

Contents

1	Introduction	1
1.1	Motivation and Introduction	1
1.2	The Wireless Spectrum	2
1.3	Assessment & Delivery	3
1.4	Module Outline	3
1.5	Textbooks	4
1.6	Basics of Wireless Communication	4
1.6.1	Main components of a transmitter	4
1.6.2	Main components of a receiver	5
2	Basic Antenna & Propagation	5

[Lecture on 1.2]

1 Introduction

Dr. Declan Delaney

1.1 Motivation and Introduction

1. Signals travel without wires
 - (a) In this module, signals travel as radio waves (optical and acoustic systems ignored)
2. Applications are mostly in communications
 - (a) Signals modulated to carry information
 - (b) Many familiar applications such as radar, navigation, etc.

Example: Modern smart phone has approximately 9 distinct wireless systems. Try identifying them?

- NFC
- Cellulars
 - 2G
 - 3G

- 4G
 - 5G
- GPS
- Bluetooth
- WiFi
- UWB
- Lidar

Advantages of Wireless

- Mobility
- Good for one-to-many transmissions
- Cheap

Increasingly used for high capacity point-to-point links (cheaper than wired)
(e.g. to serve remote areas)

Advantages of Wired

- Very little leakage
- No interference
- Multiple systems can operate adjacently without issue

but considerably more overheads. Suitable for super high capacity lines (eg. fibre-optic transatlantic cables)

1.2 The Wireless Spectrum

The EM spectrum is a shared and limited resource.
Mostly regulated by government agencies.

Frequencies must be carefully given out, but can be reused at different locations as we will see.

Overview of a wireless system:

- Start with raw data
- Source coding (compression)
- Channel coding (error detection & error correction)
- Modulation
- TX

- RX
- Demodulation
- Channel decoding
- Source decoding

This module is mainly about modulation and TX/RX, the rest is information theory.

1.3 Assessment & Delivery

Component	Timing	Weight
Lab Assignments	Varied (3 labs)	25%
Online BS quizzes	?	25%
Final Exam		50%

- Lab 1: Receiver architectures
- Lab 2: Phase-Locked Loops
- Lab 3: Amplifiers

Open book final with emphasis on design and problem solving

1.4 Module Outline

- (1) Radio Link Design
 - Link budget?
 - How far? How much power?
- (2) Non-Linear System
- (3) Frequency Generation and Synthesis
- (4) Transmitter Design
 - Requirements and specifications
 - Transmitter architecture choices
- (5) Noise
 - Sources of noise
 - Noise analysis, low-noise design
- (6) Receiver Design
 - Requirements and specifications
 - Receiver architecture choices
- (7) Transceiver Design
 - Transmitter and receiver combined!

- (8) Antennas and Propagation
 - Review of antenna theory
 - Practical antennas and propagation of radio waves
- (9) System-Level Issues and Examples

1.5 Textbooks

Purely optional, module notes should be sufficient.

- "Microwave and RF Design of Wireless Systems"
by David M. Pozar
- "Antennas"
by John D. Kraus

[Lecture on 1.3]

1.6 Basics of Wireless Communication

Amplifier to increase signal power enough to drive the antenna

Multiple Access

- CSMA: Listen to the channel, send if it's clear
- FDMA: Frequency divided MA
- TDMA: Time divided MA

You require a 'guard band' between frequency bands where no data is sent to avoid interference

CDMA is a good way to overcome this waste, OFDMA is an even better approach

1.6.1 Main components of a transmitter

- Signal is 'mixed' (modulated) with an oscillator at the frequency of the channel being used
 - The frequency has to be adjustable to allow for different channels
- A power amp is required to power an antenna

Amp goes first because high-frequency amplification is a fucking nightmare

1.6.2 Main components of a receiver

Signal arrives on an antenna (which collects EM waves in the vicinity, sometimes in a preferred direction, and puts them on a cable, waveguide, or circuit board track)

RX:

- Receive at very low power
- Select and amplify the desired signal
- Estimate the original signal

The signal is too weak to demodulate, so you need a high-frequency amplifier before the demodulator.

For most of this module, we will look at block-level circuits and not worry about precise circuit design.

Channel capacity (Shannon-Hartley): $C = B \times \log_2(1 + \frac{S}{N})$

- C is channel capacity (eg. bits per second)
- B is bandwidth (Hz)
- $\frac{S}{N}$ is the signal-to-noise ratio

Cellular:

- 2G operated at 800-900 MHz and 64 kHz channels
- 3G operated at 1-2 GHz and 8 MHz channels
- 4G operates at up to 5 GHz and 50-100 MHz channels
- 5G has channels up to 10 GHz

The increase in speed is partially due to better MA schemes, but mainly due to the bigger bandwidth.

Other options to increase capacity:

- Increase SNR
 - Increase power (limited by regulations)
 - or reduce noise (choose a frequency with less background?)

2 Basic Antenna & Propagation

Radio link design

- What will be the power at the receiver (or SNR)?
- How far away can the antennae be?
- How much power is needed?

Answers culminate in a *link budget* calculation

Antennae

- Circuitry generates the signal and amplifies to high power
- High power signal goes along a 'feed track'
 - Very little losses here
- Then into the antenna
 - Can be directed, but not guided, so loses power quickly
 - Not all power is radiated, some is lost