

# A Quadband Antenna With Reconfigurable Feedings

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**Abstract**—A compact inverted-F antenna (IFA) with switchable feeds is proposed in this letter. The antenna occupies a relatively small volume of  $50 \times 7 \times 7 \text{ mm}^3$ . Two p-i-n diodes are used to switch the antenna between two different working states. The antenna can provide the required bands of GSM850 (824–894 MHz), GSM900 (890–960 MHz), DCS (1710–1880 MHz), and PCS (1850–1990 MHz) with  $S_{11} < -10 \text{ dB}$ . Measurements including return loss, radiation patterns, and gain are presented to verify the proposed design of antenna.

**Index Terms**—Compact, reconfigurable antenna, switchable feed.

## I. INTRODUCTION

THE rapid progress of the multifrequency antenna makes it possible to realize the miniaturization in mobile devices, such as mobile phones and personal digital assistants (PDAs). However, designing an internal compact antenna for multiple bands of GSM/DCS/PCS services in small handsets is still a significant challenge. One option is the use of multistrips in one antenna [1] or a two-port antenna system [2] to work in the multifrequency. To further decrease the antenna volume, the frequency-reconfigurable antenna is an attractive approach. In this work, two frequency-reconfigurable antennas are combined for concurrent operation over cellular and connectivity bands [3]. In [4], a varactor is utilized to change the electric characteristic of an antenna element; effectively, a wider bandwidth can be achieved when all working states are combined. A varactor-tuned antenna is not suitable for applications that require transmitting high power, such as cellular communication. In [5], a switchable inverted-F antenna (IFA) based on microelectromechanical systems (MEMS) is proposed for frequency reconfiguration. Two switchable frequency bands need two different matching circuits, and the volume of the antenna is relatively large. The antenna proposed in [6] also can be switched to provide two frequency bands, but the bandwidth is not wide enough, with only  $-5 \text{ dB}$  return loss for required bands.

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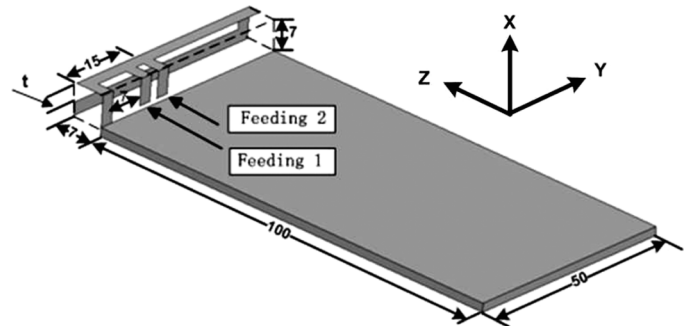


Fig. 1. 3-D geometry of proposed antenna (units: millimeters).

In this letter, a prototype antenna and feeding circuit is designed, fabricated, and measured. Dual feeding strips are switched by p-i-n diodes to excite two matched working states of the antenna; bandwidth can be broadened by combining the two states. The structure of the antenna is simple, and no matching circuit is needed. Better than  $-10 \text{ dB}$  measured return loss has been achieved in the required bandwidths of GSM850 (824–894 MHz), GSM900 (890–960 MHz), DCS (1710–1880 MHz), and PCS (1850–1990 MHz). The dimensions of the antenna are  $50 \times 7 \times 7 \text{ mm}^3$ . The effects of battery and the metal sheet of handsets are also considered in the measurement.

## II. ANTENNA CONFIGURATION AND DESIGN

Fig. 1 shows the geometry and specific dimensions of the proposed antenna. The antenna is made of a flat metallic strip folded and attached to the outer side of a foam support whose dimensions are  $50 \times 7 \times 7 \text{ mm}^3$ . The width of the strip is 3 mm. In order to further reduce the antenna's dimension, a single-branch antenna is designed by utilizing both its first- and second-order resonant mode to cover both the low- and high-frequency bands. By changing the length of the radiating element, the lower frequency can be tuned. By adjusting the gap  $t$ , as illustrated in Fig. 1, of the U-shaped antenna, the ratio between the first and second resonant frequency can be modified. By iteratively tuning both, the center frequency of both bands can be tuned to the desired locations.

