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Research paper

Analysis and Design of a Multi Octave Circularly Polarized Monopole Antenna for UWB, X and Ku-Band Applications

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Abstract

This work presents a circularly polarized, CPW-Fed multi band operating monopole antenna. The monopole antenna consists of three parasitic elements, along with a stub at ground for impedance matching. The parasitic elements so far accumulated have shown their excellence in increasing the impedance bandwidth over the 6-18GHz band. The antenna was carved on FR-4 epoxy substrate which result a copper clad laminated structure. The CPW-Fed monopole antenna exhibits excellent circular polarization levels in the frequency region 6-18GHz. The simulation resulted a Return loss of less than -10dB, with good axial ratio less than -3dB over entire band of interest. The simulation was carried out through HFSS microwave studio. The antenna measured values are in good correspondence to the simulated values.

Keywords: *Multioctave, monopole antenna, circular polarization, UWB band, parasitic patches.*

1. Introduction

Many techniques have been emerged and adopted to achieve dual band or multi- band operation through simple uniplanar, printable and compact structured antennas that/which found their applications in various communication networks such as WiMAX, WLAN, Satellite and RADAR.

Circular polarization (CP) in antennas is a desired mode of polarization compared to linear polarization as the CP antennas reduces the losses called polarization mismatches which are originated due to antenna constraints in terms of orientation. These antennas eventually reduced the complications indulged in point-to-point communications [1,2]. Some multi band / dual band antenna design techniques may inherit loading of non printable components (capacitor, inductors) to achieve the reconfigurable ability in the antennas, which causes difficulty in fabrication as well as to acquire accurate results over long period in terms of polarization purity and the gain.

The fully printable slot antennas acquired a position to be part of broad band antennas and as well as dual band characteristics as shown in [3, 4]. The radiation phenomenon, characteristics of monopole antennas of various geometries were investigated [5]. The broad band and dual band antennas [6-8] having CP excelled their performance when embedded in systems incurring diversity. The printed monopole antennas [7] are easy to integrate in any wide band communication systems. The input impedance can be improved by tuning [8].

The single stub resulted the improvement of the axial ratio along high frequency bands. The parasitic elements are placed along the monopole structures in order to have a wide band operation [9-10] resulting a double-resonance phenomenon.

Hence multi octave antenna along with independent impedance control and the CP over low and high frequency bands is the reliable criteria in antenna structuring.

The multi octave monopole antenna design has lined up with a idea to operate over 6-18GHz band, with an attribute to tune over entire X, Ku and UWB region.

2. Antenna configuration

The designed Multi octave CPW-Fed monopole antenna's structural configuration and dimensional details are shown in Fig.1. The monopole structure's radiating element is designed on FR-4 substrate having ε_r of 4.4 and δ= 0.024. The antenna is designed based on [11], over area of ($1.05\lambda_0 \times 1.25\lambda_0 \times 0.026\lambda_0$) where λ_0 is the wavelength of centre frequency. The feeding was provided through a 3.2mm width micro strip line.

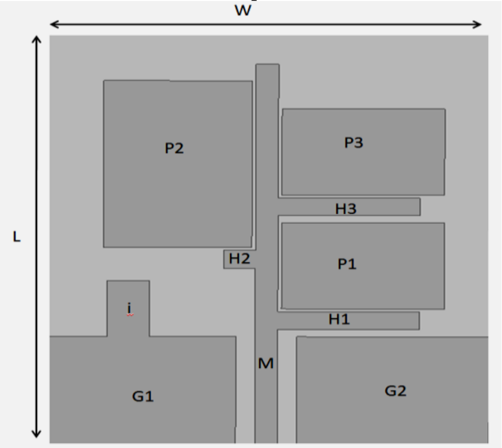


Fig. 1: Multi-octave CPW fed monopole antenna

The antenna consists of monopole with three branches H1, H2 and H3, which are horizontally attached and having same width as monopole with varying lengths. The three branches are placed at heights of 42m, 21mm and 10mm respectively.
The rectangular (parasitic) patches P1, P2, P3 are placed at height that differs with horizontal stubs by 0.5mm long length and width from monopole and horizontal stub. An I- shaped rectangular stub (I) is placed on ground plane. The dimensional values of the antenna elements were as shown in Table I. The position of stub a prominent role in the attainment of best impedance matching values at the required operating frequency values. The horizontal branches ease the way to attain the LHCP and RHCP of the radiating monopole at the upper band frequencies.

