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# UWB planar antenna technology

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**Abstract** Recent developments of the ultra-wideband (UWB) planar antennas are reviewed, where the progress in UWB plate monopole antennas, UWB printed monopole antennas and the UWB printed slot antennas is introduced and compared. In addition, the UWB printed antennas with the band-notched functions are also presented.

**Keywords** planar antenna, ultra-wideband (UWB), printed monopole, printed slot, coplanar waveguide (CPW)

## 1 Introduction

The ultra-wideband (UWB) antenna is a key component of electronic counterwork equipment in the electronic information warfare, which is also widely used in the time domain systems such as impulse radars, etc. With the development of high-speed integrated circuits and the requirement of the miniaturization and integration, the research and application of UWB planar antennas have been growing rapidly. On February 14, 2002, the Federal Communications Commission (FCC) of the United States allocated the 3.1–10.6 GHz spectrum for commercial application of UWB technology, which has sparked renewed attention in the research of ultra-wideband planar antennas. It is worth noting that the actual frequency range used of an indoor UWB communication antenna in the provision of UWB technology is from 3.1 to 10.6 GHz with a ratio bandwidth of 3.4:1, while the antenna with a ratio bandwidth not less than 10:1 is generally called the

super-wideband (SWB) antenna in antenna engineering. Both types are reviewed in this paper. In the UWB system, the former operates just like a kind of pulse figuration filter, which requires the antenna to radiate pulses without distortion. To that end, the UWB antenna should not only possess an ultra-wide impedance bandwidth, but also have good phase linearity and an omni-directional pattern. Hence, for this sort of UWB antenna some particular considerations are entailed [1], which shall not be included in this work.

The earliest antenna with wideband properties is the biconical antenna made by Lodge in 1898. It can be regarded as a uniformly tapered transmission line excited by TEM mode to possess the ultra-wideband input impedance characteristics. Its bandwidth is mainly influenced by the ending reflection due to its limited dimensions. Following improvements consists of Carter's improved match biconical antenna and conical monopole antenna (1939), Schelkunoff's spheroidal antenna (1941), Kandoian's discone antenna (1945), Brillouin's omni-directional and directional coaxial horn antenna (1948), etc [2]. All these antennas are based on three-dimensional structures with bulky volume. In the late 1950s and early 1960s, a family of antennas with more than 10:1 bandwidth ratio was developed by V. Rumsey et al., which was called frequency-independent antenna [3]. Classical shapes of such antennas basically include the equiangular spiral antenna and the planar log-periodic dipole antennas. These designs reduce the volume, but the transfer of effective radiating region for different frequencies results in waveform distortion in transmitting pulse. Since the early 1970s, many new-style ultra-wideband planar antennas have been proposed, which can be summed up as three types, namely UWB planar metal-plate monopole antennas, UWB printed monopole antennas and UWB printed slot antennas, which are introduced in order in the remaining parts.

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## 2 UWB metal-plate monopole antennas

The wideband metal-plate monopole antenna was first proposed by G. Dubost in 1976 and was continuously developed [4]. Its impedance bandwidth has been broadened by

