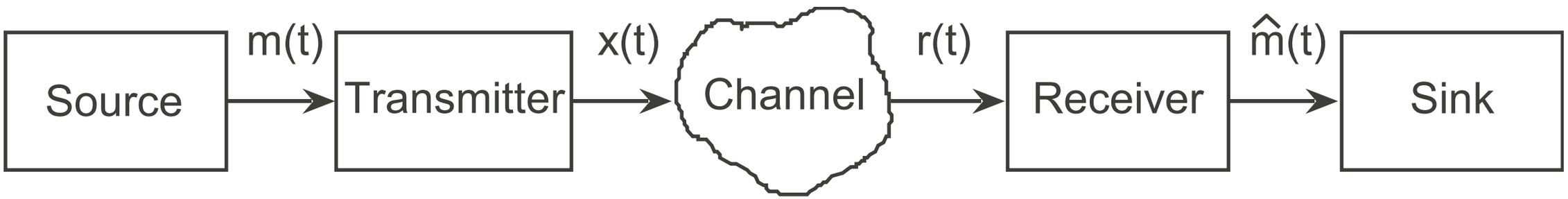
Fundamentals of Electrical Engineering

Wireless Communication Channels



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Physics of Wireless Channels

All electrical phenomena, including electromagnetic radiation, governed by Maxwell's equations

$$\nabla \times \mathbf{E} = -\frac{\partial}{\partial t}(\mu \mathbf{H})$$

$$\text{div } \epsilon \mathbf{E} = \rho$$

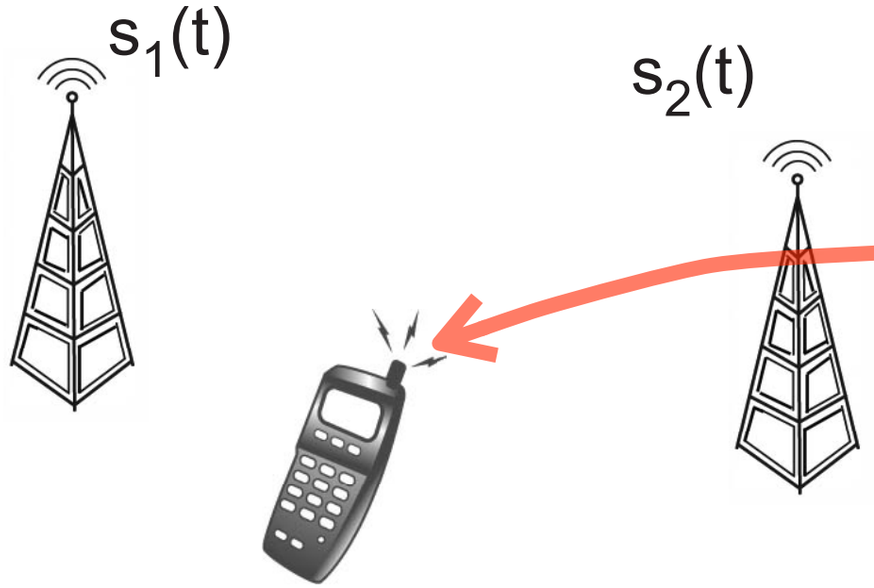
$$\nabla \times \mathbf{H} = \sigma \mathbf{E} + \frac{\partial}{\partial t}(\epsilon \mathbf{E})$$

