

**ECE 6345**  
**Spring 2015**

**Homework 3**

- 1) A nearly-square microstrip antenna fed on the diagonal is designed to obtain RHCP at 1.575 GHz (the GPS L1 band). The patch is printed on a substrate with thickness  $h = 0.1524$  cm (60 mils) and  $\epsilon_r = 2.2$ . When a square antenna (also resonant at 1.575 GHz) is printed on the same substrate and fed along the centerline (to get linear polarization) the impedance bandwidth (SWR < 2) is found to be 2%. Determine the two cavity resonance frequencies  $f_x$  and  $f_y$  for the RHCP patch.
- 2) As a continuation of the above problem, design the dimensions  $L$  and  $W$  for the RHCP antenna. (Note: Use the Hammerstad formula with iteration until you are sure that you have convergence – though one iteration might be enough.)
- 3) As a continuation of the above problem, assume that when the square patch is fed along the centerline at the edge of the patch (for linear polarization), the maximum input resistance (at the cavity resonance frequency  $f_0$ ) is found to be  $R = 150$  [ $\Omega$ ]. Based on this information, determine the distance from the corner of the RHCP patch (measured along the diagonal) to put the feed for the RHCP patch, in order to get a 50 [ $\Omega$ ] match at the resonance frequency of the RHCP patch.
- 4) As a continuation of the previous problem, determine the impedance bandwidth (SWR < 2) in percent and the CP pattern bandwidth (AR < 1.414) in percent for the RHCP patch.
- 5) A linearly-polarized rectangular microstrip antenna is designed to operate at 1.575 GHz. Assume that  $W/L = 1.5$ . The patch is printed on a substrate with thickness  $h = 0.1524$  cm and  $\epsilon_r = 2.2$ . The loss tangent of the substrate is 0.001. Assume that the conductivity of the copper material of the patch and ground plane is  $3.0 \times 10^7$  S/m (this value accounts for surface roughness). Determine all of the  $Q$  values:  $Q$ ,  $Q_d$ ,  $Q_c$ ,  $Q_{sp}$ ,  $Q_{sw}$ ,  $Q_r$ , using the CAD formulas.
- 6) As a continuation of the above problem, determine the following radiation efficiencies:  $e_r$ ,  $e_r^{sw}$ ,  $e_r^{diss}$ .
- 7) Consider the same microstrip antenna as in Prob. 5, although now the substrate thickness  $h$  is a variable. Using the CAD formulas, plot the bandwidth in percent versus  $h / \lambda_0$ , assuming a fixed frequency of 1.575 GHz. Plot over a range  $0 < h/\lambda_0 < 0.05$ .
- 8) As a continuation of the previous problem, use the CAD formulas to plot the following radiation efficiencies (in percent) versus  $h/\lambda_0$ :  $e_r$ ,  $e_r^{sw}$ ,  $e_r^{diss}$ . Plot over a range  $0 < h/\lambda_0 < 0.05$ .
- 9) Consider the same microstrip antenna as in Prob. 5, fed with an SMA connector having a probe radius of 0.635 mm. Calculate the probe reactance using the parallel-plate waveguide CAD formula.

- 10) A linearly-polarized microstrip antenna is designed to have a maximum input resistance (the resistance at the cavity resonance frequency  $f_0$ ) of  $R = 50$  Ohms. What is the maximum probe reactance that is allowed before the patch cannot be made resonant (the input reactance is zero)? (Hint: Consider what the maximum height of the reactance curve is, compared with the maximum height of the resistance curve, for a general microstrip antenna.)
- 11) For the patch of Prob. 9, what is the maximum substrate thickness that can be used if the patch is to be resonant, assuming  $R = 50$  Ohms?

### Mini Project

(This problem will be worth more than a typical HW problem.)

A linearly-polarized rectangular microstrip antenna is designed to operate with  $f_0 = 1.575$  GHz (this is the cavity resonance frequency, where  $R_{in}$  is maximum) Assume that  $W/L = 1.5$ . The patch is printed on a substrate with a variable thickness  $h$  having  $\epsilon_r = 2.2$ . The loss tangent of the substrate is 0.001. The antenna is fed with an SMA connector having a probe radius of 0.635 mm. The antenna is fed at a location so that when the input impedance is real,  $Z_{in} = 50 \Omega$ . (This means that the value of  $R$  in the circuit model is larger than  $50 \Omega$ , since we have a probe reactance.)

For various values of the substrate thickness  $h$ , you can calculate  $Q$  and then calculate the input impedance using the CAD circuit model, if you know the value of  $R$ . For any given value of  $h$ , The value of  $R$  is chosen so that  $Z_{in} = 50 \Omega$  when the input impedance is real (You can find  $R$  numerically, for a given value of  $h$ .) Hence, for any given value of  $h$ , you should be able to calculate the input impedance as a function of frequency. Therefore, for any given  $h$ , you should be able to plot the bandwidth of the antenna, based on a definition of  $SWR < 2$ .

- 1) Make a plot of the percent bandwidth of the antenna vs.  $h/\lambda_0$ , where  $\lambda_0$  is the free-space wavelength at 1.575 GHz. Plot up to  $h/\lambda_0 = 0.1$ . (Note: If the probe reactance increases to the point where the SWR never becomes less than 2, the bandwidth is said to be zero.
- 2) What value of the substrate thickness  $h$  within the plotted range maximizes the bandwidth?