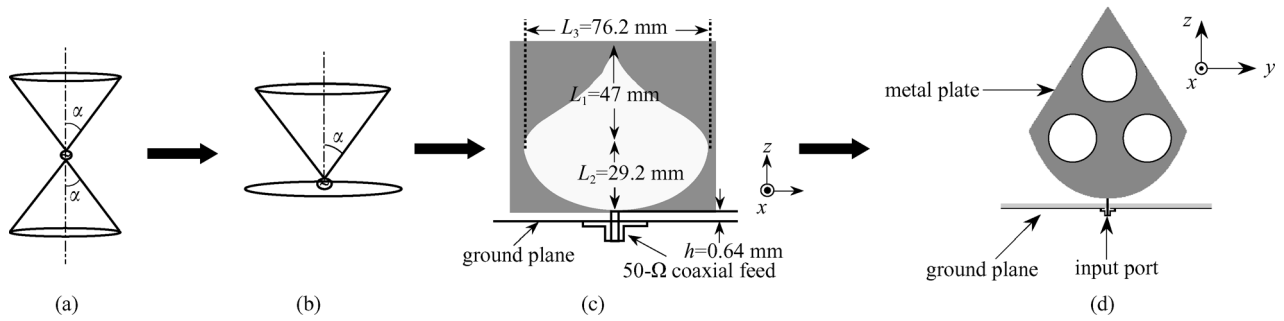


Fig. 1 Evolution from biconical antenna to metal-plate monopole antenna

optimizing the structure of the metal-plate monopole, such as discs or elliptical monopole antenna [5], trapezium monopole antenna [6], inverted cone monopole and leaf-shaped planar plate monopole antennas and so forth, as shown in Fig. 1. The planar inverted cone antenna (PICA) designed by S. Y. Suh, as shown in Fig. 1(c) [7], provides an impedance bandwidth ratio of more than 10:1, and a radiation pattern bandwidth of 4:1. The one with two circular holes has extended the radiation pattern bandwidth due to the effective changing of its surface current. In the author's laboratory, another leaf-shaped plate monopole antenna with three circular holes was developed, as shown in Fig. 1(d) [8]. It achieves an impedance bandwidth ratio better than 20 : 1, covering the frequency ranging from 1.3 to 29.7 GHz. As is well known, the rectangular metal-plate monopole antenna is a wideband metal-plate monopole antenna with the simplest structure and a steady radiating pattern, but its impedance bandwidth is only about 2 : 1 in the early period. In order to realize the ultra-wideband properties, many methods have been brought forward, such as using an offset feed, double or three feeds, shortening post with beveling technique, etc. P. V. Anob improved its impedance bandwidth to 6 : 1 by changing the location of the feeding [9]. M. J. Ammann widened the bandwidth to 10 : 1 (VSWR  $\leq 3$ ) by combining the short post and beveling technique [10], as shown in Fig. 2. Some designs, such as double or three feeds [11], not only consumedly widen the impedance bandwidth, but also improve the stability of radiation pattern. The ultra-wideband metal-plate monopole antennas always need a perpendicular metal ground plane.

### 3 UWB printed monopole antennas

The UWB printed monopole antenna consists of a monopole patch and a ground plane, both printed on the same or opposite side of a substrate, while a microstrip line or coplanar waveguide (CPW) is located in the middle of the ground plane to feed the monopole patch. Compared with the ultra-wideband metal-plate monopole antenna, the UWB printed monopole antenna does not need a perpendicular ground plane. Therefore, it is of smaller volume

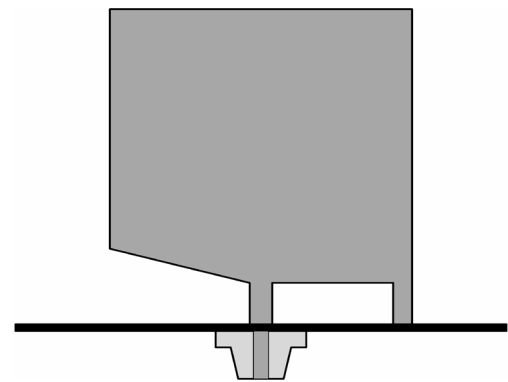


Fig. 2 Metal-plate monopole antenna with short post

and is suitable for integrating with monolithic microwave integrated circuits (MMIC). To broaden the bandwidth of this kind of antennas, a number of monopole shapes have been developed, such as heart-shape, U-shape, circular-shape and elliptical-shape, etc. A circular printed monopole antenna designed by J. Liang and L. Guo, as shown in Fig. 3(a) [12], possesses a ratio impedance bandwidth of  $S_{11} \leq -10$  dB exceeding 5.3 : 1, with the frequency range from 2.27 to 12 GHz or above. The UWB printed monopole antenna designed by J. H. Jung [13], as shown in Fig. 3(b), has a trapezium transition in the monopole patch and a rectangle slot in its ground plane, equivalent to adding a matching network between the patch and the ground plane, thereby broadening the antenna bandwidth. It covers the frequency range 3.1–11 GHz with a mere size of 16 mm  $\times$  18 mm. A printed elliptical monopole antenna designed by C. Y. Huang [14] also uses a rectangular slot in the ground plane to widen the bandwidth. The circular printed monopole antenna with an annulus, as shown in Fig. 4, possesses  $S_{11} \leq -10$  dB from 2.127 to 12 GHz [15]. All these designs are fed by a microstrip line. In the meantime some printed monopole antennas fed by CPWs have been developed too, as shown in Fig. 5 [16,17]. The ratio bandwidth of the aforementioned antennas are mostly about 3–7 : 1. Based on the idea to plate the disccone antenna, our group has developed a new type of modified printed monopole antennas with super-wide bandwidth, as shown in Figs. 6(a) and 6(b), which consists of a monopole patch and a trapeziform ground plane with a