$$\text{div } \mu \mathbf{H} = 0$$

Electromagnetic Waves

Maxwell's equations predict that electromagnetic waves have several properties

- The equations are linear, so superposition applies



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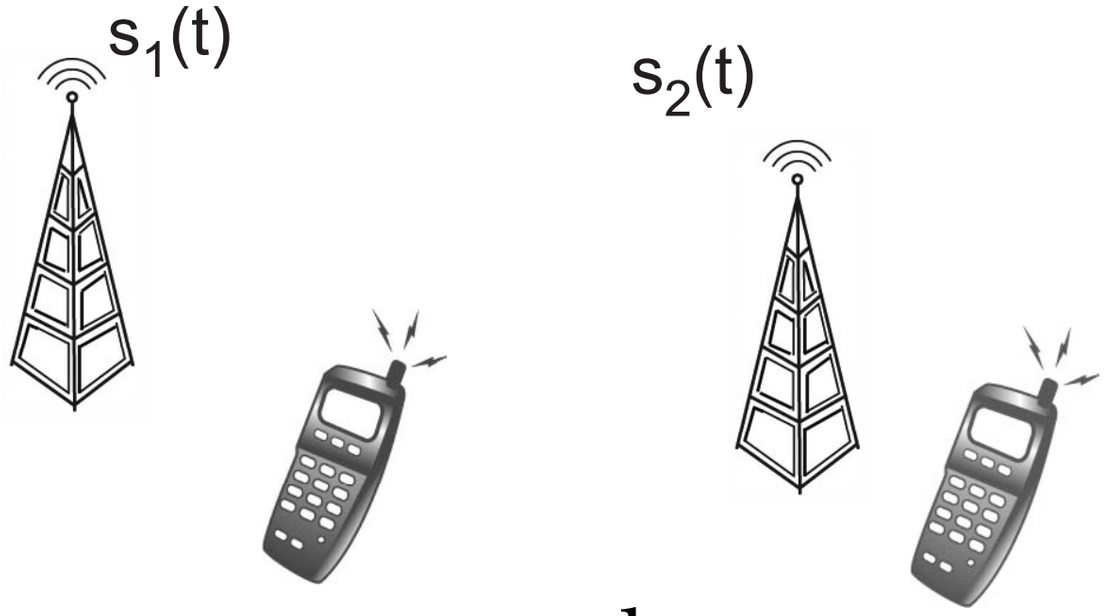

- Waves *propagate* at speed c

$$\lambda f = c \qquad c = \frac{1}{\sqrt{\epsilon\mu}}$$

- Low-frequency waves do not propagate well

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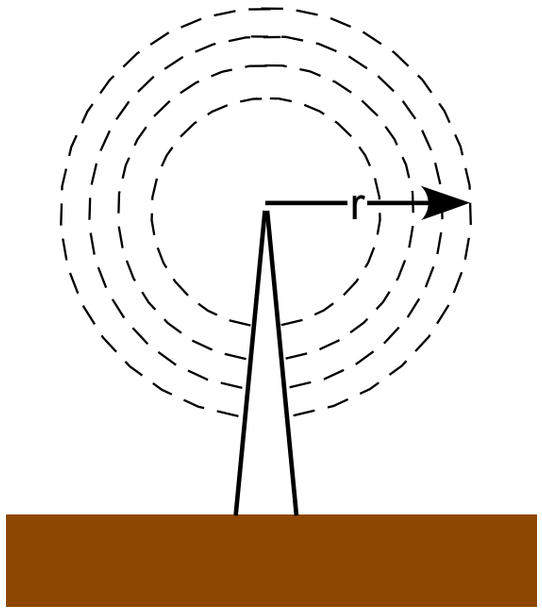
Electromagnetic Waves

