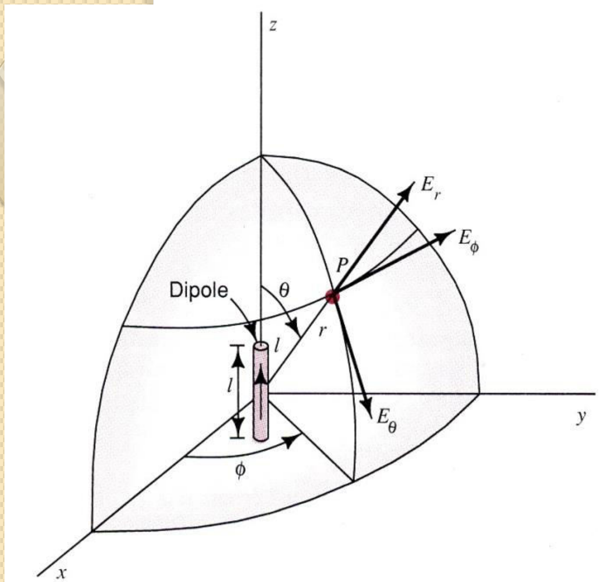
ANTENNA AND WAVE PROPAGATION

Short dipole Electric Field



$$E_r = \frac{I_0 l e^{j(\omega t - \beta r)} \cos(\theta)}{2\pi\varepsilon_0}\left(\frac{1}{cr^2} + \frac{1}{j\omega r^3}\right)$$

$$E_\theta = \frac{I_0 l e^{j(\omega t - \beta r)} \sin(\theta)}{4\pi\varepsilon_0}\left(\frac{j\omega}{c^2 r} + \frac{1}{cr^2} + \frac{1}{j\omega r^3}\right)$$

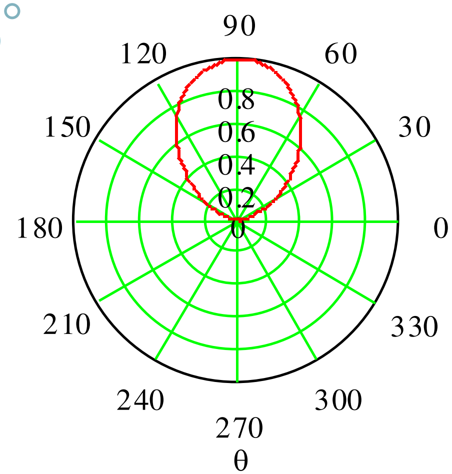
$$H_\phi = \frac{I_0 l e^{j(\omega t - \beta r)} \sin(\theta)}{4\pi}\left(\frac{j\omega}{cr} + \frac{1}{r^2}\right)$$

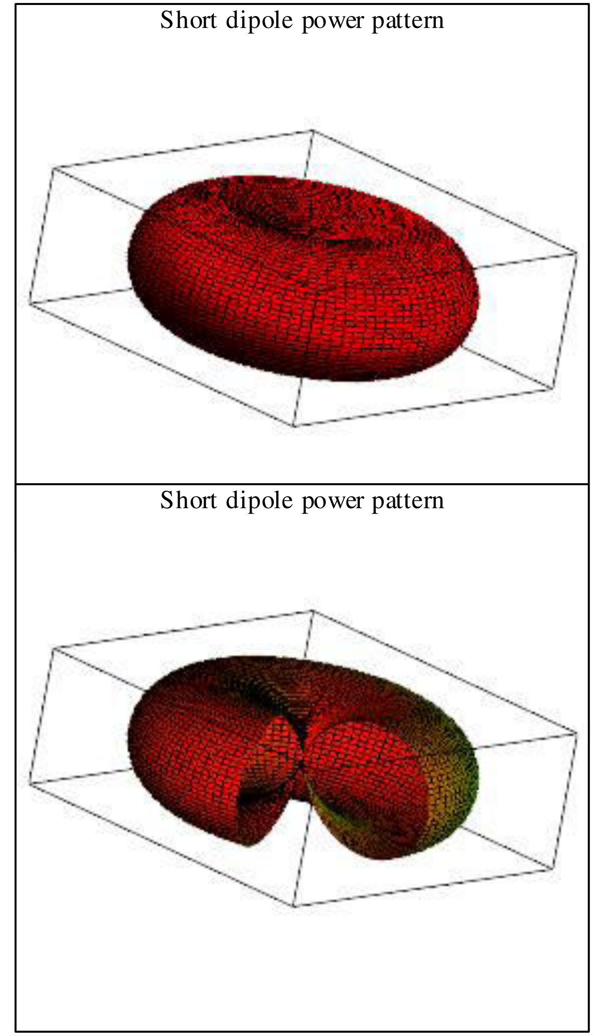
- Length much shorter than wavelength
- Current constant along the length
- Near dipole power is mostly reactive
- As r increases E_r vanishes, E and H gradually become in phase

$$\textit{for } r >> \frac{\lambda}{2\pi}, \qquad \mathrm{E}_\theta \textit{ and } \mathrm{H}_\phi \text{ vary as } \frac{1}{\mathrm{r}} \longrightarrow E_\theta = \frac{j60\pi I_0 e^{j(\omega t - \beta r)} \sin(\theta)}{r}\frac{l}{\lambda}$$

$$\text{P varies as } \frac{1}{\mathrm{r}^2}$$

Radiation Resistance of short electric dipole





PN

$$\Omega_A = \frac{8\pi}{3}$$

$$R_r = 80\pi^2\left(\frac{l}{\lambda}\right)^2$$

$$D = 1.5$$

(X, Y, Z)

Thin Linear Antenna

Collinear Array

- All elements along same axis
- Used to provide an omnidirectional horizontal pattern from a vertical antenna
- Concentrates radiation in horizontal plane

Array of two driven lambda/2 Elements

Broadside Array

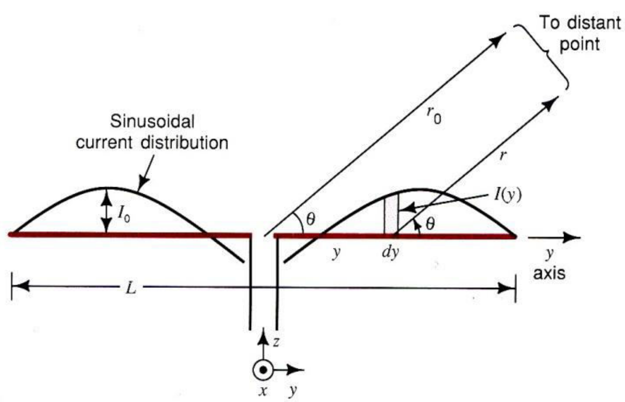
- Bidirectional Array
- Uses Dipoles fed in phase and separated by 1/2 wavelength

End-Fire Array

- Similar to broadside array except dipoles are fed 180 degrees out of phase
- Radiation max. off the ends

