Design and Performance Analysis of Slotted Microstrip Patch Antenna Array for 8GHz Frequency Applications

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Abstract: In this paper, multiple slots technique with use of C-foam (Air Substrate) as dielectric material is implemented. This improved the gain and directivity for microstrip patch antenna, 2x1 microstrip patch antenna array, and 4x1 microstrip patch antenna array. The centre frequency of 8GHz (X-Band) is chosen for this design. First, single slotted microstrip patch antenna is designed and simulated, which achieved gain of 9.25db. Second, 2x1 microstrip patch antenna array is designed to get improved gain of 11.50db. Further, gain improvement is done by designing 4x1 microstrip patch antenna array. The results for simulation are very good. Gain for 4x1 array is 15.65db. Substrate thickness and feed line network are very important parameters while designing array of antenna. The proposed antennas are designed and simulated in the Ansoft HFSS 13.0 software.
Keywords: Microstrip Patch Antenna, Antenna Array, Air Substrate, Multiple Slot Technique.

Introduction

Microstrip patch antenna is formed from two parallel conductors that are separated by a dielectric substrate. The lower conductor typically acts as a ground plane and the upper conductor acts as a patch. This is why such antennas are referred to as patch antennas [1]. Microstrip patch antennas find numerous applications in mobile and wireless communications, satellite, spacecraft, aircraft, and defense areas. The high demand of patch antenna in all these important fields can be credited to its advantages in size, weight, flexibility, performance, cost, easy installation, and easy fabrication using modern printed circuit board technology. Unfortunately, microstrip patch antenna suffers from some disadvantages such as low efficiency, low power, low gain, narrow bandwidth, and high loss which may hamper its usability many a time. This pushes for further research and improvement in patch antenna field. To overcome these disadvantages some basic techniques are applied as electromagnetic band gap (EGB) which reduces mutual coupling and suppresses surface waves [2], partial substrate removal reduces surface wave and dielectric loss [3], dielectric resonator disc placed over radiating patch of microstrip patch antenna [4], slotting in microstrip antenna patch reduces current loss [5], and building microstrip antenna array improves gain and directivity [6].

Different configuration of microstrip antenna array can give the different results for Bandwidth, Gain and other important antenna parameters. The proper impedance matching throughout the feeding network provides the highly efficient microstrip antenna. The choice of the design parameters such that dielectric constant, height of dielectric, frequency etc. is important because overall antenna performance depends on all these parameters.

Mathematical Modeling

There are three types of modeling techniques for rectangular patch microstrip antenna designing. Namely, transmission line model, cavity model and full wave model. Here the transmission line model is used to determine the parameters of the microstrip patch antenna [1].

- Calculation of Width of the patch (w):

$$w = \frac{c}{2f_o}\sqrt{\frac{2}{\epsilon_{r+1}}} \qquad (1)$$

Where c = free space speed of light
f_o = resonant frequency
ϵ_r = Dielectric constant of substrate

- Calculation of Length of the patch (L):

$$L = Leff - 2\Delta L \qquad (2)$$

Where Leff = effective length of patch
ΔL = length extension

$$\Delta L = 0.412h \frac{(\varepsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{reff-0.258})\left(\frac{W}{h}+0.8\right)} \quad (3)$$

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+2\frac{h}{W}\right]^{-\frac{1}{2}} \quad (4)$$

Where ε_{reff} = Effective dielectric constant
ε_r = Dielectric constant of substrate
h = Height of dielectric substrate

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{reff}}} \quad (5)$$

By using these equations the width and length of the radiating patch for microstrip antenna can be calculated.

Antenna Design and Simulation Results

Slotted microstrip patch antenna is designed and simulated in Ansoft HFSS 13.0. Operating frequency of 8GHz is used throughout this paper. The substrate used in this design is C-foam (Air substrate) having dielectric constant of 1.03 which is very close to dielectric constant of air [7]. Slotted microstrip patch antenna, 2x1 microstrip antenna array, and 4x1 microstrip antenna array is discussed in three different sections.

