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T-79.7001 Postgraduate Course in Theoretical Computer Science
T-79.5401 Special Course in Mobility Management: Ad hoc networks
(2 - 10 cr) P V

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Practical issues

- **How many credits:**
  - **2 cr (ECTS) for one presentation (30 minutes) +slides +summary paper.**
  - **1 cr (ECTS) for reviewing two summary papers and opponenting two other participants' presentations.**
  - **Either of them can be taken several times.**
  - **Additional credits can be achieved based on the number of presentations:**
    - **A presentation includes archivable slides and short summary. Credits are given with the following rules:**
      - **3 ECTS per topic (for dissertation)**
      - **2 ECTS per topic for master's thesis and**
      - **1 ECTS for journal/proceeding.**

Practical issues

- **Dates:**
  - **Seminar schedule: Wednesdays 14-16**
  - **Topic selection deadline: 31.1.2007**

Credits

- **Material based on**
  - **C. Siva Ram Murthy and B. S. Manoj: "Ad Hoc Wireless Networks: Architectures and Protocols**
  - **Stefano Marinoni:" Performance of wireless ad hoc routing protocols — a simulation study in realistic environments", Master's thesis http://www.tcs.hut.fi/Publications/bibdb/MarinoniMsc.pdf**

Spectrum

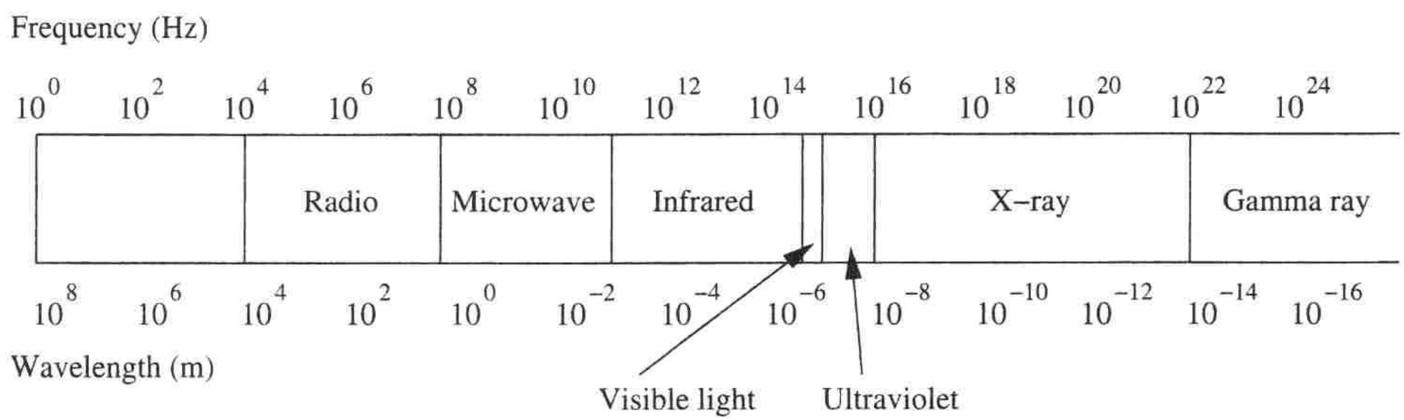

Figure 1.1. The electromagnetic spectrum.

Radio spectrum

Table 1.1. Frequency bands and their common uses

Band Name	Frequency	Wavelength	Applications
Extremely Low Frequency (ELF)	30 to 300 Hz	10,000 to 1,000 Km	Powerline frequencies
Voice Frequency (VF)	300 to 3,000 Hz	1,000 to 100 Km	Telephone communications
Very Low Frequency (VLF)	3 to 30 KHz	100 to 10 Km	Marine communications
Low Frequency (LF)	30 to 300 KHz	10 to 1 Km	Marine communications
Medium Frequency (MF)	300 to 3,000 KHz	1,000 to 100 m*	AM broadcasting
High Frequency (HF)	3 to 30 MHz	100 to 10 m	Long-distance aircraft/ship communications
Very High Frequency (VHF)	30 to 300 MHz	10 to 1 m	FM broadcasting
Ultra High Frequency (UHF)	300 to 3,000 MHz	100 to 10 cm	Cellular telephone
Super High Frequency (SHF)	3 to 30 GHz	10 to 1 cm	Satellite communications, microwave links
Extremely High Frequency (EHF)	30 to 300 GHz	10 to 1 mm	Wireless local loop
Infrared	300 GHz to 400 THz	1 mm to 770 nm	Consumer electronics
Visible Light	400 THz to 900 THz	770 nm to 330 nm	Optical communications

* Throughout this book, the unit *m* refers to meter(s).

