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A Broadband Planar Modified Quasi-Yagi Using Log-Periodic Antenna

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Abstract—In this paper, a broadband planar modified quasi-Yagi antenna using a two-element log-periodic dipole array as a driven element is proposed. To feed the two-element log-periodic dipole array, a simple microstrip to stripline transition as a balun is designed, which converts the unbalanced input to balanced output. The antenna is fabricated on a low cost glass epoxy FR4 substrate with dielectric constant = 4.4, substrate thickness = 1.6 mm, and loss tangent = 0.02. The overall size of the antenna is 84 mm × 111 mm, which is $0.41\lambda_o \times 0.54\lambda_o$ at the center frequency of 1.45 GHz. Measured results show a bandwidth of 41.4% for VSWR ≤ 2. A gain of 6.5 dBi ± 0.5 dB and front to back ratio (F/B) of better than 20 dB are achieved over the bandwidth. Measured results are in good agreement with the simulated ones. This antenna is useful for RFID, portable direction finding, spectrum monitoring systems, etc.

1. INTRODUCTION

A Yagi-Uda antenna consists of a fed dipole element with one reflector and one or more director elements [1]. Initially, cylindrical metallic wires/tubes were used to design Yagi-Uda antennas at VHF/UHF bands, which have heavy weight. These antennas were used to mount on the roof of home and buildings for television reception. There are some applications, such as wireless communication systems, phased arrays, radar systems, RFID reader, and portable direction finding, where the size and weight are the major constraints. A printed technology has advantages of low profile, light weight, compact size, simple fabrication and easy integration with other RF components, which significantly increases its applications in modern wireless communication systems [2]. To achieve these advantages, a microstrip-based planar quasi-Yagi antenna was first introduced in 1998 [3]. The main limitation of a Yagi-Uda antenna is its narrow bandwidth. To improve the bandwidth, different configurations of quasi-Yagi antennas based on different feed structures and dipole element shapes have been proposed [4–23]. It was shown in [24] that while designing a Yagi-Uda antenna, there is a trade-off among three factors viz., bandwidth, gain and front to back ratio (F/B). If one of these factors is improved, the performance of the antenna degrades in terms of the other two parameters. In [25], meandered strip dipoles were used to reduce the size of the antenna, but they degraded the bandwidth and F/B. To achieve larger bandwidth without compromising the antenna performance in terms of other parameters, double dipole technique was developed in [26–29]. In [26–28], a large ground plane was used as a reflector, which limits its applications where compact size antennas are required. In [29], a long microstrip line connecting the dipole elements was designed for feeding the elements, which increased the overall size of the antenna.

A log-periodic antenna has advantages of large bandwidth, and Yagi-Uda has advantages of higher gain. To achieve both advantages of larger bandwidth and higher gain, a log-periodic Yagi-Uda array was proposed in [30], but it was difficult to integrate with other RF components due to its non-planar structure.

