ECE 6345
Spring 2011

Class Project

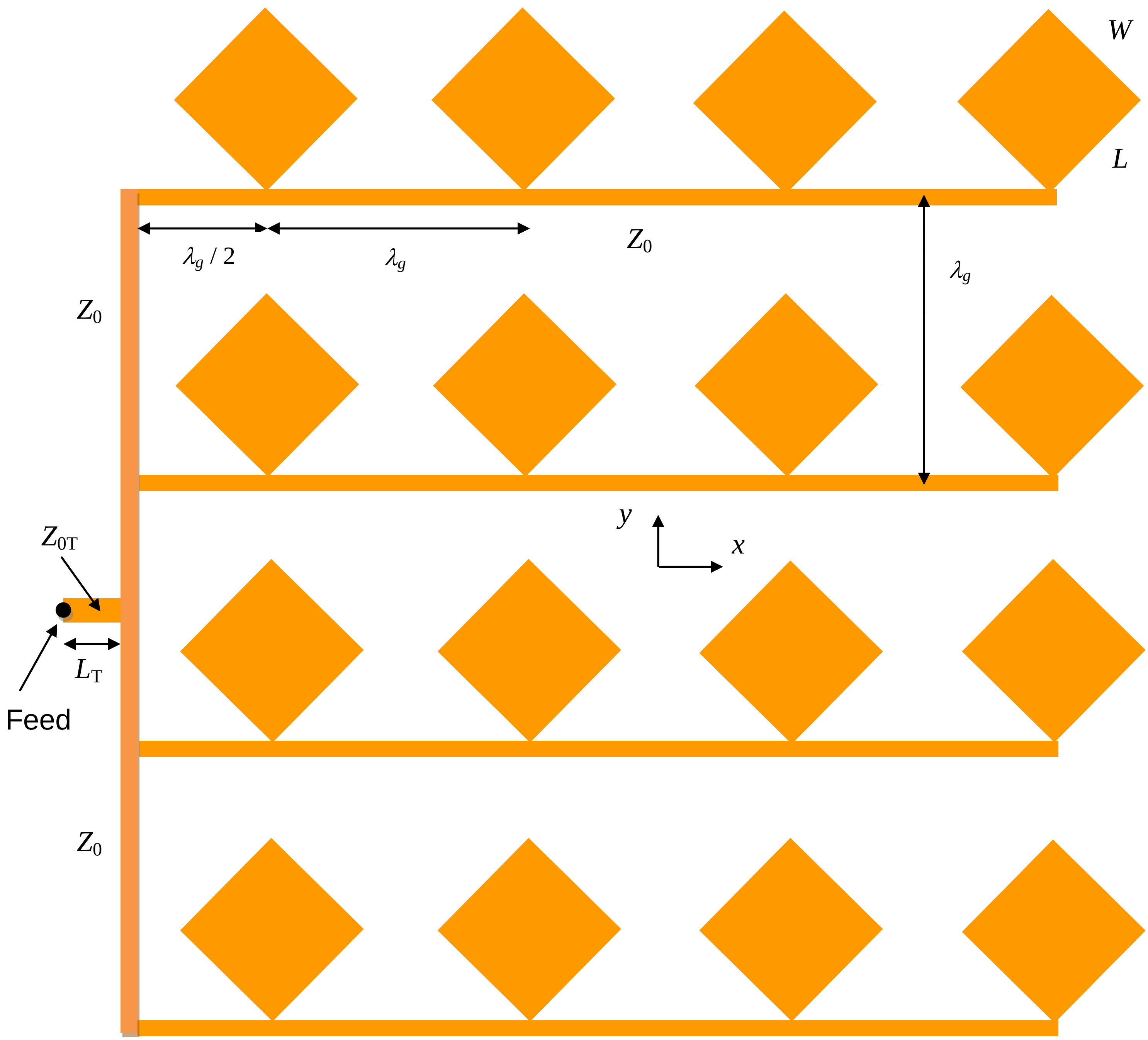
The purpose of this project is to design and analyze a 4×4 element antenna array for RHCP at 1.575 GHz. The array is shown below. Each of the 16 nearly-square patches is identical in size.

