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An Asymmetric Coplanar Strip-Fed Compact Yagi-Uda Antenna Utilizing Ground as Director

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Abstract

This paper presents a novel approach to design a printed monopole driven compact Yagi-Uda antenna, where the printed monopole is fed using asymmetric coplanar strip (ACS) line to significantly reduce the size of the driven element of the Yagi-Uda array compared to the standard coplanar waveguide (CPW)-fed case. Further, the use of ground of the ACS as a director circumvent the need of incorporating a dedicated director element making the Yagi-Uda array even more compact. It is found that an ACS-fed Yagi-Uda antenna having reflector alone and no director provides a front-to-back ratio of only 6 dB, which improves to 15 dB after successfully using the ground as director. The designed antenna, which operates in the 2.4 GHz wireless local area network (WLAN) band with 5.71% bandwidth, has the footprint of only 47 × 24 mm^2.

1. Introduction

Several innovative designs of planar Yagi-Uda antennas are conceived in recent years incorporating different kinds of feeds including viz. microstrip line feed [1], [2], coplanar waveguide (CPW) feed [3], coaxial feed [4], etc. for application in compact mobile handheld devices. The driven element, used in these Yagi-Uda antennas, also vary over a wide range starting from printed dipole [1] to printed monopole [3], printed inverted-F antenna (PIFA) [4], and loop antenna [2]. In many of the published works, the directive pattern of Yagi-Uda antenna is interestingly utilized to design MIMO antenna having low inter-element mutual coupling and envelope-correlation-coefficient (ECC) [2]–[4]. So, there is a constant need of designing a more compact Yagi-Uda antenna, which could be finally used to design a MIMO antenna, compact enough to be incorporated inside modern handheld terminals.

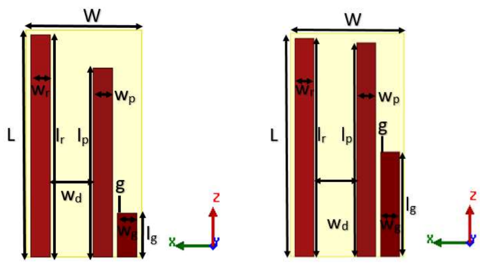
When planar dipole is used as driving element of the Yagi-Uda array, the feeding structure of such dipole requires balun and the presence of balun makes the antenna less compact for modern handheld devices [1]. It is worth noting that driving Yagi-Uda antenna using coax-fed PIFA not only compromises the front-to-back ratio (FBR) because of its relatively higher cross-polar level, but this kind of Yagi-Uda antennas are typically not of enough low profile as well [4]. Recently, a biplanar loop driven miniaturized Yagi-Uda antenna has been introduced [2]. However, even this antenna is not compact enough for mobile handhelds to be operated in the lower end of the sub 6 GHz RF spectrum due to the presence of a 'wide' partial ground plane that works as a reflector. Printed monopole driven, CPW-fed, Yagi-Uda type compact pattern diversity antenna has been introduced in [3]. However, this Yagi-Uda array is not compact enough and one cannot attempt to design a 4x4 pattern diversity MIMO antenna for mobile handhelds using the Yagi configuration, presented in [3].

Asymmetric coplanar strip (ACS) feed itself is a comparatively newer approach adopted in antenna engineering for the purpose of miniaturization [5]–[6] and to the best of the authors' knowledge, this feed has yet not been reported in the literature for designing Yagi-Uda array. In this work, we attempt to miniaturize printed Yagi-Uda antennas by a) feeding the printed monopole antenna, which is the driving element of Yagi array, using ACS feed and b) modifying the ground of the ACS feed in such a way that it work as director. So far, grounds of printed dipole-driven Yagi-Uda antennas are used as reflector [1]. However, to the best of the authors' knowledge, using ground as a director is a novel approach in context of designing planar Yagi-Uda array.

2. Design of ACS-Fed Yagi-Uda Antenna

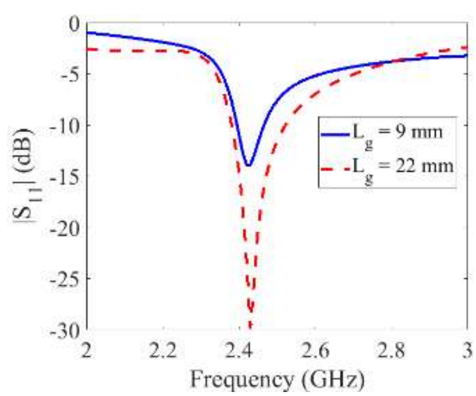
In this work, an ACS-fed printed monopole antenna is used as driven element of Yagi-Uda array. It is worth noting that the footprint area of ACS-fed printed monopole is 50% less than the same of the corresponding CPW-fed printed monopole antenna. This leads to design of highly compact driving element for Yagi-Uda configuration. Fig. 1 (a) shows the initial design of Yagi-Uda antenna, printed on FR-4 substrate having a thickness of 1.6 mm and $\varepsilon r = 4.4$. The footprint of antenna is only 47 × 24 mm^2 (i.e. 0.625 λ_g × 0.319 λ_g calculated at f = 2.43 GHz). The antennas, presented in this paper, have been simulated using the commercial full-wave electromagnetic simulator HFSS 16. The designed antenna is found to provide 10 dB return loss (RL) matching over the frequency range of 2.39–2.46 GHz (see Fig. 2 (a)). It is interesting to note that the antenna remains capacitive over almost its entire band of operation (see Fig. 3) [3]. In this antenna, evidently, there is a reflector, but there is no director in order to keep the antenna compact. Consequently, we attain a very moderate FBR of about 6 dB as shown in Fig. 4.

