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Cpw Fed Modified Triangular Shaped Upper Strip Patch Monopole Antenna for Gsm Wifi Rf Energy Harvesting

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Abstract: ***A small scale renewable energy, the development of electromagnetic energy harvesting has good potential as one of the sources of renewable energy since the electromagnetic energy is available all the time and everywhere, unlike other renewable energy (e.g., solar, wind, thermal and ocean wave). This paper presents a CPW fed Modified Triangular Shaped upper strip patch Monopole Antenna for GSM-WIFI RF Energy Harvesting. It has been found that, the antenna can be used to make operating in multiband mode More than 100% (1.8-5.5 GHz band) impedance bandwidth has been achieved for co-planer waveguide (CPW) fed triangular shaped upper strip patch monopole antenna design for RF energy harvesting. The proposed antenna has been simulate and fabricated. The Simulations results are closely matched with fabricated results.***

Index Terms: Microstrip antenna, Co Planer waveguide, and Wideband antenna. Voltage standing wave ratio (VSWR), Return loss (S11)

I. Introduction

With the advances and popularity of wireless communication devices, large amount of copious Radio Frequency energy from surrounding sources (digital TV broadcasting mobile phone services, and several other wireless systems) are scattered in our environment. Using an appropriate antenna, these EM waves can be converted into electrical energy. The RF energy scavenging related to the utilization of copious RF energy transmitted by various wireless systems to remotely distributed electronic systems with low-power requirement [1]. The basic RF scavenging unit includes an antenna followed by a matching circuitry and a rectification unit; rectified DC voltage can then be increased using step-up converters or voltage multipliers and accumulated in a battery or a capacitor. Contiguous to low RF power commensurate, the efficiency of the rancher's electronic circuitry guise hefty limitation, since it is nonlinear and strongly depends on input power commensurate [13], Latent RF energy resources relevant for scavenging comprise mostly the signals of the communication systems like GSM, UMTS, LTE, and WiFi (IEEE 802.11). The simplest scavenging units operate bygone only one frequency band [4]; narrowband antennas are thus competent for scavenging with such circuits. However, in order to accumulate as much energy as possible it is enticing to employ the diffusive RF power of multiple wireless systems. In these scenarios, multiband and wideband antennas become necessary. The RF energy scavenging antenna precondition appeases other explicit requirements akin to its application area.

II. Sources of RF Energy in India

RF sources in India which can be used for RF energy harvesting are, TV broadcasting (180-220 MHz) whose disseminate power is middling decagonal of kW, AM disseminate (540-1600 KHz) whose disseminate power is few hundreds of kW, mobile handsets (disseminate power 1 W to 2 W), Wi-Fi: 2.45GHz and 5.8 GHz and Cell Towers with transmitted power of 10-20 W per carrier [2]. Various technologies and frequency bands used for cell tower transmissions in India are as shown in Table 1.

Technology	Frequency Band
Code Division Multiple Access (CDMA)	869-889 MHz paired with 824-844 MHz
Global System for Mobile communications (GSM)	**GSM800:** 890-915 MHz paired with 935-960 MHz **GSM1800:** 1710-1785 MHz paired with 1805-1880 MHz
Wideband Code Division Multiple Access (WCDMA) - 3G	**WCDMA2100:** 1920-1980 MHz paired with 2110-2170 MHz
LTE FDD & TDD topology bands – 4G	**Band-3 (LTE-FDD)** 1710-1785 MHz (Uplink Frequency) 1805-1880 MHz (Downlink Frequency) **Band-5 (LTE-FDD)** 824-849 MHz (Uplink Frequency) 869-894 MHz (Downlink Frequency) **Band-40 (LTE-TDD)** 2300-2400 MHz (Uplink / Downlink Frequency)
5G band. (Yet to be proposed in India)	3300-3600 MHz
Broadband Wireless Access (BWA)	2.3-2.4 GHz and 2.5-2.69 Hz

Table.1 Cellphone Frequency Bands in India

India is the country with the second largest number of mobile phone users (around 337 million by December 2018), globally is home for nearly 20 Lakh Base Trans receiver Stations (BTS) with 5 Lakh mobile towers. These cell towers transmit 24 hours every day all-round the year and hence can be used as a continuous source of RF energy.

