Elliptical planar monopole antenna with extremely wide bandwidth

X.-L. Liang, S.-S. Zhong and W. Wang

A planar monopole antenna with an extremely wide bandwidth is introduced, which is composed of an elliptical monopole patch and a trapeziform ground plane, both printed on the same side of a substrate, and is fed by a tapered CPW feeder in the middle of the ground plane. The simulated and experimental results demonstrate that this antenna achieves a ratio impedance bandwidth of 21.6:1 for VSWR ≤ 2, and exhibits a nearly omnidirectional radiation pattern, while its area is only about $0.19\lambda_l \times 0.16\lambda_l$ where λ_l is the wavelength of the lowest operating frequency.

Introduction: In the late 1950s, a family of antennas with extreme-wideband (EWB) of more than 10:1 was developed by Ramsey *et al.* and was called the frequency-independent antenna [1]. Classical shapes of such antenna basically include the equiangular spiral structures and the log-periodic structures. Recently, some updated novel designs with a bandwidth ratio of more than 10:1 have been proposed, which mainly include two types. One is based on the tapered travelling-wave structures such as the 'cobra' structure [2], which is designed based on the TEM horn travelling-wave antenna and is of VSWR ≤ 2 and frequency range 800 MHz to 25 GHz. But these structures are somewhat large. Another type is the specially designed monopole antenna, e.g. the planar inverted cone antenna (PICA) [3], which provides an impedance bandwidth ratio of about 10:1. These planar monopole antennas need a perpendicular ground plane, resulting in an increase of antenna volume and the inconvenience of integrating with monolithic microwave integrated circuits. In the meantime, some planar ultra-wideband monopole antennas, without a perpendicular ground plane, have been proposed. In [4], a printed elliptic monopole juxtaposed with a ground plane in a single substrate is presented. However, it is designed for UWB communications with an impedance bandwidth ratio of about 4:1 and an area of $0.34\lambda_l \times 0.19\lambda_l$. In [5], an annular monopole antenna with a trapeziform ground plane is proposed, achieving a bandwidth ratio of 10.9:1 for VSWR ≤ 2, covering 0.79–9.16 GHz. In this Letter, a new design of planar monopole antennas is introduced, which provides about 21.6 octaves measured impedance bandwidth with compact size. Its bandwidth broadening and size miniaturisation come from three factors: an elliptical monopole shape, a trapeziform ground plane and a tapered CPW feeder.

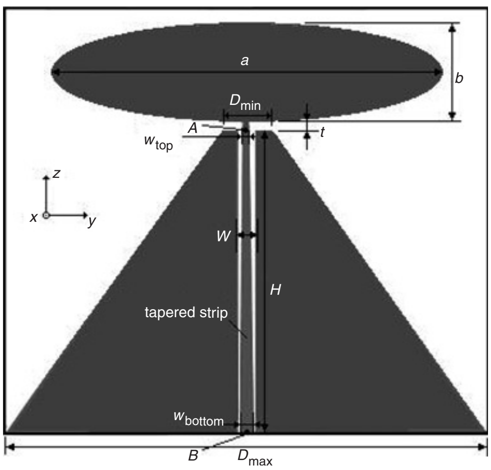

Fig. 1 *Geometry of proposed elliptical monopole antenna*

Antenna design: The proposed planar monopole antenna with a trapeziform ground plane is derived from the discone antenna first developed by Kandoian in 1945 [1], which offers satisfactory impedance performance over a wide frequency range and maintains nearly omnidirectional radiation characteristics. For the proposed antenna, as shown in Fig. 1, an elliptical monopole of major axis a and minor axis b is designed to replace the disc of a discone antenna, and a trapeziform ground plane of top length D_{min}, bottom length D_{max} and height H is designed to replace the cone, with a spacing t between them. Both the monopole and the ground plane are etched on a substrate of thickness $h = 1.524$ mm and relatively permittivity $\varepsilon_r = 3.48$. The elliptical monopole is fed by a tapered CPW feeder in the middle of the ground, where the total gap width W is fixed to 3.0 mm, but the top width of the central strip is $w_{top} = 1.0$ mm for 100 Ω characteristic impedance at point A and the bottom width $w_{bottom} = 2.7$ mm for 50 Ω impedance at point B while the width w between points A and B is linearly tapered. Here the trapeziform ground plane has three functions: the first is a ground plane for the monopole and the CPW; the second is as a radiating element; and the third is a component to form the distributed matching network with the monopole, which results in the wideband impedance characteristics at the top point A of the CPW feeder with about 100 Ω input impedance, while the tapered CPW transmission line smoothly transforms this to the 50 Ω impedance of an N-type connector at point B.

