Electromagnetically Coupled Right Hand Circularly Polarized Active Microstrip Patch Antenna for GPS Reception

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Abstract- Designing and fabricating an electromagnetically coupled active Microstrip patch antenna, by utilizing available GPS technology to trace the path of a satellite and verify accurately if the satellite orbits along the defined path. A lot of equations were used for designing the antenna using all the parameters we had. Once all the required values were calculated, we used this to design the antenna using the software Ansoft Ensemble (and Ansys HFSS). Once the antennas were fed into the software, we started the simulation process and tried to optimize the antenna parameters. Using post process, we found the center frequency, gain, bandwidth, cross polarization, beam width coverage of the antenna and all the values were much more accurate than the expected values. Hence, the software simulation was very efficient. In the hardware implementation, the fabricated antenna was tested in an anechoic chamber and results were collected. When the results of the hardware simulation were compared with the software simulation results, both the values were matching. Thus, we say that the project worked according to what we had foreseen. The figure below represents the basic model of the GPS patch antenna.

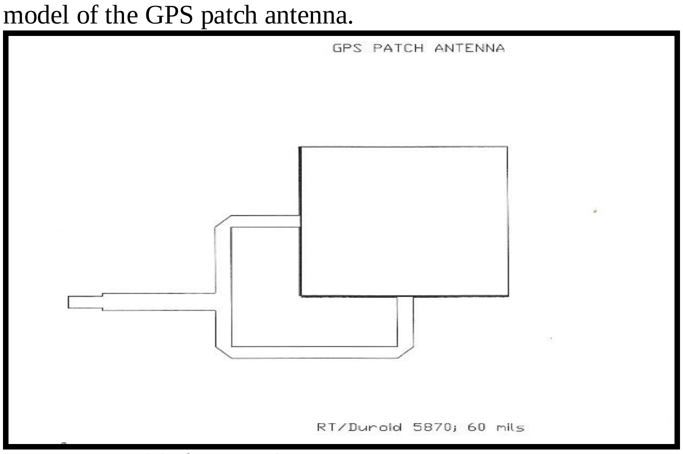

Fig.1: Basic Model of GPS patch antenna

Keywords- *GPS (Global Positioning System), Microstrip patch antenna, Ansoft Ensemble, Polarization, Electromagnetic Coupling, Anechoic Chamber, LNA (Low Noise Amplifier).*

I. INTRODUCTION

An antenna (or aerial) is an electrical device which converts electric power into radio waves, and vice versa. It is usually used with a radio transmitter or radio receiver. In transmission, a radio transmitter supplies an electric current oscillating at radio frequency (i.e. a high frequency alternating current (AC)) to the antenna's terminals, and the antenna radiates the energy from the current as electromagnetic waves (radio waves). In reception, an antenna intercepts some of the power of an electromagnetic wave in order to produce a tiny voltage at its terminals that is applied to a receiver to be amplified. A patch antenna (also known as a rectangular microstrip antenna) is a type of radio antenna with a low 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 a ground plane. The assembly is usually contained inside a plastic radome, which protects the antenna structure from damage. Patch antennas are simple to fabricate and easy to modify and customize. The patch antenna was designed on a dielectric substrate called RT Duroid 5870 with copper as the base material. The microstrip patch antenna was also made of copper and was designed for right hand circular polarization. The antenna was designed for a central frequency of 1.575GHz and using design equations the antenna dimensions were estimated. The software simulation was done using software called Ansoft Ensemble and the Anechoic Chamber was used for hardware implementation. The paper is concluded in section V.

II. SPECIFICATION OF THE ANTENNA

Center Frequency - 1.575GHz
Bandwidth - +/- 10GHz
Polarization - Right Hand Circular Polarization
Gain - 5dBi
Radiation Coverage – Hemispherical
Return Loss - -15dB
Cross Polarization Ratio - min 15dB
RF Interface - SMA

III. DESIGN EQUATIONS

1. $L = 0.49\lambda d = 0.49\lambda/\sqrt{\epsilon r}$

2. $Zo' = \sqrt{Za.Zo}$

3. $\in rre = ((\epsilon r+1)/2)+((\epsilon r-1)/2)(1/(1+12h/l)1^{0.5})$

4. $\Delta L=0.412H((\epsilon r+0.3)((w/h)+.262))/((\epsilon re-0.258)((w/h)+0.313))$

5. $Z_o = 120\pi / (\sqrt{\epsilon_{re}}(w/d + 1.393 + 0.667\ln(w/d + 1.444))$

IV. SOFTWARE IMPLEMENTATION

Ansoft Ensemble 7.0 is very similar to Ansoft HFSS, instead of simulating 3D structure in HFSS; Ensemble is focus on planar structure.Engineers can simulate problems in minutes and develop complete product prototypes on the computer in a matter of hours rather than entering into a lengthy and expensive series of design-build-and-test cycles.

