Low Profile Microstrip Antenna with Broadside Radiation Patterns and Low Cross Polarizations

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Abstract. A low profile microstrip antenna with adjustable bandwidth around 3 GHz is proposed. The compact antenna consists of a square patch with a square aperture to tune the resonance center frequency. The input impedance bandwidth is about 2.67% with stable gain around 3.2 dBi. Both the side-fed and bottom-fed modes are analyzed. According to the simulation, good broadside radiation patterns with low cross polarizations are observed in the two principal planes. The detailed design considerations are described and discussed while the surface current distribution and radiation characteristics are analyzed. This design is suitable for mobile wireless communication.

1. Introduction

Microstrip patch antennas have attracted much attention owing to their low profile, light weight and easy fabrication [1]. They are usually designed for single mode operation and linear polarization. In some applications such as closed warehouse, however, a broadside radiation patterns with low cross polarizations is more suitable because of its application scenario is relatively unchanged. Although the monopole antennas are easy to implement broad band and circular polarized characteristics, the bi-direction radiation property is not suitable for one-way transmission [2-3].

A Compact monopole antenna with triple band-notched characteristics for UWB applications is proposed in [4], however the omnidirectional property results in a relatively low gain in the low frequency gain. A miniaturized design of coplanar waveguide-fed broadband circularly polarized slot antenna in proposed in [5], however, the 3-dB beam width is about 70° and the properties of the antenna is very sensitive to the structure parameters. A meander line coupled cavity-backed slot antenna for broadband circular polarization is in [6], however, the cavity-backed structure leads the antenna too bulky.

With the development of electromagnetic related optimization design software, antennas of various types and performances emerge in endlessly.

However, the basic theory of antenna analysis remains unchanged. For example, the beginner of antenna design should first understand the half-wave dipole antenna, and ultimately design other types of antenna, or frequency selective surfaces which closely related to antenna theory [7-8]. In fact, no matter what kind of innovation occurs in the structure and function of antenna and frequency selective
surface, it can also be deduced and approximated by Maxwell equations. The most important problem is the analysis of the surface current distribution of the structure [9-10]. The most classical and stringent method is to obtain the current and magnetic current distribution of the antenna and frequency selective surface, then the scattering field, and then the antenna parameters, or the transmission and reflection characteristics of the frequency selective surface. Therefore, with the help of electromagnetic simulation software, observing the current distribution on the antenna surface, and summarizing the distribution law, even the analytical expression as far as possible, is the highest realm of the antenna designer.

In this letter, a compact and low profile square loop antenna is analyzed. The resonance center frequency is tuned by the square aperture. In order to adapt to different installation conditions, both the side-fed and bottom-fed modes are studied. The surface current distribution is analyzed together with the impedance characteristic.

2. Simulation of the side-fed antenna

Figure 1 shows the topology of Antenna I which composed of a square patch antenna and a square ground plane, together with its geometrical dimensions. The antenna is designed on FR4 epoxy substrate with thickness of 1.6 mm, relative permittivity $\varepsilon_r = 4.4$ and loss tangent $\tan\delta = 0.02$. The radiating element and feeding line are printed on the top side of the substrate and the ground plane on the bottom side. The size of dielectric plate is 80 mm*40 mm*1.6 mm. Four through holes (2.5 mm in diameter) are used to fix antennas, and they are symmetrically arranged along four corners of the dielectric. The nearest edge distance of the dielectric plate is 5 mm. The antenna is side-fed and the SMA joint is located in the middle of the long side of the dielectric.

![Figure 1. Topology of Antenna I (side-fed).](image)

The simulated reflection coefficients with different aperture dimensions are presented in Figure 2. It can be observed that, with the increase of $l$, the resonance center frequency shifts downward. It can also be observed in Figure 3 that, when the radiation patch is etched with a square aperture in the center of the antenna, the corresponding input impedance is about 50 $\Omega$ around 3 GHz. Furthermore, the smith chart is also provided in Figure 4.

![Figure 2. Figure with short caption (caption centred).](image)
Figure 3. Simulated input impedance of antenna I with ($l=6$ mm) and without ($l=0$ mm) square aperture.

Figure 4. Simulated smith chart of antenna I with ($l=6$ mm) and without ($l=0$ mm) square aperture.

As illustrated in figure 5, for the antenna without aperture ($l=0$), the current is mainly concentrated on the 50Ω feeding line and along the periphery of the square patch. Meanwhile, the current density on the other area of the patch is close to zero, as small current vector with blue in color has been observed as shown in figure 5. By adjusting the aperture dimension appropriately, the current patch is changed which results in the fundamental resonant frequency shifts downward.

Figure 5. Simulated surface current distribution of Antenna I (3 GHz) with ($l=6$ mm) and without ($l=0$ mm) square aperture.

If the antenna is required to operate around 3 GHz, $l=6$ mm. The 10 dB return loss bandwidth is 80 MHz and the relative bandwidth is 2.67%. The patterns of E and H planes of the antenna are symmetrical, and the width of 3-dB lobes is about 100°. The maximum radiation direction is perpendicular to the normal phase of the antenna, and the gain is about 3.2 dBi (figure 6). The antenna has no side lobe, low back lobe and good cross-polarization (about 30 dB).
3. Discussion of the bottom-fed antenna

Figure 7 shows the topology of antenna II with bottom-fed. The corresponding structure and dimension are similar with Antenna I except for the feeding mode. According to the simulation, it is interesting to learn that the properties of antennas I and II are almost the same.

More specifically, for Antenna II without square aperture ($l=0$ mm), the current is mainly gathered around the feeding pin (3 GHz). However for Antenna II with square aperture ($l=6$ mm), the current is distributed along the left and right side of the radiation patch.

It can be observed from Figures 8 and 9 that for the same dimensions of radiation patch, the resonance center frequency of antenna II (bottom-fed) is slighter lower than Antenna I (side-fed).

Figure 8. Simulated surface current distribution of Antenna II (3 GHz) with ($l=6$ mm) and without ($l=0$ mm) square aperture.
Figure 9. Simulated reflection coefficients of antenna II with (l=6 mm) and without (l=0 mm) square aperture.

Once more, the patterns of E and H planes of antenna II are symmetrical, and the width of 3-dB lobes is about 100°. The maximum radiation direction is perpendicular to the normal phase of the antenna, and the gain is about 2.0 dBi (figure 10). The antenna has no side lobe, low back lobe and good cross-polarization (about 30 dB).

Figure 10. Simulated radiation patterns of Antenna II at 3 GHz.

4. Conclusion
In this paper, a compact low profile microstrip antenna is analyzed. The resonance center frequency is tuned by the square aperture. Both the side-fed and bottom-fed modes are analyzed. The surface current distribution is analyzed. It is a good candidate for wireless communication in closed warehouse.

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