SELF-SIMILAR CIRCULARLY POLARIZED WIDEBAND ANTENNA FOR RECENT WIRELESS APPLICATIONS

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Abstract: A compact wideband antenna with circular polarization characteristics designed on Rogers RT/Duroid 5870(tm) substrate with constant 2.33 is proposed. This structure consisting of four self-similar double merged equilateral triangles with hexagonal modeled slot inscribed in it. This antenna covers IEEE C-band (4-8GHz) frequencies for ground based and airborne weather radar applications. The simulated and computed parameters of this proposed antenna are presented in this paper. This antenna is low cost, smaller in size and high radiation efficiency. Proposed structure maintains stable radiation characteristics in the entire wideband.

***IndexTerms* - Equilateral triangle patch, hexagonal slot, self-similar structure, wideband, circular polarization**

I. Introduction

The microstrip antennas are introduced from 1950's but these antennas are more attractive in wireless communication applications since twenty five years because of its several advantageous like smaller in size, low weight, ability to integrate it in any shape, low cost of fabrication and easily integrated with monolithic integrated circuits [1-3].Microstrip antennas are used in all long distance communication applications like radio, mobile phones, global positioning systems, RADARS, satellites and medical applications [4].

The microstrip antenna suffered due to mainly three disadvantages such as narrow bandwidth, low gain and low efficiency. The gain of the antenna can be enhanced by using parasitic elements [5-6] and efficiency of antenna can be increased by using line feed methods [7]. In this paper, these two problems will not be discussed here. This paper mainly focuses on bandwidth enhancing techniques of microstrip antenna.

There are various ways of bandwidth enhancing design techniques are presented in several research articles. The easiest way to enhancing the bandwidth is to increase the substrate thickness but it causes radiation power decreases [8].The authors proposed an antenna which resonates at 1.20GHz, 2.82GHz, 3.58GHz, 4.02GHz and 6.68GHz by applying L-slots in the Planar Inverted F-Antenna (PIFA) [9]. Wideband antenna has been designed by inserting the circular slot in the pentagon shaped patch antenna with line method [10]. Truncated circular patch antenna has been proposed a wideband antenna to cover the frequency range from 2.3 to 6.0GHz [11].One of the recent technologies is fractal implementation. It gives the number of bands and wider bandwidth due to its self-similar and space filling properties [12]. M. A. Dorostkar, R. Azim, M. T. Islam and Z. H. Firouzeh proposed one wideband antenna which operates over the ranging from 1.34 to 3.44GHz obtained by inscribed the circular slots inside the hexagonal patch element [13]. Sriyantra shaped hybrid fractal antenna with defected ground structure developed for multiband applications, this proposed antenna resonates at 4.04GHz, 4.94GHz, 5.88GHz, 6.60GHz, 7.24GHz, 8.88GHz and 10.92GHz center frequencies [14].

In this paper, a self-similar structure designed for wideband applications on FR4 epoxy substrate material. Initially star shaped patch designed by using line feeding method. After several iterations, proposed antenna has been developed. The following sections are organized into different ways for explaining this proposed design.

II. Design & development of proposed antenna design

In order to generate the wide band antenna, initially started with the two merged equilateral triangles with the line fed technique. This proposed antenna has been designed on Rogers RT/Duroid 5870(tm) dielectric material with constant 2.33 and its loss tangent is 0.0012 (named it as 0th iteration) as shown in figure 1. All the design parameters are mentioned in table 1. Partial ground also introduced in it.

