Patch Antenna Design

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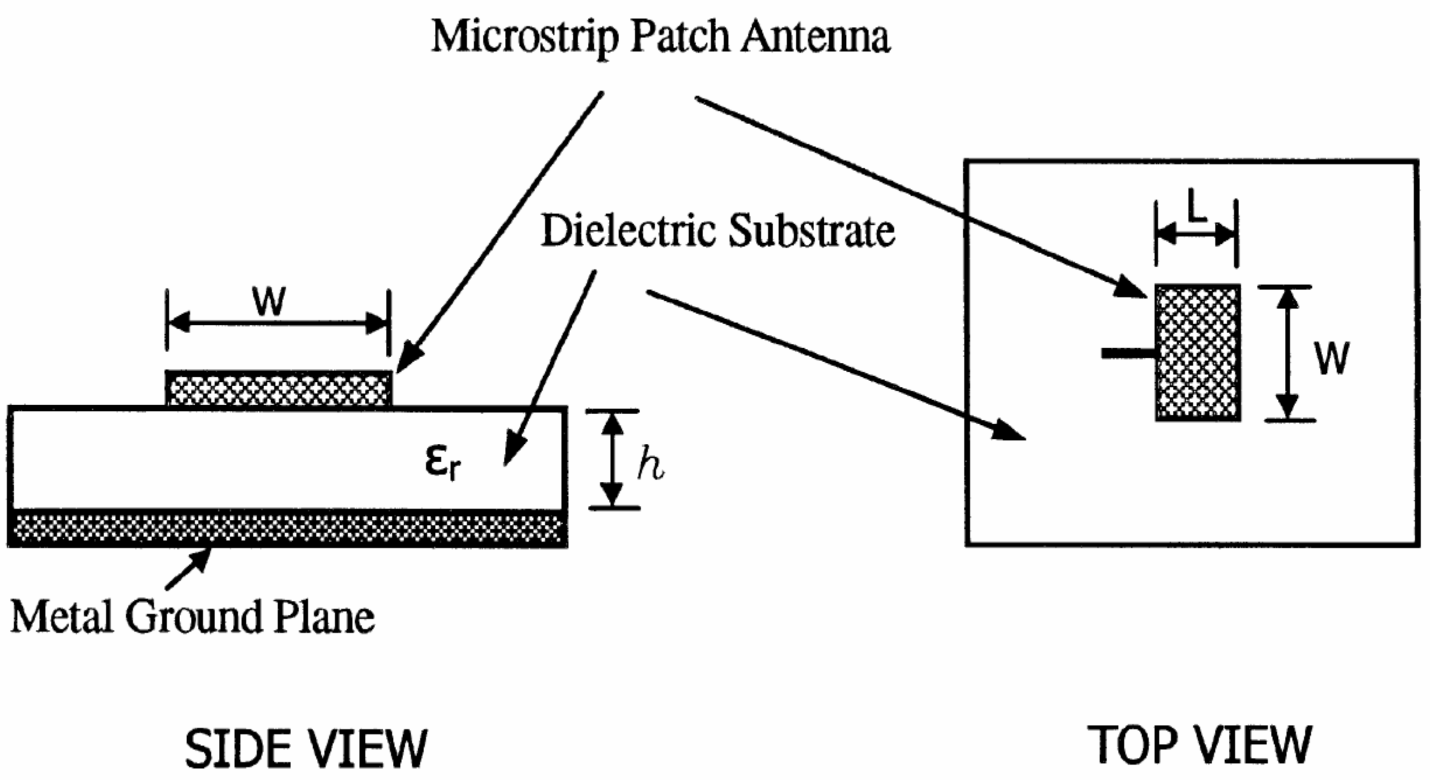
H. Miranda

