# DESIGN AND ANALYSIS OF 1X16 SQUARE MICROSTRIP LINEAR ARRAY FOR WIND PROFILING RADAR

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**ABSTRACT**

This paper describes the design and development of a narrow band linear polarization microstrip antenna array used in UHF Wind Profiling Radar. Wind profiling radars operating in Doppler beam swinging mode needs to have large antenna array in order to have a narrow beam for wind direction accuracy. In the present work, the antenna was designed for an operating frequency of 1.28 GHz and was built as an array of 1X16 probe-fed microstrip square patches. The design process starts with the theoretical design of the antenna. Finally, the results of the implementation of the designs are presented using IE3D software.

**Keywords: -** *Antenna arrays, Microstrip Patch Antenna, Wind profiling radar, Probe fed.*

## 1. INTRODUCTION

Observations of wind velocity profiles are very important for studying meteorological phenomena and weather forecasting. Atmospheric radar is one of the most suitable remote sensing instruments for observing height profiles of three components of wind velocity vector, including the vertical velocity with time and height resolutions without influence of weather conditions [1].

Propagation of radar signals through the atmosphere is strongly dependent on local meteorological conditions, especially in the atmospheric boundary layer [2] [3]. The wind profiling radar uses naturally occurring fluctuations in the radio refractive index and precipitation as targets. Due to their small apertures, UHF profilers operating around 900-1300 MHz [4][5] are most suitable for measuring the winds in the boundary layer and lower troposphere regions[6]. Unlike the VHF wind profiling radars, UHF radars are very sensitive for hydrometeors due to small wavelength [4]. Therefore these profilers are very much useful in studying convection, precipitation etc. UHF radar[4] is a potential tool to carry out research studies such as ABL Dynamics (Winds, Turbulence structure), seasonal and Inter-annual variations, Interaction between the ABL and the free troposphere, precipitating systems, Bright band characterization Rain/cloud drop size distribution etc. It is also useful in the operational Mountain meteorology and civil aviation and identification of atmospheric ducts. It also acts as a supplementary tool to large VHF MST radars by providing the atmospheric data in 0-5 Km height range [5].

Several UHF radars [4] are being operated across the globe either as research tools or as a part of wind profiler networks for operational meteorology. Atmospheric radars originally developed in 1970s for the research of mesosphere and stratosphere have been extensively applied to operational use for observations of the troposphere wind fields [7] since 1990s as demonstrated by the wind profiler demonstration network. In Japan, more than ten profilers including the MU (middle and Upper atmosphere) radar of Kyoto University have been operated for research use. Through the research and evaluation of profiler's data on the numerical weather prediction (NWP) models, JMA (Japan Meteorological Agency) established the operational wind profiler network and data acquisition system (WINDAS) for the enhancement of capability to watch and predict severe weather in

Japan. The network consists of forty 1.3 GHz wind profiling radars which are located across Japan.

In India, UHF profiler was established at Gadanki-Tirupati under Indo-Japanese collaboration program. The system, operating since 1997, has provided valuable data to characterize the boundary layer dynamics, precipitation events, bright band and several other aspects of the lower atmosphere. Recently some serious operational difficulties are faced by the system due to aging. Since this system is proved to be a potential tool for atmospheric research, NARL decided to build a new state-of-the art UHF wind profiling radar to continue the research work.

UHF wind profiling radars have several applications such as studies of low-level transport of water vapor (For example, by trade winds), boundary layer convergence, frontal passages, low-altitude turbulence, Global climate change studies, and vertical profiles of precipitation.

Operational uses include air pollution prediction, wind shear monitoring, temperature profiling in the radio acoustic sounding system (RASS) mode, Aviation operations, Mesoscale meteorological forecasting, Defense operations, Forecast fire management, Weather modification and offshore, shipboard and airborne platforms.

