Miniature Antenna Using Printed Coupled Lines Emulating Degenerate Band Edge Crystals

G. Mumcu*, K. Sertel, and J. L. Volakis
ElectroScience Lab., Dept. of Electrical & Comp. Eng., The Ohio State University, Columbus, OH, 43212, http://esl.eng.ohio-state.edu

A miniature printed antenna design that exploits the higher-order dispersion behavior in the degenerate band edge (DBE) crystals is proposed. The higher-order DBE dispersion exhibits a maximally flat band edge that further lowers the resonance frequency, and therefore provides an additional miniaturization. First, the unit cell of a DBE crystal is emulated using a simple combination of uncoupled and coupled microstrip (MS) line sections printed on a low loss dielectric substrate. Subsequently, a resonant antenna is formed by cascading two such MS-DBE unit cells in a circularly periodic fashion. The antenna/array design and characterization using a low contrast dielectric substrate (Rogers Duroid, $\epsilon_r = 2.2$) is demonstrated. Next, fabrication and design verification using a high dielectric constant substrate (alumina: Al_2O_3, $\epsilon_r = 9.6$) is given. The manufactured antenna was measured to have a broadside gain of 4.5dB at 1.48GHz with 3.0% bandwidth. For this gain and bandwidth, we demonstrate that the proposed MS-DBE antenna has a $\lambda_0/9 \times \lambda_0/9$ footprint and is among the smallest in the published literature.

In addition, we propose a multi-layered (multi-port) printed circuit unit cell to obtain multiple band edge resonances at successive frequencies. We will demonstrate that a miniature multi-band printed DBE antenna can be realized through a symmetric design. Finally, we propose an equivalent lumped element circuit model consisting of simple inductors and capacitors to model printed DBE unit cells. By identifying the lumped circuit elements that are most effective on the DBE dispersion curve, we propose modifications to the unit cell layouts that will allow further miniaturization.