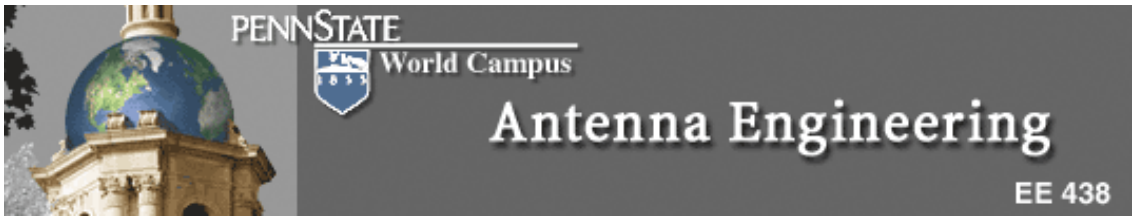



# Study Guide

Table of Contents

## *Introduction*

EE 438 Antenna Engineering is an electrical engineering technical elective course intended for students with a specialization in electromagnetics. This course presents antenna engineering concepts including in-depth studies of various antennas and arrays and computer modeling of antennas for analysis and design.

This study guide is designed to direct the instructional activities within this course. You will find all the resources needed to successfully complete this course. This study guide provides a schedule of readings and assignments and guidance on completing the course project and exams.

The course was authored by Anthony Ferraro and Douglas Werner and is based on their depth of experience and knowledge of the field. Click on each of their names to link to their Vitae.

**Dr. Anthony Ferraro**
http://www.ee.psu.edu/faculty/ferraro/ferraro1.html

**Dr. Douglas Werner**
http://www.ee.psu.edu/faculty/werner/werner1.html

Click on the image below to view a welcome message from Dr. Ferraro.

## *Course Materials*

The materials that comprise this course are:

- Study Guide
- Course Notebook
- Course CD-ROM
- Text book(s)
- EZNEC 3.0 Antenna Modeling Program

Included on the CD-ROM you will find

- The Course Launcher
- Lessons, Assignments, and Course Project
- QuickTime 6.0
- Adobe Acrobat 5.0
- EZNEC experiment file "circular_array.ez"
- Exam Proctor Form

## *Support and Communication*

You must have an email address to complete this course in order to communicate with the instructor. You may use the PSU access email account that was provided upon registering for this course or you may use a non-PSU email account. If you choose to use a non-PSU email, please send a message to the instructor indicating your preferred email address.

Questions regarding technical support and course materials should be addressed to:

**Course Materials Support**

| | |
|---|---|
| Surface mail | Thomas Iwinski<br>Office of Continuing and Distance Education<br>College of Engineering<br>The Pennsylvania State University<br>410 Rider Building II<br>227 W. Beaver Avenue<br>University Park, 16801-4819 |
| Phone | (814) 865-7643 |
| Fax | (814) 865-3969 |
| Email | tiwinski@engr.psu.edu |

Questions regarding lesson content and instruction should be addressed to the course instructor. At the beginning of the course the instructor will identify office hours during which he will be available to answer questions by telephone. Outside of those office hours, you may contact the instructor by email or fax. Questions submitted via email or fax will generally be responded to within 24 hour, excluding holidays and identified absences, i.e., business travel or vacations.

**Instructor Contact**


| | |
|---|---|
| Surface mail | Dr. Anthony Ferraro<br>Office of Continuing and Distance Education<br>College of Engineering<br>The Pennsylvania State University<br>410 Rider Building II<br>227 W. Beaver Avenue<br>University Park, 16801-4819 |
| Phone | (814) 865-7643 |
| Fax | (814) 865-3969 |
| Email | ajf4@psu.edu |


## *Prerequisites*

This course requires an understanding of basic electromagnetics and Maxwell's equations as a prerequisite.

## *Course Overview*

This course is designed for you to proceed through the material in a linear sequential order. The later lessons in this course depend upon the competence and understanding of earlier lessons.

