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Electromagnetic wave reflection of optically controlled nonlinear split-ring resonator arrays

*S. Nakamura[1], R. Kawaguchi[2], H. Takahashi[2], K. Hatano[2], S. Yamamoto[2], S. Kurumi[3], K. Suzuki[3], K.-i. Matsuda[3]

Abstract: We fabricate double-layered nonlinear split-ring resonator (nSRR) arrays. When the interaction between the nSRRs is sufficiently small, the nSRR arrays show simple resonance properties. Under strong interacting situations, on the other hand, the eigenfrequency of the nSRR split into two different ones. This phenomenon is analogous to the electron band formation in microscopic molecules.

1. Introduction

For more than a few decades, electromagnetic metamaterials have been investigated intensively because they show, for instance, negative refractive indices that can not be observed in conventional materials in nature. A split-ring resonator is one of the vital elements for realizing such remarkable electromagnetic responses of metamaterials.[1,2] In such systems, SRRs have exhibited as artificial atoms for their resonance properties.

In this paper, the electromagnetic responses of strongly interacting tunable nonlinear SRR (nSRR) arrays were investigated as a function of their interlayer distances and their resonance frequencies.

2. Experimentals

In this study, we fabricated square-shaped nSRRs having two varicap diodes (Skyworks Co., Ltd., SMV-1234-079LF) in a parallel configuration. The side length of the nSRR is 7 mm. Each nSRR has a bias circuit for controlling its resonance frequencies independently, and the circuit is optically driven via an optical isolator. A double-layered nSRR array consists of nSRRs, named #1 and #2, exhibiting very similar electromagnetic responses. A vector network analyzer (Textronix Co., Ltd, TTR503A) was used to measure the electromagnetic wave reflection (S_{11}) properties.

3. Results and Discussions

Figure1 shows S_{11} spectra for (a) nSRR #1, (b) nSRR #2, and the double-layered nSRR array structure ((c) and (d)), respectively. As can be seen clearly, both nSRR #1 and #2 have very similar S_{11} spectra, and their resonant frequencies are at about 0.66 GHz. On the other hand, for the nSRR array with interlayer distance d = 3.5 mm, the resonant frequency is split into two different frequencies. Moreover, the frequency difference between two resonant states

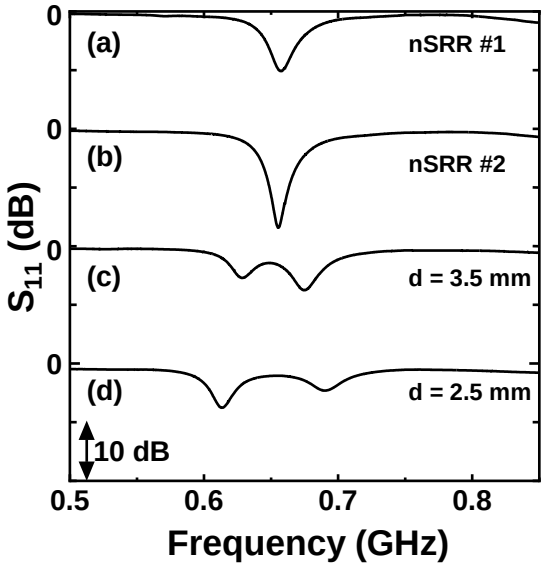

FIG 1. S11 spectra for (a) nSRR #1, (b) nSRR #2, (c) double-layered array with d = 3.5 mm, and (d) that for d = 2.5 mm, respectively.

significantly increases with decreasing d to 2.5 mm. These successive changes in S_{11} spectra imply that the interaction between two nSRR can be interpreted as the analogy of the formation of bonding and antibonding energy states of electrons in molecules.

4. Summary

We investigated S_{11} spectra for double-layered nSRR structures. It was found that the mechanism of interaction between the nSRR can be presumed to be the phenomena observed in microscopic molecules. For that reason, such nSRR array structures can be regarded as meta molecules consisting of artificial atoms.

References

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1: Dept. of Elec. Eng., Grad. School of ST, Nihon Univ.　2: Dept. of Elec. Eng., Undergraduate course of CST, Nihon Univ.
3: Dept. of Elec. Eng., CST, Nihon Univ.