M.Sc. Information and Communication Engineering (PO 2014)

Module manual
Date: 01.10.2020

TECHNISCHE UNIVERSITÄT DARMSTADT

Department of Electrical Engineering and Information Technology

Module manual: M.Sc. Information and Communication Engineering (PO 2014)

Date: 01.10.2020

Department of Electrical Engineering and Information Technology
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Contents

1 Mandatory

Module name Advanced Digital Integrated Circuit Design					
Module Nr. 18-ho-2010	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1	**Cycle offered** WiSe
Language English			**Module owner** 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	**Grade bonus compliant to §25 (2)**
8	**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. 18-ho-2010-vl	**Course name** Advanced Digital Integrated Circuit Design		
	Instructor Prof. Dr.-Ing. Klaus Hofmann		**Type** Lecture	**SWS** 3
	Course Nr. 18-ho-2010-ue	**Course name** Advanced Digital Integrated Circuit Design		
	Instructor Prof. Dr.-Ing. Klaus Hofmann		**Type** Practice	**SWS** 1

Module name Digital Signal Processing					
Module Nr. 18-zo-2060	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1	**Cycle offered** WiSe
Language English			**Module owner** 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, MSc Medizintechnik
7	**Grade bonus compliant to §25 (2)**
8	**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, M.Sc. Di Jin, M.Sc. Martin Gölz		**Type** Lecture	**SWS** 3
Course Nr. 18-zo-2060-ue	**Course name** Digital Signal Processing		
Instructor Prof. Dr.-Ing. Abdelhak Zoubir, M.Sc. Di Jin, M.Sc. Martin Gölz		**Type** Practice	**SWS** 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	**Grade bonus compliant to §25 (2)**
8	**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, M.Sc. Armin Herbert Galetzka	**Type** Lecture	**SWS** 2

Course Nr. 18-dg-2150-ue	**Course name** Technical Electrodynamics for iCE	
Instructor Prof. Dr. Irina Munteanu, M.Sc. Armin Herbert Galetzka	**Type** Practice	**SWS** 2

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. rer. nat. Thomas Kusserow		

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	**Grade bonus compliant to §25 (2)**
8	**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. rer. nat. Sascha Preu		**Type** Lecture	**SWS** 3
	Course Nr. 18-ku-1060-ue	**Course name** Optical Communications 1 – Components		
	Instructor Prof. Dr. rer. nat. Sascha Preu		**Type** Practice	**SWS** 1

Module name Communication Technology II					
Module Nr. 18-kl-2010	**Credit Points** 4 CP	**Workload** 120 h	**Self study** 75 h	**Duration** 1	**Cycle offered** WiSe
Language English			**Module owner** 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 Grade bonus compliant to §25 (2)

8 References

will be announced in the lecture

Courses

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

	Course Nr. 18-kl-2010-ue	**Course name** Communication Technology II		
	Instructor Prof. Dr.-Ing. Anja Klein, M.Sc. Bernd Simon		**Type** Practice	**SWS** 1

Module name					
Communication Networks II					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-sm-2010	6 CP	180 h	120 h	1	WiSe
Language			**Module owner**		
English			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 Grade bonus compliant to §25 (2)

8 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**
Prof. Dr.-Ing. Ralf Steinmetz, M.Sc. Philipp Achenbach, M.Sc. Tobias Meuser, M.Sc. Christoph Gärtner		Lecture	3

Course Nr.	**Course name**		
18-sm-2010-ue	Communication Networks II		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Ralf Steinmetz, M.Sc. Philipp Achenbach, M.Sc. Tobias Meuser, M.Sc. Christoph Gärtner		Practice	1

2 Optional Fundamentals

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	**Grade bonus compliant to §25 (2)**
8	**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 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	**Grade bonus compliant to §25 (2)**

8	**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, M.Sc. Matthias Nickel		**Type** Lecture	**SWS** 3
	Course Nr. 18-jk-2020-ue	**Course name** Antennas and Adaptive Beamforming		
	Instructor Prof. Dr.-Ing. Rolf Jakoby, M.Sc. Matthias Nickel		**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 Grade bonus compliant to §25 (2)

8 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. 18-kl-2020-ue	**Course name** Mobile Communications		
	Instructor Prof. Dr.-Ing. Anja Klein		**Type** Practice	**SWS** 1

Module name Mobile Networking					
Module Nr. 20-00-0748	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1	**Cycle offered** Every 2. Sem.
Language English			**Module owner** Prof. Dr.-Ing. Thorsten Strufe		

1 Content

Mobile communications and wireless networking technology has seen a thriving development in recent years. The integrated course addresses the characteristics/principles of mobile networks in detail, and practical solutions are presented. Hereby our focus is on the network layer, which is often regarded as the glue of communication systems. In addition to describing the state of the art in technology we discuss actual research problems and learn about methodologies to approach such problems systematically. The contents of the course will be deepended by exercises.

Course contents:

- Introduction to mobile and wireless communications: Applications, history, market vision
- Overview of wireless transmission: frequencies & regulations, signals, antennas, signal propagation, multiplexing, modulation, spread spectrum, cellular systems
- Medium access control in the wireless domain: SDMA, FDMA, CDMA TDMA (fixed, Aloha, CSMA, DAMA, PRMA, MACA, collision avoidance, polling)
- Wireless local area networks: IEEE 802.11 standard including physical layer, MAC layer and access schemes, quality of service and power management
- Wireless metropolitan area networks: Wireless mesh networks, IEEE 802.16 standard including modes of operation, medium access control, quality of service and scheduling
- Mobility at network layer: Concepts to support mobility on various layers, Mobile IP
- Ad hoc networks: Terminology, basics and applications, characteristics of ad hoc communication, ad hoc routing paradigms and protocols
- Performance evaluation of mobile networks: Overview of performance evaluation, systematic approach / common mistakes and how to avoid them, experimental design and analysis
- Mobility at transport layer: Variants of TCP (indirect TCP, snoop TCP, mobile TCP, wireless TCP)
- Mobility at application layer. Outlook: Applications for mobile networks and wireless sensor networks

2 Learning objectives / Learning Outcomes

After successfully attending the course, students have an in-deep knowledge on the working of mobile communication networks. They have gained insight into media access control mechanisms dedicated to wireless communication and have a thorough understanding of mechanisms based on the network and the transport layers, with a focus on ad hoc and mesh networks. Moreover, the students have acquired knowledge about the connections between the different protocol layers and are able to apply the acquired knowledge on methodological analysis of real communication systems. The students are therefore be conversant with the characteristics and basic principles of wireless and mobile communications in theory and practice. The exercise-parts of the integrated course deepen the theoretical foundations by means of exercises, which consist of literature, calculation as well as practical implementation/application examples.

3 Recommended prerequisite for participation

Basic courses in Communication Networks are recommended.