The primary method of study in this course is reading the lesson text of the Course Notebook. All lessons in the Course Notebook are included on the Course CD-ROM as Adobe Acrobat PDF files. The printed versions of the lessons offer the best visual resolution of the lesson figures and equations. You may complete this course studying the lessons from a computer screen, but you may find the figures and equations will appear slightly fuzzy or blurred. This is due to the limitations or computer displays being less than 100 dots-per-inch (dpi), where-as the printed versions of the lessons are at 600 dpi resulting in significantly sharper figures and detail in the equations. However, it is possible to view the figures and equations in greater detail from your computer display. This is accomplished by enlarging the image of the PDF file using the "magnify" tool from the Acrobat menu.

## Modules and Lessons

The course is segmented into four modules and each module contains multiple lessons. The modules and lessons are not equivalent in size or instructional intensity, but are instead segmented in to discrete topics.

Module 1: Antenna Fundamentals
- Lesson 1: Common Types of Antennas
- Lesson 2: Antenna Fundamentals and Definitions
- Lesson 3: Directivity
- Lesson 4: Antenna Gain and Efficiency
- Lesson 5: Antennas in Communications Links

Module 2: Wire Antennas
- Lesson 1: Radiation Integrals and Auxiliary Potential Functions
- Lesson 2: Solutions of the Inhomogeneous Vector Potential Wave Equation
- Lesson 3: Linear Wire Antennas – The Ideal Dipole
- Lesson 4: Electrically Short or Small Dipoles
- Lesson 5: The Half-Wave Dipole
- Lesson 6: The Dipole of Arbitrary Length
- Lesson 7: Antennas on or Near PEC Ground Planes

Module 3: Loop Antennas and Modeling Design Project
- Lesson 1: Loop Antennas
- Lesson 2: Large Loop Antennas
- Lesson 3: Scale Modeling
- Lesson 4: EZNEC Tutorial
- Lesson 5: Design of a AM/FM Mobile Telephone Tri-band Antenna

Module 4: Antenna Arrays and Impedance
- Lesson 1: Antenna Arrays
- Lesson 2: A Graphical Method for Developing the Radiation Pattern for an N Element Linear Array with Uniform Amplitude and Spacing
- Lesson 3: Pattern Multiplication Theorem with Examples
- Lesson 4: Half-Power Beam Width (HPBW) for a Uniform Linear Array of Isotropic Elements
- Lesson 5: Directivity of an N-Element Linear Array
- Lesson 6: Even Element Linear Array with Uniform Spacing and Nonuniform Excitation
- Lesson 7: Directivity for Binomial Arrays
- Lesson 8: Planar Arrays
- Lesson 9: Mutual Impedance and Driving Point Impedance of Antenna Arrays
- Lesson 10: Yagi-Uda Antennas

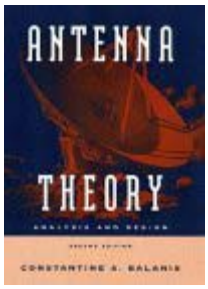
The course schedule is organized in the table below indicating how to proceed through the course material. Several smaller lessons may be completed within a week, while other larger lessons will require a longer period of time to complete. Assignments are scattered throughout the course as well as a course project, which will begin at the end of Module 3. The course schedule also includes a list of textbook readings to complete. In this schedule the modules and lessons are identified only by their sequential number, i.e., M1L1.

