

A NOVEL LOW-PROFILE WIDEBAND UHF ANTENNA

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Abstract—In this paper, an ultra high frequency (UHF) low-profile antenna is proposed; it is based on the discone antenna but with addition of a back cavity, a short-circuiting structure and a two-plate top structure in order to achieve both low-profile and wideband. It is simulated and prototyped. The test results show that the antenna has an omni-directional radiation pattern in the horizontal plane, is of low-profile, has a height of less than $0.1\lambda_{\max}$, and is wideband with an impedance bandwidth of 65% from 430 MHz to 845 MHz for $\text{VSWR} < 2.5$ and an impedance bandwidth of 43% from 440 MHz to 680 MHz for $\text{VSWR} < 2.0$. The proposed antenna can be easily flush-mounted on a planar surface and therefore has great potential for uses on aircrafts and high-speed trains due to its conformal capability.

1. INTRODUCTION

The conformal antennas or flush mounted antennas are very much desirable for uses in aircrafts and ships. Especially on aircrafts, flush-mounting is strongly favored due to aerodynamic considerations. As a result, development of conformal antennas and arrays [1–3] has been one of the important research areas in aerospace industry. A good and detailed overview of the development in the area is presented in [4].

Most conformal antennas have been designed for applications in C-band, X-band and other high frequency bands with a focus on antenna arrays. Only a few reports have been seen in UHF band. Some of them focus on wireless communications [5–7] or RFID applications [8–13], and others are slot antennas [14,15]. In [14],

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a bent-slot antenna operating at 800 MHz bands was presented for UHF portable communication equipment; its frequency bandwidth is 45 MHz and could be extended to 55 MHz with a widened slot width. In [15], other designs of the slot antennas were proposed for uses in ships.

On the other hand, a discone antenna [16,17] is wideband and can be considered as a special case of biconical antennas [18]. Because of its symmetric structure, a discone antenna has an azimuthally omni-directional radiation pattern. It is widely used in ultra-wideband (UWB) communication applications due to its wideband characteristics. Variations of the discone antennas have also been developed, such as the spiral-discone broadband antenna [19], the double discone antennas with tapered cylindrical wires [20,21].

Most of the discone antennas reported so far are for uses in the high frequency bands such as L-band; as a result, their sizes can be made small. If a discone antenna structure is applied to the UHF band directly, its features cannot be maintained: due to the relatively long wavelength of the UHF band, the height of a discone antenna is large which makes the antenna difficult to be conformal and of low-profile [22–25]. Therefore, to be of low-profile, the height of a discone antenna needs to be reduced (i.e., the discone antenna is flattened); however, the reduced height will reduce the antenna's frequency bandwidth. As a result, methods need to be introduced to compensate for or to make up the adverse effects caused by the height reduction; that is, the methods need to be developed to widen the frequency bandwidth of a height-reduced or flattened discone antenna.

In [26], a lumped-element loading method was used to widen the frequency bandwidth and the resultant discone antenna was made to have a height of less than 0.25λ . In [27], a multi-plate structure is presented to achieve a wide frequency band of 1.2 GHz to 2 GHz.

In this paper, we propose a new wideband low-profile UHF antenna; it is a further design and extension of [28] by the same authors but in different frequency bandwidths with more analysis and investigation results on operational principles. The antenna is built on a modification of a discone antenna that is flattened but with additions of a back cavity, a short-circuiting structure and a two-plate top structure. The short-circuiting structure and the two-plate top structure widen the bandwidth of the antenna. The back cavity increases the equivalent length of the antenna and reduces the antenna's emanating interferences while facilitates flush mounting capability of the antenna on a flat surface.

In the following sections, the design of this antenna is firstly described in Section 2. Then the test and measurement results of

a prototype are presented in Section 3. Finally, conclusions are made in Section 4.

