DESIGN AND DEVELOPMENT OF MICROSTRIP PATCH ANTENNA ARRAY FOR WIRELESS COMMUNICATION SYSTEMS

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***ABSTACT*:**
In this paper, a typical low-cost, low-weight microstrip base station antenna arrays with beam-scanning capabilities has been presented. This paper describes the design, simulation and testing of microstrip patch antenna array for the current wireless communication systems which operates at 1.8 GHz band, with 35^0 beam widths, up to 40^0 electronic scanning capabilities. These beam widths are chosen because they become almost standard for base station applications. The designed antenna is a 3X3 array.

I. INTRODUCTION

Microstrip patch antennas (also just called patch antennas) are among the most common antenna types in use today, particularly in the popular frequency range of 1 to 6 GHz. [1]. The antenna arrays represent a good choice to generate a radiation pattern with desired characteristics, major lobe direction, beam width, nulls position, side lobe levels, etc.

The antenna initially designed based on the empirical formulae [2]. Later, the optimization and simulation is carried out using Advanced Design Systems (ADS) electromagnetic simulator, which is based on the method of moments (MOM) numerical technique. The antenna is fabricated and evaluated. The measured results are compared with simulated results.

II.DESIGN PROCEDURE

The dielectric material selected for the design is glass (FR4) which has a dielectric constant of 4.5. The height of the dielectric substrate is selected as 1.6 mm. A substrate of a high dielectric constant when selected reduces the dimensions of the antenna.

The first step in the design is to specify the dimensions of a single microstrip patch antenna. Here, the half-wavelength rectangular patch element is chosen as the array element. Its characteristic parameters are the length L, the width W, and the thickness h.

A. Design of Single Patch

The major electrical properties taken into consideration are relative dielectric constant and loss tangent. Initially, the length and the width of the radiating patch are calculated from the empirical equations available [2].

i) Determination of Feed Point Location (X_f, Y_f)

A coaxial type feed is to be used in this design. For different locations of the feed point, the return loss is compared and that feed point is selected where the input impedance (50 Ohm) is matching with the free space impedance of 377 Ohm.

$$X_f = 19.6\ mm \quad (1)$$

$$Y_f = 10.6\ mm \quad (2)$$

ii) Designed parameters of single patch

The optimized dimensions are summarized in **table1**.

TABLE1

Length of the patch (L)	39.2mm
Width of the patch (W)	39.2mm

B. Design of 3x3 Array

Since the required antenna is a uniform 3x3 square array, the dimensions of the nine patches are chosen exactly same as the dimensions of the single patch.

i) Distance between the Patches

The distance between the antenna elements has been calculated by considering scan angle and grating lobe position. If the spacing between elements is half a wave length (d = 0.5λ), the first grating lobe does not appear in real space. Therefore the distance between antenna elements chosen is 0.5λ. [3]

ii) Relative Phase Shift between Elements

In order to position the main beam of the radiation pattern at an angle θ_o, the relative phase shift between adjacent elements of the array must be

$$\Phi = 2\Pi\ (d/\lambda) \sin \theta_o \quad (3)$$ [3]

Substituting $\theta_o = 40^0$ (Required scan angle for the main beam) $\Phi = 115^0$.

iii) Designed parameters of 3X3 patch

The optimized dimensions are summarized in **table2**.

TABLE2

Length of the patch (L)	39.2 mm
Width of the patch (W)	39.2 mm
Spacing between the patches (d)	80 mm
Relative phase shift between the patches (Φ)	115 º

III.SIMULATION RESULTS & ANALYSIS

The structure is simulated and optimized using Advanced Design Systems (ADS) EM simulation software [4]. The simulation results of single patch and 3X3 array are summarized below.

A. Single patch antenna

a) Return Loss: From **fig.2**, it is observed that the return loss is -36dB, which is fairly a good result for an antenna. This means that all the power fed is radiated by the antenna with negligible losses.

b) Radiation Pattern: The 3D radiation pattern is shown in **fig.3** and it is observed that the 3dB beam width is ± 42°.

c) Efficiency: The efficiency of the single patch antenna from the **fig.4** is 42.096%. Since the substrate material used is FR4 whose loss tangent is 0.02 (which is comparatively high), the radiation losses are more resulting less efficiency. The efficiency can be increased by selecting a low loss tangent material like RT Duroid (δ = 0.005)

d) Gain: From the **fig.4**, the gain of the single patch antenna is 2.415dB. This gain is for single patch and the gain will be increased when this element is used in 3x3 array.

e) Directivity: The directivity observed from the **fig.4** is 6.172. Here the difference between gain and directivity is more because of less efficiency which is due to high loss tangent material.