Thin wire antenna

- Wire diameter is small compared to wavelength
- Current distribution along the wire is no longer constant



$$\text{e.g.}\quad I(y) = I_0 \sin\left(\frac{2\pi}{\lambda}\left(\frac{L}{2} \pm y\right)\right)$$

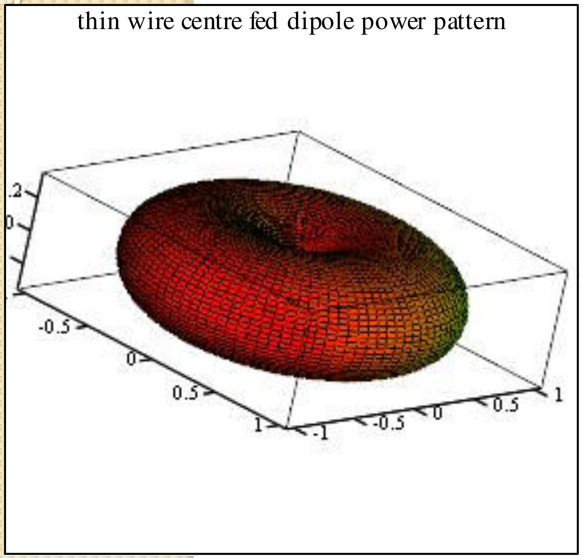
centre-fed dipole

- Using field equation for short dipole, replace the constant current with actual distribution

$$E_\theta = \frac{j60 I_0 e^{j(\omega t - \beta r)}}{r}\left(\frac{\cos\left(\frac{\beta L \cos(\theta)}{2}\right) - \cos\left(\frac{\beta L}{2}\right)}{\sin(\theta)}\right)$$

centre-fed dipole, I_0 = current at feed point

Thin wire pattern

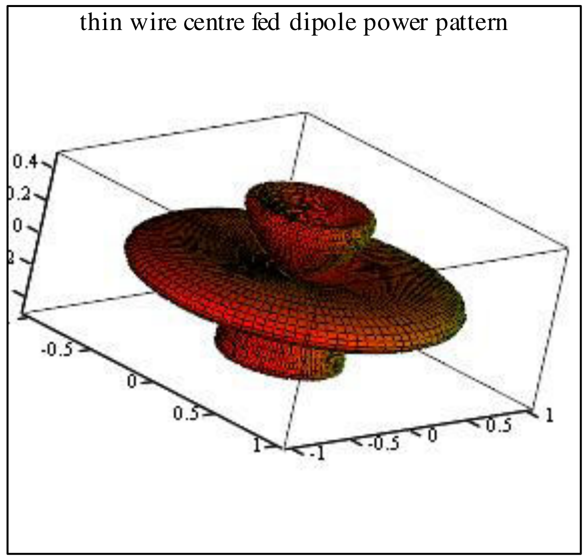


(X, Y, Z)

$l = 1\,\frac{\lambda}{2}$

$\Omega_A = 7.735$

$D = 1.625$

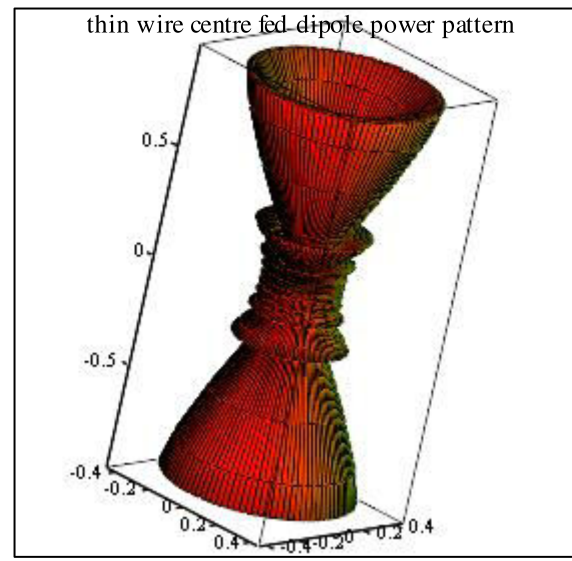


(X, Y, Z)

$l = 1.395\lambda$

$\Omega_A = 5.097$

$D = 2.466$



(X, Y, Z)