Radio propagation mechanisms

- **Direct signal**
- **Reflection**
- **Diffraction**
- **Scattering**

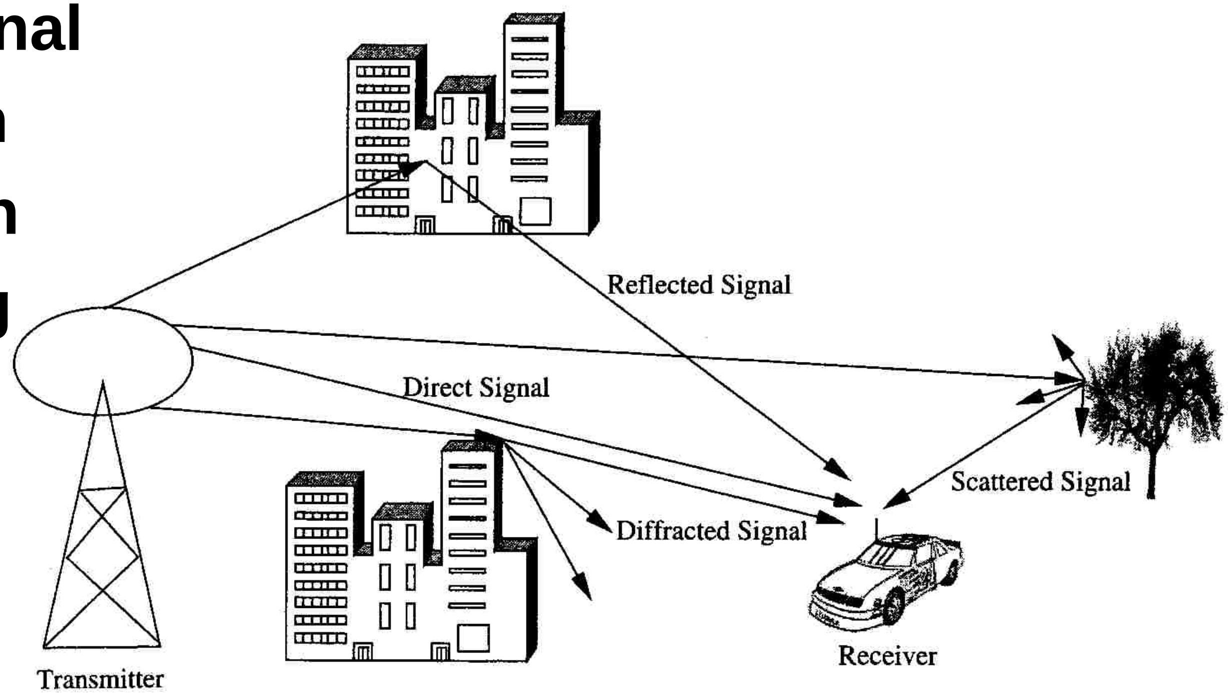

Figure 1.2. Propagation mechanisms.

Path loss: Open space

$$P_r = P_t G_t G_r \left(\frac{\lambda}{4\pi d}\right)^2$$

where

P_r *receive power*

P_t *transmission power*

G_t *transmission gain*

G_r *receive gain*

λ *wavelength*

d *distance between transmitter/receiver*

Path loss: Two ray ground model

$$P_r = P_t G_t G_r \left(\frac{h_t h_r}{d^2}\right)^2$$

where

h_r receiver height from ground

h_t transmitter height from ground

or

$$P_r = P_t G_t G_r \left(\frac{\lambda}{4\pi d}\right)^2 \left(\frac{4\pi h_t h_r}{d}\right)^2 = P_t G_t G_r \left(\frac{\lambda}{4\pi d}\right)^2 \left(\frac{d_{tresh}}{d}\right)^2$$

