JP Rao455
Balani

Page:
Date: 2-Jan

Applications of antennas :-

Mobile	Sensor computer	Bluetooth
Satellites	Radar	RFID
TV	Sonar	Pager
Radio	Jammers	GPS
Wi-fi	Wireless charging	NFC
Rovers	Radio telescope	Remote control

→ Antennas is an interface b/w free space and cable (guided medium)

- It is a transducer ⟶ convert electric to EM wave and vice-versa.
- It is used for impedence matching b/w free space impedence (373 Ω) and output impedence of system.

Types of Antennas :-

① Directional: radiates energy in a single direction

② Non-directional:

(i) Isotropic → radiates equally in all direction in all plane

(ii) Omni directional → radiates equally in one direction while does not radiates equally in other direction. Radiation pattern is in form of ideal apple.

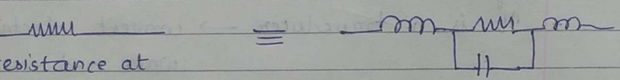
- Isotropic antennas does not exist
- Omni directional antennas exists :- ex - dipole antenna

Reciprocity theorem: Same antenna can be used as transmitting as well as receiving antenna.

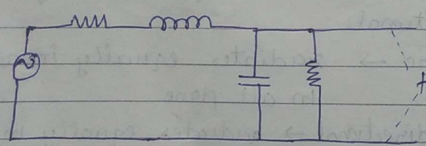
- Yaggi antenna (earlier used as TV antenna → directional) and loop antenna are mostly used for receiving but can also be used for transmission.

How does an antenna radiate ?

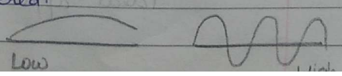
$X_L = 2\pi f L$
$X_C = 1/2\pi f C$



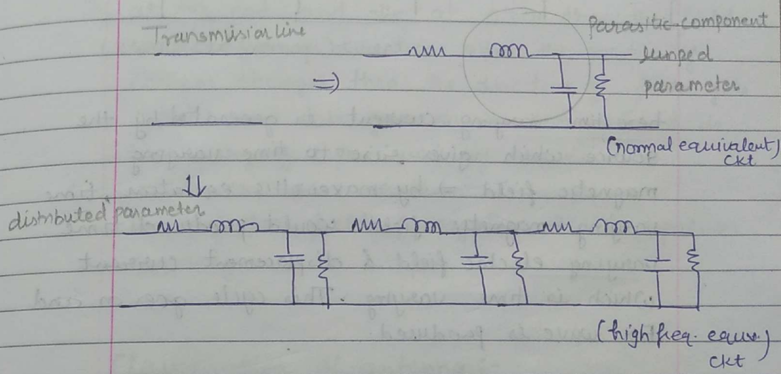
- at high frequency two parallel transmission lines will have equivalent ckt as



- this happens bcoz at high freq. X_L and X_C values are considered.

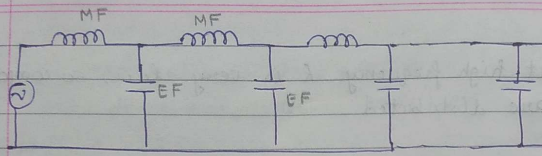


- at high frequency λ is very low, so components are distributed.



The components gets distributed bcoz the phase of signal changes very rapidly at high freq. ⇒ the values of capacitors, inductors changes accordingly.

- every conductor which conducts currents can work as antenna but the parameters are uncontrolled.
- So in antenna or anywhere else the transmission lines are very close to each other and carry current in opp. direction ⇒ field generated will be opposite ⇒ they will cancel out ⇒ radiation does not occurs by transmission line.



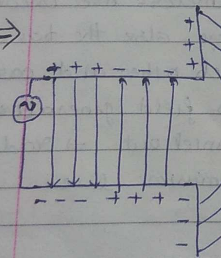
(ignoring resistance)

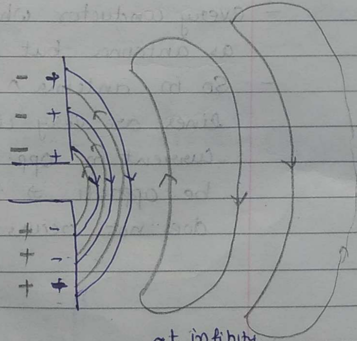
here time varying current is generated by the source which gives rise to time varying magnetic field ⇒ by maxewell's equation, time varying magnetic field would produced time varying electric field & displacement current which is time varying. This cycle goes on and EM wave is produced.

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

$$\nabla \times \vec{H} = \vec{J} + \frac{\partial \vec{D}}{\partial t}$$ ↳ displacement current

⇒





at infinity, loops gets created.

(Book's explanation)

In this, charges gets accumulate when the wire bends. So when positive charges gets accumulated at one end and -ve at other then the field would have a direction. when the position of charges changes then the direction of field gets opposite and this goes on as the current is time varying (produced by source)

⇒ loops are created

- The magnetic field propagates due to repulsion occuring.

<u>Classification of antenna</u> :-

is done on the basis of

i) <u>frequency</u>:

VLF, LF, HF, VHF

horn antenna: high freq. only if it's used at low freq. antennas sizes becomes very large.

ii) <u>polarization</u>:

Polarization of antenna is in direction of electric field vector.

- linear polarization can be in either E_x or E_y direction.
- circular polarization is in direction of E_x and E_y direction. $E_x = E_y$

90° phase shift b/w E_x & E_y

Normalization: dividing all the values with max. value.

- propagation takes place in form of helical path
  types of CP → RHCP (clockwise)
  LHCP (anticlock)

linear & circular polarization is the special case of elliptical polarization.

III) Radiations:

isotropic, omni-directional, directional

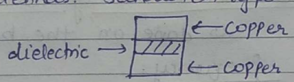
hemispherical: radiates in a hemisphere only.

iv) Aperture:

Wired (monopole, dipole, loop & helical)

Reflector

Microstrip path antennas: sandwich type



Basic Antennas parameters:

Radiation Pattern: Graphical or mathematical representation of ...ticular coordinate system: spherical

- field pattern → pattern in terms of E or H field
  Power pattern → " " " " power v/s sph. coordinate
- determined in far field region
- radiates property include

$0 < r < \infty$

$0 < \theta < \pi$

$0 < \phi < 2\pi$ (with x axis)

Azimuth & Elevation planes:

azimuth: horizontal (xy plane, $\theta = 90$)

elevation: vertical (yz plane, $\phi = 90$)

principal patterns:

[E-plane
  H-plane

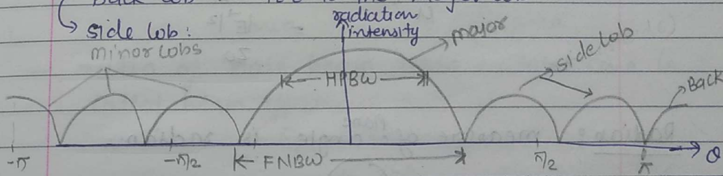
Radiation pattern lobs:

major lobs: which is in main (desired) direction

minor lobs: lob expecting major lob.

