A Printed Monopole Antenna with Extremely Wide Bandwidth

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***A*bstract — A printed monopole antenna with an extremely wide 47:1 bandwidth is introduced. It is composed of an elliptical monopole patch and a trapezoid ground plane, both printed on the same side of a substrate, and is fed by a modified tapered CPW line. Results computed from simulations indicate that this antenna has an impedance bandwidth from 520MHz to 24.5 GHz (47:1) with a VSWR≤2.**

***I*ndex terms — SWB, ratio bandwidth, current distribution**

I. INTRODUCTION

Ultra-wideband (UWB) antennas have been developed for a long time and have been used in military and industrial systems, such as electronic countermeasure, transient radars, mine detection. In 2002, the Federal Communication Commission (FCC) of the United States approved the frequency spectrum from 3.1 to 10.6 GHz for UWB communication, sparking a renewed attention in wideband antennas [1]. It is worthy noting that the maximum operating frequency range of an indoor UWB antenna in the provision of FCC-sanctioned UWB technology is from 3.1 to 10.6GHz with a ratio bandwidth of 3.4:1, while an antenna with a ratio bandwidth greater than or equal to 10:1 is generally called a super-wideband (SWB) antenna in the antenna literature.

In the late 1950s and early 1960s, a family of SWB antennas was developed by Ramsey *et al*, which was classified as a class of frequency-independent antennas [2]. Classical shapes of such antennas include equiangular spiral antennas and the log-periodic dipole antennas. These designs have small volumes but the movement of the effective radiating region with frequency results in waveform distortion of a transmitted pulse. Since 1970s several metal-plate-based planar monopole antennas with super-wide bandwidths have been proposed [3] [4]. However, they need a perpendicular ground plane, which leads to tall antennas (with high profiles that are undesirable for many electronic devices) and the inconvenience for integrating with monolithic microwave integrated circuits (MMIC). Recently, many printed monopole antennas with parallel ground planes were proposed for SWB applications. For example, a compact CPW-fed elliptical monopole antenna presented in [5] has a 2:1 VSWR bandwidth of 21:1.

In this paper, preliminary theoretical results of a printed monopole antenna, which is fed by a modified tapered CPW line, are presented. It has a theoretical impedance bandwidth of 0.52 ~ 24.5 GHz and can support most of the communication standards, such as AMPS (829–894 MHz), GSM (880–960 MHz), GPS (1.57–1.58 GHz), WCDMA (1.92–2.17 GHz), and UWB (3.1–10.6 GHz). The proposed antenna design and results are presented and discussed.

II. ANTENNA DESIGN

It has been found that the incorporation of a double feed to a planar metal-plate monopole antenna can efficiently promote vertical current distribution in the monopole patch while restraining the horizontal current distribution and the result is an improvement in impedance bandwidth [6]. In addition, an examination of the current distribution in a standard CPW-fed elliptical patch antenna (shown in Fig. 1(a)) demonstrate that the most of the surface current accumulate in the bottom of the monopole patch while other parts of the patch present a relatively low current density.

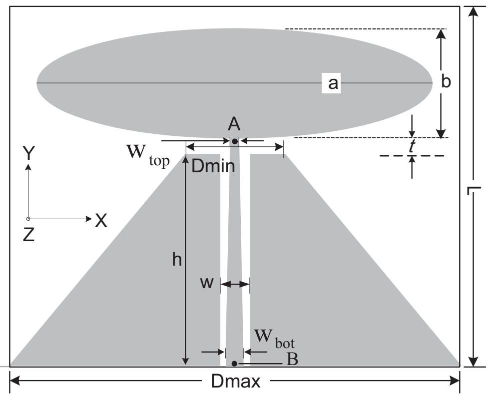

Fig. 1 (a) A standard elliptical printed monopole antenna fed by a tapered CPW line

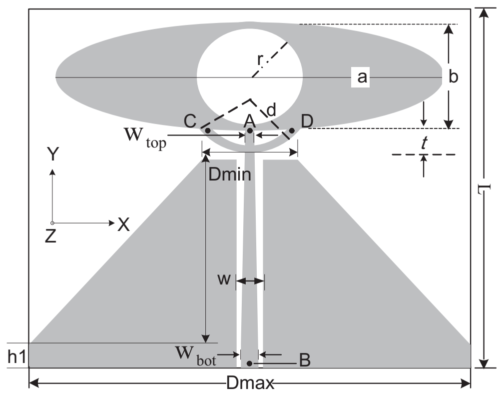

Fig. 1 (b) The proposed antenna (Dmax=124 mm, L=90mm, Dmin=9mm, a=120mm, b=30mm, t=2.3 mm, r=14mm, w_{top}=1mm, w_{bot}=2.6mm, w=3mm, t=2.3mm, h1=5mm, h=50mm, d=4.2mm)

