Triple Band microstrip patch Antenna with Aperture Reflector for Wireless Applications

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Abstract—Radiation of the electromagnetic energy through an end device connected via internet of things (IoT) iscrucial for any modern-day communication system. A novel triple band microstrip patch antenna scheme is introduced in this work for supporting IoT applications like smart distance communication. The current design consists of a substrate made of FR4.The radiating element is placed on the top layer of the substrate. The shape of the radiating element is a triple hook patch, and the bottom part consists of two symmetrical C shaped dipoles. The reflector is separated from the substrate by Teflon spacers. The reflector is a square planehaving a circular aperture cut at its centre. This enhanced the gain bandwidth performance of the antenna. The presented antenna operates in three bands at 1.56-2.5GHz, 2.6-2.71GHz and 3-3.2GHz with resonant frequencies of 1.74, 2.6 and 3.18GHz respectively. The return loss of the above bands is -21.2, -16 and -30.9dB respectively.

Keywords—Triple band patch antenna, IoT, Microstrip, Teflon spacer, Spectrum Analyzer.

1 Introduction

In recent past the fields of wireless, mobile and satellite communication have seen exponential growth. The introduction of internet of things (IoT) based services have increased the number of smart devices and terminal base stations being connected via internet. This IoT based technology is drifting towards connection with different automated systems[1], systems using artificial intelligence, smart devices and wireless sensor networks. New applications are added to the existing ones making it cumbersome for the IoT [2] based end devices to operate on the past technology. Day by day the technology advancement makes a communication device to operate at different frequencies for different applications. The communication between two devices is done by radiating electromagnetic energy through antennas. Having an antenna for every band makes the design ofthe communication system complex and size also increases. For such applications multi band operation of a single antennas is an advantage[3].

Multiple antennas are used in wireless and mobile applications a few are cavity backed dipole [2], horn, parabolic, directional, phased array, slotted antennas. Though there are several kinds of antennas, antenna required for mobile applications should operate in multiple bands. Along with operation in multiple bands the antenna also must satisfy the other parameters like stable gain, high F/B ratio[4], broad bandwidth, simple design and low cost. Microstrip patch antennas are the best available options for broadband unidirectional, low cost[5], simple design antennas. The major concentration of the present work is on fabrication of microstrip patch antenna for wireless mobile applications operating in triple bands[6].

A few of the existing works in literature are discussed in brief as below. In Cavity-backed dipole antennas, Introducing more cavities to the cavity-backed dipole antennas[7] makes its design more complex with no stable radiation. A feeding strip is designed in the form of a staircase for a dipole antenna. The operating range of the antenna is 1.8-3.4 GHz. This type of antennas cannot accommodate triple band applications. A W-shaped antenna was built for wireless communications in [8]. Though the antenna efficient the feed structure is complex. A slot antenna was designed in [9] for cellular applications the design structure is quite complex. Making the practical implementation difficult. A bowtie antenna with T shaped strip is designed in[10] the impedance parameter is improved for increasing the bandwidth but can be utilized only in indoor applications. A loaded ring structure was designed in [11] for enhancing the gain bandwidth region. However, the antenna operates only in dual band. An antenna with three polygon shaped patches which are grounded on a common plane is designed in [12] for LTE based applications. Though the antenna was able to radiate at two frequency bands the bandwidth was less. A patch antenna with parasitic metallic strip in the shape of a rectangle was designed in [13]. The design has suspended rods on patches[14]. A fractal E-shaped patch antenna was designed in [15] for supporting LTE and GSM applications[16]. Though the results were quite benefactory for applications, yet the iterative process of the antenna shape makes it complex in practical implementation.

Many antennas designed above have only considered impedance bandwidth as the important parameter, without accounting to Front-to-back Ratio (FBR). Later in [17] , a FBR of more than 20dB at 1.5/2/2.4 GHz a multibandcellular base station was implemented using tapered-slot design. And many designs like Circular formed [C][18], reflect-array with crossed-dipole elements [D], and with feed structured antennas using meandering ports [E] and tuned-shaped annular feed[19] was designed for wireless communication. In-order to test the feasibility of the proposed design the fabrication was done. A spectrum analyser having the capacity up to 20GHz is used to check the efficiency of the antenna and compared the results with that of the simulated one.

