A Log-Periodic Structure Based Quasi-Yagi Antenna for Multiband Wireless Applications

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Abstract. This communication presents a log periodic structure based quasi Yagi antenna which is suitable for state of the art multi-bands wireless applications. The antenna investigated here is fed through a coaxial feed. A balance to unbalance transfer (BALUN) has been used for impedance matching. The designed antenna exhibits five resonant frequency bands with frequencies centered at 1.795 GHz, 2.54 GHz, 3.835 GHz, 5.1 GHz and 7.11 GHz. A very good FBR (front/back) values have been obtained with respect to five operational frequencies which are 20.30 dB, 13.83 dB, 10.22 dB, 14.59 dB and 14 dB respectively. Similarly, the proposed antenna offers gain values of 5.61 dB, 4.91 dB, 4.48 dB, 3.25 dB, and 2.44 dB. Further, it offers an impedance bandwidth of 8.35%, 36.2%, 2.0%, 20.2% and 7.59%, respectively. The proposed antenna caters the demands of 5G (lower band) and multi-bands wireless applications.

Keywords: Microstrip Yagi antenna · 5G · Dual band · Triple band · Multi-bands antenna

1 Introduction

Conventional LPDAs (log periodic antennas) and Yagi-Uda antennas pose size and mobility constraints and hence are not suitable for mobile wireless applications. For such applications microstrip based quasi-Yagi antennas are preferred choices as these pose a small in size, high gain, and pattern diversity with a broad range of operational frequencies [1–8]. Further, quasi-Yagi antenna is the best candidate especially for applications like missiles and aircraft that demand for highly directional radiation patterns [9–20]. It is well known that printed quasi Yagi antenna unites the applications and advantages of the patch antennas and Yagi-Uda antennas, which enables in expanding their applications in contemporary wireless applications [11]. However, the main drawback of printed Yagi-Uda antenna is its narrow bandwidth and poor gain performance. Hence many researches have focused to address this issue to enhance the performance of antenna's input characteristics.

It is well known that a Yagi antenna in its conventional form consists of an active element known as driven element placed at the center, and a passive reflector with slightly large in dimensions compared to the active element on its left side. Similarly, one or more passive director elements on the right side of active element. The director attributes

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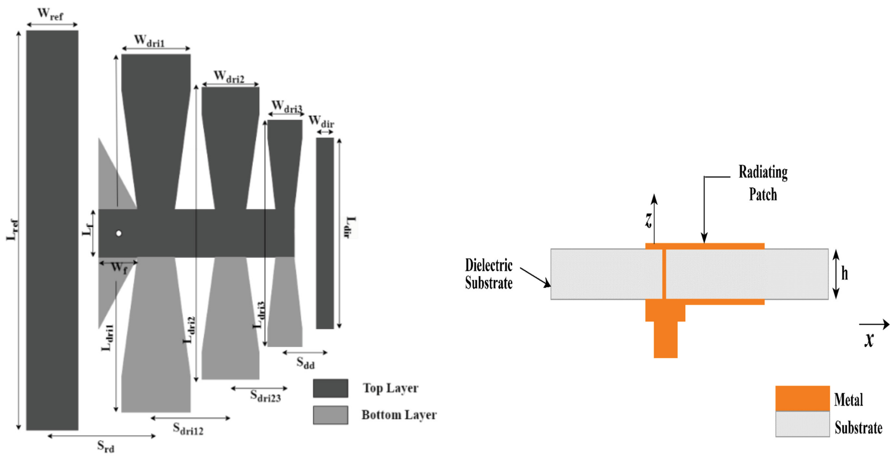
to enhance the Yagi antenna's gain and reflector is responsible for the unidirectional patterns which in turn increases the gain. The third one which is a driven element acts a main radiator. In addition to this, a BALUN element is used to match the impedance of feed-line with folded dipole [5]. This group has already reported a survey paper on number of microstrip-Yagi antennas with variety of feeding techniques, different types of driven element(s) (dipole and/or a monopole), no. of dipoles employed, and different shapes of active or driven elements [5] etc.

In order to design compact wireless devices multi-band antennas are preferred [13–21]. To meet multi-band characteristics, more than one driven elements with stub are used. The antenna proposed in [15] employs two driven elements to excite two resonances that offer an S_{11} bandwidth of 44.0% & 115.0%, respectively. Split-ring resonators [16] are used for the design of dual-band antenna. In this case, the 2nd resonance is tuned by using an additional split ring resonator. It offers a gain of 5.80 dBi and covers the GSM-800 and ISM-2450 bands.

