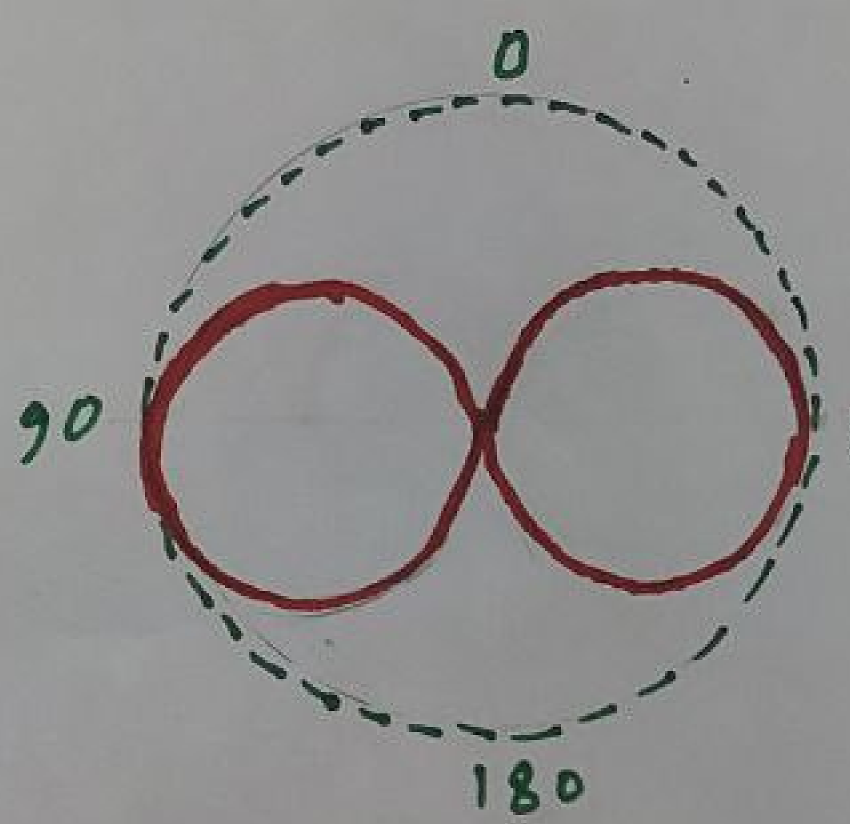
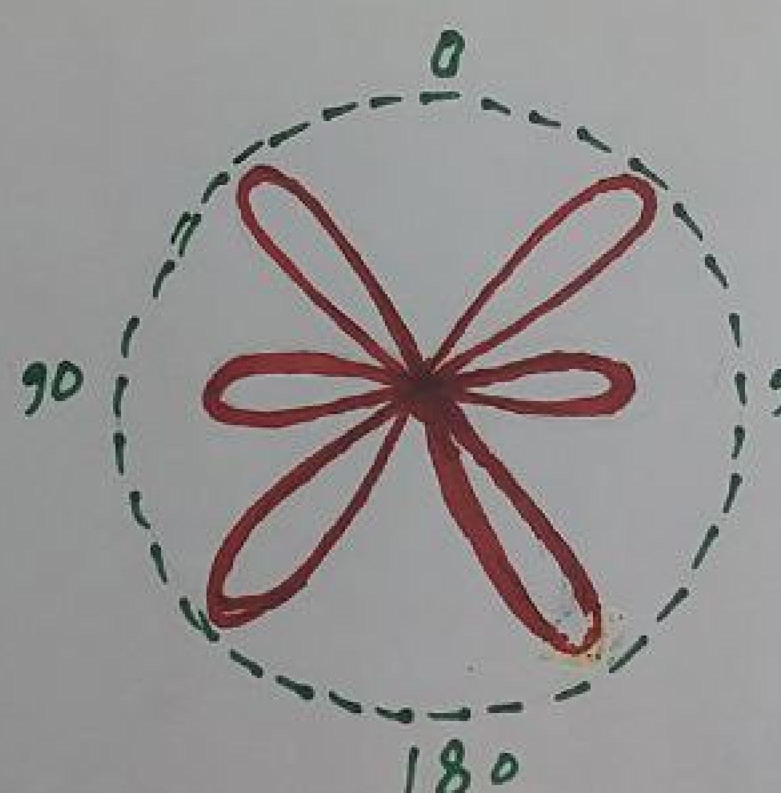
Directivity (D)

It is the ability of an antenna to focus energy in a particular direction in transmitting or receiving.

