Department of Electrical Engineering and Information Technology

Module manual of all english courses
Date: 2019-06-05

TECHNISCHE UNIVERSITÄT DARMSTADT

Department of Electrical Engineering and Information Technology

Module manual: Department of Electrical Engineering and Information Technology
Module manual of all english courses
Date: 2019-06-05

Department of Electrical Engineering and Information Technology
Email: servicezentrum@etit.tu-darmstadt.de

Contents

1 Lectures

Module name Plasma Physics					
Module Nr. 18-bf-2020	**Credit Points** 3 CP	**Workload** 90 h	**Self study** 60 h	**Duration** 1	**Cycle offered** WiSe
Language German and English			**Module owner** Prof. Dr. Oliver Boine-Frankenheim		

1	**Content** The lecture will cover the following topics: Occurrence of plasma in our environment – definition of a plasma – particle dynamics in em fields – fluid description of a plasma – waves in plasmas – plasma instabilities – kinetic description of a plasma – plasma generation – plasma diagnostics – plasma applications in the industry.
2	**Learning objectives / Learning Outcomes** The fundmental properties of plasmas, waves in plasmas as well as the interaction of electromagnetic fields with plasmas should be worked out and understood by the students during the course of this lecture.
3	**Recommended prerequisite for participation**
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Oral Examination, Duration: 30 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Oral Examination, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSc Physik
7	**References** The transparencies can be downloaded from the TUCaN site.

Courses

Course Nr. 18-bf-2020-vl	**Course name** Plasma Physics		
Instructor Prof. Dr. Oliver Boine-Frankenheim		**Type** Lecture	**SWS** 2

Module name Applied Superconductivity					
Module Nr. 18-bf-2030	**Credit Points** 3 CP	**Workload** 90 h	**Self study** 60 h	**Duration** 1	**Cycle offered** SoSe
Language German and English			**Module owner** Prof. Dr. Oliver Boine-Frankenheim		

1 Content

- Basics of electrical conductivity at DC and RF
- Kamerligh-Onnes experiment, Meissner effect
- Superconductor state diagram
- London equations, Typ I / II Superconductor
- Cooper pairs (briefly: BCS theory, GL theory)
- Flux quantization, Flux vortices
- AC superconductivity, two fluid model, RF cavities
- Cooper pair tunneling, Josephson junctions
- Metrology: SQUIDs, (quantum-) Hall effect
- Superconductor magnetization, Hysteresis, Bean‘s model
- Applications: Magnets in accelerator and medical technology, precision field and current measurements, energy engineering

2 Learning objectives / Learning Outcomes

The students obtain a phenomenological understanding of superconductivity, which enables them to apply superconductors in engineering practice. Starting from Maxwellian electrodynamics, superconductors are in introduced as perfect conductors at zero frequency. Both their DC and AC properties are discussed. Theory shall be reduced as much as possible. Quantum mechanics is not a requirement for the course, however, simplified quantum mechanical models will be introduced. The focus of the lecture is put on applications, e.g. magnet technology or precision metrology.

3 Recommended prerequisite for participation

Electrodynamics (Maxwell’s equations)

4 Form of examination

Module Final Examination:

- Module Examination (Technical Examination, Oral Examination, Duration: 30 min, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Technical Examination, Oral Examination, Weighting: 100 %)

6 Usability of this module

MSc ETiT, MSc WI-ETiT, MSc iCE, BSc/MSc CE

7 References

- W. Buckel, R. Kleiner: „Supraleitung Grundlagen und Anwendungen“; Wiley VCH, 7. Auflage 2013.
- R.G. Sharma; „Superconductivity, Basics and Applications to Magnets“; Springer International Publishing, 2015 (online available).
- H. Padamsee, J. Knobloch, T. Hays: „RF-Superconductivity for Accelerators“; 2nd edition; Wiley VCH Weinheim, 2011.
- P. Seidel (Ed.), „Applied Superconductivity“, Wiley VCH Weinheim, 2015.

Courses

	Course Nr.	Course name		
	18-bf-2030-vl	Applied Superconductivity		
	Instructor		**Type**	**SWS**
	Dr.-Ing. Uwe Niedermayer		Lecture	2

Module name
Energy Converters - CAD and System Dynamics

Module Nr.	Credit Points	Workload	Self study	Duration	Cycle offered
18-bi-2010	7 CP	210 h	135 h	1	WiSe

Language	Module owner
English	Prof. Dr. techn. Dr.h.c. Andreas Binder

1 Content

Design of cage-rotor and wound-rotor induction machines: Calculation of forces, torque, losses, efficiency, cooling and temperature rise. Transient machine performance of converter-fed dc machines and line-fed and inverter-fed ac machines. Theory is illustrated by examples: Sudden short circuit, load step, run up. For control design transfer functions of machines are derived. In the exercise lessons demonstration examples of power transformer and induction motor design are given. The students design one induction machine in small groups by themselves. Transient performance calculation is trained by using Laplace-Transformation and MATLAB.

2 Learning objectives / Learning Outcomes

With active collaboration during lectures by asking questions related to those parts, which have not been completely understood by you, as well as by independent solving of examples ahead of the tutorial (not as late as during preparation for examination) you should be able to:

- do and explain the electromagnetic design of an induction machine both analytically and with use of computer program,
- understand and predict the thermal performance of electrical drives in a simplified way,
- calculate the instationary performance of separately excited DC drives
- to predict the dynamical performance of AC polyphase machines with space vector theory and use the MATLAB/Simulink package for this purpose.

3 Recommended prerequisite for participation

Bachelor of Science in Electrical Engineering, Power Engineering or similar

4 Form of examination

Module Final Examination:

- Module Examination (Technical Examination, Optional, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Technical Examination, Optional, Weighting: 100 %)

6 Usability of this module

MSc ETiT, MSc MEC, MSc EPE

7 References

Detailed textbook and collection of exercises; Complete set of PowerPoint presentation

Leonhard, W.: Control of electrical drives, Springer, 1996
Fitzgerald, A.; Kingsley, C.: Kusko, A.: Electric machinery, McGraw-Hill, 1971
McPherson, G.: An Introduction to Electrical Machines and Transformers, Wiley, 1981
Say, M.: Alternating Current Machines, Wiley, 1983
Say, M.; Taylor, E.: Direct Current Machines, Pitman, 1983
Vas, P.: Vector control of ac machines, Oxford Univ. Press, 1990
Novotny, D,; Lipo, T.: Vector control and dynamics of ac drives, Clarendon, 1996

Courses

Course Nr.	Course name
18-bi-2010-vl	Energy Converters - CAD and System Dynamics

Instructor	Type	SWS
Prof. Dr. techn. Dr.h.c. Andreas Binder	Lecture	3

	Course Nr.	Course name		
	18-bi-2010-ue	Energy Converters - CAD and System Dynamics		
	Instructor		**Type**	**SWS**
	Prof. Dr. techn. Dr.h.c. Andreas Binder		Practice	2

Module name Large Generators and High Power Drives					
Module Nr. 18-bi-2020	**Credit Points** 4 CP	**Workload** 120 h	**Self study** 75 h	**Duration** 1	**Cycle offered** WiSe
Language German and English			**Module owner** Prof. Dr. techn. Dr.h.c. Andreas Binder		

1	**Content** Design of large electric generators: Special cooling methods with air, hydrogen and water, loss evaluation, especially eddy current losses, and measures to reduce the additional losses. Design of big hydrogenerators up to 800 MVA and turbo generators up to 2000 MVA with desing examples. Application of power electronics in large variable speed drives with synchronous motors: Synchronous converter and cyclo-converter. Numerous photographs to illustrate applications, excursion with students to special firms or plants.
2	**Learning objectives / Learning Outcomes** Expert knowledge in design of generators, large drives, their cooling systems and operational performance is acquired.
3	**Recommended prerequisite for participation** Physics, Electrical Machines and Drives, Electrical Power Engineering
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Optional, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Optional, Weighting: 100 %)
6	**Usability of this module** MSc EPE, MSc ETiT, MSc MEC, MSc WI-ETiT
7	**References** Detailed textbook with calculated examples; Vas, P.: Parameter estimation, condition monitoring, and diagnosis of electrical machines, Clarendon Press, 1993 Fitzgerald, A.; Kingsley, C.; Kusko, A.: Electric machinery, McGraw-Hill, 2003 Leonhard, W.: Control of electrical drives, Springer, 1996

Courses

Course Nr. 18-bi-2020-vl	**Course name** Large Generators and High Power Drives		
Instructor Dr. techn. Georg Traxler-Samek		**Type** Lecture	**SWS** 2

Course Nr. 18-bi-2020-ue	**Course name** Large Generators and High Power Drives		
Instructor Dr. techn. Georg Traxler-Samek		**Type** Practice	**SWS** 1

Module name Motor Development for Electrical Drive Systems					
Module Nr. 18-bi-2032	**Credit Points** 4 CP	**Workload** 120 h	**Self study** 75 h	**Duration** 1	**Cycle offered** SoSe
Language English			**Module owner** Prof. Dr. techn. Dr.h.c. Andreas Binder		

1	**Content** For the wide field of the drive technology at low and medium power range from 1 kW up to about 500 kW. . . 1 MW the conventional drives and the current trends of developments are explained to the students. Grid operated and inverter-fed induction drives, permanent-magnet synchronous drives with and without damper cage (“brushless dc drives”), synchronous and switched reluctance drives and permanent magnet and electrically excited DC servo drives are covered. As a "newcomer" in the electrical machines field, the transversal flux machines and modular synchronous motors are introduced.
2	**Learning objectives / Learning Outcomes** For the students who are interested in the fields of design, operation or development of electrical drives in their future career, the latest knowledge about • modern computational methods (e.g. finite elements), • advanced materials (e.g. high energy magnets, ceramic bearings), • innovative drive concepts (e.g. transversal flux machines) and • measurement and experiment techniques are imparted.
3	**Recommended prerequisite for participation** Completed Bachelor of Electrical Engineering or equivalent degrees
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Optional, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Optional, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSc MEC, **not** MSc EPE
7	**References** A detailed script is available for the lecture. In the tutorials design of PM machines, switched reluctance drives and inverter-fed induction motors are explained.

Courses

Course Nr. 18-bi-2030-vl	**Course name** Motor Development for Electrical Drive Systems		
Instructor Prof. Dr. techn. Dr.h.c. Andreas Binder		**Type** Lecture	**SWS** 2
Course Nr. 18-bi-2030-ue	**Course name** Motor Development for Electrical Drive Systems		
Instructor Prof. Dr. techn. Dr.h.c. Andreas Binder		**Type** Practice	**SWS** 1

Module name New Technologies of Electrical Energy Converters and Actuators					
Module Nr. 18-bi-2040	**Credit Points** 4 CP	**Workload** 120 h	**Self study** 75 h	**Duration** 1	**Cycle offered** SoSe
Language German and English			**Module owner** Prof. Dr. techn. Dr.h.c. Andreas Binder		

1 Content

Goal: The application of new technologies, i.e. super conduction, magnetic levitation techniques and magneto-hydrodynamic converter principles, are introduced to the students. The physical operation mode in principle, implemented prototypes and the current state of the development are described in detail.
Content:
Application of the superconductors for electrical energy converters:

- rotating electrical machines (motors and generators),
- solenoid coils for the fusion research,
- locomotive- and railway transformers,
- magnetic bearings.

Active magnetic bearings ("magnetic levitation"):

- basics of the magnetic levitation technique,
- magnetic bearings for high speed drives in kW to MW range,
- application for high-speed trains with linear drives.

Magneto-hydrodynamic energy conversion:

- physical principle,
- state of the art and perspectives.

Fusion research:

- magnetic field arrangements for contactless plasma inclusion,
- state of the current research.

2 Learning objectives / Learning Outcomes

Basic knowledge in application of superconductivity in energy systems is understood as well as magnetic levitation, magnetohydrodynamics and fusion technology.

3 Recommended prerequisite for participation

Physics, Electrical Machines and Drives, Electrical Power Engineering

4 Form of examination

Module Final Examination:

- Module Examination (Technical Examination, Optional, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Technical Examination, Optional, Weighting: 100 %)

6 Usability of this module

MSc EPE, MSc ETiT, MSc MEC, MSc WI-ETiT

7 References

Detailed textbook; Komarek, P.: Hochstromanwendungen der Supraleitung, Teubner, Stuttgart, 1995
Buckel, W.: Supraleitung, VHS-Wiley, Weinheim, 1994
Schweitzer, G.; Traxler, A.; Bleuler, H.: Magnetlager, Springer, Berlin, 1993
Schmidt, E.: Unkonventionelle Energiewandler, Elitera, 1975

Courses

	Course Nr. 18-bi-2040-vl	**Course name** New Technologies of Electrical Energy Converters and Actuators		
	Instructor Prof. Dr. techn. Dr.h.c. Andreas Binder		**Type** Lecture	**SWS** 2
	Course Nr. 18-bi-2040-ue	**Course name** New Technologies of Electrical Energy Converters and Actuators		
	Instructor Prof. Dr. techn. Dr.h.c. Andreas Binder		**Type** Practice	**SWS** 1

Module name Electrothermal Processes					
Module Nr. 18-bi-2070	**Credit Points** 3 CP	**Workload** 90 h	**Self study** 60 h	**Duration** 1	**Cycle offered** SoSe
Language German and English			**Module owner** Prof. Dr. techn. Dr.h.c. Andreas Binder		

1	**Content** First the technical and economic importance of electrothermal processes will be pointed out. In addition to that, advantages, characteristics and applications of electroheat processes will be shown by typical examples. The second part of the lecture is about thermotechnical and electrotechnical basics, which are necessary to understand electrothermal processes. The main part of the lecture deals with examples of electrothermal processes, like induction heating (focus), conductive and dielectric heating as well as indirect resistance heating. Examples from industry are shown, and it will be explained how the applications are designed with numerical simulation tools (FEM-based) and analytical methods (calculation of electromagnetic fields). At the end of the lecture special processes like laser applications will be shown.
2	**Learning objectives / Learning Outcomes** Understanding of design and calculation of electrothermal processes and their applications
3	**Recommended prerequisite for participation** B.Sc. Electrical Engineering or Mechatronics
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Optional, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Optional, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSc MEC, MSc EPE, MSc Wi-ETiT
7	**References** Lecture notes; Fasholz, J., Orth, G.: Induktive Erwärmung, RWE Energie AG, Essen, 4. Aufl., 1991; Nacke, B.; Baake, E. (Hsg.): Induktives Erwärmen, Vulkan-Verlag, 2014

Courses

Course Nr. 18-bi-2070-vl	**Course name** Electrothermal Processes		
Instructor Dr.-Ing. Elmar Wrona		**Type** Lecture	**SWS** 2

Module name Electric Railways					
Module Nr. 18-bi-2140	**Credit Points** 5 CP	**Workload** 150 h	**Self study** 105 h	**Duration** 1	**Cycle offered** WiSe
Language German and English			**Module owner** Prof. Dr. techn. Dr.h.c. Andreas Binder		

1	**Content** • Mechanics of traction • Electrical part of traction vehicles • Converter and motors for electrical traction • Monitoring systems • Comparison of different power supply systems • DC- and AC- systems for light- and heavy rail • Problems of earthing and earth return currents • Sub stations, converters, power plants
2	**Learning objectives / Learning Outcomes** Comprehension of the basic concepts of electric traction vehicles and power supply for electric railways
3	**Recommended prerequisite for participation** Basic knowledge in electrical machines and drives
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Optional, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Optional, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSc MEC, MSc Wi-ETiT
7	**References** Text book for the lecture. Bendel, H. u.a.: Die elektrische Lokomotive. Transpress, Berlin, 1994. Filipovic, Z: Elektrische Bahnen. Springer, Berlin, Heidelberg, 1995. Steimel, A.: Elektrische Triebfahrzeuge und ihre Energieversorgung. Oldenburg Industrieverlag, 2006. Bäzold, D. u.a.: Elektrische Lokomotion deutscher Eisenbahnen. Alba, Düsseldorf, 1993. Obermayer, H. J.: Internationaler Schnellverkehr. Franckh-Kosmos, Stuttgart, 1994; Guckow, A.; Kiessling, F.; Puschmann, R.: Fahrleitungen el. Bahnen. Teubner, Stuttgart, 1997. Schaefer, H.: Elektrotechnische Anlagen für Bahnstrom. Eisenbahn-Fachverlag, Heidelberg, 1981

Courses

Course Nr. 18-bi-2140-vl	**Course name** Electric Railways	
Instructor Prof. Harald Neudorfer	**Type** Lecture	**SWS** 3

Module name Electric drives for cars					
Module Nr. 18-bi-2150	**Credit Points** 4 CP	**Workload** 120 h	**Self study** 75 h	**Duration** 1	**Cycle offered** Every 2. Sem.
Language English			**Module owner** Prof. Dr. techn. Dr.h.c. Andreas Binder		

1 Content

This course introduces the students to the different design aspects of electric drives used in automotive applications, comprising both high power density high speed traction and small mass produced auxiliary drives. Since the target audience comprises students from different degree programmes, the course first reviews basics of electromagnetic power conversion principles and design principles of PM based machines. The discussion of the electric drives themselves comprises the various facets of their design as part of a complex system, such as operating requirements, configurations, material choices, parasitic effects and their mitigation, electric and thermal stress, as well as manufacturing related questions, notably as they affect the design of the mass produced auxiliary drives.

2 Learning objectives / Learning Outcomes

At the end of the course, the students will know about design principles of PM based machines, electric drives: topologies, operating areas, dynamic performance and configuration of traction drives for hybrid cars and electric vehicles as they apply to electric drives for cars. In addition to traction drives, they will also be familiar with auxiliary drives used in cars. They will understand the parasitic effects of inverter induced bearing currents, the insulation material used for the electric winding and the winding stress at inverter supply. They will be familiar with the different cooling principles and thermal modelling, as well as the thermal aspects of the integration into the car. They will also know about the main failure modes that may occur with electric drives used for cars, the different lamination sheets used and their manufacturing.

3 Recommended prerequisite for participation

Completed Bachelor of Electrical Engineering or equivalent degree.

4 Form of examination

Module Final Examination:

- Module Examination (Technical Examination, Optional, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Technical Examination, Optional, Weighting: 100 %)

6 Usability of this module

7 References

Courses

Course Nr. 18-bi-2150-vl	**Course name** Electric drives for cars		
Instructor Prof. Dr. Annette Mütze		**Type** Lecture	**SWS** 2

Course Nr. 18-bi-2150-ue	**Course name** Electric drives for cars		
Instructor Prof. Dr. Annette Mütze		**Type** Practice	**SWS** 1

Module name Computational Electromagnetics and Applications II					
Module Nr. 18-dg-2010	**Credit Points** 3 CP	**Workload** 90 h	**Self study** 60 h	**Duration** 1	**Cycle offered** SoSe
Language English			**Module owner** Prof. Dr.-Ing. Herbert De Gersem		

1 Content

- Fundamentals of the Finite Element Method: weighted residuals, projection methods, variational formulations, weak formulations; Finite elements: definitions, classification, first order Whitney element complex, higher order elements; convergence and precision;
- Implementation details: data structures, matrix assembly, postprocessing of the solution;
- FEM application to electromagnetic problems: electrostatics, magnetostatics, stationary currents, quasistatics, wave propagation.

2 Learning objectives / Learning Outcomes

Students will master the theoretical basics of finite element methods. They understand details regarding the implementation of the method for stationary and quasistationary fields. They can apply the finite element method in electrical engineering.

3 Recommended prerequisite for participation

Maxwell's equations, infinitesimal calculus, vector calculus. Basics of differential equations and linear algebra.

4 Form of examination

Module Final Examination:

- Module Examination (Technical Examination, Oral Examination, Duration: 30 min, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Technical Examination, Oral Examination, Weighting: 100 %)

6 Usability of this module

MSc ETiT

7 References

- Lecture slides.
- Willi Törnig, Michael Gipser, Bernhard Kaspar. Numerische Lösung von partiellen Differentialgleichungen der Technik: Differenzenverfahren, Finite Elemente und die Behandlung großer Gleichungssysteme. Teubner, 1991
- Rolf Steinbuch. Finite Elemente - Ein Einstieg. Springer, 1998.
- Alain Bossavit. Computational electromagnetism: variational formulations, complementarity, edge elements. Academic Press, 1997
- Klaus Knothe, Heribert Wessels. Finite Elemente: Eine Einführung für Ingenieure (3. Aufl.). Springer, 1999.
- P. P. Silvester, R. L. Ferrari. Finite Elements for Electrical Engineers, Cambridge Universtity Press, 1991
- O. C. Zienkiewicz, R. L. Taylor. The finite element method (4. ed.). McGraw-Hill, 1989

Courses

Course Nr. 18-dg-2010-vl	**Course name** Computational Electromagnetics and Applications II	
Instructor Prof. Dr.-Ing. Herbert De Gersem	**Type** Lecture	**SWS** 2

Module name Computational Electromagnetics and Applications III					
Module Nr. 18-dg-2020	**Credit Points** 3 CP	**Workload** 90 h	**Self study** 60 h	**Duration** 1	**Cycle offered** WiSe/SoSe
Language German and English			**Module owner** Prof. Dr.-Ing. Herbert De Gersem		

1	**Content** Finite Difference, Finite Volume and Finite Element Methods for the solution of Maxwell equations in the time domain. High order Discontinuous Galerkin methods. Stability and convergence analysis. High performance computing. Particle based simulations for beams and plasmas.
2	**Learning objectives / Learning Outcomes** Students lern the theoretical basis of advanced simulation techniques for time dependent electromagnetic fields. Furthermore, the lecture mediates practical skills for the implementation, analysis and application of simulation codes for common problems of Electrical Engineering
3	**Recommended prerequisite for participation** Maxwell's equations, infinitesimal calculus, vector calculus. Basics of differential equations and linear algebra
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Oral Examination, Duration: 30 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Oral Examination, Weighting: 100 %)
6	**Usability of this module** MSc ETiT
7	**References** Lecture slides, matlab scripts, various literature sources

Courses

Course Nr. 18-dg-2020-vl	**Course name** Computational Electromagnetics and Applications III	
Instructor Privatdozent Dr. rer. nat. Erion Gjonaj	**Type** Lecture	**SWS** 2

Module name Electromagnetics and Differential Forms					
Module Nr. 18-dg-2030	**Credit Points** 3 CP	**Workload** 90 h	**Self study** 60 h	**Duration** 1	**Cycle offered** SoSe
Language English			**Module owner** Prof. Dr.-Ing. Herbert De Gersem		

1 Content

In the recent years, the amount of literature that deals with physical models in terms of differential forms (DF) has increased strongly. For instance, DF allow a clear and elegant representation of electromagnetics (EM). The operators grad, curl, and div of vector analysis are replaced by a single operator of the exterior derivative. Similarly, the integral theorems of Gauss and Stokes are replaced by a single integral theorem. Vector analysis is limited to three dimensions, while DF can be applied to any dimensions. This is useful for the relativistic formulations in four dimensions.

Since DF can be canonically integrated over appropriate domains they lend themselves naturally to discretizations of the finite integration type.

This lecture series provides an introduction into DF calculus, and its relation to vector analysis. Maxwell's equations and the constitutive relations are expressed in terms of DF, and the main steps into discretization are outlined briefly.

2 Learning objectives / Learning Outcomes

Students will acquire a detailed understanding of how to describe EM in terms of DF.
*How "space" (and "time") can be modelled by differentiable manifolds;
*How a class of physical fields can be represented by differential forms;
*How Maxwell's equations and constitutive relations translate into the language of DF;
*How this continuous representation can be discretized.

3 Recommended prerequisite for participation

It is recommended that the students have basic knowledge about
*Electromagnetics (Maxwell's equations in differential and integral form; constitutive relations; EM potentials);
*Vector analysis (scalar and vector fields; differential operators grad, curl, and div; integral theorems of Gauss and Stokes).

4 Form of examination

Module Final Examination:

- Module Examination (Technical Examination, Oral Examination, Duration: 30 min, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Technical Examination, Oral Examination, Weighting: 100 %)

6 Usability of this module

M.Sc. CE; M.Sc. etit, particularly major in CED; M.Sc. Mechatronics

7 References

M. Fecko: Differential Geometry and Lie Groups for Physicists, Cambridge University Press, 2006
F. Hehl, Y. Obukhov: Foundations of Classical Electrodynamics, Birkhäuser, 2003
K. Jänich: Vector Analysis, Springer, 2001

Courses

Course Nr. 18-dg-2030-vl	**Course name** Electromagnetics and Differential Forms		
Instructor Prof. Dr.-Ing. Stefan Kurz		**Type** Lecture	**SWS** 2

Module name					
X-Ray Free Electron Lasers					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-dg-2110	4 CP	120 h	75 h	1	SoSe
Language			**Module owner**		
English			Prof. Dr.-Ing. Herbert De Gersem		

1 Content

Optical lasers cannot produce x-rays of photons and high-gain free-electron lasers (FELs) are being developed as extremely bright sources of x-ray radiation. The peak brightness of these facilities exceeds that of other sources by more than ten orders of magnitude. FELs produce hard x-ray beams with very high transverse coherence and femtosecond pulse length. These characteristics open up new areas of x-ray science, such as femtosecond time-domain spectroscopy etc.

In this course an overview of the basics of FEL physics is given. We start our discussion from basics principles of particle acceleration and synchrotron radiation, consider the electron motion in an undulator and explain the most important steps to derive the high-gain FEL model. The performance of the high-gain FEL in the linear and the non-linear regimes is considered.

The self-amplified spontaneous emission (SASE) option is introduced and characterized. We discuss new schemes for enhancing of the FEL performance. The theoretical considerations in the course are partially illustrated by the results of numerical simulations and experiments. The numerical algorithms are shortly discussed.

2 Learning objectives / Learning Outcomes

The student should understand the basics of physics of free electron lasers.

3 Recommended prerequisite for participation

Maxwell's equations, integral and differential calculus, vector analysis

4 Form of examination

Module Final Examination:

- Module Examination (Technical Examination, Oral Examination, Duration: 30 min, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Technical Examination, Oral Examination, Weighting: 100 %)

6 Usability of this module

MSc ETiT, MSc iST, MSc iCE, MSc Wi-ETiT

7 References

The foils of the lecture will be available at: http://www.desy.de/~zagor/lecturesFEL

K. Wille, Physik der Teilchenbeschleuniger und Synchrotron- strahlungsquellen, Teuner Verlag, 1996.
P. Schmüser, M. Dohlus, J. Rossbach, Ultraviolet and Soft X-Ray Free-Electron Lasers, Springer, 2008.
E. L. Saldin, E. A. Schneidmiller, M. V. Yurkov, The Physics of Free Electron Lasers, Springer, 1999.