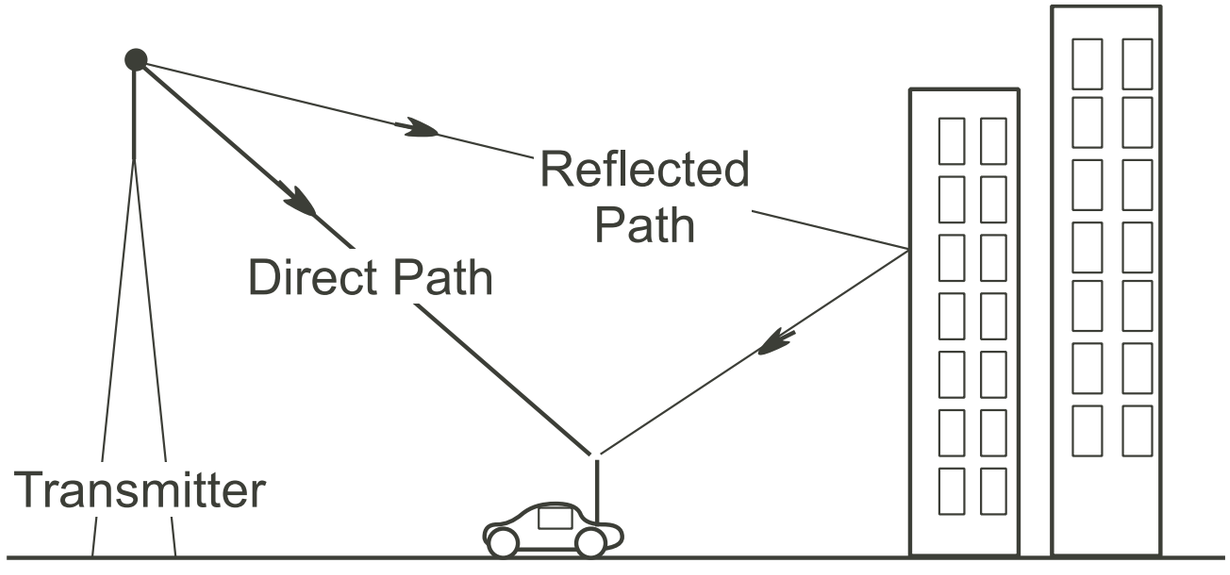
- Conservation of power means that amplitude decays with distance from transmitter



$$p(r) \cdot 4\pi r^2 = \text{constant}$$

$$\boxed{p(r) \propto \frac{1}{r^2} \qquad A(r) \propto \frac{1}{r}}$$

- Common and natural materials absorb/reflect waves



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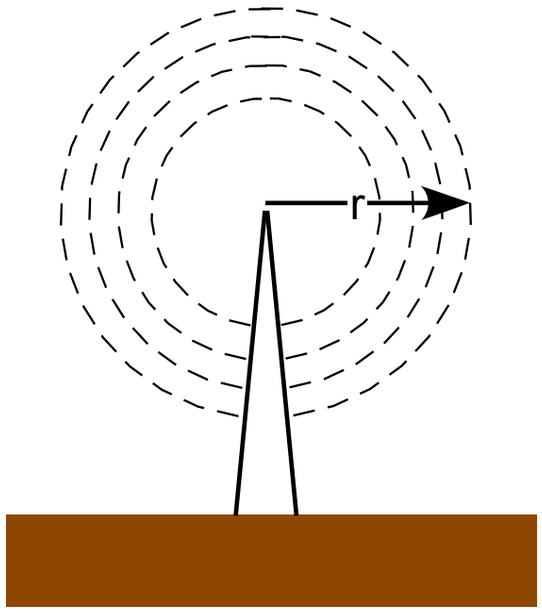