To expand the bandwidth of the antenna, a dual-feed structure is introduced. The first feed is located 10 mm away from the left side, and 15 mm for the second one, as shown in Fig. 1. In the common wisdom of designing IFAs or planar IFAs (PIFAs), the feed location is chosen to provide the best matching. If the feed location is moved away from the best location, the antenna matching will be degraded. However, it is not true for the structure shown in Fig. 1. When the antenna is connected from

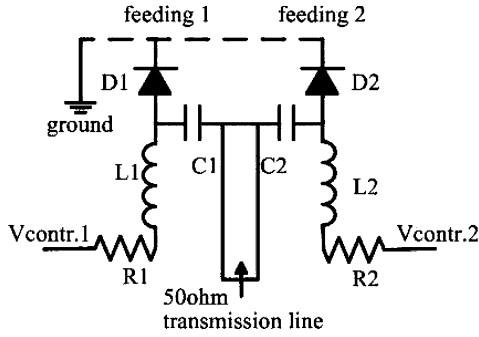


Fig. 2. Diagram of switch circuit.

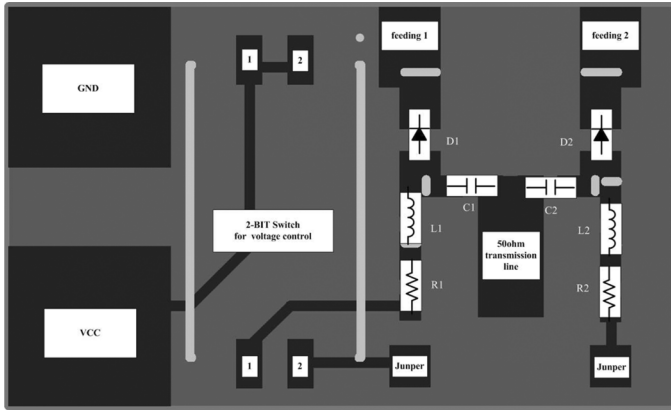


Fig. 3. PCB for p-i-n bias and switching.

feeding 1, it is equivalent to an inverted-L antenna attached by a shunt inductor, which is implemented by the ground stub on the left side of the antenna. The shunt inductance compensates the parasitic capacitance between the antenna element and ground. When the antenna is connected from feeding 2, the total length of the equivalent L element is shorter, thus causing the resonant frequency to shift higher. On the other hand, the parasitic capacitance in this case is less due to the decreased overlap between the antenna element and ground. Thus, a longer grounding stub will be better for matching the antenna, which happens to have the inherent properties of the structure shown in Fig. 1. As a result, when fed from either port 1 or port 2, the antenna can always maintain a good matching on varied working bands.

The diagram of the switch circuit is shown in Fig. 2. It consists of two p-i-n diodes (D1 and D2, Philips BAP64-03), two RF choke inductors (L1 and L2, 120 nH), two series resistors (R1 and R2, 46  $\Omega$ ), and two DC block capacitors (C1 and C2, 100 pF). The dc ground of the bias circuit is provided by the antenna's shorting strip. When D1 is in the "ON" state and D2 in the "OFF" state, the antenna is connected from port 1; when D1 in the "OFF" state and D2 in the "ON" state, the antenna is connected from port 2. The p-i-n bias voltage is supplied by two AA batteries. Fig. 3 shows the printed circuit board (PCB) of the feeding switch circuit and bias circuit for p-i-n. The coaxial cable connects to a 50- $\Omega$  microstrip line for feeding. Two pull-down bias resistors, which are vertically connected between the ground and the 2-BIT switch on the edge of the board, are not shown in the Fig. 3.



Fig. 4. Photograph of antenna prototype.

