For the rectangular microstrip antenna of part 1), compute the maximum directivity using both methods discussed in class. Compare the results and discuss any differences. Also, compute the *estimated* half-power beamwidths (HPBW) in the E- and H-planes.

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Design a rectangular microstrip antenna to operate at the center frequency of UHF TV channel 16 on a polystyrene substrate- assume h = 0.5", 2 oz. copper cladding (68 μm), loss tangent tan(δ) = 0.00013, and a relative dielectric constant $\varepsilon_r = 2.6$. The antenna is to be matched to a 75 Ω microstrip transmission line on this substrate. Discuss and justify design choices. Accurately sketch top view of final design (all dimensions in cm).

EE 583 only- Include a fully-labeled Smith chart showing $y_1 = y_2$ and y_{2t} (i.e., y_2 translated across length $L + \Delta L$ of microstrip antenna) and discuss results.

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Summary of necessary dimensions & parameters from design-

h = 0.5" = 1.27 cm, f_r = 485 MHz

Free space wavelength **λ_0 = 61.813 cm** and wave number **k_0 = 10.165 rad/m**.

Patch width ⇒ **W = 23.036 cm**

effective length of patch ⇒ **L_{eff} = 19.865 cm**

Patch length ⇒ L = 18.586 cm

Slot conductance ⇒ **G_1 = 1.4136 mS**.

mutual conductance between the slots ⇒ **G_{12} = 0.5627 mS**

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Find directivity (All calculations done using full precision of MathCad)

Both methods assume $k_0 h \ll 1$. Here, $k_0 h = 10.165(0.0127) = 0.129 \ll 1$ (fair/OK).

Method 1

Find parameter I_2 (14-55a) by numerical integration-

$$I_2 = \int_{\phi=0}^{\pi}\int_{\theta=0}^{\pi}\left[\frac{\sin\left(\frac{k_0 W}{2}\cos\theta\right)}{\cos\theta}\right]^2 \sin^3\theta\cos^2\left(\frac{k_0 L_{eff}}{2}\sin\theta\sin\phi\right)d\theta\, d\phi$$

$$= \int_{\phi=0}^{\pi}\int_{\theta=0}^{\pi}\left[\frac{\sin\left(\frac{10.165(0.2304)}{2}\cos\theta\right)}{\cos\theta}\right]^2 \sin^3\theta\cos^2\left(\frac{10.165(0.19865)}{2}\sin\theta\sin\phi\right)d\theta\, d\phi$$

⇒ $I_2 = 3.498893$.

The maximum directivity $D_{\max,1}$ (14-55) from method 1 is

$$D_{\max,1}^{\text{tot}} = \left(\frac{2\pi W}{\lambda_0}\right)^2 \frac{\pi}{I_2} = \left(\frac{2\pi \bullet 23.036}{61.813}\right)^2 \frac{\pi}{3.49889} \quad \Rightarrow \quad \underline{\mathbf{D_{\max,1} = 4.92319 = 6.922\ dBi}}$$

Method 2

Find parameter I_1 (14-53a) by numerical integration-

$$I_1 = \int_{\theta=0}^{\pi} \left[\frac{\sin\left(\frac{k_0 W}{2}\cos\theta\right)}{\cos\theta}\right]^2 \sin^3\theta \, d\theta = \int_{\theta=0}^{\pi} \left[\frac{\sin\left(\frac{10.165(0.2304)}{2}\cos\theta\right)}{\cos\theta}\right]^2 \sin^3\theta \, d\theta$$

$\Rightarrow$ $\underline{I_1 = 1.67308}$.

The maximum directivity of a single rectangular slot (14-53) is

$$D_{\max} = D_0 = \left(\frac{2\pi W}{\lambda_0}\right)^2 \frac{1}{I_1} = \left(\frac{2\pi \bullet 23.036}{61.813}\right)^2 \frac{1}{1.67308} \quad \Rightarrow \quad \underline{D_0 = 3.27726}.$$

The maximum directivity $D_{\max,2}$ (14-56) from method 1 is

$$D_{\max,2}^{\text{tot}} = D_0 \left(\frac{2}{1 + G_{12}/G_1}\right) = 3.27726 \left(\frac{2}{1 + 0.5627/1.4136}\right) \quad \Rightarrow \quad \underline{\mathbf{D_{\max,2} = 4.6884 = 6.710\ dBi}}$$

Methods 1 & 2 agree to within ~0.212 dB!

Find estimated half-power beamwidths (HPBW) in E- & H-planes (14-58) & (14-59)

$$\Theta_E \simeq 2\sin^{-1}\sqrt{\frac{7.03\lambda_0^{\,2}}{4\pi^2\left(3L_{\text{eff}}^{\,2} + h^2\right)}} = 2\sin^{-1}\sqrt{\frac{7.03(61.813)^2}{4\pi^2\left(3(19.865)^2 + 1.27^2\right)}}$$

$\Rightarrow$ $\underline{\mathbf{HPBW_E = \Theta_E = 98.505°}}$.

and

$$\Theta_H \simeq 2\sin^{-1}\sqrt{\frac{1}{2 + k_0 W}} = 2\sin^{-1}\sqrt{\frac{1}{2 + 10.165(0.2304)}} \quad \Rightarrow \quad \underline{\mathbf{HPBW_H = \Theta_H = 57.361°}}.$$