

1) A 4 element collinear array antenna is designed to operate at 2.4 GHz for wireless communication. The antenna is designed for maximum efficiency with $\lambda/2$ spacing between elements. The system operates with an input power of 20W and has an efficiency of 85%.

- Calculate the spacing between each element.
- Total length of the array
- Gain of the array, assuming each dipole has a gain of 2.15 dBi.
- Radiated power.

Soln:
 G_m ,

$$f = 2.4 \text{ GHz}$$

$$P_{in} = 20 \text{ W}$$

$$\eta = 85\%$$

$$d = \frac{\lambda}{2} \quad \left| \begin{array}{l} N = 4 \end{array} \right.$$

a)

$$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{2.4 \times 10^9}$$
$$\lambda = 0.125 \text{ m}$$

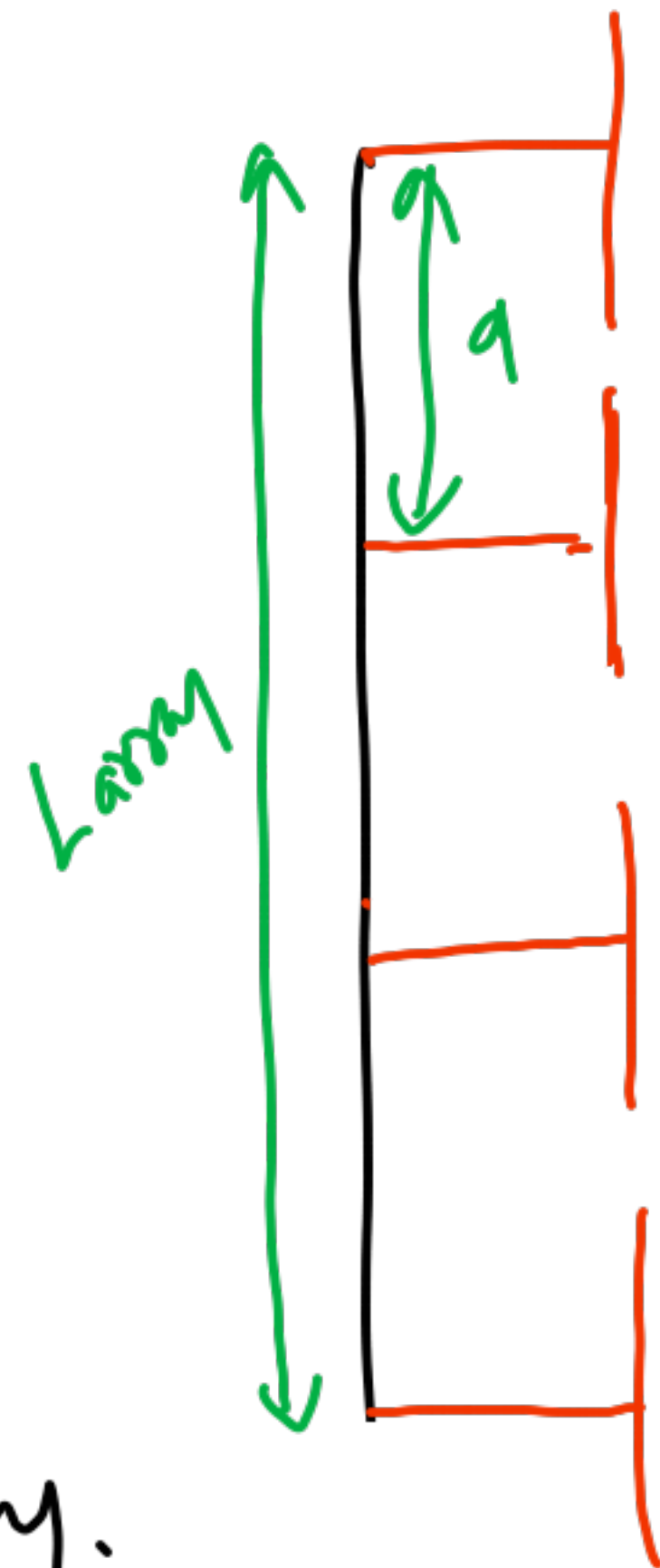
Spacing between each
each element.

