Designing of Bandwidth Improved 'h' Shaped Microstrip Patch Antenna for Bluetooth Applications using Ansoft HFSS

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Abstract: ***This paper represents the Designing of 2.4 GHZ H shaped microstrip patch antenna using electromagnetic simulation software i.e. Ansoft hfss. As the rectangular microstrip patch antenna is suffering from the narrow bandwidth hence Instead rectangular patch H shaped is used to get broad bandwidth. The model designed in Ansoft hfss v.13 and it is simulated. Simulation result includes the various parameters of antenna such as Return loss, VSWR, gain, radiation pattern, Axial ratio***

Keywords: Structure of MSA, H shape patch, designing steps, 2.4 GHZ antenna, method of analysis

1. Introduction

An antenna is a transducer that transmits or receives electromagnetic. The rising importance of wireless communication and multimedia services increasing the efforts to the design and implementation of microstrip patch structures. In the world of waves In other words, antennas convert electromagnetic radiation into electric current, or vice versa. Antennas generally deal in the transmission and reception of radio waves, and are a necessary part of all radio equipment. Antennas are used in systems such as radio and television broadcasting, point-to-point radio communication, wireless LAN, cell phones, radar, and spacecraft communication basic need is an antenna. Although antenna engineering has a history of over 60 years, the microstrip antennas form one of the most innovative areas of current antenna work. Various mathematical models were developed for this antenna and its applications were extended to many other fields. The number of papers, articles published in the journals for the last ten years, on these antennas shows the importance gained by them.

2. Microstrip Patch Antenna

The microstrip is a type of electrical transmission line which can be fabricated using PCB and it is used to convey microwave frequency signals Microstrip antennas are attractive due to their light weight, conformability and low cost. These antennas can be integrated with printed strip-line feed networks and active devices. This is a relatively new area of antenna engineering. The radiation properties of micro strip structures have been known since the mid 1950's.The application of this type of antennas started in early 1970's when conformal antennas were required for missiles. Rectangular and circular micro strip resonant patches have been used extensively in a variety of array configurations. A major contributing factor for recent advances of microstrip antennas is the current revolution in electronic circuit miniaturization brought about by developments in large scale integration. As conventional antennas is often bulky and costly. part of an electronic system, micro strip antennas based on photolithographic technology.

3. Structure of MSA

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.

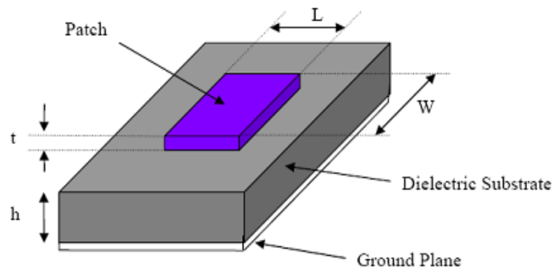


Figure 1: Structure of MSA

4. Waves on Microstrip

The mechanisms of transmission and radiation in a microstrip can be understood by considering a point current source (Hertz dipole) located on top of the grounded dielectric substrate shown in Figure This source radiates electromagnetic waves depending on the direction toward which waves are transmitted; they fall within three distinct categories, each of which exhibits different behaviors.

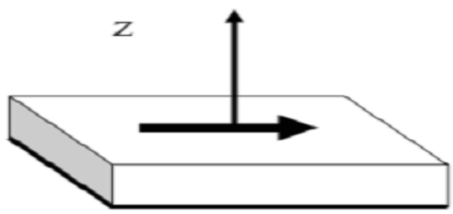


Figure 2: Hertz dipole on a microstrip substrate

4.1 Surface Waves

The waves transmitted slightly downward, having elevation angles θ between π/2 and π, meet the ground plane, which reflects them, and then meet the dielectric-to-air boundary, which also reflects them (total reflection condition). The magnitude of the field amplitudes builds up for some particular incidence angles that leads to the excitation of a discrete set of surface wave modes; which are similar to the modes in metallic waveguide. The fields remain mostly trapped within the dielectric, decaying exponentially above the interface shown in Figure The vector α, pointing upward, indicates the direction of largest attenuation. The wave propagates horizontally along β, with little absorption in good quality dielectric. With two directions of α and β orthogonal to each other, the wave is a non-uniform plane wave. Surface waves spread out in cylindrical fashion around the excitation point, with field amplitudes decreasing with distance (*r*), say 1/*r*, more slowly than space waves. The same guiding mechanism provides propagation within optical fibers.