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These understandings led to the proposed SWB antenna configuration displayed in Figure 1(b). It is reached by adding two feeding branch, etching out a circular hole in the elliptical metal patch, and modifying ground plane shape. Both the monopole and the ground plane are etched on the same side of a substrate with thickness h=1.524mm and relative permittivity ε_r=3.48. The elliptical monopole is fed by a modified, tapered CPW line in the middle of the ground plane. The gap width w of the uniform section of the CPW line is fixed to 3.0 mm. The connection between the CPW feed line and the elliptic radiator comprises three metal branches: one central branch connected to point A and two side branches of semicircular shape connected to points C and D. The semicircular braches have an outer radius of d. The width of the CPW central strip at the top end is w_{top} = 1.0 mm, corresponding to a characteristic impedance of 100Ω, and the width at the bottom end is w_{bot}= 2.6 mm, corresponding to a characteristic impedance of 50Ω. The widths of the semicircular-shaped feeding branches are set to 1 mm in this study. The tapered CPW line from point B to Point A gradually transforms the impedance from 50Ω to 100Ω. A more uniform current distribution is expected in the monopole patch because the modified feed has three feeding points symmetrically connected to the bottom of the elliptical radiation patch [7]. The tapered CPW line, the triple-branch feed and the elliptical patch with a circular aperture are integrated together. By adjusting the radius d and other parameters, a greatly enhanced impedance bandwidth can be achieved from the proposed antenna design. The ground plane is a part of impedance matching network which can lead to wideband multi-resonance characteristics of the input impedance at the top point A and it contributes to radiation as well. The other parameters values are listed under Fig 1(b).

III. RESULTS

By simulating the antenna using CST Microwave Studio software, which is based on the finite integration method, the characteristics of the proposed antenna were calculated. The calculated 2:1 VSWR bandwidth covers a frequency range from 0.52 to 24.5 GHz, with a ratio bandwidth of more than 47:1 (see Fig. 2). This result demonstrates that the proposed design has the potential to provide good impedance matching over a super-wide frequency band.

The VSWR of the proposed antenna is compared with that of a standard elliptical monopole antenna with a common tapered CPW line in [5] (shown in Fig. 3). The result indicates the novel CPW feeding arrangement mainly increases the upper limit of the bandwidth, whereas there is no significant change to the lower limit of the bandwidth.

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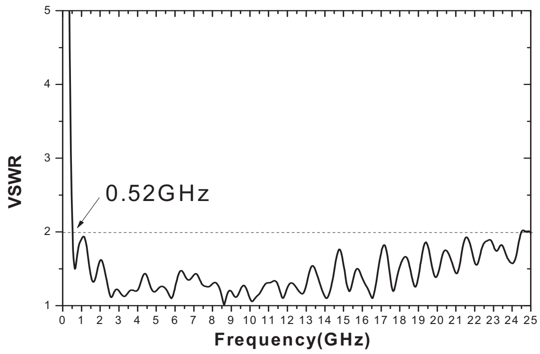


Fig. 2 VSWR of proposed antenna (d=4.2mm)

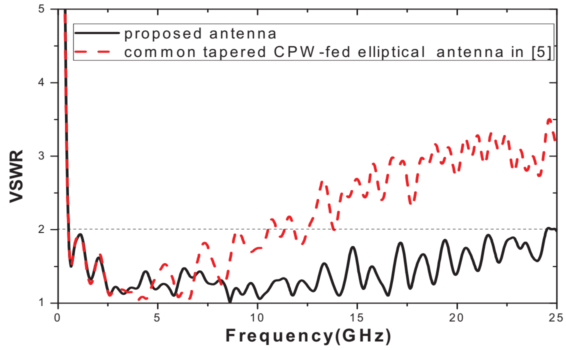


Fig. 3 VSWR comparison between the proposed antenna and the common tapered CPW-fed elliptical monopole antenna in [5]

