Tandon School of Engineering of New York University
Department of Electrical & Computer Engineering

ECE-GY 9013 Special Topics in ECE: "A Linear System Approach to Wave Propagation"

Spring, 2021

Lectures (remote - Zoom): Tuesday 9:30 – 10:45 AM, Thursday 9:30 – 10:45 AM

Course Description: This course treats systems governed by the wave equation via the tools of linear system theory: convolutions and space/time Fourier transforms. In contrast, the traditional physicist's approach to teaching the subject entails scalar and vector potentials, the method of separation of variables, spherical coordinates, and the use of special functions – all of which we circumvent. The course will benefit both wireless communication researchers and signal processing researchers. It will equip them to pursue advanced research topics, such as super-directive antenna arrays, large intelligent surfaces, holographic MIMO, wireless power transfer, wavefield extrapolation, and video motion detection. The course also serves as a physical introduction to multidimensional signal processing. The concepts learned in this course are readily applicable to geophysics, acoustics, and ultrasonics.

Prerequisites: Graduate status; undergraduate linear systems, electromagnetics, and complex variables.

Instructor: Professor Thomas Marzetta, working from my home, Email: tom.marzetta@nyu.edu, Homepage: http://engineering.nyu.edu/people/thomas-marzetta, Office hours (remote!) by email appointment.

Text Book: No text book. Lecture notes and supplementary materials will be posted on NYU Classes

Homework, Exam, and grading Policy: Midterm Exam (take-home): 35%, Final Exam (take-home): 35%, Written Homework and MATLAB exercises: 30%.

Tentative Course Schedule

- Week 01 (Jan 28, Feb 2): Classical network theory
  - N-port networks
  - impedance matrix and properties
  - real and reactive power
  - application: wireless power transmission
- Week 02 (Feb 4, 9): Scalar (acoustic) wave equation
  - physical derivation with distributed source
  - Helmholtz equation
  - review of space/time Fourier transforms

    - solution in frequency/wavenumber domain
    - 1D system (wave-guide)
- Week 03 (Feb 11, 16): Plane-wave expansion of radiated field
    - review of Cauchy residue theorem
    - plane-wave expansion of spherical wave
    - Green's function (impulse response) solution
    - plane-wave solution for arbitrary distributed source
- Week 04 (Feb 18, 23): Methods of computing real power
    - integration over far-field
    - integration over source distribution
    - integration over plane waves
- Week 05 (Feb 25, March 2): Reactive power; self/mutual impedance
    - computation in space-domain
    - computation in wavenumber domain
    - physically meaningful sources
- Week 06 (March 4, March 9): Degrees of freedom for 1D, 2D, 3D arrays
    - non-line-of-sight propagation: plane-wave scattering
    - application: MIMO communications
- Week 07 (March 11, 16): Take-home Mid-Term Exam
- Week 08 (March 18, 23): Maxwell's equations; distributed sources
    - review of Maxwell's equations
    - direct solution in frequency/wavenumber domain
- Week 09 (March 25, 30): Plane-wave expansion of radiated field
    - Polarization
    - vertical and horizontal plane-wave amplitudes
- Week 10 (April 1, 6): MIMO communications
    - degrees-of-freedom for 1D, 2D, 3D polarimetric arrays
    - non-line-of-sight propagation: plane-wave scattering
- Week 11 (April 8, 13): Power: real/reactive; self/mutual impedance
    - methods of computation
    - idealized antennas
- Week 12 (April 15, 20): Application: super-directive antenna arrays
    - wireless communications
    - wireless power transfer
- Week 13 (April 22, 27): Multi-dimensional digital signal processing
    - video motion detection using space/time fan filters
    - inference of far-field antenna pattern from near-field measurements
- Week 14: (April 29, May 4) Additional applications
    - random field models for small-scale fading
    - electromagnetic imaging
- Week 15: (May 11) Take-home Final Exam

Last updated: October 26, 2020