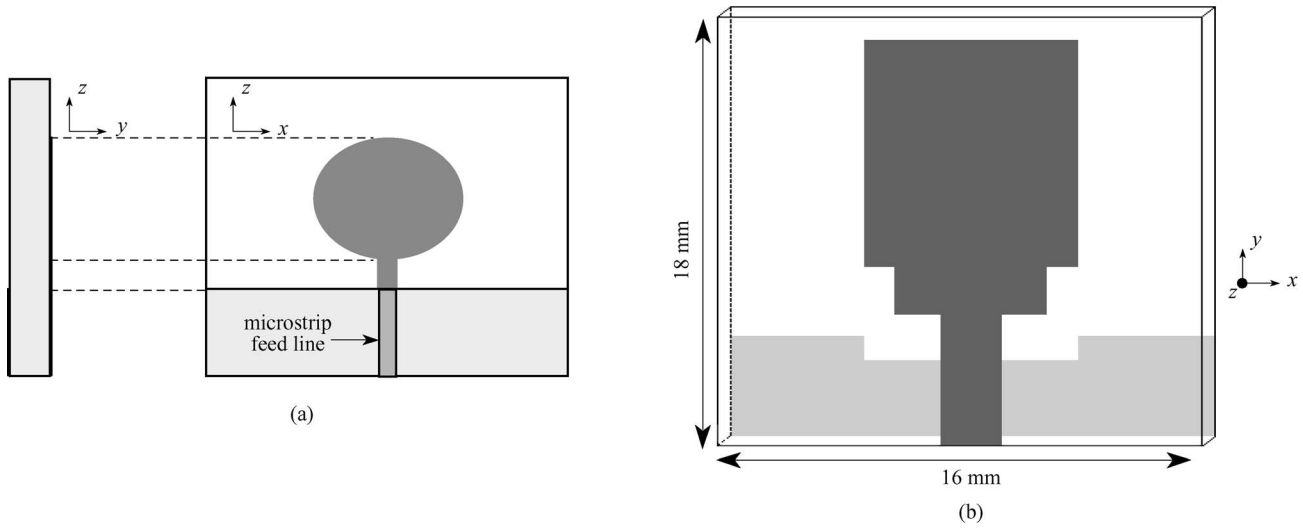


Fig. 3 Microstrip-fed printed monopole antennas

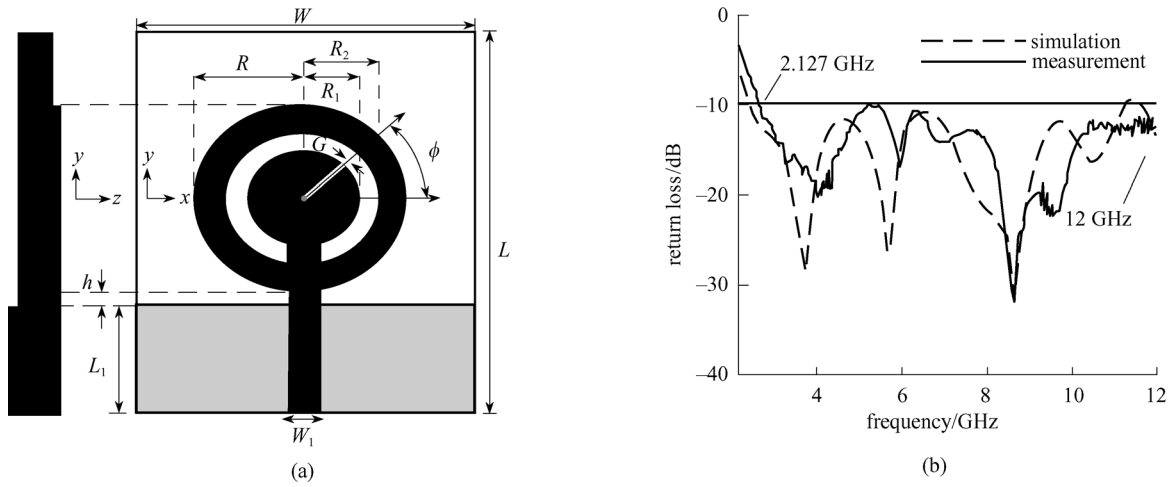


Fig. 4 Printed circular monopole antenna with an annulus

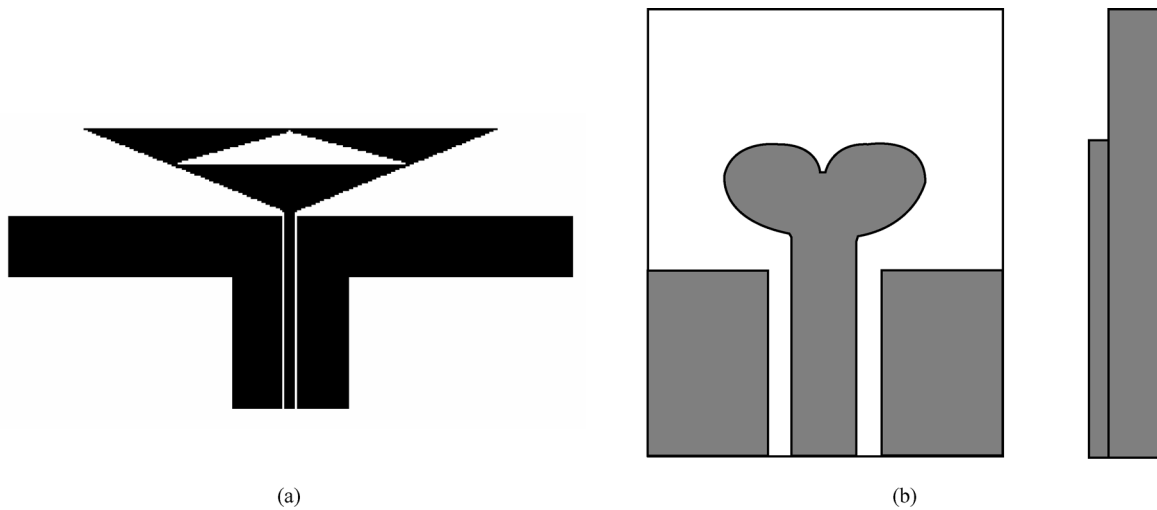


Fig. 5 Printed CPW-fed monopole antennas

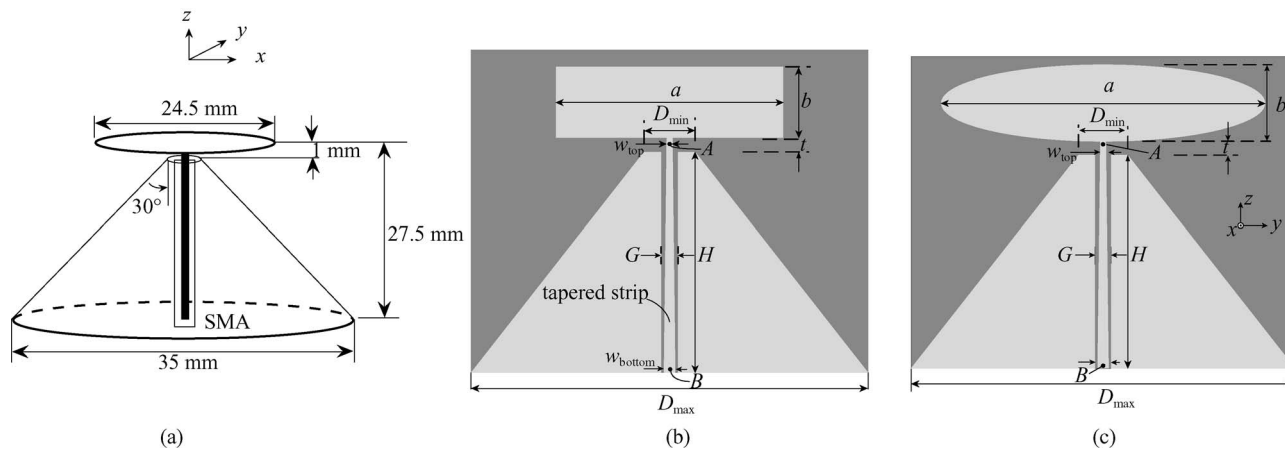


Fig. 6 UWB printed monopole antennas with trapeziform ground plane

tapered CPW feeder in the middle, achieving an impedance bandwidth ratio that exceeds 10 : 1 [18–21]. To have wider bandwidth, we have changed the rectangular patch to an elliptical patch and optimized the dimension, as shown in Fig. 6(c) [22]. This antenna achieves a measured impedance bandwidth exceeding 21 : 1, covering the frequency range from 0.41–8.86 GHz, with good omni-directional radiation characteristics and gain, as shown in Fig. 7.

#### 4 UWB printed slot antennas

A kind of tapered slot antenna with planar structure, which was called the Vivaldi antenna, was proposed by P. J. Gibson [23] in 1979. This antenna has a wide bandwidth and a medium gain, but as an end-fire antenna, its longitudinal dimension is large. Its impedance bandwidth is inherently limited by the microstrip-to-slotline

transition. A printed two-side-antipodal exponential tapered slot antenna proposed by E. Gazit [24] has resolved the transition problem, though with a relatively higher cross-polarization level. Later, the balanced antipodal Vivaldi tapered slot antenna introduced by J. D. S. Langley [25], as shown in Fig. 8(a), restrained the cross-polarization to be less than  $-17$  dB, with a ratio bandwidth of 15 : 1, covering frequencies from 1.3–20 GHz. Figure 8(b) is a dual tapered UWB design using coplanar waveguide feeding [26].

In recent years, many researches have been engaged in the printed wide-slot antenna and have realized the ultra-wideband property through a combination of changing the slot shape and using different feeding structures. Figure 9 shows two kinds of printed wide-slot antennas with different feeding structures. In Fig. 9(a) the wide-slot antenna is fed by a cross-shaped feeding with a cross-shaped stub at the end instead of the common opened microstrip feeder, which is equivalent to introducing a

