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Low-Profile Ultra-Wideband Directional Dipole Antenna as a Feed for Reflectors in Radio Telescopes

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***Abstract*—In this paper, a small top plate is found useful to improve the impedance bandwidth of an ultra-wideband dipole antenna horizontally above a ground plane. A linearly-polarized prototype based on this new and simple design methodology can operate over nearly 3.5:1 bandwidth with return losses better than 10 dB, and with nearly stable radiation patterns, high BOR_1 efficiency and aperture efficiency over the entire operating band.**

***Index Terms* – Ultra-Wideband, Dipole Antenna, Top Plate, Radio Telescopes.**

Ⅰ. INTRODUCTION

The ground plane of an antenna is typically made by flat conducting plate. In order to get stable directional radiation characteristics and high peek gains, the spacing between the radiator and the ground is about a quarter-wavelength. However, it is tricky to determine the spacing if the ultra-wideband performance is required. Therefore, the radiator is often tilted with an optimum angle from the ground plane, leading to an increase on the antenna height, as can be seen in the Eleven feed [1]-[2] and the self-grounded bow-tie antenna [3]. An alternative way to make a low-profile antenna is to incorporate a special texture on the ground surface, which is possible to alter its electromagnetic properties [4]. By introducing such a high impedance structure, the ground plane does not support surface waves and the interference between the ground and the radiating antenna is eliminated, so the directional radiation patterns can thus be achieved. Based on this idea, a reflector with high-impedance surface was designed in [5]. However the impedance bandwidth is very limited. In [6]-[7] the stable directional radiation patters cannot be obtained over the whole operating band and the impedance bandwidth is only 2:1. The paper [8] presented a novel ultra-wideband dipole with a corrugated-reflector, the antenna can operate from 2.75 to 8.35 GHz (3:1 bandwidth) with VSWRs<2.0, but the radiation patterns become poor upwards from 5.0 GHz.

To solve this problem, a novel and simple way to design ultra-wideband antenna with stable directional radiation patterns is proposed in this paper. Adding a small metal plate above an ultra-wideband radiator with an ordinary ground plane, it is possible to get stable directional radiation patterns over about 3.5:1 bandwidth. The simulated results shows that the paper provides a new design methodology for the future low-profile ultra-wideband directional antenna without using complex periodical structures on the ground plane.

The Tianlai Project in China [9] is developing a dedicated radio telescope for the dark energy detection [10]-[11]. The feed of the telescope must be able to operate from 400 to 1400 MHz (3.5:1 bandwidth) with low VSWRs (<2.5) and should have an isolation of at least 20 dB between two polarization ports. At the same time, low cross polarization, good radiation performance and stable phase center are also required. Based on the proposed linearly-polarized prototype, it is very promising to develop a dually-polarized UWB feed for the Tianlai project.

Ⅱ. THE ANTENNA DESIGN

The proposed antenna is modeled and optimized by *CST MWS*. The geometry of the source dipole [12] and the entire antenna is shown in Fig. 1 and Fig. 2, respectively; all the dimensions are listed in Table I.

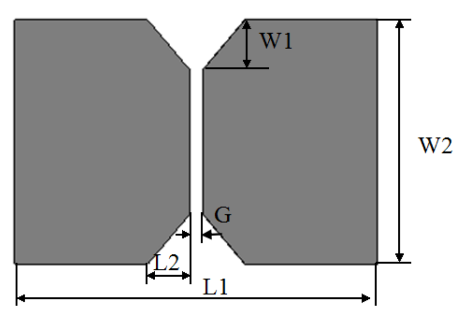


Fig.1. Geometry of the source dipole.

