An Ultrawideband Dipole With a Director as a Feed for Reflector Antennas

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An Ultra-Wideband Dipole with a Director as a Feed for Reflector Antennas

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***Abstract*—A novel ultra-wideband directional flat dipole capped by a planar director is proposed in this letter. The novelty of the antenna is the great improvement of the bandwidth of a flat dipole above an ordinary finite ground plane by using a simple parasitic top patch, referred to as the "director". A linearly-polarized prototype has been designed and manufactured, and achieved a nearly 3:1 operating bandwidth (2.2-6.5 GHz) with a return loss higher than 10 dB, nearly constant radiation patterns, and high aperture efficiency over the entire operating band.**

***Key words*—Ultra-wideband, Dipole with Director, Feed, Reflector Antennas**

I. INTRODUCTION

ULTRA-WIDEBAND (UWB) technology finds many applications in different areas, such as UWB sensor network, UWB short-range communication systems, UWB radar and imaging systems, and UWB radio astronomy. Therefore, many new UWB antenna technologies have been developed recently. Many of these new UWB antennas have quite complicated structures. The ultra-wideband log-periodic dipole arrays are tilted with an angle relative to the ground plane for Eleven feeds [1]-[2]. The curved radiating arms are connected to the ground plane in the self-grounded bow-tie antenna [3].

It is a challenge to design a low-profile antenna with constant radiation patterns over an ultra-wideband frequency band, which is required for the antenna used as a feed for reflector antennas. A lot of efforts were devoted to this topic. A typical way to lower the profile is to incorporate a special texture on the ground surface [4]-[5], which is possible to alter its electromagnetic properties. By introducing such an artificial high impedance surface (HIS), the ground plane does not support surface waves and the interference between the ground and the radiator is eliminated, so the directional radiation patterns can thus be achieved. Based on this idea, a HIS ground plane was designed in [6]. However, the impedance and radiation bandwidths are limited. A broadband dipole antenna above an electromagnetic bandgap (EBG) ground plane was investigated in [7], where the impedance bandwidth (return loss higher than 10 dB) achieved to 2:1 and the radiation bandwidth was only 1.4:1. Presented in [8] was a novel design of a printed wideband dipole antenna on EBG structures by making use of the complex interactions between the dipole impedance and the EBG reflection phase characteristics, but the bandwidth of the antenna was only 1.47:1 defined by a return loss higher than 7.5 dB. The paper [9] proposed a composite corrugated reflector for an ultra-wideband dipole, where the antenna could operate over 2.75-8.35 GHz with a return loss higher than 10 dB, but the radiation patterns became poor upwards from 5.0 GHz.

In addition, multiple dielectric layers could be used to make a very low-profile stacked dielectric resonator antenna [10], but the return-loss-higher-than-10dB bandwidth was 1.5:1. Moreover, Yagi antennas are widely used to achieve high gain and directional radiation patterns with a very simple structure. Lots of recent researches have been carried out on the printed quasi-Yagi antennas, which consists of three basic elements: a driver, a reflector and a director. The bandwidth was enhanced by using different microstrip feeding mechanisms [11]-[13], resulting in the achieved relative bandwidth about 2.1:1, 2.2:1 and 2.7:1, respectively.

A novel low-cost UWB antenna with nearly constant directional radiation patterns is proposed in this letter. The contribution (the novelty) of this work is the introduction of a parasitic metal patch above a wideband planar dipole, where the parasitic patch is referred to as the director. Capped by the simple patch, the flat dipole in close proximity to an ordinary finite ground plane rather than complex artificial surfaces or stacked dielectric layers achieved a 3:1 bandwidth (2.2-6.5 GHz) for both impedance matching and radiation characteristics.

II. ULTRA-WIDEBAND CAPPED DIPOLE

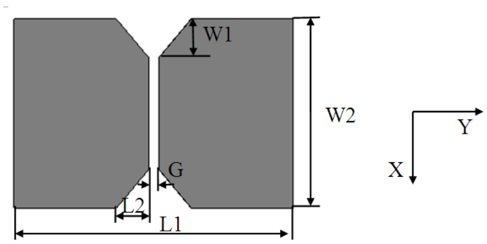

Fig.1 Geometry of the source dipole.