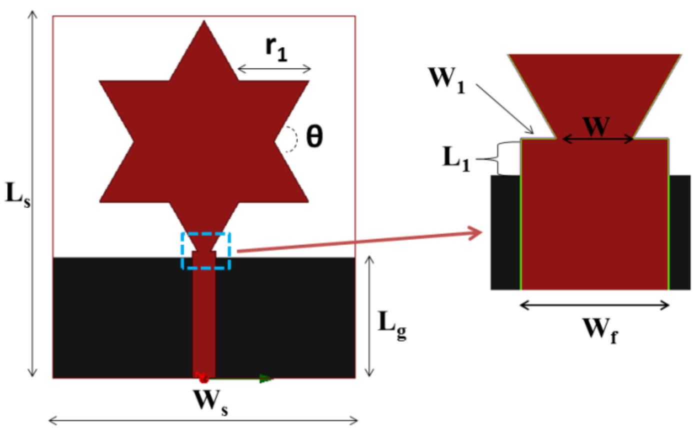
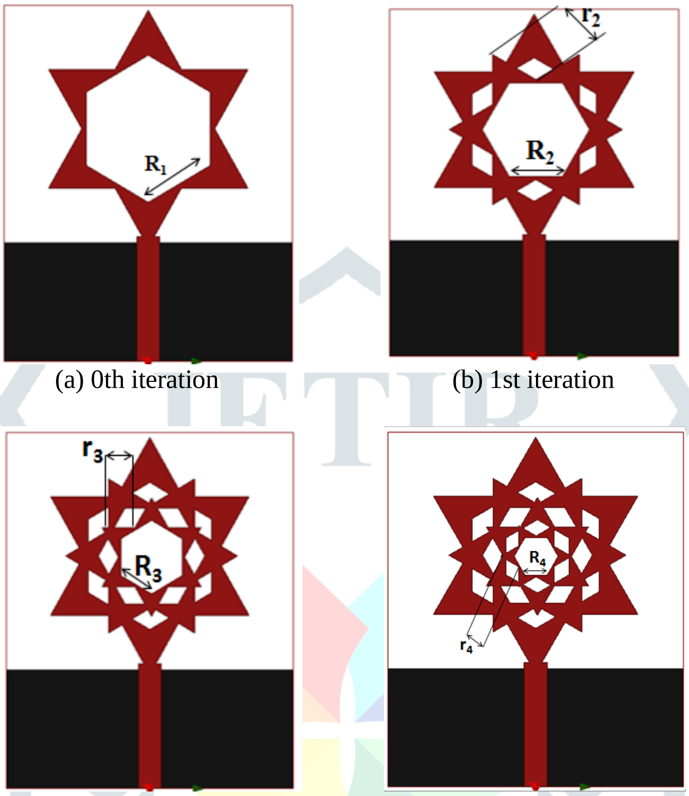


Fig 1: Merged equilateral triangles with line feed and partial ground structure (0th iteration)

Table 1: Design parameters (All units are in mm)

Ls	Ws	Lg	Wf	L1	W1	W	H
30	25	10	2	0.5	0.48	1.04	1.6
R1	R2	R3	R4	r1	r2	r3	r4
6.2	4.65	3.1	1.86	5.78	4.33	2.88	1.53

To enhance the impedance bandwidth of this antenna, hexagonal modeled slot inscribed in the 0th iteration (named as 1st iteration) as shown in figure 2(a). To enhance the bandwidth and impedance matching characteristics of a designed structure, a self-similar structure has been developed by rotating the same patch with 30o inclination with respect to the line of vertical axis. Various steps of proposed antenna have been shown in figure 2. The size of the patch can be reduced by a scaling factor.



(a) 0th iteration (b) 1st iteration

(c) 2nd iteration (d) 3rd iteration

Fig 2: Implementation of proposed antenna structure

III. Proposed Design Results & its Discussion

The behavior of proposed antenna characteristics explained in terms of electrical, far field characteristics and its surface current distributions.

a) Electrical characteristics of simulated antennas

Figure 3 shows the return loss characteristics of the two merged equilateral triangles with partial ground (0th iteration). This structure obtains a wideband characteristic in the range of 4.84-6.52GHz but it has less impedance matching.

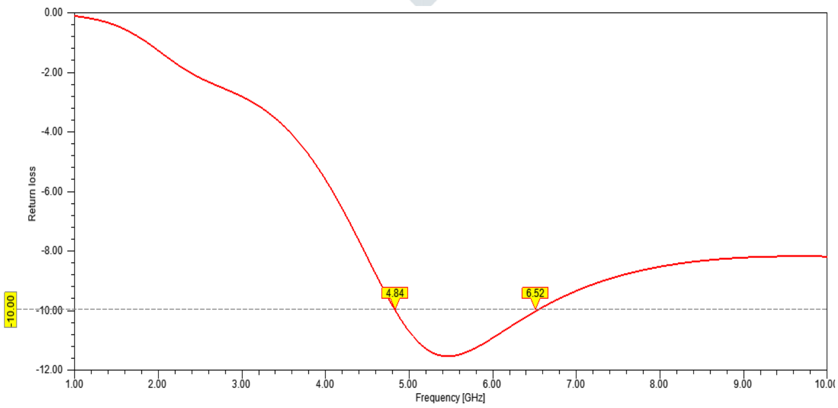


Fig 3: Return loss characteristics of 0th iteration

Figure 4 shows the return loss characteristics of the 1st iteration. This structure achieves the dual resonating frequencies with wider bandwidths by inserting a hexagonal slot in the patch. Figure 5, 6 & 7 shows the return loss characteristics of the proposed antennas. From the observation of all these simulated designs, the proposed antenna has good impedance matching characteristics as well as it obtains wideband characteristics. This proposed antenna has an impedance bandwidth of 3.31GHz in the range of 4.61-8.00GHz. This proposed antenna resonating at 5.6GHz and its reflection coefficient value is -48dB.