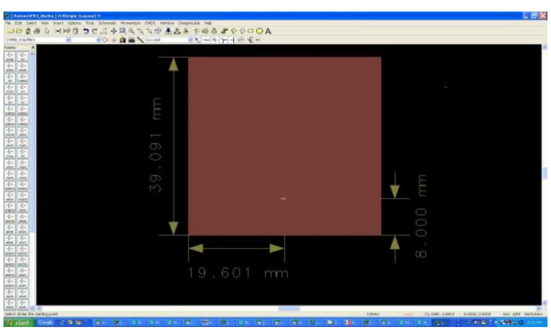

Fig.1. Layout of single patch in ADS

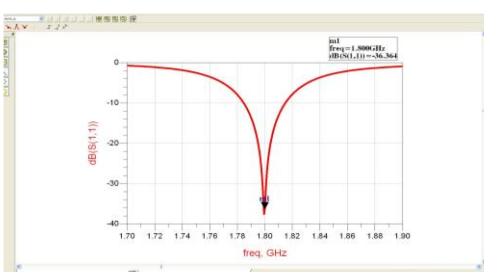

Fig.2. Return Loss for Single Patch Antenna

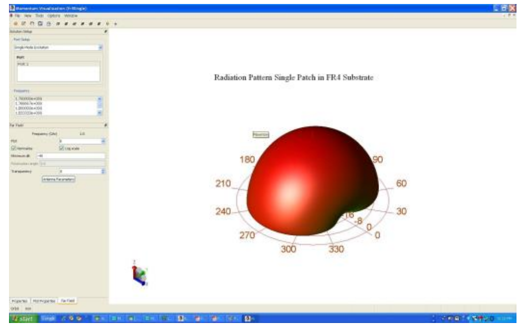

Fig.3. Radiation Pattern for single Patch Antenna

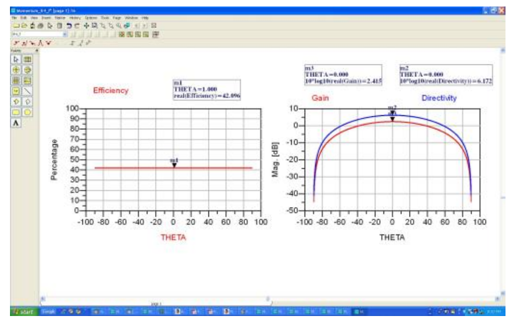

Fig.4. Efficiency, Gain and Directivity for Single Patch

B. 3X3 patch antenna Array

a) Return loss: It is observed from the **Fig.6** that the return loss is more than 30dB which is a good result for an antenna. The return loss for each patch is simulated. The variation in return loss between the patches is due to the mutual coupling between the elements.

b) Radiation Pattern: The 3D radiation pattern for 3x3 patch antenna array is shown in **Fig.7**. The required beam width 35° and the beam width observed from the results is 38° which is satisfactory.

c) Gain: From the **Fig.8**, the gain of the 3x3 patch antenna array is increased to 7.933dB.

d) Directivity: Fig.8 shows the directivity of the array 14.4 dB

e) Scan angle: The required maximum scan angle of the major lobe is 40°. From the **Fig.9**, the shift in the major beam obtained is 36°. This shows that the required scan angle is almost achieved and the result is satisfactory.

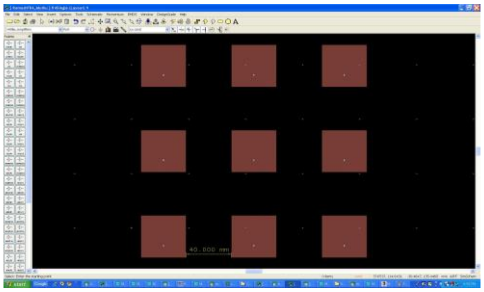

Fig.5. Layout of 3x3 patch antenna array in ADS

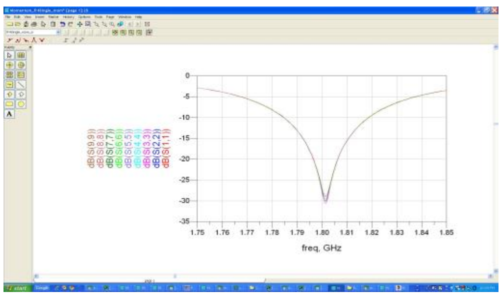

Fig.6. Return Loss for 3x3 Patch Antenna Array

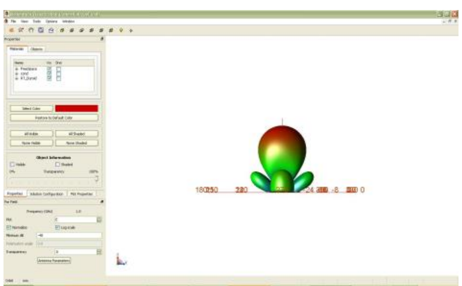

Fig.7. Radiation Pattern for 3x3 Patch Antenna Array

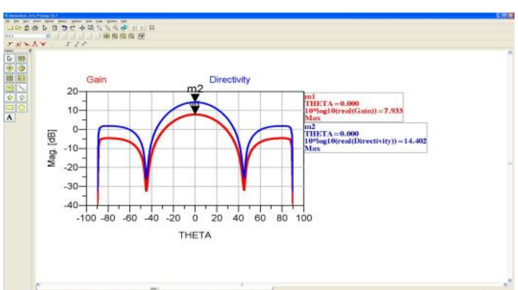

Fig.8. Gain and Directivity for 3x3 array

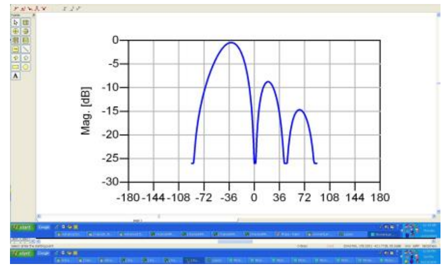

Fig.9. Radiation Pattern for Scan Angle

IV. FABRICATION AND TEST RESULTS

Fabrication of the antenna is carried out on the substrate material metalized on both sides using photolithographic process [5]. The photo copies of the fabricated antenna and antenna under measurement are shown in **Fig.10&11.**

