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Printed Dipole-Loop Antenna with High Gain for RF Energy Harvesting Applications

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Abstract—In this paper, a compact dual-band antenna for RF energy harvesting applications is presented. The basic antenna structure is formed using a combination between a dipole and a loop antenna to operate at 900 MHz and 1600 MHz, respectively. To enable the antenna to resonate at a dual- band within a compact substrate, two L-shaped vertical arms as a dipole connected with a trapezoidal slot loop. A meandered transmission line is connected to the coplanar slot line to act as a stub to match the input impedance of the dipole and the loop. On the back of the antenna, a reflector is positioned to enhance the forward to back ratio and provide a unidirectional radiation pattern. The antenna has a compact size 0.149λo 0.23λo (with respect to the wavelength at the lowest operating frequency),making it comparatively smaller than similar designs. It has a measured fractional bandwidth of 11% at 0.970 GHz at the lower band and 52.9% at the upper band from 1.5 to 2.58 GHz. The antenna performance has a peak gain of 6.5 dB. To prove the antenna normal operation, a prototype is fabricated, tested and the measurements are compared against the simulation results. This antenna is intended for the RF wireless energy harvesting applications.

I.INTRODUCTION

Exploitation of renewable energies to supply low-power electronic devices is not a new concept. The process of intercepting energy from the around ambient environment to produce DC energy is termed as energy harvesting or energy scavenging [1]. This energy can be extracted from various sources available in the ambient environment such as thermal energy, mechanical energy, and RF electromagnetic energy [2], [3]. The electromagnetic energy occupies different frequency band demands the use of a multiband antenna [4]. In the literature, there several attempts to realize a dual-band antennas [5]–[7]. The previous research works lack the miniaturization and compactness of the antenna design where most of the proposed structures have large size and complicated design. In this paper, the design of multi-band dipole-loop antenna (DLA) is performed. The DLA combines a dipole and loop antenna to cover different popular bands at mobile application. The antenna is composed of coplanar strip (CPS) feeding line within open stub attached on both sides of the feed line to tune the input impedance. A rectangular structure with a trapezoidal slot produces the higher band antenna operation. Due to the slotted structure, the upper resonating frequency has a wider bandwidth than the lower band which consists of a vertical long L-arm that provides the resonance at the lower frequency band.

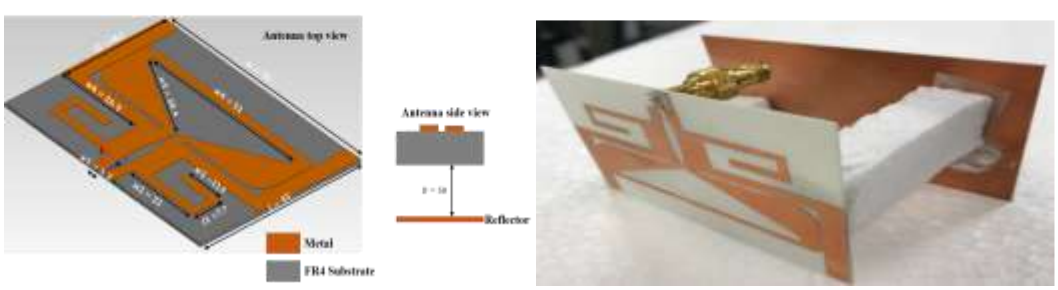

Fig. 1: Antenna configuration layout. All dimensions are given into mm.

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II. ANTENNA DESIGN ARCHITECTURE

The antenna design is based on integrating slot trapezoidal structure with a dipole L-arm geometry. The antenna is implemented using CPS transmission line so that a balun is essential for proper antenna port excitation. The balun structure is inspired from Ref. [8]. In order to realize a dual-band antenna, the proposed study employs two radiators. One radiator consists of a half-wavelength printed dipole represented by L-shape structure. The second radiator is a rectangular loop antenna with a trapezoidal slot. The dipole and loop are optimized to resonant at 900 MHz vicinity and 1600 MHz, respectively. This integration has created a small slot between them and it considered as a slot open end antenna that operates at higher frequency (around 2 GHz). The introduced antenna can be termed as a hybrid antenna due to the combination between different radiators. The geometry of the proposed DLA is depicted in Fig. 1(a). The dipole and the loop need to balance feed, therefore the slot feed is used to feed the

proposed antenna. To improve the impedance bandwidth of the proposed antenna, two stub segments are connected to the feed line to adjust the matching impedance.