$$d = \frac{\lambda}{2} = \frac{0.125}{2}$$

$$d = 0.0625 \text{ m}$$

b) Length of an array.

$$L_{array} = (N - 1) \times d$$
$$= (4 - 1) \times 0.0625$$
$$= 0.1875 \text{ m}$$



c) Gain of the array.

$$G_{\text{array}} = G_{\text{element}} + 10 \log_{10}(N)$$

$$= 2.15 + 10 \log_{10}(N)$$

$$G_{\text{array}} = 8.17 \text{ dB}$$

d) Radiated power.

$$\eta = \frac{P_{\text{rad}}}{P_{\text{input}}}$$

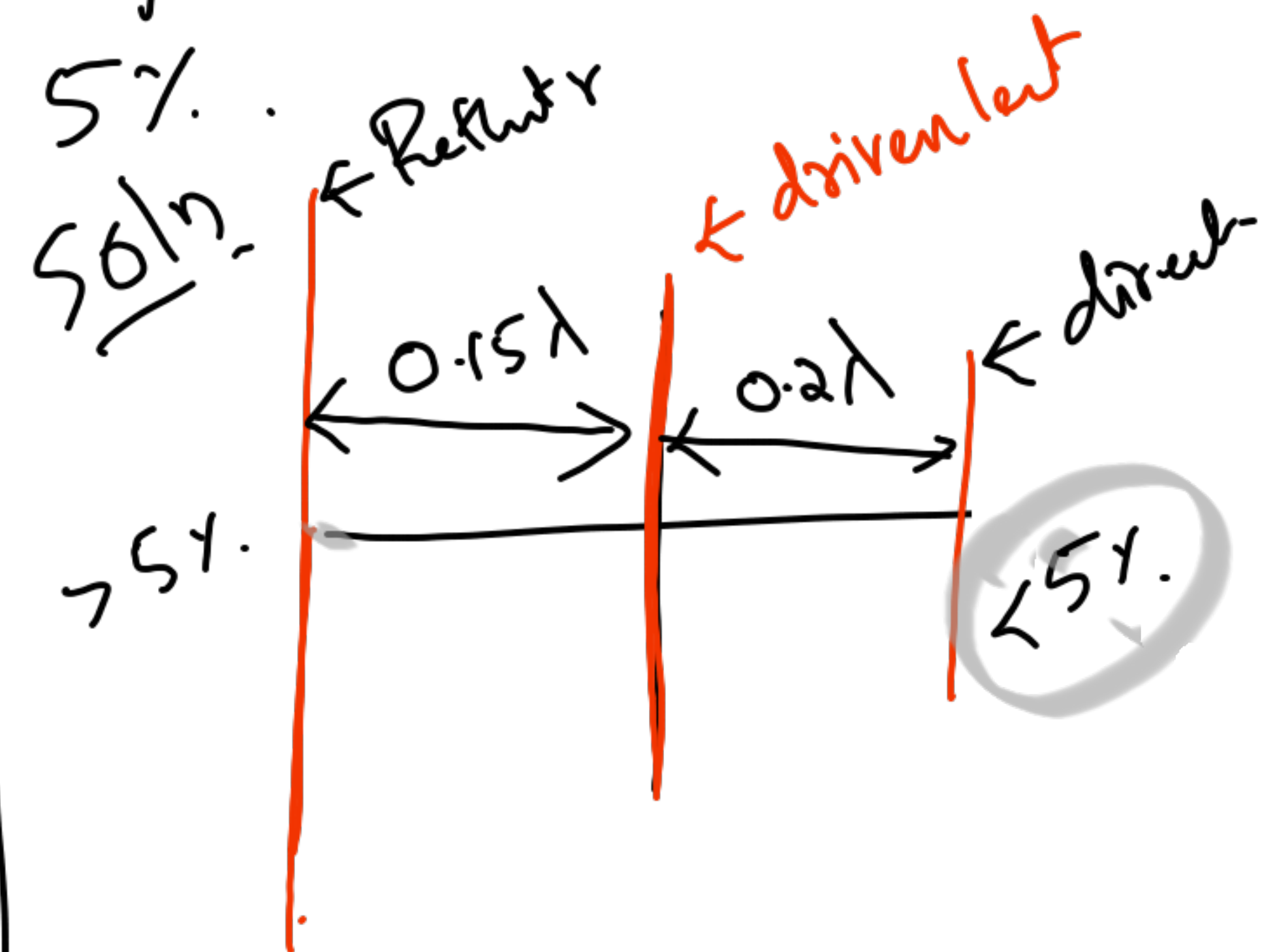
$$P_{\text{rad}} = \eta \cdot P_{\text{input}}$$

