South Dakota School of Mines & Technology
Antennas for Wireless Communications, Spring, 2023
EE 483/583-M01 & EE 483L/583L-M51 (3-1) 4 credits

Instructor Information

Instructor's Name- Thomas Montoya

Instructor's Contact Information- (605) 394-1219, Thomas.Montoya@sdsmt.edu, EEP 314

Instructor Office Hours- 8:15-9 am & 3-4 pm MWF, or when available (open door policy).

As I do not always notice voicemails in a timely fashion, e-mails or in person are the preferred contact methods. Unless I am traveling or it arrives late at night, I typically respond to e-mails the same day.

Course Information

Course Start/End Dates- 1/9/2023 to 5/5/2023

Course Meeting Times and Location- MWF from 11-11:50 am in EEP 255

Course Delivery Method- The course will be delivered in-person for lectures, quizzes, and exams. The syllabus and a link to my webpage http://montoya.sdsmt.edu will be posted on D2L. The course web page will be used for posting assignments, examples, solutions, etcetera. E-mail will be used to notify students of course-related information and events (**check daily**). Your first.last@Mines.sdsmt.edu address will be used for these e-mails.

Course 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.

Course Prerequisites- EE 382 Applied Electromagnetics

Student Learning Outcomes

Student Outcomes (SOs)

Student Outcomes are defined in ABET's accreditation standards for engineering programs:

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
2. An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
3. An ability to communicate effectively with a range of audiences
4. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

5. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies

Course Learning Outcomes (CLOs)

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, …). (SOs 1, 2)
B. Apply or use the Friis Transmission Equation and Radar Range Equation. (SOs 1, 2)
C. Use EM software to design and model antennas. (SOs 1, 2, & 7)
D. Know how to calculate magnetic and electric vector potentials given electric or magnetic current densities, respectively, and calculate the total and far-field electric and magnetic fields from the magnetic and/or electric vector potentials. (SO 1)
E. Analyze and calculate antenna quantities and parameters for commonly used antennas (e.g., linear dipole, loop, microstrip, and Yagi-Uda). (SOs 1, 2)
F. Design, match, and test commonly used antennas (e.g., linear dipole, loop, microstrip, and Yagi-Uda). (SOs 1, 2, 6, & 7)
G. Design and analyze linear antenna arrays with uniform spacing and amplitude. (SOs 1, 2, & 7)
H. Measure important antenna parameters (e.g., impedance, reflection coefficient, VSWR, radiation pattern, …) using modern test equipment (e.g., vector network analyzer). (SOs 1, 2, 6, & 7)

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 Topics- See tentative course schedule.

Course Materials

Required Textbook(s) and Materials

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

Technology Equipment Needed for the Course

The course requires use of a computer and scientific calculator (capable complex number operations). Software needed/used in the course will include a pdf reader (Acrobat), D2L, MATLAB, NEC-2 (provided), and Microsoft Office.

Technology Skills Needed for the Course

Ability to navigate D2L and internet, upload/download files (e.g., text and pdf files), using MS Office programs, communicating via email, and, **depending on COVID,** connecting audio/video and using tools such as Zoom. Matlab and/or MathCad will be used for some assignments.

Course Grading

Coursework

- Course instruction will be delivered in lectures.
- Instructor course notes are posted to course webpage, a 3-ring binder is suggested (2.5" or above).
- Students enrolled in EE 583/583L will face additional expectations, e.g., additional/harder HW problems, more extensive lab requirements, etcetera.
- Bring notes, text, and calculator to every class. Most quizzes will be unannounced and require a calculator (no smartphones). Some quizzes may be open book/notes (no borrowing, no computers).
- To facilitate grading, homework shall meet the following specifications (example on course web page):
- To aid grading, homework shall meet the following specifications (example on course web page):
  (a) Use the front (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) Writing/figures/graphs must be legible and large enough to read → illegible = no credit.
  (f) 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.
  (g) Use notation, especially for vectors, and conventional engineering units & prefixes (i.e., MKS) as given in class and text. For example, $\overline{E} = \hat{a}_\theta\, 10$ kV/m and 100 MHz ***NOT*** $\overline{E} = \hat{\theta}\, 100$ V/cm and 10^5 kHz. Answers with incorrect notation and/or without applicable units are incomplete/incorrect.
  (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, "$V_x = 0.4$ V" ***not*** "$V_x = .4$" or "$V_x = 2/5$ 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 space (~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.
- Guidelines for laboratories and logbooks:
  (a) We will not have weekly scheduled laboratories. Laboratory/project assignments and completion dates will be announced as they come up during the semester. Most lab work will be in EEP 127.
  (b) Laboratory/project work should be in ink in a bound logbook unless otherwise specified.
  (c) On cover, put a typed/word-processed label with: **EE 483L or 583L**, **Antennas for Wireless Communications**, **Spring 2023**, 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.
  (d) 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).
  (e) Mistakes should be neatly crossed out, i.e., do not scribble out, white out, etcetera.
  (f) Use only the front side of pages (hard to read otherwise).
  (g) Every page in logbook should be numbered (prefer top right-hand corner) whether used or not.

(h) 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

(i) Answers/measurements/solutions should be boxed or double underlined, with the variables, values, and units (if any), included. Answers without applicable units are incomplete.

(j) Leave space (~1/2") between consecutive parts of a lab.

(k) Writing/figures/graphs must be legible (e.g., size and neatness) → unreadable = no credit.

(l) Diagrams/figures/plots/graphs should be of a good size (e.g., 3" × 5" minimum), 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).

(m) 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).