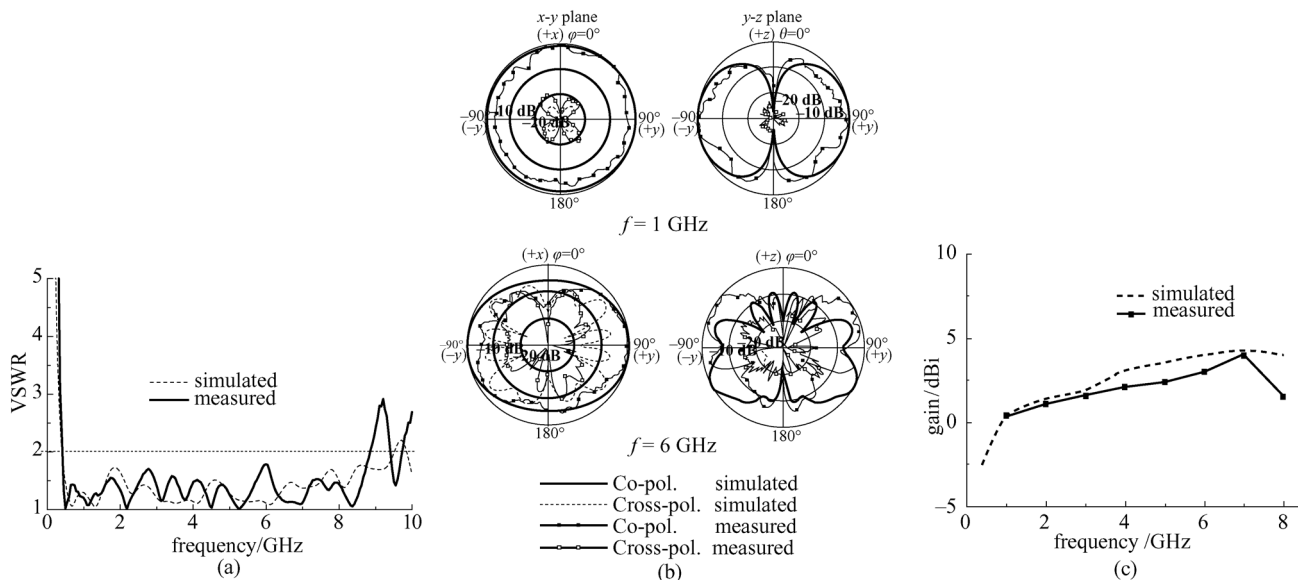


Fig. 7 Simulated and measured VSWR, radiation patterns and gain of the Fig. 6(c) antenna

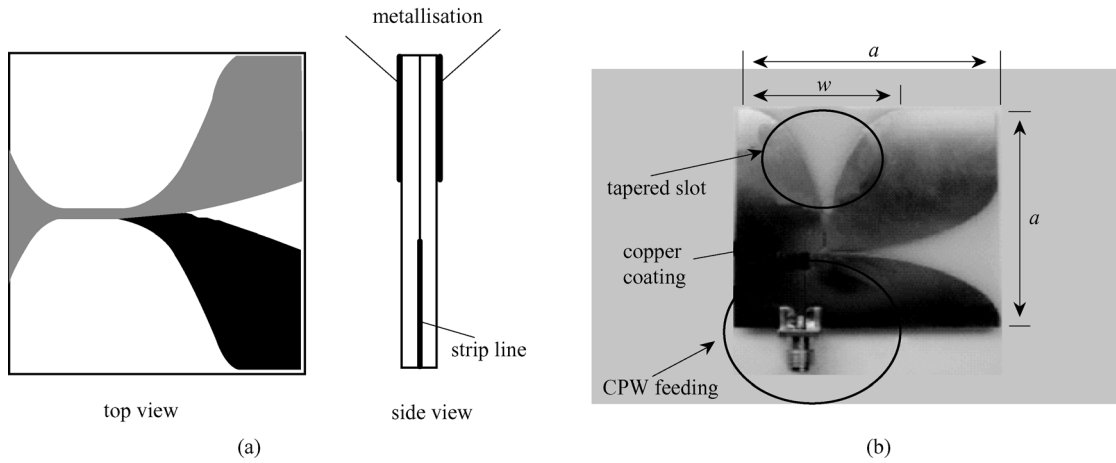


Fig. 8 Printed tapered slot antennas

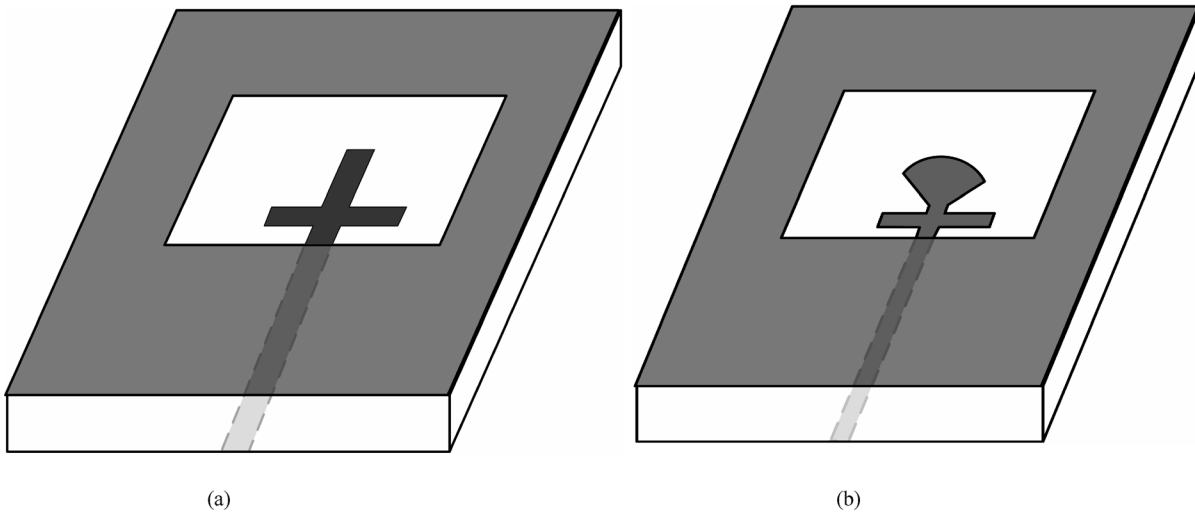


Fig. 9 Microstrip-fed rectangular slot antennas

resonance circuit and hence resulting in an impedance bandwidth of 98% [27]. The slot antenna fed by a fan-shaped stub together with a strip line proposed by our

lab, as shown in Fig. 9(b), has achieved a bandwidth of 114% by optimizing the length of the stub and the size of the fan-shape [28,29]. Figure 10 shows two