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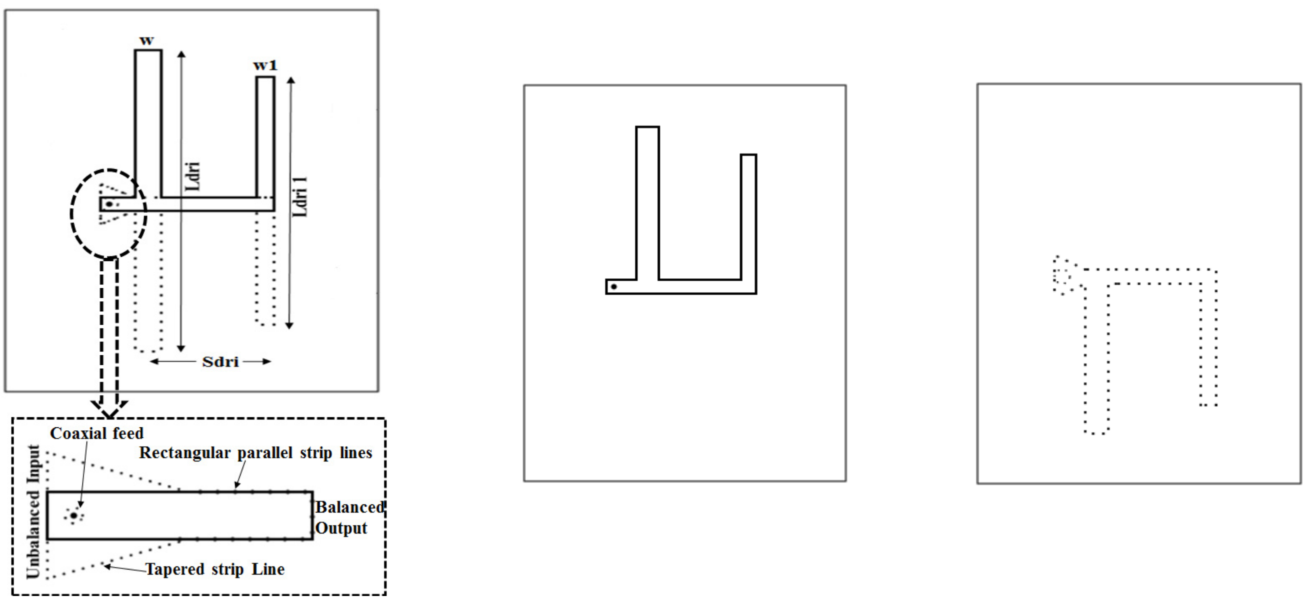
In this paper, a 2-element planar log-periodic dipole array (LPDA) antenna, which acts as a driven element for a quasi-Yagi antenna, is designed and presented to improve the bandwidth of a planar quasi-Yagi antenna without affecting other characteristics of the antenna. To design a compact and simple feed structure, a microstrip to stripline transition as a balun is used to feed the dipole elements of LPDA antenna. Other dimensions related to dipole elements namely spacing and scaling factors are chosen based on the design of LPDA antenna. To design a quasi-Yagi antenna, one reflector and one director are added at an appropriate distance from the driven elements (LPDA antenna), which improves the gain and F/B of the antenna with some improvement in the bandwidth of the antenna.

2. 2-ELEMENTS LPDA ANTENNA

Figure 1 shows a 2-element LPDA antenna designed on a low cost glass epoxy FR4 substrate with dielectric constant (ε_r) = 4.4, thickness (h) = 1.6 mm, and loss tangent ($\tan\delta$) = 0.02. The initial design parameters are calculated from the curves given in [31]. The values of scaling factor (τ) and



(a) (b) (c)

Figure 1. (a) Two elements LPDA antenna along with feed mechanism (Solid lines show metallic strip on the top side of the substrate and dotted lines show metallic strip on the bottom side of the substrate) and its (b) top and (c) bottom views.

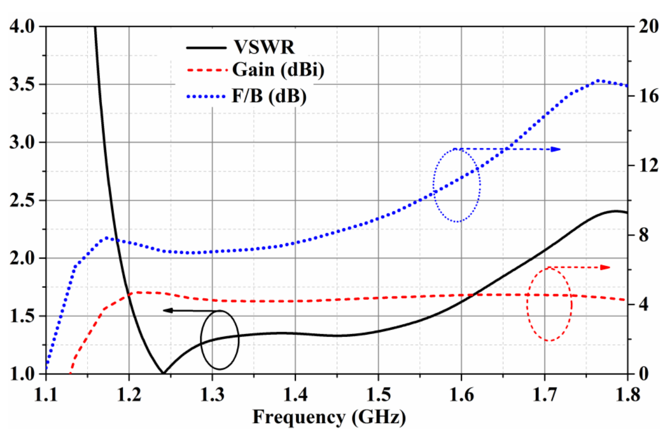


Figure 2. Simulated VSWR, gain and F/B versus frequency of 2-elements LPDA antenna.

spacing factor (σ) are chosen as 0.82 and 0.15, respectively. To feed the LPDA antenna, a simple microstrip to stripline transition is designed as a balun [32, 33].

