Design of a CPW fed circular slot loop antenna for RF/DC rectifier at low power level

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***Abstract*—This work deals with the design and implementation of a planar and compact antenna realized on Arlon AD1000 substrate, ε_r=10.35. The antenna consists of a CPW fed circular slot loop antenna with two stubs as impedance matching circuitry. The antenna was designed for 2.45 GHz in order to be implemented with a RF/DC rectifier optimized for low power level in CPW technology. Thus, allowing easy and fast fabrication of a rectenna array with a high reproducibility between one rectenna conception to another one.**

I. Introduction

Recently, energy harvesting has been the center of attention with the growth of wireless communication and development of ideas such as smart cities and the Internet of Things [1]. Those inevitable wireless data communication development and growth tend to provide reliable and constant wireless energy. Because electromagnetic waves convey information, they are also an energy vector. The majority of the communicative devices spread their signal in all direction in space. Hence, most of the signal is not used for is communication property, and so energy are wasted in the air. Rectenna are a special kind of antenna that converts electromagnetic waves to direct current. They can be used to harvest this and powered small devices and are generally build using microstrip waveguide technology. But one of the challenges relies on the repeatability of vias needed to connect surface mountain component (SMC) in this technology; as the ground and the conductive plane are on different plane in space separate by a substrate. Robustness and repeatability in rectenna should be as perfect as possible to limit differences in one conception from another. Moreover, many applications require power characteristics that may not be achievable by a single rectenna element. It may, however, be possible that an aggregate of radiating elements in an electrical and geometrical arrangement (an array) will result in the desired power characteristics. But, as the complexity of antenna and frequency number increases, phase shifting and complex matching impedance circuitry are needed. Another solution relies on rectenna array in which the combining of the DC voltage of several rectenna is accomplished to power a device. Then this second solution requires reliable and accurate rectenna conception.

This work is dedicated to rectenna array solution. In order to suppress vias in rectenna conception we uses coplanar waveguide technology (CPW). In this technology, the conductive line and the ground plane are etched on the same plane.

The topic of this paper focuses on the design and conception of a planar and compact antenna to be used with a RF/DC rectifier in CPW technology. This antenna is also simple and fast to realize, as few milling tools process is required. It consists of a patch surrounded by a ground conductor on the same plane of the substrate, without background metallization to avoid connection transition with the ungrounded CPW rectifier.

II. Design and simulation

A. *Initial Design: Circular Monopole Antenna*

The antenna for this rectenna conception is a modified CPW fed circular slot loop antenna. The study starts with a circular monopole antenna because it is one of the simplest patterns to study [2]. In this configuration, only two parameters are optimized: Patch radius (***R***) and distance (***d***) between patch and ground

The antenna feed is performed with a quarter wavelength 50 Ω CPW line. The initial patch radius ***R*** was chosen using the equation (1).

$$R=\frac{\lambda_g}{2h\left(1+\sqrt{\pi*(\epsilon_r+1)*\lambda_g*\left[1{,}7726+\ln\left(\frac{0{,}5\lambda_g*\pi}{h}\right)\right]}\right)} \qquad (1)$$

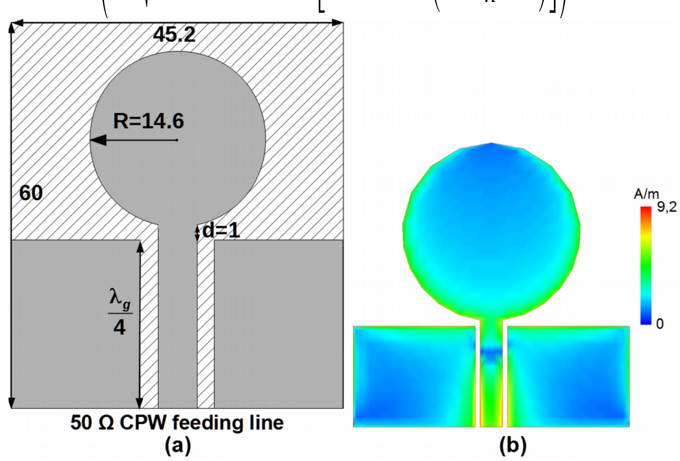

Fig. 1. (a) CPW-fed circular monopole and dimensions (mm) (b) Current propagation of the antenna at 2.45 GHz

Tuning of patch radius is performed to get proper frequency of operation at 2.45 GHz. The separation length ***d*** is tuned to match the antenna impedance at 50 Ω. The simulated antenna shows a large bandwidth typical of monopole antenna, with a gain ***G*** of 1.4 dBi and directivity of 3.16 dBi. The return loss was of -28 dB, and the total dimensions of the patch are 45*60 mm^2.

B. CPW-Fed Circular Slot Loop Antenna

Plotting the current distribution of the patch at 2,45 GHz (Fig. 1.b), we can notice that the current propagate along the edge of the circular patch and is "null" at the top of the circular monopole pattern. Hence, shielding the patch with a ground plane compels the magnetic field to propagate along the newly created slot (Fig. 2.a); thus increasing the current at the edges while maintaining similar resonant frequency.