A. Slotted microstrip patch antenna:

Initial antenna parameters are calculated using equations (1)-(5) for operating frequency 8GHz and dielectric constant r = 1.03 and antenna is designed. Later, these parameters are optimized to reach the optimal results. The optimized parameters of the purposed microstrip antenna are given in Table (1).

Table1. Antenna Design variables and there values

Antenna Variables	W	L	H	Fi	Gpf	Wf	Lf
Values (mm)	25	14	2.90	4	9	4	11

The antenna with these optimized parameters is designed. The schematic diagram of the antenna is shown in Fig. (1A) and design in HFSS shown in Fig. (1B)

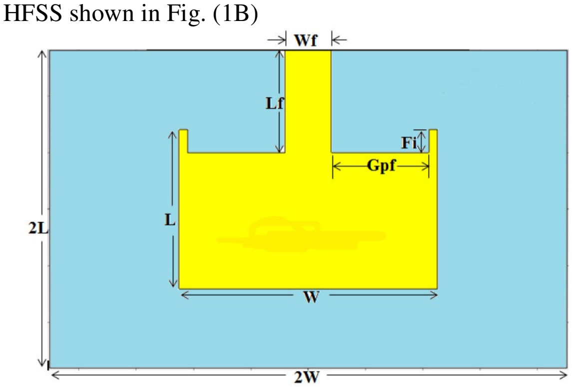

Figure1A. Schematic of Slotted microstrip patch antenna

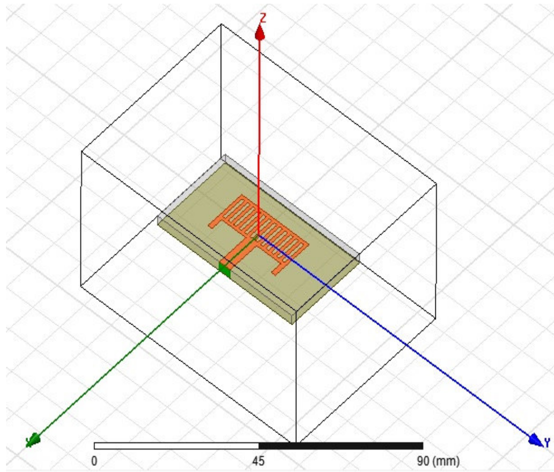

Figure1B. Design of slotted microstrip patch antenna

Slot is placed with displacement of 1mm from adjacent two slots. Width of each slot is 1mm and length is 8mm. This antenna is simulated in HFSS and results so achieved are return loss of -34db, gain of antenna is 9.25db, and directivity is 9.10db.

