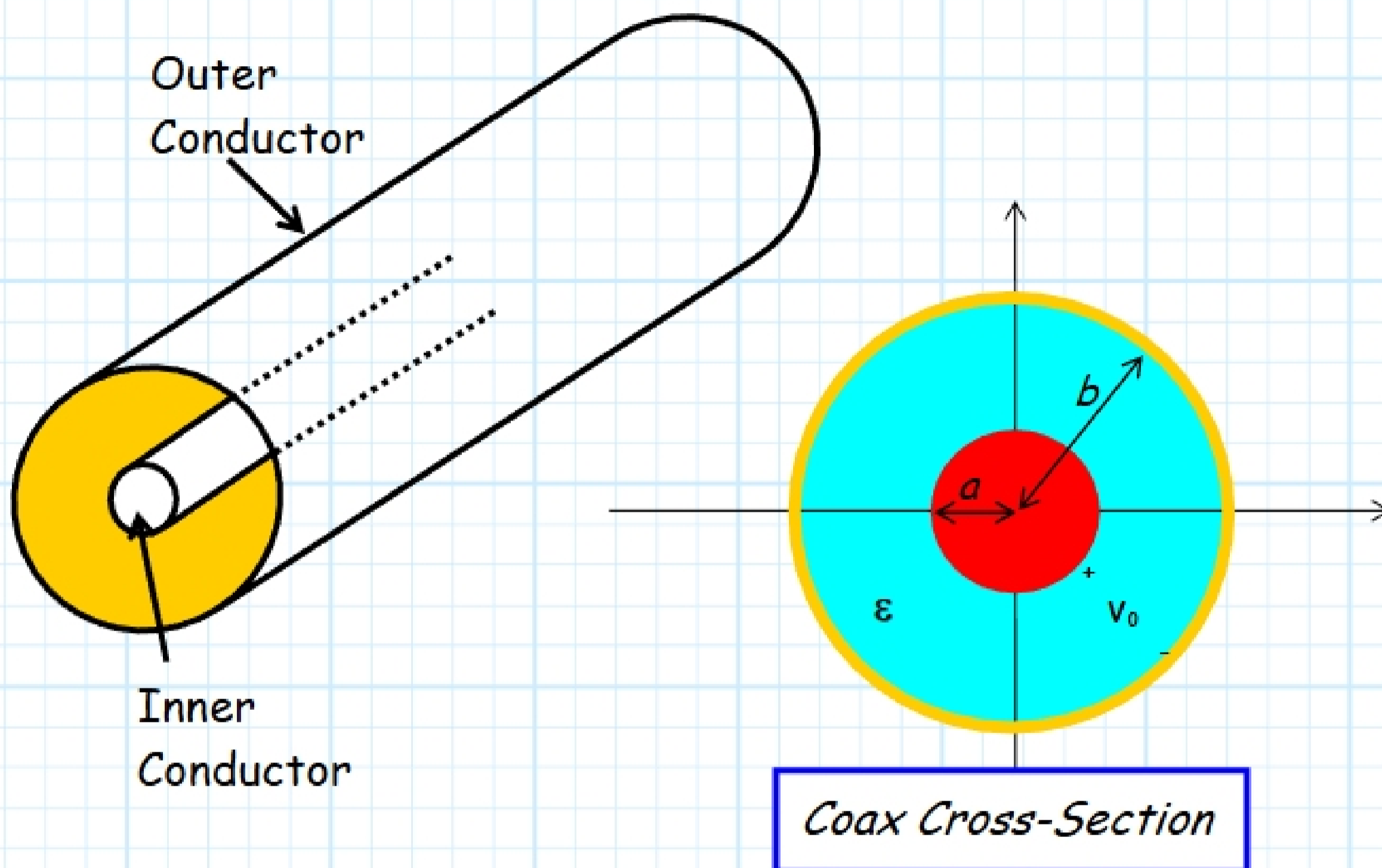


# Coaxial Transmission Lines

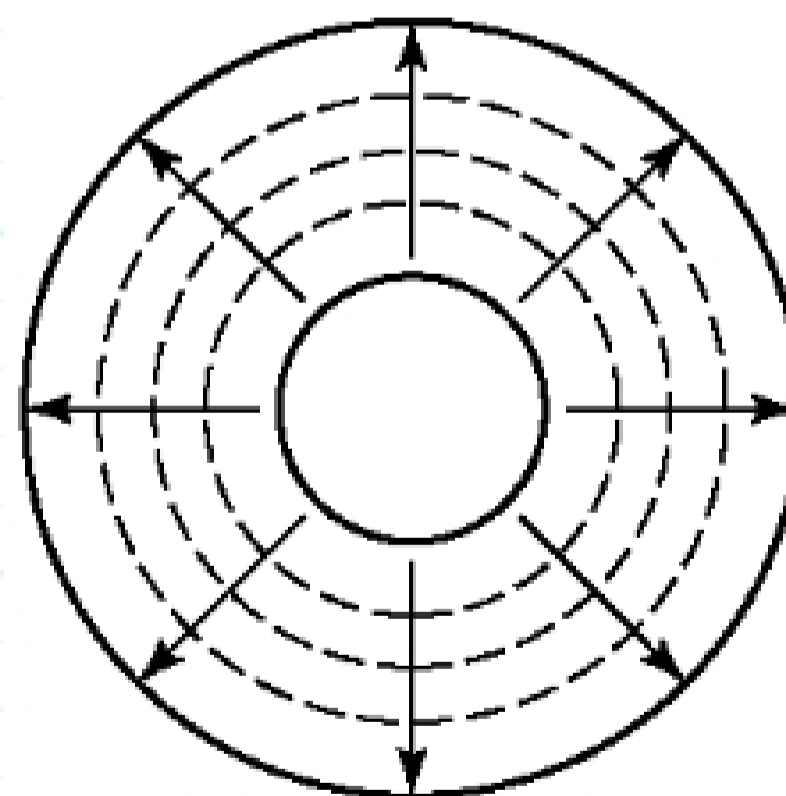
The most common type of transmission line!



The **electric** field (—→) points in the direction  $\hat{a}_\rho$ .

The **magnetic** field (- - -) points in the direction  $\hat{a}_\phi$ .

E. M. Power flows in the direction  $\hat{a}_z$ .



→ A TEM wave!

Recall from EECS 220 that the **capacitance** per/unit length of a coaxial transmission line is:

$$C = \frac{2\pi\epsilon}{\ln[b/a]} \quad \left[ \frac{\text{farads}}{\text{meter}} \right]$$

And that the **inductance** per unit length is :

$$L = \frac{\mu_0}{2\pi} \ln \left[ \frac{b}{a} \right] \quad \left[ \frac{\text{Henries}}{\text{m}} \right]$$

Where of course the **characteristic impedance** is:

$$\begin{aligned} Z_o &= \sqrt{\frac{L}{C}} \\ &= \frac{1}{2\pi} \sqrt{\frac{\mu_0}{\epsilon}} \ln \left[ \frac{b}{a} \right] \end{aligned}$$

and:

$$\beta = \omega \sqrt{LC} = \omega \sqrt{\mu_0 \epsilon}$$

Therefore the **propagation velocity** of each TEM wave within a coaxial transmission line is:

$$v_p = \frac{\omega}{\beta} = \frac{1}{\sqrt{\mu_0 \epsilon}} = \frac{1}{\sqrt{\mu_0 \epsilon_0}} \frac{1}{\sqrt{\epsilon_r}} = c \frac{1}{\sqrt{\epsilon_r}}$$

where  $\epsilon_r = \epsilon/\epsilon_0$  is the relative dielectric constant, and  $c$  is the "speed of light" ( $c = 3 \times 10^8 \text{ m/s}$ ).