UHF wind profiling radar is a potential tool for atmospheric research as well as for meteorology. These radars were developed by companies like radian (Vaisala), Mitsubishi, Miesei, ATRAD, Prosensing, Degreane etc; in collaboration with research laboratories like NOAA, University of Massachusetts, Kyoto University, CRL, Adelaide University, CNRS/CETP etc

## 2. OBJECTIVES OF THE SYSTEM

The objectives of the proposed UHF wind profiling radar are multi-fold. The present UHF radar at NARL was installed by CRL-MEC, Japan under the Indo-Japanese collaboration program in the year 1997. The system is getting aged and has many operational difficulties. As the collaboration period is over, CRL has replaced the controlling and data processing subsystems to make the system operational. The RF/IF and antenna systems also are giving operational problems; alternative wind profiling radar has been developed for continuing the research in the lower atmosphere.

` India has got expertise in developing the radars for atmospheric research. A 53MHz MST radar, 400MHz ST radar at IITM Pune, and S-band Doppler weather radar at SDSC SHAR Sriharikota have been developed. A UHF wind profiling radar is yet to be developed in INDIA.

In recent times the necessity of this system is felt by several research and operational agencies for civilian and strategic applications. The proposed system will be a potential tool to probe the lower part of the atmosphere, which is very much related to weather and climate.

The existing system at NARL is proved to be a potential research tool for studying the dynamics of the lower part of the atmosphere. The proposed research applications are listed below.

- Supplements MST radar
- Atmospheric Boundary Layer (ABL)
- Dynamics (Winds, Turbulence structure)
- Seasonal and Inter-annual variations
- Interaction between the ABL and the free troposphere
- Precipitating systems
- Bright band characterization
- Rain/cloud drop size distribution
- Identification of Atmospheric ducts.

**Scientific Specifications of the Proposed System**

| | |
|---|---|
| Mode of operation | : Doppler Beam swinging Technique |
| Minimum range | : 100m |
| Maximum range | : 6 Km (Clear air)<br>10-14 Km (Precipitation) |
| Range resolution | : 30 m up to 3 Km<br>100m up to 6 Km |
| Measured parameters | : Moments and U, V, W |
| Time resolution | : 5 minutes per profile. |

The beam width requirement for the wind profiler is about 4-5 degrees. To achieve this beam width the antenna aperture size should be at least 11λ. The maximum scan angle is about 20 degrees, which requires an inter-element spacing of 0.7λ. An array of 16X16 or more elements will satisfy these requirements. The following options are considered,

1. 16X16 Active Array Antenna with 256 numbers of 10-watt TRMs.
2. 16X16 Butler beam forming array with 256 numbers of 10-watt TRMs.
3. 24X24 or 16X16 array with Row/Column feed with 24/16 numbers of 100/250-watt TRMs.

By considering merits and demerits of all the three types, Butler Beam Forming feed array is chosen for the present radar since it is satisfying all the requirements without much complexity. The TRMs will be placed between the array and butler feed network. Each antenna element will be fed by a 10-watt TRM.

The broad specifications of the proposed system are given below
Frequency of operation: 1260-1300MHz
(Depending upon the FMO/WPC Clearance).

Mode of Operation : DBS Technique
Power-Aperture Product : $1.9X10^4 wm^2$
Peak Power : 2.5 KW
Average Power : 250 W
Duty Ratio (Max) : 10%
Pulse width : 0.2-16 Uncoded
: 0.8-16 Coded
Baud length : 0.2, 0.5, 1.00
Antenna type : Array of Microstrip patch elements
Antenna size : 2.74mX2.74m
Feeder type : Two dimensional Butler network
Gain : 33dB
Beam Width : 4.5 degrees
Modes of operation : Clear-air (Low & High modes), Precipitation (Strong & weak modes), Turbulence (3-D imaging mode). In the present work the antenna array has been chosen and designed.

