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IE3D-Based C-Band Microstrip Patch Antenna Design for Radar Applications

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Article Info

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Abstract- Recent advancements in communication systems necessitate the creation of inexpensive, lightweight, and low-profile antennas that can sustain good performance across a broad range of frequencies. The design of a microstrip patch antenna has received a lot of attention because to this technological shift. Designing a rectangular microstrip patch antenna that performs in C-band at 5GHz using microstrip line feeding is the aim of this paper. Thus, a Microstrip Patch Antenna with increased gain and bandwidth is designed using the approach of moments based IE3D software. For the study and design of 3D and planar microwave circuits, MMIC, RFIC, RFID, antennas, digital circuits, and high-speed printed circuit boards (PCBs), IE3D is an integrated full-wave electromagnetic modeling and optimization package. The most adaptable, user-friendly, effective, and precise electromagnetic simulation tool is now IE3D. One crucial factor that controls the antenna's resonance frequency is its length, which is almost half the wavelength of the dielectric. Along with the feed line size, choosing the patch's width and length are crucial design considerations. The IE3D simulator tool was used to simulate the desired patch antenna design. The National Atmospheric Research Laboratory (NARL), ISRO, is where the entire project is being conducted.

Key words: IE3D, C-Band, RADAR, wind profiler, micro strip patch

I. Introduction

II. The increase in bandwidth and gain of a 5GHz rectangular microstrip patch antenna has been thoroughly examined in this work. Over the past 20 years, microstrip patch antennas have drawn a lot of attention and are now a key part of the development of wind profile radar. A printed type of antenna, a microstrip antenna is made up of a dielectric substrate positioned between a patch and a ground plane.

Fig1: A Typical Microstrip Patch Antenna

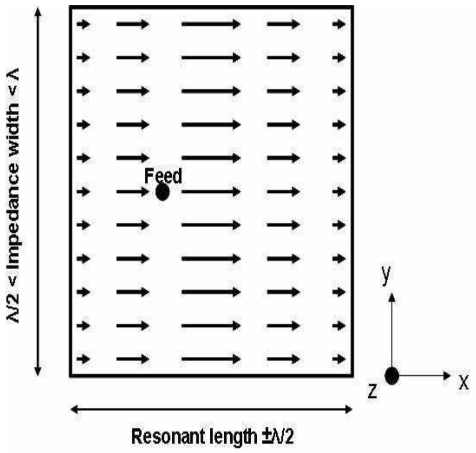
Because microstrip patch antenna technology is commercially viable and has uses in a wide range of microwave systems, personnel communication systems (PCS), wireless local area networks (WLAN), etc., it is employed in this research to construct an antenna appropriate for WPR. Although their low profile and light weight make them superior to other radiator types, their poor gain and restricted bandwidth are their main disadvantages. Researchers from all over the world have been attempting to solve this issue. We have attempted to improve the patch antenna's gain and bandwidth in this project. It has been seen that the bandwidth and gain measurements have increased significantly.

III. Fundamental Specifications of Patch Antennas

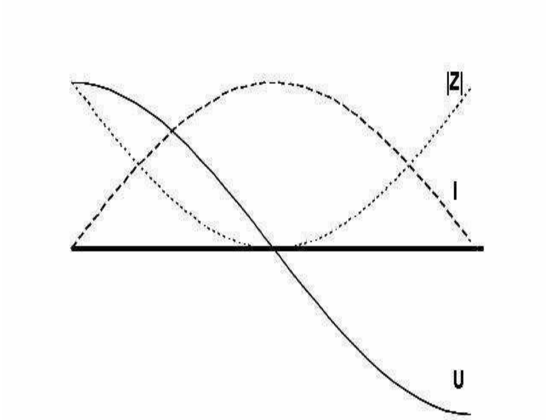
IV. Compared to other antennas, a tiny strip or patch antenna is low profile, lightweight, affordable, and simple to integrate with related devices. Although the antenna's structure can be three-dimensional (for instance, wrapped around an object), the elements are typically flat, which is why they are also known as planar antennas.

