Design of 2.4 and 5 GHz microstrip patch antennas for WiFi Applications using an EM simulator

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Project Description

Design an Antenna for wifi application at 2GHz and 5Ghz.

Software Used

HFSS 13 : It is a software for Electromagnetic simulation of various designs.

Abstract

The project was based on the designing of an antenna which can be used for wifi applications. Usually wifi network work in 2.4GHz and 5GHz. Designing was done with the help of standard formulas which can be used for determining the dimensions of the patch. We took the substrate as **FR4 EPOXY** .From the equations we had calculated the required dimensions of the patch and then used it to make the optimal design for the antenna. We got almost 97.87% and 98% percent accuracy on our design for 2.4GHz and 5GHz.

Theory

An Antenna is a transducer, which converts electrical power into electromagnetic waves and vice versa.An Antenna can be used either as a transmitting antenna or a receiving antenna.

The basic working of antenna can be explained with the help of an open transmission line where the reflected coefficient is one.

$$\tau = \frac{Zo - Z}{Zo - Z}$$

when

$$Zo = \infty,$$

$$\tau = 1$$

Thus reflection coefficient is equal to one. This implies that the power is completely reflected back. When we make the some bend in the transmission line there will be a component of the field which is not cancelled. This is basically responsible for the radiation of a dipole antenna.

When coming to quantum level this is actually happening due to the kink effect in electromagnetic radiation. When the charges are accelerating the corresponding electric and magnetic field may not be changing with the motion of an electron or a charged particle. This creates the field to lag behind the motion. The kinks travel as radiation when the charged particles cross each other when they oscillates.

In an antenna we require to have the maximum radiation intensity in one direction. That is the directivity should be maximised. It also depends on the application of the antenna. In antennas which need to transmit power over long ranges, we need to have large values of directivity. Others like that we use for mobile application needs to have omni - directional antennas.

The Width W can be calculated from the formula

$$W = \frac{c}{2f_o\sqrt{\frac{e_r+1}{2}}}$$

for the effective length calculation,

$$L_{eff} = \frac{c}{2f_o\sqrt{e_r}}$$

where,

$$e_{eff} = \frac{e_r+1}{2} + \frac{e_r-1}{2}[1+12\frac{h}{W}]^{-1/2}$$

The actual length of the patch is

$$L = L_{eff} - 2\delta L$$

for δL ,

$$\delta L = 0.412h\frac{(e_{eff}+0.3)(\frac{W}{h}+0.264)}{(e_{eff}-0.258)(\frac{W}{h}+0.8)}$$

The effective length is arriving due to the fringing effect of the capacitor. Since antenna can be modelled as capacitor with the top plate as patch and the bottom plate as the ground.

For getting maximum power transfer we have used impedance matching techniques. The one that we used is called **inset cut**. Since we know that during the antenna radiation, the patch is having a length of $\lambda/4$, the voltage maximum will be at the edges of the patch. Correspondingly we can say that the current minima will be the edges since both are $\pi/2$ out of phase. So at the middle of the patch we will have the impedance at 0 and at the edge we will have it as ∞. Thus for impedance matching we have to find a point between the half part of an antenna where the input impedance will be equal to the characteristics impedance of the transmission line. We have written code in python for easier computations.

Python Code for Computation of Inset cut

The code goes over here

```
import math
er = float(input("Enter the dielectric Constant : "))
l = float(input("Enter the Length of the antenna : "))
li = l
l = l * 100
Im = float(input("Enter the Characteristics Impedance : "))
Rin = (0.001699 * er ** 7 + 0.13761 * er ** 6 - 6.1783 * er ** 5 + 93.187
* er ** 4 - 682.69 *
er ** 3 + 2561.9 * er ** 2 - 4043 * er + 6697) * (10 ** -4) * (l/2)
y0 = math.acos(math.sqrt(Im / Rin)) * li / math.pi
print(y0, Rin)
```

From this we can see the values of y_0. The code will take input as relative permittivity e_r, the length of patch and the characteristics impedance Z_0.

Calculations

5GHz Antenna

$$f_0 = 5 * 10^9$$

$$e_r = 4.4 (FR4epoxy)$$

$$W = 18.2574185835mm$$

$$L = 13.8139659308mm$$

dielectric thickness t,

$$t = 1.5mm$$

inset feed length y_0,

$$y_0 = 5.19mm$$

2.4GHz Antenna

$$f_0 = 2.4 * 10^9$$

$$e_r = 4.4 (FR4epoxy)$$

$$W = 38.0362887156mm$$

$$L = 29.4785104164mm$$

dielectric thickness t,

$$t = 1.5mm$$

In 2.4 GHz we got considerable amount of S11 without using the impedance matching.

