DESIGN AND ANALYSIS OF DUAL BAND MEANDERED PRINTED DIPOLE ANTENNA FOR RF ENERGY HARVESTING SYSTEM AT GSM BANDS

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Abstract: This paper proclaims the design of high gain printed dual-band meandered dipole antenna at 900 MHz and 1800 MHz bands for RF Energy harvesting applications. The proposed antenna employ a meandered structure in order to achieve dual band properties as well as size miniaturization. The antenna is designed using CST Microwave Studio simulator and various parameters are altered in order to achieve maximum gain in both the bands. An experimental antenna is fabricated and tested to validate the simulation result. This proposed antenna is then amalgamated with voltage doubler circuit using impedance matching network, output voltage and efficiency are monitored.

Keywords: Harvesting Printed Dipole Antenna, RF-DC Conversion

I INTRODUCTION

There is an enterprising research area scrutinizing various possible ways to extract energy from surroundings and then transforming it to electrical energy for powering up small electronic devices directly or to store it for later use, one of these extracted energy is RF Energy.

In recent years, the RF Energy harvesting is considered as green and renewable energy schemes [1]. As the applications of RF Energy harvesting are growing day by day and are beneficial in many research areas such as portable medical devices[2], RFID Tags[3], bio-telemetry[4] and low power wireless sensors.

The RF Energy sources are classified into two general types: intentional sources and ambient sources [5]. There are inexhaustible numbers of RF Energy sources which are radiating continuously in the environment such as wireless local network routers, cellular network base station, and TV and Radio broadcasting towers. Other anonymous RF signal sources are from military, police, government or amateur radio. RF signals are freely available in ambiance, and become essentially free power resources [6].

The schematic view **of RF** Energy Harvesting setup is shown in Figure 1. It consists of antenna, matching section, RF to DC converter and load circuits. Here in this proposed design we have used, Light Emitting Diode as load.

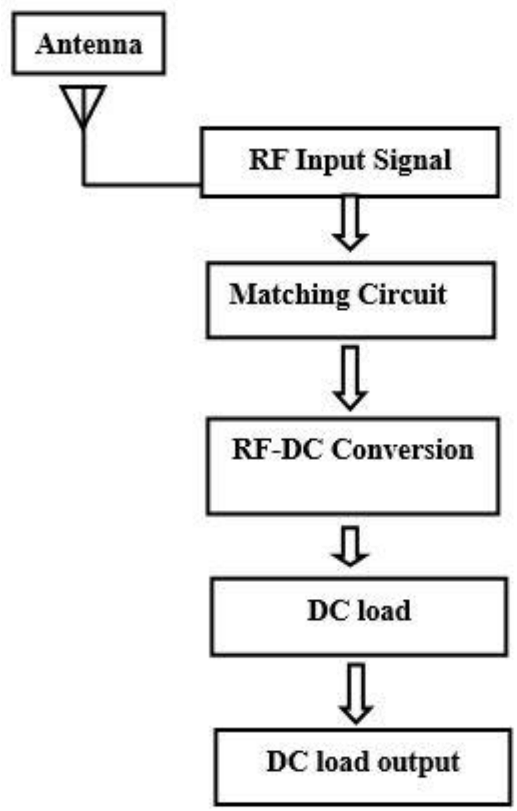

Figure.1: Schematic view of RF Energy Harvesting System

A number of researchers have proposed single band antennas for RF Energy harvesting [7], [8]. In [9], a compact dual-band monopole like antenna is proposed for

RF Energy harvesting, but the gain of antenna is very low in both the bands, due to which it is not suitable for practical implementation. In [10], a dual-band CMOS based RF Energy harvester is proposed for 900 MHz and 1900 MHz, but the efficiency is quite low.

Table 1 RF bands measured in energy density study

Band	Frequencies (MHz)
GSM/4G LTE 900	791-960
GSM/4G LTE 1800	1710-1876
3G (MTx)	1920-1980
3G (BTx)	2110-2170
ISM WiFi 2.4 GHz	2400-2495
4G LTE 2600	2500-2690

These measurements are showing a large variability of ambient electromagnetic field. These measures are timed and registered in order to get an idea of the evolution of RF signals [11].