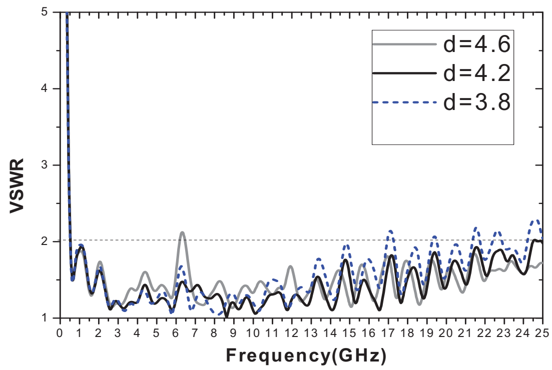


Fig. 4 The VSWR of the antenna with different radius d

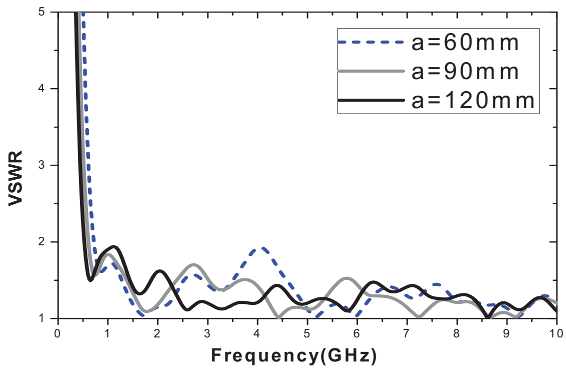
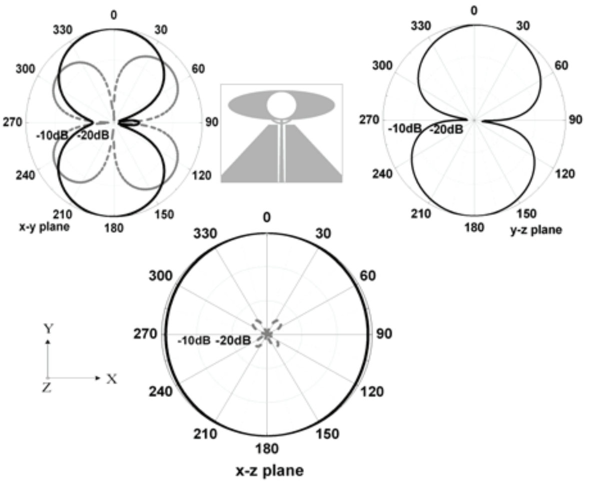
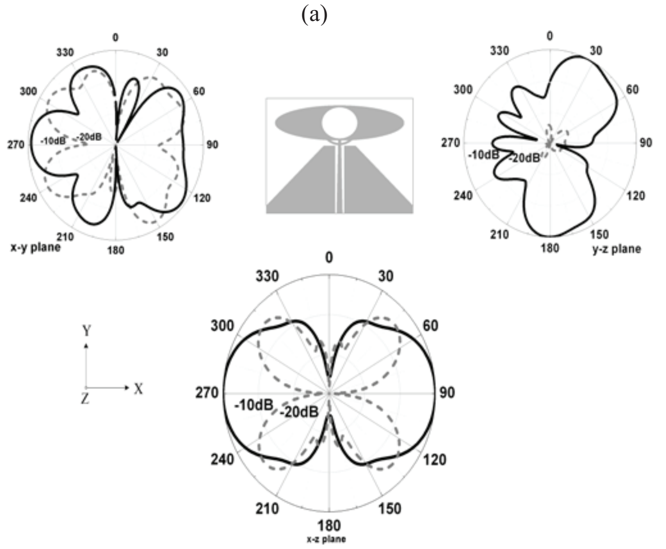


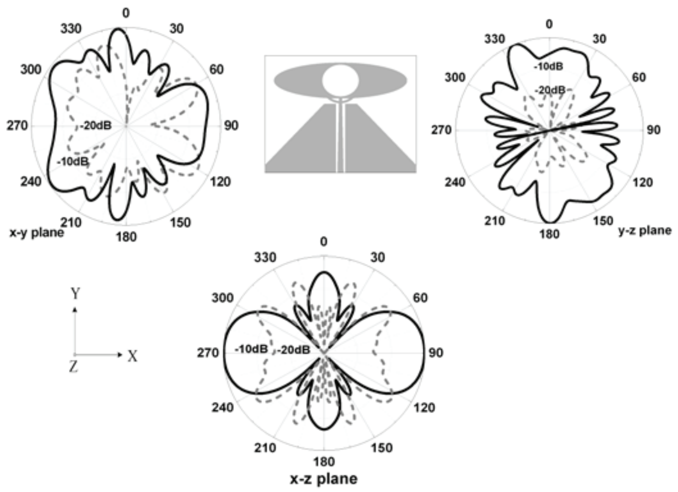
Fig. 5 The VSWR of the antenna with different major axis a of the elliptical patch



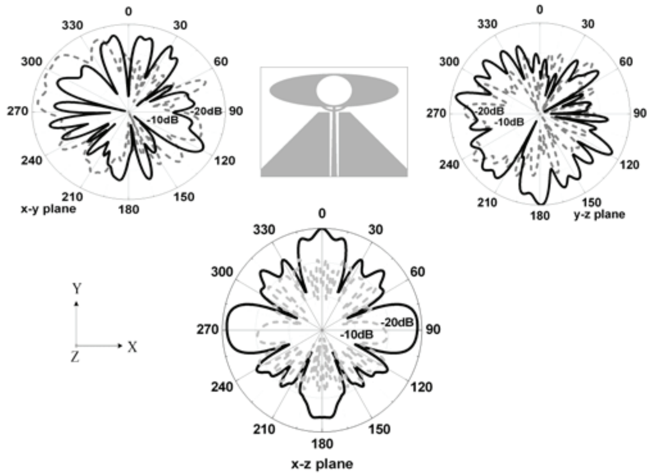
(a)



