A Novel Broadband Microstrip Patch Antenna with Small Ground Plane

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***Abstract*—A novel broadband microstrip patch antenna with a small ground plane is proposed in this paper. An additional ground radiation mode with low-frequency resonance is introduced by the small ground plane, while the patch radiation mode resonates at high frequency. The radiation patch is loaded with a pair of slots and two rows of shorting pins to obtain broadband matching. A relative bandwidth of 58.8%, from 2.11GHz-3.87GHz, is achieved for a compact size of $0.41\lambda_0*0.29\lambda_0*0.03\lambda_0$ at center operating frequency. In addition, omnidirectional radiation patterns with low cross-polarization are achieved over the operating band.**

***Index Terms*—broadband antenna; microstrip patch antenna; small ground plane; ground radiation mode; omnidirectional radiation patterns**

I. Introduction

The microstrip patch antenna (MPA) is widely used in modern wireless communication systems and radar systems for the reason of their attractive properties of low cost, low profile and easy to be integrated[1-2]. However, the traditional MPA always suffers from a narrow impedance bandwidth arising from its intrinsic high-Q factor in a thin substrate. In order to improve the impedance bandwidth of the MPA, various methods have been proposed in the past decades.

There are four traditional methods to improve the impedance bandwidth. The first is to reduce the Q factor by changing the parameters of the dielectric substrate. The most straightforward approach is to replace the high permittivity with air and increase the profile [3]. The second is to introduce the nonradiative modes around the dominant radiation mode of the patch by using various coupling feeding schemes, such as L-shaped probe[4], meandering probe[5], H-shaped slot[6]. The third is to excite additional radiation modes around the dominant radiation mode of the patch by introducing parasitic elements[7] or loading with slot [8]. The fourth is to reallocate the radiation of TM01 and TM03 modes in proximity to each other by loading shorting pins[9-10]. These traditional methods have tended to focus on the radiation patch and the feeding mechanism rather than the ground plane.

In this paper, a novel method to increase the impedance bandwidth of the MPA is proposed. The ground radiation mode resonating at low frequency is excited by introducing a small ground plane. Then the radiation patch is loaded with a pair of slots and two rows of shorting pins to obtain broadband matching. Simulated results show that the antenna can achieve a relative bandwidth of 58.8% with a reflection coefficient less than -10 dB, while the radiation patterns radiate broadside with low cross-polarization.

II. Antenna design

The Geometry of the proposed antenna is shown in Fig.1. The proposed antenna, comprising of a radiation patch, a micrstrip feeding line and a small ground plane, is implemented on two substrates with a permittivity of 2.65. The radiation patch is printed on the upper substrate and divided into three small patches by two symmetric slots. These small patches have the same size. Two rows of shorting pins are installed in the center of two side patches respectively. Each row includes 4 equally spaced shirting pins. The ground plane is located in the middle of the upper dielectric substrate and the lower dielectric substrate, which has the same size as the radiating patch. The microstrip feed line is printed on the lower dielectric substrate to feed the radiation patch through a coupling slot etched on the ground plane. The electromagnetic solver HFSS 15 is utilized to simulate and optimize the proposed antenna. All of the parameters for the proposed antenna in Fig. 1 are tabulated in Table I.

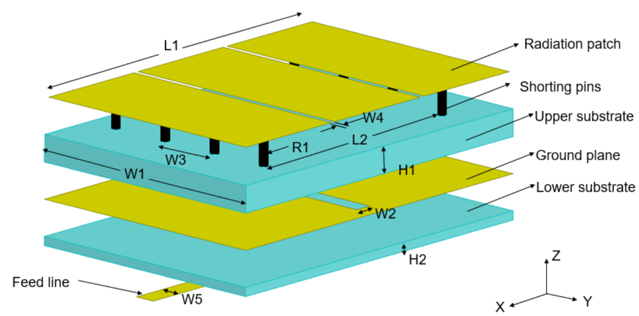


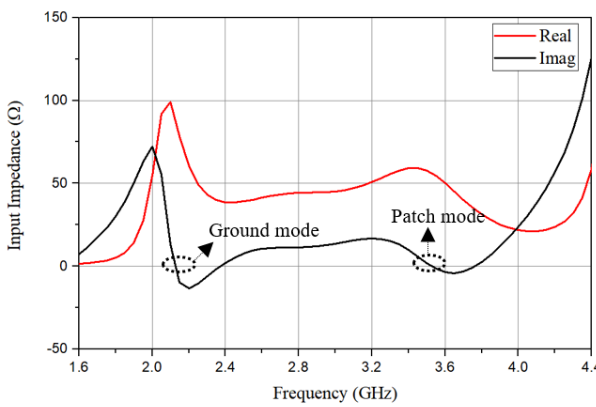
Fig. 1. Geometry of the proposed antenna.

Fig. 2(a) shows the input impedance of the proposed antenna. It can be seen that the antenna has two obvious resonances at low frequency of 2.13GHz and high frequency of 3.53GHz, corresponding to the ground radiation mode and the patch radiation mode respectively. Benefit from the two radiation modes, the antenna achieves a broad impedance bandwidth from 2.11GHz-3.87GHz with a reflection coefficient less than -10 dB, which is shown in Fig. 2(b). To verify the two different radiation modes, the surface current distributions of the radiation patch at three frequencies are shown in Fig.3. The current distributions at high frequency are similar to current distributions of patch antenna in dominant radiation mode. However, the current distributions at low frequency are obviously different, which can be considered as the result of the ground radiation mode.