4 Form of examination

Module Eccompanying Examination:

- [20-00-0748-iv] (Technical Examination, Written/Oral Examination, Standard BWS)

5 Grading

Module Eccompanying Examination:

- [20-00-0748-iv] (Technical Examination, Written/Oral Examination, Weighting: 100 %)

6 Usability of this module

	B.Sc. Informatik M.Sc. Informatik M.Sc. Wirtschaftsinformatik B.Sc. Psychologie in IT Joint B.A. Informatik B.Sc. Sportwissenschaft und Informatik M.Sc. Sportwissenschaft und Informatik Can be used in other degree programs.
7	**Grade bonus compliant to §25 (2)** In dieser Vorlesung findet eine Anrechnung von vorlesungsbegleitenden Leistungen statt, die lt. §25 (2) der 5. Novelle der APB und den vom FB 20 am 30.3.2017 beschlossenen Anrechnungsregeln zu einer Notenverbesserung um bis zu 1.0 führen kann.
8	**References** Selected literature, details are given in lecture.

Courses

Course Nr.	**Course name**		
20-00-0748-iv	Mobile Networking		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Thorsten Strufe		Integrated Course	4

3 Optionals

3.1 Device Technology and Circuit Design

3.1.1 Lectures

Module name Electromechanical Systems I						
Module Nr. 18-kn-1050	**Credit Points** 5 CP	**Workload** 150 h	**Self study** 90 h	**Duration** 1	**Cycle offered** WiSe	
Language German			**Module owner** Prof. Dr. Mario Kupnik			
1	**Content** Structure and design methods of elektromechanical systems, mechanical, acoustical and thermal networks, transducers between mechanical and acoustical networks. Design and devices of electromechanical transducers.					
2	**Learning objectives / Learning Outcomes** Comprehension, description, calculation and application of the most relevant electromechanical transducers, comprising electrostatic transducer (e.g. microphone and accelerometer), piezoelectric transducers (e.g micro motors, micro sensors), electrodynamic transducer (loudspeaker, shaker), piezomagnetic transducer (e.g. ultrasonic source). Design of complex electromechanical systems like sensors and actuators and their applications by applying the discrete element network method.					
3	**Recommended prerequisite for participation** Electrical Engineering and Information Technology I					
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, BSc WI-ETiT, MSc MEC					
7	**Grade bonus compliant to §25 (2)**					
8	**References** Book: Electromechanical Systems in Microtechnic und Mechatronic, Springer 2012, Script for lecture Electromechanical Systems I, Workbook					
Courses						
	Course Nr. 18-kn-1050-vl	**Course name** Electromechanical Systems I				
	Instructor Prof. Dr. Mario Kupnik, Prof. Dr. techn. Dr.h.c. Andreas Binder, M.Sc. Sascha Neusüs, M.Sc. Omar Ben Dali			**Type** Lecture	**SWS** 2	

	Course Nr.	Course name		
	18-kn-1050-ue	Electromechanical Systems I		
	Instructor		**Type**	**SWS**
	Prof. Dr. Mario Kupnik, Prof. Dr. techn. Dr.h.c. Andreas Binder, M.Sc. Sascha Neusüs, M.Sc. Omar Ben Dali		Practice	2

Module name Printed Electronics					
Module Nr. 16-17-5110	**Credit Points** 4 CP	**Workload** 120 h	**Self study** 90 h	**Duration** 1	**Cycle offered** SoSe
Language German			**Module owner** Prof. Dr. Edgar Dörsam		

1	**Content** Printing technologies for functional printing (printing methods and systems); Design and materials for printed electronics (aerial, OFET, RFID); Activities for quality assurance; Examples of application (aerial, RFID, OFET, photovoltaic, batteries, lab on a chip).
2	**Learning objectives / Learning Outcomes** On successful completion of this module, students should be able to: • Describe the printing technologies that are applicable for "Printed Electronics". • Name materials that are appropriate to printing processes and to describe the impact of the materials on the design e.g. of antennas and OFETs. • Classify and rate different activites for quality assurance. • Explain basic functions, configurations, materials, and specific properties of printed antennas, RFIDs, photovoltaics and batteries. • Describe "Printed Electronics" as a multidisciplinary task that consists of electrical engineering, material science, and mechanical engineering.
3	**Recommended prerequisite for participation** Mechanical components and Mechatronics I and II recommended
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Technical Examination, Standard Grading System) Oral exam 30 min
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Technical Examination, Weighting: 100 %)
6	**Usability of this module** WPB Master MPE III (Wahlfächer aus Natur- und Ingenieurwissenschaft) WPB Master PST III (Fächer aus Natur- und Ingenieurwissenschaft für Papiertechnik) Master ETiT IMNT; Master Mechatronik
7	**Grade bonus compliant to §25 (2)**
8	**References** The current lecture notes can be downloaded from the web pages of the institute while the semester is in session.

Courses

Course Nr. 16-17-5110-vl	**Course name** Printed Electronics	
Instructor	**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 Grade bonus compliant to §25 (2)

8 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 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	**Grade bonus compliant to §25 (2)**
8	**References**

Courses

Course Nr. 18-jk-2090-vl	**Course name** Microwave Measurement Technologies		
Instructor Dr.-Ing. Holger Maune		**Type** Lecture	**SWS** 2

Course Nr. 18-jk-2090-ue	**Course name** 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		**Type**	**SWS**
	Dr.-Ing. Holger Maune		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	**Grade bonus compliant to §25 (2)**
8	**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					
Introduction to Spintronics					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-me-2020	6 CP	180 h	120 h	1	WiSe
Language			**Module owner**		
English			Prof. Dr. rer. nat. Markus Meinert		

1 Content

The lecture covers the following subjects:

- Basics of atomic physics (structure of the atoms, electron hull)
- Basics of solid state physics (crystalline materials)
- Introduction to electron transport in solids (classical treatment, band structures)
- Basic notions and simple models of magnetism
- Magnetism in thin films
- Spin-dependent electronic transport
- Magnetoresistive effects, anisotropic magnetoresistance
- Giant magnetoresistance (GMR)
- Tunneling magnetoresistance (TMR)
- Spin-Transfer Torque
- Magnetic microwave oscillators
- Spin-Hall effect and other spin-orbit effects
- Materials for spintronics (ferromagnets, antiferromagnets)
- Magnetic data storage
- Spintronic devices as sensors
- Magnetic random-access memory (MRAM)

2 Learning objectives / Learning Outcomes

The students learn fundamental concepts of spintronics, from properties of magnetic materials to the design and application of spintronic devices in data storage and magnetic sensing. The students acquire the competence to make use of spintronic devices in applications. They further acquire the competence to understand current scientific literature and to dive deeper into the field.

3 Recommended prerequisite for participation

Module 11-01-6419 Materials of Electrical Engineering

4 Form of examination

Module Final Examination:

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

The examination takes place in form of a written exam (duration: 120 minutes). If one can estimate that less than 16 students register, the examination will be an oral examination (duration: 45 min.). The type of examination will be announced in the beginning of the lecture.