IV.1 Impedance Matching

V. When examining the fluctuation of the voltage (electrical field) and current (magnetic field) along the patch, the electrical field is zero in the center and maximal near the left and right edges, while the current is maximal at the center and minimal near the left and right margins. These numbers are made clear in the figures below.



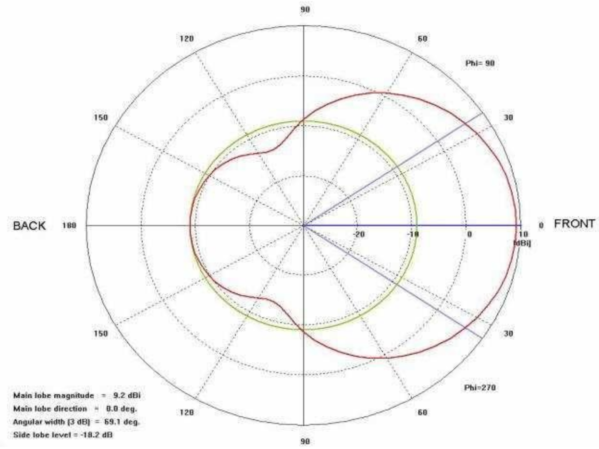
Current distribution on the patch surface.



Voltage (U), current (I) and impedance (|Z|) distribution along the patch's resonant length

V.1 Radiation Pattern

VI. A particular far field radiation pattern is produced by the patch's radiation at the bordering fields. The antenna transmits more power in one direction than another, as this radiation pattern demonstrates. It is claimed that the antenna has a specific directivity. dB is a typical way to represent this. The direction perpendicular to the patch (broadside) is where the rectangular patch's maximal directivity occurs when it is activated in its basic mode. As one moves away from broadside and toward lower heights, the directivity drops. When this directivity has rolled down 3 dB with respect to the maximum directivity, the 3 dB beam width (also known as the angular width) is twice the angle with respect to the angle of the maximum directivity.



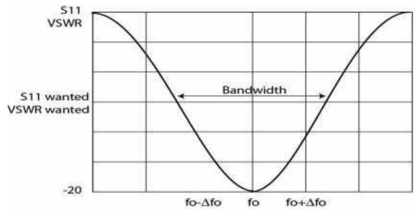
VI.1 Antenna Gain

VII. The definition of antenna gain is antenna directivity multiplied by a radiation efficiency factor. The ratio of the input power (Pi) to the radiated power (Pr) is the definition of this efficiency. A tiny amount of the input power is lost as a result of conductor and dielectric losses in the materials utilized, while the majority is converted into surface wave and radiated power. Guided waves that are partially radiated and reflected back at the substrate edges are known as surface waves. The use of thicker materials and/or materials with greater dielectric constants facilitates the excitation of surface waves. Using an air dielectric does not stimulate surface waves. The overall efficiency, rather of only the radiation efficiency, can also be used to specify antenna gain. This overall efficiency is the sum of the radiation efficiency and the antenna's impedance matching efficiency.

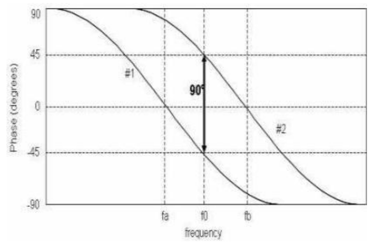
VII.1 Impedance bandwidth/return loss bandwidth

VIII. This is the range of frequencies where the structure's useful bandwidth is in relation to a specific impedance, often 50 Ω. Numerous factors pertaining to the patch antenna element itself, such as the quality factor and the feed type, affect the impedance bandwidth. A patch antenna's return loss is plotted below, along with the return loss bandwidth at the target (S11/VSWR). Usually, the bandwidth is restricted to a few percent. This is the primary drawback of simple patch antennas.

Another approach is to see the patch as a parallel RLC resonant circuit. This means a phase shift that changes



versus frequency is present, as shown in the following plot:



IX. Operation of Wind Profiler

X. Wind profilers rely on electromagnetic energy being scattered by small variations in the air's refractive index. The speed at which electromagnetic waves travel through a medium is measured by the reflective index. The medium for wind profiling is the atmosphere. A tiny quantity of energy is dispersed in all directions when a radio wave encounters a spatial variation in this index.

