(Invited) RF Energy Harvesting via Metamaterial Inspired Structures, Rank prize lecture

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RF Energy Harvesting via Metamaterial Inspired Structures

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***Abstract*—This works presents two approaches for RF energy harvesting through metamaterial inspired structures. First, an electrically small rectenna is designed and fabricated with measured RF-to-dc efficiency 14.1% for -21.1 dBm power input and sensitivity of $0.0017\ \mu\mathrm{W/cm}^2$ power density. Next, a triple-band, high efficient (i.e., ability to delivers power to a load) and wide-angle metamaterial harvester is presented.**

***Index Terms*—Metamaterials, small antennas, rectifiers.**

I. Introduction

RF energy harvesting through RF-to-dc rectification is gaining ground the last decades [1], [2]. The number of RF emitters has been rapidly increased due to the development of new wireless technologies and it remains an engineering challenge how to capture the unused, ambient RF energy and supply small electrical devices, such as backscatter radio tags.

II. Metamaterial Inspired Structures

In typical RF-to-dc rectification system, an antenna is combined with a rectifier, which mainly consists of one or more diodes, forming a *rectenna*. In order to increase the rectifier's sensitivity (i.e., ability to operate at low power density), researchers, among others, used rectenna arrays [1]. The latter, increases the total harvester system size when conventional antennas are used. Moreover, the input impedance of a typical rectifier is also highly capacitive due to the presence of diodes. Hence, the use of electrically small antennas in rectenna designs has two main advantages, a) the rectenna-arrays have relatively compact size and b) matching network design between the antenna and the rectifier is not required, since the inherent highly capacitive/inductive input impedance of a typical electrically small antenna.

A new, metamaterial inspired, electrically small antenna is designed at 868 MHz and directly (i.e., without matching network) connected with a RD-to-dc rectification system, forming an electrically small rectenna. Antenna consists of two metamaterial split ring resonators (SRRs) with maximum edge dimension $d = 23.7$ and gap $g = 1.78$, which are electrically connected through a vertical strip line with height $h = 39.6$ and width $w = 3.4$ (all in mm). The measured rectenna has electrical size $ka = 0.47$, RF-to-dc measured efficiency (i.e., dc power input to the RF power input) is 14.1% for -21.1 dBm power input and sensitivity of -36.1 dBm power input or $0.0017\ \mu\mathrm{W/cm}^2$ power density (Fig. 1).

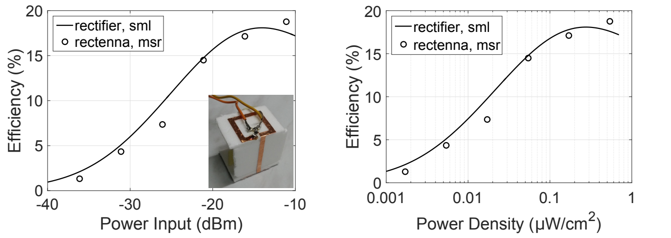

Fig. 1. Simulated rectifier's and measured rectenna's efficiency vs. power input (left) and power density (right) for 5 kOhm load at 868 MHz.

A metamaterial harvester (MH), in which the captured RF power is mainly delivered to a properly placed load, which in turn represents the input impedance of a rectification circuit, could usually outperform a conventional rectification system, i.e., a rectenna, because in general, metamaterials are periodic structures, and a typical metamaterial's unit-cell size is $\lambda/10$. Hence, a MH could be used on grids similar to photovoltaic panels and forms compact periodic structures, which are able to operate at lower frequency bands (e.g. FM radio, digital TV), which usually carry more power.

The MH (Fig. 2, left) is illuminated and the *power efficiency* at load (i.e., the ratio of the RF power delivered to the load to the RF incident power) is depicted in Fig. 2, right: at all cases, the proposed meta-harvester delivers power to the load with high efficiency for a wide-angle variation [2].

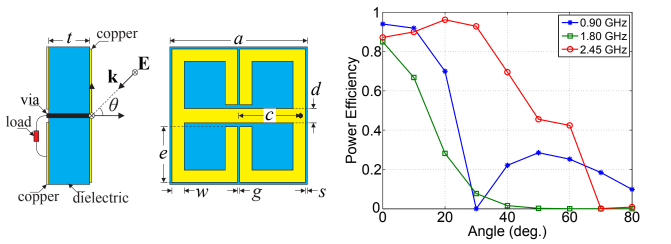

Fig. 2. The MH geometry (left) in [2] and the simulated power efficiency (right) at load for obliquely incident plane wave at 0.9, 1.8 and 2.45 GHz.

References

[1] S. D. Assimonis *et. al*, "Sensitive and efficient RF harvesting supply for batteryless backscatter sensor networks," *IEEE Trans. Microw. Theory Techn.*, vol. 64, no. 4, pp. 1327–1338, April 2016.

[2] ——, "High efficiency and triple-band metamaterial electromagnetic energy hervester," in *ELECO*, Nov 2015, pp. 320–323.