## 3. MICROSTRIP PATCH ANTENNA

A microstrip patch antenna is a narrowband, wide-beam antenna fabricated by etching the antenna element pattern in metal trace bonded to an insulating substrate. Because such antennas have a very low profile, are mechanically rugged and can be conformable, they are often mounted on the exterior of aircrafts and spacecrafts, or are incorporated into mobile radio communications devices.

Microstrip antennas have several advantages compared to conventional microwave antennas [8],[9] therefore many applications cover the broad frequency range from 100 MHz to 100 GHz. Some of the principal advantages compared to conventional microwave antennas are:

- Light weight, low volume, end thin profile configurations, which can be made conformal.
- Low fabrication cost.
- Linear, circular and dual polarization antenna can be made easily
- Feed lines and matching networks can be fabricated simultaneously with the antenna

However microstrip antennas also have limitations compared to conventional microwave antennas:

- Narrow bandwidth and lower gain
- Most microstrip antennas radiate into half space
- Polarization purity is difficult to achieve
- Lower power handling capability.

The general layout of a parallel coupled microstrip patch antenna is shown in Figure 1.

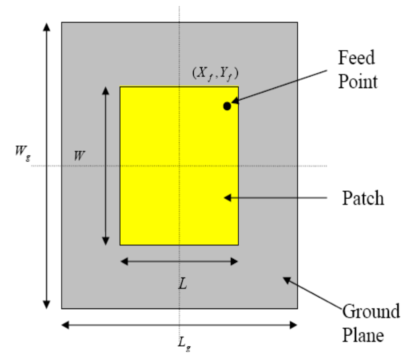



***Fig. 1 Schematic diagram of microstrip patch antenna***

There are many substrates with various dielectric constants [10] that are used in wireless applications. Those with high dielectric constants are more suitable for lower frequency applications in order to help minimize the size.

## 4. METHODOLOGIES ADAPTED

### A. DIELECTRIC SUBSTRATE SELECTION

Considering the trade-off between the antenna dimensions and its performance, it was found suitable to select a thin dielectric substrate with low dielectric constant. Thin substrate permits to reduce the size and also spurious radiation as surface wave, and low dielectric constant for higher bandwidth, better efficiency and low power loss. The simulated results were found satisfactory.

### B. FEEDING TYPE SELECTION

To induce excitation, co-axial or probe feed technique was used as its main advantage was that the feed can be placed at any place in the patch to match with its input impedance (usually 50 ohm). Also in the non-contacting techniques, there was an undesirable complexity and increase in the overall thickness of antenna. Hence the probe feed technique was used for its easiness of fabrication as well as low spurious radiation. But the problem arises when the height of the dielectric substrate increases, making the input impedance more inductive, thereby inviting undesirable matching problem [11]. Care was, therefore, taken not to increase the height of substrate beyond a certain limit.

### C. SOFTWARE SELECTION FOR SIMULATION

The software used to model and simulates the Microstrip antenna was Zeland Inc's IE3D [12]. IE3D is an integrated full-wave electromagnetic and simulation package based on the method of moments for the analysis and design of 3D (three-dimensional) microstrip antenna, high frequency printed circuits and digital circuits such as MMICs and high speed printed circuit boards (PCBs). It can be used to calculate and plot RL (Return Loss), VSWR (Voltage Standing Wave Ratio), Radiation pattern (Azimuth and Elevation), Smith chart and various other parameters.

## 5. DESIGN PROCESS OF ANTENNA

Through all the design process, air gap has been used to build the antenna structures. The reason for choosing this is because by using certain dielectric substrates the efficiency of the antenna will be reduced [13] secondly it is very easy to construct the antenna. Based on the antenna knowledge concentration has been put on the linearly polarized transmitted signal, because the bandwidth of the linearly polarized antenna is greater than the circularly polarized antenna. Linear polarization is preferred as compared to circular polarization because of the convenience of a single feed than a double feed. Moreover the construction of linearly polarized rectangular patch antenna or Square patch antenna [14] is simpler than the other polarization configurations. In the present work, The Transmission line model has been used to design a rectangular or square patch antenna.

