CST STUDIO

5G Microstrip Antenna Design

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Abstract

Despite reaching the moon and bringing life into the vast, lifeless space, the communications field is still developing. From antennas to satellites, this field is mind- blowing, and is a crucial part of every human life nowadays. This report is aimed at designing microstrip antennas and comparing the results to an actual implemented one. This paper includes an introduction about patch antennas, the design parameters, and the results after optimisation.

Introduction

Microstrip antennas are very thin conductive (metal) strips on top of a grounded substrate of any shape, however rectangular shapes are most common, with a dielectric material in between. They operate at high frequencies ranging from 3 GHz to 30 GHz and are fed by feed lines photo-etched on the same substrate with connectors on their ends. Patch antennas are widely used in wireless communication systems and other various applications such as military applications e.g on missile bodies to direct them. They radiate primarily because of the fringing fields between the patch edge and the ground plane. For a good performance, it is desirable to use a thick dielectric substrate having a low dielectric constant, this provides higher efficiency, larger bandwidths, and better radiation. Microstrip antennas have different designs such as U-shaped, E-shaped...etc. They can also be designed to look like dipoles and other antenna types. GPS and RFI, and medical applications can make use of patch antennas as well.

Antenna Design

The microstrip antenna to be designed is desired to hold the following parameters:

- Frequency: 3.5 GHz.
- Patch Size: 19.5 mm x 26.5 mm.
- Dielectric Constant: 4.3.
- Patch & Ground Material: Copper
- Substrate Type: Epoxy.
- Substrate Material: FR-4
- Dielectric (FR-4) Thickness: 1.6 mm.
- Conductor (Ground) Thickness: 0.035 mm.

Dimensions of Rectangular Patch Microstrip Antenna

Rectangular patches need the following parameters for their design:

- Length (L)
- Width (W)
- Thickness Of Substrate: h
- Dielectric Material Constant: (ε_r)
- Frequency Of Operation (fr)

These are the equations to be used in order to obtain them:

$$W = \frac{1}{2f_r\sqrt{\mu_0\varepsilon_0}}\sqrt{\frac{2}{\varepsilon_r+1}} = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}}$$

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

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{eff}}}$$

$$\Delta L = 0.412h\frac{(\varepsilon_{eff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{W}{h}+0.8\right)}$$

As for the length and width of the ground plane and substrate:

$$Lg = x\text{h} + L$$

$$W = x\text{h} + W$$

Feed Channel Width on Rectangular Patch Microstrip Antenna

The width of the antenna utilisation channel can be calculated using the equations down below:

$$w = \frac{2h}{\pi}\left\{B - 1 - \ln(2B-1)\frac{\varepsilon r - 1}{2\varepsilon r}\left[\ln(B-1) + 0.39 - \frac{0.61}{\varepsilon r}\right]\right\}$$
$$B = \frac{60\pi^2}{Zo\sqrt{\varepsilon r}}$$

Where h is the thickness of the substrate material, π is the constant that has a value of 3.14, εr is the dielectric constant of the substrate and Z is the impedance value of the feed line.