II ANTENNA DESIGN

The most important element for accomplishing a desired RF Energy harvesting setup is a high gain antenna. Figure 2 shows the design of proposed printed dipole antenna. This printed dipole antenna is designed and simulated using Computer Simulation Technology-Microwave studio [12]. In this software all the discontinuities present in the design can be calculated efficiently. This antenna is fabricated on a printed circuit board using FR4 as substrate. The designed antenna has an overall dimension of $0.72\lambda_o x 0.57\lambda_o$, where λ_o is free space wavelength at 1.8 GHz. [13]

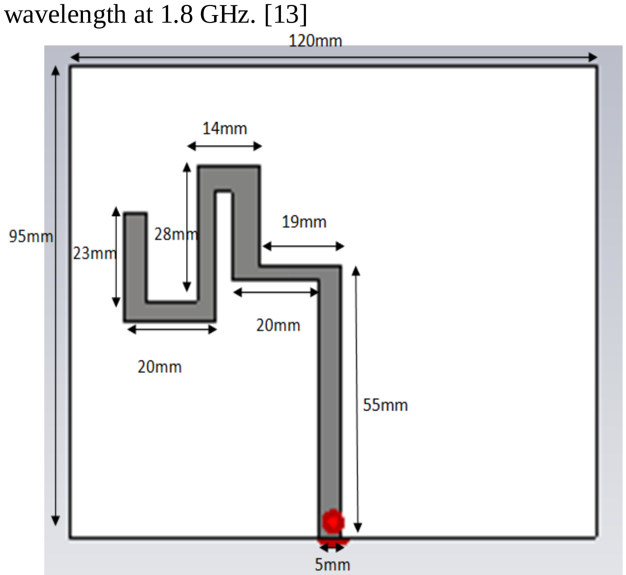

Figure 2: CST front view of proposed printed dipole antenna

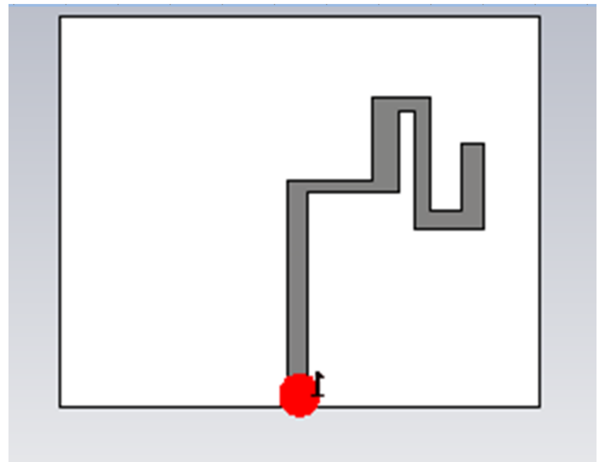

Figure 3: CST back view of proposed printed dipole antenna

As the Figure 3 shows the CST back view of designed printed dipole antenna, we can clearly see that the dimensions of both front view and back view of printed dipole antenna are same. All the dimensions of antenna are labeled in Figure 2. The designed dipole has meander pattern, which compacts the antenna by reducing the size of antenna.

III SIMULATION RESULTS

The proposed design is simulated in CST-MWS 2010 software. In the simulation the antenna is resonating over two frequency bands 795 MHz and 1795 MHz, hence covering both GSM bands as shown in table 1. Figure4 shows the reflection coefficient of proposed printed dipole.

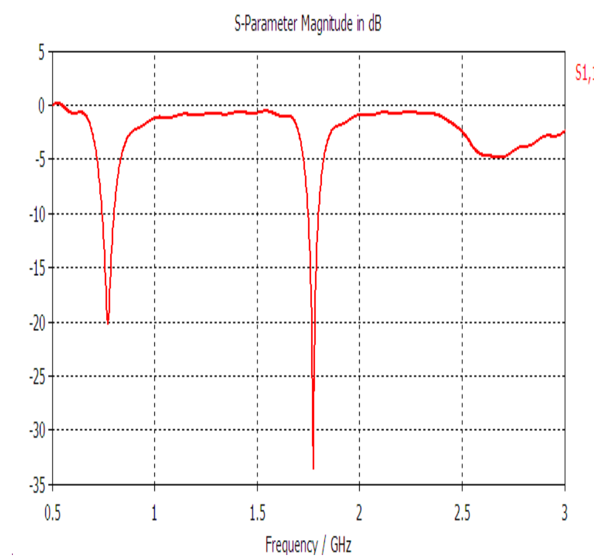

Figure 4: Simulated graph of reflection coefficient of printed dipole antenna.

Above figure shows simulated plots of S11 (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 0.795

GHz and 1.8 GHz with impedance bandwidths of 5.2% and 3.8%, respectively. It can be observed that antenna is providing low reflection coefficient at two frequencies. At 795 MHz the return loss is -20 dB and at 1800 MHz, value of return loss is 34.55 db.

As we know, for RF Energy Harvesting we need high gain antenna, and this proposed design shows sufficient high gain in both the bands. Figure 5 shows the simulated plot of gain of antenna.

