



Contract FP6-IST 508009

*ACE*  
***Antenna Centre of Excellence***

Instrument: Network of Excellence

Thematic Priority: IST - Information Society Technologies  
Mobile and wireless systems beyond 3G

**Deliverable A3.1D3**  
**Excellence in Undergraduate Education (XUNTA)**  
**Database on existing Undergraduate Courses**

Due date of deliverable: M12  
Actual submission date: Dec. 30, 2004

Start date of project: 1/1/2004

Duration: 24 months

Organization name of lead contractor for this deliverable: KTH

Revision: 1.1

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
<b>PU</b>	Public	<b>PU</b>
<b>PP</b>	Restricted to other programme participants (including the Commission Services)	
<b>RE</b>	Restricted to a group specified by the consortium (including the Commission Services)	
<b>CO</b>	Confidential, only for members of the consortium (including the Commission Services)	

**Document Number:** FP6-IST-508009-A3.1D3  
**Workpackage:** WP 3.1-2 (XUNTA)  
**Estimated Person Months:**  
**Dissemination level (PU,PP,RE,CO):** PU  
**Nature (R, P, D, O):** R,O  
**Version:** 1.1  
**Total Number of Pages:** 58  
**File name:** ACE-DELIVERABLE-3.2D3\_v.1.1.doc  
**Editors:** Miguel Ferrando  
**Participants:** Björn Lindmark, Juan Ramón Mosig

#### Abstract

This document contains a survey of current undergraduate Antenna courses and programs in European Universities and Institutes of Technology, and some selected courses in Universities in United States.

The document is organized in forms, with information about the University and the Course.

The aims, syllabus, bibliography, web references, course material and other relevant information is included.

#### Keyword List

Antenna courses, Undergraduate, syllabus, bibliography.

#### Document Evolution

Revision	Date	Reason of change
Rev. 1.0 Draft A	20 Nov, 2004	Draft Edition
Rev. 1.0	30 Dec, 2004	First Edition
Rev. 1.1	4 Jan. 2005	Revised version with new outline

## Table of contents

1. INTRODUCTION .....	3
2. SURVEY OF CURRENT UNDERGRADUATE ANTENNA COURSES AND PROGRAMMES IN EUROPEAN UNIVERSITIES.....	3
3. CONCLUSIONS AND RECOMENDATIONS .....	4
APPENDIX A: DATABASE OF EXISTING UNDERGRADUATE COURSES.....	6

## 1. Introduction

The Training and Education activity in the ACE NoE has a number of activities focused on Ph.D. students and experts in the industry including the short courses in WP 3.1-1 and web-based learning tools in WP 3.1-3. However, the area of Training and Education also concerns undergraduate students at the different universities around Europe. In our opinion, the success and world competitiveness of any European research activity depends on the existence at the European level of a coherent and well-structured undergraduate education. This is the motivation for the ACE action on *Excellence in Undergraduate Training on Antennas (XUNTA)* organized as a task in WP 3.1-2.

This deliverable includes the results of a survey of existing undergraduate courses in the antenna area. Our conclusions and recommendations follow.

## 2. Survey of current undergraduate Antenna courses and programmes in European Universities.

The complete list of contribution to this task is as follows:

Partic. Number	Participant name	Participant short name	Country
2	KATHOLIEKE UNIVERSITEIT LEUVEN	KUL	Belgium
3	DANMARKS TEKNISKE UNIVERSITET	DTU	Denmark
5	TEKNILLINEN KORKEAKOULU	HUT	Finland
11	UNIVERSITE DE MARNE LA VALLEE	UMLV	France
13	INSTITUT NATIONAL DES SCIENCES APPLIQUEES DE RENNES	IETR	France
14	TECHNISCHE UNIVERSITAET DARMSTADT	TUD	Germany
17	UNIVERSITAET KARLSRUHE (TH)	UKARL	Germany
19	UNIVERSITA DEGLI STUDI DI ROMA "LA SAPIENZA"	SAPIENZA	Italy
20	POLITECNICO DI TORINO	POLITO	Italy
21	UNIVERSITA DEGLI STUDI DELLA CALABRIA	UNICAL	Italy
22	UNIVERSITA DEGLI STUDI DI FIRENZE (3)	UNIFI	Italy

23	UNIVERSITA DEGLI STUDI DI SIENA	UNISI	Italy
26	UNIVERSITAT POLITECNICA DE CATALUNYA	UPC	Spain
27	UNIVERSIDAD POLITECNICA DE MADRID	UPM	Spain
28	UNIVERSIDAD POLITECNICA DE VALENCIA	UPV	Spain
29	CHALMERS TEKNISKA HÖGSKOLA AB	CHALMERS	Sweden
32	KUNGLIGA TEKNISKA HOEGSKOLAN	KTH	Sweden
34	LUNDS UNIVERSITET	LU	Sweden
35	ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE	EPFL	Switzerland
38	THE UNIVERSITY OF BIRMINGHAM	UNI BHAM	UK
39	UNIVERSITY OF BRISTOL	UOB	UK
40	THE UNIVERSITY OF LIVERPOOL	LIVUNI	UK

#### Additional Contributions from United States

	Michigan State University	MSU	USA
	Ohio State University (2)	OSU	USA
	University of California Los Angeles	UCLA	USA
	University of Massachusetts. Amherst	UMASS	USA
	Stanford University.	STU	USA

### 3. Conclusions and recomendations

The principal conclusions from our the study are:

- There is a big correlation between the contents and the bibliography of the courses
- The books more cited are from United States authors.
  - C.A. Balanis, *Antenna Theory*, J. Wiley & Sons., New York, 1997
  - Stutzman/Thiele, *Antenna Theory and Design*, John Wiley & Sons, 1998.
  - J.D. Kraus, *Antennas*, McGraw Hill, New York, 1991
  - J.D. Kraus *'Electromagnetics'*, McGraw-Hill, 1991.
- The European books cited (citation less frequent)
  - S. Drabowitch u.a., *Modern Antennas*, Chapman & Hall, 1998.
  - A. Cardama. L.Jofre, J.M. Rius, J. Romeu, S. Blanch, M.Ferrando, *Antenas*. 2.ed. Edicions UPC, 2002
  - Per-Simon Kildal, *Foundations of Antennas - a Unified Approach*. The book includes a CD-ROM with Mathcad electronic handbook “Antenna Design Using Mathcad”.
  - Lecture Notes: Italian, German, Spanish, Greek, English
- The minimum contents of the courses are :
  - Basic antenna parameters
  - Radiation pattern calculations
  - Impedance matching of antennas
  - Characterization of simple antennas and arrays
- More advanced courses includes:
  - Array synthesis
  - Aperture Antennas

- Reflectors
- Lenses
- Frequency independent antennas
- Antenna measurements
- There is an important lack of advanced topics
  - Numerical methods
  - High frequency methods
  - Time-domain analysis
  - Advanced Software tools
  - Wireless mobile systems
  - Ultra-broadband techniques.

Based on the above, our recommendations are:

- Promote an European Reference Antenna Book
- Increase the advanced topics in the courses
- Promote interaction between Universities and Industries

The minimum content for a sound undergraduate education in Antennas and EM radiation can be:

- Basic electromagnetic principles
- Radiation principles
- Applications of the electromagnetic theory to different types of antennas
- Analysis and design of the most common antenna configurations

And the minimum objectives can be:

- Have knowledge of the different parameters and properties used to characterize antennas.
- Be able to make theoretical calculations of fundamental antenna elements such as dipoles and aperture antennas.
- Be able to use commercially available program for antenna simulation.

The above are our preliminary recommendations. During the year 2005, we hope to extend the work with:

- A survey of short and mid term industrial needs at a European level.
- Definition of actions for introducing these conclusions in antenna courses, in the European Universities.

## **Appendix A: Database of existing undergraduate courses.**

Here follows detailed descriptions of the existing undergraduate courses found in our survey.

UNIVERSITY	Katholieke Universiteit Leuven
Faculty	Faculty of engineering
Department	
Course	Wireless and Mobile Communications
Professor	Nauwelaers Bart Van de Capelle Antoine

CREDITS	
Hours	97.5 hours
ECTS credits	

AIMS	
	This course aims at enlightening and understanding a number of wireless and mobile communication systems and to provide insight in the supporting fields of antennas and propagation.