Parameters of Single Patch Microstrip Antenna

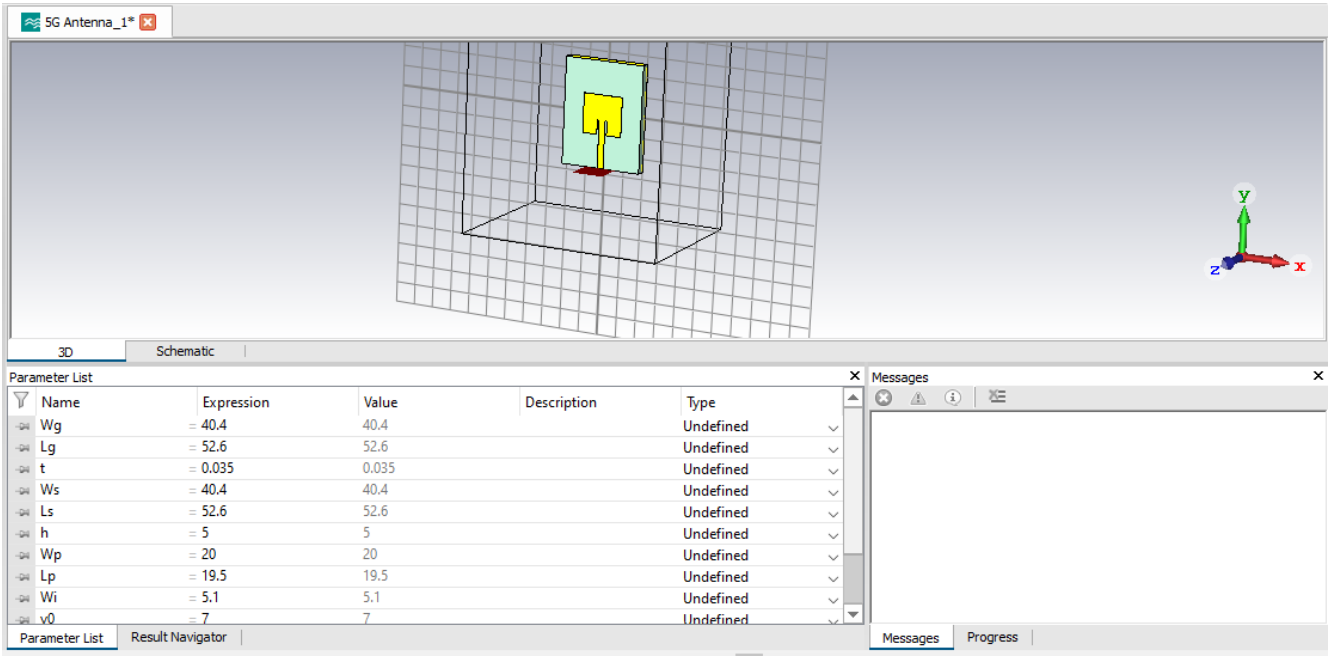
Specifications	Symbol	Value
Patch Width	Wp	20 mm
Patch Length	Lp	26.3 mm
Feedline Width	Wf	3.1mm
Feedline Length	Lf	17.8 mm
Patch Thick	tp	0.035 mm
Width Of Ground	Wg	40.4 mm
Ground Length	Lg	52.6 mm
Thick Ground	tg	0.035 mm
Width Substrate	Ws	40.4 mm
Substrate Length	Ls	52.6 mm
Substrate Thickness	h	1.6 mm

Specifications	Symbol	Value
Inset Feed Width	Wif	1 mm
Inset Feed Length	Lif	7 mm

Now the antenna can be easily designed using the CST studio.

Antenna Results

Patch Design

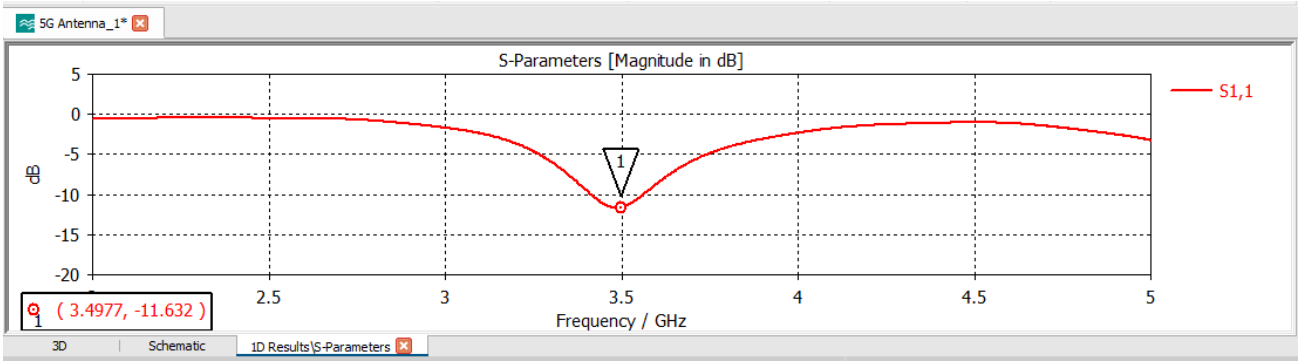


Return Loss

Return loss compares the amplitude of the reflected wave to the amplitude of the transmitted wave. Return loss can occur due to impedance mismatch