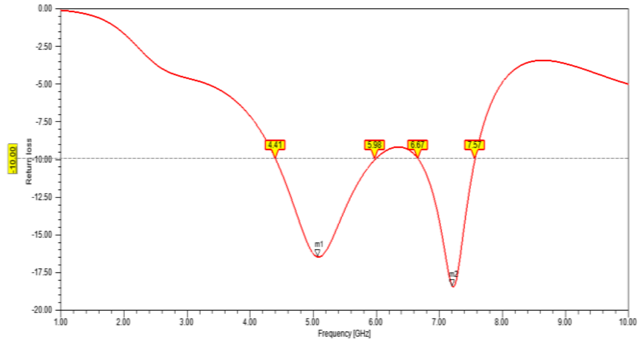


Fig 4: S11 of 1st iteration

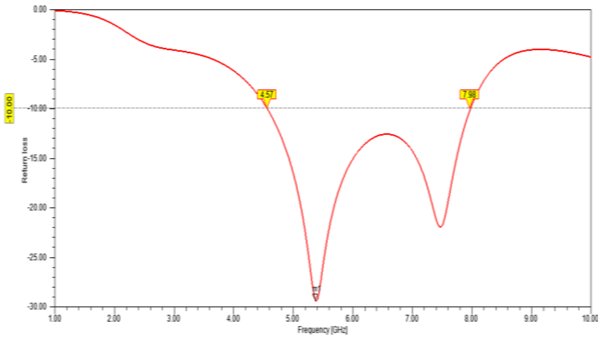


Fig 5: S11 of 2nd iteration

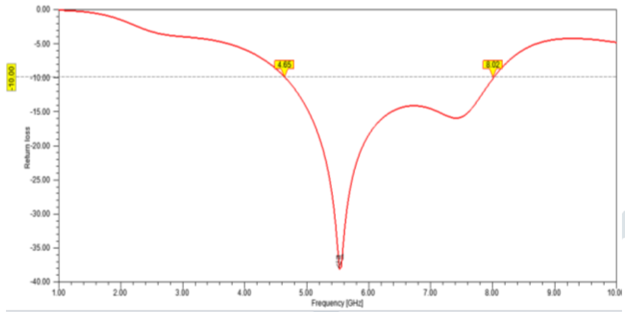


Fig 6: S11 of 3rd iteration

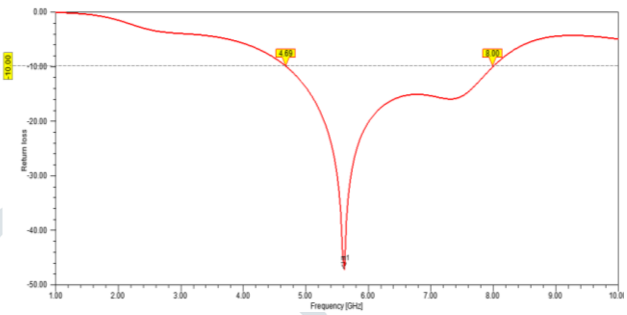
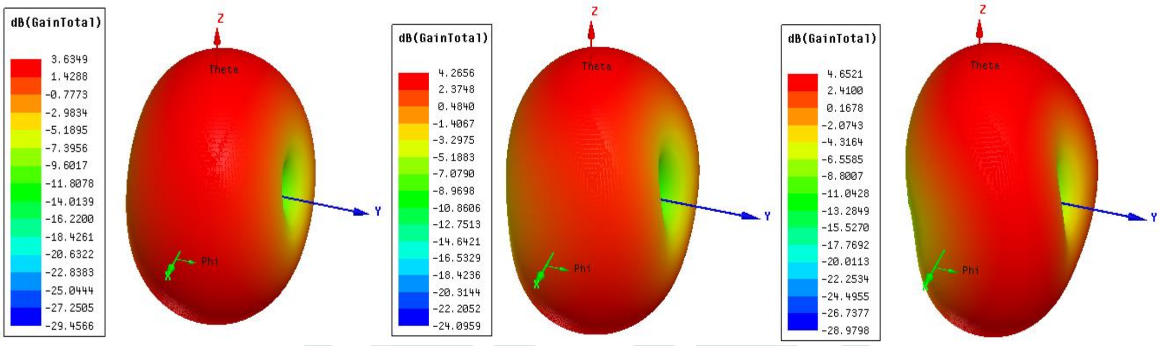


