*King Fahad University of Petroleum and Minerals*

*Electrical Engineering*

**EE 407**

**Course Project**

# Triangular Microstrip Antenna

Done By

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# I. **Objective**:

To design, simulate, and fabricate a microwave X band triangular patch Microstrip antenna.

# II. **Theoretical Background:**

Microstrip antennas are used widely in many applications such as radars and satellite communication. Microstrip antennas come in many shapes such as rectangular, circular, and triangular patch antennas. The Microstrip triangular patch antenna is shown in fig.1.

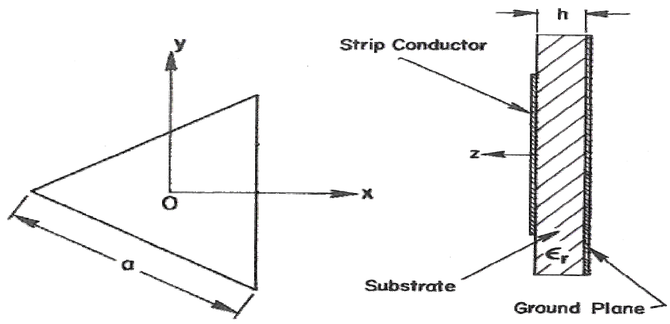


Fig.1 Triangular patch Microstrip antenna

The resonance frequency of this antenna is inversely proportional to the side length of the triangular patch and the square root of the relative permittivity. It also depends on the mode of operation ($T_{MN}$). This is shown in fig.2

$$f_{r,nm} = \left(\frac{2c_o}{3a\sqrt{\varepsilon_{req}}}\right)\sqrt{(n^2 + nm + m^2)},$$

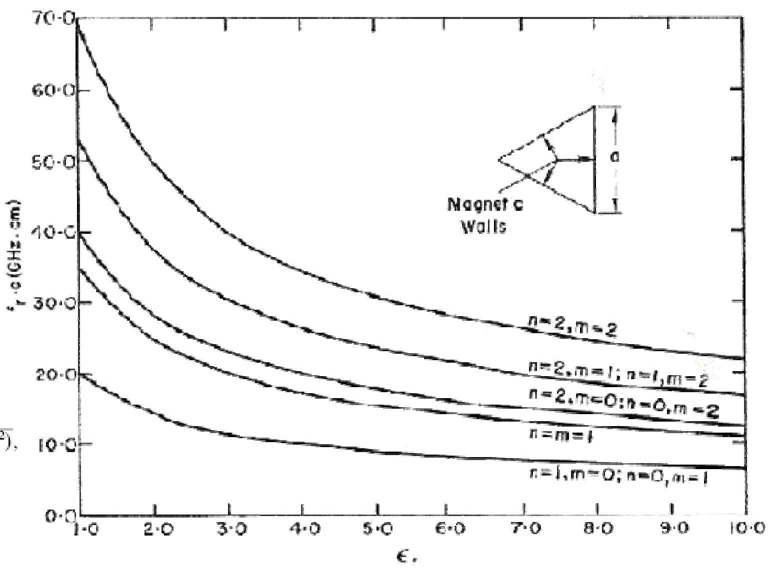


Fig.2: The resonance frequency versus $\varepsilon_r$ for different modes.

In this antenna, the radiated power increases with the resonance frequency. This is illustrated in fig.3. This antenna is more efficient at high frequencies.