SYLLABUS	
	<p>Starting from an overview of the most important wireless and mobile communication systems, we consecutively shed light on: the antennas, the wireless propagation channel and the systems.</p> <p>In the part on antennas the principles of operation of a number of classes of antennas is treated. A first principle is radiation induced by current carrying wires, like dipole antennas. Array antennas are constructed from a collection of identical antennas and the operation is based on interference. Aperture antennas are based on the theory of radiation through apertures or holes. This principle is applied to horn antennas, reflector antennas and microstrip antennas. Additionally the principles of antenna measurement techniques are discussed and shown in the lab. The determination of the antenna noise temperature is thoroughly explained.</p> <p>Radio propagation is the transmission of electromagnetic waves in the vicinity of the earth and in the presence of the atmosphere. We start in the frequency range at 100 MHz and find out that there is a curvature of the horizontal path of propagation due to dependence of the refractive index on the height above earth. Reflection to the earth's surface causes interference, and past the horizon or behind obstacles the field does not vanish due to diffraction. At frequencies between 3 and 30 MHz, reflection at the ionosphere is possible; at lower frequencies propagation of a surface wave guided by the earth's surface and at even lower frequencies ionosphere and earth surface make a waveguide. At frequencies above 100 MHz we meet</p>

guided waves in the atmosphere and with increasing frequency the influence of rain, snow, fog etc. becomes more and more important. Finally, channel models for macro and micro cells are studied with attention paid to slow and fast fading.

In the third part of this course, a number of practical systems are studied. We start with GSM and explore DECT (wireless telephone), UMTS (the third generation of mobile phone), TETRA (the digital telephone network for professionals and emergency services, HIPERLAN (for the communication between computers),...

Since the domain of wireless communication grows explosively, we cannot strive for completeness in this course. The stress is thus more on the overview of the complete systems and on structuring the available information. Our goal is also to bring forward the relation between the many specialities that are required for building a cellular system. An active input of the student is required.

#### BIBLIOGRAPHY

- A. Van de Capelle: 'Antennas' and 'Radio propagation' (Dutch), distributed by the lecturer
- B. Nauwelaers: copies of the transparencies, distributed by the lecturer.

#### COURSE MATERIAL

#### WEB REFERENCES

<http://www.kuleuven.ac.be/onderwijs/aanbod2004/syllabi/H0242AE.htm>

#### COURSES RELATED

H222 'Electromagnetic Waves'  
HB84 'Analog and Digital Communications and Telecommunication Networks'.

#### OTHER RELEVANT INFORMATION



<b>UNIVERSITY</b>	<b>Technical University of Denmark</b>
Faculty	Electromagnetic Systems
Department	
Course	31430 Antennas
Professor	

<b>CREDITS</b>	
Hours	
ECTS credits	

<b>AIMS</b>	
	The purpose of the course is to present various theoretical concepts and methods for analyzing antennas. In this way the participants obtain a field-theory based understanding of antennas which enables them to interpret the outcome of commercial software packages for analysis and design.

<b>SYLLABUS</b>	
	Some of the concepts and methods to be dealt with are: radiation from arbitrary current distributions, magnetic sources, induced sources, duality, equivalence principles, method of images, and field equivalence principles. Two classes of antennas are analyzed using the above-mentioned concepts and methods, namely wire- and aperture antennas. In addition, basic antenna concepts such as directivity, polarization, effective area, and reciprocity are dealt with on a theoretical basis.

<b>BIBLIOGRAPHY</b>	
	Warren L. Stutzman and Gary A. Thiele, Antenna theory and design, Wiley, 2nd edition, 1998.

<b>COURSE MATERIAL</b>	
	Lecture notes will supplement the text book.

<b>WEB REFERENCES</b>	
	<a href="http://www.emi.dtu.dk/education/master_courses/31430.html">http://www.emi.dtu.dk/education/master_courses/31430.html</a>

<b>COURSES RELATED</b>	
	To benefit as much as possible from the course, you should be very familiar with the following topics before the course starts: 1) Basic electromagnetics,

- 2) Maxwell's equations in differential form,
- 3) gradient, divergence, and curl,
- 4) basic antenna parameters,
- 5) transmission lines,
- 6) analytical and numerical calculation of surface and line integrals,
- 7) MATLAB programming.

#### OTHER RELEVANT INFORMATION

It is important to underline that the course is purely theoretical. If you are interested in learning the theory behind the analysis methods on which various commercial antenna software packages are based, and if you like to play with Maxwell's equations, this is the right course for you. On the other hand, if you want to learn more about how to design and construct antennas, and if you are not that interested in how to analyze them, you should consider whether the course 31490, Antenna Engineering, would be a more appropriate choice for you. Take a look on the exercises used last year (pdf) to determine whether this is the right course for you.

The exam is oral. At the first day of the course, a number of topics will be given. At the oral exam, one of these topics is selected randomly by the student. The student then has to give, without any preparation time, a viewgraph presentation of the selected topic. The mark will be given on basis of this presentation.

UNIVERSITY	HELSINKI UNIVERSITY OF TECHNOLOGY
Faculty	Master's School on Information and Communications Technology
Department	Communications Laboratory
Course	Foundations Of Radio Engineering
Professor	Antti Räisänen

CREDITS	
Hours	
ECTS credits	

AIMS	

SYLLABUS	
	<p>LECTURE 1</p> <p>Introduction</p> <p>The usage of radiowaves</p> <p>Electromagnetic Radiation</p> <p>Radio Frequencies</p> <p>History</p> <p>What is Radio Engineering</p> <p>Radio Frequency Allocation</p> <p>Radio Regulations</p> <p>LECTURE 2</p> <p>Introduction</p> <p>Maxwell's equations</p> <p>Fields in media</p> <p>Boundary conditions</p> <p>Helmholtz equation</p> <p>Polarization of a plane wave</p> <p>Reflection and transmission at a dielectric interface</p> <p>Energy and power</p> <p>LECTURE 3</p> <p>Introduction</p> <p>Common lines</p> <p>Electromagnetic Basic equations:</p> <p>TEM, TE and TM modes</p> <p>Basic equations: TEM, TE and TM modes</p> <p>Rectangular waveguide</p> <p>Circular waveguide</p>

Optical fiber  
Coaxial line  
Microstrip line  
Wave and signal velocities  
Transmission line model  
LECTURE 4  
Reflection from a mismatched load: standing wave  
Problems due to mismatch  
Smith chart  
Matching methods  
Matching with a single lumped reactive element  
Matching with an LC circuit  
Matching with tuning stubs  
Quarter-wave transformer  
Resistive matching  
LECTURE 5  
Z- and Y-parameters  
Scattering parameters, S-parameters  
Properties of scattering matrix  
Signal flow graph  
Mason's rule  
Definitions of gain  
LECTURE 6  
Radiometer  
Classification of components  
Power dividers and directional couplers  
Waveguide directional couplers  
Magic T-junction  
Microstrip directional couplers  
Planar directional couplers and hybrids  
Ferrites  
Faraday rotation  
Isolators  
Circulators, Loads and Matched loads  
Attenuators  
Phase shifters  
Connectors and adapters  
LECTURE 7  
Resonator and its quality factor  
Coupled resonator  
Waveguide section as a resonator

Dielectric resonator  
Filter  
Insertion loss method in filter design  
Richards' transformation, Kuroda identities, impedance and admittance inverters  
Practical microwave filters, including ceramic filter, SAW, BAW  
LECTURE 8  
Background  
Diodes  
Transistors  
Oscillators  
Amplifiers  
Mixers and frequency multipliers  
Detectors  
MMIC  
LECTURE 9  
Basic concepts and definitions  
Calculation of radiation from antenna  
Dipole and other wire antennas  
Aperture antennas  
Aperture antennas  
  horn antennas  
  reflector antennas  
Other antennas  
Antenna arrays  
Matching of antennas  
Link between two antennas  
LECTURE 10  
Introduction  
Propagation mechanisms and environment  
Tropospheric attenuation  
Refraction in troposphere  
LOS path  
Reflection from ground  
Multipath propagation  
Scatter link  
Propagation via ionosphere  
Propagation as a ground wave  
LECTURE 11  
Introduction  
Transmitters and receivers  
Noise

Modulation and demodulation of signals
Radio link budget
LECTURE 12
Introduction
Communications
- Broadcasting
- Radio link systems
- WLAN
- Mobile communication
Radio navigation
Radar
Remote sensing
Radio astronomy
Sensors for industrial applications
Power applications
Medical applications
Electronic warfare

#### **BIBLIOGRAPHY**

#### **COURSE MATERIAL**

#### **WEB REFERENCES**

#### **COURSES RELATED**

#### **OTHER RELEVANT INFORMATION**

UNIVERSITY	Université de Marne-la-Vallée
Faculty	Information, Communication, Modélisation et Simulation
Department	EQUIPE SYSTEMES DE COMMUNICATION(ESYCOM)
Course	Electromagnétisme, rayonnement et antennes (DEA)
Professor	Odile Picon

CREDITS	
Hours	27
ECTS credits	3

AIMS	
	Emphasize the need for electromagnetic studies in the design of microwave circuits for communication or detection systems. Describe the main features of free-space and guided propagations Consider the various electromagnetic phenomena occurring in component integration, antenna design and electromagnetic compatibility

SYLLABUS	
	Plane waves, cylindrical and spherical waves, evanescent waves, polarisation, propagation in inhomogeneous media, ray approximation, Green theorem, diffraction, equivalence principle, antenna and antenna arrays, aperture theory

