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Wideband Planar Printed Quasi-Yagi Antenna with Band-Notched Characteristic

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Abstract—A wideband planar printed quasi-Yagi antenna with band-notched characteristic is presented. The proposed antenna consists of a microstrip-to-slotline transition structure, a gradient driver dipole, and two parasitic strips as directors. Meanwhile, the arms of the driver and two directors are rotated in a certain angle to improve the gain. To avoid the frequency interference from WLAN operating in the frequency band from 5.15 GHz to 5.825 GHz, an L-shape slot etched on the driver dipole is adopted to achieve a notched band ranging from 4.8 GHz to 6.1 GHz. The ground plane is symmetrically added two stubs to implement the lateral size reduction. The measured bandwidth, determined by the reflection coefficient less than −10 dB, covers from 3 GHz to 10.8 GHz. Better than 8.1 dB F/B ratio and the measured antenna gain varying between 4.7 and 8.3 dBi are also achieved in the operating bandwidth excepting in the notched band.

1. INTRODUCTION

With the growing demands of modern wireless communication applications, the planar printed quasi-Yagi antennas have drawn much interest because of their low profile, light weight, ease of fabrication, and compatibility with printed circuitry [1]. Since the microstrip-fed quasi-Yagi antenna was introduced in 1991 [2], various quasi-Yagi antennas have been designed.

To achieve a wide bandwidth of planar printed quasi-Yagi antennas, many techniques have been developed in [3–9]. In the design of [3], a microstrip-to-coplanar stripline (CPS) is used in the quasi-Yagi antenna to increase the bandwidth, but the structure of the antenna is relatively complicated. A quasi-Yagi antenna fed by coplanar waveguide is proposed in [4]. Although the realized bandwidth is about 44% covering X-band, the asymmetric nature of the antenna degrades the radiation patterns. In [5], C-shape reflector is used to improve the bandwidth. Although the bandwidth is improved significantly, the size of the proposed antenna is too large. A modified bowtie driver is used in the quasi-Yagi antenna design for increasing the antenna bandwidth [6]. However, the size of the quasi-Yagi antenna is too large, and the width of the ground plane is larger than the length of the bowtie driver. CPS-fed and wideband balun feeding structures are also designed in planar quasi-Yagi antennas to realize a wide bandwidth [7, 8]. A wideband dipole quasi-Yagi antenna is presented in [9]. However, the bandwidth is restricted by the narrowband delay line adopted in the antenna structure.

By now, UWB technique has become the first candidate of short-range high-speed wireless communication systems. Also, some other narrowband systems such as the worldwide interoperability for microwave access (WiMAX), and the wireless local area network (WLAN) must be rejected to avoid interference to the UWB applications, so the UWB antenna with a band-notched characteristic is needed. Various methods are developed to realizing notched band. In [10], a rectangular notch embedded above the slot antenna is used to implement the band notched function. However, the notched band from 4.85 GHz to 5.50 GHz does not cover the entire band of WLAN or WIMAX. A U-shape slot in the radiating patch is used to achieve the notched band from 5.1 to 6.2 GHz [11]. However, the gain

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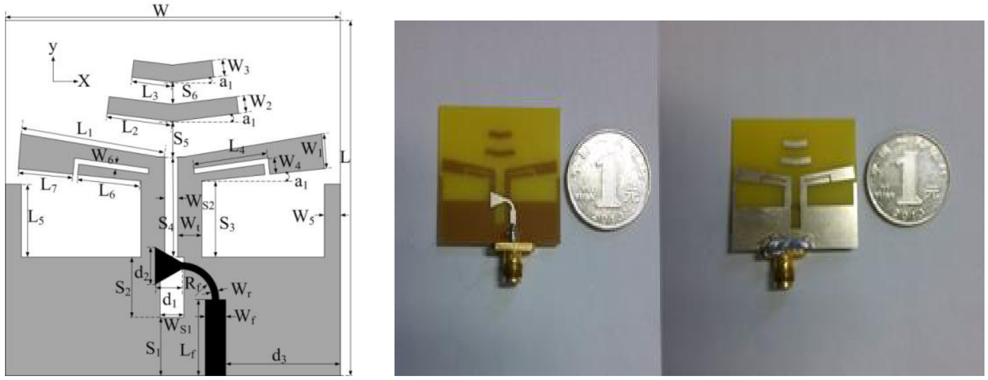
of the proposed antenna is relatively low at the operating frequency. In [12], a parasitic inverted-U strip is presented to reject the limited frequency band by IEEE 802.11a (5.15–5.85 GHz). Although the proposed antenna has a wide bandwidth and good radiation patterns, its size is too large. In [13], a notched band is achieved by slots added on the back-face "petals". However, the structure of the proposed antenna is complex.

