International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-3 Issue-12, May 2014

Design and Analysis of Slot Antenna Parameters Using HFSS

K. Phaninder Vinay, Basheer Ali Sheik, A. Trinadha Rao

Abstract: ***Micro strip slot antenna becomes very popular day by day because of its ease of analysis and fabrication, low cost, light weight, easy to feed and their attractive radiation characteristics. Although slot antenna has numerous advantages, it has also some drawbacks such as restricted bandwidth, and a potential decrease in radiation pattern. Different techniques for bandwidth enhancement of conventional rectangular micro strip antenna are proposed in this report. By increasing the height of slot, increasing the substrate thickness and decreasing the permittivity of substrate the %bandwidth is increased. HFSS Software is used for the simulation and design calculation of micro strip slot antenna. The return loss, VSWR curve, directivity and gain are to be analyzed and evaluated.***

Keywords: Probe, Feed, Patch, Antenna, HFSS, Substrate, Coax, Bandwidth.

I. INTRODUCTION

A **Patch Antenna** (also known as a rectangular microstrip antenna) is types of radio antenna with allow profile, which can be mounted on a flat surface. It consists of a flat rectangular sheet or "patch" of metal, mounted over a larger sheet of metal called aground plane. The assembly is usually contained inside a plastic redone, which protects the antenna structure from damage. Patch antennas are simple to fabricate and easy to modify and customize. They are the original type of microstrip antenna described by Howell; the two metal sheets together form a resonant piece of microstrip transmission line with a length of approximately one-half wavelength of the Radio waves. The radiation mechanism arises from discontinuities at each truncated edge of the microstrip transmission line. The radiation at the edges causes the antenna to act slightly larger electrically than its physical dimensions, for the antenna to be resonant; a length of microstrip Transmission line slightly shorter than one-half a wavelength at the frequency is used. A patch antenna is usually constructed on a dielectric substrate, using the same materials and lithography processes used to make printed circuit boards.

High Frequency Simulator Structure (HFSS):

HFSS is a high performance full wave electromagnetic (EM) field simulator for arbitrary 3D volumetric passive device modeling that takes advantage of the familiar Microsoft Windows graphical user interface. It integrates simulation, visualization, solid modeling, and automation in an easy to learn environment where solutions to your 3D EM problems are quickly and accurate obtained.

Manuscript published on 30 May 2014.
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Ansoft HFSS employs the Finite Element Method (FEM), adaptive meshing, and brilliant graphics to give you unparalleled performance and insight to all of your 3D EM problems. Ansoft HFSS can be used to calculate parameters such as S-Parameters, Resonant Frequency, and Fields. Typical uses include:

- Package Modeling – BGA, QFP, Flip-Chip
- PCB Board Modeling – Power/ Ground planes, Mesh Grid Grounds, Backplanes.
- Silicon/GaAs-Spiral Inductors, Transformers. EMC/EMI – Mobile Communications – Patches, Dipoles, Horns, Conformal Cell Phone Antennas, Quadrafilar Helix, Specific Absorption Rate (SAR), Infinite Arrays, Radar Section (RCS), Frequency Selective Surface (FSS).:
- HFSS is an interactive simulation system whose basic mesh element is a tetrahedron. This allows you to solve any arbitrary 3D geometry, especially those with complex curves and shapes, in a fraction of the time it would take using other techniques.
- The name HFSS stands for High Frequency Structure Simulator. Ansoft pioneered the use of the Finite Element Method (FEM) for EM simulation by developing / implementing technologies such as tangential vector finite elements, adaptive meshing, and Adaptive Lancozos - pade Sweep (ALPS). Today, HFSS continues to lead the industry with innovations such as Modes to Nodes and Full wave Spice.
- Ansoft HFSS has evolved over a period of years with input from many users and industries. In industry, Ansoft HFSS is the tool of choice for High productivity research, development, and virtual prototyping.

