Effects of Split Ring Coupling on Metamaterial Parameters

Vojislav Milošević[1]*, Radovan Bojanić [1], Branka Jokanović[1]

[1] *Photonics Center, Institute of Physics, Belgrade, Serbia*
**vojislav@ipb.ac.rs*

One of the most popular elements used in metamaterial design is well known split ring resonator (SRR), proposed by Pendry et al. in [1]. It represents a metallic loop, usually of square or circular shape, with a gap. Alternative realization is so-called complementary SRR, where metal and dielectric surrounding are mutually replaced according to Babinet principle [2]. If dimensions of SRR are small compared to the wavelength, which should be satisfied for most metamaterials, quasi-static model can be applied and SRR can be regarded as a LC circuit with resonant frequency $\omega^2 = \frac{1}{LC}$ [3].

In this paper we investigate configuration of two broadside-coupled split rings, i.e. one above the other, in various spatial configurations obtained by rotating the individual rings. According to the model of coupled-oscillator, there are two normal modes, i.e. resonant frequencies, which mutual positions are directly dependant of the coupling strength. There are both inductive and capacitive coupling, and rotation can affect them in various ways. Such structures, which are made of identical constituents, but in a different spatial arrangement, are termed 'stereometamaterials', according to [4].

We use coupled SRRs to build 1-D transmission line metamaterial, which unit cell consists of microstrip line on two layer substrate loaded with via and coupled with SRRs. Several unit cell configurations are shown on Fig. 1 (via is left out for sake of simplicity). It was shown that such structure exhibits negative index of refraction in the microwave region.

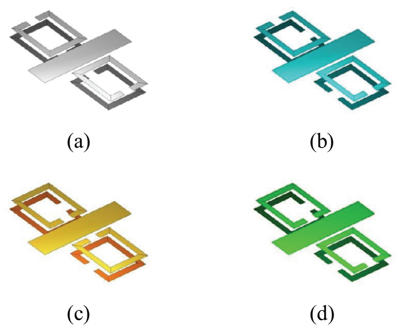

Fig. 1. Various unit cell configurations

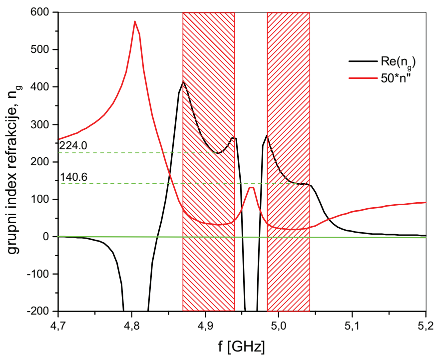

Fig. 2. Group index of refraction

It was demonstrated in [5] that a classical (non-quantum) equivalent of electromagnetically induced transparency (EIT) can occur in metamaterials due to SRR coupling. We observed that effect for the structure which consists of two low-layer SRRs twisted for 90^0 in respect to the upper-layer counterparts (Fig. 1c). Fig. 2 shows plot of the real part of group index of refraction (black) and the imaginary part of refraction index (red line, indicating losses). There is area (marked with rectangle) with low losses and high values of group index (of 224 and 140.6), indicating slow wave propagation, which is a characteristic of EIT effect.

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