In this letter, a planar printed quasi-Yagi antenna based on a microstrip-to-slotline transition structure is proposed. Compared with conventional quasi-Yagi antennas, the proposed antenna lateral size is reduced by symmetrically adding two stubs on the ground [14]. A notched band from 4.8 GHz to 6.1 GHz is implemented by L-shape slot etched on the driver dipole element. Gain is significantly improved by rotating the driver dipole and two parasitic strips compared with the antenna in [14]. Good experimental results indicate that this antenna has good performance.

2. ANTENNA DESIGN AND DISCUSSION

A three-dimensional EM-simulator (Ansoft HFSS) is used to design the proposed antenna. The geometry and photograph of the proposed planar antenna is shown in Figure 1. The antenna is printed on a low-cost FR4 glass epoxy substrate with a thickness of 0.8 mm, a dielectric constant of 4.4 and a loss tangent of 0.02. The size of the substrate is 35 mm × 34 mm ($W \times L$). The proposed antenna consists of a microstrip-to-slotline transition structure, a gradient driver dipole and two parasitic strips as directors. The driver dipole and the parasitic strips are printed on the bottom layer of the substrate and the microstrip feeding line is printed on the top layer of the substrate. The driver dipole is directly connected to the slotline with a CPS. According to principle of the Yagi antenna, the arm lengths (L_1, L_2, L_3) of driver dipole and directors are approximately equal to $0.25\lambda_g$ (λ_g is the operating wavelength in the substrate) at 4 GHz, 7 GHz and 9 GHz, respectively. The distance between driver dipole and directors (S_5, S_6) is chosen to be 0.1 to $0.25\lambda_{gc}$ (λ_{gc} is the operating wavelength of the center operating



(a) (b)

Figure 1. Geometry and photograph of the proposed planar printed quasi-Yagi antenna. (a) Geometry. (b) Photograph.

Table 1. optimized design parameters of the proposed antenna (unit: mm).

L_1	L_2	L_3	L_4	L_5	L_6	L_7	W_1	W_2	W_3
16	4.5	3.5	7.5	6	6.5	6.7	3.3	1.6	1.6
W_4	W_5	W_6	W_t	W_{S1}	W_{S2}	W_r	W_f	R_f	L_f
3	1	0.5	2	2.7	2.4	0.7	1.5	1.1	8.5
d_1	d_2	d_3	S_1	S_2	S_3	S_4	S_5	S_6	a_1
4	4	12.5	5.2	5.7	5.2	7.8	3	3	7 deg

frequency in the substrate). The distance (S_3) between the ground and driver dipole is chosen to be 0.2 to $0.35\lambda_{gc}$ to improve impendence matching performance. In order to get a good impedance matching, a tapered microstrip stub at the end of the microstrip line is adopted. The width of the microstrip feeding line is fixed at 1.5 mm to achieve 50-Ω characteristic impedance. The optimized design parameters are shown in Table 1.

The bandwidth performance of this proposed antenna is measured by the Anritsu 37269A vector network analyzer. A good agreement is obtained between the simulated and experimental results. Figure 2 shows the simulated and measured results of the reflection coefficient of the proposed antenna. The measured bandwidth for reflection coefficient less than −10 dB is from 3 GHz to 10.8 GHz. A notched band is achieved from 4.8 GHz to 6.1 GHz.