Patch Antenna Characteristics

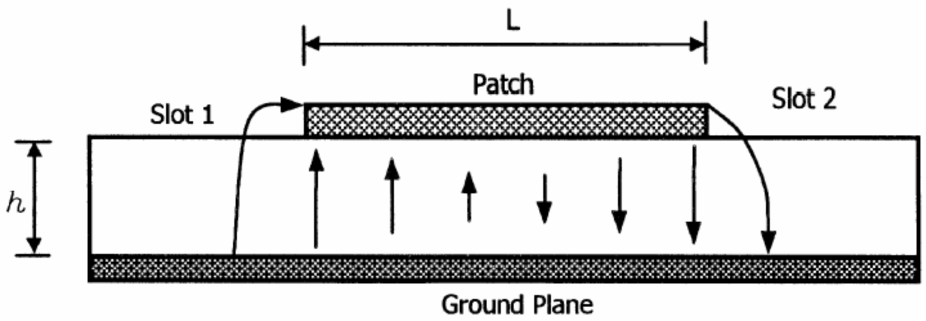
- Advantages
  - Compact
  - Conformal
  - Good efficiency
  - Easy to produce arrays
- Disadvantages
  - Very narrow band
  - Non omnidirectional patterns

Antenna Layout



$$h < 0.02\ \lambda_g$$

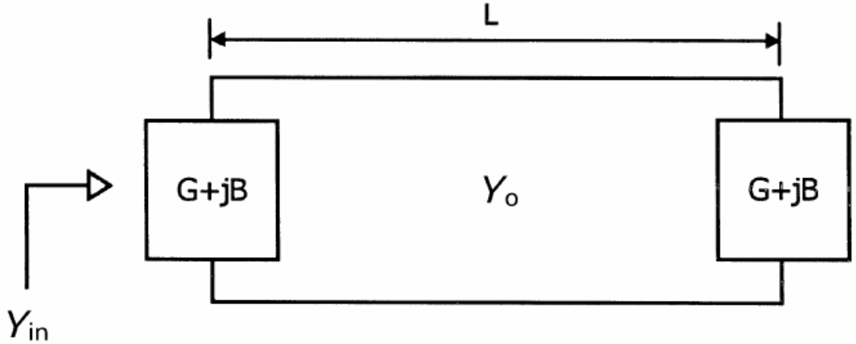
Equivalent Circuit



RADIATING PATCH ANTENNA

$$G = \frac{W^2}{90\lambda_0^2} \quad \text{for } W < \lambda_0$$

$$G = \frac{W}{120\lambda_0} \quad \text{for } W > \lambda_0$$



EQUIVALENT CIRCUIT

$$B = \frac{k_0 \, \Delta l \sqrt{\varepsilon_{\text{eff}}}}{Z_0}$$

$$Y_{\text{in}} = Y_{\text{slot}} + Y_0 \frac{Y_{\text{slot}} + jY_0 \tan \beta(L + 2\,\Delta l)}{Y_0 + jY_{\text{slot}} \tan \beta(L + 2\,\Delta l)}$$

Design Equations

$$Z_0 = \frac{120\pi h}{W\sqrt{\varepsilon_{\text{eff}}}}$$

$$\varepsilon_{\text{eff}} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{12h}{W}\right)^{-1/2}$$

$$\Delta l = 0.412h\left(\frac{\varepsilon_{\text{eff}} + 0.3}{\varepsilon_{\text{eff}} - 0.258}\right)\frac{(W/h) + 0.264}{(W/h) + 0.8}$$

$$f_r = \frac{c}{2\sqrt{\varepsilon_{\text{eff}}}(L + 2\ \Delta l)}$$

$$(L + 2\ \Delta l) = \frac{\lambda_g}{2} = \frac{\lambda_0}{2\sqrt{\varepsilon_{\text{eff}}}}$$

$$W = \frac{c}{2f_r}\left(\frac{\varepsilon_r + 1}{2}\right)^{-1/2}$$ (not critical)

Example: 3 GHz Antenna

- Substrate: Duroid 5880 (ε_r = 2.2, h=30 mils)

$$\lambda_0 = \frac{c}{f_r} = 10 \text{ cm}$$

$$W = \frac{c}{2f_r}\left(\frac{\varepsilon_r + 1}{2}\right)^{-1/2} = 3.95 \text{ cm}$$

$$\varepsilon_{\text{eff}} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + \frac{12h}{W}\right]^{-1/2} = 2.14$$

$$\Delta l = 0.412h\left(\frac{\varepsilon_{\text{eff}} + 0.3}{\varepsilon_{\text{eff}} - 0.258}\right)\left(\frac{W/h + 0.264}{W/h + 0.8}\right) = 0.04 \text{ cm}$$

$$L = \frac{c}{2f_r\sqrt{\varepsilon_{\text{eff}}}} - 2\,\Delta l = 3.34 \text{ cm}$$

