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High Gain Microstrip Patch Antenna

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Abstract

In this paper, a novel design technique for enhancing gain that improves the performance of a conventional microstrip patch antenna is proposed. This paper presents a novel wideband probe fed inverted multiple slot microstrip patch antenna. The design adopts contemporary techniques; probe feeding, inverted patch structure and stacked multiple slotted patch. The composite effect of integrating these techniques and by introducing the novel multiple shaped patch, offer a low profile, broadband, high gain, and compact antenna element. The result showed satisfactory performance with maximum achievable gain of about 12.35 dBi and a fractional impedance bandwidth of 21.48%.The design is suitable for array applications especially for base station.

Keywords: Broadband antenna, microstrip patch antenna, probe fed.

1. Introduction

Microstrip patch antennas have several well-known advantages, such as low profile, low cost, light weight, ease of fabrication and conformity (He *et al*., 2008, Zhang and Wang, 2006). However, the microstrip antenna inherently has a low gain and a narrow bandwidth. To overcome its inherent limitation of narrow impedance bandwidth and low gain, many techniques have been suggested e.g., for probe fed stacked antenna, microstrip patch antennas on electrically thick substrate, slotted patch antenna and stacked shorted patches have been proposed and investigated (Pozar and Schaubert, 1995, Sanchez-Herndez and Robertson, 1996, Chang, 2000). In general, the impedance bandwidth of a patch antenna is proportional to the antenna volume, measured in wavelengths. However, by using two stacked patches with the walls at the edges between the two patches, one can obtain enhanced impedance band width. There has recently been considerable interest in the two layer probe fed patch antenna consisting of a driven patch in the bottom and a parasitic patch (Pozar, 1992, Chair *et al*., 2000, Sze and Wong, 2000, Kuo and Wong, 2001, Wong and Hsu, 2001). By stacking a parasitic patch on a Microstrip patch antenna, the antenna with high gain or wide bandwidth can be realized (Egashira and Nishiyama, 1996). These characteristics of stacked microstrip antenna depend on the distance between a fed patch and a parasitic patch. When the distance is about 0.1λ (wavelength), the stacked microstrip antenna has a wide bandwidth (Araki *et al.*, 1986, Egashira and Nishiyama, 1996).

Recently, aperture-coupled fed stacked patch antenna in Targonski et al. (1998) have been investigated and bandwidths up to 69% have been reported, however, the major drawbacks are the level of back radiation due to the use of a resonant aperture and the surface wave excitation. Other feeding techniques such as the use of L-shaped or F-shaped probes have also been proposed yielding to wide impedance bandwidths (Ooi and Lee, 1999, Ooi *et al.*, 2001), at the expense of increased complexity of the design and fabrication, especially of the probe. In Ooi and Lee (1999), an L-probe fed stacked patch antenna was proposed with a bandwidth up to 44.4% being achieved. V-slotted rectangular microstrip antenna with a stacked patch has been shown able to achieve bandwidths as high as 47% (Rafi and Shafai, 2003). However, the gain in these designs (Ooi and Lee, 1999, Ooi *et al.*, 2001, Rafi and Shafai, 2003), are not sufficient and it's below 10dBi.

In this paper, a novel multiple slotted patch is investigated for enhancing the impedance bandwidth and gain. The design employs contemporary techniques namely, the probe feeding, inverted patch, and stacked multiple slotted patch techniques to meet the design requirement. In addition, a high gain of 12.35dBi is achieved compare to designs reported in Ooi and Lee (1999), Ooi et al. (2001), Rafi and Shafai (2003), Ng et al. (2003) and Tariqul Islam et al. (2007).

