International Journal of Electronics Communication and Computer Engineering
Volume 6, Issue 4, ISSN (Online): 2249–071X, ISSN (Print): 2278–4209

Design and Analysis of a Novel compact C-band Antenna for Wideband Applications

M. M. Gayathri
PG Student, Department of ECE,
AITAM College, Tekkali.
Email: mounikasairamana@gmail.com

Dr. B. Ramarao
Assoc. Prof., Department of ECE,
AITAM College, Tekkali

Prof. P. V. Sridevi
Professor, Department of ECE,
Andhra University, Vizag

***Abstract* – In this paper a novel compact C-band microstrip patch antenna with CPW feed for wide band applications is described. The microstrip patch antenna is employed as a pair of stepped structures to compose U-shaped cut on rectangular patch. The antenna has impermeable physical structure and designed on standard FR-4 substrate with an operating frequency of 7.5 GHz. simulation is carried out through Ansoft HFSS software indicate that the designed novel band antenna is having less than -10dB return loss from 7.14GHz to 7.77GHz with a bandwidth of 8.4%. The antenna is efficiently fabricated and characterized by measuring VSWR, return loss, and gain. Comparison between simulated and practical results exhibits the near agreement in the operating band. The consequence of significant parameters on antenna performance are analyzed and discussed as well.**

***Keywords* – C-band, CPW Feed, FR-4 Substrate, Patch Antenna, Stepped Structure, Wide Band.**

I. INTRODUCTION

Advancement in the technology leads to the miniaturization of the devices along with good performance capabilities. Same is the case with antenna technology, as the antenna technology is advancing day by day, the small antenna size with good performance are in high demand. Several antenna structures such as yagi antenna, horn antenna, parabolic reflectors are used to fulfill these needs, but in some cases where two dimensional antennas are needed these antennas can't be used due to their bulky size and 3D structures, this is a case which leads to the requirement of 2D planar antenna and microstrip patch antenna is the most important type of planar antenna structure. There are several patch shapes which provides good bandwidth and gain for various applications [1]. In last 40 years, the microstrip antennas have been developed for various communication systems such as radars, sensors, wireless, satellite, broadcasting, ultra-wideband, radio frequency identification (RFIDs), reader devices etc. [2]-[3].

In Recent years, there has been enormous growth of telecommunications services in the L-band frequencies such as radar tracking, global positioning satellite (GPS), and mobile communications. The use of circularly polarized (CP) antennas is rife in these areas since they can provide better mobility and weather penetration than the linearly polarized antennas [4].circularly polarized (CP) antennas, known for their capabilities of reducing polarization mismatch and moderately suppressing multipath interferences, require larger bandwidths to support emerging wireless-communication applications, especially those involving satellite communications [5].

Satellite communications are being developed from low-frequency bands like the L-band and the S-band to high-frequency bands such as the Ku-band and the Ka-band to obtain broader bandwidths, higher data rates, and higher gains with the same radiating aperture. Microstrip patch antennas (MPAs) adopting slits as geometric perturbations have been proposed in [6] to implement circular polarization (CP), and many other studies have been done to broaden the antennas' axial-ratio beam width [7]–[9]. A circularly polarized MPA mounted on a pyramidal ground plane and partially enclosed by a flat conducting wall was designed in [7], and a 3-dB axial-ratio beam width of more than 130^0 was realized. A dual-frequency dual circularly polarized patch antenna with 3-dB axial-ratio beam widths of more than 165^0 and 175^0 for the high- and the low-frequency bands, respectively, was presented in [8] by extending the substrate beyond the ground plane.

Cavity-backed circularly polarized antennas have been proposed to realize broadband and high-gain performances, where air-filled metallic cavities [10]–[15] or substrate-integrated cavities [16]–[19] are adopted to achieve unidirectional radiation patterns. A sequentially rotated four-element slot antenna fed by a microstrip network to achieve CP and backed by a rectangular metallic cavity was designed in [10], realizing a 3-dB axial-ratio. In [12], a combination of a cavity-backed slot and strip loop radiating circularly polarized waves at two adjacent frequencies was proposed to achieve bandwidth enhancement. A circularly polarized stacked patch antenna excited by a novel single feed was developed in [14] to increase the axial-ratio bandwidths, and a short horn was mounted to get high gain. A substrate-integrated cavity-backed circularly polarized patch antenna was investigated in [19], A cylindrical metallic cavity antenna (MCA), and circularly polarized waves are realized by structural perturbations to decompose the cavity resonant mode into two orthogonal components with the same amplitude but 90^0 phase difference, for that a metallic C-band prototype is designed and fabricated in [20].