Following this method and using a quarter wavelength matching feeding line to match the 50 Ω port, the simulated antenna shows resonant frequency at 2.2 GHz. This shift could be explained by the increase of effective dielectric of the circular patch. Indeed, with the surrounding ground the field path is changed and with it the value of the equivalent uniform dielectric, ε_{eff}. To correct this shift, a diminution of the patch radius was sufficient. The total antenna dimension was of 45.2*53 mm^2 (Fig. 2.a). The goal of this antenna is to be connected to a RF/DC rectifier in CPW technology. The rectifier is designed with an input impedance characteristic of the CPW line of 50 Ω. In order to connect this antenna to the rectifier, one could add a small line portion of 50 Ω and take in consideration the coupling between the quarter wavelength line and the 50 Ω one [3].

C. Compact CPW-Fed circular Slot Loop Antenna

To decrease the size of the antenna we use another technique for matching impedance. Two stubs are inserted inside the radiating element to match the antenna impedance at 50 Ω (Fig. 2.b). This solution gives a more compact antenna with a shorter feed line. This method because of the nature of the CPW feeding line can also be seen as a moving of the feed-point closer to the center of the circular patch. Thus, the antenna size is reduced down to 45.2*50,57 mm^2 with gain of 2.34 dBi, directivity of 3.87 dBi and peak current of 29,8 A/m.

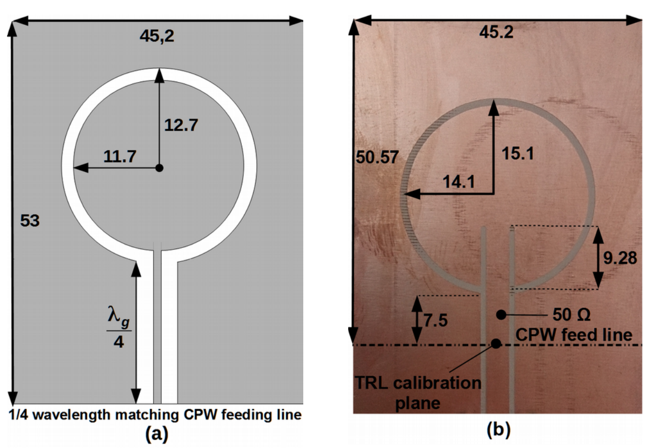

Fig. 2. CPW-fed circular slot loop antenna with (a) 1/4 wavelength matching (b) stub matching and dimensions (mm)

III. MEASUREMENT RESULTS

The proposed antenna is realized and measured (Fig. 3). Measurement presents a bandwidth **B** of 250 MHz and return loss of -23,7 dB at 2,45 GHz. The simulation and measurement are in good agreement with a small frequency drift **ΔF** of 10 MHz.

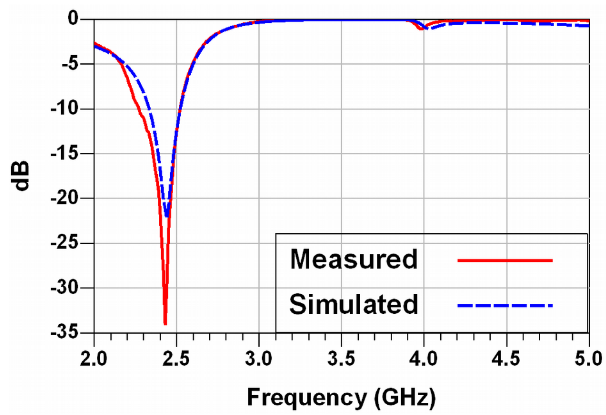

Fig. 3. Reflection coefficient of the simulated and realized antenna

IV. CONCLUSION

In this work a compact CPW-fed circular slot loop antenna was designed and measured. We show that such antenna can be derived from a circular monopole antenna as a starting point with little tuning process. This design is interesting because it has several advantages over the well-known patch antenna; such as, bad impedance matching at first higher order harmonics, larger bandwidth than microstrip patch antenna, bi-directional radiation pattern in opposite direction of space and antenna size reduction.

Subsequently to this work, the simulation of a complete rectenna in CPW technology is performed with a more accurate diode model than our previous work [4]. The rectifier is composed of a single series diode HSMS7630. The diode was modeled through I/V characteristics and S-parameter fitting between diode model and measurement at Pin=-20 dBm. It shows rectifying efficiency of approximately 9 % at 2.45 GHz for P_{in}=-20 dBm and a resistive load R_{load}=5,7 kΩ.

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REFERENCES

[1] C. Perera, A. Zaslavsky, P. Christen and D. Georgakopoulos, "Context aware computing for the internet of things: A survey", IEEE communications survey & tutorials, vol. 16, no. 1, 2014.

[2] L. Xian, "Ultra-Wideband Antenna and design", InTech, 2012.

[3] M.-J. Nie, X.-X Yang, G.-N Tan and B. Han, "A compact 2,45 GHz broadband rectenna using grounded coplanar waveguide", IEEE Antennas Wirel. Propag. Lett, vol.14, p.986-989, dec. 2015.

[4] J.Rivière, A. Douyère, F. Alicalapa and J.-D Lan Sun Luk, "DC-pass filter design with notch filters supperposition for CPW rectenna at low power level", IOP Conf. Ser. Mater. Sci. Eng., vol.120, march 2016.