Courses

Course Nr.	Course name		
18-dg-2110-vl	X-Ray Free Electron Lasers		
Instructor		**Type**	**SWS**
PD Dr. Igor Zagorodnov		Lecture	2
Course Nr.	**Course name**		
18-dg-2110-ue	X-Ray Free Electron Lasers		
Instructor		**Type**	**SWS**
PD Dr. Igor Zagorodnov		Practice	1

Module name Technical Electrodynamics for iCE					
Module Nr. 18-dg-2150	**Credit Points** 5 CP	**Workload** 150 h	**Self study** 90 h	**Duration** 1	**Cycle offered** WiSe
Language English			**Module owner** Prof. Dr.-Ing. Herbert De Gersem		

1	**Content** 1) Fundamentals of electromagnetic field theory – Maxwell's equations in differential and integral form; Electromagnetic waves: propagation in free space, polarization, reflection/refraction. 2) Numerical solution of electromagnetic field problems – Space discretization with surface and volume meshes; Main numerical algorithms for discrete local approximation of Maxwell's equations; Finite Integration Technique; Time and frequency domain solution methods; Stability, convergence. 3) Practical aspects of electromagnetic simulation – Introduction to accuracy issues; Preprocessing: 3D geometry, computational domain, boundary conditions, electromagnetic field sources; Time vs frequency domain; Postprocessing; Network parameter extraction. 4) Application to typical high-frequency devices: Waveguide / resonator structures, planar structures
2	**Learning objectives / Learning Outcomes** Students will understand fundamental principles of wave propagation, guided waves and antennas. They will be able to model microwave components with simulation software tools. They will have experience with state of the art software tools for electromagnetic fields.
3	**Recommended prerequisite for participation** Fundamentals of electrodynamics (Grundlagen der Elektrodynamik)
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Written Examination, Duration: 180 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Written Examination, Weighting: 100 %)
6	**Usability of this module** MSc iCE
7	**References** Course manuscript Additional References: • D.K. Cheng: Field and Wave Electromagnetics. Addison-Wesley, New York, 1992 • C.A. Balanis: Advanced Engineering Electromagnetics. Wiley, New York, 1989 • Andrew F. Peterson et al. Computational Methods for Electromagnetics. Wiley-IEEE Press, 1997.

Courses

Course Nr. 18-dg-2150-vl	**Course name** Technical Electrodynamics for iCE	
Instructor Prof. Dr. Irina Munteanu	**Type** Lecture	**SWS** 2

Course Nr. 18-dg-2150-ue	**Course name** Technical Electrodynamics for iCE	
Instructor Prof. Dr. Irina Munteanu	**Type** Practice	**SWS** 2

Module name
Fast Boundary Element Methods for Engineers

Module Nr.	Credit Points	Workload	Self study	Duration	Cycle offered
18-dg-2160	3 CP	90 h	60 h	1	WiSe

Language	Module owner
English	Prof. Dr.-Ing. Herbert De Gersem

1 Content

How to solve field problems numerically on the computer? The Boundary Element Method (BEM) has developed into an important alternative to domain-oriented approaches (like Finite Elements), ever since fast implementations are available. The BEM reduces the dimensionality of the problem and can easily take into account unbounded domains.
Starting from the representation formulas of Kirchhoff and Stratton-Chu boundary integral equations are derived. Next, their discretization by collocation and Galerkin methods is discussed.
The resulting fully populated matrices have to be compressed for practical applications, by Fast Multipole or Adaptive Cross Approximation methods.
Industrial examples for application of the BEM are considered, for instance acoustic and electromagnetic scattering problems, and thermal analysis.Programming homework will be assigned, to deepen the students' understanding of the contents.

2 Learning objectives / Learning Outcomes

Students will acquire a detailed understanding of Modeling and Simulation with BEM.

- Derivation: convert certain types of partial differential equations to boundary integral equations
- Discretization: obtain boundary element methods from boundary integral equations
- Compression: efficiently store and solve the resulting linear systems of equationsApplication: solve practical field problems in engineering, in the acoustic, electromagnetic and thermal domains

3 Recommended prerequisite for participation

Basic knowledge about numerical methods for the solution of partial differential equations (e.g., Finite Elements).
Basic knowledge about modelling and simulation in an application domain (e.g., acoustic domain: wave equation; electromagnetic domain: Maxwell's equations; thermal domain: heat equation).

4 Form of examination

Module Final Examination:

- Module Examination (Technical Examination, Oral Examination, Duration: 30 min, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Technical Examination, Oral Examination, Weighting: 100 %)

6 Usability of this module

MSc ETiT, MSc MEC, MSc CE

7 References

O. Steinbach: Numerical Approximation Methods for Elliptic Boundary Value Problems
S. Rjasanow, O. Steinbach: The Fast Solution of Boundary Integral Equations

Courses

Course Nr.	Course name		
18-dg-2160-vl	Fast Boundary Element Methods for Engineers		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Stefan Kurz		Lecture	2

Module name Simulation of beam dynamics and electtromagnetic fields in accelerators					
Module Nr. 18-dg-2170	**Credit Points** 3 CP	**Workload** 90 h	**Self study** 60 h	**Duration** 1	**Cycle offered** Every 2. Sem.
Language German and English			**Module owner** Prof. Dr.-Ing. Herbert De Gersem		

1	**Content** Particle tracking methods: types of particle methods, relationship to Vlasov model – Integration of equations of motion: Boris pusher, numerical stability, symplecticity – Electrostatic PIC: Green functions, FFT and FD methods, charge deposition, field interpolation, spline shape functions – DC-gun simulation: space charge limited emission – Tracking in the Lorenz frame – Map based tracking methods – Electromagnetic PIC: FDTD method, charge-conserving current deposition, Boris scheme, low dispersion methods – Wakefields and impedances: simulation of ultra-relativistic beams – Plasma Wakefield Acceleration – Parallel computing
2	**Learning objectives / Learning Outcomes** The lecture gives an overview on the numerical modeling of charged particle beams and electromagnetic fields in acceerators. Emphasis is given to the simulation of collective effects caused by space-charge and electromagnetic wakefields. The lecture targets master students focusing on different discilines of electrical engineering and physics. These include the theory of electromagnetic fields, computational engineering as well as computational and experimental accelerator physics. The level is sufficient to provide a solid foundation for contemporary simulation methods for particle beams in accelerators. Furthermre, for experimental accelerator physicists, the lecture provides insight into the different simulation tools, their application, their advantages and also their pitfalls and ranges of validity. During the course, practical simulation examples referring to actual problems at DESY, GSI and the S-DALINAC will be presented.
3	**Recommended prerequisite for participation**
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Oral Examination, Duration: 30 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Oral Examination, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSc Physik
7	**References**

Courses

Course Nr. 18-dg-2170-vl	**Course name** Simulation of beam dynamics and electtromagnetic fields in accelerators	
Instructor Privatdozent Dr. rer. nat. Erion Gjonaj	**Type** Lecture	**SWS** 2

Module name Verification Technology					
Module Nr. 18-ev-2020	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1	**Cycle offered** WiSe
Language English			**Module owner** Prof. Dr. Hans Eveking		

1	**Content** Decision diagrams, Satisfiability checking, Symbolic state-space traversal, Reachability analysis, Semantics of temporal logics (CTL, LTL), Symbolic and bounded model-checking, Property specification languages (PSL, ITL)
2	**Learning objectives / Learning Outcomes** Students understand the verification problem of complex systems and the basic principles and algorithms of modern verification tools and techniques. They are able to assess the limitations of verification tools and techniques, and are able to consider these limitations in the verification of systems. They can specify temporal properties of a system in the languages of temporal logics or in formal property specification languages like PSL.
3	**Recommended prerequisite for participation** Basic knowledge of digital circuits
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Written Examination, Duration: 90 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Written Examination, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSc Wi-ETiT, MSc iCE, MSc iST
7	**References** Th. Kropf: Introduction to formal hardware verification. W.K. Lam: Hardware design verification.

Courses

	Course Nr. 18-ev-2020-vl	**Course name** Verification Technology		
	Instructor Prof. Dr. Hans Eveking		**Type** Lecture	**SWS** 3
	Course Nr. 18-ev-2020-ue	**Course name** Verification Technology		
	Instructor Prof. Dr. Hans Eveking		**Type** Practice	**SWS** 1

Module name					
Advanced Power Electronics					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-gt-2010	5 CP	150 h	90 h	1	WiSe
Language			**Module owner**		
English			Prof. Dr.-Ing. Gerd Griepentrog		

1 Content

Switch mode power supplies (insulating DC/DC-converters) Realistic behavior of power semiconductors: Basics of semiconductor physics; Behavior of diode, bipolar transistor, SCR, GTO, MOSDFET and IGBT, Important circuits for switching real semiconductors with low losses
Forced commutation of SCRs, Loss reducing snubbers, quasi- resonant circuits, resonant switching.
Topologies and control strategies for multilevel converter
Thermal design and thermo mechanical aging of power electronics systems

2 Learning objectives / Learning Outcomes

After an active participation in the lecture, especially by asking all questions on topics which you did not fully understand as well by solving all exercises prior to the respective tutorial (i.e. not just shortly before the examination) you should be able to
1.) Explain und understand the cross sectional layers and the basic modes of operation for power semiconductors (diode, thyristor, GTO. Mosfet and IGBT). Describe the steady state and dynamic behavior of these devices.
2.) Identify the circuit diagrams for isolating DC/DC converters, especially for use in switched mode power supplies. Calculate the currents and voltages in these circuits using defined simplifications.
3.) Describe the functions of gate dive-circuits for ITGBTs.
4.) Calculate the thermal behavior and design the cooling equipment for a voltage source inverter equipped with IGBT modules.
5.) Describe the stress reliving circuits to reduce switching losses in IGBTs.
6.) Calculate the current and voltage characteristics in quasi-resonant and resonant circuits used in power electronics.
7.) Explain multilevel converters such as 3L-NPC and MMC
8.) Know the main concepts for cooling of power electronics incl. the ability to design a cooling concept and should know main aspects which influence lifetime

3 Recommended prerequisite for participation

BSc ETiT or equivalent, especially Power Electronics and Basics of Semiconductors

4 Form of examination

Module Final Examination:

- Module Examination (Technical Examination, Written Examination, Duration: 90 min, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Technical Examination, Written Examination, Weighting: 100 %)

6 Usability of this module

MSc ETiT, MSc EPE, Wi-ETiT

7 References

Script available in Moodle for download
Literature:

- Schröder, D.: “Leistungselektronische Schaltungen”, Springer-Verlag, 1997
- Mohan, Undeland, Robbins: Power Electronics: Converters, Applications and Design; John Wiley Verlag; New York; 2003
- Luo, Ye: “Power Electronics, Advanced Conversion Technologies”, Taylor and Francis, 2010

Courses

	Course Nr. 18-gt-2010-vl	**Course name** Advanced Power Electronics		
	Instructor Prof. Dr.-Ing. Gerd Griepentrog		**Type** Lecture	**SWS** 2
	Course Nr. 18-gt-2010-ue	**Course name** Advanced Power Electronics		
	Instructor Prof. Dr.-Ing. Gerd Griepentrog		**Type** Practice	**SWS** 2

Module name Control of Drives					
Module Nr. 18-gt-2020	**Credit Points** 5 CP	**Workload** 150 h	**Self study** 90 h	**Duration** 1	**Cycle offered** SoSe
Language English			**Module owner** Prof. Dr.-Ing. Gerd Griepentrog		

1	**Content** Control structures for drives; Design of controllers for drives; VSIs for drives; Space Vectors as basis of modelling AC-machines; Reference frames for description of AC-machines; Control oriented block diagram for DC-drive; Structure and design of the controllers; Control oriented block diagram for Permanent Magnet Synchronous Machine (PMSM); Control oriented block diagram for Induction machine (IM) Torque control for AC-machines using linear or switching controllers. Field Oriented Control and Direct Torque Control for PMSM and IM. Models and observers for rotor flux of IM Speed control, including oscillatory load. Resolver and Encoder.
2	**Learning objectives / Learning Outcomes** After an active participation in the course including solving all exercises prior to the respective tutorial students should be able to: 1.) develop the control-oriented block diagrams for the DC-machine operating in base speed range as well as in field weakening range. 2.) design the control loops for 1.) concerning the structure and the control parameters. 3.) Understand and apply space vectors and master their application in different rotating frames of reference. 4.) Develop the dynamic equations of the permanent exited synchronous machine and the induction machine and to simplify these equations by help of suitable rotating reference frames and represent these equations as non-linear control-oriented block diagram. 5.) Design the control loops according to 4.) especially the field-oriented control concerning the structure of the control loops and the control parameters. 6.) Understand the deduction of equations given in the literature for machine types, which are not discussed in this lecture, e.g. for the doubly fed induction machine. 7.) Derive the models and the observers for the rotor flux for the induction machine in different frames of reference and to apprise the benefits and drawbacks of the different solutions. 8.) Design the control loops for the super-imposed speed controls even for mechanically oscillating loads.
3	**Recommended prerequisite for participation** BSc ETiT or equivalent, especially Control Theory and Electrical Machines / Drives
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Written Examination, Duration: 90 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Written Examination, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSc EPE, MSc MEC, Wi-ETiT
7	**References**

Lecture notes, instructions for exercises are available in Moodle for download.
Literature:

- Mohan, Ned: “Electric Drives and Machines”
- De Doncker, Rik; et. al.: “Advanced Electrical Drives”
- Schröder, Dierk: “Elektrische Antriebe – Regelung von Antriebssystemen”
- Leonhard, W.: “Control of Electrical Drives”

Courses

Course Nr.	**Course name**		
18-gt-2020-vl	Control of Drives		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Gerd Griepentrog		Lecture	2

Course Nr.	**Course name**		
18-gt-2020-ue	Control of Drives		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Gerd Griepentrog		Practice	2

Module name					
Low-Level Synthesis					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-hb-2010	6 CP	180 h	120 h	1	SoSe
Language			**Module owner**		
English			Prof. Dr.-Ing. Christian Hochberger		

1 Content

The module deals with synthesis steps on all abstraction layers below the register transfer level focusing on approaches suitable for FPGAs. At the logic level different types of minimization are explained (exact and heuristic two level minimizations, exact and heuristic multi level logic minimizations). The transition to the technology level is achieved by different decomposition and structural mapping techniques (FlowMap). Place&Route add geometric information to the technology mapped circuit. Analytical and heuristic placers are discussed (Simulated Annealing, Genetic Placers) and routing is illustrated through the PathFinder algorithm.

2 Learning objectives / Learning Outcomes

After completion of the module, students are enabled to investigate synthesis approaches for low level synthesis tasks. They can evaluate these approaches regarding their time and space complexity, as well as regarding their applicability to specific implementation technologies.
Students can apply these approaches to new architectures and technologies.

3 Recommended prerequisite for participation

Knowledge of hardware synthesis on the basis of at least one hardware description language is required (e.g. Reese/Thornton: Introduction to Logic Synthesis Using Verilog Hdl oder Brown/Vranesic: Fundamentals of Digital Logic with VHDL Design). The student should have basic knowledge of at least one object oriented programming language, preferably Java

4 Form of examination

Module Final Examination:

- Module Examination (Technical Examination, Oral Examination, Duration: 30 min, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Technical Examination, Oral Examination, Weighting: 100 %)

6 Usability of this module

MSc ETiT, MSc iCE, MSc iST

7 References

A script of the lecture (in German) and English foils can be obtained from here: http://www.rs.tu-darmstadt.de/

Courses

Course Nr.	Course name		
18-hb-2010-vl	Low-Level Synthesis		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Christian Hochberger		Lecture	3
Course Nr.	**Course name**		
18-hb-2010-ue	Low-Level Synthesis		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Christian Hochberger		Practice	1

Module name					
High-Level Synthesis					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-hb-2020	6 CP	180 h	120 h	1	WiSe
Language			**Module owner**		
English			Prof. Dr.-Ing. Christian Hochberger		

1 Content

- Mapping of behavioral descriptions (e.g. in the form of program fragments) on FPGA and CGRA structures
- Sub-tasks allocation, scheduling, binding
- Exact or heuristic solutions
- Design principles of heuristic solutions

2 Learning objectives / Learning Outcomes

Students that have completed this module know alternative approaches for all of the tasks of the high level synthesis and can select appropriate ones for specific applications. They can evaluate the memory and time complexity of the given algorithms. They are enabled to adapt the algorithms for new constraints and new target technologies.

3 Recommended prerequisite for participation

Knowledge of hardware synthesis on the basis of at least one hardware description language is required (e.g. Reese/Thornton: Introduction to Logic Synthesis Using Verilog Hdl oder Brown/Vranesic: Fundamentals of Digital Logic with VHDL Design). The student should have basic knowledge of at least one object oriented programming language, preferably Java

4 Form of examination

Module Final Examination:

- Module Examination (Technical Examination, Oral Examination, Duration: 30 min, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Technical Examination, Oral Examination, Weighting: 100 %)

6 Usability of this module

MSc ETiT, BSc/MSc iST, MSc iCE

7 References

English slides can be obtained through Moodle.

Courses

Course Nr.	Course name		
18-hb-2020-vl	High-Level Synthesis		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Christian Hochberger		Lecture	3
Course Nr.	**Course name**		
18-hb-2020-ue	High-Level Synthesis		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Christian Hochberger		Practice	1

Module name					
Processor Microarchitecture					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-hb-2050	6 CP	180 h	120 h	1	SoSe
Language			**Module owner**		
English			Prof. Dr.-Ing. Christian Hochberger		

1 Content

Lectures (each block takes 3 * 90 minutes)

1. Processor execution. Sources of performance loss, latency. Possible techniques to improve performance. Simultaneous multi-threading as an established solution. Motivation for multi-threading – p-threads as a model of execution in SW, micro-threading as a model of execution in HW.

2. Definition of micro-threading, its requirements on the microarchitecture. Microthreaded assembly instructions, design alternatives for extended instruction sets. Required support in micro-architecture – self-synchronizing register file, cache controllers, thread scheduler.

3. Execution in the micro-threaded pipeline. Interaction between cache controllers, register file, thread scheduler, integer pipeline. Data dependences between threads and its influence on execution (embarrassingly parallel vs. sequential programs). Interaction with legacy code, execution modes, OS support.

4. Developing for the real world: Writing testbenches. Performance profiling. Indicators of efficient silicon use.

5. Microthreading in multi-core architectures. Big issues: Scalability, sufficient parallelism, trade-off between clock frequency and access latency

Labs:

1. Set up the utgrlib VHDL sources in the home directory. Set up the utbinutils in the home directory. Compilation of introductory examples.

2.-3. Analysis of execution traces for introductory examples. Design of a FIR filter in micro-threaded assembly. Compilation, execution, analysis of pipeline efficiency.

4.-9. Re-design of existing blocks (choose from dcache, icache, regfile). Preparation of a TLM testbench. Coding and testing of the block in a stand-alone testbench.

10.-15. Integration of the block in UTLEON3, execution of micro-threaded programs, evaluation of performance analysis (% performance gain over the original block, % decreased resource requirements).

2 Learning objectives / Learning Outcomes

After completion of the module, students will be able to design a customized microarchitecture of a modern RISC processor and analyze its performance.

The course will be taught using a VHDL implementation of an existing micro-threaded processor UTLEON3 in an FPGA, nevertheless the knowledge gained in the lecture will be applicable to other HDLs, different processor architectures and other implementation technologies.

3 Recommended prerequisite for participation

Hands-on experience with at least one of Verilog or VHDL is expected. Basic understanding of FPGA technology and thorough knowledge of digital circuit design and computer architecture. Several tools used throughout the labs might require additional programming languages and tools (Perl, C, bash). This knowledge can be obtained during the labs.

4 Form of examination

Module Final Examination:

- Module Examination (Technical Examination, Oral Examination, Duration: 30 min, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Technical Examination, Oral Examination, Weighting: 100 %)

6 Usability of this module

MSc ETiT, MSc iCE, MSc iST

7 References

	A script is available as a published book and English slides can be obtained through moodle.

Courses

Course Nr.	**Course name**		
18-hb-2050-vl	Processor Microarchitecture		
Instructor		**Type**	**SWS**
Ph.D. Martin Danek		Lecture	2

Course Nr.	**Course name**		
18-hb-2050-pr	Processor Microarchitecture		
Instructor		**Type**	**SWS**
Ph.D. Martin Danek		Internship	2

Module name Overvoltage Protection and Insulation Coordination in Power System					
Module Nr. 18-hi-2030	**Credit Points** 4 CP	**Workload** 120 h	**Self study** 75 h	**Duration** 1	**Cycle offered** WiSe
Language English			**Module owner** Prof. Dr.-Ing. Volker Hinrichsen		

1 Content

- Introduction, basics and overview
- Determination of representative overvoltages
  - Origin and classification of overvoltages
  - Normal distribution of overvoltage probability and derivated variables
  - Operating voltage and temporary overvoltages
  - Slow front overvoltages
  - Fast front overvoltages
  - Characteristics of overvoltage protective devices
  - Operation and design of metal-oxide surge arresters
  - Travelling wave effect and protective distance of surge arresters
  - Representative voltage and overvoltages in the case of using surge arresters
- Determination of coordination withstand voltage
  - Insulation strength for different voltage shapes and geometric configurations (gap factors)
  - Performance criterion
  - Insulation coordination procedure
- Determination of required withstand voltage
  - General remarks
  - Atmospheric correction
  - Safety factor for internal and external insulations
- Standard withstand voltage and testing procedures
  - General remarks
  - Test conversion factors
  - Determination and verification of insulation withstand by type tests
  - Table of test voltages and required clearances

2 Learning objectives / Learning Outcomes

The student have understood the main procedures of insulation coordination based on the relevant IEC standard (and the main difference with related IEEE standard procedure) which leads to selection of the electric strength of equipment in relation to the voltages which can appear on the system. In addition, they have learned the origin of different type of overvoltages as well as the protection of equipment against them. The operation and design of surge arresters as an important instrument of insulation coordination in power systems have been understood. The theoretical knowledge about the procedure of insulation coordination has been confirmed and expanded by practical case studies. The students are finally be able to carry out the insulation coordination independetly in any application.

3 Recommended prerequisite for participation

High Voltage Technology I and II

4 Form of examination

Module Final Examination:

- Module Examination (Technical Examination, Written Examination, Duration: 120 min, Standard Grading System)

5 Grading

	Module Final Examination: • Module Examination (Technical Examination, Written Examination, Weighting: 100 %)			
6	**Usability of this module** MSc ETiT, MSc EPE, MSc Wi-ETiT			
7	**References** The related IEC standard can be borrowed during the lecture time. Lecture notes (in English) and other helpful materials can be downloaded from HST homepage: www.hst.tu-darmstadt.de.			
Courses				
	Course Nr. 18-hi-2030-vl	**Course name** Overvoltage Protection and Insulation Coordination in Power System		
	Instructor Prof. Dr.-Ing. Volker Hinrichsen		**Type** Lecture	**SWS** 2
	Course Nr. 18-hi-2030-ue	**Course name** Overvoltage Protection and Insulation Coordination in Power System		
	Instructor Prof. Dr.-Ing. Volker Hinrichsen		**Type** Practice	**SWS** 1

Module name					
Power Cable Systems					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-hi-2040	3 CP	90 h	60 h	1	WiSe
Language			**Module owner**		
German and English			Prof. Dr.-Ing. Volker Hinrichsen		

1 Content

In the lecture, in addition to theoretical knowledge, also the practical side of high voltage cable technology will be treated. These are technical issues, e.g. water sensitivity of plastic cables, cable inspection, testing of already installed cables and the latest developments as in the field of superconductivity etc..
The contents of the lecture are:

- Cable construction: materials / requirements / design
- Cable Manufacturing: conductors / extrusion / shield / sheath (oil-paper insulation) / reinforcement
- Quality requirements and routine-/selection-/type- long term test / ISO 9001, standards, aging, endurance
- Cable junction technique: sockets / terminations / materials / field grading systems / cable connection
- Cable Systems: load / mech. requirements / ind. voltage / short circuit requirements / transient requirements / installation techniques
- Design and operation: route planning / laying / commissioning / monitoring / maintenance
- Trends: High-temperature superconductivity, Submarine cable, DC cable, forced cooling, GIL

2 Learning objectives / Learning Outcomes

Students learn the basic structure of a cable. They know the technical requirements both for the material and the design of a high voltage cable. The basics of manufacturing technology and the necessary tests are learned. The students are also able to evaluate new trends in cable technology.

3 Recommended prerequisite for participation

BSc. ETiT Electrical Power Systems

4 Form of examination

Module Final Examination:

- Module Examination (Technical Examination, Oral Examination, Duration: 30 min, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Technical Examination, Oral Examination, Weighting: 100 %)

6 Usability of this module

MSc ETiT

7 References

Slides, litrature sources

Courses

Course Nr.	Course name		
18-hi-2040-vl	Power Cable Systems		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Volker Hinrichsen		Lecture	2

Module name Analog Integrated Circuit Design					
Module Nr. 18-ho-1020	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1	**Cycle offered** SoSe
Language German			**Module owner** Prof. Dr.-Ing. Klaus Hofmann		

1	**Content** Basic analog Building Blocks: Current Mirrors, Reference Circuits; Multi Stage Amplifier, internal Structure and Properties of Differential and Operational Amplifiers, Feedback Techniques, Frequency Response, Oscillators
2	**Learning objectives / Learning Outcomes** A student is, after successful completion of this module, able to 1. derive the fundamental properties of the MOS-Transistors from knowledge of the layout or fabrication process, 2. derive fundamental MOSFET-circuits (current source, current mirror, switch, active resistors, inverting amplifiers, differential amplifiers, output amplifiers, operational amplifiers, comparators) and knows their fundamental properties (y-Parameters, DC- and AC-properties), 3. understands simulation methods for analog circuits on transistor level using SPICE, 4. analyse feedback amplifiers regarding frequency gain, stability, bandwidth, root locus, amplitude and phase-margin, 5. derive and calculate the analog propierties of digital logic gates
3	**Recommended prerequisite for participation** Lecture “Electronics”
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Written Examination, Duration: 90 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Written Examination, Weighting: 100 %)
6	**Usability of this module** BSc ETiT, BSc Wi-ETiT, MSc iCE, BSc/MSc iST, BSc/MSc MEC, MSc EPE
7	**References** Lecture Slide Copies; Richard Jaeger: Microelectronic Circuit Design

Courses

Course Nr. 18-ho-1020-vl	**Course name** Analog Integrated Circuit Design		
Instructor Prof. Dr.-Ing. Klaus Hofmann		**Type** Lecture	**SWS** 3

Course Nr. 18-ho-1020-ue	**Course name** Analog Integrated Circuit Design		
Instructor Prof. Dr.-Ing. Klaus Hofmann		**Type** Practice	**SWS** 1

Module name					
Advanced Digital Integrated Circuit Design					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-ho-2010	6 CP	180 h	120 h	1	SoSe
Language			**Module owner**		
English			Prof. Dr.-Ing. Klaus Hofmann		

1 Content

MOS Transistor Models, CMOS Logic Gates, Chip Layout and Design Rules, Static and Dynamic Behavior of CMOS Circuits, Synchonous CMOS Circuits, Performance and Power Characterisation, Design Techniques and CAD Tools, FPGA and Gate Array Technologies, Memory Technologies, Chip Test.

