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Fabrication of a Low Profile V Shaped Ground Radiation Antenna for IoT Applications

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Abstract: This research presents the simulated as well as fabricated design of a V shaped ground radiation antenna for IoT (internet of things) applications. The new structure in this article was designed for 2.45 GHz frequency. Traditional material of FR4 is used in substrate which has a dielectric constant of 2.4. The height of this dielectric material is $1.6\times\ 10^{-3}m$. The main lobe gain and the efficiency of the proposed antenna is 2.22 dB and 85% at 2.45 GHz respectively. Lumped elements such as capacitors and inductors are used for impedance matching and resonance. The antenna is matched with a VSWR equals to 1.06 at the operating band. The design was simulated to attain the desirable results and after the simulations the structure was fabricated and the fabricated design validates the reflection coefficient of the antenna in the operating band.

Keywords: Internet of Things, Ground Radiation Antenna, Impedance Matching, Gain, Computer Simulation Technology.

1. INTRODUCTION

Mobile antennas are needed to be of low profile due to limited space in mobile ground plane. The demands of the small antennas for Internet of things applications are increasing day by day due to their high performance. The physical size of the low profile antenna determines its performance (McLean, 1996). The small ground plane high performance antenna needs to be well coupled with the leading mode of the mobile ground plane. The mobile devices have given a gift to a loop type ground radiation (Liu, *et al.*, 2011), (Cho, *et al.*, 2011). However in mobile antennas due to the limited space, it is difficult to achieve high gain and wider bandwidth (Zahid and Kim, 2017), (Hansen, 1981). The wider bandwidth can be obtained by improving the coupling between the patch element and the ground of the antenna (Volakis 2007), (Vainikainen, *et al.*, 2002). In (Liu 2013) a ground radiation antenna having a slot with coupling capacitor has been used which gave a 13 % impedance bandwidth. Numerous pattern reconfigurable antennas have been elaborated in (Catarinucci, *et al.*, 2014), (Ha, *et al.*, 2012). However these types of antennas use additional RF switches which are not used in ground type radiation antenna for IoT devices. Some reconfigurable antennas are recommended for IoT wireless sensors networks in (Ramadan, *et al*, 2010), (Ha, *et al.*, 2011), (Hwang, *et al.*, 2010), (Kim, *et al.*, 2012).

Scientists have been working on IoT technology for the last few years only. Novel integrated internet services are being offered by the IoT technology and will be used in daily life.

The devices using IoT Technology need low data throughput for the transmission of short data bursts. The IoT are in the low band frequencies, providing most favorable radio characteristics for most IoT applications. The ISM band is rapidly occupied by the IoT applications.2.4GHz channel is employed as low range and high bandwidth channel for IoT applications. Some applications of IoT with their frequency bands are elaborated in **(Table-1)**

Table 1: IoT Frequency Bands

Application Area	IoT	Frequency
Smart Home, Smart Building	Zigbee	915MHz, 2.4GHz
	Bluetooth	2.4GHz
	WiFi	2.4GHz, 3.6GHz, 4.9GHz,5GHz
IIoT	Wireless HART	2.4GHz
	ISA 100.11a	2.4GHz
Medical	IEEE802.15.6 (MBAN)	2360MHZ to 2400MHz
	IEEE802.15.6 (WBAN)	2.4GHz, 900MHz,800MHz,400 MHz

A polygon shaped multiband antenna having partial ground plane on FR-4 substrate material is elaborated in (Das, *et al.*, 2018) and this multiband antenna is recommended for Internet of Things applications.

This paper has structured as follow. Section II presents the design methodology and antenna operation

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while Section III and IV presents the results and conclusion of the proposed antenna.

This article presents the design, simulation and fabrication of a low profile V shaped antenna for IoT applications. This paper has been structured as follow. Section 2 presents the design methodology and the operation of the antenna while Sections 3 and 4 present the results and conclusion of the proposed antenna.