Next, we propose to use the ACS ground plane as a director in order to improve the FBR of the Yagi-Uda antenna and the length of the ground plane is increased from 9 mm to 22 mm towards this end as shown in Fig. 1 (b). A close observation of antenna input impedance reveals the fact

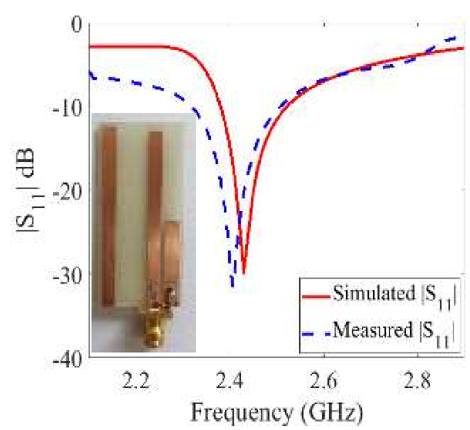


(a) (b)

Figure 1. Proposed antenna with L = 47 mm, W = 24 mm, lr = 46 mm, wg = 4 mm, wp = 4 mm, wr = 4 mm, wd = 9 mm, g = 1 mm. (a) lg = 9 mm and lp = 39 mm (***Initial Design***); (b) lg = 22 mm and lp = 45 mm (***Final Design***).



(a)



(b)

Figure 2. (a) Simulated $|S_{11}|$ of Yagi-Uda antenna with different ground lengths; (b) Comparison of simulated and measured $|S_{11}|$ of the final design.

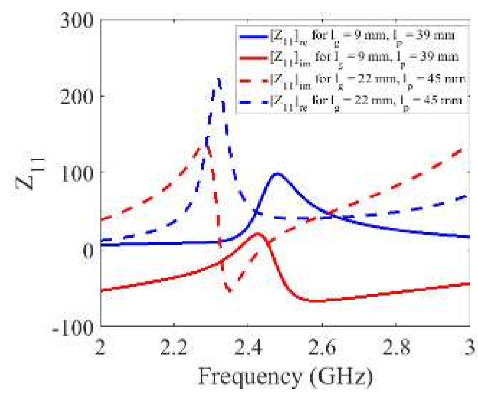


Figure 3. Input impedance of both the ACS-fed Yagi-Uda antennas, i.e. one with longer director and the otherone with shorter director

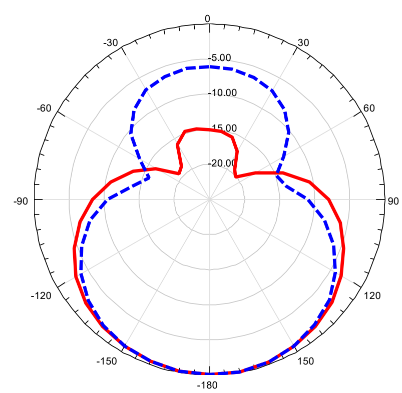


Figure 4. Simulated radiation pattern at f = 2.43 GHz in the XY-plane (Solid line for lg = 22 mm and lp = 45 mm; dashed line for lg = 9 mm and lp = 39 mm).

that the length of monopole has to be increased from 39 mm to 45 mm in order to make the antenna radiate in the 2.4 GHz (wireless local area network) WLAN band. This antenna is found to provide 10 dB RL matching over the frequency range of 2.38–2.52 GHz (see Fig. 2 (a)). The final design of the antenna has been fabricated on low cost FR4 substrate using MITS ELEVEL-Lab PCB prototyping machine. The photograph of the final antenna structure is shown in Fig. 2 (b). The S-parameter is measured using Agilent N5222A PNA Vector Network Analyzer. Fig. 2 (b) shows that the simulated and measured $|S_{11}|$ of the designed antenna are in good agreement. Interestingly, as per Fig. 3, the modified Yagi-Uda antenna is no longer predominantly capacitive as it has a longer ground plane [3]. It is found from Fig. 3 that lengthening of the ACS ground has increased the FBR dramatically from 6 dB to 15 dB. It is worth mentioning that radiation pattern measurement of this antenna is under progress and the corresponding measured result will be furnished in the symposium if this paper gets accepted for presentation.

3. Conclusion

The fact that lengthening of ground is causing significant improvement of FBR leads to the conclusion that the ACS ground of the antenna, shown in Fig. 1 (b), is working as a director of Yagi-Uda passive array. This work may further be extended by designing Yagi-Uda type pattern diversity MIMO antennas for handheld mobile terminals.

4. References

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