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RESEARCH PAPER

# Dual-band low-profile planar antenna for mobile communication application

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*A novel dual-band planar antenna with a low profile for mobile communication system is proposed in this paper. The antenna is composed of one shorted patch with two radiating notches for low frequency resonance and one square patch for high frequency resonance. The low profile is achieved via the shorting patch, which introduces the parallel electrical field between the reflector and antenna. A step-impedance microstrip line is used to feed the antenna. The coupling between the square patch and microstrip line cancels out the inductance of shorting probe, which increases the working bandwidth of proposed antenna. A prototype with a low profile of 0.0286λ is fabricated and measured. The antenna achieves dual impedance bandwidths of 1.6% for the low frequency band and 60% for the high frequency band, covering the frequency range 851–865 MHz and 1.97–3.65 GHz, respectively. The measured results show good agreements with the simulated ones.*

**Keywords:** Low profile, Shorted patch, Dual band, Step-impedance

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## I. INTRODUCTION

In recent years, the development of mobile communication industry has prompted antenna toward the direction of low profile and multi bands [1–3]. Different mobile communication systems have its own frequency band, which makes numerous frequency ranges currently in use [4]. Such as GSM900 systems operate in 890–915 MHz for uplink and 935–960 MHz for downlink, while Time Division Long Term Evolution (TD-LTE) system should operate in the 2300–2400 and 2550–2690 MHz. More and more devices integrate with two or more communication system standards [5]. A dipole with a balun is most frequently used for a unidirectional radiation pattern. However, it must be placed at the front of a reflector with a distance of about 0.25λ. The large height makes it difficult to apply in some devices. Therefore, antenna with dual impedance bandwidths and low profile is necessary for multi communication systems. Researchers have devised various types of broadband or multi-band low-profile antenna over the past decades. Microstrip antenna has a low profile, but it is not suitable for multi communication systems due to its narrow bandwidth. In [6], patch antenna with an L-shaped probe instead of coaxial probe has a bandwidth of 24% for return loss > 10 dB. Four shorting posts at particular positions are used to vary the resonant frequency bands and reduce the size of the patch antenna. Meanwhile, antenna can radiate two independent linearly polarized beams with different radiation patterns. However, it has a moderate height with only one working frequency band. Fed with an integrated balun, a printed dipole features a broadband performance [7]. By adjusting the position of the feed point of the integrated balun, a printed dipole can directly match to a 50 Ω feed and has a bandwidth of more than 40%. However, the height of the integrated balun is determined with the working frequency, and increases the profile of antenna. Composed of a pair of folded dipoles which are coupling fed by an L-shaped microstrip line, a broadband planar antenna with a bandwidth of 53% was proposed in [8]. However, the profile of antenna has a relatively large height (0.25λ), and limits its application in some device that a low profile property is desired.

An effective solution to achieve low profile is to use the electromagnetic band-gap (EBG) structure instead of metal reflector [9–11]. With carefully designed EBG structure, a low-profile unidirectional spiral antenna was proposed in [10]. However, the realization of broadband EBG structure needs unconventional substrate with different permeability

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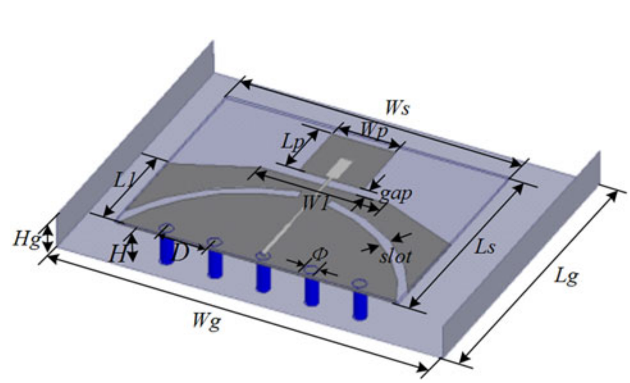



