

**EE 483/L 583/L Antennas for Wireless Communications, 3-1 (4 credit hours)**  
**South Dakota School of Mines & Technology**  
**Spring 2020**

**Lecture Room & Time:** MWF 11-11:50 am in EP 255

**Instructor:** Dr. Thomas Montoya, EEP 310, 394-1219, [tmontoya@ieee.org](mailto:tmontoya@ieee.org) or [tmontoya@sdsmt.edu](mailto:tmontoya@sdsmt.edu).

**Office Hours:** 8-9 am & 3-4 pm MWF, or when available (open door policy).

**WWW:** See link from <http://montoya.sdsmt.edu>. The course web page will be heavily utilized for posting **assignments**, examples, solutions, ... E-mail will be utilized to notify students of course-related information and events (**check daily**). Your [first.last@Mines.sdsmt.edu](mailto:first.last@Mines.sdsmt.edu) address will be used.

**Catalog Description:** Introduction to antenna design, measurement, and theory for wireless communications including fundamental antenna concepts and parameters (directivity, gain, patterns, etc.), matching techniques, and signal propagation. Theory and design of linear, loop, and patch antennas, antenna arrays, and other commonly used antennas. Students will design, model, build, and test antenna(s). Students enrolled in EE 583/583L will be held to a higher standard than those enrolled in EE 483/483L.

**EE 483/L 583/L Prerequisites:** EE 382/382L Applied Electromagnetics.

**Text:** *Antenna Theory: Analysis and Design* (Fourth Edition), Balanis, Wiley, 2016, ISBN 1-118-64206-6.

**Course Policies:**

- Course instruction will be delivered in lectures. Attendance is required. Notify instructor in advance (when possible) if you will be absent from class.
- Except when otherwise specified, all coursework is to be individually completed. See the *Community Standards* and *Cheating Academic Integrity Policy* links under the *Policies/Definitions* link of the catalog (<http://ecatalog.sdsmt.edu/>). Under *Community Standards*, links to the *Student Code of Conduct* and *Academic Misconduct Policy* can be found.
- Students are encouraged to discuss homework with classmates in general terms. However, copying, plagiarism ... is not acceptable and will be penalized (e.g., grade of zero).
- Homework (HW) is due at the beginning of class on the specified days (up to 20% penalty for being late w/out doctor's note, etc.). If you know that you will be missing a class, it may be turned in early. HW will **not** be accepted or graded after solutions are posted on the course web page.
- Bring notes, text, and calculator (capable of complex number & linear algebra operations) to every class. Most quizzes will be unannounced and require a calculator (no smartphones). Occasionally a quiz may be open book/notes (no borrowing, no computers).
- Missed quizzes will **not** be made up. If you know that you will be missing a class for a school-related activity (athletic travel, conference, etc.), you may stop by the day before and ask to take a quiz early (if available). Make-ups for exams only allowed for school-sponsored events, documented illness, ...
- If 2/3 of quizzes and 2/3 of HW are completed at a **passing** level, the lowest HW grade and lowest two quiz grades will be dropped (no questions asked). If not, **all** quizzes and HW will count (no drops). The drops are meant to cover any absences, including those due to illness, interviews, trips ...
- Students enrolled in EE 583/583L will face additional expectations, e.g., additional/harder HW problems, more extensive lab requirements, etc.
- To aid grading, homework shall meet the following specifications (see example at course web page):
  - a) Use the front side (i.e., single-sided) of 8.5" × 11" engineering graph paper or plain white paper (NO pages torn from spiral notebooks) for assignments.
  - b) At the top of **each** page put date, course number, your name, and page numbering (i.e., page  $x$  of  $y$  or  $x/y$  formats in upper right-hand corner). Ensure problems & pages are in order.

- c) All work exceeding one page should be stapled - no paper clips, folded corners, or folders.
- d) Write-out problem numbers & descriptions, copy/draw figures, and **show all** work so it can be understood without the text. No work (i.e., “magic” answer) → no credit.
- e) Reference equations derived in the text (e.g., equation number and/or page number). Fundamental equations (e.g., Maxwell’s equations, Ohm’s Law ...) are excluded from this requirement.
- f) Use notation, especially for vectors, and conventional engineering units & prefixes (i.e., MKS) as given in class and text. For example,  $\vec{E} = \hat{a}_\theta 10 \text{ kV/m}$  and 100 MHz **NOT**  $\vec{E} = \hat{\theta} 100 \text{ V/cm}$  and  $10^5 \text{ kHz}$ . Answers with incorrect notation and without applicable units are incomplete/incorrect.
- g) Writing/figures/graphs must be legible and large enough to read → illegible = no credit.
- h) Answers should be boxed/double underlined, in **decimal** format if a number (no fractions) with variables, values & units (if any) included. Also, use lead zeros for fractional answers. For example, “ $V_x = 0.4 \text{ V}$ ” **not** “ $V_x = .4$ ” or “ $V_x = 2/5 \text{ V}$ ”. Typically, 4-6 significant digits are used.
- i) Work problems sequentially in a **single** vertical column with subparts clearly labeled, e.g., a), b) ... Leave a space (e.g., 1/2”) between consecutive parts of a problem, and draw a line across the page at the end of each problem if there is more than one.
- j) **No** more than **two** problems on any single page.

