A Dual Band Meandered Printed Dipole Antenna for RF Energy Harvesting Applications

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Abstract - **In this paper, a high gain printed dual-band meandered dipole antenna is proposed for RF energy harvesting applications in the GSM-1800 and WiFi (2.45 GHz) bands. The proposed antenna utilizes a meandered structure in order to achieve dual band properties as well as size miniaturization. The antenna is designed using the CST Microwave Studio full-wave simulator and various parameters are optimized in order to achieve maximum gain in both the bands. A prototype of the proposed antenna is fabricated and tested to validate the simulation results. The proposed antenna is integrated with a Villard voltage doubler circuit using an impedance matching network and the output voltage and efficiency are monitored. The overall design of the proposed RF harvesting circuit is carried out using the Agilent ADS and a maximum efficiency of 46.82 % is achieved.**

Index Terms — **RF Energy Harvesting, Meandered Dipole Antenna, Rectifier, Impedance matching.**

I. Introduction

With the rapid growth in cellular communication and wireless technology, there has been a large increase in the number of mobile base stations and WiFi routers [1]. As a result, wireless RF Energy Harvesting has become a popular and reliable alternate source of energy. The harvesting technology aims at converting the freely available RF energy, present in the environment, into dc, so that it can be used to charge up devices requiring low power. The primary components of the RF energy harvesting unit are the antenna and rectifier, which are commonly known as Rectenna together.

In the past, a number of researchers have proposed single-band antennas for RF energy harvesting [2]-[3]. In [4], a dual-band 1×4 quasi-yagi antenna-array is proposed for RF energy harvesting, but the size is large due to the array configuration. A compact dual-band monopole-like antenna is proposed in [5] for RF energy harvesting, but the gain of the antenna is very less in both the bands, which makes it unsuitable for practical application purpose. In [6], a dual-band CMOS based RF energy harvester is reported for 900 MHz and 1900 MHz bands, but the efficiency is quite low (9% at -19 dBm input RF level). The aim of this paper is to propose a dual band printed meandered dipole antenna with sufficiently high gain, which can be employed as an efficient receiving antenna element in the RF energy harvesting unit at 1.8 GHz GSM/LTE and 2.45 GHz WiFi frequencies. The design procedures of the dual-band antenna as well as the integrated rectenna system are described in the subsequent sections.

II. Antenna Design And Results

A. *Dual-bad Antenna design*

The primary component for successful energy harvesting is design of high-gain antenna. The schematic of the proposed antenna is given in Fig. 1. The antenna is fabricated on a printed circuit board using 1.6 mm FR4 substrate with dielectric constant of 4.4 and loss tangent of 0.02. The proposed antenna consists of a meandered dipole and a partial ground plane. The proposed antenna has an overall dimension of $0.72\lambda_0 \times 0.57\ \lambda_0$, where λ_0 is the free space wavelength at 1.8 GHz ($\lambda_0 = 16.67$ cm).

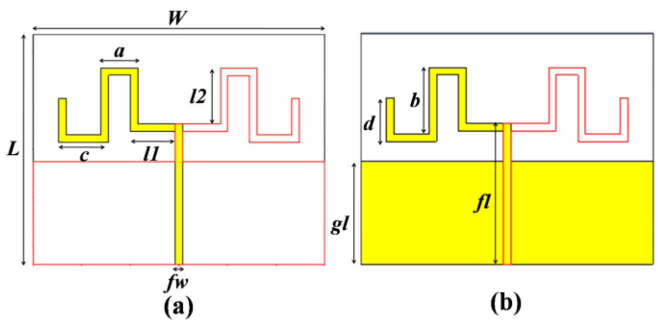
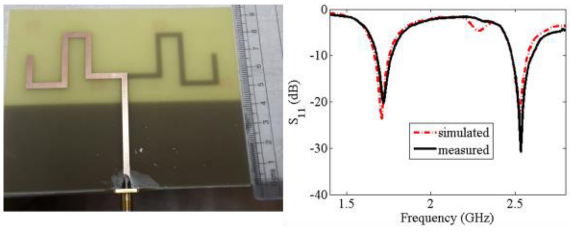


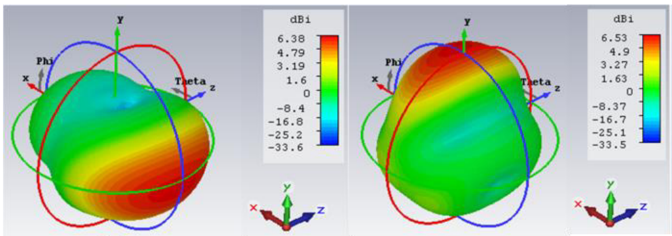
Fig. 1. Structure of the proposed antenna. (a) Front view. (b) Back view. Optimized design parameters: L=120, W=95, a=12, b=27.5, c=17.5, gl=42.5, d=18, $l1$=21.5, $l2$=20, fl=55, fw=3, all units are in mm