2. ANTENNA DESIGN

The configuration of the proposed antenna is shown in Figure 1. It is built on a discone antenna that is flattened but with three major additions: (1) an open-end cylindrical cavity that surrounds the cone, (2) a short-circuiting structure that is made of an open-ended cylindrical wall with its upper edge connected to the top circular plate of the discone antenna through three solid metal angles placed 120° apart, and (3) a circular metal plate added above the top circular metal plate with supporting metal posts in between the two plates (forming

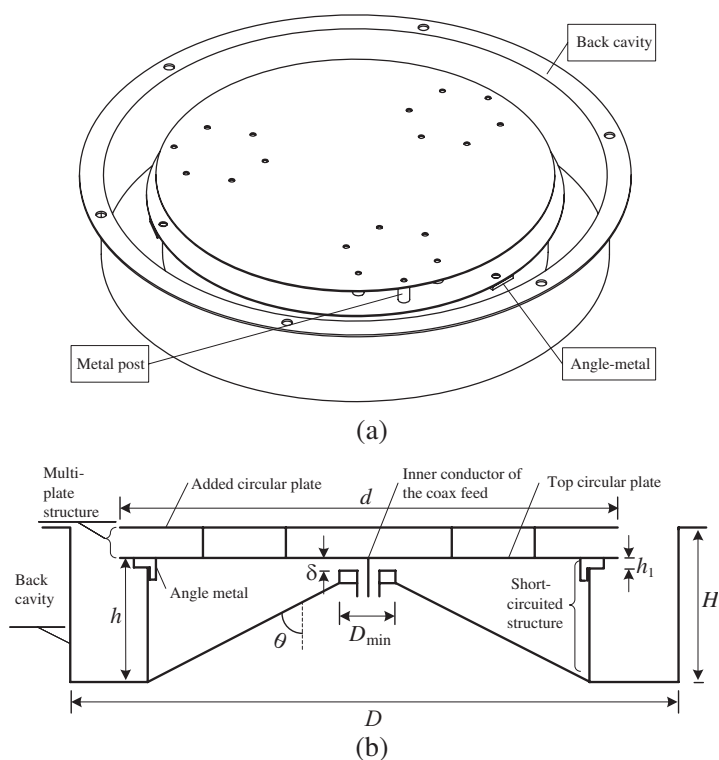


Figure 1. Configuration of the proposed antenna. (a) 3D view. (b) 2D side view. Two angle-metals are depicted in (b) to indicate their locations relative to the top circular plate and short-circuited cylinder. In reality, they should not be in the figure simultaneously.

a parallel plate structure above the top of the cone). The proposed antenna is fed by 50Ω coaxial cable. The other physical parameters are as follows: d is the diameter of the top plates, δ is the feed gap of the discone antenna, D_{\min} is the diameter of the feeding plate of the discone antenna, h is the height of discone antenna, θ is half of the cone angle, h_1 is the height of angle-metals, D is the diameter of the overall antenna, and H is the height of the overall antenna.

In other words, the proposed antenna has the discone antenna as its basic part but with a large cone angle to reduce the height. Then three structures are added: (i) a back cavity, (ii) an open-ended cylindrical wall with three angle metals fixing its upper edge with the top circular plate, and (iii) an additional circular metal plate above the top circular plate.

The back cavity changes the resonances of the proposed antenna and therefore affects the bandwidths. It also facilitates flush mounting of the antenna and reduction of interference emanation (or surface waves) produced by the antenna.

The open-end cylindrical wall and the three angle metals form the short-circuiting structure that provides short-circuited current paths between the top circular plate of the discone antenna and the ground or the bottom of the cone (see Figure 1(b)). They change the current distribution of the original cavity-backed antenna and reduce the reflections from the edge of the top circular plate. They compensate for the adverse effects caused by the height reduction of the cone (i.e., the increase of the cone angle).