Each antenna is a nearly-square patch that is on a substrate of relative permittivity $\varepsilon_r = 2.2$ with a thickness of h = 0.1524 cm and a loss tangent of 0.001. Assume that the conductivity of the patch and ground plane metal is 3.0×10^{7} S/m.

The four patches in each row are connected by a microstrip line that has a characteristic impedance $Z_0 = 100\,\Omega$. The center-to-center spacing between patches is λ_g in both directions, where λ_g is the guided wavelength on the $Z_0 = 100\ \Omega$ line. At the left end of each row is a length of microstrip line that extends $\lambda_g / 2$ to the left of the leftmost patch feed point, and then connects to a vertical feed line that also has $Z_0 = 100\ \Omega$. There should be a 50 Ω match at the feed point, so a microstrip quarter-wave transformer is placed at the input of the array. This transformer is made from a microstrip line having a characteristic impedance $Z_{0\mathrm{T}}$ (corresponding to a width W_{T}) and length L_{T}. Assume that all transmission lines are lossless.

As part of the design process, you will need to calculate the Q of each patch. Make sure that you account for all effects (space-wave power, surface-wave power, conductor loss, and dielectric loss) when you do this. Please use the effective dimensions of the patches in the CAD formula for the Q of the patch (though it should not matter too much whether you use effective or actual dimensions).

Layout of Patch Array



PROJECT TASKS

1) Provide a complete design for the array, using the CAD formulas for the rectangular patch as the basis for the design. Give all dimensions for the patches, the microstrip line feed network, and the matching transformer. Ignore feed inductance in the design.

2) For a single RHCP patch element, oriented as shown in the array, plot the RHCP and LHCP pattern amplitudes versus angle θ in the $\phi = 0$ and $\phi = \pi / 2$ planes. Plot both patterns on the same plot, using a normalized dB scale so that the RHCP pattern is zero dB at the maximum. Plot on a polar chart, using 10 dB/division with zero dB at the outside of the chart and -40 dB at the center of the chart.

3) For the entire array, plot the RHCP and LHCP pattern amplitudes versus angle θ in the $\phi = 0$ and $\phi = \pi / 2$ planes. Plot both patterns on the same plot, using a normalized dB scale so that the RHCP pattern is zero dB at the maximum. Plot on a polar chart, using 10 dB/division with zero dB at the outside of the chart and -40 dB at the center of the chart.

4) Using CAD formulas and plot the input impedance of the single antenna vs. frequency. Using CAD formulas and transmission line theory, plot the input impedance of the entire array (seen at the input feed) vs. frequency.

NOTES

1) Microstrip line design formulas may be found in a variety of places, such as the Pozar microwave book.

2) The amplitude of the RHCP and LHCP components of the far-field pattern may be found from E_θ and E_ϕ, using the formulas developed in ECE 6340 (Notes 16). In particular, we have

$$A_{RHCP} = \frac{1}{\sqrt{2}} (E_\theta + j E_\phi)$$

$$A_{LHCP} = \frac{1}{\sqrt{2}} (E_\theta - j E_\phi) .$$

Your project should have enough derivation so that all of the steps are clearly understandable. However, you do not need to re-derive anything that was already derived in class or in ECE 6340.

EXTRA CREDIT

Feel free to do others tasks beyond those suggested above, for extra credit. For example, you may wish to use Ansoft Designer or HFSS to validate your design (single patch and/or complete array) to see if it is performing as expected (though there may be a slight shift in the optimum frequency (of best CP) from that predicted by the CAD design.

You might also wish to explore how loss in the feed network affects the results (the wavenumber and characteristic impedances for the lines now become complex).