QMD 10:15 am–12:00 pm
Room: 201

Metamaterials

Jeremy J Baumberg, Univ. of Southampton, UK, Presider

QMD1 10:15 am

Microwave Transmission through Metamaterials in Free Space

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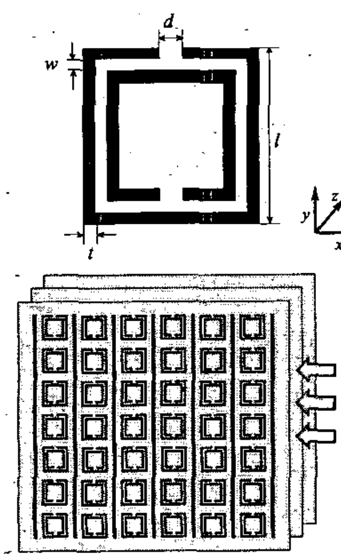
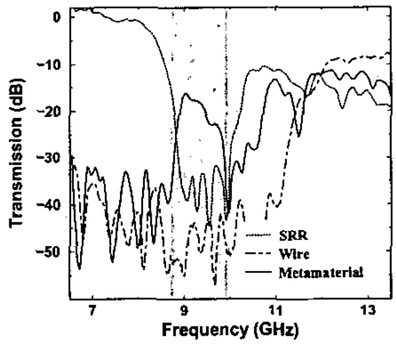
Recently, the composite metamaterials, which was first theoretically proposed by Veselago in 1968,[1] have inspired great attentions due to interesting physical properties and novel applications.[2,3,4,5] The electric and magnetic behaviors of materials are determined by two important material parameters, ε (dielectric permittivity) and μ (magnetic permeability). Together the permeability and the permittivity determine the response of the material to the electromagnetic radiation. Generally, ε and μ are both positive in ordinary materials. Negative dielectric medium at microwave domain can be obtained by arranging thin metallic wires periodically.[6] Below plasma frequency, dielectric permittivity will take negative values. Pendry *et al.* proposed negative magnetic permeability by using special configurations of metals, named as split ring resonator and swiss roll capacitor.[2]

In order to investigate properties of metamaterials, we constructed a composite structures which consists of periodical arrangement of thin copper wires and SRRs on a circuit board (see Fig. 1). We first measured the transmission spectra of the thin wire and SRR mediums individually. The measurements are performed in free space by using a HP 8510C network analyzer and microwave horn antennas. Figure 2 exhibits the measured transmission spectra of SRRs (dotted line), thin wires (dot-dashed line), and the composite metamaterials (solid line). The SRR medium exhibits a stop band extending from 8.7 to 10.3 GHz. The thin wire structure has a plasma frequency around 11.3 GHz. As shown in Fig. 2, there appears a transmission band for the composite metamaterial within the stop bands of SRR and thin wire structures.

In summary, we investigated the transmission properties of composite metamaterials at microwave frequencies. We observed that a passband is formed within the forbidden transmission bands of thin wire and SRR structures.



QMD1 Fig. 1. [Top panel] Schematic drawing of a single SRR with parameters $l = 3$ mm and $d = t = w = 0.33$ mm. [Bottom panel] The schematics of composite metamaterial consisting of thin wires and SRRs. The structure is consisted of $N_x = 25$, $N_y = 25$, and $N_z = 20$ unit cells, and each unit cell has dimensions $a_x = 5$ mm, $a_y = 3.63$ mm, and $a_z = 5$ mm. The thickness of thin wire is 0.5 mm.



QMD1 Fig. 2. Measured transmission spectra corresponding to thin wires, SRRs, and metamaterials.

References

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3. D.R. Smith, W. Padilla, D.C. Vier, S.C. Nemat-Nasser, and S. Schultz, "Composite medium with simultaneously negative permeability and permittivity," Phys. Rev. Lett. 84, 4184 (2000).
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QMD2 10:30 am

Chiral Gratings—a New Class of Polarization Sensitive Metamaterials

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Recently a new group of layered planar and quasi-planar metamaterials has emerged which promise unique polarization characteristics. Metallic bilayered structures with chirality and inductive coupling are predicted[1] to show huge optical polarization rotatory power resembling that of liquid crystals. The semi-chiral planar gratings described here belong to a distinctively different class of 2D structures known as planar chiral structures.[2] By definition, two planar chiral objects of different chirality cannot be brought into congruence, unless they are lifted out of the plane by rotating by 180° about an axis in the plane of the structure. A gammadion is an example of such an object. It was expected that planar chiral structures would have pronounced polarization properties when interacting with light,[3] however, to the best of our knowledge, this has never been confirmed experimentally. Here we report what we believe is the first experimental demonstration of such polarization activity.

Gold semi-planar chiral gratings were manufactured on silicon substrates using a combination of direct-write electron beam lithography and either ion beam milling or a lift-off process. We have manufactured two-dimensional gratings consisting of regular square patterns of gammadions or anti-gammadions. We have studied a range of gratings with different pitches, containing gammadions of various characteristic sizes ranging from 700 nm to 4 μm, and different senses of chirality as illustrated on Fig. 1. A typical grating has an area of approximately 1.0×1.0 mm^2, with a density of gammadions of between 6×10^5 cm^{-2} and 6×10^6 cm^{-2}.

These gratings show a well-defined rectangular diffraction pattern as illustrated in Fig. 2. The polarization properties of the diffracted waves have been investigated at a wavelength of 632 nm for S and P polarizations at an angle of incidence of 60°. The polarization state of the diffracted beams was found to be different from that of the incident beam. In general the diffracted beams become elliptically polarized and the polarization azimuth rotates. Rotations in excess of 30° were seen. It should be noted that for S and P incident polarizations no polarization change is expected on reflection from an isotropic unstructured interface. For a given diffraction order the polarization azimuth rotation was found to have opposite sign for samples, which only differ in their handedness. On the same sample different diffraction orders show different polarization azimuth rotation, as illustrated in Fig. 2.

Another startling feature of these samples has been their ability to alter the perceived color of reflected light when viewed through a low magnification polarizing microscope, even though the typical feature sizes of these structures are much