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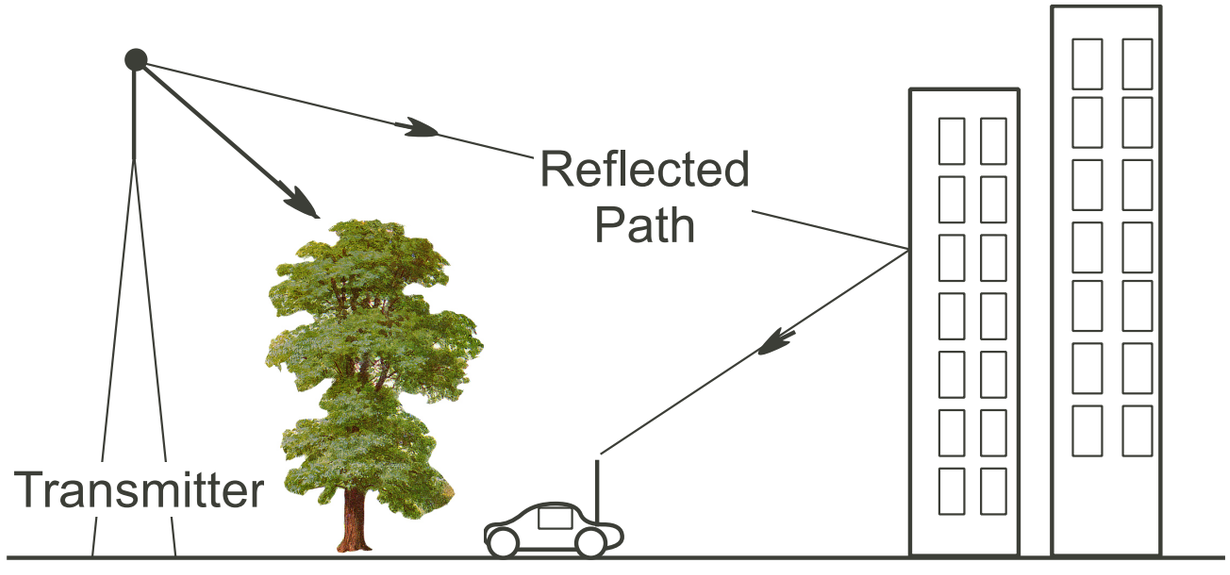
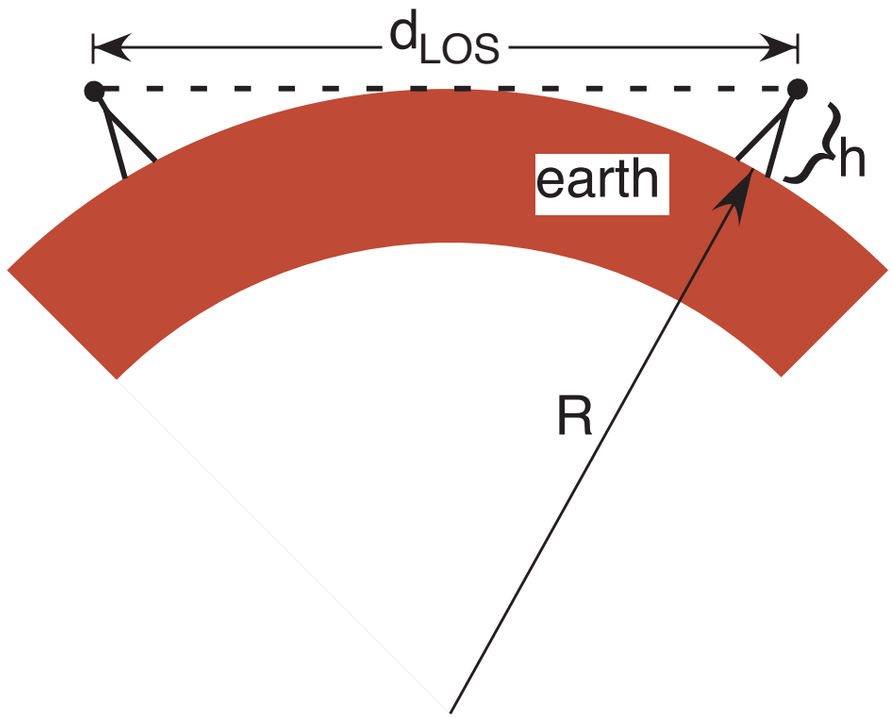


Wireless Channels

Line-of-sight (LOS) communication



$$d_{\mathrm{LOS}} = 2\sqrt{2Rh + h^2} \approx 2\sqrt{2Rh}, \quad R = 6.38 \times 10^6 \text{ m}$$

