EE161: Digital Communication Systems

Introduction

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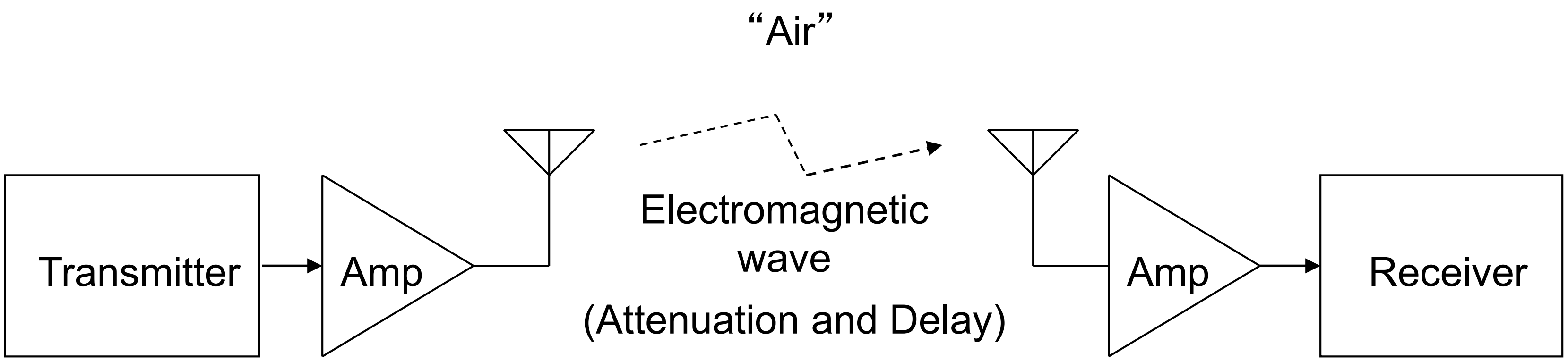
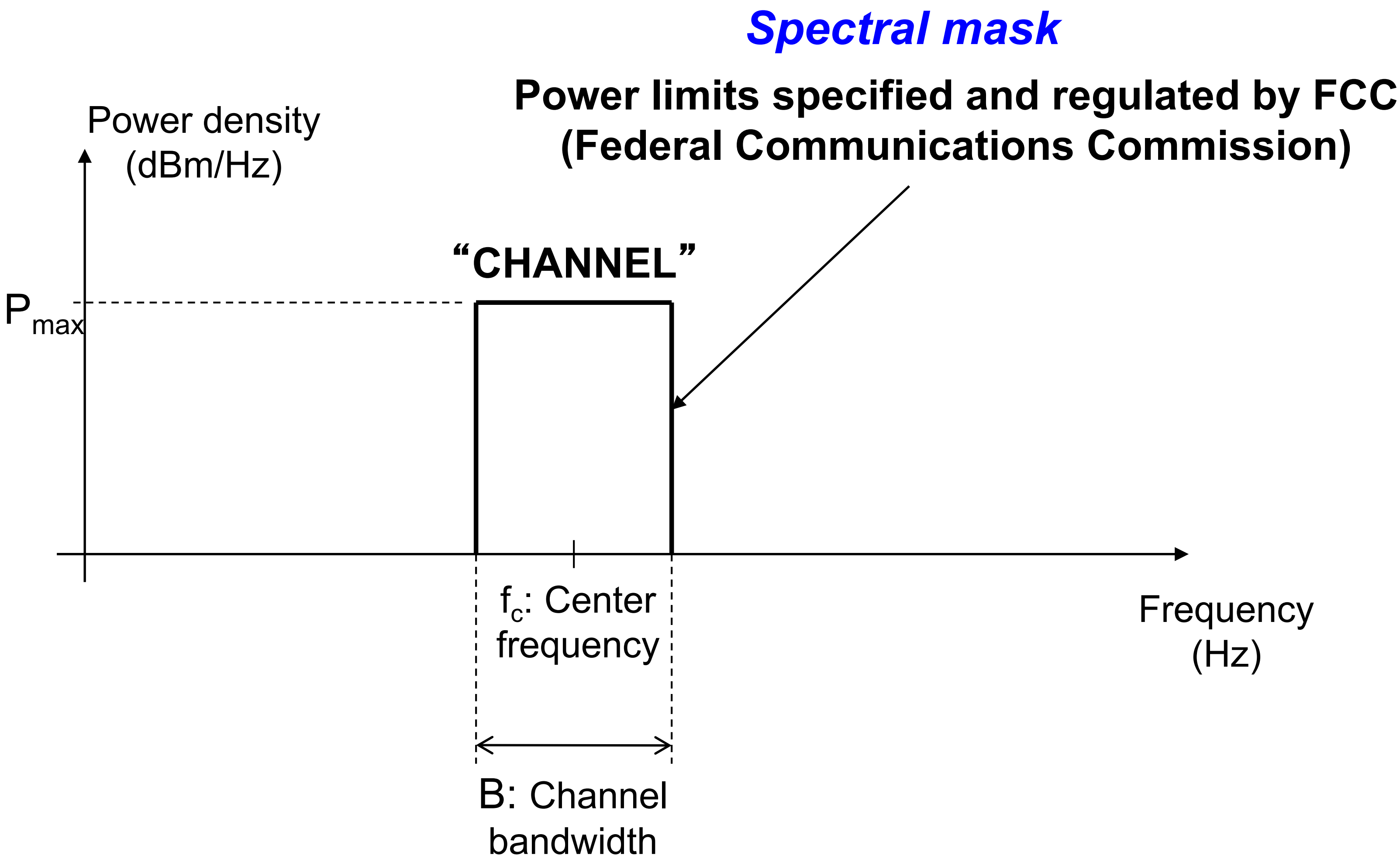
Wireless Communication