XI. There are slight variations in the refractive index in the troposphere and stratospheric of this environment, spanning a broad range of sizes. The air's temperature, pressure, and humidity have the most effects on the refractive index. The radar relies on the air's electromagnetic wave energy being scattered by clear air turbulence (CAT). Over a broad range of refraction diameters, there are slight variations in the index refraction in the atmosphere.
The wind creates turbulent eddies, which are tiny swirling currents of air, as it changes direction or speed. The turbulent eddies are produced in a range of diameters, from centimeters to several tens of meters.

The velocity of air along the beams can be ascertained by analyzing the back-scattered signals using wind profiler radars, which are vertically directed pulsed Doppler radars. The horizontal and vertical components of the air velocity can be derived by directing the beams, usually 15° from zenith.
The concept of wind profiler radar systems and their behavior in the electromagnetic environment must be clearly understood in order to identify the different compatibility and/or sharing options.
Short-range forecasting, convective storm initiation, climates, air pollution, aviation operations and flight planning, rocket and missile launching, and other applications are among the key uses for a traditional wind profile radar.

XII. Overview of IE3D Software

XIII. IE3D is a complete wave electromagnetic simulator that uses the method of moments (MOM) to analyze and optimize 3D and planar structures in a multi-layer dielectric environment. Wave effects, discontinuity effects, coupling effects, and radiation effects are among the integral form solutions to Maxwell's equation. S, Y, and Z parameters, VSWR, RLC equivalent circuits, current field distribution, estimation of the near and far fields, radiation pattern, and other information are all included in the simulated result. When designing MMICs, RFICs, RF printed circuits, wired and micro strip RF antennas, multilayer PCBs, and IC interconnections, IE3D is a very helpful tool.

XIII.1 The important features of Zeland Software, Inc. IE3D Version 12:

XIV. (a) IE3D Fast EM Design Kit for adjusting, optimizing, and synthesizing full-wave electromagnetic fields in real time. (b) Support for several CPUs and a multi-fold speed increase or significantly increased efficiency.(c) Boolean operations in an equation-based schematic-layout editor for simple and adaptable parameterization and geometry manipulation.(d) Automatic extraction and optimization of lumped element equivalent circuits for practical circuit designs. (e) Applied Wave Research's enhanced incorporation into Microwave Office.

XIV.1 Applications of IE3D:

XV. (a) RF circuits, RF ICs, and LTCC circuits.
(b) Wireless, radio frequency, and microwave antennas.
(c) RFID tag antennas.

(d) filters for HTTP.
(e) Signal integrity and electronic packaging.

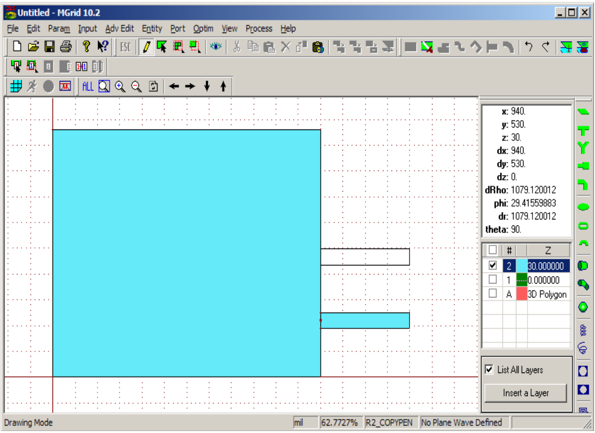
(f) MMICs and microwave circuits.
(g) A wide range of additional low-to-high frequency structures.

XV.1 Applications of IE3D in Antennas:

XVI. (a) Planar antennas, like slot and micro strip antennas. (b) Wire antennas, including monopole, helix, dipole, and quadrifilar antennas.(c) Small antennas, including derivatives of inverted-F antennas. (d) Antennas with dielectric resonators. RFID antennas (e). (f) Antennas with optical frequencies. (g) A wide variety of additional antenna types.