The geometry of the source planar dipole (placed along y-axis) is depicted in Fig. 1. Similar to that in [14], it is wideband standalone (50Ω reference) as an omnidirectional antenna in H-plane. However, the impedance matching becomes worse if a planar reflector (ground plane) is in the proximity to make the radiation directional. According to the parameter H2 sweep curves shown in Fig. 2, the upper end of the bandwidth is limited to about 5 GHz; and the bandwidth becomes slightly

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wider as the height H2 increases, at the cost of a shift downwards in frequency in the meanwhile.

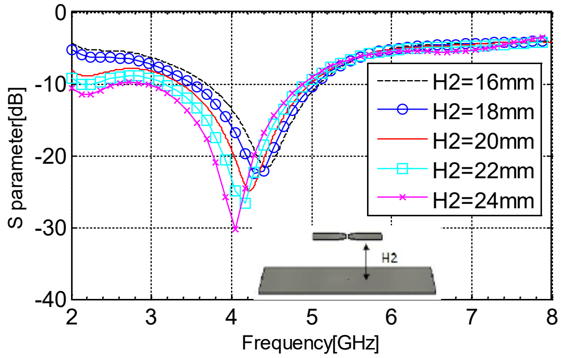


Fig. 2 S_{11} sweep by H2 for a dipole without the parasitic patch

Inspired by the stacked patch antenna where a parasitic patch was used for broadening the bandwidth, a parasitic element referred to as the director, is introduced above the arms of the planar dipole, which looks like a cap onto the dipole (Fig. 3 shows the director and the antenna structure). It is found that the bandwidth of the abovementioned same dipole antenna (with ground reflector) can be greatly enhanced by just adding a simple director overhead.

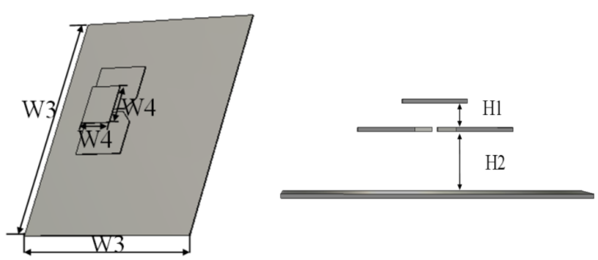


Fig.3 The proposed antenna geometry: 3D view (left), Side view (right).

The proposed antenna is modeled and optimized by *CST MWS*. The source dipole, the director and the ground plane are made of copper plates with thickness of 0.5 mm. The parametric studies of critical parameters of the director, the height H1 and the side length W4, are given in Figs. 4-7, respectively. It is indicated in Figs. 4 and 5 that the director can greatly enhance the impedance bandwidth when proper dimensions of H1 and W4 are chosen. In the meanwhile, it can be observed from Figs. 6 and 7 that the aperture efficiencies (defined in [15]-[16], when the proposed capped dipole feeds a paraboloidal reflector with a half subtended angle of 60°) become much more sensitive to the size of the director (W4) than to the height (H1).

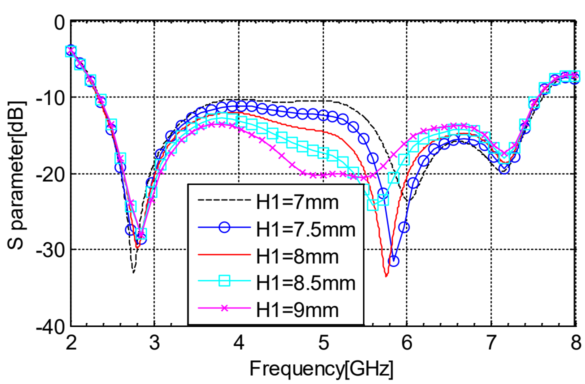


Fig. 4 S_{11} sweep by H1 when others set as in Tab. I

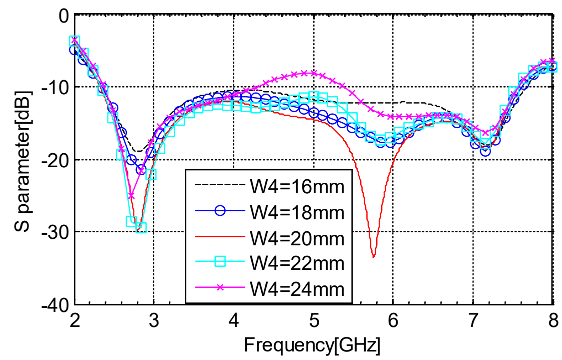


Fig. 5 S_{11} sweep by W4 when others set as in Tab. I.