- **Amplifiers are needed to reverse attenuation effects**

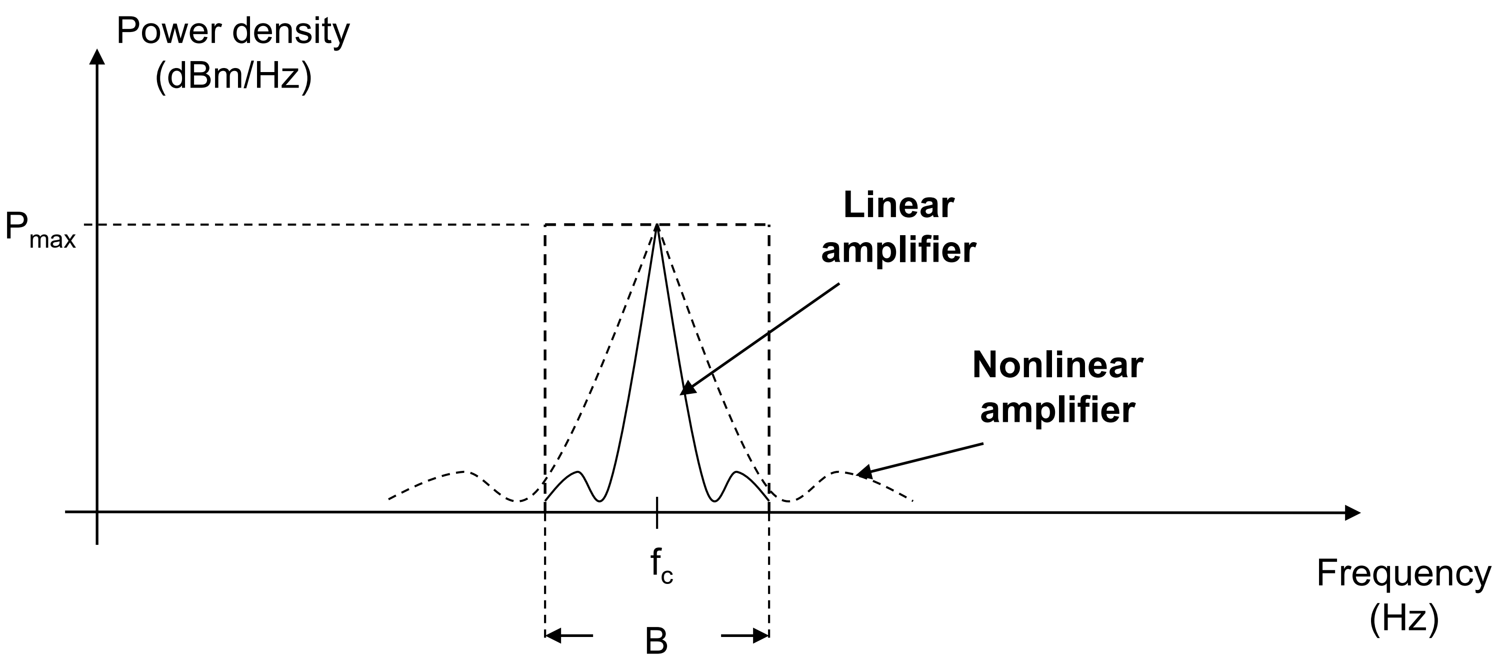
- **The "Air" is a national resource.**
- **Its use is regulated by the government …**

Spectral Occupancy



Nonlinearities

- <u>Nonlinearities</u> of RF (radio-frequency) *amplifiers* may cause additional spectral components (related to harmonics) that fall outside of the allocated channel bandwidth:



Example (EE160): Two-tone test

- Non-linear amplifier modeled via the input-output relation

$$V_o = a_1 V_i + a_3 V_i^3$$

- Input:

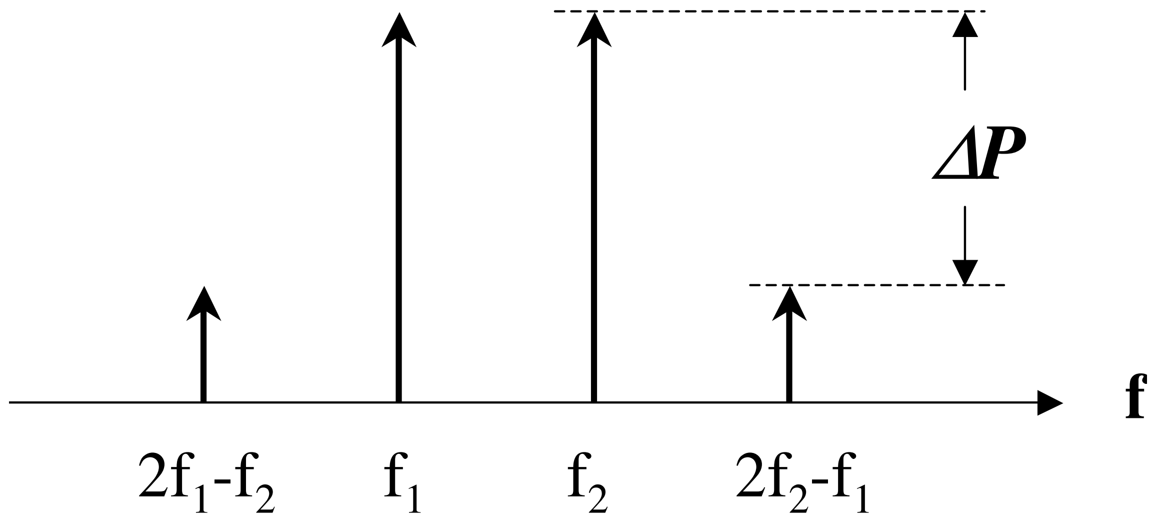
$$V_i = A\left[\cos\left(2\pi f_1 t\right) + \cos\left(2\pi f_2 t\right)\right]$$

- Output:

$$V_o = A\left(a_1 + \frac{9a_3A^2}{4}\right)\left[\cos\left(2\pi f_1 t\right) + \cos\left(2\pi f_2 t\right)\right]$$

$$+\frac{3a_3A^3}{4}\left[\cos\left(2\pi\left(2f_1 - f_2\right)t\right) + \cos\left(2\pi\left(2f_2 - f_1\right)t\right)\right]$$