2 Learning objectives / Learning Outcomes

A student is, after successful completion of this module, able to

- understand the short-channel effects of modern CMOS transistors,
- derive and analyse the most important circuit concepts for digital logic gates,
- understand the design flow of digital ASICs based on standard cells (design, layout, simulation/verification),
- knows the pros and cons of synchronous vs. asynchronous logic, multiclockphase systems,
- understands the differential design methods of integrated circuits (ASIC, ASIP, Full-custom/Semicustom, PLA, PLD, FPGA),
- understands basic circuitry of logic and arithmetic units (adders, multipliers, PLL/DLL),
- knows the design principles and properties of integrated semiconductor memory (DRAM, SRAM, Flash. MRAM, FeRAM)

3 Recommended prerequisite for participation

Lecture “Electronics”

4 Form of examination

Module Final Examination:

- Module Examination (Technical Examination, Written Examination, Duration: 90 min, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Technical Examination, Written Examination, Weighting: 100 %)

6 Usability of this module

MSc ETiT, MSc Wi-ETiT, MSc iCE, MSc iST, MSc MEC, MSc EPE

7 References

Lecture Slide Copies; John P. Uyemura: Fundamentals of MOS Digital Integrated Circuits; Neil Weste et al.: Principles of CMOS VLSI Design

Courses

Course Nr.	Course name		
18-ho-2010-vl	Advanced Digital Integrated Circuit Design		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Klaus Hofmann		Lecture	3
Course Nr.	**Course name**		
18-ho-2010-ue	Advanced Digital Integrated Circuit Design		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Klaus Hofmann		Practice	1

Module name Microprocessor Systems					
Module Nr. 18-ho-2040	**Credit Points** 4 CP	**Workload** 120 h	**Self study** 75 h	**Duration** 1	**Cycle offered** SoSe
Language English			**Module owner** Prof. Dr.-Ing. Klaus Hofmann		

1	**Content** Microprocessor Architectures, DSP Architectures and Hardware related Programming
2	**Learning objectives / Learning Outcomes** A student is, after successful completion of this module, able to 1. gain the overview on the fundamentals of computer architecture and the different processor classes (RISC, CISC, Mikrocontroller, CPU, DSP), 2. understand the central building blocks of a CPU 3. understand the major properties of the required semiconductor memories, I/O blocks and data busses (USB, PCI, RS232), 4. understand the most commonly used Interrupt- and Trap-handling algorithms, 5. know the common software development methodologies for microcontrollers (assembler, pseudooperations, makros, subprograms and subroutines), 6. understand the most important fundamentals of hardware oriented programming using C.
3	**Recommended prerequisite for participation** Basics of Computer Architectures
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Written Examination, Duration: 90 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Written Examination, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSc Wi-ETiT, MSc iCE, MSc iST, MSc MEC, MSc EPE
7	**References** Slide Copies

Courses

	Course Nr. 18-ho-2040-vl	**Course name** Microprocessor Systems		
	Instructor Prof. Dr.-Ing. Klaus Hofmann		**Type** Lecture	**SWS** 2
	Course Nr. 18-ho-2040-ue	**Course name** Microprocessor Systems		
	Instructor Prof. Dr.-Ing. Klaus Hofmann		**Type** Practice	**SWS** 1

Module name Circuit Building Blocks for Communication Systems					
Module Nr. 18-ho-2190	**Credit Points** 4 CP	**Workload** 120 h	**Self study** 75 h	**Duration** 1	**Cycle offered** Every 2. Sem.
Language English			**Module owner** Prof. Dr.-Ing. Klaus Hofmann		

1	**Content** Methods and Algorithms for the Circuit Implementations in communication systems
2	**Learning objectives / Learning Outcomes** A student is, after successful completion of this module, able to understand 1. the essential circuit building blocks of a communication system and able to describe them on transistor level, 2. Protocols and hardware-implementations of high-speed bus-systems , 3. Clock/data recovery techniques (DLL, PLL, Timing Recovery), 4. Aspects of error-detection and – avoidance.
3	**Recommended prerequisite for participation** Lecture “Advanced Digital Integrated Circuit Design” and "Hardware Description Languages:Verilog and VHDL"
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Written Examination, Duration: 90 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Written Examination, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSc Wi-ETiT, MSc iCE, MSc MEC, MSc EPE
7	**References** Slide Copies

Courses

	Course Nr. 18-ho-2190-vl	**Course name** Circuit Building Blocks for Communication Systems		
	Instructor Prof. Dr.-Ing. Klaus Hofmann		**Type** Lecture	**SWS** 2
	Course Nr. 18-ho-2190-ue	**Course name** Circuit Building Blocks for Communication Systems		
	Instructor Prof. Dr.-Ing. Klaus Hofmann		**Type** Practice	**SWS** 1

Module name					
Computer Aided Design for SoCs					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-ho-2200	5 CP	150 h	90 h	1	SoSe
Language			**Module owner**		
English			Prof. Dr.-Ing. Klaus Hofmann		

1 Content

CAD-Concepts for the design and simulation of integrated system-on-chips

2 Learning objectives / Learning Outcomes

A student is, after successful completion of this module, able to understand

- The most important design and verification abstractions as well as the design flow for the design of integrated electronic systems,
- Selected algorithms for optimization, simulation and solving of design tasks,
- Advanced methods for the design and simulation of analog integrated circuits in modern CMOS technologies,
- Advanced concepts of hardware description languages and their concepts (Verilog, VHDL, Verilog-A, Verilog-AMS, System-Verilog)

3 Recommended prerequisite for participation

Lecture "Advanced Digital Integrated Circuit Design" (can be attended in parallel) and „Analog Integrated Circuit Design" and "Logic Design"

4 Form of examination

Module Final Examination:

- Module Examination (Technical Examination, Written Examination, Duration: 90 min, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Technical Examination, Written Examination, Weighting: 100 %)

6 Usability of this module

MSc ETiT, MSc iST, MSc MEC, MSc Wi-ETiT, MSc iCE

7 References

Slide Copies

Courses

Course Nr.	Course name		
18-ho-2200-vl	Computer Aided Design for SoCs		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Klaus Hofmann		Lecture	2
Course Nr.	**Course name**		
18-ho-2200-ue	Computer Aided Design for SoCs		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Klaus Hofmann		Practice	1
Course Nr.	**Course name**		
18-ho-2200-pr	Computer Aided Design for SoCs		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Klaus Hofmann		Internship	1

Module name Industrial Electronics					
Module Nr. 18-ho-2210	**Credit Points** 4 CP	**Workload** 120 h	**Self study** 75 h	**Duration** 1	**Cycle offered** WiSe
Language German and English			**Module owner** Prof. Dr.-Ing. Klaus Hofmann		

1	**Content** Typical Struture of Industrial Electronics Components. Characteristics of Typical Building Blocks (Digital Core, Sensor Frontend, Actuator Frontend, Supply and Reference Level), Functioning of Relevant Field Bus Systems, Knowledge of Relevant Standards and Technical Regulations.
2	**Learning objectives / Learning Outcomes** After successfull completion of the module, students are able to: 1. understand the use of electronic components in typical industrial environments, 2. understand the function of the building blocks of typical IE comonents, 3. deeply understand the functioning of analog bulding blocks, 4. understand relevant field bus systemes, 5. understand the regulatory and technical standards of industrial electronics components.
3	**Recommended prerequisite for participation** Lecture “Elektronik“ and “Analog IC Design”
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Optional, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Optional, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, M.Sc. iCE, M.Sc. MEC
7	**References** • Dietmar Schmid, Gregor Häberle, Bernd Schiemann, Werner Philipp, Bernhard Grimm, Günther Buchholz, Jörg Oestreich, Oliver Gomber, Albrecht Schilling: „Fachkunde Industrieelektronik und Informationstechnik“; Verlag Europa-Lehrmittel, 11 th Ed. 2013. • Gunter Wellenreuther, Dieter Zastrow; „Automatisieren mit SPS – Theorie und Praxis“; Springer Verlag, 6 th Ed. 2015. • Ulrich Tietze, Christoph Schenk, Eberhard Gamm: „Halbleiter-Schaltungstechnik“; Springer Verlag, 15 th Ed. 2016.

Courses

Course Nr. 18-ho-2210-vl	**Course name**		
Instructor Dr.-Ing. Roland Steck		**Type** Lecture	**SWS** 2
Course Nr. 18-ho-2210-ue	**Course name**		
Instructor Dr.-Ing. Roland Steck		**Type** Practice	**SWS** 1

Module name Antennas and Adaptive Beamforming					
Module Nr. 18-jk-2020	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1	**Cycle offered** WiSe
Language English			**Module owner** Prof. Dr.-Ing. Rolf Jakoby		

1	**Content** Overview of most important antenna parameters types as well as their applications. Fundamental theories: Fourier transform for far-field pattern calculations, antenna modeling techniques, antenna synthesis methods, image theory, determination of field regions of line sources, of the average radiated power density and power, directivity and gain. Antennas as key elements in power budgets of radio links, introducing the effective aperture of an antenna, deriving the relation between gain and effective aperture. Array antennas are a key hardware for beamforming and smart antenna systems: fundamentals of phased-scanning arrays, non-uniformly excited, equally spaced linear arrays, multi-dimensional planar arrays and mutual coupling effects. Wire antennas: still the most prevalent of all antenna forms, relatively simple in concept, easy to construct, very inexpensive. Antenna radiation fields and antenna parameters for different types of antennas are derived from Maxwell´s equations, applied for aperture antennas (horns, lenses or reflector antennas) and printed antennas (microstrip-patch and coplanar-slot antennas) Some basic numerical calculation methods: 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. Smart antennas in communication and radar systems, with focus on beam steering and adaptive beamforming.
2	**Learning objectives / Learning Outcomes** Students will know basic antenna parameters: pattern, gain, directivity, half-power beamwidth, side- lobe-level, efficiency and input impedance to compare, assess and evaluate different antennas for various applications and operating frequencies. The antenna field regions, reactive near-field, near-field and far-field, can be differentiated and the far-field pattern of an antenna can be determined from given current distributions along the antenna by using Fourier transformation or integral solutions with distributed ideal dipoles as basic elements (antenna analysis). To assess in general physical requirements, constrains and limitations of antennas, students can use fundamental antenna theory: impedance matching techniques, antenna modeling and far-field pattern analysis, antenna synthesis, image theory and fundamental limits of electrically small antennas. After being incorporated into the different adaptive beamforming techniques, the array theory enables the student to design antenna systems that are assembled of a certain number of separate elements, feeding network, beamforming network etc. for phased-scanning or smart antennas in communications and sensing. Moreover, students are able to determine, analyze and evaluate the most important classes of antennas in wireless technology for many applications, operating frequencies, desired requirements or practical constrains: (1.) wire- dipole antennas, (2.) planar antennas (microstrip, dipole and slot antennas), (3.) aperture antennas (horn antennas, parabolic reflector antennas, lens antennas, Cassegrain and Gregorian double-reflector configurations), (4.) broadband and frequency-independent antennas (V antennas, biconical antennas, helical antennas, spiral and log-periodic antennas).
3	**Recommended prerequisite for participation** Fundamentals of Communications, Microwave Engineering 1
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Optional, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Optional, Weighting: 100 %)
6	**Usability of this module** BSc ETiT, MSc ETiT, MSc iCE, Wi-ETiT
7	**References**

	Jakoby, Skriptum Antennas and Adaptive Beamforming, wird am Beginn der Vorlesung verkauft und kann danach im FG-Sekretariat erworben werden

Courses

	Course Nr. 18-jk-2020-vl	**Course name** Antennas and Adaptive Beamforming		
	Instructor Prof. Dr.-Ing. Rolf Jakoby		**Type** Lecture	**SWS** 3
	Course Nr. 18-jk-2020-ue	**Course name** Antennas and Adaptive Beamforming		
	Instructor Prof. Dr.-Ing. Rolf Jakoby		**Type** Practice	**SWS** 1

Module name Microwave Measurement Technologies					
Module Nr. 18-jk-2090	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1	**Cycle offered** SoSe
Language German and English			**Module owner** Prof. Dr.-Ing. Rolf Jakoby		

1	**Content** Introduction to microwave measurement technoloies, high frequency components and their poperties: rf power measurement, spectrum analysis, vertor network analysis (s-parameter, x-parameter, calibration techniques), on-wafer measurements, load/source-pull, material characterization
2	**Learning objectives / Learning Outcomes** By this module, Students will be enabled to undetstand the basic principles of microwave measuement technologies. They are able to use them in measurement applications. The following objectives are linked to the lecture: • The students understand the basic features of the power measurements and the effects of a mismatch or pulsed signals and can independently carry out and interpret measurements. • The students understand the basics of spectrum analysis and can carry out and interpret measurements independently. • The students understand the basics of s-parameter measurements and calibration of network analyzers and can carry out and interpret measurements independently • Students are familiar with various methods for material characterization
3	**Recommended prerequisite for participation** Recommended: Grundlagen der Nachrichtentechnik, Hochfrequenztechnik I
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Oral Examination, Duration: 45 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Oral Examination, Weighting: 100 %)
6	**Usability of this module** MSc etit, MSc WI-etit, MSc iCE, MSc iST
7	**References**

Courses

Course Nr.	**Course name**		
18-jk-2090-vl	Microwave Measurement Technologies		
Instructor Dr.-Ing. Holger Maune		**Type** Lecture	**SWS** 2
Course Nr.	**Course name**		
18-jk-2090-ue	Microwave Measurement Technologies		
Instructor Dr.-Ing. Holger Maune		**Type** Practice	**SWS** 1
Course Nr.	**Course name**		
18-jk-2090-pr	Microwave Measurement Technologies Lab		
Instructor Dr.-Ing. Holger Maune		**Type** Internship	**SWS** 1

Module name Acceleration of Charged Particles in Electromagnetic Fields					
Module Nr. 18-kb-2010	**Credit Points** 5 CP	**Workload** 150 h	**Self study** 90 h	**Duration** 1	**Cycle offered** SoSe
Language German and English			**Module owner** Prof. Dr.-Ing. Harald Klingbeil		

1	**Content** Basics of Tensor Analysis, Basics of Special Relativity, Covariant Form of Maxwell's Equations, Basics of Nonlinear Dynamics, Hamilton Formalism, Phase Space, Basics of Longitudinal Beam Dynamics, Liouville's Theorem, Beam Equations, Particle Tracking, Accelerating Cavities and Systems, Longitudinal Beam Manipulations.
2	**Learning objectives / Learning Outcomes** The lecture shows how different theories like electrodynamics, special relativity and nonlinear dynamics merge together in accelerator engineering for the motion of charged particles in electromagnetic fields. The student will get a good understanding of these theories, and he will be able to understand more advanced literature in the area of accelerator engineering and accelerator physics.
3	**Recommended prerequisite for participation** Vector analysis, infinitesimal calculus, basics in differential equations, first contact with Maxwell's equations.
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Oral Examination, Duration: 30 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Oral Examination, Weighting: 100 %)
6	**Usability of this module** MSc ETiT
7	**References** Lecture slides. List of textbooks.

Courses

	Course Nr. 18-kb-2010-vl	**Course name** Acceleration of Charged Particles in Electromagnetic Fields		
	Instructor Prof. Dr.-Ing. Harald Klingbeil		**Type** Lecture	**SWS** 2
	Course Nr. 18-kb-2010-ue	**Course name** Acceleration of Charged Particles in Electromagnetic Fields		
	Instructor Prof. Dr.-Ing. Harald Klingbeil		**Type** Practice	**SWS** 2

Module name					
Communication Technology II					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-kl-2010	4 CP	120 h	75 h	1	WiSe
Language			**Module owner**		
English			Prof. Dr.-Ing. Anja Klein		

1 Content

linear and nonlinear digital modulation schemes, optimum receivers for AWGN channels, error probability, channel capacity, channel models, channel estimation and data detection for multipath channels, multicarrier schemes, OFDM

2 Learning objectives / Learning Outcomes

After completion of the lecture, students possess:

- the ability of comparing, evaluating, classifying an analyzing linear and nonlinear modulation schemes by means of signal space representations;
- the ability to understand, describe and analyze the influence of AWGN on the signal;
- the ability to understand and derive optimum receivers in case of AWGN channels;
- the ability to understand, describe and analyze the influence of multipath propagation on the signal;
- the ability to describe the influence of a multipath channel mathematically (channel model) and estimate the multipath channel at the receiver;
- the knowledge of equalizing the received signal in order to undo the influence of multipath propagation, as well as the ability to derive and design several equalizer structures;
- the ability to analyze and evaluate the properties and application areas of multicarrier transmission systems, e.g. OFDM-systems;
- the ability to design and evaluate the system parameters of multicarrier schemes for the application in realistic mobile radio scenarios;

3 Recommended prerequisite for participation

Electrical Engineering I and II, Deterministische Signale und Systeme, Stochastische Signale und Systeme, Communication Technology I, Basics of Telecommunication, Mathematics I to IV

4 Form of examination

Module Final Examination:

- Module Examination (Technical Examination, Written Examination, Duration: 90 min, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Technical Examination, Written Examination, Weighting: 100 %)

6 Usability of this module

MSc ETIT, MSc Wi-ETiT, MSc CE, MSc iCE, MSc iST, MSc MEC

7 References

will be announced in the lecture

Courses

Course Nr.	Course name		
18-kl-2010-vl	Communication Technology II		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Anja Klein		Lecture	2
Course Nr.	**Course name**		
18-kl-2010-ue	Communication Technology II		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Anja Klein		Practice	1

Module name Information Theory I					
Module Nr. 18-kp-1010	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1	**Cycle offered** WiSe
Language English			**Module owner** Prof. Dr. techn. Heinz Köppl		

1	**Content** This lecture course introduces the fundamentals of information and network information theory. Outline: information, uncertainty, entropy, mutual information, capacity, differential entropy, typical sequences, Gaussian channels, basics of source and channel coding, linear block codes, Shannon's source coding theorem, Shannon's channel coding theorem, capacity of Gaussian channels, capacity of bandlimited channels, Shannon's bound, bandwidth efficiency, capacity of multiple parallel channels and waterfilling, Gaussian vector channel, Multiple Access Channel, Broadcast Channel, rate region..
2	**Learning objectives / Learning Outcomes** Students will understand the fundamentals of classic information theory.
3	**Recommended prerequisite for participation** Knowledge of basic communication theory und probability theory
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Written Examination, Duration: 120 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Written Examination, Weighting: 100 %)
6	**Usability of this module** BSc ETiT, BSc iST, MSc iCE, BSc Wi-ETiT, BSc/MSc CE
7	**References** 1. T.M. Cover and J.A. Thomas, Elements of Information Theory, Wiley & Sons, 1991. 2. Abbas El Gamal and Young-Han Kim, Network Information Theory, Cambrige, 2011. 3. S. Haykin, Communication Systems, Wiley & Sons, 2001.

Courses

Course Nr. 18-kp-1010-vl	**Course name** Information Theory I		
Instructor Prof. Dr. techn. Heinz Köppl		**Type** Lecture	**SWS** 3
Course Nr. 18-kp-1010-ue	**Course name** Information Theory I		
Instructor Prof. Dr. techn. Heinz Köppl		**Type** Practice	**SWS** 1

Module name Mobile Communications					
Module Nr. 18-kl-2020	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1	**Cycle offered** SoSe
Language English			**Module owner** Prof. Dr.-Ing. Anja Klein		

1 Content

The lecture covers aspects of mobile communication systems with particular focus on the physical layer.
Mobile radio systems, services, market, standardization
duplex and multiple access techniques, cellular concept
mobile radio channel, deterministic and stochastic description
modulation schemes
code division multiple access (CDMA)
orthogonal frequency division multiplexing (OFDM)
optimum and suboptimum receiver techniques
cellular radio capacity and spectrum efficiency
diversity methods
multiple input multiple output (MIMO) systems
power control and handover
architecture of mobile radio systems

2 Learning objectives / Learning Outcomes

After completion of the lecture, students possess

- a profound understanding of physical layer aspects ,e.g., transmission schemes, multiple access schemes of mobile communication systems, duplex schemes, multi carrier schemes, receiver techniques, multi antenna schemes
- a profound understanding of signal propagation in mobile radio systems (mobile radio channel)
- the ability to understand and solve problems of the field of the physical layer
- the ability to compare, analyse and evaluate different system concepts
- knowledge on modelling of the transmission properties of the mobile radio channel

3 Recommended prerequisite for participation

Electrical Engineering I and II, Deterministic Signals and Systems, Communication Technology I, Mathematics I to IV

4 Form of examination

Module Final Examination:

- Module Examination (Technical Examination, Written Examination, Duration: 90 min, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Technical Examination, Written Examination, Weighting: 100 %)

6 Usability of this module

MSc ETIT, MSc Wi-ETiT, MSc CE, MSc iCE, MSc iST, MSc MEC

7 References

will be announced in the lecture

Courses

Course Nr. 18-kl-2020-vl	**Course name** Mobile Communications	
Instructor Prof. Dr.-Ing. Anja Klein	**Type** Lecture	**SWS** 3

	Course Nr.	Course name		
	18-kl-2020-ue	Mobile Communications		
	Instructor		**Type**	**SWS**
	Prof. Dr.-Ing. Anja Klein		Practice	1

Module name					
Simulation and Modelling Techniques and Tools for Mobile Communication Systems					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-kl-2060	3 CP	90 h	60 h	1	SoSe
Language			**Module owner**		
English			Prof. Dr.-Ing. Anja Klein		

1 Content

Introduction to simulators

Basics

- Probability theory
- Statistics
- General description of simulators (classification, models, components, man-agement)

Mobile communication systems

- Introduction to mobile networks
- Structure of mobile networks
- Important elements of radio access networks (PHY, MAC, RRC)
- Core networks

Simulation of mobile networks

- Link Level (Structure, Wireless channel, Coding, Multi-antenna, Receivers, Imperfectness)
- System Level (Structure, Deployments, Channels, Multi-user, Multi-cell, Re-lays, Imperfectness)
- Packet Level (Structure, Queues, QoS, Protocols, Abstractions, Imperfectness)

Languages and Tools

- MATLAB
- C++ libraries
- OPNET
- NS-3

Standards

2 Learning objectives / Learning Outcomes

After this lecture, students are able to:

- Implement mobile network simulators
- Calibrate based on mobile network standards
- Transfer algorithm and standards descriptions towards mobile network simulators
- Understand the limitations of simulators

3 Recommended prerequisite for participation

Communication Technology, Signal Processing
Related to Communication Networks and Mobile Communication

4 Form of examination

Module Final Examination:

- Module Examination (Technical Examination, Oral Examination, Duration: 30 min, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Technical Examination, Oral Examination, Weighting: 100 %)

6 Usability of this module

MSc ETiT, MSc iST, MSc iCE, MSc Wi-ET, MSc CE

7 References

	Will be given in lexture (mostly online available)

Courses

Course Nr.	**Course name**		
18-kl-2060-vl	Simulation and Modelling Techniques and Tools for Mobile Communication Systems		
Instructor		**Type**	**SWS**
Dr.-Ing. Peter Rost		Lecture	2

Module name Computational Methods for Systems and Synthetic Biology					
Module Nr. 18-kp-2080	**Credit Points** 4 CP	**Workload** 120 h	**Self study** 75 h	**Duration** 1	**Cycle offered** SoSe
Language English			**Module owner** Prof. Dr. techn. Heinz Köppl		

1 Content

The course covers mathematical methods used in the area of systems and synthetic biology. On the one hand it deals with practical modeling of molecular processes but also with theoretical investigations that reveal general properties of those processes. The course follows a microscopic approach and introduces those processes using probabilistic methods. For that, necessary prerequists are recapitulated, such as definition of Markov processes in different spaces and their properties. With this background, the dynamics of stochastic reaction kinetics in terms of population models is investigated. Limiting cases are introduced, such as the diffusion approximation or the deterministic approximation (fluid approximations) of those systems. Often methods from statistical physics are applied. Numerical methods for solving the corresponding Fokker-Planck and Master equations are discussed. For the limiting case of a deterministic approximation, traditional methods for the stability analysis of nonlinear differential equations are introduced and methods are discussed that just rely on the topology of the reaction network to determine stability properties. In this context, a derivation of the moment dynamics and approximation methods based on moment closure are given. Connections to queueing theory models are shown.
Furthermore, the question is addressed of how the introduced dynamical models are calibrated to data from molecular biology. For that, general methods of statistical inference from statistics and of machine learning from computer science are discussed and specialized algorithms for the considered system class are presented. Additionally, a short introduction to the theory of nonlinear optimal filtering is given and special cases such as hidden Markov models are discussed.
Beyond reaction kinetics, the course provides a basic introduction to the modeling and numerical methods used in molecular dynamics. Newtonian multi-body simulations and classical potentials and their use in molecular dynamics are discussed. Most of the topics in this course are introduced through practical examples from applied modeling in the domain of systems biology. The applicability of the respective methods in synthetic biology is highlighted.

2 Learning objectives / Learning Outcomes

Students that successfully passed that course should be able to perform practical modeling of molecular processes and to determine dynamical properties of model using mathematical methods. It relies on the understanding of the following topics:

- Mathematical abstraction of molecular mechanisms
- General properties of stochastic processes
- Approximation methods for Markovian population models
- Stability analysis of nonlinear differential equations
- Numerical methods for solving/simulating stochastic systemsSystem identification/machine learning for stochastic systems

3 Recommended prerequisite for participation

Basic knowledge of programming, Matlab.

4 Form of examination

Module Final Examination:

- Module Examination (Technical Examination, Optional, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Technical Examination, Optional, Weighting: 100 %)

6 Usability of this module

MSc ETiT, MSc iST, MSc Wi-ETiT, MSc MEC

7 References

	http://www.bcs.tu-darmstadt.de/			
Courses				
	Course Nr. 18-kp-2080-vl	**Course name** Computational Methods for Systems and Synthetic Biology		
	Instructor Prof. Dr. techn. Heinz Köppl		**Type** Lecture	**SWS** 2
	Course Nr. 18-kp-2080-ue	**Course name** Computational Methods for Systems and Synthetic Biology		
	Instructor Prof. Dr. techn. Heinz Köppl		**Type** Practice	**SWS** 1

Module name Machine Learning in Information and Communication Technology (ICT)					
Module Nr. 18-kp-2110	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1	**Cycle offered** SoSe
Language English			**Module owner** Prof. Dr. techn. Heinz Köppl		

1 Content

The module provides an introduction to the emerging field of machine learning from an engineering perspective. Important models and learning methods are presented and exemplified through problems from information and communication technology.

- Fundamentals of probability theory and multivariate statistics
- Taxonomy of machine learning problems and models (supervised, unsupervised, generative, discriminative)
- Regression and classification: theory, methods and ICT applications
- Dimensionality reduction, clustering and big data analytics: methods and application in communications and signal processing
- Probabilistic graphical models: categories, inference and parameter estimation
- Fundamentals of Bayesian inference, Monte Carlo methods, Bayesian non-parametrics
- Fundamentals of convex optimization: Solution methods and application in communications
- Approximate algorithms for scalable Bayesian inference; application in signal processing and information theory (e.g. decoding of LDPC codes)
- Hidden Markov models (HMM): Theory, Algorithms and ICT applications (e.g. Viterbi decoding of convolutional codes)
- High-dimensional statistics (“large p small n” setting), learning dependency structure in high-dimensional data, learning causality relations from observational data.
- Sparse estimation, random projections, compressive sensing: Theory and applications in signal processing
- Deep neural networks (deep learning): Models, learning algorithms, libraries and ICT applications

2 Learning objectives / Learning Outcomes

Students are able to interpret and categorize specific engineering problems from the ICT domain in terms of machine learning problems.
They are able to reduce such problems to standard machine learning problems and are able to determine suitable solution methods for them.
They are able to implement all necessary algorithms from scratch, but they are also familiar with the state-of-the-art libraries in machine learning.
They are able to determine the involved computational complexity of a method and choose an appropriate solution algorithms based on application constraints.
They are able to apply the acquired methods to other domains, such as data analysis in biomedical engineering, analysis of social network data, etc.