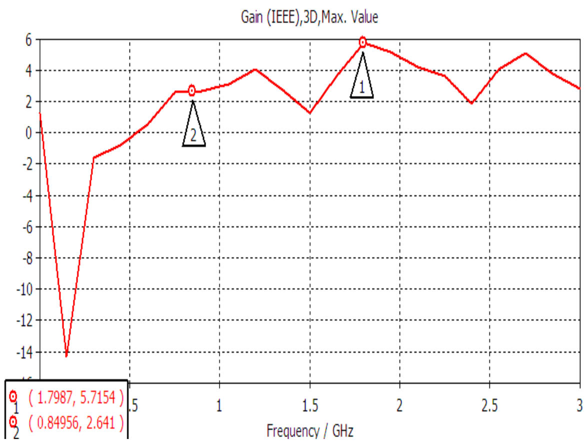

Figure 5: Gain of printed dipole antenna

The peak gains at 0.795 GHz and 1.795 GHz are 2.64 dBi and 5.73 dBi, respectively.

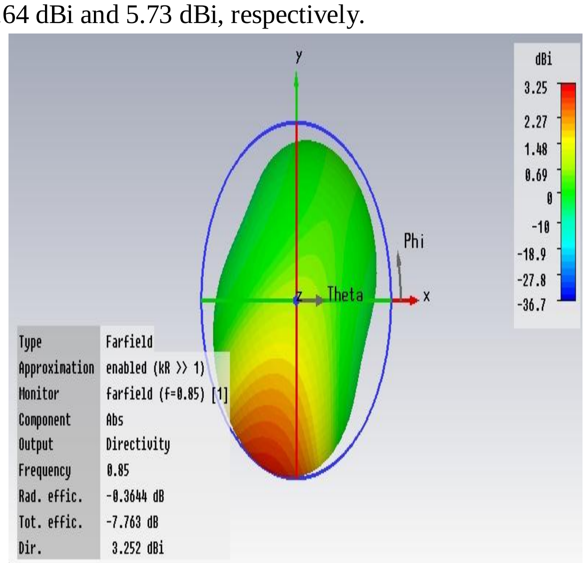

Figure 6: 3D radiation pattern and directivity of designed antenna at 0.85 GHz

Figure 6 shows the radiation pattern for this frequency where null is observed along θ=90o, φ=90o and higher radiation along θ=90o, φ=180o. On the other hand, Figure 7 shows the pattern at 1.795 GHz, which has maximum radiation along θ=90o, φ=90o, which is typical for such printed dipole antennas with partial ground planes. The designed antenna has the directivity of 3.25 dBi at 0.85 GHz and 6.07 dBi at 1.8 GHz. Hence the antenna is capable of better transmission in GSM bands[13].

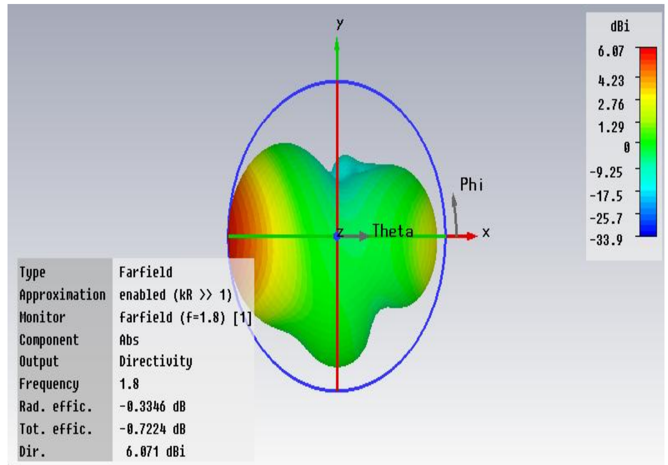

Figure 7: 3D radiation pattern and directivity of designed antenna at 1.80 GHz

IV RECTIFIER DESIGN

We have numerous voltage multiplier circuit topologies. The topology used in here is evolved from the function of peak detector or a half wave peak rectifier. This Villard voltage multiplier circuit is used in this rectenna design of this paper because it can produce double voltage of the input signal voltage to the ground at a single output and can be cascaded to form a voltage multiplier because of its optimized output and design simplicity.[14]

Figure8 depicts a single stage voltage multiplier circuitry. The circuit is also known as a voltage doubler because, the voltage that is obtained on the output is approximately double of that at the input. The circuit has two sections; each comprises a diode and a capacitor for rectification. The RF input signal is rectified in the positive half of the input cycle, followed by the negative half of the input.

Here we have used a single stage voltage doubler, and at load we have used one LED for fulfilling the purpose of RF energy harvesting. In this project, the voltage doubler is fabricated over bread board using lumped elements such as 1N4148 ZENER Diode and capacitor of value 10 nF and at load 1.5 Volt LED is used, which glows when a call is made using cell phone near the complete circuitry.