Fig 7: S11 of 4th iteration (proposed design)

b) Far field characteristics of simulated antenna

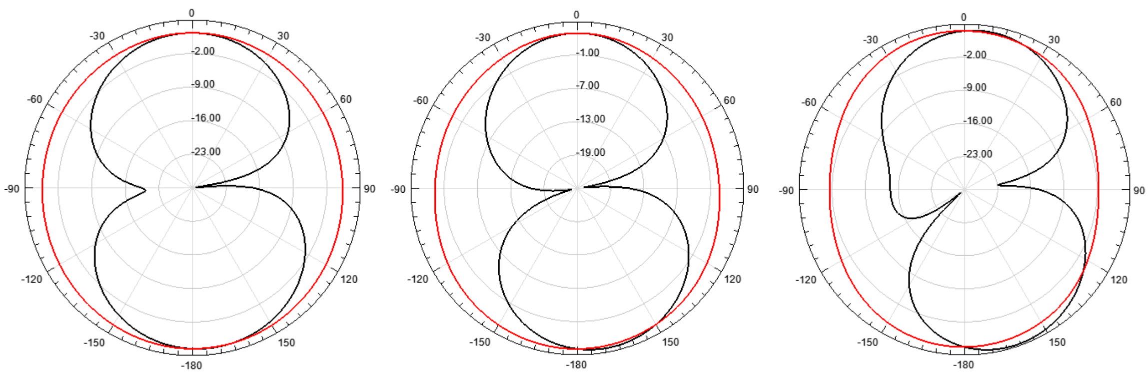
Far fields nothing the behavior of proposed antenna with respect to elevation and azimuth angles. Figure 8 shows the 3D polar plots of the proposed antenna at three different frequencies in the operating band. From the observations of figures, the polar plot pattern maintains similar characteristics at the different frequencies in the operating band.



(a) 5.62GHz (b) 6.4GHz (c) 7.5GHz

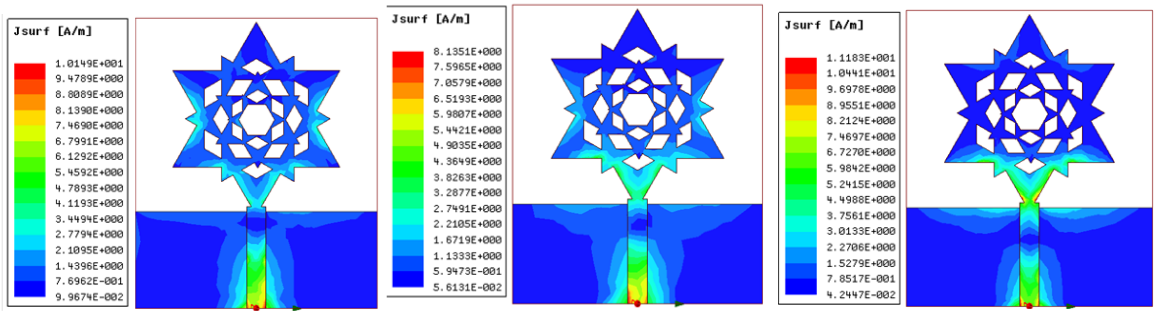
Fig 8: 3D Gain polar plot of proposed antenna at different frequencies

Radiation pattern is nothing the graphical representation of the electric field strength of EM waves from or to an antenna. The 2D representations of far fields are shown in figure 9. The elevation and azimuth planes for Φ=0o & Φ=90o at different frequencies are shown in this figure. The magnitude current distributions of the proposed antenna are shown in figure 10. Figure 11 shows the axial ratio characteristics for understanding the behavior of polarization. Axial ratio of the proposed antenna is less than 3 (i.e., AR < 3) then this antenna obeys the circularly polarized characteristics.