3 Recommended prerequisite for participation

Good command of Matlab (for instance knowledge from course 18-st-2030 Matlab Grundkurs) and engineering mathematics

4 Form of examination

Module Final Examination:

- Module Examination (Technical Examination, Optional, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Technical Examination, Optional, Weighting: 100 %)

6 Usability of this module

MSc etit, BSc/MSc iST, MSc iCE, MSc CE

7 References

- Kevin P. Murphy. Machine Learning – A probabilistic perspective, MIT Press, 2012
- Christopher M. Bishop. Pattern recognition and Machine Learning, Springer, 2006
- Peter Bühlmann und Sara van de Geer. Statistics of high-dimensional data – Methods, theory and applications, Springer, 2011

Courses

Course Nr.	**Course name**		
18-kp-2110-vl	Machine Learning in Information and Communication Technology (ICT)		
Instructor		**Type**	**SWS**
Prof. Dr. techn. Heinz Köppl		Lecture	2
Course Nr.	**Course name**		
18-kp-2110-pr	Machine Learning in Information and Communication Technology (ICT) Lab		
Instructor		**Type**	**SWS**
Prof. Dr. techn. Heinz Köppl		Internship	1
Course Nr.	**Course name**		
18-kp-2110-ue	Machine Learning in Information and Communication Technology (ICT)		
Instructor		**Type**	**SWS**
Prof. Dr. techn. Heinz Köppl		Practice	1

Module name Optical Communications 1 – Components					
Module Nr. 18-ku-1060	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1	**Cycle offered** SoSe
Language English			**Module owner** Prof. Dr.-Ing. Franko Küppers		

1 Content

Optical telecommunication and data networks
Optical transmisison systems
The nature of light / wave-partical dualism
Wave equation / planar wave
Polarization
Absorption, transmission, reflexion, refraction
Connectors and splices
Mirrors, HR-/AR coatings
Film waveguides
Fiber-optic waveguides
Attenuation, modes, dispersion
Fiber types
Dispersion and dispersion compensation
Kerr nonlinearity and self-phase modulation
Optical filters
Wavelength division multiplexers
Magneto-optical effect / optical isolator / circulator
Lasers / basics, concepts, types
Erbium-doped fiber lasers / amplifiers (EDFL / EDFA)
Optical semiconductor laser / amplifier (laser diode)
Electro-optic modulator
Other selected components and devices

2 Learning objectives / Learning Outcomes

Students understand concepts, basics of physics, design criteria and system requirements (component specifications) of the most important passive and active components of optical communications.

3 Recommended prerequisite for participation

ET 1-4, Physics

4 Form of examination

Module Final Examination:

- Module Examination (Technical Examination, Written Examination, Duration: 90 min, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Technical Examination, Written Examination, Weighting: 100 %)

6 Usability of this module

BSc ETiT, MSc ETiT, MSc iCE

7 References

Lecture slides
Textbook (M. Cvijetic, I. B. Djordjevic: „Advanced Optical Communication Systems and Networks“)

Courses

Course Nr. 18-ku-1060-vl	**Course name** Optical Communications 1 – Components	
Instructor Prof. Dr.-Ing. Franko Küppers	**Type** Lecture	**SWS** 3

	Course Nr.	Course name		
	18-ku-1060-ue	Optical Communications 1 – Components		
	Instructor		**Type**	**SWS**
	Prof. Dr.-Ing. Franko Küppers		Practice	1

Module name					
Microwave Engineering II					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-ku-2040	6 CP	180 h	120 h	1	WiSe
Language			**Module owner**		
English			Prof. Dr.-Ing. Franko Küppers		

1	**Content** Part 1 Passive microwave components: Calculation of the properties of simple passive components (microstrip line, filter, resonator, capacitor, inductance) for MMICs Part 2 Active microwave components: * Semiconductor material systems: properties, fabrication and requirements * Contacts to semiconductor devices: properties and characteristics * Charge carrier transport: characteristics and scattering processes * Field Effect Transistor (FET) and heterostructure transistors (HEMTs) Part 3 Active microwave circuits (main part): * Wave parameter and S-parameter * FET amplifier: operation, equivalent circuit, gain, matching circuit, stability and circuit implementation * Oscillator design * Mixer design Applications of these circuits range from communication systems such as cell phones to satellite transceivers as well as high-frequency souces up to Terahertz.
2	**Learning objectives / Learning Outcomes** Students will gain knowledge on the physics of microwave waveguides, resonators, microwave components (passive and active) as well as microwave circuits.
3	**Recommended prerequisite for participation** Desirable: Introduction to Electrodynamics, Microwave Engineering I
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Written Examination, Duration: 90 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Written Examination, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSc iCE, MSc IST, Wi-ETiT
7	**References** Script and slides will be handed out. Literature will be recommended in the lecture.

Courses

	Course Nr. 18-ku-2040-vl	**Course name** Microwave Engineering II		
	Instructor PD Dr.-Ing. Oktay Yilmazoglu		**Type** Lecture	**SWS** 3
	Course Nr. 18-ku-2040-ue	**Course name** Microwave Engineering II		
	Instructor PD Dr.-Ing. Oktay Yilmazoglu		**Type** Practice	**SWS** 1

Module name Optical Communications 2 – Systems					
Module Nr. 18-ku-2070	**Credit Points** 4 CP	**Workload** 120 h	**Self study** 75 h	**Duration** 1	**Cycle offered** WiSe
Language English			**Module owner** Prof. Dr.-Ing. Franko Küppers		

1	**Content** Optical networks / structure, topology, layers System design Time division multiplexing, wavelength division multiplexing Modulation schemes for optical signals Transmission schemes Dispersion compensation and management Signal characterization, performance parameters
2	**Learning objectives / Learning Outcomes** Students understand selected, advanced concepts of optical communications systems and their respective basics of physics, design criteria, limitations, and optimization.
3	**Recommended prerequisite for participation** Optical Communications 1 – Components
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Written Examination, Duration: 90 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Written Examination, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSc iCE, BEd
7	**References** Lecture slides, textbook (M. Cvijetic, I. B. Djordjevic: „Advanced Optical Communication Systems and Networks“)

Courses

Course Nr. 18-ku-2070-vl	**Course name** Optical Communications 2 – Systems		
Instructor Prof. Dr.-Ing. Franko Küppers		**Type** Lecture	**SWS** 2
Course Nr. 18-ku-2070-ue	**Course name** Optical Communications 2 – Systems		
Instructor Prof. Dr.-Ing. Franko Küppers		**Type** Practice	**SWS** 1

Module name Technology of Electronic and Optoelectronic Devices					
Module Nr. 18-ku-2210	**Credit Points** 3 CP	**Workload** 90 h	**Self study** 60 h	**Duration** 1	**Cycle offered** WiSe
Language English			**Module owner** Prof. Dr. rer. nat. Thomas Kusserow		

1	**Content**
2	**Learning objectives / Learning Outcomes**
3	**Recommended prerequisite for participation**
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Written Examination, Duration: 90 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Written Examination, Weighting: 100 %)
6	**Usability of this module**
7	**References**

Courses

	Course Nr. 18-ku-2210-vl	**Course name** Technology of Electronic and Optoelectronic Devices	
	Instructor Prof. Dr. rer. nat. Thomas Kusserow	**Type** Lecture	**SWS** 2

Module name Information Theory II					
Module Nr. 18-pe-2010	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1	**Cycle offered** SoSe
Language English			**Module owner** Prof. Dr.-Ing. Marius Pesavento		

1	**Content** This lecture course is devoted to advances of network information theory. Outline: overview of Shannon capacity, outage and ergodic capacity, capacity of channels with state, capacity of Gaussian vector channels, capacity regions of multi-user channels, capacity regions of multiple-access and broadcast fading channels, interference channel, relay channel, multiuser bounds, multi-user diversity., wiretap channel, secrecy rate and physical layer security.
2	**Learning objectives / Learning Outcomes** Students will understand advanced concepts and strategies in networkinformation theory.
3	**Recommended prerequisite for participation** Knowledge of basic communication theory
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Optional, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Optional, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, BSc iST, MSc Wi-ETiT, MSc iCE, BSc/MSc CE
7	**References** 1. Abbas El Gamal and Young-Han Kim, Network Information Theory, Cambrige, 2011. 2.. T.M. Cover and J.A. Thomas, Elements of Information Theory, Wiley Sons, 1991. 3.. D. Tse and P. Vishwanath, Fundamentals of Wireless Communications, Cambridge University Press, 2005.

Courses

Course Nr. 18-pe-2010-vl	**Course name** Information Theory II		
Instructor Prof. Dr.-Ing. Marius Pesavento		**Type** Lecture	**SWS** 3
Course Nr. 18-pe-2010-ue	**Course name** Information Theory II		
Instructor Prof. Dr.-Ing. Marius Pesavento		**Type** Practice	**SWS** 1

Module name					
Convex Optimization in Signal Processing and Communications					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-pe-2020	6 CP	180 h	120 h	1	SoSe
Language			**Module owner**		
English			Prof. Dr.-Ing. Marius Pesavento		

1	**Content** This graduate course introduces the basic theory of convex optimization and illustrates its use with many recent applications in communication systems and signal processing. Outline: Introduction, convex sets and convex functions, convex problems and classes of convex problems (LP, QP, SOCP, SDP, GP), Lagrange duality and KKT conditions, basics of numerical algorithms and interior point methods, optimization tools, convex inner and outer approximations for non convex problems, sparse optimization, distributed optimization, mixted integer linear and non-linear programming, applications.
2	**Learning objectives / Learning Outcomes** Students will learn the basic theory of convex optimization and its applications.
3	**Recommended prerequisite for participation** Knowledge in linear algebra and the basic concepts of signal processing and communications.
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Oral Examination, Duration: 40 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Oral Examination, Weighting: 100 %)
6	**Usability of this module** MSc ETiT
7	**References** 1. S. Boyd and L. Vandenberghe, Convex Optimization, Cambridge University Press, 2004. (online Verfügbar: http://www.stanford.edu/~boyd/cvxbook/) 2. D. P. Bertsekas, Nonlinear Programming, Athena Scientific, Belmont, Massachusetts, 2nd Ed., 1999. 3. Daniel P. Palomar and Yonina C. Eldar, Convex Optimization in Signal Processing and Communications, Cambridge University Press, 2009.

Courses

Course Nr. 18-pe-2020-vl	**Course name** Convex Optimization in Signal Processing and Communications		
Instructor Prof. Dr.-Ing. Marius Pesavento		**Type** Lecture	**SWS** 2
Course Nr. 18-pe-2020-ue	**Course name** Convex Optimization in Signal Processing and Communications		
Instructor Prof. Dr.-Ing. Marius Pesavento		**Type** Practice	**SWS** 1
Course Nr. 18-pe-2020-pr	**Course name** Convex Optimization in Signal Processing and Communications Lab		
Instructor Prof. Dr.-Ing. Marius Pesavento		**Type** Internship	**SWS** 1

Module name MIMO - Communication and Space-Time-Coding					
Module Nr. 18-pe-2030	**Credit Points** 4 CP	**Workload** 120 h	**Self study** 75 h	**Duration** 1	**Cycle offered** WiSe
Language English			**Module owner** Prof. Dr.-Ing. Marius Pesavento		

1	**Content** This lecture course introduces the principles of space-time and multiple-input multiple-output (MIMO) communications. Outline: Motivation and background; overview of space-time and MIMO communications; fading MIMO channel models, MIMO information theory, receive and transmit diversity; channel estimation, MIMO detectors, Alamouti space-time block code, orthogonal space-time block codes; linear dispersion codes; coherent and non-coherent decoders, differential space-time block coding; MIMO with limited feedback, Multiantenna- and multiuser diversity, BER performance analysis, MIMO in moden wireless communication networks, multicell and multiuser MIMO (coordinated multipoint).
2	**Learning objectives / Learning Outcomes** Students will understand modern MIMO communications and existing space-time coding techniques.
3	**Recommended prerequisite for participation** Knowledge of basic communication theory and basic information theory.
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Optional, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Optional, Weighting: 100 %)
6	**Usability of this module** MSc ETiT
7	**References** 1. A.B.Gershman and N.D.Sidiropoulos, Editors, Space-Time Processing for MIMO Communications, Wiley and Sons, 2005. 2. E.G.Larsson and P.Stoica, Space-Time Block Coding for Wireless Communications, Cambridge University Press, 2003; 3. A.Paulraj, R.Nabar, and D.Gore, Introduction to Space-Time Wireless Communications, Cambridge University Press, 2003. 4. Lin Bai and Jinho Choi, Low Complexity MIMO detectors, Springer, 2012. 5. Howard Huang, Constantinos B. Papadias, and Sivarama Venkatesan, MIMO Communication for Cellular Networks, Springer, 2012.

Courses

Course Nr. 18-pe-2030-vl	**Course name** MIMO - Communication and Space-Time-Coding		
Instructor Prof. Dr.-Ing. Marius Pesavento		**Type** Lecture	**SWS** 2
Course Nr. 18-pe-2030-ue	**Course name** MIMO - Communication and Space-Time-Coding		
Instructor Prof. Dr.-Ing. Marius Pesavento		**Type** Practice	**SWS** 1

Module name Sensor Array Processing and Adaptive Beamforming					
Module Nr. 18-pe-2060	**Credit Points** 4 CP	**Workload** 120 h	**Self study** 75 h	**Duration** 1	**Cycle offered** SoSe
Language English			**Module owner** Prof. Dr.-Ing. Marius Pesavento		

1 Content

This lecture course introduces the principles of modern sensor array processing and adaptive beamforming.
Outline: Motivation and background; applications, narrowband and wideband signal model
Direction-of-arrival estimation (DoA):
traditional methods based on beamforming, super resolution methods, Maximum-Likelihood methods, Subspace based methods, MUSIC, ESPRIT, MODE, root-MUSIC, multidimensional source localization, beamspace processing, array interpolation, partly calibrated arrays, wideband DOA estimation, spatial smoothing, forward-backward averaging, redundancy averaging, correlated sources, minimum redundancy arrays, compressed sensing and sparse reconstruction based DoA estimation, performance bounds
Adaptive beamforming:
Point-source model, covariance model, Wiener-Hopf equation, Minimum Variance Distortionless Response (MVDR) beamformer, Capon Beamformer, sample matrix inversion, signal self-nulling effect, robust adaptive beamforming, Hung-Turner projection beamformer, Generalized Sidelobe canceller beamformer, Eigenspace-based beamformer, non-stationary environments, modern convex optimization based beamforming, worst-case based beamforming, multiuser beamforming.

2 Learning objectives / Learning Outcomes

Students will standard and modern sensor array processing techniques for source localization and transmit/receive beamforming

3 Recommended prerequisite for participation

Knowledge in linear algebra.

4 Form of examination

Module Final Examination:
- Module Examination (Technical Examination, Optional, Standard Grading System)

5 Grading

Module Final Examination:
- Module Examination (Technical Examination, Optional, Weighting: 100 %)

6 Usability of this module

BSc / MSc etit, BSc / MSc WI-etit, MSc MEC, MSc iST, MSc iCE

7 References

- Academic Press Library in Signal Processing: Volume 3 Array and Statistical Signal Processing Edited by Rama Chellappa and Sergios Theodoridis, Section 2, Edited by Mats Viberg, Pages 457-967 (2014)
  - Chapter 12 - Adaptive and Robust Beamforming, Sergiy A. Vorobyov, Pages 503-552
  - Chapter 14 - DOA Estimation Methods and Algorithms, Pei-Jung Chung, Mats Viberg, Jia Yu, Pages 599-650
  - Chapter 15 - Subspace Methods and Exploitation of Special Array Structures, Martin Haardt, Marius Pesavento, Florian Roemer, Mohammed Nabil El Korso, Pages 651-717

- Spectral Analysis of Signals, Petre Stoica, Randolph Moses, Prentice Hall, April 2005Optimum Array Processing: Part IV of Detection, Estimation, and Modulation Theory, Harry L. Van Trees, Wiley Online, 2002.

Courses

	Course Nr. 18-pe-2060-vl	**Course name** Sensor Array Processing and Adaptive Beamforming		
	Instructor Prof. Dr.-Ing. Marius Pesavento		**Type** Lecture	**SWS** 2
	Course Nr. 18-pe-2060-ue	**Course name** Sensor Array Processing and Adaptive Beamforming		
	Instructor Prof. Dr.-Ing. Marius Pesavento		**Type** Practice	**SWS** 1

Module name					
Matrix Analysis and Computations					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-pe-2070	6 CP	180 h	120 h	1	SoSe
Language			**Module owner**		
English			Prof. Dr.-Ing. Marius Pesavento		

1 Content

This graduate course is a foundation class on matrix analysis and computations, which are widely used in many different fields, e.g., machine learning, computer vision, systems and control, signal and image processing, communications, networks, optimization, and many more...

Apart from the theory this course will also cover the design of efficient algorithm and it considers many different examples from the aforementioned fields including examples from social media and big data analysis, image processing and medical imaging, communication network optimization, and written text classification.

Specific topics: (i) basic matrix concepts, subspace, norms, (ii) linear least squares (iii) eigendecomposition, singular value decomposition, positive semidenite matrices, (iv) linear system of equations, LU decomposition, Cholesky decomposition (v) pseudo-inverse, QR decomposition (vi) advanced tensor decomposition, advanced matrix calculus, compressive sensing, structured matrix factorization

2 Learning objectives / Learning Outcomes

Students will learn matrix analysis and computations at an advanced or research level.

3 Recommended prerequisite for participation

Basic knowledge in linear algebra.

4 Form of examination

Module Final Examination:

- Module Examination (Technical Examination, Optional, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Technical Examination, Optional, Weighting: 100 %)

6 Usability of this module

7 References

1.Gene H. Golub and Charles F. van Loan, Matrix Computations (Fourth Edition), John Hopkins University Press, 2013.

2.Roger A. Horn and Charles R. Johnson, Matrix Analysis (Second Edition), Cambridge University Press, 2012.

3.Jan R. Magnus and Heinz Neudecker, Matrix Differential Calculus with Applications in Statistics and Econometrics (Third Edition), John Wiley and Sons, New York, 2007.

4.Giuseppe Calaore and Laurent El Ghaoui, Optimization Models, Cambridge University Press, 2014.

ECE 712 Course Notes by Prof. Jim Reilly, McMaster University, Canada (friendly notes for engineers) http://www.ece.mcmaster.ca/faculty/reilly/ece712/course_notes.htm

Courses

Course Nr.	Course name		
18-pe-2070-vl	Matrix Analysis and Computations		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Marius Pesavento		Lecture	3
Course Nr.	**Course name**		
18-pe-2070-ue	Matrix Analysis and Computations		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Marius Pesavento		Practice	1

Module name					
Terahertz Systems and Applications					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-pr-2010	4 CP	120 h	75 h	1	SoSe
Language			**Module owner**		
English			Prof. Dr. rer. nat. Sascha Preu		

1	**Content** The lecture will give an overview of Terahertz applications, sources and detectors with the focus on semiconductor-based devices and Terahertz systems. Terahertz detection and generation will be discussed in detail for two types of highly important devices: Schottky diodes (mixers, multi-pliers and rectifiers) and photomixers (photo-diode based and photoconductive). The exercise, where performance parameters of the discussed devices will be derived for experimentally rele-vant cases, will help to deepen the under-standing. The last day will be used for a lab tour showing our measurements facilities and hands-on experiments.
2	**Learning objectives / Learning Outcomes** After attending this lecture, the student has gained basic knowledge in the fields of THz generation, detec-tion, systems, and applications of THz radiation, with deepened knowledge in: *Working principle, spectra and limits of continuous-wave photomixers *Working principle of Schottky diode mixers/multipliers and rectifiers in the THz range *THz Applications
3	**Recommended prerequisite for participation** Recommended: Bachelor in Electrical engineering, Physics, or Material Science Helpful: Basic knowledge in semiconductor physics, High frequency 1
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Oral Examination, Duration: 30 min, Standard Grad-ing System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Oral Examination, Weighting: 100 %)
6	**Usability of this module** MSc etit-KTS, MSc etit-IMNT, MSc etit, MSc iCE
7	**References** *Yun-Shik Lee, „Principles of Terahertz Science and Technology,“ Springer 2009, ISBN 978-0-387-09540-0 *G. Carpintero et al., “Semiconductor Terahertz Technology: Devices and Systems at Room Temperature Operation,” Wiley 2015, ISBN: 978-1-118-92042-8

Courses

Course Nr.	**Course name**		
18-pr-2010-vl	Terahertz Systems and Applications		
Instructor		**Type**	**SWS**
Prof. Dr. rer. nat. Sascha Preu		Lecture	2
Course Nr.	**Course name**		
18-pr-2010-ue	Terahertz Systems and Applications		
Instructor		**Type**	**SWS**
Prof. Dr. rer. nat. Sascha Preu		Practice	1

Module name					
Communication Networks I					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-sm-1010	6 CP	180 h	120 h	1	SoSe
Language			**Module owner**		
English			Prof. Dr.-Ing. Ralf Steinmetz		

1 Content

In this class the technologies that make today's communication networks work are introduced and discussed.

This lecture covers basic knowledge about communication networks and discusses in detail the physical layer, the data link layer, the network layer and parts of the transport layer.

The physical layer, which is responsible for an adequate transmission across a channel, is discussed briefly. Next, error control, flow control and medium access mechanisms of the data link layer are presented. Then the network layer is discussed. It comprises mainly routing and congestion control algorithms. After that basic functionalities of the transport layer are discussed. This includes UDP and TCP. The Internet is thoroughly studied throughout the class.

Detailed Topics are:

- ISO-OSI and TCP/IP layer models
- Tasks and properties of the physical layer
- Physical layer coding techniques
- Services and protocols of the data link layer
- Flow control (sliding window)
- Applications: LAN, MAN, High-Speed LAN, WAN
- Services of the network layer
- Routing algorithms
- Broadcast and Multicast routing
- Congestion Control
- Addressing
- Internet protocol (IP)
- Internetworking
- Mobile networking
- Services and protocols of the transport layer
- TCP, UDP

2 Learning objectives / Learning Outcomes

This lecture teaches about basic functionalities, services, protocols, algorithms and standards of network communication systems. Competencies aquired are basic knowledge about the lower four ISO-OSI layers: physical layer, datalink layer, network layer and transport layer; Furthermore, basic knowledge about communication networks is taught. Attendants will learn about the functionality of today's network technologies and the Internet.

3 Recommended prerequisite for participation

4 Form of examination

Module Final Examination:

- Module Examination (Technical Examination, Written Examination, Duration: 120 min, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Technical Examination, Written Examination, Weighting: 100 %)

6 Usability of this module

Wi-CS, Wi-ETiT, BSc CS, BSc ETiT, BSc iST

7 References

- Andrew S. Tanenbaum: Computer Networks, 5th Edition, Prentice Hall, 2010
- Andrew S. Tanenbaum: Computernetzwerke, 3. Auflage, Prentice Hall, 1998
- Larry L. Peterson, Bruce S. Davie: Computer Networks: A System Approach, 2nd Edition, Morgan Kaufmann Publishers, 1999
- Larry L. Peterson, Bruce S. Davie: Computernetze, Ein modernes Lehrbuch, 2. Auflage, Dpunkt Verlag, 2000
- James F. Kurose, Keith W. Ross: Computer Networking: A Top-Down Approach Featuring the Internet, 2nd Edition, Addison Wesley-Longman, 2002
- Jean Walrand: Communication Networks: A First Course, 2nd Edition, McGraw-Hill, 1998

Courses

Course Nr.	**Course name**		
18-sm-1010-vl	Communication Networks I		
Instructor		**Type**	**SWS**
Dr.-Ing. Amr Rizk		Lecture	3
Course Nr.	**Course name**		
18-sm-1010-ue	Communication Networks I		
Instructor		**Type**	**SWS**
Dr.-Ing. Amr Rizk		Practice	1

Module name Communication Networks II					
Module Nr. 18-sm-2010	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1	**Cycle offered** WiSe
Language English			**Module owner** Prof. Dr.-Ing. Ralf Steinmetz		

1 Content

The course Communication Networks II covers the principles and practice of computer networking and telecommunications with emphasis on the Internet. Starting with the history, the course discusses past, current and future aspects of communication networks. In addition to the basics including well known protocols and technologies, recent developments in the area of multimedia communication (e.g., Video Streaming, P2P, IP-Telephony, Cloud Computing and Service-oriented Architectures) will be examined thoroughly. The course is designed as follow-up to Communication Networks I.

Topics are:

- Basics and History of Communication Networks (Telegraphy vs. Telephony, Reference Models, ...)
- Transport Layer (Addressing, Flow Control, Connection Management, Error Detection, Congestion Control, ...)
- Transport Protocols (TCP, SCTP)
- Interactive Protocols (Telnet, SSH, FTP, ...)
- Electronic Mail (SMTP, POP3, IMAP, MIME, ...)
- World Wide Web (HTML, URL, HTTP, DNS, ...)
- Distributed Programming (RPC, Web Services, Event-based Communication)
- SOA (WSDL, SOAP, REST, UDDI, ...)
- Cloud Computing (SaaS, PaaS, IaaS, Virtualization, ...)
- Overlay Networks (Unstructured P2P, DHT Systems, Application Layer Multicast, ...)
- Video Streaming (HTTP Streaming, Flash Streaming, RTP/RTSP, P2P Streaming, ...)
- VoIP and Instant Messaging (SIP, H.323)

2 Learning objectives / Learning Outcomes

The course Communication Networks II covers the principles and practice of computer networking and telecommunications with emphasis on the Internet. Starting with the history, the course discusses past, current and future aspects of communication networks. In addition to the basics including well known protocols and technologies, recent developments in the area of multimedia communication (e.g., Video Streaming, P2P, IP-Telephony, Cloud Computing and Service-oriented Architectures) will be examined thoroughly. The course is designed as follow-up to Communication Networks I.

3 Recommended prerequisite for participation

Basic courses of first 4 semesters are required. Knowledge in the topics covered by the course Communication Networks I is recommended. Theoretical knowledge obtained in the course Communication Networks II will be strengthened in practical programming exercises. So, basic programming skills are beneficial.

4 Form of examination

Module Final Examination:

- Module Examination (Technical Examination, Written Examination, Duration: 120 min, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Technical Examination, Written Examination, Weighting: 100 %)

6 Usability of this module

MSc ETiT, MSc iST, Wi-ETiT, CS, Wi-CS

7 References

Selected chapters from following books:

- Andrew S. Tanenbaum: Computer Networks, Fourth 5th Edition, Prentice Hall, 2010
- James F. Kurose, Keith Ross: Computer Networking: A Top-Down Approach, 6th Edition, Addison-Wesley, 2009
- Larry Peterson, Bruce Davie: Computer Networks, 5th Edition, Elsevier Science, 2011

Courses

Course Nr.	**Course name**		
18-sm-2010-vl	Communication Networks II		
Instructor		**Type**	**SWS**
Dr. Ing. Björn Richerzhagen		Lecture	3
Course Nr.	**Course name**		
18-sm-2010-ue	Communication Networks II		
Instructor		**Type**	**SWS**
Dr. Ing. Björn Richerzhagen		Practice	1

Module name					
Communication Networks IV					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-sm-2030	3 CP	90 h	60 h	1	WiSe
Language			**Module owner**		
English			Prof. Dr.-Ing. Ralf Steinmetz		

1 Content

The lecture communication networks IV deals with modelling and performance evaluation of computer networks and communication systems. The emphasis is on current analytical approaches. Owing to these methods a fundamental understanding of major performance related aspects in networking is achieved and basic knowledge for planning, optimization and advancement of communications networks is provided. The relevance and implications of individual theories are illustrated using examples which are drawn mainly from the Internet. Apart from analytical methods the lecture gives an introduction to simulation of communication networks as well as measuring in real or prototypical systems and testbeds. In addition to well-known methods and their applications selected aspects of current research questions will be elaborated on.