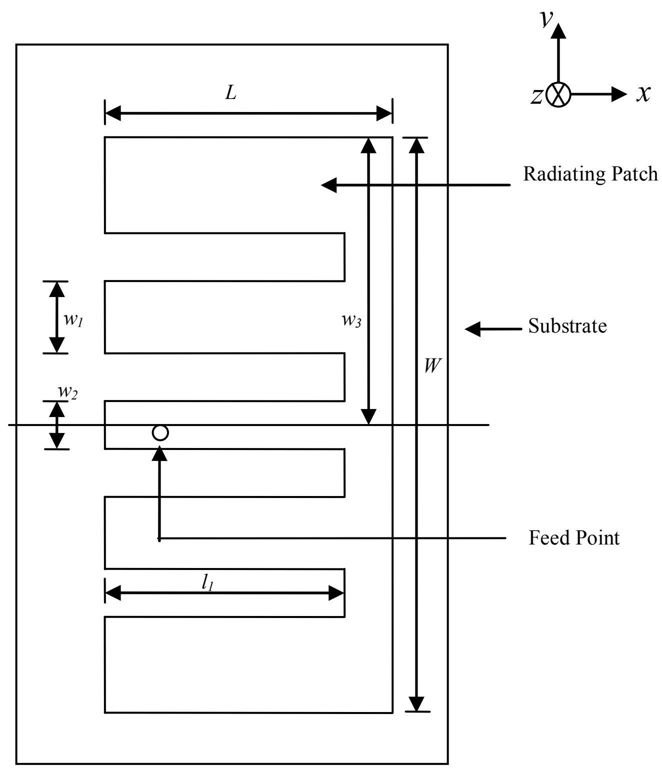
2. Antenna Layout and Structure

The geometry of the proposed antenna structure is shown in Fig. 1. The antenna is made of two stacked patches, two layers (air substrats), and a vertical probe connected to the lower patch. The lower patch, with width W and length L is supported by a low dielectric substrate with dielectric permittivity ε_1 and thickness h_1. An air-filled layer with dielectric permittivity ε_o and thickness h_o is sandwiched between the substrate and a ground plane. The upper patch with the same width and length as lower patch is stacked at the height h_2 above the lower substrate and supported by another air-filled layer with permittivity ε_1 and thickness h_2.

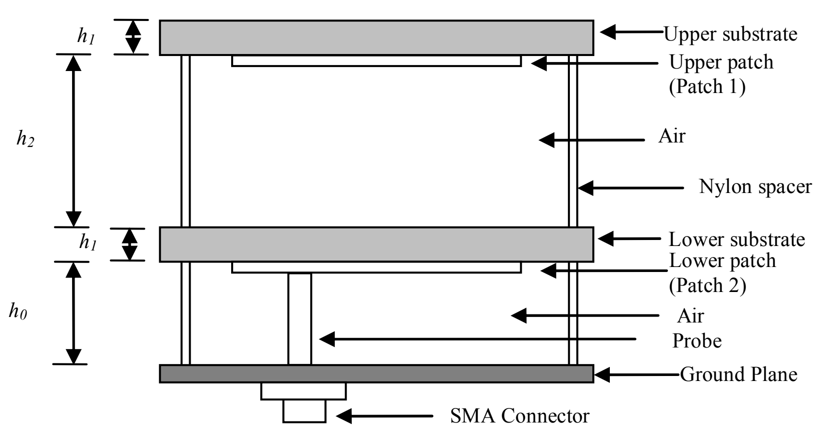
The proposed two stacked patches, using different radiating element, are multiple slotted and embedded in parallel on the radiating edge of the patch symmetrically with respect to the centerline (x-axis) of the patch. The multiple slots are shown in Fig. 1(a), where, *l and w* are the length and width of the slots. The patch is fed by a direct connected probe along the centerline (x-axis) as shown in Fig. 1(b). Table 1 shows the optimized design parameters obtained for the proposed patch antenna. A dielectric substrate with dielectric permittivity, ε_1 of 2.2 and thickness, h_1 of 1.5748mm has been used at the lower and upper patch respectively. The thickness of the air-filled, h_0 and h_2 substrates are 12.5mm and 73.5mm respectively. An Aluminum plate with dimensions of $1.397\lambda_0 \times 1.257\lambda_0$ (where λ_0 is the guided wavelength of the center operation frequency) and thickness of 1 mm is used as the ground plane.

The use of probe feeding technique with thick air-filled substrate provides the bandwidth enhancement. The use of inverted substrates provides the necessary protections for the patch from the environmental effects. The use of parallel slots in this design enhances bandwidth as well as reduces the crosspolarization level. By using stack patch, gain has been increased and able to achieve an improved gain of more than 12dBi. These techniques offer easy patch fabrications, especially for array structures.

