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A Wideband Compact Quasi-Yagi Antenna with U-shaped Slots on The Ground Plane

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Abstract

This paper presents a wideband compact quasi-Yagi antenna for C, X and Ku-Band applications. The proposed antenna structure has a simple feeding mechanism consists of a microstrip line and a transmission line. Half of the driver and director are printed on the opposite side of the substrate to ensure good coupling between the antenna elements and achieve a stable radiation pattern. In addition, the ground plane is also modified with U-shaped slots allowing better impedance matching and enhanced bandwidth performance. The proposed antenna can achieve -10 dB bandwidth of 90% between $5.2-13.7$ GHz and a gain of $3.6-6.5$ dBi across the bandwidth with a compact size of $0.85\lambda_c \times 0.69\lambda_c$ at the center frequency. The antenna is a good candidate for wireless communication systems, phased arrays, and mm-wave imaging systems.

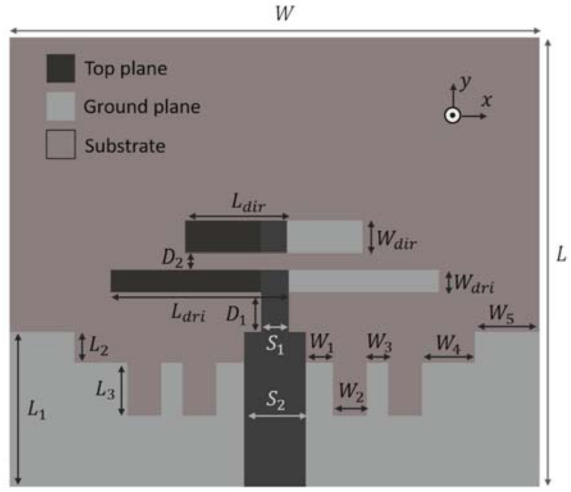

Figure 1. Schematic configuration of the proposed antenna with design parameters (in mm). $W = 27$, $L = 22$, $L_1 = 7$, $L_2 = 1.4$, $L_3 = 2.4$, $W_1 = 1.3$, $W_2 = 1.6$, $W_3 = 1$, $W_4 = 2.5$, $W_5 = 4.1$, $S_1 = 2.9$, $S_2 = 1.3$, $W_{dri} = 1$, $W_{dir} = 1.5$, $L_{dir} = 4.8$, $L_{dri} = 8.4$, $D_1 = 1.8$, $D_2 = 0.8$.

1 Introduction

There is an increasing demand for high-performance antennas due to rapidly developing wireless communications and mm-wave systems. Planar antennas are typically good candidates for these types of applications due to their favorable characteristics such as; ease of fabrication, ease of integration with other circuit components, low cost and weight, wide bandwidth, and stable radiation characteristics. Among many, quasi-Yagi antennas, particularly, have attracted considerable interest in the literature. The conventional quasi-Yagi antenna was first introduced by Qian et al. [1] and further studied by others [2–4]. Despite their decent characteristics, many attempts have been made to further improve their characteristics via modifying the main elements (driver, director, and feeding structure with ground plane) of the quasi- yagi antenna [2–8]. Due to aforementioned characteristics, quasi-Yagi antennas have been extensively studied for applications such as; wireless communication [9–11], mm-wave [12–14], energy harvesting [15].

Quasi-Yagi antennas are naturally broadband antennas consist of three main elements, the director, driver, and reflector along with the feeding structure [1]. Due to their versatile design structure, different approaches have been proposed in order to improve their bandwidth. These approaches include mostly a modification on the main elements of the quasi-Yagi antenna. In addition, the overall bandwidth of the quasi-Yagi antenna is limited with the bandwidth of the feeding structure [1,3]. Thus, in order to achieve wideband characteristic proper feeding mechanism needs to be used. Naturally, most of the work is devoted to improving the feeding mechanism of the quasi-Yagi antenna [16–19]. The feeding structure is also crucial in terms of achieving a stable radiation pattern. Furthermore, the bandwidth can also be increased by means of modifying the driver [20–23] and the addition of director or other parasitic elements [24–26].

In this paper, we present a wideband compact quasi-Yagi antenna with a defected ground structure (DGS). The driver and the director elements of the antenna were realized by printing half of the metal parts at the opposite side of the substrate as shown in Fig. 1 The driver is directly fed by a transmission line connected to a microstrip line. The microstrip and transmission line parameters are optimized to obtain the best results. In addition, by using a simple microstrip line to excite the antenna, the ground plane is modified with symmetric slots on the ground plane, as shown in Fig. 1 in order to further enhance the bandwidth. The proposed antenna has a bandwidth of 90% for -10dB return loss with and gain of 3.6 – 6.5 dBi across the bandwidth. Furthermore, the antenna shows a stable radiation characteristic over the frequency range. The overall size of the antenna is $0.85\lambda_c \times 0.69\lambda_c$ at the center frequency ($f_c = 9.45$ GHz).