Topics of the lecture are:

- Introduction to performance evaluation and applications
- Leaky bucket traffic regulators, deterministic traffic models, deterministic and empirical envelopes
- Scheduling, generalized processor sharing
- Network calculus, min-plus systems theory, deterministic performance bounds
- Poisson processes, Markov-chains, classical queuing theory, M|M|1 and M|G|1 models
- Modeling of packet data traffic, self-similarity
- Effective bandwidths, moment generating functions, statistical multiplexing
- Statistical network calculus, effective envelopes, effective performance bounds
- Simulation, generation of random numbers, distributions, confidence intervals
- Instrumentation, measurements, bandwidth estimation in the Internet

2 Learning objectives / Learning Outcomes

Students attending this lecture obtain an overview on the impact, fundamental methods, and important applications of performance evaluation of communication networks. They are acquainted with characteristic mechanisms and scheduling algorithms used in quality of service networks and are able to explain their functionality in terms of network calculus and the framework of min-plus systems theory. In addition to basic queuing theory the students acquire sound knowledge of the theory of effective bandwidths and thus exhibit a theoretically founded understanding of statistical multiplexing. Beyond analytical methods, the students gain insight into simulation as well as selected measurement methods and tools used in real networks. They are able to define the scope of individual theories and methods, select suitable, problem tailored techniques, apply these to typical problems, and draw relevant conclusions.

3 Recommended prerequisite for participation

Basic courses of the first 4 semesters are required. Knowledge of lectures Communication Networks I and II are recommended.

4 Form of examination

Module Final Examination:

- Module Examination (Technical Examination, Oral Examination, Duration: 30 min, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Technical Examination, Oral Examination, Weighting: 100 %)

6 Usability of this module

Wi-CS, Wi-ETiT, BSc/MSc CS, MSc ETiT, MSc iST

7 References

Ausgewählte Kapitel aus folgenden Büchern:

- J.-Y. Le Boudec, P. Thiran: “Network Calculus: A Theory of Deterministic Queuing Systems for the Internet”, Springer LNCS 2050, http://ica1www.epfl.ch/PS_files/netCalBookv4.pdf, 2004.
- A. Kumar, D. Manjunath, J. Kuri: "Communication Networking: An Analytical Approach", Morgan Kaufmann, 2004.
- A. M. Law, W. D. Kelton: "Simulation, Modeling and Analysis", McGraw Hill, 3rd Ed., 2000.
- Selected Journal Articles and Conference Papers

Courses

Course Nr.	**Course name**		
18-sm-2030-vl	Communication Netzworks IV: Performance Evaluation of Communication Networks		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Ralf Steinmetz		Lecture	2

Module name					
Wireless Sensor Networks					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-sm-2160	6 CP	180 h	120 h	1	WiSe
Language			**Module owner**		
English			Prof. Dr.-Ing. Ralf Steinmetz		

1 Content

The lecture Wireless Sensor Networks (WSN) presents an overview on fundamentals and applications of WSNs. A wireless sensor network is a collection of tiny, autonomously powered devices – commonly called sensor nodes – endowed with sensing, communication, and processing capabilities. Once deployed over a region of interest, sensor nodes can collect fine-grained measurements of physical variables, like the temperature of a glacier, the concentration of a pollutant, or the electricity consumption of a building. To report their readings to one or more data sinks, sensor nodes communicate using their integrated radio-transceivers and build ad-hoc – possibly multi-hop – relay networks. Thanks to the potentially large number of nodes they are composed of and their ability to operate unattended for long periods of time, wireless sensor networks allow monitoring the environment at an unprecedented spatial and temporal scale.
The lecture provides an overview on applications and fundamental topics within and beyond WSNs. This includes hardware platforms, programming, energy-efficient medium access control and routing, data collection and dissemination, localization, synchronization, and integration of WSNs with the Internet and the Web.
The lecture also includes hand-on tutorials on WSN programming during which students will be given the possibility to implement and deploy simple applications using real WSN hardware.

2 Learning objectives / Learning Outcomes

The lecture aims at providing a sound overview of WSN applications and protocols. Students will understand the challenges related to the design and practical realization of such systems and learn how to trade off different factors depending of the specific requirements of the application scenario.

3 Recommended prerequisite for participation

The lecture Wireless Sensor Networks is open to Masters students but is also suitable for advanced Bachelor students. Familiarity with fundamentals of wireless communication, distributed systems, and operating systems is beneficial.

4 Form of examination

Module Final Examination:

- Module Examination (Technical Examination, Written Examination, Duration: 120 min, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Technical Examination, Written Examination, Weighting: 100 %)

6 Usability of this module

MSc ETiT, BSc/MSc iST, MSc CE, MSc Wi-Inf, MSc CS

7 References

Lecture notes as well as selected readings will be made available during the lecture. The following books are also recommended:
[1] Protocols and Architecture for Wireless Sensor Networks: H. Karl and A. Willig, Wiley, Chichester, 2005, ISBN 0-470-09510-5.
[2] Wireless Sensor Networks: An Information Processing Approach: F. Zhao and

Courses

Course Nr.	Course name		
18-sm-2160-vl	Wireless Sensor Networks		
Instructor		**Type**	**SWS**
Dr.-Ing. Doreen Böhnstedt		Lecture	3

	Course Nr. 18-sm-2160-ue	**Course name** Wireless Sensor Networks		
	Instructor Dr.-Ing. Doreen Böhnstedt		**Type** Practice	**SWS** 1

Module name					
Software Defined Networking					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-sm-2280	6 CP	180 h	120 h	1	WiSe
Language			**Module owner**		
German and English			Prof. Dr.-Ing. Ralf Steinmetz		

1 Content

The course deals with topics in the area of software defined networking:

- SDN Data Plane
- SDN Control Plane
- SDN Application Plane
- Network Function Virtualization
- Network Virtualization and Slicing
- QoS and QoE in Software Defined Networks

2 Learning objectives / Learning Outcomes

Students will get a deep insight into Software Defined Networking as well as underlying technologies and applications.

3 Recommended prerequisite for participation

Basic courses of the first 4 semesters are required. Knowledge of lectures Communication Networks I and II are recommended.

4 Form of examination

Module Final Examination:

- Module Examination (Technical Examination, Optional, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Technical Examination, Optional, Weighting: 100 %)

6 Usability of this module

MSc ETiT, BSc/MSc iST, MSc Wi-ETiT, CS, Wi-CS

7 References

Textbooks as indicated.
Slides and paper copies as necessary.

Courses

Course Nr.	Course name		
18-sm-2280-vl	Software Defined Networking		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Ralf Steinmetz		Lecture	2
Course Nr.	**Course name**		
18-sm-2280-ue	Software Defined Networking		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Ralf Steinmetz		Practice	2

Module name Electrical Engineering and Information Technology					
Module Nr. 18-st-3020	**Credit Points** 5 CP	**Workload** 150 h	**Self study** 90 h	**Duration** 1	**Cycle offered** WiSe
Language English			**Module owner** Prof. Dr. rer. nat. Florian Steinke		

1	**Content** Euler's formula, plane of complex numbers, variables of electrical engineering, vector and rotating fields, Coulombs law, Maxwell relation, electrical displacement density, Gauss theorem, capacity, inductivity, operational amplifier, non-linear parts, electric induction, law of refraction, theorem of Kirchhoff, Ohm's law, periodic and non-periodic processes, transfer locus, power calculation, transformers, transmission line equations, travelling waves, Fourier series and transformation
2	**Learning objectives / Learning Outcomes** After the course, the student is able to name the electric variables, to calculate the electric components and networks, to calculate and adopt the electric and magnetic fields, to utilize direct- and alternating current circuits, to use vector diagrams and is aware of multiphase systems and travelling waves.
3	**Recommended prerequisite for participation**
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Written Examination, Duration: 120 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Written Examination, Weighting: 100 %)
6	**Usability of this module** MSc ESE
7	**References** A lecture script and slides are provided via Moodle.

Courses

	Course Nr. 18-st-3020-vl	**Course name** Electrical Engineering and Information Technology		
	Instructor Prof. Dr.-Ing. Volker Hinrichsen		**Type** Lecture	**SWS** 3
	Course Nr. 18-st-3020-ue	**Course name** Electrical Engineering and Information Technology		
	Instructor Prof. Dr.-Ing. Volker Hinrichsen		**Type** Practice	**SWS** 1

Module name Adaptive Filters					
Module Nr. 18-zo-2010	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1	**Cycle offered** SoSe
Language German and English			**Module owner** Prof. Dr.-Ing. Abdelhak Zoubir		

1 Content

Theory:

1) Derivation of optimal filters for stochastic processes, e.g. Wiener filter or linear prediction filter based on suitable cost functions.

2) Elaboration of adaptive procedures, which allow to iteratively approach the optimal solution for non-stationary signals in non-stationary environments. Here, the adaptive procedures such as NLMS adaptation, affine projection, and the RLS algorithm are derived and extensively analysed.

3) Analysis of the adaptation behaviour and control procedures of adaptive filters based on the NLMS procedure.

4) Derivation and analysis of the Kalman filter as optimal filter for non-stationary input signals.

5) Procedures for the decomposition of signals into sub-bands for the realization of optimal filters in the frequency domain, e.g. noise reduction procedures.

Applications:

Parallel to the theory, practical applications are explained. As an example for the Weiner filter, the acoustic noise reduction procedures are explained. Acoustic echo cancellation and feedback cancellation are given as examples for adaptive filters. Furthermore beamforming approaches are introduced.

It is planned to offer an excursion to Siemens Audiology Engineering Group in Erlangen.

In the 4 to 5 exercises, some content of the lecture will be implemented in MATLAB which allows the students to get familiar with practical realizations of the theoretical procedures.

2 Learning objectives / Learning Outcomes

During the lecture, basics of adaptive filters are taught. The necessary algorithms are derived, interpreted and applied to examples of speech, audio and video processing.

Based on the content of the lecture you are able to apply adaptive filters to real practical applications.

For the admission to the exam you give a talk about a topic in the domain of adaptive filters chosen by you. This will allow you to acquire the know-how to read and understand scientific literature, familiarize yourself with an unknown topic and present your knowledge, such as it will be certainly required from you in your professional life as an engineer.

3 Recommended prerequisite for participation

Digital Signal Processing

4 Form of examination

Module Final Examination:

- Module Examination (Technical Examination, Optional, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Technical Examination, Optional, Weighting: 100 %)

6 Usability of this module

MSc ETiT

7 References

Slides of the lecture.

Literature:

- E. Hänsler, G. Schmidt: Acoustic Echo and Noise Control, Wiley, 2004 (Textbook of this course);
- S. Haykin: Adaptive Filter Theory, Prentice Hall, 2002;
- A. Sayed: Fundamentals of Adaptive Filtering, Wiley, 2004;
- P. Vary, U. Heute, W. Hess: Digitale Sprachsignalverarbeitung, Teubner, 1998 (in German)

Courses				
	Course Nr. 18-zo-2010-vl	**Course name** Adaptive Filters		
	Instructor Prof. Dr.-Ing. Henning Puder		**Type** Lecture	**SWS** 3
	Course Nr. 18-zo-2010-ue	**Course name** Adaptive Filters		
	Instructor Prof. Dr.-Ing. Henning Puder		**Type** Practice	**SWS** 1

Module name					
Digital Signal Processing					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-zo-2060	6 CP	180 h	120 h	1	WiSe
Language			**Module owner**		
English			Prof. Dr.-Ing. Abdelhak Zoubir		

1	**Content** 1) Discrete-Time Signals and Linear Systems – Sampling and Reconstruction of Analog Signals 2) Digital Filter Design – Filter Design Principles; Linear Phase Filters; Finite Impulse Response Filters; Infinite Impulse Response Filters; Implementations 3) Digital Spectral Analysis - Random Signals; Nonparametric Methods for Spectrum Estimation; Parametric Spectrum Estimation; Applications; 4) Kalman Filter
2	**Learning objectives / Learning Outcomes** Students will understand basic concepts of signal processing and analysis in time and frequency of deterministic and stochastic signals. They will have first experience with the standard software tool MATLAB.
3	**Recommended prerequisite for participation** Deterministic signals and systems theory
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Written Examination, Duration: 180 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Written Examination, Weighting: 100 %)
6	**Usability of this module** BSc ETiT, Wi-ETiT
7	**References** Course manuscript Additional References: • A. Oppenheim, W. Schafer: Discrete-time Signal Processing, 2nd ed. • J.F. Böhme: Stochastische Signale, Teubner Studienbücher, 1998

Courses

	Course Nr. 18-zo-2060-vl	**Course name** Digital Signal Processing		
	Instructor Prof. Dr.-Ing. Abdelhak Zoubir		**Type** Lecture	**SWS** 3
	Course Nr. 18-zo-2060-ue	**Course name** Digital Signal Processing		
	Instructor Prof. Dr.-Ing. Abdelhak Zoubir		**Type** Practice	**SWS** 1

Module name
Advances in Digital Signal Processing: Imaging and Image Processing

Module Nr.	Credit Points	Workload	Self study	Duration	Cycle offered
18-zo-2080	5 CP	150 h	90 h	1	SoSe

Language	Module owner
English	Prof. Dr.-Ing. Abdelhak Zoubir

1 Content

- Basics
  - Detection, Estimation and Classification
- Imaging
  - Radar Signal Processing
  - Array Signal Processing
  - Image formation
  - Applications of Imaging
- Image Processing
  - Random fields
  - Image segmentation
  - Image reconstruction
  - Image classification
- Project work

2 Learning objectives / Learning Outcomes
After attending the lecture, a student understands the basic principles of imaging systems with radar and sonar. He also is capable of applying image formation with sensor arrays as well as image processing techniques such as segmentation, image reconstruction and classification.

3 Recommended prerequisite for participation
DSP

4 Form of examination
Module Final Examination:

- Module Examination (Technical Examination, Optional, Standard Grading System)

5 Grading
Module Final Examination:

- Module Examination (Technical Examination, Optional, Weighting: 100 %)

6 Usability of this module
BSc/MSc ETiT, MSc Wi/ETiT, BSc/MSc iST, MSc iCE, BSc/MSc MEC

7 References

- Mark Richards, Principles of Modern Radar: Basic Principles. SciTech Publishing 2010
- Didier Massonnet and Jean-Claude Souyris, Imaging with Synthetic Aperture Radar. EPFL Press, 2008
- Gerhard Winkler, Image Analysis, Random Fields and Markov Chain Monte Carlo Methods, 2nd edition, Springer Verlag 2003

Courses

Course Nr.	Course name
18-zo-2080-vl	Advances in Digital Signal Processing: Imaging and Image Processing

Instructor	Type	SWS
Dr.-Ing. Christian Debes	Lecture	2

	Course Nr.	Course name		
	18-zo-2080-ue	Advances in Digital Signal Processing: Imaging and Image Processing		
	Instructor		**Type**	**SWS**
	Dr.-Ing. Christian Debes		Practice	2

Module name Robust Signal Processing With Biomedical Applications					
Module Nr. 18-zo-2090	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1	**Cycle offered** SoSe
Language English			**Module owner** Dr.-Ing. Michael Muma		

1 Content

1. Robust Signal Processing and Learning
   - Measuring robustness
   - Robust estimation of the mean and the variance
   - Robust regression models
   - Robust filtering
   - Robust location and covariance estimation
   - Robust clustering and classification
   - Robust time-series and spectral analysis

2. Biomedical Applications
   - Body-worn sensing of physiological parameters
   - Electrocardiogram (ECG)
   - Photoplethysmogram (PPG)
   - Eye research
   - Intracranial Pressure (ICP)
   - Algorithms for cardiac activity monitoring

The lecture covers fundamental topics and recent developments in robust signal processing. Unlike classical signal processing, which relies strongly on the normal (Gaussian) distribution, robust methods can tolerate impulsive noise, outliers and artifacts that are frequently encountered in biomedical applications. Robust signal processing and biomedical application lectures alternate. Exercises revise the theory and apply robust signal processing algorithms to real world data.

2 Learning objectives / Learning Outcomes

3 Recommended prerequisite for participation

Fundamental knowledge of statistical signal processing

4 Form of examination

Module Final Examination:
- Module Examination (Technical Examination, Written Examination, Duration: 180 min, Standard Grading System)

5 Grading

Module Final Examination:
- Module Examination (Technical Examination, Written Examination, Weighting: 100 %)

6 Usability of this module

MSc ETiT, MSc Wi-ETiT, MSc iCE, MSc iST

7 References

A manuscript and lecture slides can be downloaded via Moodle. Further reading

- Zoubir, A. M. and Koivunen, V. and Ollila, E. and Muma, M.: Robust Statistics for Signal Processing. Cambridge University Press, 2018.
- Zoubir, A. M. and Koivunen, V. and Chackchoukh J, and Muma, M. Robust Estimation in Signal Processing: A Tutorial-Style Treatment of Fundamental Concepts. IEEE Signal Proc. Mag. Vol. 29, No. 4, 2012, pp. 61-80.
- Huber, P. J. and Ronchetti, E. M.: Robust Statistics. Wiley Series in Probability and Statistics, 2009.
- Maronna, R. A. and Martin, R. D. and Yohai, V. J.: Robust Statistics: Theory and Methods. Wiley Series in Probability and Statistics, 2006.

Courses

Course Nr.	**Course name**		
18-zo-2090-vl	Robust Signal Processing With Biomedical Applications		
Instructor		**Type**	**SWS**
Dr.-Ing. Michael Muma		Lecture	3

Course Nr.	**Course name**		
18-zo-2090-ue	Robust Signal Processing With Biomedical Applications		
Instructor		**Type**	**SWS**
Dr.-Ing. Michael Muma		Practice	1

2 Practical courses

Module name Power Laboratory I					
Module Nr. 18-bi-2091	**Credit Points** 4 CP	**Workload** 120 h	**Self study** 75 h	**Duration** 1	**Cycle offered** WiSe
Language German and English			**Module owner** Prof. Dr. techn. Dr.h.c. Andreas Binder		

1	**Content** Safety instructions for laboratory; Topic of experiments: • Electrical energy conversion • Power electronics • High voltage technology • Electrical energy supply • Renewable energies
2	**Learning objectives / Learning Outcomes** Practical knowledge is gained in measuring and operating electrical devices and apparatus of electrical power engineering in small groups of students.
3	**Recommended prerequisite for participation** Power Engineering or similar
4	**Form of examination** Module Final Examination: • Module Examination (Study Achievement, Written Examination, Duration: 120 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Study Achievement, Written Examination, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSc MEC, MSc WI-ETiT
7	**References** Binder, A. et al.: Textbook with detailed description of experiments; Hindmarsh, J.: Electrical Machines and their Application, Pergamon Press, 1991 Nasar, S.A.: Electric Power systems. Schaum's Outlines Mohan, N. et al: Power Electronics, Converters, Applications and Design, John Wiley & Sons, 1995 Kind, D., Körner, H.: High-Voltage Insualtion Technology, Friedr. Vieweg & Sohn, Braunschweig Wiesbaden, 1985, ISBN 3-528-08599-1

Courses			
	Course Nr. 18-bi-2091-pr	**Course name** Power Laboratory I	
	Instructor Prof. Dr. techn. Dr.h.c. Andreas Binder	**Type** Internship	**SWS** 3

	Course Nr.	Course name		
	18-bi-2090-tt	Laboratory Briefing		
	Instructor		**Type**	**SWS**
	Prof. Dr. techn. Dr.h.c. Andreas Binder		Tutorial	0

Module name					
Power Laboratory II					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-bi-2092	4 CP	120 h	75 h	1	SoSe
Language			**Module owner**		
German and English			Prof. Dr. techn. Dr.h.c. Andreas Binder		

1	**Content** Practical course on power engineering - Distribution and Application. About 50% of the units are devoted to power distribution and high voltage engineering; About 50% are dealing with application in drive systems, concerning “field-oriented control” of variable speed drives, encoder sytems, linear permanent magnet and switched reluctance machines.
2	**Learning objectives / Learning Outcomes** Practical knowledge is gained in measuring and operating electrical devices and apparatus of electrical power engineering in small groups of students.
3	**Recommended prerequisite for participation** Master program: Power Lab 1
4	**Form of examination** Module Final Examination: • Module Examination (Study Achievement, Written Examination, Duration: 120 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Study Achievement, Written Examination, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSc MEC, MSc WI-ETiT
7	**References** Text book with detailed laboratory instructions

Courses

	Course Nr. 18-bi-2092-pr	**Course name** Power Laboratory II		
	Instructor Prof. Dr. techn. Dr.h.c. Andreas Binder		**Type** Internship	**SWS** 3
	Course Nr. 18-bi-2090-tt	**Course name** Laboratory Briefing		
	Instructor Prof. Dr. techn. Dr.h.c. Andreas Binder		**Type** Tutorial	**SWS** 0

Module name Practical Training with Drives					
Module Nr. 18-bi-2100	**Credit Points** 4 CP	**Workload** 120 h	**Self study** 75 h	**Duration** 1	**Cycle offered** WiSe/SoSe
Language German and English			**Module owner** Prof. Dr. techn. Dr.h.c. Andreas Binder		

1	**Content** The purpose of this laboratory is gaining extented knowledge about realization and behaviour of drive systems. An introduction in measurement problems concerning drives is given. The contents of the laboratory is setting drives to work and investigating drive systems under laboratory conditions. Special attention is paid to inverter-fed AC drives. The laboratory experiments are individually coordinated with the previous knowledge of the respective courses (ETiT or MEC).
2	**Learning objectives / Learning Outcomes** The students get the ability of measurement for electrical motors, generators and transformers.
3	**Recommended prerequisite for participation** Bachelor of Science in Electrical Engineering, Power Engineering or similar
4	**Form of examination** Module Final Examination: • Module Examination (Study Achievement, Oral Examination, Duration: 30 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Study Achievement, Oral Examination, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSc MEC, MSc WI-ETiT
7	**References** Textbook with lab instructions; Nürnberg, W.: Die Prüfung elektrischer Maschinen, Springer, 2000; Leonhard, W.: Control of electric drives, Springer, 2000; Textbook – Binder, A.: Motor Developement for Electrical Drive Systems; Lecture notes – Mutschler, P.: Control of Drives

Courses

Course Nr. 18-bi-2100-pr	**Course name** Practical Training with Drives		
Instructor Prof. Dr. techn. Dr.h.c. Andreas Binder		**Type** Internship	**SWS** 3
Course Nr. 18-bi-2090-tt	**Course name** Laboratory Briefing		
Instructor Prof. Dr. techn. Dr.h.c. Andreas Binder		**Type** Tutorial	**SWS** 0

Module name Processor Microarchitecture					
Module Nr. 18-hb-2050	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1	**Cycle offered** SoSe
Language English			**Module owner** Prof. Dr.-Ing. Christian Hochberger		

1 Content

Lectures (each block takes 3 * 90 minutes)

1. Processor execution. Sources of performance loss, latency. Possible techniques to improve performance. Simultaneous multi-threading as an established solution. Motivation for multi-threading – p-threads as a model of execution in SW, micro-threading as a model of execution in HW.
2. Definition of micro-threading, its requirements on the microarchitecture. Microthreaded assembly instructions, design alternatives for extended instruction sets. Required support in micro-architecture – self-synchronizing register file, cache controllers, thread scheduler.
3. Execution in the micro-threaded pipeline. Interaction between cache controllers, register file, thread scheduler, integer pipeline. Data dependences between threads and its influence on execution (embarrassingly parallel vs. sequential programs). Interaction with legacy code, execution modes, OS support.
4. Developing for the real world: Writing testbenches. Performance profiling. Indicators of efficient silicon use.
5. Microthreading in multi-core architectures. Big issues: Scalability, sufficient parallelism, trade-off between clock frequency and access latency

Labs:

1. Set up the utgrlib VHDL sources in the home directory. Set up the utbinutils in the home directory. Compilation of introductory examples.
2.-3. Analysis of execution traces for introductory examples. Design of a FIR filter in micro-threaded assembly. Compilation, execution, analysis of pipeline efficiency.
4.-9. Re-design of existing blocks (choose from dcache, icache, regfile). Preparation of a TLM testbench. Coding and testing of the block in a stand-alone testbench.
10.-15. Integration of the block in UTLEON3, execution of micro-threaded programs, evaluation of performance analysis (% performance gain over the original block, % decreased resource requirements).

2 Learning objectives / Learning Outcomes

After completion of the module, students will be able to design a customized microarchitecture of a modern RISC processor and analyze its performance.

The course will be taught using a VHDL implementation of an existing micro-threaded processor UTLEON3 in an FPGA, nevertheless the knowledge gained in the lecture will be applicable to other HDLs, different processor architectures and other implementation technologies.

3 Recommended prerequisite for participation

Hands-on experience with at least one of Verilog or VHDL is expected. Basic understanding of FPGA technology and thorough knowledge of digital circuit design and computer architecture. Several tools used throughout the labs might require additional programming languages and tools (Perl, C, bash). This knowledge can be obtained during the labs.

4 Form of examination

Module Final Examination:

- Module Examination (Technical Examination, Oral Examination, Duration: 30 min, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Technical Examination, Oral Examination, Weighting: 100 %)

6 Usability of this module

MSc ETiT, MSc iCE, MSc iST

7 References

	A script is available as a published book and English slides can be obtained through moodle.