A multi-hook patch antenna is proposed in this work. The designed antenna can be used for LTE applications. The design comes with enhanced gain and enhanced Front-to-Back ratio. This antenna consists of a cooper reflector with circular aperture in a square plane, a multi-hook microstrip line is placed on the top of the substrate which escalates the bandwidth, the bottom part of the substate consists of C-type twin dipoles. The feed to the antenna is provided by coaxial cable. The simulated results show that the antenna operates in 1.5-2.4, 2.6-2.7 and 3.0-3.2 GHz. The design of the reflector encourages unidirectional radiation with a maximum Front-to-Back ratio of 26.1dB and the maximum gain of 7.81 dBi is achieved.

The gain remains unaltered because of the circular apertured etched on the reflector. This is achieved by improving the front-to back-ratio (FBR). The present design of the antenna resonates at 1.7, 2.6, 3.1 GHz and supports the IOT and LTE applications.

2 Antenna Geometry

The top view and the 3-D view of the antenna are presented in fig.1 and fig.2 respectively. The antenna structure is designed in a three-step process. The top part is the radiating element, and the bottom part constitutes of twin C-type dipoles[20] and they are supported on a square shaped reflector having circular aperture by a Teflon thin cylindrical stirps.

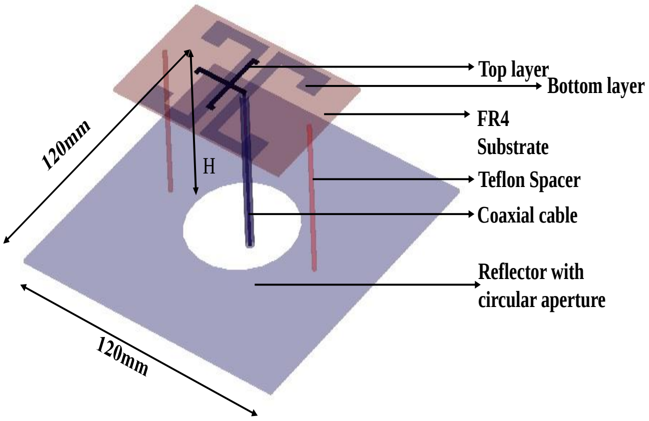

Fig. 1. Three-dimensional illustration of the proposed antenna.

The top radiating element is a multi-hook shaped patch. The path is made of copper. The thickness of the copper is 0.035 mm. Form the figure the arms of the radiating element represented by (A6,A5,A4) are optimized by using cat swarm optimization (CSO). The CSO is a nature inspired algorithm which uses the adaptive nature of the cats and helps in finding the optimum values of A6, A5, A4 for fabrication. After the optimization A6, A5, A4 values are taken as (8.4,14.7,3.125) mm respectively.

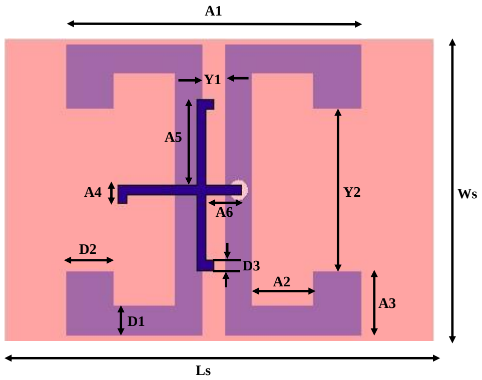

Fig. 2. Two-dimensional geometry of the bottom and top layers of the proposed antenna.

Table1. Overall Geometry of the presented antenna

Parameter	Value	Parameter	Value
Ls	80 mm	Y2	10 mm
Ws	52 mm	A1	52.99 mm
H		A2	11.52 mm
D1	5 mm	A3	20 mm
D2	8.9 mm	A4	3.125 mm
D3	1.7 mm	A5	14.7 mm
Y1	2.15 mm	A6	8.4 mm

The radiating element is laced on the top of the substrate. The substrate chosen FR4 material with 4.4 dielectric constant having a height of 0.8 mm. The intention of choosing this material is FR4 it comes at low cost and is abundantly available. The purpose of the substrate is to produce a time varying electro-magnetic field.

The bottom layer of the substrate is the twin C-type dipoles. The twin dipoles are coupled with each other electromagnetically.