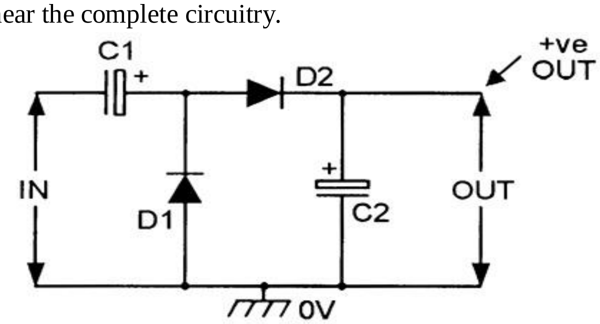

Figure 8: A single stage voltage multiplier circuit [15]

V FABRICATION AND MEASUREMENT

The micro strip antennas are simulated and fabricated on the FR4 Lossy material having substrate parameters ($\varepsilon_r = 4.3$, h = 1.6mm and loss tangent $\tan\delta = 0.02$). The proposed micro strip rectenna is fabricated using the photolithography process by exporting the layout on Auto-CAD software .The fabricated meandered printed dipole antenna is shown in Figure 9. This fabricated antenna is then connected to our designed half wave rectifier with fast switching diode 1N4148, this diode is silicon diode and widely used for the Radio frequency energy harvesting applications.

Figure 9: Fabricated meandered dipole antenna

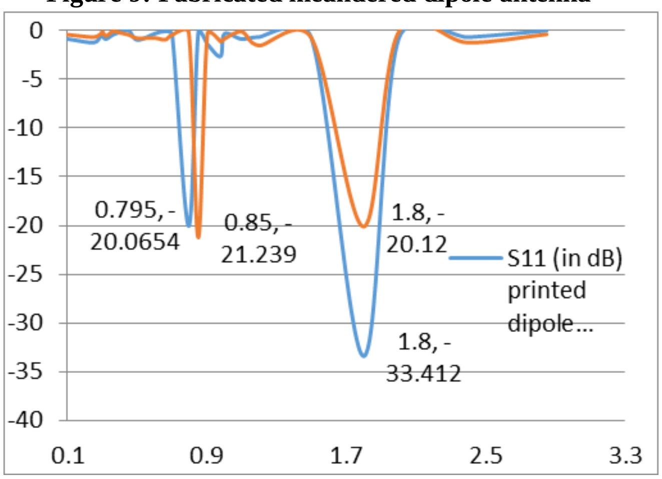

Figure 10: Compared results of simulated and fabricated proposed antenna

Figure 9 shows the fabricated design of printed dipole antenna. This fabricated antenna is then tested using spectrum analyzer and we found that measured and simulated results are approximately same, as shown in Figure 10.

The complete Radio Frequency energy harvesting setup is demonstrated in Figure 11 below. The glowing LED proves that energy is harvested from ambience using cell phone.

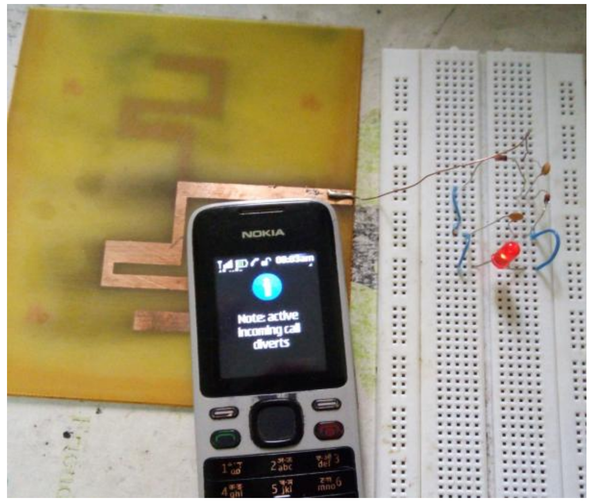

Figure 11: Glowing LED in Setup shows RF energy Harvesting

In this setup when cell phone is kept near the rectenna and a call is initiated, the LED starts to blink and an output voltage of approximately 300mV is obtained across the load. This shows that the RF energy is harvested and enough amount of output voltage is generated that can light up low power devices directly or it can be stored to use for later use.

VI CONCLUSION

This design of rectenna concludes that the RF energy can be efficiently harvested using meandered printed dipole antenna. The output voltage measured across load is 300 mV and this DC power can be used to power up low voltage devices directly or we can store it for future use. These rectenna designs are also useful in making mobile charging circuitry using RF energy harvesting.

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