Table 1: Antenna Design Standards

Element	W(mm)	L(mm)
G1,G2	27.2	20
M	3.2	71
P1&P3	23	15.5
P2	21	30
H1&H3	20	3.2
H2	4.5	3.2
i	6	14

The best gain and circular polarization values are only possible with appropriate alignment of the rectangular elements, stub and the ground's position, length, width are key and significant factors that progress result to be at required level.

3. Antenna Design Development and Evolution

The Multi octave monopole antenna developed in five steps as shown in Fig. 2. The return loss followed by axial ratio plots shows the extent of circular polarization and return loss enhancement among the stages of evolution.

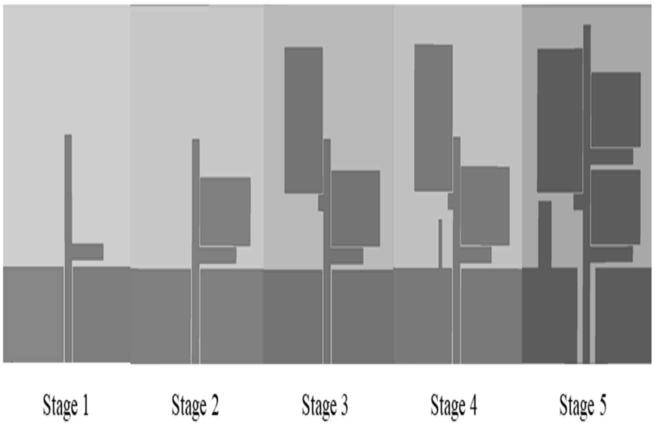


Fig. 2: Evolution stages of the Multioctave form

The monopole antenna resonance directly depends upon its guided wavelength. Thence resonance frequency and the wavelength of a monopole antenna are obtained from equation (1)

$$F_L = \frac{7.2}{(l+r+p)}\,\text{GHz} \quad (1)$$

As shown in stage 1, a H1 is added to M so that the resultant currents are in orthogonal; with this geometry of antenna CP radiation is obtained around 2.4GHz. The length of vertical and horizontal strip should be < $\lambda_g/2$ at 2.4GHz.
Therefore the input current and the voltage M attain same phase as H1 is in resonance with. The input current and voltage in vertical branch are phase shifted by 90^0 as the input impedance is inductive. As a result we attain RHCP (right hand circular polarization) as the currents so far directed are in perpendicular. The change in length of the Y-directed branch results change in input impedance and thus resulting a equal magnitude in the both resonating branches. A patch element P1 is added as shown in stage 2 of Fig. 2 to obtain wideband impedance matching. To improve the impedance matching further a horizontal branch H2 and another parasitic element P2 is added in stage3.
The width of the ground planes G1 and G2 is about λg/2 at the center frequency at the high frequencies. Hence these planes are also in resonant condition. As a result the fields produced by them would be opposite to each other. Therefore an I-shaped stub is attached to ground plane G1 as shown in Antenna 4 to inhibit the CP radiation from this plane.
The impedance matching is attained by stub matching technique. The stub's length and position are tuned in such a way that there would be no CP radiation from G1. The two main design considerations of a single stub are given in equation (2) and (3)

Length of the stub

$$L_{stub} = \frac{\lambda}{2\pi}\tan^{-1}\left[-\frac{1}{Zo\,B(dstub)}\right] \quad (2)$$

Stub location is obtained by

$$d_{stub} = \frac{\theta}{4\pi}\lambda \quad (3)$$

where $\theta = 2\beta d = \frac{4\pi}{\lambda} d$

Depending upon length, the position of the stub may be tuned over the possible places in order to attain the impedance matching. The solutions can be retained using smith chart [12]. These eliminate the impedance mismatch and polarization problems, so that it only ground plane. Thence circular polarization is achieved at the upper band (left hand side).
The parasitic element which was placed along the right hand side along with the horizontal strip resulted in the enhancement of bandwidth of the antenna (i.e., at stage 5). This arrangement is a mimic to the process to obtain CP at lower band frequency. The gain is also stabilized at the higher bands.