The current distribution of an antenna delineates the performance of the other antenna parameters like antenna impedance, antenna pattern, resistance etc. The radiation resistance of the antenna is estimated based on the current distribution patterns. It also ensures the flow of current to every end of the antenna. Fig 3a represents the current distribution in the antenna without reflector, fig 3b represents the current distribution of the patch antenna with square plane reflector and fig 3c represents the flow of current in designed antenna having circular aperture in the reflector. The presence of slot in reflector produces preferable radiation pattern. Theoretically the current distribution of an antenna is governed by Pocklington equation as below

$$Current\ distribution = A_0 \sin\left(\frac{2\pi y}{\lambda}\right) \sin \omega t$$

Where A_0 is maximum current

$\frac{y}{\lambda}$ is the wavelength distance at open end

ω is the frequency

t is the time period

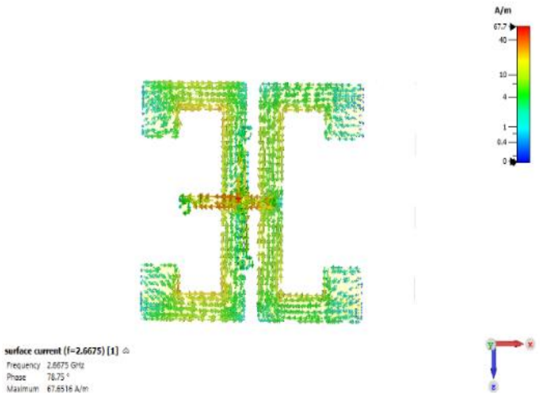

Fig. 3. The Current densities of the patch antenna a) without reflector

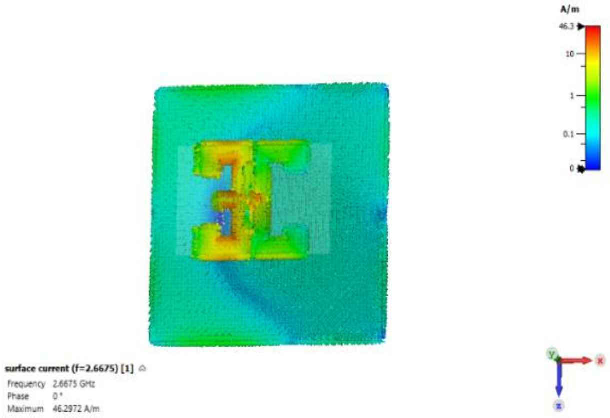

Fig. 3. The Current densities of the patch antenna b) with square plane reflector

Fig. 3. Current distribution of the patch antenna c) with circular aperture in reflector

3 Simulationresultsand discussions

The reflection coefficient S11 represents the amount of electromagnetic energy that is reflected from an antenna. Theoretically it is computedas ratio of the amplitude of the incident wave to reflected wave. Figure 4a represents the S11 of the single hook antenna [20] . Figure 4b represents the S11 of the proposed antenna. Between 1.56-2.5GHz a wide band can be observed which is below -10dB. Another band can be observed between 2.6-2.71GHz this band is

