Abstract—This paper presents the design and development of an X-band microstrip patch planar array antenna with high gain and low sidelobes. The antenna geometry comprises of a rectangular array of 512 radiating patches arranged in a 16x32 lattice. The radiating patches are fed using a microstrip feed distribution network on a thin grounded substrate. The geometry has a common ground for patch and the feed. All the 512 array elements are fed using a direct feeding technique. This was achieved by utilizing a thin copper wire soldered at the patch and feed network ends. The array operates in the 10.1-10.5 GHz frequency band with a 2:1 VSWR. A high gain of > 30.5 dBi with sidelobe level of better than -23 dB in both the planes was achieved with the array. The antenna finds application in medium range radar systems operating at X-band.

Keywords: arrays, microstrip patch antenna, radar.

I. INTRODUCTION

Microstrip patch antennas due to their merits like light weight, small size, planar structure and ease of fabrication for mass production are used widely in radar systems. However they also exhibit narrow bandwidth characteristics [1]. Design of a microstrip array antenna with high gain and low side lobe levels at X-band becomes complex due to high fabrication tolerance requirements, mutual coupling, and surface wave effects within the substrate [2]. Use of multiple substrates to enhance gain had been reported by researchers in open literature [3-4].

In direct feed methods such as inset fed patch antennas, the feed is on the same side as the radiating elements. Hence radiation occurs from the feed-line in the same direction as the radiating patch. This deteriorates the antenna gain and the cross polarization level. The issue becomes more severe in array antennas when the complexity in the feed network grows up significantly. Feed network consisting of several power divider junctions, multiple section and transformers contribute in reflections, surface waves, and multiple mode excitation. The reflected waves enhance the current distribution that increase the feed network loss and alter the power and phase distributions in the array. This reduces the array gain and efficiency. Similarly, the sidelobes and cross polarization also increases. The slot coupled feed is one such feed, where the entire feed network is moved below the ground plane and coupled to the radiating patch through a slot in the ground plane. However, the fabrication of the antenna becomes more complex at X-band due to manufacturing tolerances and alignment requirements.

In this article, a 16x32 microstrip planar array antenna with direct feed was designed in a double layer configuration using thick substrate for patch radiators and thin substrate for feed. The array was optimized for good VSWR bandwidth and pattern performance using a commercial EM software HFSS [5] from Ansoft Corp. The array was fabricated, assembled and tested at in-house near field antenna measurement setup.

II. ANTENNA DESIGN

The design of single radiating element was done prior to the planar array design. Fig. 1 below shows the geometry of the single patch antenna with cross-sectional view and top view.

![Fig. 1. (a) cross-sectional view (b) top view](image)

Fig. 2. Single element geometry

The basic patch radiator is rectangular in shape with width \( W_p \) and length \( L_p \). It is etched on a RT/duroid 5880 substrate with parameters \( h_1=1.58\text{mm}, \varepsilon_{r1}=2.2 \) and \( \tan\delta=0.0009 \) as shown in Fig. 1b. The feed substrate used was RT/duroid 5880 with...
parameters \( h_2 = 0.381 \text{mm}, \varepsilon_r = 2.2 \) and \( \tan \delta = 0.0009 \). The interconnection mechanism between the feed and radiating patch was through a thin copper wire of diameter 0.51 mm with arrangement as shown in Fig. 1a. A low dielectric foam supports the two substrates on a metallic base-plate. Table 1 depicts the optimized patch dimensions against the theoretical calculated values based on transmission line method.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Parameter</th>
<th>Theoretical calculated</th>
<th>Optimized using HFSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>W</td>
<td>11.51 mm</td>
<td>11.7 mm</td>
</tr>
<tr>
<td>2.</td>
<td>( \varepsilon_{eff} )</td>
<td>1.97</td>
<td>1.98</td>
</tr>
<tr>
<td>3.</td>
<td>L</td>
<td>8.76 mm</td>
<td>8.58 mm</td>
</tr>
</tbody>
</table>

Fig. 3. shows the structure of the simulated planar array. The array elements shown are fed using a corporate microstrip feed network. The array is distributed over a rectangular aperture of 920 mm x 430 mm x 45 mm. To obtain the desired SLL, a 30 dB Taylor distribution has been used to design the array.

### III. SIMULATED AND MEASURED RESULTS

The simulated return loss of the optimized single antenna element as depicted in Fig. 2 is shown in Fig. 5. The 10 dB return loss bandwidth obtained for the single radiating element was 8.25% (9.92-10.77 GHz).

![Simulated return loss of single radiating element](image)

Next the antenna array comprising of 16x32 elements was simulated, optimized, fabricated and tested. The measured return loss for the 16x32 array is shown in the Fig. 6. The measured return loss was better than 15 dB over the desired frequency band.

![Measured return loss of 16x32 array antenna](image)

![Simulated radiation patterns in the two principal planes of the 16x32 planar array antenna at 10.3 GHz.](image)
The developed 16x32 array antenna was tested for radiation patterns in near field test range (NFTR). Fig.7-9 shows the simulated and measured H-plane and E-plane radiation patterns of the proposed planar array antenna. Table-II shows a comparison of the simulated and measured results. The results are in a good agreement however small variation in the radiation pattern is attributed to feed network tolerances during antenna fabrication & assembly. The photograph of fabricated 16x32 array antenna is shown in the Fig. 10.

### Table II: Comparison of Measured & Simulated Results

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Radiation Pattern Measurement @ 10.3GHz</th>
<th>Parameters</th>
<th>Simulated (in HFSS)</th>
<th>Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Azimuth Beamwidth</td>
<td></td>
<td>2.1°</td>
<td>2.35°</td>
</tr>
<tr>
<td>2</td>
<td>Elevation Beamwidth</td>
<td></td>
<td>4.94°</td>
<td>5.09°</td>
</tr>
<tr>
<td>3</td>
<td>Azimuth Side Lobe Level</td>
<td></td>
<td>-28 dB</td>
<td>-25.1 dB</td>
</tr>
<tr>
<td>4</td>
<td>Elevation Side Lobe Level</td>
<td></td>
<td>-27 dB</td>
<td>-26.6 dB</td>
</tr>
<tr>
<td>5</td>
<td>Gain</td>
<td></td>
<td>32.05 dB</td>
<td>31.2 dB</td>
</tr>
<tr>
<td>6</td>
<td>Cross Polarization</td>
<td></td>
<td>36 dB</td>
<td>32.2 dB</td>
</tr>
</tbody>
</table>

Fig. 9. Measured radiation pattern in elevation (E-plane) of 16x32 planar array antenna at 10.3 GHz

IV. CONCLUSION

The design and development of a 16x32 planar array antenna realized with direct feed technique is presented. The proposed antenna exhibited a high gain, low side lobe levels and wide impedance bandwidth. The measured 2:1 VSWR bandwidth was 14.5% (9.4-10.9 GHz). The gain and sidelobe levels of the array were better than 30.5 dBi and -23 dB respectively over the band. The array antenna is highly suitable for use in ground based lightweight surveillance radar systems.

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REFERENCES