A NEW DUAL-POLARIZED HORN ANTENNA EXCITED BY A GAP-FED SQUARE PATCH

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Abstract—A new dual-polarized horn antenna fed by a microstrip patch is proposed. The patch is excited in two orthogonal polarizations by small gaps between the patch edge and the microstrip open end. A horn antenna operating at 14.9 GHz is designed, fabricated and tested. Measurements show that the horn has a reflection coefficient of less than -10 dB, and a port isolation greater than 30 dB, over 14.6–15.2 GHz, and a gain of 12.34 dBi and 10-dB beamwidths of 87° and 88° at 14.9 GHz.

1. INTRODUCTION

Dual-polarized antennas are used in such diverse applications as radio astronomy, radar polarimetry, frequency-reuse and polarization-diversity communications, and antenna measurements [1, 2]. Dual-polarized antennas can be realized by exciting two linearly polarized waves whose electric field vectors are at 90 degrees to each other or by simultaneously utilizing right- and left-hand circularly polarized.

Dual-polarized horn antennas have been traditionally realized by feeding the input square waveguide with two orthogonal coaxial probes [3]. In some applications, it is favorable to excite a horn with a printed-circuit structure. In this case, a transition between the coaxial cable and the printed-circuit transmission line can be eliminated, making it easy to integrate the horn with printed circuits.

There have been some research results on horn antennas excited by printed circuit structures such as the microstrip probe, dipole and patch antennas [4, 5]. Dual-polarized horn antennas fed by printed circuit elements have been studied in [6–8]. In existing results [6–8], the port isolation is not high due to a strong mutual coupling between feeding elements.

In this paper, we propose a new compact dual-polarized horn antenna with high port isolation. A square patch antenna is excited at two orthogonal edges by coupling through a small gap between the patch edge and the microstrip open end. The patch launches two orthogonal and linear polarized waves in the square waveguide of the horn. The dual-polarized horn proposed in this paper has a narrow bandwidth due to the use of a microstrip patch in the feeding circuit so that it is suitable for narrow-band applications. The proposed antenna is analyzed and optimized using the widely-used electromagnetic simulation software Microwave Studio$^{\text{TM}}$ by CST. The designed antenna is fabricated and its performance is measured and compared with the simulation.

2. ANTENNA DESIGN

Figure 1 shows the structure of the proposed horn antenna. The horn consists of two microstrip lines, a gap-fed dual-polarized patch, a square waveguide and a pyramidal horn.

Open ends of two microstrip lines excite orthogonal currents on the patch by the capacitive coupling through a small gap at the patch edge. The patch launches TE_{10} and TE_{01} fundamental modes in the square waveguide. Walls of the square waveguide are electrically connected to the ground plane of the circuit board via closely-spaced through holes. The horn and the circuit board are joined together with a silver-epoxy conductive adhesive. Small screws can also be used for the assembly.

The horn antenna is designed in three steps. First, we design a pyramidal horn antenna with specified characteristics. Next, we design a dual gap-fed rectangular patch. Finally, we combine the patch and the horn, and adjust relevant dimensions for good impedance matching. Design requirements of the proposed antenna call for the center frequency of 14.9 GHz with impedance bandwidth of 200 MHz and 10-dB beamwidths of 87° in both E- and H-planes. The antenna is to be used as a feed in a dual-polarized reflector antenna for terrestrial point-to-point communications.