XVII. Design of a Rectangular Micro strip Patch Antenna

XVIII. The chosen parameters in this paper are: Resonant frequency = 5 GHz (C band), dielectric material = RT-DUROID5880, dielectric constant €r = 2.2, and dielectric substrate height h = 3.172 mm. The Rectangular Patch's dimensions are 600 by 480 mils, with tan χ = 0.0004.



Automatic Edge Cell (AEC) enabled and Edge Cell Width = 6 mils. MGRID will show the AEC Width vs. Regular Size = 9.6%.Fmax = 10 GHz, N cells = 15 cells/λ.

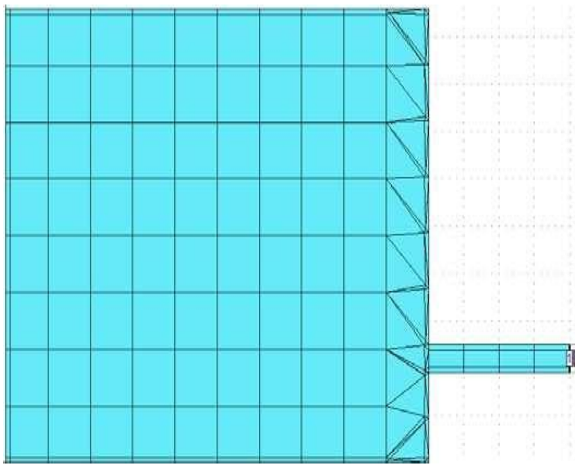


Fig.2: Meshed structure

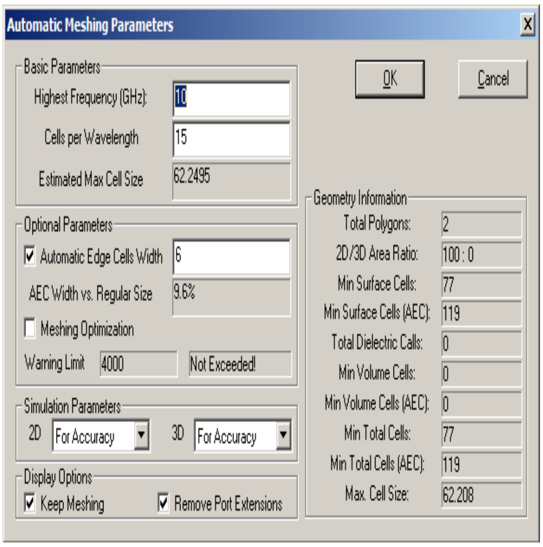


Fig.3: MGRID Box

XIX. Simulated Result for Different Parameters

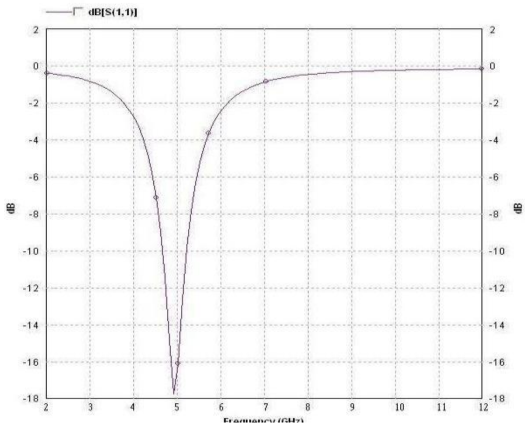


Fig. 4: Return Loss vs frequency plot

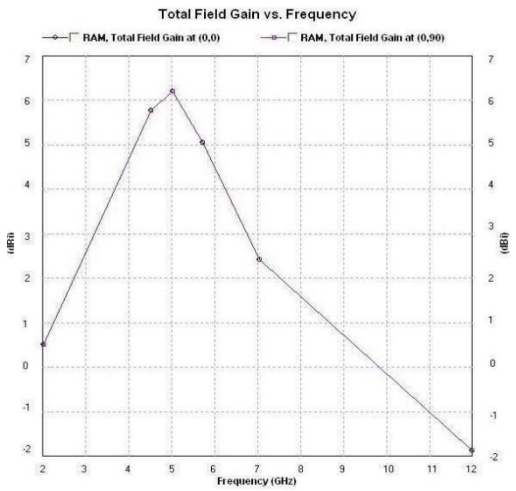


Fig. 5: Gain vs frequency plot

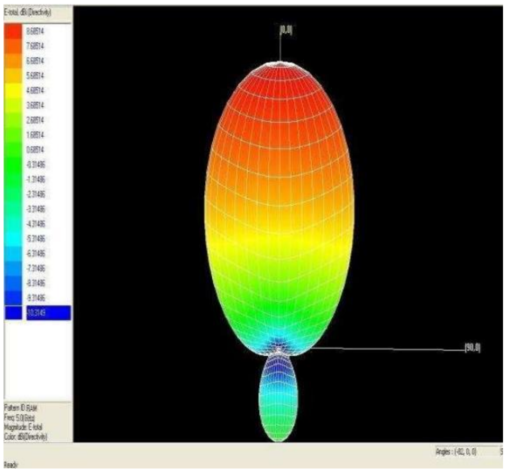


Fig. 6: 3D Radiation Pattern of Patch Antenna

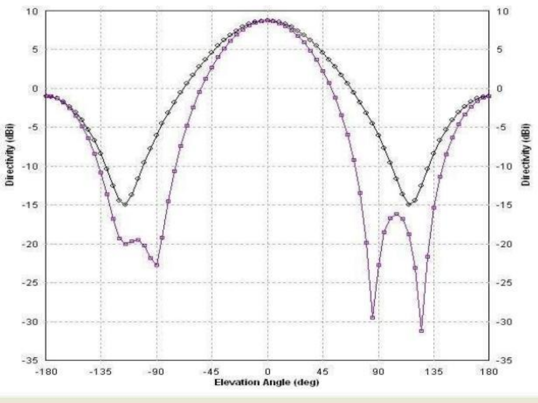


Fig.7: 2D Radiation Pattern of Patch Antenna