A. Single Feed Power Divider

Power dividers (also power splitters and, when used in reverse, power combiners) and directional couplers are passive devices used in the field of radio technology. They couple a defined amount of the electromagnetic power in a transmission line to a port enabling the signal to be used in another circuit. An essential feature of directional couplers is that they only couple power flowing in one direction. Power entering the output port is coupled to the isolated port but not to the coupled port**.** The conventional patch antennas usually have a dual power feed but what is used here is a single power feed line which is more efficient in terms of power losses and hence gives a much better result.The figure below is a screenshot of the single feed power divider used.

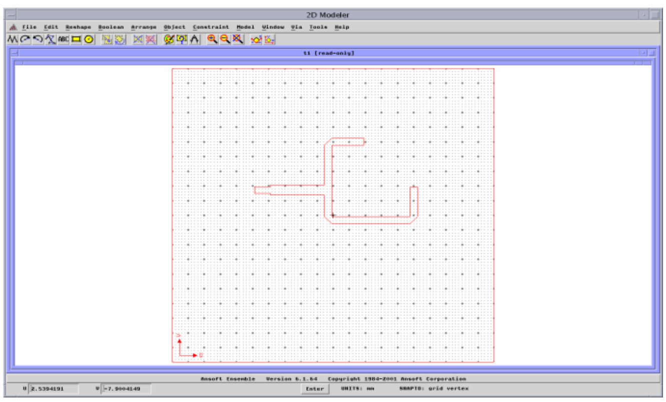

Fig.2: Single feed power divider used

B. Patch Antenna with Single Feed Line

The dimensions calculated from the design equations are used to draw the patch antenna and couple it with the power feeder line. The input given at the power feeder line is transferred to the patch by electromagnetic coupling. The power feeder line is electromagnetically coupled to the patch through a rectangular structure whose length is the same as the patch with thickness being 0.3mm which is placed at a distance of 0.3mm from the patch. Electromagnetic coupling is a process of transferring modulated data or energy from one system component to another, by means of an electromagnetic field. It is often referred to as inductive coupling because the process occurs due to electrical inductance, where a transferring of electromagnetic properties from one location to another occurs without physical contact taking place. The figure below is a screenshot of the 2D view of the complete microstrip patch antenna model.

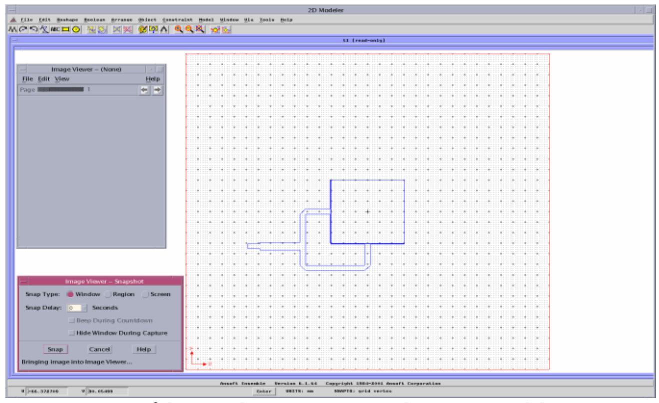

Fig.3: 2D view of the complete microstrip patch antenna model

The figure below is the 3D view of the complete microstrip patch antenna model.