Figure 2 shows a pyramidal horn antenna with a square input waveguide. The width and height of the square waveguide are chosen to be same as the broad wall width (15.75 mm) of a standard rectangular
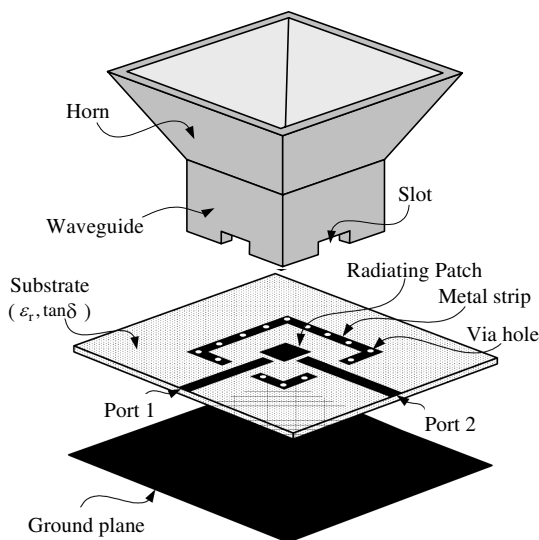
**Figure 1.** Structure of the proposed antenna.
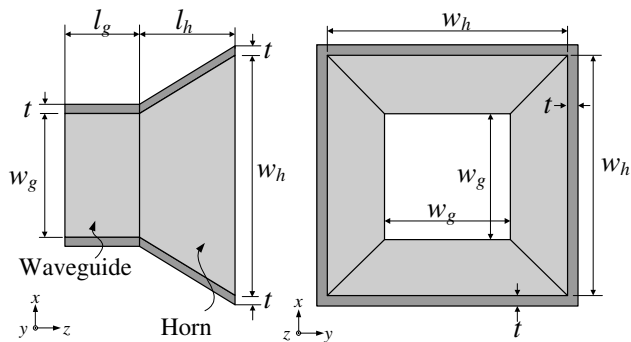
Figure 2. Structure of a horn with a square waveguide.

waveguide WR-28. The initial length of the square waveguide is chosen to be $l_g = \lambda_0/2$, which is a half wavelength at 14.9 GHz. The square waveguide length has an effect on the reflection coefficient, which is minimum when l_g is around $\lambda_0/2$. For the pyramidal section we choose initial dimensions such that $w_h = 2w_g$ and $l_h = \lambda_0/2$. The length and aperture size of the horn determine the bandwidth. The larger they are, the smaller the beamwidth will be. For a given beamwidth and the antenna size limitation, one can determine their values by gradually increasing them until the desired beamwidth is obtained. In

the simulation, the square waveguide is excited with the TE_{10} mode using the wave port in Microwave Studio^{TM} software.

Starting from initial dimensions of the horn, we first adjust the length of the square waveguide such that a minimum reflection coefficient occurs at 14.9 GHz. Next we adjust the length and aperture size of the pyramidal section so that both E- and H-plane 10-dB beamwidths are approximately 83 degrees, taking into consideration that beamwidths are increased when the horn is excited by a patch. After numerous sessions of parameter sweeping, we obtained the following optimum dimensions: $w_g = 15.8$ mm, $l_g = 9.0$ mm, $w_h = 30.76$ mm, $l_h = 13.0$ mm, and $t = 2.0$ mm.

Figure 3 shows the reflection coefficient and gain patterns of the designed horn. The horn has a reflection coefficient less than -30 dB over 14–16 GHz with a minimum value of -52 dB occurring at 14.9 GHz. At 14.9 GHz, the horn has a gain of 12.9 dBi and 10-dB beamwidths of $81°$ and $83°$ in E- and H-planes, respectively.
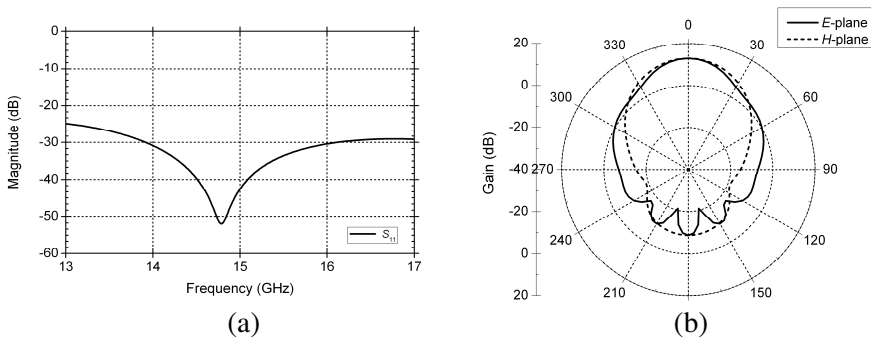

Figure 3. Simulated performances of the horn alone. (a) Reflection coefficient and (b) gain patterns.