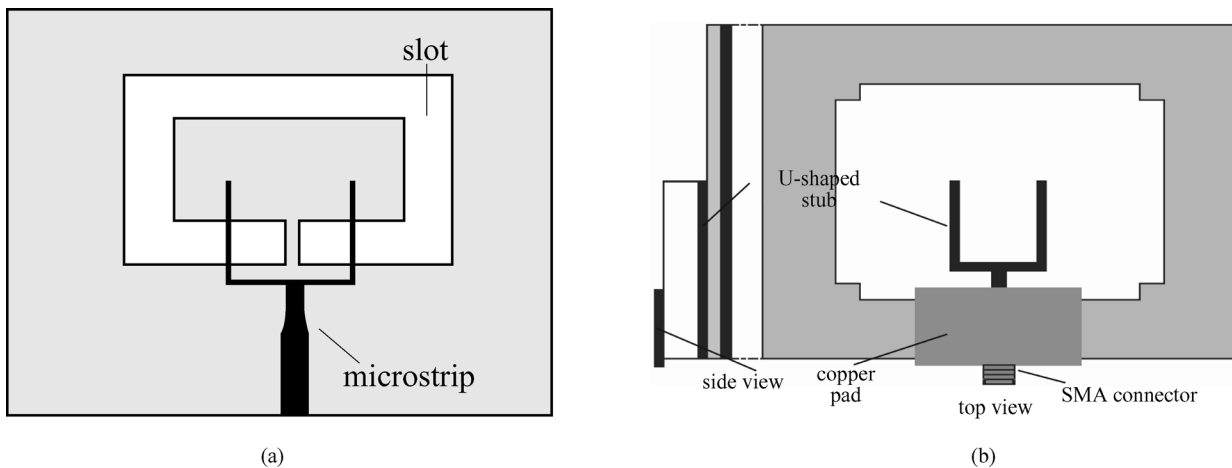


Fig. 10 U-shaped microstrip-fed printed slot antennas

printed slot antennas using U-shaped microstrip feedings. Figure 10(a) adds a rectangular patch in the middle of the rectangular slot and connect it with the ground plane to achieve a measured impedance bandwidth of 111% [30]. In Fig. 10(b), by adding a rectangular copper sheet in one side of the microstrip to adjust the port impedance of the antenna, its impedance bandwidth extends to 135.7%, covering frequencies 2.3–12 GHz [31].

The printed wide-slot antenna also has been designed to use various shapes of the guide strip terminal of its CPW feeder to excite the slot, and accordingly obtain the broadening of its impedance bandwidth. The antenna shown in Fig. 11(a) achieves an impedance bandwidth about 114% [32], whose CPW terminal is a rectangular patch with a concave gap. The elliptical slot antenna with an elliptical patch as its feed, as shown in Fig. 11(b), widens the impedance bandwidth to 175%, covering frequencies from 1.3 to 20 GHz or above with a ratio bandwidth of about 15 : 1 [33].

Another type of printed slot antenna is the printed bow-tie slot antenna, as shown in Fig. 12, which has the virtue of simple configuration, wider bandwidth, lower cross-polarization level and higher gain.

Figure 12(a) was designed at our lab, which widens the impedance bandwidth by using a linearly tapered slot at the joint of the coplanar waveguide and the bow-tie slot [34]. In Fig. 12(b) a small bow-tie slot is added under the bow-tie slot antenna, and excited by the coupling of the coplanar waveguide. In addition, a tapered coplanar waveguide feeder is applied, so that the antenna achieves an impedance bandwidth of 123% [35].

A comparison of the main performances of several UWB planar antennas is listed in Table 1. It is noted that UWB printed monopole antennas have dimensions close to those of UWB plate monopole antennas, whereas without a perpendicular metal ground plane. For example, a printed elliptical monopole antenna with a trapezium ground plane has the dimension of only  $0.19 \times 0.16 \lambda_f^2$ ,