The different feeding techniques are also used for enhancing the bandwidth of microstrip patch antenna; coplanar waveguide feeding is one of them. It has several advantages on any other feeding method such as low radiation loss, less dispersion; uniplanar configuration and easy mounting of shunt lumped elements or active devices without via hole as for the microstrip line. Coplanar waveguide (CPW) fed antennas have been increasingly

International Journal of Electronics Communication and Computer Engineering
Volume 6, Issue 4, ISSN (Online): 2249–071X, ISSN (Print): 2278–4209

studied in recent years. Recently, several researchers have explored with large efforts to develop antennas that satisfy the demands of the wireless communication industry for improving performances.

Antennas using CPW-fed line also have many attractive features including low radiation loss, less dispersion, easy integration for monolithic microwave circuits (MMICs) and a simple configuration with single metallic layer, since no backside processing is required for integration of devices. Therefore, the designs of CPW-fed antennas have recently become more and more attractive. One of the main issues with CPW-fed antennas is to provide an easy impedance matching to the CPW-fed line. In order to obtain multiband and broadband operations, several techniques have been reported in the literatures based on CPW-fed slot antennas [21].

In this paper a discernible, novel compact C-band antenna design is proposed for wide band applications. As maintaining a very good radiation efficiency and reasonable gain for a wide band antenna is difficult, the design considerations made to implement this are described in the paper. Furthermore, good control of the antenna bandwidth is realized by varying the length of the ground plane, without significantly affecting the antenna input impedance or resonant frequency.

II. Antenna Design Specifications

The geometry of the proposed compact C-band antenna for wide band applications is depicted in Figure 1.The fabrication of the proposed antenna is done using a conventional FR4 substrate, often used to make printed circuit boards with thickness (*h*) of 1.6mm and relative permittivity of 4.4, which makes it easy and inexpensive to manufacture. The three essential parameters for the design of a microstrip Antennas are:

A. Resonant frequency (fr):

The resonant frequency of the antenna must be selected appropriately. The IEEE C-band have the frequency range from 4GHz to 8GHz, hence the antenna designed must be able to operate in this frequency range. The resonant frequency selected for the design is 7.5 GHz.

B. Dielectric constant of the substrate (€r):

The dielectric material selected for our design is FR4 epoxy which has a dielectric constant of 4.4. A substrate with a high dielectric constant has been selected since it reduces the dimensions of the antenna.

C. Height of dielectric substrate (h):

For the microstrip Patch antenna to be used in wireless applications, it is essential that the antenna is not bulky. Hence, the height of the dielectric substrate is selected as 1.6 mm.

Hence, the essential parameters for the design are:

- *fo* = 7.5 GHz
- *€r* = 4.4
- *h* = 1.6 mm

Step 1: Calculation of the width of the patch (W):

Equation (1) gives the width of the microstrip patch antenna as:

$$W = \frac{c}{2 f_0 \sqrt{\frac{(\varepsilon_r + 1)}{2}}} \quad (1)$$

Step 2: Calculation of the Effective dielectric constant (€r):

Equation (2.1& 2.2) gives the effective dielectric constant as:

$$for\ \frac{w}{h} \geq 1\ ,$$

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{w}\right]^{-\frac{1}{2}} \quad (2.1)$$

$$for\ \frac{w}{h} \leq 1,$$

$$\in_{reff} = \frac{\in_r + 1}{2} + \frac{\in_r - 1}{2}\left[1 + 12\frac{h}{w}\right]^{-\frac{1}{2}} + 0.041\left[1 - \sqrt{\frac{w}{h}}\right] \quad (2.2)$$

Step3: Calculation of the effective Length of Strip (L_{eff}):

