Transmission and reflection properties of composite metamaterials in free space

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Abstract: We measured transmission and reflection from SRRs, thin wires, and composite metamaterials in free space. X-band measurement exhibits high transmission magnitude for frequencies where both SRR and wire have effective negative permeability and permittivity, respectively.

OCIS codes: (120.5700) Reflection, (120.7000) Transmission, (350.4010) Microwaves

1. Introduction

Composite metamaterials (CMMs) have attracted great attention due to their unique physical properties [1-5]. The effective permittivity ε_{eff} and permeability μ_{eff} possess negative values for certain structures. A negative permittivity medium can be obtained by arranging thin metallic wires periodically [6]. On the other hand, a negative effective magnetic permeability medium is obtained by combining an array of split ring resonators (SRRs) [7]. By combining SRRs and thin wires, it is possible to obtain a composite medium that exhibit left-handed characteristics. In this work, we investigated transmission and reflection properties of SRRs, discontinuous thin wires and double negative composite metamaterials in free space.

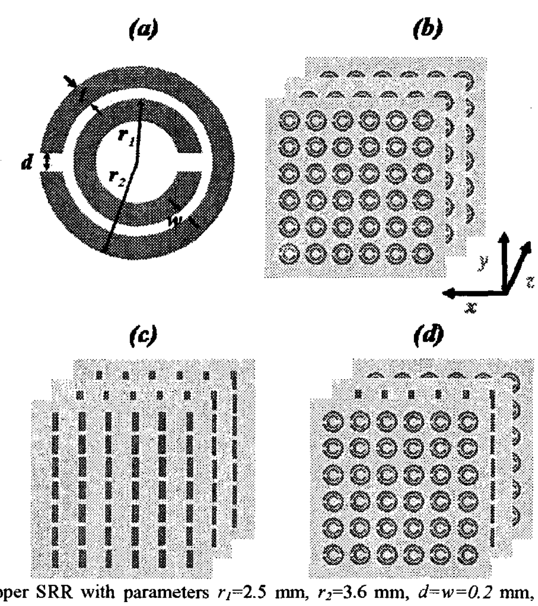

Fig. 1. (a) A single copper SRR with parameters r_1=2.5 mm, r_2=3.6 mm, $d=w=0.2$ mm, and $t=0.9$ mm. Schematic drawing of (b) the negative μ medium, (c) the negative ε medium, and (d) the composite double negative metamaterial.

2. Split ring resonators

We first constructed the negative permeability medium that consists of periodical arrangement of copper SRRs on circuit boards [5]. The details of the single SRR structure is shown in Fig.1a. The transmission, reflection, and phase measurements are performed in free space by using an HP 8510C network analyzer and microwave horn antennas. The measured transmission and reflection characteristics of the SRR medium were given in Fig. 2a. There are several pass and stop bands throughout the spectrum. The measured photon lifetime for first pass band, which was derived from phase measurements, was plotted in the inset of Fig. 2a.

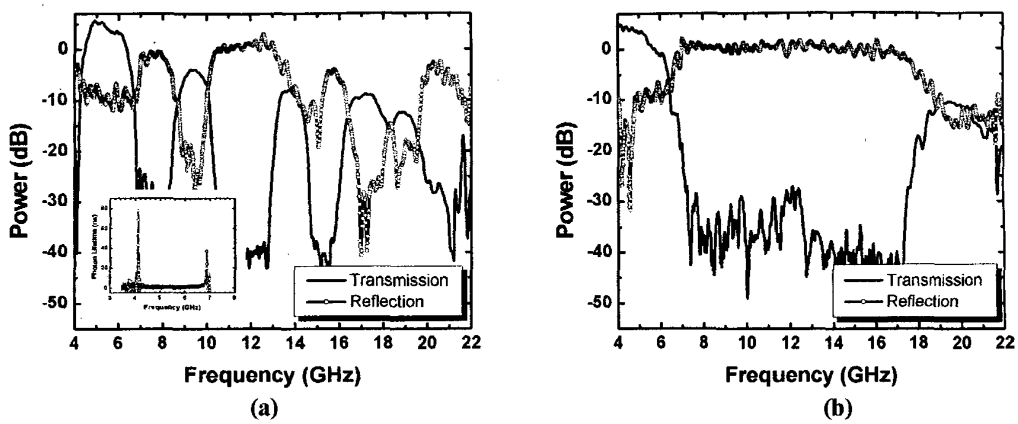

Fig. 2. (a) Measured broad-range transmission and reflection spectra of the SRR medium in free space. Inset: Measured delay time, photon lifetime, as a function of frequencies. (b) Measured transmission and reflection characteristics of the thin wire medium. The transmission spectrum exhibits a wide stop band extending from 7 to 18 GHz..

3. Thin Wires

The thin wire medium was constructed by depositing discontinuous wire strips on the circuit board (Fig. 1c). We stacked the thin wire stripes with parameters periodically with a lattice parameter a_z=*6.5*. We investigated transmission and reflection characteristics of thin wires (see Fig. 2b). In contrary to the continuous wire structures [6], the present configuration exhibits a stop band centered around 12 GHz, and the lower edge of the stop band does not extend to the zero frequency.

4. Composite Metamaterials

The composite double negative medium was constructed by stacking the SRR and wire mediums periodically as shown in Fig. 1d. The periodicity along *z* direction is a_z=*6.5* mm, the same as in SRR and wire mediums.

We measured the transmission and reflection properties of the double negative composite metamaterials as displayed in Fig. 3. There appeared a broad and high amplitude transmission band extending from 9.6 to 14.3 GHz. In this frequency range both effective permeability and permittivity are negative. The reflection spectrum also clearly shows that the EM waves within this frequency range can penetrate into the double negative composite medium.

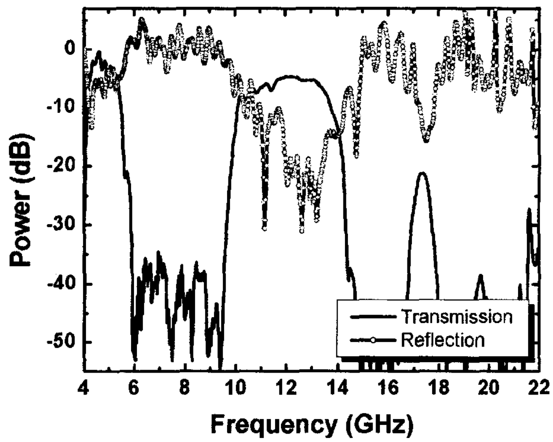

Fig. 3. Measured transmission and reflection spectra of the double negative composite metamaterials. Relatively high power, -4.5 dB, is measured between frequencies 9.5 and 14.5 GHz in which both effective permittivity and permeability have negative values. The reflection spectrum also has average -20dB rejection throughout this region.

7. References

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