### Design Calculation Formulae

The operating frequency $f_r$

Thickness of the dielectric medium,

$$h \le 0.3 \times \frac{c}{2 \times \prod \times f_r \times \sqrt{\varepsilon_r}}$$

Thickness of the grounded material alumina,

$$h \le 0.3 \times \frac{c}{2 \times \prod \times f_r \times \sqrt{\varepsilon_r}}$$

Width of metallic patch,

$$W = \left(\frac{c}{2 \times f_r}\right) \times \left(\frac{\varepsilon_r + 1}{2}\right)^{\frac{-1}{2}}$$

Length of metallic patch, L

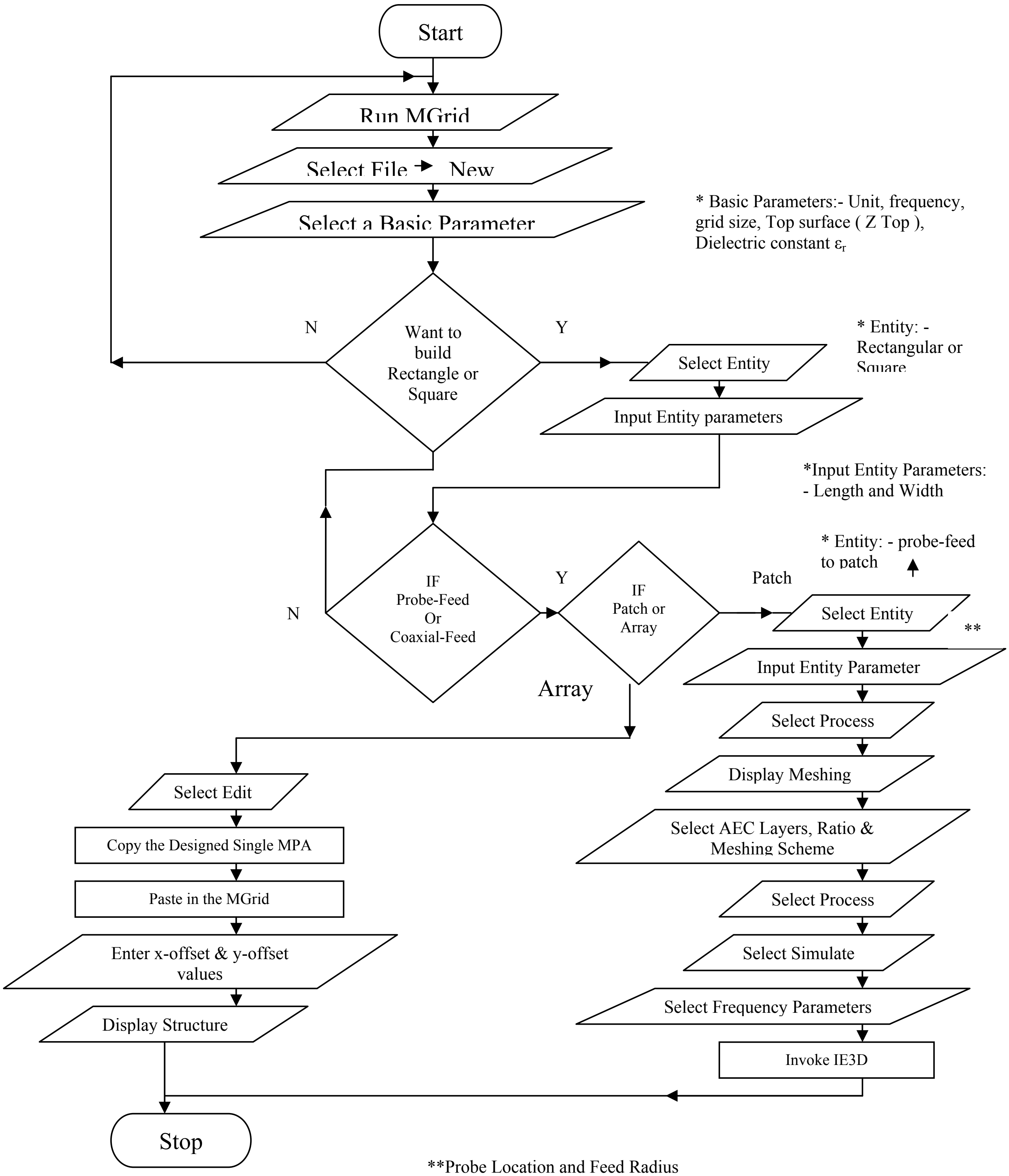
$$L = \frac{c}{2 \times f_r \times \sqrt{\varepsilon_{reff}}} - 2\Delta l$$

