Long Wire Antennas* (Also introduction to traveling wave antennas)

Sinusoidal current distribution assumed for dipoles is a standing wave

$$I_o \sin\left[k\left(\frac{\ell}{2}-|z|\right)\right] = \frac{I_o}{2j}\left[\underbrace{e^{jk\left(\frac{\ell}{2}-z\right)}}_{+z \text{ traveling wave}} - \underbrace{e^{-jk\left(\frac{\ell}{2}-z\right)}}_{\substack{-z \text{ traveling wave} \\ (\text{reflected, } R=-1)}}\right]$$

What if reflected wave were absent?

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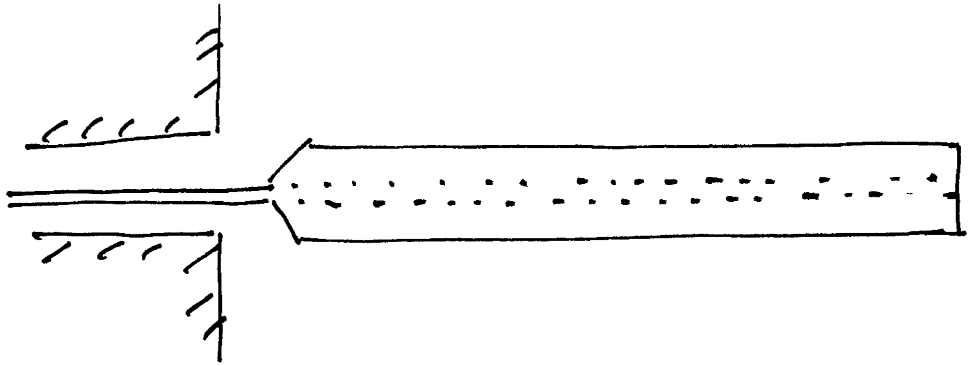
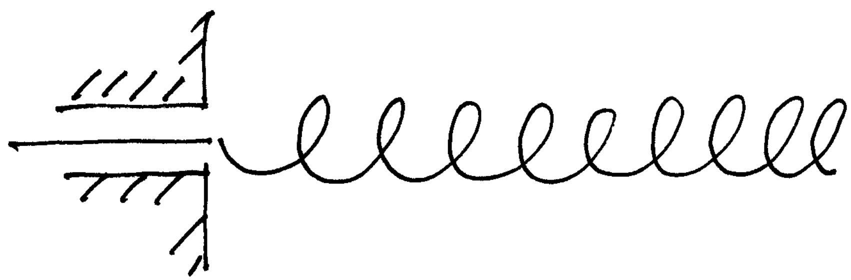
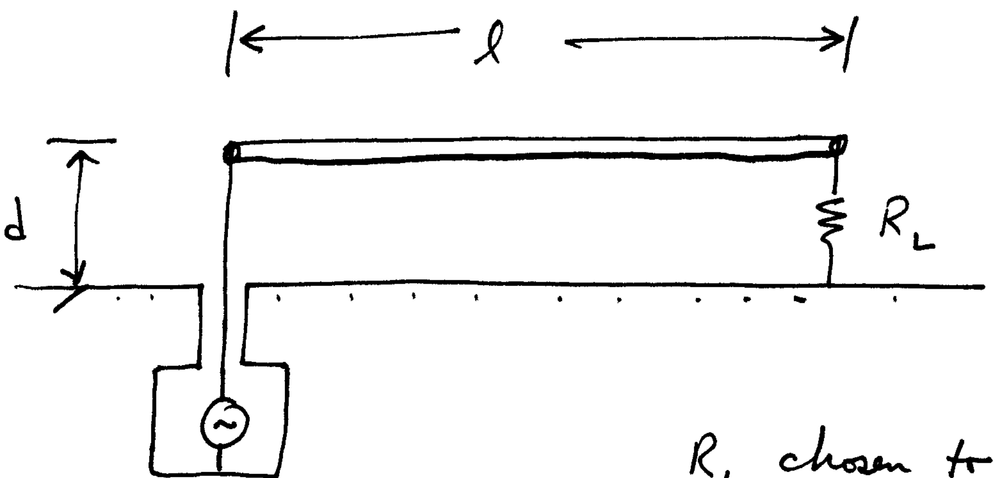
* See section 5.6 pp. 239 – 244, S & T.





