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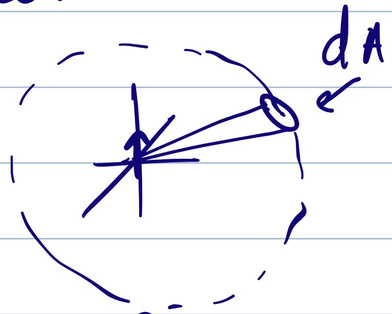
# Antenna Descriptions

Starting point: Poynting vector (far field).

e.g. for a Hertz dipole:

$$\vec{S}_{rad} = \frac{\eta}{8}\left(\frac{I\Delta z}{\lambda}\right)^2 \frac{\sin^2\theta}{r^2}\,\hat{r}$$




From here, the total power is

$$W = \oint \vec{S}\cdot dA\,\hat{r} =$$

$dA \rightarrow r^2\sin\theta\, d\theta\, d\phi\ \hat{r}$

Recall:

$$S = \frac{1}{2}\mathrm{Re}[E\times H^*]$$

Another way of seeing this integral:


$$\text{Solid angle} = d\Omega = \frac{dA}{r^2}$$

$$\therefore\ W = \oint r^2\vec{S}\cdot d\Omega\,\hat{r}$$

which is equivalent to $\oint \vec{S}\cdot dA\,\hat{r}$

Which is more convenient to compute and more practical for discussion?

Since $|S| \propto 1/r^2 \rightarrow$ I will need to know $r$ to talk/compute $|S|$.

But not so for $|S r^2|$ since in f.f $S \propto \frac{1}{r^2}$.

$\therefore$ More convenient qty is $U = r^2 S$
which is called radiation intensity.
units ? $U$: W/solid angle.
$S$: W/$m^2$

More precisely: $U = \frac{r^2}{\eta}|E|^2$

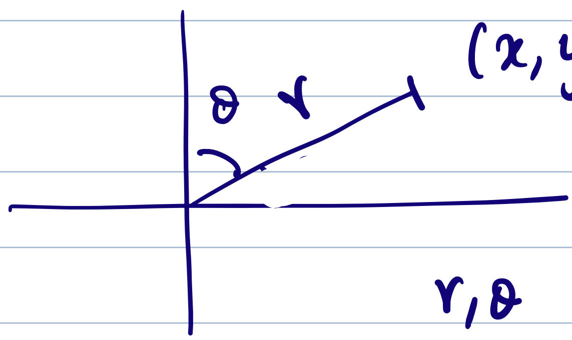
$$= \frac{r^2}{\eta}\Big[\underbrace{|E_\theta|^2 + |E_\phi|^2}_{}\Big]$$

depend on $\frac{1}{r}$.

e.g. for a Hertz dipole $U = U_0 \sin^2\theta$

Then total radiated power $= \int U \, d\Omega$
$= \iint U \sin\theta \, d\theta \, d\phi$

Also a useful qty to plot in polar coordinates.

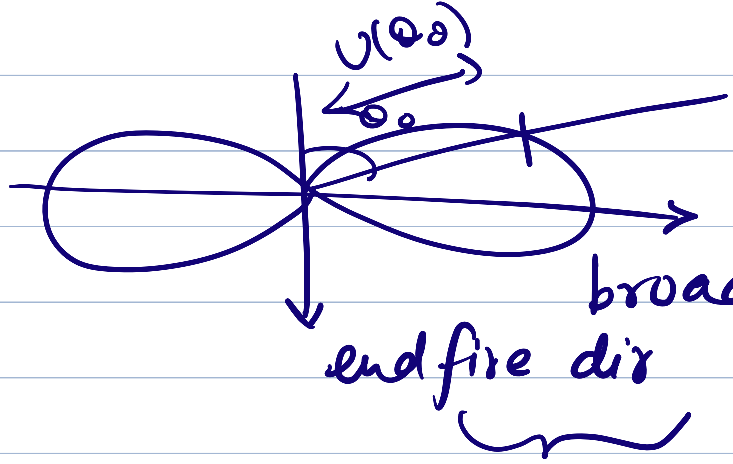



$(x, y) = r(\sin\theta, \cos\theta)$

$r, \theta$ plot $\rightarrow$ not the $r, \theta$ of the antenna but of the 2D plot.