Courses

	Course Nr. 18-hb-2050-vl	**Course name** Processor Microarchitecture	
	Instructor Ph.D. Martin Danek	**Type** Lecture	**SWS** 2
	Course Nr. 18-hb-2050-pr	**Course name** Processor Microarchitecture	
	Instructor Ph.D. Martin Danek	**Type** Internship	**SWS** 2

Module name HDL Lab					
Module Nr. 18-ho-1090	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 135 h	**Duration** 1	**Cycle offered** SoSe
Language English			**Module owner** Prof. Dr.-Ing. Klaus Hofmann		

1	**Content** Realisation of a VHDL- or Verilog-based VLSI System Design Project in a Team with industrial constraints
2	**Learning objectives / Learning Outcomes** A student is, after successful completion of this module, able to 1. design, optimize and verify a complex digital system (e.g. a pipelined CPU or signal processor) using Verilog or VHDL, 2. synthesize the HDL description using commercial CAD software to a gate level description
3	**Recommended prerequisite for participation** Mandatory Prerequisite: Lecture Computer Aided Design for System on Chips, At least one high-level Programming Language, Basic Know-How Linux/Unix, Computer Architectures
4	**Form of examination** Module Final Examination: • Module Examination (Study Achievement, Optional, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Study Achievement, Optional, Weighting: 100 %)
6	**Usability of this module** BSc/MSc ETiT, BSc/MSc Wi-ETiT, MSc iCE, BSc/MSc iST, BSc/MSc MEC, MSc EPE
7	**References** Lecture slides „HDL: Verilog and VHDL“

Courses

	Course Nr. 18-ho-1090-pr	**Course name** HDL Lab		
	Instructor Prof. Dr.-Ing. Klaus Hofmann		**Type** Internship	**SWS** 3

Module name Advanced Integrated Circuit Design Lab					
Module Nr. 18-ho-2120	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 135 h	**Duration** 1	**Cycle offered** SoSe
Language English			**Module owner** Prof. Dr.-Ing. Klaus Hofmann		

1	**Content** Practical Design Tasks in Full Custom Design of Digital or Analog Ciruits using State-of-the-Art Commercial CAD Tools
2	**Learning objectives / Learning Outcomes** A student is, after successful completion of this module, able to 1. develop and verify transistor circuitry using Cadence 2. simulate logic and analog circuits (Pre- and Postlayout) 3. draw, verify and extract layout
3	**Recommended prerequisite for participation** Lecture “Advanced Digital Integrated Circuit Design” or “Analog Integrated Circuit Design”
4	**Form of examination** Module Final Examination: • Module Examination (Study Achievement, Optional, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Study Achievement, Optional, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSc Wi-ETiT, MSc iCE, MSc iST, MSc MEC, MSc EPE
7	**References** ADIC Lecture Slide Copies; John P. Uyemura: Fundamentals of MOS Digital Integrated Circuits; Neil Weste et al.: Principles of CMOS VLSI Design

Courses

Course Nr. 18-ho-2120-pr	**Course name** Advanced Integrated Circuit Design Lab	
Instructor Prof. Dr.-Ing. Klaus Hofmann	**Type** Internship	**SWS** 3

Module name Computer Aided Design for SoCs					
Module Nr. 18-ho-2200	**Credit Points** 5 CP	**Workload** 150 h	**Self study** 90 h	**Duration** 1	**Cycle offered** SoSe
Language English			**Module owner** Prof. Dr.-Ing. Klaus Hofmann		

1	**Content** CAD-Concepts for the design and simulation of integrated system-on-chips
2	**Learning objectives / Learning Outcomes** A student is, after successful completion of this module, able to understand • The most important design and verification abstractions as well as the design flow for the design of integrated electronic systems, • Selected algorithms for optimization, simulation and solving of design tasks, • Advanced methods for the design and simulation of analog integrated circuits in modern CMOS technologies, • Advanced concepts of hardware description languages and their concepts (Verilog, VHDL, Verilog-A, Verilog-AMS, System-Verilog)
3	**Recommended prerequisite for participation** Lecture "Advanced Digital Integrated Circuit Design" (can be attended in parallel) and „Analog Integrated Circuit Design" and "Logic Design"
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Written Examination, Duration: 90 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Written Examination, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSc iST, MSc MEC, MSc Wi-ETiT, MSc iCE
7	**References** Slide Copies

Courses

	Course Nr. 18-ho-2200-vl	**Course name** Computer Aided Design for SoCs		
	Instructor Prof. Dr.-Ing. Klaus Hofmann		**Type** Lecture	**SWS** 2
	Course Nr. 18-ho-2200-ue	**Course name** Computer Aided Design for SoCs		
	Instructor Prof. Dr.-Ing. Klaus Hofmann		**Type** Practice	**SWS** 1
	Course Nr. 18-ho-2200-pr	**Course name** Computer Aided Design for SoCs		
	Instructor Prof. Dr.-Ing. Klaus Hofmann		**Type** Internship	**SWS** 1

Module name Laboratory Communication and Sensor Systems					
Module Nr. 18-jk-2050	**Credit Points** 5 CP	**Workload** 150 h	**Self study** 105 h	**Duration** 1	**Cycle offered** WiSe
Language German and English			**Module owner** Prof. Dr.-Ing. Rolf Jakoby		

1 Content

The student communications lab consist of 7 fundamental experiments out of the field of Communication Engineering:
Mobile Radio Channel + Diversity (SW)
Signal Detection and Parameter Estimation (Matlab)
Digital Modulation (HW)
Coding (SW)
Parasitic Effects in Passive RF Devices (SW)
RF FET Amplifier (HW)
Polarization of Light (HW)
Antennas:
Fields and Impedance (HW)

2 Learning objectives / Learning Outcomes

The students are guided to acquaint themselves with given topics. They learn to perform prepared experiments within a defined frame and minute, analyze and discuss the results. In this training the fundamentals of free scientific work are practiced.

3 Recommended prerequisite for participation

Fundamentals of:

- Communications
- Microwave Engineering
- Digital Signal Processing

4 Form of examination

Module Final Examination:

- Module Examination (Study Achievement, Optional, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Study Achievement, Optional, Weighting: 100 %)

6 Usability of this module

MSc ETiT, MSc iCE, Wi-ETiT

7 References

A description of experiments is offered. It can be bought from Mr. Ziemann (S306/409) or being loaded from the WEB page.

Courses

Course Nr. 18-jk-2050-pr	**Course name** Laboratory Communication and Sensor Systems	
Instructor Prof. Dr.-Ing. Rolf Jakoby	**Type** Internship	**SWS** 3

Module name Microwave Measurement Technologies					
Module Nr. 18-jk-2090	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1	**Cycle offered** SoSe
Language German and English			**Module owner** Prof. Dr.-Ing. Rolf Jakoby		

1	**Content** Introduction to microwave measurement technoloies, high frequency components and their poperties: rf power measurement, spectrum analysis, vertor network analysis (s-parameter, x-parameter, calibration techniques), on-wafer measurements, load/source-pull, material characterization
2	**Learning objectives / Learning Outcomes** By this module, Students will be enabled to undetstand the basic principles of microwave measuement technologies. They are able to use them in measurement applications. The following objectives are linked to the lecture: • The students understand the basic features of the power measurements and the effects of a mismatch or pulsed signals and can independently carry out and interpret measurements. • The students understand the basics of spectrum analysis and can carry out and interpret measurements independently. • The students understand the basics of s-parameter measurements and calibration of network analyzers and can carry out and interpret measurements independently • Students are familiar with various methods for material characterization
3	**Recommended prerequisite for participation** Recommended: Grundlagen der Nachrichtentechnik, Hochfrequenztechnik I
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Oral Examination, Duration: 45 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Oral Examination, Weighting: 100 %)
6	**Usability of this module** MSc etit, MSc WI-etit, MSc iCE, MSc iST
7	**References**

Courses

Course Nr.	**Course name**		
18-jk-2090-vl	Microwave Measurement Technologies		
Instructor Dr.-Ing. Holger Maune		**Type** Lecture	**SWS** 2
Course Nr.	**Course name**		
18-jk-2090-ue	Microwave Measurement Technologies		
Instructor Dr.-Ing. Holger Maune		**Type** Practice	**SWS** 1
Course Nr.	**Course name**		
18-jk-2090-pr	Microwave Measurement Technologies Lab		
Instructor Dr.-Ing. Holger Maune		**Type** Internship	**SWS** 1

Module name Multimedia Communications Lab I					
Module Nr. 18-sm-1020	**Credit Points** 3 CP	**Workload** 90 h	**Self study** 45 h	**Duration** 1	**Cycle offered** WiSe/SoSe
Language German and English			**Module owner** Prof. Dr.-Ing. Ralf Steinmetz		

1 Content

The course deals with cutting edge development topics in the area of multimedia communication systems. Beside a general overview it provides a deep insight into a special development topic. The topics are selected according to the specific working areas of the participating researchers and convey technical and basic scientific competences in one or more of the following topics:

- Network planning and traffic analysis
- Performance evaluation of network applications
- Discrete event simulation for network services
- Protocols for mobile ad hoc networks / sensor networks
- Infrastructure networks for mobile communication / mesh networks
- Context-aware communication and services
- Peer-to-peer systems and architectures
- Content distribution and management systems for multimedia/e-learning
- Multimedia authoring and re-authoring tools
- Web service technologies and service-oriented architectures
- Applications for distributed workflows
- Resource-based Learning

2 Learning objectives / Learning Outcomes

The ability to solve simple problems in the area of multimedia communication shall be acquired. Acquired competences are:

- Design of simple communication applications and protocols
- Implementing and testing of software components for distributed systems
- Application of object-oriented analysis and design techniques
- Presentation of project advances and outcomes

3 Recommended prerequisite for participation

Keen interest to explore basic topics of cutting edge communication and multimedia technologies. Further we expect:

- Basic experience in programming Java/C# (C/C++).
- Knowledge in computer communication networks. Lectures in Communication Networks I and/or Net Centric Systems are recommended.

4 Form of examination

Module Final Examination:

- Module Examination (Study Achievement, Optional, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Study Achievement, Optional, Weighting: 100 %)

6 Usability of this module

BSc ETiT, BSc/MSc iST, MSc MEC, Wi-CS, Wi-ETiT, BSc/MSc CS

7 References

Each topic is covered by a selection of papers and articles. In addition we recommend reading of selected chapters from following books:

- Andrew Tanenbaum: “Computer Networks”. Prentice Hall PTR (ISBN 0130384887)
- Christian Ullenboom: "Java ist auch eine Insel: Programmieren mit der Java Standard Edition Version 5 / 6" (ISBN-13: 978-3898428385)
- Kent Beck: "Extreme Programming Explained - Embrace Changes" (ISBN-13: 978-0321278654)

Courses

Course Nr.	**Course name**		
18-sm-1020-pr	Multimedia Communications Lab I		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Ralf Steinmetz		Internship	3

Module name Multimedia Communications Lab II					
Module Nr. 18-sm-2070	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 135 h	**Duration** 1	**Cycle offered** WiSe/SoSe
Language German and English			**Module owner** Prof. Dr.-Ing. Ralf Steinmetz		

1 Content

The course deals with cutting edge development topics in the area of multimedia communication systems. Besides a general overview it provides a deep insight into a special development topic. The topics are selected according to the specific working areas of the participating researchers and convey technical and basic scientific competences in one or more of the following topics:

- Network planning and traffic analysis
- Performance evaluation of network applications
- Discrete event simulation for network services
- Protocols for mobile ad hoc networks / sensor networks
- Infrastructure networks for mobile communication / mesh networks
- Context-aware communication and services
- Peer-to-peer systems and architectures
- Content distribution and management systems for multimedia / e-learning
- Multimedia authoring and re-authoring tools
- Web service technologies and service-oriented architectures
- Applications for distributed workflows

2 Learning objectives / Learning Outcomes

The ability to solve and evaluate problems in the area of design and development of future multimedia communication networks and applications shall be acquired. Acquired competences are:

- Design of complex communication applications and protocols
- Implementing and testing of software components for distributed systems
- Application of object-oriented analysis and design techniques
- Acquisition of project management techniques for small development teams
- Writing of software documentation and project reports
- Presentation of project advances and outcomes

3 Recommended prerequisite for participation

Keen interest to explore challenging topics which are cutting edge in technology and research. Further we expect:

- Solid experience in programming Java and/or C# (C/C++)
- Solid knowledge in object oriented analysis and design
- Solid knowledge in computer communication networks are recommended
- Lectures in Communication Networks I (II, III, or IV) are an additional plus

4 Form of examination

Module Final Examination:

- Module Examination (Study Achievement, Optional, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Study Achievement, Optional, Weighting: 100 %)

6 Usability of this module

MSc ETiT, MSc iCE, BSc/MSc iST, Wi-ETiT, BSc/MSc CS, Wi-CS,

7 References

Each topic is covered by a selection of papers and articles. In addition we recommend reading of selected chapters from following books:

- Andrew Tanenbaum: “Computer Networks”. Prentice Hall PTR (ISBN 0130384887)
- Christian Ullenboom: "Java ist auch eine Insel: Programmieren mit der Java Standard Edition Version 5 / 6" (ISBN-13: 978-3898428385)
- Joshua Bloch: "Effective Java Programming Language Guide" (ISBN-13: 978-0201310054)
- Erich Gamma, Richard Helm, Ralph E. Johnson: "Design Patterns: Objects of Reusable Object Oriented Software" (ISBN 0-201-63361-2)
- Kent Beck: "Extreme Programming Explained - Embrace Changes" (ISBN-13: 978-0321278654)

Courses

Course Nr.	**Course name**		
18-sm-2070-pr	Multimedia Communications Lab II		
Instructor		**Type**	**SWS**
		Internship	3

Module name					
Multimedia Communications Project II					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-sm-2130	9 CP	270 h	180 h	1	WiSe/SoSe
Language			**Module owner**		
German and English			Prof. Dr.-Ing. Ralf Steinmetz		

1 Content

The course deals with cutting edge scientific and development topics in the area of multimedia communication systems. Besides a general overview it provides a deep insight into a special scientific topic. The topics are selected according to the specific working areas of the participating researchers and convey technical and scientific competences in one or more of the following topics:

- Network planning and traffic analysis
- Performance evaluation of network applications
- Discrete event simulation for network services
- Protocols for mobile ad hoc networks / sensor networks
- Infrastructure networks for mobile communication / mesh networks
- Context-aware communication and services
- Peer-to-peer systems and architectures
- Content distribution and management systems for multimedia / e-learning
- Multimedia authoring and re-authoring tools
- Web service technologies and service-oriented architectures
- Resource-based Learning

2 Learning objectives / Learning Outcomes

The ability to solve and evaluate technical and scientific problems in the area of design and development of future multimedia communication networks and applications using state of the art scientific methods shall be acquired. Acquired competences are:

- Searching and reading of project relevant literature
- Design of complex communication applications and protocols
- Implementing and testing of software components for distributed systems
- Application of object-oriented analysis and design techniques
- Acquisition of project management techniques for small development teams
- Systematic evaluation and analyzing of technical and scientific experiments
- Writing of software documentation and project reports
- Presentation of project advances and outcomes

3 Recommended prerequisite for participation

Keen interest to develop and explore challenging solutions and applications in cutting edge multimedia communications systems using scientific methods. Further we expect:

- Solid experience in programming Java and/or C# (C/C++).
- Solid knowledge in object oriented analysis and design.
- Basic knowledge of design patterns, refactoring and project management.
- Solid knowledge in computer communication networks is recommended.
- Lectures in “Communication Networks I” and “Communication Networks II” are recommended

4 Form of examination

Module Final Examination:

- Module Examination (Study Achievement, Optional, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Study Achievement, Optional, Weighting: 100 %)

6 Usability of this module

	MSc Wi-ETiT, BSc/MSc CS, MSc Wi-CS, MSc ETiT, MSc iST
7	**References** Each topic is covered by a selection of papers and articles. In addition we recommend reading of selected chapters from following books: • Andrew Tanenbaum: “Computer Networks”. Prentice Hall PTR (ISBN 0130384887) • Raj Jain: "The Art of Computer Systems Performance Analysis: Techniques for Experimental Design, Measurement, Simulation, and Modeling" (ISBN 0-471-50336-3) • Joshua Bloch: "Effective Java - Programming Language Guide" (ISBN-13: 978-0201310054) • Erich Gamma, Richard Helm, Ralph E. Johnson: "Design Patterns: Objects of Reusable Object Oriented Software" (ISBN 0-201-63361-2) • Martin Fowler: "Refactorings - Improving the Design of Existing Code" (ISBN-13: 978-0201485677) • Kent Beck: "Extreme Programming Explained - Embrace Changes" (ISBN-13: 978-0321278654)

Courses

	Course Nr.	**Course name**		
	18-sm-2130-pr	Multimedia Communications Project II		
	Instructor		**Type**	**SWS**
	Prof. Dr.-Ing. Ralf Steinmetz		Internship	6

Module name Digital Signal Processing Lab					
Module Nr. 18-zo-2030	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 135 h	**Duration** 1	**Cycle offered** WiSe/SoSe
Language English			**Module owner** Prof. Dr.-Ing. Abdelhak Zoubir		

1	**Content** 1) Introduction to MATLAB 2) Discrete-Time Signals and Systems 3) Frequency-Domain Analysis using the DFT 4) Digital FIR Filter Design 5) IIR Filter Design using Analog Prototypes 6) Nonparametric Spectrum Estimation 7) Parametric Spectrum Estimation.
2	**Learning objectives / Learning Outcomes** The students are able to apply skills acquired in the course Digital Signal Processing. These include the design of digital FIR and IIR filters as well as non-parametric and parametric spectrum estimation. Students learn how MATLAB is used to apply theoretical concepts and to demonstrate signal processing techniques by using hands-on application examples.
3	**Recommended prerequisite for participation** Deterministic signals and systems theory
4	**Form of examination** Module Final Examination: • Module Examination (Study Achievement, Written Examination, Duration: 120 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Study Achievement, Written Examination, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSc iCE
7	**References** Lab manual

Courses

Course Nr. 18-zo-2030-pr	**Course name** Digital Signal Processing Lab		
Instructor Prof. Dr.-Ing. Abdelhak Zoubir		**Type** Internship	**SWS** 3

3 Project seminars

Module name Energy Converters and Electric Drives					
Module Nr. 18-bi-2130	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 135 h	**Duration** 1	**Cycle offered** WiSe/SoSe
Language German and English			**Module owner** Prof. Dr. techn. Dr.h.c. Andreas Binder		

1	**Content** From the topics of proposed scientific theses, subtasks are derived. Groups of two to four students will work on these subtasks under supervision of a tutor. The focus of the work can be either theo-retical or experimental and contains scientific problems in the field of electric energy conversion and electric drives. For study program Mechatronics this corresponds to the Advanced Design Project.
2	**Learning objectives / Learning Outcomes** Energy Converters, Electric Drives, Control of Electric Drives, Teamwork, Writing Scientific Reports, Pre-sentation
3	**Recommended prerequisite for participation** Fundamentals on Electrical Engineering, Three-phase Systems, Mechanics; Lecture „Electrical Machines and Drives“
4	**Form of examination** Module Final Examination: • Module Examination (Study Achievement, Optional, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Study Achievement, Optional, Weighting: 100 %)
6	**Usability of this module** MSc MEC, MSc ETiT,MSc EPE
7	**References** Depending on the project task; manuscripts from the lectures „Electrical Machines and Drives“, „Motor development for electric Drive Systems“, „Regelungstechnik 1“

Courses

Course Nr. 18-bi-2130-pj	**Course name** Energy Converters and Electric Drives	
Instructor Prof. Dr. techn. Dr.h.c. Andreas Binder	**Type** Project Seminar	**SWS** 3

Module name Project Seminar Electromagnetic CAD					
Module Nr. 18-dg-1060	**Credit Points** 8 CP	**Workload** 240 h	**Self study** 180 h	**Duration** 1	**Cycle offered** WiSe/SoSe
Language German and English			**Module owner** Prof. Dr.-Ing. Herbert De Gersem		

1	**Content** Work on a more complex project in numerical field calculation using commercial tools or own software.
2	**Learning objectives / Learning Outcomes** Students will be able to simulate complex engineering problems with numerical field simulation software. They are able to estimate modelling and numerical errors. They know how to present the results on a scientific level in talks and a paper. Students are able to organize teamwork.
3	**Recommended prerequisite for participation** Good understanding of electromagnetic fields, knowledge about numerical simulation methods.
4	**Form of examination** Module Final Examination: • Module Examination (Study Achievement, Oral Examination, Duration: 20 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Study Achievement, Oral Examination, Weighting: 100 %)
6	**Usability of this module** MSc ETiT
7	**References** Course notes “Computational Electromagnetics and Applications I-III”, further material is provided.

Courses

Course Nr.	**Course name**		
18-dg-1060-pj	Project Seminar Electromagnetic CAD		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Herbert De Gersem		Project Seminar	4

Module name Science in Practice I					
Module Nr. 18-dg-2130	**Credit Points** 8 CP	**Workload** 240 h	**Self study** 180 h	**Duration** 1	**Cycle offered** WiSe/SoSe
Language German and English			**Module owner** Prof. Dr.-Ing. Herbert De Gersem		

1	**Content** Acquiring basic scientific skills based on concrete examples from the literature.
2	**Learning objectives / Learning Outcomes** The students possess basic scientific skills. They are able to discover important literature for a given topic and to judge critically the corresponding content. They are familiar with numerical techniques, especially convergence studies relevant for praxis. The students are capable of analyzing errors within simulations and of judging accuracy requirements, e.g., with respect to errors in input data.
3	**Recommended prerequisite for participation** Good understanding of electromagnetic fields, knowledge about numerical simulation methods.
4	**Form of examination** Module Final Examination: • Module Examination (Study Achievement, Oral Examination, Duration: 20 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Study Achievement, Oral Examination, Weighting: 100 %)
6	**Usability of this module** MSc ETiT
7	**References** Material related to the topic is provided.

Courses

	Course Nr. 18-dg-2130-pj	**Course name** Science in Practice I		
	Instructor Prof. Dr.-Ing. Herbert De Gersem		**Type** Project Seminar	**SWS** 4

Module name Science in Practice II					
Module Nr. 18-dg-2140	**Credit Points** 8 CP	**Workload** 240 h	**Self study** 180 h	**Duration** 1	**Cycle offered** WiSe/SoSe
Language German and English			**Module owner** Prof. Dr.-Ing. Herbert De Gersem		

1	**Content** Working on different scientific topics based on techniques acquired in Science in Practice I.
2	**Learning objectives / Learning Outcomes** The students are capable of succesfully working on new scientific topics from the numerical field simulation in a reasonable time. They are able to understand new methods, to implement them if necessary and to carry out simulations. Thereby methodologies discussed in Science in Practice I, especially concerning the solution of systems of equations, as well as convergence and error analysis are employed. They know how to document the results by means of a report and how to present them.
3	**Recommended prerequisite for participation** Good understanding of electromagnetic fields, knowledge about numerical simulation methods.
4	**Form of examination** Module Final Examination: • Module Examination (Study Achievement, Oral Examination, Duration: 20 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Study Achievement, Oral Examination, Weighting: 100 %)
6	**Usability of this module** MSc ETiT
7	**References** Material related to the topic is provided.

Courses

Course Nr. 18-dg-2140-pj	**Course name** Science in Practice II		
Instructor Prof. Dr.-Ing. Herbert De Gersem		**Type** Project Seminar	**SWS** 4

Module name Project Seminar Design for Testability					
Module Nr. 18-ho-2130	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 135 h	**Duration** 1	**Cycle offered** SoSe
Language English			**Module owner** Prof. Dr.-Ing. Klaus Hofmann		

1	**Content** Learning advanced Methods for Testing Microchips after Manufacturing and Practical Application in small Design Scenarios, Final Presentation
2	**Learning objectives / Learning Outcomes** Learning advanced Methods for Testing Microchips after Manufacturing and Practical Application in small Design Scenarios, Final Presentation
3	**Recommended prerequisite for participation** Lecture “Advanced Digital Integrated Circuit Design”
4	**Form of examination** Module Final Examination: • Module Examination (Study Achievement, Optional, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Study Achievement, Optional, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSc Wi-ETiT, MSc iCE, MSc iST, MSc MEC, MSc EPE
7	**References** Slide Copies

Courses

Course Nr. 18-ho-2130-pj	**Course name** Project Seminar Design for Testability	
Instructor Prof. Dr.-Ing. Klaus Hofmann	**Type** Project Seminar	**SWS** 3

Module name Project Seminar Communication and Sensor Systems					
Module Nr. 18-jk-1041	**Credit Points** 8 CP	**Workload** 240 h	**Self study** 180 h	**Duration** 1	**Cycle offered** WiSe/SoSe
Language German and English			**Module owner** Prof. Dr.-Ing. Rolf Jakoby		

1	**Content** Investigating and solving specific problems concerning communication and sensor systems (Problems concerning communications engineering, microwave technology, signal processing, sensor networks etc. are possible, topics will be defined out of the recent research topics of the involved labs), working on a a given task by one's own, organizing and structuring of a seminar task, searching and analyzing of scientific reference publications for a given task, summarizing achieved results and conclusions by means of a written report, presenting achieved results and conclusions and defending them in an oral discussion including audience.
2	**Learning objectives / Learning Outcomes** After completion of the course, students possess: • the ability to apply methods of communication and sensor systems to practical problems • deep and special knowledge in a particular field of communication and sensor systems (communications engineering), RF technology, signal processing, sensor networks • the skills to find, analyze and evaluate scientific reference papers for a particular topic • the capability to summarize the achieved scientific findings in the form of a concise report • the ability to present and discuss achieved results in the form of a presentation in front of an audience
3	**Recommended prerequisite for participation** Previous knowledge in chosen discipline, e.g. communication technology, signal processing, microwave technology, sensor networks
4	**Form of examination** Module Final Examination: • Module Examination (Study Achievement, Optional, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Study Achievement, Optional, Weighting: 100 %)
6	**Usability of this module** BSc ETiT, BSc Wi-ETiT, BSc CE, BSc iST, BSc MEC
7	**References** Will be announced in the lecture

Courses

Course Nr.	**Course name**		
18-jk-1041-pj	Project Seminar Communication and Sensor Systems		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Rolf Jakoby		Project Seminar	4

Module name Project Seminar Advanced μWave Components & Antennas					
Module Nr. 18-jk-2060	**Credit Points** 8 CP	**Workload** 240 h	**Self study** 180 h	**Duration** 1	**Cycle offered** WiSe/SoSe
Language German and English			**Module owner** Prof. Dr.-Ing. Rolf Jakoby		

1 Content

Groups of 2-3 students per project. Students work out a well defined fundamental or actual research- related problem. The projects will be actualized in each cycle being offered and introduced at the beginning. Each group will be supervised individually. The projects comprises modern antennas for multitudinous applications, electronically-steerable antennas, RFIDs, RF sensors, adaptive tunable components such as matching networks, filter, passive mixer and modulator for next-generation mobile terminals and sensor systems.

2 Learning objectives / Learning Outcomes

Research-oriented Project Seminar in groups of 2-3 students per project with individual supervision. Students will learn

- how to solve scientific hardware-oriented problems
- working out concepts
- how to design, realize and characterize RF devices
- how to use commercial software and characterization tools
- to evaluate and discuss their work in the context of the state-of-art in this field
- to write a brief scientific report about their work
- to present and discus their results at the end of the Project Seminar

3 Recommended prerequisite for participation

Fundamentals of Microwave Engineering I and Antennas and Adaptive Beamforming

4 Form of examination

Module Final Examination:

- Module Examination (Study Achievement, Oral Examination, Duration: 30 min, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Study Achievement, Oral Examination, Weighting: 100 %)

6 Usability of this module

MSc ETiT, MSc iCE, Wi-ETiT

7 References

Publications will be hand out to them. Software and characterization tools as well as tools to realize RF devices are available.