Back lob: 180° to the major lob

side lob:



HPBW → half power beam width

- Unit is angle (degree or radian)

* $\boxed{E_\theta(\theta, \phi)_n = 0.707}$ (3dB down)

FNBW → first null beam width

- normalised field pattern:

$$E_\theta(\theta, \phi)_n = \frac{E_\theta(\theta, \phi)}{E_\theta(\theta, \phi)_{max}}$$

- poynting vector → power ~~at a particular point~~ per unit area

$$S = \frac{1}{\mu}(\vec{E} \times \vec{H})$$

for $E(\theta)$ at half power $= 0.707$
$\cos\theta = 0.707$
$\theta = 33°$

$HPBW = 2\theta = 66°$
for FNBW $E(\theta) = 0°$

6-jan-2017

$S(\theta, \phi)$ = poynting vector
$= E_\theta^2(\theta, \phi) + E_\phi^2(\theta, \phi) / Z_0$

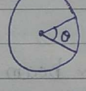
$Z_0 \rightarrow$ intrinsic impedence of space $= 376.7\,\Omega$

Power per unit area : $P_n(\theta, \phi)_n = \dfrac{S(\theta, \phi)}{S(\theta, \phi)_{max}}$

poynting vector gives the power per unit area and gives the direction of EM wave propagate

$$S = \frac{1}{\mu}(\vec{E} \times \vec{H}) = \vec{E}\,\vec{H}\sin(90)$$
$$= \frac{|\vec{E}|^2}{Z_0}$$

Radian : measure of plane angle is radian.



in circle 2π radian.

steradian : in sphere 4π steradian.

Solid angle : $d\Omega = \dfrac{dA}{r^2} = \sin\theta\, d\theta\, d\phi$ (sr)

beam area : $\Omega_A = \displaystyle\int_{\phi=0}^{2\pi}\int_{\theta=0}^{\pi} P_n(\theta, \phi)\sin\theta\, d\theta\, d\phi$

is the solid angle through which all of power radiated by the antenna

By changing the size of antenna, side lobs will there
(dipole)

$$\Omega_A = \theta_{HP}\,\phi_{HP}$$

radiation intensity : power radiated by antenna per unit solid angle called as rad. intensity.

normalised power (Unit $\rightarrow$ Power/sr)

$$P_n(\theta, \phi) = \frac{U(\theta, \phi)}{U(\theta, \phi)_{max}}$$

Beam efficiency :

$$\Omega_A = \Omega_M + \Omega_m$$

$\Omega_A \downarrow$ total beam area
$\Omega_M \downarrow$ major
$\Omega_m \downarrow$ minor lobe area

- ratio of main beam area to total area is called beam efficiency.

$$\varepsilon_M = \frac{\Omega_M}{\Omega_A}$$

- ratio of minor beam area to total area is called stray factor.

$$\varepsilon_m = \frac{\Omega_m}{\Omega_A}$$

$$\varepsilon_M + \varepsilon_m = 1$$

Directivity (D) : direction property of antenna
ratio of the max. power density to its avg. value over a sphere as observed in the far field of an antenna.

$$D = \frac{P(\theta, \phi)_{max}}{P(\theta, \phi)_{avg}}$$

directivity is dimensionless ratios ≥ 1

$$\text{avg. Power} = \frac{1}{4\pi} \int_{\theta}\int_{\psi} P(\theta,\psi) \sin\theta \, d\theta \, d\psi$$

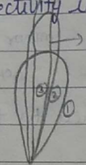
$$\boxed{D = \frac{4\pi}{\Omega_A}}$$ $\Omega_A \rightarrow$ beam area

Unit $\rightarrow$ dBi

$$\therefore D = \frac{P_{max}}{P_{avg}} = \frac{4\pi}{\iint P(\theta,\psi)/P(\theta,\psi)_{max} \, d\Omega} = \frac{4\pi}{\Omega_A}$$

$P(\theta,\psi)/P(\theta,\psi)_{max}$ → normalised Power

- directivity is the inversly proportional to the beam area.



→ beam area ↓ ses ③ < ② < ①

directivity is ↑ses ③ > ② > ①

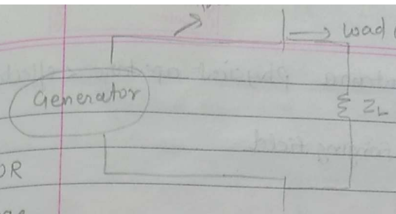
- pencil beam antennas whereas beam area is very less and directivity is very high.
- for isotropic antennas $\Omega_A = 4\pi$ sr ; so $D = 1 \rightarrow$ lowest possible directivity
- Unit of D is dBi (decibles over isotropic i.e wrt isotropic antenna)

Gain: Gain of an antenna is a quantity which is less than the D due to ohmic losses in the antenna.

- mismatch in feeding also reduces gain

antenna efficiency → ratio of gain to directivity is called antenna efficiency factor.

$G = KD$ $K \rightarrow$ efficiency factor



VSWR (Voltage standing wave ratio) = 1

- Highest the VSWR → reflected wave is there, some losses is theres. it will occur due to mismatch of the impedence b/w transmission line and load.

$$\text{Gain} = \frac{P_{max}(AUT)}{P_{max}(\text{ref. ant})} \times G(\text{ref. ant})$$

AUT → antenna under test

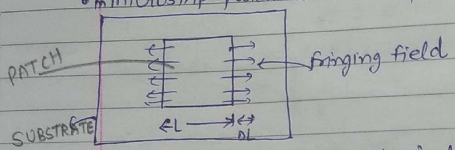
Antenna Apertures:

aperture of antenna is area that captures energy from a passing radio wave.

