

# Introduction

## Wireless Communication

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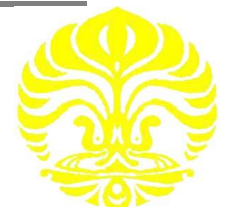
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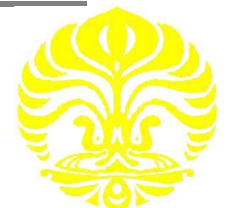


Slide 1



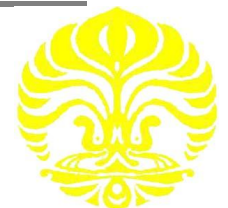
# Physical Properties of Wireless

- Makes wireless network different from wired networks
- Should be taken into account by all layers

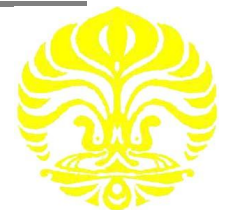
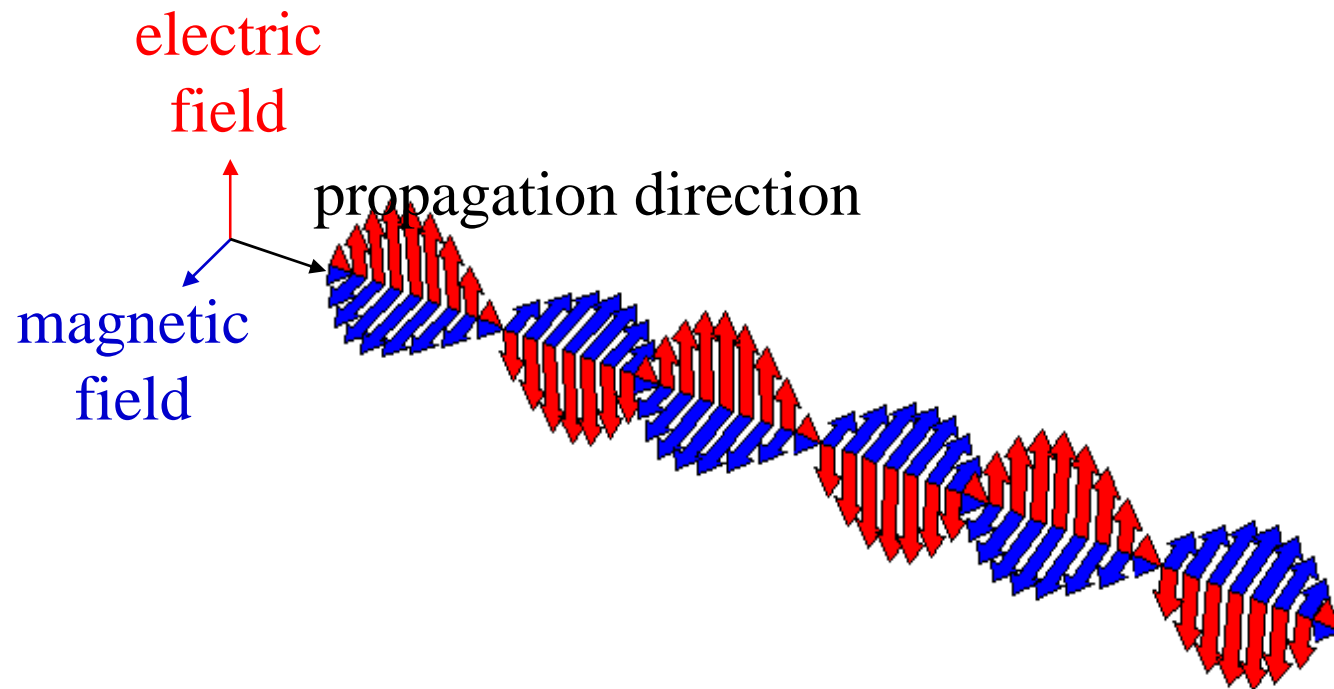


# Wireless = Waves (?)

- Electromagnetic radiation
- Emitted by sinusoidal current running through a wire (transmitting antenna)
- Creates propagating sinusoidal magnetic and electric fields according to Maxwell's equations
- Fields induce current in receiving antenna



# Wave Propagation Example



# Frequency & Public Use Bands

- Propagating sinusoidal wave with some frequency/wavelength
- C (speed of light) =  $3 \times 10^8$  m/s

$$f = \frac{c}{\lambda}$$

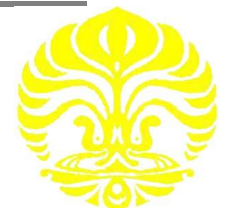
Name	900 Mhz	2.4 Ghz	5 Ghz
Range	902 - 928	2.4 - 2.4835	5.15 - 5.35
Bandwidth	26 Mhz	83.5 Mhz	200 Mhz
Wavelength	.33m / 13.1"	.125m / 4.9"	.06 m / 2.4"



# Free-space Path-loss

- Power of wireless transmission reduces with square of distance (due to surface area increase of sphere)
- Reduction also depends on wavelength
  - Long wave length (low frequency) has less loss
  - Short wave length (high frequency) has more loss

$$P_L = \left( \frac{4\pi D}{\lambda} \right)^2$$



# Other Path-loss Exponents

- Path-Loss Exponent Depends on environment:

Free space

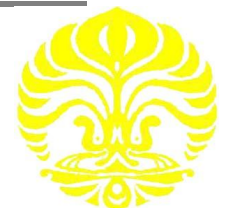
Urban area cellular

Shadowed urban cell

In building LOS

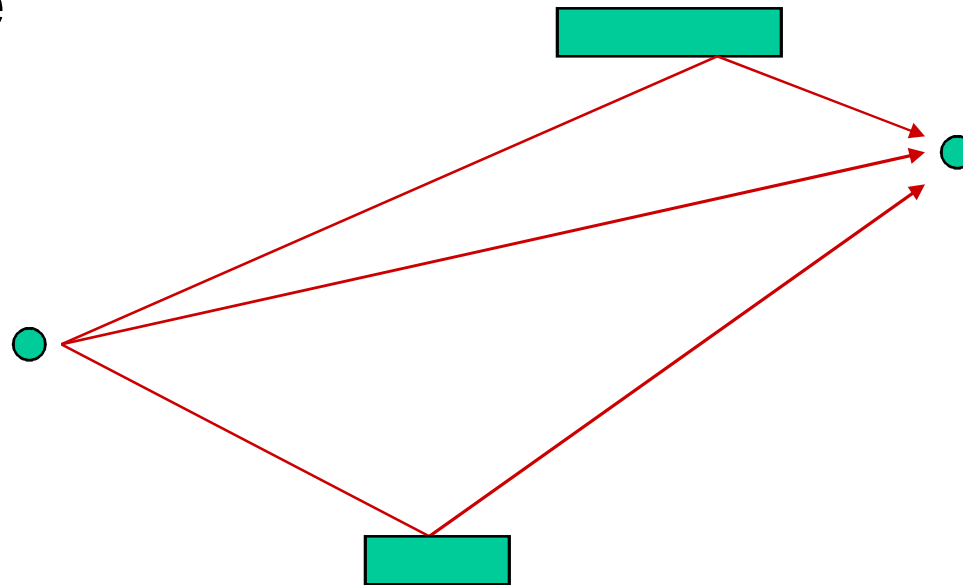
Obstructed in building

Obstructed in factories



# Multi-path Propagation

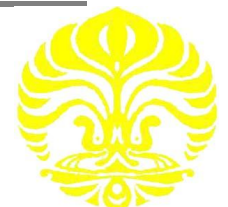
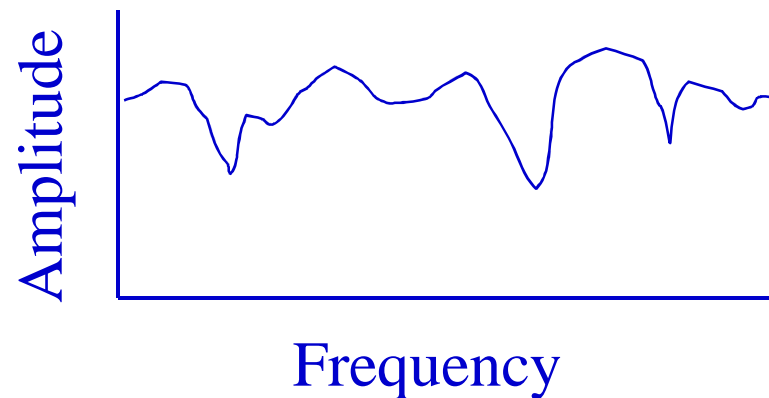
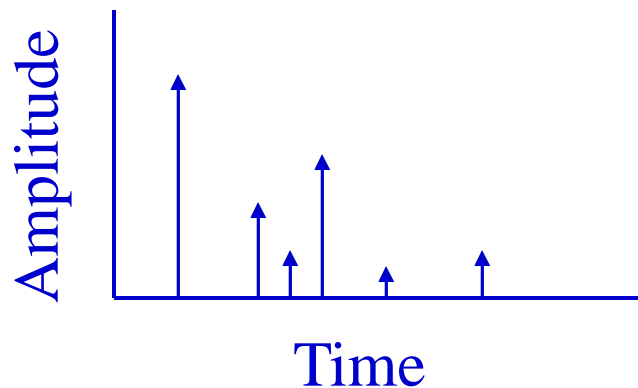
- Electromagnetic waves bounce off of conductive (metal) objects
- Reflected waves received along with direct wave





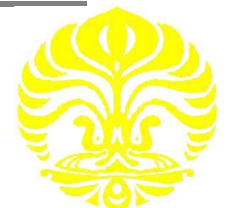
# Multi-Path Effect

- Multi-path components are delayed depending on path length (delay spread)
- Phase shift causes frequency dependent constructive / destructive interference



# Modulation

- Modulation allows the wave to carry information by adjusting its properties in a time varying way
  - Amplitude
  - Frequency
  - Phase
- Digital modulation using discrete “steps” so that information can be recovered despite noise/interference
  - 8VSB - US HDTV
  - BFSK - Mote Sensor Networks
  - QPSK - 2 Mbps 802.11 & CMDA(IS-95)



## Multi-transmitter Interference

- Similar to multi-path
- Two transmitting stations will constructively/destructively interfere with each other at the receiver
- Receiver will “hear” the sum of the two signals, which usually means garbage