where

$$d_{tresh} = \frac{4\pi h_t h_r}{\lambda}$$

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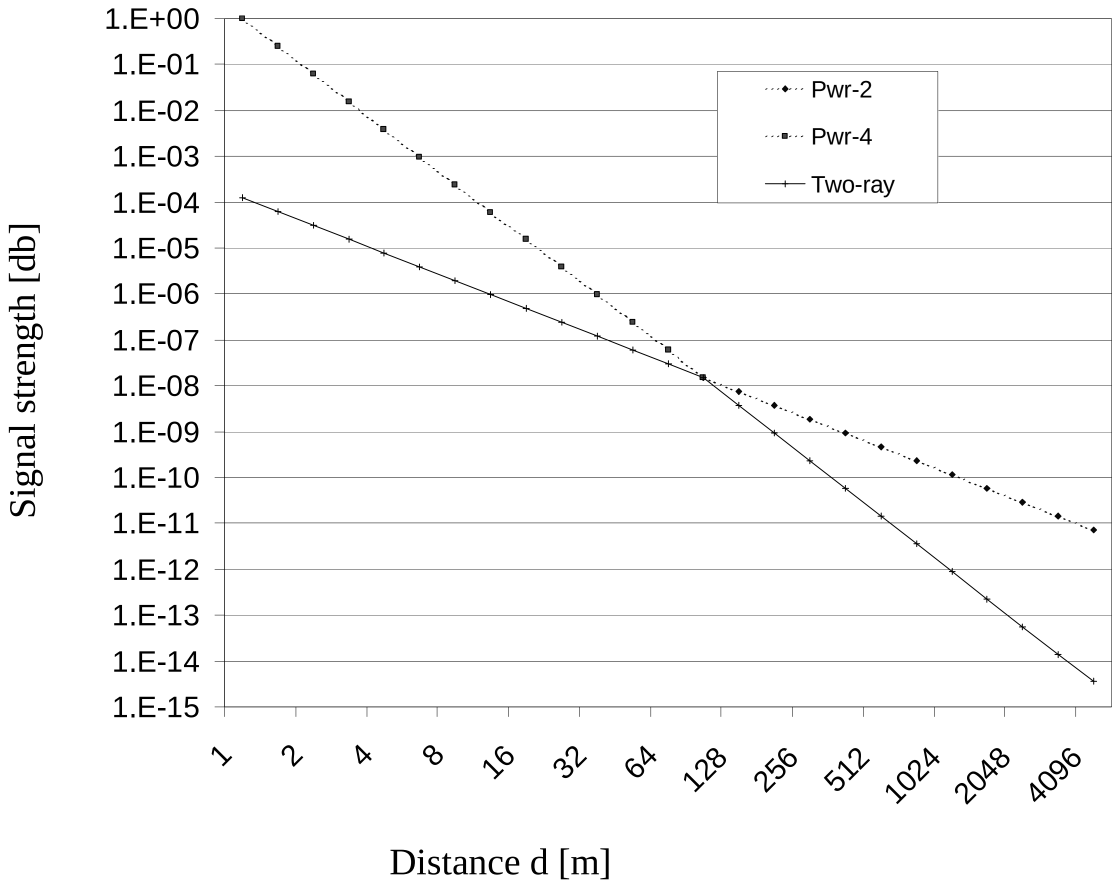
Path loss: Two ray ground model



Path loss:
Strong attenuation

$$P_r = P_t G_t G_r \left(\frac{\lambda}{4\pi}\right)^2 \frac{1}{d^\gamma}$$

where

γ propagation coefficient between 2 (open space) and 5 (strong fading)