A metallic tapered line is used on the bottom side of the substrate, and a rectangular microstrip line is designed on the top side of the substrate as shown in Fig. 1. Tapering off a line on the bottom side is done to gradually transform the coaxial cable transmission mode to balanced transmission mode. Thus, an unbalanced input is converted into a balanced output.

The antenna is simulated using CST Microwave studio based on FDTD method. The simulated VSWR, gain and F/B versus frequency plots of the 2-element LPDA antenna are shown in Fig. 2. VSWR is shown on the left side of the vertical axis, and gain and F/B are shown on the right side of the vertical axis. The bandwidth for VSWR ≤ 2 is from 1.19 to 1.69 GHz (34.7%). A gain of 4.5 dBi $\pm$ 0.2 is obtained over the bandwidth. Front to back ratio (F/B) is 7 dB at lower frequencies, which improves at higher frequencies.

3. MODIFIED QUASI-YAGI ANTENNA DESIGN

Figures 3(a) and 3(b) show the geometry of a simple 3-element Yagi-Uda and modified quasi-Yagi antenna using 2-element LPDA, respectively. To feed these antennas, a simple and compact microstrip

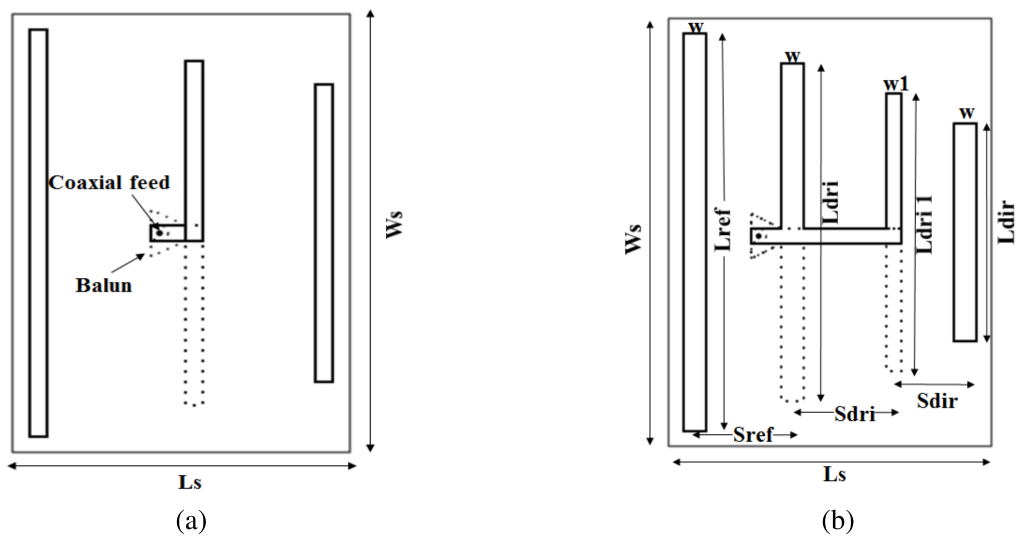


Figure 3. (a) 3-elements Yagi-Uda antenna and (b) modified quasi-Yagi antenna designed using 2-elements LPDA antenna.

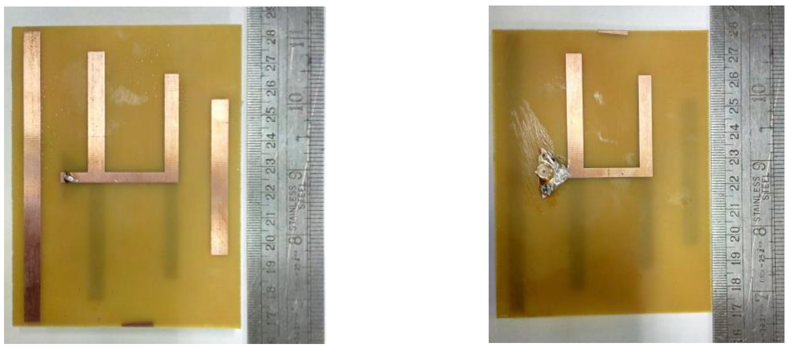
Table 1. Dimensions of modified quasi-Yagi using 2-elements log-periodic antenna.

