (2011).
4. S.Y. Wang, W. Liu, and W. Geyi, *Appl. Phys. B Lasers Opt.* 124, 126 (2018).
5. N. Sha, S.Y. Wang, and W. Geyi, *Appl. Phys. A Mater.* 124, 525 (2018).
6. S.Y. Wang, W. Liu, and W. Geyi, *Sci. Rep.* 8, 3791 (2018).
7. Y.H. Ren, J. Ding, C.J. Guo, Y. Qu, and Y.C. Song, *J. Electron. Mater.* 46, 1 (2016).