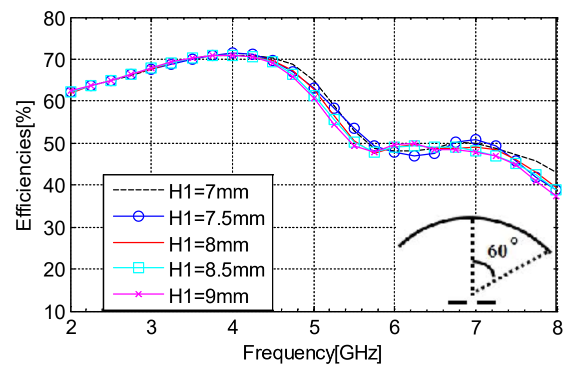


Fig. 6 Aperture efficiency (when feeding a paraboloidal reflector with a half subtended angle 60°) sweep by H1 when others set as in Tab. I

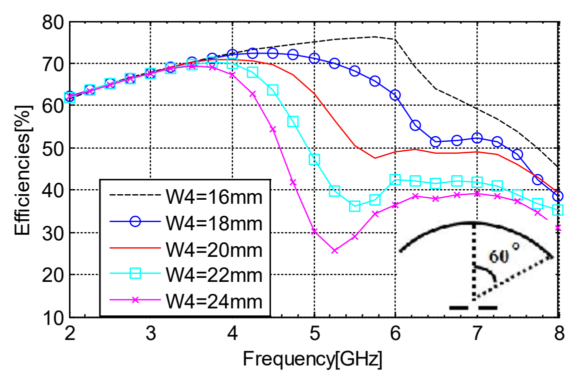


Fig. 7 Aperture efficiency (when feeding a paraboloidal reflector with a half subtended angle 60°) sweep by W4 when others set as in Tab. I.

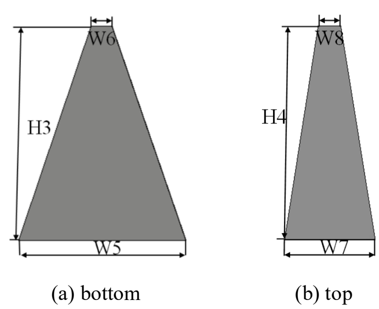


Fig. 8 Microstrip tapered balun: (a) W5=16mm, W6=2mm, H3=20.5mm. (b) W7=3.6mm, W8=2mm, H4=19.5mm.

A linearly tapered air-substrate microstrip balun is designed to feed the dipole by a 50Ω coaxial cable through an SMA connector, as illustrated in Fig. 8. The SMA connector is placed under the ground plane, and its outer conductor is soldered on the ground plane while its inner one is connected to the balun.

The fabricated prototype is exhibited in Fig. 9. All the dimensions of the proposed antenna are illustrated in Tab. Ⅰ. Note that the total height of the antenna (including the balun and the ground plane) is 29 mm, which is about 0.21 of the longest operating wavelength (at the lowest operating frequency point 2.2 GHz).

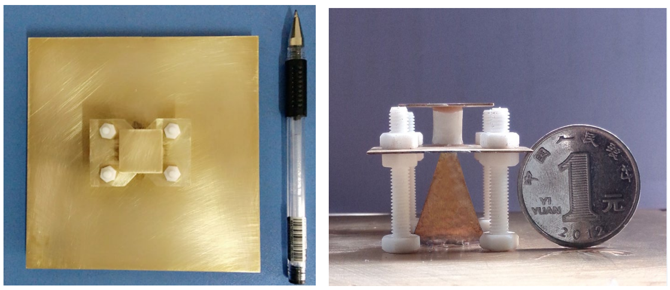


Fig. 9 The fabricated prototype in top and side views.

TABLE Ⅰ THE PARAMETERS OF THE PROTOTYPE ANTENNA

Parameter	Value (mm)	Parameter	Value (mm)	Parameter	Value (mm)
H1	8	**W2**	32	**W7**	3.6
H2	20	**W3**	120	**W8**	2
H3	20.5	**W4**	20	**L1**	47.8
H4	19.5	**W5**	16	**L2**	5.5
W1	6.5	**W6**	2	**G**	1.8

III. RESULTS AND DISCUSSION

The simulated and measured S_{11} parameters are compared in Fig. 10. The measured impedance bandwidth is about 3:1 (return loss better than 10 dB) from 2.2-6.5 GHz. A minor shift in frequency is observed between the simulated and measured curves, primarily due to the tolerances of the balun and the soldering, etc. Nevertheless, the results indicate pretty good agreement between simulation and measurement of the S-parameters.