BIBLIOGRAPHY	
	“Antenna Theory” Balanis, “Foundation of microwave engineering”, Collin

COURSE MATERIAL	
	Labs

WEB REFERENCES	
	<a href="http://www.univ-mlv.fr/enseignements/organisation/formations/fiche_ue_matiere.php?specialite=148&amp;ue=2831">http://www.univ-mlv.fr/enseignements/organisation/formations/fiche_ue_matiere.php?specialite=148&amp;ue=2831</a>

COURSES RELATED	
	Propagation, optical components, electromagnetic compatibility

OTHER RELEVANT INFORMATION	
	In French

UNIVERSITY	Institut National des Sciences Appliquees de Rennes
Faculty	
Department	Electronique & Systèmes de Communication
Course	ANTENNAS
	Mhamed.Drissi@insa-rennes.fr bernard.uguen@insa-rennes.fr renaud.loison@insa-rennes.fr

CREDITS	
Hours	43.5
ECTS credits	4

AIMS	

SYLLABUS	
	Fundamental parameters of antennas: radiation patterns, radiation power density, directivity, gain, equivalent area, radiating impedance. Linear wire antennas: small dipole, finite length dipole: Yagi and log-periodic antennas. Feeding circuits. Aperture antennas rectangular and circular apertures : horns and reflector antennas

BIBLIOGRAPHY	
	<ul style="list-style-type: none"> <li>C. A. BALANIS, " Antenna theory, Analysis and design ", John Wiley 1997</li> <li>R.E. COLLIN, " Antenna theory " McGraw-Hill 1969</li> </ul>

COURSE MATERIAL	

WEB REFERENCES	
	<a href="http://www.insa-rennes.fr/d-esc/ects/esc42s8a.html">http://www.insa-rennes.fr/d-esc/ects/esc42s8a.html</a>

COURSES RELATED	

OTHER RELEVANT INFORMATION	



UNIVERSITY	Technische Universitaet Darmstadt
Faculty	Elektrotechnik + Informationstechnik
Department	Electrical Engineering and Information Technology
Course	Antennas and Adaptive Beamforming
Professor	Prof Dr.-Ing. R. Jakoby

CREDITS	
Hours	
ECTS credits	

AIMS	

SYLLABUS	
	<p>At the beginning, an overview will be given of the most important antenna parameters and antenna types as well as their applications. Chap. 1 deals with some fundamental theories such as the Fourier transform for far-field pattern calculations, antenna modeling techniques, antenna synthesis methods and image theory as well as with the determination of field regions of line sources, of the average radiated power density and power, directivity and gain. At the end of this chap., antennas will be considered as key elements in power budgets of radio links, introducing the effective aperture of an antenna and deriving the relation between gain and effective aperture.</p> <p>For future satellite-based and terrestrial mobile communication systems as well as automotive and imaging radar sensors, array antennas are a key hardware for beamforming and hence smart antenna systems. The following Chap. 2 describes some fundamentals of phased-scanning arrays, non-uniformly excited, equally spaced linear arrays, multi-dimensional planar arrays and mutual coupling effects.</p> <p>Wire antennas, considered in Chap. 3, are the oldest and still the most prevalent of all antenna forms, because they are relatively simple in concept, easy to construct and very inexpensive.</p> <p>Because of its importance in practice and because of its simplicity, i.e., allowing often analytical solutions, most calculations of the antenna pattern are carried out by using far-field approximations and assuming current distributions along the sources, except in Chap. 4 and 7.</p> <p>In Chap. 4, antenna radiation fields and antenna parameters for different types of antennas are derived from Maxwell's equations. They will be applied for aperture antennas (horns, lenses or reflector antennas) in Chap.5 and printed antennas (microstrip-patch and coplanar-slot antennas) in Chap. 6. In Chap. 7 some basic numerical calculation methods such as integral equation methods in the time and frequency domain, physical optics and uniform theory of diffraction are briefly summarized and compared for antennas and scattering problems.</p>

The last Chap. 8 deals with smart antennas in communication and radar systems, where the focus will be on beam steering and adaptive beamforming. To give an impression of the wide field of applications of antennas in wireless systems, there are many examples in the lecture and exercises, carrying out a more detailed treatment of various antennas. Few examples are: Modeling of continuous and discrete (array) antennas, Satellite links for broadcasting, Radar equation, Array antennas in mobile communication systems and radar sensors, Wire antennas in navigation and broadcasting systems, Horn and reflector antennas for point-to-multipoint radio access above 10 GHz, Calculations of thick linear dipole antennas etc.

## BIBLIOGRAPHY

- [0] R. Jakoby, Antenna and Adaptive Beamforming, Script in English, about 240 pages, 2003.
- [1] C. A. Balanis, Antenna Theory, John Wiley & Sons, 1997.
- [2] Stutzman/Thiele, Antenna Theory and Design, John Wiley & Sons, 1998.
- [3] J. D. Kraus, Antennas, McGraw Hill, 1988.
- [4] K. Fujimoto, J.R. James, Mobile Antenna Systems Handbook, Artech House, 1994.
- [5] J. Litva, T. Kwok-Yeung Lo, Digital Beamforming in Wireless Communications, Artech House, 1996.
- [6] S. Drabowitch u.a., Modern Antennas, Chapman & Hall, 1998.
- [7] J.F. Zürcher, F.E. Gardiol, Broadband Patch Antennas, Artech House, 1995.
- [8] C. J. Sletten, Reflectors and Lens Antennas, Artech House, 1988.
- [9] T.S.M MacLean, Principles of Antennas, Cambridge University Press, 1986.

## COURSE MATERIAL

<http://www.hf.e-technik.tu-darmstadt.de/lehre/>

## WEB REFERENCES

<http://www.tu-darmstadt.de/vv/comments/18.214.en.tud>

## COURSES RELATED

Fundamentals of Communications,  
Recommended in parallel: Communication Technology II

## OTHER RELEVANT INFORMATION

UNIVERSITY	UNIVERSITÄT KARLSRUHE (TH)
Faculty	Fakultät für Elektrotechnik und Informationstechnik
Department	Institut für Höchstfrequenztechnik und Elektronik
Course	23410 - Antennas and Antenna Systems
Professor	W. Wiesbeck

CREDITS	
Hours	3 per week
ECTS credits	4,5

AIMS	

SYLLABUS	
	<ul style="list-style-type: none"> <li>• Maxwells equations</li> <li>• Introduction in electromagnetic field theory (as far as necessary for the calculation of antennas and propagation effects)</li> <li>• Deduction of the wave equation</li> <li>• Propagation and Polarization of plane waves</li> <li>• Introduction of antenna parameters (gain, directivity, radiation pattern, effective antenna area etc.)</li> <li>• Presentation and demonstration of different types of antennas</li> <li>• Infinitesimal dipole</li> <li>• Principle of radiation from current or field sources</li> <li>• Linear wire antennas, aperture antennas</li> <li>• Principle of duality for slot radiations, broadband antennas and antenna arrays</li> <li>• Measurement techniques</li> <li>• Wave propagation</li> <li>• Propagation effects (reflection, diffraction, scattering, and refraction)</li> <li>• Propagation of electromagnetic waves along the earth surface and through troposphere and ionosphere (effects occuring in radio broadcasting and communication links)</li> </ul>

COURSE MATERIAL	
	<ul style="list-style-type: none"> <li>• Lecture notes (in German)</li> </ul>

WEB REFERENCES	
	<a href="http://www.ihe.uni-karlsruhe.de/lehre/hf2/hf2.en.html">http://www.ihe.uni-karlsruhe.de/lehre/hf2/hf2.en.html</a>

COURSES RELATED	
	23407/23409 - High Frequency Technologies

UNIVERSITY	Università “La Sapienza” di Roma
Faculty	Facoltà di Ingegneria
Department	Dip. di Ingegneria Elettronica
Course	ANTENNE
Professor	Prof. Frank Silvio Marzano

<b>CREDITS</b>	
Hours	50
ECTS credits	

<b>AIMS</b>	
	Explaining the fundamental concepts of antenna theory and applications.

