Benha University	**Antennas &Wave Propagation**	**Electrical Eng. Dept.**
Faculty of Engineering		**4th year communication**
Shoubra	PART2_SHEET (5)	**2020-2021**

1. Design a rectangular microstrip patch antenna, based on the dominant mode, the desired center frequency is 1.6GHz, the dielectric constant of the substrate is 10.2(i.e. RT/duroid) and the thickness of the substrate is 0.127 cm. determine:

a. Dimension of rectangular patch in cm
b. Resonant input impedance, assume no coupling between two radiating slots
c. If there is coupling and mutual conductance between two slots G12=3.92904×10^{-4}, find resonant input impedance
d. Position of the feed to match the antenna patch to 75 ohm line.

2. Repeat the design for question 1 using substrate with a dielectric constant of 2.2 (i.e. RT/duroid 5880) and with height 0.1575 cm. the mutual conductance between two slots equals 4.58053×10^{-4} are the new dimensions of the patch realistic for the roof of personal car?

3. A rectangular microstrip patch antenna operating at 10 GHz with substrate with dimensions of length L=0.497cm width w=0.634 cm and substrate height h=0.127 cm. it is desired to feed the patch using a probe feed. Neglecting mutual coupling calculate:

a. Input impedance of the patch
b. The feed position from one of the radiating patch edges so the input impedance is 50 ohms?

Giving Formulas:

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + \frac{12h}{W}\right]^{-1/2}$$

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{reff} + 0.3)(\frac{W}{h} + 0.264)}{(\varepsilon_{reff} - 0.258)(\frac{W}{h} + 0.8)}$$

$$G_1 = \frac{1}{120\pi^2}\int_0^{\pi}\left[\frac{\sin(\frac{WK_0}{2}\cos\theta)}{\cos\theta}\right]^2 \sin^3\theta \, d\theta$$

GOOD LUCK *Dr. Gehan Sami*

14-3 a. Using (14-6), the width of the patch is

$$W = \frac{30}{2(1.6)}\sqrt{\frac{2}{10.2+1}} = 3.962 \text{ cm}$$

$$\epsilon_{reff} = \frac{10.2+1}{2} + \frac{10.2-1}{2}\left[1+12\cdot\left(\frac{0.127}{3.962}\right)\right]^{-1/2} = 9.51$$

$$\Delta L = (0.127)(0.412)\frac{(9.51+0.3)}{(9.51-0.3)}\cdot\frac{\left(\frac{3.962}{0.127}+0.264\right)}{\left(\frac{3.962}{0.127}+0.8\right)} = 0.05455 \text{ cm}$$

$$L = \frac{\lambda}{2} - 2\Delta L = \frac{30}{2(1.6)\sqrt{9.51}} - 2(0.05455) = 2.931 \text{ cm}$$

b. Using (14-12) and (14-12a)

$$G_1 = \frac{I_1}{120\pi^2}, \quad I_1 = -2+\cos(X)+XS_i(X)+\frac{\sin(X)}{X}, \quad X = k_0 W$$

$$X = \frac{2\pi}{\lambda_0}\cdot W = \frac{2\pi}{18.75}(3.962) = (0.4226)\cdot\pi = 1.3277$$

$$I_1 = -2+\cos(1.3277)+(1.3277)(1.204348)+\frac{\sin(1.3277)}{1.3277}$$

$$= 0.57075$$

$$G_1 = 0.57075/(120\cdot\pi^2) = 4.81916\times10^{-4} \text{ Siemens}$$

Resonant input impedance, $R_{in} = Z_{in} = \frac{1}{2G_1} = 1.0375\times10^3 = 1037.5$ ohms

Direct numerical calculation from (14-12) results into

$$G_1 = 4.819021\times10^{-4}, \quad R_{in} = \frac{1}{2G_1} = 1037.56 \text{ ohms}$$

C. Numerical calculation from (14-18a)

$$G_{12} = 3.92904\times10^{-4}$$

d. $$R_{in} = \frac{1}{2(G_1 \pm G_2)} = \frac{1}{2(4.819+3.929)\times10^{-4}} = 571.56 \text{ ohms}$$

e. $$R_{in}(y=y_0) = R_{in}(y=0)\cos^2\left(\frac{\pi}{L}y_0\right)$$

$$75 = 571.56\cos^2\left(\frac{\pi}{2.931}\cdot y_0\right)$$

$$y_0 = 1.1197 \text{ cm } (0.4408 \text{ inch})$$

14-4 a. $W = \frac{30}{2(1.6)}\sqrt{\frac{2}{2.2+1}} = 7.412\ cm$

$$\epsilon_{reff} = \frac{2.2+1}{2} + \frac{2.2-1}{2}\left[1 + 12\left(\frac{0.1575}{7.412}\right)\right]^{-1/2} = 2.1356$$

$$\Delta L = (0.1575)(0.412)\frac{2.1356+0.3}{2.1356-0.258}\frac{\frac{7.412}{0.1575}+0.264}{\frac{7.412}{0.1575}+0.8} = 0.0832\ cm$$

$$L = \frac{\lambda}{2} - 2\Delta L = \frac{30}{2(1.6)\sqrt{2.1356}} - 2(0.0832) = 6.2487\ cm$$

∴ The Patch is a realistic dimension for the roof of a personal car.

b. From (14-12), with numerical calculation

$G_1 = 1.57259 \times 10^{-3}$, $R_{in} = \frac{1}{2G_1} = 317.95$ ohms

c. Using (14-18a), $G_{12} = 4.58053 \times 10^{-4}$

d. $R_{in} = \frac{1}{2(G_1+G_{12})} = \frac{1}{2(1.57259\times10^{-3} + 4.58053\times10^{-4})} = 246.23$ ohms

e. $R_{in}(y=y_0) = R_{in}(y=0)\cdot\cos^2\left(\frac{\pi}{L}y_0\right)$

$$75 = 246.23\cdot\cos^2\left(\frac{\pi}{6.2487}y_0\right)$$

$y_0 = 1.9615$ cm (0.7722 inch)

14-9. $W = 0.634$ cm, $L = 0.4097$ cm, $h = 0.127$ cm, $f = 10$ GHz, $\epsilon_r = 10.2$

a. Using (14-12) and (14-12a), $G_1 = 4.82 \times 10^{-4}$ Siemens

which compares with $G_1 = 0.00175592$, $R_{in} = \frac{1}{2G_1} = 1037.30084$

b. $50 = 1037.30084\cdot\cos^2\left(\frac{\pi}{L}y_0\right)$

$$\cos\left(\frac{\pi}{L}y_0\right) = \sqrt{\frac{50}{1037.30084}} = 0.21955$$

$\frac{\pi}{L}y_0 = \cos^{-1}(0.21955) = 1.3494$. ∴ $y_0 = 0.1759$