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Gain and Bandwidth Enhanced Planar Printed Quasi-Yagi Antenna

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ABSTRACT: A Gain and bandwidth enhanced compact planar printed quasi-Yagi antenna is presented. The antenna consists of a driver dipole, three parasitic strips as directors and a microstrip line to slotline transition structure. The driver dipole connected with slotline using coplanar stripline (CPS).The conventional directors in one row is divided in to two and arranged symmetrically and arms of the driver dipole and directors are rotated in certain angle to improve gain. Simulated and experimental results show that the proposed planar printed quasi-Yagi antenna has an ultra wide bandwidth and good unidirectional radiation characteristics. Its operational bandwidth (VSWR<2) is from 3.4–12.7 GHz and a moderate gain, which is better than 5 dB is obtained.

KEYWORDS: Planar printed Quasi-Yagi antenna; Gain enhancement; Bandwidth enhancement.

I. INTRODUCTION

With the fast development of wireless communication systems, the requirement for wideband and low profile antennas with good electrical characteristics is steadily increasing [1], [2]. More and more multiple high speed wireless applications are integrated to small terminals day by day, which also increase the demand for compact wide band antennas provide stable radiation pattern throughout the wide bandwidth [3]. In some cases, for example, high-speed point-to-point data communication systems and wireless local networks, antennas with low profile, stable unidirectional radiation patterns, small size and high gain are urgently needed.

Since the microstrip-fed quasi-Yagi antenna was first introduced by Huang in 1991 [4], various quasi-Yagi antennas have been designed and the planar printed quasi-Yagi antenna has attracted much attention for using in microwave and millimeter wave application because of the advantages such as low profile, light weight, ease of fabrication and installation, high directivity, high radiation efficiency etc. The conventional quasi-Yagi antenna has inherent narrow band property and low gain when compared with the gain owing by the Yagi-Uda antenna.

To enhance the bandwidth of the quasi-Yagi antenna, many techniques have developed in [5]-[13]. The simplest technique of bandwidth enhancement is to increase the distance between the ground plane and radiator [5]. But it will increase substrate thickness. From the literature it is clear that the main limiting factor of bandwidth of quasi-Yagi antenna is its feed. So many attempts are reported [6]-[13] in which the feed structure and feeding method is modified. A printed quasi-Yagi antenna with microstrip-to-slotline transition structure [6] was presented. By using this, a fractional bandwidth of approximately 46% was achieved. But the antenna has a large ground plane, which increases the overall antenna size. A broadband microstrip-to-coplanar stripline transition structures (CPS) is used to enhance the impedance bandwidth of the quasi-Yagi antenna in [7] and [8]. Approximately 38.3% and 48% bandwidth were achieved respectively. However the delay line used in the balun structures still restrict the antennas bandwidth. Ultra wideband balun or coplanar waveguide feeding were presented to enhance the bandwidth in some papers [9], [10]. A wide bandwidth of 44% was obtained in [10]. However, the unidirectional radiation patterns are affected by the asymmetric nature of the quasi-Yagi antenna. Some other feeding techniques are also used to enhance bandwidth, like CPS feeding [11] and slot feeding structure [12]. The maximum fractional bandwidth achieved by these techniques is about 55%. A recently developed quasi-Yagi antenna with microstripline to slot line transition structure and modifications in ground plane achieves an approximate fractional bandwidth of 100% and a size reduction of around 16% [13].

The gain of the quasi-Yagi antenna is also an important parameter. The gain of the antenna can be increased by adding more director element, but it will reduce the bandwidth. Many gain enhancement techniques are described in literature. The gain of the antenna is significantly improved by rotating the driver and parasitic strips in [14]. But due to the grating lob occur at high frequencies, only moderate gain is achieved in high frequencies. In [15], different strip widths and spacing between the elements are used to enhance the gain and bandwidth. A vertically stacked structure is used in [16], in which the patches slit with slots act as the parasitic and driving elements instead of dipoles. This method also improves gain but the antenna volume is also increased. It is clear that the method, in which each director is divided into two and arrange symmetrically on both sides of the dielectric substrate is also increases the gain [17]. Another method is by using zero index metamaterials [18]. By using this method the antenna gain increases for a frequency range over the metamaterial shows the zero index metamaterial property.

In this paper, a planar printed quasi-Yagi antenna is presented. The antenna consists of a driver dipole, three parasitic strips as directors and a microstrip line to slotline transition structure. The driver dipole is connected with the slotline using coplanar stripline (CPS). The overall size of the antenna is reduced by adding two stubs on the ground [13].The conventional directors in one row is divided in to two and arranged symmetrically and arms of the driver dipole and directors are rotated in certain angle to improve gain [14].