between the transmission line and load input impedance (antenna). The return loss value must be less than -10 dB for the antenna to be used. So the smaller the return loss value, the better the antenna to be designed.

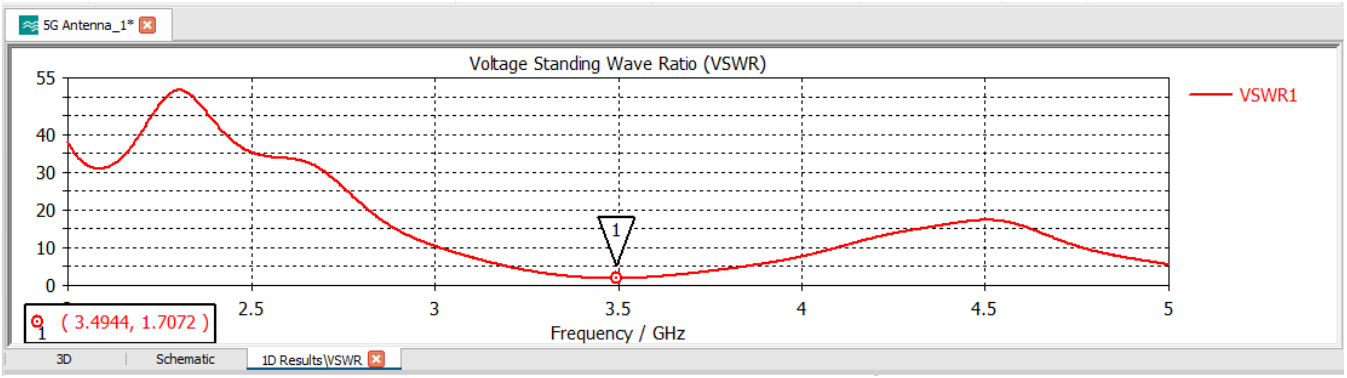
This is the S-parameter simulation result:



The antenna is considered operating well if the peak of the curve is below the -10dB magnitude.

Voltage Standing Wave Ratio (VSWR)

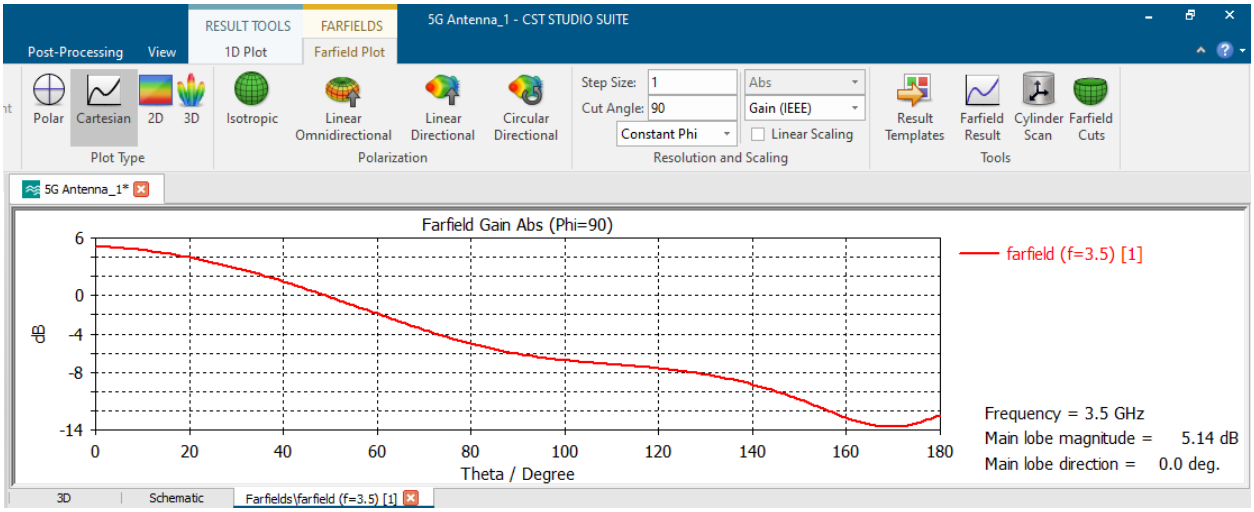
VSWR is the ratio between the maximum standing wave amplitude (standing wave) (| V|max) with minimum (|V|min).