2. DESIGN OF V SHAPED ANTENNA

A V shaped ground radiation antenna is presented as shown in **(Fig. 1).** The geometry of the designed antenna consists of a 1.6 mm substrate material (FR-4) having relative permittivity and loss tangent of 2.2 and 0.02 respectively. A V shaped metal strip is etched on FR-4. The design of the proposed antenna occupies a volume of 30×60×1.6 mm^3. The X shaped slot lengths are 8.6 mm in which a V shaped antenna is placed having a discrete port attached to the ground plane. The V shaped antenna is located in the middle of the bottom corner of the ground plane to radiate the ground plane.

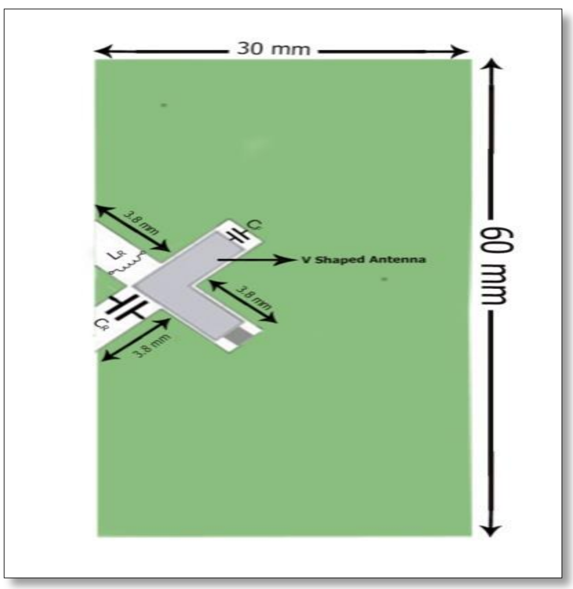

Fig. 1: Geometry of V Shaped Ground Radiation Antenna

Two capacitors and an inductor are used for impedance matching and resonant frequency. The values of C_F and C_R are 0.3 pF and 0.7 pF respectively whereas the value of L_R are 0.4 nH. Since the antenna is located at the bottom center of the ground plane so it works as a magnetic coupler which produces a loop type current around the slot through the magnetic flux. The resonant frequency is controlled by varying the capacitance and inductance of the antenna.

3. RESULTS AND DISCUSSION

In this section the return loss, voltage standing wave ratio (VSWR), surface current, efficiency and gain of the proposed ground radiation antenna are discussed.

3.1 Return Loss

The Return loss of the V shaped antenna is shown in the **(Fig. 2).** The -6 dB impedance bandwidth is 240 MHz which covers the band from 2.32 GHz to 2.56 GHz. The measured and simulated return loss is -25.67 dB and -28.7 dB, respectively. The center frequency of the fabricated antenna shifted a bit towards 2.66GHz.

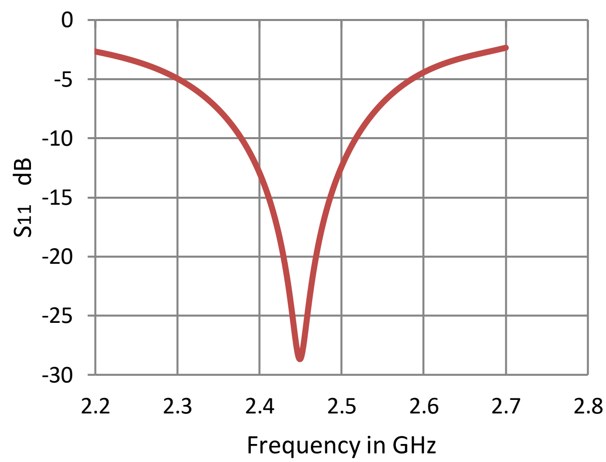

Fig. 2: Return loss of V Shaped Simulated as well as Fabricated Antenna

3.2 Voltage Standing Wave Ratio

The antenna performance is checked by measuring its VSWR and its value will be less than 1.3. VSWR occurs when water or dust particle enter the antenna ports. It also occurs when the antenna port received high power resulting in mismatching the antenna. Furthermore, the bending of semi rigid cable makes VSWR greater than 1.3 which make the antenna mismatched and also its return loss cannot be measured through VNA. The VSWR of the V shaped antenna is 1.07 at the center frequency of the antenna as depicted in **(Fig. 3).** This value of 1.07 justifies proper impedance matching which was attained by selecting the appropriate values of capacitance and inductance.

