

Lecture-4

D. Conductance:

Each radiating slot of the microstrip patch is represented by a parallel equivalent admittance Y (with conductance G and susceptance B). The equivalent circuit is shown in the fig .5.11.

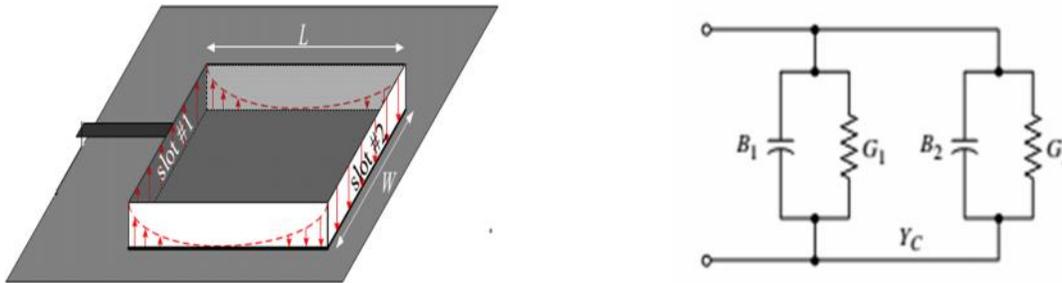


Fig.5.11 Rectangular microstrip patch and its equivalent circuit transmission-line model.

The equivalent admittance of slot #1 is

$$Y_1 = G_1 + jB_1$$

G_1 and B_1 for a slot of finite width W can be given by:

$$\begin{aligned} G_1 &= \frac{W}{120} \left[1 - \frac{1}{24} (k_o h)^2 \right] \quad \frac{h}{\lambda_o} < 0.10 \\ B_1 &= \frac{W}{120} \left[1 - 0.636 \ln(k_o h) \right] \quad \frac{h}{\lambda_o} < 0.10 \end{aligned} \quad (5.5)$$

Since slot #2 is identical to slot #1, its equivalent admittance is

$$Y_1 = Y_2, G_1 = G_2 \text{ and } B_1 = B_2$$

More accurate values for the conductance G can be obtained using the cavity model. In general, the conductance:

$$G_1 = \frac{I_1}{120f^2} \quad (5.6)$$

where

$$I_1 = \int \left[\frac{\sin\left(\frac{k_0 W}{2} \cos \theta_n\right)}{\cos \theta_n} \right]^2 \sin^3 \theta_n d\theta_n = -2 + \cos(X) + X \cdot Si(X) + \frac{\sin(X)}{X} \quad (5.7)$$

$$X = k_0 W, k_0 = w \sqrt{-\epsilon_0 \epsilon_0}$$

which finally gives:

$$G_1 = \left\{ \begin{array}{ll} \frac{1}{90} \left(\frac{W}{\lambda_0} \right)^2 & W \ll \lambda_0 \\ \frac{1}{120} \left(\frac{W}{\lambda_0} \right) & W \gg \lambda_0 \end{array} \right\} \quad (5.8)$$

E. Resonant Input Resistance

The total admittance at slot #1 (input admittance) is obtained by transferring the admittance of slot #2 from the output terminals to input terminals using the admittance transformation equation of transmission lines. (see Fig. 5.12)

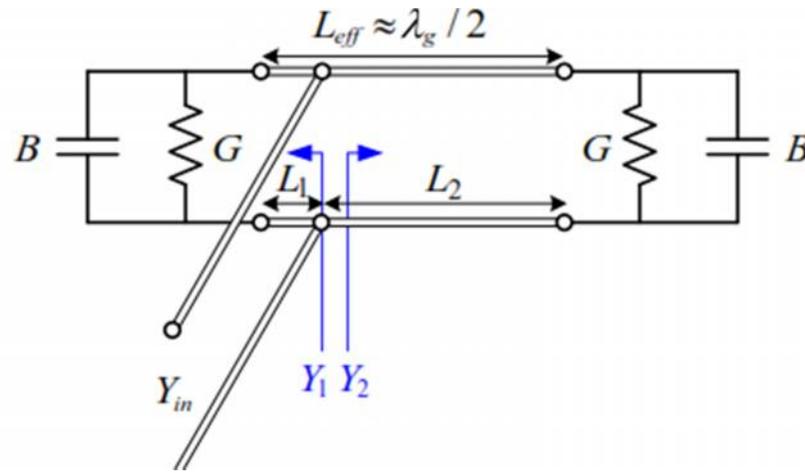


Fig.5.12 Transmission line equivalent of microstrip patch

Using the transmission line theory, the admittance transformation is given by

$$Y_{in} = Y_c \frac{Y_L + jY_c \tan(S_g L)}{Y_c + jY_L \tan(S_g L)} = Y_L \Bigg|_{S_g L = f} ; Y_c = Z_c^{-1} \quad (5.9)$$

