Broadband Stacked Patch Antenna with Low VSWR and Low Cross-Polarization

Zhongbao Wang, Shaojun Fang, and Shiqiang Fu

A low cross-polarization broadband stacked patch antenna is proposed. By means of the stacked patch configuration and probe-fed strip feed technique, the VSWR 1.2:1 bandwidth of the patch antenna is enhanced to 22% from 804 MHz to 1,002 MHz, which outperforms the other available patch antennas (<10%). Furthermore, the antenna has a cross-polarization level of less than –20 dB and a gain level of about 9 dBi across the operating bandwidth. Simulation results are compared with the measurements, and a good agreement is observed.

Keywords: Low cross-polarization, low VSWR, broadband, probe-fed strip, stacked patch antenna.

I. Introduction

Currently, patch antennas are widely used due to their low cost, low profile, and ease of manufacture. However, their intrinsic weakness is narrow impedance bandwidth. Some excellent techniques [1]-[3] have been proposed. Unfortunately, using the VSWR 1.2:1 requirement, the impedance bandwidth of the available patch antennas is still narrow (<10%). It is well known the VSWR of the antennas for digital audio broadcasting (DAB) and digital video broadcasting (DVB) transmission systems is less than 1.2. The colossal growth of DAB and DVB necessitates the development in the VSWR 1.2:1 bandwidth broadening techniques.

It is also well known that a high cross-polarization wave is radiated from the vertical portion of the feed probe [4], which reduces the polarization purity of the antennas [1]-[3]. In view of this, using an aperture-coupled feed [5], differential feeds [6], or a meandering probe [7], patch antennas have low cross-polarization levels. However, the aperture-coupled patch antenna needs a reflecting plate to block back radiation, and the differential-fed patch antenna needs a broadband feed network to provide two 180°-out-of-phase probes, which increases the complexity of the antenna configuration. In addition, the meandering probe is not easily manufactured, especially when the substrate is used.

In this letter, by using the stacked patch configuration and probe-fed strip feed technique, the impedance bandwidth for VSWR<1.2 is enhanced to 22% from 804 MHz to 1,002 MHz. Furthermore, by means of the probe-fed strip, the high cross-polarization of the antenna is suppressed effectively. The antenna has a cross-polarization level of less than –20 dB and a gain level of about 9 dBi across the operating bandwidth.

II. Antenna Design

The geometry of the proposed antenna is shown in Fig. 1. The center frequency of the antenna is chosen at f_0=900 MHz (λ_0=333 mm). The feed strip and lower and upper patches are made of the 0.1 mm thick copper foil, which are supported by foam layers (ε_r=1.05). The lower and upper patches are rectangle in shape and have dimensions of $L_1 \times W_1$= 134 mm ×160 mm ($0.40\lambda_0 \times 0.48\lambda_0$) and $L_2 \times W_2$= 113 mm×140 mm ($0.34\lambda_0 \times 0.42\lambda_0$), respectively. The antenna has a ground plane with dimensions of 300 mm×350 mm ($0.9\lambda_0 \times 1.05\lambda_0$), and the patch is positioned at the center of the ground plane. The chosen spacing between the lower patch and the ground is 18 mm ($0.05\lambda_0$). To broaden the impedance bandwidth, the height h_1 between the upper patch and the lower patch is optimized to be 24.5 mm ($0.07\lambda_0$). A narrow copper strip of

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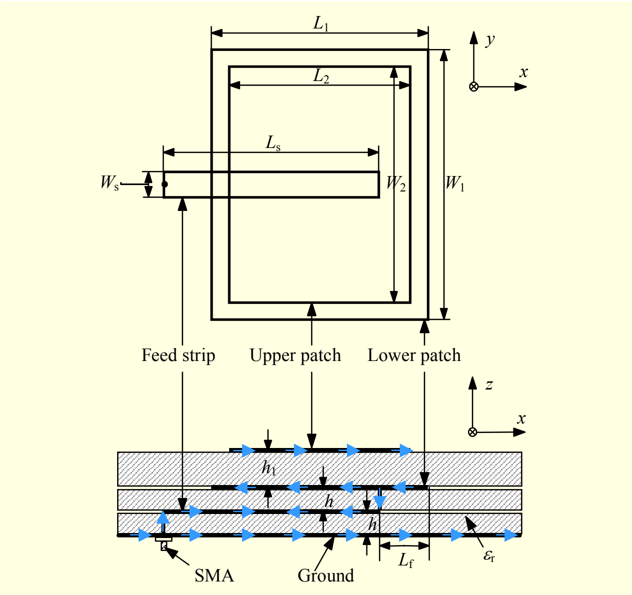

Fig. 1. Geometry and current vector density of the proposed antenna.