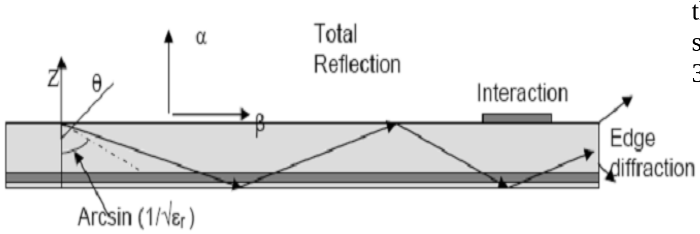


Figure 3: Surface waves

4.2 Leaky Waves

Waves directed more sharply downward, with θ angles between (π - arcsine ($1/\sqrt{\varepsilon_r}$) and π, are also reflected by the ground plane but only partially by the dielectric-to air boundary. They progressively leak from the substrate into the air which is shown in Figure, hence their name leaky waves, and eventually contribute to radiation. The leaky waves are also non-uniform plane waves for which the attenuation direction α points downward, which may appear to be rather odd; the amplitude of the waves increases as one moves away from the dielectric surface.

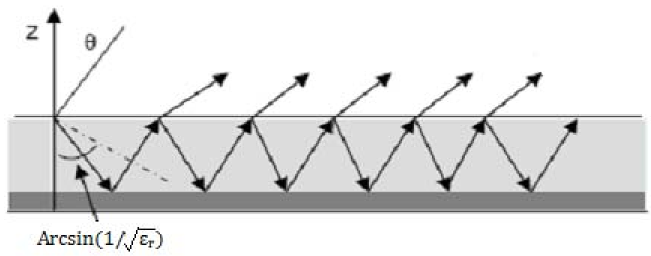


Figure 4: Leaky waves

5. Methods of Analysis

The preferred models for the analysis of Microstrip patch antennas are the transmission line model, cavity model, and full wave model (which include primarily integral equations/Moment Method). The transmission line model is the simplest of all and it gives good physical insight but it is less accurate. The cavity model is more accurate and gives good physical insight but is complex in nature. The full wave models are extremely accurate, versatile and can treat single elements, finite and infinite arrays, stacked elements, arbitrary shaped elements and coupling. These give less insight as compared to the two models mentioned above and are far more complex in nature.

6. Transmission Line Model

This model represents the microstrip antenna by two slots of width W and height h, separated by a transmission line of length L. The microstrip is essentially a non-homogeneous line of two dielectrics, typically the substrate and air. Hence, as seen from Figure no 5, most of the electric field lines reside in the substrate and parts of some lines in air. As a result, this transmission line cannot support pure transverse-electric-magnetic (TEM) mode of transmission, since the phase velocities would be different in the air and the substrate. Instead, the dominant mode of propagation would be the quasi-TEM mode. Hence, an effective dielectric constant (ε_{reff}) must be obtained in order to account for the fringing and the wave propagation in the line. The value of $\varepsilon_{reff}$is slightly less than ε_r because the fringing fields around the periphery of the patch are not confined in the dielectric substrate but are also spread in the air as shown in Figure 3.2.

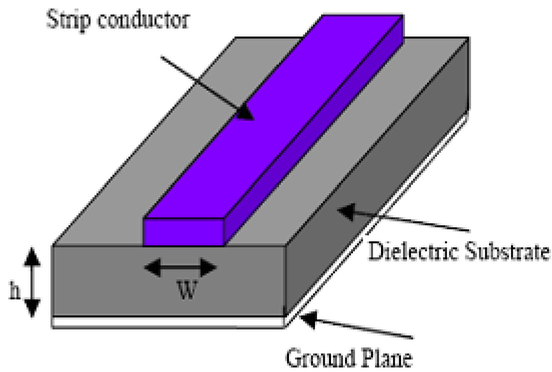


Figure 5: Microstrip Line

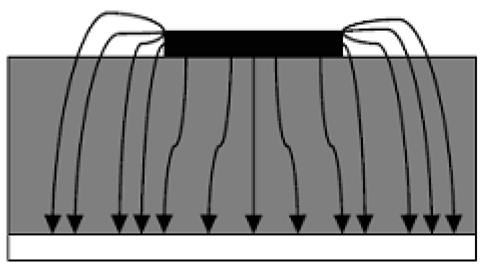


Figure 6: Electric Field Lines

The expression for ε_{reff} is given as:

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

Where ε_{reff} = Effective dielectric constant

ε_r = Dielectric constant of substrate
h = Height of dielectric substrate
W = Width of the patch

Figure no 6 shows a rectangular microstrip patch antenna of length L, width W resting on a substrate of height h. The coordinate axis is selected such that the length is along the x direction, width is along the y direction and the height is along the z direction.