$$= 0.85 \times 20$$

$$P_{\text{rad}} = 17 \text{ W}$$

2) Calculate the length of the driven element, director and reflector for a 3 element Yagi - Uda antenna designed to operate at a frequency of 300 MHz. Also calculate the distance between each elements, if the distance from the driven element to the reflector is 0.15λ

and the distance from the driven element to the director is 0.2λ . Note that the difference between the length of each adjacent antenna element is 5%.



Soln.

Given, $f = 300 \text{ MHz}$.

$$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{300 \times 10^6}$$

$$\lambda = 1 \text{ m}$$

Length of driven element.

$$L = \frac{\lambda}{2} = \frac{1}{2} = 0.5 \text{ m}$$

Length of director.
(5% less than driven element)

$$\begin{aligned} L_{\text{Director}} &= 0.95 \times L \\ &= 0.95 \times 0.5 \\ &= 0.475 \text{ m} \end{aligned}$$

Length of Reflector.

$$\begin{aligned} L_{\text{Reflector}} &= 1.05 \times L \\ &= 1.05 \times 0.5 \\ &= 0.525 \text{ m} \end{aligned}$$

Distance between Reflector and driven element (0.15λ)

$$D_{\text{Reflector}} = 0.15 \times 1 \\ = 0.15\text{m.}$$

Distance between Director and driven element (0.2λ)

$$D_{\text{director}} = 0.2\lambda = 0.2 \times 1 \\ = 0.2\text{m}$$

3) A 4-element end-fire antenna array is designed to operate at 5 GHz for a high directional communication system. The elements are spaced $\frac{\lambda}{4}$ apart and are fed using a series feed network with an additional 90° progressive phase shift at each element to ensure end-fire radiation.

a) Calculate the wavelength.

b) Determine the element spacing (d)

c) Calculate the total length of the array (L_{array})

d) determine the phase shift due to $\frac{\lambda}{4}$ spacing

e) Calculate the total phase shift per element.

f) Calculate the total phase shift between first and the last element

g) Calculate the gain of array, if gain for each element is 2.15 dBi

Soln:

$G_n, f = 5 \text{ GHz.}$	$N = 4$
$d = \frac{\lambda}{4}$	

Progressive phase shift = 90°

a) To find λ .

$$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{5 \times 10^9}$$

$$\lambda = 0.06 \text{ m}$$

b) determine the element spacing

$$d = \frac{\lambda}{4} = \frac{0.06}{4} = 0.015 \text{ m.}$$

c) Total length of array.

$$\begin{aligned} L_{\text{array}} &= (N - 1) \times d \\ &= (4 - 1) \times 0.015 \end{aligned}$$

$$L_{\text{array}} = 0.045 \text{ m}$$

d) phase shift due to $\frac{\lambda}{4}$ spacing

$$\phi = kd.$$

we know that.