Figure 3 shows the reflection coefficient of the antenna as a function of the arm length (L_1) of the driver dipole. As the arm length (L_1) increases from 13 to 15 mm in increments of 1 mm, it can be seen that the lowest operating frequency moves to the lower frequency, which shows that the arm length of the driver dipole determines the lower resonant frequency of the antenna. So, increasing L_1 appropriately can broaden the bandwidth of the proposed quasi-Yagi antenna.

The director works as a parasitic element, realizing the function of adjusting the input impedance at high frequency band. Figure 4 shows the reflection coefficient varying with the arm length (L_2) of the director. As the arm length (L_2) increases from 3.5 to 4.5 mm in increments of 0.5 mm, the impedance

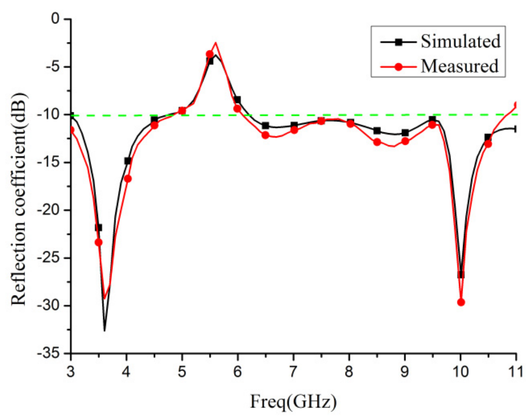


Figure 2. Simulated and measured reflection coefficients of the proposed antenna.

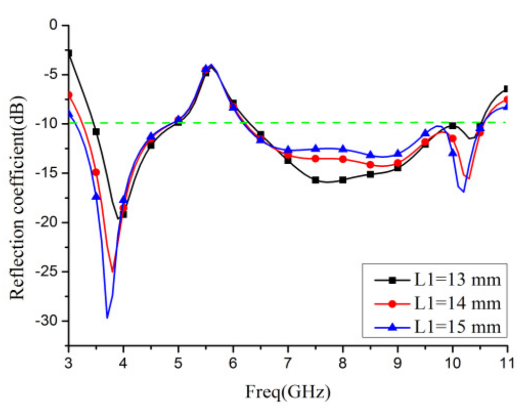


Figure 3. Simulated reflection coefficients of the proposed antenna with different the arm length (L_1) for the driver dipole.

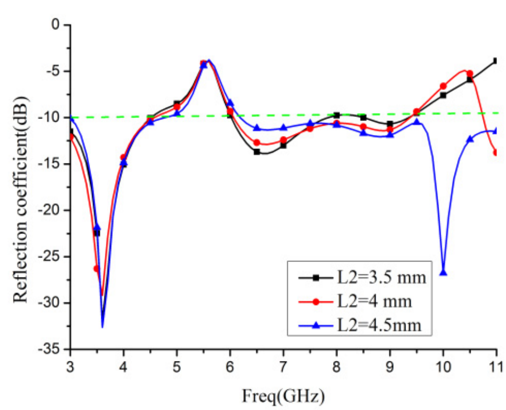


Figure 4. Simulated reflection coefficients of the proposed antenna with different the arm length (L_2) for the director.

matching performance is improved, which indicates that the length of the director is a significant factor in determining the impedance matching at high frequency band.

The coplanar stripline is usually used to connect the slotline and the driver dipole. A stepped connection structure between the CPS and the slotline is employed to improve the impedance matching. The effect of gap (W_{S2}) between the striplines of the CPS is studied to illustrate the impedance matching with respect to the gap (W_{S2}). As shown in the Figure 5, as W_{S2} increases from 2.4 to 3.4 mm in increments of 0.5 mm, the reflection coefficient increases significantly at the higher resonant frequency. This indicates that the gap size is of great importance for broadband impedance matching of the antenna.

