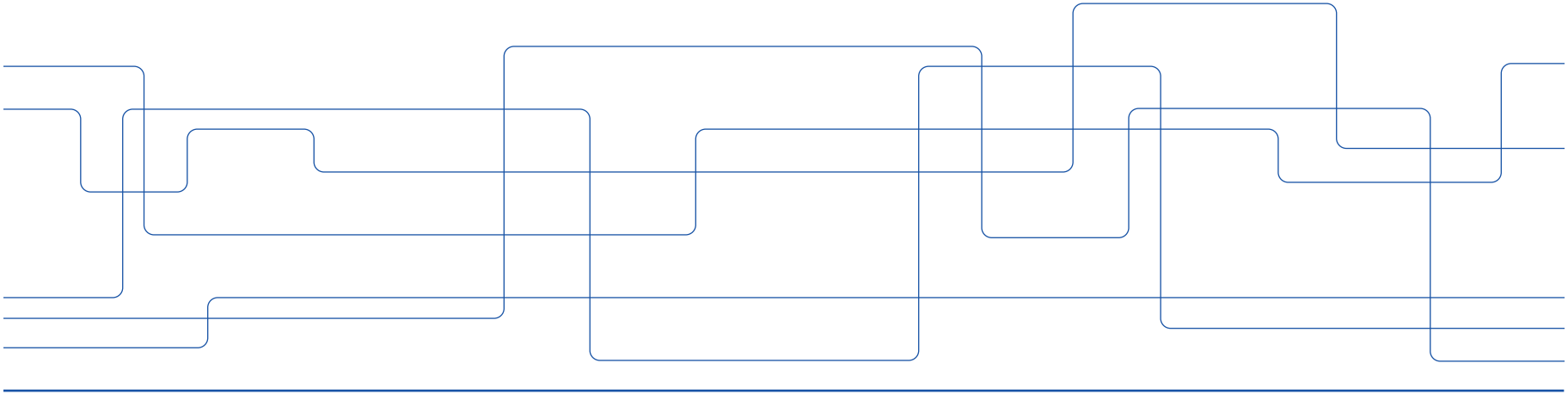
KTH ROYAL INSTITUTE OF TECHNOLOGY

Introduction to Mobile Networks and Services

Fundamentals of Wireless Channels



Three components of wireless channels

1. Transmit antenna

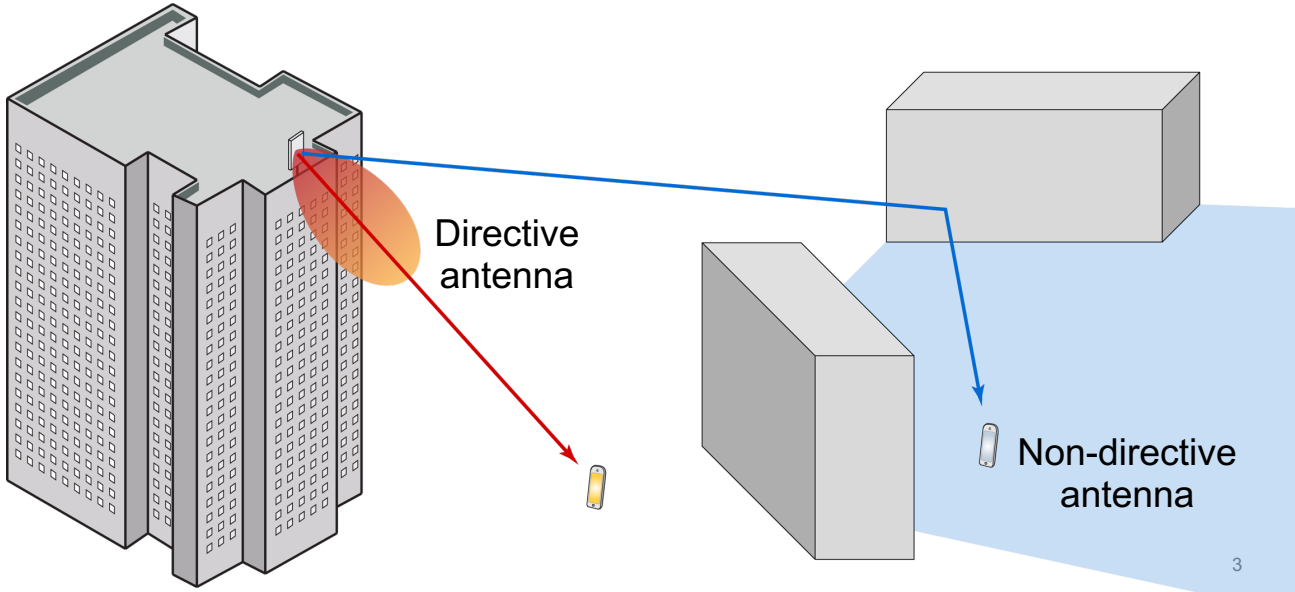
3. Receive antenna

2. Wireless signal propagation

They all determine the channel quality!