dimensions of $W_s \times L_s$ = 14.5 mm×133 mm is horizontally placed between the lower patch and the ground both at the distance of 9 mm and is symmetrically located along the midline of the patches. One end of the strip is excited by a 50 Ω coaxial probe extended from an SMA connector, and the other end is vertically extended to the lower patch. By properly selecting the distance between the vertical strip and the edge (L_f=37 mm), one can control the impedance matching condition between the probe-fed strip and the lower patch. The proposed feed structure with two vertical segments is similar to the differential feed scheme [6]. However, the present scheme differs from those of [6], in which a broadband impedance matching network is inserted by means of the electromagnetic coupling between the strip and the lower patch. Basically, this simple but effective technique to broaden the impedance bandwidth is a little bit similar to that of the design with the L-shaped feed strip [8]. Based on a detailed parametric study, the dimensions of the antenna have experimentally been optimized to suppress the cross-polarization levels across a 22% bandwidth. For example, compared with the aforementioned design, the antenna fed by a narrower feed strip has a smaller impedance bandwidth and hardly changed cross-polarization levels. Increasing the height h from 9 mm to 12 mm causes higher cross-polarization levels especially at the high frequency (1,002 MHz) and a narrow impedance bandwidth. The cross-polarization levels drop down, but the impedance bandwidth becomes smaller when reducing the height h from 9 mm to 7 mm.

III. Experimental Results and Analysis

The VSWR of the fabricated prototype were measured by an HP8753D vector network analyzer, and the far field performances were measured using the SATIMO system in an anechoic chamber. In addition, the commercial software called HFSS was also used to simulate the antenna performance.

The current directions at a time instance are depicted in Fig. 1. As shown, the currents in the two vertical segments at the front and back ends of the feed strip are opposite in direction. Also, the currents in the front and back parts of the feed strip are 180° out of phase. This explains why the unwanted radiation excited from the vertical segments at the front and back ends of the feed strip can be suppressed effectively.

Figure 2 gives the simulated input impedance curve in the Smith chart. It is clear that the input impedance curve varies around the 50 Ω within a broad frequency range to achieve a good impedance matching. The large reactance usually resulted from the feed probe can effectively be cancelled out by the strong electromagnetic coupling between the probe-fed strip and the lower patch. The 50 Ω resistance can be achieved by properly selecting the position of the feed point at the lower patch. Good impedance matching can be obtained by adjusting the size of the antenna (L_f, W_s, and h_1).

A comparison between the simulated and measured VSWR shows good agreement as displayed in Fig. 3. The antenna can be operated from 772 MHz to 1,020 MHz with a bandwidth of about 27.5% (VSWR<2) experimentally. For VSWR less than 1.2, the impedance bandwidth of the proposed antenna reaches up to 22% from 804 MHz to 1,002 MHz, which attributes to the stacked patch configuration and probe-fed strip feed technique. A comparison of the simulated and measured gain against the frequency is also shown in Fig. 3. The 3 dB gain bandwidth of the antenna is 31% from 750 MHz to 1,030 MHz with a peak antenna gain of about 9.8 dBi at 988 MHz.

Figure 4 shows the simulated and measured radiation

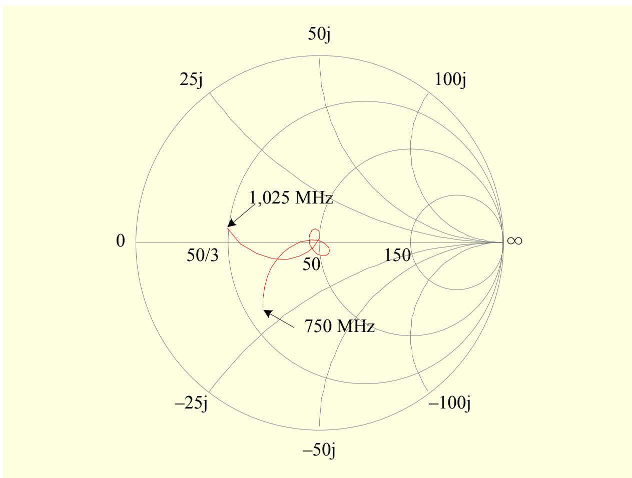

Fig. 2. Input impedance curve in the Smith chart.

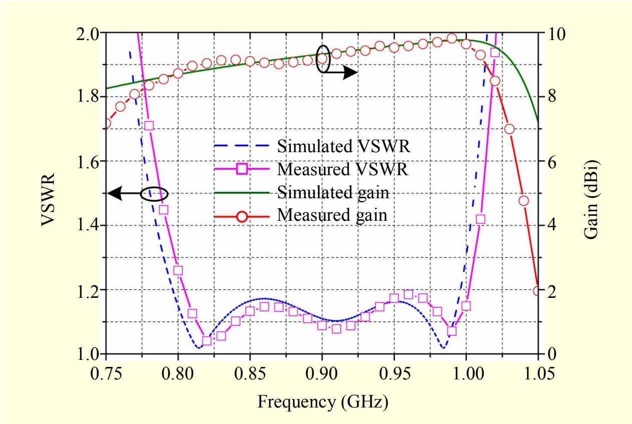

Fig. 3. Comparison of VSWR and gain between simulation and measurement.