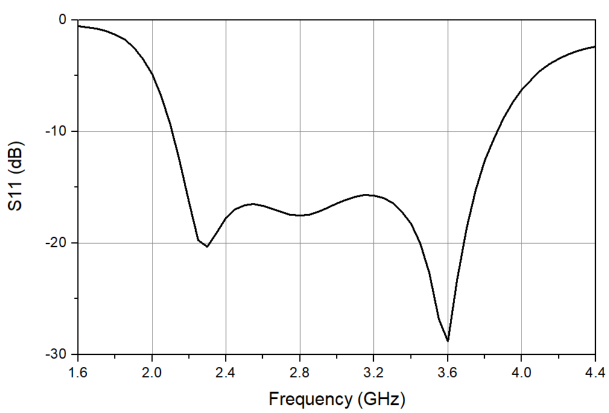
TABLE I

DIMENSIONS OF THE PROPOSED ANTENNA

Parameters	Value	Parameters	Value
L1	40.8mm	L2	27.2mm
W1	28.6mm	W2	2mm
W3	7mm	W4	0.6mm
W5	2.4mm	R1	0.5mm
H1	3mm	H2	1mm

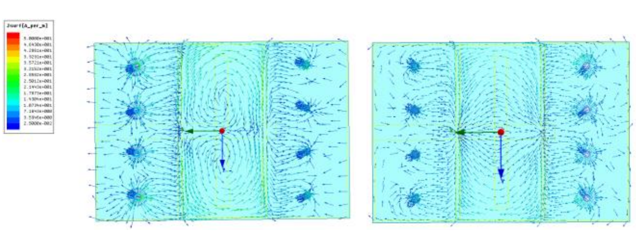


(a)

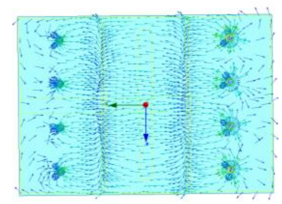


(b)

Fig. 2. Simulation results of the proposed antenna: (a) input impedance, (b) reflection coefficient.



(a) (b)



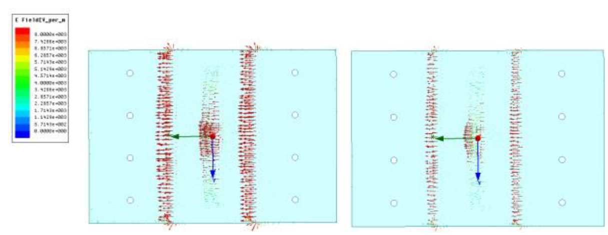
(c)

Fig. 3. Surface current distribution of proposed antenna at (a) 2.15GHz, (b) 2.8GHz and (c) 3.85GHz.

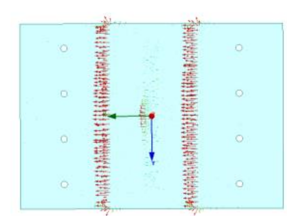
III. RADIATION PROPERTIES

Figure 4 shows the transverse electric field distribution of the antenna at high, center and low frequencies. It can be seen obviously that the transverse electric field has only the X-axis component, which is mainly present in the loading slot pair of the patch and coupling slot of the ground. Therefore, the radiation pattern shown in Fig. 5 can be equivalent to the array pattern of the three magnetic currents along Y-axis.

The H-plane pattern is omnidirectional over the entire band, which can be contributed to the reduced-size ground plane and the radiation of the coupling slot. In addition, the omnidirectivity gradually deteriorates with increasing frequency. This tendency is caused by the intensity of the transverse electric field in the coupling slot decreases with increasing frequency as depicted in Fig. 5. The E-plane pattern shows the similar tendency as the H-plane. At low frequency, the radiation pattern of the antenna is similar with that of a single magnetic dipole. But at high frequency, the radiation pattern of the antenna is similar with that of a patch antenna because the intensity of the transverse electric field at the coupling slot decreases. Furthermore, low cross-polarization level less than -32dB can be obtained over the range from -60° to 60° across the entire frequency band.



(a) (b)



(c)

Fig. 4. Tangential field distribution on the proposed antenna at (a) 2.15GHz, (b) 2.8GHz and (c) 3.85GHz.

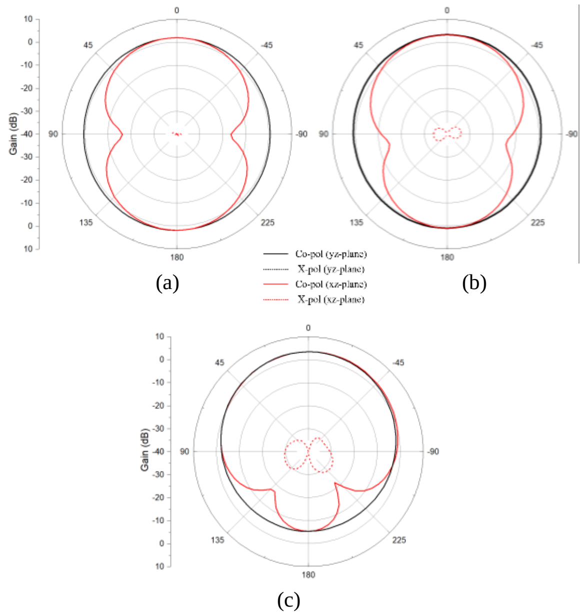


Fig. 5. Radiation pattern of the proposed antenna at (a) 2.15GHz, (b) 2.8GHz and (c) 3.85GHz.

IV. CONCLUSION

A novel broadband microstrip patch antenna with small ground plane is proposed in this paper. An extra ground mode resonating at low frequency can be achieved through the small ground plane. Broadband performance of the antenna is obtained through the dominant patch mode and the extra ground mode. Simulation results show that a relative bandwidth of 58.8% can be achieved for a compact size of $0.41\lambda_0*0.29\lambda_0*0.03\lambda_0$.

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