**Fig. 1.** Geometry of proposed antenna.

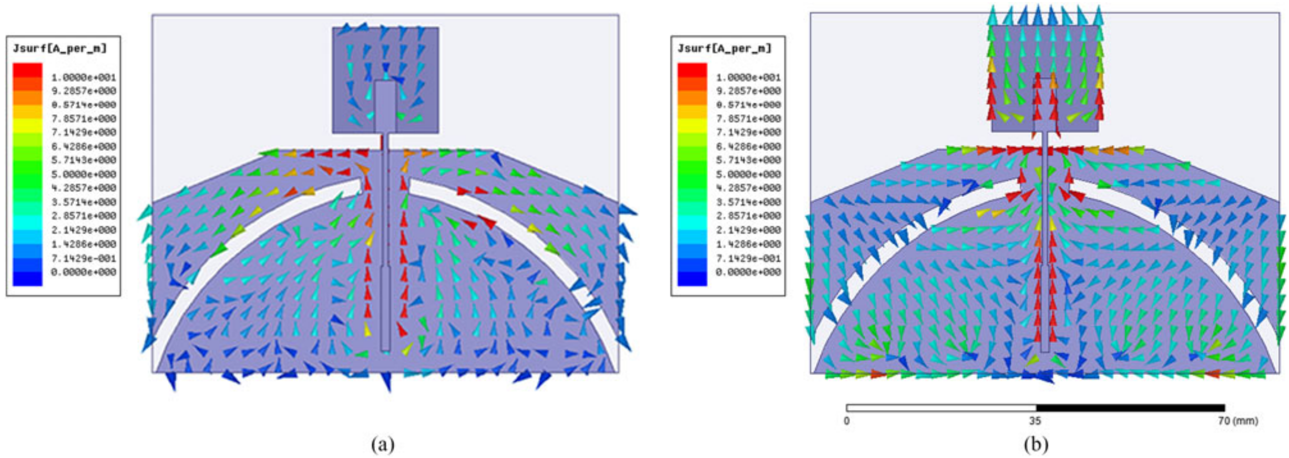



**Fig. 2.** Currents distributions on the patch at different frequencies. (a) 0.86 GHz, (b) 2.8 GHz.

and permittivity simultaneously. The magneto-electric dipole was proposed by Luk et al. for wideband application. Using the concept of complementary antenna, a wideband planar antenna with a low profile was proposed in [12]. With connection of two shorted quarter-wave microstrip antenna and two planar electric dipoles, the antenna exhibits an impedance bandwidth of 51.5% and a low profile of 0.095λ.

In this paper, a dual-band antenna with a low profile is presented for mobile communication system. Consisting of one shorted patch and one square patch, the antenna exhibits