At the desired frequency, the VSWR is close to 1 (Precisely = 1.7). As long as it is < or = to 2. This is considered a good result.

Gain

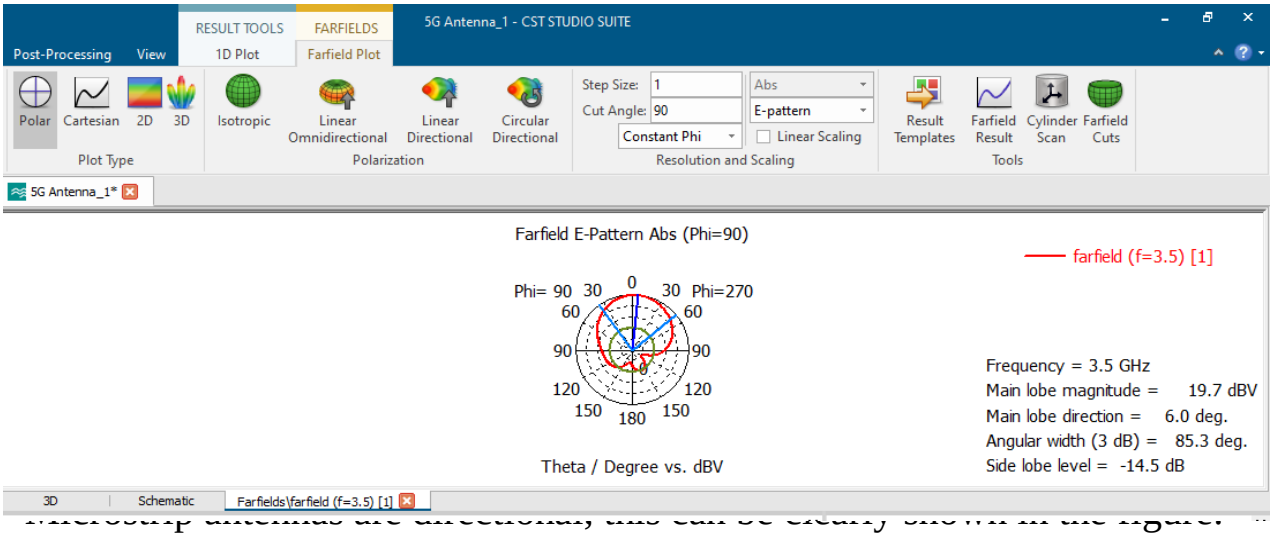
A gain is related to the antenna's ability to direct its signal radiation and also the reception of the signal from a certain direction. The gain of an antenna is the ratio of the maximum radiation intensity of an antenna to the radiation intensity of a reference antenna with the same input power.



The required gain to be achieved was 5.5 dB. This is too close only using a single element patch antenna.