The remainder of this paper is organized as follows. Section II discusses design and geometry of proposed PIFA planar printed quasi-Yagi antenna. The simulated and measured results are presented in Section III. Finally, section IV presents our conclusions.

II. ANTENNA DESIGN AND CONFIGURATION

A three-dimensional EM-simulator based on the Finite Element Method (FEM) is used to design and optimize the proposed antenna. We select a geometry almost similar to the geometry in [13].The geometry of the proposed planar antenna is shown in Fig. 1. The antenna is printed on a low-cost FR4 glass epoxy substrate with a thickness of 0.8mm, a dielectric constant of 4.4 and a loss tangent of 0.02. The size of the substrate is 34mm × 34mm ($W \times L$). The proposed antenna consists of a microstrip-to-slotline transition structure, a gradient driver dipole and three parasitic strips as directors. The driver dipole and ground (reflector) are printed on the bottom layer of the substrate and the microstrip feeding line and parasitic strips are printed on the top layer of the substrate. The driver dipole is directly connected to the slotline with a CPS. According to principle of the Yagi antenna, the arm lengths ($L1$, $L2$, $L3$) of driver dipole and directors are approximately equal to $0.25\lambda g$ (λg is the operating wavelength in the substrate) at 4 GHz, 7 GHz and 9 GHz respectively.

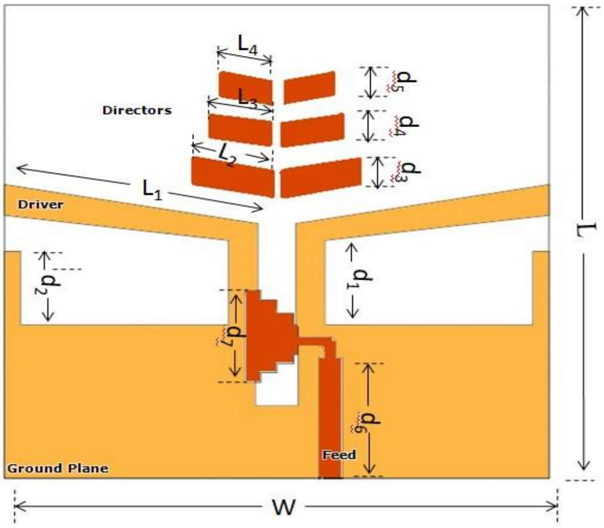


Fig. 1. Structure of the proposed antenna

The length of the driver dipole, directors, length of the stub extended from the ground, the distance between the stripline of coplanar strip line, distance between the directors and the angle or rotation of driver dipoles directors are optimized to get maximum bandwidth and gain. The final dimensions of the proposed antenna after optimization are shown in the table 1 below and the photographs of the fabricated antenna is shown in the fig. 2.

Table 1: Dimensions of the proposed antenna

Parameter	Value(mm)	Parameter	Value(mm)
L	34	d_2	5.3
W	34	d_3	1.9
L_1	16	d_4	1.6
L_2	5	d_s	1.6
L_3	3.9	d_6	8.7
L_4	3.2	d_7	6.6
d_1	6.1	d_f	1.5

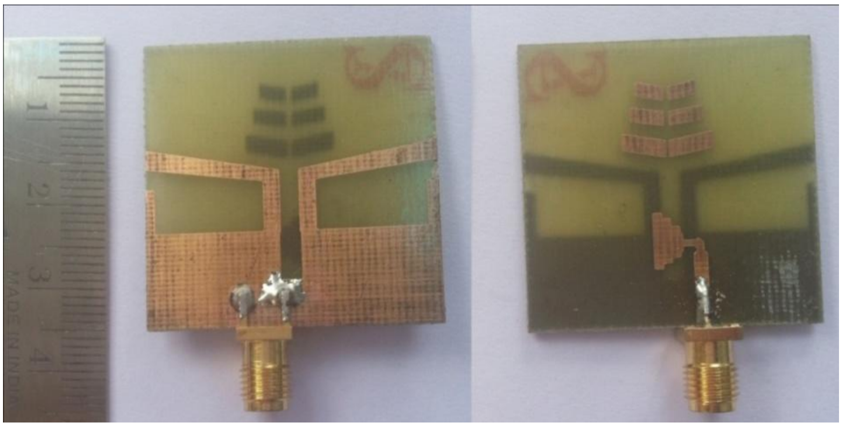


Fig. 2. Photographs of the Fabricated Quasi Yagi antenna

III. SIMULATION RESULTS

The designed antenna is simulated using a Finite Element Method based electromagnetic simulator and after optimization for maximum bandwidth and gain, the antenna is fabricated using normal low cost PCB etching process and measurement is obtained by using vector network analyzer (Agilent pna n5234a).