Courses

Course Nr. 18-jk-2060-pj	**Course name** Project Seminar Advanced μWave Components & Antennas	
Instructor Prof. Dr.-Ing. Rolf Jakoby	**Type** Project Seminar	**SWS** 4

Module name Project Seminar Particle Accelerator Technology					
Module Nr. 18-kb-1020	**Credit Points** 9 CP	**Workload** 270 h	**Self study** 210 h	**Duration** 1	**Cycle offered** WiSe/SoSe
Language German and English			**Module owner** Prof. Dr.-Ing. Harald Klingbeil		

1	**Content** Work on a more complex project in the field of particle accelerator technology. Depending on the specific problem, measurement aspects, analytical aspects, and simulation aspects will be included.
2	**Learning objectives / Learning Outcomes** Students will be able to solve complex engineering problems with different measurement techniques, analytical approaches or simulation methods. They are able to estimate measurement errors and modeling and simulation errors. They know how to present the results on a scientific level in talks and a paper. Students are able to organize teamwork.
3	**Recommended prerequisite for participation** Good understanding of electromagnetic fields, broad knowledge of different electrical engineering disciplines.
4	**Form of examination** Module Final Examination: • Module Examination (Study Achievement, Oral Examination, Duration: 20 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Study Achievement, Oral Examination, Weighting: 100 %)
6	**Usability of this module** BSc ETiT
7	**References** Suitable material is provided based on specific problem.

Courses

Course Nr. 18-kb-1020-pj	**Course name** Project Seminar Particle Accelerator Technology	
Instructor Prof. Dr.-Ing. Harald Klingbeil	**Type** Project Seminar	**SWS** 4

Module name Project seminar Applications of Lighting Engineering					
Module Nr. 18-kh-2051	**Credit Points** 5 CP	**Workload** 150 h	**Self study** 105 h	**Duration** 1	**Cycle offered** WiSe/SoSe
Language German and English			**Module owner** Prof. Dr.-Ing. Khanh Quoc Tran		

1	**Content** The project seminar deals with the following subjects: automotive lighting, interior lighting, exterior lighting; generation, perception and cognition of the visual stimulus (luminaires, displays, projection); LED/OLED technology; physical and psychophysical light measurement; illuminating engineering, color perception.
2	**Learning objectives / Learning Outcomes** The objective of this project seminar is the practice oriented implementation of the material learned during the lectures in form of a project work. Via communication of the interdisciplinary way of thinking of the lighting engineer, students should carry out autonomous project work on their own or in a team.
3	**Recommended prerequisite for participation** Lighting Technology I-II (desireable)
4	**Form of examination** Module Final Examination: • Module Examination (Study Achievement, Optional, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Study Achievement, Optional, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSc iST, MSc WI-ETiT, MSc MEC, MSc MPE, MSc Phys
7	**References** Lecture notes of Lighting Technology I (Khanh); Lecture slides of our Laboratory; Book “LED Lighting: Technology and Perception” (Khanh et al., Wiley); Book „Farbwiedergabe“ (Khanh et al., Pflaum-Verlag); specific literature depending on the topic, publications.

Courses

Course Nr. 18-kh-2051-pj	**Course name** Project seminar Applications of Lighting Engineering	
Instructor Prof. Dr.-Ing. Khanh Quoc Tran	**Type** Project Seminar	**SWS** 3

Module name Project Seminar Communication and Sensor Systems					
Module Nr. 18-kl-1041	**Credit Points** 8 CP	**Workload** 240 h	**Self study** 180 h	**Duration** 1	**Cycle offered** WiSe/SoSe
Language German and English			**Module owner** Prof. Dr.-Ing. Anja Klein		

1	**Content** Investigating and solving specific problems concerning communication and sensor systems (Problems concerning communications engineering, microwave technology, signal processing, sensor networks etc. are possible, topics will be defined out of the recent research topics of the involved labs), working on a a given task by one's own, organizing and structuring of a seminar task, searching and analyzing of scientific reference publications for a given task, summarizing achieved results and conclusions by means of a written report, presenting achieved results and conclusions and defending them in an oral discussion including audience.
2	**Learning objectives / Learning Outcomes** After completion of the course, students possess: • the ability to apply methods of communication and sensor systems to practical problems • deep and special knowledge in a particular field of communication and sensor systems (communications engineering), RF technology, signal processing, sensor networks • the skills to find, analyze and evaluate scientific reference papers for a particular topic • the capability to summarize the achieved scientific findings in the form of a concise report • the ability to present and discuss achieved results in the form of a presentation in front of an audience
3	**Recommended prerequisite for participation** Previous knowledge in chosen discipline, e.g. communication technology, signal processing, microwave technology, sensor networks
4	**Form of examination** Module Final Examination: • Module Examination (Study Achievement, Optional, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Study Achievement, Optional, Weighting: 100 %)
6	**Usability of this module** BSc ETiT, BSc Wi-ETiT, BSc CE, BSc iST, BSc MEC
7	**References** Will be announced in the lecture

Courses

Course Nr.	**Course name**		
18-kl-1041-pj	Project Seminar Communication and Sensor Systems		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Anja Klein		Project Seminar	4

Module name Project Seminar Wireless Communications					
Module Nr. 18-kl-2040	**Credit Points** 8 CP	**Workload** 240 h	**Self study** 180 h	**Duration** 1	**Cycle offered** SoSe
Language English			**Module owner** Prof. Dr.-Ing. Anja Klein		

1 Content

Solving special Problems concerning mobile communications (problems concerning signal transmission and processing as well as problems concerning the network are possible, topics will be defined out of the current research topics of the lab),
working on the project in teams together (2-3 students)
organizing and structuring of a project
dealing with scientific publications, reading up the theoretical background of the task
practical work on a complex task
scientific presentation of the results (report/presentation)
defending the work in an oral discussion including an audience

2 Learning objectives / Learning Outcomes

After completion of the course, students possess

- the ability to classify and analyze special problems concerning mobile communications,
- the knowledge to plan and organize projects with temporal limitation,
- the capability to setup and test methodologies for analysis and simulation- environments,
- skills to evaluate and present achieved results and achieved conclusions.

3 Recommended prerequisite for participation

Previous knowledge in digital communications, signal processing, mobile radio

4 Form of examination

Module Final Examination:

- Module Examination (Study Achievement, Oral Examination, Duration: 20 min, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Study Achievement, Oral Examination, Weighting: 100 %)

6 Usability of this module

MSc ETiT, MSc Wi-ETiT, MSc CE, MSc iCE, MSc iST, MSc MEC

7 References

Lecture documentation will be provided and specific literature will be announced during the course.

Courses

Course Nr. 18-kl-2040-pj	**Course name** Project Seminar Wireless Communications		
Instructor Prof. Dr.-Ing. Anja Klein		**Type** Project Seminar	**SWS** 4

Module name Project Seminar Communication and Sensor Systems					
Module Nr. 18-kp-1041	**Credit Points** 8 CP	**Workload** 240 h	**Self study** 180 h	**Duration** 1	**Cycle offered** Every Sem.
Language German and English			**Module owner** Prof. Dr. techn. Heinz Köppl		

1 Content

Investigating and solving specific problems concerning communication and sensor systems (Problems concerning communications engineering, microwave technology, signal processing, sensor networks etc. are possible, topics will be defined out of the recent research topics of the involved labs), working on a a given task by one's own, organizing and structuring of a seminar task, searching and analyzing of scientific reference publications for a given task, summarizing achieved results and conclusions by means of a written report, presenting achieved results and conclusions and defending them in an oral discussion including audience.

2 Learning objectives / Learning Outcomes

After completion of the course, students possess:

- the ability to apply methods of communication and sensor systems to practical problems
- deep and special knowledge in a particular field of communication and sensor systems (communications engineering), RF technology, signal processing, sensor networks
- the skills to find, analyze and evaluate scientific reference papers for a particular topic
- the capability to summarize the achieved scientific findings in the form of a concise report
- the ability to present and discuss achieved results in the form of a presentation in front of an audience

3 Recommended prerequisite for participation

Previous knowledge in chosen discipline, e.g. communication technology, signal processing, microwave technology, sensor networks

4 Form of examination

Module Final Examination:

- Module Examination (Study Achievement, Optional, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Study Achievement, Optional, Weighting: 100 %)

6 Usability of this module

BSc ETiT, BSc Wi-ETiT, BSc CE, BSc iST, BSc MEC

7 References

Will be announced in the lecture

Courses

Course Nr. 18-kp-1041-pj	**Course name** Project Seminar Communication and Sensor Systems		
Instructor Prof. Dr. techn. Heinz Köppl		**Type** Project Seminar	**SWS** 4

Module name Project Seminar Communication and Sensor Systems					
Module Nr. 18-ku-1041	**Credit Points** 8 CP	**Workload** 240 h	**Self study** 180 h	**Duration** 1	**Cycle offered** WiSe/SoSe
Language German and English			**Module owner** Prof. Dr. rer. nat. Thomas Kusserow		

1	**Content** Investigating and solving specific problems concerning communication and sensor systems (Problems concerning communications engineering, microwave technology, signal processing, sensor networks etc. are possible, topics will be defined out of the recent research topics of the involved labs), working on a a given task by one's own, organizing and structuring of a seminar task, searching and analyzing of scientific reference publications for a given task, summarizing achieved results and conclusions by means of a written report, presenting achieved results and conclusions and defending them in an oral discussion including audience.
2	**Learning objectives / Learning Outcomes** After completion of the course, students possess: • the ability to apply methods of communication and sensor systems to practical problems • deep and special knowledge in a particular field of communication and sensor systems (communications engineering), RF technology, signal processing, sensor networks • the skills to find, analyze and evaluate scientific reference papers for a particular topic • the capability to summarize the achieved scientific findings in the form of a concise report • the ability to present and discuss achieved results in the form of a presentation in front of an audience
3	**Recommended prerequisite for participation** Previous knowledge in chosen discipline, e.g. communication technology, signal processing, microwave technology, sensor networks
4	**Form of examination** Module Final Examination: • Module Examination (Study Achievement, Optional, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Study Achievement, Optional, Weighting: 100 %)
6	**Usability of this module** BSc ETiT, BSc Wi-ETiT, BSc CE, BSc iST, BSc MEC
7	**References** Will be announced in the lecture

Courses

Course Nr.	**Course name**		
18-ku-1041-pj	Project Seminar Communication and Sensor Systems		
Instructor		**Type**	**SWS**
Prof. Dr. rer. nat. Thomas Kusserow		Project Seminar	4

Module name Project Seminar Communication and Sensor Systems					
Module Nr. 18-pe-1041	**Credit Points** 8 CP	**Workload** 240 h	**Self study** 180 h	**Duration** 1	**Cycle offered** WiSe/SoSe
Language German and English			**Module owner** Prof. Dr.-Ing. Marius Pesavento		

1	**Content** Investigating and solving specific problems concerning communication and sensor systems (Problems concerning communications engineering, microwave technology, signal processing, sensor networks etc. are possible, topics will be defined out of the recent research topics of the involved labs), working on a a given task by one's own, organizing and structuring of a seminar task, searching and analyzing of scientific reference publications for a given task, summarizing achieved results and conclusions by means of a written report, presenting achieved results and conclusions and defending them in an oral discussion including audience.
2	**Learning objectives / Learning Outcomes** After completion of the course, students possess: • the ability to apply methods of communication and sensor systems to practical problems • deep and special knowledge in a particular field of communication and sensor systems (communications engineering), RF technology, signal processing, sensor networks • the skills to find, analyze and evaluate scientific reference papers for a particular topic • the capability to summarize the achieved scientific findings in the form of a concise report • the ability to present and discuss achieved results in the form of a presentation in front of an audience
3	**Recommended prerequisite for participation** Previous knowledge in chosen discipline, e.g. communication technology, signal processing, microwave technology, sensor networks
4	**Form of examination** Module Final Examination: • Module Examination (Study Achievement, Optional, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Study Achievement, Optional, Weighting: 100 %)
6	**Usability of this module** BSc ETiT, BSc Wi-ETiT, BSc CE, BSc iST, BSc MEC
7	**References** Will be announced in the lecture

Courses

Course Nr. 18-pe-1041-pj	**Course name** Project Seminar Communication and Sensor Systems	
Instructor Prof. Dr.-Ing. Marius Pesavento	**Type** Project Seminar	**SWS** 4

Module name Projekt Seminar Advanced Algorithms for Smart Antenna Systems					
Module Nr. 18-pe-2040	**Credit Points** 8 CP	**Workload** 240 h	**Self study** 180 h	**Duration** 1	**Cycle offered** SoSe
Language English			**Module owner** Prof. Dr.-Ing. Marius Pesavento		

1	**Content** This project-seminar course introduces the basics of the theory and applications of smart antennas including space-time and multiple-input multiple-output communications, direction-of-arrival estimation and source localization in antenna arrays, and adaptive multiantenna techniques for interference suppression, adaptive transmit and receive beamforming, concensus and defusion algorithms for wireless sensor networks.
2	**Learning objectives / Learning Outcomes** Students will understand theory, algorithms and applications of smart antennas.
3	**Recommended prerequisite for participation** Knowledge of basic communication theory
4	**Form of examination** Module Final Examination: • Module Examination (Study Achievement, Oral Examination, Duration: 40 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Study Achievement, Oral Examination, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSc Wi-ETiT, MSc iCE
7	**References** 1. Daniel P. Palomar and Yonina C. Eldar, Convex Optimization in Signal Processing and Communications, Cambridge University Press, 2009. 2. Harry L. Van Trees, Optimum Array Processing: Part IV of Detection, Estimation, and Modulation Theory, John Wiley & Sons, 2002. 3. Y. Hua, A.B. Gershman and Q. Cheng (Editors), High-Resolution and Robust Signal Processing, Marcel Dekker, NY, 2004. 4. A.B. Gershman and N.D. Sidiropoulos (Editors), Space-Time Processing for MIMO Communications, Wiley & Sons, 2005.

Courses

Course Nr. 18-pe-2040-pj	**Course name** Projekt Seminar Advanced Algorithms for Smart Antenna Systems		
Instructor Prof. Dr.-Ing. Marius Pesavento		**Type** Project Seminar	**SWS** 4

Module name					
Projekt Seminar Procedures for Massive MIMO and 5G					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-pe-2050	8 CP	240 h	180 h	1	SoSe
Language			**Module owner**		
English			Prof. Dr.-Ing. Marius Pesavento		

1 Content

This project-seminar introduces the basics concepts of the signal processing algorithms and cross-layer procedures for extremely large so-called Massive MIMO systems and mobile communication networks of the 5th generation (5G).
In Massive MIMO systems the number of base transmit and receive antennas at the base station are scaled up, as compared to usual MIMO systems, by several orders of magnitude.In this seminar we investigate advanced signal processing algorithms which allow to exploit the advantages of Massive MIMO in an optimum way (which are high data rate, high reliability, favorable propagation characteristics), to cope with the enormous date volume (linear signal processing) and to master the challenges (pilot contamination, low-cost hardware). Massive MIMO is an integral part of the emerginjg 5G mobile communication networks. In the course of the seminar the fundamental concepts and challenges of 5G networks will be discussed. It includes concepts as Small Cells, Cloud RAN, Network Virtualization, Network slicing, Machine-to-Machine communication, Millimeter Wave Transmission, Flexible Waveforms, etc.

2 Learning objectives / Learning Outcomes

Students will learn the fundamental concepts, procedures, theories, algorithms and applications of Massive MIMO systems and 5 G mobile communication networks by the latest scientific publications.

3 Recommended prerequisite for participation

4 Form of examination

Module Final Examination:

- Module Examination (Study Achievement, Oral Examination, Duration: 40 min, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Study Achievement, Oral Examination, Weighting: 100 %)

6 Usability of this module

MSc ETiT, MSc Wi-ETiT, MSc iCE

7 References

- http://www.commsys.isy.liu.se/vlm/icc_tutorial_P1.pdf
- http://www.commsys.isy.liu.se/vlm/icc_tutorial_P2.pdf
- http://www.massivemimo.eu/
- A. Chockalingam and B. Sundar Rajan. *Large MIMO Systems*, Cambridge University Press. Cambridge, 2015
- NGMN Alliance (2015) 5G White Paper https://www.ngmn.org/uploads/media/NGMN_5G_White_Paper_V1_0.

Courses

Course Nr.	Course name		
18-pe-2050-pj	Projekt Seminar Procedures for Massive MIMO and 5G		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Marius Pesavento		Project Seminar	4

Module name
Project Seminar Terahertz Systems & Applications

Module Nr.	Credit Points	Workload	Self study	Duration	Cycle offered
18-pr-1020	9 CP	270 h	210 h	1	WiSe/SoSe

Language	Module owner
German and English	Prof. Dr. rer. nat. Sascha Preu

1 Content

Investigating and solving specific problems concerning the development of Terahertz devices and systems as well as of applications of THz technology. The specific task will be defined based on current research topics. The project seminar includes working on a given task by one's own, organizing and structuring of a seminar task, searching and analyzing of scientific reference publications, summarizing achieved results and conclusions by means of a written report, presenting achieved results and conclusions and defending them in an oral discussion including audience. Topics include, e.g.:

- Optics on chip
- Semiconductor devicesLight-matter interaction

2 Learning objectives / Learning Outcomes

After completion of the course, students possess:

- the ability to apply theoretical models to practical problems
- deep and special knowledge in a particular field related to THz science, optics or semiconductor physics
- the skills to find, analyze and evaluate scientific reference papers for a particular topic
- the capability to summarize the achieved scientific findings in the form of a concise reportthe ability to present and discuss achieved results in the form of a presentation in front of an audience

3 Recommended prerequisite for participation

Previous knowledge one of the following disciplines: Optics, semiconductor physics, or THz technology

4 Form of examination

Module Final Examination:

- Module Examination (Study Achievement, Optional, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Study Achievement, Optional, Weighting: 100 %)

6 Usability of this module

BSc ETiT, BSc Wi-ETiT, BSc/MSc iST

7 References

Will be announced once the topic is defined

Courses

Course Nr.	Course name		
18-pr-1020-pj	Project Seminar Terahertz Systems & Applications		
Instructor		**Type**	**SWS**
Prof. Dr. rer. nat. Sascha Preu		Project Seminar	4

Module name
Project Seminar Communication and Sensor Systems

Module Nr.	Credit Points	Workload	Self study	Duration	Cycle offered
18-pr-1041	8 CP	240 h	180 h	1	WiSe/SoSe

Language	Module owner
German and English	Prof. Dr. rer. nat. Sascha Preu

1 Content

Investigating and solving specific problems concerning the development of Terahertz sensors and -systems as well as of applications of THz technology. The specific task will be defined based on current research topics. The project seminar includes working on a given task by one's own, organizing and structuring of a seminar task, searching and analyzing of scientific reference publications, summarizing achieved results and conclusions by means of a written report, presenting achieved results and conclusions and defending them in an oral discussion including audience. Topics include, e.g.:

- Optics on chip
- Semiconductor devicesLight-matter interaction

2 Learning objectives / Learning Outcomes

After completion of the course, students possess:

- the ability to apply theoretical models to practical problems
- deep and special knowledge in a particular field related to THz science, optics or semiconductor physics
- the skills to find, analyze and evaluate scientific reference papers for a particular topic
- the capability to summarize the achieved scientific findings in the form of a concise reportthe ability to present and discuss achieved results in the form of a presentation in front of an audience

3 Recommended prerequisite for participation

Previous knowledge one of the following disciplines: Optics, semiconductor physics, or THz technology

4 Form of examination

Module Final Examination:

- Module Examination (Study Achievement, Optional, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Study Achievement, Optional, Weighting: 100 %)

6 Usability of this module

BSc ETiT, BSc Wi-ETiT, BSc CE, BSc iST, BSc MEC

7 References

Will be announced once the topic is defined.

Courses

Course Nr.	Course name		
18-pr-1041-pj	Project Seminar Communication and Sensor Systems		
Instructor		**Type**	**SWS**
Prof. Dr. rer. nat. Sascha Preu		Project Seminar	4

Module name					
Multimedia Communications Project I					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-sm-1030	9 CP	270 h	210 h	1	WiSe/SoSe
Language			**Module owner**		
German and English			Prof. Dr.-Ing. Ralf Steinmetz		

1 Content

The course deals with cutting edge scientific and development topics in the area of multimedia communication systems. Besides a general overview, it provides a deep insight into a special scientific topic. The topics are selected according to the specific working areas of the participating researchers and convey technical and scientific competences in one or more of the following topics:

- Network planning and traffic analysis
- Performance evaluation of network applications
- Discrete event simulation for network services
- Protocols for mobile ad hoc networks / sensor networks
- Infrastructure networks for mobile communication / mesh networks
- Context-aware communication and services
- Peer-to-peer systems and architectures
- Content distribution and management systems for multimedia/e-learning
- Multimedia authoring and re-authoring tools
- Web service technologies and service-oriented architectures
- Applications for distributed workflows
- Resource-based Learning

2 Learning objectives / Learning Outcomes

The ability to solve and evaluate technical problems in the area of design and development of future multimedia communication networks and applications using state of the art scientific methods. Acquired competences are among the following:

- Searching and reading of project relevant literature
- Design of communication applications and protocols
- Implementing and testing of software components
- Application of object-orient analysis and design techniques
- Acquisition of project management techniques for small development teams
- Evaluation and analyzing of technical scientific experiments
- Writing of software documentation and project reports
- Presentation of project advances and outcomes

3 Recommended prerequisite for participation

Keen interest to develop and explore challenging solutions and applications in cutting edge multimedia communication systems. Further we expect:

- Basic experience in programming Java/C# (C/C++).
- Basic knowledge in Object oriented analysis and design.
- Knowledge in computer communication networks. Lectures in Communication Networks I and/or Net Centric Systems are recommended.

4 Form of examination

Module Final Examination:

- Module Examination (Study Achievement, Optional, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Study Achievement, Optional, Weighting: 100 %)

6 Usability of this module

	BSc ETiT, BSc/MSc iST, MSc MEC, Wi-CS, Wi-ETiT, BSc/MSc CS
7	**References** Each topic is covered by a selection of papers and articles. In addition we recommend reading of selected chapters from following books: • Andrew Tanenbaum: “Computer Networks”. Prentice Hall PTR (ISBN 0130384887) • Raj Jain: "The Art of Computer Systems Performance Analysis: Techniques for Experimental Design, Measurement, Simulation, and Modeling" (ISBN 0-471-50336-3) • Erich Gamma, Richard Helm, Ralph E. Johnson: "Design Patterns: Objects of Reusable Object Oriented Software" (ISBN 0-201-63361-2) • Kent Beck: "Extreme Programming Explained - Embrace Changes" (ISBN-13: 978-0321278654)

Courses

	Course Nr.	**Course name**		
	18-sm-1030-pj	Multimedia Communications Project I		
	Instructor		**Type**	**SWS**
	Prof. Dr.-Ing. Ralf Steinmetz		Project Seminar	4

Module name					
Multimedia Communications Project Seminar II					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-sm-2080	6 CP	180 h	135 h	1	WiSe/SoSe
Language			**Module owner**		
German and English			Prof. Dr.-Ing. Ralf Steinmetz		

1 Content

The course deals with cutting edge scientific and development topics in the area of multimedia communication systems. Besides a general overview it provides a deep insight into a special scientific topic. The topics are selected according to the specific working areas of the participating researchers and convey technical and scientific competences in one or more of the following topics:

- Network planning and traffic analysis
- Performance evaluation of network applications
- Discrete event simulation for network services
- Protocols for mobile ad hoc networks / sensor networks
- Infrastructure networks for mobile communication / mesh networks
- Context-aware communication and services
- Peer-to-peer systems and architectures
- Content distribution and management systems for multimedia / e-learning
- Multimedia authoring and re-authoring tools
- Web service technologies and service-oriented architectures
- Applications for distributed workflows

2 Learning objectives / Learning Outcomes

The ability to solve and evaluate technical and scientific problems in the area of design and development of future multimedia communication networks and applications using state of the art scientific methods shall be acquired. Acquired competences are:

- Searching and reading of project relevant literature
- Design of complex communication applications and protocols
- Implementing and testing of software components for distributed systems
- Application of object-oriented analysis and design techniques
- Acquisition of project management techniques for small development teams
- Systematic evaluation and analyzing of technical and scientific experiments
- Writing of software documentation and project reports
- Presentation of project advances and outcomes

3 Recommended prerequisite for participation

Keen interest to develop and explore challenging solutions and applications in cutting edge multimedia communications systems using scientific methods. Further we expect:

- Solid experience in programming Java and/or C (C/C++)
- Solid knowledge in object oriented analysis and design
- Basic knowledge of design patterns, refactoring and project management
- Solid knowledge in computer communication networks are recommended
- Lectures in Communication Networks I (II, III, or IV) are an additional plus

4 Form of examination

Module Final Examination:

- Module Examination (Study Achievement, Optional, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Study Achievement, Optional, Weighting: 100 %)

6 Usability of this module

	Wi-CS, Wi-ETiT, BSc/MSc CS, MSc ETiT, MSc iST
7	**References** Each topic is covered by a selection of papers and articles. In addition we recommend reading of selected chapters from following books: • Andrew Tanenbaum: “Computer Networks”. Prentice Hall PTR (ISBN 0130384887) • Raj Jain: "The Art of Computer Systems Performance Analysis: Techniques for Experimental Design, Measurement, Simulation, and Modeling" (ISBN 0-471-50336-3) • Joshua Bloch: "Effective Java - Programming Language Guide" (ISBN-13: 978-0201310054) • Erich Gamma, Richard Helm, Ralph E. Johnson: "Design Patterns: Objects of Reusable Object Oriented Software" (ISBN 0-201-63361-2) • Martin Fowler: "Refactorings - Improving the Design of Existing Code" (ISBN-13: 978-0201485677) • Kent Beck: "Extreme Programming Explained - Embrace Changes" (ISBN-13: 978-0321278654)

Courses

	Course Nr.	**Course name**		
	18-sm-2080-pj	Multimedia Communications Project Seminar II		
	Instructor		**Type**	**SWS**
	Prof. Dr.-Ing. Ralf Steinmetz		Project Seminar	3

Module name					
Advanced Topics in Micro- and Nano Electronics					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-sw-2030	4 CP	120 h	90 h	1	SoSe
Language			**Module owner**		
German and English			Prof. Dr. rer. nat. Udo Eugen Schwalke		

1 Content

- Choice of an up-to-date theme complex or issue of the field of semiconductor technology
- Investigation and conditioning of the extracted material
- Orientation in a specific project using simulation techniques
- Compilation of a concept and presentation
- Preparation of a presentation in conference style
- Presentation of recitation with subsequent discussion in plenum

2 Learning objectives / Learning Outcomes

gain practice in searching relevant scientific informations in technical publications, conference articles, etc. learn, how and where to acquire information about specific scientific topics elaborate one specific topic complex into a consistent presentation
presentation of the theme with presentation slides, handouts and subsequent critical discussion with the audience
ability to condition results of research for presentations for international conferences and company- internal talks and to present them in a stilistically correct manner

3 Recommended prerequisite for participation

- Electrical Measuring Techniques
- Laboratory Measuring Techniques
- Microelectronic devices - the basics
- Electrical Engineering and Information Technology 1
- Electrical Engineering and Information Technology 2
- Laboratory ETiT 1
- Laboratory ETiT 2
- Mathematics 1
- Mathematics 2
- Introductory Physics

4 Form of examination

Module Final Examination:

- Module Examination (Study Achievement, Oral Examination, Duration: 30 min, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Study Achievement, Oral Examination, Weighting: 100 %)

6 Usability of this module

MSc ETiT

7 References

Courses

Course Nr.	Course name		
18-sw-2030-pj	Advanced Topics in Micro- and Nano Electronics		
Instructor		**Type**	**SWS**
Prof. Dr. rer. nat. Udo Eugen Schwalke		Project Seminar	2

