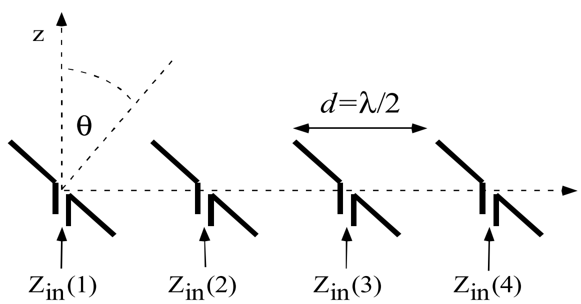
**Reading:** Balanis Chapter 6,14, plus Handouts

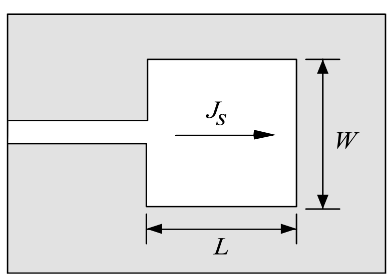
**Homework #5** **Due: Wednesday, 14 May 2003**

1) Consider the four-element phased array pictured below, using half-wave dipoles spaced at a half free-space wavelength along the $z$-axis:




Using the induced EMF theory for self- and mutual-impedances, plot the variation in driving-point impedance for each antenna as the radiation pattern is scanned from the broadside through endfire positions. Assume that the array is uniformly fed, so that the excitation currents differ only by a constant phase gradient. Note that you only have to compute the impedance matrix for this 4-port *once*, and that there is a nice symmetry that can be exploited.

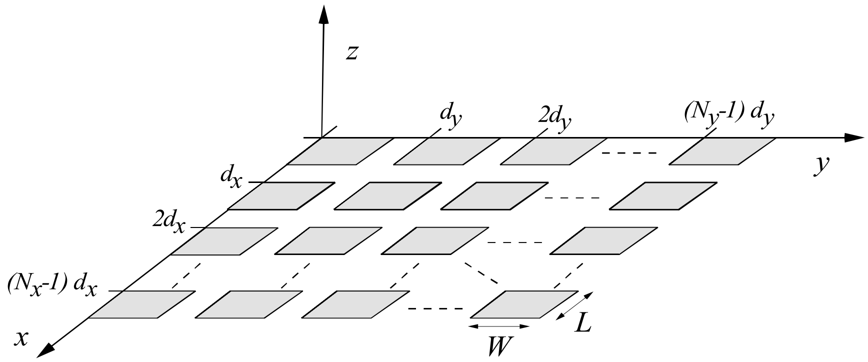
2) Design a microstrip patch antenna for operation at a frequency of 4 GHz (C-band satellite down-link) using a standard Teflon substrate ($\epsilon_r \approx 2.2$) of thickness 1.575 mm. Account for the effective length extension due to fringing (or fringing capacitance). Using the transmission-line model (fig. 14-8b in Balanis) and your knowledge of transmission-line theory, make a plot of input impedance versus frequency in the vicinity of the first resonance if the patch is fed from a radiating edge; your answer should resemble fig. 14.27. Account for both the self and mutual conductance of the two radiating edges in your model, using (14-12) and (14-18a). Note: equation 14-20 in Balanis only applies exactly at resonance!




Plot the E-plane and H-plane patterns at the center frequency for the patch antenna designed above, and calculate the directivity (remember, the patch only radiates into a half-space).

3) Directivity calculations are an extremely important part of array analysis, and usually must be done numerically (analytic expressions for array directivities can be obtained only for very simple antennas, such as isotropic radiators and Hertzian dipoles, and simple array geometries and excitation coefficients). Write a short Mathematica, MatLab, or MathCAD program to compute the directivity of a two-dimensional patch antenna array lying in the $x$-$y$ plane as shown

below.




There are $N_x$ elements uniformly spaced by $d_x$ in the $x$-direction, and $N_y$ elements uniformly spaced by $d_y$ in the $y$-direction. Each patch has a resonant length $L$ in the $x$-direction, and width $W$ in the $y$-direction. Assume uniform phase progressions of $\Delta\phi_x$ and $\Delta\phi_y$ in the $x$ and $y$ directions, respectively. Use the same patch pattern that you used in the previous assignment. Although not as accurate as the numerical integration routines built into the math programs, it is usually simpler to use a crude numerical approximation to the integral as follows

$$\oiint P(\theta, \phi) \sin\theta \, d\theta \, d\phi \approx \sum_i \sum_j P(\theta_i, \phi_j) \sin\theta_i \, \Delta\theta \, \Delta\phi$$

Use your program to compute the directivity of a <u>broadside</u> array with $N_x = 3$, $N_y = 6$, $d_x = 2.38\,\text{cm}$, $d_y = 2.20\,\text{cm}$, $L = 0.85\,\text{cm}$, and $W = 1.45\,\text{cm}$, operating at $11.0\,\text{GHz}$. The patches are on a $0.787\,\text{mm}$ Duroid substrate with $\epsilon_r = 2.2$.