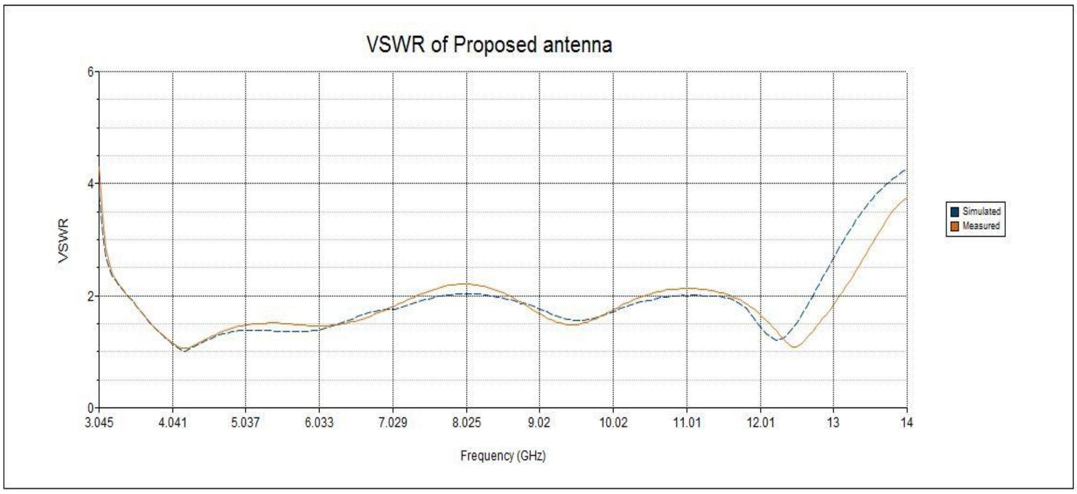


Fig.3. Measured and simulated VSWR of the fabricated prototype

Fig. 3 depicts the measured and simulated reflection coefficients of the proposed quasi-Yagi antenna. As shown in the figure, the measured and simulated results match well. The simulated impedance bandwidth defined by VSWR<2 is from 3.4 to 12.7 GHz and the measured impedance bandwidth defined by VSWR<2 is from 3.4 to 13.1 GHz. The operating bandwidth is wider than that of the antennas in [13] and [14]. The difference between the simulated and the measured results is due to the effect of the SMA connector and fabrication imperfections.

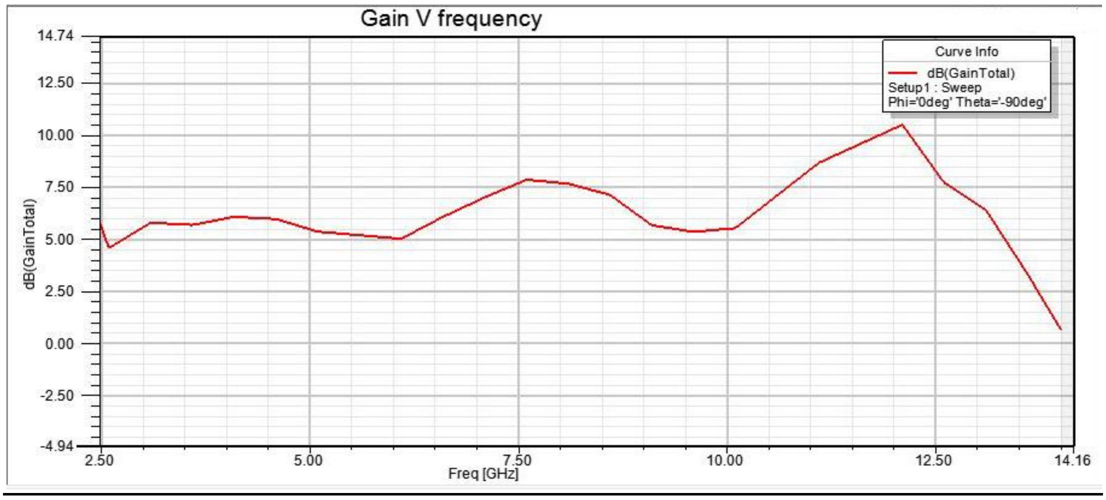
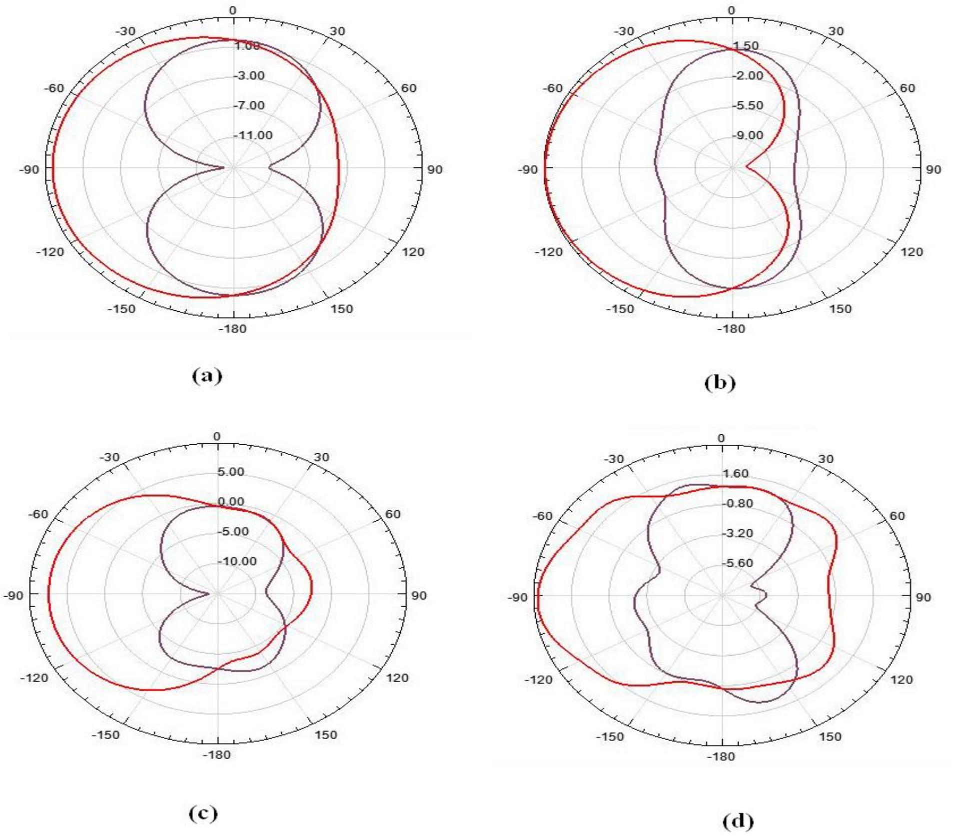