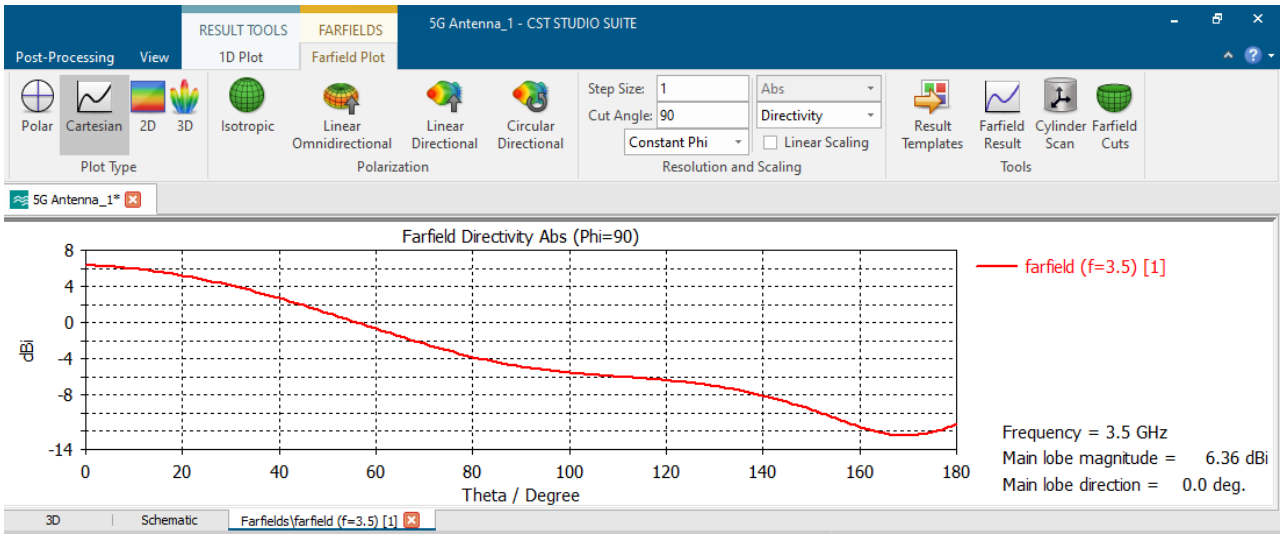
Radiation Pattern

A radiation pattern is a graphically characteristic image of the radiation of an antenna. Antenna radiation patterns are called field patterns if the ones depicted are strong fields.