Where,

$$\Delta l = 0.412 \times h \times \left[\frac{(\varepsilon_{reff} + 0.03) \times (W + 0.264h)}{(\varepsilon_{reff} - 0.258) \times (W + 0.8h)}\right]$$

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \times \left(1 + \left(\frac{12 \times h}{W}\right)\right)^{\frac{-1}{2}}$$

Now the designed values are substituted in the IE3D software. Then the schematic is drawn using MGRID in that software and the results are obtained using Modua curve. The procedure used in the IE3D is given in a Flowchart which is shown below.


Start
Run MGrid
Select File → New
Select a Basic Parameter
* Basic Parameters:- Unit, frequency, grid size, Top surface ( Z Top ), Dielectric constant $\varepsilon_r$
N
Want to build Rectangle or Square
Y
Select Entity
* Entity: - Rectangular or Square
Input Entity parameters
*Input Entity Parameters: - Length and Width
* Entity: - probe-feed to patch
N
IF Probe-Feed Or Coaxial-Feed
Y
IF Patch or Array
Patch
Select Entity
**
Input Entity Parameter
Array
Select Process
Display Meshing
Select Edit
Copy the Designed Single MPA
Select AEC Layers, Ratio & Meshing Scheme
Paste in the MGrid
Select Process
Enter x-offset & y-offset values
Select Simulate
Display Structure
Select Frequency Parameters
Invoke IE3D
Stop
**Probe Location and Feed Radius

## 6. IMPLEMENTATION OF THE PATCH USING IE3D

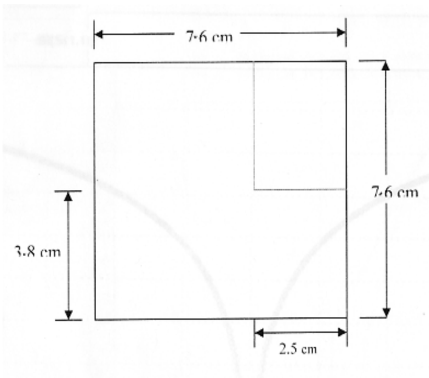



*Fig 2 Dimensions of single patch antenna*

**Performance Analysis**

The finalized single element is used for the design of 1X16 linear array. This single element as the basic building block for the entire 1X16 array. The sixteen elements are designed in a 1X16 linear grid configuration with element spacing 0.73λ (λ is the free space wavelength). Using RT/Duroid as dielectric material at 1.28 GHz frequency, arrays are designed and performance is studied.