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III. PARAMETER RELATED TO ANTENNA DESIGN FOR RF ENERGY HARVESTING

3.1 Frequency of operation

In the diffusive environment RF energy is mainly found in the frequency scope of 800 MHz to 2.5 GHz (cellular bands and Wi-Fi hot spots).

The selection of operational frequency of antenna enmeshes more facets apart from ensuring the maximum efficiency, for the diffusive energy at that frequency must exhibit sufficient power density & the higher the operational frequency the larger the optimal input power.

A key issue in diffusive RF energy harvesting is that the available power density is very low in diffusive RF environment, which essentially restricts the availability of power for harvesting and this result in lower PCE. To increase harvested diffusive RF energy, the antenna need to receive the RF signals from multiple frequency bands in the diffusive environment; hence a multiband antenna is ideal for collecting more signals & to achieve more PCE.

3.2 Radiation pattern & Polarization

In diffusive RF energy harvesting, the received signal may come from any direction because of the uncertainty of RF power source location. Therefore, an omnidirectional antenna with circularly polarized; dual polarized [3], dual circularly polarized [4] antennas will be a good choice for improvement in PCE.

3.3 Bandwidth

Bandwidth describes the range of frequencies over which the antenna can properly radiate or receive energy. A narrow band rectenna can give higher power PCE, but the amount of scavenging power is low, whereas a multi-band rectenna can has the lower PCE, but more scavenging power [5]. The favorable solution is to design a multi-band rectenna to have maximized PCE at the precise frequencies where more diffusive signals are available.

3.4 Gain

In a acquiring antenna, the gain exemplifies how well the antenna novitiates radio waves appear from a specified direction into electrical power. Antenna efficiency is increased when gain of antenna increased, so a high gain antenna is preferable in order to collect signals from various directions simultaneously. For improvement in gain techniques like, rectenna array [6-9], differential antenna [10.11], use of defected ground structures, metamaterial rectenna, slotted antennas are implemented.

3.5 Impedance

Generally most of antennas are designed for 50Ω impedance, but by using increased impedance antenna having impedance in range of 100 – 200Ω, matching network can be eliminated, thus improving PCE. For a given power Pr received by antenna, the developed voltage at output of antenna is given by;

$$V = \sqrt{2}\,Pr\;Rant$$

Where, Vant is voltage at output of antenna in open circuit condition & Rant is antenna input impedance. This shows by improving antenna impedance voltage across output of antenna is increased & provides passive voltage amplification [12].

3.6 Antenna Aperture

The maximum amount of energy harvested by the antenna is proportionate to the effective aperture of the antenna and therefore, the overall antenna aperture becomes the critical factor that determines rectenna performance. Horn antenna, Reflector antennas are having maximum aperture, however these antennas having large size & due to this they are not used for applications like RF energy harvesting.

3.7 Substrate Material

Generally a low cost, easily available substrate material like FR4 (εr=4.4, tanδ=0.02) is used for antenna, but a substrate material with lower losses like Rogers RT6002 (εr=2.94, tanδ=0.0035) improves PCE of rectenna.

IV. DESIGN OF ANTEENA

Fig. 1 shows the design view of the antenna. The shape is basically a CPW fed commensurable antenna [11]. The substrate material used for design and analysis is a FR4 material whose properties are chosen as listed in Table 2. Effective dielectric constant can be analyzed from the design expressions listed in [6, 7]. The antenna parameter upper strip patch width and length, also ground length and ground width was optimized using the Ansoft HFSS [12] which is the commercially available electromagnetic software based on finite element method. The physical dimension of the antenna has been listed in Table 2. Detailed of superficial studies on this geometry can be found in [11].