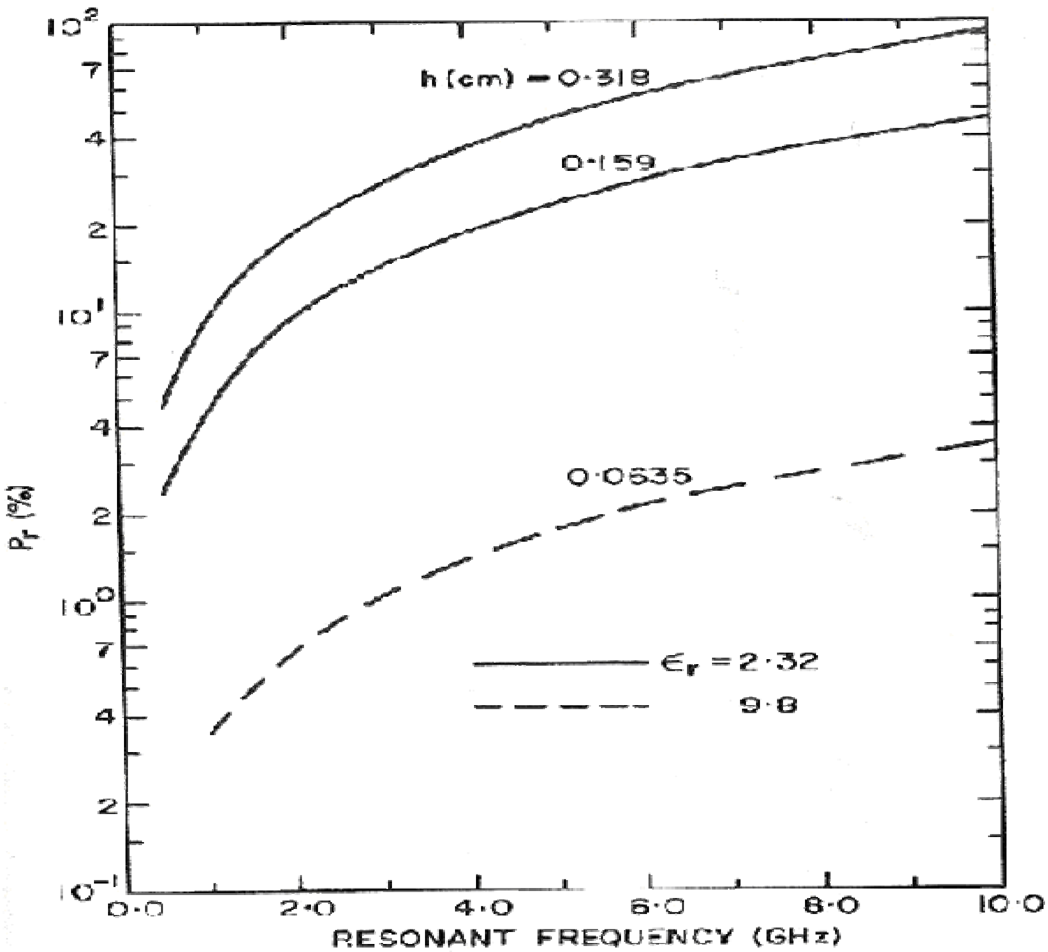

Fig.3: The radiated power versus resonance frequency

## III. Design calculations:

It was found that the resonance frequency is given by:

$$f_{r,nm} = \left( \frac{2c_o}{3a\sqrt{\varepsilon_{req}}} \right) \sqrt{(n^2 + nm + m^2)},$$

where m, n are related to the operating mode
$C_o$: Speed of light
a: side length of the equilateral triangle
We want the simplest case: m = 1 and n = 0 (TM mode)
This simplifies the formula to:

$$f_{r,nm} = \left(\frac{2c_o}{3a\sqrt{\varepsilon_{req}}}\right)$$

The desired resonance frequency of the antenna is 10GHz.
In the lab, the available substrate has a relative permittivity of 2.2. Hence the only messing parameter now is the side length.

By calculation, a = 13 .48 mm

# IV. Simulating Triangular Microstrip Antenna:

*A) Correction in the triangle side length:*

After simulate the antenna in a professional simulator, the resonance frequency was found to be around 8.5 GHz. The problem was corrected by decreasing the side length since ‘f’ and ‘a’ are inversely proportional. It was found that f is around 10 GHz when a = 11.94 mm

*B) Optimize the antenna using Professional Simulator*

After simulating and verifying the design is working, we could move the fabrication process. Giving illustrations on how the design was build in software model in the class will be useful. The design steps are next illustrated.

