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DESIGN OF A 24GHz RECTANGULAR MICROSTRIP PATCH ANTENNA USING HFSS

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ABSTRACT

Advancements are being made in the field of asatellite communication every day. Traditional frequency bands that are used for satellite communication are S-band and Ku-band. This leads to congestion in these bands. Hence, nowadays more importance is given to designing analog devices at higher frequency bands. Antennas are the most essential component in a satellite, if not the most important. They are responsible for receiving and transmitting signals at different frequencies. Needless to say, a lot of thought needs to be given to the design of antennas. This paper presents a design for a 24GHz antenna. The design consists of a rectangular microstrip patch on a RT/Duroid 5880 substrate using stripline feeding.

KEYWORDS: Antenna, Length, dielectric, width, patch, HFSS, radiation.

1. INTRODUCTION

Antennas are devices that receive or transmit RF signals and also convert these signals to electrical signals so that analog or digital devices can process these signals. HFSS software is used for designing and simulating antenna for the aforementioned transponder. Microstrip antennas can be used in applications where cost, size, performance and ease of design are needed. [1] This thesis work also presents a microstrip patch antenna for Ka-band, receiving at 24GHz and transmitting at 18GHz. Microstrip antennas are extremely popular in wireless applications because of their small size and simple structure. They are used for telemetry in missiles and have huge applications in

Satellite communication. They are compact, lightweight and less expensive than its other counterparts. However, they do suffer from narrow bandwidth, low power handling and lesser efficiency. [1] The trade-offs are always there but the design options are chosen in such a way that if trade-offs can be tolerated then it is fine to go with a particular design.

In this type of antenna a small patch is made on a dielectric substrate which is the base of the antenna. The patch is made from an electrical conductor and can have any shape, usually rectangular is chosen. This patch now needs a feed and there are many kinds of feeding techniques available e.g. coaxial feed, strip line feed, aperture coupled feed etc.[1]

2. LITERATURE REVIEW

Antennas can be of different types i.e. probe-feed antenna, co-axial antenna, patch antennas etc. This project makes use of a microstrip patch antenna for satellite applications.

Deng Qun et al have presented a design for a 2.4GHz patch antenna with a rectangular patch. The length and width of the substrate and antenna were calculated by using the proper equations and the antenna was designed using the software HFSS.[5] Another design at 2.4GHz is presented by Ogunlade Michael Adegoke for Wireless LAN networks microstrip line is used and FR4 epoxy dielectric is chosen as substrate. Return loss is measured to be around -29dB and VSWR ratio is 1:2. Bandwidth achieved was optimum for WLAN applications.

Muhammad Saqib Rabbani provided improvements to a 60GHz and X band microstrip patch antenna design for wireless applications. Dielectric for the substrate was chosen as RT/Duroid 5880.[6] A Ka-band micromachinedmicrostrip antenna was designed by V.K.Singh to provide a superior performance than other conventional antennas. The design showed a return loss better than -23dB.[4] Mark S. Reese et al proposed design for stacked microstrip patch antenna. It was designed to provide applications in wide band impedance matching. Operating frequency ranges between 1.5 – 1.7GHz. After making sufficient changes proposed design can also work at S-band and L-band. The basic idea is to choose a frequency range for operation. Choice of frequency helps in determining the type of dielectric for the substrate. Designing of patch and substrate by calculating the length and width and other dimensions are taken up in the following sections.

3. DESIGN PROCEDURE

Just like the other components, antennas also have a set of defined parameters that define its performance. They are:

- Bandwidth

- Radiation pattern
- Gain
- Return loss
- VSWR (Voltage Signal Wave Ratio)

The antenna needs to be defined keeping in mind that these are the parameters that need to be optimized. Firstly, desired frequency of operation is chosen post which a good dielectric substrate is chosen such that it matches the frequency selected.[5] Next step is to determine the size of the antenna. For this purpose length and width of the antenna patch and substrate needs to be calculated. Input impedance depends on the width of the antenna. It is given as;

$$W = \frac{c}{2f_r}\left(\frac{\epsilon_r}{2}\right)^{-1/2} \qquad (1)$$

Where, C is speed of light, f_r is resonant frequency and ϵ_r is the dielectric constant.

To calculate the length we use the formula;

$$L_{eff} = \frac{c}{2f\sqrt{\epsilon_{eff}}} \qquad (2)$$

Or

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

The effective dielectric constant ϵ_{eff} is given as;

$$\epsilon_{eff} = \frac{\epsilon_r+1}{2}\frac{\epsilon_r-1}{2}\left(\frac{1}{\sqrt{1+\left(\frac{12h}{W}\right)}}\right) \qquad (4)$$

Where h is the height of substrate and W is the width.

