A Dual-band Slot Quasi-Yagi Antenna with Very Low Profile

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***Abstract*—A novel dual-band slot Quasi-yagi antenna with an extremely low profile for WLAN and WiMAX communication systems has been proposed. The antenna is designed with multilayered structure. The traditional slot antennas printed on the PCBs are applied to be the antenna elements of the proposed quasi-yagi antenna. A long-slot mode and a short-slot mode are generated simultaneously to give the antenna dual-band property. An extremely low profile of 0.097λ and 0.14λ has been obtained at 2.4GHz and 3.5GHz, respectively. Meanwhile good end-fire radiation patterns and relatively high gain of 8.14dB and 9.43dB at the two frequencies have been obtained.**

***Index Terms*—quasi-yagi antenna, slot, dual-band antenna, low profile.**

I. Introduction

Yagi-uda antennas have been widely used for their high gain, low cost and ease of fabrication. The conventional yagi-uda antenna consists of a driver, a reflector and several directors. There should be a distance of nearly 0.25λ between the two elements, which hence make the antenna own a bulky structure [1]. Meanwhile, narrow impedance bandwidth also restrains the use of the antenna in wireless communication systems where dual-band and wideband properties are urgently needed. Some innovative designs like printed or microstrip quasi-yagi antennas are investigated to enhance the bandwidth and reduce the whole antenna profile. Printed dipoles are utilized as the antenna elements and many fantastic results like wideband or dual-band properties have been obtained [2, 3]. Nevertheless, antenna gains are usually sacrificed and to realize improved impedance bandwidth, low antenna profile and high gain still remains a challenging problem. In [4], a multilayered slot yagi-uda antenna with enhanced bandwidth has been proposed. By adjusting the basic resonant frequency generated by the slot and an extra resonant mode excited by the metal sticks to merge together, one enhanced working band is realized. But the antenna profile is still up to 0.7λ. A quasi-yagi antenna using metal patches as the elements are proposed in [5], which shows good antenna gain and impedance bandwidth. However large horizontal size and high antenna profile in the end-fire direction are still problems remaining to be solved.

In this paper, a dual-band quasi-yagi antenna is proposed applying a multilayered topology. Traditional slot antennas instead of electric dipoles are used as antenna elements. Two different modes, the long-slot mode and short-mode, are generated to cover the WLAN and WiMAX band. The application of the three-dimensional and the proposed multilayered structure allows a good size reduction in the end-fire direction of yagi-uda antenna and makes it used more easily in the integrated circuit design. Meanwhile, the dual-band property and high antenna gains have been realized simultaneously. There are applications and wireless sensor networks that need high-directivity, large bandwidth and small footprint antennas, the proposed yagi-like antenna can be a good candidate.

The working principle is analyzed. The simulated results are compared and discussed.

II. Antenna Design

The antenna configuration of the proposed dual-band antenna is given in Fig.1. The antenna consists of a metal patch as the reflector, a metal patch etched with a rectangular slot antenna as the director. Another two patches etched with two identical slots are closely placed and fed by an aperture-coupled microstrip. For they are both close enough to the feeding strip, the upper driver_2 slot can be fed by the microstrip and meantime get coupled by the lower driver_1 slot. The two slots can act as the drivers of the proposed antenna. The antenna elements are all printed on a Rogers RO4350 (tm) substrate with a dielectric constant of 2.66. Meanwhile, the substrates share the same length of L and width W but different height of d_1, d_2 and d_3. Four cylindrical sticks are used to connect the four antenna elements through holes cut on the substrates and metal patches. Meanwhile, in order for the SMA connecter to be properly soldered to the patch of driver_1, a cuboid with both length and width of l is cut on dirver_2. The total height of the proposed antenna is 11.6mm, which implies that an extremely low profile in the end-fire direction of 0.093λ at 2.4GHz and 0.135λ at 3.5GHz