- physical aperture   complete antenna
- effective aperture   part of antenna which radiates

- $P = SA$ (W) S → poynting vector
- effective aperture is not always equal to the physical aperture. Example is
- $$\text{Aperture efficiency} = \frac{A_e}{A_p} \quad A_e \rightarrow \text{effective}, \; A_p \rightarrow \text{physical}$$
- reflector antenna and horn antenna

- in microstrip patch antenna physical aperture < effective App



size of antenna = L (physical aperture)

$L + \Delta L + \Delta L$ (effective aperture)

$\Omega_A \rightarrow$ beam area

$A_e \rightarrow$ effective aperture

$\because S = E^2/Z \Rightarrow P = SA$

$$P = \frac{E^2}{Z_0} A_e$$

(from slide)

and $D = 4\pi \frac{A_e}{\lambda^2}$ (λ is constant, for a particular freq. antenna is designed so that λ is fix)

So directivity $\propto$ effective aperture

Directivity of horn antenna (size is bigger than the patch) > D of patch anetnna (size is less)

$$\left\{ \begin{aligned} D &= \frac{P(\theta,\phi)_{max}}{P(\theta,\phi)_{avg}} \\ D &= \frac{4\pi}{\Omega_A} \\ D &= 4\pi \frac{A_e}{\lambda^2} \end{aligned} \right\}$$

region of Antenna:

$\frac{2D^2}{\lambda}$ $D \rightarrow$ largest dimension of an antenna

Effective Height $A_e = \frac{h_e^2 Z_0}{4R_r}$

Page:
Date: 10 - jan - 17

near and far field region is differentiate or decided by the $\left(\frac{2d^2}{\lambda} \rightarrow \text{near field}\right)$

where $d \rightarrow$ largest dimension of antenna
$\lambda \rightarrow$ wavelength

if dipole antenna is there length or radius, which is large, offcourse largest dimension of antenna is length of antenna)

near

freshnel → independent of distance ~~from~~ in far field antenna

fraun hoffer → dependent on distance ~~for~~ in near field antenna region.

far

So we have taken in far field region.

$A_e =$

Return loss:

return loss $S_{11} = -25\,dB, -5\,dB$

Scatter parameter

$-25\,dB \rightarrow$ less reflection is there and return loss is less as compare to $-5\,dB$

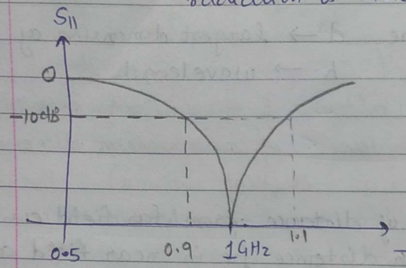
$-5\,dB \rightarrow$ more reflection are there

at high freq. : when SC $\rightarrow$ inductor
when OC $\rightarrow$ capacitor

in scatter parameter, we don't talk about the current & voltage. we only talk about ~~the~~ in term of power. $\rightarrow$ so we used S-parameter.

- in antenna only $S_{11} \rightarrow$ parameter only there becaz only one port is there and S_{11} $11 \rightarrow$ represents the $1 \rightarrow$ i/p & $1 \rightarrow$ reflection.

- VSWR = 2, corresponds to $S_{11} = -10dB$
- $S_{11} \rightarrow 0dB$ (comp. i/p will reflected back completly, no radiation is there), corresponds to VSWR = ∞



for example in horn antenna, $S_{11} = -20dB$, so reflection is less, so we are not allowed to reflection.

- Smaller the value of S_{11} → less reflection is occurs.
- By ~~for~~ impedence matching, S_{11} will improve, for doing that antennas dimensions will changes. as if we have designed the antenna for 1GHz but it's radiates at 2GHz, so we have to decrease the frequency and wavelength will increases → means distance between two antennas ↑ses.

Relation between effective height and Ae:

$$A_e = \frac{h_e^2 Z_0}{4 R_r}$$

$R_r \rightarrow$ radiation resistance (tells about the how our antennas radiates)

- loss resistance → how much antennas losses occur in antennas.
- higher the R_r, radiation by antenna is more. higher the R_L, losses due to impedence mismatching, losses is higher in antenna.

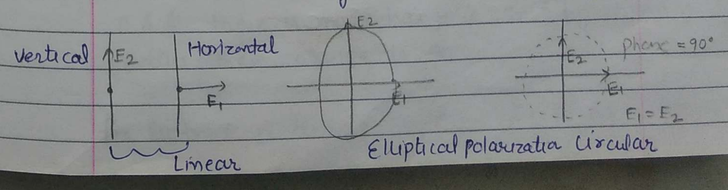
$$\text{efficiency} = \frac{R_r}{R_r + R_L}$$

friss-space equation:

$$P_r = \frac{G_r G_T P_T}{4\pi d^2}$$

polarization:

Orientation of E-field vector of a wave



axial ratio = $\frac{\text{Major axies of polarization ellips}}{\text{Minor}}$

Polarization	AR	
Linear	∞	(bcoz minor = 0)
Circular	1	major = minor
elliptical	>1	major > minor

signal to noise ratio ⟶ ratio of signal fed to the n/w to the noise.

ratio of energy in main lob to that in back lob

front to back ratio ⟶ $\frac{\text{main lob/major lob}}{\text{back lob}}$

* is the parameter of the only directional antenna only.

antenna tempr ⟶ fictitious tempr at the i/p of an antenna which would account for noise AN at the o/p.

- We don't define the front to back ratio for the dipole antenna.

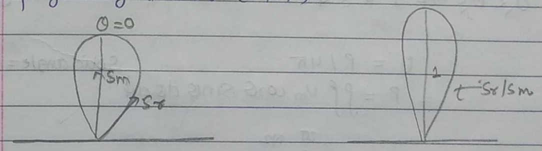
? numerical: JD Krauss — Online solution

- polarization of 2 antenna & their axial ratio questions.

