Design, Fabrication, and Testing of Nonvolatile Tunable Metamaterials

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We present experimental results of nonvolatile tunable metamaterials that are digitally addressable split-ring resonators (SRRs) or electric field couplers (ELCs). The individual SRR and ELC cells are creating by forming copper traces on an FR4 substrate. These cells are loaded with varactor diodes placed in appropriate locations in the metamaterial structure so that the voltage tunable capacitance created by the reverse biased diode creates a tunable resonant frequency in the metamaterial element. Voltage control is provided through a small, surface-mount nonvolatile digital potentiometer in each unit cell. We also make each unit cell individually addressable through a second chip that can be accessed through a single wire serial line. In this way, each unit cell can be tuned individually, and when voltage and communication link are disconnected from the metamaterial sample, the state remains in memory in each cell and can be recovered simply by applying voltage to the sample.

Using *Ansoft* HFSS^{TM} simulations, we designed SRR unit cells designed to resonate near 1.5 GHz and ELC cells designed to resonate near 2.4 GHz. These circuit boards were fabricated and populated, and then each sample was characterized using waveguide or free space transmission and reflection measurements. The measurements confirm that for these two different resonant structures and frequencies, the metamaterial cells could be tuned to a specific frequency or response, turned off, completely removed from the measurement setup, then replaced while recovering the previous tuned state. Nonvolatile tunable metamaterials like this can be used to create reconfigurable electromagnetic structures suitable in a wide variety of RF applications.