Parameter	**Dimensions (mm)**
Substrate Length (L_s)	84
Substrate Width (W_s)	111
Dipole width (w)	6
Dipole width ($w_1 = w * \tau$)	4.92
Driven Length (L_{dri})	91
Driven Length ($L_{dri1} = L_{dri} * \tau$)	74.6
Spacing between driven (S_{dri})	27.3
Reflector Length (L_{ref})	106
Reflector Spacing (S_{ref})	23.3
Director Length (L_{dir})	56.2
Spacing Director (S_{dir})	17.4

to stripline transition is used as a balun, which is explained in the previous section. The modified quasi-Yagi antenna consists of one reflector, one director, and one 2-element LPDA antenna, in which the 2-element LPDA antenna is used as a driven element to achieve the advantage of broad bandwidth. To improve the gain and F/B, one reflector and one director are added to the 2-element LPDA antenna. The length and spacing of the reflector and director elements are chosen based on the design of the Yagi-Uda antenna. In this way, advantages of both the antennas, LPDA and Yagi-Uda, are achieved using this configuration. The various parameters of modified quasi-Yagi antenna are given in Table 1.

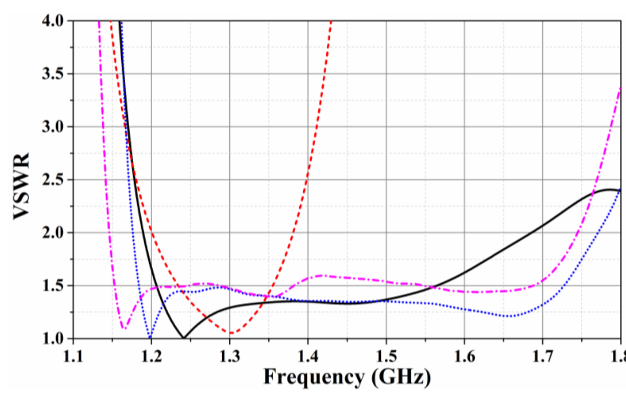
4. SIMULATED AND MEASURED RESULTS

Figure 4 shows photographs of the front and back sides of the fabricated modified quasi-Yagi antenna using a 2-element LPDA as a driven element on a low-cost FR4 substrate. Fig. 5 shows the simulated

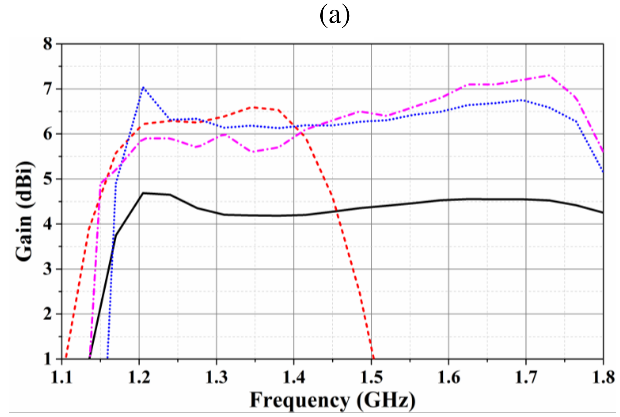


(a) (b)

Figure 4. Photograph of fabricated modified quasi-Yagi antenna using 2-elements LPDA as a driven element, (a) front and (b) backsides.