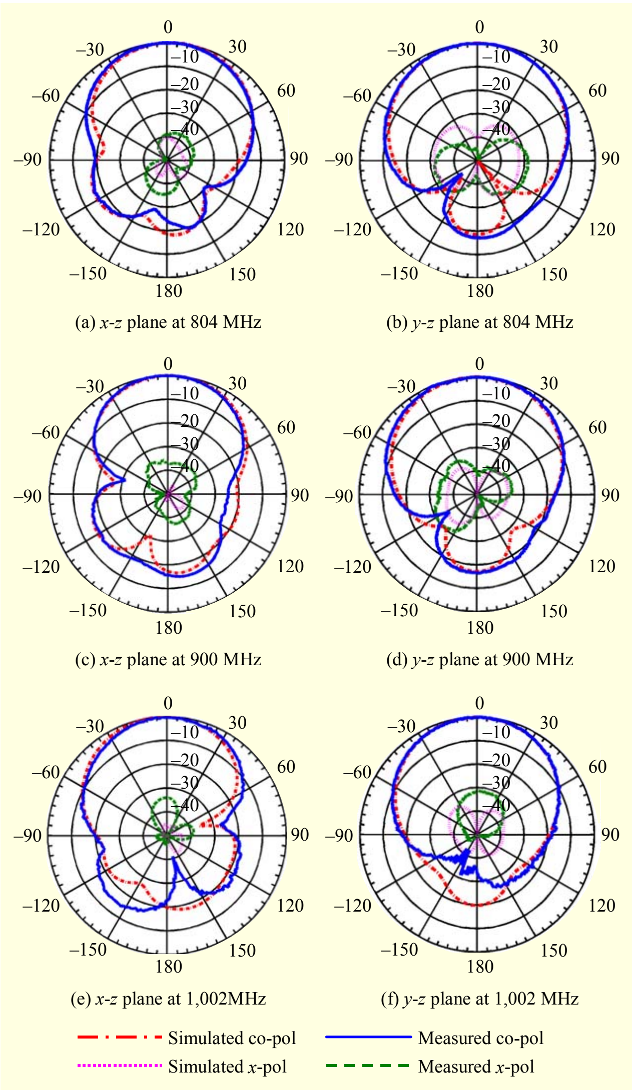

Fig. 4. Comparison of simulated and measured radiation patterns.

patterns of the proposed antenna in *E*-plane (*x*-*z*) and *H*-plane (*y*-*z*) at 804 MHz, 900 MHz, and 1,002 MHz, respectively.

Table 1. Half-power beamwidths.

Frequency (MHz)	Half-power beamwidths			
	E-plane		*H*-plane	
	Simulated	Measured	Simulated	Measured
804	65°	67°	76°	78°
900	60°	58°	69°	75°
1002	62°	58°	64°	62°

Both of the simulated and measured cross-polarization levels are less than –20 dB, and the back-lobe radiation levels are below –16 dB within the operating frequencies. It is well known that there is a high amount of leakage radiation from the feed probe. The probe radiation, which has a pattern similar to that of a short monopole, can contribute significantly to the cross-polarization level. Typically, on boresight, the cross-polarization level remains fairly low, however off-boresight angles in the *H*-plane, the cross-polarization levels can be increased dramatically. In the *E*-plane, the effect of probe radiation is to distort the co-polarized pattern, usually causing an undesirable null on one side. In this study, by the introduction of a feed strip, the effect of probe radiation can be significantly reduced. The two vertical segments at the front and back ends of the feed strip with the currents of a 180° phase shift act as the dual-probe-fed structure [6]. The resultant cross-polarization levels in *H*-planes come down.

Simulated and measured results of the half-power beamwidth extracted from the radiation patterns are summarized in Table 1. The measured half-power beamwidths are 58° in the *E*-plane and 75° in the *H*-plane at 900 MHz, which is in good agreement with the simulated half power beamwidths of 60° in the *E*-plane and 69° in the *H*-plane. Results in Table 1 show that the half-power beamwidths are stable in both *E*- and *H*-planes within the operating bandwidth.

IV. Conclusion

A low cross-polarization broadband stacked patch antenna is presented. The proposed antenna has a wide VSWR 1.2:1 bandwidth (22%) and a low cross-polarization level (<–20 dB). The VSWR of the antenna is much lower than other available broadband patch antennas. This is attributed to the stacked patch configuration and probe-fed strip feed technique. The antenna also has a high gain level of about 9 dBi.

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