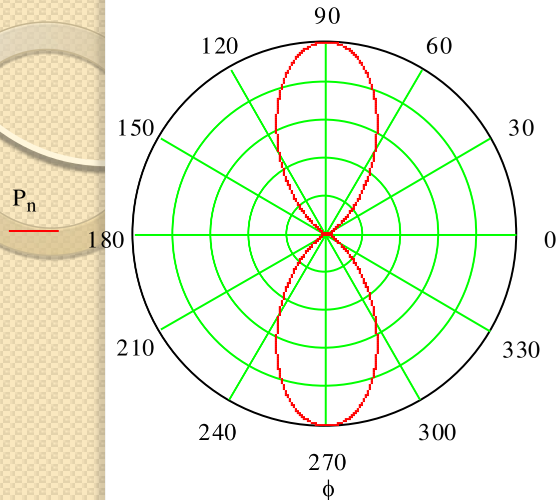
$l = 10\lambda$

$\Omega_A = 1.958$

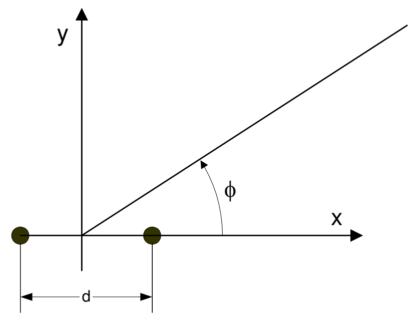
$D = 6.417$

Array of isotropic point sources – beam shaping

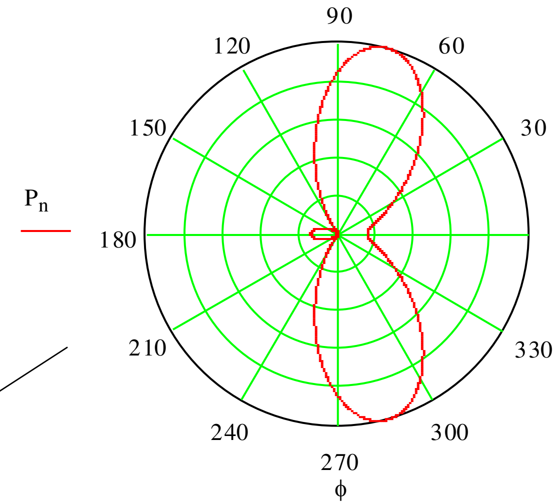
Power pattern of 2 isotropic sources



$d = 1\frac{\lambda}{2}$ $\delta = 0\,\mathrm{deg}$

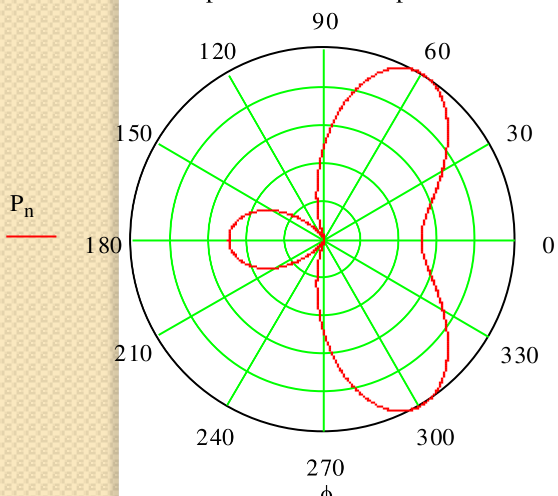


Power pattern of 2 isotropic sources



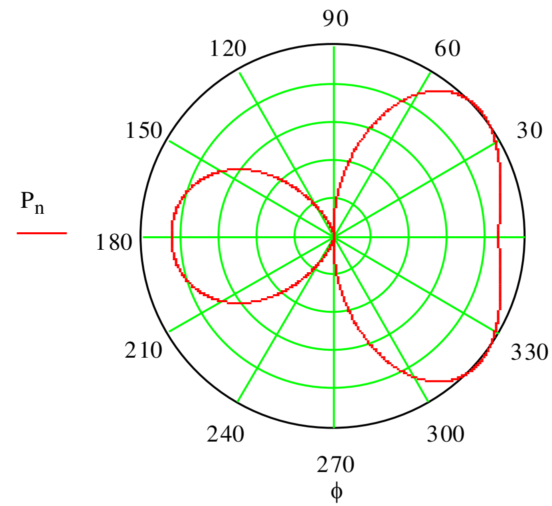
$d = 1\frac{\lambda}{2}$ $\delta = -45\,\mathrm{deg}$

Power pattern of 2 isotropic sources



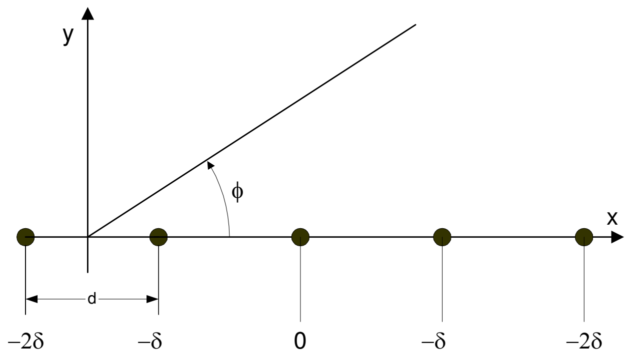
$d = 1\frac{\lambda}{2}$ $\delta = -90\,\mathrm{deg}$

Power pattern of 2 isotropic sources



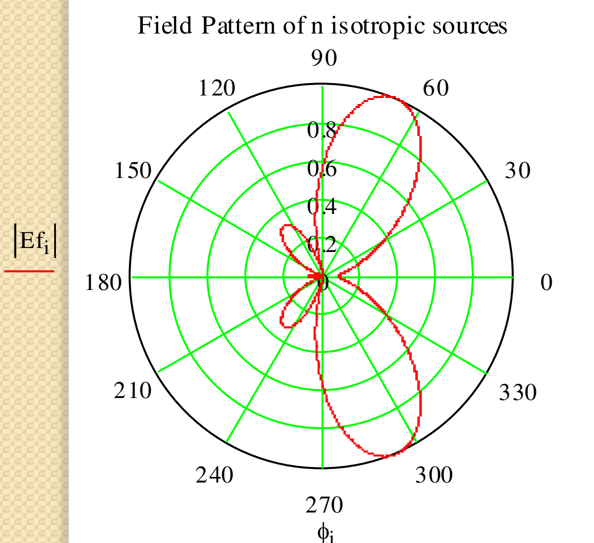
$d = 1\frac{\lambda}{2}$ $\delta = -135\,\mathrm{deg}$

Array of isotropic point sources – centre-fed array

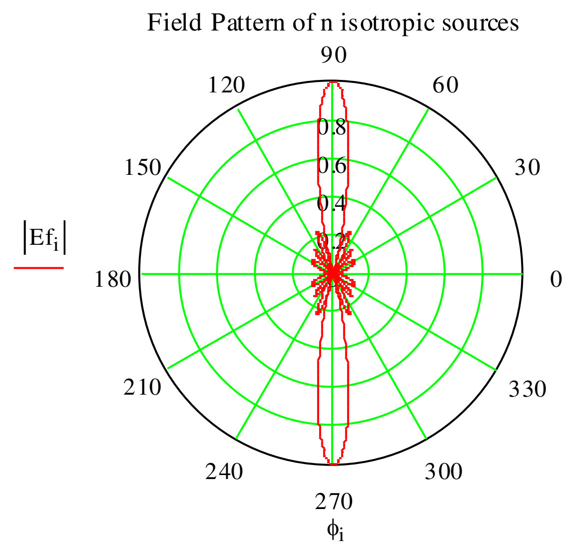


$$\psi(\phi) = \frac{2\pi d}{\lambda}\cos(\phi) + \delta$$

$$E_n(\psi) = \frac{1}{n}\frac{\sin\left(\frac{n\psi}{2}\right)}{\sin(\psi/2)}$$



$n = 3$ $\delta = -67.5\mathrm{deg}$ $d = 0.5\lambda$

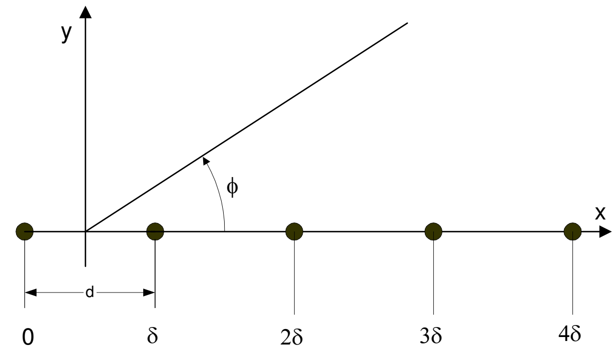


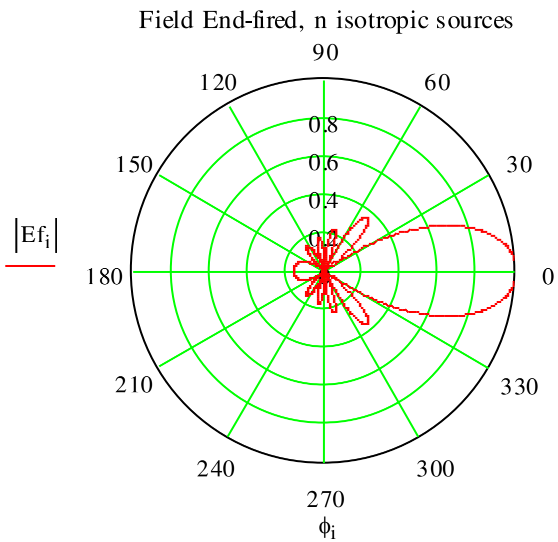
$n = 8$ $\delta = 0\,\mathrm{deg}$ $d = 0.5\lambda$