5 Grading

Module Final Examination:

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

6 Usability of this module

7 Grade bonus compliant to §25 (2)

Yes

8 References

- A script will be made available electronically
- Coey, Magnetism and Magnetic Materials, 2009, Cambridge University Press
- Skomski, Simple Models of Magnetism, 2008, Oxford University Press
- Felser, Fecher, Spintronics: From Materials to Devices, 2013, Springer
- Dietl, Awschalom, Kaminska, Ohno, Spintronics, 2008, Academic Press
- Blachowicz, Ehrmann, Spintronics, 2019, de Gruyter
- Tsymbal, Zutic, Spintronics Handbook, Volume One: Metallic Spintronics, 2019, CRC Press
- Xu, Awschalom, Nitta, Handbook of Spintronics, 2016, Springer

Courses

Course Nr.	**Course name**		
18-me-2020-vl	Introduction to Spintronics		
Instructor		**Type**	**SWS**
Prof. Dr. rer. nat. Markus Meinert		Lecture	3
Course Nr.	**Course name**		
18-me-2020-ue	Introduction to Spintronics		
Instructor		**Type**	**SWS**
Prof. Dr. rer. nat. Markus Meinert		Practice	1

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	**Grade bonus compliant to §25 (2)**
8	**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, Dr.-Ing. Martin Schüßler	**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	**Grade bonus compliant to §25 (2)**
8	**References** Slide Copies

Courses

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

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	**Grade bonus compliant to §25 (2)**
8	**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	**Grade bonus compliant to §25 (2)**
8	**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 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	**Grade bonus compliant to §25 (2)**					
8	**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	

3.2 Electronic System Design

3.2.1 Lectures

Module name Computer Systems II						
Module Nr. 18-hb-2030	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1	**Cycle offered** WiSe	
Language German			**Module owner** Prof. Dr.-Ing. Christian Hochberger			
1	**Content** • Configurable Technologies • FPGA architectures and properties • System-On-Chip, HW components, SW toolchain, support SW • Coarse grained reconfigurable architectures, PE architecture, Modulo schedu-ling					
2	**Learning objectives / Learning Outcomes** After completion of the module, students know reconfigurable technologies as well as chip architecture that employ them (e.g. FPGAs and CGRAs). They can select an ap-propriate technology for a given specific application. They know the components a system-on-chip (SoC) consists of. Students can configure and program an application specific SoC. They can map simple applications to a CGRA and know the limitations and pitfalls of this mapping.					
3	**Recommended prerequisite for participation** Thorough basic knowledge of digital circuits and computer achitecture. as can be ob-tained in the lectures “Logischer Entwurf” and “Rechnersysteme I”. Additionally, stu-dents should be able to write simple programs in the programming language C.					
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	**Grade bonus compliant to §25 (2)**					
8	**References** The slides (in German) of the lecture can be obtained through moodle.					
Courses						
	Course Nr. 18-hb-2030-vl	**Course name** Computer Systems II				
	Instructor Prof. Dr.-Ing. Christian Hochberger, M.Sc. Johanna Rohde			**Type** Lecture	**SWS** 3	
	Course Nr. 18-hb-2030-ue	**Course name** Computer Systems II				
	Instructor Prof. Dr.-Ing. Christian Hochberger, M.Sc. Johanna Rohde			**Type** Practice	**SWS** 1	

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	**Grade bonus compliant to §25 (2)**
8	**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. 18-hb-2010-vl	**Course name** Low-Level Synthesis		
Instructor Prof. Dr.-Ing. Christian Hochberger		**Type** Lecture	**SWS** 3
Course Nr. 18-hb-2010-ue	**Course name** Low-Level Synthesis		
Instructor Prof. Dr.-Ing. Christian Hochberger		**Type** Practice	**SWS** 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 Grade bonus compliant to §25 (2)

8 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 Real-Time Systems					
Module Nr. 18-su-2020	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1	**Cycle offered** SoSe
Language German			**Module owner** Prof. Dr. rer. nat. Andreas Schürr		

1	**Content** The lecture basically covers a model-driven software engineering process which is specially customized for real-time systems. This process is more deeply explored in the exercise using an automotive example. A focus is laid on object-oriented techniques. In this context, a real-time specific state-of-the-art CASE tool is introduced and used. Furthermore, fundamental characteristics of real-time systems and system architectures are introduced. Scheduling algorithms are discussed to get insights into real-time operating systems. Finally, a comparison between the Java programming language and its expansion for real-time operating systems (RT Java) will conclude the lecture.
2	**Learning objectives / Learning Outcomes** Students, who have successfully attended this lecture have acquired skills needed for the model-driven and object-oriented development of embedded real-time systems. This includes a deeper understanding of the following topics: • classification of real-time systems • create and analyze executable models • application of real-time scheduling algorithms • evaluation and comparison of pros/cons of real-time programming languages as well as real-time operating systems
3	**Recommended prerequisite for participation** Basic knowledge of software engineering techniques and excellent knowledge of at least one object-oriented programming language (preferably Java)
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, BSc Informatik
7	**Grade bonus compliant to §25 (2)**
8	**References** www.es.tu-darmstadt.de/lehre/es/

Courses

Course Nr. 18-su-2020-vl	**Course name** Real-Time Systems		
Instructor Prof. Dr. rer. nat. Andreas Schürr		**Type** Lecture	**SWS** 3
Course Nr. 18-su-2020-ue	**Course name** Real-Time Systems		
Instructor Prof. Dr. rer. nat. Andreas Schürr		**Type** Practice	**SWS** 1

Module name					
Microprocessor Systems					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-ho-2040	4 CP	120 h	75 h	1	SoSe
Language			**Module owner**		
English			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	**Grade bonus compliant to §25 (2)**
8	**References** Slide Copies

Courses

Course Nr. 18-ho-2040-vl	**Course name** Microprocessor Systems		
Instructor Dr.-Ing. Matthias Rychetsky		**Type** Lecture	**SWS** 2
Course Nr. 18-ho-2040-ue	**Course name** Microprocessor Systems		
Instructor Dr.-Ing. Matthias Rychetsky		**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	**Grade bonus compliant to §25 (2)**
8	**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 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	**Grade bonus compliant to §25 (2)**
8	**References** Slide Copies

Courses

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

Module name Projektseminar Rekonfigurable Systems					
Module Nr. 18-hb-2040	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 135 h	**Duration** 1	**Cycle offered** WiSe/SoSe
Language German			**Module owner** Prof. Dr.-Ing. Christian Hochberger		

1	**Content** Students will work in small groups in this course. Topics and application context will be defined individually for each group. All projects will follow the same approach. At first, the given problem will be described in a programmatic way. Following, it will be implemented by a reconfigurable system. Depending on the nature of the application, either predefined architectures will be used, parameterizable architectures will be adapted to the needs of the application or new architectures may be designed. The programmatic description will now be mapped (semi-)automatically to the chosen architecture with the help of the supporting tools. Usually, this requires to rewrite the programmatic description to better suit the tools. Finally, the solution will be evaluated using some benchmark data sets.
2	**Learning objectives / Learning Outcomes** Successful students will know how to use reconfigurable systems within a given application context. They can use tools to program these systems and know how to map an application onto a given reconfigurable architecture. They are capable to evaluate the performance critical parts of an application. They understand the implications of different coding styles for a particular task.
3	**Recommended prerequisite for participation** • Knowledge of reconfigurable devices (cf. course computer systems II) • Knowledge of computer architecture (cf. course computer systems I) • Solid programming skills (either in C or Java depending on the application scenario).
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 iST, MSc Informatik, MSc iCE
7	**Grade bonus compliant to §25 (2)**
8	**References** Will be made available through the Moodle page for this course.