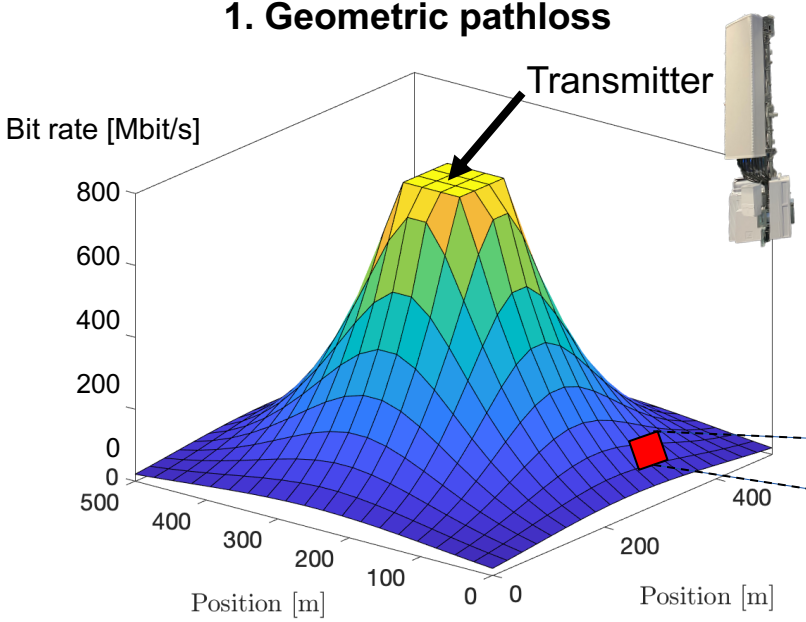
Antennas

- An antenna is an electrical conductor or system of conductors
  - Transmission: radiates electromagnetic energy into space
  - Reception: collects electromagnetic energy from space
- In two-way communications, the same antenna can be used for transmission and reception

