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Design and Analysis of 8x1 Array Microstrip Patch Antenna Using IE3D

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Abstract— Wind profilers depend upon the scattering of electromagnetic energy by minor irregularities in the refractive index of air. The refractive index is a measure of the speed at which electromagnetic wave propagates through a medium. Atmosphere is the medium for wind profiling. 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. To meet the above requirement, in the present work an array with 8 elements configured in an 1X8 is designed. The antenna inserted is a co-axial probe (Probe feed) to the patch near its resonance in 'L' band is carried out. Principal plane 2-dimensional radiation patterns at 430MHz have been computed for single element and 1X8 linear array. The results of linearly polarized coaxial probe single element are generated using IE3D software. Using single element as basic building block, an 1X8 linear array was designed. In this paper Aluminum sheet is used as material for ground plate and patch, air is used as dielectric substrate. IE3D software is used to design and simulation of antenna array. The results obtained are presented succinctly. The inferences from the design of coaxial probe antenna are presented.

Key Words: **Wind profile, Microstrip, Antenna Array, Dielectric, Patch, probe feed, IE3D.**

I. INTRODUCTION

Microstrip antenna is printed type of antenna consisting of a dielectric substrate sandwiched in between a ground plane and a patch [1]. The concept of Micro strip antenna was first proposed in 1953, twenty years before the practical antennas were produced. Since the first practical antennas were developed in early 1970's, interest in this kind of antennas was held in New Mexico [6]. The microstrip antenna is physically very simple and flat, these are two of the reasons for the great interest in this type of antenna. Microstrip antennas have several advantages compared to other bulky type of antennas. Some of the main advantages of the microstrip antennas are that it has low fabrication cost, its lightweight, low volume, and low profile configurations that it can be made conformal, it can be easily be mounted on rockets, missiles and satellites without major modifications and arrays of these antennas can simply be produced.

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

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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.

II. DESIGN PROCEDURE

The designed antenna is an 1X8 linear array. The first step in the design is to specify the dimensions of a single microstrip patch antenna. The patch conductor can be assumed at any shape, but generally simple geometries are used, and this simplifies the analysis and performance prediction. Here, the half-wavelength rectangular patch element is chosen as the array element (as commonly used in microstrip antennas) [9]. Its characteristic parameters are the length L, the width w, and the thickness h, as shown in below Figure.

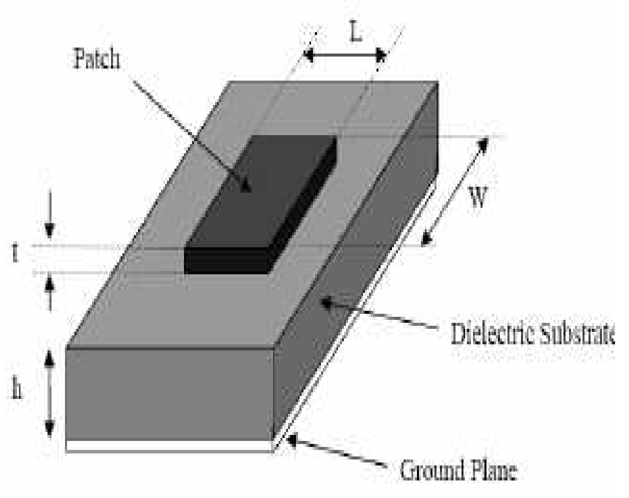

Fig .1. Block Diagram of Antenna

To meet the initial design requirements (operating frequency = 430 MHz, and beam width = 90) various analytical approximate approaches may be used. Here, the calculations are based on the transmission line model [12]. Although not critical, the width w of the radiating edge is specified first. In practice, the length L is slightly less than a half wavelength (in the dielectric). The length may also be specified by calculating the half wavelength value and then subtracting a small length to take into account the fringing fields [15-17], the parameters of patch antenna can be calculated using the below steps.