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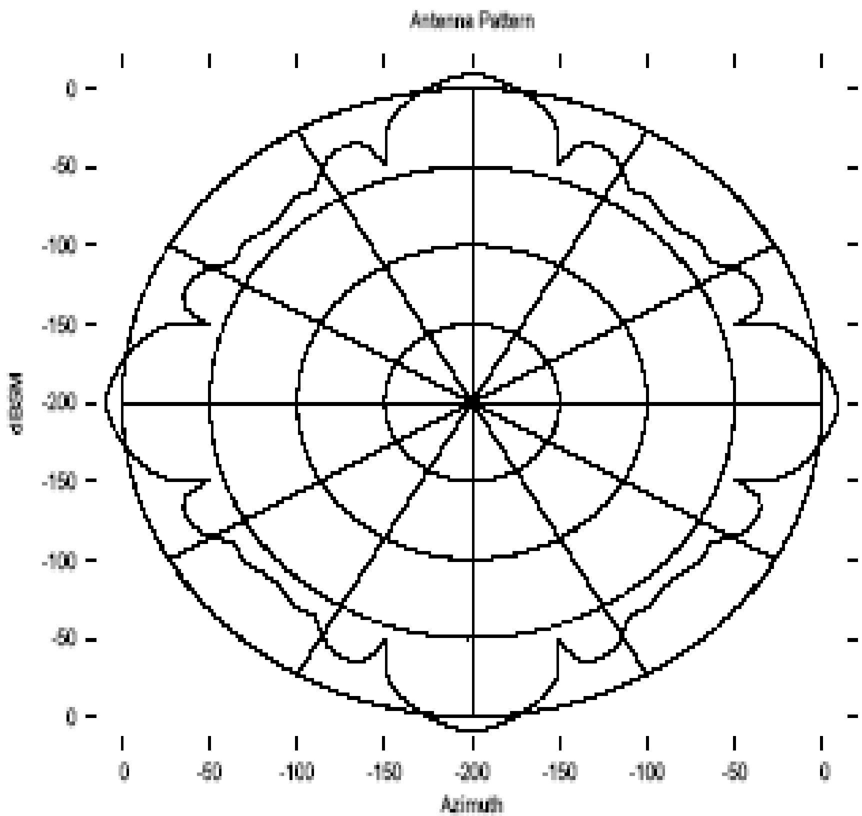
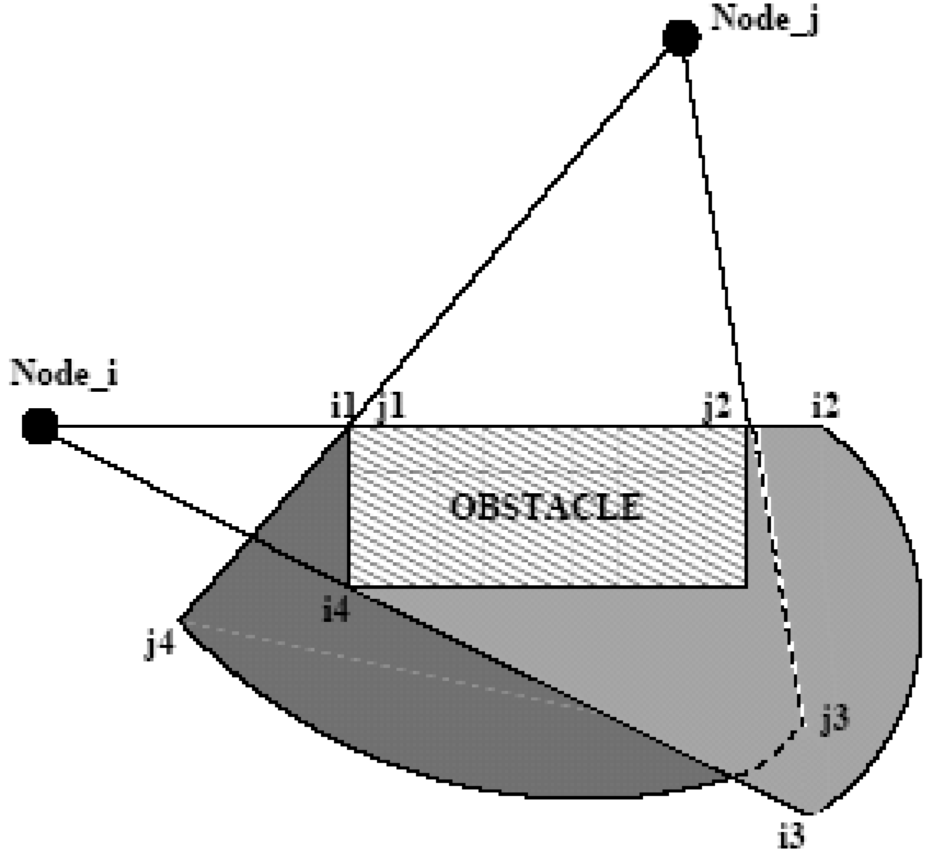
Impact of antenna