1. The substrate (See fig.4)

The substrate was build using the "Draw device" properties. The material of the substrate was chosen to be Drude whose relative permittivity is 2.2. The thickness of the substrate was chosen to be 1.6 mm. The side length was chosen to be 75 mm along x and y axis.

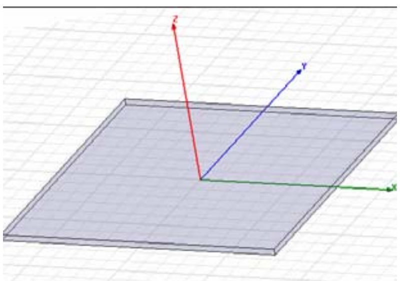

Fig.4: The substrate

2. The triangular patch and the ground plane (See fig.5)

We drew a ground plane and using "Draw Device" property and we assigned it a perfect E boundary. We also drew a cupper triangular patch with thickness (t) = 0.1 mm and side length (a) is 11.94 mm. This is done by first drawing a rectangular patch. Then, the "Minus" property was used to convert the rectangle to triangle ( as will be shown). Finally, the "Frequency Sweep" property was used to change the 2D patch to a 3D patch with very small thickness. The material of the patch was chosen to be cupper.

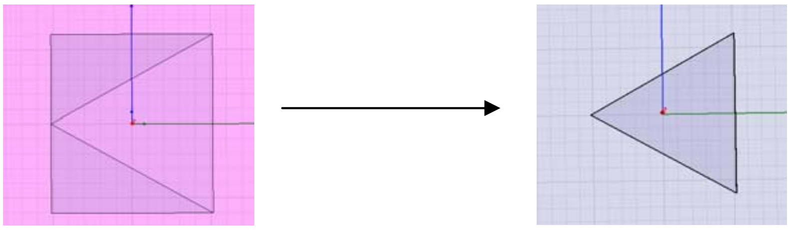

Fig.5: The triangular patch

3. The coaxial feed: (See fig.6)

A small circle is subtracted from the ground plane using "Subtract property. We built the inner cupper conductor of the coaxial cable which penetrates the substrate using "Draw device" property. This conductor touches the patch. We also built the outer conductor which is a very thin cupper cylindrical sheet with a thickness of 1 mm. This conductor touches the ground plane. The medium between the inner and outer conductors is Drude ( relative permittivity = 2.2).

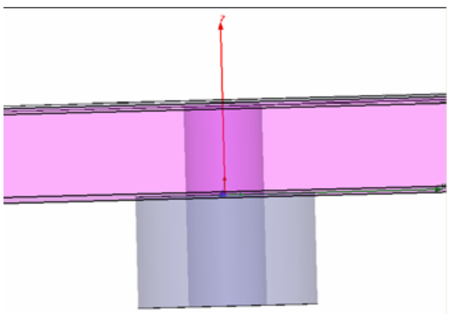

Fig.6: The coaxial feed

4. Final design steps: (See fig.7)

An air box was drawn which completely surrounds the circuits. A radiation boundary was assigned to the surfaces of the air, except at the input of the coaxial cable, where an excitation was applied between the two conductors.