Next, we design a dual-polarized patch antenna that will excite the square waveguide. Fig. 4 shows the structure and dimensional notations of the patch. The patch is excited by a gap between the microstrip open end and the patch edge. With gap coupling, good impedance matching and high isolation between ports are achieved. The detailed design of the patch is described in [9]. Following the procedures in [9], we obtain the final optimized dimensions of the patch: $w_p = 5.35$ mm, $g = 0.20$ mm, $w_m = 2.26$ mm, $w = 40.00$ mm, $\varepsilon_r = 2.5$ and $h = 0.787$ mm, and $\tan \delta = 0.001$. The initial patch size is determined by the resonant condition [9]. The coupling gap width is adjusted for the minimum reflection coefficient. This process is repeated until the feed circuit has the lowest possible reflection at the
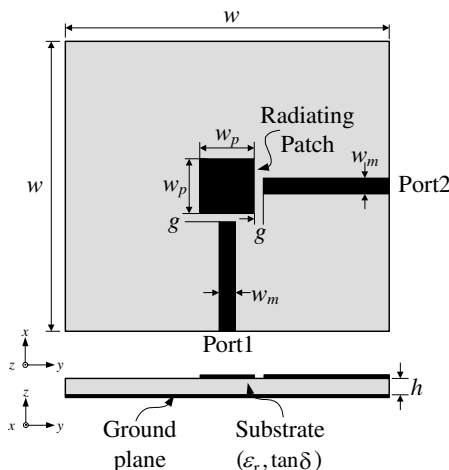
Figure 4. Dual-polarized patch fed by gap coupling.
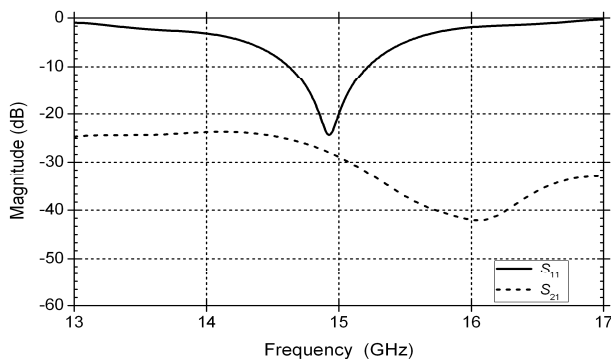
Figure 5. Simulated reflection coefficient and port isolation of the patch.

center frequency. Fig. 5 shows the performance of the designed patch. At 14.9 GHz, the patch has a reflection coefficient of -26 dB and a port isolation of 29 dB. The impedance bandwidth (-10 dB reflection) is 4.3% (644 MHz) and the antenna gain is 6.7 dBi.

Finally the patch is installed inside the square waveguide in a manner shown in Fig. 1. A rectangular metal strip is printed around the patch. Closely spaced via holes on the strip connect the waveguide wall to the substrate's ground plane. Microstrip lines feeding the patch

enter the square waveguide through small slots in the waveguide wall as shown in Fig. 1.

After assembly, the reflection coefficient of the entire antenna structure is computed. Only the length of the square waveguide, the width and height of the slot are adjusted to obtain an optimum reflection coefficient. The horn antenna of final design has a square waveguide length of 11.00 mm and slot width and height of 6.00 mm and 2.00 mm, respectively. All other dimensions of the antenna remain unchanged from those obtained in the design of each part.

3. ANTENNA FABRICATION AND MEASUREMENT

The designed antenna is fabricated and tested. The fabricated antenna is shown in Fig. 6. Two coaxial-to-microstrip adapters are installed on the substrate to measure the antenna performance. Antenna gain, reflection coefficient, port isolation and radiation patterns are measured in an anechoic chamber using the HP 8720C network analyzer and far-field antenna test instruments.

Figure 7 shows a comparison of the measured and simulated reflection coefficients, and the port isolation of the fabricated antenna.

(a)   (b)

(c)
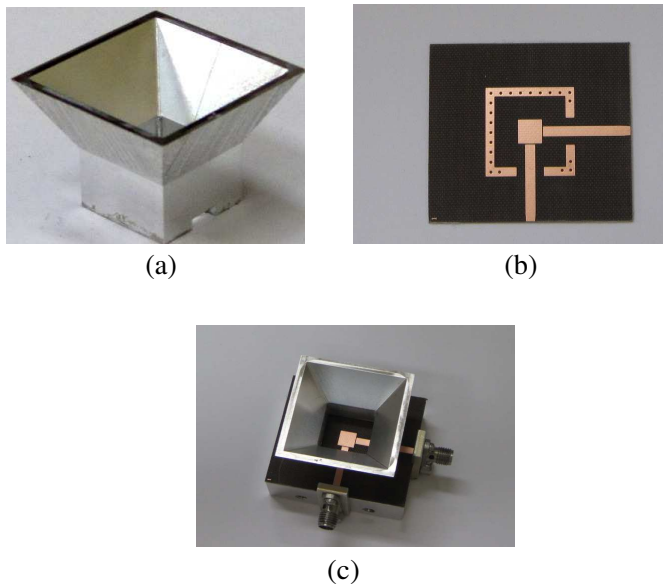
Figure 6. Fabricated antenna. (a) Horn, (b) patch and (c) assembled antenna.