Array of isotropic point sources – end-fired

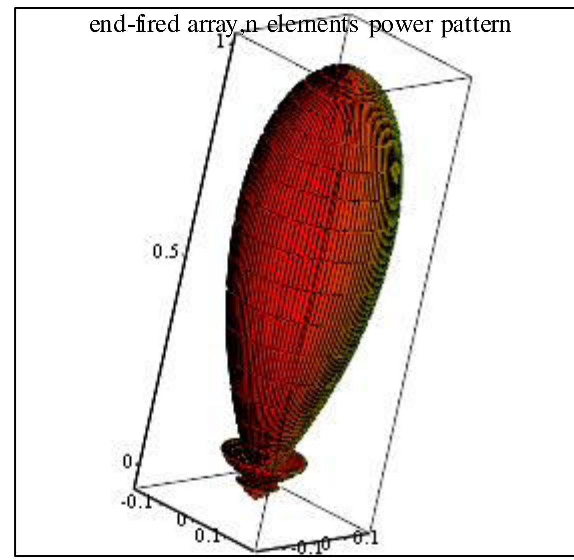
$$\psi(\phi) = \frac{2\pi d}{\lambda}(\cos(\phi) - 1) - \frac{\pi}{n}$$

$$E_n(\psi) = \sin\left(\frac{\pi}{2n}\right)\frac{\sin\left(\frac{n\psi}{2}\right)}{\sin\left(\frac{\psi}{2}\right)}$$





$n = 10$ $\delta = -108\,\mathrm{deg}$ $d = 1\,\frac{\lambda}{4}$



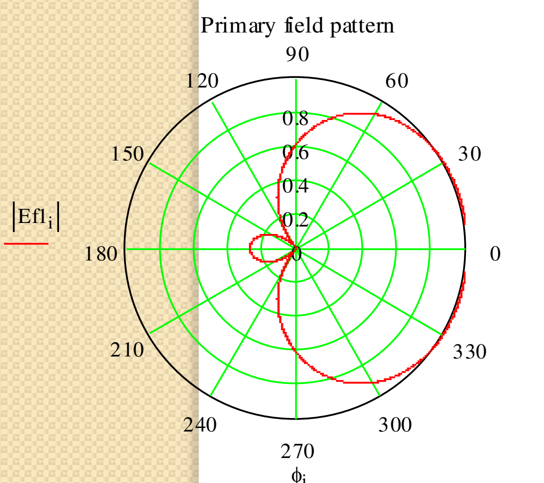
(X, Y, Z)

$n = 10$ $d = 0.25\lambda$

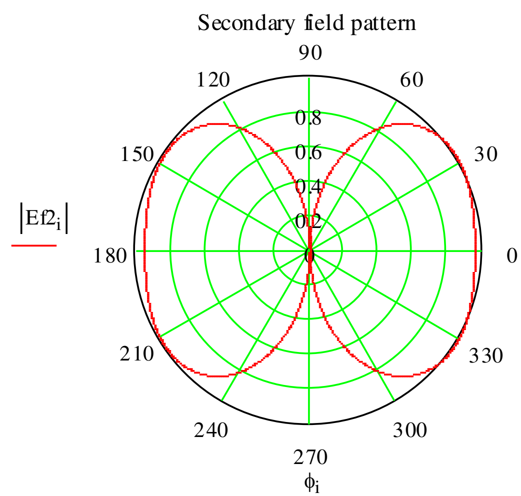
$\Omega_A = 0.713$ $D = 17.627$

Pattern multiplication

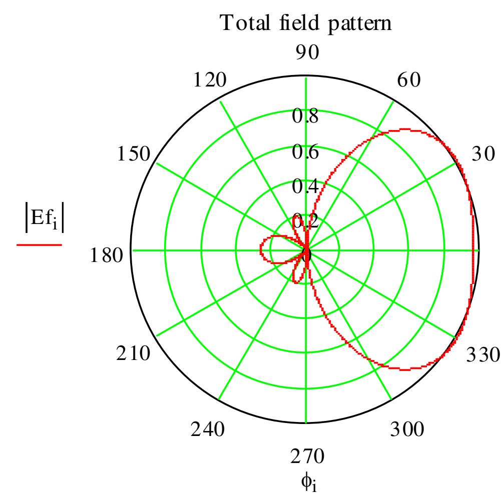
The total field pattern of an array of non-isotropic but similar point sources is the product of the individual source pattern and the pattern of an array of isotropic point sources having the same locations,relative amplitudes and phases as the non-isotropic point sources.



$n = 2$ $\delta1 = -104\text{deg}$ $d1 = 0.3\lambda$



$n = 2$ $\delta2 = 180\text{deg}$ $d2 = 0.6\lambda$



Total pattern of two primary sources (each an array of two isotropic sources) replacing two isotropic sources (4 sources in total).

Patterns from line and area distributions

- When the number of discrete elements in an array becomes large, it may be easier to consider the line or the aperture distribution as continuous.

- line source:

$$E(u) = \frac{l}{2}\int_{-1}^{+1} f(x)e^{jux}dx \qquad \mathrm{u} = \frac{\pi d}{\lambda}\sin(\phi)\,,\ \mathrm{l} = \text{length},\ \phi = \text{angle from normal to line}$$