Procedure

1. We have made the required calculation using the current formula. We have chosen the height as 1.5mm and the substrate dimensions as $60mmX60mm$.
2. Created a new Hfss file and made the substrate with box(material: FR4 epoxy).
3. Create the ground plane, make sure to name all the components(material copper).
4. Create the patch with the calculated dimensions. Select the material to be copper.
5. Create the Microstrip feed and click unite to make it unite with the patch.
6. Then create the port for the transfer of power.
7. Make the port as lumped port.
8. Create the Radiation box and make the material as air. Right click and make the boundary as radiation.
9. Now check and validate our design. Run the simulation with the appropriate number of steps.

Inference

The simulated results of the antennas are attaching below.

Figure 1 shows the Frequency vs dB plot for 5Ghz. From this we have can see that the maximum power loss happen around 4.9GHz which is almost close to 5GHz. Thus our model is 98% accurate.

Figure 2 shows the Frequency vs dB plot for 2.4Ghz. From this we have can see that the maximum power loss happen around 2.3489GHz which is almost close to 2.4GHz. Thus our model is 97.87% accurate.

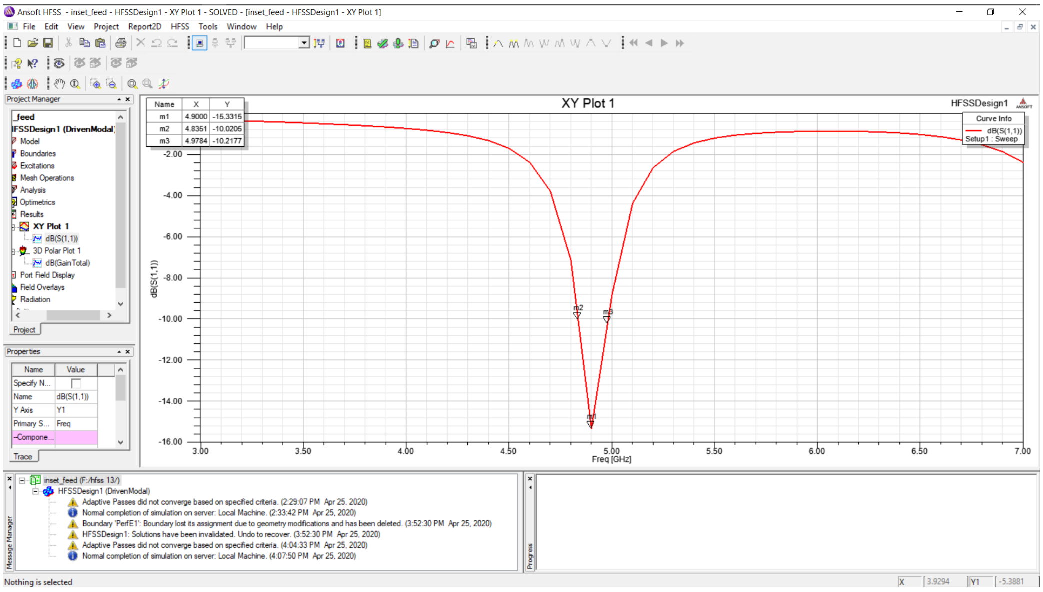

Figure 1: frequency *vs* dB plot

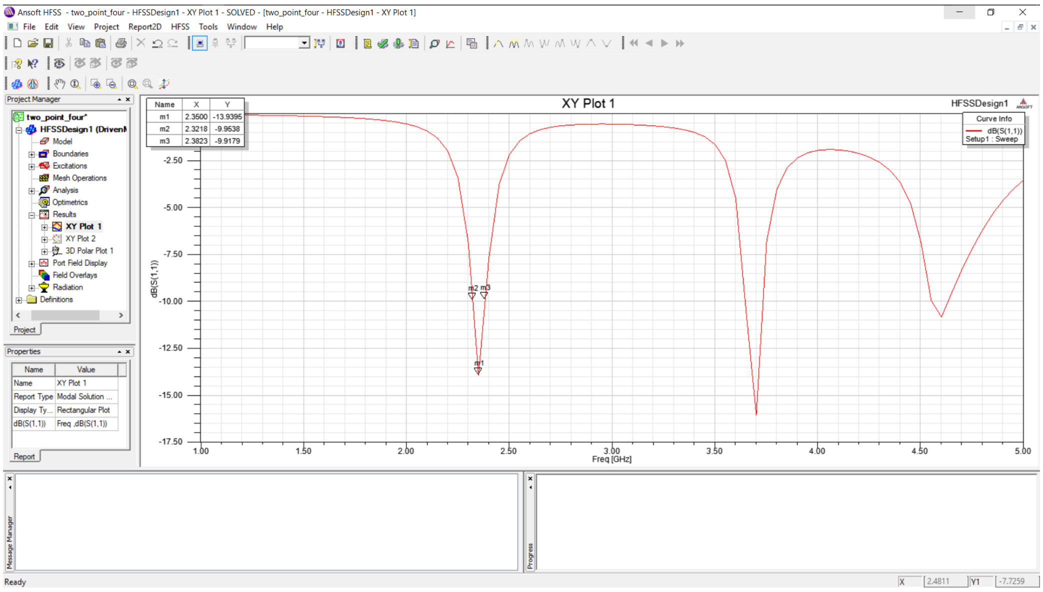

Figure 2: frequency *vs* dB plot

Far Field plots The far field radiation pattern of the two frequencies are also shown below.