Date: 11 - jan

chapter- point source and their array

- any antenna can be considered as point source, when ~~bcoz~~ field is very far we are taken.
- we fixed the observation point and antenna is moving or rotating.(and vice - versa)
- two types of - field
  - Power
- poynting vector (W/m²)



making equals to 1, we do this Sr/Smax → normalize

- Power theorem:

$$P = \oiint S\, ds$$

$$ds = r^2 \sin\theta\, d\theta\, d\phi$$

$$P = \oiint S_r\, ds$$

- $S_r \neq 0$ while S_θ & S_ϕ is equal to zero bcoz it acts as equipotential surface so by changing θ & φ there is no change is S_r but by changing radius there change is S_r.

for isotropic antenna: $P = S_r \oiint ds$

$$P = S_r(4\pi r^2)$$

$$\boxed{S_r = \frac{P}{4\pi r^2}}$$

$S_r \rightarrow$ radial changes in poynting vector

radiation intensity $U = \frac{P}{4\pi}$ (W/sr)

<u>Example:</u> a source has a cosine radiation intensity $U = U_m \cos\theta$
$0 \leq \theta \leq \pi/2$; $0 \leq \phi \leq 2\pi$. find the Directivity?

<u>Solution:</u>

$U = P/4\pi$ solid angle $= \sin\theta\, d\theta\, d\phi$

$P = \iint U_m \cos\theta \sin\theta \, d\theta\, d\phi$

$= \frac{U_m}{2} \int_0^{2\pi}\int_0^{\pi/2} \sin 2\theta \, d\theta\, d\phi$

$= \frac{U_m}{2}(2\pi) \left[\frac{\cos 2\theta}{2}\right]_{\pi/2}^{0} = U_m(\pi)\left(\frac{1}{2} + \frac{1}{2}\right)$

$P = U_m \pi$

directivity $= \frac{U_m}{U_0}$ → Power radiated by the ~~(isotropic)~~ point source

$\pi U_m = 4\pi U_0$

πU_m ↓ Power radiated by point source

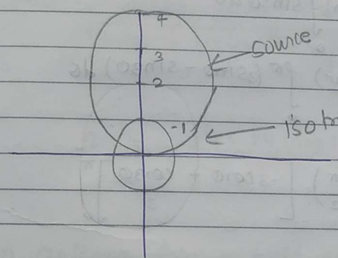
$4\pi U_0$ ↓ Power radiated by isotropic

$\frac{U_m}{U_0} = 4$

So Directivity = 4

isotropic antenna having $D = 1$; $\theta = 0$ to π
$\phi = 0$ to 2π

but for point source $D = 4$; $\theta = 0$ to $\pi/2$
$\phi = 0$ to 2π



(ii) $U = U_m \sin\theta$; $0 \leq \theta \leq \pi$
$0 \leq \phi \leq 2\pi$

$P = \frac{U_m}{2}\int_0^{2\pi}\int_0^{\pi} \cancel{\sin 2\theta \, d\theta}\, d\phi$

$= \frac{U_m}{2}\left[\frac{\cos 2\theta}{2}\right]_0^{\pi}(2\pi) = \frac{U_m}{2}(2\pi)\left(\frac{-1}{2} + \frac{1}{2}\right) = 0$

$= U_m(2\pi)\int_0^{\pi} \sin^2\theta \, d\theta = \frac{U_m(2\pi)}{2}\int_0^{\pi}(1 - \cos 2\theta)\, d\theta$

$= U_m(\pi)\left[\theta - \frac{\sin 2\theta}{2}\right]_0^{\pi} = U_m \pi[\pi - 0] = U_m \pi^2$

(iii) $U = U_m \sin^2\theta$; $0 \leq \theta \leq \pi$
$0 \leq \phi \leq 2\pi$

$P = \frac{U_m}{2}\int_0^{2\pi}\int_0^{\pi} \sin^2\theta \sin\theta \, d\theta\, d\phi$

Scanned by CamScanner

$\sin 3\theta = 3\sin\theta - 4\sin^3\theta$

$\sin^3\theta = \dfrac{3\sin\theta - \sin 3\theta}{4}$

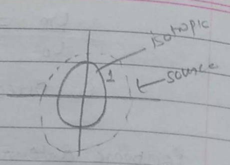
Page:

Date:

(ii) $\pi^2 U_m = 4\pi U_0$

$\dfrac{U_m}{U_0} = \dfrac{4}{\pi}$

$D = \dfrac{4}{\pi}$



(iii) $P = U_m(2\pi)\int_0^\pi \sin^3\theta \, d\theta$

$= \dfrac{U_m(2\pi)}{4}\int_0^\pi (3\sin\theta - \sin 3\theta)\, d\theta$

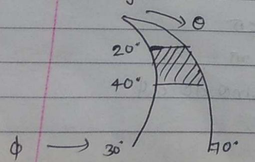
$= U_m\left(\dfrac{\pi}{2}\right)\left[-3\cos\theta + \dfrac{\cos 3\theta}{3}\right]_0^\pi$

$= U_m\left(\dfrac{\pi}{2}\right)\left[3 - \dfrac{1}{3} - \left(-3 + \dfrac{1}{3}\right)\right]$

$= U_m\left(\dfrac{\pi}{2}\right)\left[6 - \dfrac{2}{3}\right]$

$= U_m(\pi)\left(\dfrac{16}{3\times 2}\right)$

<u>Numerical</u>: find the no. of square degree in the solid angle $d\Omega$ on the spherical surface.



Page:

Date: 17-jan

$d\Omega = \sin\theta \, d\theta \, d\phi$

$\Omega = \int_{\phi=30°}^{70°}\int_{\theta=20}^{40°} \sin\theta \, d\theta \, d\phi$

$= [-\cos\theta]_{20}^{40°}\ (70° - 30°)$

$= 0.69 \times (0.17)$

$= 0.119\ Sr = 0.12\ Sr$

$\boxed{1\ Sr = (1\,rad)^2 = \left(\dfrac{180}{\pi}\right)^2 = 3282\,(deg.)^2}$

$\Omega = 393.84\,(deg.)^2$ <u>Ans.</u>

Ex 8- An antenna has a field pattern given by $E(\theta) = \cos^2\theta$; $0 \le \theta \le 90°$ find the beam area

<u>Ans</u>

$\Omega_A = \iint P_n(\theta,\phi) \sin\theta \, d\theta \, d\phi$

$\boxed{\text{power pattern} = \dfrac{1}{2}\dfrac{(\text{field Patter})^2}{Z_0}}$ $Z_0 = 377\Omega$ (free space)

$\dfrac{1}{2\,Z_0} = 1.3\times10^{-3} \cong 0$

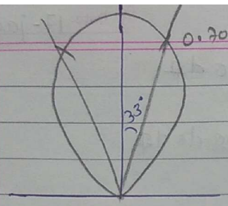
$= \int_{\phi=0}^{2\pi}\int_{\theta=0}^{\pi/2} \cos^4\theta \sin\theta \, d\theta \, d\phi$

let $\cos\theta = t$

$\sin\theta \, d\theta = -dt$

$= 2\pi\int_1^0 -t^4 \, dt$

$= \dfrac{2\pi}{5}\left[t^5\right]_0^1 = \dfrac{2\pi}{5} = 1.25\ Sr = 4102\,(deg)^2$



$0.707 \; (1/\sqrt{2})$ $\qquad P = E^2$

$\cos^2\theta = 0.707$

$\theta = 33^\circ$

$$\Omega \cong \underset{(E)}{\theta^\circ_{HPBW}} \times \underset{(H)}{\theta^\circ_{HPBW}}$$

$$P_d(\theta,\phi) \propto |E(\theta,\phi)|^2$$

- Current distribution along the antenna is constant then antennas donot radiates.