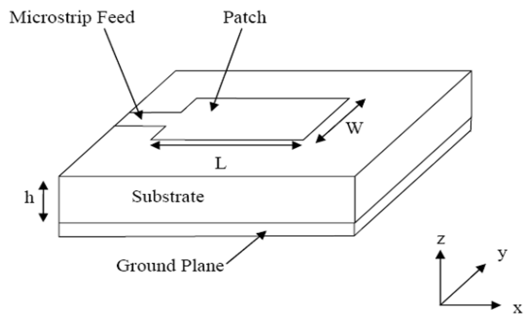


Figure 6: Microstrip Patch Antennas

In order to operate in the fundamental TM_{10} mode, the length of the patch must be slightly less than λ/2 where λ is the wavelength in the dielectric medium and is equal to $\lambda_0/\sqrt{\varepsilon_{reff}}$ where λ_o is the free space wavelength. The TM_{10} mode implies that the field varies one λ/2 cycle along the length, and there is no variation along the width of the patch. In the Figure 4.3 shown below, the microstrip patch antenna is represented by two slots, separated by a transmission line of length L and open circuited at both the ends. Along the width of the patch, the voltage is maximum and current is minimum due to the open ends. The fields at the edges can be resolved into normal and tangential components with respect to the ground plane. It is seen from Figure 3.4 that the normal components of the electric field at the two edges along the width are in opposite directions and thus out of phase since the patch is λ/2 long and hence they cancel each other in the broadside direction. The tangential components (seen in Figure 3.5), which are in phase, means that the resulting fields combine to give maximum radiated field normal to the surface of the structure. Hence the edges along the width can be represented as two radiating slots, which are λ/2 apart and excited in phase and radiating in the half space above the ground plane.

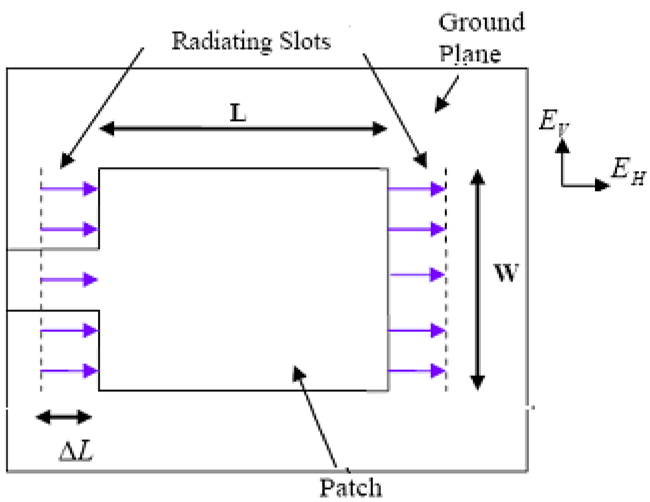


Figure 7: Top View of Antenna

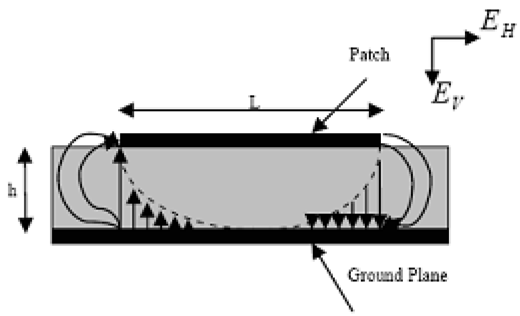


Figure 8: Side View of Antenna

The fringing fields along the width can be modeled as radiating slots and electrically the patch of the microstrip antenna looks greater than its physical dimensions. The dimensions of the patch along its length have now been extended on each end by a distance ΔL, which is given as:

$$\Delta L = 0.412h \frac{(\varepsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{W}{h}+0.8\right)} \quad (2)$$

Where

ε_{reff}= Effective dielectric constant
h = Height of dielectric substrate
W = Width of the patch

The effective length of the patch L_{eff} now becomes:

$$L_{eff} = L + 2\Delta L \quad (3)$$

Where,

L = Actual length of patch.
Leff = Effective length.
ΔL = small difference between length.