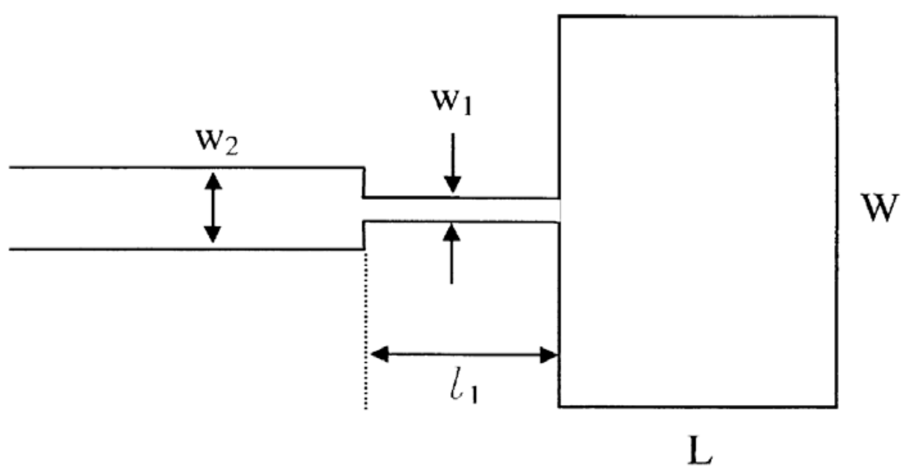
Example

$$Y_{\text{in}} = 2G = \frac{1}{45}\frac{W^2}{\lambda_0^2} = \frac{1}{R_{\text{in}}}$$

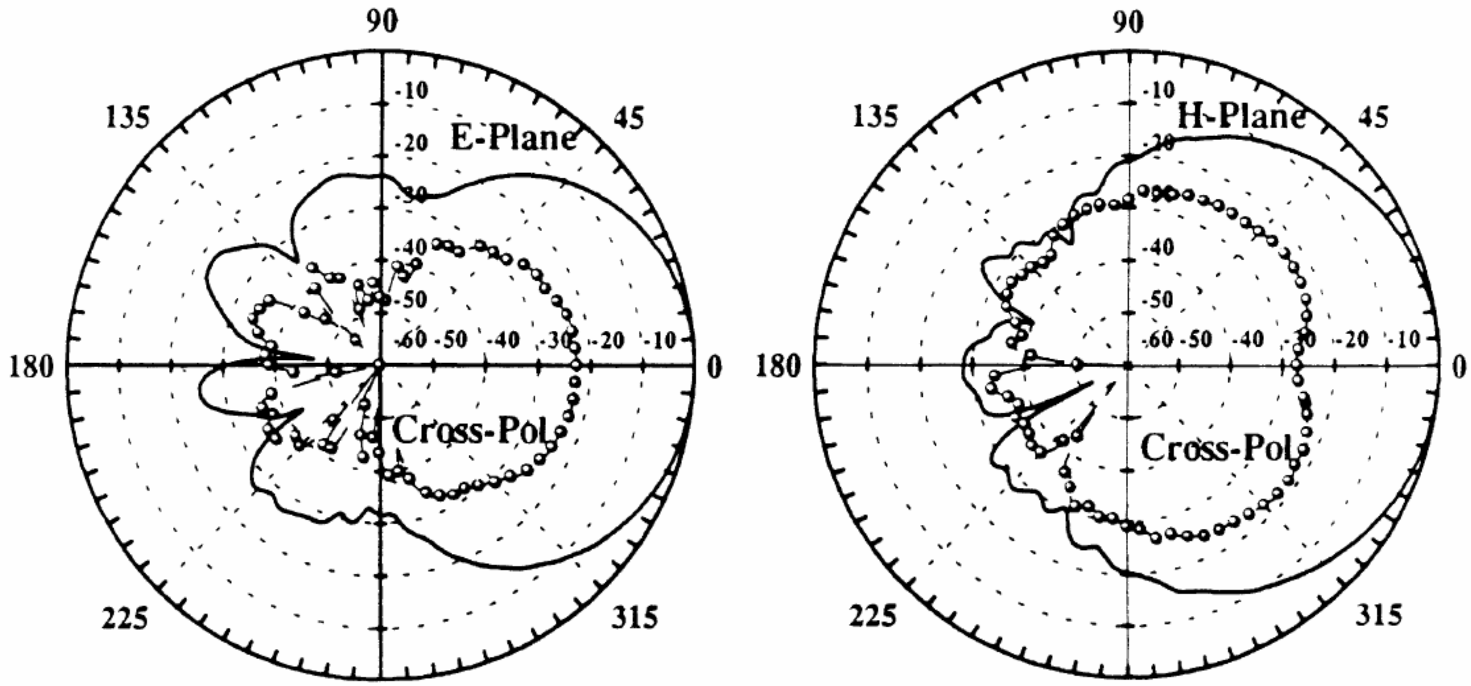
$$R_{\text{in}} = 288\ \Omega = \text{input impedance}$$