Courses

Course Nr.	**Course name**		
18-hb-2040-pj	Projektseminar Rekonfigurable Systems		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Christian Hochberger		Project Seminar	3

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	**Grade bonus compliant to §25 (2)**
8	**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 Software System Technology					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-su-2080	4 CP	120 h	90 h	1	SoSe
Language			**Module owner**		
German			Prof. Dr. rer. nat. Andreas Schürr		

1	**Content** In this course, the students produce scientific reports from changing subject areas. Each student has to explore a subject related to IT system development and produce a written report as well as a final talk with a presentation. A list of the subjects of the current semester is available at www.es.tu-darmstadt.de/lehre/sst.
2	**Learning objectives / Learning Outcomes** After a successful participation, the students will be able to explore an unknown topic under scientific aspects. The students learn to support the exploration by a literature research and to analyze the subject critically. They achieve the skills to present a definite subject in a written report as well as in an oral presentation.
3	**Recommended prerequisite for participation** Basic knowledge in software engineering and programming languages
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 iST, BSc Informatik, MSc ETiT
7	**Grade bonus compliant to §25 (2)**
8	**References** www.es.tu-darmstadt.de/lehre/sst

Courses

Course Nr.	**Course name**		
18-su-2080-se	Seminar Software System Technology		
Instructor		**Type**	**SWS**
Prof. Dr. rer. nat. Andreas Schürr		Seminar	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	**Grade bonus compliant to §25 (2)**
8	**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 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	**Grade bonus compliant to §25 (2)**
8	**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

3.3 Communication Technology

3.3.1 Lectures

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	**Grade bonus compliant to §25 (2)**
8	**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.	**Course name**		
18-zo-2010-vl	Adaptive Filters		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Henning Puder		Lecture	3

Course Nr.	**Course name**		
18-zo-2010-ue	Adaptive Filters		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Henning Puder		Practice	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	**Grade bonus compliant to §25 (2)**

8	**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, M.Sc. Matthias Nickel		**Type** Lecture	**SWS** 3
	Course Nr. 18-jk-2020-ue	**Course name** Antennas and Adaptive Beamforming		
	Instructor Prof. Dr.-Ing. Rolf Jakoby, M.Sc. Matthias Nickel		**Type** Practice	**SWS** 1

Module name					
Computer Vision in Engineering					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-ad-2090	4 CP	120 h	75 h	1	WiSe
Language			**Module owner**		
German			Prof. Dr.-Ing. Jürgen Adamy		

1 Content

A Basics

- Scene Representation2D and 3D Geomtery
- Image Acquisition
  - Geometric Projections Camera Calibration
- Objective and Illumination
- Discrete 2D signals
  - Separability, Sampling
  - Transformation, Interpolation
  - Convolution, Correlation
  - Discrete Fourier Transformation

B Basics of Image Analysis

- Filtering
  - Basics2D Filter Design
  - Linear Filtering
  - Nichtlinear Filtering
- Image Decompositions
  - Multi-scale Representation
  - Pyramids
  - Filter Banks
- Image Features
  - Structure
  - Moments, Histograms

2 Learning objectives / Learning Outcomes

The lecture communicates mathematical basics needed to solve computer vision problems in the field of engineering. The focus is on methods that are relevant for measuring and control tasks. Applications range from visual quality inspection, visual robotics, photogrammetry, visual odometry up to visually guided driver assistance etc.
The students should obtain a good understanding for the relations between the three-dimensional world and its two-dimensional projection onto the image plane of a camera. They also should learn about methods that exist to infer knowledge from the world given image data. They should develop some feeling for the different kinds of problems that arise in computer vision and how to choose an efficient solution in terms of algorithms.

3 Recommended prerequisite for participation

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 CE, MSc iST
7	**Grade bonus compliant to §25 (2)**
8	**References** References / Textbooks: Lecture slides, exercise sheets and matlab-code. Further reading • Yi Ma, Stefano Soatto, Jana Kosecka und Shankar S. Sastry, An Invitation to 3-D Vision - From Images to Geometric Models, Springer, 2003. • Richard Hartley and Andrew Zisserman, Multiple View Geometry in Computer Vision, Second Edition, Cambridge University Press, 2004. • Karl Kraus, Photogrammetrie, Band 1 Geometrische Informationen aus Photographien und Laserscanneraufnahmen 7. Auflage, de Gruyter Lehrbuch, 2004. • Christopher M. Bishop, Pattern Recognition and Machine Learning, Springer 2006. • Bernd Jähne, Digital Image Processing, 6. Auflage, 2005.

Courses

Course Nr. 18-ad-2090-vl	**Course name** Computer Vision in Engineering		
Instructor Dr.-Ing. Volker Willert, Prof. Dr.-Ing. Jürgen Adamy		**Type** Lecture	**SWS** 2
Course Nr. 18-ad-2090-ue	**Course name** Computer Vision in Engineering		
Instructor Dr.-Ing. Volker Willert		**Type** Practice	**SWS** 1

Module name Microwave Engineering II					
Module Nr. 18-jk-2130	**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

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 Grade bonus compliant to §25 (2)

8 References

Script and slides will be handed out. Literature will be recommended in the lecture.