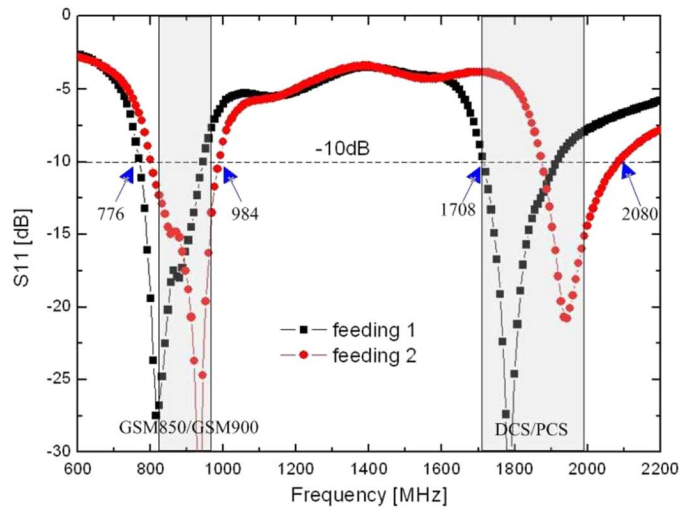


Fig. 5. Measured return loss.

### III. MEASUREMENT RESULTS

To demonstrate the effect of the switch of feeding strips, the proposed antenna has been fabricated and measured. As shown in Fig. 4, the antenna is installed on a single-sided PCB (FR4,  $\epsilon_r = 4.4$ ,  $\tan \delta = 0.01$ ). The size of the board is  $100 \times 50 \text{ mm}^2$  with a thickness of 1.6 mm. Fig. 5 shows the measured return loss of the proposed antenna. The impedance bandwidth defined for  $S_{11} < -10 \text{ dB}$  ( $\text{VSWR} < 2 : 1$ ) reaches 208 MHz (776–984 MHz) for the first resonant mode, which covers the GSM band. For the second resonant mode, the impedance bandwidth reaches over 372 MHz (1708–2080 MHz), which covers the DCS and PCS bands.

Fig. 6 shows the measured radiation patterns of proposed antenna at 875 and 1875 MHz; a quasi-unidirectional pattern is achieved in the  $x$ - $z$  plane for vertical and horizontal polarization. The measured gain in low bands, shown in Fig. 7, peaks at 1.3 dBi and fluctuates less than 2 dB; in the high bands, it peaks at 2.9 dBi and fluctuates less than 2.3 dB.

### IV. CONCLUSION

A compact IFA with switchable feeds is proposed. The feed of the antenna can be switched to broaden the bandwidth