* if Harzion dipole antenna is then

$$P_d(\theta,\phi) \cong E^2(\theta,\phi)$$

(bcoz current is constant)

But ~~other than this antenna~~ only in Linear dipole

$$P_d(\theta,\phi) \cong \frac{E^2(\theta,\phi)}{220}$$ → we have to considerd this

Ex8- Radiation efficiency for certain antenna is 95%. The max. radiation intensity 0.5 W/Sr. Calculate the Directivity of antenna if

i) I/P Power = 0.4W

ii) radiated Power = 0.34W

Sol: $D = \frac{P_d(\theta,\phi)}{P_{avg}} = \frac{U_{max}}{U_{avg}} = \frac{U_{max}}{P_{rad}/4\pi}$

$= \frac{P_d(\theta,\phi)}{(P_{rad}/4\pi r^2)}$

$= \frac{r^2 P_d(\theta,\phi)}{(P_{rad}/4\pi)}$

$= \frac{U(\theta,\phi)}{(P_{rad}/4\pi)}$

$\eta\% = \frac{P_{rad}}{P_{in}} \times 100$

ii) $D = \frac{U_{max}}{P_{rad}/4\pi} = \frac{0.5\ W/Sr}{0.34/4\pi} = 18.47$

i) $P_{rad} = .95 \times 0.4 = 0.38$

$D = \frac{0.5 \times 4\pi}{0.38} = 16.53$

Ex8- The loss resistance of antenna is 25Ω. Calculate its radiation resistance Power gain = 30, D=42

Sol: $G = KD \Rightarrow K = \frac{30}{42} = 0.712$

$K = \frac{R_{rad}}{R_{rad} + R_{loss}}$

$0.712 = \frac{R_{rad}}{R_{rad} + 25}$

$17.85 = R_{rad}(1 - 0.712)$

$R_{rad} = 61.80\ \Omega$

Ex8- Radiation intensity = 6 cos θ, find D = ? pattern is Unidirectional

$$U = \frac{P}{4\pi} \quad \{\because U_m = 6$$

$$P = \int\int U_m \cos\theta \sin\theta \, d\theta \, d\phi$$

$$= \int\int 6 \cos\theta \sin\theta \, d\theta \, d\phi$$

$$= 3 \int_0^{2\pi}\int_0^{\pi/2} \sin(2\theta) \, d\theta \, d\phi$$

$$= \frac{3(2\pi)}{2} \left[-\cos 2\theta\right]_0^{\pi/2}$$

$$= 3\pi [+1+1]$$

$$P = 6\pi = U_m \times \pi$$

$$\cancel{6\pi U_m = 4\pi U_0}$$

$$\cancel{\frac{U_m}{U_0} = \frac{4\pi}{6\pi}}$$

$$\cancel{\boxed{D = \frac{2}{3}}}$$

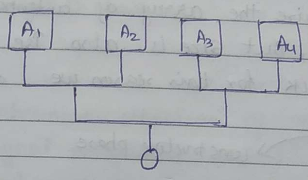
$$U_m \times \pi = 4\pi U_0$$

$$\boxed{D = 4}$$

Page:
Date: 18-jan

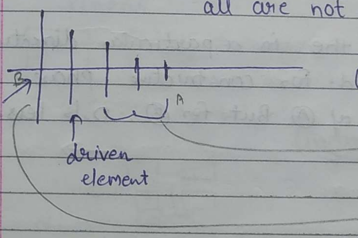
ARRAY OF ANTENNA :

group of antennas which are having different amplitude and phase $\longrightarrow$ array of antenna



- all antennas are in physical contact. all antennas are ~~fets~~ feed by only single source then it called array.

- yaggi antenna is parasitic antenna. In this all are not in physical contact.



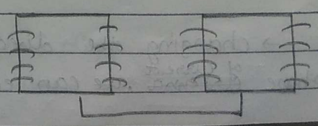
(it depends on the host means (A) depends on only (B)

- array of antenna get the excitation through a single source.
- disadvantage of array is sidelobs.

Advantages:

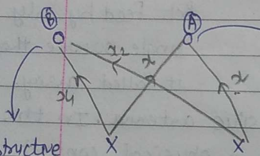
- (1) $D \propto A_e$ (effective apertune)

for example: patch antenna



In patch antenna as effective aperture is increases then directivity is increases. So for ↑ing the directivity, we used array of antenna.

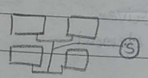
• (for reflector antenna as we know that Ae is higher, So we don't require the array of antenna for ↑ing the directivity, But size is also ↑se that is the draw back for this reason we don't used it)



Directivity is the in a particular direction max. power is radiated. For constructive phase, D is ↑ses in a direction of (A) But for (B), D is less.

- 

Reflector Antenna



Patch Antenna

By using array of Patch antennas D is ↑ses and area is also less as compare to single reflector antenna.

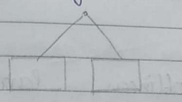
- D is increases, beam area is decreases

- (2) D is ↑ses then gain is also ↑ses

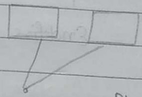
$$G = KD$$

(3) Beam stearing → changing the direction of beam

By changing the phase of current ~~antenna~~, we can easily change the beam direction.



phase Diff = 0



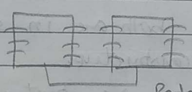
Phase Diff ≠ 0

(4) Determine direction of receiving signal.