Ideally the two slots should be separated by $\lambda/2$, where λ is the wavelength in the dielectric (substrate). However, because of fringing, the length of the patch is electrically longer than the actual length. Therefore the actual separation of the two slots is slightly less than $\lambda/2$ (typically $0.48\lambda < L < 0.49\lambda$), the transformed admittance of slot #2 becomes

$$Y_2 = G_2 + jB_2 = G_1 - jB_1 \quad (5.10)$$

or

$$G_2 = G_1 \quad B_2 = -B_1$$

Therefore the total resonant input admittance is real and is given by

$$Y_{in} = Y_1 + Y_2 = 2G_1 \quad (5.11)$$

Since the total input admittance is real, the resonant input impedance is also real, or

$$Z_{in} = \frac{1}{Y_{in}} = R_{in} = \frac{1}{2G_1} \quad (5.12)$$

In reality, there is some mutual influence between the two slots, described by a mutual conductance and it should be included for more accurate calculations:

$$R_{in} = \frac{1}{2(G_1 \pm G_{12})} \quad (5.13)$$

where the plus (+) sign relates to the odd modes, while the minus (-) sign is used for even modes. For typical microstrip antennas, the mutual conductance obtained is small compared to the self conductance G_1 .

The input resistance is not strongly dependent upon the substrate height h . In fact for very small values of h (thin substrate), such that $k_0 h \ll 1$, the input resistance is not dependent on h . It is apparent from (5.5) and (5.13) that the resonant input resistance can be decreased by increasing the width W of the patch.

The resonant input resistance, as calculated by (5.16), is referenced at slot #1. However, it has been shown that the resonant input resistance can be changed by using an inset feed, recessed a distance y_0 from slot #1, as shown in Fig. 5.13. This technique can be used effectively to match the patch antenna using a microstrip-line feed whose characteristic impedance is given in equation (5.14)

$$Z_c = \begin{cases} \frac{60}{\sqrt{\epsilon_{\text{reff}}}} \ln \left[\frac{8h}{W_0} + \frac{W_0}{4h} \right], & \frac{W_0}{h} \leq 1 \\ \frac{120f}{\sqrt{\epsilon_{\text{reff}} \left[\frac{W_0}{h} + 1.393 + 0.667 \ln \left(\frac{W_0}{h} + 1.444 \right) \right]}}, & \frac{W_0}{h} > 1 \end{cases} \quad (5.14)$$

where W_0 is the width of the microstrip line, as shown in Fig. 5.13.

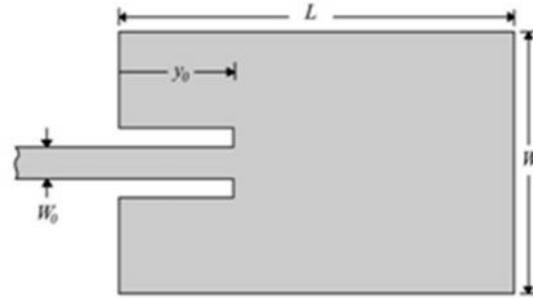


Fig.5.13 Microstrip-line feed

Using modal-expansion analysis, the input resistance for the inset feed is given approximately by

$$R_{in}(y = y_0) = \frac{1}{2(G_1 \pm G_{12})} \left[\cos^2\left(\frac{f}{L} y_0\right) + \frac{G_1^2 + B_1^2}{Y_c^2} \sin^2\left(\frac{f}{L} y_0\right) - \frac{B_1}{Y_c} \sin\left(\frac{2f}{L} y_0\right) \right] \quad (5.15)$$

where $Y_c = 1/Z_c$

Since for most typical microstrips $G_1/Y_c \gg 1$ and $B_1/Y_c \ll 1$, so

$$\begin{aligned} R_{in}(y = y_0) &= \frac{1}{2(G_1 \pm G_{12})} \cos^2\left(\frac{f}{L} y_0\right) \\ &= R_{in}(y = 0) \cos^2\left(\frac{f}{L} y_0\right) \end{aligned} \quad (5.16)$$

A plot of the normalized value of (5.19) is shown in Fig. 5.14.

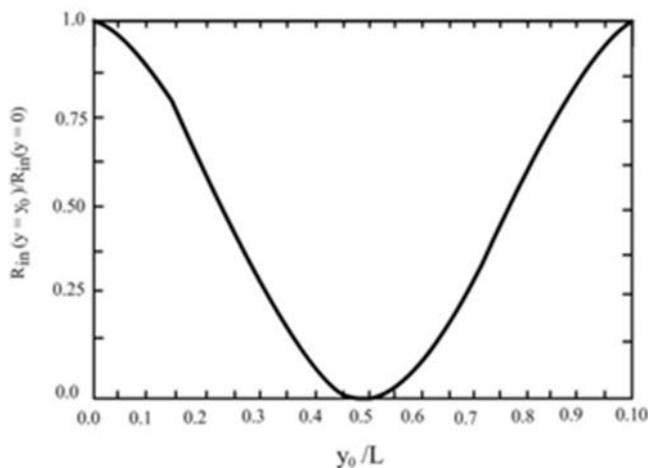


Fig.5.14 Normalized input resistance

It is apparent from (5.16) and Fig. 5.14 that the maximum value occurs at the edge of the slot ($y_0 = 0$) where the voltage is maximum and the current is minimum; the minimum value (zero) occurs at the center of the patch ($y_0 = L/2$), where the voltage is zero and the current is maximum. As the inset feed point moves from the edge toward the center of the patch the resonant input impedance decreases monotonically and reaches zero at the center.