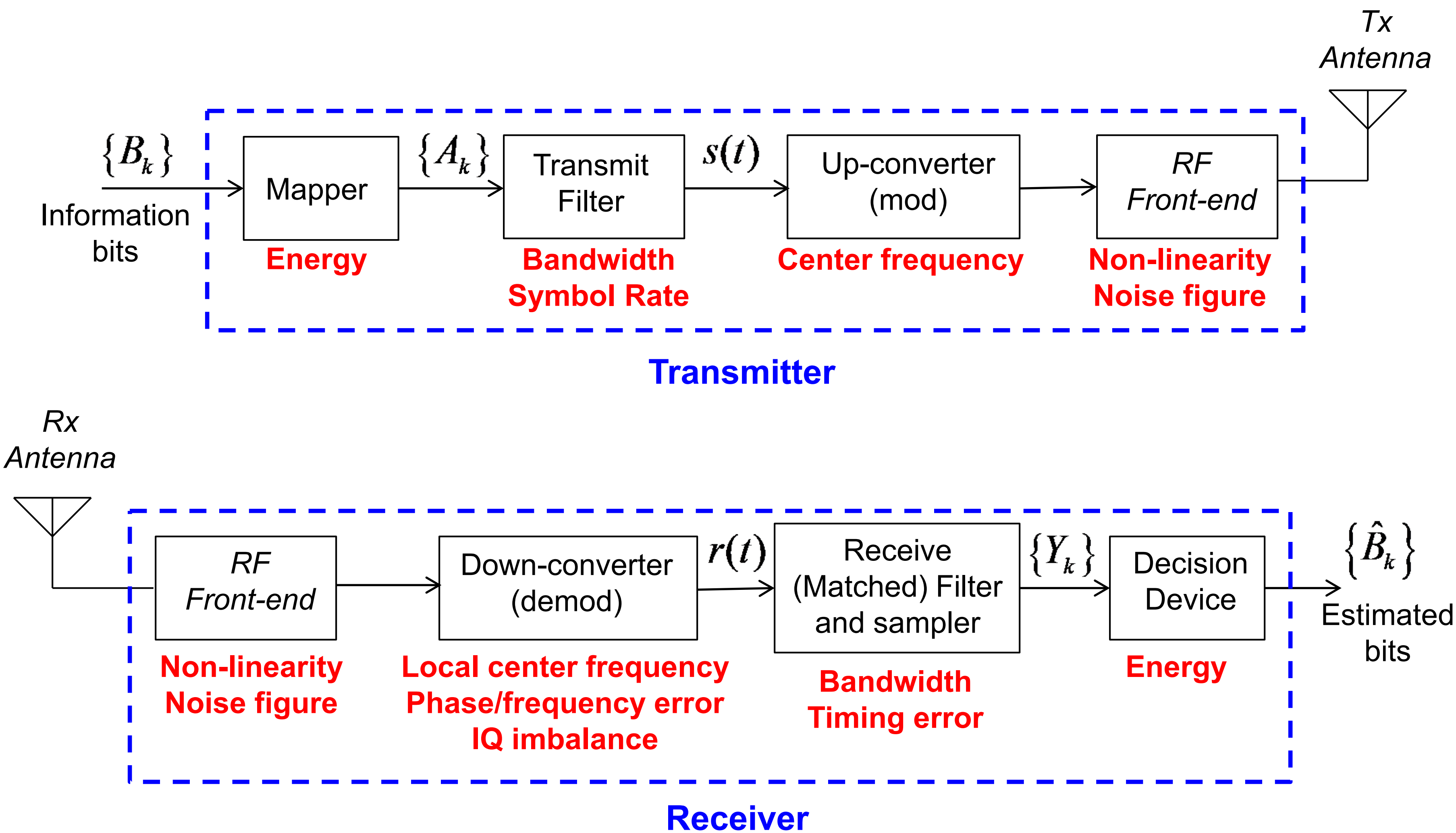
Spectral Regrowth



Measure of non-linearity (Third-order intercept point):

$$\text{IIP3 (dBm)} \approx \frac{\Delta P\ \text{(dB)}}{2} + 20\log_{10} A\ \text{(dBm)}$$

A Wireless Communication System



Elements – I

- **Information bits**: Assumed to be *uniformly distributed*
  - Scrambler using a pseudo-noise (PN) sequence
  - Bit rate: Rb=1/Tb
- **Mapper**: BPSK (L=1 bit/symbol), QPSK (2 bits/symbol), 16-QAM (4 bits/symbol), etc ..
  - Symbol rate: $Rs=Rb/L$
  - Symbol duration: $T=LTb$
- **Transmit/receiver filters**: Designed to limit bandwidth and *remove intersymbol interference* (ISI)
  - Square-Root Raised-Cosine (SRRC) filter

Elements – II

- **Up-converter**
  - Amplitude (quadrature) modulator
- **RF Front-ends (Tx and Rx)**
  - Mixers, Amplifiers and Filters
- **Down-converter**
  - Amplitude (quadrature) demodulator
  - Propagation delay, phase error and frequency error
  - Multipath
- **Sampling**
  - Symbol rate at receiver is different from transmitter!
  - This causes symbol *timing errors*
  - Need to *oversample* and select or interpolate

Outline of EE161 course

1. Pulse shaping and mapping of bits to amplitudes
2. Binary modulations: BPSK, BFSK
3. Nonbinary modulations: M-PAM, M-PSK, M-QAM
4. Bandimited channels: ISI and raised-cosine spectrum
5. Error control coding (ECC) via signal space
6. Modeling of wireless channels, multipath and fading
7. Modulations that are robust under wireless multipath fading conditions
8. Signal diversity techniques for wireless channels
   - ✓ Time: Interleaving/ECC, spread-spectrum
   - ✓ Frequency: OFDM with interleaving/ECC
   - ✓ Space: Receive/transmit diversity and MIMO

Canvas, textbook and MATLAB

- In Canvas there are samples of previous homework and exams as well as numerous MATLAB scripts and models
- The textbook is the same as that of EE160:

  J.G. Proakis and M. Salehi, *Fundamentals of Communication Systems*, 2nd ed., Prentice Hall, 2014.

- This course uses MATLAB systems in homework and exams, to examine the functionality and performance of wireless communication

Grading policy

- *Homework* is due one-week after posting
  - Solutions (PDF file) posted in the webpage
  - **MATLAB** based as much as possible
- Two *midterm exams*
  - May need MATLAB or other graph-producing software
- One *final project*: Oral presentation and written report

Item	Percentage
Homework	15%
Midterm 1	20%
Midterm 2	30%
Final presentation/report	35%

Next time: From bits to waveforms

- **Pulse shapes**: NRZ, RZ and Manchester
- **Mappings** of bits to amplitudes: Polar, unipolar and AMI
- Power spectral densities

This and other presentations can be found in Canvas under *Files/Lectures*