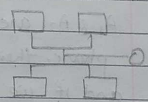
(5) signal intaference and noise ratio (SNR ↑ses)

<u>Classification of array of antenna:</u>

(A) linear / Planer (non similar)



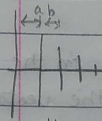
Patch



(B) Linear (similar)

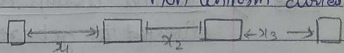
Uniform: distance b/w adjcant elements is same & in phase current

Non Uniform: distance b/w adjcant elements is not same & non uniform current



Yaggi

$a = b$



$x_1 \neq x_2 \neq x_3$

Binomial array

- In dipole antenna can have the sidelobs, when size of antenna we are changing.

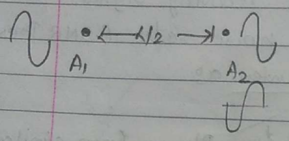
linear array

Broad side | Endfire | Collinear | Parasitic

$\cdot$ A
constructive

$\cdot$ D
Destructive

Broadside :



A_1 & A_2 are $\lambda/2$ apart and both are in same phase. then at point A → constructive.
and if we want at point B → constructive then Both A_1 & A_2 are out in phase → end fired array antenna.

- By changing the distance b/w two antenna, and By changing the phase we can get the Directivity in a particular (desired) direction.

~~Ex~~ ⇒ "Antenna arrays" can be defined as directed to get required High directivity in the desired direction. The total field is the vector sum of fields ~~provide~~ produce by the Individual antenna of an array.

~~Sol~~

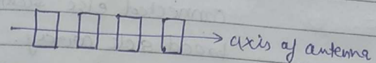
for ex: if Phase shift is $\pi/3$ the what is distance b/w sources: →

$\pi \longrightarrow \lambda/2$

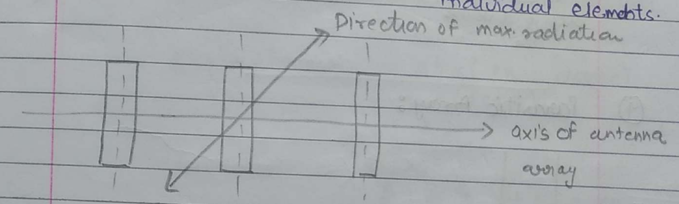
$\pi/3 \longrightarrow \lambda/2\pi \times \pi/3 = \lambda/6$

Types :

① Broadside :

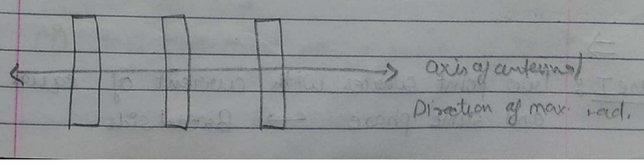


- same elements
- equal spacing
- in-phase current
- direction of max. radiation = normal to both axis of antenna array & axis of individual elements.



② End fire :

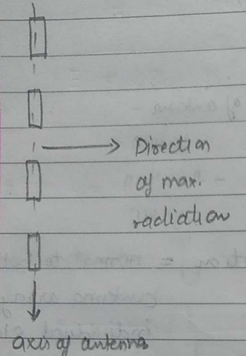
- same elements
- equal spacing
- out of phase current
- Direction of max. rad. is along the axis of antenna arrays.



Scanned by CamScanner

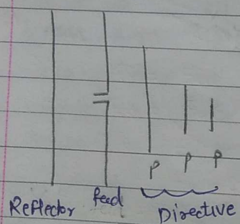
material for antenna is copper ...
(Density & conductivity → both factors are we have to consider)

③ Collinear array:



- antennas are end-to-end connected else same as broad side array.
- not used mostly.

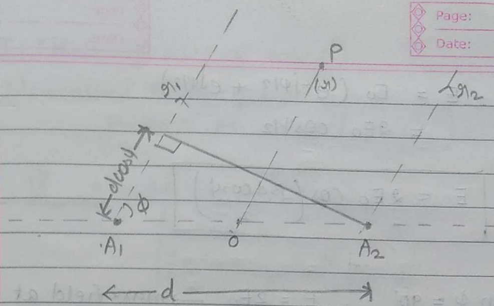
④ Parasitic Array:



For a spacing b/w ~~given~~ driven element & parasitic elements if it is $\lambda/4$ and phase diff of $\pi/2$ rad then unidirectional radiation pattern is achieved.

⇒

Case I: Two point sources with current of equal mag. and same phase → Broad side



A_1 & A_2 → Point source

if 'p' is at large distance $r_1 = r_2 = r$

path difference $= d\cos\phi$

path difference in terms of λ = $\dfrac{d\cos\phi}{\lambda}$

phase change $= 2\pi \times$ (phase change)
$= \dfrac{2\pi}{\lambda}(d\cos\phi)$

$\beta = 2\pi/\lambda$ → wave no.

phase change/shift $\boxed{\psi = \beta d \cos\phi}$

ψ is the phase change b/w point source A_1 & A_2 and point P.

E_1 → is the electric field at point P due to point source A_1

E_2 → due to A_2

(i) taking O point as reference $\overleftarrow{E_1}\ O\ \overrightarrow{E_2}$

$E_1 = E_0\, e^{-j\psi/2}$

$E_2 = E_0\, e^{+j\psi/2}$

Scanned by CamScanner

$$E = E_0 \left(e^{-j\psi/2} + e^{j\psi/2}\right)$$
$$= 2E_0 \cos\psi/2$$

$$\boxed{E = 2E_0 \cos\left(\frac{\beta d \cos\phi}{2}\right)}$$

↳ when $\phi = 90^\circ$; $E = 2E_0 \rightarrow$ max. field at point P

↳ when $\phi = 0^\circ$; $d = \lambda/2$, $E = 0 \rightarrow$ min.

$$\boxed{\text{Array factor} = \frac{E}{|E_{max}|}}$$

Case (ii) taking A_1 point as reference

$$E_1 = E_0$$
$$E_2 = E_0 e^{j\psi}$$
$$E = E_0 (1 + e^{j\psi})$$
$$= E_0 (e^{j0} + e^{j\psi})$$
$$= \cancel{2E_0 \cos}$$
$$= E_0 e^{j\psi/2} \left[e^{-j\psi/2} + e^{j\psi/2}\right]$$
$$\boxed{E = 2E_0 e^{j\psi/2} \cos(\psi/2)}$$

Variation of amplitude of electric field

Variation of Phase if reference is A_1

case I: (it is the part of case I)

