## 4.5 Design of Nearly Square Telemetry Element – Cylindrical Surface

In the next three sections, the circularly polarized telemetry and GPS element designs for 6, 8, and 14-inch diameter cylinders are presented. The designs are accomplished by running Clementine simulations until the desired radiation characteristics are obtained. As mentioned earlier, the design is essentially a three step process. The first step is to use basic formulas to determine approximate dimensions of the patch element. The second step is to tune the patch's perturbation segment until the axial ratio is approximately 0 dB. The third step is to adjust the patch length and width equally until the 0 dB axial ratio of the patch is shifted to the operating frequency. This third step will only work if the 0 dB axial ratio is near the operation frequency. Otherwise, changing the width and length equally will not guarantee that the axial ratio will be 0 dB once the dimensions are modified. This is because the axial ratio will increase when the Q of the patch changes.

This section investigates the design of the nearly square patch telemetry element. The next two sections will investigate the truncated corner telemetry patch element and the truncated corner GPS patch element designs.

### 4.5.1 Effects of Varying Nearly Square Patch Dimensions

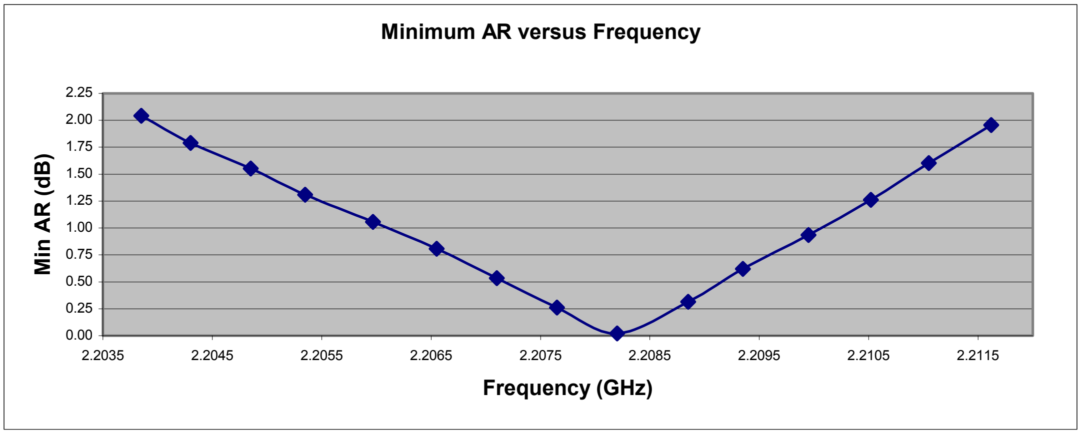
The axial ratio of the nearly square patch is tuned by adjusting the width of the perturbation segment (see figure 3.3). In order to observe the effect the perturbation width has on the axial ratio, the nearly square patch was simulated using Clementine for several different patch widths. Figure 4.12 shows how the minimum axial ratio changes as the width of the patch is varied while the length of the patch is kept constant (only the narrow perturbation segment is modified). It should be stressed that the plots are not the axial ratio of one patch but the minimum axial ratio of several patches with different perturbation widths. In other words, each point represents only the minimum axial ratio, and the frequency at which it occurs for the patch analyzed. As seen in the figure, by adjusting only one dimension of the patch slightly, the minimum axial ratio can change significantly.

Once the minimum axial ratio is determined, the patch can be tuned so the minimum axial ratio is located precisely at the operating frequency (2.2155 GHz in this case). The frequency tuning is accomplished by modifying both dimensions of the patch equally. Figure 4.13 shows the effects that varying both patch dimensions equally has on the frequency where the minimum axial ratio occurs. The value of the minimum axial ratio is not shown. Over the frequency ranges plotted, the minimum axial ratio value remained essentially constant ($\approx 0$ dB) as the patch width and length were varied equally.