The two-plate top structure is composed of the two parallel plates, one being the circular top plate of the discone antenna and another being the one above it; the two plates are connected by several

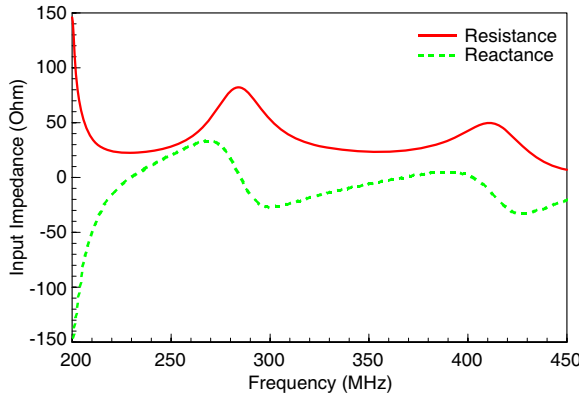
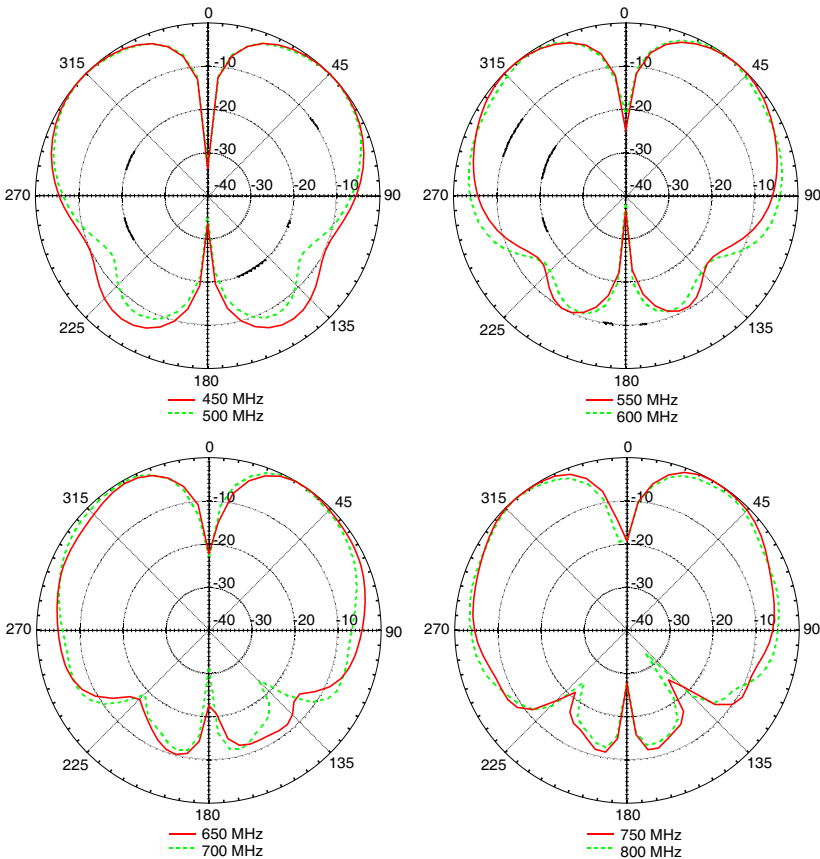