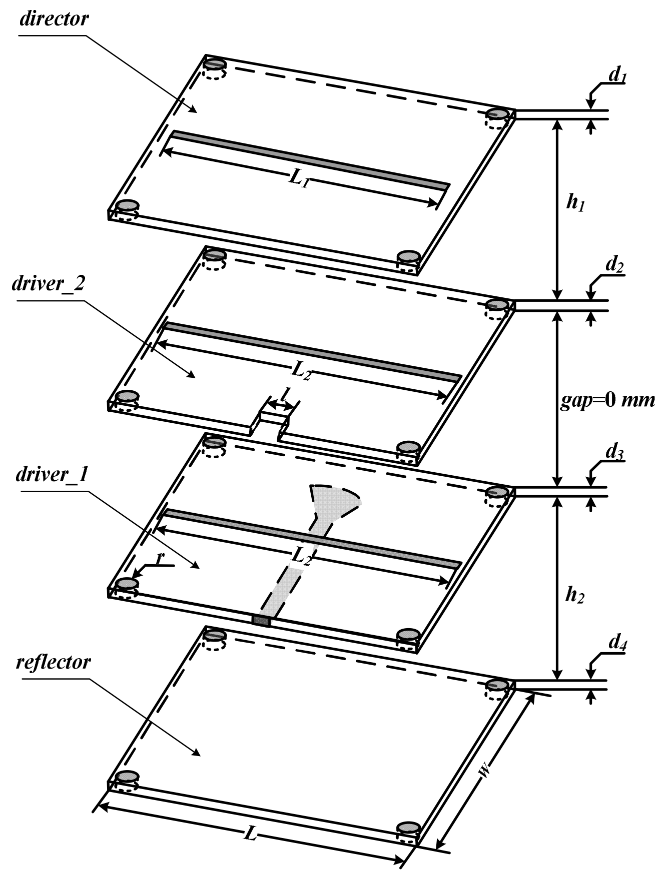


Fig. 1. Geometry of the proposed antenna.

has been obtained. The specific dimensions of the proposed antenna are illustrated in Table I.

TABLE I
DETAILED DIMENSIONS OF THE PROPOSED ANTENNA

Parameters	L	W	L_1	L_2	d_1	d_2
Value(mm)	65	61	64	62	2	2.2
Parameters	d_3	d_4	h_1	h_2	l	r
Value(mm)	2.2	1.5	1.9	1.8	4	1

III. Modes Analysis

The simulated variations of S_{11} with frequencies are given in Fig.3 in later section. It can be observed that with the proposed structure, antenna can work at two different frequencies of 2.4GHz and 3.5GHz. Following analysis will show that long-slot mode and short-slot mode have been generated at the two frequencies respectively.

The current distributions of driver_1, driver_2 and director are shown in Fig.2. For conventional yagi-uda antennas, electric dipoles instead of slot antennas are used as elements. However, from the extension of Babinet's principle, it can be known that the equivalent form of the half wavelength slot used in the paper is a magnetic dipole. They have the same radiation properties but different polarizations with the traditional electric dipoles, which makes it possible for the *half wavelength slot* to act as elements of quasi-yagi antennas [1].

It is known that resonant λ/2 slot own an impedance of 530+*j*0Ω, while the resonant λ/2 dipole has a lower impedance of 67+*j*0Ω.This property makes the proposed antenna easier to be matched to the 50Ω coaxial line when the elements of the quasi-yagi antenna need to be placed closer. And low antenna profile will thus much convenient to be acquired.

A. Long-slot mode

Fig.3 (a) shows the simulated electric field distribution in the slot at 2.4GHz. It can be seen that the tangential electric field is distributed along the whole slot, which means the lower resonant frequency is determined by the overall effective length of the slot [1]. Eq. (1) and Eq. (2) gives the relationship between the effective length L of the slot and the wavelength λ at the working frequency f.

$$L = \lambda/2 \tag{1}$$

$$\lambda = c/f \tag{2}$$

With the length of the slot known as 64mm, it can be calculated from the equations above that the first resonant frequency is 2.34GHz, which is very close to the simulated 2.4GHz. The little difference can be caused by the finite metal patch, for the calculation formulas are derived under the condition that the slot is etched on an infinite metal sheet.

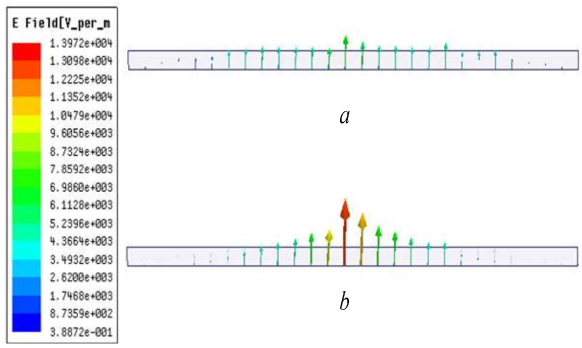


Fig. 2. Electric distributions in driver slot (driver_1) at (a) 2.4GHz and (b) 3.5GHz.