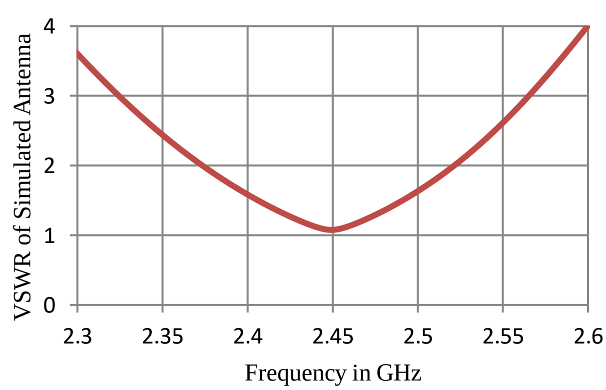

Fig. 3: Voltage Standing Wave Ratio

3.3. Radiation Pattern

The radiation pattern shows the antenna directivity, and its efficiency in the far field region. The gain of the antenna in its polar form shows that the antenna pattern is a dipole which is due to the changing of magnetic flux, creating dipole type current as depicted in the **(Fig. 4).**

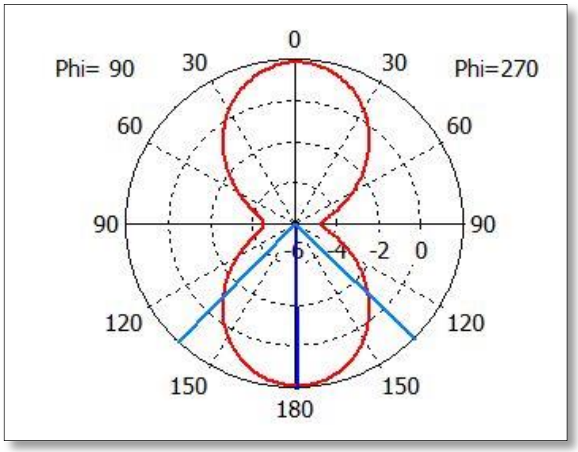

Fig. 4: Radiation Pattern (Gain) at 2.45 GHz

The directivity of the simulated structure is depicted in **(Fig 5).** The peak value of the directivity is 2.72dBi which took place at the frequency of 2.41GHz.

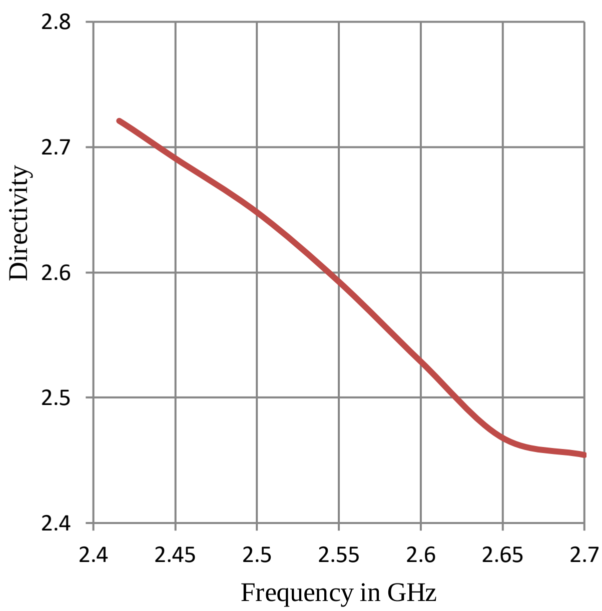

Fig. 5: Directivity of the Antenna

The 3D radiation pattern of the V shaped antenna at 2.45 GHz frequency band is shown in **(Fig.5).** The antenna can be efficiently employed for IoT application in the lower frequency band from 2.32 GHz to 2.56 GHz as it is efficiency is 85% in the mentioned band.