Fig. 4. Simulated Gain of the proposed Quasi Yagi antenna

The realized gain variation with frequency of the antenna is shown in Fig. 4. Within the operating frequency ranging from 3.4 to 13 GHz, the simulated gain varies between 5 and 10 dBi, which is considered as good gain with wide bandwidth.

In order to demonstrate the radiation characteristics of the quasi-Yagi antenna, its radiation patterns are measured. The simulated radiation patterns in E-plane and H–plane at 4, 6, 8, and 10 GHz are depicted in Fig. 5. It is observed from the plots that, the main lobe of the radiation pattern is fixed to the endfire direction in the effective bandwidth. Stable radiation patterns are also obtained.



(a) (b) (c) (d)

Fig. 5. Simulated Radiation patterns of the proposed Quasi Yagi antenna in both E-plane and H-plane at different frequencies. (a) 4GHz, (b) 6GHz, (c) 8GHz, (d) 10 GHz

In table 2, some of the important characteristics of proposed antenna are compared with some of the best quasi-Yagi antennas in literature in terms of wide band width and gain. From the table, it is clear that the proposed antenna's size is equal to that of the antenna in [14] and slightly greater than antenna in ref [13]. If the fractional bandwidth and obtained gain is considered, our proposed antenna is superior to other two.

Table 2: Comparison of the obtained results with reference antenna

Antenna design	**Overall dimension(mm^3)**	**Frequency band covered** (GHz)	**Fractional Bandwidth** (%)	**Gain**(dB)
Reference [13]	30x34x0.8	3.6 -11.6	105	4.1 - 6.8
Reference [14]	34x34x0.8	3-10.8 except 5-6	100	4.7-8.2
Proposed	34x34x0.8	3.4-12.7	115	5-10

IV. CONCLUSIONS

A compact wide band planar printed quasi-Yagi (QY) antenna is designed and studied it's performance. The proposed antenna consists of a microstrip line to slotline transition structure, a driver dipole element and three parasitic elements. The driver dipole element is connected with the slotline using coplanar stripline (CPS). We divided the conventional directors in to two and arranged symmetrically and directors and driver are rotated certain angle to improve the gain of the antenna. Simulated and experimental results show that the proposed planar printed quasi-Yagi antenna has an ultra wide bandwidth and good unidirectional characteristics. Its operational bandwidth (VSWR<2) is from 3.4–12.7 GHz and a moderate gain, which is better than 5 dB is obtained

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BIOGRAPHY

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