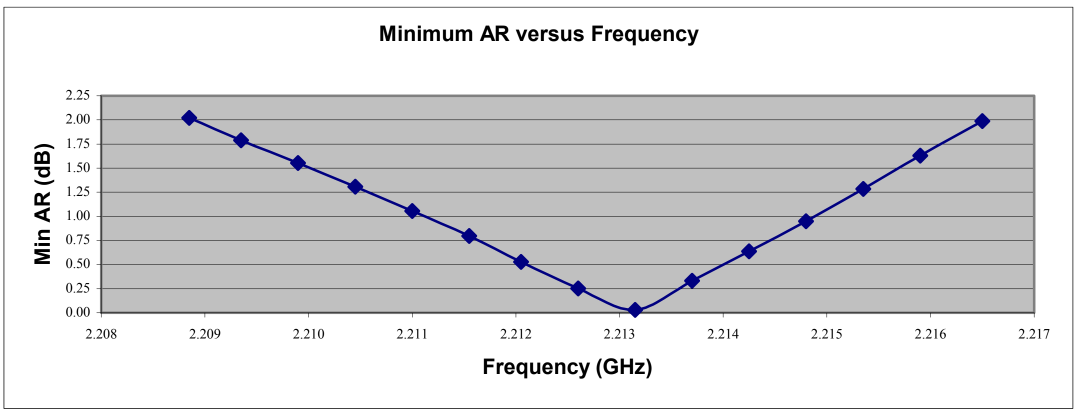
The results of figures 4.12 and 4.13 are summarized in tables 4.10 and 4.11. When a nearly square patch is fabricated, it will most likely require both axial ratio and center frequency tuning. The data in these tables provide valuable information in the design process because they specify how to tune the patch dimensions.

**Table 4.10.** Axial ratio tuning information for nearly square telemetry patch as perturbation segment is changed while length is held constant. 'Left' and 'Right' refer to the end points of each plot in figure 12.

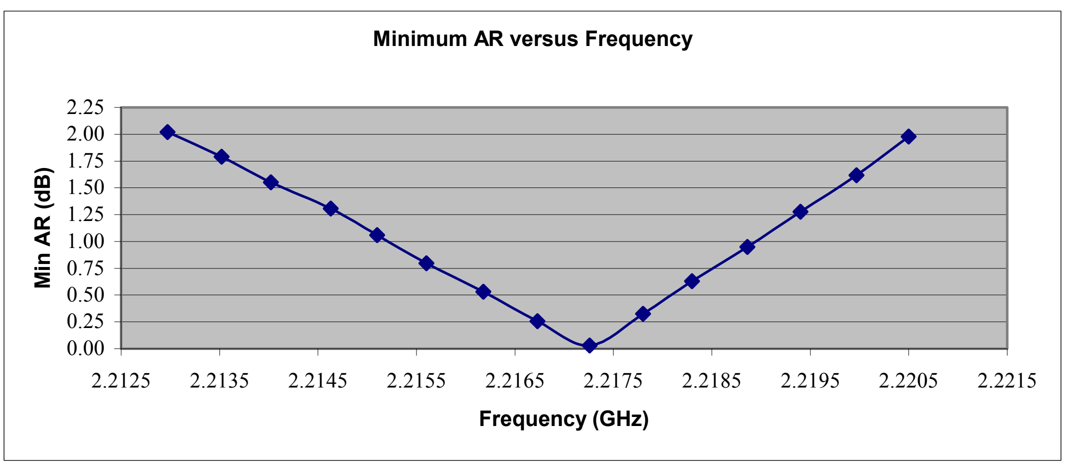
| AR versus Frequency | | | | | | | Rate of Change | |
|---|---|---|---|---|---|---|---|---|
| | Left AR | | Middle AR | | Right AR | | AR Factor | |
| Diameter | AR | Frequency | AR | Frequency | AR | Frequency | Left of Minimum AR | Right of Minimum AR |
| (inches) | (dB) | (GHz) | (dB) | (GHz) | (dB) | (GHz) | (mm/dB) | (mm/dB) |
| 14 | 2.041 | 2.20385 | 0.02 | 2.20820 | 1.956 | 2.21162 | -0.09896 | 0.07748 |
| 8 | 2.020 | 2.20885 | 0.03 | 2.21315 | 1.990 | 2.21650 | -0.10050 | 0.07653 |
| 6 | 2.020 | 2.21297 | 0.03 | 2.21726 | 1.978 | 2.22050 | -0.10050 | 0.07700 |