Step 1: Calculation of width (W): The width of the Micro strip antenna is given by the equation

$$W = \frac{c}{2f_0\sqrt{\frac{(\varepsilon_r+1)}{2}}}$$

Step 2: Calculation of Effective Dielectric Constant (ε_{reff}):

The Effective Dielectric constant is given by

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{w}\right]^{-1/2}$$

Step3: Calculation of Effective Length (L_{eff}):

The Effective Length is given by

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{reff}}}$$

Step4. Calculation of the Length extension (ΔL):

The actual length is obtained by the equation

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

Step5: Calculation of actual length of the Patch (L):

The actual length of the patch is given by:

$$L = L_{eff} - 2\,\Delta L$$

Step6: Calculation of the ground plane dimensions (Lg and Wg):

The transmission line model is applicable to infinite ground plane only. However, for practical considerations, it is essential to have finite ground plane. It has been shown by that similar results for finite and infinite ground plane can be obtained if the size of the ground plane is greater than the patch dimensions by approximately six times the substrate thickness all around the periphery. Hence, for this design the ground plane dimensions would be given as:

$$Lg=6h+L$$

$$Wg=6h+W$$

Step7: Determnation of Feed point location (X_f,Y_f):

A coaxial probe type feed is to be used in this design. As shown in the center of the patch is taken as the origin and the feed point location is given by the co-ordinates (X_f,Y_f) from the origin. The feed point must be located at that point on the patch, where the input impedance is 50 ohms for the resonant frequency. Hence, a trial and error method is used to locate the feed point. For different locations of the feed point, the return loss (R.L) is compared and that feed point is selected where the return loss is most negative. According to there exists a point along the length of the patch where the return loss is minimum. Hence in this design Y_f will be zero and only Xf will be varied to locate the feed point.

In this paper Aluminum sheet is used as material for ground plate and patch, air is used as dielectric substrate. IE3D software is used to design and simulation of antenna array.

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III. SIMULATED RESULTS FOR 1X8 PATCH ANTENNA ARRAYS

A. Return loss Measurement

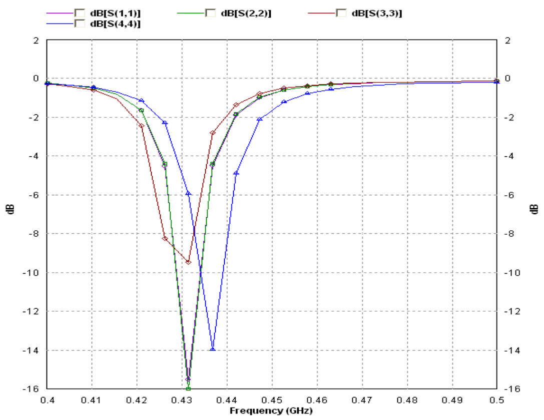

Fig. 2. Graph of Return loss Measurement

From figure 2 The Return loss obtained at 430 MHZ is -16 dB and band width obtained at -10 dB is about 7 MHZ.

B. 2-Dimensional Radiation Pattern

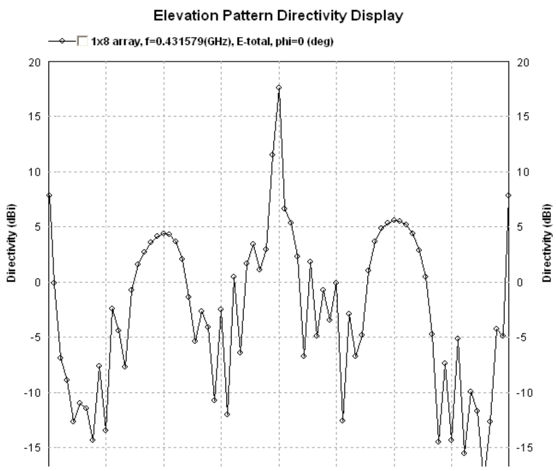

Fig. 3. Graph of 2-Dimensional Radiation Pattern

From figure 3, the 3 dB Beam Width obtained at pi=0^0 is 105^0 and at 90^0 is 95^0