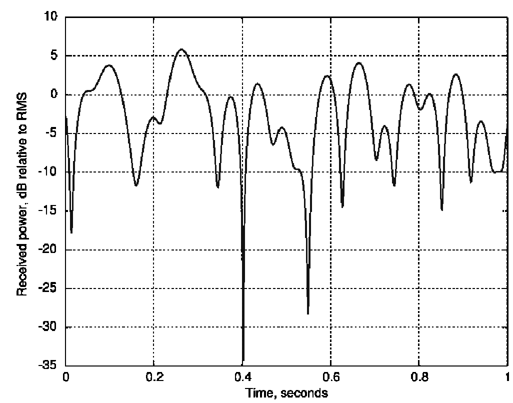


Impact of obstacles



Fading

- **Fast fading (small-scale fading)**
  - **Rapid fluctuation of signal (amplitude, phase, interference due to multi-path transmission**
  - **If no line-of-sight signal: Rayleigh fading**



  - **If line-of-sight signal available: Ricean distribution (indoor situation)**
- **Slow fading (large-scale fading)**
  - **Attenuation due to objects between transmitter and receiver**
  - **Fading lasts longer time (seconds or minutes)**

Interference

- **Adjacent channel interference**
  - **Signal disturbed by adjacent frequency transmission**
- **Co-channel interference**
  - **Interference caused by transmission at the same frequency**

Doppler shift

- **Caused by movement of transmitter and receiver (actually relative movement of them)**

$$f_d = \frac{v}{\lambda}$$

$$\textit{where}$$

$$f_d \text{ doppler effect on frequency}$$

$$v \text{ relative frequency}$$

$$\lambda \text{ wavelenght}$$

Transmission rate constraints

- **Nyquist's theorem**

$$C = 2B\log_2 L$$

where

C maximum channel capacity

B used bandwidth [Hz]

L number of discrete signal levels

- **Shannon's theorem**

$$C = B\log_2(1+(S/N))$$

where

C maximum data rate

B bandwidth [Hz]

S signal power

N noice power

$$SNR = 10\log_{10}(S/N)$$

S/N	bit/s/Hz	SNR
1	1	0
2	1.584963	3
4	2.321928	6
10	3.459432	10
100	6.658211	20

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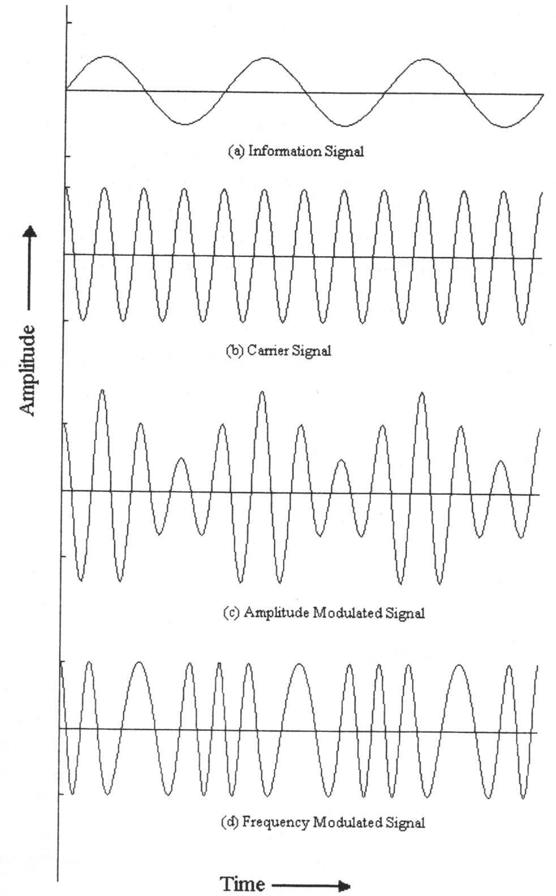
Modulation techniques: Analog modulations