(a) 5.62GHz (b) 6.4GHz (c) 7.5GHz

Fig 9: 2D radiation pattern of proposed antenna at different frequencies



(a) 5.62GHz (b) 6.4GHz (c) 7.5GHz

Fig 10: Magnitude surface current distributions of proposed antenna at different frequencies

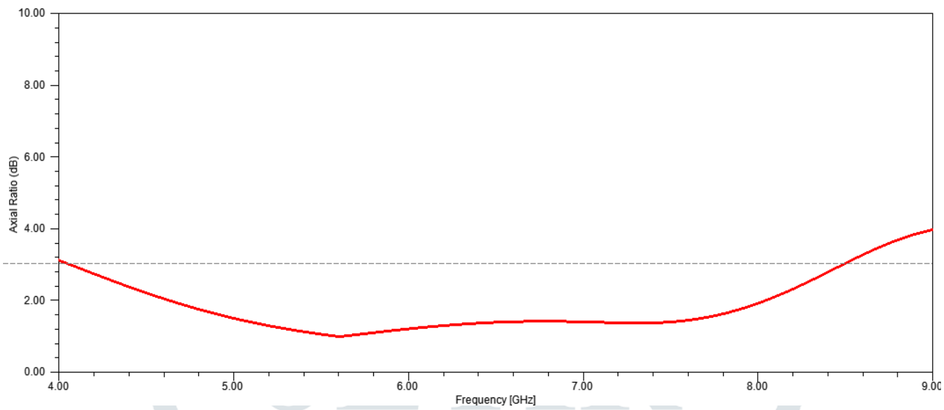


Fig 11: Axial ratio vs frequency

IV. Design summary of simulated antennas

All the simulated parameters like reflection coefficient (S11), impedance bandwidth, resonant frequency (fr in GHz), VSWR and its maximum gain values of all the simulated antennas are presented in table 2. The computed parameters at the simulating frequency of proposed antennas are mentioned in table 3.

Table 2: Simulated parameters of designed antenna

Parameter	0th iteration	1st iteration	2nd iteration	3rd iteration	4th iteration
S11	-11.52dB	-16.46dB	-28.41dB	-38.04dB	-47.19dB
		-18.42dB			
fr	5.47GHz	5.08GHz	5.38GHz	5.53GHz	5.62GHz
		7.21GHz			
Impedance Bandwidth	1680MHz	1570MHz	3410MHz	3370MHz	3310MHz
		910MHz			
VSWR	1.77	1.35	1.07	1.02	1.01
		1.27			
Max. Gain	3.87dB	3.60dB	3.6dB	3.63dB	3.63dB
		5.21dB			
Radiation pattern	Omnidirectional	Omnidirectional	Omnidirectional	Omnidirectional	Omnidirectional

Table 3: Computed parameters of designed antennas

Computing parameter	0th iteration	1st iteration		2nd iteration	3rd iteration	4th iteration
Max U	1.8189mW/sr	1.754 mW/sr	2.4769 mW/sr	1.8496mw/Sr	1.8348mw/Sr	1.837mw/Sr
Peak directivity	2.374dB	2.2388dB	3.159dB	2.2309dB	2.2492dB	2.251dB
Peak Gain	2.4421dB	2.2948dB	3.324dB	2.2909dB	2.3076dB	2.309dB
Peak Realized Gain	2.2858dB	2.204dB	3.112dB	2.2867dB	2.3071dB	2.308dB
Radiated power	9.6283mW	9.846mW	9.851mW	10.25mw	10.257mw	10.257mw
Accepted power	9.3601mW	9.606mW	9.362mW	9.981mw	9.998mw	9.998mw
Incident power	10mW	10mW	10mW	10mw	10mw	10mw
Rad Efficiency	1.0287	1.025	1.052	1.0259	1.0259	1.0259
FBR	-N/A-	-N/A-	-N/A-	-N/A-	-N/A-	-N/A-
Decay Factor	0	0	0	0	0	0

IV. Conclusion

In this paper, a wideband circularly polarized antenna is proposed for the recent wireless applications like handheld devices, wireless data transfer units and long distance communication applications. The compact size of this structure is 0.42λo x 0.35λo (where λo is the wavelength in free space). Due to the self-similar structures, impedance bandwidth increased to 3310MHz. By inserting the polygon shape slots in this structure, antenna achieves the maximum impedance matching property. The additional feature of this antenna is it obeys the circularly polarized principle so it could be useful for global navigation satellite systems (GNSS).

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