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Enhancement of Bandwidth and Gain of a Microstrip Antenna Applicable for 430 MHz Wind Profiling Radar Using Elliptical Slot

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Abstract The main aim of this project is to develop a suitable antenna working at 430 MHz frequency. In applications where size, weight, cost, performance, ease of installation, and aerodynamic profile are constraints, low profile antennas like micro strip and printed slot antennas are required. At first, we have designed a simple Rectangular Micro strip Patch Antenna. We have obtained its usable Bandwidth, Radiation pattern and related graphical representations. After that an elliptical slot is cut inside a rectangular patch which is shifted towards right. The results of both the designs are compared and it was found that an increase in the bandwidth of 28% and gain of 8.85 dB is being achieved as that of a simple Rectangular micro strip patch antenna. In this project, all the simulations have been done using the Zealand Inc. IE3D software. By using this software it is possible to obtain the 3D radiation pattern of planar circuit. It uses naturally occurring fluctuations in the radio refraction index and precipitations as targets. 400-500 MHz is considered as the best frequency band for wind profilers due to their optimal size and optimal performance. In India, the allotted band for this type of profiler is 420-435 MHz. The entire project is being carried out at National Atmospheric Research Laboratory (NARL), ISRO. These radars play a key role in weather forecasting that is for lower atmospheric research applications.
Keywords *Elliptical Slot, IE3D, Micro Strip Patch, SODAR, Wind Profiler*

1. Introduction

In its most fundamental form, a Microstrip Patch antenna consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side as shown in Figure 1.The patch is generally made of conducting material such as copper or gold and can take any possible shape. The radiating patch and the feed lines are usually photo etched on the dielectric substrate.

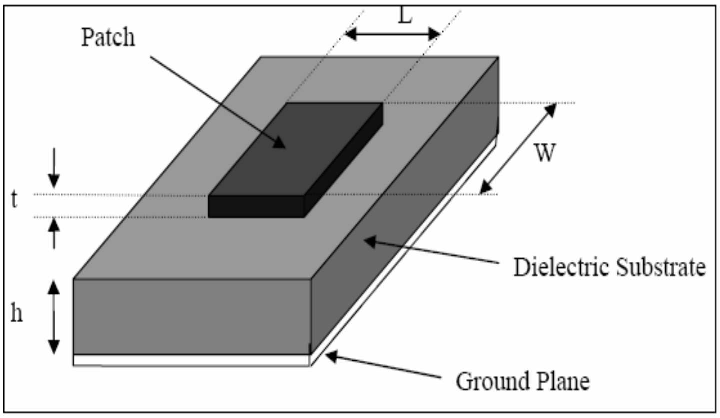


Figure 1: *A Typical Microstrip Patch Antenna*

Microstrip patch antennas radiate primarily because of the fringing fields between the patch edge and the ground plane. For good antenna performance, a thick dielectric substrate having a low dielectric constant is desirable since this provides better efficiency, larger bandwidth and better radiation. However, such a configuration leads to a larger antenna size. In order to design a compact Microstrip patch antenna, substrates with higher dielectric constants must be used which are less efficient and result in narrower bandwidth. Hence a trade- off must be realized between the antenna dimensions and antenna performance. In this paper, a rectangular Micro Strip patch has been designed in order to observe the lower atmospheric behavior for the 430 MHz Wind profiling radar applications.

2. Overview of IE3D Software

IE3D is a full wave Electromagnetic simulation tools, based on Method of Moments (MOM); that includes S, Y, and Z parameters, VSWR, RLC equivalent circuits, current field distribution, near and far field estimation, radiation pattern etc. It is a very useful tool in the design of RFICs, MMICs, printed circuits, Microstrip and wired RF Antennas, PCB and IC connections.

A) Applications of IE3D

(a) RF circuits, LTCC circuits and RF ICs.
(b) Microwave, RF and wireless antennas.
(c) RFID tag antennas.
(d) HTS filters.
(e) Electronic packaging and signal integrity.
(f) Microwave circuits and MMICs.
(g) Many other low to high frequency structures.