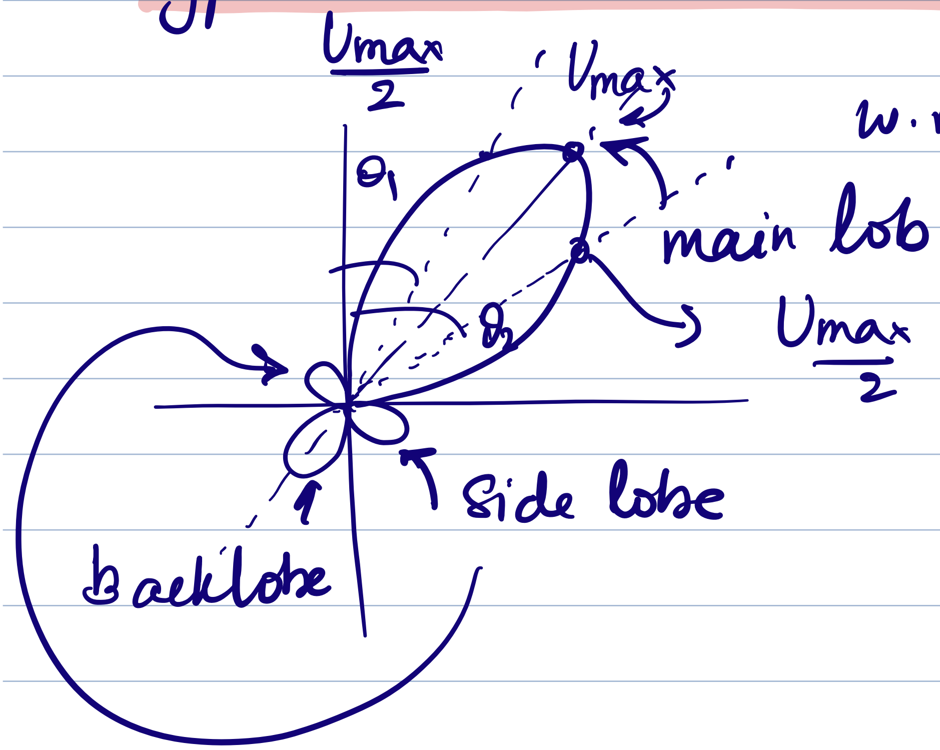
So when we want to plot rad pattern of Hertz dipole
Map: $r \rightarrow U$
$\theta \rightarrow \theta$

⇒




θ from 0 to 360.

## Typical Radiation Patterns




w.r.t. antenna axis.

Half power beam width $= \theta_2 - \theta_1$
$=$ HPBW

**Directivity**: Way to characterize the focussing power of an ant.

In general: $$D(\theta,\phi) = \frac{U(\theta,\phi)}{\langle U(\theta,\phi)\rangle}$$

where $$\langle U(\theta,\phi)\rangle = \frac{\int U(\theta,\phi)\, d\Omega}{\int d\Omega}$$

i.e. avg intensity.

Typically when antenna directivity is mentioned without qualification, it refers to $D(\theta,\phi)\big|_{max}$.

e.g. Hertz dipole $U = U_0 \sin^2\theta$

$$\Rightarrow \langle U \rangle = \frac{U_0 \int_0^{2\pi}\int_0^{\pi} \sin^2\theta \, \sin\theta \, d\theta \, d\phi}{4\pi}$$

and $D_{max} = 3/2. \longleftrightarrow 1.76$ dB

an isotropic antenna would be $D = 1$
$\Rightarrow 0$ dB.

Antenna gain: Takes ohmic losses into account.

$$P_{input} = W_{rad} + P_{loss}$$

$$\text{efficiency} = \eta_r = \frac{W_r}{P_i}$$

So gain $= G = \eta_r \times D$ book uses $e_{cd}$.

$$G_{dB} = \underbrace{10 \log \eta_r}_{<0} + D_{dB}$$

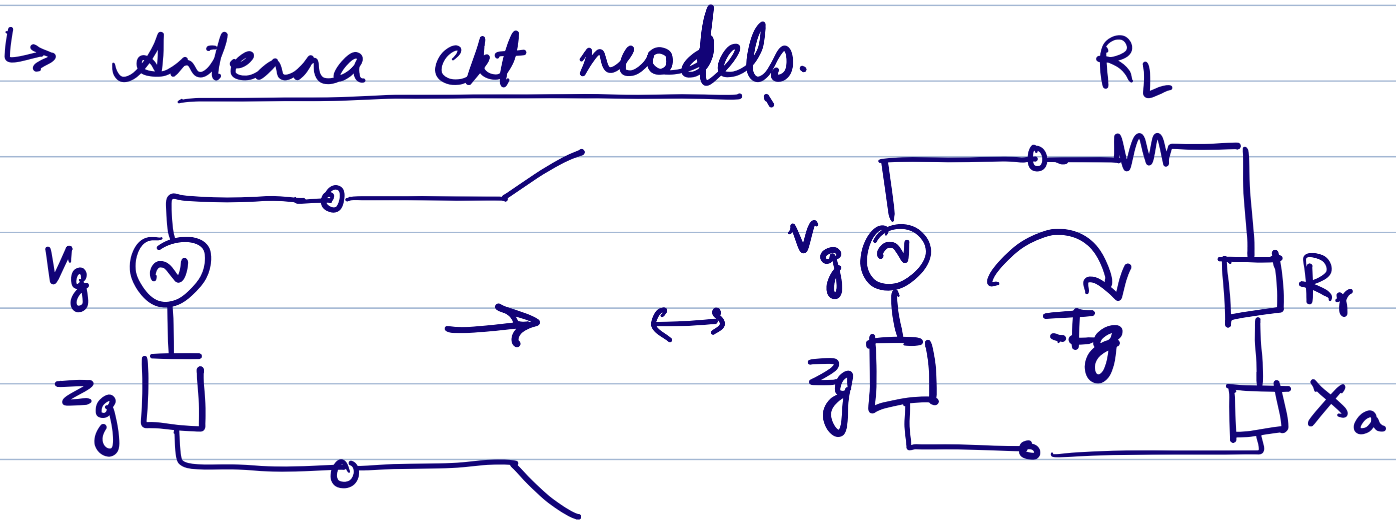
Another related term: '**Realized**' gain