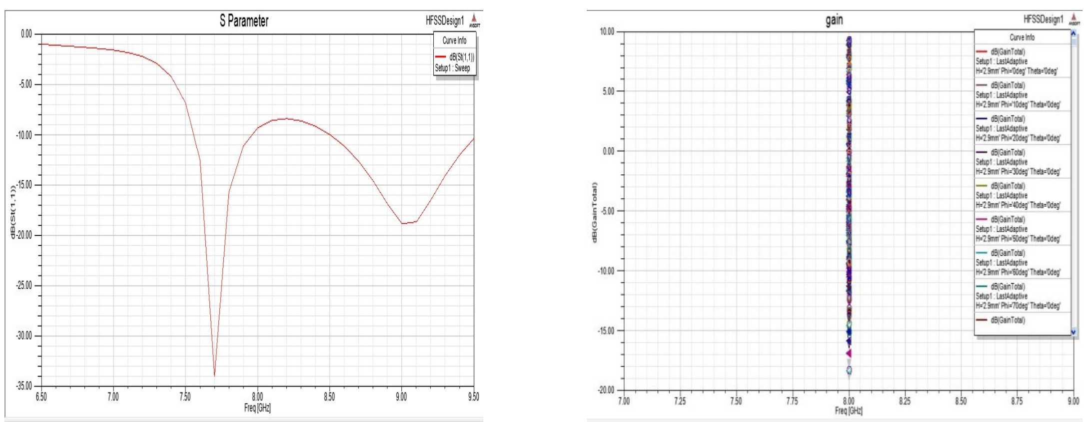

Figure2. Return Loss and Gain Plot

B. 2x1 Slotted microstrip antenna array:
In order to enhance the gain and directivity microstrip antenna is placed in 2x1 array structure and simulated. Height of dielectric substrate is optimized to 3.6mm. Results achieved are Return loss for 2x1 array is -36db, gain is 11.50db, and directivity is 11.25db.

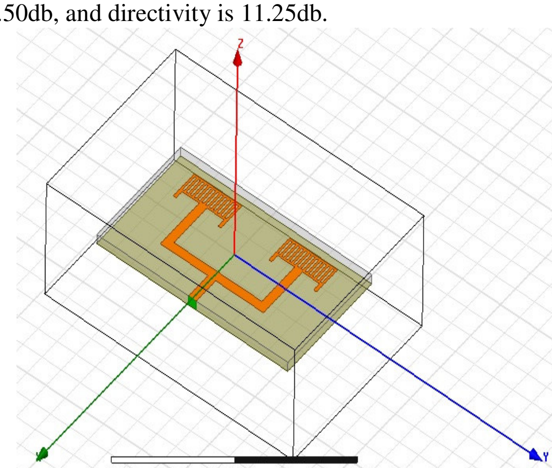

Figure3. Design of 2x1 Slotted microstrip patch antenna

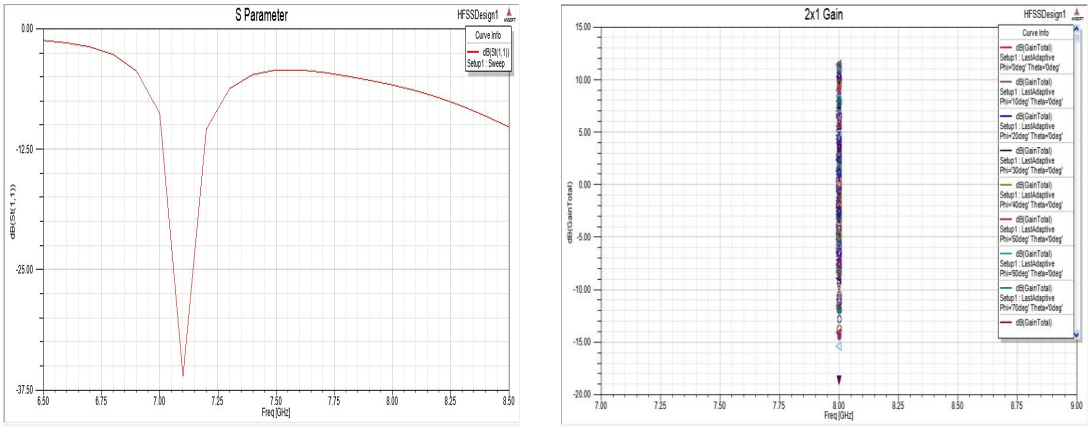

Figure4. Return Loss and Gain plot for 2x1 array

C. 4x1 Slotted microstrip antenna array:

Further, improvement in antenna performance is achieved by designing 4x1 slotted microstrip patch antenna array. Height of dielectric substrate is optimized to 1.9mm. After simulation of 4x1 array we achieved better results. Return loss is -37.5db. Also, we achieved high gain for 4x1 antenna array. Gain is 15.60db and directivity is 15.35db.