There are many types of traveling wave antennas.

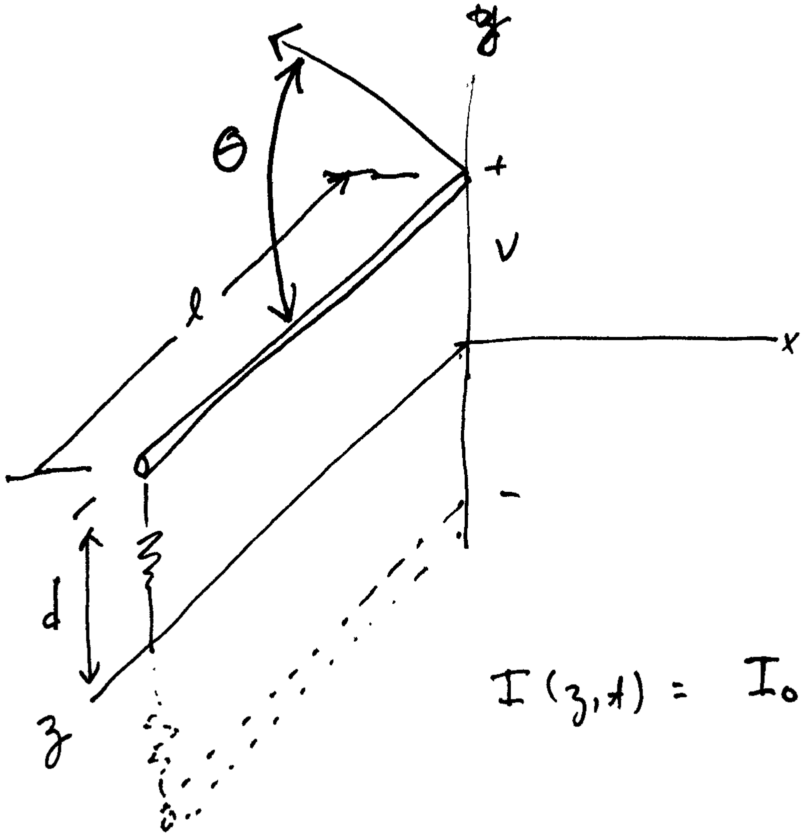
Simplest (?) Beverage Antenna



R_L chosen to match incident wave.

$\frac{d}{\lambda}$ "significant", not too small - $\frac{\ell}{\lambda} \gtrsim 1$

ohmage may or may not be important.



Model for long wire

Analyze radiation from wire, then add the radiation from the image, if necessary.

$$I(z,t) = I_0 e^{j\omega t - \gamma z}$$

$$\gamma = \alpha + j\beta$$

When d/λ not negligible, system will radiate because fields from conductor and its image do not cancel. (Do they ever cancel exactly?)

/...

/... So treat the upper wire as though it were in free space,

to calculate the fields we need —

$$\mu \frac{e^{-jkr}}{4\pi r}$$

$$\int_0^\ell I(z')\, e^{-jkR}\, dz' = \int_0^\ell \underbrace{I_0 e^{-\gamma z'}}_{I(z,t)}\, e^{jkz'\cos\theta}\, dz'$$

$$= I_0 \int_0^\ell e^{(jk\cos\theta - \gamma) z'}\, dz'$$

$A = \frac{1}{4\pi} \int_0^\ell I(z')\, \frac{e^{-jkR}}{R}\, dz'$, substitute from previous page for $I(z)$ to obtain integral, above. /...

$$\int_0^{\ell} - \, dz' = I_o \left. \frac{e^{(jk\cos\theta - \gamma)z'}}{jk\cos\theta - \gamma} \right|_0^{\ell}$$

$$= I_o \frac{e^{(jk\cos\theta - \gamma)\ell} - 1}{jk\cos\theta - \gamma} = F(\theta)$$

The above is exact and can be evaluated for any α, β.