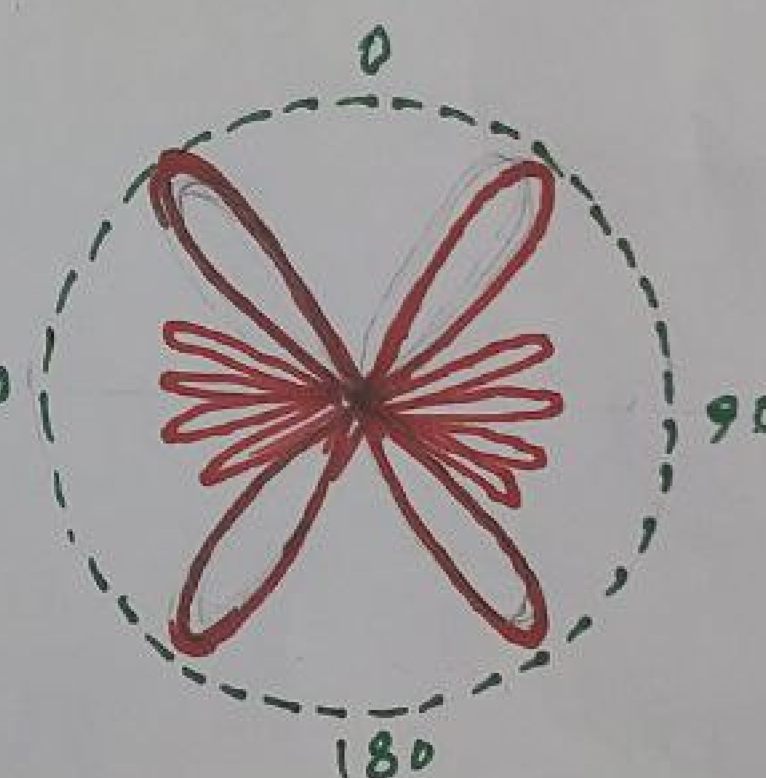
- The parameter that measures the degree of directivity of an antenna radiation pattern is known as gain.
- The lowest directivity is one, which it is satisfy antenna radates in all directions (isotropic antenna)
- Antenna with large directivity (large dimenssion) tends to create one or more narrow beams of radiation.



Short dipole
$d \ll \lambda$, $D = 1.5$



longer dipole
$d = 3\lambda$, $D = 3$



Long dipole
$d = 9\lambda$, $D = 6$

- Directivity is dimension less.
- Directivity in dB $= 10 \log_{10}(D)$

(A) If the direction is spesified (given)

so, directivity in general, is the ratio of radiation intensity in a given direction from the antenna to the radiation intensity averaged over all directions