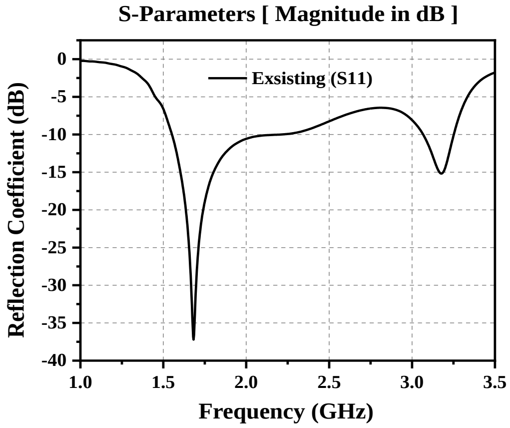

Fig. 4.a) S11 Reflection Coefficient of the existing antenna

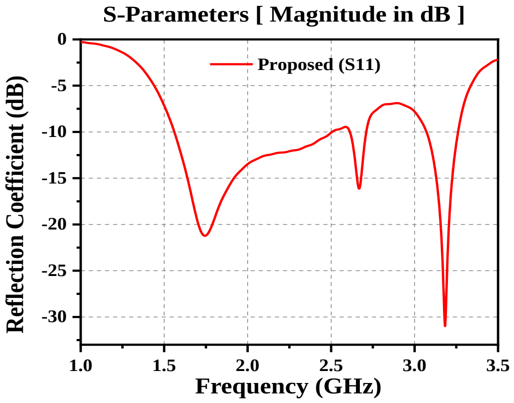

Fig. 4.b) S11 Reflection Coefficient of the proposed antenna

wider when compared with the existing work. Another narrow band is obtained at 3-3.2GHz. Being a triple band design will be effective in implementing smart distance communication and IOT applications. A comparisongraph is provided in figure 4c for S11 between the proposed and the existing works which clearly outlines the advantage of the proposed approach. The front and back ratio indicates the radiation of electromagnetic energy by the antenna and figure 5a indicates the front-to-back ratio of the proposed antenna without reflector and figure 5b indicates the f/b ratio of the proposed antenna with reflector. The front-to-back ratio of the antenna with a reflector proves to be better. The reflector unit helps to radiate the energy towards the front side of the antenna without being dispersed. The gain of the antenna without reflector is indicated in figure 6a and the gain with reflector is indicated in figure 6b. The gain with the reflector is high when compared to the other one. The gain with the reflector is maintained at 7dBi for the total range of bandwidth and it remained stable when compared to the patch antenna without reflector having a gain around 5.9dBi around 3 to 3.5GHz frequency range.

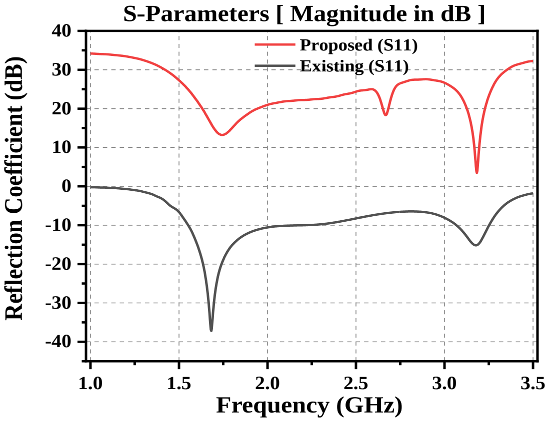

Fig. 4.c) Comparison of reflection coefficient between existing antenna and proposed antenna.

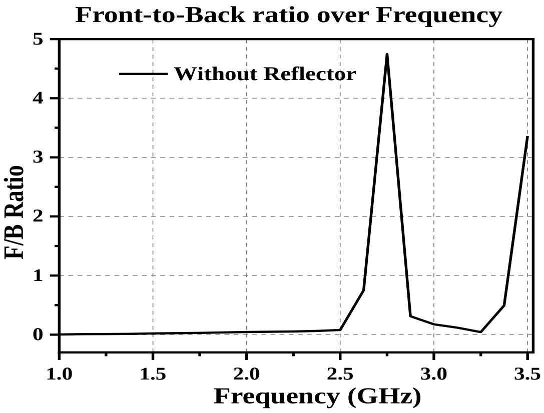

Fig. 5. a) F/B ratio without reflector

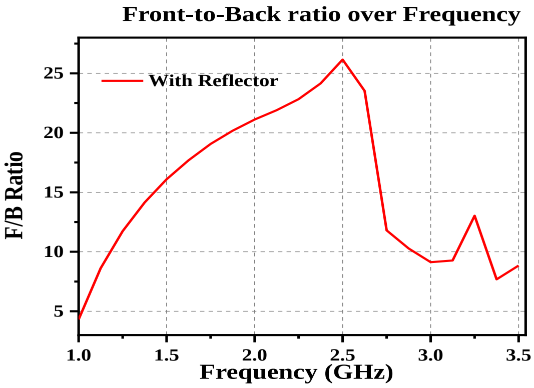

Fig. 5. b) F/B ratio with reflector

The radiation patterns of the antenna for far field region at frequencies of 1.74GHz, 2.66GHz and 3.18GHz is calculated at ϕ values of 0^0 and 90^0. The figures 7a and 7b represent the radiation pattern at a far field region with frequency 1.74GHz, figures 7c and 7d represent the radiation pattern at a far field region with frequency 2.66GHz and figures 7e and 7f represent the radiation pattern at a far field region with frequency 3.18GHz. The radiation patterns are represented in the form of polar plots.