## Single Element

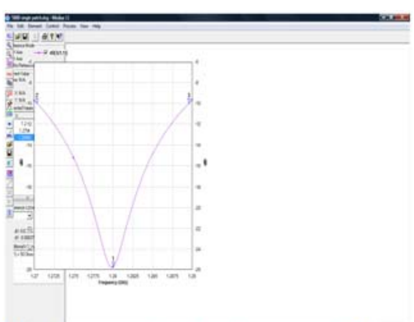


*Fig 3 Return Loss Response*

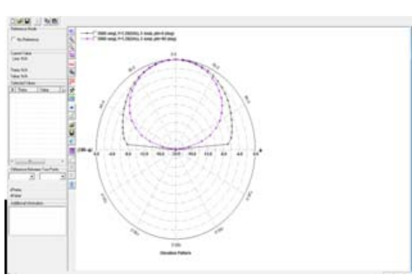


*Fig.4 Radiation Response*

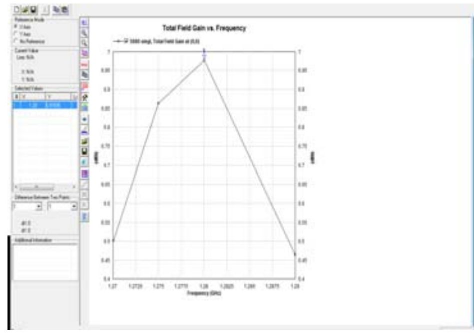



*Fig.5 Frequency Vs Gain*

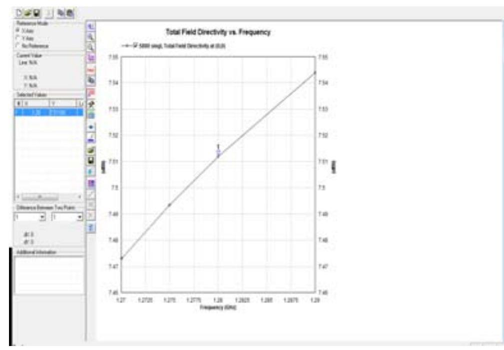



*Fig.6 Frequency Vs Directivity*

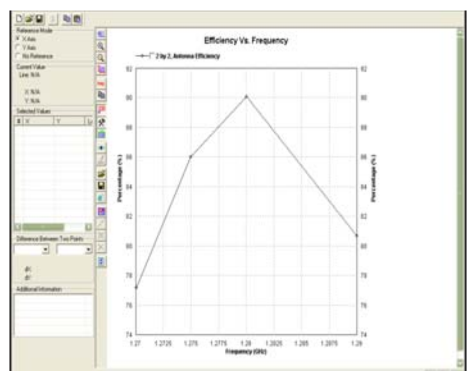



*Fig.7 Frequency Vs Efficiency*

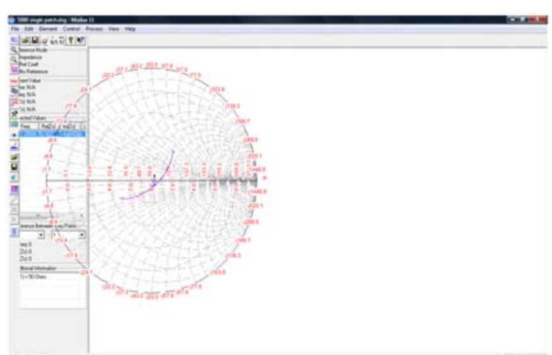


*Fig.8 Smith Chart*

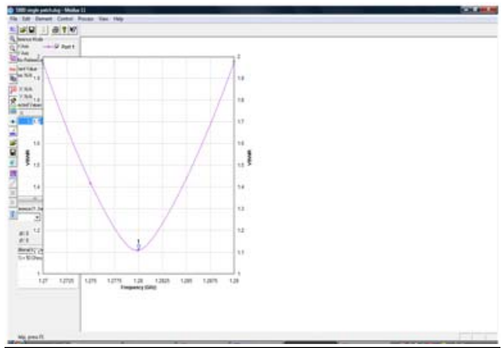


*Fig.9 VSWR Response*

## 1X16 Planar Array

*Fig.10 1X16 Microstrip Planar Array*

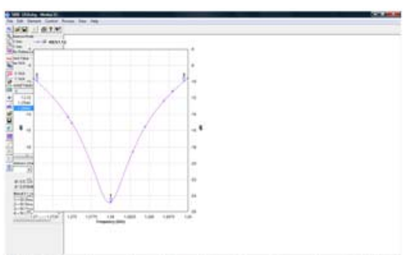


*Fig.11 Return Loss Response*

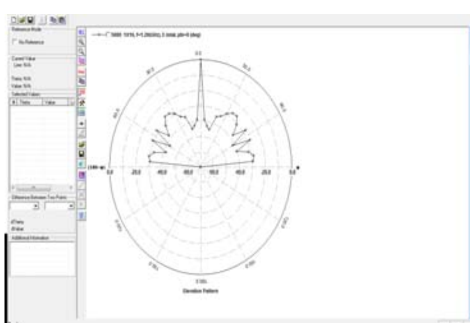


*Fig.12 Radiation Response at Φ=0*

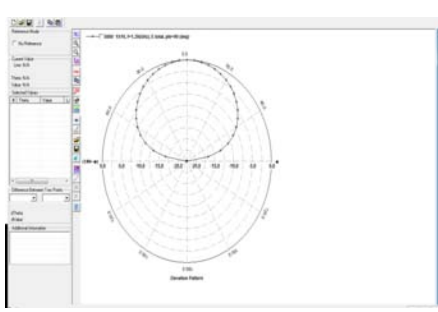


*Fig.13 Radiation Response at Φ=90*

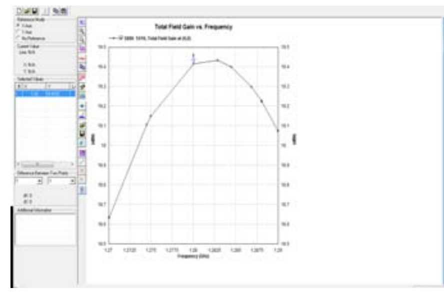


*Fig.14 Frequency Vs Gain*

