5.8 GHz Directional PCB Antenna

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Specifications

A directional PCB antenna was required to operate in the 5.725 - 5.850 GHz ISM band with linearly polarized waves. The antenna had to interface with a 50 Ω SMA connectorization and be fabricated entirely from circuit traces, metal components, and solder. No discrete electrical components could be used. Additionally, the entire device had to fit within a 10 cm x 10 cm x 1 cm rectangular prism.

Design

A microstrip patch antenna was chosen because it is both an effective means of directing radiation and a simple device to fabricate on a PCB. A patch antenna is essentially a thin flat rectanglular conductor separated from a ground plane by a dielectric layer (Fig. 1).

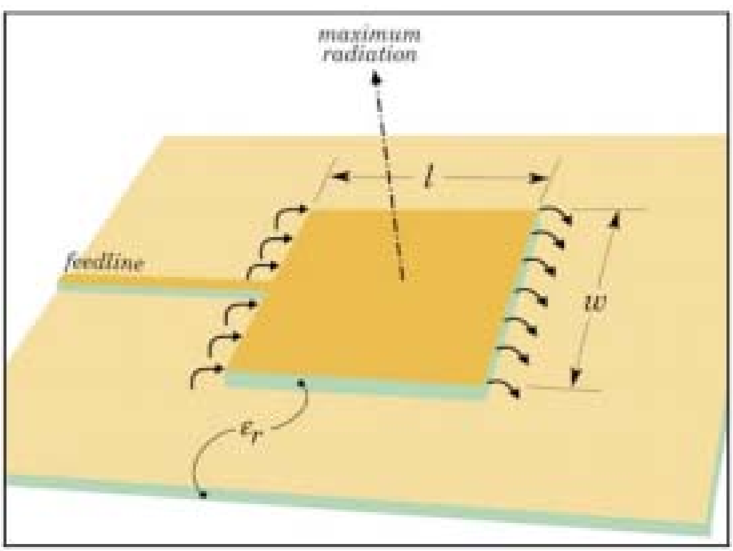

Figure 1. Typical patch antenna layout.

The edges of the rectangular patch are what provide the actual radiation. Coupled with the ground plane beneath, they act similarly to slot antennas. The currents in the patch "spill over" the edges, resulting in the desired radiation. Maximum gain occurs in a direction perpendicular to the plane occupied by the antenna, and polarization is parallel to the longest edges of the patch. The ground plane shields radiation on its side of the dielectric, reducing rearward gain. Larger ground planes provide more shielding, so to maximize gain in the forward direction, a ground plane much larger than the patch is preferred. The other factor for large ground plane is for the fringing field.

The patch was fed from the rear (through the bottom layer of the PCB) as opposed to the side. This eliminated any possible interaction that may have occurred between the antenna's edges and the feed system. The dimensions of an ideal rectangular patch were calculated using the equations shown in Figure 2.

$$Z_0 = \frac{120\pi h}{W\sqrt{\varepsilon_{\text{eff}}}}$$

$$\varepsilon_{\text{eff}} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{12h}{W}\right)^{-1/2}$$

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

$$f_r = \frac{c}{2\sqrt{\varepsilon_{\text{eff}}}(L + 2\ \Delta l)}$$

Figure 2. The equations used to calculate the patch antenna dimensions.

The antenna was then created by simply cutting a piece of copper tape to the calculated dimensions, and attaching it to a 10 cm x 10 cm PCB with a rear-fed connection. In testing, slight adjustments were made to the dimensions to tune the antenna to 5.8 GHz. The final dimensions of the patch were 1.476 in. x 0.820 in. Figures 3 and 4 show images of the final antenna.

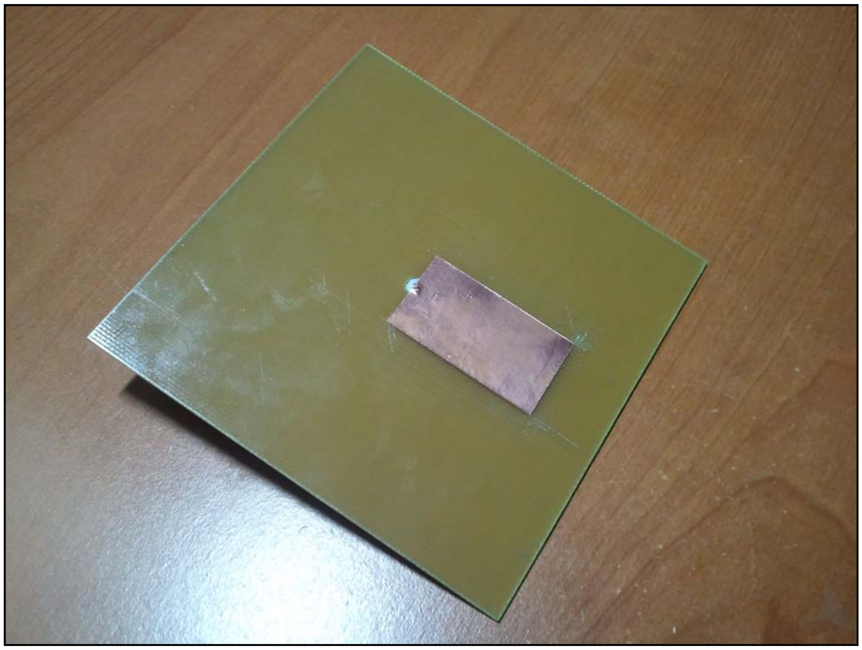

Figure 3. Patch antenna front.