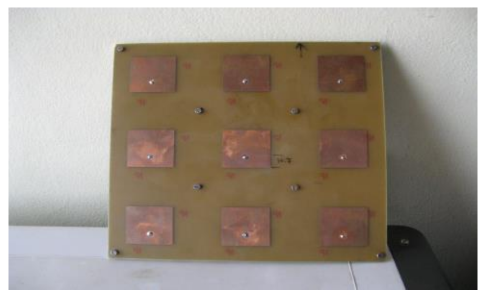

Fig.10. Front view of fabricated antenna

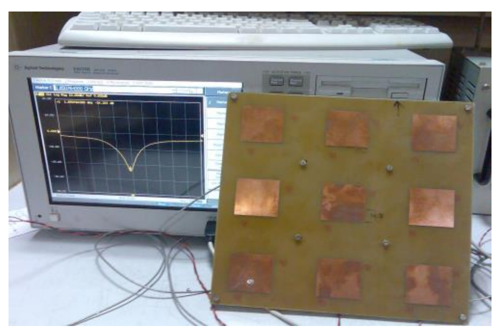

Fig.11. Antenna Under Measurement.

A. TESTING OF FABRICATED ANTENNA

Vector Network Analyzer has been used for testing the antenna. The nomenclature of the equipment is Agilent-8720, 50MHz-20GHz, Transmission Reflection Network Analyzer. Return loss, Input impedance and VSWR of the fabricated antenna have been measured.

B. TEST RESULTS

The return loss observed from **Fig.12** is -18.14 dB which is a good result for an antenna. This means almost all the power is radiated by the antenna with negligible losses. **Fig.13** gives the measured input impedance of the fabricated antenna ie; 52 Ω which is a fair result. VSWR close to one is quite good result for an antenna. From **Fig.14**, the measured VSWR is 1.215, a satisfactory result.

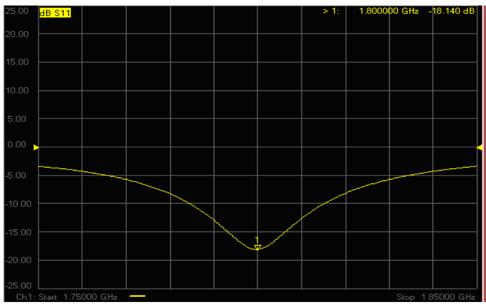

Fig.12. Measured Return Loss against Frequency

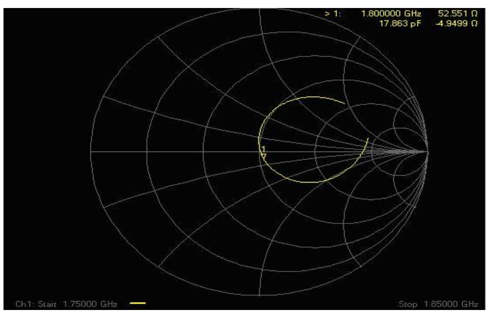

Fig.13. Measured Input Impedance

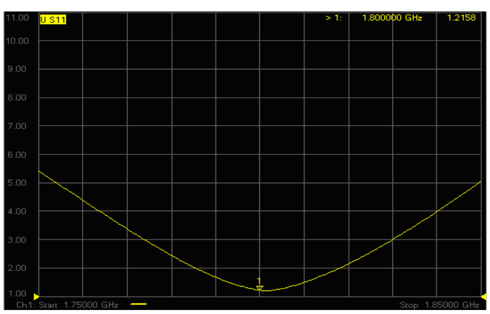

Fig.14. VSWR Measurement against Frequency

V. CONCLUSIONS

The design, simulation and experimentation of microstrip patch arrays with beam steering capabilities are obtained. Initial design is done via an analytical approximate approach (i.e.; the transmission line model), and then accurate characteristics are determined via numerical simulations. First a single patch antenna is designed and simulated using Advanced Design Systems simulation software. Then 3x3 arrays is designed and simulated. The optimizations of the dimensions are done with several iterations for getting best results.

With satisfactory simulated results, the designed antenna is fabricated. The fabricated antenna is assembled and tested using the Network Analyzer. Finally, the parameters of the designed antenna are measured and it is found that the simulated and measured results are satisfactory.

REFERENCES

[1] Girish Kumar and K.P.Ray "*Broad band Microstrip Antenna*", Artech House Publication, IEEE Microwave Magazine, pp. 59-71, Dec 2001.

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