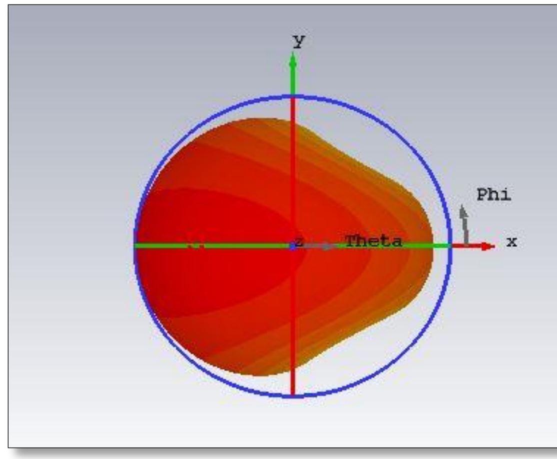

Fig. 6: Far Field Pattern at 2.45 GHz

The peak gain and efficiency of the antenna are 2.22 dB and 85% respectively which shows satisfactory performance for use in IoT applications. The mentioned values of peak gain and efficiency has been recorded at the center frequency of 2.45GHz. The efficiency and gain plot is depicted in **(Fig. 7)** and (**Fig. 8)**, respectively.

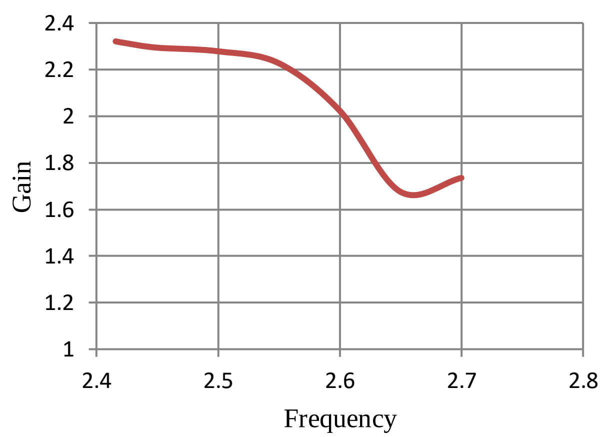

Fig. 7: Gain of the Design

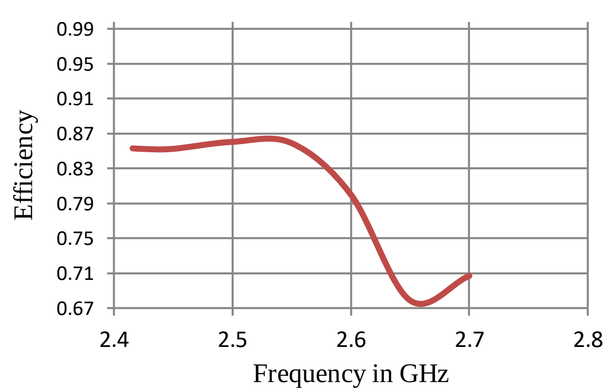

Fig. 8: Efficiency of the Design

3.5 Surface Current Pattern

The surface current shows the current flows in the antenna and ground plane which is due to the arrangement of various current modes. The current modes are depicted in the **(Fig. 9).** This shows that TM mode i.e. vertical current is produced. The TM mode is the first radiating mode in which the current is zero near the corners of the ground plane, agreeing to a dipole-type radiation.

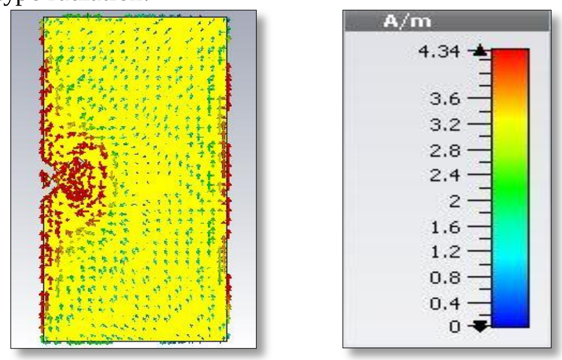

Fig. 9: Surface Current Distribution at 2.45 GHz

Fabricated Antenna:

The V shaped antenna was fabricated and its performance was conducted through experiments by etching the lumped elements and port. The values of C_f, C_r and L_r are 0.3 pF, 0.2 pF and 0.35 nH respectively for the fabricated antenna. The fabricated antenna is shown in **(Fig. 10).** The reflection coefficient i.e. S_{11} was measured using Agilent's E8362 Network Analyzer. The reflection coefficient of the fabricated antenna almost follows the reflection coefficient of the simulated antenna as shown in **(Fig 2)**. This graph validates the performance of the simulated antenna.