By inserting an L-shaped slot in the driven dipole, the current distribution on patch at 5.6 GHz is mainly concentrating around L-shaped slot, which results in impedance mismatching, so the band-notched characteristic is achieved. The length of the slot is determined by Equation (1):

$$L_4 + W_4 = \frac{c}{4 f_{notch} \sqrt{\varepsilon_{eff}}} \tag{1}$$

In (1), c is the speed of light, f_{notch} is the center frequency of the required notch band and ε_{eff} is defined as the effective dielectric constant of structure. In this design, f_{notch} is set to be 5.6 GHz. The effect of the L-shape slot length (L_4) on band-notched performance of the antenna is investigated

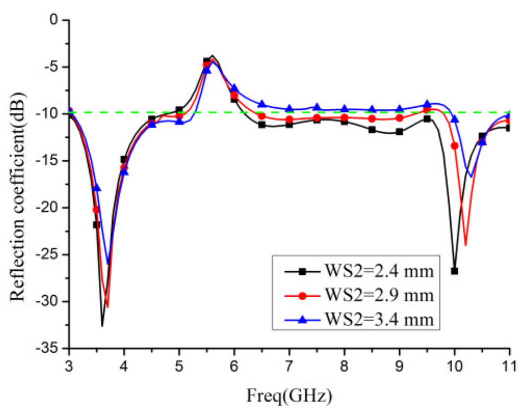


Figure 5. Simulated reflection coefficients of the proposed antenna with different gap (W_{S2}).

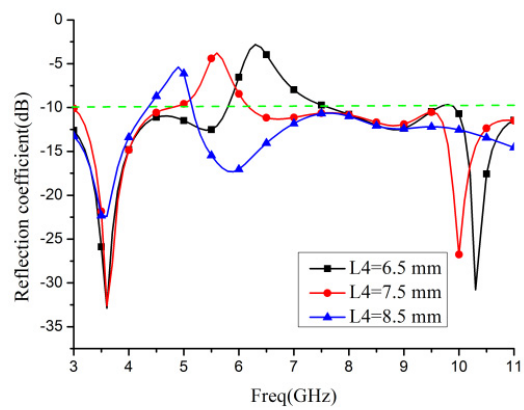


Figure 6. Simulated reflection coefficients of the proposed antenna with different L-shape slot length (L_4).

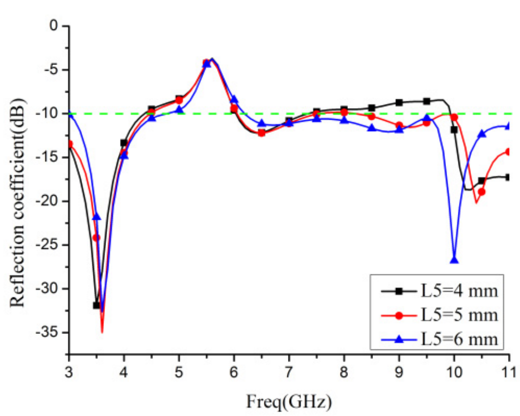


Figure 7. Simulated reflection coefficients of the proposed antenna with different stub length (L_5).

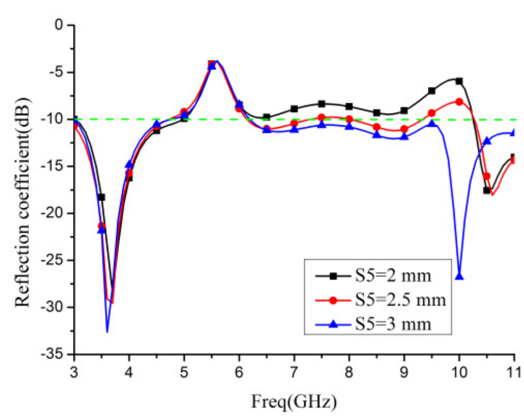


Figure 8. Simulated reflection coefficients of the proposed antenna with different the distance (S_5).

in detail. As shown in Figure 6, the parameter L_4 affects the resonant frequency dramatically. As the length (L_4) of the L-shape slot increases from 6.5 to 8.5 mm in increments of 1 mm, the central frequency of notched band decreases. Obviously, the L-shape slot length (L_4) is a significant factor in determining the band-notched characteristics. A good notched band is achieved from 4.8 GHz to 6.2 GHz when L_4 and W_4 are equal to 7.5 mm and 3.5 mm, respectively.