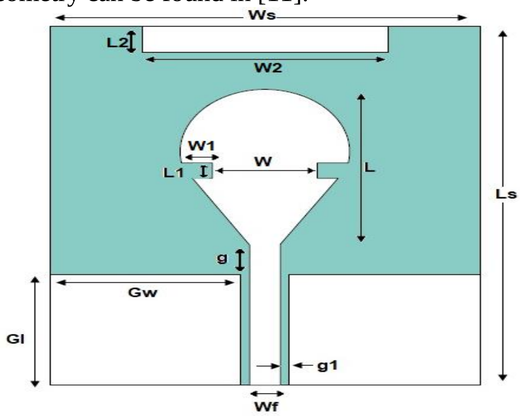

Fig 1: Geometry of CPW fed Modified Triangular Shaped upper strip patch Monopole Antenna for GSM-WIFI RF Energy Harvesting.

In order to achieve extended band operation, upper strip patch aspect of the antenna has been motley and optimized for the wideband operation. It may also be noted that these ground dimensions length and width can be motley and optimized for multiband operation.

Parameters	Dimensions (mm)
L	10.3
W	15.4
Ls	35.0
Ws	28.0
L2	2.5

W2	16.0
Gw	12.4
Gl	11.8
Wf	2.0
g	1.3
g1	0.6
L1	1.5
W1	2.0
Dielectric constant (ε_r)	4.4
Loss tangent (tanδ)	0.001
Height of substrate (h)	1.6

Table 2: Optimized dimensions of the proposed antenna

V. SIMULATION RESULT OF PROPOSED ANTEENA

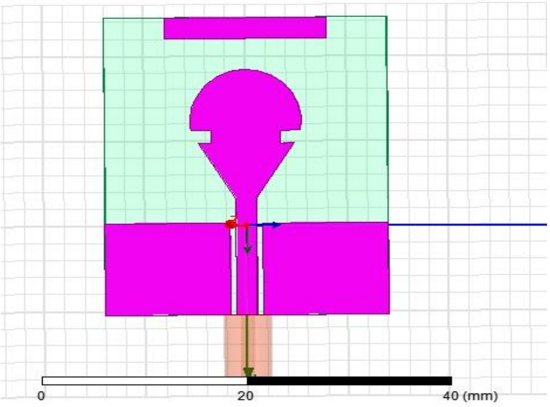

Fig 2: simulation setup of CPW fed modified triangular shaped upper strip monopole antenna using HFSS

Figure 2 shows simulation setup of the antenna. The simulation was carried out by using commercially available EM analysis HFSS software. In Fig. 2 the centered triangular patch having small slit on patch separated by two monopole ground plane shown by using magenta color. Above of triangular patch upper strip patch is shown. The substrate material is shown by stunt color and SMA connecter is shown by using pink color.

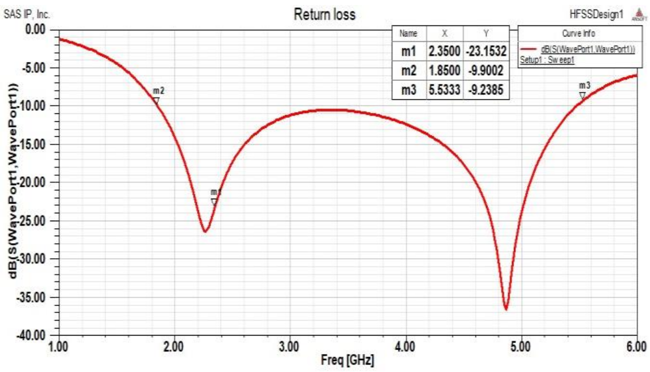

Fig 3: Return loss (S11) of antenna shown in fig. no. 2.

There are several other parameters associated with a patch, which define various performance measures of the antenna , e.g., some of these parameters are return loss, gain, impedance, VSWR, etc. Considering the return loss as the first parameter, the performance of the triangular patch is evaluated at (1.8 GHz-5.5 GHz) bands. This return loss gives an idea about the impedance matching between the microstrip patch and the feed line. It not only depends on the dimensions of the metallic patch, substrate, ground plane, but also on the position of the feed and feed dimensions. The Fig. 3 shown Return loss (S11) of antenna shown in Fig. 2 the antenna can be used to receive from (1.8 GHz -5.5 GHz) with slight crunch at 4 GHz. As antenna should have less than -10 dB for any band to work. Where ever it is decreasing below -10 dB we can say as much as efficiency as much as it decreased.