For a give resonance frequency f_r, the effective length is given as:

$$L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{eff}}} \quad (4)$$

Where

c - Free space velocity of light, 3 x 10^8 m/s.
f_r - frequency of operation.
ε_{reff} - effective dielectric constant.
Leff- Effective length.`

For a rectangular Microstrip patch antenna, the resonance frequency for any TM_{mn} mode is given as:

$$f_r = \frac{c}{2\sqrt{\varepsilon_{reff}}}\left[\left(\frac{m}{L}\right)^2 + \left(\frac{n}{W}\right)^2\right]^{\frac{1}{2}} \quad (5)$$

Where
f_r - frequency of operation.
ε_{reff} - effective dielectric constant m, n are mode along L and W respectively.

For efficient radiation, the width W is given as

$$W = \frac{c}{2f_r\sqrt{\left(\frac{\varepsilon_r+1}{2}\right)}} \quad (6)$$

Where c - Free space velocity of light, 3 x 10^8 m/s

f_r - Frequency of operation.
ε_r - dielectric constant.

7. Coaxial feed

In this method the inner conductor of the coaxial connector extends through the dielectric and it is soldered to the patch, while the outer conductor is connected to the ground plane. The feed co-ordinates were calculated as y=W/2,X=X-Δ*L*. The advantage of coaxial feed is that it can be placed at any desired location inside the patch .It is easy to fabricate.

8. Design Considerations

8.1 Material used

Table 1: Material used

Elements	*Material used*
Substrate	Glass epoxy
Patch	Pec
Ground plane	Pec

8.2 Dimensions of Antenna

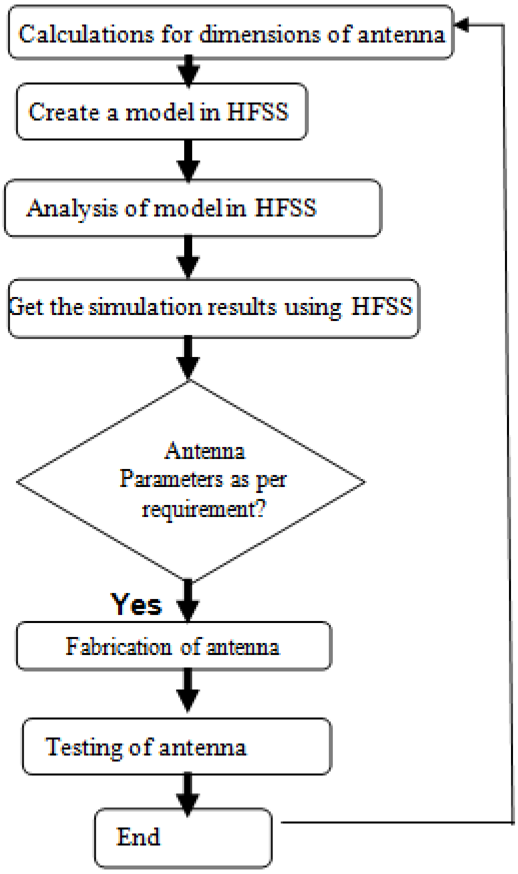
Table 2: Dimensions of antenna

Element	*Length*	*Width*	*Height*
Substrate	58 mm	49.44mm	1.6mm
Patch	38mm	20.74mm	1.6mm
Ground Plane	58mm	49.44mm	1.6mm

8.3 Software used

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 accurately 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. 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 Lanczos-Pade Sweep (ALPS). Today, HFSS continues to lead the industry with innovations such as Modes-to-Nodes and Full- Wave Spice