**Course Schedule**

| Week | Module, Lesson | Textbook Reading | Assignment |
|---|---|---|---|
| 1 | M1L1 | Ch.1, Antennas; All sections | |
| | M1L2 | Ch. 2, Fundamental Parameters of Antennas; Sections 2.1, 2.2, and 2.3 | #1 |
| | M1L3 | Ch. 2; Sections 2.4, 2.5, 2.6 and 2.7 | #2 |
| 2 | M1L4 | Ch. 2; Sections 2.8, 2.11, 2.12, 2.13 and 2.14 | #3 |
| 3 | M1L5 | Ch. 2; Sections 2.15, 2.16, 2.17 and 2.18 | |
| | M2L1 | Ch. 3, Radiated Integrals and Auxiliary Potential Functions; Sections 3.1, 3.2 and 3.3 | |
| | M2L2 | Ch. 3; Sections 3.4, 3.5 and 3.6 | #4 |
| 4 | M2L3 | Ch. 4; Linear Wire Antennas, Sections 4.1 and 4.2 | |
| 5 | M2L4 | Ch. 4; Sections 4.3 and 4.4 | #5 |
| | M2L5 | Ch. 4; Sections 4.5 and 4.6 | |
| 6 | M2L6 | Ch. 4; Continue with sections 4.5 and 4.6 | #6 and #7 |
| 7 | M2L7 | Ch. 4; Sections 4.7 and 4.8 | #8 |
| 8 | Midterm Exam | | |
| 9 | M3L1 | Ch. 5, LOOP Antennas; All sections | #9 and #10 |
| | M3L2 | Continue reading Ch.5, Large Loop Antennas | |
| 10 | M3L3 | | #11 |
| | M3L4 | EZNEC Modeling Basics and Tutorial; refer to CD-ROM Lecture | |
| | M3L5 | | |
| | Course Project | | |
| 11 | M4L1 | Ch. 6, Arrays: Linear, Planar and Circular; Sections 6.1, 6.2, 6.3 and 6.4 | #12 |
| 12 | M4L2 | Ch. 6; Sections 6.6 and 6.7 | |
| | M4L3 | | #13 |
| 13 | M4L4 | Ch. 6; Review section 6.3 | |
| | M4L5 | Ch. 6; Section 6.4 | |
| | M4L6 | Ch. 6; Section 6.8 | |
| 14 | M4L7 | Ch. 6; Continue with section 6.8 | #14 and #15 |
| | M4L8 | Ch. 6; Section 6.10 | |
| 15 | M4L9 | Ch. 8, Self and Mutual Impedances; Sections 8.5, 8.6 and 8.7 | #16 |
| 16 | M4L10 | Ch. 10, Yagi-Uda Antennas; Section 10.3.3 | |
| 17 | Final Exam | | |

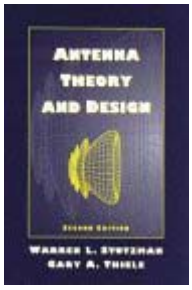
## Textbook

This course has one required text and a second recommended text. The following text by Constantine A. Balanis is required for the readings in this course:




*Antenna Theory, Analysis and Design*, Second edition, by Constantine A. Balanis. John Willey and Son, Inc.

An additional text by Warren L. Stutzman and Gary A. Thiele is recommended, but not a requirement.