Courses

Course Nr. 18-jk-2130-vl	**Course name** Microwave Engineering II	
Instructor PD Dr.-Ing. Oktay Yilmazoglu, Prof. Dr. rer. nat. Sascha Preu	**Type** Lecture	**SWS** 3

	Course Nr.	Course name		
	18-jk-2130-ue	Microwave Engineering II		
	Instructor		**Type**	**SWS**
	PD Dr.-Ing. Oktay Yilmazoglu, Dr.-Ing. Shihab Al-Daffaie, Prof. Dr. rer. nat. Sascha Preu		Practice	1

Module name					
MIMO - Communication and Space-Time-Coding					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-pe-2030	4 CP	120 h	75 h	1	WiSe
Language			**Module owner**		
English			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	**Grade bonus compliant to §25 (2)**
8	**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, M.Sc. Fabio Nikolay, M.Sc. Tianyi Liu		**Type** Practice	**SWS** 1

Module name					
Speech and Audio Signal Processing					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-zo-2070	6 CP	180 h	120 h	1	WiSe
Language			**Module owner**		
German			Prof. Dr.-Ing. Abdelhak Zoubir		

1	**Content** Algorithms of speech and audio signal processing: Introduction to the models of speech and audio signals and basic methods of audio signal processing. Procedures of codebook based processing and audio coding. Beamforming for spatial filtering and noise reduction for spectral filtering. Cepstral filtering and fundamental frequency estimation. Mel-filterind cepstral coefficients (MFCCs) as basis for speaker detection and speech recognition. Classification methods based on GMM (Gaussian mixture models) and speech recognition with HMM (Hidden markov models). Introduction to the methods of music signal processing, e.g. Shazam-App or beat detection.
2	**Learning objectives / Learning Outcomes** Based on the lecture you acquire an advanced knowledge of digital audio signal processing mainly with the help of the analysis of speech signals. You learn about different basic and advanced methods of audio signal processing, to range from the theory to practical applications. You will acquire knowledge about algorithms such as they are applied in mobile telephones, hearing aids, hands-free telephones, and man-machine-interfaces (MMI). The exercise will be organized as a talk given by each student with one self-selected topic of speech and audio processing. This will allow you to acquire the know-how to read and understand scientific literature, familiarize 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** Knowlegde about satistical signal processing is required (lecture „Digital Signal Processing“). Desired – but not mandatory – is knowledge about adaptive filters.
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Written/Oral Examination, Duration: 20 min, Standard Grading System) Seminar presentation: Scientific talk about a topic in the field of “Speech and Audio Signal Processing”, single (duration 10-15 min) or in groups of two students (15-20 min)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Written/Oral Examination, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSc iCE
7	**Grade bonus compliant to §25 (2)**
8	**References** Slides (for further details see homepage of the lecture)

Courses

Course Nr. 18-zo-2070-vl	**Course name** Speech and Audio Signal Processing		
Instructor Prof. Dr.-Ing. Henning Puder		**Type** Lecture	**SWS** 2
Course Nr. 18-zo-2070-ue	**Course name** Speech and Audio Signal Processing		
Instructor Prof. Dr.-Ing. Henning Puder		**Type** Practice	**SWS** 1

	Course Nr.	Course name		
	18-zo-2070-se			
	Instructor		**Type**	**SWS**
	Prof. Dr.-Ing. Henning Puder		Seminar	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) *Oral exam (mandatory)
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	**Grade bonus compliant to §25 (2)**
8	**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. 18-pr-2010-vl	**Course name** Terahertz Systems and Applications		
Instructor Prof. Dr. rer. nat. Sascha Preu		**Type** Lecture	**SWS** 2
Course Nr. 18-pr-2010-ue	**Course name** Terahertz Systems and Applications		
Instructor Prof. Dr. rer. nat. Sascha Preu		**Type** Practice	**SWS** 1

Module name Computational Electromagnetics and Applications I					
Module Nr. 18-dg-1030	**Credit Points** 3 CP	**Workload** 90 h	**Self study** 60 h	**Duration** 1	**Cycle offered** SoSe
Language German			**Module owner** Prof. Dr.-Ing. Herbert De Gersem		

1	**Content** Basics FIT, electrostatics, magnetostatics, magnetoquasistatics, high frequency simulations, convergence studies, discretisation, time- and frequency domain simulations.
2	**Learning objectives / Learning Outcomes** Students learn the basic concepts of the Finite Integration Technique (FIT) for the numerical solution of Maxwell's equations. Students are, furthermore, introduced to the practical application of the method for numerical field problems.
3	**Recommended prerequisite for participation** Basics of Maxwell's equations, linear algebra. Recommended: Basic knowledge in knowledge in "Technical Electrodynamics"
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** BSc ETiT
7	**Grade bonus compliant to §25 (2)**
8	**References** Course notes, lecture slides.

Courses

Course Nr. 18-dg-1030-vl	**Course name** Computational Electromagnetics and Applications I	
Instructor Prof. Dr. rer. nat. Sebastian Schöps	**Type** Lecture	**SWS** 2

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	**Grade bonus compliant to §25 (2)**
8	**References**

Courses

Course Nr. 18-jk-2090-vl	**Course name** Microwave Measurement Technologies		
Instructor Dr.-Ing. Holger Maune		**Type** Lecture	**SWS** 2

Course Nr. 18-jk-2090-ue	**Course name** 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		**Type**	**SWS**
	Dr.-Ing. Holger Maune		Internship	1

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

Students understand the basics of robust signal processing and data science and are able to apply them to a variety of problems. They are familiar with various biomedical applications and know the causes of artifacts, outliers and impulsive noise. They can apply algorithms for robust regression, cluster analysis, classification and spectral analysis.

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 Grade bonus compliant to §25 (2)

8 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

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 Grade bonus compliant to §25 (2)

8 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					
Data Science I					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-zo-2110	5 CP	150 h	90 h	1	SoSe
Language			**Module owner**		
English			Prof. Dr.-Ing. Abdelhak Zoubir		

1 Content

The course covers the following topics:

- Python programming basics
- Data science introduction
- Data storage and formats
- Data exploration and visualization
- Statistical methods and inference
  - Descriptive statistics (uni & bivariate)
  - Inferential statistics
- Feature extraction
  - Time Series Data
  - Image data
  - Audio data
- Statistical learning
  - Cross-validation, overfitting, annotation
  - Regression
  - Classification

2 Learning objectives / Learning Outcomes

The course provides a full introduction to data science with an emphasis on hands-on examples. Students will acquire relevant knowledge of the whole data science chain: From storage/acquisition to statistical inference to visualization. It also serves as an introductory course to the Data Science project seminar.

3 Recommended prerequisite for participation

4 Form of examination

Module Final Examination:

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

In general, the examination takes place in form of a written exam (duration: 90 minutes). If up to 15 students register, there will will be an oral examination (duration: 45 min.). The type of examination will be announced within one working week after the end of the examination registration phase.

5 Grading

Module Final Examination:

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

6 Usability of this module

7 Grade bonus compliant to §25 (2)

Yes

8 References

- Lecture notes and slides can be downloaded here:
  - http://www.spg.tu-darmstadt.de
  - moodle

- Further reading:
  - Wes McKinney: Python for Data Analysis, O'Reilly, 2017
  - Christopher M. Bishop: Pattern Recognition and Machine Learning, 2011
  - James, Witten, Hastie and Tibshirani, Introduction to Statistical Learning, Springer, 2017

Courses

Course Nr.	**Course name**		
18-zo-2110-vl	Data Science I		
Instructor		**Type**	**SWS**
Dr.-Ing. Christian Debes		Lecture	2
Course Nr.	**Course name**		
18-zo-2110-ue	Data Science I		
Instructor		**Type**	**SWS**
Dr.-Ing. Christian Debes		Practice	2

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	**Grade bonus compliant to §25 (2)**
8	**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.	**Course name**		
18-jk-2060-pj	Project Seminar Advanced μWave Components & Antennas		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Rolf Jakoby, Dr.-Ing. Martin Schüßler		Project Seminar	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	**Grade bonus compliant to §25 (2)**
8	**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, M.Sc. Gerta Kushe	**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 Grade bonus compliant to §25 (2)

8 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 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	**Grade bonus compliant to §25 (2)**
8	**References** Course notes “Computational Electromagnetics and Applications I-III”, further material is provided.