<b>SYLLABUS</b>	
	<ol style="list-style-type: none"><li>1. Antenna Basics</li><li>2. Electromagnetic Radiation</li><li>3. Linear Antennas</li><li>4. Apertura Antennas</li><li>5. Array Antennas</li></ol>

<b>BIBLIOGRAPHY</b>	
	<ul style="list-style-type: none"><li>• Balanis C.A., Antenna theory, analysis and design, J. Wiley &amp; Sons, New York (NY, USA), 1982.</li><li>• Chatterjee R., Antenna theory and practice, J. Wiley &amp; Sons, New Delhi (IN), 1988.</li><li>• Collin R.E., Antennas and radiowave propagation, McGraw-Hill ISE, New York (NY, USA), 1985.</li><li>• Kraus J.K., Antennas, McGraw-Hill ISE, New York (NY, USA), 1988.</li><li>• Paraboni A., Antenne, McGraw-Hill Libri Italia, Milano (I), 1999.</li></ul>

<b>COURSE MATERIAL</b>	
	<ul style="list-style-type: none"><li>• Marzano F.S. e N. Pierdicca, Elementi di Antenne, Facoltà di Ingegneria, Roma, 2001.</li></ul>

<b>WEB REFERENCES</b>	
	<a href="http://www.die.uniroma1.it/strutture/labant/teaching/Prog_AntenneVO.htm">http://www.die.uniroma1.it/strutture/labant/teaching/Prog_AntenneVO.htm</a>

<b>COURSES RELATED</b>	
	Mathematics, Physics, Electromagnetic Fields, Signal Theory, Circuit Theory

UNIVERSITY	POLITECNICO DI TORINO
Faculty	FACOLTÀ DI INGEGNERIA
Department	
Course	Antennas for wireless communications
Professor	Giusseppe Vecchi

CREDITS	
Hours	
ECTS credits	5

AIMS	
	<p>Wireless communication systems have undergone a fast growth during the last few years, giving rise to a huge support infrastructure.</p> <p>Further developments of wideband systems are expected to sustain the expansion of this segment of the telecommunication and electronic market, linking it more closely to data communication and Internet world.</p> <p>In the next future, a substantial amount of skilled personnel will be engaged in running wireless systems both at a network level and in the maintenance and organization of field apparatuses. At the same time, short time-to-market is becoming a must for companies engaged in the development and design of wireless hardware, which requires advanced skills in terms of analog and digital design, but also a broad vision of the wireless world at large.</p> <p>Finally, openings for new technical positions are expected to experience a substantial growth not only in Europe and in the United States, but also in other areas, like Latin America and Far East, where a fast development in the wireless market is already in progress.</p> <p>A Master in Wireless Systems and Technology is an effective answer to the work market demands in terms of high level technicians endowed with a broad vision of the wireless world but also with specific skills.</p>

SYLLABUS	
	<p>Review of RF and Radiowave basics</p> <p>Transmission lines; Radiation of radiowaves; polarization</p> <p>Basics of Radio Communications</p> <p>Basic principles of antennas as system components (gain, polarization, temperature, input impedance).</p> <p>Radiowave propagation and link budget</p> <p>Small and/or compact antennas</p> <p>Dipole and derived antennas; monopole, helix, patch antennas</p> <p>Directive antennas</p> <p>Reflector antennas: a qualitative overview</p>

Arrays: 1-D and 2-D (planar) arrays; beam-scanning, beam-forming; introduction to adaptive ("smart") antennas (arrays)

## BIBLIOGRAPHY

## COURSE MATERIAL

## WEB REFERENCES

<http://didattica.polito.it/master/III/prof/wireless/vecchi.html>

## COURSES RELATED

### MASTER WIRELESS SYSTEMS AND RELATED TECHNOLOGIES

- Wireless RF and microwave devices and technologies (prof. Carlo Naldi)
- Transmission over the wireless channel (prof. Ezio Biglieri)
- Telecommunication Networks (prof. Andrea Bianco)
- Antennas for wireless communications (prof. Giuseppe Vecchi)
- RF microelectronics for wireless systems (prof. Giovanni Ghione)
- Coding for the wireless channel (prof. Ezio Biglieri)
- Mobile networks (prof. Renato Lo Cigno)
- Architectures and circuits for low power wireless systems (prof. Maurizio Zamboni)
- Evolution of mobile networks ((prof. Carla Chiasserini)
- Cellular network design (prof. Marco Ajmone)

## OTHER RELEVANT INFORMATION

To profitably follow the Master program, candidates should have some background in the areas:

- Fourier Transforms
- Stochastic Variables and Processes
- Elements of Digital Transmission
- Elements of Communication Networks
- Protocols Basics of Semiconductor Devices and Materials
- Transmission Line Theory
- Basics of Analog and Digital Electronic Circuits
- Basics of Electromagnetic Wave Propagation

UNIVERSITY	Università della Calabria
Faculty	Facoltà di Ingegneria
Department	
Course	MICROONDE
Professor	Prof. Giuseppe Di Massa

CREDITS	
Hours	
ECTS credits	

AIMS	

SYLLABUS	
	Waveguides Conformal Transformations. TEM lines. Variational Methods. Microwave components Microwave filters Microstrip Antennas.

BIBLIOGRAPHY	
	E. Collin, Fundation of microwave engineering, McGraw Hill, New York  Ramo-Winnery-Van Duyer, Campi e Onde nell'elettronica per le comunicazioni, F. Angeli, Milano.

COURSE MATERIAL	

WEB REFERENCES	
	<a href="http://wwwinfo.deis.unical.it/microonde.html">http://wwwinfo.deis.unical.it/microonde.html</a>

UNIVERSITY	Università degli Studi di Firenze
Faculty	Engineering
Department	Electronics and Telecommunications
Course	Antennas and propagation – Academic year 2004/05
Professor	Mario Calamia

CREDITS	
Hours	56
ECTS credits	5

AIMS	
	The course is designed to provide students with basic notions in radiated and guided propagation, within its main application context. In addition to providing theoretical principles, the course will also focus on some of the most common antennas.

SYLLABUS	
	<p><i>Foundations of radiation theory</i></p> <p>Theory of electromagnetic potentials: vector and scalar potentials, the Lorentz condition, homogeneous vector and scalar Helmholtz equations and solutions. Hertzian electrical dipole. Duality theorem. Hertzian magnetic dipole. Small loop antenna.</p> <p><i>Antennas</i></p> <p>Wire transmitting antennas: Hallen's integral equation, radiation resistance, transmitting effective length, radiation intensity, directivity, gain, radiation efficiency. Reciprocity theorem. Wire receiving antennas: receiving effective length, effective area. Antenna equivalent circuits. Communicating antennas. Antenna arrays: translational phase shift, array pattern multiplication. One-dimensional arrays. Visible region. Grating lobes. Uniform arrays. Equivalence theorem. Aperture antennas: uniformly illuminated rectangular aperture. Huygens source. General characteristics of reflector antennas.</p> <p><i>Guided Propagation</i></p> <p>Electromagnetic theory of guiding structures. Separation of the transverse and longitudinal components of the field. Scalar and vector modal functions. Transverse electromagnetic modes (TEM). Coaxial Cable, and linking the electromagnetic and circuit approaches. Transverse electric (TE) and transverse magnetic (TM) modes. Rectangular wave guide. Operating bandwidth. Power transfer and group velocity. Analogy between guided propagation and transmission lines.</p>

BIBLIOGRAPHY	
	<ul style="list-style-type: none"> <li>G. Franceschetti, <i>Lezioni di campi elettromagnetici e circuiti</i>, L. &amp; D.</li> </ul>



Pironti, Napoli.

- G. Conciauro, *Introduzione alle onde elettromagnetiche*, McGraw-Hill.
- G. Franceschetti, *Campi elettromagnetici*, Boringhieri, 1988.
- R. E. Collin, *Antennas and radiowave propagation*, McGraw-Hill, New York, 1985.
- R. E. Collin, *Foundation for microwave engineering*, McGraw-Hill.
- J. D. Kraus, *Electromagnetics*, McGraw-Hill.

## COURSE MATERIAL

Course transparencies

## WEB REFERENCES

<http://srtm.det.unifi.it/lab/>

## RELATED COURSES

Antennas

## OTHER RELEVANT INFORMATION

UNIVERSITY	Università degli Studi di Firenze
Faculty	Engineering
Department	Electronics and Telecommunications
Course	Computational Electromagnetics – Academic year 2004/05
Professor	Angelo Freni

CREDITS	
Hours	56
ECTS credits	5

AIMS	
	<p>The course will cover basic computational techniques for the numerical analysis of electromagnetic problems, including the finite difference, finite element, and moment methods. Emphasis will be placed on the formulation of physical problems into mathematical boundary-value problems, the numerical discretization of continuous problems into discrete problems, and the development of rudimentary computer codes for the simulation of antenna problems using each of these techniques.</p>

SYLLABUS	
	<p>Introduction to computational electromagnetics.          Review of vector analysis and electromagnetic theory.          Finite difference method. Finite difference time domain method. Absorbing boundary conditions, perfectly matched layers. Applications of FDTD to electromagnetic problems.          Finite element method. High-order elements, parametric elements, vector elements. Application of FEM to electromagnetic problems.          Integral representations and integral equations. Method of moments (MoM). MoM solution of electromagnetic problems. Advanced MoM methods. Hybridization.          Mode Matching Method. Advanced Modal Analysis.          Project presentations.</p>

BIBLIOGRAPHY	
	<ul style="list-style-type: none"> <li>• M.N.O. Sadiku, <i>Numerical Techniques in Electromagnetics</i>, CRC Press, New York, 2000.</li> <li>• A.F. Peterson, S.L. Ray, R. Mittra, <i>Computational Methods for Electromagnetics</i>, IEEE Press, 1998.</li> <li>• P.P. Silvester, R.L. Ferrari, <i>Finite Elements for electrical engineers</i>, Cambridge University Press, Melbourne, 1996.</li> <li>• J. Jin, <i>The Finite Element Methods in Electromagnetics</i>, J. Wiley &amp; Sons, New York, 1993.</li> <li>• J.L. Volakis, A. Chatteyjee, L.C. Kempel, <i>Finite Element Method for</i></li> </ul>

*Electromagnetics*, IEEE Press, 1998.

