Design of a Microstrip Patch Antenna Radiating at 3 GHz using *Ansys HFSS*

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In Microstrip Patch Antennas (MPAs), a patch of metal foil is separated from a ground plane foil by a dielectric. They can be fed in a variety of ways, one of which is by a coaxial feed. The inner conductor of the coax is connected to the radiation patch in a coaxial feed, while the outer conductor is connected to the ground plane. MPAs are widely used because they are simple and inexpensive to manufacture using modern PCB technology, easily integrable with modern electronic devices, mechanically robust when mounted on rigid surfaces, and very versatile in terms of resonant frequency, polarisation, pattern, and impingement when the particular patch shape and mode is chosen. Additionally, adaptive elements with changeable resonant frequency, impedance, polarisation, and pattern can also be constructed by inserting loads between the patch and the ground plane.

Design Parameters

The problem statement states "Design a microstrip patch antenna using coaxial feeding in Ansys HFSS software radiating at 3 GHz". So, we are given the frequency of radiation of the antenna in the problem statement. We fix the height of the substrate and its relative permittivity based on commonly used parameters and commonly available materials. The values hence given are as follows:

$$f_r = 3\ GHz\ ; \qquad h = 1.6\ mm\ ; \qquad \epsilon_r = 4.4$$

Patch Width Calculation

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{1+\epsilon_r}} = 30.4290\ mm$$

Effective Dielectric Constant

$$\epsilon_{reff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\left[1 + \frac{12h}{W}\right]^{-\frac{1}{2}} = 4.031$$

Patch Length Extension

$$\Delta L = 0.412 \cdot h \cdot \frac{(\epsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\epsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)} = 0.7360\ mm$$

Patch Length Calculation

$$L = \frac{c}{2f_r\sqrt{\epsilon_{reff}}} - 2\Delta L = 23.4318\ mm$$

Coaxial Connector Design

The dielectric material used for the insulator is Bakelite. The outer diameter of the connector is taken to be 5 mm. We use the standard input impedance of 50 Ω for the connector.

$$\epsilon_r = 2.8\ ; \qquad D_d = 5\ mm\ ; \qquad Z_O = 50\ \Omega$$

Hence, the inner diameter of the connector would be:

$$D_c = D_d \cdot e^{-z_O\sqrt{\epsilon_r}} = 1.2379\ mm$$

Results

The final antenna model is given below:

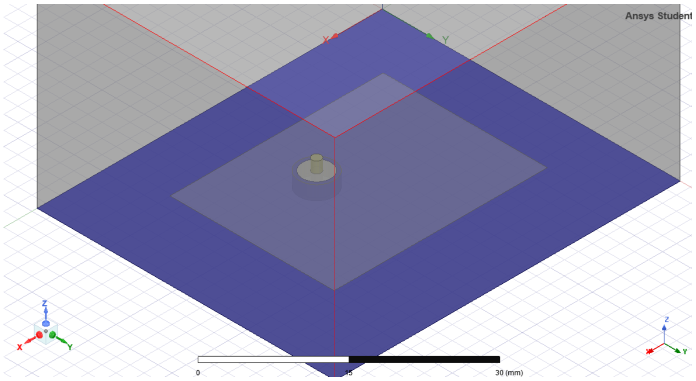

Figure 1: The Antenna Model

The variation of S-parameter magnitude with frequency obtained initially is as follows:

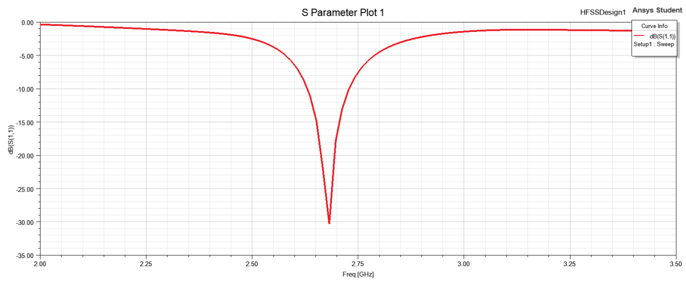

Figure 2: S-parameter vs Frequency (Before Optimization)

The plot obtained for our initial design indicates that this antenna is optimized for a frequency around 2.7 GHz. For that reason, we tried tweaking some parameters of our design such as the probe position, the dimensions of the coaxial connector, and the dimensions of the patch.