8.4 Flow Chart for Designing in HFSS



9. Results and Discussions

9.1 Antenna Model in HFSS

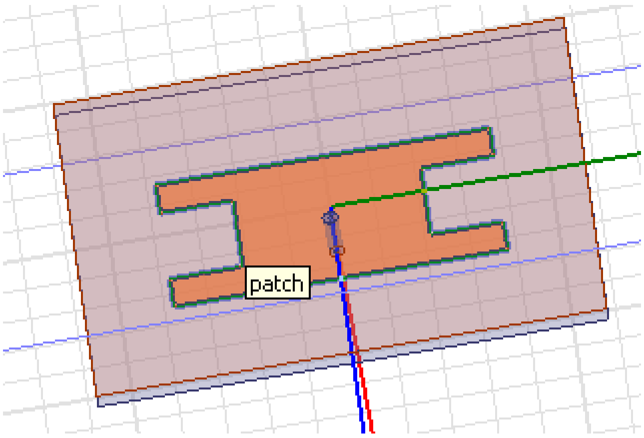


Figure 9: Created model in Ansoft HFSS

9.2 Return Loss

The Return Loss is a parameter which indicates the amount of power that is “lost” to the load and does not return as a reflection. As explained in the preceding section, waves are reflected leading to the formation of standing waves, when the transmitter and antenna impedance do not match. Hence the RL is a parameter similar to the VSWR to indicate how well the matching between the transmitter and antenna has taken place.

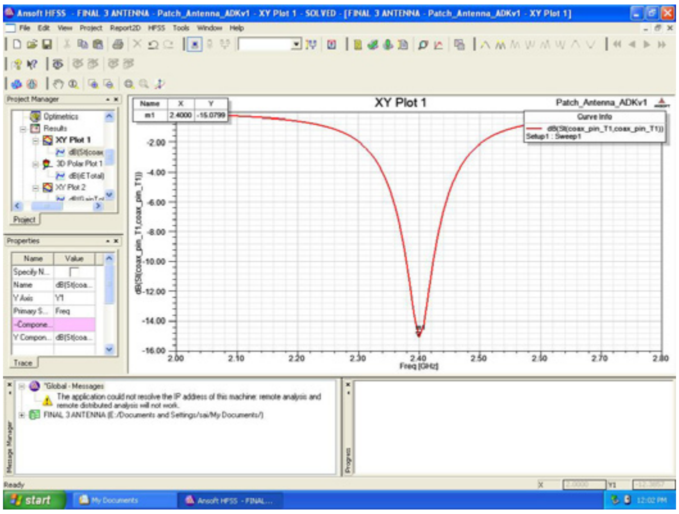


Figure 10: return loss curve for 2.4 GHZ antenna

9.3 VSWR

The VSWR is basically a measure of the impedance mismatch between the transmitter and the antenna. The higher the VSWR, the greater is the mismatch. The minimum VSWR which corresponds to a perfect match is unity. A practical antenna design should have an input impedance of either 50Ω or 75Ω since most radio equipment is built for this impedance. Practically its value should be </2

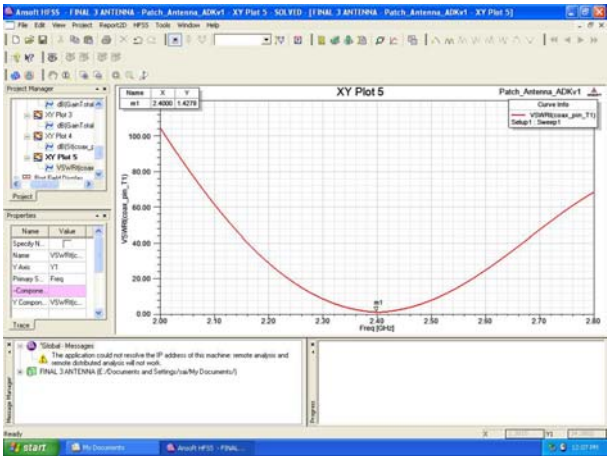


Figure 11: VSWR curve for 2.4 GHZ antenna

9.4 3D Radiation pattern

The radiation pattern is the representation of radiation properties of antenna in a spatial coordinates.