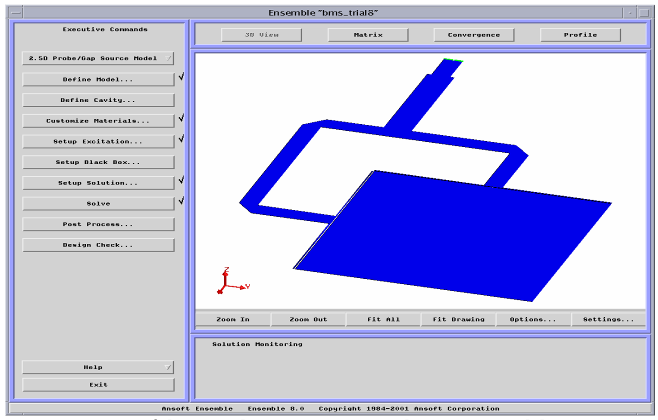

Fig.4: 3D view of the complete microstrip patch antenna model

C. Antenna Measurements

Antenna measurement techniques refer to the testing of antennas to ensure that the antenna meets specifications or simply to characterize it. Typical parameters of antennas are gain, radiation pattern, beamwidth, polarization, and impedance.

(a) Frequency Plot

The figure below shows that the center frequency after software simulation is 1.575GHz.

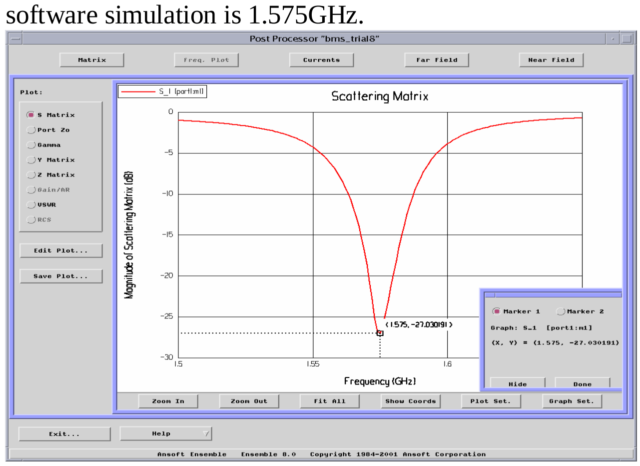

Fig.5: Center frequency after software simulation

(b) Bandwidth

Two markers are placed on the 10dB line and the difference between these points gives the bandwidth. The range of frequencies within which the performance of the antenna, with respect to some characteristic, conforms to a specified standard is called the bandwidth. In other words, bandwidth depends on the overall effectiveness of the antenna through a range of frequencies, so all of these parameters must be understood to fully characterize the bandwidth capabilities of an antenna. The figure below shows the measured bandwidth value.

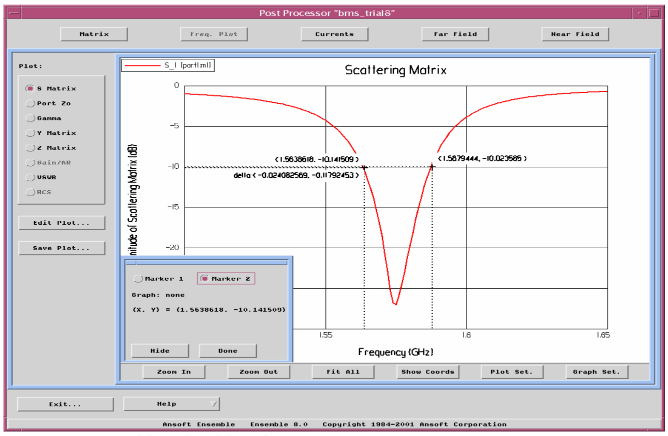

Fig.6: Measured bandwidth value

(c) Gain

Gain measures the directionality of a given antenna. An antenna with a low gain emits radiation in all directions equally, whereas a high-gain antenna will preferentially radiate in particular directions. Specifically, the Gain or Power gain of an antenna is defined as the ratio of the intensity (power per unit surface) radiated by the antenna in a given direction at an arbitrary distance divided by the intensity radiated at the same distance by an hypothetical isotropic antenna. The figure below depicts the gain measured.