- R.F. Harrington, *Field Computation by Moment Methods*, IEEE Press, 1993.
- T. Itoh (ed), *Numerical Techniques for Microwave and Millimeter Wave Passive Structures*, J. Wiley & Sons, New York, 1999.
- T. Itoh and B. Houshmand (ed), *Time Domain Methods for Microwave Structures*, IEEE Press, 1997.

#### COURSE MATERIAL

handwritten notes

#### WEB REFERENCES

<http://srtm.det.unifi.it/lab>

#### RELATED COURSES

#### OTHER RELEVANT INFORMATION

UNIVERSITY	Università degli Studi di Firenze
Faculty	Engineering
Department	Electronics and Telecommunications
Course	Antennas
Professor	Giuseppe Pelosi

CREDITS	
Hours	72
ECTS credits	7

AIMS	
	The lectures will provide students with the criteria for the analysis and design of the most common antenna configurations. Particular emphasis will be placed on HF and microwave radiators for telecommunication systems.

SYLLABUS	
	History, radiation mechanism. Radiation patterns, power density. Directivity, gain, bandwidth. Polarization, input impedance. Efficiency, effective aperture. Radiation integrals. Basic wire antennas. Linear wire antennas. Cylindrical and folded dipoles. Balun. Antenna arrays: linear, planar, circular arrays. Biconical and bowtie antennas. Long-wire, V, and rhombic antennas. Helical and Yagi antennas. Spiral and Log Periodic antennas. Horns and reflectors. Patch antennas. Method of moments. High frequency methods: UTD, GO, PO, PTD.

BIBLIOGRAPHY	
	<ul style="list-style-type: none"><li>• C.A. Balanis, <i>Antenna Theory</i>, J. Wiley &amp; Sons., New York, 1982</li><li>• J.D. Kraus, <i>Antennas</i>, McGraw Hill, New York, 1991</li><li>• Y.T. Lo, S.W. Lee Eds., <i>Antenna Handbook</i>, Van Nostrand Reinhold, New York, 1988</li><li>• C.A. Balanis, <i>Advanced Engineering Electromagnetics</i>, J. Wiley &amp; Sons., New York, 1989</li></ul>

COURSE MATERIAL	

WEB REFERENCES	
----------------	--

--	--

<b>RELATED COURSES</b>
------------------------

	Antennas and propagation
--	--------------------------

<b>OTHER RELEVANT INFORMATION</b>
-----------------------------------

--	--

UNIVERSITY	UNIVERSITA'DEGLI STUDI DI SIENA
Faculty	FACOLTA' DI INGEGNERIA
Department	Department of Information Engineering,
Course	Antenne
Professor	Stefano Maci

CREDITS	
Hours	
ECTS credits	

AIMS	
	To provide the Basic Fundamentals of electromagnetic radiation in frequency domain and antennas in low and high frequency, with particular emphasis in telecommunications systems.

SYLLABUS	
	Radiation theory Potential theory Antenna parameters in transmission and reception Reciprocity theorem Wire Antennas. Mutual coupling, balun, Yagi-Uda. Broadcast Antennas Wide Band Antennas: Spiral, Log-periodic antennas, Microstrip antennas. Wireless applications Array antennas: Array factor, applications. Aperture Antennas: Rectangular and Circular, Horn. Reflector Antennas. Satellite applications.

BIBLIOGRAPHY	
	Antenna theory: analysis and design - C. A. Balanis Antenna theory and design - W. L. Stutzman, G. Thiele Antennas - J. D. Kraus Foundations of antennas: a unified approach - P. S. Kildal

COURSES RELATED	
	Campi Elettromagnetici, Elettrotecnica

UNIVERSITY	UNIVERSIDAD POLITECNICA DE CATALUÑA
Faculty	ETSI Telecomunicación
Department	Teoría de la Señal y Comunicaciones
Course	Antenas
Profesor	A. Cardama, L.Jofre, J. Romeu, J.M. Rius, S. Blanch.

CREDITS	
Hours	60
ECTS credits	5

AIMS	
	To analyse radiating structures. Basic content of the course is: Antennas.

SYLLABUS	
	I. Fundamentals of radiation (3 weeks) Maxwell Equations. Radiating vectors. Fresnel and Fraunhofer zones. II. Basic antennas (4 weeks) Elemental dipole and coil antennas. Cylindrical antennas. Monopoles. Input impedance and mutual impedance. Feeding systems. III. Arrays (2 weeks) Array Factor. Typical distributions. Two-dimensional arrays. Array synthesis. IV. Aperture antennas (4 weeks) Equivalence Theorem. Aperture radiated fields. Horns. Slots. Reflectors.

BIBLIOGRAPHY	
	A. CARDAMA, L. JOFRE, J.M. RIUS, J. ROMEU, S. BLANCH, Antenas. 2a.ed. Edicions UPC, 2002 C.A. BALANIS, Antenna theory. 2nd.ed. Wiley, 1997

WEB REFERENCES	

COURSES RELATED	
	Campos Electromagnéticos Radiación y Ondas Guiadas.

OTHER RELEVANT INFORMATION	

UNIVERSITY	UNIVERSIDAD POLITÉCNICA DE MADRID
Faculty	ETS Ingenieros de Telecomunicación
Department	Señales Sistemas y Radiocomunicaciones (SSR)
Course	Antennas (ANTE -5207 )
Professors	Leandro de Haro Ariet (Coordinador) José Luis Besada Sanmartín Manuel Sierra Perez

CREDITS	
Hours	60
ECTS credits	4,8

AIMS	
	<p>The objective is to give the student a basic knowledge of the design and synthesis of the different antenna types used in communication systems.</p> <p>Special emphasis is done on microwave antennas (arrays, horn and reflectors) used in the professional field nowadays, both for radar applications and satellite communications systems.</p> <p>Through the knowledge gain in the lectures the student should be able to realize simple designs with help of software tools that will be provided.</p>

SYLLABUS	
	<p>Introduction (4 hours) Equivalence principles (6 hours) Linear antennas (4 hours) Arrays: analysis (8 hours) Arrays: synthesis (8 hours) Horn antennas (6 hours) Reflectors (8 hours) Reflectors design (4 hours) Frequency independent antennas (4 hours) Antennas measures (4 hours)</p>

BIBLIOGRAPHY	
	<p>"Antenas", Ángel Cardama y otros. Edicions UPC 1993. "Antenna Theory. Analysis and Design", Constatine Balanis. John Wiley &amp; Sons 1997. "Antenna Theory and Design". W.L. Stutzman. Wiley. 1981. "Modern Antenna Design". T. Milligan. Mc Graw-Hill. 1985.</p>

COURSE MATERIAL
-----------------



SOFTWARE
MOMENTOS: Yagis and dipoles arrays
ASIA: Arrays.
SABOR: Horns and reflectors

#### WEB REFERENCES

<a href="http://www.gr.ssr.upm.es/antenas">http://www.gr.ssr.upm.es/antenas</a> <a href="http://www.ssr.upm.es">http://www.ssr.upm.es</a>
--

#### COURSES RELATED

#### OTHER RELEVANT INFORMATION

UNIVERSITY	UNIVERSIDAD POLITECNICA DE VALENCIA
Faculty	ETS ingenieros de Telecomunicación
Department	Comunicaciones
Course	Antenas
Professor	Miguel Ferrando Alejandro Valero

CREDITS	
Hours	60
ECTS credits	4,5

AIMS	

SYLLABUS	
	<ul style="list-style-type: none"><li>• Introduction. Antennas. Antenna Parameters.</li><li>• Radiation principles and equations</li><li>• Hertz dipole and small loops</li><li>• Antenna arrays.</li><li>• Linear wire antennas</li><li>• Antenna impedance and antenna coupling</li><li>• Aperture antennas</li><li>• Horn antennas</li><li>• Slot and microstrip antennas</li><li>• Reflector and lenses</li></ul>

BIBLIOGRAPHY	
	<ul style="list-style-type: none"><li>• Antenas. Angel Cardama, Lluís Jofre, Juan Manuel Rius, Jordi Romeu, Sebastián Blanch, Miguel Ferrando. EDICIONS UPC, 2002</li><li>• Antenna Theory: Analysis and Design, 2nd Edition. Constantine A. Balanis, Wiley.</li><li>• Antenna theory and design. Warren L. Stutzman, Gary A Thiele. ,Wiley</li><li>•</li></ul>