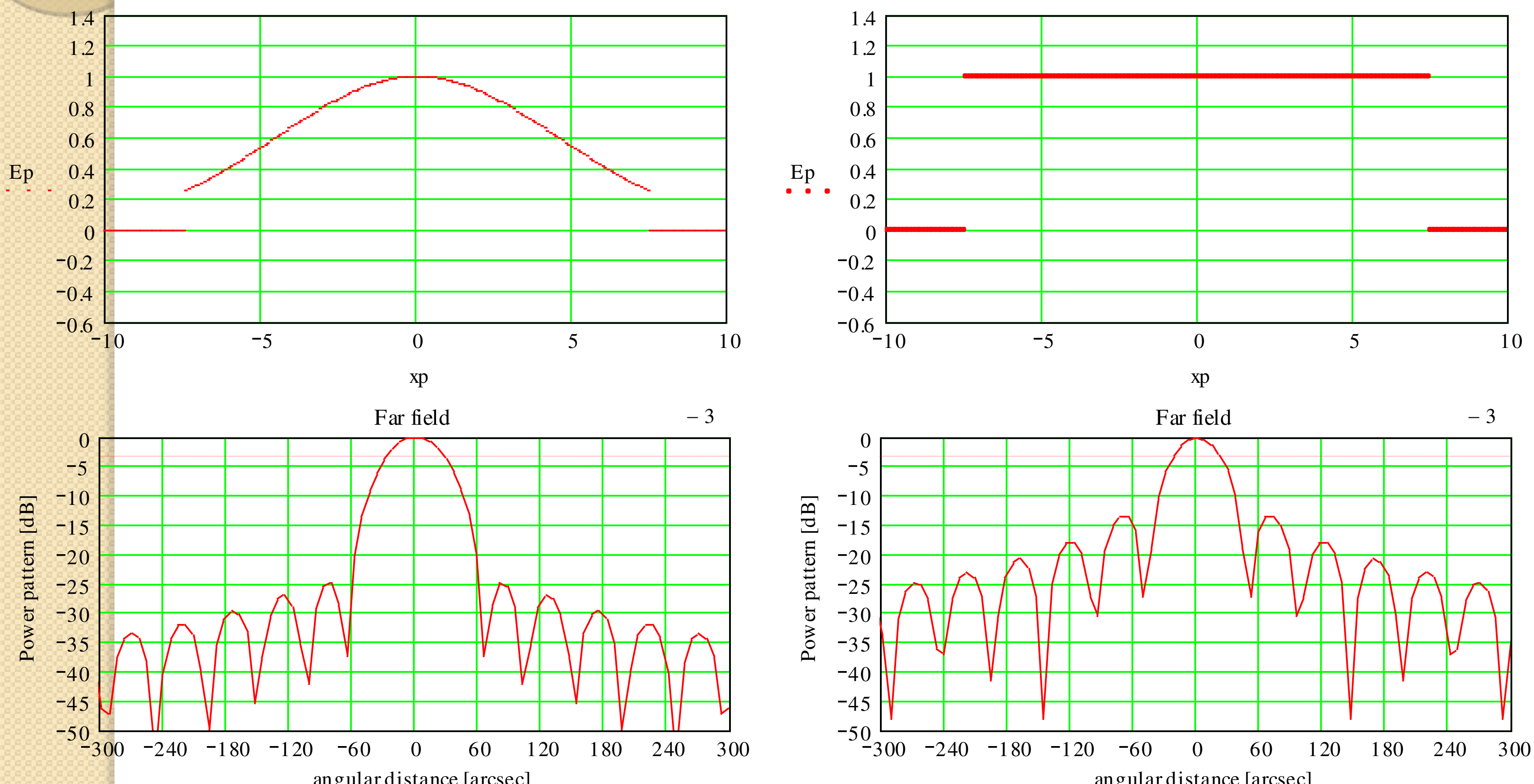
- 2-D aperture source:

$$E(\theta,\phi) = \iint_{aperture} f(x,y)e^{j\beta\sin(\theta)(x\cos(\phi)+y\sin(\phi))}dx\,dy$$

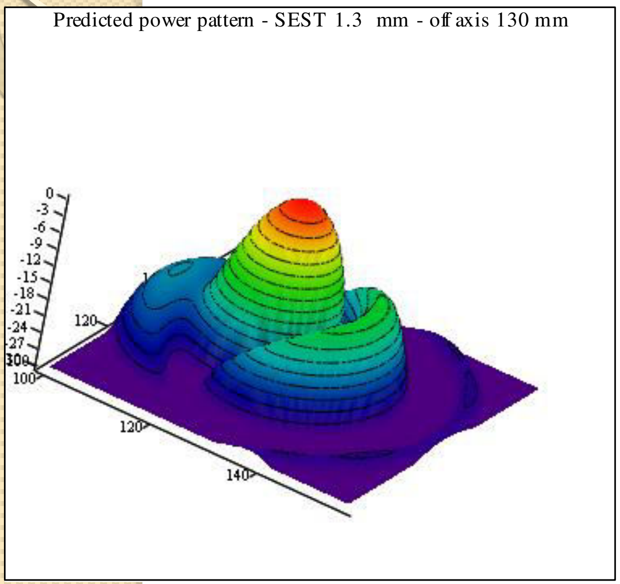
$$f(x,y) = \text{aperture field distribution}$$

Fourier transform of aperture illumination
Diffraction limit

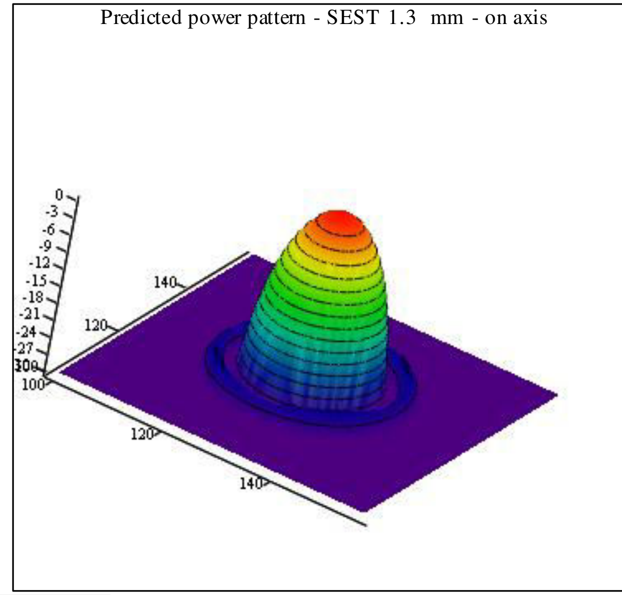
$$HPBW = \frac{\lambda}{D} \quad \text{rough estimate only}$$