Courses

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

Module name Signal Detection and Parameter Estimation					
Module Nr. 18-zo-2050	**Credit Points** 8 CP	**Workload** 240 h	**Self study** 180 h	**Duration** 1	**Cycle offered** SoSe
Language English			**Module owner** 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 Grade bonus compliant to §25 (2)

8 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

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 Grade bonus compliant to §25 (2)

8 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 Robust and Biomedical Signal Processing					
Module Nr. 18-zo-2100	**Credit Points** 8 CP	**Workload** 240 h	**Self study** 180 h	**Duration** 1	**Cycle offered** WiSe
Language English			**Module owner** Prof. Dr.-Ing. Abdelhak Zoubir		

1 Content

A series of 3 lectures provides the necessary background on robust signal processing and machine learning:

- Background on robust signal processing
- Robust regression and robust filters for artifact cancellation
- Robust location and covariance estimation and classification

They are followed by two lectures on selected biomedical applications, such as:

- Body-worn sensing of physiological parameters
- Optical heart rate sensing (PPG)
- Signal processing for the electrocardiogram (ECG)
- Biomedical image processing

Students then work in groups to apply robust signal processing algorithms to real-world biomedical data. Depending on the application, the data is either recorded by the students, or provided to them. The group results are presented during a 20-minute presentation. The final assessment is based on the presentation and an oral examination.

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 (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 Wi-ETiT, MSc iCE, MSc iST

7 Grade bonus compliant to §25 (2)

8 References

- 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. 18-zo-2100-se	**Course name** Robust and Biomedical Signal Processing		
Instructor Dr.-Ing. Michael Muma		**Type** Seminar	**SWS** 4

Module name					
Data Science II					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-zo-2120	8 CP	240 h	180 h	1	WiSe
Language			**Module owner**		
English			Prof. Dr.-Ing. Abdelhak Zoubir		

1 Content

The course covers the following topics:

- Data Science Advanced Methods
- Data Management + Big data frameworks
- Statistical Learning
  - Recommender Systems
  - Deep Learning
  - Unsupervised Learning
  - Text data analysis

- Final application project. Flexibility to choose from list of projects or come up with own project. Examples:
  - Sound classification
  - Heart rate analysis
  - Activity recognition with acceleration data
  - Hyperspectral data
  - Image classification
  - Health survey

2 Learning objectives / Learning Outcomes

This seminar provides an advanced understanding of data science with an emphasis on hands-on projects. Students will get to know latest data science technologies – from big data to advanced machine learning and apply them in a real-world project.

3 Recommended prerequisite for participation

Data Science I (Lecture)

4 Form of examination

Module Final Examination:

- Module Examination (Study Achievement, Written/Oral Examination, Duration: 90 min, Standard Grading System)

In general, the examination takes place in form of a written exam (duration: 90 minutes). If up to 14 students register, there will will be an oral examination (duration: 45 min.). The type of examination will be announced in the first lecture. Possible types include a project presentation, etc.

5 Grading

Module Final Examination:

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

6 Usability of this module

7 Grade bonus compliant to §25 (2)

8 References

Lecture notes and slides can be downloaded here:

- http://www.spg.tu-darmstadt.de
- Moodle platform

Further reading:

- Wes McKinney: Python for Data Analysis, O'Reilly, 2017
- Christopher M. Bishop: Pattern Recognition and Machine Learning, 2011
- James, Witten, Hastie and Tibshirani, Introduction to Statistical Learning, Springer, 2017

Courses

Course Nr.	**Course name**		
18-zo-2120-se	Data Science II		
Instructor		**Type**	**SWS**
Dr.-Ing. Christian Debes		Seminar	4

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	**Grade bonus compliant to §25 (2)**
8	**References** Lab manual

Courses

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

Module name					
Software Lab Computational Electromagnetics and Applications I					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-dg-1041	8 CP	240 h	195 h	1	SoSe
Language			**Module owner**		
German			Prof. Dr.-Ing. Herbert De Gersem		

1	**Content** Various topics are: 1. Introduction, 2. Basics of FIT I, 3. Basics of FIT II, 4. Static problems (electrical/magnetical) (scalar potential), 5. Magnetostatic problems, frequency domain, 5. Time domain integration techniques: Leapfrog I, 7. Time domain integration techniques: Leapfrog II, 8. Other physical problems: heat conduction, 9. Other discretization methods: Finite Element Method.
2	**Learning objectives / Learning Outcomes** Students will understand basic concepts of numerical solution techniques to field problems related to different physical domains. They will exhibit the ability to write small simulation programs in Matlab.
3	**Recommended prerequisite for participation** Recommended: “Computational Electromagnetics and Applications” (also in parallel).
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, MSc ETiT, BSc CE
7	**Grade bonus compliant to §25 (2)**
8	**References** Course notes will be provided.

Courses

Course Nr.	Course name		
18-dg-1041-pr	Software Lab Computational Electromagnetics and Applications I		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Herbert De Gersem		Internship	3

3.4 Communication Systems

3.4.1 Lectures

Module name Acoustics I					
Module Nr. 18-se-2010	**Credit Points** 3 CP	**Workload** 90 h	**Self study** 60 h	**Duration** 1	**Cycle offered** WiSe
Language German			**Module owner** Prof. (em.) Dr. Gerhard Sessler		

1	**Content** 1.Basic concepts of vibrations; impedance; electromechanical analogues, 2.sound field: wave equation; plane waves; sound absorption and dispersion; room absorption, 3.sound radiation: spherical, dipole, and cardioid source; linear arrays;circular piston membrane, 4.physiological and psychological acoustics: hearing organ; acoustic perception; speech production and-speech intelligibility, 5. electroacoustic transducers; reciprocity relations; electrostatic, piezoelectric, electrodynamic, and other transducers; directional microphones; microphone calibration, 6. acoustic measuring methods: measurements of fundamental acoustic quantities; acoustic testing chambers; vibration measurements, 7 analogical and digital sound recording: digital and analogical disc and magnetic tape methods; movie sound, 8. ultrasound and hypersound: generation and detection; applications
2	**Learning objectives / Learning Outcomes** After completion of the lecture, students possess: • the understanding of basic phenomena of generation, propagation, reception, storage and reproduction of sound; • the ability to analyze acoustic components and systems; • the ability to judge and design applications in the audio and ultrasonic frequency ranges.
3	**Recommended prerequisite for participation** Electrical Engineering I and II, Mathematics I to IV, Physics, Basics of Telecommunication
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	**Grade bonus compliant to §25 (2)**
8	**References** H. Kuttruft, Akustik (Hilzel 2004); M. Zollner u. E. Zwicker, Elektroakustik, 3. Auflage (Springer, corrected reprint 1998); H. Fastl, E. Zwicker, Psychoacoustics (Springer 2005); J. Blauert, Communication Acoustics (Springer 2005); R.Lerch, G. Sessler u. D. Wolf, Technische Akustik (Springer 2009)
Courses	