The work presented in [17] is a DRA (dielectric resonator antenna) based microstrip Yagi antenna that uses a magnetic dipole with differential feed for exciting dual modes. In another work reported by [18], two operating frequencies with peak gain are excited by two driven-elements with ground plane truncated. This antenna has operational range between 1.71 GHz & 9 GHz, and 2.5 GHz & 2.7 GHz with peak gains of 6.0 dBi & 7.0 dBi respectively. Antennas with triple band operations are covered in [19, 20]. The geometry with stub is described in [20] that has dual dipole elements to excite triple bands. Whereas, in [21] four bands operational antenna using substrate-integrated waveguide technique (SIW) is presented. A balanced microstrip slot line is used to feed the quasi Yagi antenna with band-pass filter that has a poor cross-polarization and dual band operation [22]. Here, the Yagi antenna is combined with a frequency splitter to have the dual output. This antenna is suitable and enhances the transmission of power and data. Further, in [24] airgap has been used for triple bands operation and [25] has reported four bands Yagi without airgap. Similarly, works reported in [26–38] have addressed various issues including broadband/multiband/tilted beam operation etc. It may be noticed that among these works many have some drawbacks such as having only dual bands or triple bands, and/or a complex design methods.

In general the design of quasi Yagi antenna focuses on improving impedance bandwidth, gain, and FBR parameters. Therefore, the present work focuses on improving these characteristics. The proposed antenna has a reflector followed by three stage driven elements and a director to excite five resonant modes. In the present design, three driven-elements have been appended with stub like structure to excite five resonant modes. The antenna presented here is realized on a Rogers' make RT-5880 laminate which has a dielectric constant value of 2.20 and a tanδ (loss-tangent) of 0.0009. As mentioned earlier it offers five resonances, each with a resonant frequency centered at 1.795 GHz, 2.54 GHz, 3.835 GHz, 5.1 GHz, and 7.11 GHz. This antenna is suitable for state-of-the-art wireless applications including Wi-Fi, Bluetooth, and 5G mobile networks. Proposed microstrip quasi Yagi antenna's basic structure with operation is presented in Sect. 2. Experimental setup and results are discussed in Sect. 3. Comparison of the presented work with existing literature is also presented there. Conclusions of the presented work are drawn in Sect. 4.



(a) Proposed geometry (b) Side view

Fig. 1. Geometry of proposed quasi-Yagi antenna.

2 Proposed Quasi-Yagi Antenna Geometry

Figure 1 illustrates the proposed antenna which is derived from [9, 24, 25] with necessary modifications. Rogers made RT duroid (RT 5880) substrate is used for the design and development of proposed antenna with a dielectric permittivity of 2.2, and a thickness 3.12 mm (two pieces of substrates with 1.56 mm thickness are used to get 3.12 mm). Stubs have been employed on driven elements to excite multi-modes. As shown in Fig. 1(a), top portion of the proposed antenna is fabricated on one side of the substrate and the bottom portion is printed on the other side of the substrate (Fig. 1. (b)). A tapered BALUN is also printed on the back side portion of the antenna as suggested in [24]. The use of BALUN helps in impedance matching by converting unbalanced input into balanced output [11, 24].

Table 1 Lists the optimized parameters (A detailed parametric study was conducted and arrived at the final design) of the antenna which was fabricated and tested. A detailed parametric study was conducted by varying the key design parameters of the proposed antenna such as width and length of driven elements, their stubs, spacing between the elements etc. to investigate their effect on the performance of the antenna.

3 Experimental Validation

The antenna geometry shown in Fig. 1 (a, b) was fabricated and measured for its input parameters. The fabricated antenna's prototype along with its measurement setup is shown in Fig. 2. As mentioned in Sect. 2, the proposed antenna is printed on a Rogers make RT-Duroid 5880 substrate with 3.12mm thickness(clubbed two dielectric substrates of thickness 1.56mm back to back) and dielectric constant (ε_r) of 2.2 with a tan (δ) (loss tangent) value of 0.009. Input impedance parameters are shown in Fig. 3. From

Table 1. The proposed quasi-yagi antenna's physical parameters.

Proposed antenna's dimensional parameters		Dimensions in (mm)
Length of	Reflector: L_{ref}	75.00
	Driven element 1: L_{dri1}	61.50
	Driven element 2: L_{dri2}	50.43
	Driven element 3: L_{dri3}	41.35
	Director: L_{dir}	34.00
Width of	Reflector: W_{ref}	7.00
	Driven element 1: W_{dri1}	15.74
	Driven element 2: W_{dri2}	12.90
	Driven element 3: W_{dri3}	10.59
	Director: W_{dir}	3.16
Spacing between	Driven element 1 & 2 (S_{dri12})	18.43
	Driven element 2 & 3 (S_{dri23})	15.11
	Reflector and driven element 1 (S_{rd})	15.37
	Driven element 3 & the Director (S_{dd})	9.08

this it may be observed that and as mentioned above it offers a total of five resonant frequencies at 1.795 GHz, 2.54 GHz, 3.835 GHz, 5.1 GHz and 7.11 GHz.