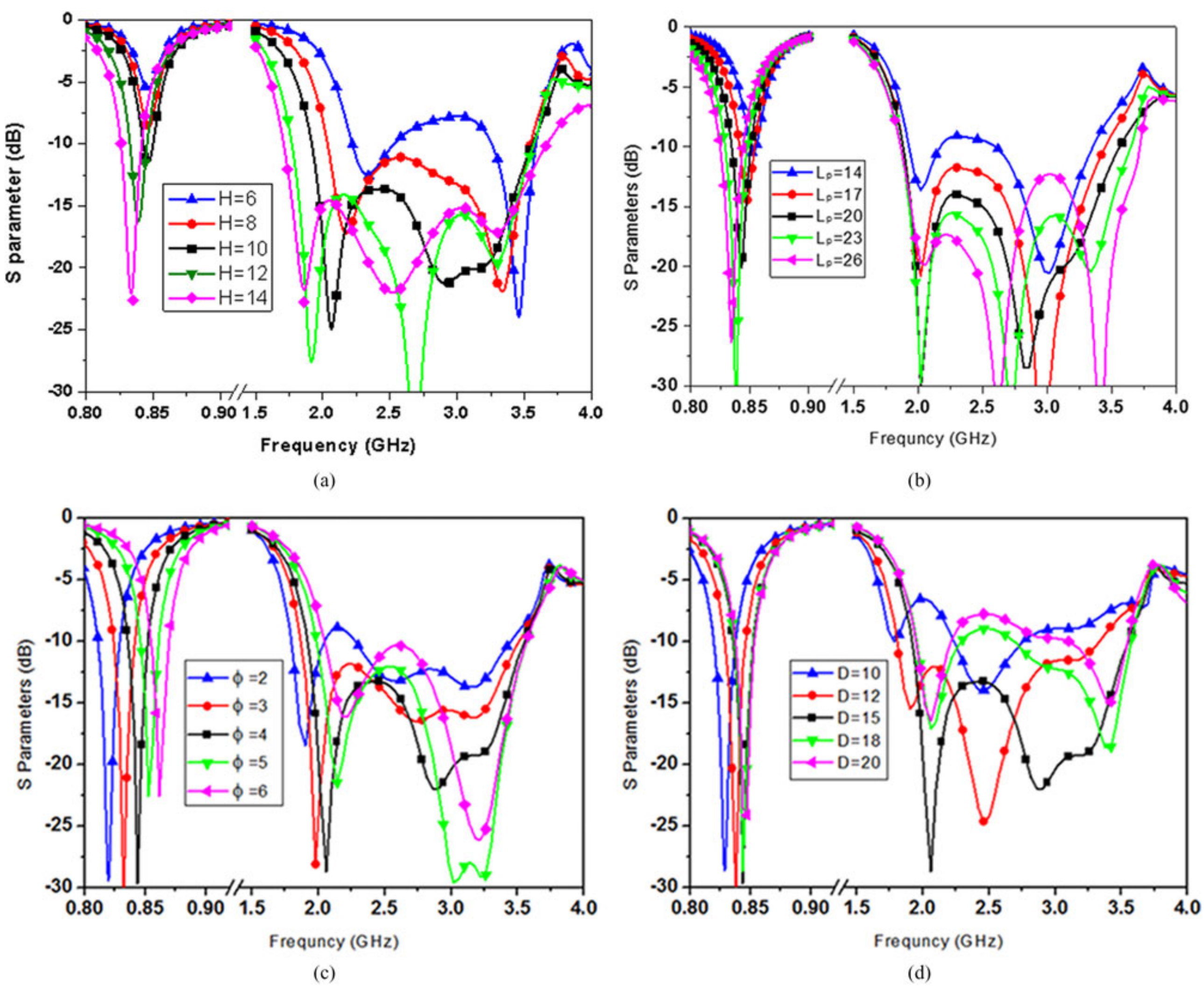



**Fig. 3.** Simulated $S_{11}$ versus frequency with different values of structure parameters. (a) $H$, (b) $L_p$, (c) $\Phi$, and (d) $D$.

**Table 1.** Geometric parameters of proposed antenna.

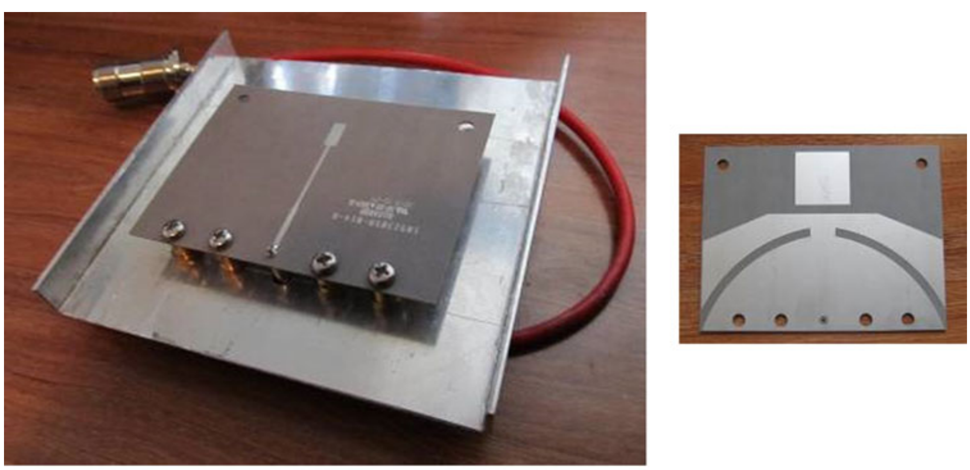
| Parameter | Value (mm) | Parameter | Value (mm) |
|---|---|---|---|
| $W_s$ | 88 | $L_s$ | 120 |
| $W_g$ | 120 | $L_g$ | 100 |
| $W_p$ | 20 | $L_p$ | 20 |
| $W_1$ | 40 | $L_1$ | 32 |
| $H_g$ | 11 | *Gap* | 3.2 |
| *Slot* | 3 | $H$ | 10 |
| $\Phi$ | 4 | $D$ | 15 |

dual-band low-profile properties, covering the frequency range 851–865 MHz and 1.97–3.65 GHz. A step-impedance microstrip line is applied to cancel out the impedance of shorting probes, which increases the bandwidth of high frequency band. Dual impedance bandwidths of 1.6% for the low frequency band and 60% for the high frequency band are achieved for proposed antenna.

