A Dielectric Patch Antenna

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Abstract

An aperture-coupled microstrip antenna with a dielectric patch is proposed. The performance of this new low-profile antenna is similar to the conventional metallic patch antenna. A prototype operated at around 3.98GHz was fabricated and tested. The antenna exhibits a symmetric radiation pattern, an impedance bandwidth of 1% and a gain of 5dBi. This new antenna has good radiation efficiency which is attractive for millimetre wave applications.

Keywords : Patch antenna, Dielectric antenna

1. Introduction

A low-profile unidirectional antenna can be realized by several techniques. The microstrip antenna which consists of a metal patch printed on a thin dielectric substrate backed by a ground plane is a kind of antenna with small thickness [1]. Normally, it exhibits a gain of 6.5 dBi. It is however low in radiation efficiency when operated at very high frequencies due to high metallic loss. Alternatively, a dielectric resonator antenna with a thin dielectric resonator with high dielectric constant is also low in profile. The dielectric resonator antenna is believed to have higher efficiency at millimeter wave frequencies in comparison with the microstrip antenna as metallic loss is reduced [2]. In [3], a thin circular disk dielectric resonator antenna with very high permittivity was characterized experimentally. The antenna is excited by aperture coupling with the dielectric resonator attaching to the ground plane. In order to achieve good impedance matching, the coupling aperture cannot be too small and has to be offset from the dielectric disk. As a result, the back radiation is quite high, about -10 dB, and the radiation pattern is not very symmetrical. It has a low gain of 4.5 dBi and a bandwidth of 3.8%. To achieve higher gain, lower back radiation and more symmetrical radiation pattern, the dielectric resonator can be attached to the top surface of a grounded dielectric substrate of low permittivity and the antenna is excited by a microstrip line. A gain of 5 dBi was reported with other characteristics unchanged [4].

In many applications, it is more preferable to excite an antenna or array by the aperture coupling technique as feedline radiation can be isolated and integration with RF circuits and components can be easily implemented. In this paper, it is demonstrated that the structure of a thin dielectric resonator disk of high permittivity attaching to a grounded dielectric substrate of low permittivity [4] can also be excited by aperture coupling with good performance. The principle of operation of this antenna is similar to that of the microstrip antenna, but with the replacement of the metallic patch by a dielectric patch. The antenna is attractive for millimetre wave applications as metallic loss is minimized.

2. Antenna Geometry

Figure 1 shows the geometry of the proposed dielectric patch antenna. The antenna basically has three main layers, which include a dielectric patch in the top layer, a dielectric substrate (Substrate 1) in the middle layer and a double layer PCB in the bottom layer. The dielectric patch is a thin dielectric cylinder of radius DP_R = 12.5mm (0.284λ_g) and height DP_H = 2mm (0.455λ_g). It has a dielectric constant of 82. This high permittivity allows the dielectric patch perform like a metallic patch. There exists a microstrip patch resonant mode in the cavity between the dielectric patch and the ground plane. The dielectric patch is supported above the ground plane by Substrate 1 which is square in shape and has a length of Gnd_L = 100mm (2.27λ_g) and a thickness of H_1 = 0.762mm (0.017 λ_g). It has dielectric constant of 2.94.

The double sided PCB (Substrate 2) has a slotted ground plane on the top surface and a 50ohm microstrip line printed on the bottom surface. The double side PCB has the same length, height ($H_1 = H_2$) and dielectric constant as Substrate 1. The slot on the ground plane has a length of S_L = 6mm and a width of S_W = 1.3mm. The microstrip line has a length of L_L =62.5mm (1.42λ_g) and a width of L_w = 1.9mm (0.043 λ_g). The length of the microstrip line includes the open ended quarter wavelength stub extended from the edge of the slot. The 50ohm microstrip line combined with the slot forms an aperture coupling structure. This feeding mechanism excites the dielectric patch antenna. The other end of the microstrip line is connected to the inner conductor of a SMA connector. The outer conductor of the SMA connector is solder to the ground plane.

3. Results

The dielectric patch antenna was analyzed with the aid of a commercial EM software HFSS version 12. A prototype was fabricated and tested. The return loss of the antenna was measured by using an Agilent E5071C Network Analyzer. Figure 2 shows the simulated and measured return losses against frequency of the dielectric patch antenna. It can be observed that the input impedances by measurement and simulation are well matched. The measured and simulated resonant frequencies are 3.98GHz and 3.945GHz, respectively, with their respective bandwidths given by 1% and 2%.