(n) Do **not** insert loose material or multiple pages in logbook, e.g., multiple pages stapled together.

Attendance Policy

Attendance is required. Notify instructor in advance (when possible) if you will be absent from class.

Late/Make-up Assignment Policy

- 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, etcetera). 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.
- 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, etcetera), 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…

Academic Integrity

South Dakota Mines is committed to academic honesty and scholarly integrity. The South Dakota Board of Regents Policy 2:33 provides a comprehensive definition of "Academic Dishonesty", which include cheating and plagiarism. All Instructors at South Dakota Mines are required to report allegations of academic misconduct to the Student Conduct Officer. The South Dakota Board of Regents Policy 3:4 provides detailed information regarding key definitions, policy information, prohibited conduct, and the Student Conduct process adhered to at South Dakota Mines. Any student suspected of violating academic integrity standards will be reported in accordance with the process outlined on the South Dakota Mines website.

- 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).

Grading and Assessment

Student learning is assessed by a combination of laboratories/projects, exams, and quizzes as well as homework.

Description	Percent
Two (2) Hourly exams @ 12.5% each	25%
Quizzes	15%
Homework	15%
Labs/Projects	25%
Final exam	20%
Total	**100%**

Grading Scale- 100 > A > 90, 89 > B > 80, 79 > C > 70, 69 > D > 60, F < 60.

ADA Statement

South Dakota Mines strives to ensure that physical resources, as well as information and communication technologies, are reasonably 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 or 605.394.2533, who will work to resolve the issue as quickly as possible.

Freedom in Learning Statement

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 judgement 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 at provost@sdsmt.edu to initiate a review of the evaluation.

Electronic Devices Policy

Please silence/turn off your cell phone before class starts. No text messaging or headphones in class. You may use a laptop/tablet in 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.

Topics/Course Schedule: Selected topics from Chapters 1-6, 9, 10, 11, and 14, supplemented by notes. See attached tentative schedule.

Class | Date	Tentative Topics/Activities	Reading/Text
1 | 1/9/23 2 | 1/11/23	**Antennas-** Intro, types of antennas, radiation mechanism, methods of analysis, history	• 1.1 - 1.3 • 1.3 - 1.5
3 | 1/13/23 **1/16/23** 4 | 1/18/23 5 | 1/20/23 6 | 1/23/23 7 | 1/25/23 8 | 1/27/23	**Fundamental Parameters of Antennas-** Intro; radiation pattern(s); 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	• 2.1 - 2.4 **Holiday** • 2.5 - 2.6 • 2.7 - 2.12 • 2.12 - 2.13 • 2.14 - 2.16 • 2.17 - 2.18
9 | 1/30/23 10 | 2/1/23	**Radiation Integrals & Aux. Potential Functions-** Intro, vector potentials for electric & magnetic currents, far-field radiation	• 3.1 - 3.4 • 3.4 - 3.6
11 | 2/3/23 12 | 2/6/23 13 | 2/8/23	**Numerical Electromagnetics Code (NEC)-** Introduction, background, and usage	• Notes • Notes • Notes
14 | 2/10/23	**Exam #1**- Covers material from Chapters 1, 2, and 3	
15 | 2/13/23 16 | 2/15/23 17 | 2/17/23 **2/20/23** 18 | 2/22/23	**Linear Wire Antennas-** Introduction; infinitesimal & small dipoles, region separation, finite length dipole, half-wavelength dipole	• 4.1 - 4.2 • 4.3 - 4.4 • 4.4 - 4.5 **Holiday** • 4.5 - 4.6
19 | 2/24/23 20 | 2/27/23	**Log-periodic dipole arrays (LPDA)-** Introduction, background, design	Notes, 11.4
21 | 3/1/23 22 | 3/3/23 23 | 3/6/23	**Yagi-Uda arrays-** Introduction, background, design	Notes, 10.3.3
24 | 3/8/23	**Folded Dipoles-** Introduction, background, design	Notes, 9.6
25 | 3/10/23 **3/13 - 3/17/23** 26 | 3/20/23 27 | 3/22/23	**Matching Techniques-** T-Match, modified T-Match, Gamma match, Modified Gamma match, Omega match, other matches/baluns (time allowing)	• Notes **Spring Break** • Notes • Notes, 9.8
28 | 3/24/23 29 | 3/27/23 30 | 3/29/23	**Microstrip Antennas-** Introduction; rectangular patch, quality factor, bandwidth, & efficiency; input impedance	• 14.1 • 14.2, notes • 14.4 - 14.5
31 | 3/31/23	**Exam #2**- Covers material from NEC to matching techniques	
32 | 4/3/23 33 | 4/5/23	**Loop Antennas-** Introduction, small circular loop, circular loop with constant and nonuniform current	• 5.1 - 5.2 • 5.3 - 5.4
4/7/23		**Holiday**
34 | 4/10/23 35 | 4/12/23 36 | 4/14/23	**Helical Antennas-** Introduction, normal mode, axial mode, design, matching	• 10.3.1, Notes • Notes • Notes
37 | 4/17/23 38 | 4/19/23 39 | 4/21/23 40 | 4/24/23 41 | 4/26/23	**Arrays: Linear, ... -** Introduction, two-element arrays, *N*-element linear array: Uniform Amplitude & Spacing, *N*-element linear array: Directivity, & Uniform spacing	• 6.1, Notes • 6.2 - 6.3 • 6.3 - 6.4 • 6.4 • 6.5, 6.7
42 | 4/28/23	**Review/Catch-up**	
	Final Exam- Wednesday, May 3, 2023 from 1 - 2:50 pm, EEP 255	