For good conductor in air, $\alpha \ll \beta = k$, E.g.,

$\alpha \simeq 2\%$ of k, corresponding to more than 1dB power loss to radiation per wavelength.

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Ignoring α,

$$|F(\theta)| = I_o \ell \left| \frac{\sin \Psi}{\Psi} \right| ,$$

where $\Psi = \frac{\pi \ell}{\lambda}(1 - \cos\theta)$

Returning to our notes for the far field of a linear current,

$$E_\theta = j \eta k \frac{e^{-jkr}}{4\pi r} \sin\theta \int_0^\ell I(z') e^{-jkz'\cos\theta} dz'$$

/...

/...

we find $\quad |E_\theta| = \dfrac{\eta k I_0 \sin\theta}{4\pi r} |F(\theta)|$ $\Big\}$ check consistency I_0

$$|E_\theta| = \eta \frac{k \ell I_0}{4\pi r} \sin\theta \ \mathrm{sinc}\, X,$$

$$X = \frac{\pi \ell}{\lambda}(1 - \cos\theta).$$

The pattern is determined by the competition between $\sin\theta$ and $\mathrm{sinc}\, X$.

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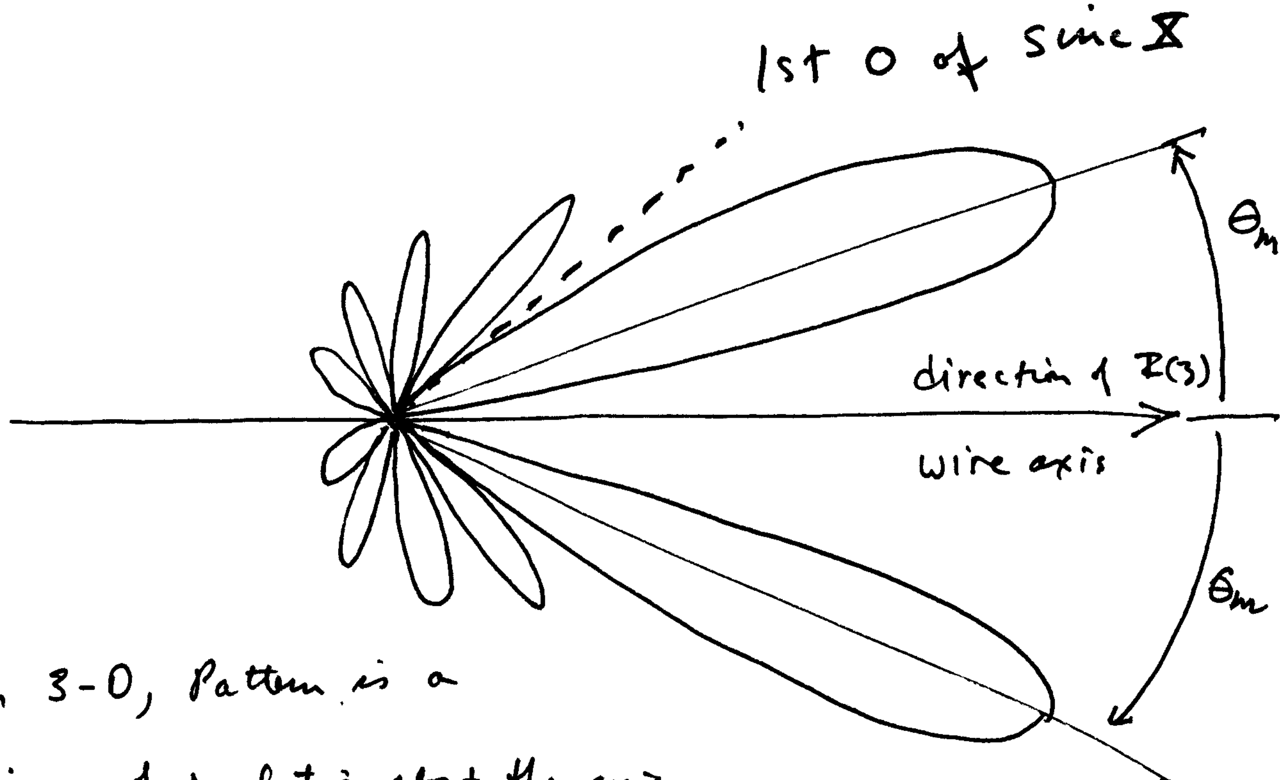
$\phi \cdots$