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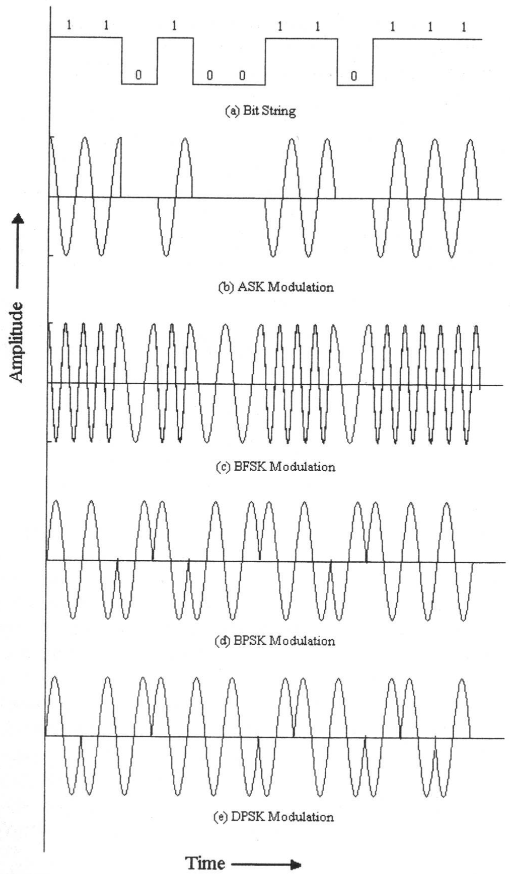
Modulation techniques: Digital modulations



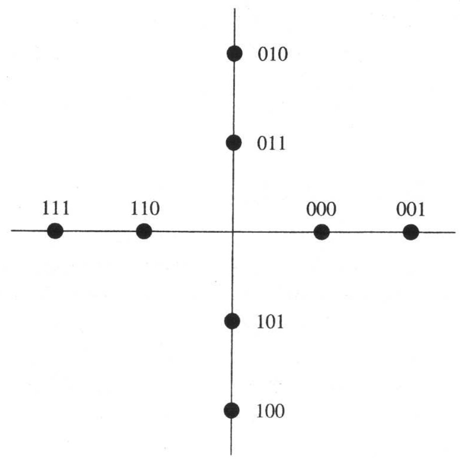


Figure 1.6. Constellation pattern in 8-QAM.

FDMA: Frequency Division Multiple Access

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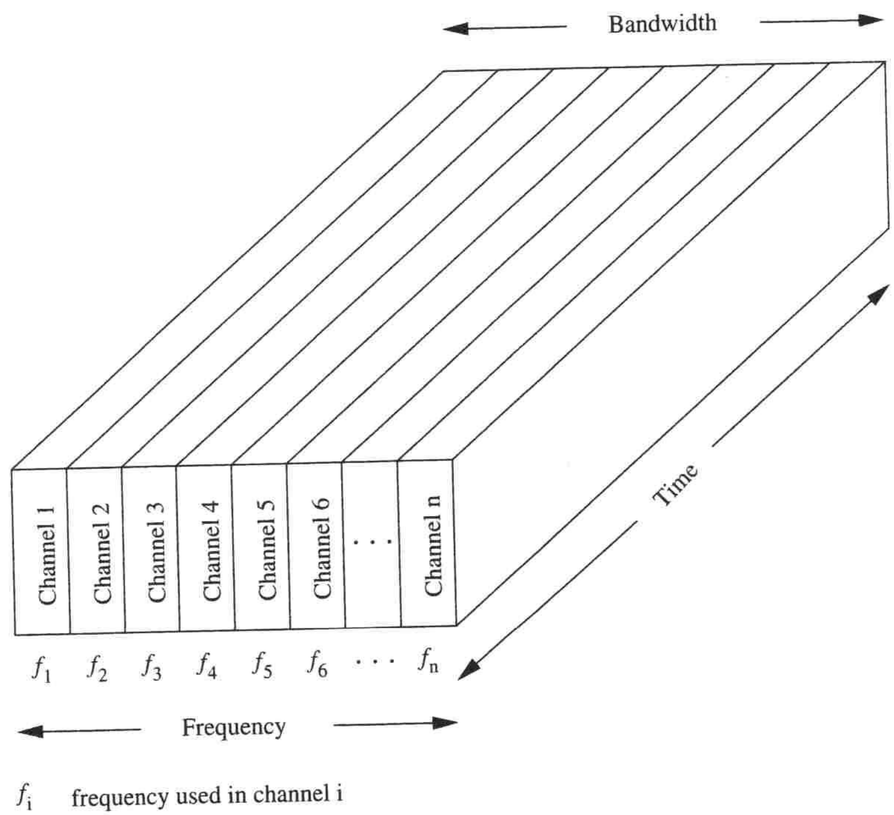
automobile telepho...