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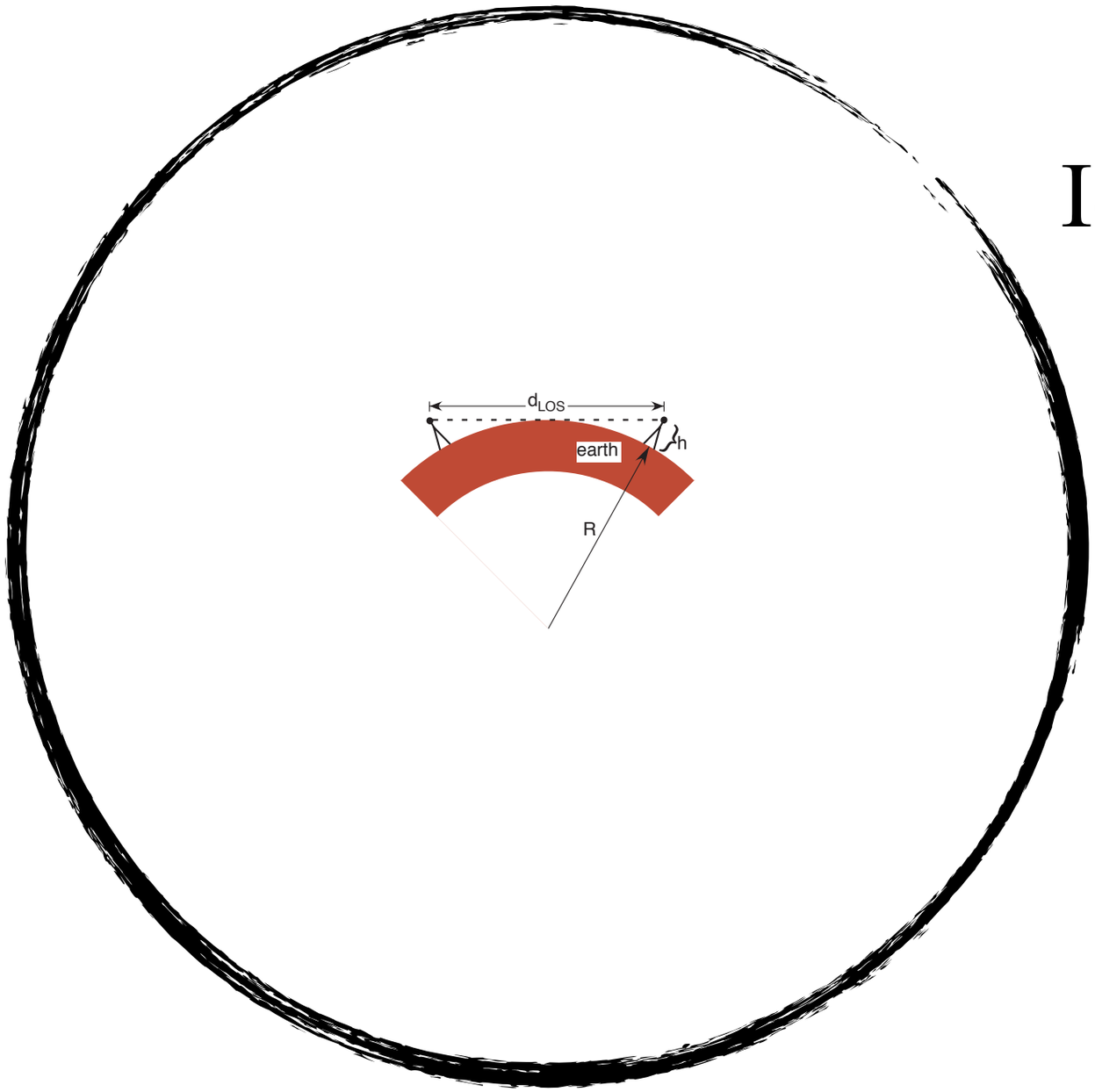
Wireless Channels