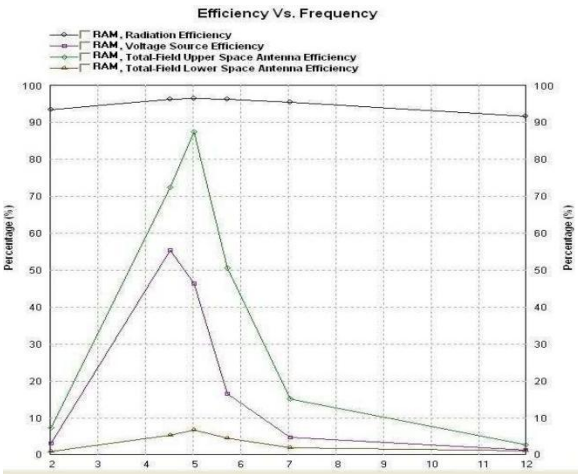


Fig. 8: Efficiency vs frequency plot

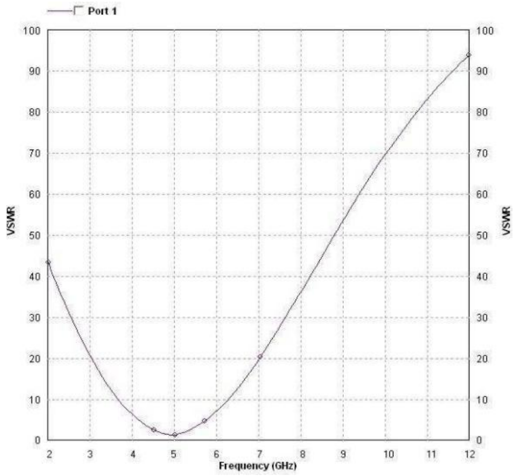


Fig. 9: vswr vs frequency plot

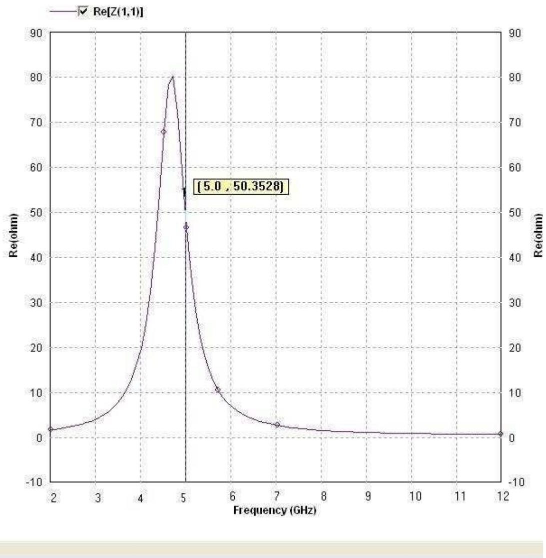


Fig.10 input impedance of patch antenna

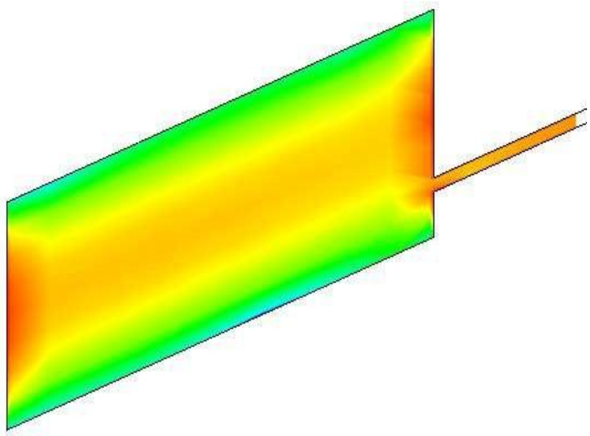


Fig. 11: Average current distribution with colour for the average strength of the current

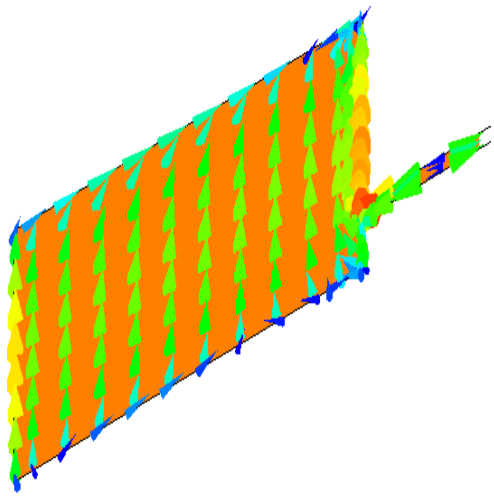


Fig. 12: Vector current distribution with properly adjusted Vector Size of the 3D View window.

XX. Advantage of Wide Bandwidth for Wind Profiler Applications

XXI. A significant issue with all radars, including wind profiler radars, is the significant bandwidth needed. A wind profiler could occupy almost the whole width of the TV channel, so the bandwidth problem is no longer a significant concern as long as the separation areas between television stations operating in the same channel are sufficiently large to permit the operation of a wind profiler in this channel and in this separation region.

XXII. Conclusion

XXIII. The goal of this project is to construct a rectangular Microstrip patch antenna that operates in the C-band at 5 GHz for atmospheric Wind Profile Radar applications. Patch antenna design and simulation are done using the IE3D electromagnetic simulator. A 50 ohm line feed rectangular patch antenna has been designed. The developed antenna has an impedance bandwidth of 20 MHz, an antenna gain of 6.43 dB, a directivity of 8.68, a return loss of -18 dB, and a radiation efficiency of about 95% and 85% at 5 GHz. An additional benefit for the application of atmospheric wind profile radar is that the adoption of an amplitude taper kept the SLL inside the maximum scan angle limit, as can be seen from the radiation pattern. The single element patch's gain and bandwidth indicate the direction of future antenna arrays and dual polarization research.

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