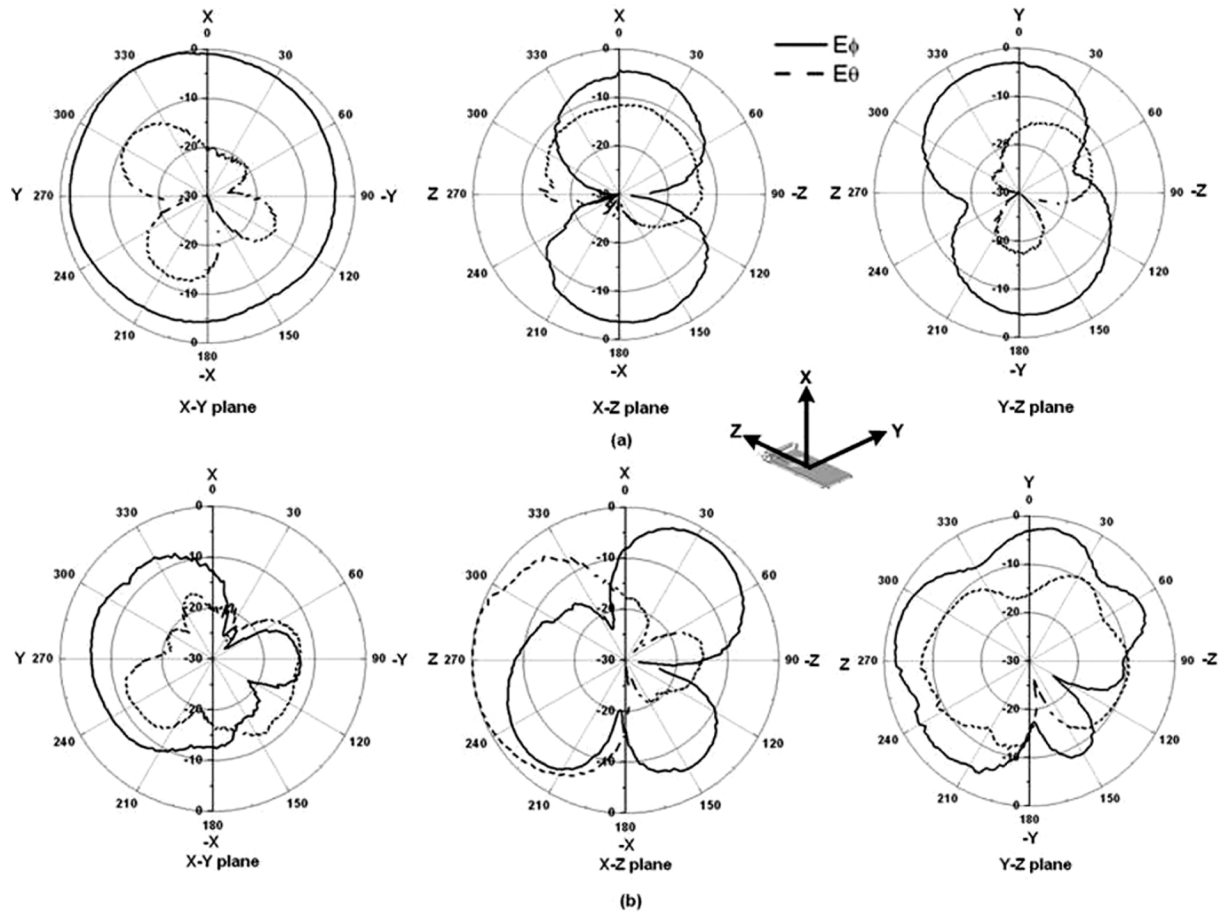


Fig. 6. Measured radiation patterns: (a) 875 and (b) 1875 MHz.

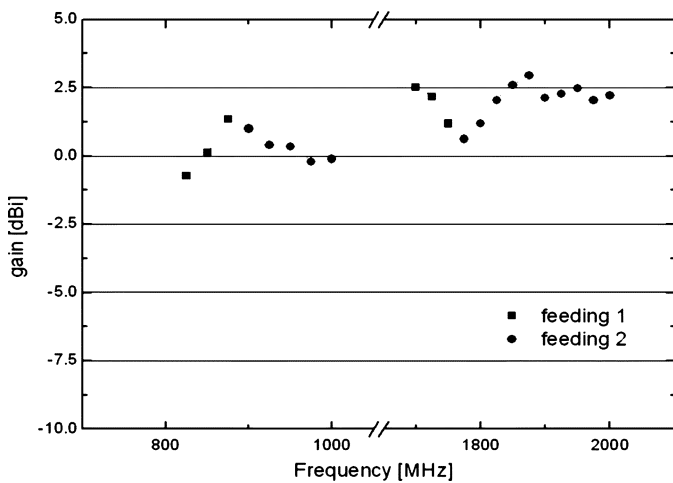


Fig. 7. Measured gain.

without breaking the good matching. Two p-i-n diodes are utilized to control the switch. The antenna only occupies small

volume of  $50 \times 7 \times 7 \text{ mm}^3$ , but can cover the require bands of GSM850 (824–894 MHz), GSM900 (890–960 MHz), DCS (1710–1880 MHz), and PCS (1850–1990 MHz) with good performance.

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