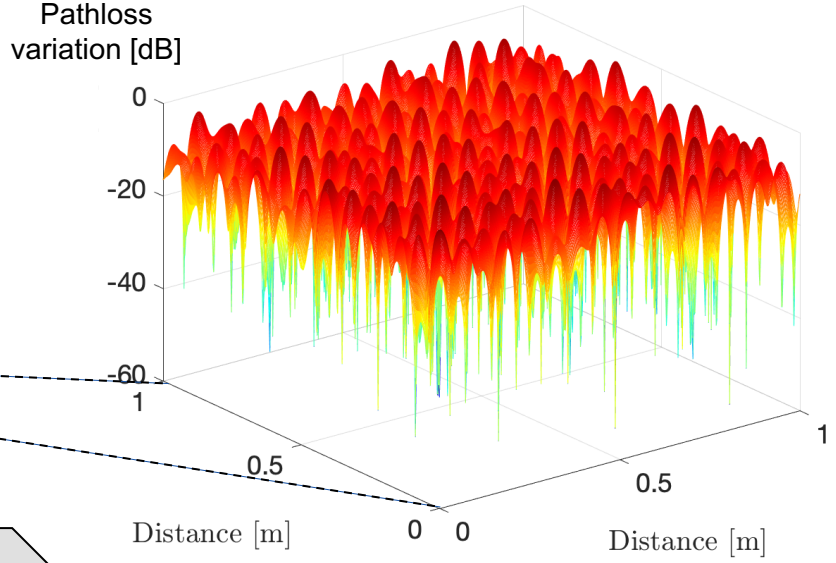


Three Wireless Propagation Phenomena

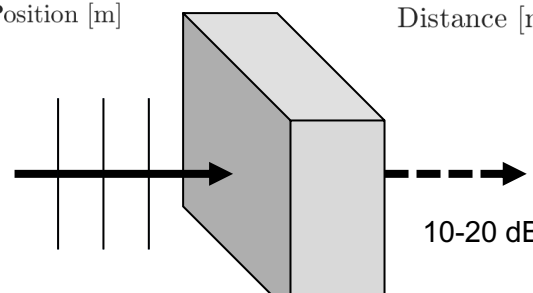
1. Geometric pathloss



2. Small-scale fading



3. Shadowing



10-20 dB loss per wall

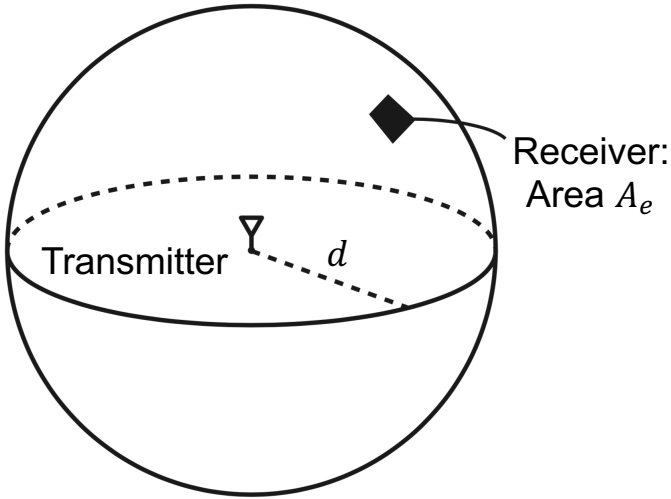
Free-space pathloss (attenuation)

- Transmit power P_t
  - Received power:

$$P_r = P_t \frac{A_e}{4\pi d^2} = \frac{P_t}{L}$$

  - Pathloss:

$$L = \frac{4\pi d^2}{A_e}$$



Example: Isotropic antenna

$$A_{\text{iso}} = \frac{\lambda^2}{4\pi},\ L_{\text{iso}} = \frac{4\pi d^2}{A_{\text{iso}}} = \left(\frac{4\pi d}{\lambda}\right)^2$$

$\lambda = 0.1$ m (3 GHz)
0.006% received at 1 m ($L = 42$ dB)
0.00006% received at 10 m ($L = 62$ dB)

Only a tiny fraction of transmit power is received!

Directive antennas

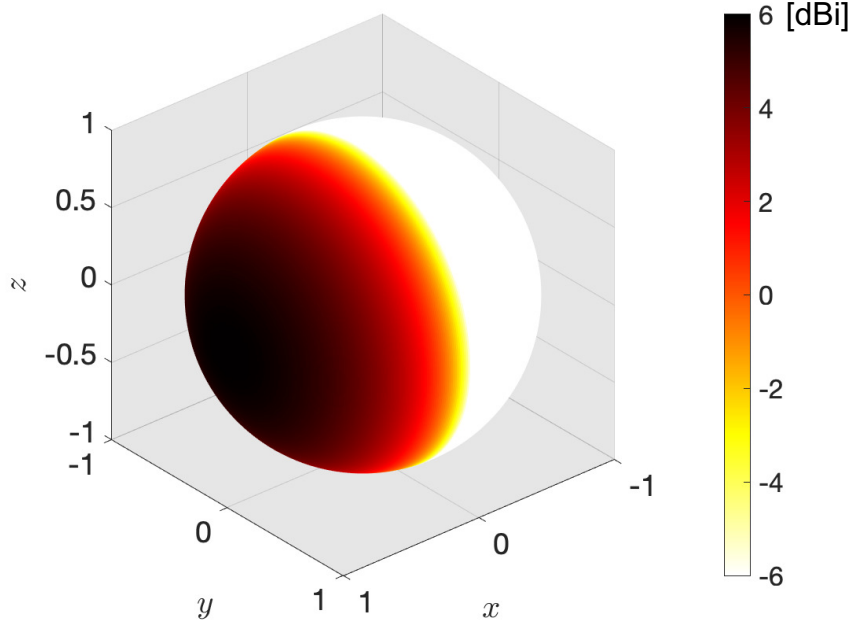
- Larger area A_e: Higher maximum gain
  - Directional transmission
  - Effective area ≤ Physical area