→ Normalised E we get

$$E_{norm} = AF = \cos\left(\frac{\beta d \cos\phi}{2}\right)$$

if $\beta = \frac{2\pi}{\lambda}$; & $d = \lambda/2$

$$\boxed{E_{norm} = \cos\left(\frac{\pi}{2}\cos\phi\right)}$$

i) max. points

$$E_{max} = \cos\left(\frac{\pi}{2}\cos\phi\right) = \pm 1$$

$$\frac{\pi}{2}\cos\phi = \pm n\pi \qquad \because n = 0, 1, 2, \ldots$$

take $n = 0$; $\frac{\pi}{2}\cos\phi = 0$

$$\boxed{\phi = 90^\circ, 270^\circ \ldots}$$

ii) min. points

$$E_{min} = \cos\left(\frac{\pi}{2}\cos\phi\right) = 0$$

X

$$\frac{\pi}{2}\cos\phi = \frac{n\pi}{2} \qquad n = 1, 3, 5 \ldots$$

take $n = \phi$; $\cos\phi = \phi$

$$\boxed{\phi = 0, \ldots}$$

$$\frac{\pi}{2}\cos\phi = \pm (2n+1)\frac{\pi}{2}$$

for $n = 0$; $\cos\phi = \pm\phi$

$$\boxed{\phi = 0, \pi}$$

(iii) for half power points:

$$E_{half} = \pm \frac{E}{\sqrt{2}}$$

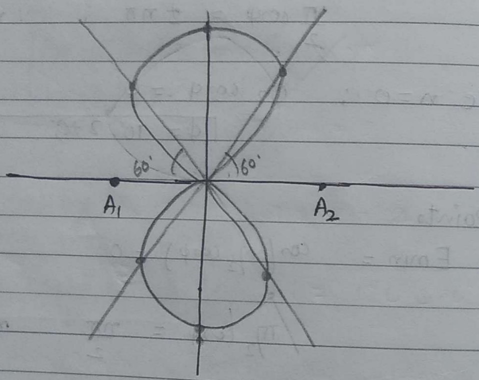
$\boxed{P \propto E^2}$

$$\cos\left(\frac{\pi}{2}\cos\phi\right) = \pm \frac{1}{\sqrt{2}}$$

$$\frac{\pi}{2}\cos\phi = \pm (2n+1)\frac{\pi}{4}$$

take $n = 0$ $\quad \pi/2 \cos\phi = \pm \pi/4$

$$\boxed{\phi = 60^\circ / 120^\circ}$$



<u>Case II</u>: Two point sources with current of ~~same~~ diff^n magnitude and opposite phase. (out of phase)

⟶ end fire

$E_0 e^{j(\psi/2+\pi)}$ $\quad$ $\longleftarrow -E_0 \quad \longrightarrow E_0$

$$E = -E_0 e^{j\psi/2} + E_0 e^{-j\psi/2}$$

$$= E_0 \left[-e^{j\psi/2} + e^{-j\psi/2}\right]$$

$$= -2E_0 j \sin(\psi/2)$$

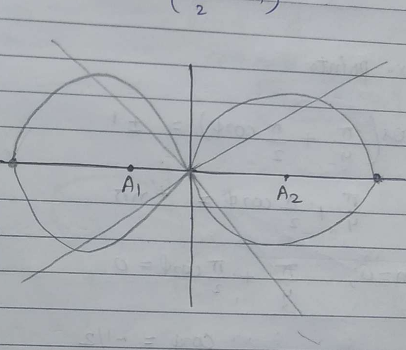
ignored

normalised field

$$E = \sin\left(\frac{\beta d \cos\phi}{2}\right)$$

if $d = \lambda/2$; $\beta = 2\pi/\lambda$

$$E = \sin\left(\frac{\pi}{2}\cos\phi\right)$$



<u>Case III</u>: two isotropic point sources of same amplitude and in phase quadrature

$$E = E_0 e^{j(\psi/2 + \pi/4)} + E_0 e^{-j(\psi/2+\pi/4)}$$

A_1 $\quad$ 0 $\quad$ A_2

$\pi/4$ $\quad\quad$ $-\pi/4$

phase shift introduces by the point sources

phase shift due to path diff^n

$$E = 2E_0 \cos\left(\frac{\psi}{2} + \frac{\pi}{4}\right)$$

$$E = 2E_0 \cos\left(\frac{\pi}{4} + \frac{\beta d \cos\phi}{2}\right)$$

$$\boxed{E_{norm} = \cos\left(\frac{\pi}{4} + \frac{\pi}{2}\cos\phi\right)}$$

i) max. points

$$\cos\left(\frac{\pi}{4} + \frac{\pi}{2}\cos\phi\right) = \pm 1$$

$$\frac{\pi}{4} + \frac{\pi}{2}\cos\phi = \pm n\pi$$

for $n=0$; $\frac{\pi}{4} + \frac{\pi}{2}\cos\phi = 0$

$$\cos\phi = -1/2$$

$$\boxed{\phi = 120°/240°}$$

ii) min points

$$\cos(\pi/4 + \pi/2 \cos\phi) = 0$$

$$\pi/4 + \pi/2 \cos\phi = \pm(2n+1)\pi/2$$

for $n=0$; $\pi/4 + \pi/2\cos\phi = \pm \pi/2$

$$1/2 + \cos\phi = \pm 1$$

$$\cos\phi = 1/2, -3/2 \rightarrow \times$$

$$\boxed{\phi = 60°/300°}$$

iii) Half power points

$$\cos(\pi/4 + \pi/2\cos\phi) = \pm\frac{1}{\sqrt{2}}$$

$$\pi/4 + \pi/2\cos\phi = \pm(2n+1)\pi/4$$

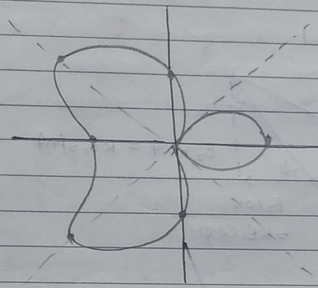
for $n=0$;