Figure 1: The geometry proposed patch antenna. (a) Top view, (b) Side view.



(a)



(b)

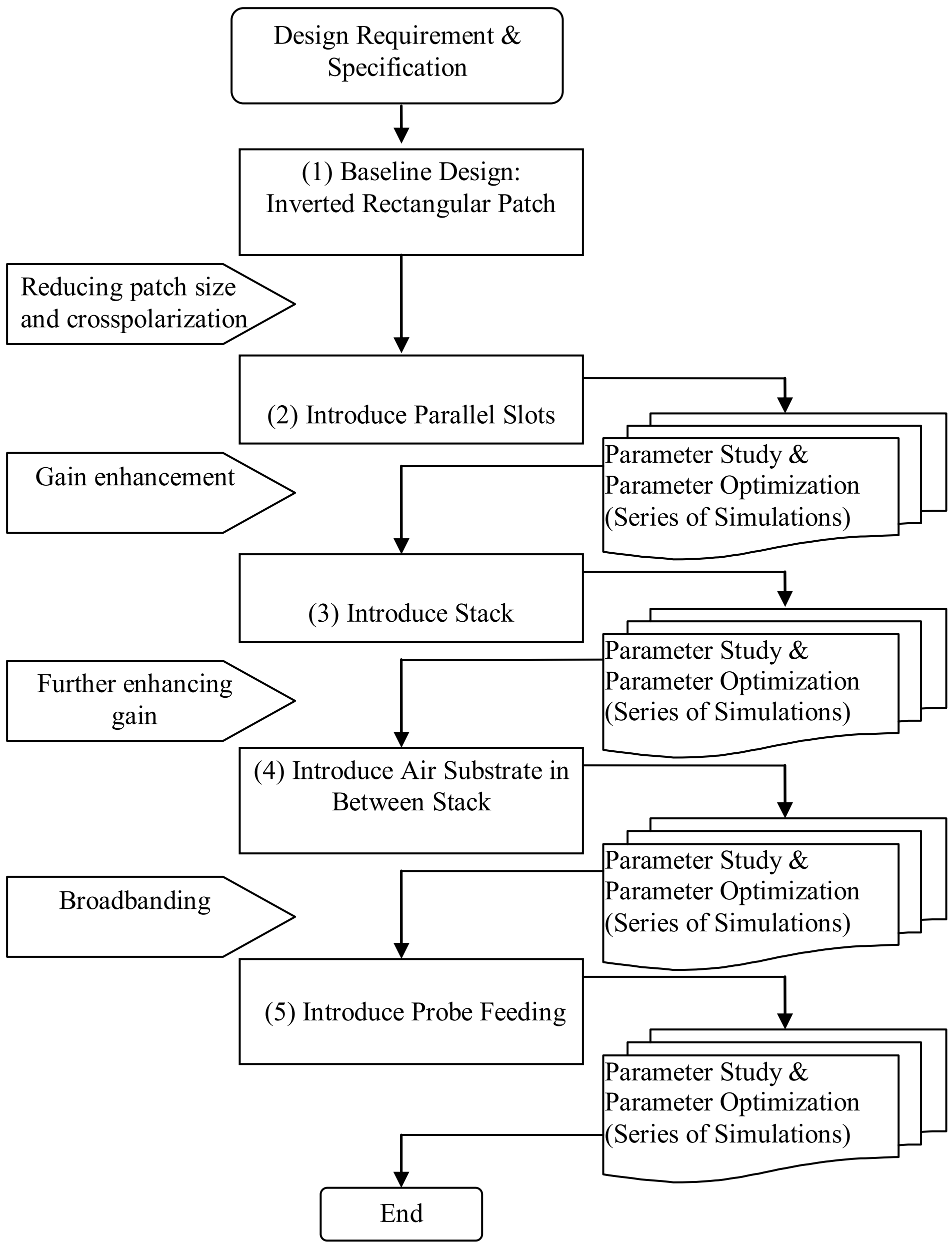
Table 1: Proposed patch antenna design parameter.