$\sin\theta$ is max for $\theta = \pi/2$

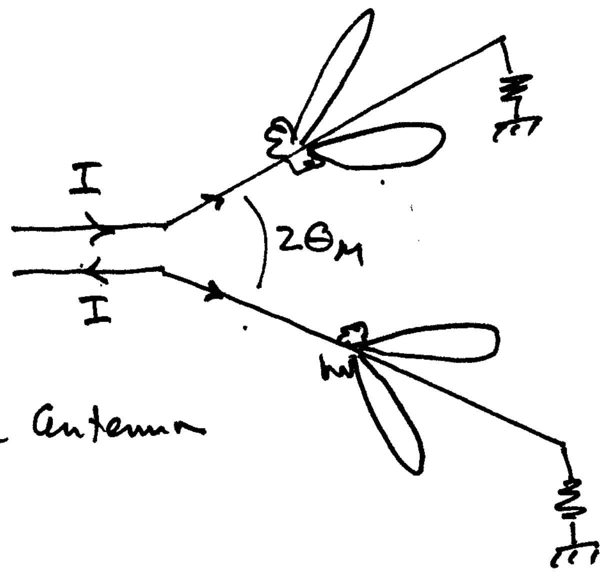
$\sin c\, X$ is max for $\theta = 0$, it represents an "end-fire" condition wherein $\bar{A}$ is maximized along the line of the wire. But $E_\theta \sim A_T$, so no E field, and hence no power, is radiated in the $\theta = 0$ direction. In the other hand, the width and strength of the forward "A" lobe is controlled by "l" – the bigger "l", - stronger, more narrow the forward lobe factor associated with "$\bar{A}$".

Typical Radiation Pattern of Long Wire

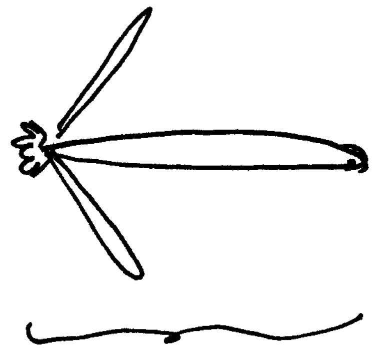


In 3-D, Pattern is a
figure of revolution about the axis.

Patterns from individual wire elements can be combined.



Vee antenna



Resultant pattern.

Angle of the vee is chosen so that individual lobes from two elements reinforce one another