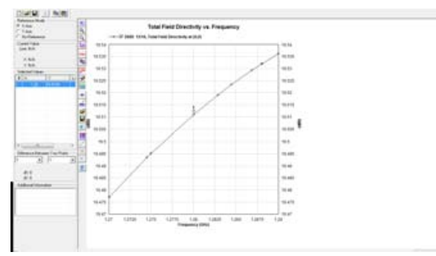


*Fig.15 Frequency Vs Directivity*

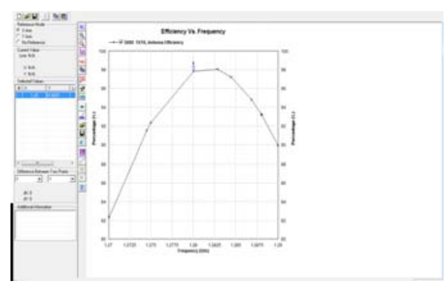


*Fig.16 Frequency Vs Efficiency*

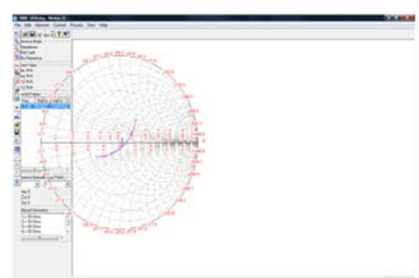


*Fig.17 Smith Chart*

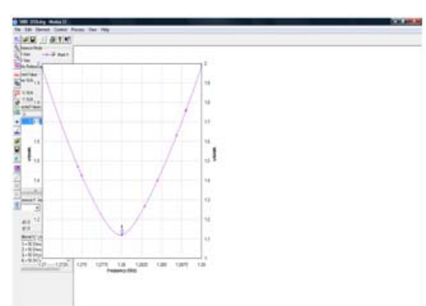


*Fig.18 VSWR Response*

## 7. RESULTS AND DISCUSSIONS

The microstrip patch antenna was designed and simulated for single element, and 1X16 linear array. It was concluded that the overall impedance bandwidth (Return loss ≤ -10 dB at resonant frequency of 1.28 GHz is around 19 MHz. The proposed antenna at the frequency of 1.28 GHz, the peak antenna gain for a single element and 1X16 element array are increased. Similarly, the measured antenna efficiency for single element and 1X16 are greatly improved. Thus increasing the number of patches or elements in linear enhances the performance of antenna.