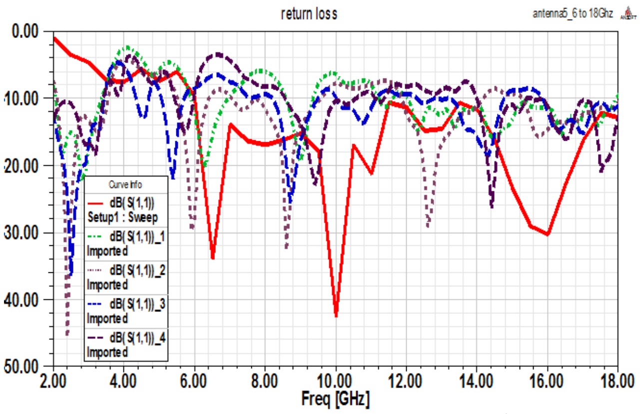


Fig. 3: Plot showing return loss enhancement over upper frequency bands through the five stages of evolution

The above Fig.3 shows excellent operating conditions in 5 stages of evolution in the means of return loss of minimum -10dB to maximum value -42dB. The axial ratios so far obtained shows good circular polarization levels and the gain values of acceptable range.
The fabricated antenna shown in Fig. 4 similar to the software designed antenna to attain the operation in 6-18GHz band.

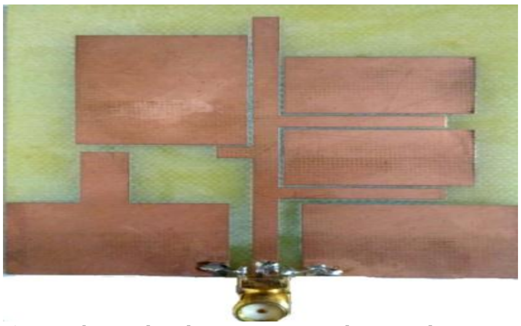


Fig. 4: Fabricated Multioctave CPW-Fed Monopole antenna

4. Results and Discussions

Fig. 5, 6 shows the various parametric analysis steps involved in the evolution of the Multioctave circularly polarized antenna. The crucial elements that involved in the characterization of the designed antenna were the length of the monopole, width of the ground plane, stub's length (Ls) and width (i) and the positioning of the stub.

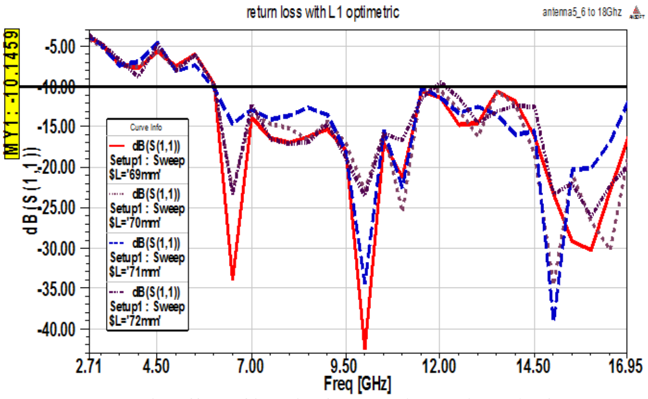


Fig. 5: The effect of length of monopole at values >λg /2

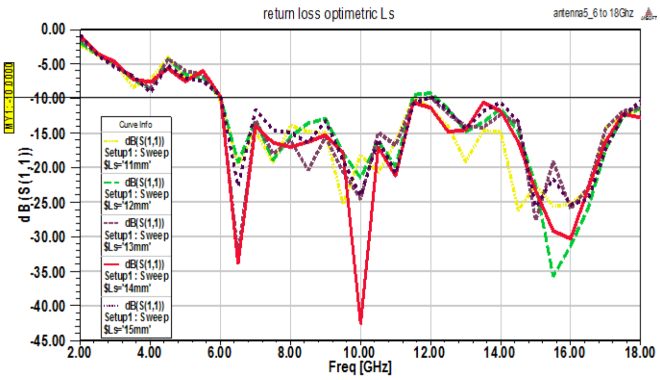


Fig. 6: Stub length tuning from Ls 11to14mm effect on antenna return loss characteristics

Usually the single stub is placed in parallel to the transmission line in order to provide the impedance match this indirectly poses the effect on the polarization efficiency. Fig. 5,6 shows the effect of stub length and width on the characteristics of antenna.