COURSE MATERIAL	
	Notes, videos and exercises in <a href="http://www.upv.es/antenas/">http://www.upv.es/antenas/</a>

WEB REFERENCES	
	<a href="http://www.upv.es/antenas/">http://www.upv.es/antenas/</a> <a href="http://www.etsit.upv.es/">http://www.etsit.upv.es/</a>

COURSES RELATED	
	Radiocomunicaciones
	Microondas
	Laboratorio de Microondas

UNIVERSITY	Chalmers University of Technology
Faculty	Electrical and Computer Engineering
Department	Dep. of Electromagnetics
Course	ANTENNA ENGINEERING
Professor	Prof. Per-Simon Kildal Dr. Jian Yang

CREDITS	
Hours	50
ECTS credits	

AIMS	
	<p>The course covers the basic electromagnetic principles and their applications to different types of antennas, all in a unified and complete vector notation. In addition, we demonstrate a Mathcad handbook that easily provides numerical results of classical antenna design formulas. The book includes among other things: the definitions of the radiation field function, the phase reference point and the phase centre; characteristics of rotationally symmetric antennas (BOR); incremental electric and magnetic sources, and the Huygens's source for modelling apertures; the theories of apertures, Gaussian beams and spectral domain analysis; and practical antennas such as dipoles, slots, horn antennas, corrugated horn antennas, reflector antennas, microstrip antennas, and linear and planar arrays. The material is presented with emphasis on physical interpretations. The course is given in English.</p>

SYLLABUS	
	<ul style="list-style-type: none"> <li>• Introduction with examples of antennas</li> <li>• Polarization of plane waves.</li> <li>• The radiation field function.</li> <li>• Maxwell's equations.</li> <li>• Phase reference point. Phase center.</li> <li>• System performance.</li> <li>• BOR antennas.</li> <li>• Incremental sources.</li> <li>• General field concepts. Imaging.</li> <li>• Moment Method.</li> <li>• Monopoles and dipoles.</li> <li>• Loop antennas.</li> <li>• Waveguide slot antennas.</li> <li>• Microstrip antennas.</li> <li>• Spectral domain methods.</li> <li>• Characterization of small antennas.</li> <li>• Radiation from apertures.</li> </ul>

- Plane apertures.
- Horn antennas.
- Introduction to Gaussian beams.
- Linear arrays.
- Mutual coupling and scan impedance.
- Planar arrays.
- Gaussian beam model of corrugated horns.
- Introduction to reflector antennas.
- Physical optics, rays, reflector antennas.

## BIBLIOGRAPHY

Per-Simon Kildal, Foundations of Antennas - a Unified Approach. The book includes a CD-ROM with Mathcad electronic handbook "Antenna Design Using Mathcad".

## COURSE MATERIAL

Memo: "Correlation and capacity of MIMO systems and mutual coupling, radiation efficiency and diversity gain of their antennas: Simulations and measurements in reverberation chamber."

## WEB REFERENCES

<http://www.elmagn.chalmers.se/elmagn/antenna/courses/u-course-m-w-a.html>

## COURSES RELATED

## OTHER RELEVANT INFORMATION

### LABORATORY EXERCISES:

- 1) Measurements of radiation patterns of several antennas
- 2) Measurements of admittance of waveguide slot antenna
- 3) Measurements of total radiated power from GSM mobile phones by using a reverberation chamber

UNIVERSITY	Royal Institute of Technology (KTH)
Faculty	
Department	Signals, Sensors and Systems
Course	Antenna Systems Technology
Professor	

CREDITS	
Hours	50
ECTS credits	5

AIMS	
	<p>After the course, the student should:</p> <ul style="list-style-type: none"> <li>• have knowledge of the different parameters and properties used to characterize antennas.</li> <li>• be able to make theoretical calculations of fundamental antenna elements such as dipoles and aperture antennas.</li> <li>• be able to use commercially available program for antenna simulation.</li> <li>• have knowledge of some antenna systems and the demands of such on the antenna components.</li> </ul>

SYLLABUS	
	<p><b>Introduction</b> – Examples of antenna systems, radiation patterns, directivity, polarization, antenna impedance, effective area, Friis' equation, the radar equation, antenna temperature and noise.</p> <p><b>Antenna radiation</b> – the antenna as a source of radiation, duality and reciprocity, near- and far-field from a dipole, image theory, mutual coupling. Aperture antennas and Babinet's principle, microstrip antennas. Linear and planar antenna arrays, synthesis of radiation patterns.</p> <p><b>Physical limits</b> – Super directivity, bandwidth vs. size, mutual resistance and correlation.</p> <p><b>Practical design</b> – High gain, conformal, low frequency, and terminal antennas.</p> <p><b>System aspects</b> – Radar, radar cross-section of antennas, radio propagation, link budget, fading space and polarization diversity. Cellular and sector systems, adaptive and multi-beam antennas.</p>

BIBLIOGRAPHY	
	Balanis: Antenna Theory.

COURSE MATERIAL	
-----------------	--

Lecture notes from the department

**Computer exercises**

1. (MatLab) Synthesis of radiation patterns  
Linear arrays, comparison with approximate expression for gain  
Planar arrays
2. (CST) Design of a microstrip patch antenna
  - a) RHCP for simple link at 3 GHz with cross-polarization < -20 dB
  - b) PIFA design for hand terminal, 2 GHz, 7% bandwidth at VSWR<2.3
3. (CST) Design of a simple Yagi antenna  
Start from two ideal thin dipoles in free space, calculate  $Z_{11}$ ,  $Z_{21}$  using available MatLab function. Find distance between the two that maximizes the peak gain. Use this design as the start in CST. Add a director and modify the reflector to maximize the gain.

**WEB REFERENCES**

<http://www.s3.kth.se/antenn/edu/2H1260/description.htm>

**COURSES RELATED**

Electromagnetic Theory and must be well understood. Some knowledge of computer programs, e.g. Matlab, is necessary.

**OTHER RELEVANT INFORMATION**

The course provides knowledge in general properties of antennas, the electromagnetic theory behind their operation, and an overview of different antenna systems. Equal weight is placed on the electromagnetic aspects important for antenna design and on system aspects. Among the systems discussed are radar, cellular, and adaptive antenna systems.

The course is suited both for antenna designers and those who encounter the antenna as a sub-component in a system.

The course includes three computer exercises which are solved using MatLab and commercially available antenna software.

UNIVERSITY	Lunds Universitet
Faculty	LUND INSTITUTE OF TECHNOLOGY
Department	
Course	ANTENNA TECHNOLOGY ETE100
Professor	Anders Derneryd <a href="mailto:Anders.Derneryd@es.lth.se">Anders.Derneryd@es.lth.se</a>

CREDITS	
Hours	
ECTS credits	4

AIMS	
	<p>The aim of the course is to give the student:</p> <ul style="list-style-type: none"><li>– introductory knowledge of antenna technology</li><li>– familiarity with the concepts, methods and models used in antenna technology</li><li>– ability to analyse and construct antennas</li><li>– capacity to read antenna specialist literature</li></ul>

SYLLABUS	
	<p>Repetition of Maxwell's equation and boundary conditions. Antenna parameters, fundamental relations, radiation integrals. Omni and directional antennas. Resonant and non-resonant antenna elements. Various antenna types such as wire antennas, micro strip antennas, aperture antennas, array antennas including pattern synthesis, reflector antennas and measurement techniques.</p> <p>In the laboratory work part a patch antenna is designed, manufactured and measured.</p>

BIBLIOGRAPHY	
	Kraus, John D: Antennas For All Applications, third edition.



