Metamaterial Claddings for Waveguide Miniaturization

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The study of waveguides loaded with metamaterials has become quite popular in recent years (R. Marques et al., PRL, 89-18, 183901, 2002, S. Hrabar et al., IEEE Trans. Antennas Propag., vol. 53, no. 1, pp.110-119, 2005). It was pointed out that a rectangular waveguide below cut-off behaves as a 1-dimensional electric plasma for TE modes (R. Marques et al., PRL, 89-18, 183901, 2002). Likewise it behaves as magnetic plasma for TM modes (J. Esteban et al., IEEE Trans. on Microwave Theory and Techniques, vol. 53, no. 4, 2005). Since the rectangular waveguide naturally provides negative permittivity below cut-off, when combined with negative permeability materials, such loaded waveguide mimics the double negative materials in the frequency range where the negative permeability and permittivity overlaps. Backward waves in such waveguide were also experimentally verified. It is also of interest to investigate what happens when the waveguide is loaded with negative permittivity medium. It turns out that negative permittivity medium provides a pass band below cut-off inside the negative permittivity region (Y. Dong and T. Itoh, IEEE Microwave Magazine, 2012). The waves in such waveguide are forward waves unlike the former.

Metamaterial loaded waveguides are of interest mainly for two reasons. The first reason is that it provides an alternative approach to design double negative materials. Secondly the waveguides can be miniaturized significantly. In this study, we investigate waveguides that are loaded with electric-field-coupled resonators, providing negative permittivity, on the side walls of the waveguides. We show that such waveguides can be significantly miniaturized. Furthermore, we also verify that the waves inside such waveguide are forward wave by examining the dispersion diagram.