B) Applications of IE3D in Antennas

(a) Planar antennas such as micro strip antennas and slot antennas.
(b) Wire antennas such as various types of dipole, monopole, helix and quadrifilar antennas.
(c) Small antennas such as inverted-F antennas and its derivations.
(d) Dielectric resonator antennas.
(e) RFID antennas.
(f) Optical frequency antennas.
(g) Many other types of antennas.

3. Design of a Rectangular Micro Strip Patch Antenna without Introducing Slot

In this paper, the useful design parameters are given below:

Operating Frequency: 430 MHz
Substrate Thickness (Z_{top}): 3.175mm
Loss Tangent: 0.0009
Length of the Patch: 223.3mm
Width of the Patch: 265.6mm
Feed Length: 55.82mm
Feed Width: 0.86mm

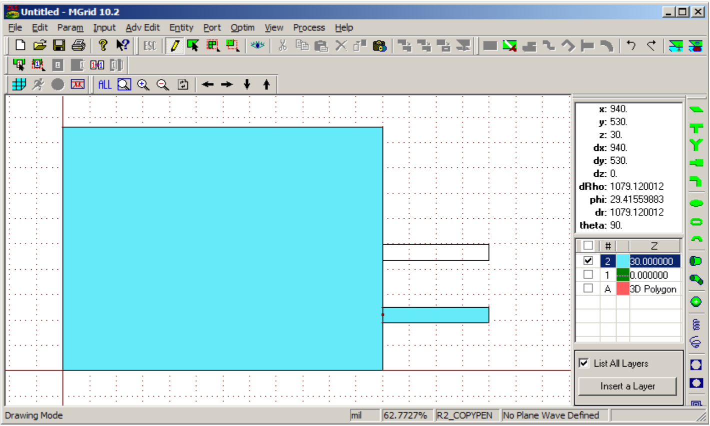


Figure 2: *Structure of Rectangular MSPA*

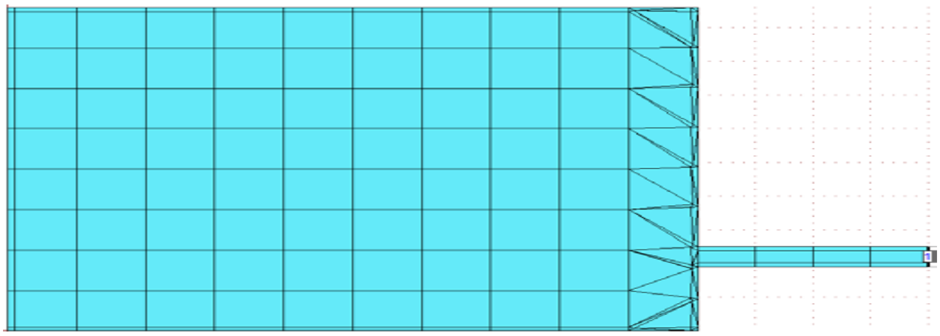


Figure 2.1: *Meshed Structure*

The above figure is the meshed rectangular patch with meshing frequency 10 GHz and cells/ wavelength = 15.