### **Guideline for laboratories:**

- We will not have weekly scheduled laboratories. Laboratory/project assignments and completion dates will be announced as they come up during the semester. Most work will take place in EEP 127.
- Laboratory/project work should be in ink in a bound logbook unless otherwise specified.
- On cover, put a typed/word-processed label with: **EE 483L or 583L, Antennas for Wireless Communications, Spring 2020, and your name**. Optional- it is a good idea to put contact information on the cover or inside the front cover in case you misplace your logbook.
- Make a **Table of Contents** on the first page- include lab number (if applicable), description/title, date(s), and page(s) (both start and finish).
- Mistakes should be neatly crossed out (i.e., don’t scribble out, white out, etc.)
- Use only the front side of pages (hard to read otherwise).
- Every page in logbook should be numbered (prefer top right hand corner) whether used or not.
- Goal- another person should be able to duplicate the lab/work without outside references. For example, partner(s), equipment list (include description, brand & model #s), dates, block/circuit diagrams of test set-up ... should be included, as applicable. Comments, conclusions, summaries, ... are always valuable in meeting this goal, and, therefore, expected
- Answers/measurements/solutions should be boxed or double underlined, with the variables, values and units (if any), included. Answers without applicable units are incomplete.
- Leave a space (e.g., 1/2”) between consecutive parts of a lab.
- Writing/figures/graphs must be legible (e.g., size and neatness)→ unreadable = no credit.
- Diagrams/figures/plots/graphs should be of a good size (e.g., 3” × 5”), and may contain colors. As applicable, they should be captioned (at bottom), labeled (i.e., names / units on axes), scaled (i.e., numbers on axes), and clearly drawn. Tables should also be captioned (at top).
- Diagrams/figures/plots/graphs/tables may be done using computer software and affixed (pasted or taped) on pages in the logbook. The bottom should be oriented toward the bottom or right hand side of the page. These items should be formatted fit logbook pages without needing to be folded over (limited exceptions for large and/or complicated drawings/tables).
- Do **not** insert loose material or multiple pages in logbook, e.g., multiple pages stapled together.

**Course Goals:** The objective of this course is to introduce students to the basic concepts of antenna design, measurement, and theory. Fundamental antenna concepts and parameters (directivity, gain,

patterns, etc.), the theory and design of some common antennas (e.g., linear, loop, patch, linear arrays, Yagi-Uda), matching techniques, and signal propagation are introduced. By the end of the course, the students should be able to design, model, build, and test simple antennas.

**Course Learning Objectives:**

Upon completion of this course, students should demonstrate the ability to:

- A. Apply, calculate, or produce fundamental parameters or quantities of antennas (e.g., radiation patterns, radiation intensity, directivity, ...).
- B. Apply or use the Friis Transmission Equation and Radar Range Equation.
- C. Use EM software to design and model antennas.
- D. Know how to calculate the magnetic and electric vector potentials given the electric or magnetic current densities, respectively, as well as electric and magnetic fields for simple problems.
- E. Calculate the total and far-field electric and magnetic fields from the magnetic and/or electric vector potentials.
- F. Analyze and calculate antenna quantities and parameters for commonly used antennas (e.g., linear dipole, loop, microstrip, and Yagi-Uda).
- G. Design, match, and test commonly used antennas (e.g., linear dipole, loop, microstrip, and Yagi-Uda).
- H. Design and analyze linear antenna arrays with uniform spacing and amplitude.
- I. Measure important antenna parameters (e.g., impedance, reflection coefficient, VSWR, radiation pattern, ...) using modern test equipment (e.g., vector network analyzer).

<b><u>Evaluation:</u></b>	Two Hour Exams @ 12.5%/each .....	25%
	Quizzes .....	15%
	Homework .....	15%
	Labs/Projects .....	25%
	Final Exam (required) .....	20%
	<b>Total .....</b>	<b><u>100%</u></b>

**Grading scale:** 100 > A > 90, 89 > B > 80, 79 > C > 70, 69 > D > 60, F < 60.

**ADA:** SD Mines strives to ensure that physical resources, as well as information and communication technologies, are accessible to users in order to provide equal access to all. If you encounter any accessibility issues, you are encouraged to immediately contact the instructor of the course and the Title IX and Disability Coordinator, Ms. Amanda Lopez at [disabilityservices@sdsmt.edu](mailto:disabilityservices@sdsmt.edu) or 394-2533. Students with special needs or requiring special accommodations should also contact the instructor and the Title IX and Disability Coordinator. More information can be found at <https://www.sdsmt.edu/Campus-Life/Student-Support/Disability-Services/>