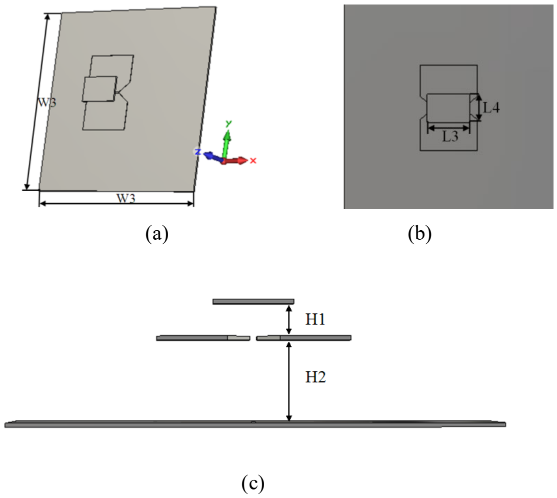


Fig.2. Geometry of the proposed antenna prototype: (a) 3D view, (b) Front view (c) Side view.

TABLE Ⅰ. THE PARAMETERS OF THE ANTENNA PROTOTYPE

Parameter	Value (mm)	Parameter	Value (mm)
H1	9	L3	24
H2	20	L4	16
L1	48.8	G	0.8
L2	6	W1	7.5
W2	32	W3	120

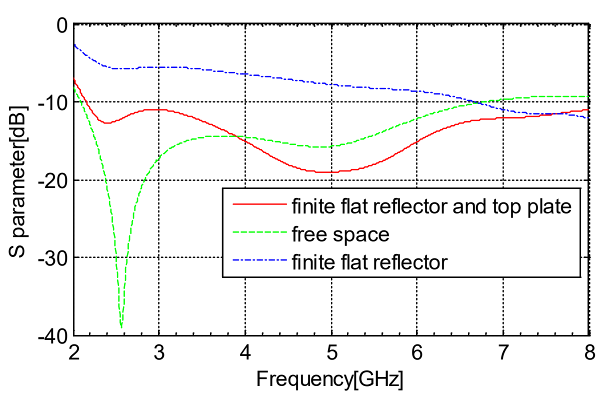


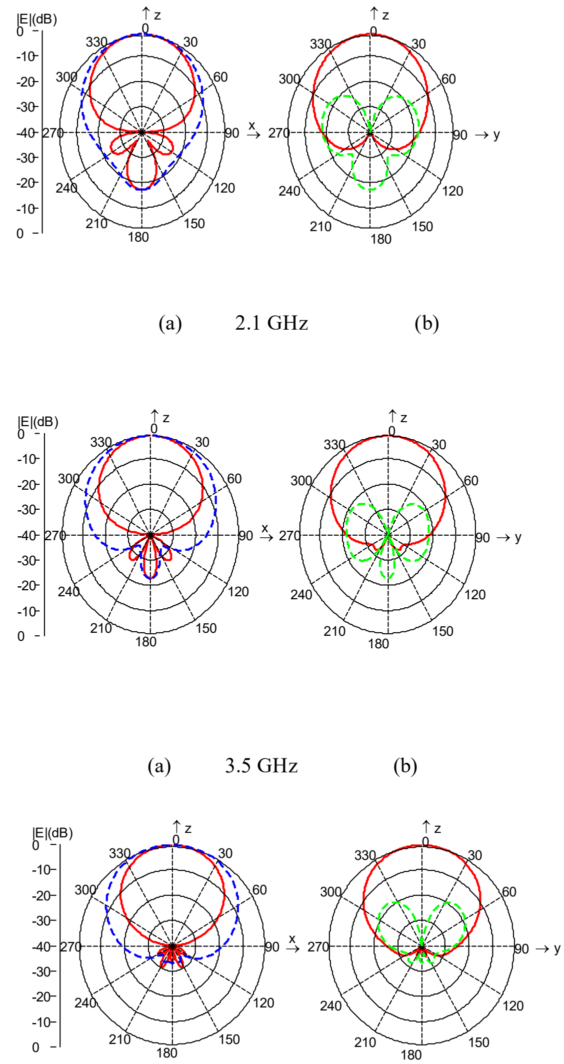
Fig.3. Simulated S-parameters.