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TDMA: Time Division Multiple Access

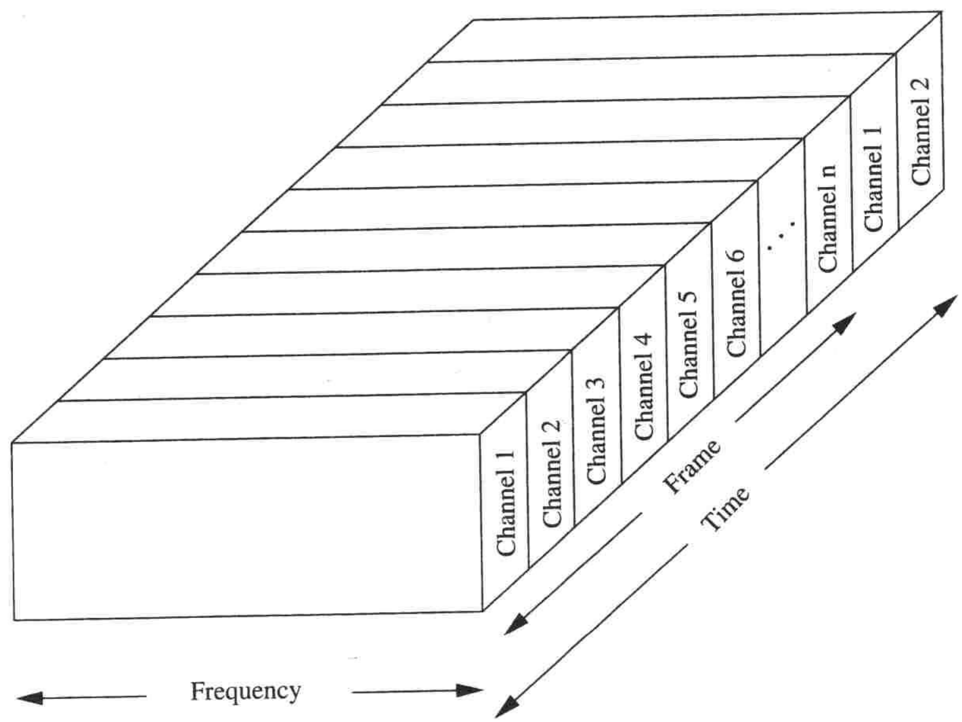

Figure 1.8. Illustration of TDMA.

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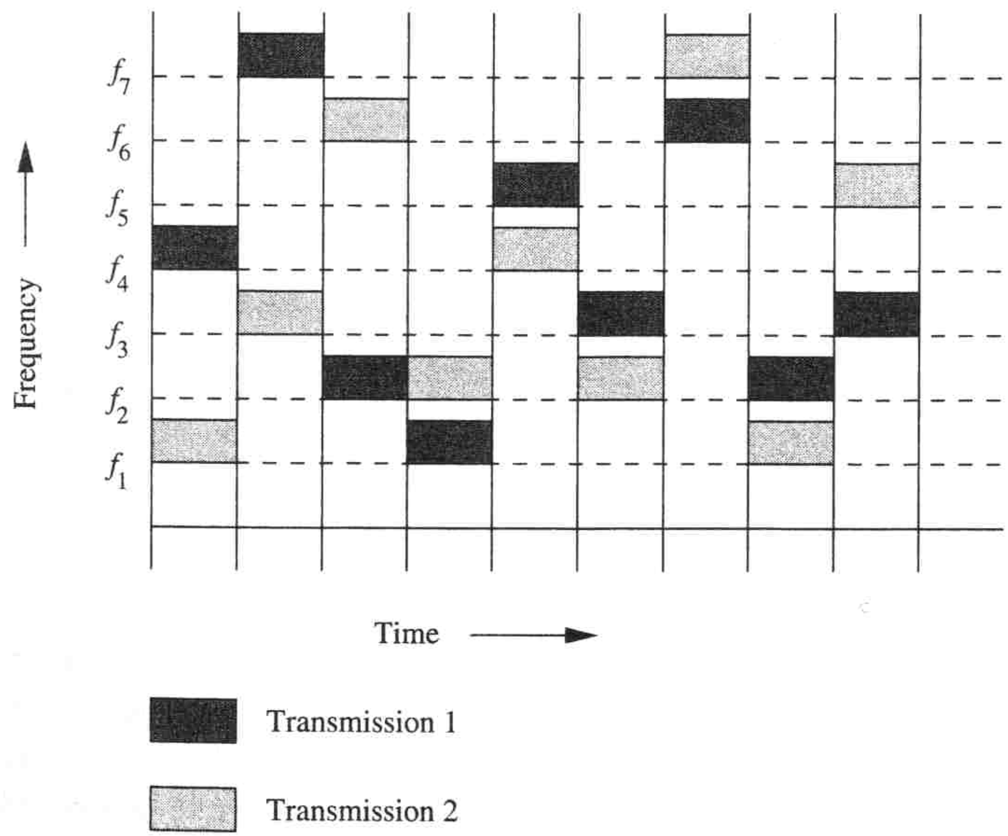
CDMA: Code Division Multiple Access