**Freedom in learning:** Under Board of Regents and University policy student academic performance may be evaluated solely on an academic basis, not on opinions or conduct in matters unrelated to academic standards. Students should be free to take reasoned exception to the data or views offered in any course of study and to reserve judgment about matters of opinion, but they are responsible for learning the content of any course of study for which they are enrolled. Students who believe that an academic evaluation reflects prejudiced or capricious consideration of student opinions or conduct unrelated to academic standards should contact the Provost and Vice President for Academic Affairs to initiate a review of the evaluation.

**Electronic Devices Policy:** Please silence/turn off your cell phone before class starts. No text messaging in class. No headphones. You may use a laptop/tablet in this class for purposes of note taking (NOT allowed for exams or quizzes). No other use of any other electronic/computer media, **other than calculators**, is allowed during class time.

**Software:** As part of the coursework, we will use several programs including Numerical Electromagnetics Code (NEC), MATLAB, ... to simulate, analyze, and present antennas, related data, and/or measurements.

### Tentative Course Schedule/Topics

Class	Date(s)	Topics	Reading/ Text
1	1/13	<b>Antennas-</b> Intro, types of antennas, radiation mechanism, methods of analysis, history	1.1-1.3
2	1/15		1.3-1.5
3	1/17	<b>Fundamental Parameters of Antennas-</b> Intro; radiation pattern(s)	2.1-2.2
<b>1/20</b>		<b>Holiday</b>	
4	1/22	power density, intensity; directivity; numerical techniques; gain; antenna efficiency; beamwidth; directivity; beam efficiency; bandwidth; polarization; input impedance; antenna radiation efficiency, effective length, & effective area; maximum directivity & effective area; Friis transmission & radar range equations	2.3-2.5
5	1/24		2.5-2.6
6	1/27		2.7-2.11
7	1/29		2.12-2.13
8	1/31		2.14-2.15
9	2/3		2.15-2.18
10	2/5	<b>Radiation Integrals &amp; Aux. Potential Functions-</b> Intro, vector potentials for electric & magnetic currents, far-field radiation	3.1-3.4
11	2/7		3.5-3.6
12	2/10	<b>Numerical Electromagnetics Code (NEC)-</b> Intro, background, and usage	Notes
13	2/12		
14	2/14	<b>Exam #1 (Chapters 1-3)</b>	
<b>2/17</b>		<b>Holiday</b>	
15	2/19	<b>Linear Wire Antennas-</b> Intro; infinitesimal & small dipoles, region separation, finite length dipole, half-wavelength dipole	4.1-4.2
16	2/21		4.2-4.4
17	2/24		4.4-4.5
18	2/26		4.5-4.6
19	2/28	<b>Log-periodic dipole arrays (LPDA) -</b> Intro, background, design	Notes, 11.4
20	3/2		
21	3/4	<b>Yagi-Uda arrays-</b> Intro, background, design	Notes, 10.3.3
22	3/6		
<b>3/9 - 3/13</b>		<b>Spring Break</b>	
23	3/16	More Yagi-Uda	
24	3/18	<b>Folded Dipoles</b>	Notes, 9.5
25	3/20	<b>Matching Techniques-</b> T-Match, modified T-Match, Gamma match, Modified Gamma match, Omega match	Notes, 9.7.3-9.7.5
26	3/23		
27	3/25		
28	3/27	<b>Microstrip Antennas-</b> Intro; rectangular patch, quality factor, bandwidth, & efficiency; input impedance	14.1
29	3/30		14.2, notes
30	4/1		14.4-14.5
31	4/3	<b>Exam #2 (exam 1 to matching techniques; parts of chapters 4, 9, 10, 11 &amp; notes)</b>	
32	4/6	<b>Loop Antennas-</b> Intro, small circular loop, circular loop w/ constant and nonuniform current	5.1-5.2
33	4/8		5.3-5.4
<b>4/10</b>		<b>Holiday</b>	
34	4/13	<b>Helical Antennas-</b> Intro, normal mode, axial mode, design, matching	Notes, 10.3.1
35	4/15		
36	4/17		
37	4/20	<b>Arrays: Linear, ...-</b> Introduction, two-element arrays, N-element linear array: Uniform Amplitude & Spacing, N-element linear array: Directivity, & Uniform spacing	6.1, notes
38	4/22		6.2-6.3
39	4/24		6.3-6.4
40	4/27		6.4
41	4/29		6.5,6.7
42	5/1		<b>Review/Catch-up</b>
<b>EE 483/583 Final Exam- 1-2:50pm, Wednesday, 5/6/2020, EP 255</b>			