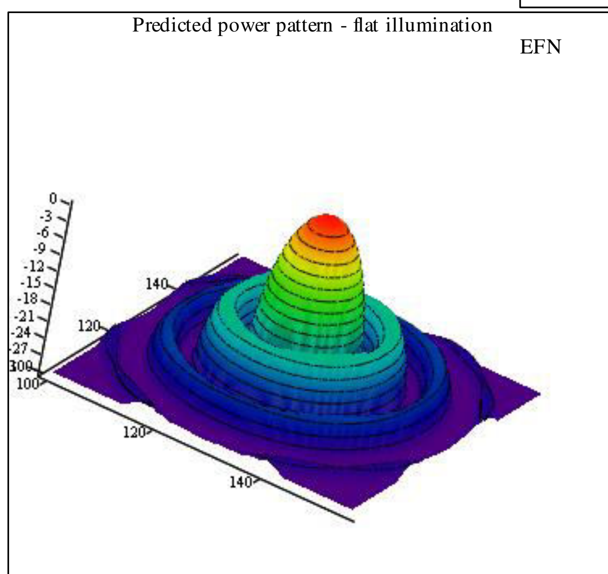


Far field pattern from FFT of Aperture field distribution



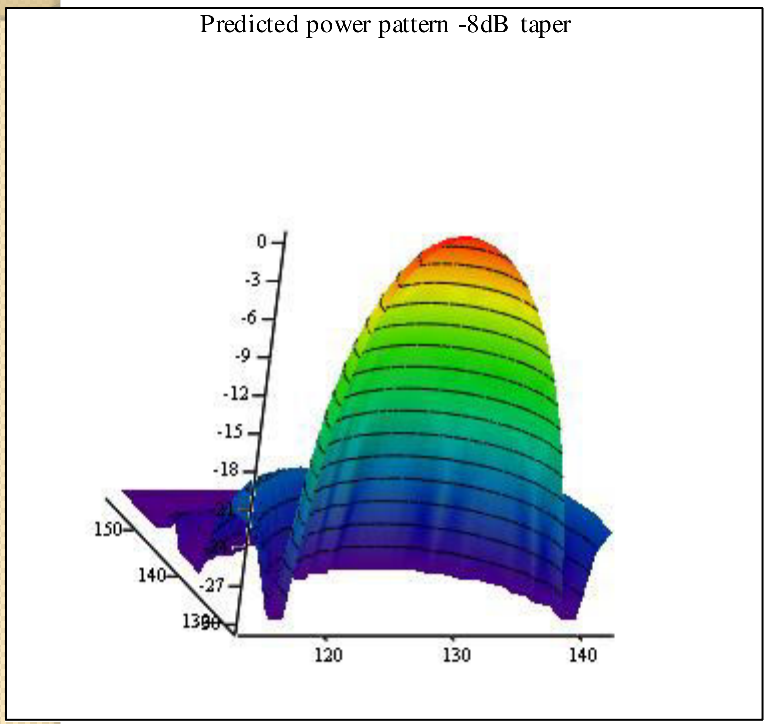
EFN



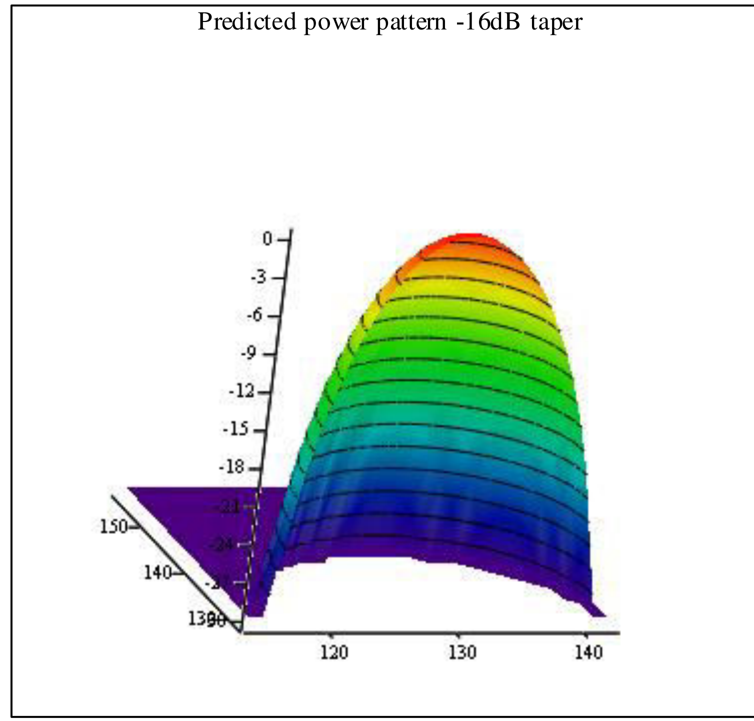


EFN

Effect of edge taper



EFN

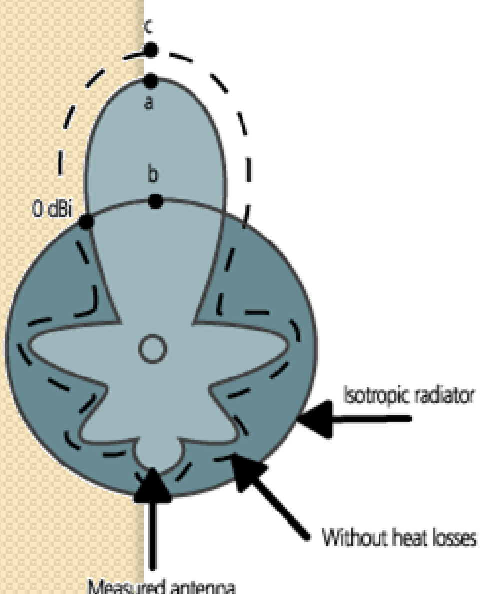


EFN

dBi versus dBd

- **dBi** indicates gain vs. isotropic antenna
  - Isotropic antenna radiates equally well in all directions, spherical pattern

- **dBd** indicates gain vs. reference half-wavelength dipole
  - Dipole has a doughnut shaped pattern with a gain of 2.15 dBi



$$dBi = dBd + 2.15\,dB$$

Feed and line matching

- The antenna impedance must be matched by the line feeding it if maximum power transfer is to be achieved
- The line impedance should then be the complex conjugate of that of the antenna
- Most feed line are essentially resistive

Signal transmission, radar echo

- Transmitting antenna $A_{et}, P_t, G_t, \lambda$
- Receiving antenna A_{er}, P_r, G_r

$$P_r = \underbrace{\frac{G_t P_t}{4\pi \cdot r^2}}_{\text{S, power density}} \underbrace{\frac{\lambda^2 G_r}{4\pi}}_{\text{Effective receiving area}} = \left(\frac{\lambda}{4\pi \cdot r}\right)^2 G_t G_r P_t$$

Radar return

$$P_r = \underbrace{\frac{G_t P_t}{4\pi \cdot r^2}}_{\text{S, power density}} \underbrace{\frac{\sigma}{4\pi \cdot r^2}}_{\text{Reflected power density}} \underbrace{\frac{G_r \lambda^2}{4\pi}}_{\text{Effective receiving area}} = P_t G_t G_r \frac{\lambda^2}{(4\pi)^3 r^4} \sigma$$

$\sigma =$ radar cross section (area)

Yagi Uda Antenna

PRINCIPLE

- ***YAGI-UDA ANTENNA IS AN ELECTROMAGNETIC DEVICE THAT COLLECTS RADIO WAVES. AN ANTENNA TUNED TO A PARTICULAR FREQUENCY WILL RESONATE TO A RADIO SIGNAL OF THE SAME FREQUENCY.***

CONSTRUCTION

- THE YAGI-UDA ANTENNA CONSISTS OF 2 PARTS:

  - THE ANTENNA ELEMENTS
  - THE ANTENNA BOOM

- THERE ARE THREE TYPES OF ELEMENTS:

  - THE REFLECTOR (REFL)
  - THE DRIVEN ELEMENT (DE)
  - THE DIRECTORS (DIR)

WORKING

- REFLECTOR HERE DERIVES IT'S MAIN
  POWER FROM A DRIVER , IT REDUCES THE SIGNAL STRENGTH IN IT'S OWN DIRECTION AND THUS REFLECTES THE RADIATION TOWARDES THE DRIVER AND DIRECTORS.

- THE DRIVEN ELEMENT IS WHERE THE SIGNAL IS INTERCPETED BY THE RECEIVING EQUIPMENT AND HAS THE CABLE ATTACHED THAT TAKES THE RECEVIED SIGNAL TO THE RECEIVER

- THE RADIATOR AND DRIVER CAN BE PLACED MORE CLOSER TO INCREASE THE RADIATION LENGTH TOWARDS THE DIRECTORS.