The radiation pattern and gain were measured by using a Satimo StarLab system. The measured radiation pattern of the dielectric patch antenna is depicted in Figure 3(a). The corresponding simulation result is plotted in Figure 3(b) for comparison. Both results show that the antenna has a very symmetric broadside radiation pattern with a cross-polarization level less than -24 dB. The front to back ratio is larger than 15dB which implies that the unwanted radiation from the slot is relatively low. The antenna has a gain of 5 dBi. The measurements are confirmed by HFSS simulations.

The size and permittivity of the dielectric patch used in this paper is identical to the dielectric resonator used in [4]. Also, the structures of the two antennas are similar except the feed mechanisms. It may be expected that their characteristics should be similar. However, the radiation patterns of the two antennas are quite different. This confirms that the antenna studied in [4] is operated in a dielectric resonator mode while the proposed dielectric patch antenna is operated in a patch mode.

4. Conclusion

A new type of patch antenna is presented. It employs a thin dielectric material with very high permittivity as the patch layer. For the basic design demonstrated in this paper, it has an impedance bandwidth of 1% by measurement, which can be enhanced by common techniques developed for the metallic patch antenna. The antenna has very good radiating characteristics, including low cross polarization level and low back lobe radiation. The gain of this antenna is higher than the gain of the dielectric resonator antenna. Due to the reduction in metallic loss, it is believe that this antenna will have high efficiency in millimetre wave operation.