COURSE MATERIAL	

WEB REFERENCES	
	<a href="http://www.es.lth.se/ugradcourses/antennteknik">www.es.lth.se/ugradcourses/antennteknik</a>

COURSES RELATED	
	Electromagnetic Fields, basic course

OTHER RELEVANT INFORMATION	

UNIVERSITY	
Faculty	THE SCHOOL OF COMPUTER AND COMMUNICATION SCIENCES
Department	
Course	Radiation and Antennas
Professor	Juan MOSIG

CREDITS	
Hours	42 (3 per week)
ECTS credits	

AIMS	
	<p>Students will be able to analyze a radiating system and to predict its performances and the characteristics of the radiated fields. They will also know the basic principles underlying the radiation and propagation of electromagnetic waves and their interaction with a material environment.</p> <p>Finally, they will be able to select an antenna according to existing technical and legal constraints.</p>

SYLLABUS	
	<ol style="list-style-type: none"><li>1. Free propagation of electromagnetic waves. Radiation mechanism and elementary sources. Spherical, cylindrical and plane waves. The electromagnetic spectrum: frequency allocation.</li><li>2. Parameters and characteristics of radiating sources: radiation pattern, impedance, directivity, gain, polarization, bandwidth. Main types of antennas.</li><li>3. Radiation through slots. Huyghens' principle, aperture theory, reflector and horn antennas.</li><li>4. Hertzian links and communication satellites. Diversity techniques. Environmental effects: mobiles, propagation in urban cells, electromagnetic interaction with material media (remote sensing) and with living tissues (hyperthermia).</li><li>5. Arrays, adaptive antennas, signal processing and smart antennas.</li><li>6. Antenna and radiation measurements. Impedance, radiation pattern, gain, polarization, power density.</li></ol>

BIBLIOGRAPHY	
	<p>Balanis</p> <p>Stutzman</p>

COURSE MATERIAL	
-----------------	--

Technical papers
------------------

#### WEB REFERENCES

<a href="http://ic2.epfl.ch/ssc/lc/2004_2005/cycle2/ra.pdf">http://ic2.epfl.ch/ssc/lc/2004_2005/cycle2/ra.pdf</a>
---

#### COURSES RELATED

Electromagnétisme Propagation, Hyperfréquences, CEM
--

#### OTHER RELEVANT INFORMATION

--

UNIVERSITY	UNIVERSITY OF BIRMINGHAM
Faculty	ELECTRONIC, ELECTRICAL AND COMPUTER ENGINEERING
Department	
Course	Electromagnetics and Antennas
Professor	Dr M J Lancaster, Dr C Constantinou

CREDITS	
Hours	32
ECTS credits	

AIMS	
	The aim of this module is to familiarise the students with the fundamentals of the basic principles of electromagnetic theory.

SYLLABUS	
	The module starts with the basic mathematical methods required for the solution of problems. This is followed by a formal mathematical treatment of antennas. A good grasp of these fundamental principles allows the student to proceed confidently through the following material and to quickly grasp the basic principles which need to be applied to many practical situations that may be encountered at a later stage in their career. At the end of this module the student should be able to solve simple electromagnetic problems for the tutorial sheets and examinations but more importantly a good basic understanding of electromagnetics should enable a student to be able to tackle more complex problems of a practical nature. The student should be able to understand the principles related in Maxwell's equations, which are related through examples including a number of different antenna types

BIBLIOGRAPHY	

COURSE MATERIAL	

WEB REFERENCES	
	<a href="http://www.eng.bham.ac.uk/eece/ug/eee/Level_4_modules.htm">http://www.eng.bham.ac.uk/eece/ug/eee/Level_4_modules.htm</a>

COURSES RELATED	
-----------------	--

EEM4T	RF and Microwave Engineering
EM3K	Communications Electromagnetics

#### OTHER RELEVANT INFORMATION

<b>UNIVERSITY</b>	<b>University of Bristol</b>
Faculty	
Department	Department of Electrical & Electronic Engineering
Course	Antennas
Professor	Dr Geoffrey Hilton

#### CREDITS

Hours	
ECTS credits	

#### AIMS

#### SYLLABUS

The antenna is an integral part of any wireless communications system. This unit predominantly considers intentional radiators (i.e. antennas), though also provides a basis for analysis of unintentional electromagnetic radiation (i.e. potential sources of interference). The first part of the unit concentrates on defining, and practical measurement of, antenna characteristics. Antenna element and array theory is then developed to show how the antennas radiation pattern can be shaped and steered. The application and design of some of the wide variety of antenna configurations is considered, with examples given of practical antennas (dipoles, slots, arrays, reflectors). It is also important to show how the antenna is integrated with feed-lines and RF circuitry. This area is covered in lectures and reinforced through a design exercise where students have to specify antenna and RF component requirements for a satellite communications system uplink/downlink.

#### BIBLIOGRAPHY

#### COURSE MATERIAL

#### WEB REFERENCES

<http://www.bris.ac.uk/tsu/unitcat/2004/units/EENG35010>

#### **COURSES RELATED**

Lines and Waves  
Antennas and Electromagnetic Compatibility

#### **OTHER RELEVANT INFORMATION**

UNIVERSITY	UNIVERSITY OF LIVERPOOL
Faculty	Faculty of Engineering
Department	Electrical Engineering and Electronics
Course	ANTENNAS
Professor	Dr BA Austin

CREDITS	
Hours	25
ECTS credits	3

AIMS	
	<p>To introduce fundamental antenna principles and concepts based on the underlying electromagnetic theory</p> <p><b><i>Knowledge and Understanding</i></b></p> <p>After successful completion of the module, the student should be able to:</p> <p>Demonstrate their familiarity with fundamental antenna concepts such as near and far fields and their distribution, radiation resistance and its calculation, radiation patterns and their relationship to antenna gain as well as the relationship between gain and directivity.</p> <p>Demonstrate the manipulation of Maxwell's equations which underpin these concepts that are fundamental to the module.</p> <p><b><i>Intellectual Abilities</i></b></p> <p>On successful completion of the module, students should be able to:</p> <p>Demonstrate their ability to analyse simple antenna systems.</p> <p><b><i>Practical Skills</i></b></p> <p>On successful completion of the module the student should be able to:-</p> <p>Apply their theoretical knowledge to the design and evaluation of simple antenna systems.</p> <p><b><i>General Transferable Skills</i></b></p> <p>On successful completion of the module, students should be able to show experience and enhancement of the following key skills:</p> <p>Independent learning</p>

Problem solving and design skills

## SYLLABUS

Applications and Types of Antennas

The antenna as a transducer in radio, radar and remote sensing. Circuit and field characteristics.

Analysis of single-element antennas

Effect of current distribution on impedance and radiation patterns. Radiation and reactive fields. Elemental and short dipoles. Impedance, efficiency, directivity and gain. Retarded potentials, resonant antennas. Electrical loading to force resonance or to improve matching or bandwidth.

Simple Array Theory

Array factor and pattern multiplication. Broadside and endfire arrays. Parasitic and log-periodic arrays.

## BIBLIOGRAPHY

'Antennas', Kraus, J.D., McGraw-Hill, 1988.

'Electromagnetics', Kraus, J.D., McGraw-Hill, 1991.

## COURSE MATERIAL

## WEB REFERENCES

[https://cis.liv.ac.uk/spi/modules/vital/vital\\_ELEC312\\_200405.htm](https://cis.liv.ac.uk/spi/modules/vital/vital_ELEC312_200405.htm)

## COURSES RELATED

ELEC209 Electromagnetics

ELEC210 Electromagnetic Waves (for Aerospace students)

ELEC381 R.F. Engineering

## OTHER RELEVANT INFORMATION



UNIVERSITY	Michigan State University
Faculty	
Department	Electrical and Computer Engineering
Course	Antenna Theory
Professor	Ed Rothwell

CREDITS	
Hours	50
ECTS credits	

AIMS	

SYLLABUS	
	<ol style="list-style-type: none"><li>1. The far-field integrals, reciprocity, directivity Ch. 1</li><li>2. Radiation patterns of dipoles, loops and helices Ch. 2</li><li>3. Linear Arrays: analysis Ch. 4</li><li>4. Self impedance and mutual impedance of antenna elements Ch. 7</li><li>5. Radiation patterns of horns, patches and slot antennas Ch. 3</li><li>6. Frequency-independent antennas Ch. 8</li><li>7. Reflectors and lenses Ch. 10</li><li>8. The singularity expansion method Notes</li></ol>

BIBLIOGRAPHY	
	<p>Antenna Theory and Design, Robert S. Elliott, John Wiley and Sons (IEEE Press Series on Electromagnetic Wave Theory), 2003.</p> <p>C.A. Balanis, Antenna Theory: Analysis and Design, New York : Harper &amp; Row, 1982.</p> <p>R.F. Harrington, Field Computation by Moment Methods, New York: MacMillan, 1968.</p> <p>R.F. Harrington, Time-Harmonic Electromagnetic Fields, New York: McGraw-Hill, 1961.</p> <p>R.W.P. King and C.W. Harrison, Antennas and Waves: A Modern Approach, Cambridge, Mass.: M.I.T. Press, 1969</p> <p>S. Ramo, J.R. Whinnery, and T. Van Duzer, Fields and Waves in</p>

Communications Electronics,  
New York: Wiley, 1994.  
V.H. Rumsey, Frequency-Independent Antennas, New York: Academic Press, 1966  
E.J. Rothwell, Electromagnetics, Boca Raton, Florida: CRC Press, 2001.  
S. Silver, Ed., Microwave Antenna Theory and Design, New York: McGraw-Hill, 1949.  
W.L. Weeks, Antenna Engineering, New York: McGraw-Hill, 1968

#### COURSE MATERIAL

#### WEB REFERENCES

<http://www.angel.msu.edu>

#### COURSES RELATED

#### OTHER RELEVANT INFORMATION

UNIVERSITY	Ohio State University
Faculty	
Department	Dept. of Electrical and Computer Engineering
Course	Advanced Antenna Theory
Professor	Lee, J