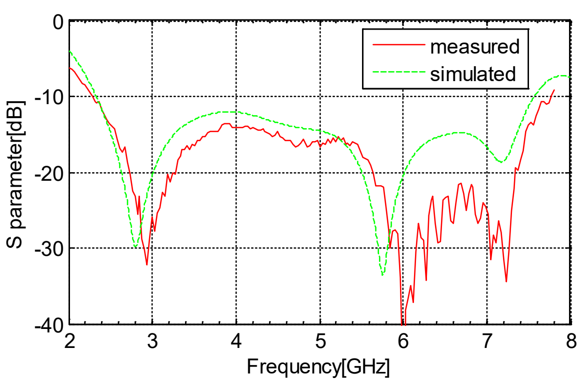


Fig. 10 Simulated and measured S_{11} of the antenna

A comparison of the simulated 3D radiation patterns (co-polar components) for the cases without/with a parasitic patch over the dipole is illustrated in Fig. 11. The main lobe will be split when the frequency is higher than 5.5 GHz if the dipole antenna is without a parasitic director, while nearly stable directional radiation patterns are maintained up to 6.5 GHz if a parasitic director is in presence.

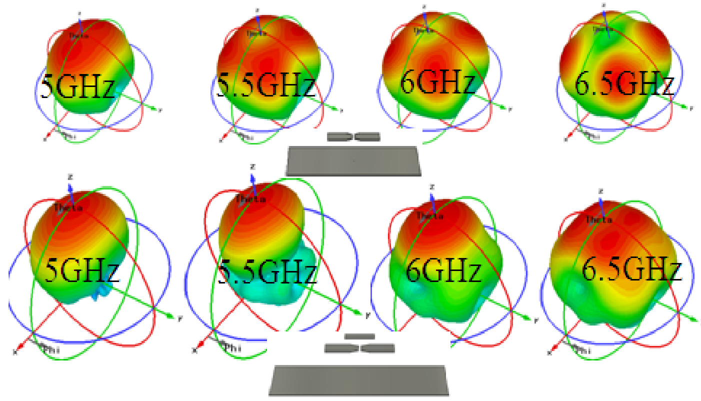
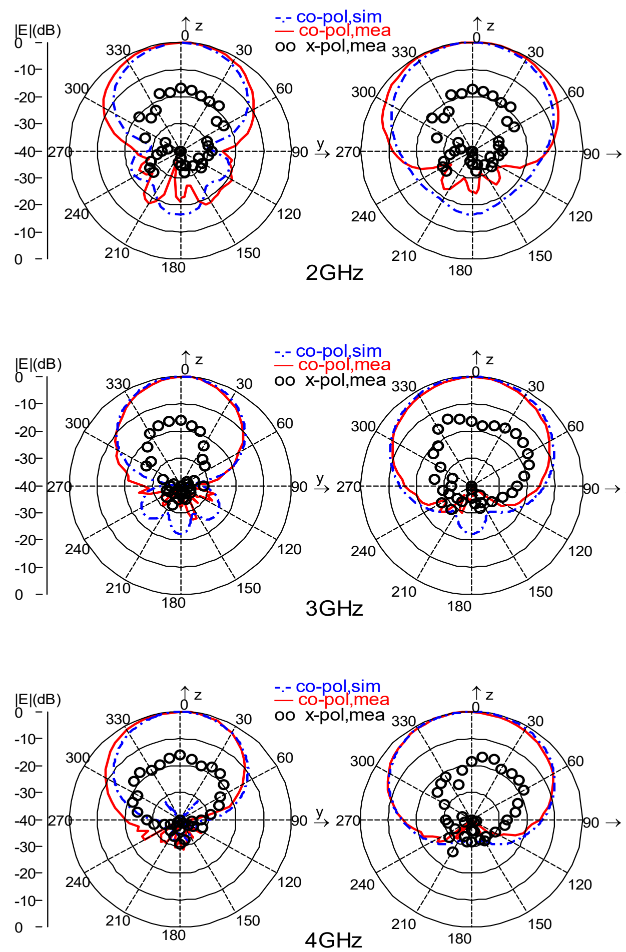


Fig. 11 Simulated co-polar components of the radiation patterns for the dipole antenna without (upper) and with (bottom) a parasitic patch director.