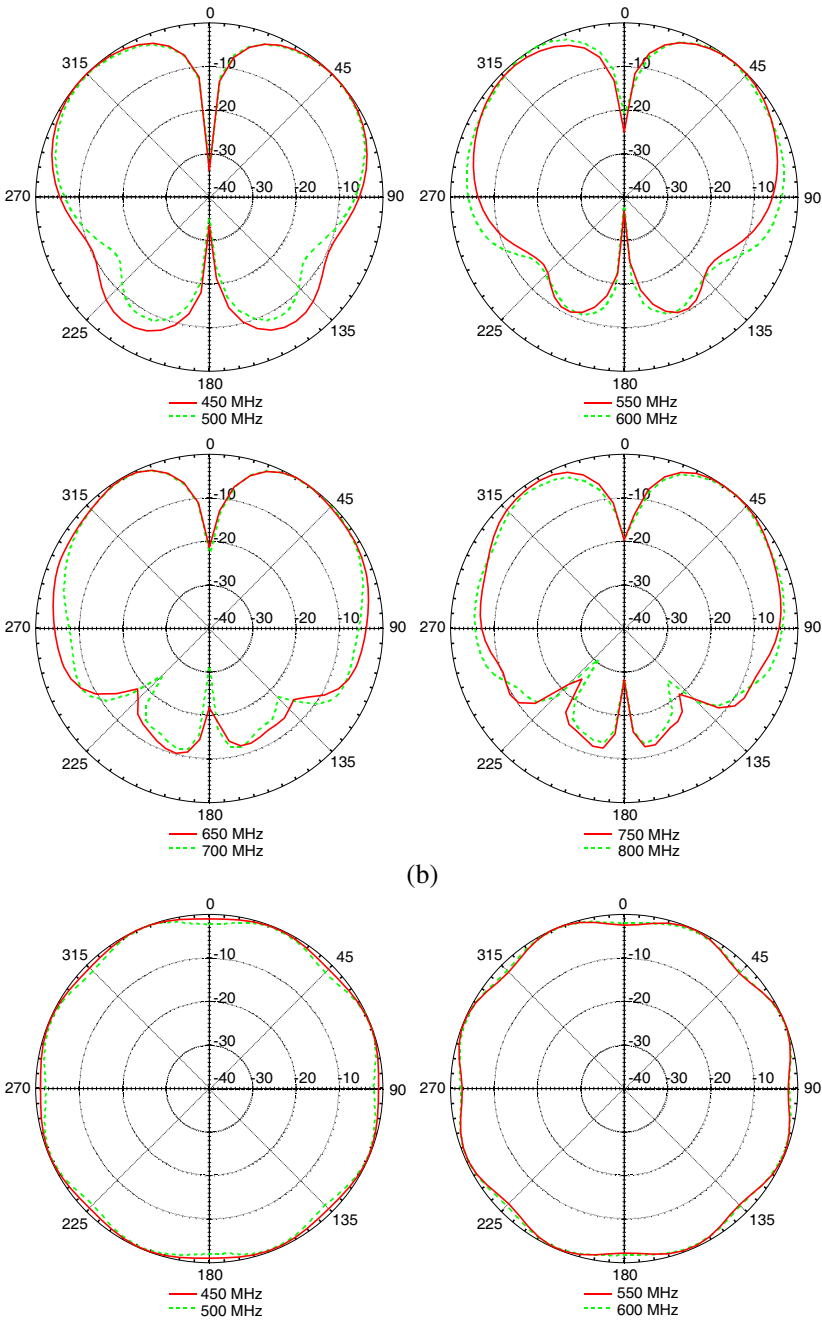
Figure 2. Input impedance of the proposed antenna.

thin metal posts (see Figure 1). The two-plate structure enlarges the equivalent electrical length of the antenna, thus improving the performance of the antenna at both the lower end of the frequency bands, leading to a wider bandwidth.

Figures 2 and 3 are the computed input impedance and normalized radiation patterns of the proposed antenna respectively; they are obtained with the Ansoft HFSS software. In the simulations, the top of the antenna was covered with FRP (Fiber Reinforced Plastics) of 4.0 in relative dielectric constant and was flush-mounted on a square meal plate which represents the surface of an aircraft. As can be seen from Figure 2, with the combination of the three parts of the proposed antenna, there arise three resonances at low, medium and high frequencies respectively, thus improving the bandwidth of the



(a)