CREDITS	
Hours	30
ECTS credits	

AIMS	
	<p>Students will become familiar with the following topics in antenna theory:</p> <ol style="list-style-type: none"><li>1. Analysis and design parameters pertaining to horn, lens and reflector antennas.</li><li>2. Analysis and design parameters pertaining to microstrip patch antennas and arrays.</li><li>3. Analysis and design parameters pertaining to waveguide slot arrays.</li><li>4. Analysis of near field antenna measurement techniques (including compact ranges), and antenna diagnostics.</li><li>5. The solutions to some antenna analysis/design problems in this course will require the use of a computer for calculating the antenna fields.</li></ol>

SYLLABUS	
	<p>Definition of antenna parameters (2) Antenna equivalent circuits and antenna theorems (4) Antenna mutual coupling (2) Horn antennas (3) Reflector and lens antennas (5) Microstrip patch antennas and arrays (5) Waveguide slot antennas and arrays (5) Analysis of near field antenna measurements, and antenna diagnostics (4)</p>

BIBLIOGRAPHY	
	<p>Antenna Theory, 2nd Ed., 1996 Balanis Harper &amp; Row</p> <p>References (supplemental reading)</p> <p>[1] R.E. Collin, Antennas and Radio Wave Propagation, McGraw-Hill, N.Y., 1985. [2] R.E. Collin and F.J. Zucker (Eds.), Antenna Theory, Vols. I and II, McGraw-Hill, N.Y., 1969.</p>

[3] S. Silver (Ed.), Microwave Antenna Theory and Design, MIT Radiation Lab. Series, McGraw- Hill, N.Y., 1949.

## COURSE MATERIAL

## WEB REFERENCES

## COURSES RELATED

## OTHER RELEVANT INFORMATION

### PREREQUISITES BY TOPIC

Familiarity with solution of classical boundary value problems in electromagnetics (interior and exterior problems); knowledge of basic electromagnetic theorems (reciprocity, image theory, equivalence theorems); familiarity with vector potentials

### CATALOG DESCRIPTION

Mutual impedance; moment method, aperture antennas; ground plane effects; horn and reflector antennas; pattern synthesis; antenna measurements.

UNIVERSITY	Ohio State University
Faculty	
Department	Electrical Engineering
Course	Radiation from Antennas
Professor	Rojas-Teran

CREDITS	
Hours	50
ECTS credits	

AIMS	
	<ol style="list-style-type: none"><li>1. Students will become familiar with basic antenna parameters.</li><li>2. Students will become familiar with radiation pattern calculations.</li><li>3. Students will become familiar with impedance matching of antennas.</li><li>4. Students will become familiar with characterization of simple antennas and arrays.</li><li>5. Students will become familiar with use of computers to solve simple antenna problems.</li></ol>

SYLLABUS	
	<p>Basic antenna parameters (6)</p> <p>Radiation pattern calculations (8)</p> <p>Impedance matching of antennas (6)</p> <p>Characterization of simple antennas and arrays (9)</p>

BIBLIOGRAPHY	
	<ul style="list-style-type: none"><li>• Antenna Theory and Design, 2nd Ed. Stutzman and Thiele. Wiley</li><li>• C.A. Balanis, Antenna Theory, Analysis and Design, J. Wiley, 1982.</li></ul>

COURSE MATERIAL	

WEB REFERENCES	
	<a href="http://www.ece.osu.edu/abet/std_syl_ec711.htm">http://www.ece.osu.edu/abet/std_syl_ec711.htm</a>

COURSES RELATED	
	Maxwell's equations, boundary conditions, vector potentials

## OTHER RELEVANT INFORMATION

### CATALOG DESCRIPTION

Dipole, loop, aperture, reflector, lens, surface wave, and other antennas; array theory; radiation resistance, directivity, and input impedance.

UNIVERSITY	STANFORD UNIVERSITY
Faculty	
Department	Electrical Engineering
Course	ANTENNAS FOR TELECOMMUNICATIONS AND REMOTE SENSING
Professor	Len Tyler

## CREDITS

Hours	54
ECTS credits	

## AIMS

SYLLABUS
<ul style="list-style-type: none"> <li>• Introduction to course</li> <li>• Vector Helmholtz Equation from Maxwell's Equations Solutions</li> <li>• Application of Vector Potential to Simple Antennas:</li> <li>• Antenna Parameters</li> <li>• Finite Length Dipole</li> <li>• Short Dipole and Half-Wavelength Dipole Compared</li> <li>• Driving Point Impedance: an Example Analytic Calculation</li> <li>• Moment Method Approach to Numerical Solution</li> <li>• Fields from Small Loops</li> <li>• Magnetic Dipoles</li> <li>• Electric and Magnetic Dipoles Compared</li> <li>• Balanced and Unbalanced Antennas/Transmission Line Systems</li> <li>• The "Balun"</li> <li>• Balanced and Unbalanced Systems</li> <li>• Introduction to Arrays</li> <li>• Discrete in line</li> <li>• Parasitic Arrays — the Yagi-Uda</li> <li>• Log-Periodic Arrays</li> <li>• Introduction to Aperture Antennas</li> <li>• The Equivalence Principle</li> </ul>

- Aperture in a Conducting Plane
- Optics of Large Aperture Antennas
- Antenna Optics
- Antenna Temperature and Noise

#### BIBLIOGRAPHY

- Stutzman & Thiele, Antenna Theory and Design, 2nd Edition, 1998
- Kraus, Antennas 2nd ed., McGraw-Hill, 1988.
- Balanis, Antenna Theory, 2nd Ed., 1996 Harper & Row

#### COURSE MATERIAL

#### WEB REFERENCES

<http://www.stanford.edu/class/ee252/handouts/ee252syllabus.pdf>

#### COURSES RELATED

#### OTHER RELEVANT INFORMATION

The Final Project will combine numerical solution for the properties of an antenna structure with either a design and analysis problem.

UNIVERSITY	University of California Los Angeles
Faculty	
Department	Electrical Engineering
Course	Wireless Communication Links and Antennas
Professor	Y. Rahmat-Samii

CREDITS	
Hours	30
ECTS credits	

AIMS	
	<p>This is an elective course for electrical engineering and biomedical engineering majors. The goal of the course is to introduce students to the fundamentals of antenna theory, to expose them to examples of applications, and to exercise them to engineering design and problem solving skills. This course contributes to the Educational Objectives 1 (Fundamental Knowledge), 2 (Specialization), 3 (Design Skills), and 5 (Self-Learning).</p>

SYLLABUS	
	<p>Introduction to basic theory of antennas and applications to wireless communication link design, including array synthesis. Adaptive arrays. Friis transmission formula, wireless communication link budget, radar equations. Cell-site and mobile antennas, broadband antennas, multipath fading, and other propagation phenomena.</p> <ul style="list-style-type: none"><li>□ Maxwell Equations and boundary conditions. 3 hrs.</li><li>□ Wave equations and vector potentials. 1.5 hrs.</li><li>□ Radiation pattern and other antenna parameters. 3 hrs.</li><li>□ Dipole and small loop antennas. 3 hrs.</li><li>□ Friis transmission formula, Link budget and wireless propagation issues. 3 hrs.</li><li>□ Linear array, array feed and planar array. 4.5 hrs.</li><li>□ Computational EM (MoM for line antennas). 1.5 hrs.</li><li>□ Yagi-Uda and large loop antennas. 4.5 hrs.</li><li>□ Fundamental theorems. 3 hrs.</li><li>□ Microstrip antennas &amp; Broadband antennas. 3 hrs.</li></ul>

BIBLIOGRAPHY	
	<ul style="list-style-type: none"><li>□ W. L. Stutzman and G. A. Thiele, Antenna Theory and Design, 2nd edition, Wiley, NY, 1998.</li><li>□ Y. Rahmat-Samii and Y. Wang, Lecture Notes.</li></ul>



COURSE MATERIAL	

WEB REFERENCES	

COURSES RELATED	
	Electromagnetic Waves

OTHER RELEVANT INFORMATION	

UNIVERSITY	University of Massachusetts. Amherst
Faculty	
Department	Electrical and Computer Engineering
Course	Antenna Theory & Design
Professor	

CREDITS	
Hours	
ECTS credits	

AIMS	

SYLLABUS	
	Antenna patterns, gain, directivity, polarization, effective aperture; radiated fields of short dipoles and linear antennas and loop antennas; linear and planar arrays; array design techniques; antenna self- and mutual impedance; broadband and frequency-independent antennas; log-periodic structures; rectangular and circular aperture antennas; reflectors; Fourier transform methods; microstrip antennas.

BIBLIOGRAPHY	
	"Antenna Theory: Analysis and Design", 2nd edition by Constantine A. Balanis, 1996, John Wiley & Sons, ISBN 0471592684

COURSE MATERIAL	

WEB REFERENCES	

COURSES RELATED	

OTHER RELEVANT INFORMATION	
	Prerequisite: basic knowledge of electromagnetic theory including Maxwell's equations, the wave equation and differential and integral calculus