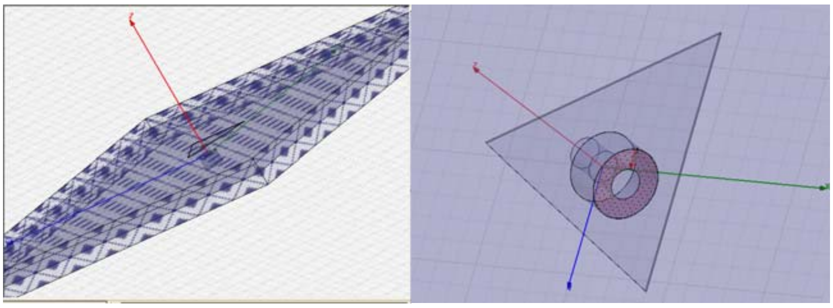

Fig.7: Left: The air box with radiation boundary. Right: The input excitation

*C) Testing the circuit:*

The complete design is shown in fig.8. a frequency sweep analysis was chosen for a frequency range of 2-12 GHz. The software was asked to plot S11 parameter which represents the input reflection coefficient. The result is shown in fig.6. The minimum input reflection coefficient was found to be Minimum S11 = 25.3 dB at 9.87 GHz which is satisfactory. The 3 dB frequencies are roughly 7.5 GHz and 12 GHz. The bandwidth is roughly 4.5 GHz. Since the simulation mode is working successfully, It the time now to move to the fabrication process.

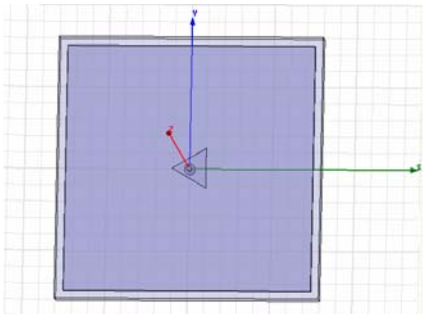

Fig.8: The complete design of the simulation model for the triangular patch antenna

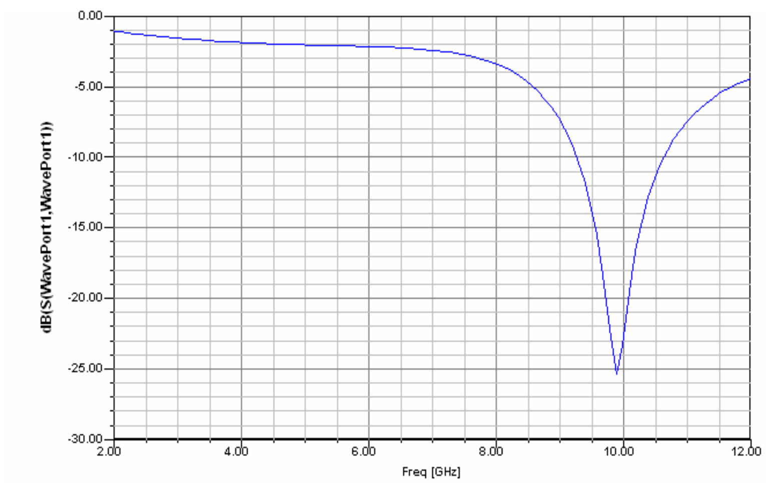

Fig.9: Reflection coefficient versus frequency plot.

# V. Fabricating Triangular Microstrip Antenna:

The antenna was fabricated with same dimensions that were used in the simulation model. The fabrication process is demonstrated as follows:

*A) Preparing the antenna:*

The substrate available in the lab has a height of 1.6 mm and a relative permittivity of 2.2. It is covered cupper on the top and the bottom surface. The two cupper plates were also covered by a tape. To remove the unwanted cupper. The tape should be removed and the substrate should be placed intro a liquid that eats the cupper that’s unprotected by the tape. On the top cupper plate, we drew a triangle with side length = 11.94 mm and we removed the tape from the surrounding area. The triangle was drawn by first drawing a rectangle and then removing the extra parts. On the bottom cupper plate, we removed the tape from a small circle whose diameter is slightly less than the diameter of the input feed coaxial cable. This prevents the inner part of the coaxial cable from touching the ground plane. The circle was drawn at the center of the original rectangle. The process is illustrated in fig.1. After that putting the antenna into the liquid, the liquid ate the cupper around the triangular patch in the cupper inside the feed circle. Finally, the tape was removed from the whole circuit.