## II. ANTENNA GEOMETRY AND DESIGN

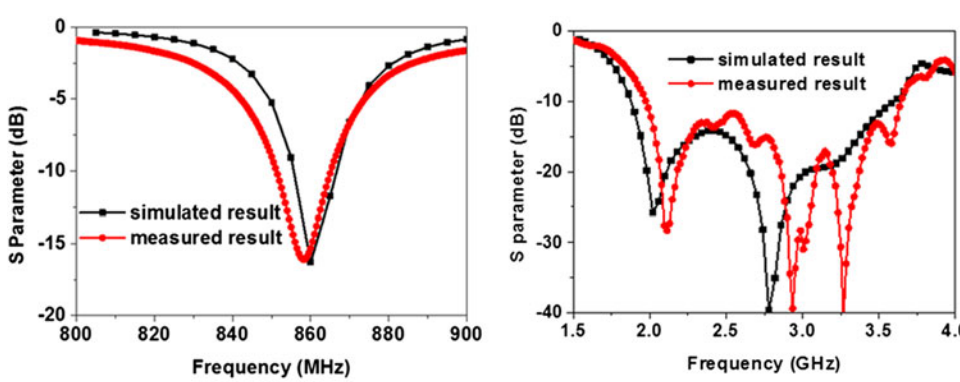
The configuration of the proposed dual-band low-profile antenna is shown in Fig. 1. The overall geometry mainly consists of a U-shaped reflector, four shorting probes, and a dielectric substrate. One side of the substrate consists of one square patch and one shorted patch with two radiating notches. The other side of the substrate is a step-impedance microstrip line with the end open. The 50 Ω coaxial cable is used to penetrate the ground plane and connect the dielectric substrate. The outer conductor of the cable is connected to the ground plane as well as the shorted patch. The inner conductor of the cable is connected to the feeding line.

The patches and the feeding line are printed on Arlon AD255A substrate with a thickness of 0.8 mm and a relatively dielectric constant of 2.55. The feeding line is constituted of three different segments with their widths and lengths: (1.6, 16 mm), (1.0, 25 mm), and (4.0, 10 mm), respectively. The distance between the substrate and the ground plane is $H = 10$ mm, which is about $0.0286\lambda_1$ for the low frequency band or $0.093\lambda_2$ for the high frequency band. The U-shaped reflector is constituted of two side walls and one metal plane with $W_g = 120$ and $L_g = 100$ mm. The height of side wall is $H_g = 11$ mm, which has an influence on the gain and back radiation of proposed antenna. The shorting probes with the size of $\Phi = 4$ and $H = 10$ mm are used to connect the patch and U-shaped reflector. The shorted patch antenna can produce a generally parallel electric field, which is equivalent to a magnetic dipole. Two radiating notches can resonant at the low frequency band. The coupling between the feeding line and the square patch can introduce capacitance to cancel out the inductance of shorting probes and improve the impedance



(a) (b)

**Fig. 4.** Photograph of proposed antenna. (a) Overview, (b) back side of the substrate.




(a) (b)