The length variants resulted in the main beam radiation to be less than 3dB at the expected frequencies and even some instances at length of the stub 11mm the polarization values reached the ideal condition. The width of the stub along with positional variations resulted in the attainment of CP over the operating band .The width of 6mm enabled this functionality. Even the axial ratio at the higher bands is prominent but lower bands are seriously affected due to the variation in the stub length.

The Multioctave monopole antenna with all these design development's resulted the operation over ultra wide and X, Ku band (6-18GHz) with circular polarization over the band with gain values ranging between 2 to 10dB, claiming best operating performance. Fig. 7, 8 shows the $|S_{11}|$ parameters, axial ratio of the simulated and fabricated antenna in the operating band respectively.

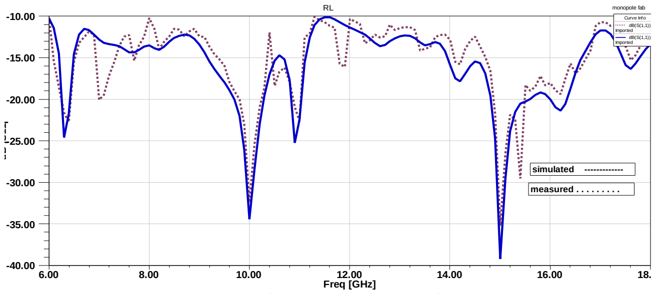


Fig. 7: Return loss plot of the simulated and fabricated antenna.

Table 2: Multi Octave Antenna Design Assessment

Frequency (GHz)	Return loss (dB)	
	Simulated	Measured
6	-24.6	-22.7
10	-34.4	-32.4
14	-15.9	-12.9
15	-39.2	-35.2
18	-11.3	-11.9

Table 2 shows the comparison showing the performance enhancement of the simulated and fabricated antenna, in means of return loss.

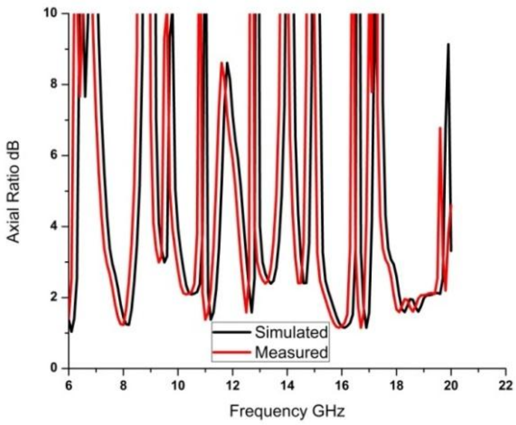
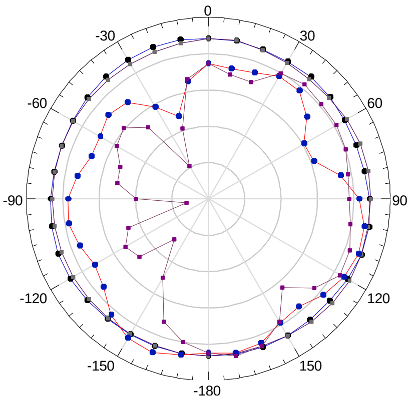
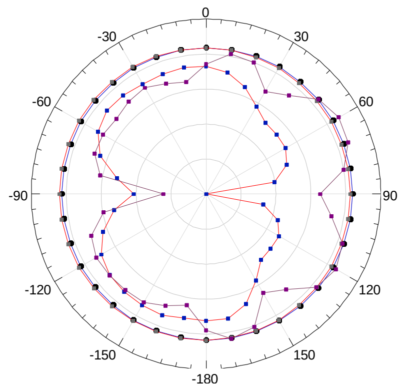


Fig. 8: Axial ratio of the simulated and fabricated antenna.