The difference in length is given by;

$$\Delta L = 0.412h\frac{(\epsilon_e+0.3)}{(\epsilon_e-0.258)}\frac{(w/h+0.264)}{(w/h+0.8)} \qquad (5)$$

By substituting these values, we get the dimensions of the antenna and now we can design it on ADS or HFSS software tools. The design starts with defining a ground plane and then building the substrate over it. The dielectric material chosen for this thesis is RT/Duroid 5880 with a substrate thickness of 0.254mm. On the substrate we have to model the rectangular patch by calculating the dimensions using above equations. Stripline feeding is used as the electrical field is strongest at the centre of the patch and stripline is modeled closer to the centre of the patch. After designing the antenna, now simulations are done to observe working of the devices.

4. SIMULATION RESULTS

After successfully designing the antenna and validating the design using software tools, next step is to set up a simulation of the design. A bandwidth is selected to observe the behavior of the antenna. The patch almost works like a resonant cavity. Exciting antenna at resonant frequency induces current at the centre of the patch which in turn produces radiations. Below is a top and lateral view of the antenna;

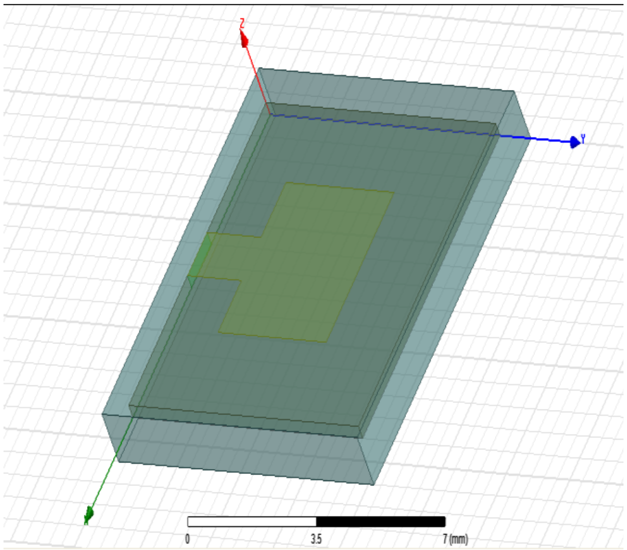

Figure 1:Designed antenna

The design consists of a ground plane over which a substrate is formed. Entire design is enclosed by an air box which serves as the radiation boundary. The yellow rectangle shows the patch on the substrate made from a perfect electric conductor. Patch is connected to a port through a stripline made from the same material used for patch.

Following figure shows the port (light green) and lateral view of the design. Port is taken as a waveport and substrate and patch are given perfect E boundaries.

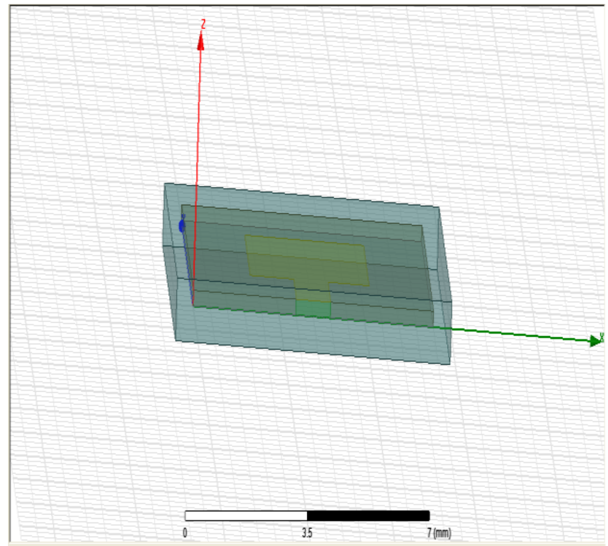

Figure 2

Following waveforms show the simulated results of the antenna.