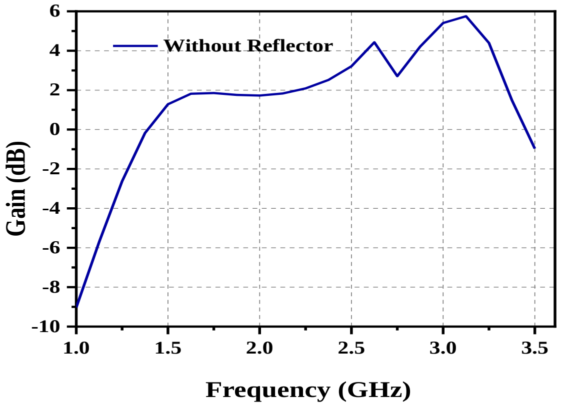

Fig. 6. a) Gain of the antenna without reflector

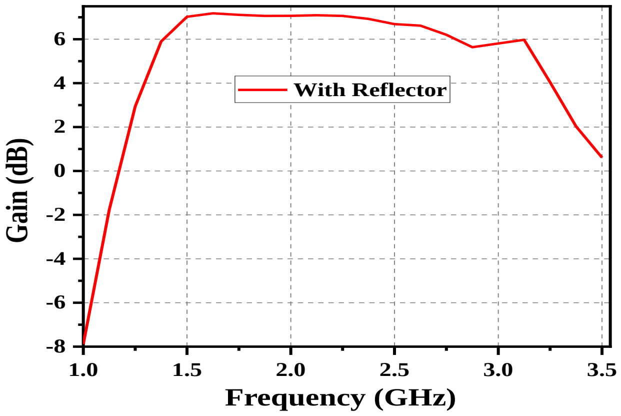

Fig. 6. b) Gain of the antenna with reflector

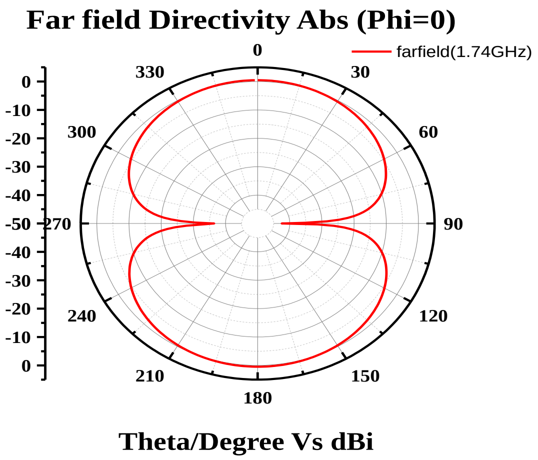

Fig. 7. Radiation pattern of proposed antenna

a) At f_1=1.7478 GHz, ϕ= 0°

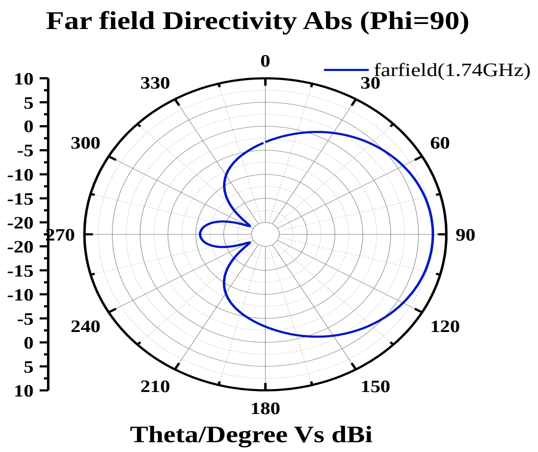

Fig. 7. Radiation pattern of proposed antenna

b) At f_1=1.7478 GHz, ϕ= 90

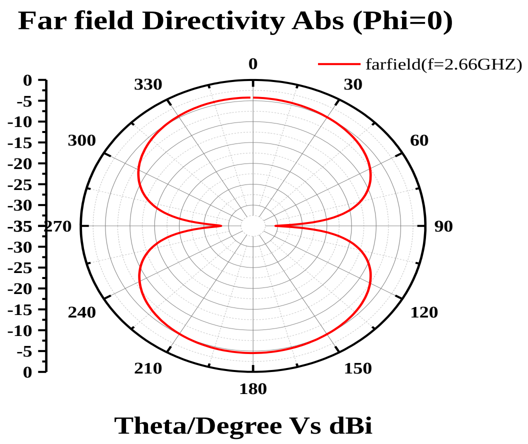

Fig. 7. Radiation pattern of proposed antenna

c) At f_2=2.6675 GHz, ϕ= 90°

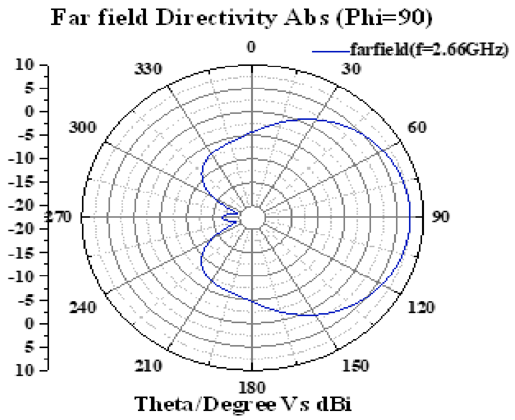

Fig. 7. Radiation pattern of proposed antenna

d) At f_2=2.6675 GHz, ϕ= 90°

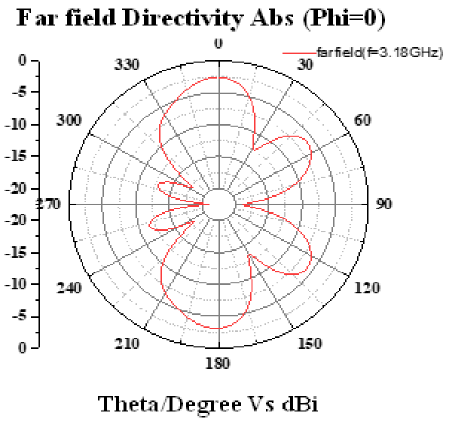

Fig. 7. Radiation pattern of proposed antenna

e) At f_3=3.1825 GHz, ϕ= 0^{o}

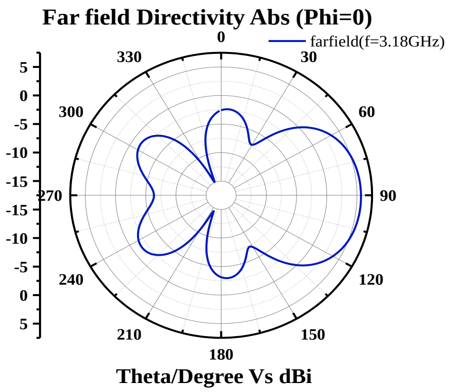

Fig. 7. Radiation pattern of proposed antenna

f) At f_3=3.1825 GHz, ϕ=9 0^{o}

4 Measured Results

To practically test the feasibility of the presented design the antenna is fabricated. Figure 8a, 8bshow the dimensions of the antenna the antenna. Figure8c depicts the reflection coefficient values measured by connecting to spectrum analyser. Figure 8d depictsthe reflection coefficient values of the proposed antenna without reflector unit. When parametric analysis is done and the without reflector design is compared with that of the reflector unit the antenna was able to produce triple bands. The triple operating bands when used in modern IOT connected devices supports multi frequency operation.

