Comment on "Superwide-band negative refraction of a symmetrical E-shaped metamaterial with two electromagnetic resonances"

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(Received 11 October 2008; revised manuscript received 16 January 2010; published 22 April 2010)

The superwide-band negative refraction of the symmetrical E-shaped structure designed by Yan *et al.* [Phys. Rev. E **77**, 056604 (2008)] may not exist. While we accepted the validity of scattering parameter simulations completely, the process of retrieving material parameters could not be justified.

DOI: 10.1103/PhysRevE.81.048602 PACS number(s): 41.20.Jb, 78.20.Ci, 73.20.Mf, 42.25.Bs

In a recent paper [1], Yan *et al.* studied the symmetrical E-shaped structure by means of numerical simulations. They claimed that the negative-refractive band of the symmetrical E-shaped structure was superwide. While we accepted the validity of the simulations presented in Ref. [1], the process of retrieving material parameters could not be justified.

In short, their retrieval method is based on Eqs. (4), (9), and (10) in Ref. [2], namely,

$$n = \frac{1}{kd}\cos^{-1}\left[\frac{1}{2S_{21}}(1 - S_{11}^2 + S_{21}^2)\right], \tag{1}$$

$$z = \sqrt{\frac{(1+S_{11})^2 - S_{21}^2}{(1-S_{11})^2 - S_{21}^2}}, \tag{2}$$

$$\varepsilon = n/z, \mu = nz. \tag{3}$$

Equation (1) could be manipulated to yield

$$n = \frac{1}{kd}\left(2m\pi + \arccos\left[\frac{1}{2S_{21}}(1 - S_{11}^2 + S_{21}^2)\right]\right), \tag{4}$$

$$(m = 0, \pm 1, \pm 2, \ldots).$$

In Eq. (4), the multiple branches problem associated with the inverse cosine in Eq. (1) makes it difficult to determine the material parameters because of ambiguity.

In Fig. 2 of Ref. [1], in the regime where the frequency is lower than the magnetic resonant frequency, there was no magnetic resonance, but both negative permeability and negative-refractive index n appeared. This is unphysical. As we have known, the negative permeability is realized by a certain kind of magnetic resonance [3,4], that is to say, no magnetic resonance and no negative permeability.

In the frequency range from 10.0 to 50.6 GHz, where the wavelength may be considered much larger than d (2.5 mm), the proper value of m is 0; in the frequency range from 50.6 to 60.0 GHz, where the wavelength may considered comparative with d, the proper value of m is −1 [5,6]. Then we could retrieve the right values for the complex refractive index n, wave impedance z, effective permittivity ε, and effective permeability μ, as shown in Fig. 1.

The S parameters in Fig. 1(a) are in good agreement with those in Fig. 2(a) in Ref. [1]. By making a comparison between Fig. 1(b) here and Fig. 2(b) in Ref. [1], we find that there is a major difference between them, that is, the broad negative-refractive band between 10 and 47.8 GHz which appeared in Fig. 2(b) in Ref. [1] Does not show up in Fig. 1(b). In addition, the retrieved impedance, the retrieved permittivity, and the retrieved permeability are shown in Figs. 1(c)–1(e), respectively. As shown in Figs. 1(c)–1(e), simultaneously negative real parts of permittivity and permeability in the frequency regime from 10 to 47.8 GHz could not be obtained.

However, within the two narrow bands in the vicinity of the resonances of the structure the retrieved material parameters are questionable [7] because in these regions the half wavelength inside the medium is smaller than the lattice constant. This means that the structure actually operates in the Bragg regime, where the propagation is mainly determined by scattering and interference effects and the definition of an effective index of refraction is not justified.

On the basis of the above analyses, we accepted the validity of scattering parameter simulations completely. However, we are afraid that the superwide negative-refractive

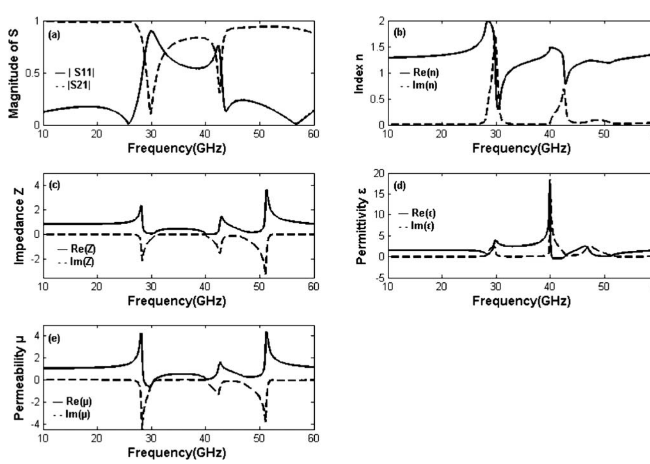

FIG. 1. (a) Magnitude of the simulated S parameters for the unit cell; (b) retrieved refractive index; (c) retrieved impedance; (d) retrieved permittivity; and (e) retrieved permeability.

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band of the symmetrical E-shaped structure designed by Yan *et al.* may not exist.

This work was supported by the National Natural Science Foundation of China (Grant No. 60871027). The authors thank Changchun Yan from Southeast University, Nanjing, China for valuable discussions and O. Paul *et al.* from University of Kaiserslautern, Germany for their work from which we benefited.

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