Module name Project Seminar Communication and Sensor Systems					
Module Nr. 18-zo-1041	**Credit Points** 8 CP	**Workload** 240 h	**Self study** 180 h	**Duration** 1	**Cycle offered** WiSe/SoSe
Language German and English			**Module owner** Prof. Dr.-Ing. Abdelhak Zoubir		

1	**Content** Investigating and solving specific problems concerning communication and sensor systems (Problems concerning communications engineering, microwave technology, signal processing, sensor networks etc. are possible, topics will be defined out of the recent research topics of the involved labs), working on a a given task by one's own, organizing and structuring of a seminar task, searching and analyzing of scientific reference publications for a given task, summarizing achieved results and conclusions by means of a written report, presenting achieved results and conclusions and defending them in an oral discussion including audience.
2	**Learning objectives / Learning Outcomes** After completion of the course, students possess: • the ability to apply methods of communication and sensor systems to practical problems • deep and special knowledge in a particular field of communication and sensor systems (communications engineering), RF technology, signal processing, sensor networks • the skills to find, analyze and evaluate scientific reference papers for a particular topic • the capability to summarize the achieved scientific findings in the form of a concise report • the ability to present and discuss achieved results in the form of a presentation in front of an audience
3	**Recommended prerequisite for participation** Previous knowledge in chosen discipline, e.g. communication technology, signal processing, microwave technology, sensor networks
4	**Form of examination** Module Final Examination: • Module Examination (Study Achievement, Optional, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Study Achievement, Optional, Weighting: 100 %)
6	**Usability of this module** BSc ETiT, BSc Wi-ETiT, BSc CE, BSc iST, BSc MEC
7	**References** Will be announced in the lecture

Courses

Course Nr. 18-zo-1041-pj	**Course name** Project Seminar Communication and Sensor Systems	
Instructor Prof. Dr.-Ing. Abdelhak Zoubir	**Type** Project Seminar	**SWS** 4

4 Seminars

Module name Design of Electrical Machines and Actuators with Numerical Field Calculation					
Module Nr. 18-bi-2110	**Credit Points** 5 CP	**Workload** 150 h	**Self study** 120 h	**Duration** 1	**Cycle offered** SoSe
Language German and English			**Module owner** Prof. Dr. techn. Dr.h.c. Andreas Binder		

1	**Content** Introduction to Finite Element Method (FEM), Basic examples of electromagnetic devices designed in 2D with FEM, 2D electromagnetic Design of transformers, AC machines, permanent magnet devices; eddy current applications such as squirrel-cage machines (Example: Wind generator); Cooling systems and thermal design: Calculation of temperature distribution within power devices
2	**Learning objectives / Learning Outcomes** A good knowledge in applying FEMAG and ANSYS software package to basic field problems is gained.
3	**Recommended prerequisite for participation** Strongly recommended is the attendance of lecture and active co-operation in the tutorial “Energy Converters - CAD and System Dynamics”
4	**Form of examination** Module Final Examination: • Module Examination (Study Achievement, Optional, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Study Achievement, Optional, Weighting: 100 %)
6	**Usability of this module** MSc EPE, MSc ETiT, MSc MEC
7	**References** Detailed textbook; User manual FEMAG and ANSYS. Müller, C. Groth: FEM für Praktiker – Band 1: Grundlagen, expert-Verlag, 5. Aufl., 2000

Courses

	Course Nr. 18-bi-2110-se	**Course name** Design of Electrical Machines and Actuators with Numerical Field Calculation	
	Instructor Prof. Dr. techn. Dr.h.c. Andreas Binder	**Type** Seminar	**SWS** 2

Module name Accelerator Physics and Technology					
Module Nr. 18-dg-2070	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 165 h	**Duration** 1	**Cycle offered** WiSe/SoSe
Language German and English			**Module owner** Prof. Dr.-Ing. Herbert De Gersem		

1	**Content** Learn and understand the theoretical contexts in the field of accelerator physics; application of the theoretical background to practical examples related to current projects in the field.
2	**Learning objectives / Learning Outcomes** The seminar addresses various topics relevant to accelerator physics and technology which in detail depend on the guest lecturers. So, insight into the current developments as well as into the different projects in the area is given. Moreover, the focus is put on the practical challenges arising during the design, construction and commissioning phase of the particular accelerator projects.
3	**Recommended prerequisite for participation** Basic knowledge in the field of accelerator physics and technology is useful, though not mandatory.
4	**Form of examination** Module Final Examination: • Module Examination (Study Achievement, Oral Examination, Duration: 30 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Study Achievement, Oral Examination, Weighting: 100 %)
6	**Usability of this module** MSc ETiT
7	**References**

Courses

Course Nr. 18-dg-2070-se	**Course name** Accelerator Physics and Technology	
Instructor Prof. Dr.-Ing. Herbert De Gersem	**Type** Seminar	**SWS** 1

Module name
Application, Simulation and Control of Power Electronic Systems

Module Nr.	Credit Points	Workload	Self study	Duration	Cycle offered
18-gt-2030	8 CP	240 h	180 h	1	WiSe/SoSe

Language	Module owner
German and English	Prof. Dr.-Ing. Gerd Griepentrog

1 Content

In an introductory meeting topics according to power electronics and control of drives are given to the students. During the seminary problems can be treated concerning the following topics:

- Simulation of power electronic systems plus analysis and evaluation of the models
- Implementing and startup of power electronic systems, test stand development plus measurement of characteristic parameters
- Modeling and simulation in the field of control of electrical drives
- Implementing and startup of controlled drive systems
- Suggested topics from the students are welcome

The students are working autonomous on the chosen problem. The results are documented in a written report and at the end of the module, a presentation about the problem must be held.

2 Learning objectives / Learning Outcomes

The Competences are:

- Autonomous familiarization with a given problem
- Selection and evaluation of appropriate development tools
- Familiarization with the used development tools
- Practical experience in power electronics and control of drives
- Logical presentation of the results in a report
- Presentation skills

3 Recommended prerequisite for participation

Lecture „Leistungselektronik 1“ or „Einführung Energietechnik“ and ggf. „Regelungstechnik I“ or similar

4 Form of examination

Module Final Examination:

- Module Examination (Study Achievement, Optional, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Study Achievement, Optional, Weighting: 100 %)

6 Usability of this module

MSc ETiT, MSc Wi-ETiT, MSc MEC

7 References

Definition of project task

Courses

Course Nr.	Course name		
18-gt-2030-se	Application, Simulation and Control of Power Electronic Systems		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Gerd Griepentrog		Seminar	4

Module name Seminar Integrated Electronic Systems Design A					
Module Nr. 18-ho-2160	**Credit Points** 4 CP	**Workload** 120 h	**Self study** 90 h	**Duration** 1	**Cycle offered** WiSe/SoSe
Language English			**Module owner** Prof. Dr.-Ing. Klaus Hofmann		

1	**Content** Research oriented Formulation of a Topic within the area of Microelectronics System Design; Creation of a written Documentation and Presentation; Team Work
2	**Learning objectives / Learning Outcomes** A student is, after successful completion of this module, able to 1. gain a deep understanding of the chosen research subject in the field of integrated electronic systems, 2. write an essay on the chosen subject in a comprehesive form and present the outcome to an audience
3	**Recommended prerequisite for participation** Advanced Digital Integrated Circuit Design, CAD Methods, Computer Architectures, Programming Know-How
4	**Form of examination** Module Final Examination: • Module Examination (Study Achievement, Oral Examination, Duration: 45 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Study Achievement, Oral Examination, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSc Wi-ETiT, MSc iCE, MSc iST, MSc MEC
7	**References** Topic-oriented Materials will be provided

Courses

Course Nr. 18-ho-2160-se	**Course name** Seminar Integrated Electronic Systems Design A	
Instructor Prof. Dr.-Ing. Klaus Hofmann	**Type** Seminar	**SWS** 2

Module name Seminar: Integrated Electronic Systems Design B					
Module Nr. 18-ho-2161	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 135 h	**Duration** 1	**Cycle offered** WiSe/SoSe
Language English			**Module owner** Prof. Dr.-Ing. Klaus Hofmann		

1	**Content** Research oriented Formulation of a Topic within the area of Microelectronics System Design; Creation of a written Documentation and Presentation; Team Work
2	**Learning objectives / Learning Outcomes** A student is, after successful completion of this module, able to 1. gain a deep understanding of the chosen research subject in the field of integrated electronic systems, 2. write an essay on the chosen subject in a comprehesive form and present the outcome to an audience
3	**Recommended prerequisite for participation** Advanced Digital Integrated Circuit Design, CAD Methods, Computer Architectures, Programming Know-How
4	**Form of examination** Module Final Examination: • Module Examination (Study Achievement, Oral Examination, Duration: 45 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Study Achievement, Oral Examination, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSc Wi-ETiT, MSc iCE, MSc iST, MSc MEC
7	**References** Topic-oriented Materials will be provided

Courses

Course Nr. 18-ho-2161-se	**Course name** Seminar: Integrated Electronic Systems Design B	
Instructor Prof. Dr.-Ing. Klaus Hofmann	**Type** Seminar	**SWS** 3

Module name Future Electrical Power Supply					
Module Nr. 18-hs-2020	**Credit Points** 4 CP	**Workload** 120 h	**Self study** 90 h	**Duration** 1	**Cycle offered** WiSe/SoSe
Language German and English			**Module owner** Prof. Dr.-Ing. Jutta Hanson		

1	**Content** The goal of this seminar is to acquire a comprehensive knowledge of a promising topic for the power system of the future. Two topics from the field of electrical power supply will be offered. These topics are assigned to groups. The groups consist of four participants. Each group is supervised by an academic staff from the department E5 who has knowledge of the specified topic. During the seminar, dates for appointments will be regularly offered by the tutor for the participants. During these meetings technical issues will be discussed. At the end of the seminar each group is required to write a final report and do a presentation (duration 20 min. plus questions) about its topic. Both the final report and presentation can be done in English or in German.
2	**Learning objectives / Learning Outcomes** The education goals are: • Acquisation of comprenhensive knowledge about a promising topic in the electrical power system • Individual working on technical subjects • Elaboration of a written report • Logical presentation of the results in a presentation
3	**Recommended prerequisite for participation** Successful participation in “Elektrische Energieversorung I” or lectures with similar contents at other universities. Good German language skills are desirable, but not required.
4	**Form of examination** Module Final Examination: • Module Examination (Study Achievement, Optional, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Study Achievement, Optional, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSc Wi-ETiT, MSc EPE
7	**References**

Courses

Course Nr. 18-hs-2020-se	**Course name** Future Electrical Power Supply	
Instructor Prof. Dr.-Ing. Jutta Hanson	**Type** Seminar	**SWS** 2

Module name					
Computational Modeling for the IGEM Competition					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-kp-2100	4 CP	120 h	90 h	1	WiSe/SoSe
Language			**Module owner**		
English			Prof. Dr. techn. Heinz Köppl		

1 Content

The International Genetically Engineered Machine (IGEM) competition is a yearly international student competition in the domain of synthetic biology, initiated and hosted by the Massachusetts Institute of Technology (MIT), USA since 2004. In the past years teams from TU Darmstadt participated and were very successfully in the competition. This seminar provides training for students and prospective IGEM team members in the domain of computational modeling of biomolecular circuits. The seminar aims at computationally inclined students from all background, but in particular from electrical engineering, computer science, physics and mathematics. Seminar participants that are interested to become IGEM team members could later team up with biologists and biochemists for the 2017 IGEM project of TU Darmstadt and be responsible for the computational modeling part of the project.
The seminar will cover basic modeling approaches but will focus on discussing and presenting recent high-impact synthetic biology research results and past IGEM projects in the domain of computational modeling.

2 Learning objectives / Learning Outcomes

Students that successfully passed that seminar should be able to perform practical modeling of biomolecular circuits that are based on transcriptional and translational control mechanism of gene expression as used in synthetic biology. This relies on the understanding of the following topics:

- Differential equation models of biomolecular processes
- Markov chain models of biomolecular processes
- Use of computational tools for the composition of genetic parts into circuits
- Calibration methods of computational models from experimental measurement
- Use of bioinformatics and database tools to select well-characterized genetic parts

3 Recommended prerequisite for participation

4 Form of examination

Module Final Examination:

- Module Examination (Study Achievement, Optional, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Study Achievement, Optional, Weighting: 100 %)

6 Usability of this module

BSc etit, MSc etit

7 References

Courses

Course Nr.	Course name		
18-kp-2100-se	Computational Modeling for the IGEM Competition		
Instructor		**Type**	**SWS**
Prof. Dr. techn. Heinz Köppl		Seminar	2

Module name International Summer School 'Microwaves and Lightwaves'					
Module Nr. 18-ku-2050	**Credit Points** 4 CP	**Workload** 120 h	**Self study** 90 h	**Duration** 1	**Cycle offered** SoSe
Language English			**Module owner** Prof. Dr.-Ing. Franko Küppers		

1	**Content** This lecture covers the fundamentals and the latest deveolpments of microwave electronics, THz technology, and optical communication systems with particular focus on the physical concepts involved.
2	**Learning objectives / Learning Outcomes** Students understand • the background of microwave enginering, THz engineering, and optical communications and • of related electronics, and • the influence of the relevant properties of materials and of waveguides on signal processing. They gain inside into the latest developments in these fields.
3	**Recommended prerequisite for participation**
4	**Form of examination** Module Final Examination: • Module Examination (Study Achievement, Oral Examination, Duration: 30 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Study Achievement, Oral Examination, Weighting: 100 %)
6	**Usability of this module** BSc ETiT, MSc ETiT
7	**References** A script (English) will be distributed and English slides can be downloaded.

Courses

Course Nr.	**Course name**		
18-ku-2050-se	International Summer School "Microwaves and Lightwaves"		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Franko Küppers		Seminar	2

Module name Optical Communications 3 – Seminar WDM Lab					
Module Nr. 18-ku-2080	**Credit Points** 4 CP	**Workload** 120 h	**Self study** 90 h	**Duration** 1	**Cycle offered** SoSe
Language English			**Module owner** Prof. Dr.-Ing. Franko Küppers		

1	**Content** Building blocks and design of a high-bit rate transmission system Experimental set-up Characterizing componennts and signals by taking measurements Simulation and optimization of the system Presentation
2	**Learning objectives / Learning Outcomes** Students are able to design, to simulate, to optimize, to build, and to characterize an optical transmission system.
3	**Recommended prerequisite for participation** Optical Communications 2 – Systerms
4	**Form of examination** Module Final Examination: • Module Examination (Study Achievement, Oral Examination, Duration: 30 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Study Achievement, Oral Examination, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSc iCE
7	**References** Seminar slides, script, laboratory.

Courses

Course Nr. 18-ku-2080-se	**Course name** Optical Communications 3 – Seminar WDM Lab	
Instructor Prof. Dr.-Ing. Franko Küppers	**Type** Seminar	**SWS** 2

Module name Seminar Terahertz Components & Applications					
Module Nr. 18-pr-1010	**Credit Points** 4 CP	**Workload** 120 h	**Self study** 90 h	**Duration** 1	**Cycle offered** WiSe/SoSe
Language German and English			**Module owner** Prof. Dr. rer. nat. Sascha Preu		

1 Content

Investigating and solving specific problems concerning the development of Terahertz devices as well as of applications of THz technology. The specific task will be defined based on current research topics. The project seminar includes working on a given task by one's own, organizing and structuring of a seminar task, searching and analyzing of scientific reference publications, summarizing achieved results and conclusions by means of a written report, presenting achieved results and conclusions and defending them in an oral discussion including audience. Topics include, e.g.:

- Optics on chip
- Semiconductor devicesLight-matter interaction

2 Learning objectives / Learning Outcomes

After completion of the course, students possess:

- the ability to apply theoretical models to practical problems
- deep and special knowledge in a particular field related to THz science, optics or semiconductor physics
- the skills to find, analyze and evaluate scientific reference papers for a particular topic
- the capability to summarize the achieved scientific findings in the form of a concise reportthe ability to present and discuss achieved results in the form of a presentation in front of an audience

3 Recommended prerequisite for participation

Previous knowledge one of the following disciplines: Optics, semiconductor physics, or THz technology

4 Form of examination

Module Final Examination:

- Module Examination (Study Achievement, Optional, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Study Achievement, Optional, Weighting: 100 %)

6 Usability of this module

BSc ETiT, BSc Wi-ETiT, BSc/MSc iST

7 References

Will be announced once the topic is defined.

Courses

Course Nr.	Course name		
18-pr-1010-se	Seminar Terahertz Components & Applications		
Instructor		**Type**	**SWS**
Prof. Dr. rer. nat. Sascha Preu		Seminar	2

Module name					
Multimedia Communications Seminar II					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-sm-2090	4 CP	120 h	90 h	1	WiSe/SoSe
Language			**Module owner**		
German and English			Prof. Dr.-Ing. Ralf Steinmetz		

1 Content

This seminar deals with current and upcoming trends relevant to the future development of multimedia communication systems. The educational objective of this seminar is to gain knowledge about future research trends in different areas. To this aim, an extensive literature research will be performed, as well as the writing-up of a report and the presentation of selected, high-quality research topics from current leading magazines, newspapers and conferences in the web technologies research area.
Some potential topics are:

- Knowledge & Educational Technologies
- Self organizing Systems & Overlay Communication
- Mobile Systems & Sensor Networking
- Service-oriented Computing
- Multimedia Technologies & Serious Games

2 Learning objectives / Learning Outcomes

Students shall acquire profound knowledge from current scientific publications, standards and literature on multimedia communication systems and applications which will build the future Internet. In so doing, the students will develop the following competencies:

- Search for and review relevant scientific literature.
- Analyse and evaluate complex technical and scientific information.
- Write technical and scientific abstracts and summary reports.
- Present technical and scientific information.

3 Recommended prerequisite for participation

Solid knowledge in computer communication networks. Lectures in Communication Networks I and II are recommended.

4 Form of examination

Module Final Examination:

- Module Examination (Study Achievement, Optional, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Study Achievement, Optional, Weighting: 100 %)

6 Usability of this module

CS, Wi-CS, ETiT, Wi-ETiT, MSc CS, MSc ETiT, MSc iST

7 References

Depending on specific topic (selected articles of journals, magazines, and conferences).

Courses

Course Nr.	Course name		
18-sm-2090-se	Multimedia Communications Seminar II		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Ralf Steinmetz		Seminar	2

Module name Multimedia Communications Seminar I					
Module Nr. 18-sm-2300	**Credit Points** 4 CP	**Workload** 120 h	**Self study** 75 h	**Duration** 1	**Cycle offered** WiSe/SoSe
Language German and English			**Module owner** Prof. Dr.-Ing. Ralf Steinmetz		

1 Content

The seminar investigates current and upcoming topics in multimedia communication systems, which are expected to be of utmost importance for the future evolution of the Internet and information technolgy in goal. The goal is to learn more about multimedia communication systems by studying, summarizing, and presenting top quality papers from recent high quality networking research journals, magazines, or conferences. The selection of topics corresponds to the research area of participating researchers.
Possible topics are:

- Knowledge & Educational Technologies
- Self organizing Systems & Overlay Communication
- Mobile Systems & Sensor Networking
- Service-oriented Computing
- Multimedia Technologies & Serious Games

2 Learning objectives / Learning Outcomes

The students are actively studying cutting edge scientific articles, standards, and books about multimedia communication systems and applications, which are expected to be of utmost important for the future of the Internet.
Students acquire competences in the following areas:

- Searching and reviewing of relevant scientific literature
- Analysis and evaluation of complex technical and scientific information
- Writing of technical and scientific summaries and short papers
- Presentation of complex technical and scientific information

3 Recommended prerequisite for participation

4 Form of examination

Module Final Examination:

- Module Examination (Study Achievement, Optional, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Study Achievement, Optional, Weighting: 100 %)

6 Usability of this module

CS, WiCS, ETiT, Wi-ETiT, BSc/MSc iST

7 References

Depending on specific topic (selected articles of journals, magazines, and conferences).

Courses

Course Nr. 18-sm-2300-se	**Course name** Multimedia Communications Seminar I	
Instructor Prof. Dr.-Ing. Ralf Steinmetz	**Type** Seminar	**SWS** 3

Module name Pathways of Decarbonization					
Module Nr. 18-st-2050	**Credit Points** 2 CP	**Workload** 60 h	**Self study** 45 h	**Duration** 1	**Cycle offered** WiSe/SoSe
Language German and English			**Module owner** Prof. Dr. rer. nat. Florian Steinke		

1	**Content** Participants will examine different studies about future multi-modal energy systems. The course will focus mostly on works describing the transition of the energy system today into one with CO2 emissions reduced by 80% in 2050. Each student will examine one study on this topic, extract the most important messages and arguments, understand the background that lead to the publication of the study, and crosscheck the most important facts (either via own calculations or via comparison with further studies). All results will be summarized into a compact, but informative presentation and a short summary report. In a block meeting, students will present their results to their peers. They will thereby obtain a wide overview of future energy scenarios and related discussions.
2	**Learning objectives / Learning Outcomes** Students extend their understanding of the current (political) discussions about the energy transition. They improve their presentation skills and exercise critical reasoning about the studies' results and claims.
3	**Recommended prerequisite for participation** Knowledge of the modules „Energiemanagement & Optimierung “ or „Energiewirtschaft“ is helpful but not necessary.
4	**Form of examination** Module Final Examination: • Module Examination (Study Achievement, Optional, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Study Achievement, Optional, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSc Wi-ETiT, MSc ESE
7	**References**

Courses

Course Nr. 18-st-2050-se	**Course name** Pathways of Decarbonization		
Instructor Prof. Dr. rer. nat. Florian Steinke		**Type** Seminar	**SWS** 1

Module name					
Advanced Topics in Statistical Signal Processing					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-zo-2040	8 CP	240 h	180 h	1	WiSe
Language			**Module owner**		
English			Prof. Dr.-Ing. Abdelhak Zoubir		

1 Content

This course extends the signal processing fundamentals taught in DSP towards advanced topics that are the subject of current research. It is aimed at those with an interest in signal processing and a desire to extend their knowledge of signal processing theory in preparation for future project work (e.g. Diplomarbeit) and their working careers. This course consists of a series of five lectures followed by a supervised research seminar during two months approximately. The final evaluation includes students seminar presentations and a final exam.

The main topics of the Seminar are:

- Estimation Theory
- Detection Theory
- Robust Estimation Theory
- Seminar projects: e.g. Microphone array beamforming, Geolocation and Tracking, Radar Imaging, Ultrasound Imaging, Acoustic source localization, Number of sources detection.

2 Learning objectives / Learning Outcomes

Students obtain advanced knowledge in signal processing based on the fundamentals taught in DSP and ETiT 4. They will study advanced topics in statistical signal processing that are subject to current research. The acquired skills will be useful for their future research projects and professional careers.

3 Recommended prerequisite for participation

DSP, general interest in signal processing is desirable.

4 Form of examination

Module Final Examination:

- Module Examination (Study Achievement, Optional, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Study Achievement, Optional, Weighting: 100 %)

6 Usability of this module

MSc ETiT, BSc/MSc iST, MSc iCE, Wi-ETiT

7 References

- L. L. Scharf, Statistical Signal Processing: Detection, Estimation, and Time Series Analysis (New York: Addison-Wesley Publishing Co., 1990).
- S. M. Kay, Fundamentals of Statistical Signal Processing: Estimation Theory (Book 1), Detection Theory (Book 2).
- R. A. Maronna, D. R. Martin, V. J. Yohai, Robust Statistics: Theory and Methods, 2006.

Courses

Course Nr.	Course name		
18-zo-2040-se	Advanced Topics in Statistical Signal Processing		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Abdelhak Zoubir		Seminar	4

Module name					
Signal Detection and Parameter Estimation					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-zo-2050	8 CP	240 h	180 h	1	SoSe
Language			**Module owner**		
English			Prof. Dr.-Ing. Abdelhak Zoubir		

1 Content

Signal detection and parameter estimation are fundamental signal processing tasks. In fact, they appear in many common engineering operations under a variety of names. In this course, the theory behind detection and estimation will be presented, allowing a better understanding of how (and why) to design "good" detection and estimation schemes.
These lectures will cover: Fundamentals
Detection Theory Hypothesis Testing Bayesian Tests
Ideal Observer Tests
Neyman-Pearson Tests
Receiver Operating Characteristics
Uniformly Most Powerful Tests
The Matched Filter Estimation Theory Types of Estimators
Maxmimum Likelihood Estimators
Sufficiency and the Fisher-Neyman/Factorisation Criterion
Unbiasedness and Minimum variance
Fisher Information and the CRB
Asymptotic properties of the MLE

2 Learning objectives / Learning Outcomes

Students gain deeper knowledge in signal processing based on the fundamentals taught in DSP and EtiT 4. Thexy will study advanced topics of statistical signal processing in the area of detection and estimation.
In a sequence of 4 lectures, the basics and important concepts of detection and estimation theory will be taught. These will be studied in dept by implementation of the methods in MATLAB for practical examples. In sequel, students will perform an independent literature research, i.e. choosing an original work in detection and estimation theory which they will illustrate in a final presentation.
This will support the students with the ability to work themselves into a topic based on literature research and to adequately present their knowledge. This is especially expected in the scope of the students' future research projects or in their professional carreer.

3 Recommended prerequisite for participation

DSP, general interest in signal processing

4 Form of examination

Module Final Examination:
- Module Examination (Study Achievement, Optional, Standard Grading System)

5 Grading

Module Final Examination:
- Module Examination (Study Achievement, Optional, Weighting: 100 %)

6 Usability of this module

MSc ETiT,MSc iST, MSc iCE, Wi-ETiT

7 References

- Lecture slides
- Jerry D. Gibson and James L. Melsa. Introduction to Nonparametric Detection with Applications. IEEE Press, 1996.
- S. Kassam. Signal Detection in Non-Gaussian Noise. Springer Verlag, 1988.
- S. Kay. Fundamentals of Statistical Signal Processing: Estimation Theory. Prentice Hall, 1993.
- S. Kay. Fundamentals of Statistical Signal Processing: Detection Theory. Prentice Hall, 1998.
- E. L. Lehmann. Testing Statistical Hypotheses. Springer Verlag, 2nd edition, 1997.
- E. L. Lehmann and George Casella. Theory of Point Estimation. Springer Verlag, 2nd edition, 1999.
- Leon-Garcia. Probability and Random Processes for Electrical Engineering. Addison Wesley, 2nd edition, 1994.
- P. Peebles. Probability, Random Variables, and Random Signal Principles. McGraw-Hill, 3rd edition, 1993.
- H. Vincent Poor. An Introduction to Signal Detection and Estimation. Springer Verlag, 2nd edition, 1994.
- Louis L. Scharf. Statistical Signal Processing: Detection, Estimation, and Time Series Analysis. Pearson Education POD, 2002.
- Harry L. Van Trees. Detection, Estimation, and Modulation Theory, volume I,II,III,IV. John Wiley & Sons, 2003.
- A. M. Zoubir and D. R. Iskander. Bootstrap Techniques for Signal Processing. Cambridge University Press, May 2004.

Courses

Course Nr.	**Course name**		
18-zo-2050-se	Signal Detection and Parameter Estimation		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Abdelhak Zoubir		Seminar	4