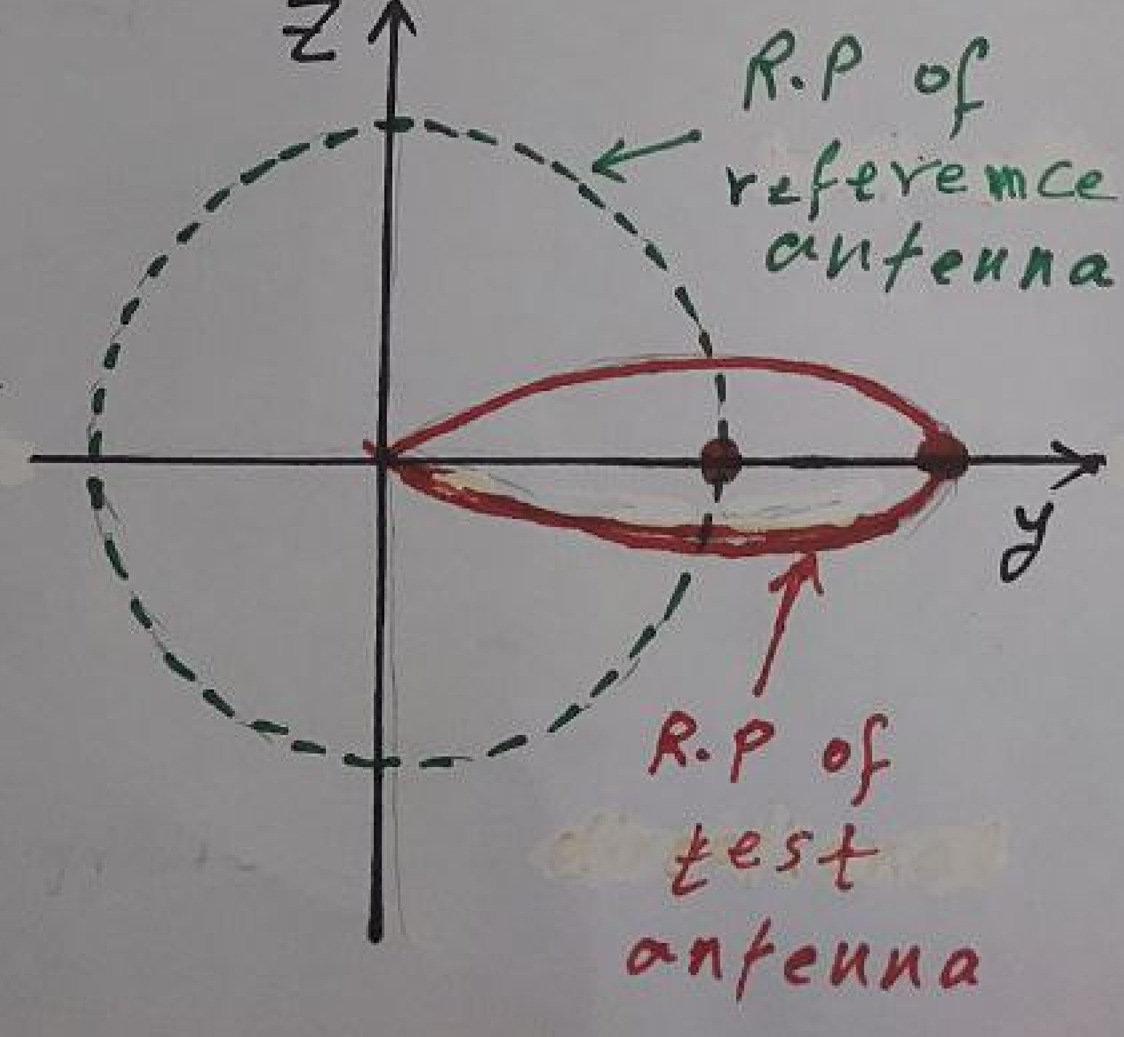
$$D = \frac{U_{\text{given direct.}}}{U_{\text{averged}}}$$

In addition, if there are two antennas, one from them is known directionality, then, directivity is the ratio of radiation intensity of test antenna in a given direction to radiation intensity of reference antenna,

$$D(\theta, \phi) = \frac{U(\theta, \phi)_{\text{test}}}{U(\theta, \phi)_{\text{reference}}} \quad \text{(dimensionless)}$$

so, directivity depends on:

① test antenna
② reference antenna
③ Particular direction (θ, ϕ)



when the reference antenna is an isotropic antenna, then

$$D(\theta,\phi) = \frac{U(\theta,\phi)_{test}}{U(\theta,\phi)_{iso}} \text{, where}$$