FIVE ELEMENT YAGI-UDA

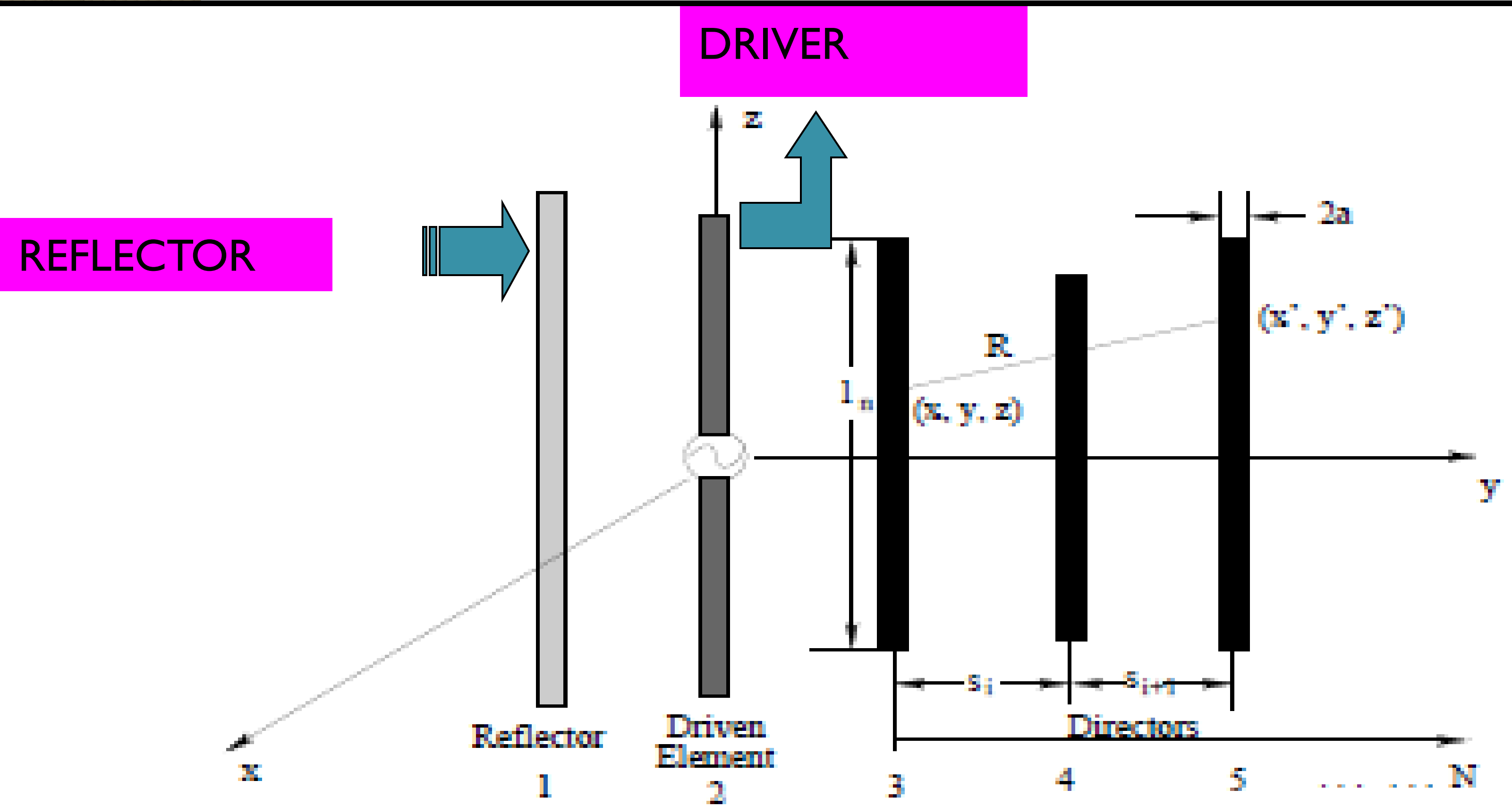


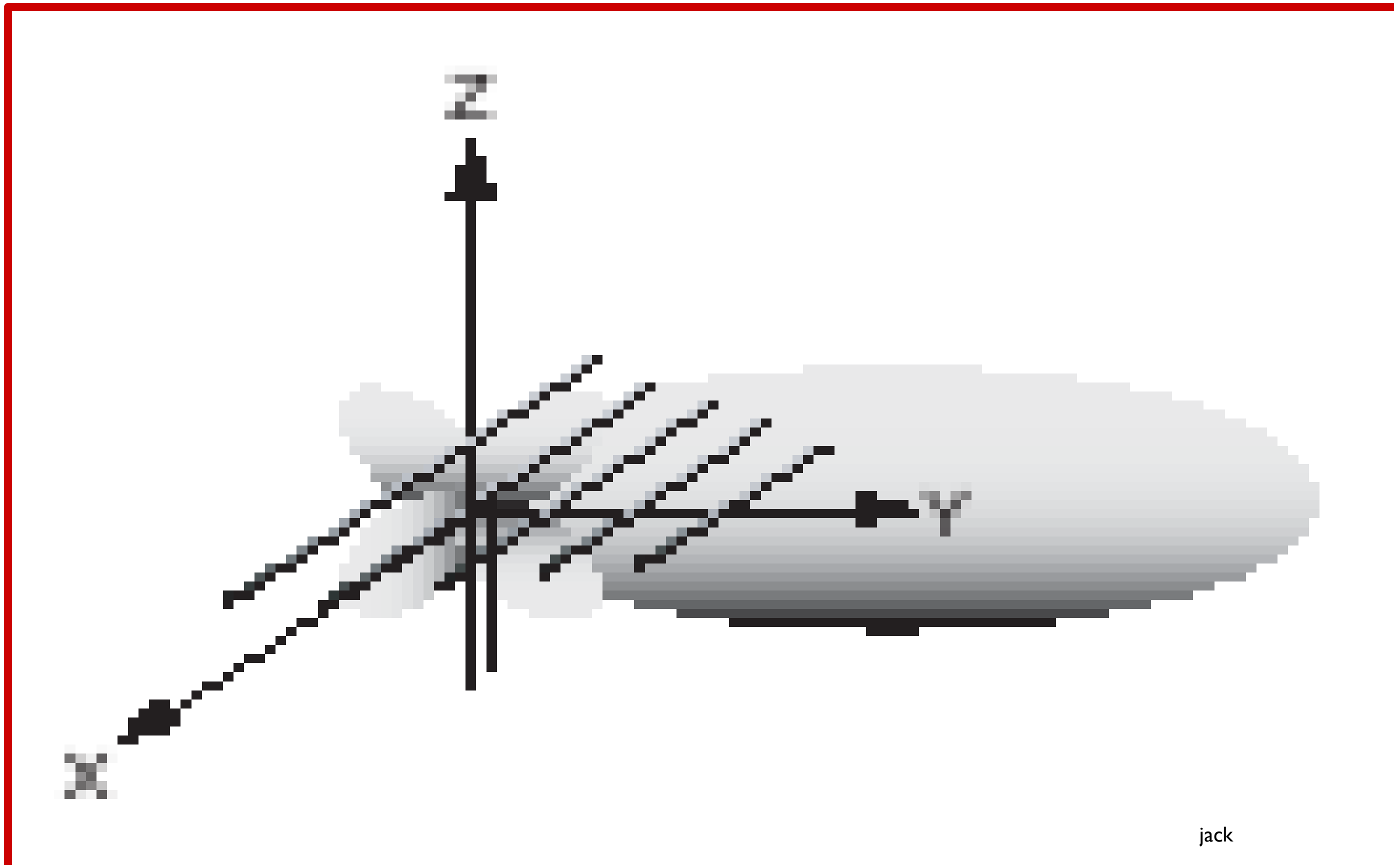
Figure 1.1: Geometry of Yagi-Uda array

- WAVELENGTH = 3*10^8 / FERQUENCY(MHz)

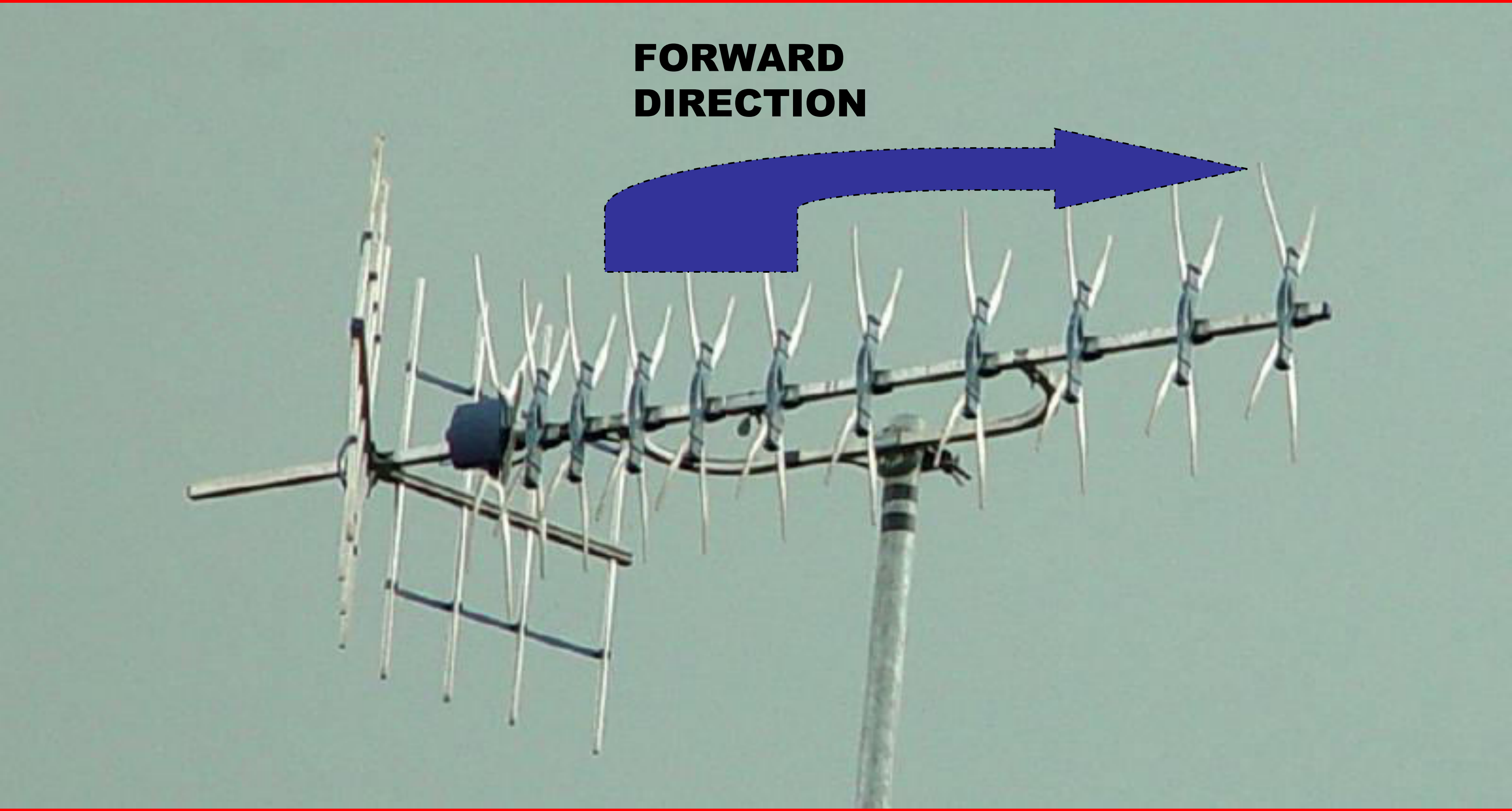
- TO DETERMINE THE WAVE-LENGTH OF A RADIO STATION WITH A FREQUENCY OF 92.1 MHz , SIMPLY DIVIDE THE SPEED OF LIGHT (300,000,000 METERS PER SECOND) BY 92,100,000 CYCLES PER SECOND.

THE SECONDS CANCELS OUT IN THE FORMULA WITH THE WAVE-LENGTH ENDING UP AT 3.26 METERS. IN OTHER WORDS THE WAVES PASSING YOU BUY RIGHT NOW FROM A RADIO STATION TRANSMITTING AT 92.1 MHz ARE 3.26 METERS LONG.

Radiation pattern formed by the directional antenna



PICTURE OF ANTENNA



ELEVEN ELEMENT'S OF YAGI-UDA ANTENNA

ADVANTAGES

- IT HAS A MODERATE GAIN OF ABOUT 7 (DB).
- IT IS A DIRECTIONAL ANTENNA.
- CAN BE USED AT HIGH FREQUENCY.
- ADJUSTABLE FROM TO BACK RATIO.

DISADVANTAGES

- *THE GAIN IS NOT VERY HIGH.*
- *NEEDS A LARGE NUMBER OF ELEMENTS TO BE USED.*

APPLICATIONS

TELEVISION RECEIVERS.

- IT IS ALSO THE ANTENNA WINDLY USED WITH
- USED AT HF AT VHF A T.V

  RECEIVING ANTENNA.
- A STACK OF YAGI ANTENNA CAN BE

  USED AS A SUPER GAIN.

CONCLUSION

YAGI-UDA ANTENNA IS A UNIDIRECTIONAL ANTENNA. USED FOR TELEVISION RECIVERS.THEY PROVIDE BETTER TUNNING BECAUSE OF LARGE BANDWIDTH AND HAS DECENT GAIN.