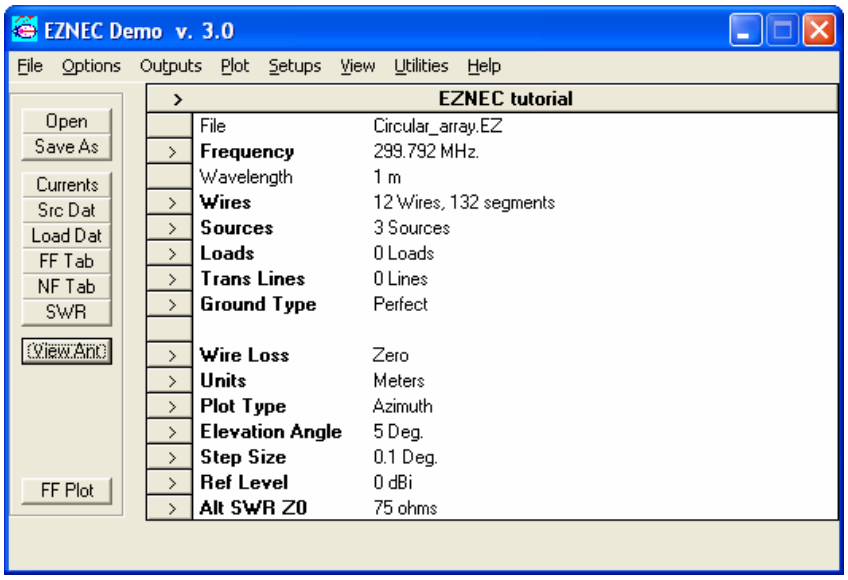



*Antenna Theory and Design, 2nd Edition,* by Warren L. Stutzman, Gary A. Thiele. John Willey and Son, Inc.

The readings are assigned to follow the lessons on the course CD-ROM to further support each lesson and/or assignments. These textbooks are excellent resources that will be invaluable to you in your engineering career.

## EZNEC 3.0 Antenna Modeling Program

You need to install the supplied EZNEC 3.0 Antenna Modeling Program. The EZNEC application will be used in Module 4 for modeling and analyzing antennas. It is recommended that you complete the EZNEC tutorial prior to Module 4 so that you are familiar with the features of the applications. Below is a screen shot of the main EZNEC screen.




## Assignments, Course Project, and Exams

Assignments are embedded within the lessons and often require the direct application of lesson content to be completed. Completed assignments may be handwritten or typed then submitted to the instructor for grading. You may submit assignments via email attachment (preferred), fax, or surface mail to the address provided in the Support and Communication Section of this study guide. If you choose to fax your assignment, you need to send a clear original copy in the mail. If you type the assignments, they must be submitted as email attachments in either MS Word or WordPerfect files. All assignments are due to the instructor within one week of the date assigned.

The course project is described in detail in Module 3, Lesson 5 during the tenth week of the course. This project is ideally completed by small groups, but may be completed individually. Based on student ability and general performance of the class, the instructor may assign small groups. The course project must be submitted to the instructor prior to the Final Exam.

The course has a mid-term and a final examination; both are open book and open notes. The mid-term exam covers the first eleven lessons up to Module 2, Lesson 6. The final exam is cumulative and covers all lessons, but has emphasis on material covered since the mid-term. Each examination must be proctored. You will need to identify a proctor and contact the College of Engineering Continuing and Distance Education office to

arrange for exam materials and instructions to be sent to the proctor. Proctor must be trustworthy and responsible, such as a job supervisor or a clergy member. A proctor request form must be completed and approved before exams can be administered. Family relatives are not eligible to act as proctors.

The grading scale for the course is:

| | |
|---|---|
| Mid-term Exam | 30% |
| Project | 20% |
| Final Exam | 35% |
| Homework | 15% |
| Total | 100% |

All exams, assignments, and projects will be returned to each student with their grade, shortly after they are submitted for grading

## *Getting Started*

To begin this course, you will need to have Adobe Acrobat and QuickTime installed on your PC. All lesson material is in Acrobat PDF file format. Apple QuickTime is needed to play the supporting audio and multimedia in each lesson. If you have Acrobat 5.0 or higher and QuickTime 6.0 or higher installed on your PC, simply click on the Course Launcher icon on the CD-ROM. This will open Acrobat and provide a menu of the course lessons. If you do not have Acrobat and QuickTime installed or need to update the versions currently installed, open the applications folder on the CD-ROM and install the applications needed. You will also need to install the EZNEC Antenna Modeling Software. You do not need to use the EZNEC software until the end of Module 3, but it is advised that you install the EZNEC software now, just in case a problem occurs, so it can be resolved before the software in needed for assignments in Module 3. Installing EZNEC now will also give you an opportunity to explore the software tutorials and explore the application's capabilities.

- First: Check for Acrobat and QuickTime
- Second: Install any needed software and EZNEC Antenna Modeling Software
- Third: Review the course schedule and study guide
- Fourth: Begin Lesson 1