$$Z_{0T} = \sqrt{R_{\text{in}} \times 50} = 120\ \Omega$$

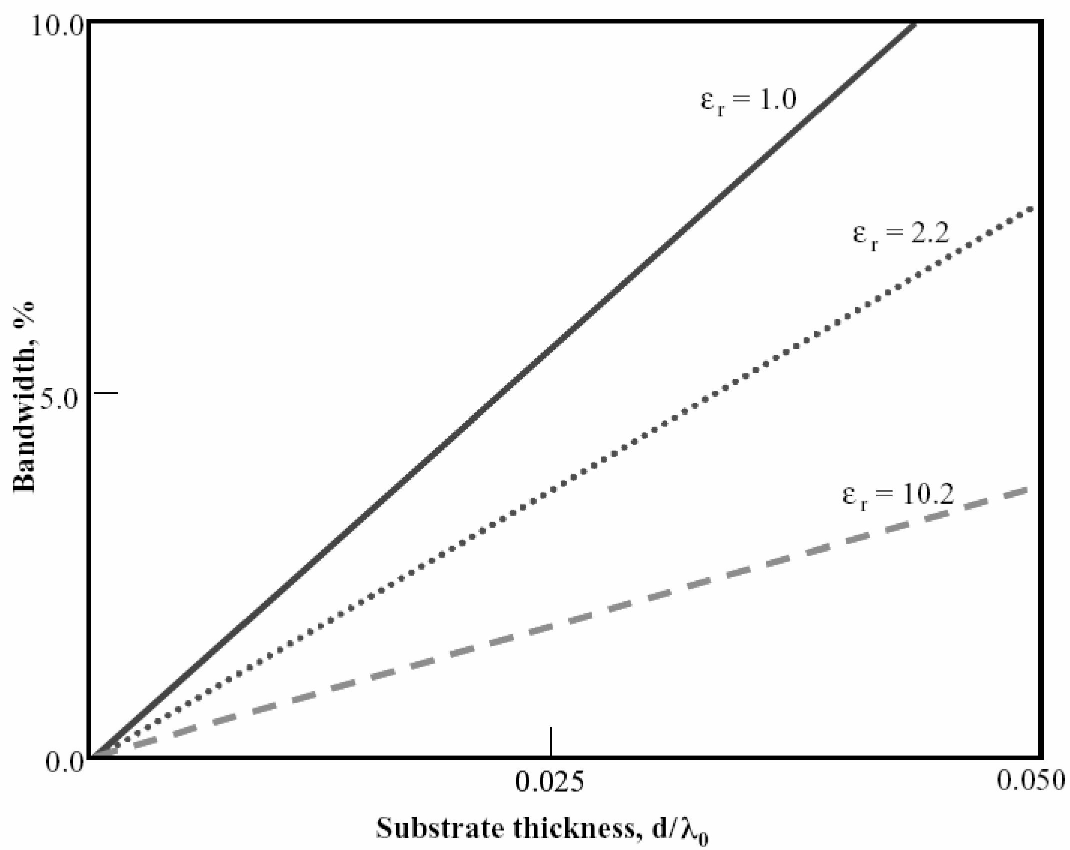
$$w_1 = 0.0442\ \text{cm} \qquad l_1 = \tfrac{1}{4}\lambda_{g1} = 1.90\ \text{cm}$$