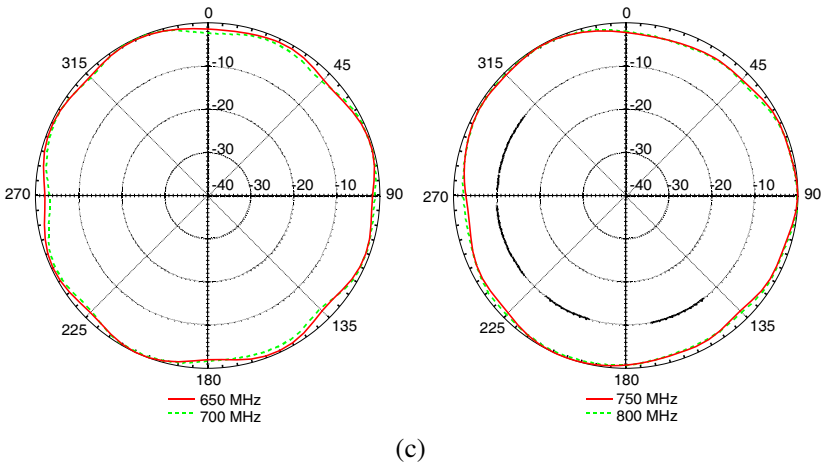


Figure 3. Simulated radiation patterns at 450 MHz, 500 MHz, 550 MHz, 600 MHz, 650 MHz, 700 MHz, 750 MHz and 800 MHz in the plane of (a) $\Phi = 0^\circ$, (b) $\Phi = 90^\circ$, (c) $\Theta = 90^\circ$.

Table 1. The optimized geometric parameters.

| Parameter | Quantity (mm) |
|------------|---------------|
| h | 46.75 |
| H | 65 |
| D_{\min} | 20 |
| d | 270 |
| D | 350 |
| δ | 2.25 |

antenna. And from Figure 3, it can be concluded that the proposed antenna radiates like a dipole-type antenna and the radiation patterns in the horizontal plane are omni-directional.

3. TEST RESULTS OF A PROTOTYPE

The simulated results presented above provide the guidelines for the final design of the antenna. Based on them, optimization of the geometrical parameters is made with HFSS. The configuration of the antenna optimized for the widest possible band is determined. The final optimized geometric parameters are shown in Table 1.

With Table 1, an UHF antenna prototype operating from 430 MHz to 845 MHz has been fabricated and measured (see Figures 4 and 5). The diameter and the thickness of the top FRP are 350 mm and



Figure 4. Photographs of the fabricated antenna. (a) Front view. (b) Back view.



Figure 5. Photographs of the fabricated antenna with FRP and mounting plate. (a) Front view. (b) Back view.

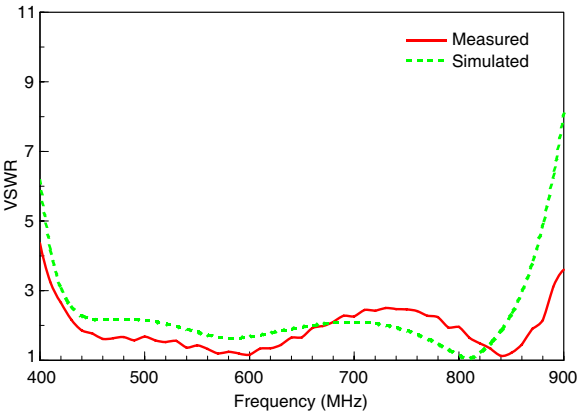


Figure 6. Simulated and measured VSWR.

1 mm, respectively. And the relative permittivity of FPR is 4.0. The diameter of the antenna is 350 mm and the size of the mounting plate is $600 \times 600 \text{ mm}^2$. The overall height of the antenna $H = 65 \text{ mm}$ which is only $0.093\lambda_{\text{max}}$, making the antenna very low-profile. Here $\lambda_{\text{max}} = 698 \text{ mm}$ is the largest operating wavelength of the antenna corresponding to the frequency of 430 MHz.