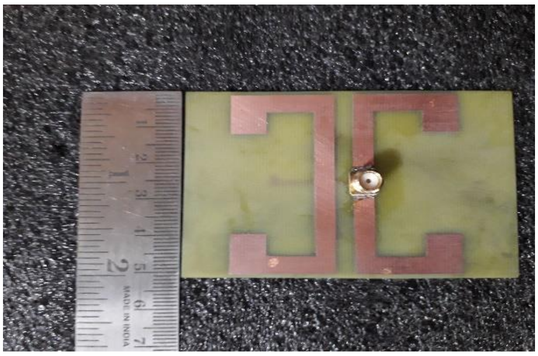

Fig. 8. a) Bottom view of the antenna

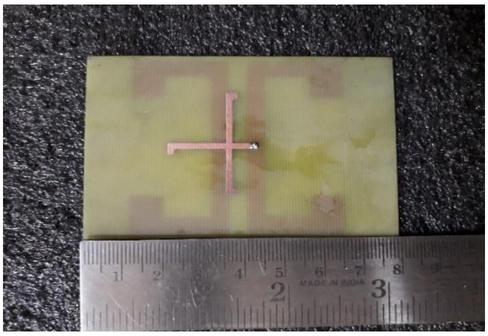

Fig. 8.b) Top view of the antenna

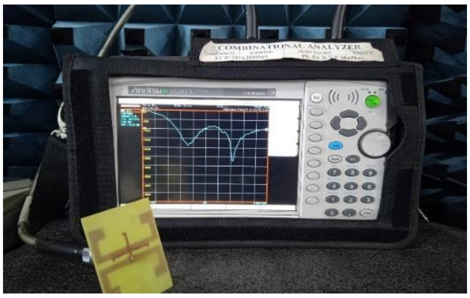

Fig. 8. c) Antenna connected to the Spectrum Analyzer

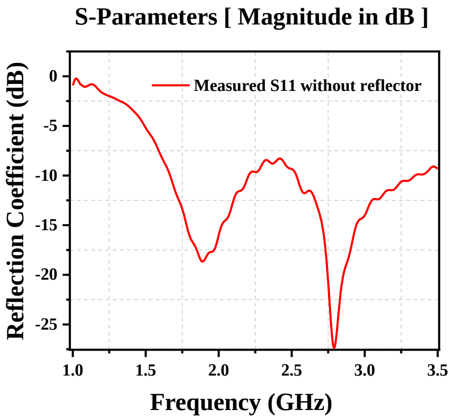

Fig. 8.d) Measured Reflection Coefficient of the antenna without reflector

5 Conclusion

A novel triple band antenna with C-shaped dipole is presented in this paper. The substrate is designed in such a to support smart distance applications in wireless communications. A C-shaped dipole is placed on the bottom of the substrate and hook shaped microstrip lines on the top. The ground plane reflector has a circular aperture and input is given through a coaxial feed. The antenna operates at .56-2.5GHz, 2.6-2.71GHz and 3-3.2GHz. Moreover, the return loss for above bands is -21.2, -16 and -30.9dB which supports the IOT applications. Along with IOT applications the LTE based applications can also be served as the antenna has three bands of operation.

6 References

[1] M. S. Islam, M. T. Islam, M. A. Ullah, G. K. Beng, N. Amin, and N. Misran, “A Modified Meander Line Microstrip Patch Antenna with Enhanced Bandwidth for 2.4 GHz ISM-Band Internet of Things (IoT) Applications,” IEEE Access, vol. 7, pp. 127850–127861, 2019, doi: 10.1109/ACCESS.2019.2940049.

[2] P. Njogu, B. Sanz-Izquierdo, A. Elibiary, S. Y. Jun, Z. Chen, and D. Bird, “3D Printed Fingernail Antennas for 5G Applications,” IEEE Access, vol. 8, pp. 228711–228719, 2020, doi: 10.1109/ACCESS.2020.3043045.

[3] M. B. Hossain and M. F. Hossain, “Design of a Triple Band Rectangular Slot Microstrip Patch Antenna for Wireless Applications,” 2020 IEEE Reg. 10 Symp. TENSYMP 2020, no. June, pp. 1832–1835, 2020, doi: 10.1109/TENSYMP50017.2020.9230997.

[4] J. H. Lee, J. M. Lee, K. C. Hwang, D. W. Seo, D. Shin, and C. Lee, “Capacitively Coupled Microstrip Comb-Line Array Antennas for Millimeter-Wave Applications,” IEEE Antennas Wirel. Propag. Lett., vol. 19, no. 8, pp. 1336–1339, 2020, doi: 10.1109/LAWP.2020.3001945.

[5] Minakshi, A. Sharma, S. Yadav, and R. Paliwal, “A novel reconfigurable microstrip patch antenna for triple band wireless applications,” Appl. Electromagn. Conf. AEMC 2017, vol. 2018-Janua, pp. 1–2, 2018, doi: 10.1109/AEMC.2017.8325695.

[6] Z. Zeng, W. Cao, and X. Lv, “Triple-band triple-mode microstrip endfire antenna based on periodic bowtie dipoles,” 2017 IEEE 6th Asia-Pacific Conf. Antennas Propagation, APCAP 2017 - Proceeding, pp. 1–3, 2018, doi: 10.1109/APCAP.2017.8420966.

[7] H. W. Lai and K. M. Luk, “Dual polarized patch antenna fed by meandering probes,” IEEE Trans. Antennas Propag., vol. 55, no. 9, pp. 2625–2627, 2007, doi: 10.1109/TAP.2007.904158.