Parameters	**Value [mm]**
W	96
L	48
W_1	10
W_2	7
W_3	48
L_1	42
H_0	12.5
H_1	1.5748
h_2	73.5

4. Simulation Setup

The resonant properties of the proposed antenna have been predicted and optimized using a frequency domain three- dimensional full wave electromagnetic field solver (Ansoft HFSS). The design flow diagram is shown in Fig. 2, starting with a baseline design of the rectangular patch with air-filled dielectrics, the baseline parameters (*L, W*, h_1, h_o, h_2,) are determined at centre frequency. The multiple slots and stacked are then introduced on the patch with the initial values slots parameters to reduce the patch size and crosspolarization level and to increase the gain. Next, the probe is introduced to feed the patch and its parameters are adjusted to achieve the broadband requirement.

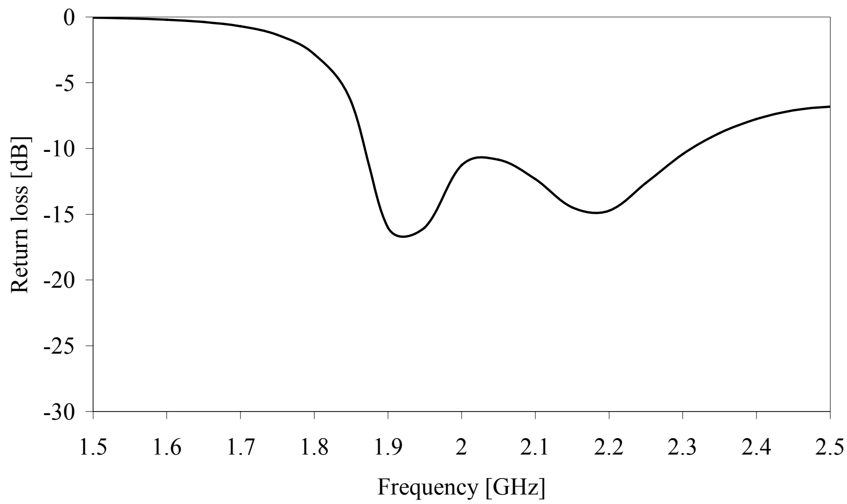
Figure 2: Design flow diagram for the proposed patch antenna.



5. Result and Discussion

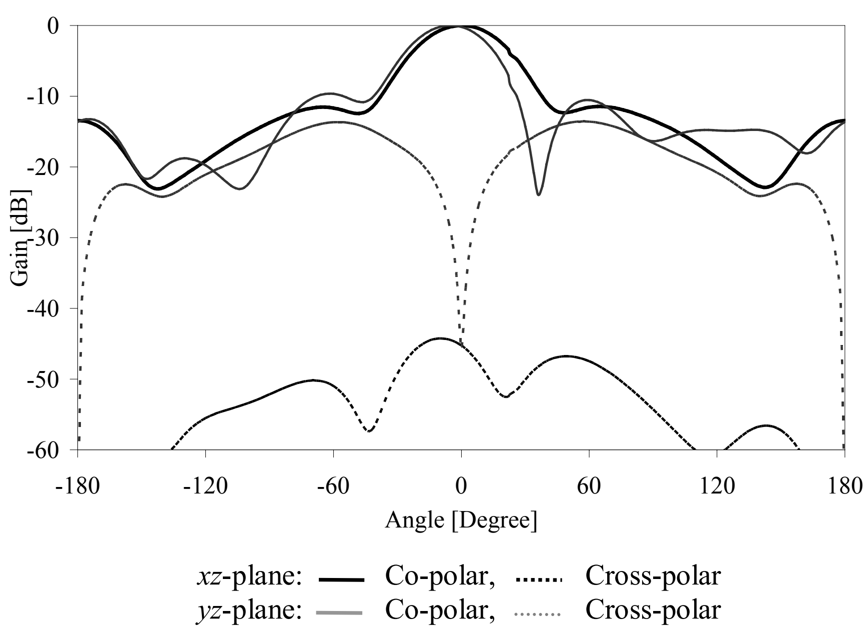
Fig. 3 shows the simulated result of the return loss of the proposed antenna. The two closely excited resonant frequencies at 1.95 GHz and at 2.2 GHz as shown in the figure gives the measure of the wideband characteristic of the patch antenna. The simulated impedance bandwidth of 21.48% from 1.87 GHz to 2.32 GHz is achieved at 10 dB return loss (VSWR≤2).