HFSS is a commercial finite element method solver for electromagnetic structures from Ansys. The acronym originally stood for high frequency structural simulator .It is one of several commercial tools used for antenna design, and the design of complex RF electronic circuit elements including filters, transmission lines and packaging.

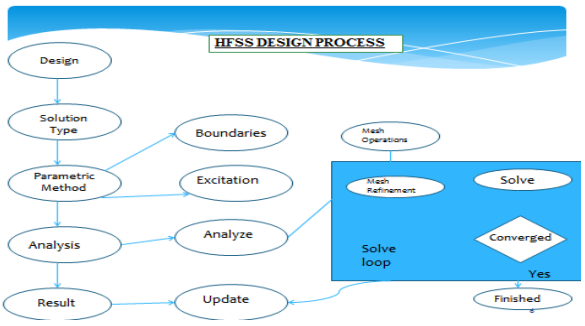

fig1:HFSS design process.

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II. PROPOSED SUBSTRATE DESIGN

The reflections, combined with the incident field, create constructive or destructive interferences depending on the characteristics of the materials. If this basic concept is applied to the design of micro strip antennas, the characteristics of the substrate can be modified, by using two or more materials, to reflect the surfaces waves. The reflected field can then enhance the maximum antenna gain by reducing the surface wave propagation in the substrate. RTduroid5880 and FR4 are the substrates used for the design of patch antenna. By using these substrates the bandwidth enhancement is observed.

Features of RT DUROID 5880

- Low electrical loss
- Isotropic
- Low moisture absorption
- Excellent chemical resistance
- Uniform electrical properties over frequency.
- RTduroid5880 laminates are easily cut, sheared and machined to shape.
- Because of its low dissipation factor its usefulness extends to Ku band.

Features of FR4:

- FR4 is made up of fiber material and is bonded with epoxy resin so as to be flame redundant. Hence it is named as flame redundant.
- It consists of halogen, bromine compounds as they possess the properties of flame redundancy.
- These are used in applications like buzzers, switches etc.
- The most important application is that it is used in fabrication of PCB
- It is water resistant also.

FEATURES OF BAKELITE:

Bakelite is one of the first plastics to be made from synthetic components. Properties of Bakelite include its resistance to heat and its electrical non-conductivity. This plastic was used in radio and telephone casings, jewelry, pipe stems, kitchenware, and similar applications. Bakelite has a significance as the world's first synthetic plastic and has thusly been deemed a retro collectible for any of the products made with Bakelite

PROPERTIES OF BAKELITE:

- At 300k. Thermal conductivity - 1.4 w/mk
- Density - 1300 kg/m3
- Specific heat at constant pressure- Cp-1465 j/kg k.

Properties of benzocyclobutene:

Benzocyclobutene (**BCB**) is a benzene ring fused to a cyclobutane ring. It has chemical formula C_8H_8. BCB is frequently used to create photosensitive polymers. BCB-based polymer dielectrics may be spun on or applied to various substrates for use in Micro Electro-Mechanical Systems (MEMS) and microelectronics processing. Applications include wafer bonding, optical interconnects, low-K dielectrics, or even intracortical neural implants.

III. GEOMETRY

The geometry is based on the calculations of width, height and thickness etc. by mathematical analysis.

Patch dimensions

$$W = \frac{c}{2f\sqrt{\varepsilon_{eff}}}$$

$$L = \frac{c}{2f\sqrt{\varepsilon_{eff}}} - 2\Delta$$

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 - \frac{10H}{W}\right)^{-\frac{1}{2}}$$

$$\frac{\Delta}{H} = 0.412\,\frac{\varepsilon_{eff} + 0.3}{\varepsilon_{eff} - 0.258}\,X\,\frac{\frac{W}{H} + 0.262}{\frac{W}{H} + 0.813}$$

