Metamaterials: translation from physicists to engineers and *vice versa*

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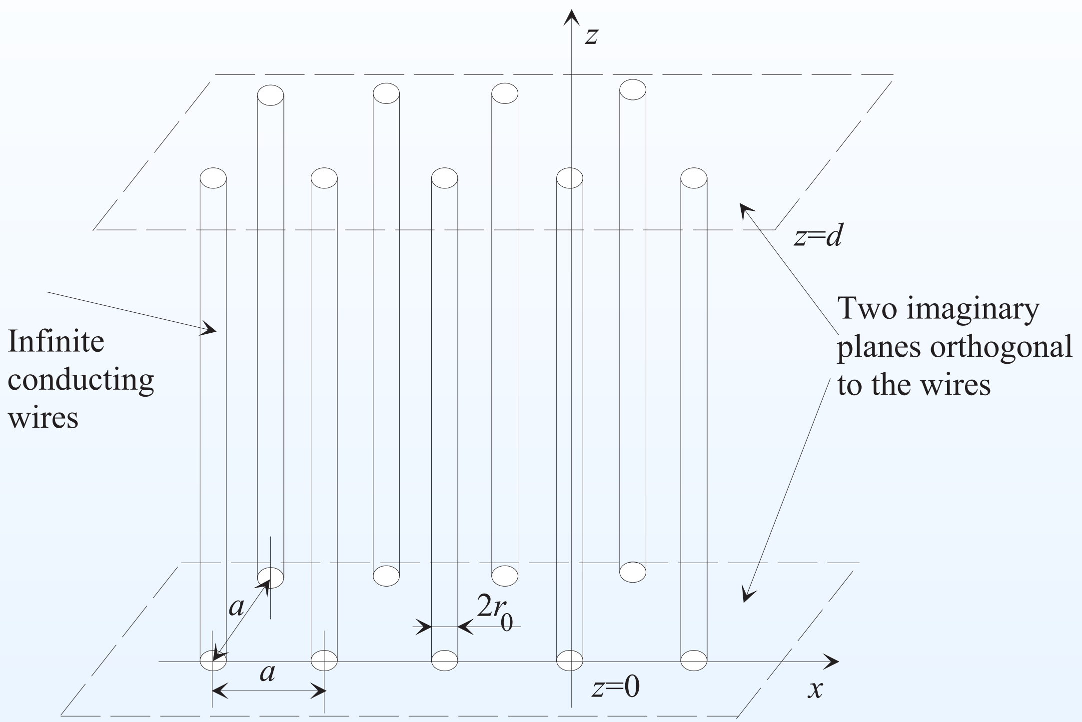
Lecture plan

- Effective material parameters and transmission-line parameters
- Electromagnetic field energy and equivalent circuit model

Quasistatic model of wire media



$$U = Ij\omega Ld \quad \text{and} \quad U = E_z d \quad \Rightarrow \quad E_z = j\omega L\, I$$

Inductance per unit length L

Approximation:

$$H_y = \frac{I}{2\pi}\left(\frac{1}{x} - \frac{1}{a-x}\right)$$

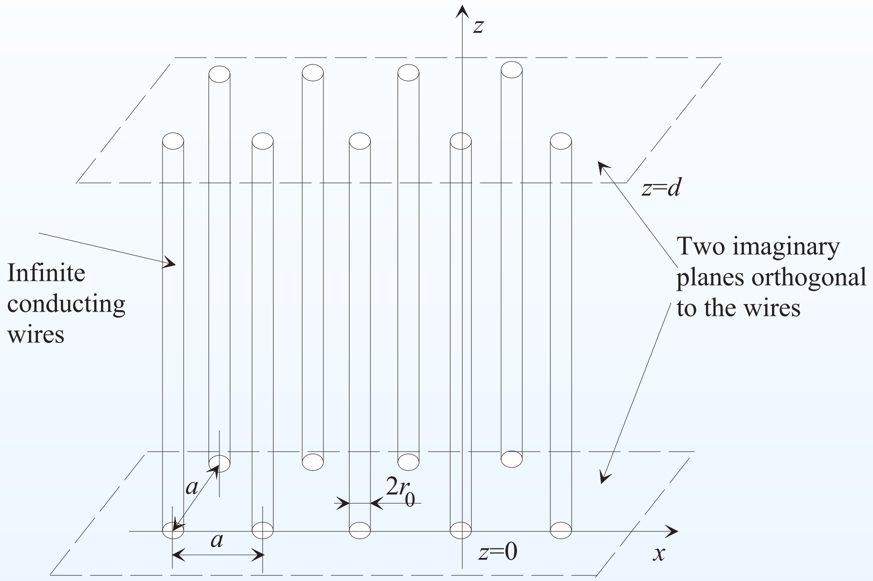
Magnetic flux per unit length:

$$\Psi = \mu_0 \int_{r_0}^{a/2} H_y(x)\, dx = \frac{\mu_0 I}{2\pi} \log \frac{a^2}{4r_0(a-r_0)}$$

Inductance per unit length:

$$L = \frac{\mu_0}{2\pi} \log \frac{a^2}{4r_0(a-r_0)}$$

Polarization in wire media



$$\mathbf{D} = \epsilon_0 \mathbf{E} + \mathbf{P}, \quad \text{where} \quad \mathbf{P} = \frac{\mathbf{J}}{j\omega} = \mathbf{z}_0 \frac{I}{j\omega a^2} = -\mathbf{z}_0 \frac{E_z}{\omega^2 a^2 L}$$

Material relation:

$$D_z = \left(\epsilon_0 - \frac{1}{\omega^2 a^2 L} \right) E_z$$