Table 1: Impedance bandwidth for different major axis a

Number	a (mm)	Axis ratio a/b	Frequency range of VSWR ≤ 2		Ratio bandwidth of VSWR ≤ 2	
			Calculated	Measured	Calculated	Measured
1	30	1:1	0.9–9.55 GHz	0.97–8.98 GHz	10.6:1	9.2:1
2	60	2:1	0.58–9.54 GHz	0.64–8.94 GHz	16.4:1	14:1
3	120	4:1	0.4–9.51 GHz	0.41–8.86 GHz	23.8:1	21.6:1
4	180	6:1	0.4–1.35 GHz 1.66–9.22 GHz	——	5.6:1 (23.1:1, VSWR ≤ 2.2)	——

Parameters: $b = 30$ mm, $t = 2.3$ mm, $D_{min} = 9$ mm, $D_{max} = 140$ mm, $H = 75$ mm, $w_{top} = 1.0$ mm, $w_{bottom} = 2.7$ mm

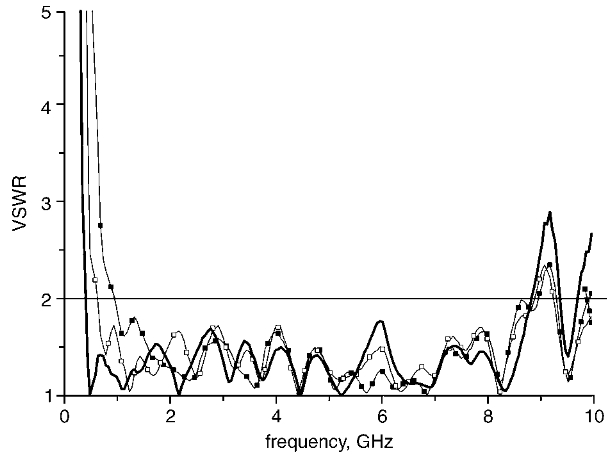

Fig. 2 *Measured impedance bandwidth for different major axis a (for other parameters see Table 1)*

—■— $a = 30$ mm
—□— $a = 60$ mm
——— $a + 120$ mm

Simulation and measurement results: By means of simulation using CST Microwave Studio software based on the finite integration technology method, the impedance bandwidths of the elliptical monopole antenna with different axial ratios are compared. In Table 1, the minus axis b is fixed to 30 mm and the major axis a is selected as 30, 60, 120 and 180 mm, which correspond to the axial ratios of 1:1, 2:1, 4:1 and 6:1, respectively. It is seen that, as the major axis a increases from 30 to 60 and 120 mm, the calculated impedance bandwidth ratios change from 10.6:1 to 16.4:1 and 23.8:1, respectively, while the impedance bandwidth ratios measured using the Agilent 8719ES network analyser change correspondingly from 9.2:1 to 14:1 and 21.6:1, as in Fig. 2. There is a slight discrepancy between the simulation and the experiment, due mainly to the effect of an N-type connector in addition to errors in the processing. That N-type connector is not accounted for in the simulation but was used in the experiment, so that a varying reactance is loaded, leading to the movement of resonant points, especially for the highest one. Note also that increase of the major axis a mainly decreases the lowest resonant frequency and slightly influences the highest resonant frequency, resulting in broadening of the impedance bandwidth. However, as the major axis a increases to 180 mm, the impedance bandwidth is decreased. Therefore the major axis is assumed to be

$a = 120$ mm. Then the measured lowest operating frequency is about 410 MHz, and thus the area of the test antenna is about $0.19\lambda_l \times 0.16\lambda_l$, where the measured highest frequency for VSWR ≤ 2 is 8.86 GHz; the measured ratio impedance bandwidth then reaches 21.6:1.