Ground Dimensions

$W_g = 6H + W$

$L_g = 6H + L$

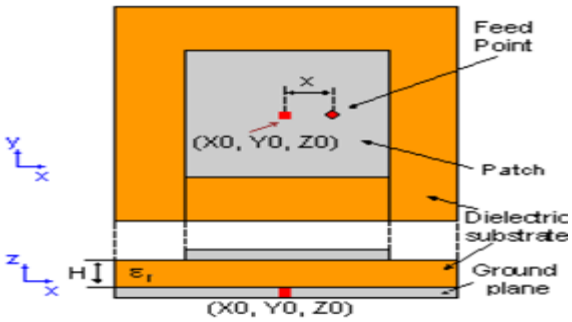

fig2: patch antenna

IV. SOFTWARE USED

HFSS is a commercial finite element method solver for electromagnetic structures from Ansys .The acronym originally stood for high frequency structural simulator .It is one of several commercial tools used for antenna design , and the design of complex RF electronic circuit elements including filters, transmission lines and packaging. HFSS is a high performance full wave electromagnetic (EM) field simulator for arbitrary 3D volumetric passive device modeling that takes advantage of the familiar Microsoft Windows graphical user interface. It integrates simulation, visualization, solid modeling, and automation in an easy to learn environment where solutions to your 3D EM problems are quickly and accurate obtained. Ansoft HFSS employs the Finite Element Method (FEM), adaptive meshing, and brilliant graphics to give you unparalleled performance and insight to all of your 3D EM problems. Ansoft HFSS can be used to calculate parameters such as S-Parameters, Resonant Frequency, and Fields. Typical uses include:

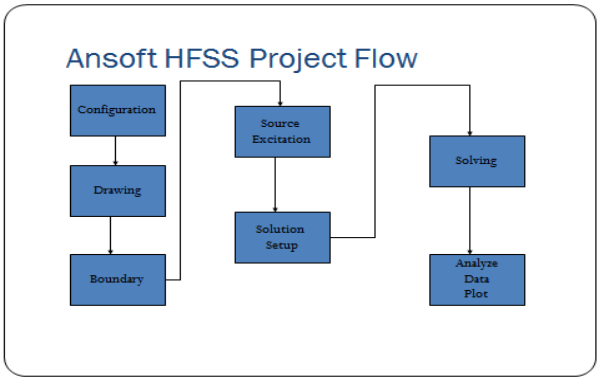

fig3: ANsoft HFSS Project Flow

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V. DESIGN

Patch antenna details:

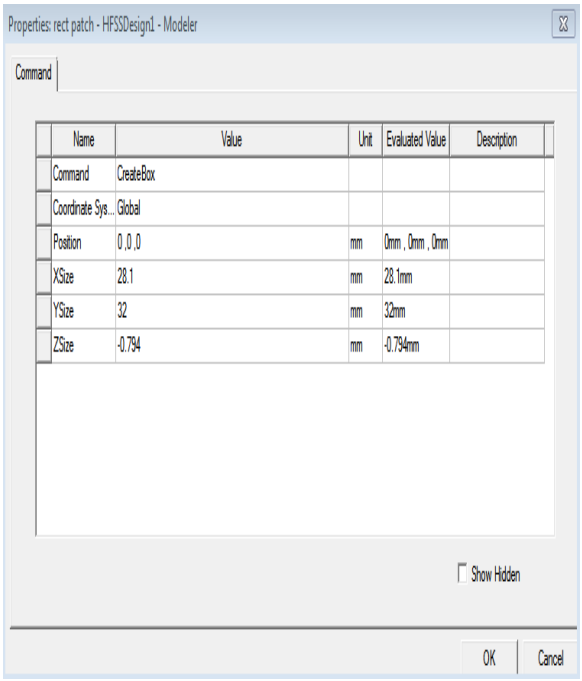

Fig4:dimensions of antenna

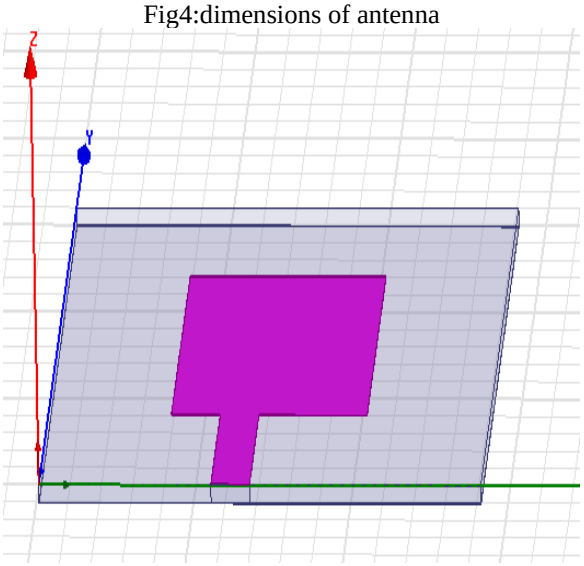

fig5:patch antenna

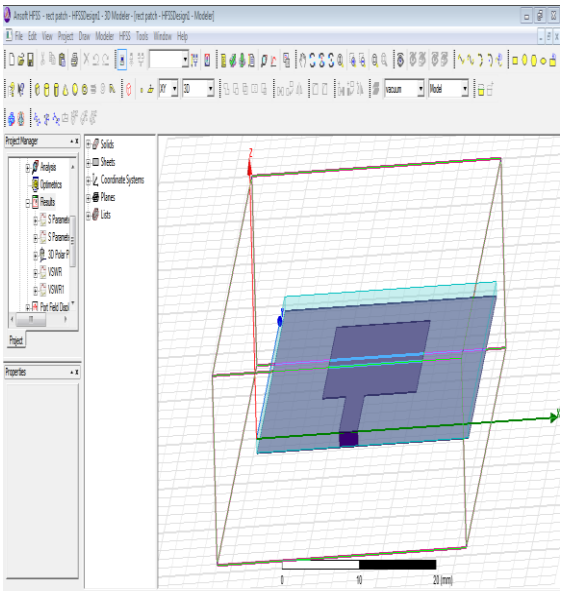

fig 6:Final geometry of slot antenna design

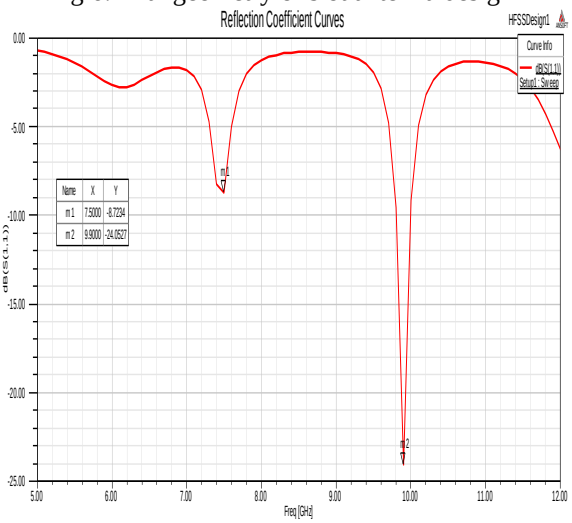

fig7:reflection coeffient curve with The antenna is resonating around 7.5 GHz.