SDMA: Space Division Multiple Access

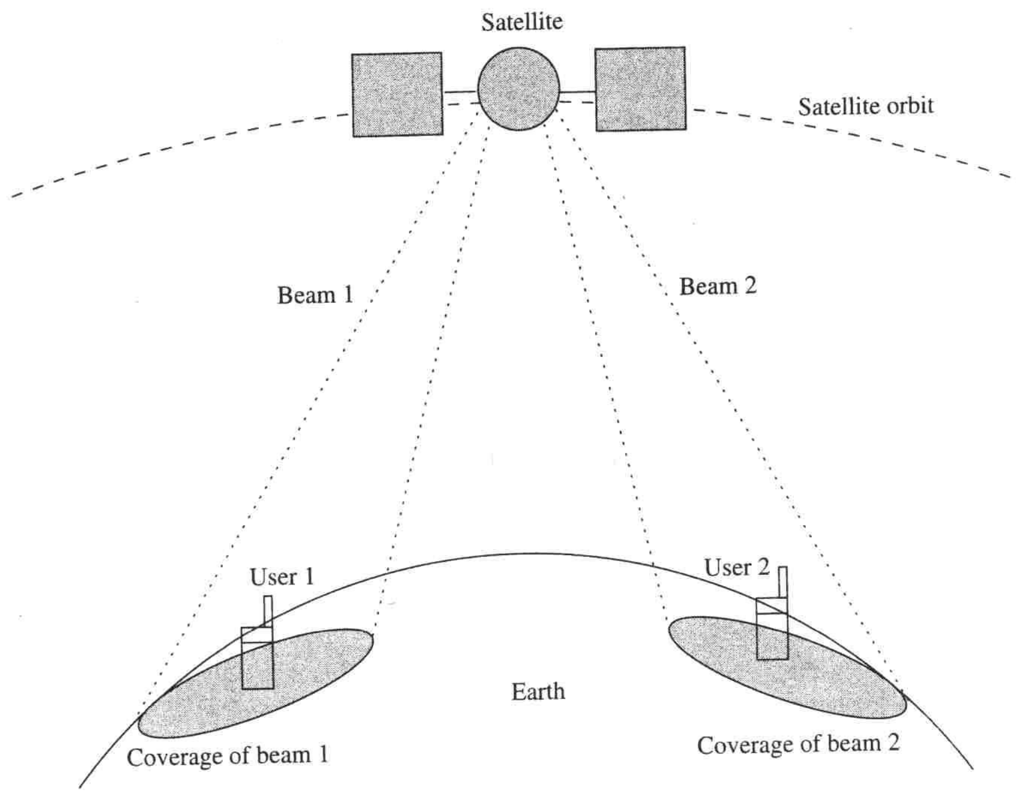


Figure 1.11. Illustration of SDMA.

Error control

- **Detection**
  - **Parity check**
  - **Cyclic Redundancy Check**
  - **Digital signatures**
- **Forward error correction (FEC)**
  - **Hamming coding**
  - **Convolutional coding**
  - **Turbo codes**
- **Automatic Retransmission reQuest (ARQ)**

Questions

- **Why X-rays or Gamma rays are not used in communication?**
- **Which modulation mechanism is best for ad hoc networks:**
  - **FDMA, TDMA, CDMA, or SDMA?**
- **Is there need to consider doppler shift in ad hoc networks**
- **Impact of Fast/Slow fading in ad hoc networks and simulating them?**
- **Impact of asymmetry of antenna?**
- **Impact of obstacles?**