## 8. CONCLUSIONS

This paper has concentrated on an antenna design for Wind Profiling Radars. A method for the rigorous calculation of the antenna has also been developed. The simulated responses are in good agreement with the theoretical predictions.

The main quality of the proposed antenna is that it allows an effective design maintaining all the advantages of microstrip antennas in terms of size, weight and ease of manufacturing.

The compactness in the circuit size makes the design quite attractive for further developments and applications especially in Wind Profiling Radars.

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## REFERENCES

[1]. Hiroyuki Hashiguchi, Shoichiro Fukao, Toshitaka Tsuda and Manabu D Yamanaka, “Observations of the planetary layer over equatorial Indonesia with an L band clear-air Doppler Radar: Initial results”, Radio Science, Vol. 30, No.4, pp 1043-1054, July-August 1995.

[2]. R R Rogers, W L Ecklund, D A Carter, “First Results of the HARP Boundary-Layer Radar”, 25th Conference on Radar Meteorology, Paris, June 1991.

[3]. R R Rogers, W L Ecklund, D A Carter, K S Gage and S A Ethier, “Research Applications of a Boundary Layer Wind Profiler”, Bulletin of the American Meteorological Society, Vol.74, No.4, pp 567-580, April 1993.

[4]. C H Liu and K C Yeh, “Scattering of VHF and UHF Radar Signals from the Turbulent Air”, Radio Science, Vol.15, No.2, pp 277-282, March-April 1980.

[5]. A S Frisch, B L Weber, R G Strauch, D A Merritt and K P Moran, “The Altitude Coverage of the Colorado Wind Profilers at 50, 405 and 915 MHz”, Journal of Atmospheric and Oceanic Technology, Vol.3, No.4, pp 680-692, December 1986.

[6]. W L Ecklund, D A Carter, B B BAlsley, P E Currier, J L Green, B L Weber and K S Gage, “Field Tests of a Lower Tropospheric Wind Profiler”, Radio Science, Vol.25, No.5, pp 899-906, September-October 1990.

[7]. D A Carter, K S Gage, W L Ecklund, W M Angevine, P E Johnston, A C Riddle, J Wilson and C R Williams, “Developments in UHF Lower Tropospheric Wind Profiling at NOAA’s Acronomy Laboratory”, Radio Science, Vol.30, No.4, pp 977-1001, July-August 1995.

[8]. E Hammerstad, F A Bekkadal,”Microstrip Handbook”, ELAB Report, STF 44 A74169, University of Trondheim, Norway, 1975.

[9]. Dimitris T Notis, Phaedra C Liakou and Dimitris P Chrissoulidis, “Dual Polarized Microstrip Patch Antenna Reduced in size by the use of Peripheral slits”, IEEE paper.

[10]. A Derneryd, “Linearly Polarized Microstrip Antennas”, IEEE Trans. Antennas and Propagation, AP-24, pp. 846-851, 1976.

[11]. Kumar G and Ray K P, “Broadband Microstrip Antennas”, Artech House, Inc., 2003.

[12]. IE3D Software Release 11.0 (Zeland Software Inc., Fremont, California, USA).

[13]. E J Denlinger, “Losses in Microstrip Lines”, IEEE Trans. Microwave Theory Tech., Vol. MTT-28, pp.513-522, June 1980.

**[14].** Bryant, T G And J A Weiss, “Parameter of Microstrip Transmission Lines and of Coupled pairs of Microstrip Lines”, IEEE Transactions on MTT-16, No.12, pp., 1021-1027, December 1968.