C. VSWR Measurement

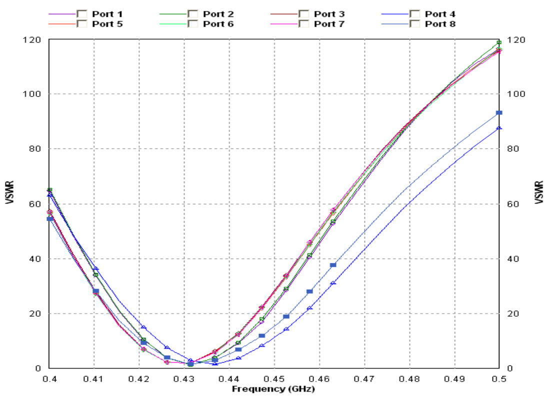

Fig. 4. Graph of VSWR Measurement

From the figure 4.the VSWR obtained at 430 MHZ is 1.35

D. Directivity vs. Frequency

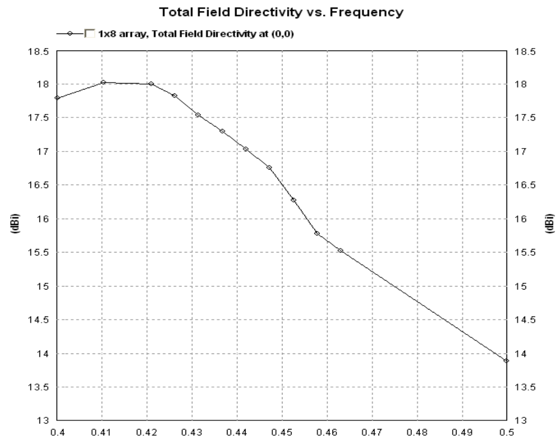

Fig .5. Graph of Directivity vs. Frequency

From the figure 5, gain obtained at 430 MHz is 18.2 dBi

E. Antenna Efficiency vs. Frequency

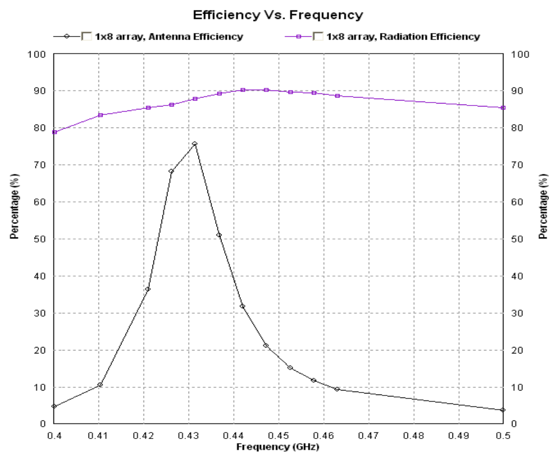

Fig. 6. Graph of Antenna Efficiency vs. Frequency

From the figure 6, the Antenna Efficiency is about 80% and radiation efficiency is about 85 %

F. Gain vs frequency

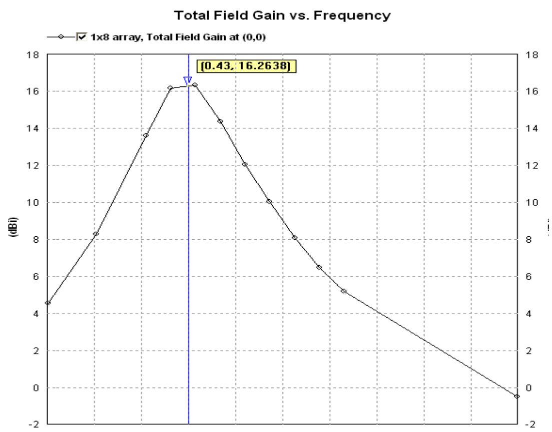

Fig. 7. Graph of Gain vs frequency

From the figure 7, gain obtained at 430 MHz is 16.2 dBi

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G. Radiation pattern (3-D) for 1x8 arrays:

E –theta pattern

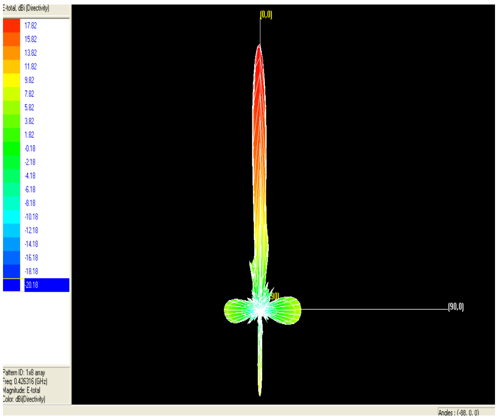

Fig. 8. Graph of Radiation pattern (3-D) for 1x8 arrays E –theta pattern

From figure 8, the Directivity of the 3-dimensional Radiation Pattern is 17.8 dBi