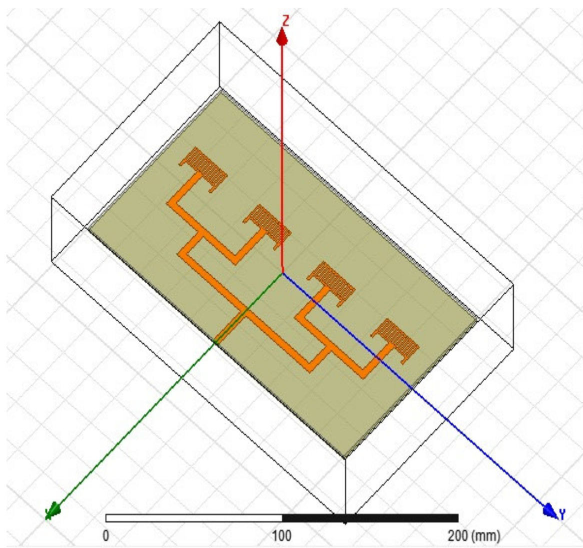

Figure5. Design of 4x1 Slotted microstrip patch antenna

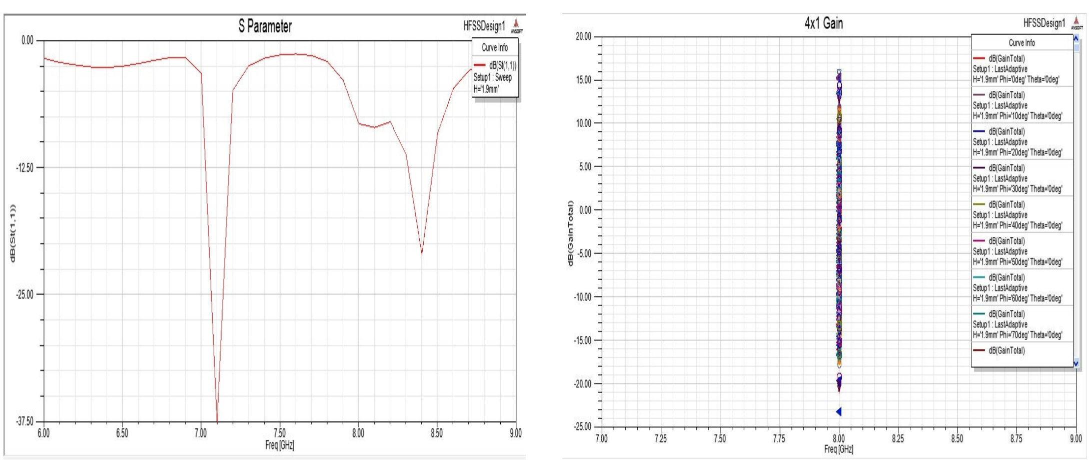

Figure6. Return Loss plot for 4x1 array

Results

The antenna model is simulated on Ansoft HFSS 13.0 software. HFSS addresses the various ranges of the EM problems, including losses due to reflection, radiation, attenuation and coupling. The power behind HFSS lies in the mathematics of the finite element method and this is integral, proven automatic adaptive meshing technique.

The simulation of slotted microstrip antenna, 2×1 slotted microstrip antenna array, and 4×1 slotted microstrip antenna array gives different values of Gain, Directivity, and Return Loss. All parameter values are shown in the table below:

Table2. Simulated Results

Parameters	Slotted Microstrip Antenna	2x1 Antenna Array	4x1 Antenna Array
Return Loss	-34db	-36db	-37.5db
Gain	9.25db	11.50db	15.60db
Directivity	9.10db	11.25db	15.35db

Conclusion

Multiple slot technique with Air Substrate (C-Foam) as dielectric substrate is successfully implemented in this paper. Gain, directivity, and return loss improvements are achieved for 8GHz (X-Band) applications. 2x1 array has improved results over single antenna while 4x1 array provided further improved results than 2x1 array. Applications where antenna size is not a constraint can even go for large antenna array. Antenna design and arrays purposed in this paper are very simple, efficient, and easy to fabricate.

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