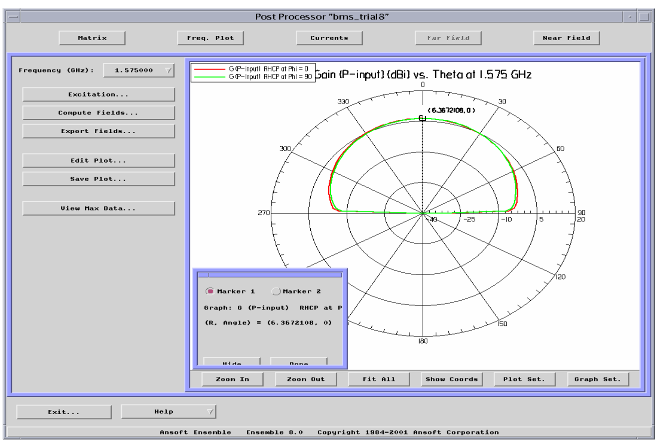

Fig.7: Gain Measured

(c) Cross Polarization

Two markers are placed, one at RHCP maximum, and the other at LHCP maximum. The difference between the two gives the Cross Polarization value. The figure below shows the measured cross polarization value.

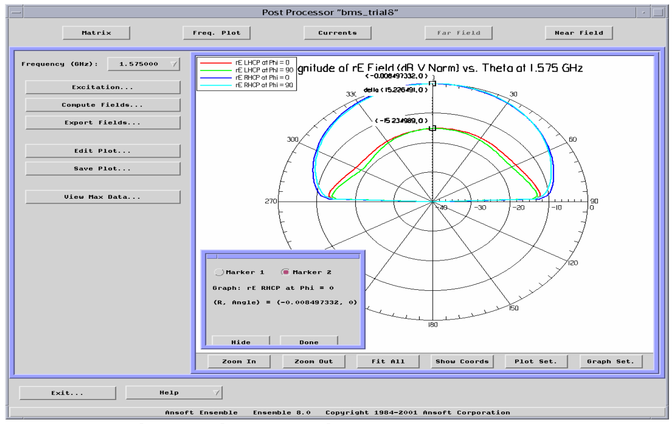

Fig.8: Measured cross polarization value

(d) Beamwidth Coverage

To measure the beamwidth coverage, one marker is placed at the maxima of RHCP and the other is placed at around 80 - 85 degrees. The difference between the two markers determines the beamwidth coverage. The figure below depicts the beamwidth coverage after simulation.

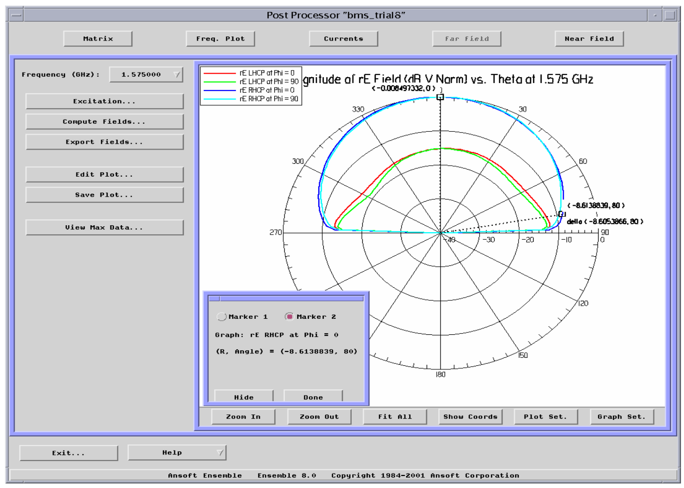

Fig.9: Beamwidth coverage after simulation

V. HARDWARE IMPLEMENTATION

A. Anechoic Chamber

An anechoic chamber (an-echoic meaning non-reflective, non-echoing or echo-free) is a room designed to completely absorb reflections of either sound or electromagnetic waves. They are also insulated from exterior sources of noise. The combination of both aspects means they simulate a quiet open-space of infinite dimension, which is useful when exterior influences would otherwise give false results. The figure below represents the block diagram of the chamber.