Fig. 2(a) shows the photograph of the fabricated antenna prototype. Fig. 2(b) shows both simulated and measured plots of S_{11} (dB) with frequency which confirms the presence of two operating bands in the proposed antenna. The meandering of the dipole arms generates two operating modes at 1.72 GHz and 2.52 GHz with impedance bandwidths of 5.2% and 3.8%, respectively. Fig. 3(a) shows the radiation pattern for this frequency where null is observed along $\theta=90^o$, $\varphi=90^o$ and higher radiation along $\theta=90^o$, $\varphi=180^o$. On the other hand, Fig. 3(b) shows the pattern at 2.52 GHz, which has maximum radiation along $\theta=90^o$, $\varphi=90^o$, which is typical for such printed dipole antennas with partial ground planes. The peak gains at 1.72 GHz and 2.52 GHz are 6.38 dBi and 6.53 dBi, respectively.



(a) (b)

Fig. 2. (a) Photograph of fabricated antenna. (b) Variation of simulated magnitude of S_{11} (dB) with frequency.



(a) (b)

Fig. 3. Simulated 3D radiation pattern of the proposed antenna in CST at: (a) 1.72 GHz and (b) 2.52 GHz.

B. Integration of Dual-Band Antenna with Impedance Matching Unit and Rectifier

The dual band rectifier and the impedance matching unit are designed and integrated with the dual-band antenna as shown in Fig. 4. The voltage doubler type rectifier along with the matching unit needed for maximum power transfer between the rectifier and antenna are simulated in Agilent ADS software. The impedance matching unit comprises distributed microstrip lines, in lieu of of any additional lumped elements to reduce the complexity. The Schottky diodes HSMS285C of AVAGO Technologies are used in the design of the Villard voltage doubler. The rectifier and matching units are designed on Rogers RT Duroid 5880 substrate (thickness= 0.787mm, $\varepsilon_r = 2.2$, $\tan\delta = 0.0004$). The length and width of the transmission line sections in the matching unit are varied to tune the matching frequencies at 1.72 GHz and 2.52 GHz. The harvesting unit is terminated by a 6 kΩ load resistance.

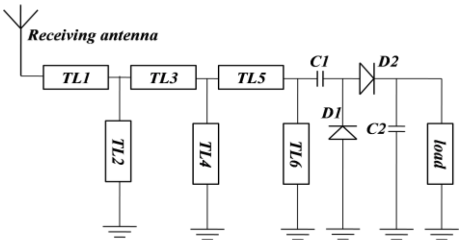
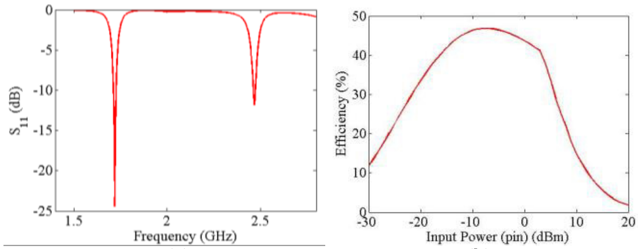


Fig. 4. Block diagram of the rectifier and matching unit integrated with the proposed receiving antenna. Optimized lengths of the transmission line sections are: *TL1*=5.5, *TL2*=24.8, *TL3*=3, *TL4*=10.5, *TL5*=42.4, *TL6*=57, all units in mm. *load* = 6 KΩ.

The performance of the circuit is assessed by the percentage RF-to-DC conversion efficiency η=100*($P_{out,DC}$ / $P_{in,RF}$). Here $P_{in,RF}$ represents the input RF power from ambient sources and $P_{out,DC}$ is the DC output power from the rectifier unit. Harmonic Balance analysis technique is used to simulate the nonlinearity of the rectifier unit. The input power is varied from -30 dBm to +20 dBm. The proposed antenna described in Section *II* is integrated with the rectifier unit, and the resultant S_{11} of the rectifier is shown in Fig. 5(a), which confirms the dual-band characteristics. The RF-to-DC conversion efficiency is finally plotted with respect to input power as depicted in Fig. 5(b). A maximum efficiency of 46.8 % is observed at an input power of 7 dBm. At -20 dBm input power, overall rectifier efficiency of 33.5% is observed with only single stage voltage doubler.



(a) (b)

Fig. 5. (a) S_{11} (dB) versus frequency for the rectifier. (b) Variation of total RF-to-DC conversion efficiency with input RF power.

III. Conclusion

In this paper, a dual-band printed meandered dipole antenna has been designed for ambient RF energy harvesting applications in 1.8 GHz GSM/LTE and 2.45 GHz WiFi frequency bands. The numerical simulation using the CST Microwave Studio indicates that the proposed antenna exhibits high gain (>6 dBi) in both the working bands. A dual-band rectifier unit has also been designed using the Agilent ADS for integration with the proposed dual-band antenna. The maximum rectifier efficiency of 46.8 % is achieved, which can be further improved by increasing the number of voltage doubler stages.

References

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