Note then that we can likewise express  $\beta$  in terms  $\epsilon_r$ :

$$\beta = \omega \sqrt{\mu_0 \epsilon} = \omega \sqrt{\mu_0 \epsilon_0} \sqrt{\epsilon_r} = \frac{\omega}{c} \sqrt{\epsilon_r}$$

Now, the **size** of the coaxial line ( $a$  and  $b$ ) determines **more** than simply  $Z_0$  and  $\beta$  ( $L$  and  $C$ ) of the transmission line. Additionally, the line radius determines the **weight** and bulk of the line, as well as its **power handling** capabilities.

Unfortunately, these two characteristics **conflict** with each other!

**1.** Obviously, to **minimize** the weight and bulk of a coaxial transmission line, we should make  $a$  and  $b$  as **small** as possible.

**2.** However, for a given line voltage, reducing  $a$  and  $b$  causes the **electric field** within the coaxial line to **increase** (recall the units of electric field are  $V/m$ ).

A higher electric field causes **two** problems: first, it results in greater **line attenuation** (larger  $\alpha$ ); second, it can result in **dielectric breakdown**.

Dielectric breakdown results when the electric field within the transmission line becomes so large that the dielectric material is **ionized**. Suddenly, the dielectric becomes a **conductor**, and the value  $G$  gets **very** large!