For the conventional printed quasi-Yagi antenna, the lateral length of the ground plane as a reflector is larger than that of the driver dipole for achieving good radiations. Reducing the lateral size of the ground plane will decrease the electrical size of the ground plane, in order to remedy the defect, two stubs

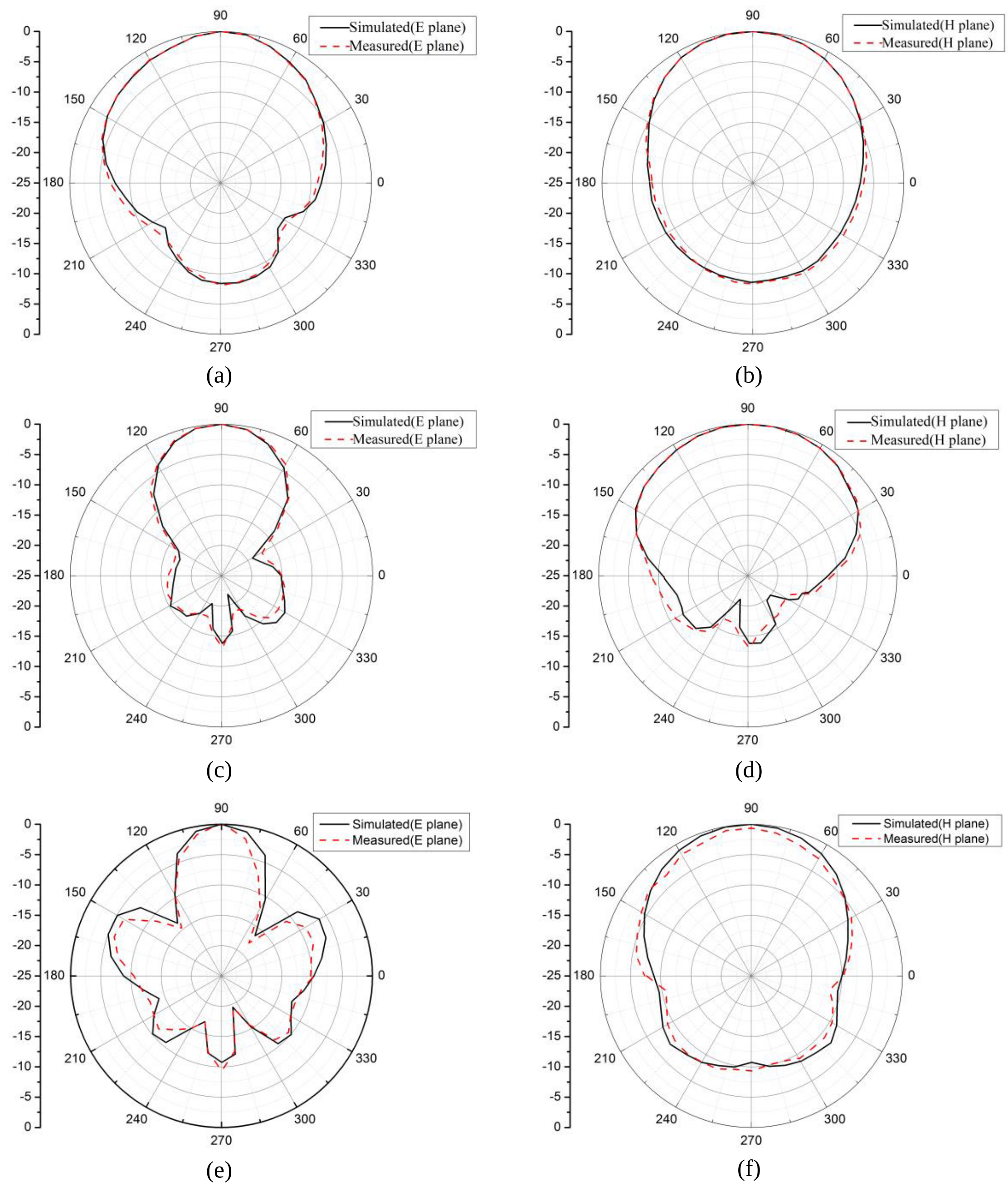


Figure 9. Simulated and measured radiation patterns of the proposed antenna at (a), (b) 4 GHz, (c), (d) 7.5 GHz and (e), (f) 10 GHz.