**a.** Nearly square patch on 14-inch diameter cylinder.

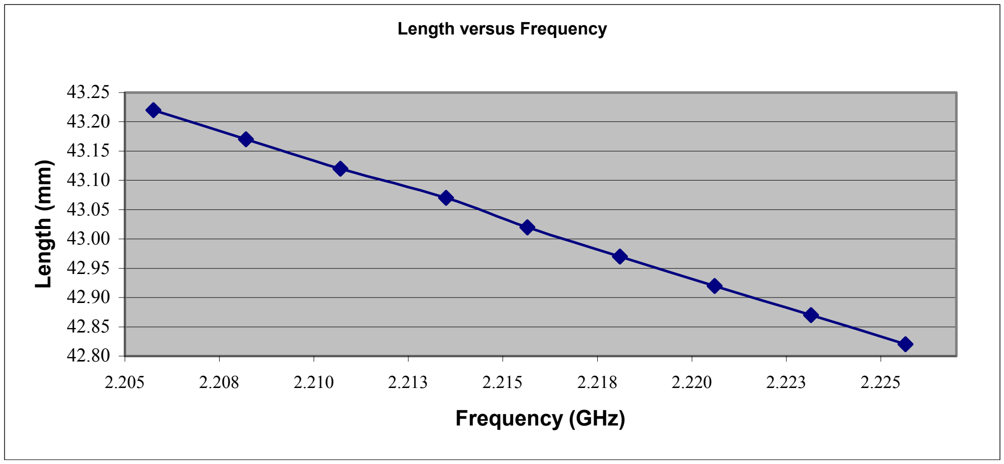



**b.** Nearly square patch on 8-inch diameter cylinder.

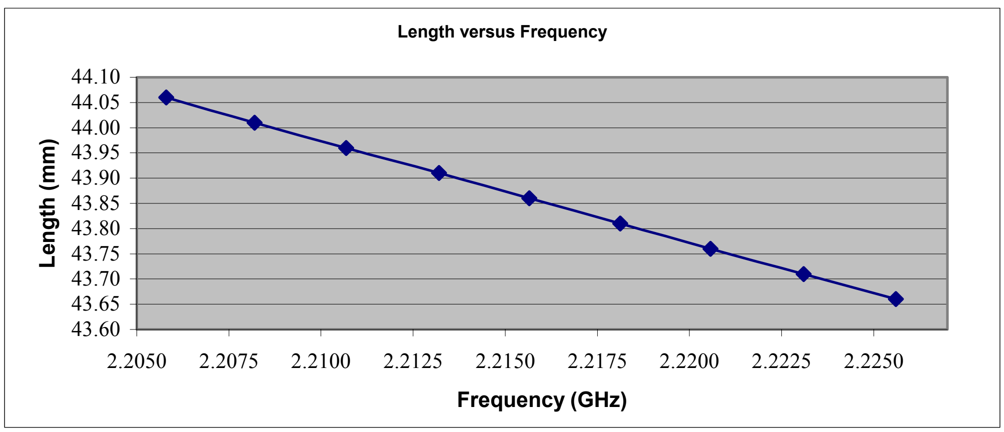



**c.** Nearly square patch on 6-inch diameter cylinder.

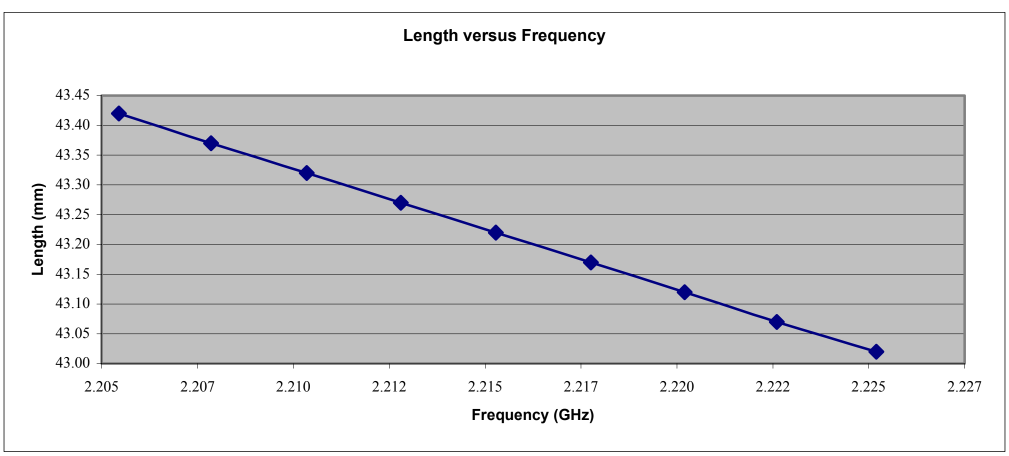
**Figure 4.12.** Minimum AR versus frequency as the perturbation width is varied in 0.025 mm steps while the length is held constant.




**a.** Nearly square patch on 14-inch diameter cylinder.




**b.** Nearly square patch on 8-inch diameter cylinder.




**c.** Nearly square patch on 6-inch diameter cylinder.

**Figure 4.13.** Length versus frequency for nearly square patch as length and width are reduced equally in 0.05 mm steps. Note that axial ratio remains nearly constant at $\approx 0.0$ dB.

**Table 4.11.** Frequency tuning information for nearly square telemetry patch as length and width are varied by equal amounts. 'Left' and 'Right' pertain to the end points of each plot in figure 4.13.

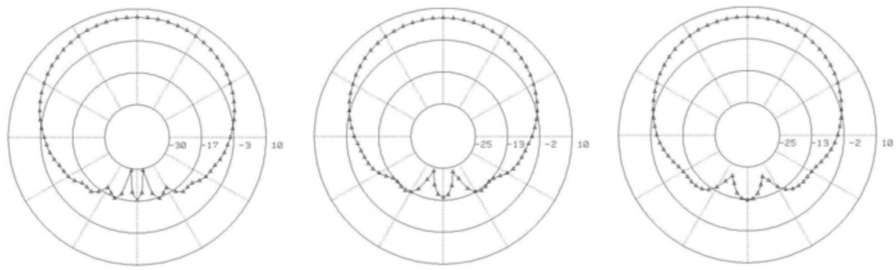
| AR versus Frequency | | | | | | Rate of Change |
|---|---|---|---|---|---|---|
| | Left Data Point | | Right Data Point | | | Frequency Factor |
| Diameter | Length | Frequency | Length | Frequency | | |