E –Pi pattern

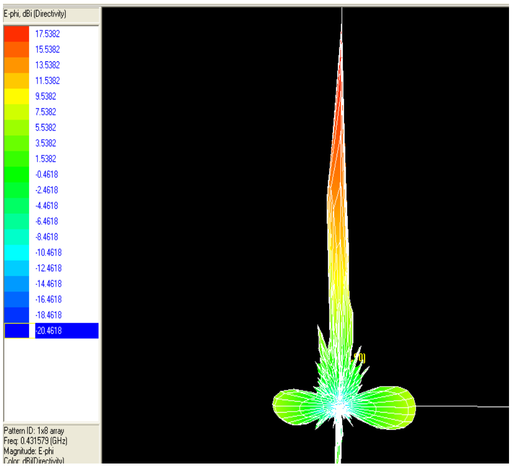

Fig. 9. Graph of E –Pi pattern

E- Left pattern

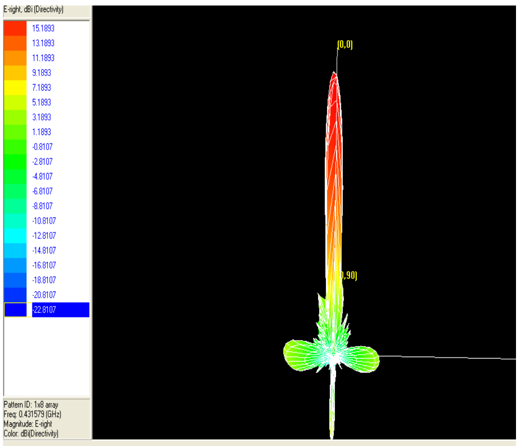

Fig. 10. Graph of E – Left pattern

E- Right pattern:

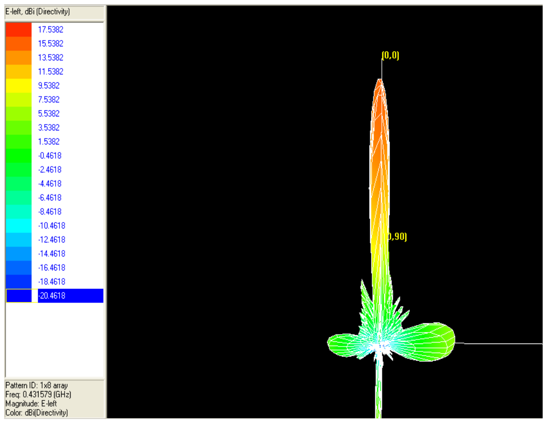

Fig. 11. Graph of E- Right pattern

IV. CONCLUSION

Hence an 1X8 element array has been realized for wind profiling radars. It consists of a single layer narrow band antenna element based on this 1x8 element array was designed. Gain, Bandwidth and radiation patterns have been computed over a frequency at 430 MHz. From the data analysis, it has been pointed out that the side lobe level is the most critical factor, and thus determines the operating bandwidth. However, considering the impedance, gain and maximum side lobe at 430 MHz frequency, a 20 MHz bandwidth has been obtained.

As demonstrated by the design 1x8 patch Antenna Array at 430 MHz has been successfully designed and simulated using IE3D. From the radiation pattern, it is observed that use of amplitude taper maintained the SLL within the maximum scan angle limit, which is an added advantage for Atmospheric Wind Profile Radar application.

Using this 1x8 antenna array 17.82 dB gain and 10 MHz bandwidth were obtained which is sufficient for data processing for the system. These results are better when we compare with the existing system at NARL. So we can replace existing micro strip antennas operating with 1280 MHZ with this Microstrip array operating with 430 MHZ. The future work of this Project is to extend the design to 1x16 Antenna Array and later 16x16 Antenna Array.

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