$$k = \frac{2\pi}{\lambda}$$

$$k = \frac{2\pi}{0.06} = 104.72 \text{ rad/m}$$

$$\phi = kd = 104.72 \times 0.015$$

$$\phi = 1.57 \text{ rad}$$

$$\text{Degree} = \text{rad} \times \frac{180}{\pi}$$

$$= 1.57 \times \frac{180}{\pi} = 89.95$$

$$\phi = 90^\circ$$

$$\approx 90^\circ$$

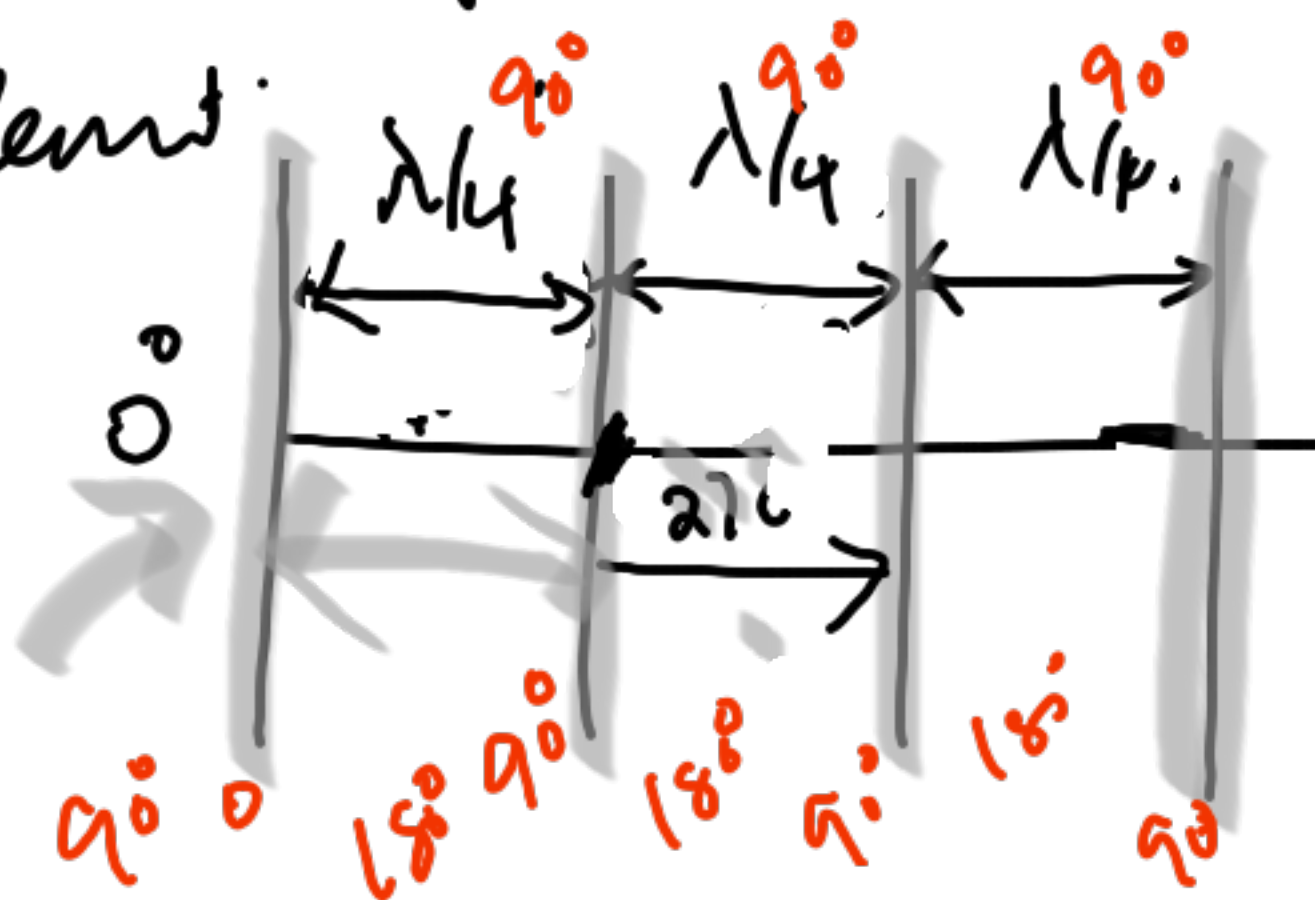
e) Calculate the total phase shift per element:

$$\phi_{\text{total/element}} = kd + \beta$$

$$\beta = 90^\circ$$

$$\phi_{\text{total/element}} = 90^\circ + 90^\circ = 180^\circ$$

f) Calculate the phase shift of first and last element:



$$\begin{aligned} \phi_{\text{total}} &= (N-1) \phi_{\text{total/element}} \\ &= 3 \times 180^\circ \\ &= 540^\circ \end{aligned}$$

g) gain of the array

$$\begin{aligned} G_{\text{array}} &= G_{\text{element}} + 10 \log_{10}(N) \\ &= 2.15 + 10 \log_{10}(4) \end{aligned}$$

$$G_{\text{array}} = 8.17 \text{ dBi}$$