The below Fig.9 shows the ration pattern of the multioctave monopole antenna have been investigated at frequencies 6GHz,10 GHz,14 GHz and 16 GHz respectively in the E plane with XY at 0^0 (θ)and XY at 90^0 (ϕ).In comparison with the base work the designed antenna radiation patterns shown maximum intensity of radiation at these frequencies.



(a)



(b)

Fig. 9: Radiation patterns (a) 6GHz and 12 GHz (b) 16 GHz and 18 GHz in XY plane

5. Conclusion

The Multioctave circularly polarized monopole antenna employing the vertical stubs and the parasitic elements to attain circular polarization with a tunable stub along the ground to provide impedance match and as well work as a tuner .The antenna has a wide impedance bandwidth with appreciable gain and axial values. The designed antenna is supposed to facilitate the operability over the entire Ultra wide band, majorly in satellite, radar, TV broadcasting and in many commercial applications. This approach can be further extended for bandwidth enhancement and miniaturization of antenna by preserving the polarization characteristics attaining low frequency bands into confidence.

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References

[1] W. Cao, A. Liu, B. Zhang, T. Yu, and Z. Qian, “Dual-band spiral patch antenna with slot n Omni directional CP and unidirectional CP properties,” *IEEE Transactions Antennas Propagations*, Vol. 61, No. 4, pp. 2286–2289, Apr. 2013.

[2] Kang Ding, Cheng Gao, Yanjie Wu, Dexin Qu, and Bing Zhang, “A Broadband Circularly Polarized Printed Monopole Antenna With Parasitic Strips,” *IEEE Antennas and wireless Propagation Letters*, Vol.16, pp. 2509-2512, July 2017.

[3] H.G.Xue, X.-X. Y.Z. Ma, “A novel microstrip-CPW fed planar slot antenna with wideband and circular polarization,” *IEEE Antennas Wireless Propagation Letters*, Vol.14, pp. 1392-1395, 2015.

[4] R. K. Saini, and S. Dwari, “CPW-fed broadband circularly polarized rectangular slot antenna with L-shaped feed line and parasitic elements”, *Microwave Optical Technology Letters*, Vol. 57, No. 8, pp. 1788–1794, Aug. 2015.

[5] R. K. Saini, and S. Dwari, “Broadband dual circularly polarized square slot antenna,” *IEEE Transactions Antennas Propagations*, Vol. 64, No. 1, pp. 290-294, Jan. 2016.

[6] C. F. Jou, J.-W.Wu, and C.-J. Wang, “Novel broadband monopole antenna with dual-band circular polarization”, *IEEE Transactions Antennas Propagations*, Vol. 57, No.4, pp. 1027-1034, Apr. 2009.

[7] Y.Y. Chen, Y.-C.Jiao, G. Zhao, F. Zhang, Z.-L. Liao, and Y. Tian, “Dual-band dual-sense circularly polarized slot antenna with a C-shaped grounded strip,” *IEEE Antennas and wireless Propagation Letters*, Vol. 10, pp. 915-918, 2011.

[8] Yong-Ling Ban, Jin-Hua Chen, Si-Cheng Sun, Joshua Le-Wei Li, Fellow, IEEE, and Jin-Hong Guo,” Printed Monopole Antenna With a Long Parasitic Strip for Wireless USB Dongle LTE/GSM/UMTS,” *IEEE Antennas and wireless Propagation Letters*, Vol. 11, pp.767-770, July 2012.

[9] Rohit Kumar Saini, Santanu Dwari and Mrinal Kanti Mandal, “CPW-Fed Dual-Band Dual-Sense Circularly Polarized Monopole Antenna,” *IEEE Antennas and Propagation Letters* doi: 10.1109/LAWP.2017.2726545.

[10] José R. Pereira, Pedro Pinho,” Bandwidth Analysis of a Single-Stub Matching System Using the Smith Chart,” *IEEE Antennas and Propagation and Magazines*,” Vol.54, Issue.6,December 2012.

[11] W.K. Chen, “Linear Networks and Systems,” Belmont, CA Wadsworth, 1993, pp. 123-135.

[12] H. Poor, “An Introduction to Signal Detection and Estimation,” New York: Springer-Verlag, 1985, chapter 4.