GENERAL NOTES:

1) Vectors in the textbook are denoted by **boldface**, here arrows are used. Note that, in general, they are **vector phasors** or complex vectors (i.e., each vector component is a complex number or function).
2) QUICK REVIEW: vector phasor $\vec{A} = A_x\vec{a}_x + A_y\vec{a}_y + A_z\vec{a}_z$, where $A_x = A_{x1} + jA_{x2}$, $A_y = A_{y1} + jA_{y2}$, and $A_z = A_{z1} + jA_{z2}$. In general $\left|\vec{A}\right|^2 = \vec{A} \bullet \vec{A}^*$, where "*" denotes the complex conjugate only (not also transposed as in linear algebra). Note that it denotes the absolute value with respect to both the real and imaginary parts as well as with respect to the coordinate directions. For example, If $\vec{A} = \left(\mathrm{A}_{x1} + jA_{x2}\right)\vec{a}_x + \left(\mathrm{A}_{z1} + jA_{z2}\right)\vec{a}_z$ then $\left|\vec{A}\right|^2 = \mathrm{A}_{x1}^2 + A_{x2}^2 + \mathrm{A}_{z1}^2 + A_{z2}^2$. Note that this is different than taking the dot-product only:
$\vec{A} \bullet \vec{A} = \mathrm{A}_{x1}^2 + 2jA_{x1}A_{x2} - A_{x2}^2 + \mathrm{A}_{z1}^2 + 2jA_{z1}A_{z2} - A_{z2}^2$
3) MKS (meter-kilogram-second) system is used here and in the book.
4) **All quoted text (" ") is the professor's own, written freely and expressing his own views of the subjects, derived from experience and discussions but normally not available in references.**
5) See Appendix G for information on the computer codes distributed with the book.

The antennas below represent the majority of radiating systems encountered in practice. For each type below there will be lectures detailing the theory, such that the students will be able to predict/<u>analyze</u> with good precision the electrical performance of each structure. In addition, practical design/<u>synthesis</u> techniques and computer codes will also be provided for various types of antennas.

A) Aperture Antennas:

The fields at the aperture are KNOWN (i.e., previously determined or approximated). Currents are computed from the aperture fields using the equivalence principle. Then the far-field patterns can be obtained by integrating the currents.

B) Wire Antennas:

Geometry is known, but current distribution is not (kernel of integral is unknown). The current distribution is then approximated by an expansion (sum) of known functions spanning discrete sections or points over the wire(s). Through the enforcement of the boundary condition $E_{tan} = 0$ (for $\sigma = \infty$), a linear system of equations is generated, which solution yields the current distribution. As before, the far-field patterns can then be obtained by integrating the currents.

C) Antenna Arrays:

Array theory: Principle of pattern multiplication and exact formulations (superposition).

D) Microstrip Antennas:

Transmission-line model based on TEM theory and cavity technique based on modal expansion.

- **ANALYSIS OF ANTENNAS** (<u>Linear systems</u> in <u>free space</u>)
  - Analytical/Empirical Techniques:

- ✓ Integral equation - Green's function approach/Superposition for the free space (all)
- ✓ Gain and directivity formulas (all)
- ✓ Efficiency equation (all)
- ✓ Equivalence principle (aperture)
- ✓ Cozzen's technique (horns)
- ✓ Physical Optics and Geometrical Optics (aperture)
- ✓ Principle of pattern multiplication (arrays)
- ✓ Exact formulation/superposition (arrays)
- ✓ Transmission-line technique based on basic TEM theory (microstrip)
- ✓ Cavity technique based on modal expansion (microstrip)

- Numerical Techniques (theory and/or implementation):
  - ✓ Physical Optics and Geometrical Optics (aperture)
  - ✓ Exact formulation/superposition (arrays)
  - ✓ Transmission-line technique based on basic TEM theory (microstrip)
  - ✓ Cavity technique based on modal expansion (microstrip)
  - ✓ Method of moments (wires)
- Codes:
  - ✓ PRAC: Physical optics (reflectors)
  - ✓ PCARRPAT and ARRAYS: Principle of pattern multiplication and exact formulation (arrays)
  - ✓ GRADMAX and WIRE: Method of Moments - Integral equation/Green's function approach (wires)
  - ✓ ENSEMBLE: Method of moments - Integral equation/Green's function approach for <u>dielectrics</u> (microstrips)
  - ✓ HFSS: Finite Element Method – Differential equation approach for <u>dielectrics</u> (microstrips)

➢ DESIGN / SYNTHESIS OF ANTENNAS

"All analysis techniques and codes listed previously can also be employed for the synthesis process, either to validate the final result or manually in an iterative mode"

Listed below are closed-form and numerical-based synthesis algorithms (i.e., the desired performance is used as the input and the output is the required geometry):

- Analytical/Empirical Techniques:
  - ✓ Efficiency equation (all)
  - ✓ Cozzen's technique (horns) – MT (horns)
  - ✓ Reflector synthesis technique – MT (reflectors)
  - ✓ Yagi antennas (wires)
  - ✓ Log-periodic antennas (wires)
- Numerical/Optimization Techniques (theory and/or implementation):
  - ✓ Gradient method – MT (all; shaped reflectors, shaped and conventional Yagis and arrays of wires)
  - ✓ Neural Networks – MT (all; reflectors and wires)
  - ✓ Genetic Algorithms – MT (all; reflectors and wires)
- Codes:
  - ✓ PRAC with the reflector synthesis technique: Physical optics (reflectors)
  - ✓ GRADMAX: Method of Moments - Integral equation/Green's function approach with the gradient method as the optimization algorithm (shaped and conventional Yagis and arrays of wires)