$U(\theta,\phi)_{iso}$ is rad. intensity of isotropic antenna $= U_0$, so

$$U_0 = \frac{P_{rad}}{\Omega} = \frac{P_{rad}}{4\pi} \Rightarrow$$

$$\therefore \; D(\theta,\phi) = \frac{U(\theta,\phi)_{test}}{P_{rad}/4\pi} \Rightarrow$$

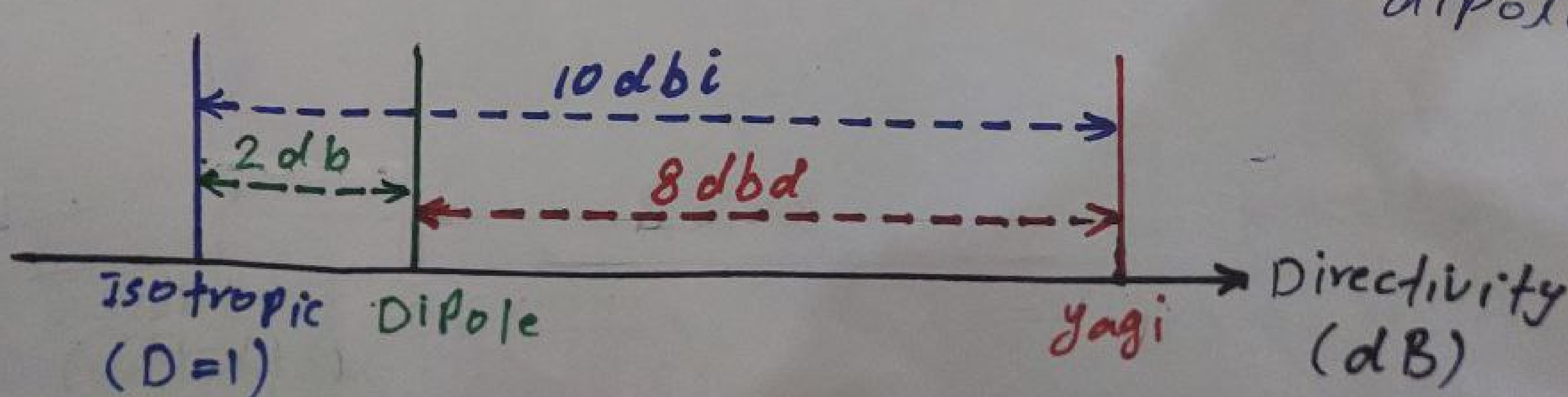
$$D(\theta,\phi) = \frac{4\pi \cdot U(\theta,\phi)_{test}}{P_{rad}}$$

<u>note-1</u> In Practical, the directivity of test antenna is always more than the directivity of isotropic antenna

$$U_{test} > U_0 \Rightarrow D > 1$$

<u>note-2</u> D = 2 dbi ⇒ derectivity relative to isotropic

D = 8 dbd ⇒ directivity relative to an ideal dipole



B) If the direction is not spesified (not given). then, the directivity is always in the maximum radiation. so, the directivity is,

The ratio of radiation intensity in maximum direction to the radiation intensity of isotropic antenna, and D_{max} will be defined as D_o.

$$\Rightarrow D_o = \frac{U_{max}}{U_o} = \frac{U_{max}}{P_{rad}/4\pi} = \frac{4\pi U_{max}}{P_{rad}} \quad \text{---} \ (1)$$

where, $D_o = D_{max}$ = maximum directivity

U_o = radiation intensity of isotropic antenna

U_{max} = max. radiation intensity (watts/sr)

U = radiation intensity (watts/sr)