Figure 3: Simulated return loss of the proposed patch antenna.



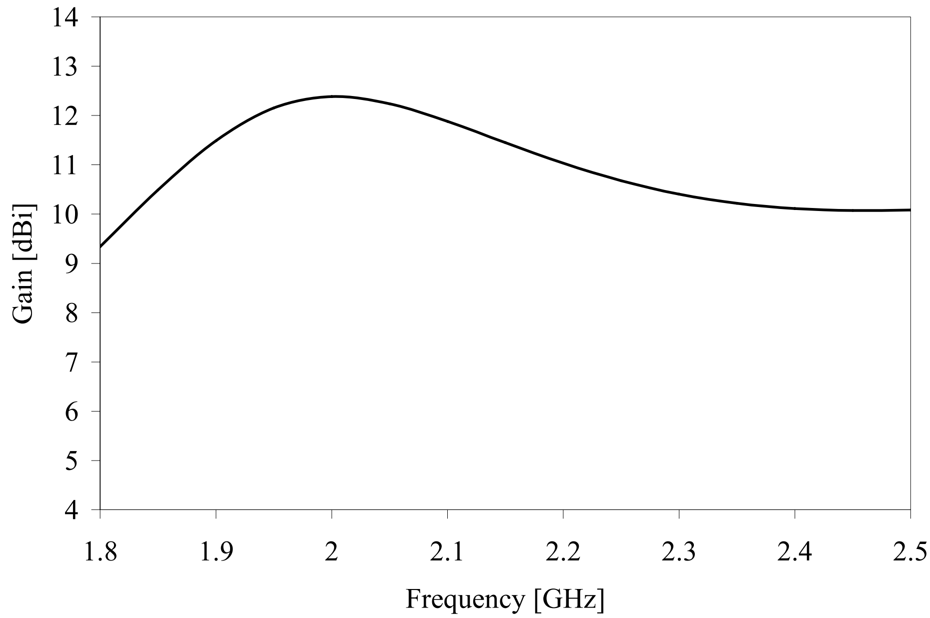
The simulated radiation patterns at the second resonant frequencies in the *xz*-plane and *yz*-plane are plotted in Fig. 4. For the sake of brevity, only simulated radiation pattern for second resonant frequency is given in this paper. As shown in Fig. 4, the designed antenna displays good broadside radiation patterns in the *xz*-plane and *yz*-plane at frequency of 2.2 GHz. It can be seen that 3-dB beamwidth of 42º and 38º for *xz*-plane and *yz*-plane respectively at 2.2 GHz. The cross-polarization pattern is lower than about -44dB in *xz*-plane. The proposed patch antenna exhibits better crosspolarization than the design reported in Tariqul Islam et al. (2007). Notable, the radiation characteristics of the proposed antenna are better to those of the conventional patch antenna. The radiation patterns at other bands, which are similar to those at 1.95 GHz, are not presented here in detail.

Figure 4: Radiation pattern of proposed patch antenna at 2.2 GHz for *xz*-plane and *yz*-plane.



The simulated gain of the proposed patch antenna at various frequencies is shown in Fig. 5. As shown in the figure, the maximum achievable gain is 12.35 dBi at the frequency of 2.0 GHz and the gain variation is 2 dBi at the operating frequency.

Figure 5: Simulated gain of proposed patch antennas at different frequencies.



6. Conclusion

A wide-band multiple slotted stacked patch antenna has been designed for high gain. A novel technique for enhancing bandwidth and gain of microstrip patch antenna is successfully designed in this paper. The proposed microstrip patch antenna achieves a fractional bandwidth of 21.48% (1.87 to 2.32 GHz) at 10 dB return loss. The maximum achievable gain of the antenna is 12.35 dBi. The proposed patch has a compact dimension of 0.670 λ_0 × 0.335 λ_0. The design has demonstrated that stacked patch with multiple slots and probe fed can be used to form an antenna with the broad bandwidth of 21.48%, furthermore due to its high gain and broad bandwidth more applications can be anticipated.

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