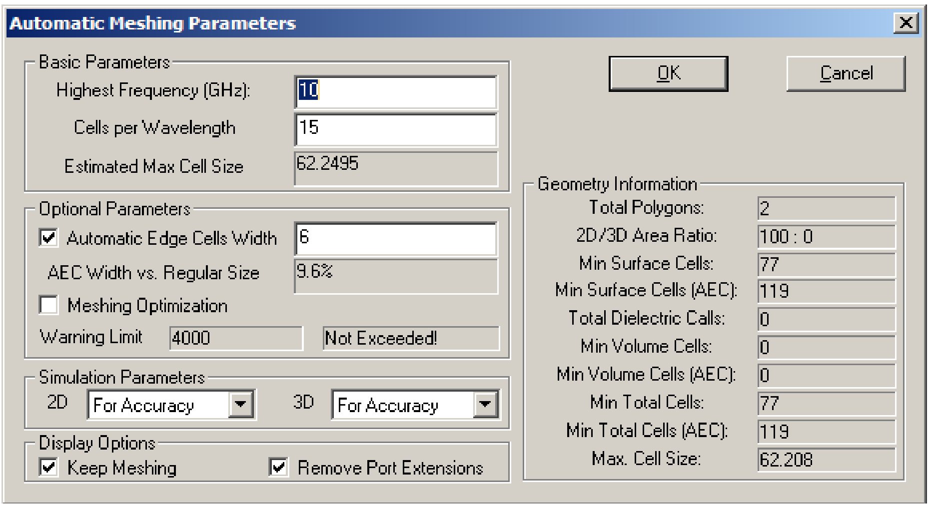


Figure 3: *MGRID Box*

4. Simulated Result for Different Parameters

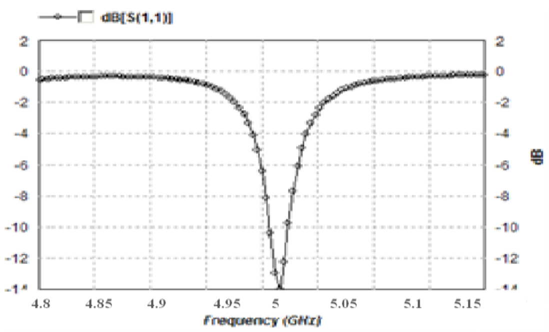


Figure 4: *Return Loss vs Frequency Plot*

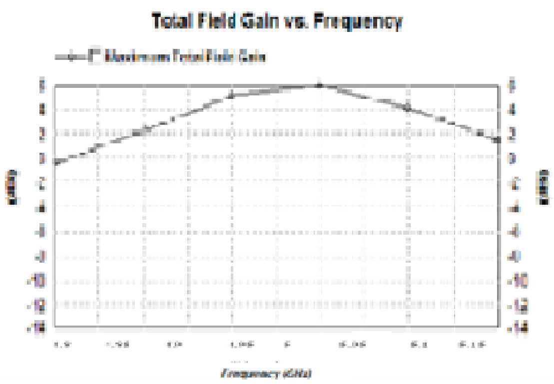


Figure 5: *Gain vs Frequency Plot*

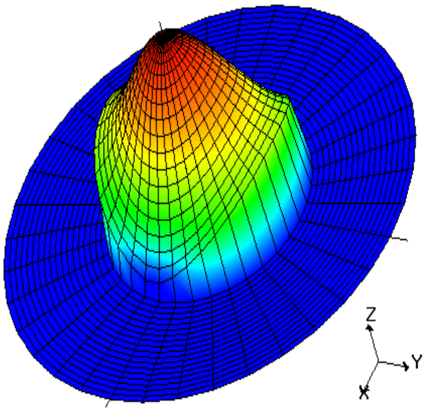


Figure 6: *3D Radiation Pattern of Patch Antenna*

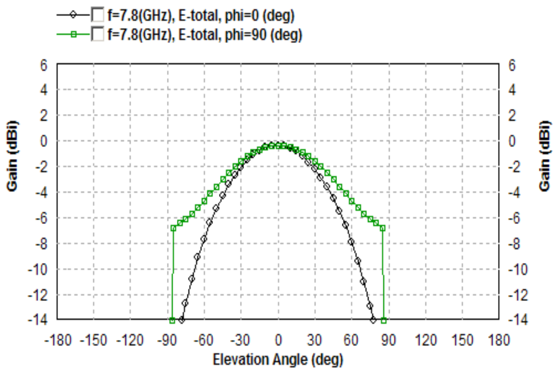


Figure 7: *2D Radiation Pattern of Patch Antenna*

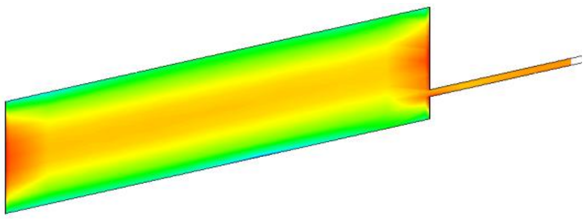


Figure 8: *Average Current Distribution with Colour for the Average Strength of the Current*