P_{rad} = Power radiated (watts)

$$\because \ U = B_o F(\theta, \phi) \quad \text{---} \ (2)$$

where B_o constant

then, for maximum value

$$U_{max} = B_o F(\theta, \phi)_{max} \Rightarrow$$

$$U_{max} = B_o F_{max}(\theta, \phi)$$

$\because P_{rad} = \oiint U(\theta,\phi)\, d\Omega = \int_0^{2\pi}\int_0^{\pi} U \sin\theta\, d\theta\, d\phi$ --- ③

by substituting ② in ③ $\Rightarrow$

$$P_{rad} = B_o \int_0^{2\pi}\int_0^{\pi} F(\theta,\phi) \sin\theta\, d\theta\, d\phi \text{ --- ④}$$

so,

$$D(\theta,\phi) = \frac{4\pi U}{P_{rad}} = \frac{\cancel{B_o}\, 4\pi\, \cancel{F(\theta,\phi)}}{\cancel{B_o} \int_0^{2\pi}\int_0^{\pi} \cancel{F(\theta,\phi)} \sin\theta\, d\theta\, d\phi} \text{ --- ⑤}$$

$$\Rightarrow D(\theta,\phi) = \frac{4\pi}{\Omega} \text{ --- ⑥} \quad \text{where } \iint \sin\theta\, d\theta\, d\phi = \Omega$$

but this equation (eq-6) can used just for isotropic antenna

For maximum directivity,

$$D(\theta,\phi) = \frac{4\pi U}{P_{rad}} \xrightarrow{\text{becomes}} D_o(\theta,\phi) = \frac{4\pi U_{max}}{P_{rad}}$$

$$= \frac{B_o\, 4\pi\, F_{max}(\theta,\phi)}{B_o \int_0^{2\pi}\int_0^{\pi} F(\theta,\phi) \sin\theta\, d\theta\, d\phi} \quad * \quad \frac{\frac{1}{F_{max}(\theta,\phi)}}{\frac{1}{F_{max}(\theta,\phi)}}$$

$$\Rightarrow D_o = \frac{4\pi}{\int_0^{2\pi}\int_0^{\pi} P_n(\theta,\phi) \sin\theta\, d\theta\, d\phi} \quad \frac{B_o F(\theta,\phi)}{B_o F_{max}(\theta,\phi)} = \frac{U}{U_{max}} = P_n$$

$$\Rightarrow D_o = \frac{4\pi}{\Omega_A}$$ and this explaine the relation between directivity & beam area

(C) Approximate expression for directivity

$$\because D_o = \frac{4\pi}{\Omega_A} \quad \& \quad \Omega_A \simeq \theta_E \cdot \theta_H$$

where θ_E : HPBW in E-Plane

θ_H : HPBW in H-Plane

So,
$$D_o = \frac{4\pi}{\Omega_A} \simeq \frac{4\pi}{\theta_E \cdot \theta_H}$$

$$4\pi (sr) = 4\pi * \left(\frac{180}{\pi}\right)^2 = 41253^{\square}$$

$$\Rightarrow D_o \simeq \frac{41253^{\square}}{\theta_E^{\circ} \cdot \theta_H^{\circ}}$$

where $\square$ is sqquare degree

<u>note: 1</u> From eq $D_o \simeq \frac{4\pi}{\Omega_A}$,

smaller the beam area, larger directivity

<u>note-2</u> From eq Ω_A in $D_o \simeq \frac{4\pi}{\Omega_A}$, large directivity, when HPBW is small because

$$\Omega_A \simeq \theta_E \cdot \theta_H$$

ex.

what is the directivity for isotropic antenna?

solution:
$$D_o = \frac{4\pi}{\Omega_A}$$

where $\Omega_A = \iint P_n \, d\Omega$

$\because P_n = \frac{U}{U_{max}} = 1$ because it radiates equally in all directions

so,

$$\Omega_A = \iint 1 \, d\Omega = 4\pi$$

$$\Rightarrow D_o = \frac{4\pi}{\Omega_A} = \frac{4\pi}{4\pi} = 1$$

or directly,

$$D = D_o = \frac{4\pi}{\Omega} = \frac{4\pi}{4\Omega} = 1$$