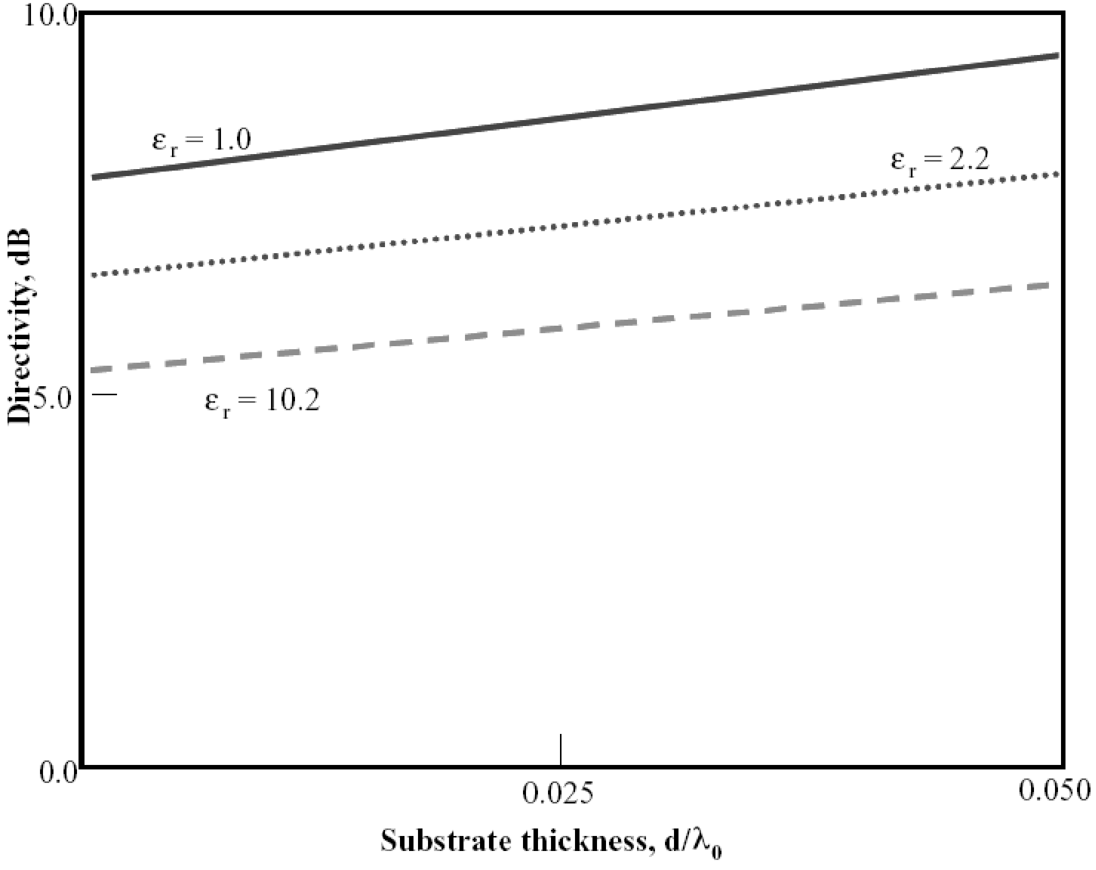
Radiation Patterns



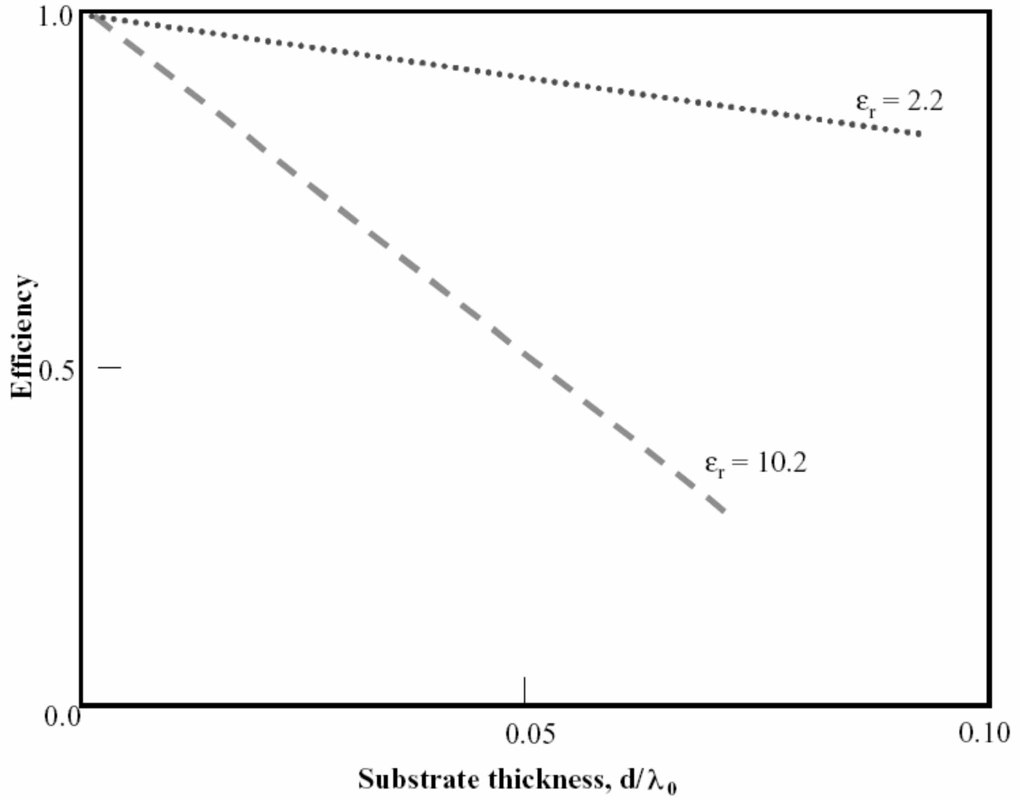
Bandwidth performance



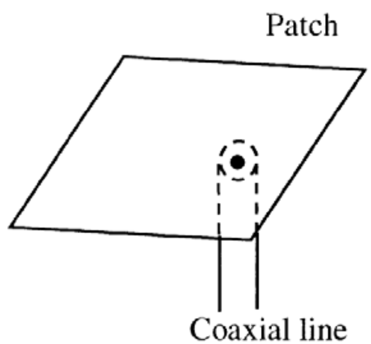
Directivity performance



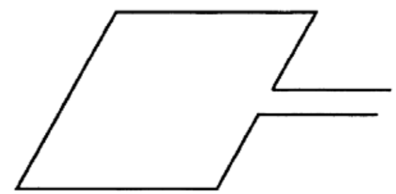
Efficiency performance