5. Figures

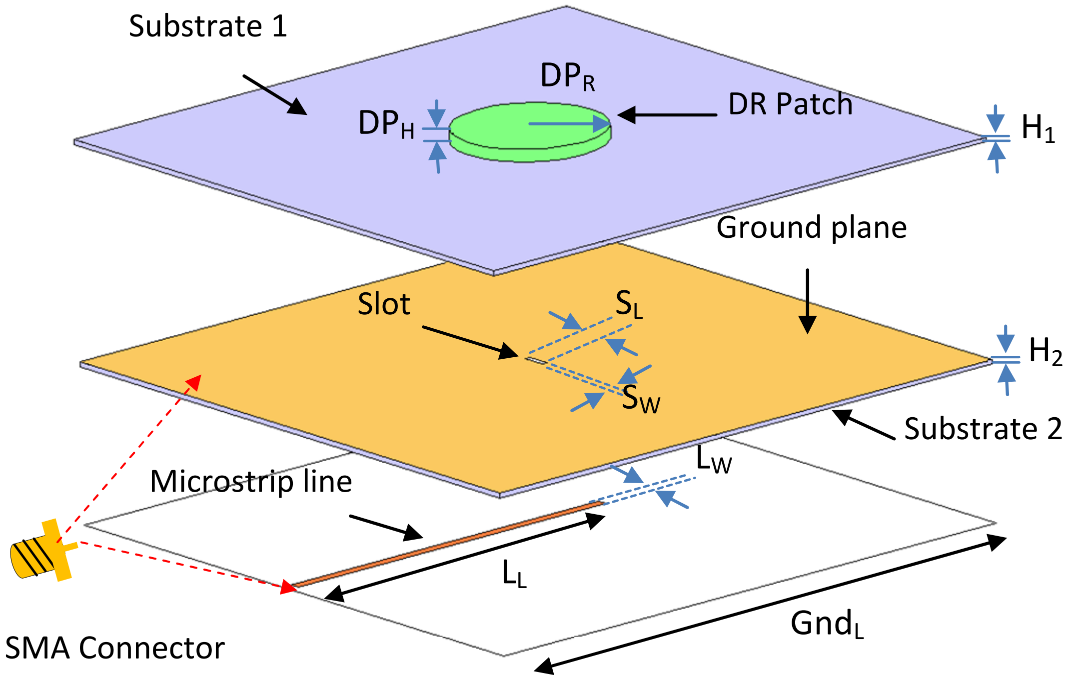

Figure 1 Geometry of the dielectric patch antenna

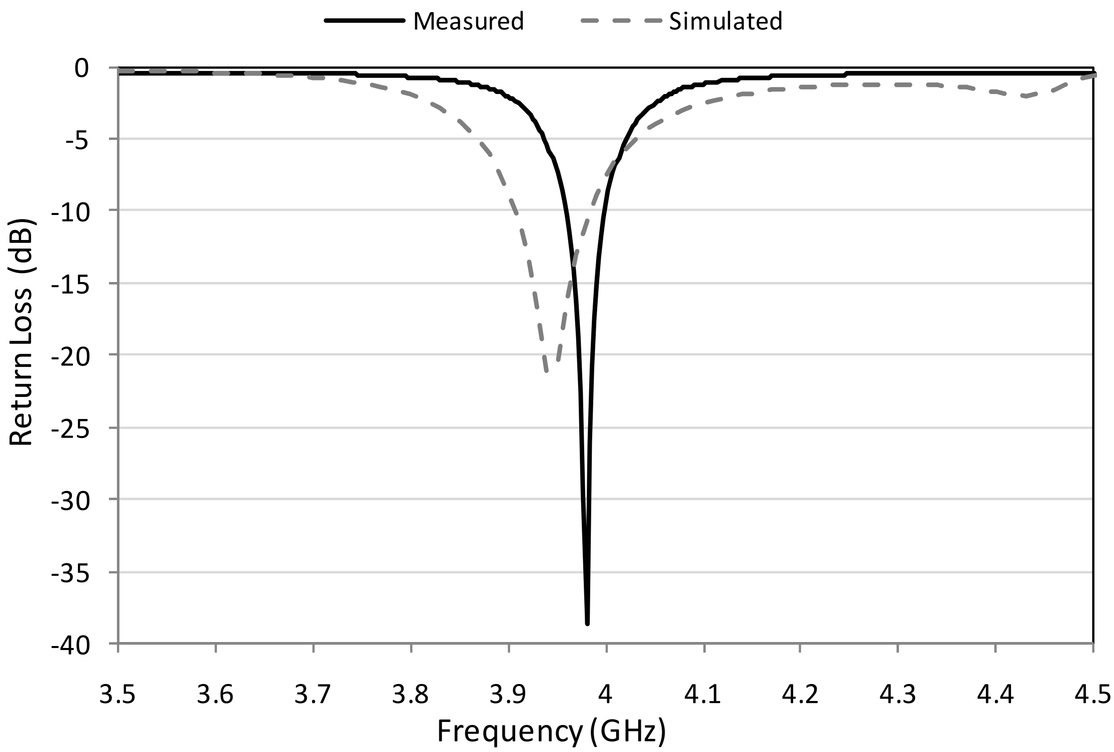

Figure 2 Return Loss against frequency of the proposed DR patch antenna (f_c=3.98GHz)

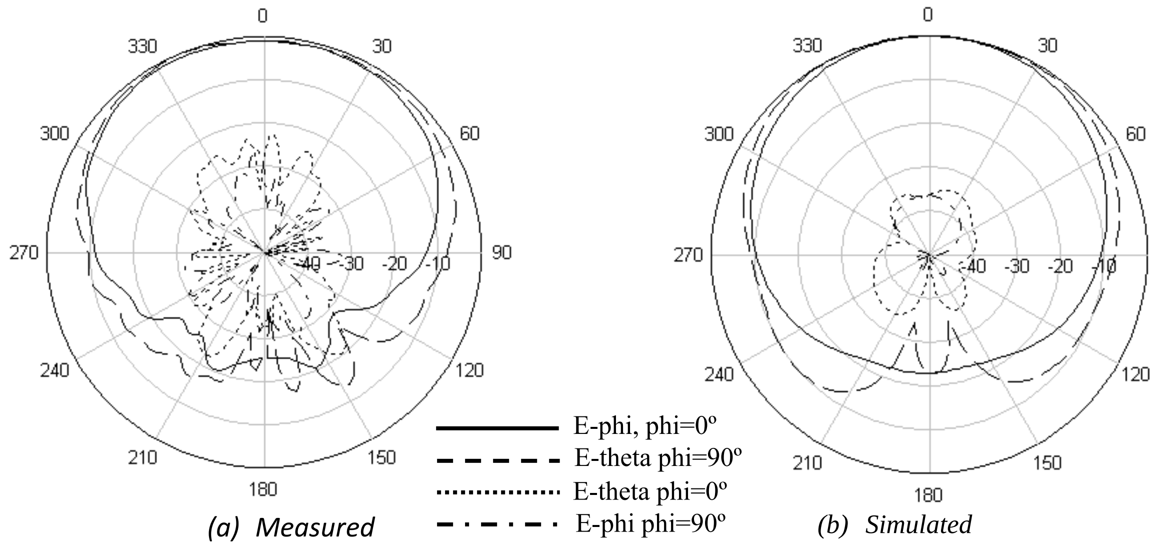

Figure 3 Radiation pattern at 3.98GHz

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