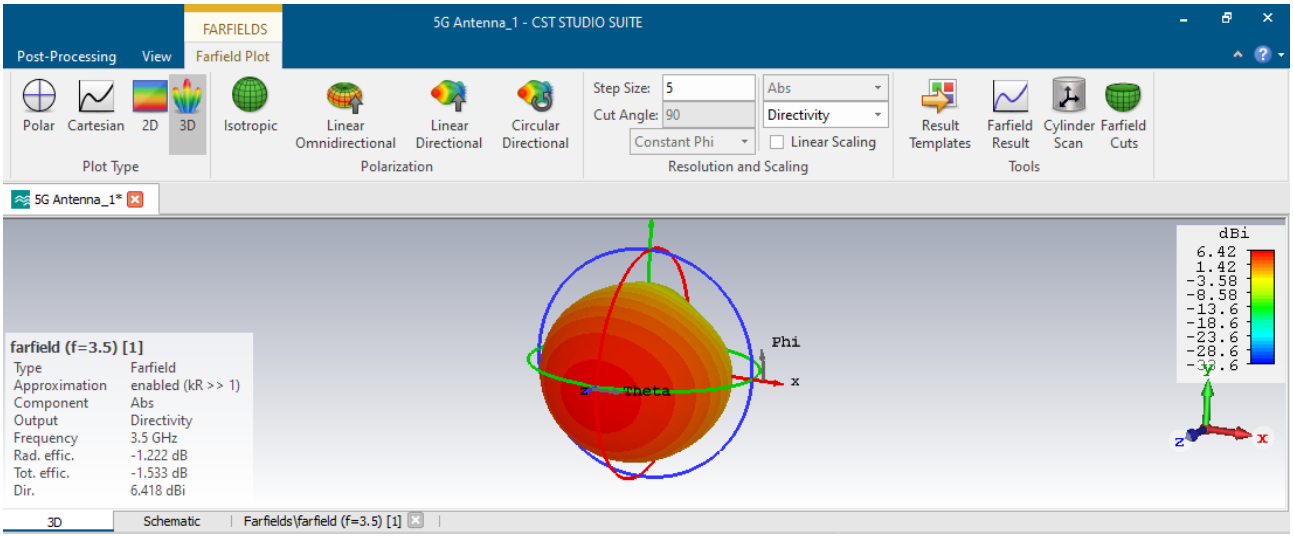
Directivity

It is the measure of the degree to which the emitted radiation is concentrated in a certain direction. It is the ratio of the radiation intensity in a given direction from the antenna to the radiation intensity averaged over all directions.



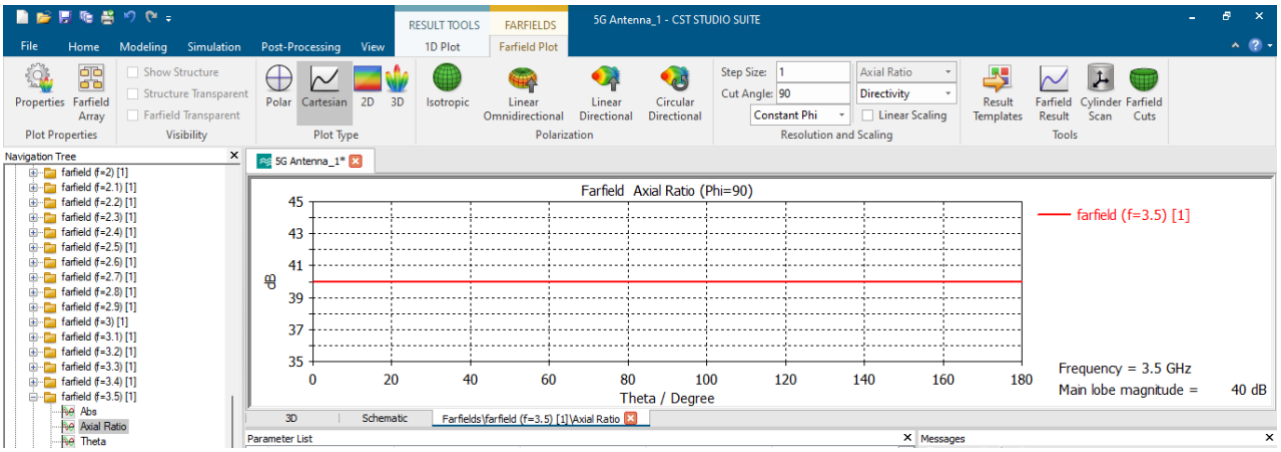
An antenna is considered directional if its directivity is greater than or equal to 4 dB. So this one is definitely a directional antenna.

3D view



Axial Ratio

It is the ratio between the major axis and minor axis of an antenna. It is an indication to the antenna polarization. If the anetnna is Circularly Polarized this ratio would be 1 (0dB), However, if the antenna has an elliptical polarization then this ratio would be greater than 1 (>0 dB). As the axial ratio increases (Tends to infinity) the polarization becomes linear.



This is a linearly polarized antenna as shown in the figure.

Conclusion

These results were obtained using only a single patch microstrip antenna. This indicates how microstrip antennas are very powerful and useful especially with their small sizes and easy fabrication. However, this type of antennas also has its drawbacks, some of these are: Their narrow bandwidth, and their small gain, yet these problems can be solvable using arrays. This project has been very useful in showing how antennas are designed and optimized, as a crucial step for any communications Engineer.

References

- https://www.researchgate.net/publication/356806188_Design_of_Rectangular_Microstrip_Antenna_1x2_Array_for_5G_Communication
- https://www.everythingrf.com/community/what-is-axial-ratio-of-an-antenna