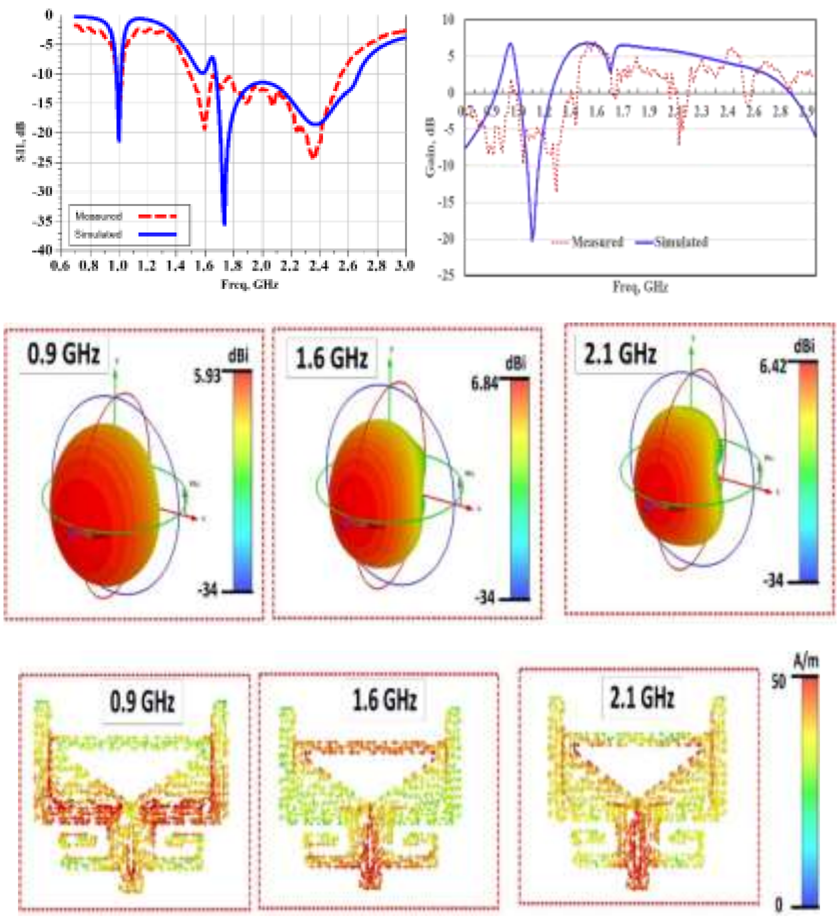

Fig. 2: Antenna measurement setup and results (a) Antenna input return loss S11 , (b) Antenna realized gain, (c) The 3D radiation pattern at several; in-band frequencies, (d) Surface current distribution.

III.EXPERIMENTAL RESULTS DISCUSSION

Photograph of the proposed design is depicted in Fig. 1(b).It is printed on FR4 substrate with a dielectric constant of 4.4, loss tangent of 0.02, and a thickness of 0.8 mm. The antenna is excited using coaxial connector that has 50Ω input impedance. The antenna has an overall size 45X70X50 mm3.The final design was fabricated, and its performance was tested in free space. The antenna performance was tested via full-wave electromagnetic simulations and measurements, and the results are depicted in Fig. 2. There is a fairly good agreement between the measured and simulated results with a slight discrepancies due to fabrication tolerance. The proposed antenna achieves wide impedance bandwidth as shown Fig. 2(a). It is noticed that the proposed antenna covers 100 MHz at lower band and 1 GHz at the higher band with good agreement between the measured and simulated input reflection coefficient. To understand the antenna performance, the surface current of the proposed antenna at 0.9 GHz, 1.6 GHz and 2.1 GHz are introduced in Fig. 2(d). From the figure, it is observed the two arms of the dipole produces the resonant of the antenna at 0.9 GHz and the loop is responsible for the resonant at 1.6 GHz. Therefore the combination between the dipole and the loop gives a wide bandwidth at 2.1 GHz. The reflector is inserted at a separation distance of 50 mm (0.15λo) at the backside of the antenna to suppress the back lobes and enhance the front-back ratio and to achieve high gain with a unidirectional radiation pattern as indicated in Fig. 2(c). The antenna achieves 5.93 dBi, 6.42 dBi, 6.39 dBi for 0.9 GHz,1.6 GHz, and 2.1 GHz. furthermore, the antenna can provide a large front to back ratio of 30 dB.

IV.CONCLUSIONS

In this article a simple, single layer and dual band DLA antenna design was presented. The proposed antenna provides dual band operation at 900 MHz and 1600 MHz frequency band. The antenna geometry is extremely simple and compact structure. The antenna was fabricated, tested and the measure- ment results was verified against the simulation data. This antenna could find several applications for wireless energy harvesting. In future, this antenna will be integrated with a dual band rectifier to realize the energy harvesting rectenna.

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