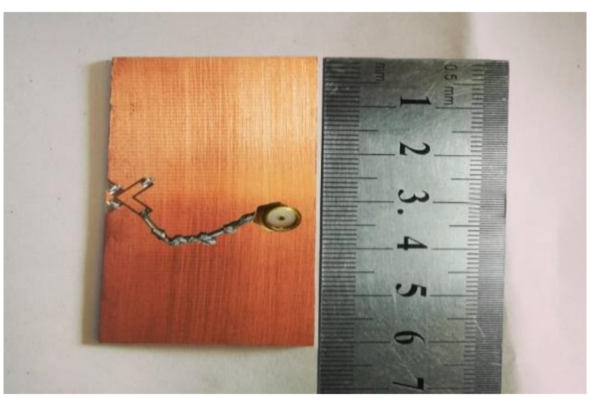

Fig. 10: Fabricated Antenna

The measured and simulated return loss is compared here. The return loss at the center frequency of 2.66GHz of the fabricated antenna is -25.67 dB as shown in **(Fig. 11)** and the return loss of the simulated structure at the center frequency of 2.45 GHz is -28.7dB. The center frequency of the fabricated antenna shifted a bit towards 2.66GHz.

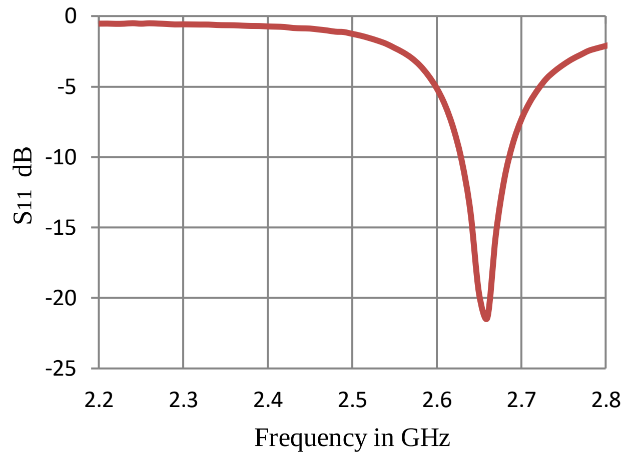

Fig. 11: S_{11} dB of the Fabricated Structure

The minimum value of VSWR is 1.18 which occurred at the center frequency of 2.66GHz as shown in **(Fig. 12).**

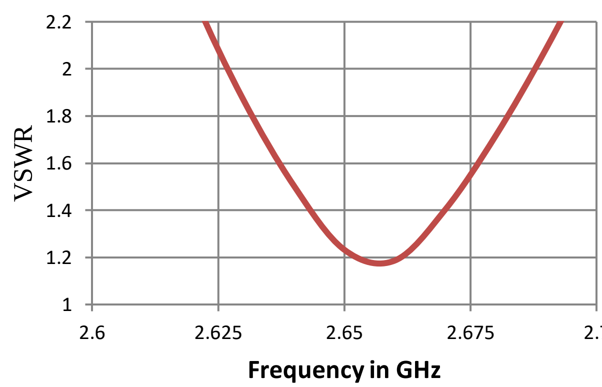

Fig. 12: VSWR of the Fabricated Structure

4. CONCLUSION

In this paper a V shaped ground radiation antenna is proposed for IoT applications resonating at 2.45 GHz frequency band. The Gain of the antenna is 2.22dB at the center frequency. Capacitance and inductance were used for impedance matching and resonance frequency. VSWR of the antenna was 1.07 at the center frequency of 2.45GHz. The antenna attained efficiency of 85% in the entire working band from 2.32 GHz to 2.56 GHz. The reflection coefficient of the antenna was -28.7dB at its center frequency. The efficiency, bandwidth and gain of the antenna show that it is applicable for IoT devices. It can also be designed for 5G devices.

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