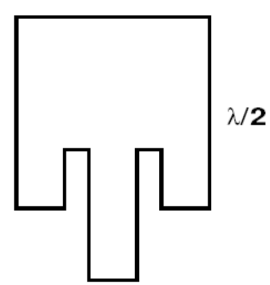
Other Feeding Methods



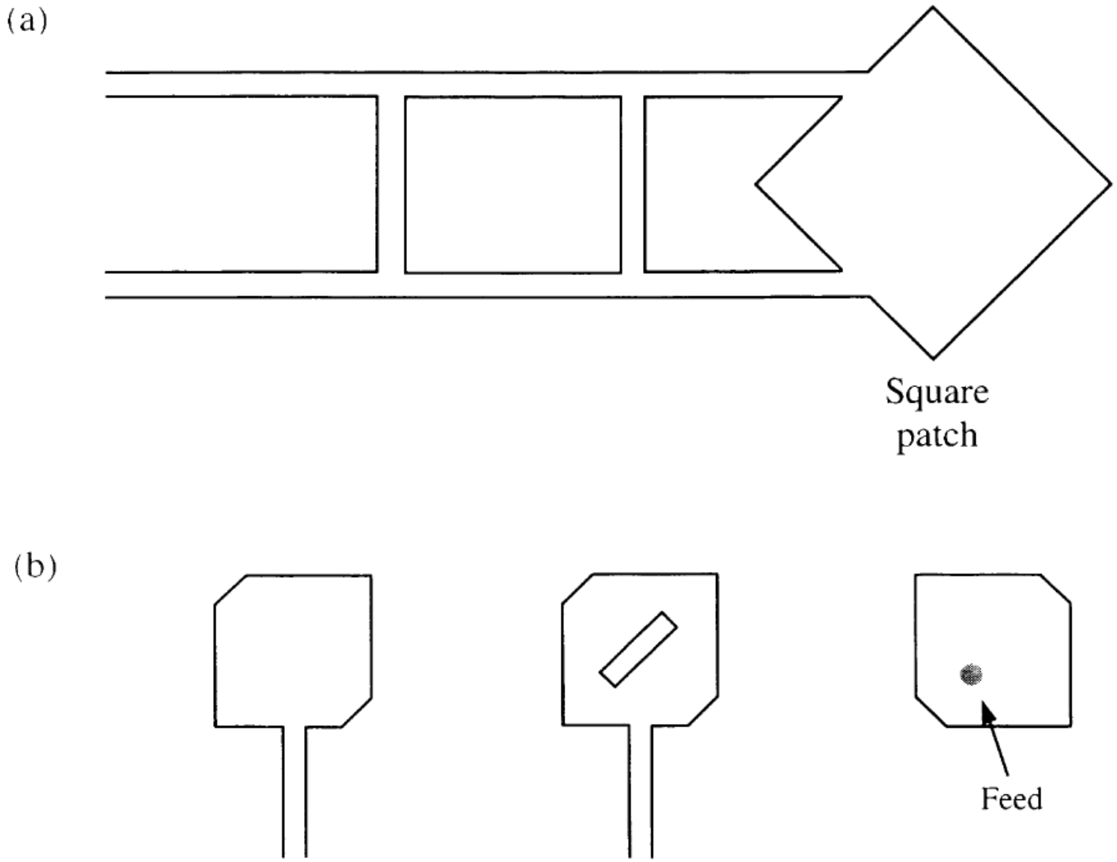
Probe Feed via Hole



Microstrip-Line Edge Feed



Circular Polarization



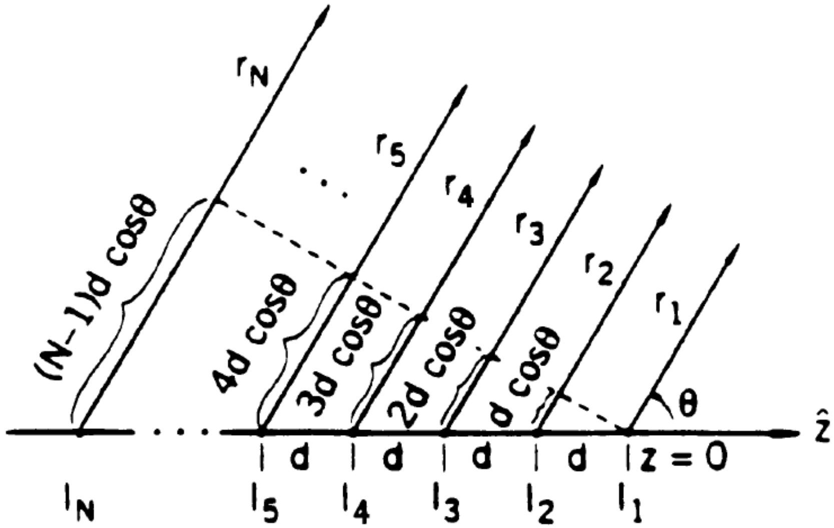
Phased arrays

Far Field Amplitude Variations