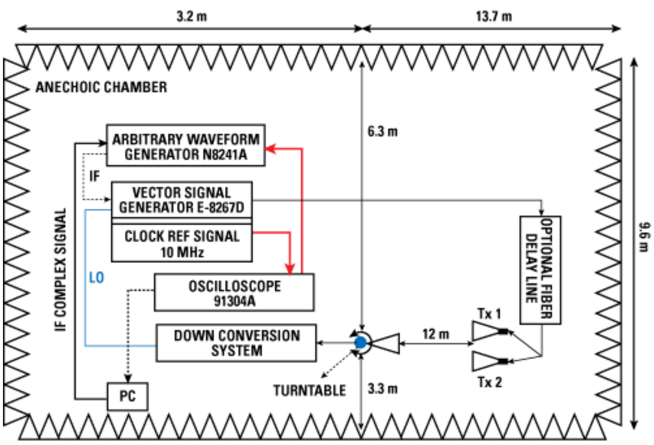

Fig.10: Block diagram of the chamber

B. *Implementation Results*

The hardware implementation in the chamber was done in the following way. There were present two antennas, one for transmission and one for reception, placed at opposite ends of the room. The antenna used for reception was the patch antenna designed, and the transmitting antenna could be of two variations, RCP or LCP. The screenshot below depicts the information captured by the patch antenna, moving through an angle of -120 to +120 degrees, while the RCP or LCP starts transmitting.

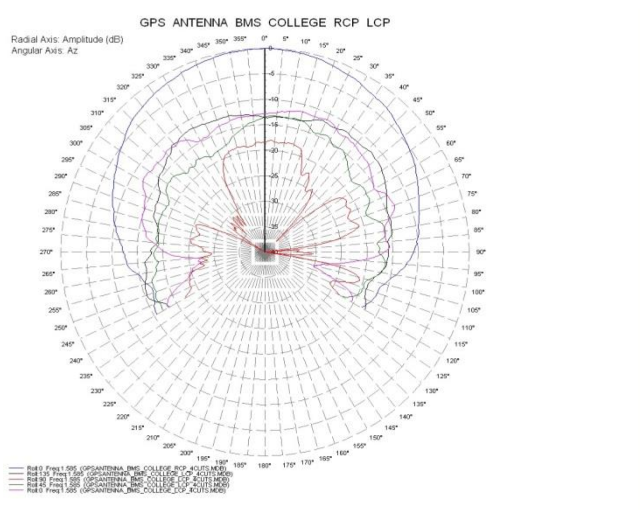

Fig.11: Information captured by the patch antenna

The screenshot below shows CUT 0 for both LCP and RCP transmitting antennas. The RCP CUT is well defined compared to the distorted CUT 0 of LCP. This is because the patch antenna is designed for Right Hand Circular Polarization.

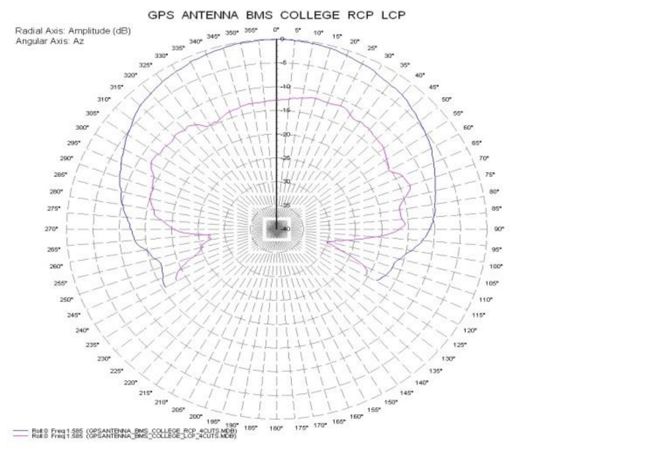

Fig.12: CUT 0 for both LCP and RCP transmitting antennas.

VI. Results

The final results after combining the patch antenna with the quarter wave transformer and the single feed line are as follows

- Return Loss = - 27dB against - 15dB
- Bandwidth = 24MHz against 10MHz
- Far Field Cross Polarization = 15.2dB against 15dB
- Gain = 6.36dBi against 4 or 5 dBi
- Beam Width or Coverage = - 8.6 dB against - 10dB

VII. Conclusion

The Microstrip patch Antenna for GPS reception was designed using software called Ansoft. The designing and optimization of the antenna parameters were done using Ansoft. Certain specifications were set and the antenna was tested to see if it is meeting the required specification. This marked the end of the software simulation. The antennas were fabricated and the hardware implementation of the antenna was carried out in the anechoic chamber. Since both the hardware and software implementation results matched, we could say that the antenna was perfectly designed. This antenna is used for tracking the path of a satellite, orbiting the earth. The major use of this antenna is to check whether the satellite is following the pre-defined path. This antenna can be designed for a different central frequency and can be used for higher level applications in the space industry.

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