The effective length of the Microstrip Antenna given by the equation (3)

$$L_{eff} = \frac{c}{2 f_0 \sqrt{\varepsilon_{reff}}} \quad (3)$$

Step 4: Calculation of the actual length of the patch (L):

The actual length of the patch can be calculated by the equation (4)

$$L = L_{eff} - 2\Delta L \quad (4)$$

Step 5: Calculation of the Width of Ground plane (Wg):

The length of the ground plane can be calculated by the equation (5)

$$Lg = 6h + L \quad (5)$$

Step 6: Calculation of the width of ground plane (W_g):

Here the length of the ground plane is obtained by equation (6)

$$Wg = 6h + W \quad (6)$$

By using the Design Equations the dimensions of C-band microstrip antenna are having the values L=17mm, H=24mm, W=18mm, Lg=6mm W_g=2mm,ε_r = 4.44.The proposed antenna are simulated using HFSS, Fig 1.shows the simulated antenna.

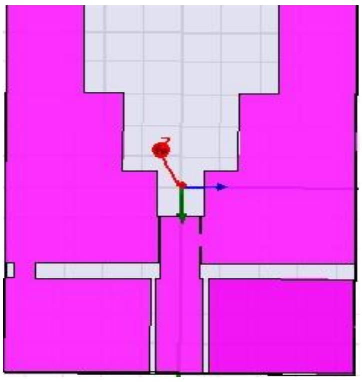

Fig.1. HFSS modal for C-band antenna

International Journal of Electronics Communication and Computer Engineering
Volume 6, Issue 4, ISSN (Online): 2249–071X, ISSN (Print): 2278–4209

The created antenna type will be printed on a cover and it is pasted in the copper substrate which will be both sides of the substrate and is painted for darkening because the antenna is to be printed clearly. Then the substrate is dipped in to the Ferrite Chloride ($FeCl_2$). Fluid which will cleans the remaining copper except the antenna shape and then it is connected to the connectors which will connect to the network analyzer with the help of the probe and the connectors.

III. C-Band Microstrip Antenna Design Process

Fig.2 shows the geometry of the proposed C-band microstrip coplanar waveguide (CPW) fed antenna. The proposed antenna was fabricated on FR4 substrate with dielectric constant 4.4 and thickness of 1.6 mm. The antenna structure is chosen to be a rectangular patch element with dimensions of width W and length L, and with a vertical spacing of 'h' away from the ground plane. A conventional CPW fed line designed with a gap of distance 'd' between the signal strip and the coplanar ground plane is used for exciting the radiating patch element. Two finite ground planes with the same size of width Wg and length Lg, are situated symmetrically on each side of the CPW feeding line.

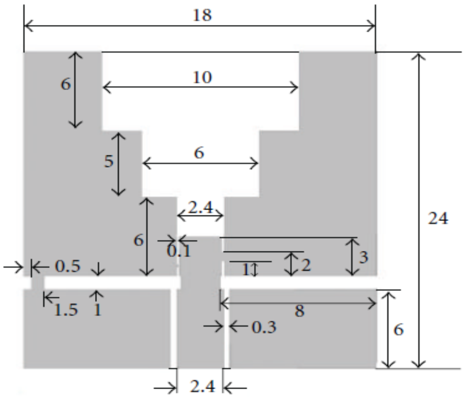

Fig.2. C-band microstrip antenna

The Table I show the dimensions of the proposed C-band antenna.

Table I: Dimensions of the C-band microstrip antenna

Configuration	Parameters	Dimensions
Substrate-FR4	W	60mm
	L	45mm
	h	1.6mm
	ε_r	4.38mm
Ground plane	W_g	2.4mm
	L_g	6mm
Antenna	L	17mm
	H	24mm
	W	18mm

The fig.3 shows the prototype of fabricated C-band microstrip antenna.

(a) (b)

Fig.3. Photograph of proposed compact C-band antenna (a) top layer (b) bottom layer

IV. Results

A prototype of the compact C-band microstrip antenna is simulated, constructed and tested.

The performance of the C-band microstrip antenna has been investigated by using HFSS. The Fig.4and fig.5 shows the simulated return loss, VSWR and the Fig.6 shows the radiation pattern and Fig.7, fig.8 shows the tested return loss, and VSWR of the C-band microstrip antenna from the frequency 4 GHz to 8GHz.

