Antenna Gain Determination using a Microwave CAD Tool – HFSS

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Abstract – **Antennas have been increasingly studied in recent years. Different antennas have been designed for different applications based on the characteristics of the receiving side. Antennas cannot be fabricated as such and then be studied on. This leads to waste of material and requires a lot of iterations until we get the final design. In order to study the characteristics of an antenna without fabricating it, we need a special tool called a "SIMULATOR TOOL". It can determine all possible characteristics of an antenna under test. In this paper we'll be simulate few of the antennas using HFSS simulator tool.**

Index Terms -- **Antenna, Coplanar, Gain, Microstrip, Simulation.**

I. INTRODUCTION

A. Fabrication and Design

The process of fabricating a real antenna is very tedious and should be done with extreme care. The fabricated antenna should have the exact dimensions and design values. The return loss of the fabricated antenna can vary provided it lies within the allowable limit but there should not be any compromise on the operating frequency.

In HFSS, a substrate of the desired qualities is taken. Each substrate will vary in effective permittivity, tangent loss and other parameters which determine the characteristics of antenna.

Once the substrate is chosen we have to draw the design of the antenna on it using different tools available. This process is similar to lithography. There are few antennas which cannot be designed using a single substrate but require more than two materials. In these cases the two or more entities can be designed separately and then be combined together into a single entity. Any number of entities can be combined together.

B. Excitation and Boundary Conditions

An airbox has to be defined in to model open space so that the radiation from the structure is absorbed and not reflected back. The airbox should be a quarter-wavelength long of the frequency of interest in the direction of the radiated field. Any antenna under test (AUT) will have well-defined field regions. In general, almost all antennas under test will have an environment comprising of both E and H fields. Finite conductivity boundary using proper material as assigned to the bottom faces and patch area.

Antennas are designed for specific applications. Ideally, an antenna is designed to have the effect on the region extending up to infinity. There are antennas whose active region is a sphere of very small radius. There are few antennas with active region greater than this sphere. These cases can be chosen accordingly.

Once designed, the antenna must be provided with a feed, usually a RF wave. Microstrip antennas require the feed to be directly connected to it. In the directions where the radiation is minimal, this quarter-wavelength condition does not have to be met and an air "space" may not even have to be defined. This is the case of the wave port excitation. The better the match, the better is the antenna performance. The match may be obtained with the use of a quarter wave transformer, gamma match, delta match etc., depending on which suits the system best.

C. Simulation

After the design of the antenna is done (feed and excitation inclusive), the antenna should be 'validated' in HFSS. This step notifies the user of errors in design, if any. Next, the antenna is analyzed on the fronts of various parameters as given by the user. Thereafter, the results of the analysis are obtained. The simulation results may be in the form of 2D or 3D plots or simply numerical values. Based on the antenna and its characterization, the required type of result is sought. Manually meshing should be performed to get accurate results for the antenna properties such as efficiency, directivity, and radiation pattern. It also allows us to plot various parameters in a single graph. For example if both gain and return loss is to be computed over a particular range of frequency, HFSS does it in a single graph.

II. SIMULATED ANTENNAS

A. CPW Fed Bowtie Antenna

This antenna is fed using a co-planar waveguide through lumped port. It uses Arlon Cuclad as a substrate. This uses a lumped port; hence there will be physical contact between both the antenna and the fed line. The resistance of the antenna in this case is 50Ω and justifying our choice of a 50Ω fed line to have perfect match.

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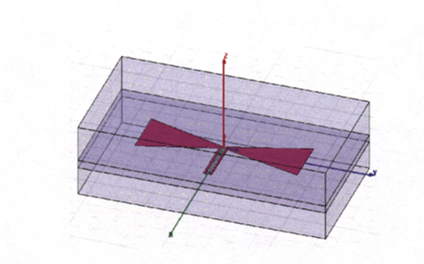

Fig. 1. Structure of CPW fed Bowtie Antenna

The frequency, over which the analysis was done, ranged from 8-12 GHz and from the simulated results it was found out that the functioning of the antenna was best at 10.44 GHz.

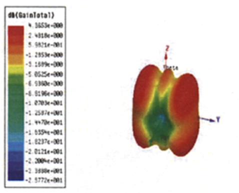

Fig. 2. 3-D Plot of Gain

Fig. 3. Graph of Directivity versus 2-D angle

B. Microstrip Patch Antenna

The microstrip patch antenna is a resonant antenna for narrow-band microwave wireless links that require semi-hemispherical coverage. Due to its planar configuration and ease of integration with microstrip technology, the microstrip patch antenna has been heavily studied and is often used as elements for an array. We illustrate here a 2.4 GHz microstrip patch antenna fed by a microstrip line on a 2.2 permittivity substrate.

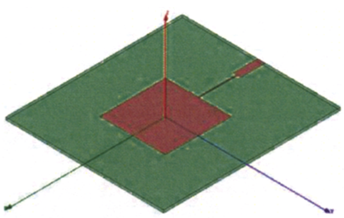

Fig. 4. Structure of Microstrip Patch Antenna

Design Data

Height of the substrate = 1.57 mm
Feedline width = 4.84 mm
Waveport size = 5 * 50 mm^2
Height of the airbox = 31.25 mm
Design Frequency = 2.4 GHz

In order to excite the structure an excitation source has to be chosen. The waveport will excite the first mode of the microstrip line and then HFSS will use this field to excite the entire structure. After the waveport rectangle is drawn, the waveport excitation was assigned to it.