The simulated and measured 2D radiation patterns of the proposed antenna are illustrated in Fig. 12. As can be observed, nearly stable directional radiation patterns are obtained over the whole operating band, and the relative cross-polarization levels are better than -12 dB.



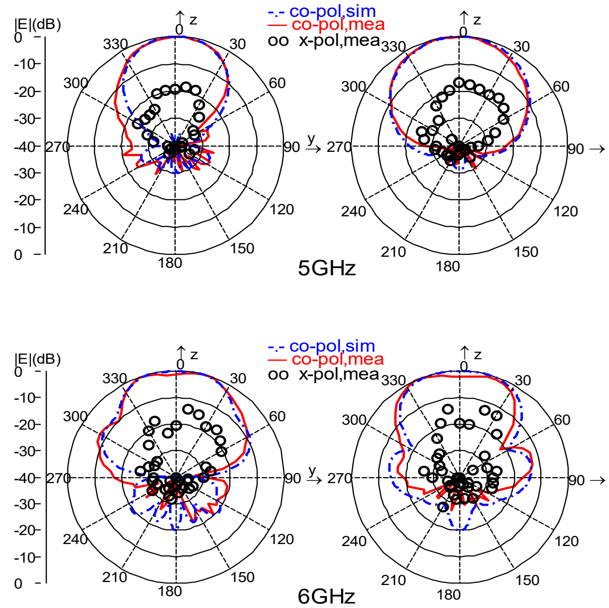


Fig. 12 Simulated and measured radiation patterns at different frequencies (2, 3, 4, 5 and 6 GHz) in E-plane (left) and H-plane (right): -.- simulated co-polarization. — measured co-polarization, oo measured cross-polarization.

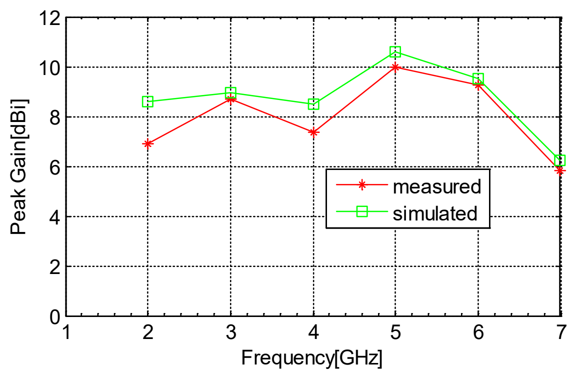


Fig. 13 Simulated and measured peak gains of the antenna.

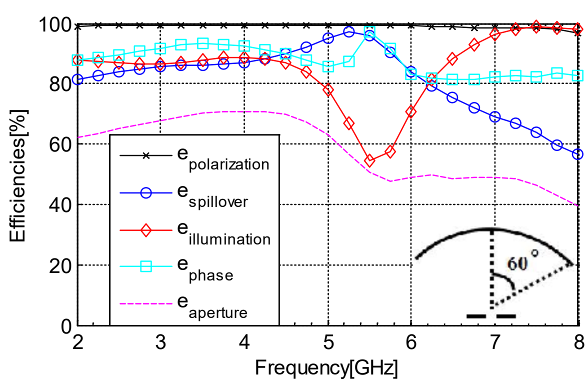


Fig. 14 Aperture efficiency and sub-efficiencies (when feeding a paraboloidal reflector with a half subtended angle 60°) when parameters set as in Tab. I

The simulated and measured gains shown in Fig. 13 reveals that the prototype antenna achieves a high gain ranging from 7.0 to 10.0 dBi between 2.2 and 6.5 GHz. When the proposed capped dipole feeds a paraboloidal reflector with a 60° half subtended angle, the aperture efficiency and its sub-efficiencies are simulated and calculated by formulas in [15]-[16], as shown in Fig. 14. The feed antenna obtains better than 50% aperture efficiencies over 2.2-6.5 GHz.

IV. CONCLUSION

A novel ultra-wideband high-gain dipole antenna is proposed in this letter. It has been demonstrated that by simply capping a proper squared metal patch, a planar dipole in close proximity to an ordinary ground plane can achieve a 3:1 bandwidth, peak gains as high as 7.0-10.0 dBi and better than 50% aperture efficiencies over 2.2-6.5 GHz. Compared with other dipole antennas using a corrugated reflector or an artificial high-impedance surface, the proposed solution outperforms in terms of bandwidth, manufacture cost and feeding structure. Future work is focusing on developing a dually-polarized prototype as a feed for reflector antennas for use in telecommunications and radio telescopes, etc.

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