B. Short-slot mode

The electric distribution in the slot at 3.5GHz is given in Fig.3 (b). It clearly shows that only part of the slot is filled with tangential electric field, which well explains the existence of the higher resonant frequency. The effective length is approximately 44mm and it can also be calculated using the previous formula that the higher resonant frequency is about 3.41GHz, which is also very close to the simulated one.

IV. Results and Discussion

A. S-parameter

Variations of S_{11} with frequency are illustrated in Fig.3. It reveals that the proposed antenna can work at both WLAN

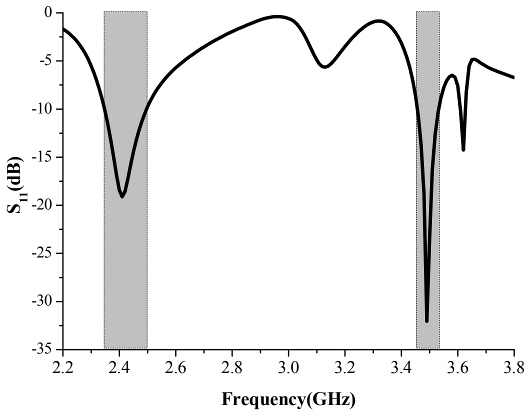
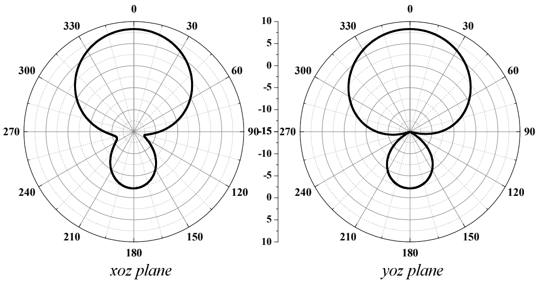
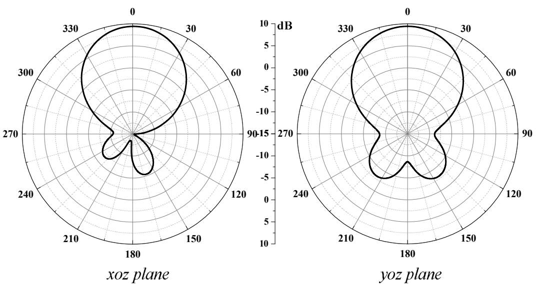


Fig. 3. Simulated variations of S_{11} against frequencies.



(a)



(b)

Fig.4. Simulated radiation patterns in *xoz*-plane and *yoz*-plane at (a) 2.4 GHz, (b) 3.5 GHz.

band from 2.33GHz to 2.5GHz and WiMAX band from 3.45GHz to 3.53GHz.

B. Radiation properties

The simulated radiation patterns at 2.4GHz and 3.5GHz are given in Fig.4. It can be observed that good end-fire radiation patterns have been obtained. High gains of 8.14dB and 9.43dB at the two frequencies have been observed. The front-to-back ratios are larger than 10dB at both the working frequencies.

Fig.5 illustrates the variations of antenna gains versus frequencies. It can be seen that gains are over 8.1dB and 8.6dB

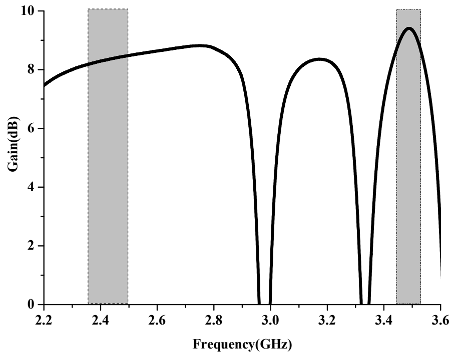


Fig. 5. Simulated variations of gains versus frequencies.

through the two operating band respectively, which indicates that relatively good directivity has been obtained.

V. CONCLUSION

A dual-band slot quasi-yagi antenna has been proposed for WLAN and WiMAX band communication systems. Two modes, long-slot mode and short-slot mode, have been generated simultaneously to give the antenna dual-band property. Meanwhile, the proposed antenna has an extremely low profile of 0.097λ and 0.14λ at 2.4GHz and 3.5GHz respectively, which makes it more easily used in the integrated circuit design. The proposed Yagi-like antenna can be a good candidate in the applications and wireless sensor networks that need high-directivity, dual-band property and small footprint antennas.

ACKNOWLEDGMENT

This work is supported by Program for National Science and Technology Major Project of China (2014ZX03001014-003) and by the National Natural Science Foundation of China (No. 61372001).

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