Above we assumed that input is matched to antenna impedance.

If not, $G_{re} = \underbrace{(1-|\Gamma|^2)}_{\text{reflection loss.}} \underbrace{\eta_r D}_{G}$

book uses $e_r$

↳ Antenna ckt models.




generator    antenna

$Z_a \begin{cases} R_L : \text{loss resistance} \\ R_r : \text{Rad resistance} \\ X_a : \text{Ant reactance} \end{cases}$

near field reactive energy.

Max power corresponds to

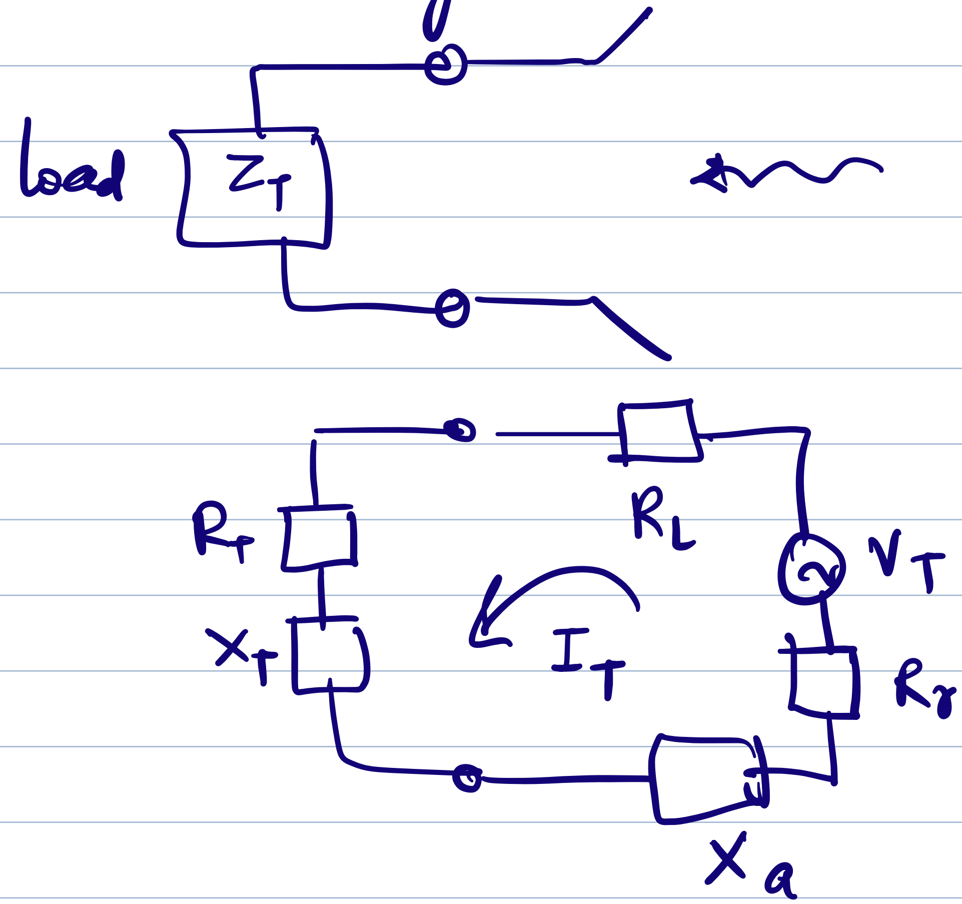
$z_g = Z_a^*$ , i.e

$R_g = R_L + R_r$

$X_g = -X_a.$

Power radiated by ant: $P_r = \frac{1}{2} |I_g|^2 R_r$

Similarly in the $R_x$ mode




In this case, collected power $= P_c = \frac{1}{2} |I_T|^2 R_T$

$P_T = \frac{1}{2} |I_T|^2 R_T \longrightarrow$ to load

$P_r = \frac{1}{2} |I_T|^2 R_r \longrightarrow$ scattered / re radiated

$P_L = \frac{1}{2} |I_T|^2 R_L \longrightarrow$ heat

Total $P_c = \frac{1}{2} V_T I_T^* \rightarrow$ collected power.