| (inches) | (mm) | (GHz) | (mm) | (GHz) | | (mm/MHz) |
| 14 | 43.22 | 2.20575 | 42.82 | 2.22565 | | -0.02010 |
| 8 | 44.06 | 2.2058 | 43.66 | 2.22560 | | -0.02020 |
| 6 | 43.42 | 2.20495 | 43.02 | 2.22470 | | -0.02025 |

### 4.5.2 Performance of Nearly Square Telemetry Patch

Nearly square telemetry patches were tuned (axial ratio of 0 dB at 2.2155 GHz) for 6-, 8-, and 14-inch diameter cylinders using Clementine. The dimensions of these patches are listed in table 4.12. The patches were matched to 50 ohm microstrip feeds using L-section matching networks. The performance of these patches is shown in figures 4.14 – 4.19 and tabulated in table 4.13. As seen in the table, the performance of the patches on each of the cylinders is nearly the same, with the exception of the minimum return loss for the patch on the 14-inch diameter cylinder. The reason for the degraded $S_{11}$ performance is due to the matching network and not the patch design or its performance. Since the dimensions of the patches on the 6 and 8-inch diameter cylinders are approximately the same as the dimensions for the patch on the 14-inch diameter cylinder, these results show that the basic planar equations can be used to design patch antennas for cylinders having radii greater than a guided wavelength.