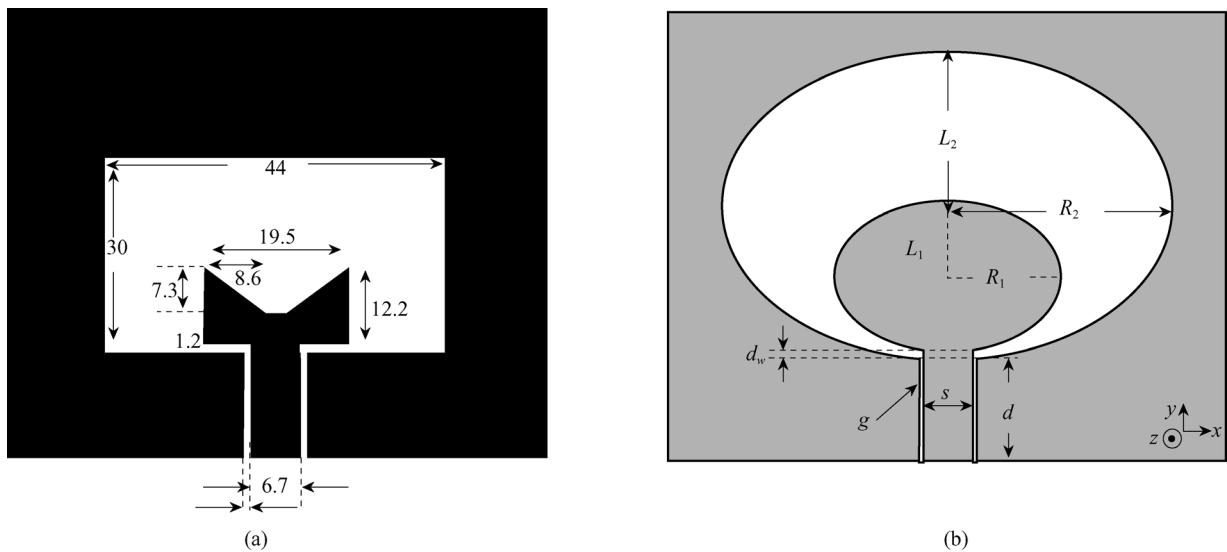


Fig. 11 CPW-fed printed wide-slot antennas

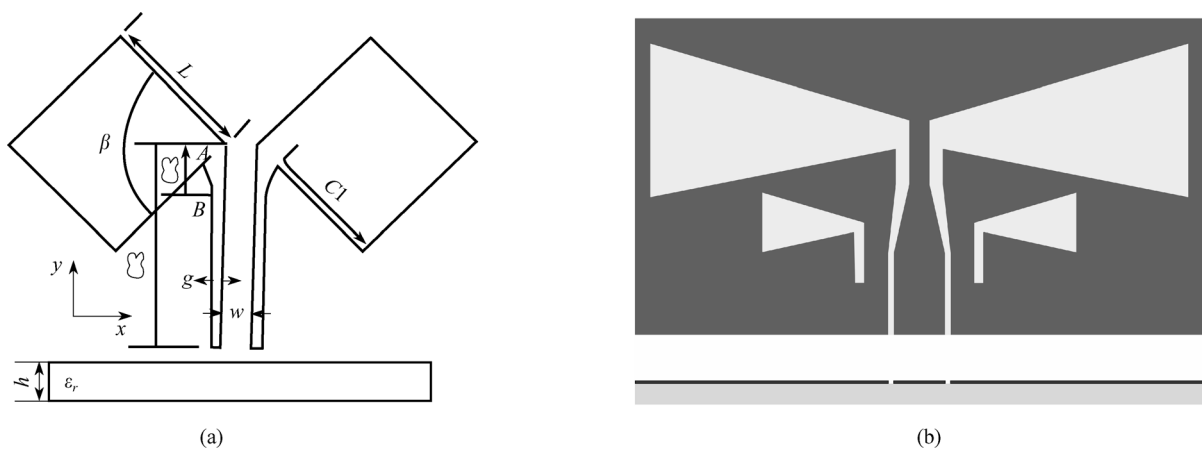


Fig. 12 CPW-fed bow-tie printed slot antennas

**Table 1** Comparison of UWB planar antennas

No.	antenna type	bandwidth/GHz (VSWR ≤ 2)	ratio bandwidth (VSWR ≤ 2)	gain/dBi	size/(λ <sub>l</sub> <sup>2</sup> )
1	trapezoidal metal plate monopole [ 6]	1.07–12.2	11.4 : 1	0.5–4.5	0.89 × 0.89*
2	planar inverted cone antenna [7]	1–10	10 : 1	0.3–8.6	0.25 × 0.25
3	fan-shaped plate monopole [8]	1.3–29.7	22.8 : 1	3–5	0.35 × 0.35
4	circular monopole with a trapeziform ground plane [20]	0.79–9.16	11.6 : 1	0.8–4.1	0.37 × 0.24
5	rectangular monopole with a trapeziform ground plane [21]	1.76–8.17	10.7 : 1	0.65–4.2	0.35 × 0.30
6	elliptical monopole with a trapeziform ground plane [22]	0.41–8.86	21.6 : 1	0.4–4	0.19 × 0.16
7	tapered slot antenna [26]	1.3–20	15.4 : 1	3.2–9	0.43 × 0.32
8	printed elliptical slot antenna [33]	1.3–20	15.4 : 1	-----	0.39 × 0.39

\* Ground plane dimension

where λ<sub>l</sub> is the wavelength of the lowest operating frequency, and an impedance bandwidth of 21.6 : 1. UWB printed slot antennas possess a relatively higher gain compared with the other two types of UWB antennas, and a relatively larger size.