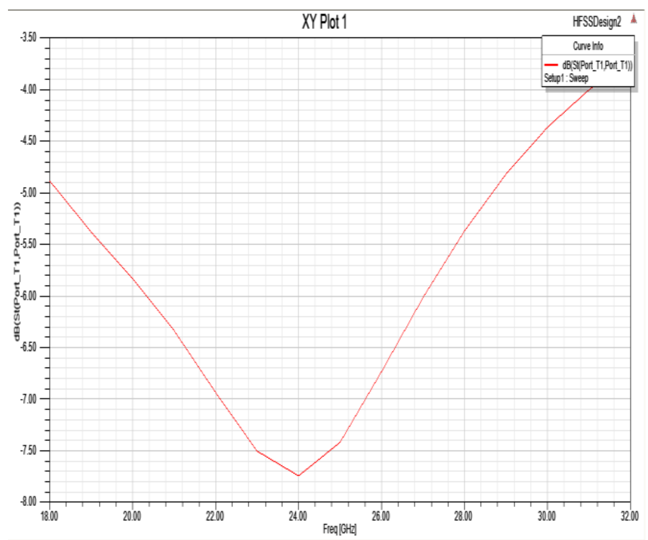

Figure 3:S

Figure 3 and 4 show the S_{11} and VSWR plots. They both follow almost the same pattern and converging at 24GHz which is the desired frequency.

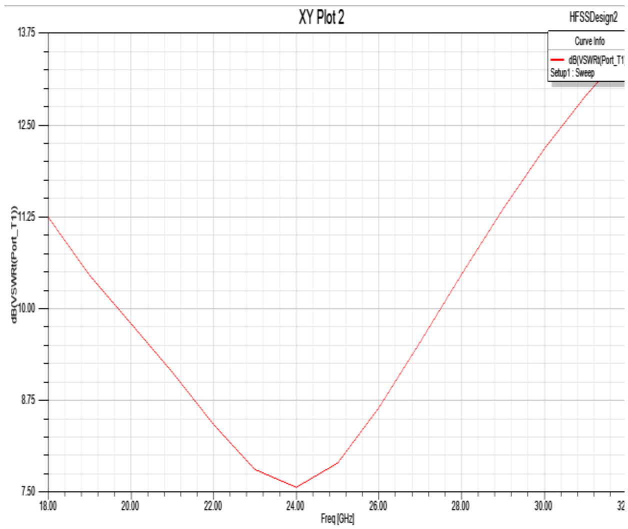

Figure 4:VSWR

For an antenna, far field analysis is also very important. It is done to observe the radiation pattern and polar plot of the antenna. By observing them we can get an idea about how strong the radiation is in different directions and also observes its polar behavior.

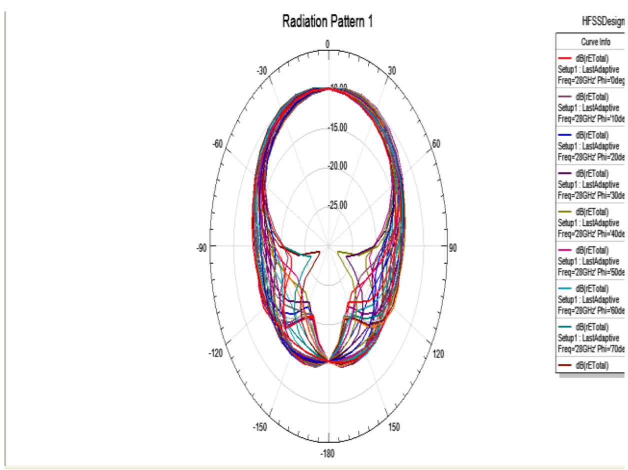

Figure 5: Radiation Pattern

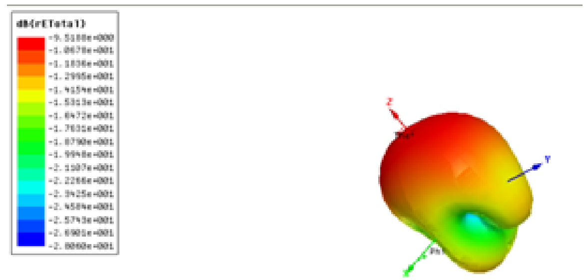

Figure 6:Polar Plot

5. CONCLUSION

This paper presents a design of a 24GHz rectangular microstrip patch antenna with stripline feeding. Patch is made on a dielectric substrate; RT/Duroid 5880 with a thickness of 0.254mm and a relative permittivity of 2.2. This dielectric is best suited for higher frequency operations. Length and width of the patch are calculated as 3.466mm and 4.232mm respectively. Loss tangent for the dielectric is 0.0009. Minimum value of S_{11} is -7.75dB at 24GHz. At the same frequency VSWR is 7.55dB. Polar plot shows the formations of dipoles that are present during radiation and a good radiation is also observed. This designed antenna can also be used in satellite transponders operating at higher frequency bands.

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