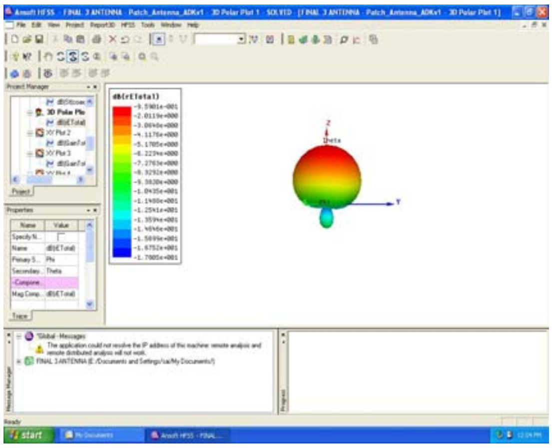


Figure 12: Radiation pattern for 2.4 GHZ antenna

9.5 Gain

Antenna gain is a parameter which is closely related to the directivity of the antenna. We know that the directivity is how much an antenna concentrates energy in one direction in preference to radiation in other directions. Hence, if the antenna is 100% efficient, then the directivity would be equal to the antenna gain and the antenna would be an isotropic radiator. Since all antennas will radiate more in some direction that in others, therefore the gain is the amount of power that can be achieved in one direction at the expense of the power lost

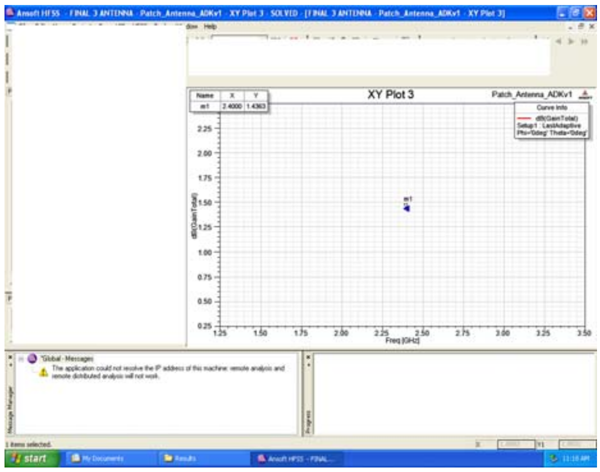


Figure 13: Gain of 2.4 GHZ antenna

9.6 Field overlays

9.6.1 H field overlays

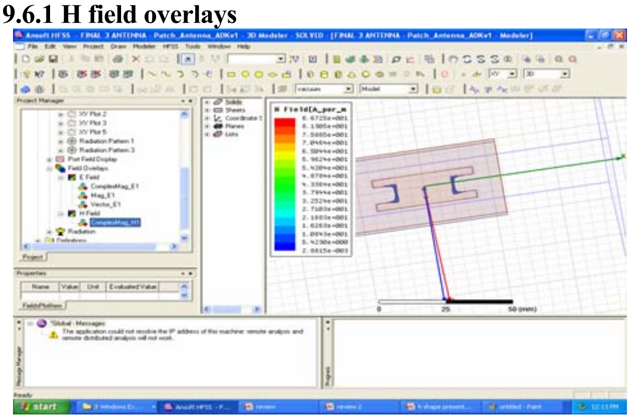


Figure 13: H field overlays of 2.4 GHZ antenna

9.6.2 E field overlays

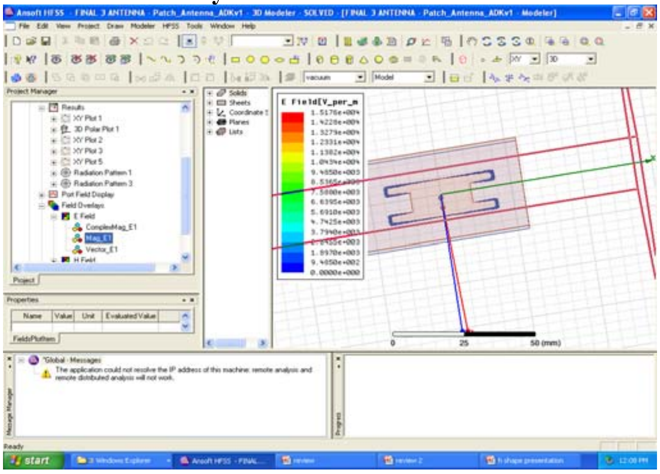


Figure 13: E field overlays of 2.4 GHZ antenna

10. Antenna Parameter Obtained Values

Table 3: parameters obtained values

Parameter	*Obtained value*
Bandwidth	2.4 GHZ
Return loss	-15.0799
VSWR	1.4278
Gain	1.4365

11. Conclusion

2.4 GHZ H shaped microstrip patching h antenna is designed successfully using ansoft HFSS v.13. Simulation results are also obtained.

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