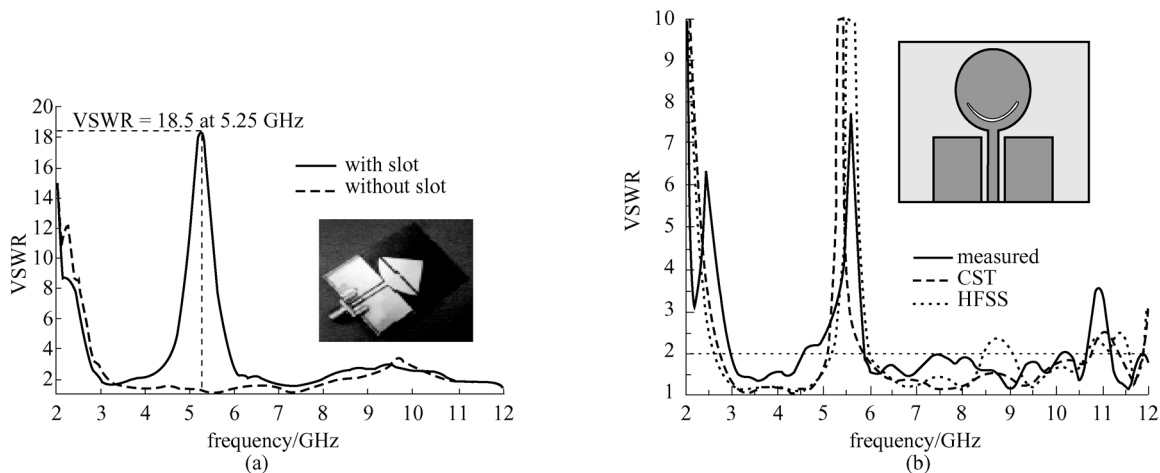
### 5 UWB band-notched planar antennas

To avoid interference between the UWB system and the wireless local area network (WLAN) 802.11a system with 5.15 to 5.825 GHz frequency band, a band-notch filter in the UWB system is needed. To avoid adding filters and possible interference with existing WLAN systems, UWB antennas with band-notched characteristics have been developed. The sail-boat antenna, as shown in Fig. 13(a), achieves UWB property by using an inverse taper planar patch, and forms the band-notch function near the 5 GHz frequency by cutting two slots in the patch, which possesses a bandwidth of 3–11 GHz for VSWR ≤ 2 except frequencies neighboring 5.2 GHz [36]. A UWB circular disc monopole antenna designed by our lab, as shown in

Fig. 13(b), provides the band notched function by inserting an arched slot in the circular monopole patch [37]. The antenna of Fig. 14 achieves the wide bandwidth property by using a step-shape taper in the pear-shape monopole patch, thus forming the band-notch function by introducing two parasitic printed patches [38].

### 6 Conclusions

The recent progress in the development of UWB planar antenna technology has been reviewed. Some types of UWB metal-plate monopole antennas, UWB printed monopole antennas and UWB printed slot antennas are presented. The comparison results indicate that the UWB printed monopole antennas can realize relatively smaller dimensions, and that the UWB printed slot antennas can achieve relatively higher gain. Finally, some realization manners for the band-notch function of UWB printed monopole antennas have been introduced. Along with the wide application of the UWB technology, compact UWB antennas will achieve further development.



**Fig. 13** UWB printed monopole antennas with band-notch function

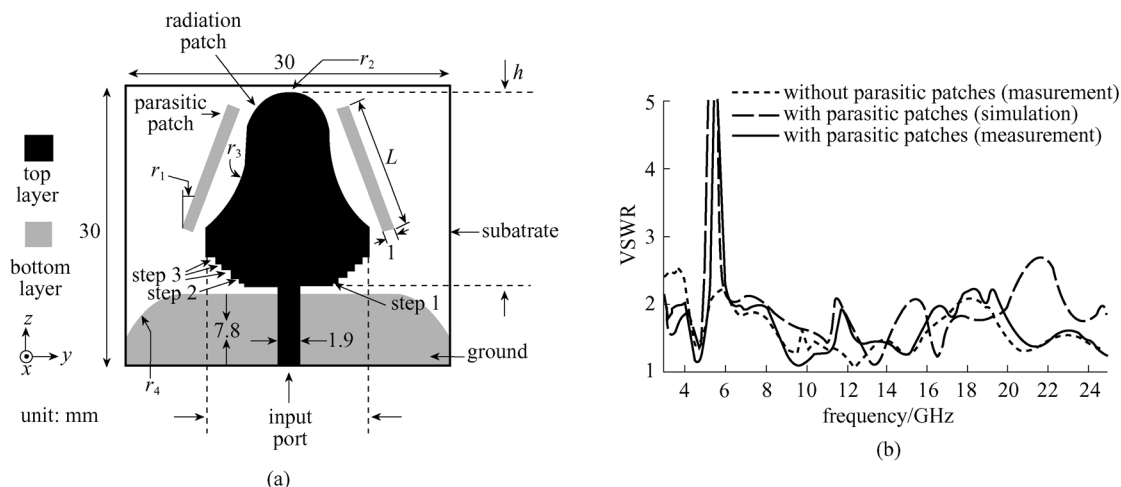


Fig. 14 UWB printed monopole antenna with two parasitic patches

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