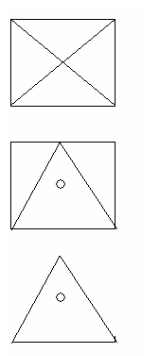

Fig.1: Building the triangular antenna

*B) Connecting the feed-in coaxial pin:*

A whole was made through substrate at the input feed location using a special drill. Then, the coaxial cable pin is inserted through the whole. The circuit and the coaxial pin were soldered together. The soldering process made a dome of silicon on the triangular patch. This unwanted dome was removed by careful grinding. The final circuit is shown in fig.2

Fig.2: Upper left: the antenna. Upper right top view of the triangular patch. Lower left: bottom view of the coaxial feed. Lower right: Side view of the circuit.

*C) Testing the circuit using network analyzer:*

Network analyzer is a useful device in testing microwave antennas by applying an input signal and measuring the reflection coefficient for a range of frequencies. The triangular antenna was tested using network analyzer. The result is shown in fig.3. The resonance frequency was 10.52 GHz where the reflection coefficient was -46.178 dB. The reflection coefficient was about -10 dB in the range of 10.14-10.76 GHz frequencies.

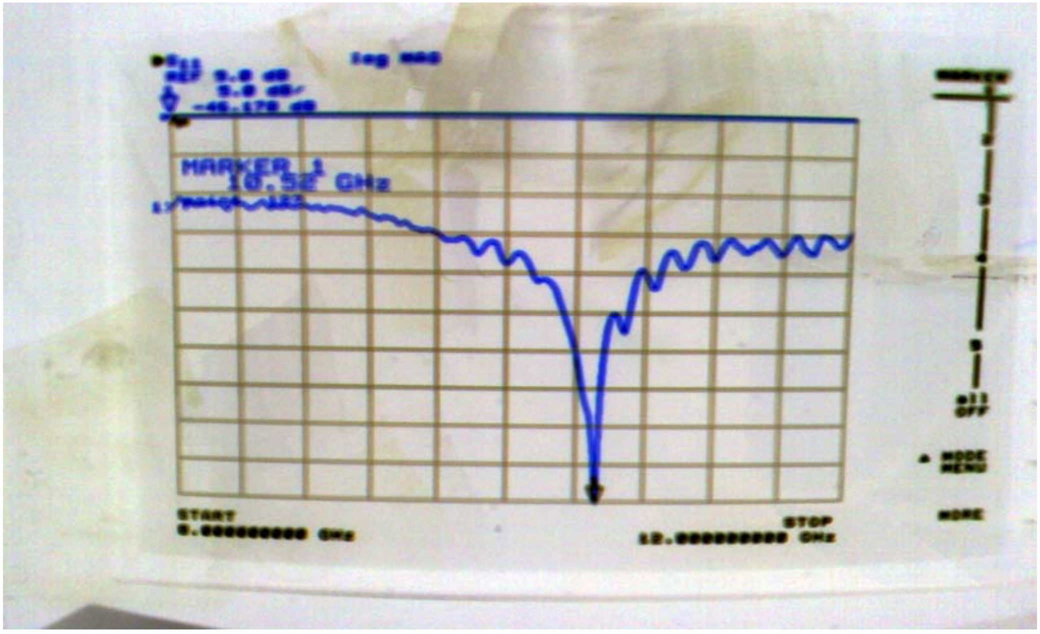

Fig.3: The Network Analyzer test results.

This result shows that the design was successful and the antenna is working at the desired frequency.

## VI. Conclusion:

In this project, an X band triangular patch Microstrip antenna was designed from hand calculation to fabrication. The project consisted of three main part. The first part is hand calculation to find the side length of the antenna. It was found that a side length of 13.48 mm is required for the desired operation characteristics. In the second part, the antenna is built and tested using simulating tool. One of the advantages of using simulator was the realizing that the side length should be corrected to 11.94 mm. The final part is fabricating the antenna. The final product was tested using Network Analyzer by testing the input reflection coefficient. This test has shown that the device performance was excellent.

# References


- Bahl,I.J.,”Microstrip Antennas,”Artech House,1982,PP.140-157.