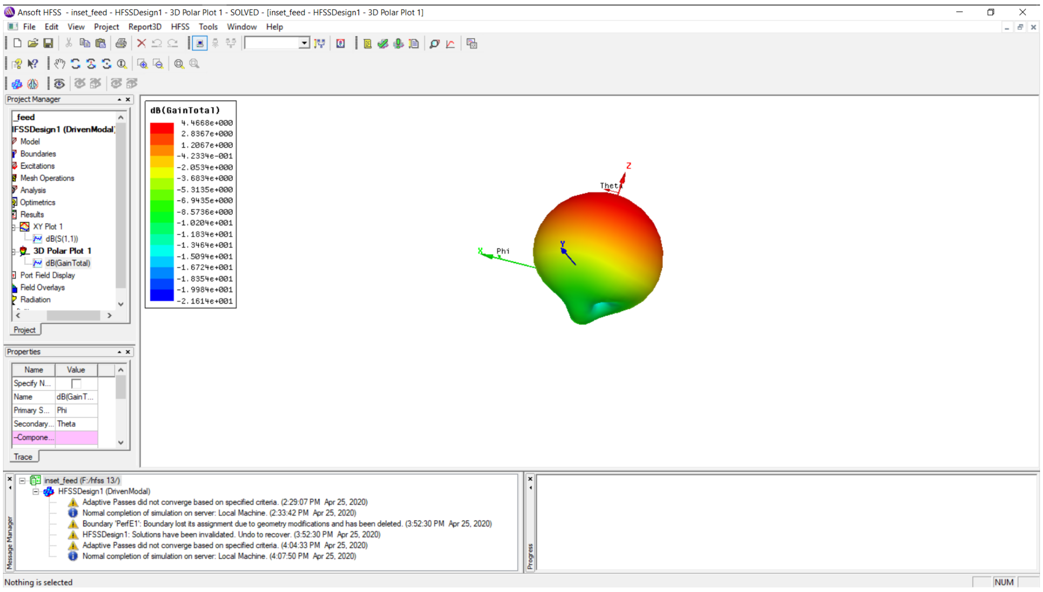

Figure 3: frequency - 5GHz

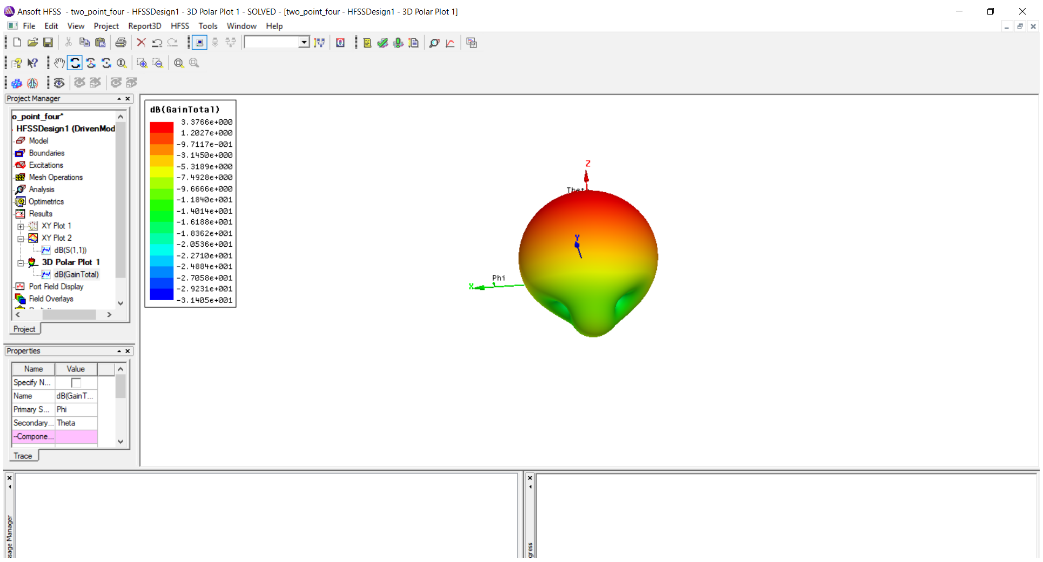

Figure 4: frequency - 2.4GHz

Conclusion

Antenna design is a one of the leading research areas in the emerging technologies. They are being used in a variety of applications. The underlying principle of antenna design at electronic level is that charge particle under ac-

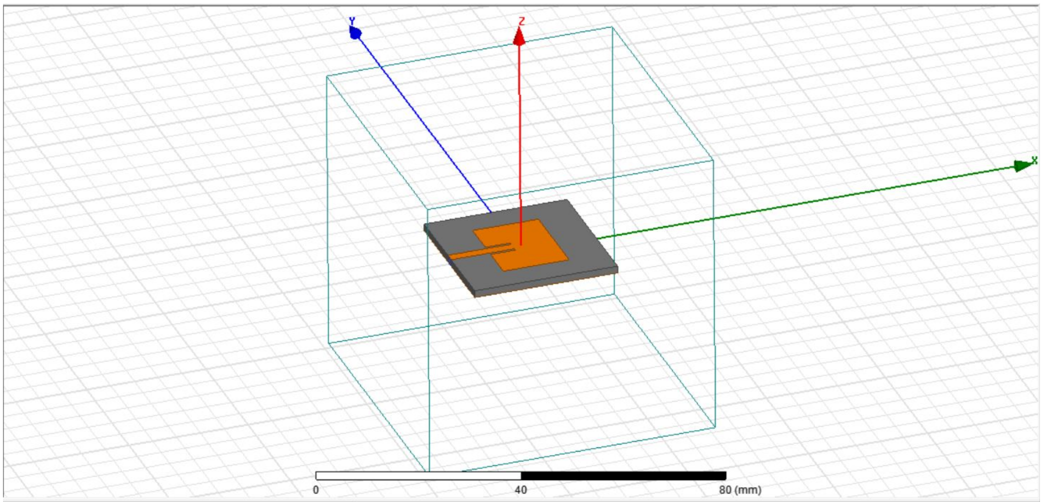

Figure 5: design frequency - 5GHz

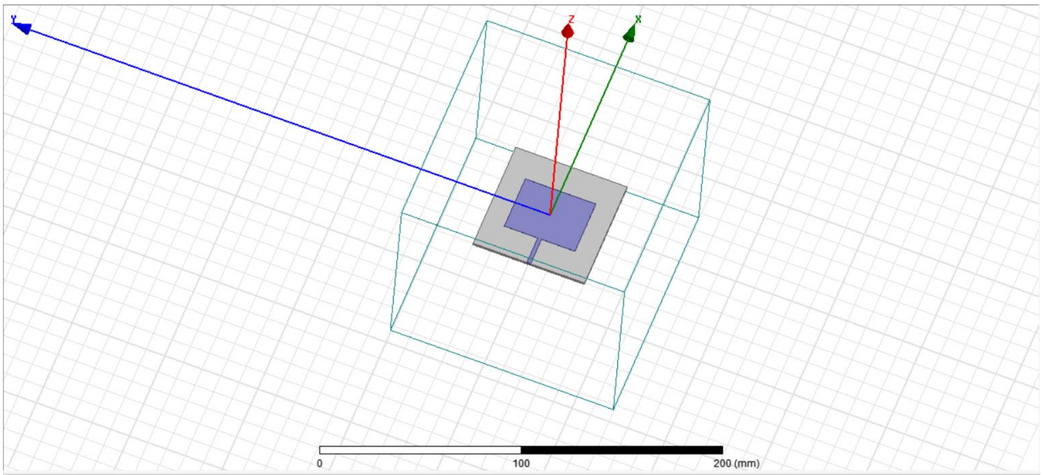

Figure 6: design frequency - 2.4GHz

celeration will emit electromagnetic radiation. The interesting thing is that we can decide the frequency of this radiation. This can be made used by different technological agencies as their bandwidth. Specific bandwidth has been allocated for special purposes. The communication, data reception everything is restricted to this bandwidth. Antennas are created such that they operate at this specific frequency so that it wont interfere with the others. So antenna design play a crucial role in modern day technologies.