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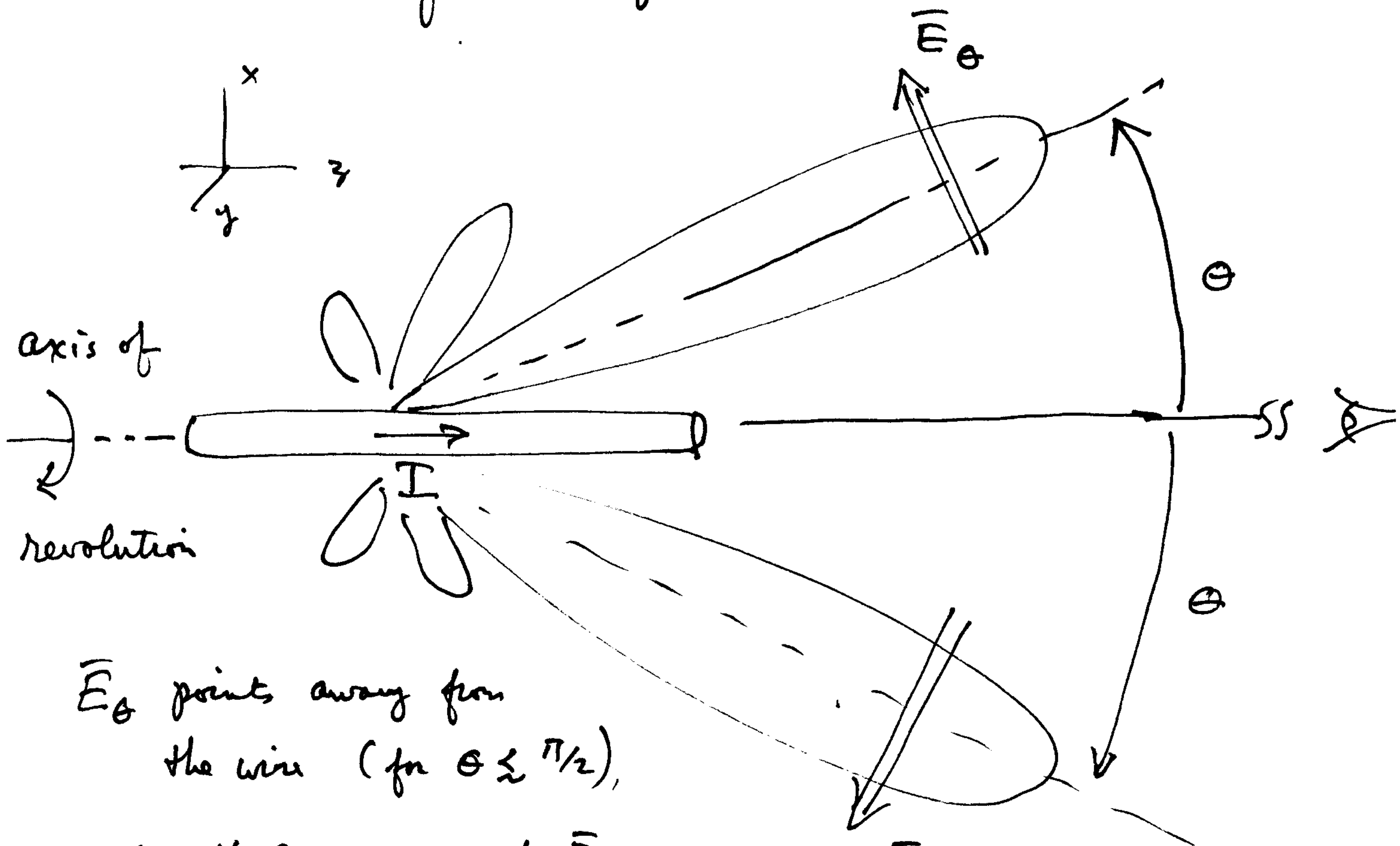
Radiation from long wire