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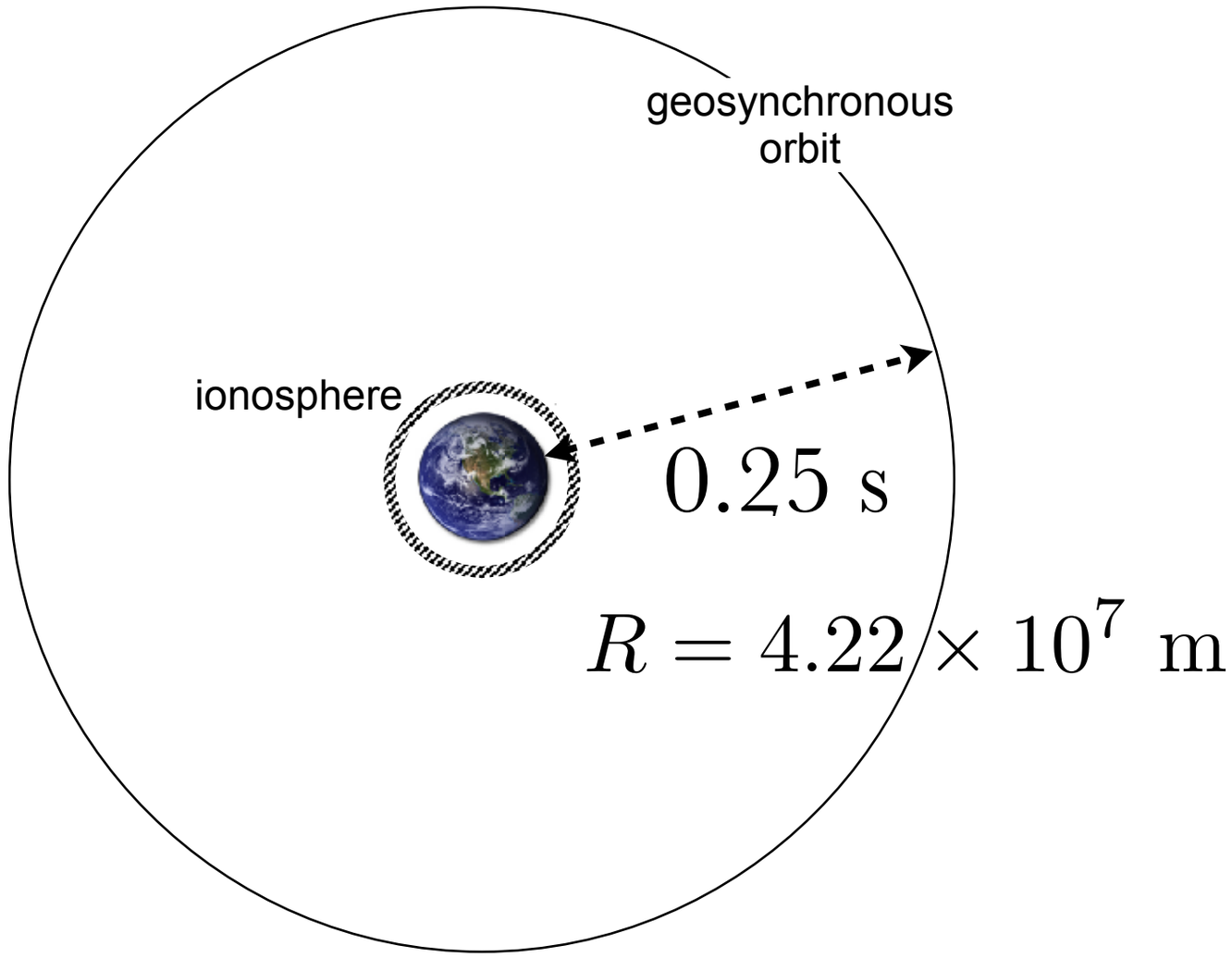
Wireless Channels

Satellite Communication



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Wireless Channels

- Received power decays as the inverse-square of the distance from transmitter
- Although signals travel at the speed of light, significant delay between transmission and reception can occur
- Maxwell's equations are linear, which means that superposition applies
  - ✳ Broadcast possible, which also means no privacy
  - ✳ Lots of interference possible

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