(a)



(b)

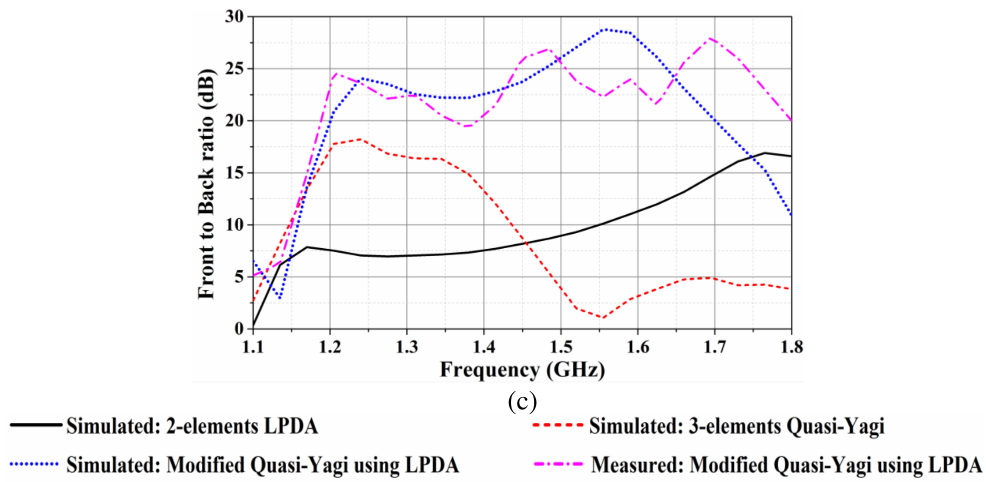


Figure 5. Simulated and measured (a) VSWR, (b) gain and (c) F/B versus frequency plots of modified quasi-Yagi antenna using 2-elements LPDA along with simulated results of 2-elements LPDA and 3-elements Yagi-Uda antenna.

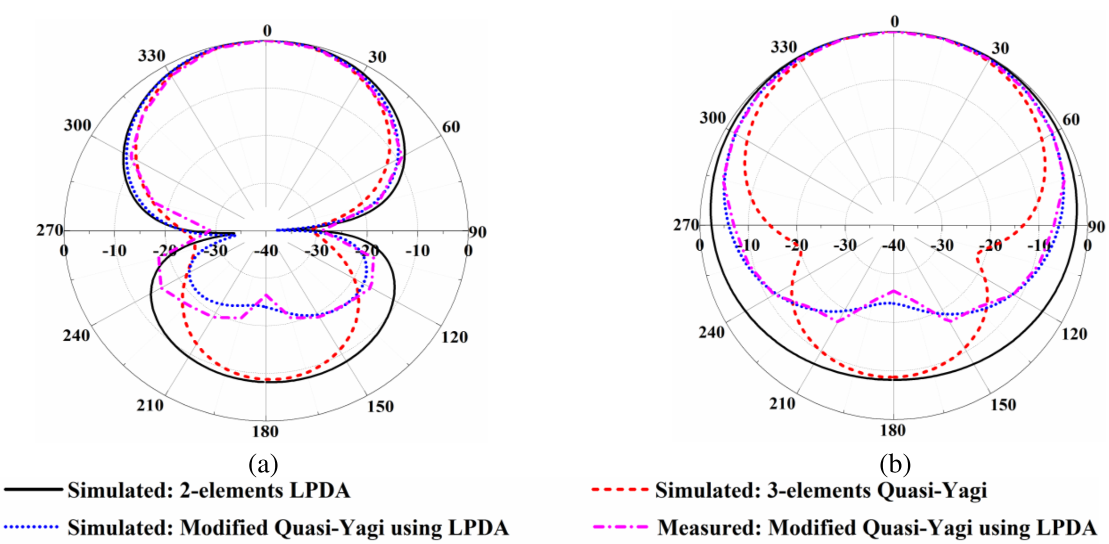


Figure 6. Simulated and measured normalized radiation pattern in (a) E and (b) H-planes at 1.45 GHz of modified quasi-Yagi using 2-elements LPDA along with simulated results of 2-elements LPDA and 3-elements Yagi-Uda antenna.

and measured VSWRs, gains and F/B versus frequency plots of the proposed antenna. Measured bandwidth for VSWR ≤ 2 is from 1.15 to 1.75 GHz (41.4%). A gain of 6.5 dBi $\pm$ 0.5 dB and F/B of better than 20 dB are achieved over the bandwidth. Figs. 6(a) and 6(b) show the simulated and measured normalized radiation patterns in E and H-planes at a frequency of 1.45 GHz. Measured half-power beamwidths (HPBWs) are 68° and 136° in E and H-planes, respectively.