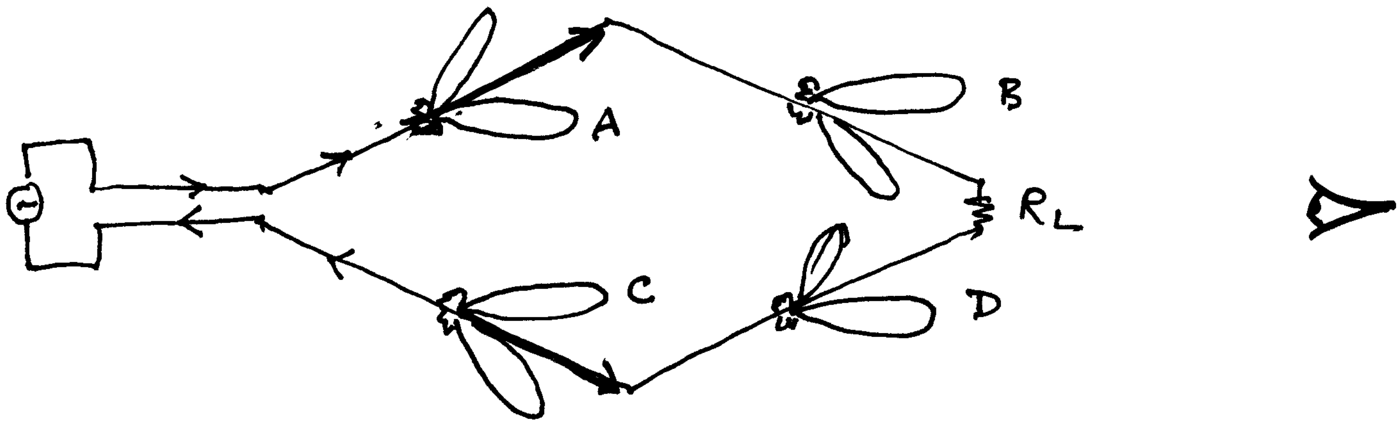


$\bar{E}_\theta$ points away from the wire (for $\theta \lesssim \pi/2$),

so X-components of $\bar{E}$

are <u>reversed</u> for top and bottom lobes shown.

Rhombic goes one step further: Main lobes of four individual elements are combined.



N.B. Even though the currents in the top and bottom halves are flowing in opposite directions (at points immediately above and below one another), their projections as seen by a distant observer on the axis of the rhombic are the same, i.e. in phase.

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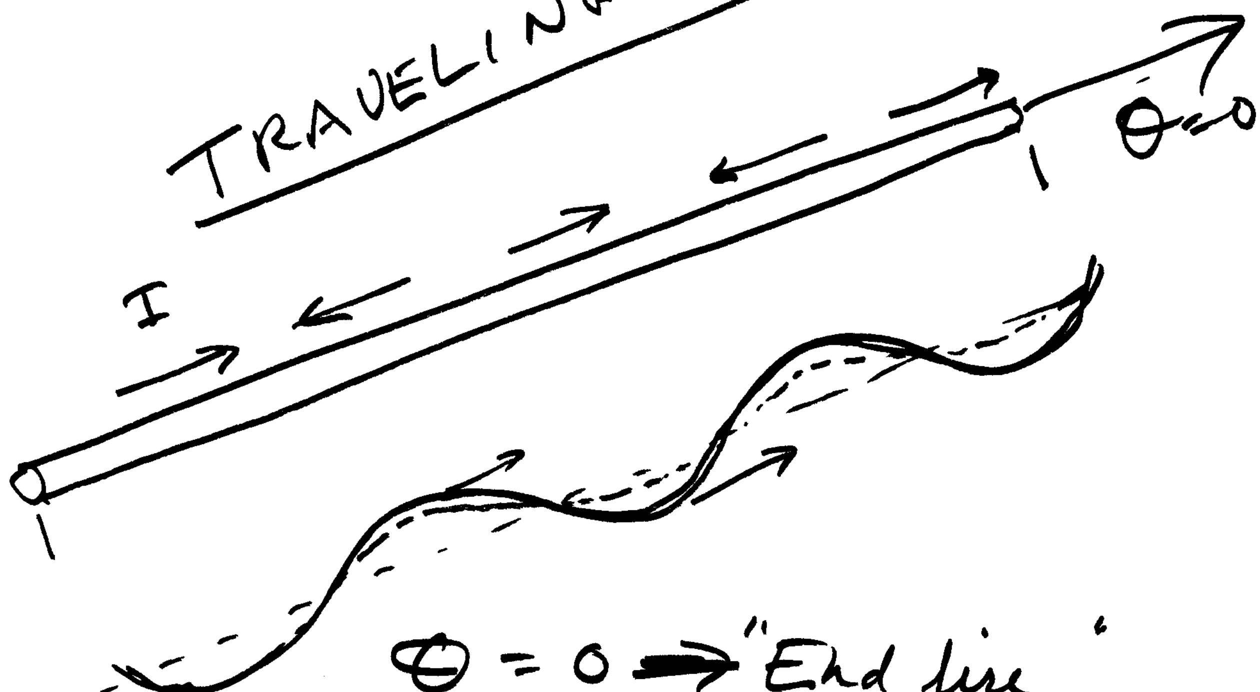
Something to think about

Does an infinitely long wire TEM mode transmission line radiate?

Or is the radiation somehow connected with the finite length of the TW structure?

Does this (your answer) depend on $\alpha = 0$, $\alpha \neq 0$?

TRAVELING WAVE



$\theta = 0 \Rightarrow$ "End fire"

$\theta = \frac{\pi}{2} \Rightarrow$ "Broadside"