**Fig. 5.** Simulated and measured *S* parameters against frequency. (a) Low frequency band; (b) high frequency band.

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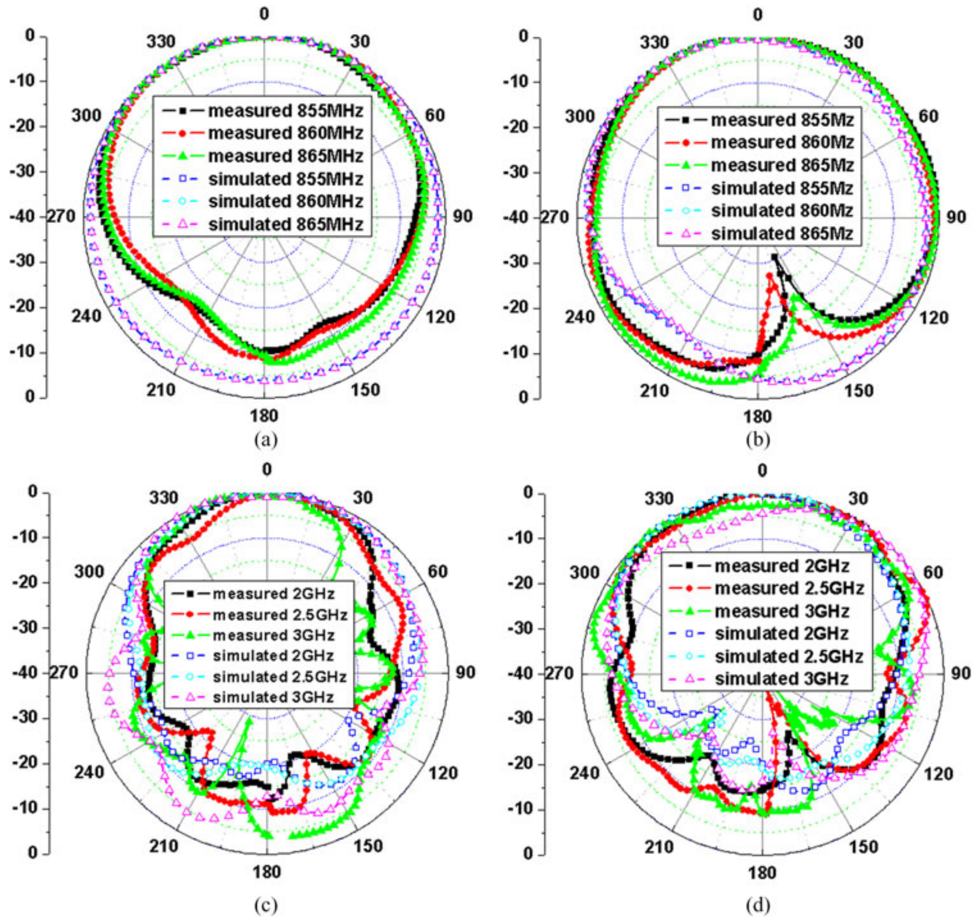


**Fig. 6.** Simulated and measured radiation patterns of proposed antenna. (a) *H*-plane at 855, 860, and 865 MHz; (b) *E*-plane at 855, 860, and 865 MHz; (c) *H*-plane at 2, 2.5, and 3 GHz; (d) *E*-plane at 2, 2.5, and 3 GHz.

matching effectively at the high frequency. Figure 2 shows the current distributions on the patch at different resonant frequencies. It can be observed that the current is mainly concentrated in the nearby of slots at the frequency of 860 MHz. Meanwhile, the current propagates along the top edge of shorted patch and square patch at 2.8 GHz.

In order to find the influences of structure parameters on the resonant frequencies, a parametric study has been carried out. The distance *H* between the substrate and the ground plane, which is also the height of shorting probes, plays an important role in matching of proposed antenna. By altering the parameter *H* and fixing other parameters, the simulated reflection coefficient ($S_{11}$) is shown in Fig. 3(a). It can be noticed that when the value of *H* varies from $H = 6$ to $H = 14$ mm, the resonant frequencies of the low and high frequency band decrease. Figure 3(b) shows the simulated $S_{11}$ of the proposed antenna with different values of $L_p$. It is observed that when the value of $L_p$ varies from 14 to 26 mm, the low resonant frequency decreases, and the high resonant frequencies remain similar. However, there is a strong influence of patch length on the matching of high frequency band, which can be seen in Fig. 3(b). Figure 3(c) shows that the diameter of shorting probes has a large effect on the low resonant frequency. It can be seen that when the diameter increases from 2 to 6 mm, the low resonant frequency can increase from 820 to 862 MHz. Figure 3(d) shows the influence of the spacing between the shorting probes on the reflection coefficient. The value of the spacing has a huge impact on the matching of high frequency band, while it can change the low resonant frequency slightly. The final optimal parameters of the proposed antenna are listed in Table 1.

## III. EXPERIMENTAL RESULTS AND DISCUSSION

According to the design parameters in Table 1, a prototype of proposed antenna is fabricated, which is shown in Fig. 4. The top substrate is supported with four copper posts, which are

