Design and Realization of Transistor-Embedded Active RF Metamaterials

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We present several results that use transistors within the context of metamaterials. Transistors are a fundamental device in the construction of several RF systems and applications. The basic device physics of the transistor allow for the convenient construction of variable resistors, oscillators, switches, and amplifiers. Embedding transistors within the confines of a split ring resonator (SRR), metamaterials can be designed to have a tunable resonant frequency, a tunable bandwidth, controlled loss cancellation and gain, and controlled oscillation. We will demonstrate how to design and realize all of the aforementioned properties.

The simplest of these properties is the ability of the transistor embedded SRR to have either a tunable frequency or a tunable bandwidth. The structure of the transistor presents several pn-junctions that can be utilized using different biasing conditions. Reverse-biasing the pn-junctions will create the same effect that has been previously shown using varactor diodes, meaning the depletion regions will expand and contract, creating a variable capacitance. Bandwidth tuning, on the other hand, is almost as simple, but a much more novel effect. Again, the basic structure of the transistor can be manipulated to create a variable resistor, which can, in turn, control the overall resistance of the SRR loop, modulating the quality factor of the resonance (Q) and the operating bandwidth.

Expansion from the basic transistor structure into fully biased transistor circuits creates the ability to produce metamaterials that are loss compensated, able to amplify incident signals, and produce RF oscillations. These types of circuits are the result of a transistor circuit providing a frequency region that yields negative differential resistance (NDR). By controlling the stability, loss compensated, amplifying, and oscillating metamaterials can be designed and realized.