First, we tried changing the dimensions of the coaxial connector, followed by the position of the probe, as this seemed to us to be one of the first things that could be optimized.

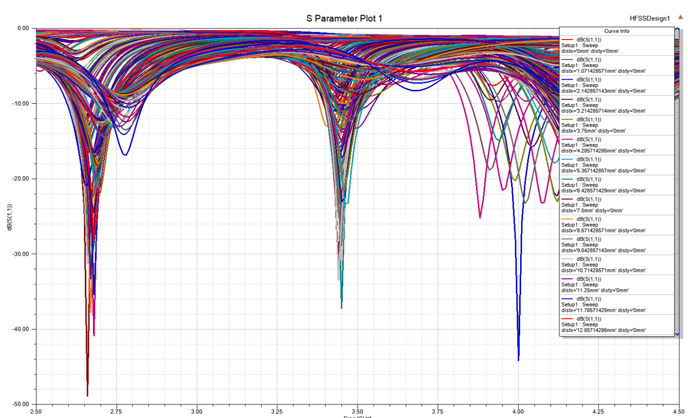

Figure 3: S-parameter vs Frequency (Probe Position Optimization)

Optimizing the probe parameters alone did not substantially improve the results. Since the equations used for calculating the design parameters are only an approximation, as a last step, we tried tweaking the dimensions of the patch a bit.

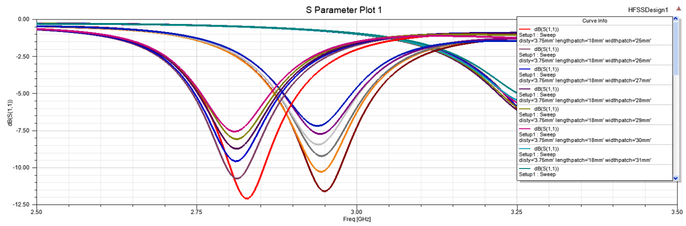

Figure 4: S-parameter vs Frequency (Patch Dimension Optimization)

Decreasing the patch length and width a bit seems to take care of the problem. We are finally getting a strong resonance at a frequency of 3 GHz. The final variation of S-parameter magnitude with frequency is as follows:

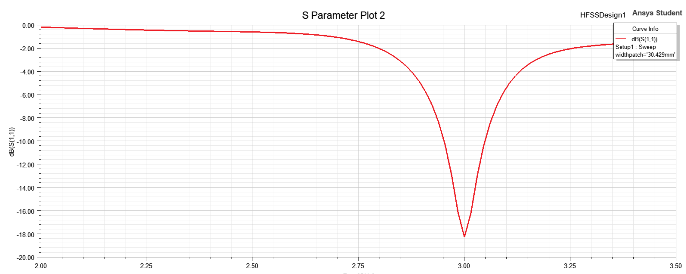

Figure 5: S-parameter vs Frequency (After Optimization)

The radiation pattern for our final design is as shown:

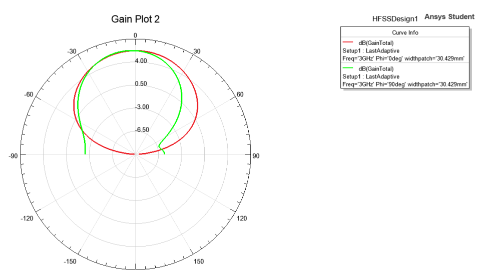

Figure 6: Radiation Pattern (After Optimization)

Hence, we have designed a Microstrip Patch Antenna with a coaxial feed radiating at 3 GHz using Ansys HFSS.