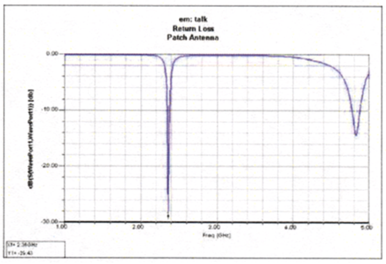

Fig. 5. Return loss (dB) vs. frequency

C. CPA fed at Non-Radiating Edges

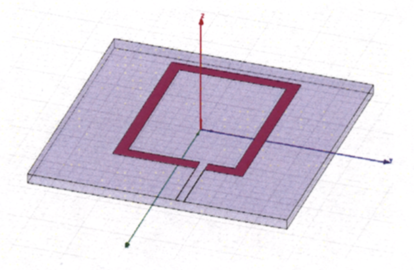

Fig. 6. Structure of the Coplanar Patch Antenna

The design of CPA is obtained by choosing L of the non-radiating edges to be $\lambda_g/2$ at the required operating frequency, where λ_g is the guide wavelength of the CPW resonant line. The antenna was designed on a 30-mil thick RT/Duroid 6002 substrate (ε_r = 2.94) with ¼ ounce copper cladding.

The patch width W and slot width S were chosen to be 30mm and 2.2mm, respectively. The dimension of a 50Ω CPW feed line were calculated to be g=0.1mm and w=1.642mm. The various physical parameters of the CPA along with its structure are shown below.

Design Data

Length of the patch (L) = 21 mm
Width of the patch (W) = 30 mm
Slot width of the patch (s) = 2.2 mm
Feed width (g) = 0.1 mm
Gap between the feds (w) = 1.642 mm
Relative permittivity (ε_r) = 2.94

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The designed CPA would resonate at a frequency slightly lower than 4 GHz due to fringing field effects at the radiating edges.

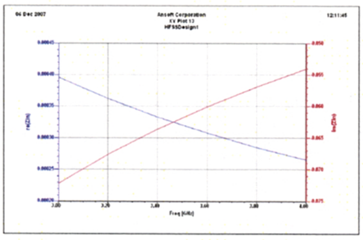

Fig. 7. Impedance vs. Frequency

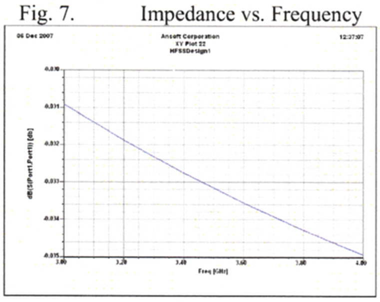

Fig. 8. Return loss vs. Frequency

D. UHF Probe

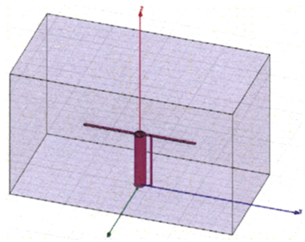

Fig. 9. Structure of Ultra High Frequency Probe

The Fig. 9 shows a ultra high frequency probe. This employs the excitation through wave port as the feed is external to the antenna. The antenna is made of copper.

<u>Design Data</u>

Design Frequency = 0.55 GHz
Inner radius of ring1 = 0.31mm
Outer radius of ring1 = 0.37mm
Inner radius of ring2 = 0.435mm
Outer radius of ring2 = 0.5mm
Height of probe : = 5mm
Length of left arm = 4.69 mm
Length of right arm = 5 mm
Width of left arm = 0.2 mm
Width of right arm = 0.2 mm
Height of left arm = 0.065 mm
Height of right arm = 0.065 mm

The simulation is done on a far field region which is considered as a sphere of infinite radius. The graph below shows the gain versus angle from which we can infer that the gain and directivity is maximum along the axis of the probe along the z-axis.

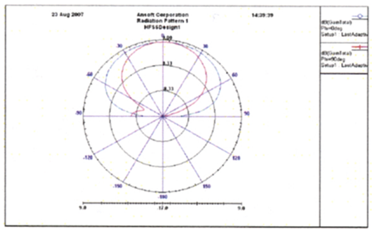

Fig. 10. Gain (dB) vs. 2D angle (deg)

The graph below shows return loss in terms of scattering parameters versus frequency. From the graph it can be clearly seen that the return loss is minimum at the designed frequency of 0.55GHz. Any value less than -10 dB is an acceptable value at the range of designed frequency. The return loss obtained for the above mentioned design value is -32 dB which lies well above the acceptable limit.

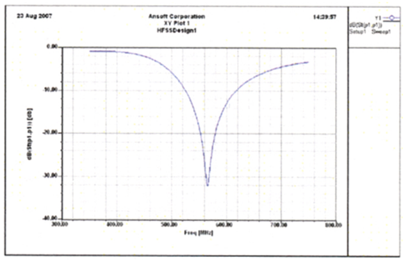

Fig. 11. Return Loss (dB) vs. Frequency (GHz)

III. CONCLUSION

The use of HFSS as a simulator tool has been studied through the simulation of CPW Bowtie, Microstrip, Coplanar Patch Antennas and the associated plots for Return Loss, Gain, Directivity amongst other common parameters used to describe antennas.

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