The Gain vs. Frequency graph of the proposed antenna is shown in Fig. 4. It is observed that the improvement in gain as compared to [24, 25]. This may be due to improved matching with the feed and changing the shape of the driven elements to conical. Here the maximum gain obtained is 5.61 dBi for the dominant mode and

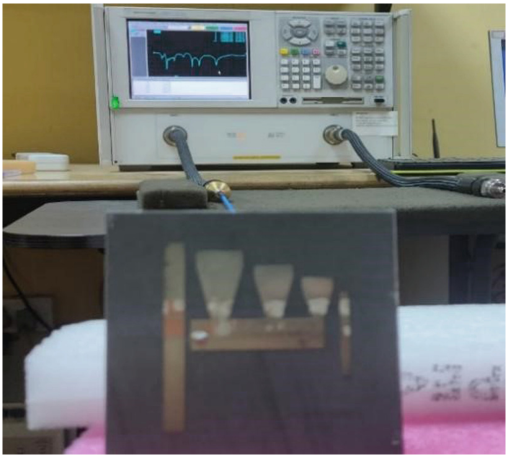


Fig. 2. Measurement setup of proposed antenna.

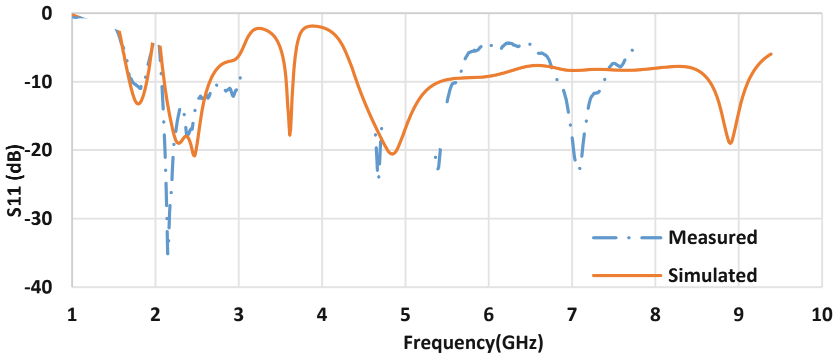


Fig. 3. Comparison of return loss characteristics of the proposed antenna.

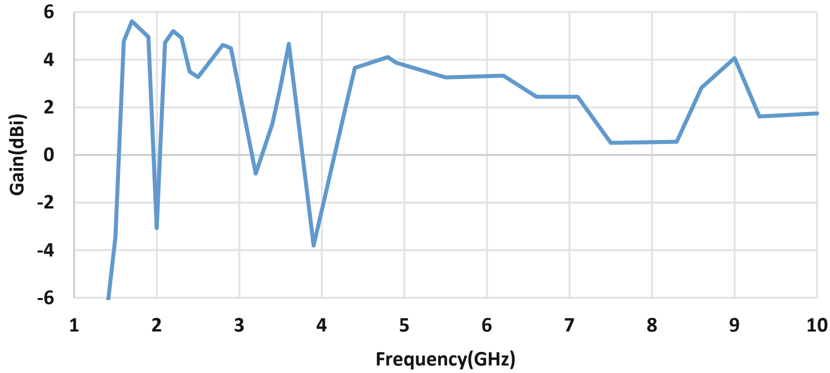
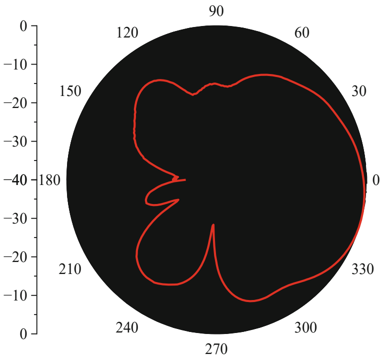


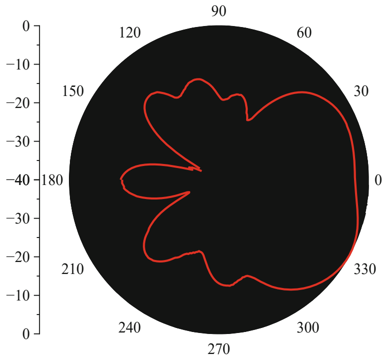
Fig. 4. Gain vs. Frequency characteristics of the proposed antenna.