[8] K. L. Chung and C. H. Wong, “Wang-shaped patch antenna for wireless communications,” IEEE Antennas Wirel. Propag. Lett., vol. 9, pp. 638–640, 2010, doi: 10.1109/LAWP.2010.2055820.

[9] K. Itoh, K. Konno, Q. Chen, and S. Inoue, “Design of compact multiband antenna for triple-band cellular base stations,” IEEE Antennas Wirel. Propag. Lett., vol. 14, pp. 1–4, 2015, doi: 10.1109/LAWP.2014.2354057.

[10] Z.-Y. Zhang, Z. Shao-Li, and Z. Jia-Yue, “WIDEBAND FOLDED BOWTIE ANTENNA WITH C-SHAPED STRIP FEED AND TUNING STUBS,” Microw. Opt. Technol. Lett., vol. 55, no. 11, pp. 2145–2149, 2013, doi: 10.1002/mop.

[11] Z. Liang, J. Liu, Y. Li, and Y. Long, “A Dual-Frequency Broadband Design of Coupled-Fed Stacked Microstrip Monopolar Patch Antenna for WLAN Applications,” IEEE Antennas Wirel. Propag. Lett., vol. 15, no. c, pp. 1289–1292, 2016, doi: 10.1109/LAWP.2015.2505091.

[12] H. Wen, Y. Qi, Z. Weng, F. Li, and J. Fan, “A Multiband Dual-Polarized Omnidirectional Antenna for

2G/3G/LTE Applications," IEEE Antennas Wirel. Propag. Lett., vol. 17, no. 2, pp. 180–183, 2018, doi: 10.1109/LAWP.2017.2778761.

[13] Y. Cheng and Y. Dong, "Wideband Circularly Polarized Split Patch Antenna Loaded with Suspended Rods," IEEE Antennas Wirel. Propag. Lett., vol. 20, no. 2, pp. 229–233, 2021, doi: 10.1109/LAWP.2020.3045988.

[14] F. Ren, W. Hong, and K. Wu, "Three-Dimensional SIW-Driven Microstrip Antenna for Wideband Linear and Circular Polarization Applications," IEEE Antennas Wirel. Propag. Lett., vol. 16, no. c, pp. 2400–2403, 2017, doi: 10.1109/LAWP.2017.2720627.

[15] N. Bayatmaku, P. Lotfi, M. Azarmanesh, and S. Soltani, "Design of simple multiband patch antenna for mobile communication applications using new E-shape fractal," IEEE Antennas Wirel. Propag. Lett., vol. 10, no. 1, pp. 873–875, 2011, doi: 10.1109/LAWP.2011.2165195.

[16] O. Noori, J. Chebil, S. Khan, M. H. Habaebi, M. R. Islam, and R. A. Saeed, "Design and analysis of triple-band microstrip patch antenna with h-shaped slots," 2012 Int. Conf. Comput. Commun. Eng. ICCCE 2012, no. July, pp. 441–445, 2012, doi: 10.1109/ICCCE.2012.6271226.

[17] H. X. Xu et al., "Analysis and design of two-dimensional resonant-type composite right/left-handed transmission lines with compact gain-enhanced resonant antennas," IEEE Trans. Antennas Propag., vol. 61, no. 2, pp. 735–747, 2013, doi: 10.1109/TAP.2012.2215298.

[18] L. Li, Y. Huang, L. Zhou, and F. Wang, "Triple-Band Antenna with Shorted Annular Ring for High-Precision GNSS Applications," IEEE Antennas Wirel. Propag. Lett., vol. 15, no. c, pp. 942–945, 2016, doi: 10.1109/LAWP.2015.2482604.

[19] X. W. Dai and T. Zhou, "Dual-band reflectarray with crossed-dipole elements for GSM and LTE applications," AEU - Int. J. Electron. Commun., vol. 70, no. 5, pp. 1–6, 2016, doi: 10.1016/j.aeue.2016.01.016.

[20] M. H. Rezvani and P. Mohammadi, "Microstrip antenna with aperture reflector and C-shaped dipoles for LTE and wireless communications," AEU - Int. J. Electron. Commun., vol. 94, no. June, pp. 12–18, 2018, doi: 10.1016/j.aeue.2018.06.041.