

## **Multi-frequency and dual mode patch antennas partially filled with left-handed structures**

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### **Abstract-**

**Multifrequency microstrip patch antennas partially filled with left-handed (LH) structures are presented. The presence of LH structures also enables miniaturized antennas. Thus, multifrequency, dual-mode, and miniaturized antennas based on single patches partially filled with LH structures have been obtained. First, multiple operation over several band frequencies is proven from the transmission-line theory. Then, an implementation based on microstrip patches partially filled with mushroom-like structures is proposed. Two multifrequency patch antennas have been designed, built, and measured. The first one shows two dipolar (patch like) modes at 1.06 GHz and 2.16 GHz and a monopolar mode (null at broadside) at 1.45 GHz. The ratio between the resonant frequencies of both dipolar modes can be arbitrarily chosen (by means of a proper design of the patch and the LH structures) and, in this case, is 2.04. The second antenna is designed to work at closer frequencies. In this case, the frequency ratio is dramatically reduced to produce a dual dipolar antenna working at 1.81 GHz and 2.20 GHz (giving a ratio of 1.21).**

**Index Terms-** Left-handed (LH) metamaterials, microstrip antennas, multifrequency antennas.

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