III. Simulation Results

The simulated S-parameters (50Ω reference) of the evolved models are plotted in Fig. 3. First, the source dipole alone can operate over 2.0-6.5 GHz in free space without a reflector. Second, when the source dipole is placed above a finite ground plane ($1.6\lambda_{4GHz} \times 1.6\lambda_{4GHz}$) with a spacing of 12.5 mm ($1/4\times\lambda_{6GHz}$), the return loss becomes much worse, which implies that the reflector makes significant influence on the impedance matching. Finally, good matching can be obtained again over 2.0-6.5 GHz by using a top plate, where the lengths of H1 and H2 can be adjusted for optimization.

Simulated radiation patterns of the antenna prototype are illustrated in Fig.4. As can be observed, relatively stable directional radiation patterns are obtained over the whole band and the cross-polarization level is below -25 dB at the same time. The result in Fig. 6 reveals that the antenna achieves a stable high gain from 8 to 10 dBi.

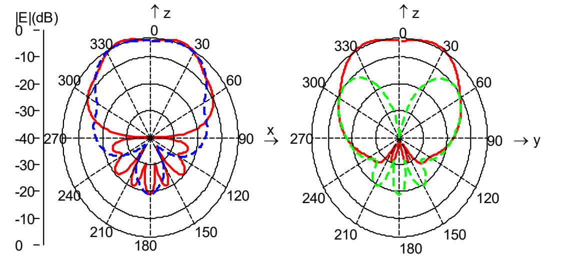
Fig. 5 shows the aperture efficiency and its subefficiencies defined in [13]-[14]. The BOR_1 efficiency is higher than 90% and the aperture efficiency is higher than 50% over the whole band 2.0-6.5 GHz.



(a) 2.1 GHz (b)

(a) 3.5 GHz (b)

(a) 5.0 GHz (b)



(a) 6.5 GHz (b)

Fig .4. Simulated radiation patterns at different frequencies: (a) —— simulated E-plane (zoy-plane), ----- simulated H-plane (zox-plane). (b) —— simulated co-pol. and -----simulated cross-pol. at +45° plane.

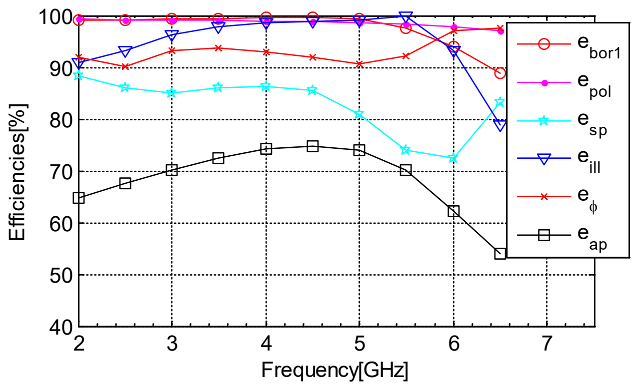


Fig.5. Simulated aperture efficiency and its subefficiencies.

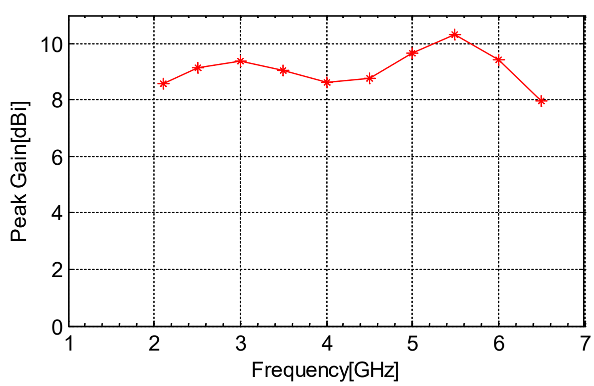


Fig.6. Simulated gain of the antenna.

Ⅳ CONCLUSION

A simple low-cost low-profile ultra-wideband directional dipole antenna is proposed in this paper. Merely with a well-designed top plate, a horizontal flat dipole radiator can operate over an ultra-wide bandwidth above an ordinary solid ground plane. Based on this idea, a linearly-polarized model is studied by simulations and calculations. The linearly-polarized prototype can operate over 2.0-6.5 GHz (nearly 3.5:1 bandwidth) with return losses better than 10 dB, and with aperture efficiencies better than 50%. The fabrication and measurement of the antenna will be carried out in the near future.

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