remaining gain values are 4.91 dB, 4.48 dB, 3.25 dB, and 2.44 dB. Similar to [25], the antenna presented here does not utilize any airgap. Further, an additional driven element is appended to excite the fifth resonant band. The substrate size has been increased to 3.12mm to get multi-band operation as shown in Fig. 3. The radiation patterns of the proposed antenna are plotted in Figs. 5 and 6. at all five resonant frequencies 1.795GHz, 2.54GHz, 3.835GHz, 5.1GHz and 7.11GHz. These patterns show that the corresponding impressive FBR values of 20.30 dB, 13.83 dB, 10.22 dB, 14.59 dB and 14 dB.

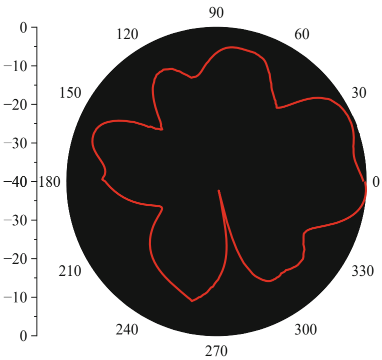
As presented in the Table 2, the presented results are compared with the existing works in the literature. The comparison is w.r.t. geometry size, resonant frequency bands, front/back (FBR) ratio, and the gain of antenna. In comparison with the works reported in [9, 24], the number of resonant bands are nearly similar but the impedance bandwidths of these bands are increased and the peak gain is improved from 3.30 dBi to 5.30 dBi. The whole geometry size also shrinks by eliminating the airgap (as suggested in [24]). The geometry of the antenna presented in this work has a small size of $0.4\lambda_0 \times 0.5\lambda_0 \times 0.0213\lambda_0$. The proposed antenna uses stubs to excite multiple resonances making it desirable for wide range of state of the art wireless applications.