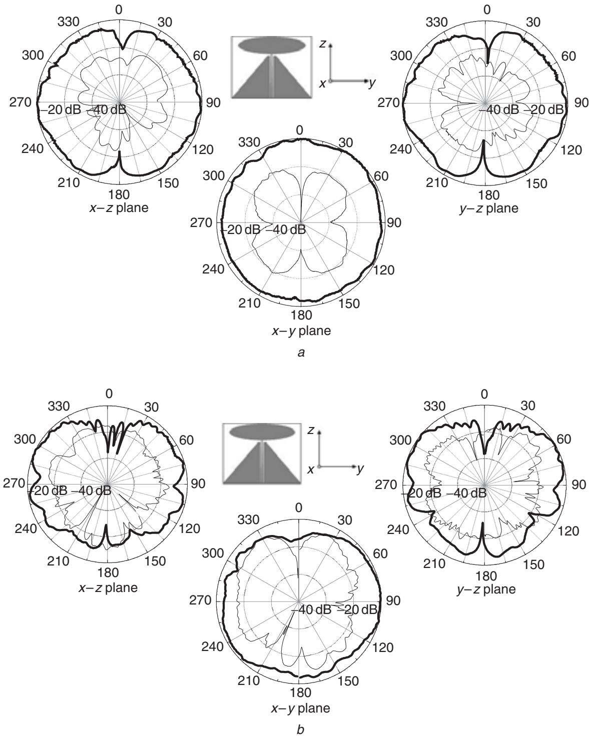

Fig. 3 *Measured radiation patterns*

a $f = 1$ GHz
b $f = 6$ GHz
——— co-pol
——— cross-pol

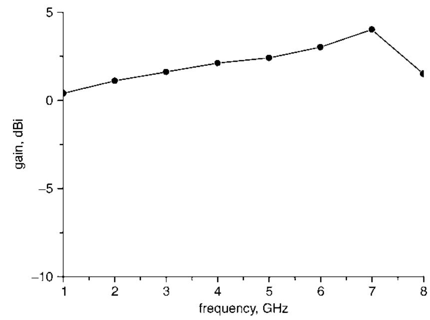

Fig. 4 *Measured gain*

The radiation patterns of the elliptical monopole antenna were measured in an anechoic chamber over the entire impedance bandwidth. For brevity, Fig. 3 only gives the measured radiation patterns at 1.0 and 6.0 GHz. It is seen that this antenna has nearly omnidirectional radiation characteristics, while the cross-polarisation level rises with frequency increase owing to the horizontal components of the surface currents. The measured gain in the broadside direction at 1–8 GHz is shown in Fig. 4. Up to 7 GHz, the antenna gain monotonically increases from 0.4 to 4.0 dBi, and then decreases to 1.5 dBi as the frequency increases further.

Conclusions: A novel EWB elliptical planar monopole antenna is presented. By combining three techniques, an elliptical monopole patch, a trapeziform ground plane and a tapered CPW feeder, the elliptical monopole antenna has achieved a measured ratio bandwidth of 21.6:1 for VSWR ≤ 2 and exhibited a nearly omnidirectional radiation pattern, while its area is only about $0.19\lambda_l \times 0.16\lambda_l$. The simulated results agree with the experimental ones, confirming the validity of the design. This antenna has a simple structure, thin profile and low cost, and therefore it will be an attractive candidate for various military and civil EWB applications.

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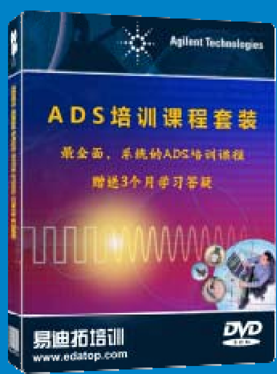

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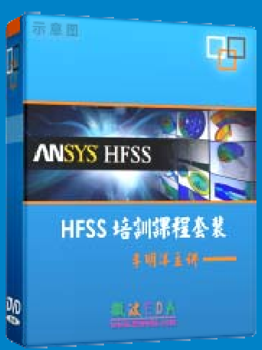

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