For comparison, simulated results of 2-element LPDA and 3-element Yagi-Uda antennas are included in Figs. 5 and 6. Simulated results of 3-element Yagi-Uda antenna show a bandwidth of 14% as compared to 41.4% for the modified quasi-Yagi antenna. A peak gain of 6.4 dBi is achieved, which is comparable to that of the modified quasi-Yagi antenna. A F/B of 15 dB is obtained as compared to 20 dB for the modified quasi-Yagi antenna. The proposed modified quasi-Yagi antenna using a 2-element LPDA has an improvement of 7% in bandwidth, 2 dB in gain and 13 dB in F/B as compared to corresponding 2-element LPDA antenna results.

Current distribution at various frequencies is shown in Fig. 7. At lower frequencies, longer element of LPDA acts as driven element, and smaller element acts as director. As the frequency increases, longer element acts as a reflector for smaller element, which now acts as driven element as observed from current distribution shown in Fig. 7.

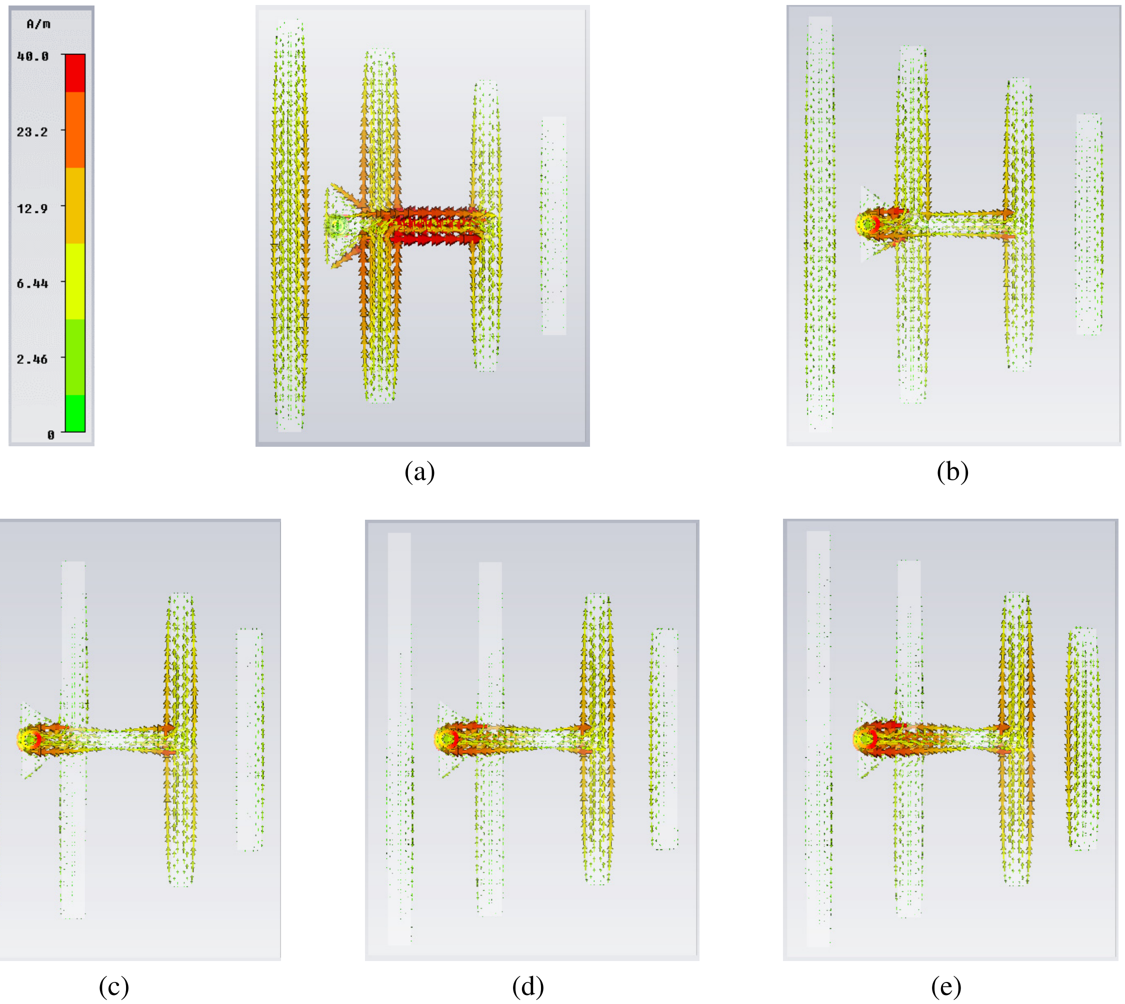


Figure 7. Current distribution at various frequencies (a) 1.15, (b) 1.3, (c) 1.45, (d) 1.6 and (e) 1.75 GHz.

Table 2. Comparison of proposed modified quasi-Yagi using 2-elements LPDA with reported papers.

REF.	Center freq. (GHz)	% Bandwidth (VSWR ≤ 2)	Gain approx. (dBi)	F/B (dB)	Substrate, dielectric constant	Size Ls × Ws (λ_o^2)	Feed structure (balun type) or any other remarks
Proposed Design	1.45	39.1	6-7	20-28	FR4, 4.4	0.41 × 0.54	Simple and compact tapered microstrip to stripline transition structure
[4]	10	48	3.4-5.1	12	Duroid, 10.2	0.5 × 0.5	Microstrip to CPS
[8]	X-band	40	--	15	Duroid, 10.2	2 × 1	Large truncated ground as reflector
[10]	X-band	44	7.4	15	Duroid, 10.2	0.67 × 1	CPW feed
[15]	4.9	37	6.5-8	12	Duroid, 10.2	1.35 × 1	CPS feed
[23]	10	40	2.2-3.2	11	RT6010, 10.2	0.3 × 0.5	CPW feed with curved dipoles
[26]	15	46.7	--	18	RO4350, 3.66	--	Large truncated ground as reflector