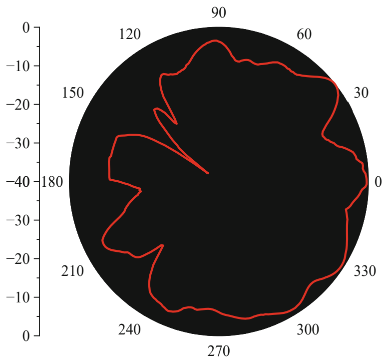
(a) 1.795GHz



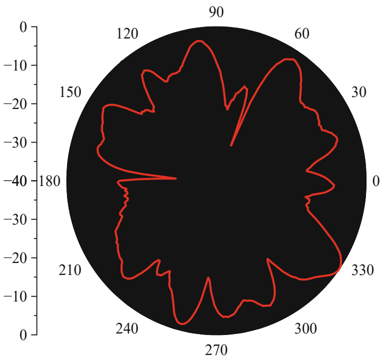
(b) 2.54GHz



(c) 3.835 GHz

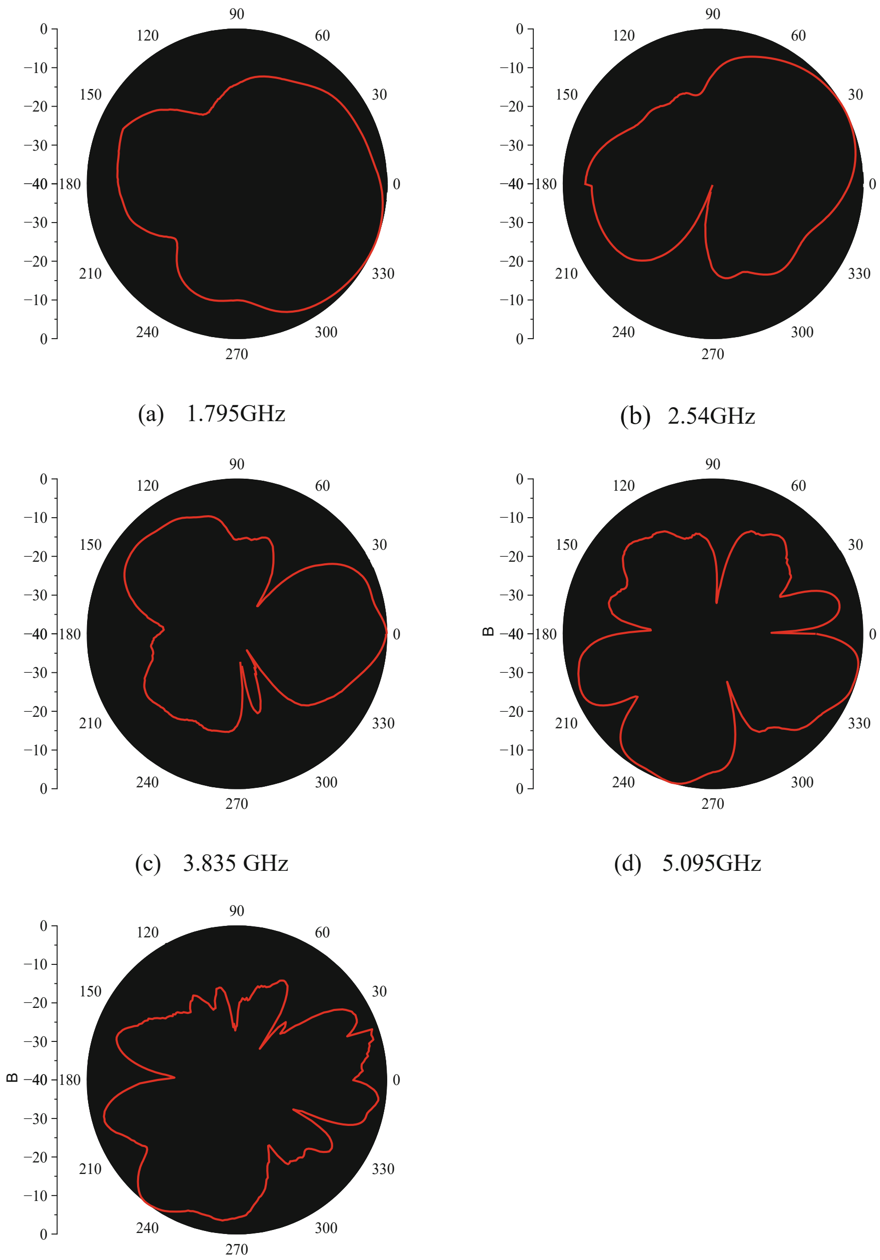


(d) 5.095GHz



(e) 7.11GHz

Fig. 5. Radiation patterns in E plane. (Measured); (---- Simulated).



(a) 1.795GHz

(b) 2.54GHz

(c) 3.835 GHz

(d) 5.095GHz

(e) 7.11GHz

Fig. 6. Radiation patterns in H plane. (Measured); (---- Simulated).

Table 2. Comparison with reported work.

Ref no	Area (λ^2)	No. of bands	Centre-frequency (GHz)	Max. Gain (dBi)	% BW	Front-to back ratio (dB)
[15]	0.058	2	1.10 & 3.70	3.40 & 3.60	44 &115	8.30
[16]	0.286	2	1.80 & 2.50	6.14& 6.80	12.0& 6.0	14 & 15
[17]	0.63	2	9.62 & 11.13	8.0	21.7 & 15.5	--
[18]	0.46	2	1.80 & 2.60	6.0 & 7.70	10.5 & 4.0	22.0& 18.4
[20]	0.12	3	3.90,5.62& 8.27	4.67, 2.83 & 4.19	15.4, 4.60 & 7.90	18, 15, & 9.0
[24]	0.192	4	2.05,2.75,3.8 & 6.5	2.0,1.3,3.10 & 3.30	3.98, 5.48, 19.27	14, 13, 12 & 19
[25]	0.163	4	2.11,5.4,6.55,8.55	5,3.7,2.6, 3.3	42.6,14.8, 7.63, 22.22	10.5,5, 7, 5.5
This Work	0.2	5	1.795,2.54, 3.835,5.1, 7.11	5.61,4.91,4.4,3.25, & 2.44	8.35,36.2, 2.0,20.2, 7.59	20.30,13.83, 10.22,14.59, & 14

4 Conclusions

The antenna designed and developed here exhibits multi-mode & multi-bands characteristics. It offers five resonant working bands with center frequencies at 1.795 GHz, 2.54 GHz, 3.835 GHz, 5.1 and 7.11 GHz respectively. A simple feed is used for antenna realization that may be used for various applications that demand end-fire patterns. The planar antenna concept used in this paper further reduces the size of antenna making it desirable for state of the art wireless applications. The overall size of the antenna is $0.2\lambda^2$. It has good front to back ratio corresponding to five operational bands centered at 1.795 GHz, 2.54 GHz, 3.835 GHz, 5.1 GHz and 7.11 GHz are 20.30 dB, 13.83 dB, 10.22 dB, 14.59 dB and 14 dB respectively. The antenna proposed here is suited for modern wireless application like 5G (lower band) and multi-bands systems.

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