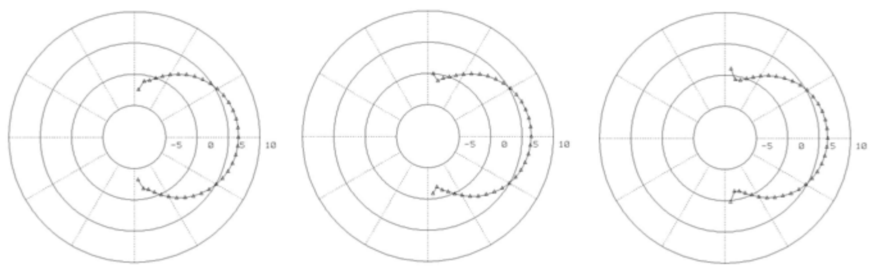
**Table 4.12.** Telemetry nearly square patch dimensions.

| Diameter (in) | 6 | 8 | 14 |
|---|---|---|---|
| Frequency (GHz) | 2.2155 | 2.2155 | 2.2155 |
| Height (mm) | 1.524 | 1.524 | 1.524 |
| Permittivity | 2.33 | 2.33 | 2.33 |
| Loss Tangent | 0.001 | 0.001 | 0.001 |
| Length (mm) | 43.206 | 43.122 | 43.02 |
| c (mm) | 0.74 | 0.74 | 0.75 |
| Zin (Ohms) | 162.4 - j 104.7 | 175.8 - j 122.6 | 196.4 - j 113.5 |