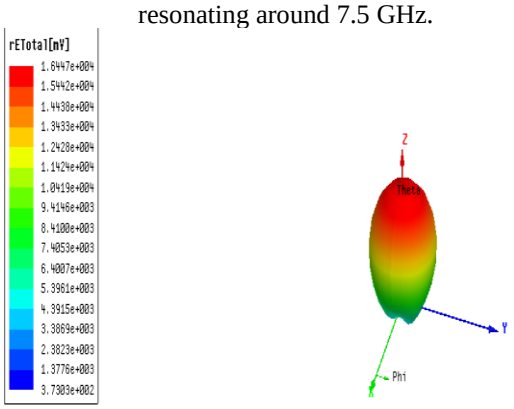

fig8: output 3d polar plot for rt duroid5880

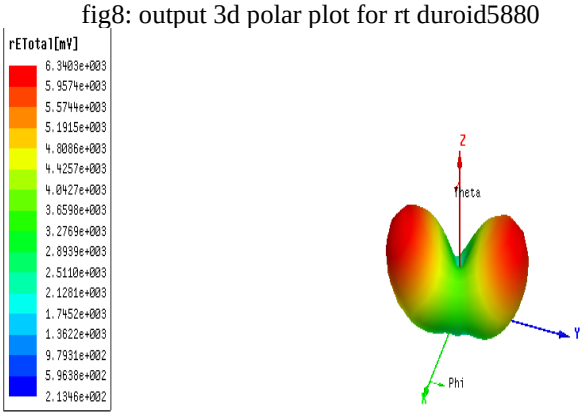

fig9: output radiation pattern of FR4

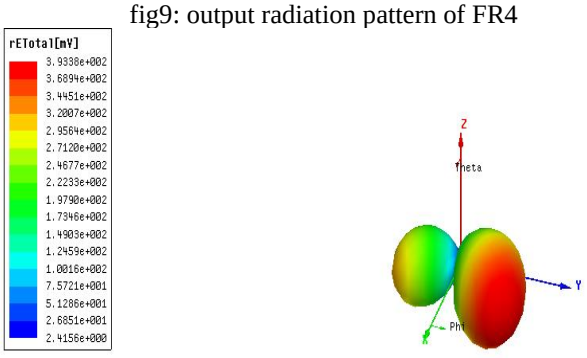

fig10: Output radiation pattern of benzocyclobutene

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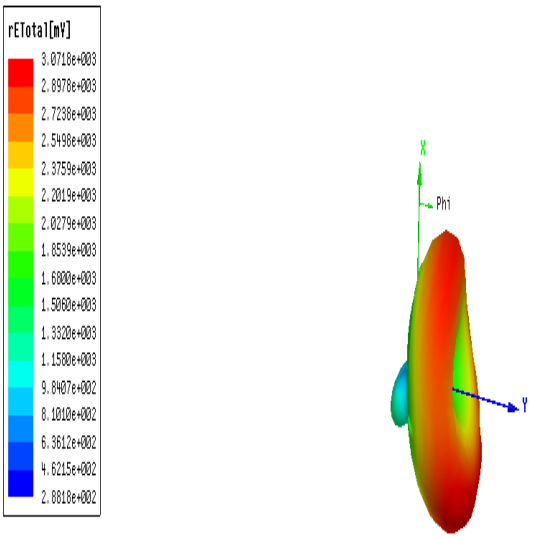

fig11: Output 3d polar plot of beklite

VI. RESULT ANALYSIS

The project results were satisfactory and thus by changing the substrate which has dielectric constant in optimum range can improve the radiation pattern of slot antenna.
Also using this HFSS software we can easily design and analyze the required parameters of the geometry constructed by us without the requirement of any code.

VII. CONCLUSION

A microstrip or patch antenna is a low profile antenna that has a number of advantages over other antennas it is lightweight, inexpensive, and easy to integrate with accompanying electronics. The properties of Probe Feed Patch Antenna using fr4,Bekelite, Benzocyclobutene and RTduroid5880 as the substrate material have been analyzed thoroughly with the help of appropriate simulation results. A detailed knowledge of Gain and Directivity is necessary in order to design a Probe Feed Patch Antenna. Choosing a substrate for antenna design also plays an important role. Selecting a suitable substrate, may fulfill the antenna requirements. Among all other substrates, RTduroid5880 is capable of providing optimum simulation results. In near future, various other substrate materials will be considered and the antenna characteristics will be analyzed with generalized and quantized results.

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