(b)



(c)



(d)

Fig. 6 Computed radiation patterns.
(a)f=1GHz, (b)f=5GHz, (c)f=10GHz, (d)f=20GHz

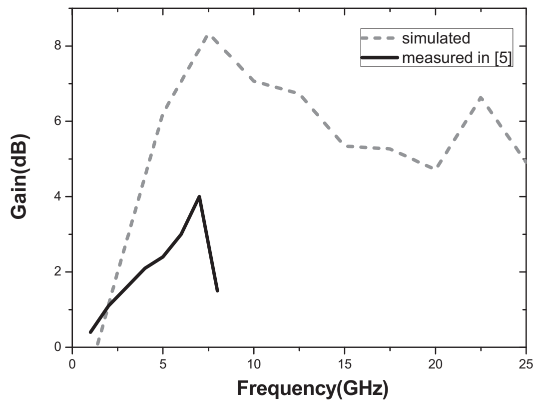


Fig. 7 Comparison between simulated gain of proposed antenna and measured gain of [5]

Figure 4 shows the VSWR of the antenna for different outer radius *d* of the semicircular-shaped feeding branch. It is found that the impedance bandwidth first increases with the increase of *d*. However, the VSWR has an intense fluctuation, sometimes even exceeding the value 2, when *d* is more than 4.2 mm. When the radius is equal to 4.2 mm, the impedance bandwidth reaches the maximum.

Figure 5 shows the VSWR variation with different major axis lengths of the elliptical patch. It is shown that the lower limit decreases from 710 MHz to 520 MHz when *a* is increased from 60mm to 120mm, which can increase the impedance ratio bandwidth effectively. Considering the impedance bandwidth and the size of the monopole antenna, the value of *a* is fixed at 120mm.

The computed radiation patterns of the antenna, at 1, 5, 10 and 20 GHz, are shown in Fig. 6. They indicate that this antenna has nearly omni-direction radiation characteristics at the low operating frequencies. The cross-polarization level,

Table 1

Comparison of several planar antennas with bandwidths greater than 10:1

No.	Type of antenna	Bandwidth (GHz) (VSWR≤2)	Ratio bandwidth (VSWR≤2)	Size (λ_l^2)
1	Planar inverted cone antenna [8]	1 ~ 10	10:1	0.25×0.25
2	Leaf-shaped monopole antenna [9]	1.3 ~ 29.7	22.8:1	0.35×0.35
3	Elliptical slot antenna [10]	1.3 ~ 20	15.4:1	0.39×0.39
4	Rectangular printed monopole antenna [11]	0.79 ~ 9.16	11.6:1	0.37×0.24
5	Elliptical printed monopole antenna [5]	0.41 ~ 8.86	21.6:1	0.19×0.16
6	Proposed antenna	0.52 ~ 24. 5	47:1	0.21 ×0.16

especially on the y-z plane, rises with frequency owing to the horizontal component of the surface currents.

Fig. 7 compares the computed gain of the antenna with the measured gain of antenna in [5]. It is seen that the gain expected from the proposed antenna is higher than that of a standard elliptical monopole antenna fed by a tapered CPW line in [5]. In the proposed antenna, some gain fluctuations are witnessed within the operating bandwidth of the antenna. For frequencies higher than 4 GHz, gain is more than 4 dB, and it rises to about 8 dB at 7 GHz. From 7GHz to 18GHz, gain is greater than 5dB although there is a tendency to decrease with frequency.

It is noted that the antenna area is only about $0.21\lambda_l \times 0.16\lambda_l$ (λ_l is the free-space wavelength at the lowest operating frequency). Table 1 compares several planar antennas with greater than 10:1 bandwidths, showing that the proposed antenna has the widest ratio impedance bandwidth with a compact size.

IV. CONCLUSION

A printed monopole antenna is introduced by modifying the tapered CPW feeding arrangement. The proposed antenna design exhibits an extremely wideband impedance matching. Its theoretical 2:1 VSWR ratio bandwidth is over 47:1, covering frequencies from 0.52 to 24.5 GHz. In addition, the proposed triple-segment feeding arrangement can be easily integrated with patch-type planar monopoles, thus the proposed antenna can be fabricated at a low cost.

V. ACKNOWLEDGMENT

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