Figure 4. Patch antenna back.

Testing

The return loss of the patch antenna was tested using a network analyzer. Measurements were taken over a frequency range of 1 GHz to 11 GHz. At 5.8 GHz, the return loss was measured at -26.97 dB (Fig. 5). The bandwidth was measured at approximately 500 MHz.

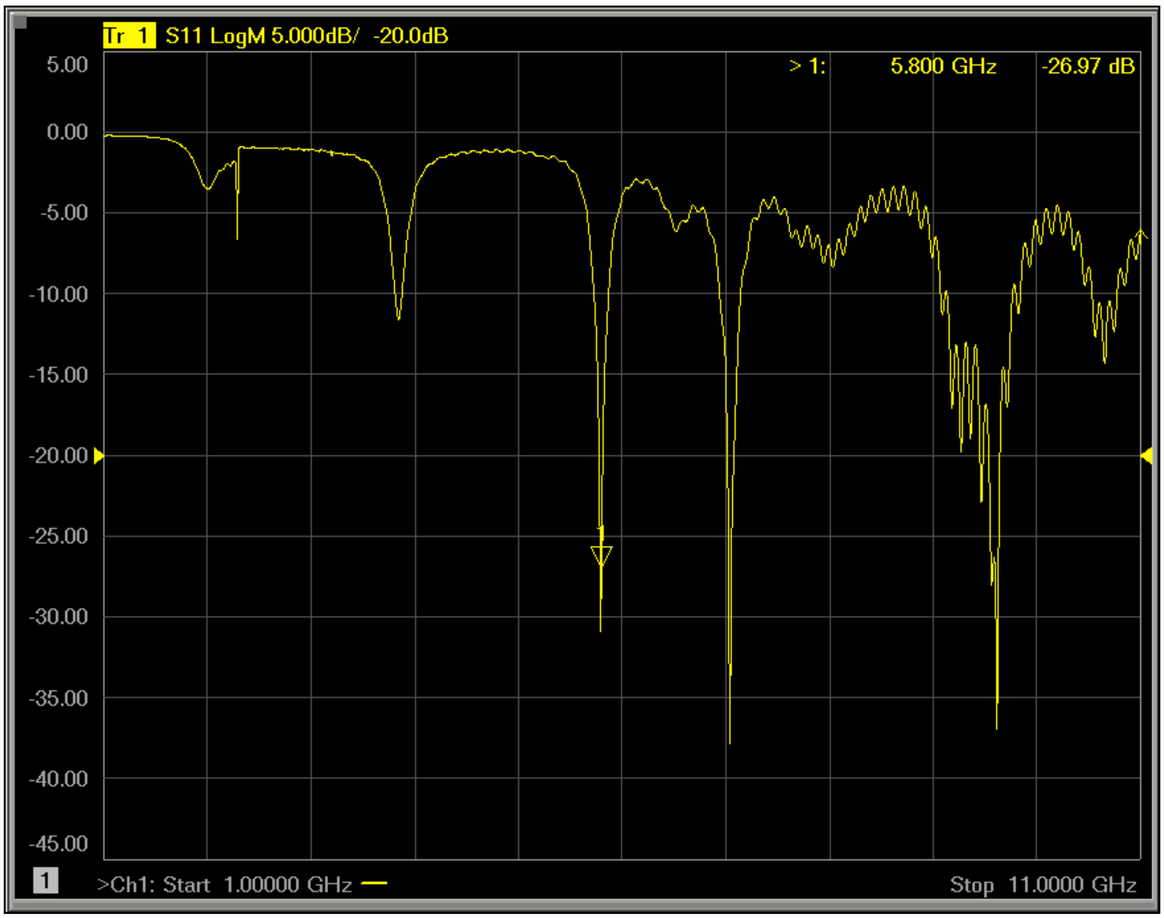

Figure 5. Return loss of the patch antenna, measured with a network analyzer.

References

1) Balanis, Constantine A. *Antenna Theory: Analysis and Design*, ed. 3. Hoboken, New Jersey: John Wiley & Sons, Inc., 2005.

2) Breed, Gary. "The Fundamentals of Patch Antenna Design and Performance". *High Frequency Electronics,* pp 48 – 51. Summit Technical Media, LCC, March 2009. http://www.highfrequencyelectronics.com/Archives/Mar09/HFE0309_Tutorial.pdf

3) Miranda, H. "Patch Antenna Design". Stanford, EE144/245, Spring 2007. https://ccnet.stanford.edu/cgi-bin/course.cgi?cc=ee144&action=handout_download&handout_id=ID11797377905639