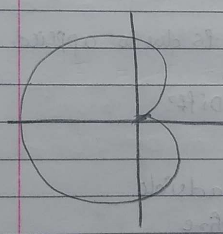
$$1 + 2\cos\phi = \pm 1$$

$2\cos\phi = 0$; $2\cos\phi = -2$

$\cos\phi = 0$; $\cos\phi = -1$

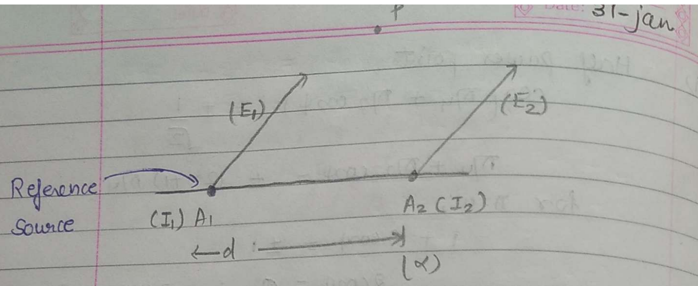
$\boxed{\phi = 90°/270°}$ $\boxed{\phi = \pi}$





Case IV: General case of 2-isotropic point sources of unequal amplitude & at any phase:

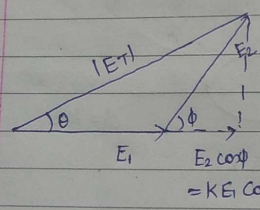
Date: 31-jan



$|E_1| > |E_2|$

$\frac{E_2}{E_1} = K$

$K < 1$



$E_2 \sin\phi = K E_1 \sin\phi$ —— (A)

$\psi = \beta d \cos\phi + \alpha$

ψ → total Ps

$\beta d \cos\phi$ → Ps due to Path Diff^n

α → Ps due to applied source

When $\alpha = 0° \longrightarrow$ broadside

$\alpha = 180° \longrightarrow$ end fire

When $0 \leq \alpha \leq 180°$

$E_T = E_1 e^{j0} + E_2 e^{j\psi}$

$= E_1 + E_2 e^{j\psi}$

Page:
Date:

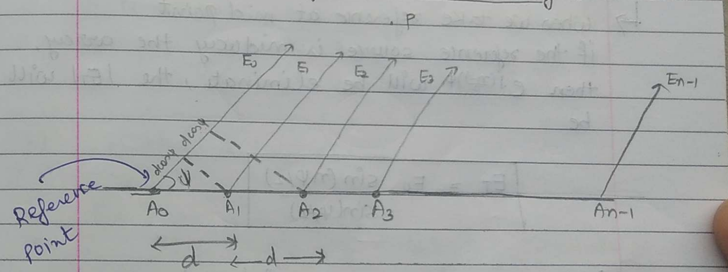
$= E_1 \left(1 + \frac{E_2}{E_1} e^{j\psi}\right)$

$E_T = E_1 (1 + K e^{j\psi})$

– magnitude of $|E_T| = |E_1| \sqrt{(1 + K\cos\psi)^2 + (K\sin\psi)^2}$

– angle $\theta = \tan^{-1}\left(\frac{K\sin\psi}{1 + K\cos\psi}\right)$ (from Dia (A))

⇒ <u>n-elements uniform linear Array :</u>



Uniform : $E_0 = E_1 = E_2 = \_\_\_ = E_{n-1}$

$E_T = E_0 e^{j0} + E_1 e^{j\psi} + E_2 e^{j2\psi} + \_\_\_ E_{n-1} e^{j(n-1)\psi}$

$E_T = E_0 [1 + e^{j\psi} + e^{2j\psi} + e^{3j\psi} + \_ e^{(n-1)j\psi}]$ —(1)

$\because \psi = \beta d \cos\phi$

$e^{j\psi} E_T = E_0 [e^{j\psi} + e^{2j\psi} + e^{3j\psi} + \_\_ + e^{nj\psi}]$ —(2)

Scanned by CamScanner

$$E_T(1 - e^{j\psi}) = E_0(1 - e^{jn\psi})$$

$$E_T = E_0 \frac{(1 - e^{jn\psi})}{(1 - e^{j\psi})}$$

$$= E_0 \frac{e^{jn\psi/2}\left[e^{-jn\psi/2} - e^{jn\psi/2}\right]}{e^{j\psi/2}\left[e^{-j\psi/2} - e^{j\psi/2}\right]}$$

$$\boxed{E_T = E_0\, e^{j(n-1)\psi/2} \frac{\sin(n\psi/2)}{\sin(\psi/2)}}$$

when $n = 2$; $E_T = 2E_0\, e^{j\psi/2} \cos(\psi/2) \longrightarrow$ broadside cond(ii)

↳ when we take reference at mid point
if the reference source is midway the array, then $e^{j(\frac{n-1}{2})\psi}$ will be eliminate, the $|E_T|$ will be

$$\boxed{E_T = E_0 \frac{\sin(n\psi/2)}{\sin(\psi/2)}}$$

for max. value $\lim_{\psi \to 0} E_0 \frac{\sin(n\psi/2)}{\sin(\psi/2)} = nE_0$

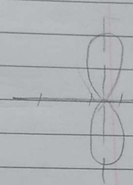
array factor $\longrightarrow$ $\boxed{E_{norm} = \frac{|E_T|}{|E_{Tmax}|} = \frac{\sin(n\psi/2)}{n \cdot \sin(\psi/2)}}$

When $n = 4$ (four sources)
$\alpha = \pi/2$
$d = \lambda/2$

Page:
Date:

$\Longrightarrow$ Condition for linear array of n-isotropic point sources with equal amplitude and phase :

a) Broad side array :



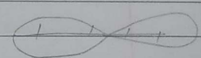
$\alpha = 0$

$\psi = \beta d \cos\phi + \alpha$

for max. rad. $\psi = 0$

$\boxed{\phi = \pi/2, 3\pi/2}$

b) end fire array :



for max. rad. $\psi = 0$

$\beta d \cos\phi + \alpha = 0$ along the axis so that $\phi = 0°$

$\alpha = -\beta d$

↳ $\alpha = -\frac{2\pi}{\lambda} \times \frac{\lambda}{4}$

$\boxed{\alpha = -\pi/2}$

depends on spacing b/w sources
$d = \lambda/2$; $\alpha = -\pi$
$d = \lambda/4$; $\alpha = -\pi/2$

↳ when $d = \lambda/2$

$\alpha = -2\pi/\lambda \times \lambda/2$

$\boxed{\alpha = -\pi}$

* Hazen woodyard: end fire array with increase directivity $\boxed{\alpha = -\left(\beta d + \frac{\pi}{n}\right)}$