Measured results agree well with the simulation. The impedance bandwidth (-10 dB reflection) is 4.1% (600 MHz). The bandwidth of the dual-polarized horn is determined by the microstrip patch of the feeding circuit since the horn alone has a much larger bandwidth. The bandwidth of the feeding circuit can be increased by placing another patch with a slightly different resonant frequency on top of the base patch as often done to increase the bandwidth of a microstrip patch [10]. The reflection coefficient of the antenna is less than -10 dB and the port isolation greater than 30 dB over 14.6–15.2 GHz. The port isolation of the assembled antenna is better than that of the patch alone.

Figure 8 shows gain patterns at 14.9 GHz of the fabricated antenna with port 1 excited and port 2 connected to a matched
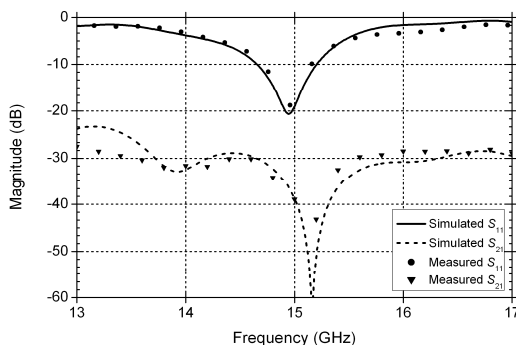
Figure 7. Reflection and isolation performances of the fabricated.
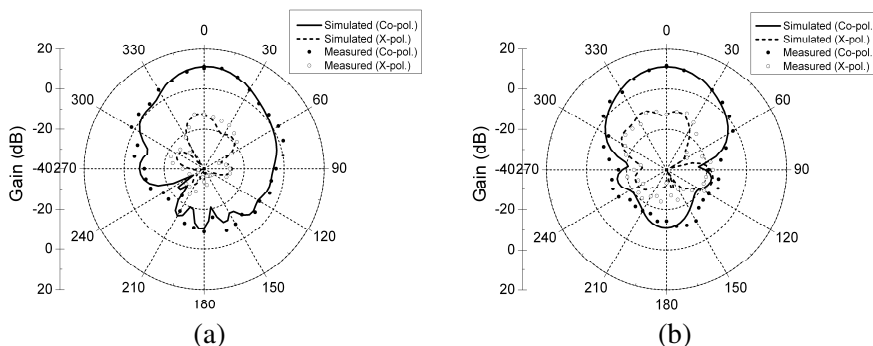
Figure 8. Gain patterns of the fabricated antenna at 14.9 GHz on (a) E- and (b) H-planes.

load. The proposed antenna's maximum gain is 12.34 dBi, and its 10-dB beamwidths are 87° and 88° in E- and H-planes, respectively. Measured gain patterns agree well with the simulation in the upper hemisphere, where the maximum error is about 3 dB.

4. CONCLUSION

In this paper, we proposed a new compact dual-polarized horn antenna operating at Ku-band. Good impedance matching, high port-isolation, and compactness of feeding are achieved by exciting the horn with a square patch fed by two orthogonal gaps between the microstrip open end and the patch edge. The proposed horn antenna can be easily integrated with printed circuits.

The horn antenna and the patch are designed separately and assembled into one structure. Only minor adjustments of dimension are required in optimizing the assembled antenna structure. The designed antenna is fabricated and tested. Measurements of the fabricated antenna show that the proposed antenna has a gain of 12.34 dBi, 10-dB beamwidths of 87° and 88° in E- and H-planes, respectively, at 14.9 GHz. The reflection coefficient is less than -10 dB and the port isolation is greater than 30 dB over 14.6–15.2 GHz (600 MHz).

The dual-polarized horn antenna proposed in this paper can be utilized in such applications as feeding a prime focus parabolic dual-polarized reflector antenna and dual-polarized horn arrays where the horn needs to be easily integrated with printed circuits.

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