A. Return Loss:

Power will not deliver to the load and is a return of the power, that is called loss, and this loss that is returned is called the return loss. Larger return loss indicates higher power being radiated by the antenna which eventually increases the gain. In the Fig.4 it shows that the C-band microstrip patch antenna resonating at 7.5GHz having a maximum return loss of -31db.

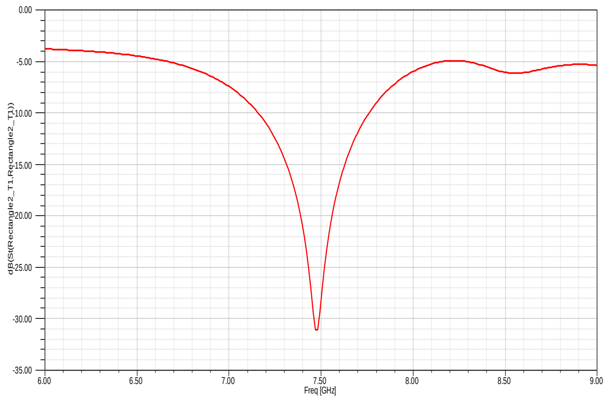

Fig.4. Return loss curve for L_g of C-band microstrip antenna

B. Voltage Standing Wave Ratio (VSWR):

The VSWR is an important specification for all communication devices. It measures how well an antenna is matched to the cable impedance where the reflection, $|\Gamma| = 0$. This means that all power is transmitted to the antenna and there is no reflection. The simulation result of Voltage Standing Wave Ratio, (VSWR) is shown in Fig.5 below. By referring to Fig 5, at operating frequency 7.5 GHz, the VSWR value obtained is 1.04.

International Journal of Electronics Communication and Computer Engineering
Volume 6, Issue 4, ISSN (Online): 2249–071X, ISSN (Print): 2278–4209

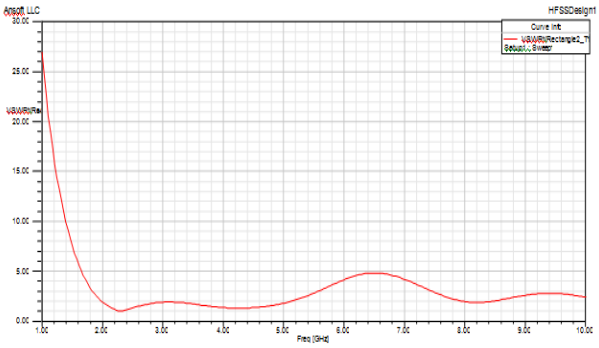

Fig.5. VSWR curve for L_g=2mm

C. Radiation Pattern:

The radiation pattern of microstrip Patch Antenna is the power radiated or received by the antenna. It is the function of angular position and radial distribution from the antenna. The radiation pattern for the proposed microstrip patch antenna is shown in Fig 6.

Fig.6. Radiation pattern of C-band microstrip antenna

Ansoft HFSS is a high performance full wave electromagnetic (EM) field simulator. It integrates simulator, visualization, solid modelling and Automation in an easy-to-learn environment where solution of 3D EM problem is quickly and accurately obtained. Ansoft HFSS can be used to calculate parameters such as return loss, gain, band width and VSWR etc. The experimental return loss and VSWR is shown below.

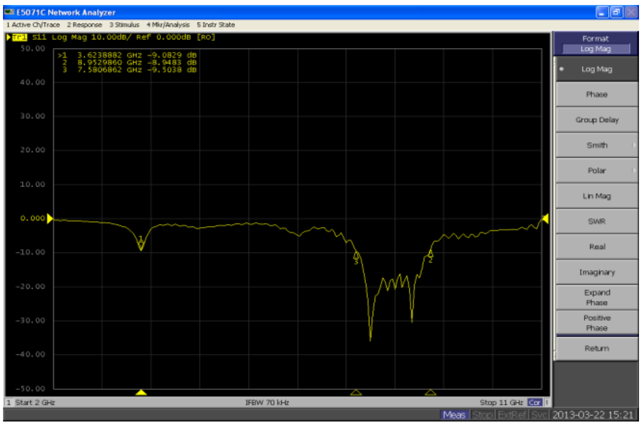

Fig.7. Experimental Return loss curve from VNA (E5071C)

