High Gain Microstrip Patch Antenna as Illuminating Source for Near Field Imaging

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***Abstract*—The design of a high gain circular patch antenna with the superstrate technique is presented. The antenna was used as an illuminating source for near field imaging. The antenna was designed, constructed and its radiation pattern measured in an open range measurement setup. Measured results showed a maximum antenna gain of 12.0 dBi at 3.0 GHz, and an operating bandwidth of 7.7% (2.86-3.09 GHz). Measured 3-dB beamwidths in the E- and H-planes are 30° and 40° respectively. Maximum side-lobe level is -12 dB at +/- 100° angle in the H-plane, and the front-to-back ratio is 15 dB.**

I. Introduction

In this paper, we describe the design, construction and measurement of a high gain (12.0 dBi) microstrip patch antenna that uses the superstrate technique to enhance its gain. The constructed antenna can be used as an illuminating source in a near field imaging system similar to [1]. In conjunction with a near field probe, the imaging system is intended to image inhomogeneous material of different dielectric permittivity values.

The superstrate method was initially referred to as the resonance gain method [2]. Analyzed using the transmission line analogy in [3] and numerical electromagnetic solver in [4], this method has been a popular design in recent years [5, 6], especially when high gain is required. In section 2, we describe the design, optimization and construction of the patch antenna. In section 3, we present the measurements that were conducted to evaluate the achievement of its design performance.

II. Antenna Design and Construction

The antenna consists of a feed structure, a primary patch, two parasitic radiating patches and a superstrate. The feed structure is a shorted microstrip line and a rectangular aperture on the ground plane that broadside couples the microwave signal to the patch antenna. The primary patch is a circular microstrip patch antenna designed to resonate in the TM_{11} mode at 3.0 GHz. The circular patch antenna has a diameter of 29 mm, on a 1.5 mm thick Rogers 4533 substrate (ε_r = 3.3, tan δ = 0.002). At 10 mm above the primary patch, two radiating patches sit on a 1.5 mm thick Rogers 4533 substrate, further extending the bandwidth and gain of the antenna. Doing this increases the distance between the radiating patches and the ground plane, allowing the superstrate to effectively enhance the antenna gain while maintaining a good bandwidth performance. The superstrate is a 1.5 mm thick Rogers 4010 substrate (ε_r = 10.2, tan δ = 0.0022) that is placed 50 mm above the two radiating patches.

The antenna design was optimized for operation at 3.0 GHz using a numerical electromagnetic solver (Ansys Electronics Desktop). The optimized design achieved an operational bandwidth from between 2.9 GHz to 3.1 GHz. At the center frequency of 3.0 GHz, the antenna achieved a maximum (simulated) gain of 11.9 dBi in the broadside direction, with 3-dB beamwidths of 32° in the E-plane, and 42° in the H-plane. Fig. 1 presents the design diagrams of the antenna, showing both the plan- and side-views with labelled antenna dimensions. The dimensions are: l_0 = 120 mm, l_1 = 1.6 mm, w_0 = 100 mm, w_1 = 16.6 mm, d_1 = 29 mm, d_2 = 23 mm, x_1 = 32 mm, x_2 = 17 mm, x_3 = 10.5 mm, h_1 = 50 mm, h_2 = 10 mm. Two copies of the antenna were constructed so that they can be used as transmit and receive antennas in the antenna gain measurement. Fig. 2 shows one of the constructed antennas, with supporting Nylon spacer posts located at the four corners of the antenna.

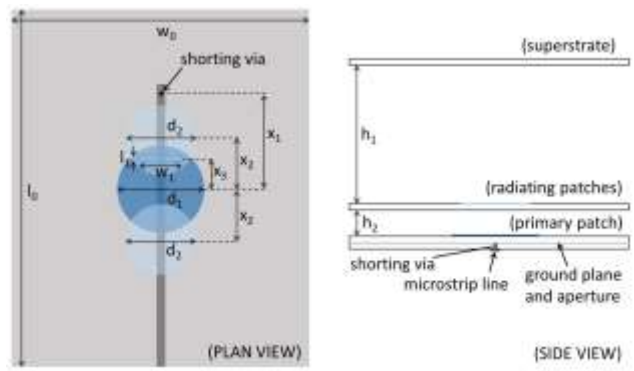

Figure 1. Antenna design diagrams showing the plan and side-views of the antenna

Figure 2. Photo showing the constructed antenna.

III. Measurement and Result

The antenna was evaluated for their return loss performance and gain patterns in the E- and H-planes. The input reflection coefficient was measured with the Keysight Fieldfox N9923A vector network analyzer (VNA) at frequencies between 2.5 and 3.5 GHz. Fig. 3 compares the simulated (blue dashes) and measured (black solid line) $|S_{11}|$ of the antenna. The measured operational bandwidth of the antenna deviates slightly from the design; achieving a slightly lower center frequency at 2.98 GHz, and 10 dB bandwidth spanning 2.86 GHz to 3.09 GHz.