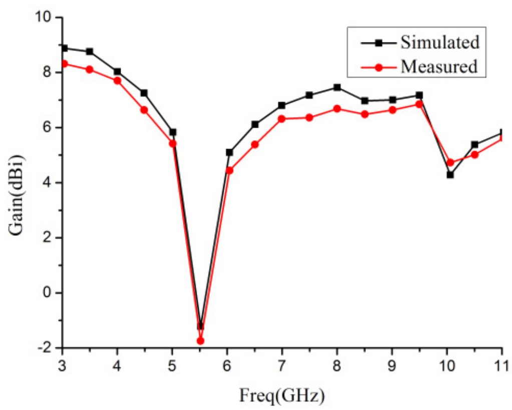


Figure 10. Simulated and measured gain of the proposed antenna.

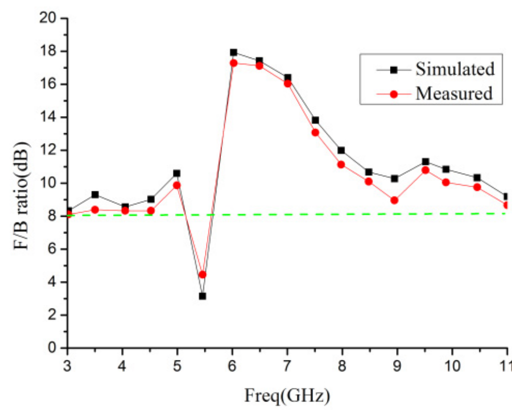


Figure 11. Simulated and measured F/B ratios of the proposed antenna.

are symmetrical extended from its ground plane [14]. Figure 7 shows the reflection coefficient varying with different length (L_5) of the stub. Obviously, it can be observed that the impedance matching is improved increasing with the stub length.

Figure 8 shows the reflection coefficient of the antenna as a function of the distance (S_5) between the driver and director. As S_5 increases from 2 to 3 mm in increments of 0.5 mm, the reflection coefficient decreases significantly in the higher resonant frequency, which indicates antenna impedance matching is improved.

As shown in Figure 9, the normalized simulated and measured radiation patterns in E-plane (xoy-plane) and H-plane (yoz-plane) measured using an anechoic chamber at 4 GHz, 7.5 GHz and 10 GHz are depicted, where it can be observed that the measured patterns are in close agreement with the simulated patterns. Moreover, the main lobe of the radiation pattern is fixed to the endfire direction (y-axis direction).

The realized gain varying with frequency is shown in Figure 10. The measured results agree well with the simulated results. Within the operating bandwidth ranging from 3 GHz to 10.8 GHz, excepting in the notched band from 4.8 GHz to 6.1 GHz, the measured antenna gain varying between 4.7 and 8.3 dBi is achieved. Gain decreased is mainly due to the fact that the grating lobe also occurred at higher frequency.

The F/B ratio is a critical parameter for a unidirectional antenna. Figure 11 shows the simulated and measured F/B ratio for the proposed quasi-Yagi antenna. It can be observed that the measured F/B ratio, which is better than 8.1 dB within the band from 3 GHz to 10.8 GHz excepting in the notched band from 4.8 GHz to 6.1 GHz, indicates that the proposed antenna has good unidirectional characteristics. The F/B ratio is low both in lower and higher frequency band because of the insufficient electrical length of the ground plane and the occurred grating lobe, respectively.

3. CONCLUSION

In this letter, a planar printed quasi-Yagi antenna with band-notched characteristics is designed. A prototype of the proposed antenna is fabricated and tested to demonstrate the effectiveness of the design. A measured operating bandwidth is from 3 GHz to 10.8 GHz, and a measured notched band is from 4.8 GHz to 6.1 GHz avoiding the frequency interference from WLAN. The measured gain is from 4.7 dBi to 8.3 dBi and the measured F/B ratio is better than 8.1 dB within the operating bandwidth excepting in the notched band. These characteristics and the simple, compact, low cost, and easy integration make the proposed planar printed quasi-Yagi antenna highly suitable for the UWB systems.

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