A Metamaterial-Inspired Approach to RF Energy Harvesting

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Low-power RF energy harvesting has become a field of interest due to the need to acquire power in situations where the use of wires and/or batteries is impractical such as in structural or health monitoring. The prevalence of RF signals due to cell phones, Wi-Fi networks etc. make for a readily available power source with the potential to be scavenged as useable energy. Historically there has been difficulty with efficient power rectification in cases of low input power. Here we show that the use of metamaterials in the construction of energy harvesting rectennas provides a promising solution to this issue.

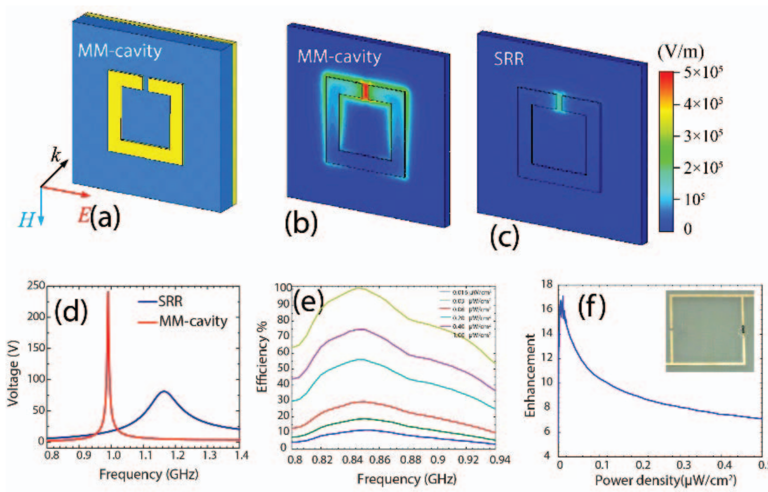

Figure 1 The MM-cavity consisting of SRR (yellow) + dielectric spacer (blue) + metal plate (yellow). (b,c) Simulated electric field in MM-cavity (b) and SRR (c) at their resonance frequencies. (d) The simulated voltage across the gap for the MM-cavity (red) and the SRR (blue). The Q-factor of the red and blue curves are 206.3 and 12.5, respectively. (e) Measured RF-DC conversion efficiency of a sample consisting of 4x4 array of SRRs. (f) Enhancement of efficiency of MM-cavity compared to SRR design. The insert picture shows one unit cell of the sample.

In this study we utilize an ultra-thin metamaterial (MM) cavity to achieve high efficiency of RF to DC power conversation at low RF power level. The metamaterial cavity improves the efficiency in the following two aspects: (i) It captures 100% RF energy passing through the effective area of the antenna array. (ii) The cavity resonance mode significantly increases the oscillating voltage across the schottky diodes embedded in the gap of the SRR (see Fig. 1(d)), and hence enhances the RF-DC conversion efficiency at low RF power level. As shown in Fig. 1(a), the unit cell of the MM-cavity design consists of a split-ring resonator (SRR) and a ground plane separated by an insulating layer. Fabry-Perot resonance occurs between the SRR and the ground plane in the MM-cavity as incident RF wave illuminates the sample, which enhanced the electric field across the gap (Fig. 1(b)) compared to SRR only (Fig. 1(c)). As shown in Fig. 1(d), the Q-factor and the amplitude of the voltage across the gap are significantly improved. Our measurement (Fig. 1(f)) shows that the RF-DC conversion efficiency is enhanced by factor of 16 compared to a regular SRR resonator design.