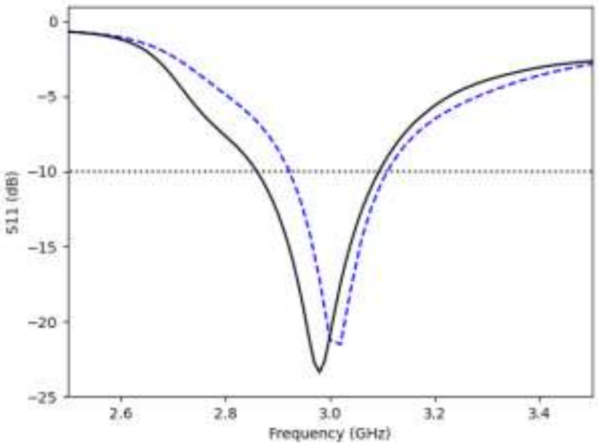

Figure 3. Simulated (blue dashes) and measured (black solid line) S_{11} of one the constructed antenna.

Figure 4. Photo of the open range measurement setup for antenna gain pattern measurements.

The radiation patterns of the antenna were measured in an open range measurement setup shown in Fig. 4. The measurement setup was placed in the middle of a 10 m by 20 m lawn, with the transmitting and receiving antennas mounted on metal poles at a height of 3.0 m. The distance between the two antennas is 3.0 m, with the transmitting antenna being rotated on an electronically controlled turn-table at angles between -180° to 180° in 1° intervals. Microwave absorbing foam blocks were placed on the ground area in between the two antennas during measurements to minimize ground reflection. Fig. 5 compares the simulated (blue dashes) and measured (black solid line) antenna gain patterns, in dBi, for both E- and H-planes.

The antenna gain patterns in the E-plane are shown in Figs. 5a-5c for frequencies of 2.9 GHz, 3.0 GHz and 3.1 GHz respectively; and gain patterns in the H-plane are shown in Figs. 5d-5f. Measured antenna gain patterns exhibit good correspondence with simulation for both E- and H-planes. At 3.0 GHz, measured antenna achieved gain of 12.0 dBi in the broadside direction, with 3-dB beamwidths of 30° and 40° in the E- and H-planes. Side-lobe level is at -12 dB, occurring at +/-100° angle in the H-plane, and the front to back ratio is 15 dB.

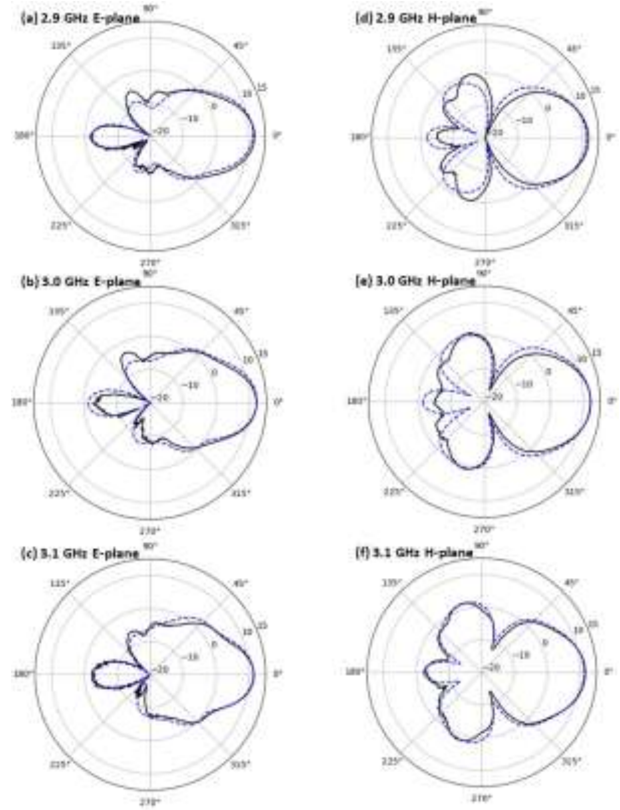

Figure 5. Simulated (blue dashes) and measured (black solid line) antenna gain patterns, in dBi, for E- and H-planes.

IV. Conclusion

We presented the design and measurement of a high gain microstrip patch antenna that is based on the superstrate technique. The antenna design was optimized using an electromagnetic simulation software, and was constructed for evaluation. The antenna achieved a measured gain of 12.0 dBi, 3-dB beamwiths of 30° and 40° in the E- and H-planes, and fractional bandwidth of 7.7% at the center frequency of 3.0 GHz.

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