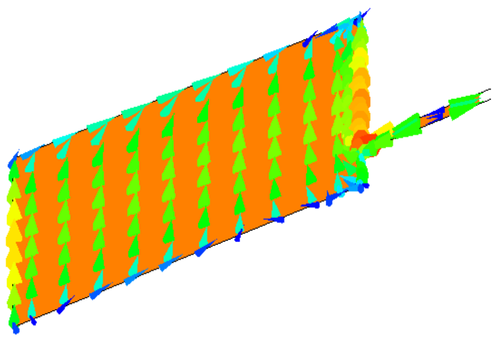


Figure 9: *Vector Current Distribution with Properly Adjusted Vector Size of the 3D View Window*

5. Design of Rectangular Patch with Introduction of Conventional Rectangular Slots

The optimization of the proposed rectangular patch antenna as shown in Figure 1 has been done by designing patch antenna on a rectangular ground plane and ending up with a slot shape, for both the radiator and the ground plane. The conventional shape of slot patch antenna shown in Figure 1 has a substrate 124.4mm*93.3mm. Slot length of 62.2 mm, width 3.11mm and the operating frequency is 0.43 GHz.

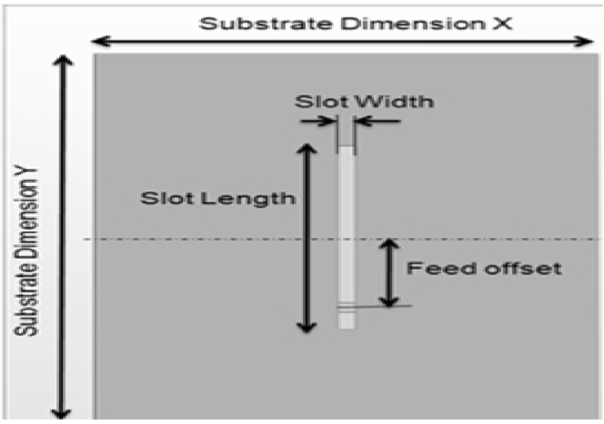
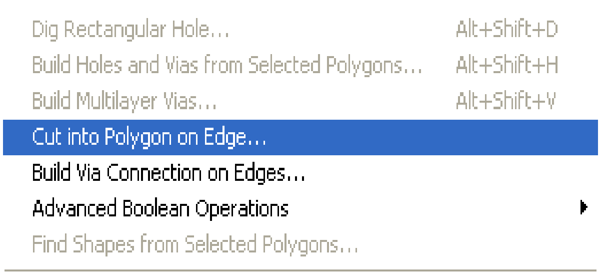


Figure 10: *Single Slotted Microstrip Patch Antenna*

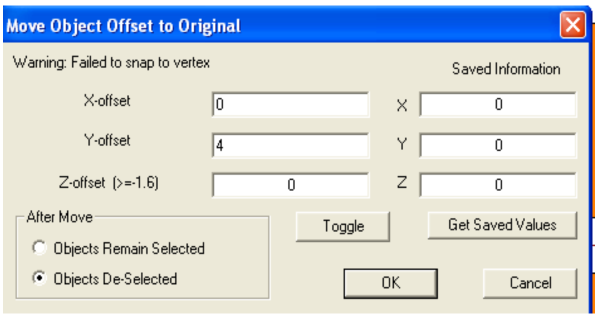
A) Slot Antenna Design Using IE3D Software

At first we selected cut polygon into edges to cut slots in formats. The snapshot is shown here.