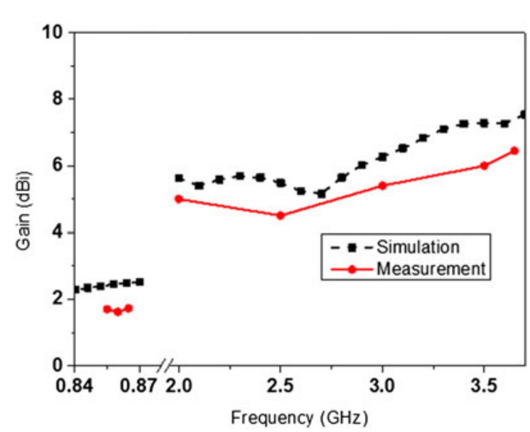


**Fig. 7.** Comparison of simulated and measured gains.

**Table 2.** Comparison of proposed antenna with previous designs.

| Antenna type | First band | | | Second band | | |
|---|---|---|---|---|---|---|
| | Height ($\lambda_1$) | Bands width (%) | Gain (dBi) | Height ($\lambda_2$) | Bands width (%) | Gain (dBi) |
| Complementary antenna [12] | 0.095 | 51.5 | ~6.9 | na | | |
| *L*-probe antenna [6] | 0.12 | 24 | 4–8.5 | | | |
| Surface wave antenna [13] | 0.042 | 1.1 | ~4.9 | 0.05 | 3.94 | ~5.4 |
| Crossed asymmetric dipole antenna [14] | 0.088 | 16.7 | na | 0.19 | 11.5 | na |
| Dual reflector antenna [15] | 0.06 | 3.3 | 5.45 | 0.125 | 3.8 | 7.9 |
| Proposed antenna | 0.0286 | 1.6 | 1.6 | 0.093 | 60 | 4.5–6.5 |

fixed on the reflector with screws. The antenna is fed with 50 Ω coaxial cable, which penetrates the reflector and connects the feeding line. The impedance characteristics of the proposed antenna were simulated using Electromagnetic (EM) software (High-Frequency Structure Simulator-HFSS. 13) and measured with an Agilent E8719ES network analyzer. Figure 5 shows the comparison between the simulated and measured reflection coefficients ($S_{11}$) against frequency of the proposed antenna. Good agreement between the simulation and measurement can be observed. The antenna achieves corresponding impedance bandwidths of 1.6% for the low frequency band and 60% for the high frequency band, covering the frequency range 851–865 MHz and 1.97–3.65 GHz, respectively. According to the parameter study of the height of shorting probes, the air gap between the substrate and ground has a large influence on the resonant frequency. So the shift of resonant frequency between the simulated and measured results is mainly due to the factors of the imprecise assembling and manufacturing tolerance.

The simulated and measured far-field radiation patterns at the low and high frequency bands for the proposed antenna are depicted in Fig. 6. It can be seen that the antenna exhibits good unidirectional radiation characteristic. The forward gain is improved due to the U-shaped reflector. The measured results show the good agreement with the simulated ones. The discrepancy between the simulation and measurement is attributed to the factor of manufacture tolerance and test environment.

Figure 7 shows the simulated and measured gains of the proposed antenna. It can be seen that the gain is about 1.6 dBi in the lower frequency band, while it varies from 4.5 to 6.5 dBi in the high frequency band. The existence of the coaxial cable and the connector that are used for testing brings loss to the proposed antenna; meanwhile, the imprecise air gap brings other loss. A difference of less than 1 dB between the simulation and measurement is achieved in two working frequency bands.

The key performance of our work is compared with previous designs, which is summarized in Table 2. Compared with other antenna, the proposed antenna has a very low profile and exhibits a wide impedance bandwidth. Both complementary antenna and *L*-probe antenna just have one operation frequency band, even though they have the advantage of low profile. It is noted that [13] provides a technique of using periodic patches to propagate surface waves, which produces monopole like radiation patterns at two frequencies. A carefully designed dual-band artificial magnetic conductor is utilized to reduce the profile of antenna in [14], which increase the complex of structure and design. By placing the dual band dipole at the front of two layers artifical magnetic conductor (AMC), the dual-band reflector antenna exists a directional radiation pattern with a low profile in [15]. However, the size of AMC is $\lambda_{01} \times \lambda_{01}$ or $2\lambda_{02} \times 2\lambda_{02}$ ($\lambda_{01}$ and $\lambda_{02}$ are the wavelengths corresponding to center frequencies of first and second bands, respectively), which is too large and limits its application.

## IV. CONCLUSION

The design of a dual-band low-profile antenna is presented in this paper. Consisting of one shorted patch and one square patch, the proposed antenna achieves operating bandwidths of 1.6% ranging from 851 to 865 MHz and 60% ranging from 1.97 to 3.65 GHz. The fabricated antenna exhibits a unidirectional radiation pattern and a low profile of 0.0286λ for the low frequency band. This antenna has a good potential for mobile communication system because of its simple configuration, low profile, and dual-band operation.

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