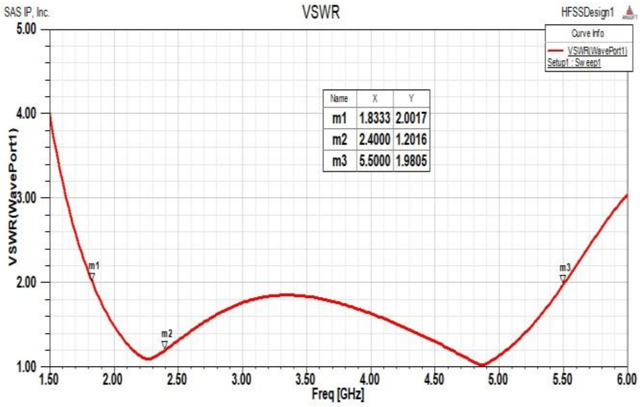

Fig 4: VSWR of antenna

Fig. 4 shows VSWR plot of the antenna. The maximum value of VSWR is 1.19 at 2.4 GHz. These low VSWR values suggest that most of the input power is transferred to the antenna at the desired frequencies and less power is reflected back

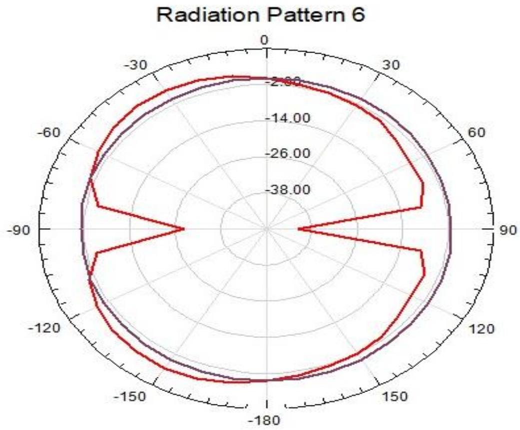

Fig 5: radiation pattern of antenna at 2.4 GHz

The evaluated radiation impression is presented in fig 4. The E- and H-plane radiation impression is evaluated at 2.4 GHz. The radiation impressions are bidirectional in the E-plane and H-plane. It should be noted that cross polarization levels are well controlled in E-plane and H-plane. Moreover, antenna is linearly polarized. The evaluated peak antenna gain is 2.5 dBi at 2.4 GHz.

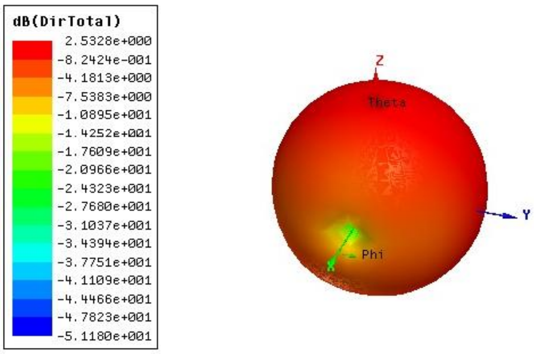

Fig 6: Gain of antenna at 2.4 GHz

The directivity and gain of antenna are related closely to each other, directivity measures the directional capabilities of radiation and gain represents the efficiency of antenna as in fig. 5. The gain of the antenna is 2.5 dB. The directivity obtained for the proposed antenna elements are 5.7dB.

VI. RESULT AND DISCUSSIONS

6.1 Fabrication result of proposed antenna

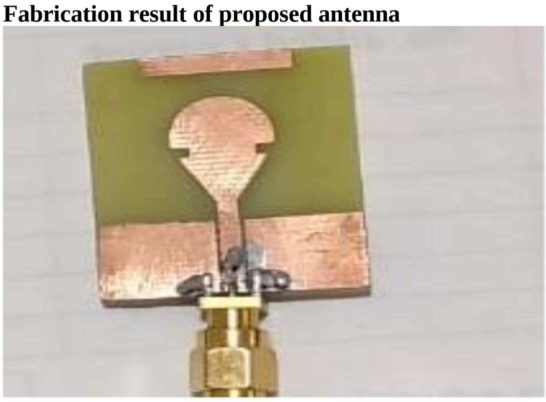

Fig 7: Fabricated geometry of CPW fed modified triangular shaped upper strip monopole antenna using HFSS.