[27]	5.8	80	7.4	--	RT6010, 10.2	1.16 × 1.55	Slotline to coplanar stripline
[28]	6.15	53.7	4	17	FR4, 4.4	0.78 × 0.82	Large truncated ground plane
[29]	2.6	78	6.4-7.4	10	FR4, 4.4	0.78 × 1.21	Large connecting coplanar striplines

5. COMPARISON WITH REPORTED WORK

Comparison of the proposed modified quasi-Yagi antenna designed using a 2-element LPDA with some of the reported papers is given in Table 2. Since the center frequency is different for different reported antennas in the literature, comparison is done by normalizing the size of antenna with wavelength. Compared to [4], the gain is improved by almost 2–3 dB with nearly same size. In [8, 10, 15], the size of the antenna is very large with small variations in other characteristics of the antenna. Compared to [23], the gain is higher by almost 4–5 dB with almost similar dimensions and other characteristics. In [26–29], either the size of the ground plane or the length of connecting strip-lines is very large compared to that of the proposed antenna.

6. CONCLUSIONS

A broadband compact planar modified quasi-Yagi antenna using a 2-element LPDA antenna with simple microstrip balun has been designed and fabricated. Measured results are in good agreement with the simulated ones. Measured bandwidth for VSWR ≤ 2 is 41.4% with an average gain of 6.5 dBi. Front to back ratio is better than 20 dB over the bandwidth. The proposed antenna has an improvement of nearly 7% in bandwidth, 2 dB in gain and 13 dB in F/B ratio as compared to a 2-element LPDA antenna. Compared to a 3-element Yagi-Uda antenna, it has an improvement of 27% in bandwidth and 5 dB in F/B with approximately similar gain. This antenna can be used in applications such as RFID, portable direction finding, and spectrum monitoring systems, where large bandwidth, compact size, good F/B with moderate gain are the primary requirements.

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