Antenna gain
(compared to isotropic antenna):

$$G = \frac{A_e}{A_{\text{iso}}} = \frac{4\pi A_e}{\lambda^2}$$

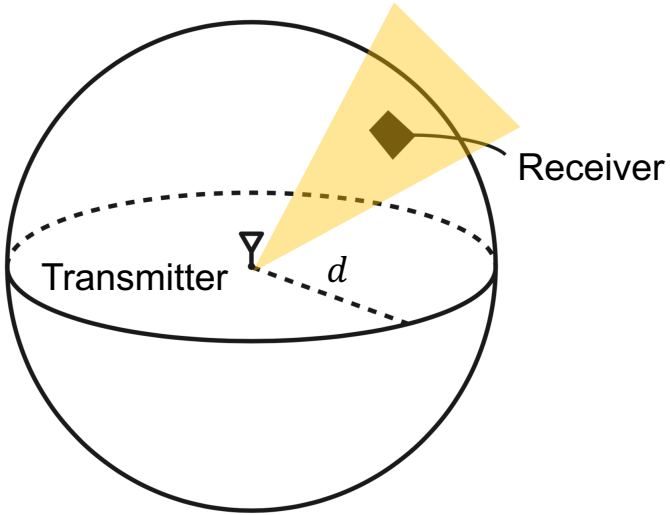
Often reported as $10\log_{10}(G)$ dBi

Example:



Free-space pathloss with antenna gains

- Transmitter gain towards receiver: $G_t = \frac{4\pi A_t}{\lambda^2}$
- Receiver gain towards transmitter: $G_r = \frac{4\pi A_r}{\lambda^2}$



- Free-space pathloss with isotropic antennas

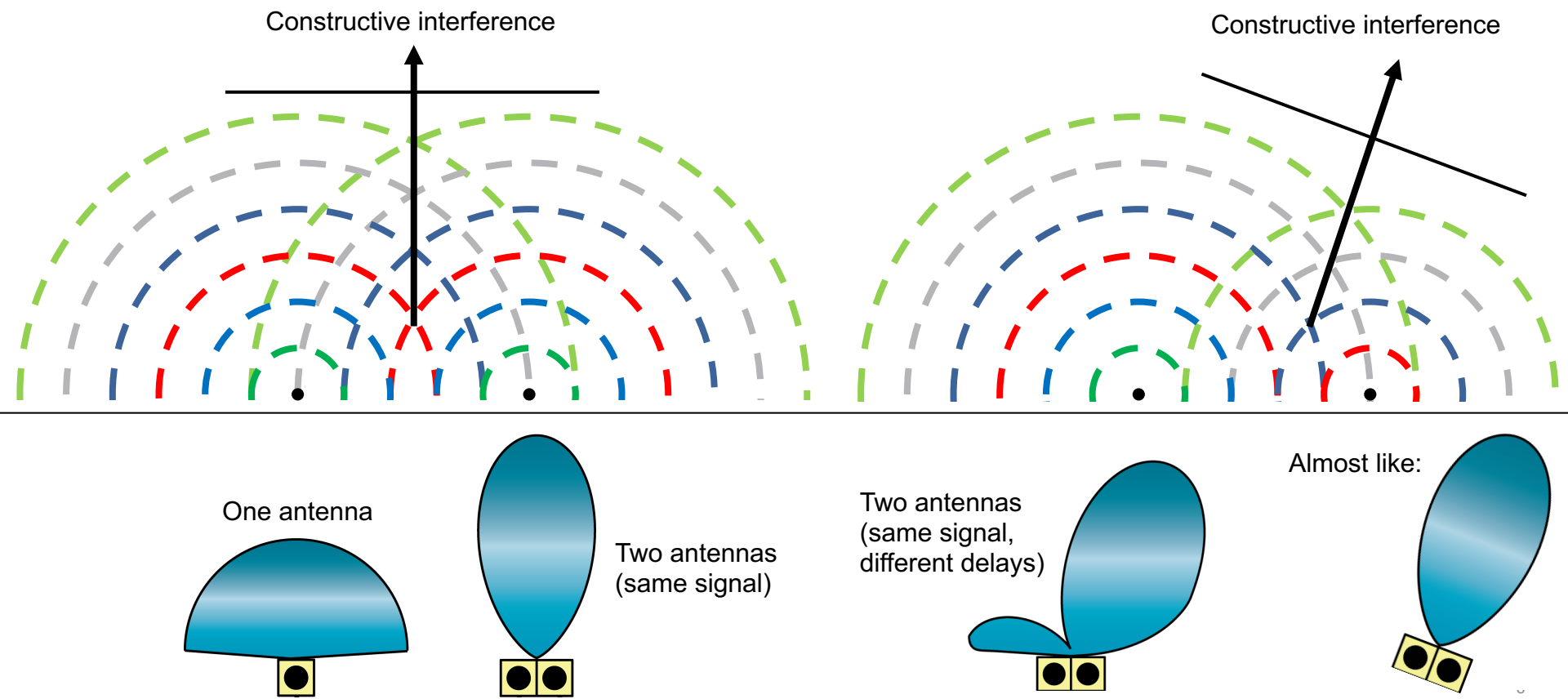
$$L_{\text{iso}} = \left(\frac{4\pi d}{\lambda}\right)^2$$