	Course Nr.	Course name		
	18-se-2010-vl	Acoustics I		
	Instructor		**Type**	**SWS**
	Prof. (em.) Dr. Gerhard Sessler, Prof. Dr. Mario Kupnik		Lecture	2

Module name					
Information Theory I					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-kp-1010	6 CP	180 h	120 h	1	WiSe
Language			**Module owner**		
English			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 Grade bonus compliant to §25 (2)

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

Module name					
Information Theory II					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-pe-2010	6 CP	180 h	120 h	1	SoSe
Language			**Module owner**		
English			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	**Grade bonus compliant to §25 (2)**
8	**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.	Course name		
18-pe-2010-vl	Information Theory II		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Marius Pesavento		Lecture	3
Course Nr.	**Course name**		
18-pe-2010-ue	Information Theory II		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Marius Pesavento		Practice	1

Module name					
MIMO - Communication and Space-Time-Coding					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-pe-2030	4 CP	120 h	75 h	1	WiSe
Language			**Module owner**		
English			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	**Grade bonus compliant to §25 (2)**
8	**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.	**Course name**		
18-pe-2030-vl	MIMO - Communication and Space-Time-Coding		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Marius Pesavento		Lecture	2
Course Nr.	**Course name**		
18-pe-2030-ue	MIMO - Communication and Space-Time-Coding		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Marius Pesavento, M.Sc. Fabio Nikolay, M.Sc. Tianyi Liu		Practice	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 Grade bonus compliant to §25 (2)

8 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. 18-kl-2020-ue	**Course name** Mobile Communications		
	Instructor Prof. Dr.-Ing. Anja Klein		**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 Grade bonus compliant to §25 (2)

8 References

Courses

Course Nr. 18-jk-2090-vl	**Course name** Microwave Measurement Technologies		
Instructor Dr.-Ing. Holger Maune		**Type** Lecture	**SWS** 2

Course Nr. 18-jk-2090-ue	**Course name** 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		**Type**	**SWS**
	Dr.-Ing. Holger Maune		Internship	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, Written/Oral Examination, Duration: 120 min, Standard Grading System) In general, the examination takes place in form of a written exam (duration: 120 minutes). If up to 13 students register, there examination can be an oral examination (duration: 20 min.). The type of examination will be announced in the beginning of the lecture or in semesters without a lecture within one working week after the end of the examination registration phase.
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Written/Oral Examination, Weighting: 100 %)
6	**Usability of this module** MSc ETiT
7	**Grade bonus compliant to §25 (2)**
8	**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.	Course name		
18-pe-2020-vl	Convex Optimization in Signal Processing and Communications		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Marius Pesavento		Lecture	2
Course Nr.	**Course name**		
18-pe-2020-ue	Convex Optimization in Signal Processing and Communications		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Marius Pesavento		Practice	1

	Course Nr.	Course name		
	18-pe-2020-pr	Convex Optimization in Signal Processing and Communications Lab		
	Instructor		**Type**	**SWS**
	Prof. Dr.-Ing. Marius Pesavento		Internship	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 Grade bonus compliant to §25 (2)

8 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 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.-Ing. Anja Klein		

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	**Grade bonus compliant to §25 (2)**			
8	**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. 18-kp-2110-vl	**Course name** Machine Learning in Information and Communication Technology (ICT)		
	Instructor Prof. Dr. techn. Heinz Köppl, Prof. Dr.-Ing. Anja Klein, Prof. Dr.-Ing. Abdelhak Zoubir, Prof. Dr.-Ing. Marius Pesavento		**Type** Lecture	**SWS** 2
	Course Nr. 18-kp-2110-pr	**Course name** Machine Learning in Information and Communication Technology (ICT) Lab		
	Instructor Prof. Dr. techn. Heinz Köppl, Prof. Dr.-Ing. Anja Klein, Prof. Dr.-Ing. Abdelhak Zoubir, Prof. Dr.-Ing. Marius Pesavento		**Type** Internship	**SWS** 1
	Course Nr. 18-kp-2110-ue	**Course name** Machine Learning in Information and Communication Technology (ICT)		
	Instructor Prof. Dr. techn. Heinz Köppl, Prof. Dr.-Ing. Anja Klein, Prof. Dr.-Ing. Abdelhak Zoubir, Prof. Dr.-Ing. Marius Pesavento		**Type** Practice	**SWS** 1

Module name					
Graph signal processing, learning and optimization					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-pe-2080	6 CP	180 h	120 h	1	WiSe
Language			**Module owner**		
English			Prof. Dr.-Ing. Marius Pesavento		

1 Content

The course covers the following topics:

- Motivation, Applications
- Fundamentals
  - definition of graphs, classes of graphs, properties of graphs, signals defined over graphs
  - Adjecency matrix, Graph Laplacian, Graph shift operator
  - Covariance matrix, conditional dependence, precision matrix
- Graph signal processing
  - Consensus, Diffusion
  - Graph spectral analysis, Graph Fourier Transform
  - Total variational norm, Graph Frequencies
  - Bandlimited graph signals, smoothness
  - Graph filters, Graph sampling theorem
  - Applications
- Network topology inference
  - Link prediction
  - Association network inference
  - Tomographic network topology inference
  - Pearson product-moment correlation
  - Causality, Partial correlation
  - Conditional independence graph
  - Gaussian Markov Random Fields
  - Graphical LASSO, Graphical LASSO with Laplacian constraint
  - Applications
- Graph analysis
  - Subgraph identification
  - Cliques identification
- Optimization over graphs
  - Average consensus, diffusion, exact diffusion
  - Gradient tracking, push-sum algorithm, etc.
  - Applications
- Graph neuronal (convolutional) network

2 Learning objectives / Learning Outcomes

Graph signal processing (i.e., processing of signals defined over graphs) and network analysis form an interdisciplinary research area with many diverse applications. The course provides a systematic introdution to the theory of graph signal processing, graphical network analysis, graph topology learning, optimization over graphs and learning with graph neuronal networks. In this course the students will learn the main concepts, algorithms and application areas that are fundamental in graph signal processing.

3 Recommended prerequisite for participation

Basic knowledge in linear algebra and matrix analysis.

