Tunneling Behavior of Waveguides with Inserted Single Split-Ring Resonator

Elena Semouchkina[1], Sandeep Mudunuri[1], George Semouchkin[1], and Raj Mittra*[2]
[1]Materials Research Institute
[2]Electromagnetic Communication Laboratory
The Pennsylvania State University, University Park, PA 16802
Emal: rajmittra@ieee.org

Abstract

In this paper we present the results of investigation of waveguides containing a single split-ring resonator (SRR) (Fig.1). In difference from other studies of backward waves (BW) in SRR-filled waveguides, dimensions of the SRRs were small compared to dimensions of the waveguide cross-sections so that the SRR's "magnetic" resonance was expected at frequencies far above cut-off. In confirmation, our simulations and experiments have demonstrated corresponding drops in waveguide transmission at frequencies exceeding cut-off frequency by several GHz. At the same time, we have also observed, in both simulations and experiments, transmission peaks below cut-off frequency (Fig.2) similar to those related in literature to tunneling due to BWs. According to common views, such peaks should appear if magnetic resonance of the SRRs provides for negative permeability at frequencies when EM waves in waveguide are evanescent and can be described in terms of negative permittivity. To get deeper insight in the problem we have simulated the amplitude distributions of electric and magnetic field oscillations near the SRR at frequencies close to the peak band. The simulations have revealed second appearance of "magnetic" and "electric" resonances at these frequencies. In K-band waveguide, the resonance modes were disturbed, while in Ku-band waveguide they appeared quite clear, although the difference between their resonant frequencies did not exceed 0.75 GHz (Fig.3). The presence of "magnetic" resonance in the SRR allows us to relate the observed waveguide tunneling to BWs. However, these BWs should be very slow since they support resonance formation in the SRR below cut-off.

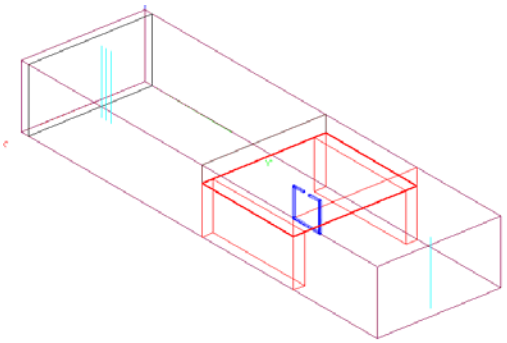

Fig.1. FDTD model of waveguide with inserted SRR

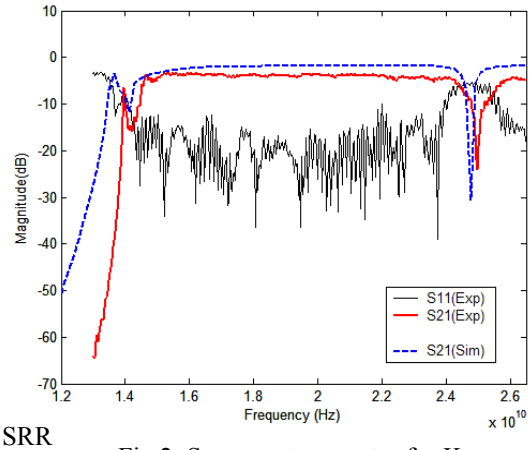

Fig.2. S-parameter spectra for K-band waveguide with inserted SRR having the perimeter of 6.2 mm

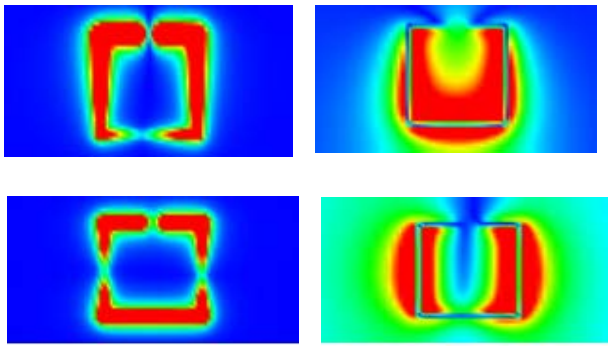

Fig.3. Magnitude distributions for oscillations of electric (left column) and magnetic (right column) field components directed normally to the SRR plane at 8.25 GHz (upper row) and 9.0 GHz (lower row).