Shanghai Jiao Tong University
Department of Electronic Engineering
EE 367 Fundamentals of Communication Circuits
Spring 2019

Lecture:
Tuesday 8:00-9:40 (02/26-04/16)
Thursday 10:00-11:40 (02/28-06/14)
East Middle Hall (东中院) 4-101

Instructor:
Yuye Ling, Ph.D.
yuye.ling@sjtu.edu.cn
Office hour: Monday 12PM-1PM.
Software Building 1-1062

Textbooks:
1. B. Razavi, *RF Microelectronics Second Edition* (Prentice Hall, 2011).
2. T. H. Lee, *The Design of CMOS Radio-Frequency Integrated Circuits Second Edition* (Cambridge University Press, 2003).

Reference:
张肃文。高频电子线路（第 5 版）。北京：高等教育出版社，2009。

Course description:
This is an introductory course on the radio-frequency circuits design for wireless communications applications. By the end of the semester, students will learn the working principles of important building blocks for wireless communication systems including amplifiers, mixers, oscillators, and passive devices. The course aims to help students to develop their capability conducting analysis and synthesis on radio-frequency circuits in various applications. The course is also accompanied with an experimental development project, in which students will build a radio system.

Special notes: This class is fully taught in English. Everything, including but not limiting to classroom lecturing, homework assignments, exams, and office hours, is in English. Students are expected to improve their academic English proficiency in reading, listening, writing and speaking after the course.

The course is designed for students who have already completed a full semester of communication theory, analog circuits, and signal and system, and are ready to advance their knowledge and skills in RF circuits design.

Syllabus
Lecture 1 (02/26/2019): Introduction of wireless communications and RF circuits
- History of wireless communications: early days of radio, from Maxwell's equations to Armstrong's superheterodyne.
- Evolution of modern wireless communications from 1G to 5G. Why the wireless

communications are important?
- Challenges to circuits designers

Lecture 2 (02/28/2019): Basic concepts in RF circuits design I
- Basic units: voltage vs power
- System characteristics
  - Linear vs nonlinear
  - Time-variant vs time-invariant
  - Memoryless and static system
- Why we care about nonlinearities?
  - Harmonic distortion: mixing

Lecture 3 (03/05/2019): Basic concepts in RF circuits design II
- Why we care about nonlinearities?
  - Gain compression, cross modulation, and intermodulation: definition and their impacts on different modulation (communication) schemes.
  - Third intercept point (IP3) and cascaded nonlinearity

Lecture 4 (03/07/2019): Basic concepts in RF circuits design III
- Noise in the communication system and how are they connected with circuits components
  - Noise spectrum and noise figure
  - Noise in semiconductors: excess noise, shot noise, 1/f noise
- Sensitivity and dynamic range.

Lecture 5 (03/12/2019): Basics of passive RLC networks
- Series RLC tank, parallel RLC tank
  - Quality factor, frequency response and bandwidth
  - Phasor picture
  -

Lecture 6 (03/14/2019): Network transformations
- Series/parallel-to-parallel/series conversion
- Impedance matching:
  - L-match
  - π-match
  - T-match
  - Tapped capacitor/inductor match

Lecture 7 (03/19/2019): Brief review on communication theory
- Analog modulation formats: amplitude modulation, phase modulation, frequency modulation
- Digital modulation formats: ASK, PSK, FSK, QPSK
- Wireless standards

Lecture 8 (03/21/2019): Basic receivers

- Basic receiver structure
  - Bandpass filtering
  - (Super)heterodyne and image problem
  - Tradeoff between image-rejection and bandpass filtering

Lecture 9 (03/26/2019): Modern receivers

- Modern receivers:
  - Dual downconversion, zero second IF, sliding IF, direct conversion
- Transmitter structures:
  - Example

Lecture 10 (03/28/2019): Transmitter design

- Design considerations for transmitter
  - I/Q mismatch, carrier leakage, linearity, and oscillator pulling
- Modern direct-conversion transmitter

Lecture 11 (04/02/2019): Introduction to low-noise amplifiers

- A brief review on the small-signal model of MOSFET
- Considerations on the amplifier's design parameters: noise figure, gain, linearity, and bandwidth.

Lecture 12 (04/04/2019): Different forms of low-noise amplifiers I

- Basic configurations: common source, common gate
- Feedforward and feedback

Lecture 13 (04/09/2019): Different forms of low-noise amplifiers II

- Cascaded low-noise amplifiers
- Impedance matching

Lecture 14 (04/11/2019): Different forms of low-noise amplifiers III

- Design examples for low-noise amplifiers
- Midterm review

Lecture 15 (04/16/2019): Midterm (tentative) & Introduction to mixers

- Ideal switch and how can it be used as a mixer
  - Performance evaluation: linearity, noise and gain
  - Feedthrough

Lecture 16 (04/18/2019): Passive mixer

- Single-balanced mixers: structure, derivation and performance
- Double-balanced mixers: structure, derivation and performance
- Passive down-conversion mixer
  - Single-balanced
  - Double-balanced
  - Sampling mixer: conversion gain

Lecture 17 (04/25/2019): Active mixer

- Block diagram and single-balanced
- Double-balanced
- Conversion gain
- Design examples

Lecture 18 (05/02/2019): Passive devices

- Why the RF experiment is so hard (random)
- Integrated inductor
    - Parasitic capacitor
    - Loss
    - Transformer
- Varactor (varicap, variable capacitors)

Lecture 19 (05/09/2019): Oscillators I

- The basic principles of LC oscillators
    - Time-domain analysis
    - Barkhausen's Criteria
    - Feedback

Lecture 20 (05/16/2019): Oscillators II

- Cross-coupled oscillators
- Ring resonators
- Nagative resistance
- Three-points Oscillators
    - Hartley
    - Clapp

Lecture 21 (05/23/2019): Oscillators III

- Crystal oscillators
- Voltage controlled oscillators
    - VCO as a frequency modulator

Lecture 22 (05/30/2019): Power amplifiers I

- The difference between power amplifiers and low noise amplifiers
- The working principles for power amplifiers
- Class-A power amplifiers

Lecture 23 (06/06/2019): Power amplifiers II

- Induction angle
- Class- B and class-C amplifiers

Lecture 24 (06/12/2019): Power amplifiers III and Final reviews

- Design examples for power amplifiers