Figure 6 shows the simulated and measured VSWRs. It can be seen that VSWR is less than 2.5 from 430 MHz to 845 MHz. It corresponds to a relative bandwidth of 65%, which indicates a wideband antenna. The measured VSWR is less than 2.0 from 440 MHz to 680 MHz, corresponding to a wide bandwidth of 43%. Nevertheless,

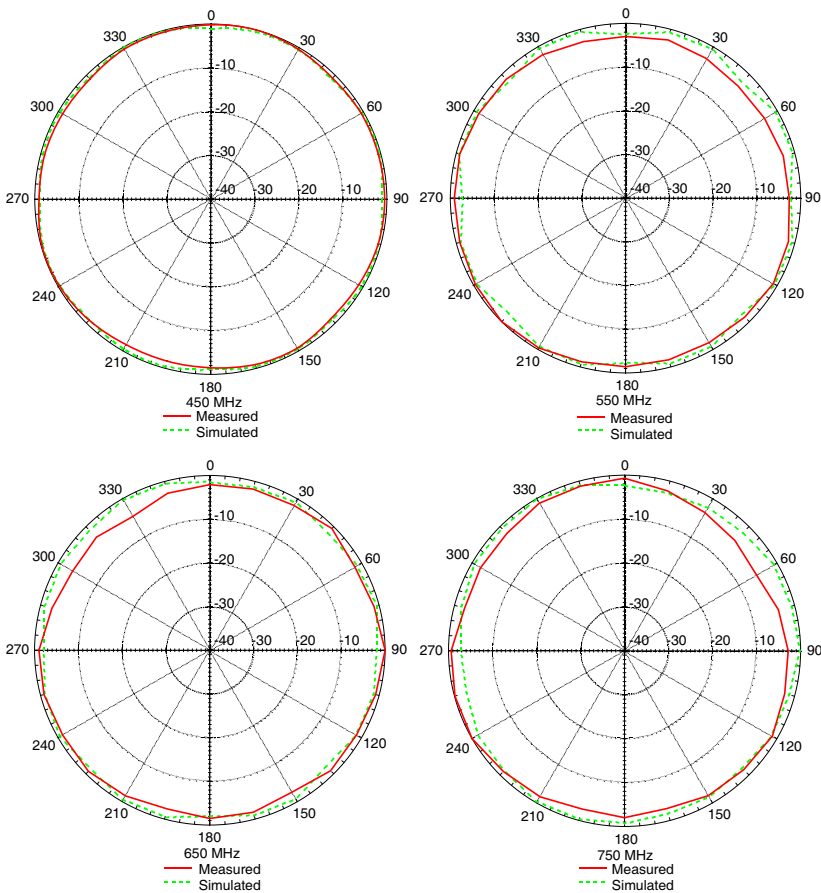


Figure 7. Simulated and measured horizontal radiation patterns at 450 MHz, 550 MHz, 650 MHz and 750 MHz.

the specification of bandwidth of VSWR of less than 2.5 was specified by the sponsor of this work; this is acceptable in some applications, just like those presented in [29–43], where the VSWR was specified in the range of 2.5 to 6.0. Figure 6 also indicates some difference between the simulated and measured results. We can attribute the difference to unavoidable errors in fabrication and variations in properties of actual materials.

The radiation patterns of the prototype were also measured. Since the sponsor of this work was interested in the radiation patterns in the horizontal plane which is also important when mounted on a plane, only the horizontal radiation patterns were measured. Figure 7 shows the horizontal normalized radiation patterns at four selected frequencies. As can be seen from Figure 7, the radiation patterns are omni-directional.

4. CONCLUSION

A novel low-profile wideband UHF antenna is presented in this paper. The antenna is built on a discone antenna that is flattened with addition of a back cavity, a short-circuited structure and a two-plate top structure. With these three additional structures, several adjacent resonant frequencies are generated, thus widening the bandwidth.

A prototype was built and tested. Its height is only $0.093\lambda_{\max}$, achieving a very low profile. The measured results show that the VSWR is less than 2.5 from 430 MHz to 845 MHz (a wide bandwidth of 65%) and the VSWR is less than 2.0 from 440 MHz to 680 MHz (a wide bandwidth of 43%). The horizontal radiation pattern is omni-directional, meeting most communication requirements.

Because it is of low profile and has a planar top, it can be easily flush-mounted on a flat platform. As a result, if used on an aircraft, its negative effects on aerodynamic performance of the aircraft can then be minimized.

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