2 Antenna Structure

A schematic configuration of the proposed antenna is illustrated in Fig. 1. The proposed antenna is designed on a low-cost FR4 substrate with a dielectric constant of $\varepsilon_r = 4.3$ and a loss tangent of $\text{loss}\delta = 0.023$ and thickness of $h = 1.6$mm. The overall size of the antenna $(W \times L = 27mm \times 22mm)$ which is about $0.85\lambda_c \times 0.69\lambda_c$ where λ_c is the free-space wavelength at center frequency ($f_c = 9.45$GHz). The antenna has a simple feeding mechanism consists of a microstrip line and a transmission line [4], avoiding a complicated balun design [1–3]. With this simplified feeding mechanism, the ground plane is modified with U-shaped slots without significantly distorting the overall antenna performance. In addition, the driver and director elements are printed as half both on the top and bottom plate of the substrate to have a better matching between the antenna elements. Simulations are carried out using CST Microwave Studio software. The details of the optimized parameters are given in the caption of Fig. 1.

2.1 Evolution of the Antenna

Quasi-yagi antennas generally shows wide bandwidth. In this design, the drivers and directors were brought closer to the side of ground plane ending edge in order to obtain a compact and simple structure but the wideband feature was lost. Then, additionally optimized length slots were added to achieve very wide bandwidth again and the antenna reached its final shape. The all modifications is made in the ground plane. Fig. 2 shows the evolution of the ground plane. The first antenna (Fig. 2) is equivalent to the traditional quasi-Yagi antenna, only its elements are minimized while maintaining the main elements to achieve a compact design. This antenna includes the ground plane acts as reflector, the simplified feed structure, the driver and the directors. As shown in the Fig. 3, the bandwidth of this antenna is very low and has a very high operating frequency with respect to the size of the antenna and does not have the desired characteristics. In order to provide the desired bandwidth, firstly, as shown in the second antenna (in Fig. 2), two wide slots with short length are applied on the first antenna. It is observed in Fig. 3 that the slots increase the bandwidth. However, the desired bandwidth could not be reached according to the antenna size. Finally, four long and narrow width slots were opened over the wide slots(in Antenna 2) and the proposed antenna with compact size, very wide bandwidth was obtained as can be seen clearly in the S_{11} graph(Fig. 3).

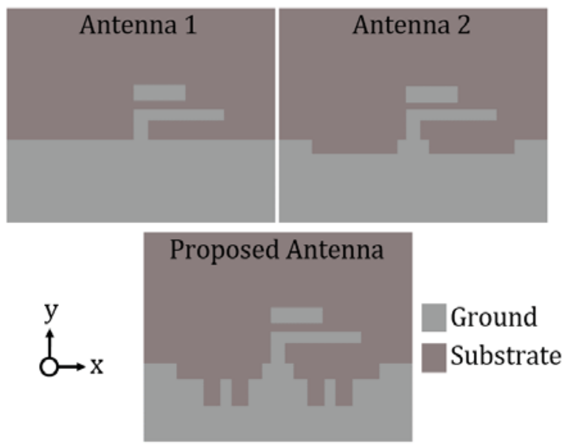

Figure 2. Ground plane evolution of the antennas.

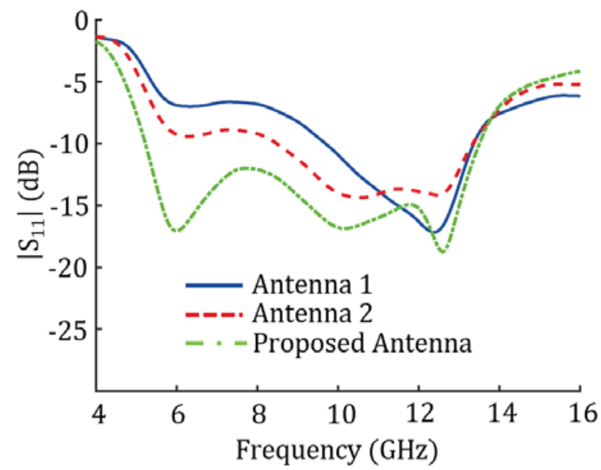

Figure 3. Simulated reflection coefficients (S_{11}) parameters of the antennas.

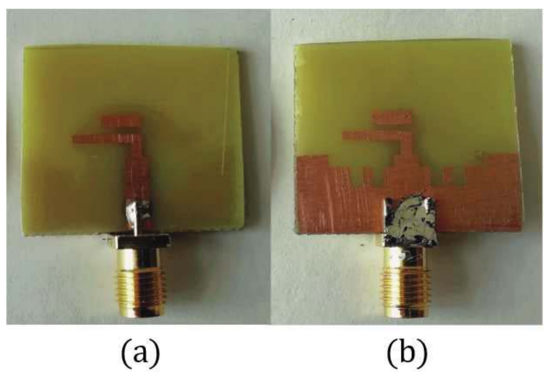

Figure 4. The fabricated antenna. (a) Front view, (b) back view

3 Results and Discussions

The antenna is fabricated and measured to test the simulation results. Fig. 4 demonstrates the manufactured antenna. In the Fig. 5, the simulated and measured S_{11} parameters of the proposed quasi-Yagi antenna can be seen. The antenna has wide impedance bandwidth of 90% between 5.2 and 13.7 GHz ($S_{11} < -10$ dB). The measurement results confirm the simulation results very well. Fig. 6 demonstrates the simulated gain and efficiency values of the antenna. In the the operating bandwidth, it showed a gain of $3.6-6.5$ dBi, 70% and above efficiency.