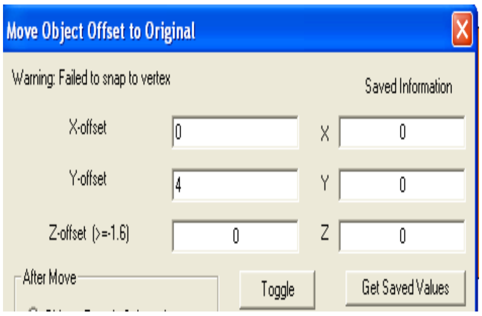


(a) Snapshot for Polygon Cut

Now it is required to define the required parameters for the slot

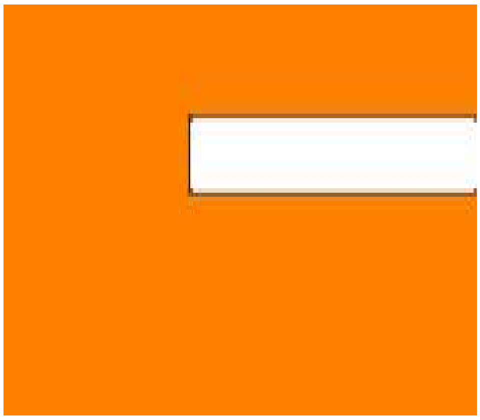


(b) Snapshot for Determination of Exact Point



(c) Snapshot for Coordinate Set Up

Finally we got cut where we want.



(d) Snapshot for Slotted Patch

6. Simulated Result for Conventional Rectangular Slotted Patch Antenna

The proposed antenna has been designed and simulated using *Zealand IE3D* software. Figure 11 represents the variation of Return Loss with Frequency. Plot shows resonant frequency at 4.9 GHz. Minimum -29.28 dB return loss is available at resonant frequency.

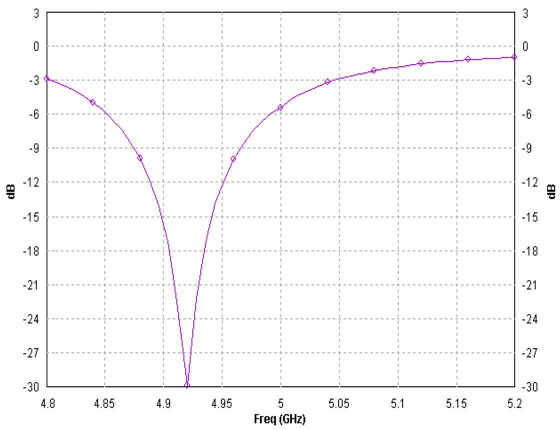


Figure 11: *Return Loss vs. Frequency*

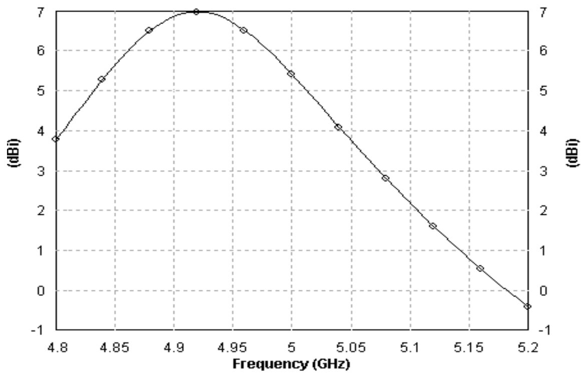


Figure 12: *Gain vs. Frequency*

7. Design of Rectangular Patch with Introduction of Shifted Slot of Elliptical Shape

Almost 25% enhancement in return loss and 27% increment in gain have been obtained after we changed the rectangular shaped slot into an elliptical one. The primary radius R_p = 3mm and secondary radius R_s = 7mm. The following figure represents the design of shifted elliptical slotted RMSPA.