$$r_1 = r_2 = r_3 = \cdots = r_N = r$$

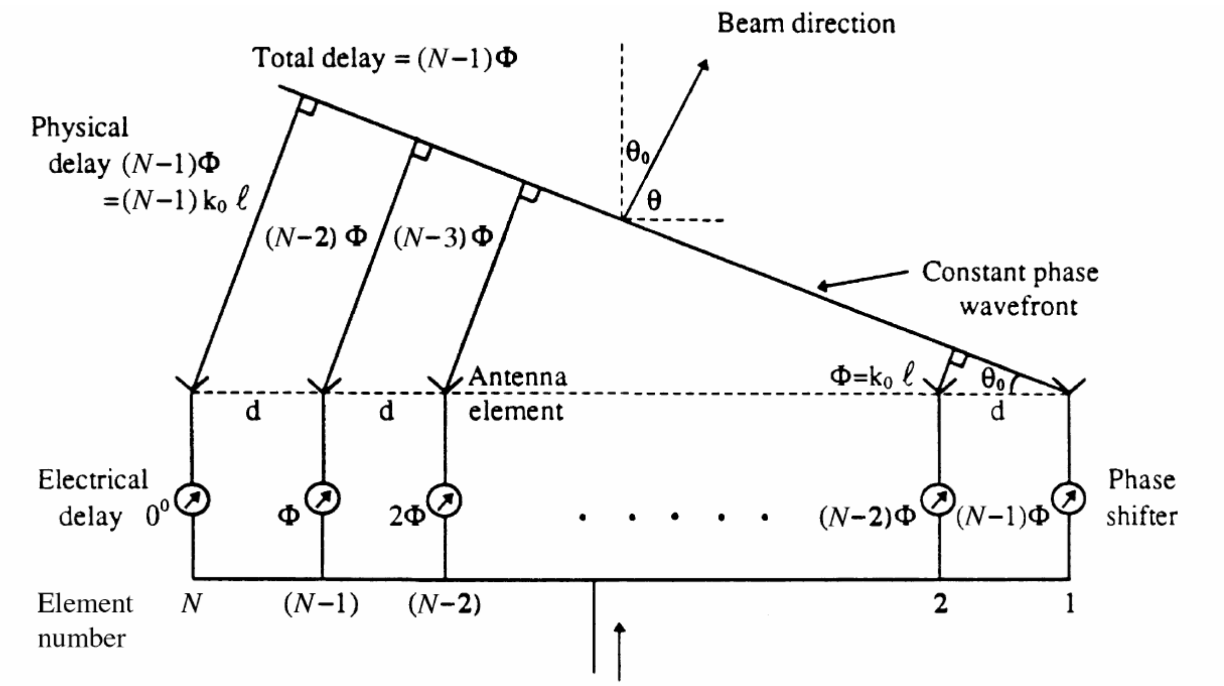
Far Field Phase Variations

$$r_1 = r$$
$$r_2 = r + d\cos\theta$$
$$r_3 = r + 2d\cos\theta$$
$$\vdots$$
$$r_N = r + (N-1)d\cos\theta$$



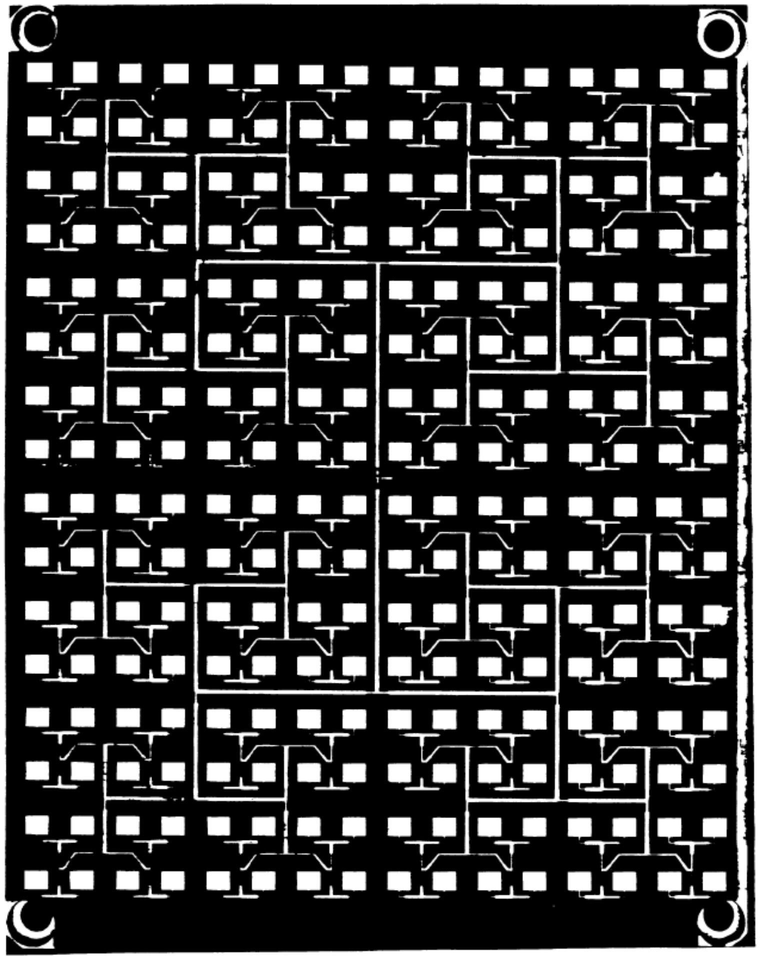
$$\text{Array Factor} = \sum_{i=1}^{N} I_i e^{j(i-1)(kd\cos\theta - \Phi)}$$

Phased Array Design



$$\Phi = k_0 d \, \sin(\theta_0)$$

Phased array example (16x16)



$$\theta_{\mathrm{BW}} \approx \frac{100}{\sqrt{N}}$$

$$G \approx \eta \pi N$$