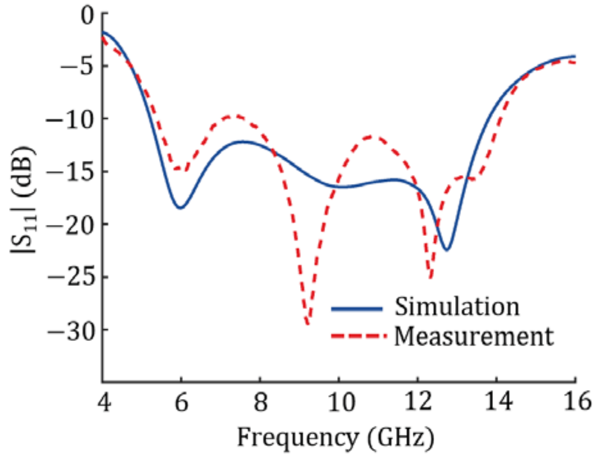

Figure 5. Simulation and measurement of S_{11} results of the proposed antenna

One important characteristic of quasi-Yagi antennas is that they have almost the same radiation pattern inside the operating frequency range. Thus it is also of importance that these characteristics are preserved when any modification is done. Fig. 7 shows the radiation pattern for both E and H plane at $f=6$GHz, $f=9$GHz, and $f=12$GHz, respectively. Note that the proposed antenna has a stable radiation pattern inside the frequency range.

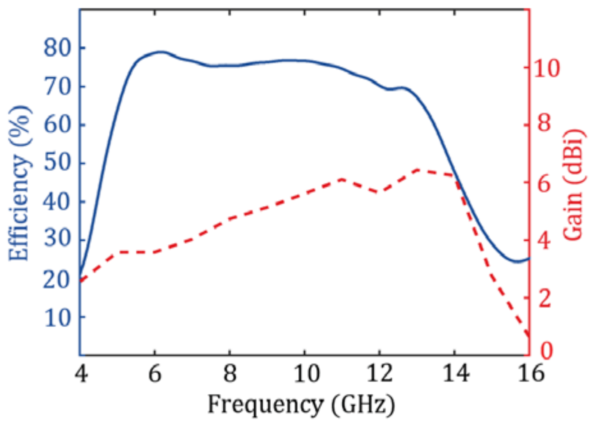

Figure 6. Simulated efficiency and gain values of the antenna

4 Conclusion

A wideband, compact, simple, modified quasi-Yagi antenna is proposed. The antenna is fed through a simple microstrip line and a transmission line. The ground plane is modified using U-shaped slots to improve the impedance matching and the bandwidth of the antenna. A -10 dB bandwidth of %90 and a gain of $3.6-6.5$ dBi is achieved across the frequency range. The radiation patterns show a quite stable performance inside the bandwidth. The proposed antenna can find applications in wireless communications systems, phased arrays, and mm-wave systems.

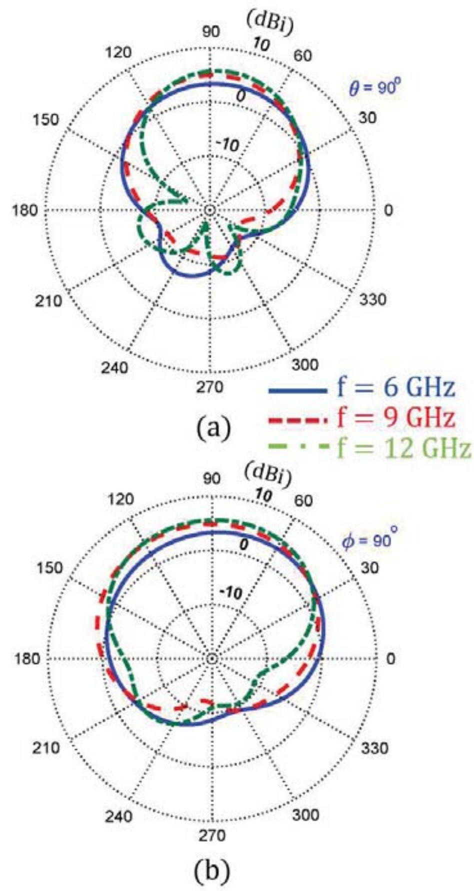

Figure 7. Simulated radiation pattern of the proposed antenna for $f=6,9,12$ GHz. (a)E-plane (b)H-plane

5 Acknowledgements

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