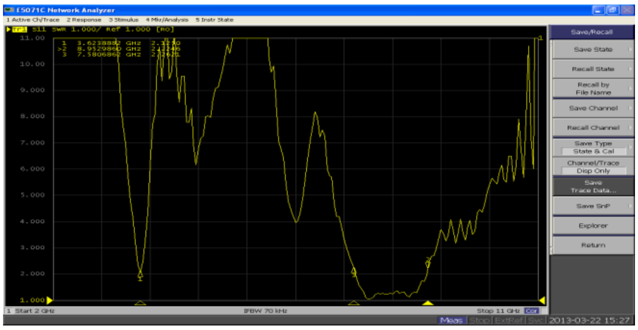

Fig.8. Experimental VSWR curve from VNA (E5071C)

V. Conclusion

A novel design of a compact C-band antenna specifically made for wideband operation has been presented. The proposed antenna has a gain of 9.1 dBi. The C-band antenna is resonating at 7.5 GHz and impedance bandwidth ($S11 < -10$ dB) from 7.14 GHz to 7.77 GHz is 8.4% the practical value. The designed antenna can be used for Wi-FI and satellite communications.

References

[1] Amit Kumar Gupta, R.K. Prasad and D. K. Srivastava, " Design and Analysis of Quad-Band Rectangular Microstrip Patch Antenna", *IOSR Journal of Electronics and Communication Engineering (IOSRJECE), ISSN: 2278-2834 Volume 1, Issue 6 (July-Aug 2012), PP 19-23.*

[2] Munish Kumar, M-Tech Electronics and Communication, Department of ECE, USICT, G.G.S. Indraprastha University, New Delhi ,"Design and analysis of minkowski fractal antenna using microstrip feed" *international Journal of Application or Innovation in Engineering & Management (IJAIEM), Volume 3, Issue 1, January 2014.*

[3] M. T. Islam, M. N. Shakib and N. Misran, "Multi-slotted microstrip patch antenna for wireless communication" *Progress In Electromagnetics Research Letters, Vol. 10, 11-18, 2009.*

[4] Ka-Leung Lau, Member, IEEE, and Kwai-Man Luk, Fellow, IEEE, "A Wide-Band Circularly Polarized L-Probe Coupled Patch Antenna for Dual-Band Operation" ,*IEEE transactions on antennas and propagation, vol. 53, no. 8, august 2005.*

[5] J.-Y. Sze andW.-H. Chen, "Axial-ratio-bandwidth enhancement of a microstrip-line-fed circularly polarized annular-ring slot antenna," *IEEE Trans. Antennas Propag. vol. 59, no. 7, pp. 2450–2456, 2011.*

[6] Nasimuddin, Z. Chen, and X. Qing, "Compact asymmetric-slit microstrip antennas for circular polarization," *IEEE Trans. Antennas Propag. vol. 59, no. 1, pp. 285–288, 2011.*

[7] C.-W. Su, S.-K. Huang and C.-H. Lee, "CP microstrip antenna with wide beamwidth for GPS band application," *Electron. Lett.*, vol. 43, no. 20, pp. 1062–1063, 2007.

[8] X. L. Bao and M. J. Ammann, "Dual-frequency dual circularly-polarized patch antenna with wide beamwidth," *Electron. Lett.* vol. 44, no. 21, pp. 1233–1234, 2008.