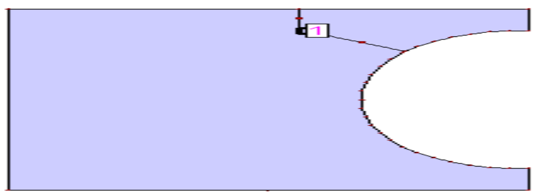


Figure 13: *Shifted Elliptical Slot Rectangular Microstrip Patch Antenna Design*

8. Simulated Result for Shifted Elliptical Slotted Patch Antenna

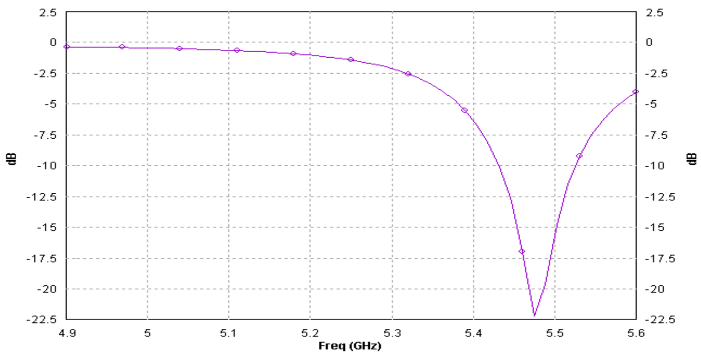


Figure 14: *Return Loss vs. Frequency*

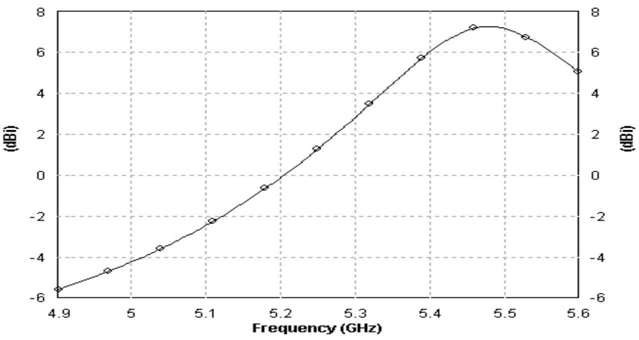


***Figure 15**: Gain vs. Frequency*

This calculated Bandwidth and Gain is more than that of single rectangular slotted Microstrip patch antenna.

9. Characteristics of the Adjacent Frequencies of 430 MHz Wind Profiler Radar

(i) 420 to 430 MHz

This band is internationally allocated to the fixed and mobile services (except aeronautical mobiles) on a primary basis and radiolocation on a secondary basis. It is used by high power fixed, transportable ship-borne and airborne radars. The land mobile, and the fixed and amateur operations sharing with wind profiler radars in these bands seem to be possible.

(ii) 430 to 440 MHz

This frequency range is is used for amateur control, aeronautical radio allocation, space operation etc. This 430-440 MHz band is shared with highly mobile reallocation systems. Out of that, 435-438 MHz band is used for amateur-satellite operations.

10. Advantage of Wide Bandwidth for Wind Profiler Applications

The advantages of using wide bandwidth in any radar including our Wind Profiler are shown below:

- The data rate will be high and therefore the range resolution is high
- The pulse compression will be smaller with the increment of frequency bandwidth
- In mobile and broadband communications, it will be very useful
- Radiolocation, amateur, space operations, amateur-satellite and aeronautical radiolocation services.

11. Conclusion

It can be observed that the drawback of Rectangular Micro strip Patch Antenna that is its narrow bandwidth can be easily overcome by introducing a rectangular slot followed by an elliptical slot. The gain and bandwidth increment of a single element patch shows the path of further experiments with arrays of antennas and in the case of dual polarization. Here, in this paper, the enhancement of bandwidth varies from 10% to 37% for each kind of structure, whereas, the gain varies from 18% to 26%. The other parameters are also observed. But mainly these two parameters are focused. The gradual change in the return loss and gain varying from simple rectangular to rectangular slotted to elliptical shaped slotted patch shows that depending upon the implemented values, the behavior of the patch changes abruptly. More negative the return loss is, the patch is more efficient. In case of Dual Polarization, we will observe the isolation value between two different feeds.

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