  - Pathloss with directive antennas:

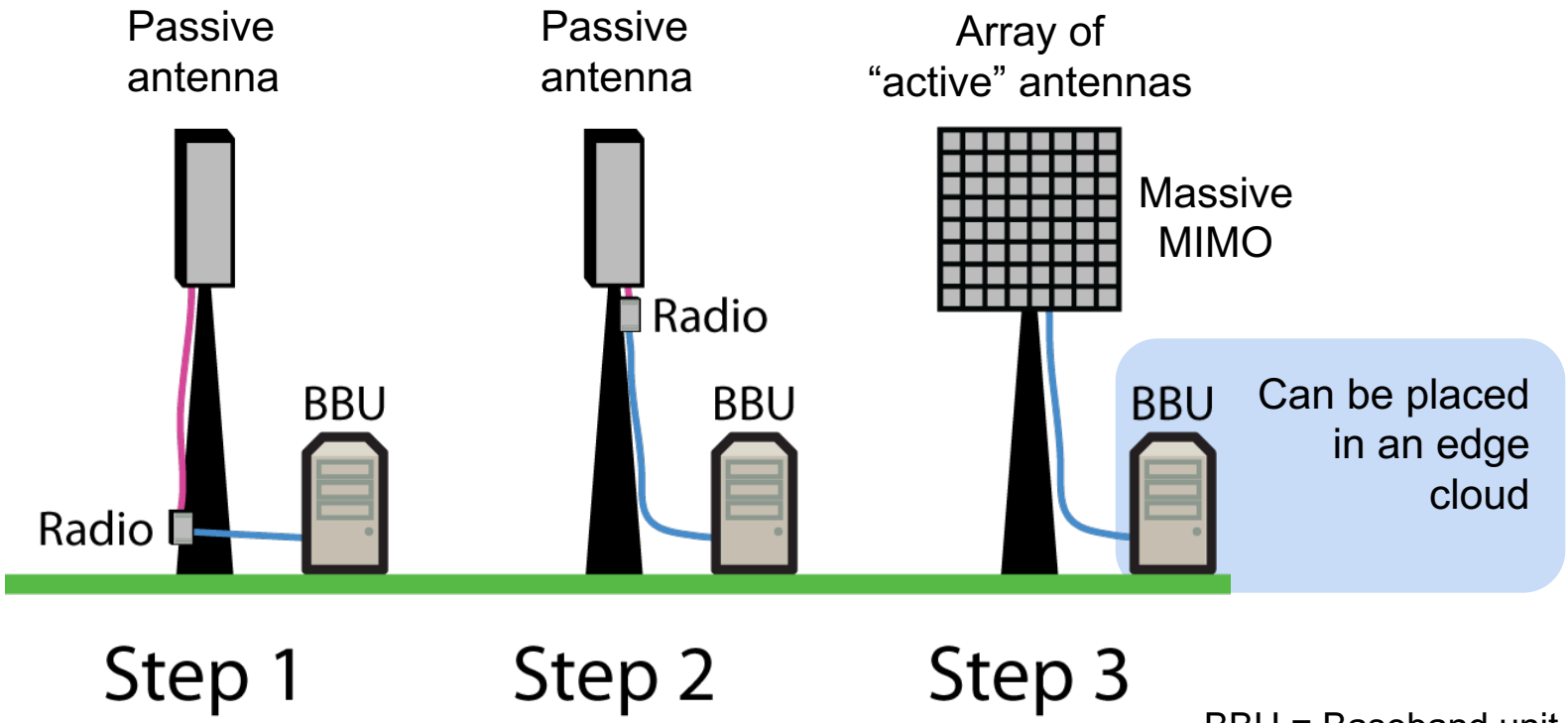
$$L = \frac{L_{\text{iso}}}{G_t G_r} = \frac{(4\pi d)^2}{G_t G_r \lambda^2} = \frac{(\lambda d)^2}{A_t A_r}$$

Reducing the wavelength λ
- G_t, G_r fixed: Larger pathloss
- A_t, A_r fixed: Smaller pathloss

Antenna arrays: Adaptive directivity



Evolution of base station antennas



BBU = Baseband unit

Thank you for watching!