The simulated results for gain (dB) are shown in fig (6) respectively. It can be observed that maximum of 5.8dB as normalized in polar plot representation with Omni-directional radiation pattern. As the antenna would be well for ISM band of (Wi-Fi and WiMax) wireless communications, the obtained gain can be more valuable in our acceptable limit. The fabricated antenna with a FR-4 substrate is shown in fig (7). The antenna results such as S11 and VSWR are shown in fig. (8) and (9). The results obtained by using Vector network analyzer (VNA) are closed match simulated results listed in fig. (5) and (4). The Comparison of simulated result with practical results are shown in Table no. 3.

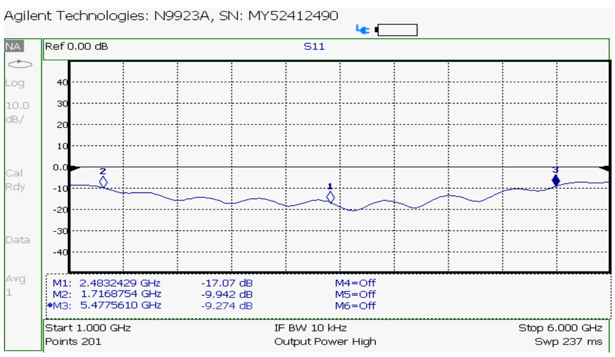

Fig. 8: Practical Measurement of return loss (S11) of antenna shown in fig. no. 7.

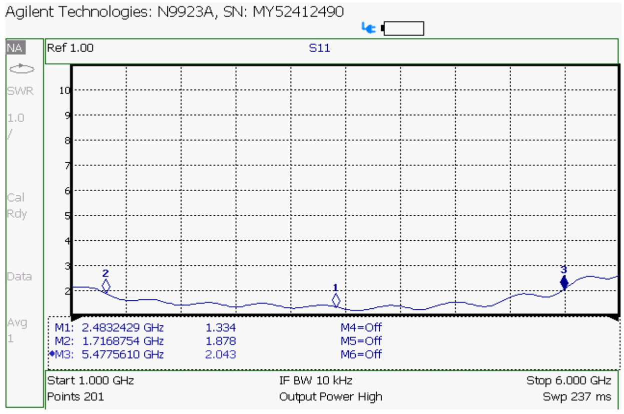

Fig. 9: Practical Measurement of VSWR (S11) of antenna shown in fig. no. 7.

Geometry	Simulated	Measured
Freq (GHz)	1.8-5.5	1.76-5.57
Return Loss(dB)	-23.15	-19.08
VSWR	1.19	1.22
Bandwidth (MHz)	3700	3674
Gain (dB)	2.5	---

TABLE 3: COMPARISON OF SIMULATED RESULT WITH ACTUAL MEASURED RESULTS

VII. CONCLUSION

A CPW fed Modified Triangular Shaped upper strip patch Monopole antenna has been presented and exhibits a S11 of < -10dB in (1.7– 5.5 GHz) frequency range. An introduction of two monopole slot on patch and strip on upper side considerable to cover GSM band. This antenna is capable to harvest RF Energy from the existing GSM (1.8GHz), ISM (2.4GHz), WiMax (2.5/3.5GHz) and the future low band 5G and its possible extension frequencies. Through measured results, the reflection coefficient is achieved <-10dB from (1.76-5.57GHz).

Impedance bandwidth with good gain allover the band of operation was obtained. The fabricated prototype is tested and results are compared. To the best of our knowledge, the antenna presented here is one of the best configurations for RF Energy harvesting operation especially capable for receive power from Wi-Fi router, cell towers etc. All the results of presented antenna are based on the simulation and practical testing. Hence proposed future work will be the fabrication of matching circuit and testing of whole circuit may also be investigated in future.

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