[9] K. M. Mak and K. M. Luk, "A circularly polarized antenna with wide axial ratio beamwidth," *IEEE Trans. Antennas Propag. vol. 57, no. 10, pp. 3309–3312, Oct. 2009.*

[10] Q. Li and Z. Shen, "An Inverted microstrip-fed cavity-backed slot antenna for circular polarization," *IEEE Antennas Wireless Propag. Lett. vol. 1, pp. 190–192, 2002.*

[11] S.-W. Qu, J.-L. Li, C. H. Chan, and Q. Xue, "Cavity-backed circularly polarized dual-loop antenna with wide tunable range," *IEEE Antennas Wireless Propag. Lett. vol. 7, pp. 761–763, 2008.*

[12] R. Li, BoPan, A. N. Traille, J. Papapolymerou, J. Laskar, and M. M. Tentzeris, "Development of a cavity-backed broadband circularly polarized slot/strip loop antenna with a simple feeding

structure," *IEEE Trans. Antennas Propag., vol. 56, no. 2,* pp. 312–318, Feb. 2008.

[13] N.-S. Seong and S.-O. Park, "A microstrip-fed cavity-backed circularly polarized horn antenna," *Microw. Opt. Technol. Lett., vol. 48, no. 12,* pp. 2454–2456, 2006.

[14] Nasimuddin, K. P. Esselle, and A. K. Verma, "Wideband high-gain circularly polarized stacked microstrip antennas with an optimized C-type feed and a short horn," *IEEE Trans. Antennas Propag. vol. 56, no. 2,* pp. 578–581, Feb. 2008.

[15] K.-F. Hung and Y.-C. Lin, "Novel broadband circularly polarized cavity-backed aperture antenna with traveling wave excitation," *IEEE Trans. Antennas Propag. vol. 58,* no. 1, pp. 35–42, Jan. 2010.

[16] G. Q. Luo, Z. F. Hu, Y. Liang, L. Y. Yu, and L. L. Sun, "Development of low profile cavity backed crossed slot antennas for planar integration," *IEEE Trans. Antennas Propag.,* vol. 57, no. 10, pp. 2972–2979, Oct. 2009.

[17] D. Kim, J. W. Lee, C. S. Cho, and T. K. Lee, "X-band circular ringslot antenna embedded in single-layered SIW for circular polarisation," *Electron. Lett.* vol. 45, no. 13, pp. 668–669, 2009.

[18] D.-Y. Kim, J. W. Lee, T. K. Lee, and C. S. Cho, "Design of SIW cavity backed circular-polarized antennas using two different feeding transitions," *IEEE Trans. Antennas Propag.,* vol. 59, no. 4, pp. 1398–1403,Apr. 2011.

[19] Yang Zhao, Zhijun Zhang, *Senior Member, IEEE,* and Zhenghe Feng, *Fellow, IEEE* "An Electrically Large Metallic Cavity Antenna with Circular Polarization for Satellite Applications", *IEEE antennas and wireless propagation letters, vol. 10*, 2011.

[20] Ramanjit Singh, Geetanjali Singla, Rajesh Khanna," Broadband Cpw Fed Slotted Ground Antenna", IOSR *Journal of Electronics and Communication Engineering (IOSRJECE)* ISSN: 2278-2834 Volume 2, Issue 2 (July-Aug 2012), PP 36-39.

[21] Sarawuth Chaimool and Prayoot Akkaraekthalin "CPW-Fed Antennas for WiFi and WiMAX Wireless Communication", *Research Group (WCRG*), Electrical Engineering, Faculty of Engineering, King Mongkut's University of Technology North Bangkok, Thailand.

AUTHOR'S PROFILE

M. M. Gayathri

completed her B.Tech. in Electronics and communication engineering in the year of 2013.She is pursuing her master degree in VLSI System Design in Aditya Institute of Technology And Management, Tekkali, India. Her areas of interests are Antenna and propagation, VLSI Design.

B. Rama Rao

completed his B.E. in Electronics and communication and Master of Technology in the stream of Radar and microwave engineering in the year of 1998, 2004 respectively. He is completed his Ph.D in Microstrip fractal antennas in the year of 2015. Now, he is working as Assoc. Professor in Aditya Institute of Technology And Management, Tekkali, India. He is the Life member of IETE, ISTE. His area of interests are Antenna and propagation, Microwave and Radars.

Dr. P. V. Sridevi

completed her Master of Engineering in the stream of applied electronics from PSG college of Engg. In the year of 1988 and Ph.D in the area of Antennas and Microwave communications from Andhra University, Visakhapatnam Now, she is working as Professor in Andhra University College of Engineering. Andhra University Visakhapatnam, India.