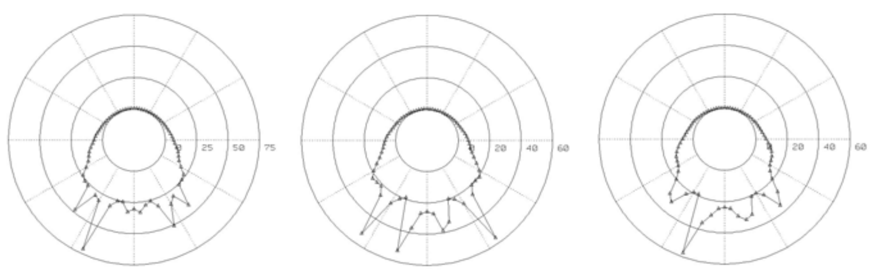

**a.** 14-inch diameter **b.** 8-inch diameter **c.** 6-inch diameter

**Figure 4.14.** Gain for nearly square telemetry element in the azimuth plane.



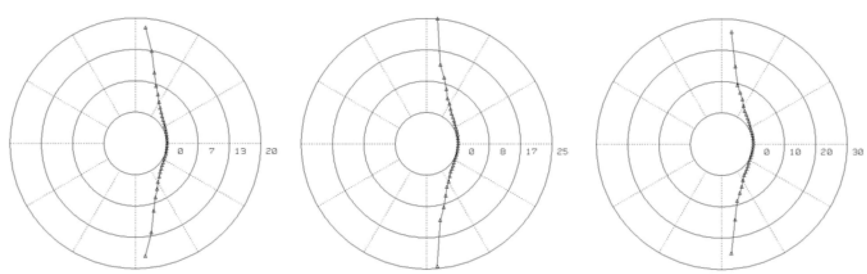

**a.** 14-inch diameter **b.** 8-inch diameter **c.** 6-inch diameter

**Figure 4.15.** Gain for nearly square telemetry element in the elevation plane.




**a.** 14-inch diameter **b.** 8-inch diameter **c.** 6-inch diameter

**Figure 4.16.** Axial ratio for nearly square telemetry element in the azimuth plane.




**a.** 14-inch diameter **b.** 8-inch diameter **c.** 6-inch diameter

**Figure 4.17.** Axial ratio for nearly square telemetry element in the elevation plane.

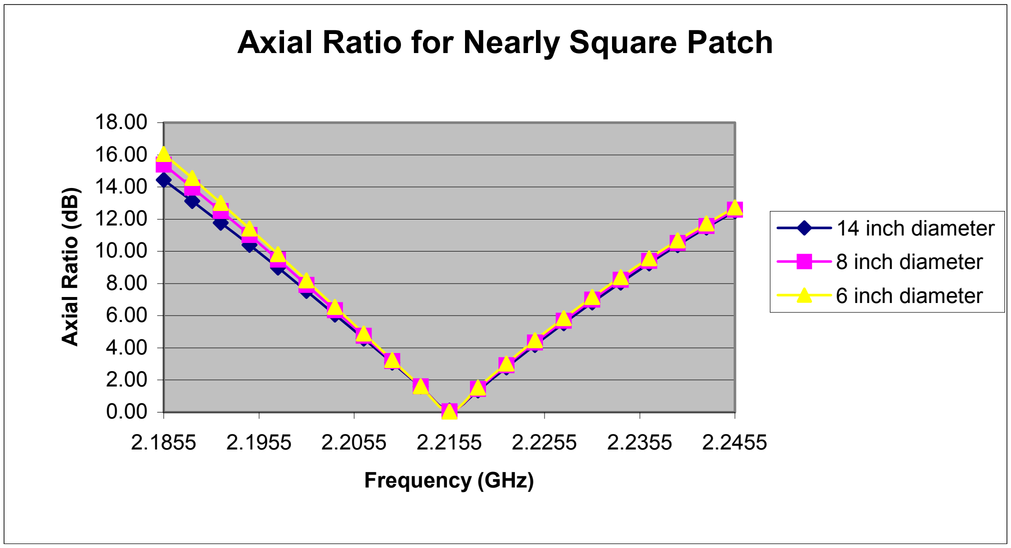



**Figure 4.18.** Nearly square telemetry patch axial ratio versus frequency.

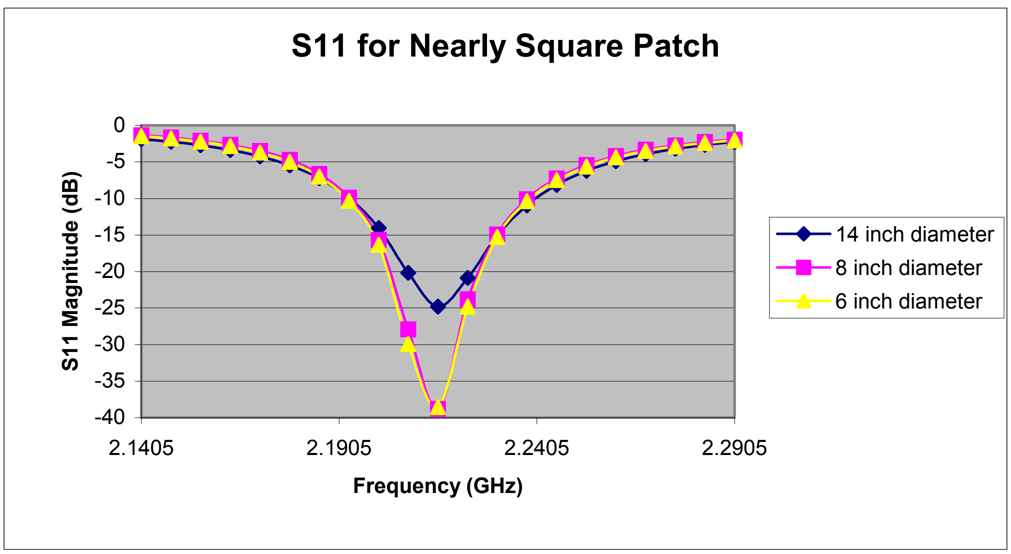



**Figure 4.19.** $S_{11}$ versus frequency for nearly square telemetry patch.

**Table 4.13.** Telemetry nearly square patch performance data.

| Diameter | Azimuth Plane | | Elevation Plane | | Broadside | | |
|---|---|---|---|---|---|---|---|
| | 3 dB Beamwidth | 6 dB AR Beamwidth | 3 dB Beamwidth | 6 dB AR Beamwidth | Gain | Impedance Bandwidth | 6 dB AR Bandwidth |
| (inches) | (degrees) | (degrees) | (degrees) | (degrees) | (dB) | (MHz) | (MHz) |
| **14** | 90 | 180 | 90 | 145 | 6.6 | 112 | 24.9 |
| **8** | 90 | 180 | 90 | 140 | 6.5 | 105 | 24 |
| **6** | 90 | 180 | 90 | 140 | 6.4 | 119 | 23.3 |