4 Form of examination

	Module Final Examination: • Module Examination (Technical Examination, Written/Oral Examination, Duration: 120 min, Standard Grading System) In general, the examination takes place in form of a written exam (duration: 120 minutes). If up to 20 students register in semesters in which the lecture does not take place, there will will be an oral examination (duration: 20 min.). The type of examination will be announced within one working weeks after the end of the examination registration phase.
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Written/Oral Examination, Weighting: 100 %)
6	**Usability of this module**
7	**Grade bonus compliant to §25 (2)**
8	**References** • Lecture notes and slides can be downloaded here: – www.nts.tu-darmstadt.de – moodle • Further reading: – Petar M. Djuric, Cédric Richard, Cooperative and Graph Signal Processing, Academic Press, 2018, ISBN 9780128136775.

Courses

Course Nr. 18-pe-2080-vl	**Course name** Graph signal processing, learning and optimization		
Instructor Prof. Dr.-Ing. Marius Pesavento		**Type** Lecture	**SWS** 3
Course Nr. 18-pe-2080-ue	**Course name** Graph signal processing, learning and optimization		
Instructor Prof. Dr.-Ing. Marius Pesavento		**Type** Practice	**SWS** 1

Module name International Summer School 'Microwaves and Lightwaves'					
Module Nr. 18-pr-2020	**Credit Points** 4 CP	**Workload** 120 h	**Self study** 90 h	**Duration** 1	**Cycle offered** SoSe
Language English			**Module owner** Prof. Dr. rer. nat. Sascha Preu		

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	**Grade bonus compliant to §25 (2)**
8	**References** A script (English) will be distributed and English slides can be downloaded.

Courses

Course Nr. 18-pr-2020-se	**Course name** International Summer School "Microwaves and Lightwaves"	
Instructor Prof. Dr. rer. nat. Sascha Preu, Prof. Dr.-Ing. Rolf Jakoby, Prof. (em.) Dr.-Ing. Dr.h.c. Hans Ludwig Hartnagel, Prof. Dr.-Ing. Franko Küppers	**Type** Seminar	**SWS** 2

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	**Grade bonus compliant to §25 (2)**
8	**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 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 Grade bonus compliant to §25 (2)

8 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.	**Course name**		
18-jk-2050-pr	Laboratory Communication and Sensor Systems		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Rolf Jakoby, Prof. Dr.-Ing. Anja Klein, Dr.-Ing. Martin Schüßler		Internship	3

3.5 Communication Science and Media Technology

3.5.1 Lectures

Module name Communication Networks IV					
Module Nr. 18-sm-2030	**Credit Points** 3 CP	**Workload** 90 h	**Self study** 60 h	**Duration** 1	**Cycle offered** WiSe
Language English			**Module owner** 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	**Grade bonus compliant to §25 (2)**
8	**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**
Dr.-Ing. Amr Rizk, Prof. Dr.-Ing. Ralf Steinmetz		Lecture	2

Module name					
Network Security					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
20-00-0512	6 CP	180 h	120 h	1	Every 2. Sem.
Language			**Module owner**		
English			Dr.-Ing. Michael Kreutzer		

1 Content

The integrated course Network Security covers the principles and practice of computer and telecommunication network security with particular emphasis on Internet security. After transferring the fundamentals of IT security and cryptography to the networking domain, we follow a top-down approach to network security. Starting with the application layer, the course provides a detailed discussion of network security principles and protocols. In addition to well known mechanisms, selected recent developments in the area of network security will be examined.

Course contents:

- Network security: introduction, motivation, and challenges
- Fundamentals: a reference model for network security, security standards for networks and the Internet, security threats, attacks, services, and mechanisms
- Cryptographic foundations for networking security: symmetric crypto and its use in networks, public-key crypto and its use in networks, support functions to implement network security
- Application layer security
- Transport layer security
- Network layer security
- Link layer security
- Physical layer security and physical security
- Operational network security: firewalls, intrusion detection systems
- Selected topics in network security

2 Learning objectives / Learning Outcomes

After successfully attending the course, students have aquired an in-deep knowledge in the domain of communication network security with emphasis on Internet security. Students are able to apply and transfer the most important fundamentals from IT security and cryptography to the field of communication networks. Students are able to distinguish the most important basic techniques for securing communication networks. They have a thorough understanding of security mechanisms on the different network layers (application layer, transport layer, network layer, link layer, physical layer). As a result, they are able to thoroughly discuss the characteristics and principles in the area of network security and exhibit detailed theoretical and practical knowledge in this field. Additionally, students are able to describe recent developments in the area of network security (e.g. peer-to-peer security, mobile network security, etc.). The exercise deepens the theoretical foundations by means of exercises, which consist of literature, calculation as well as practical implementation/application examples.

3 Recommended prerequisite for participation

Knowledge in the area IT Security, Introduction to Cryptography and Communication Networks

4 Form of examination

Module Eccompanying Examination:

- [20-00-0512-iv] (Technical Examination, Written/Oral Examination, Standard BWS)

5 Grading

Module Eccompanying Examination:

- [20-00-0512-iv] (Technical Examination, Written/Oral Examination, Weighting: 100 %)

6 Usability of this module

	B.Sc. Informatik M.Sc. Informatik M.Sc. Wirtschaftsinformatik B.Sc. Psychologie in IT Joint B.A. Informatik B.Sc. Sportwissenschaft und Informatik Can be used in other degree programs.
7	**Grade bonus compliant to §25 (2)** In dieser Vorlesung findet eine Anrechnung von vorlesungsbegleitenden Leistungen statt, die lt. §25 (2) der 5. Novelle der APB und den vom FB 20 am 30.3.2017 beschlossenen Anrechnungsregeln zu einer Notenverbesserung um bis zu 1.0 führen kann.
8	**References** Charlie Kaufman, Radia Perlman, Mike Speciner: Network Security – Private Communication in a Public World, 2nd Edition, Prentice Hall, 2002, ISBN: 978-0-14-046019-6; additional texts may be announced

Courses

Course Nr.	**Course name**		
20-00-0512-iv	Network Security		
Instructor		**Type**	**SWS**
Dr.-Ing. Michael Kreutzer		Integrated Course	4

Module name					
Project on Secure Mobile Networking					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
20-00-0553	9 CP	270 h	180 h	1	Every 2. Sem.
Language			**Module owner**		
German and English			Prof. Dr. rer. nat. Karsten Weihe		

1 Content

The Project on Secure Mobile Networking covers the applied software development as well as hardware-software development. Topic areas covered are communication networks, IT security, mobile netwokrs and wireless communications as well as the combination of these. Goal is to independently carry out a development project in a team.

Course contents:

- Independent solving of a development project in the area of communication networks, IT security, mobile netwokrs and wireless communications
- Project planning and project management
- Survey on solution alternatives and discussion of pros and cons
- Conception of a software architecture or a combined hardware-software architecture
- Software/hardware design for the target platform
- Prototypical realization on the target platform
- Evaluation of the system with respect to performance aspects
- Documentation of the implemented solution as well as extensive documentation of the project management

2 Learning objectives / Learning Outcomes

After successfully attending the course, students have aquired the ability to solve complex problems in the area of secure mobile networking using software technology. To this end, the students are able to independently define, manage and carrry out a project.

The students have gained insight into the design/implementation of complex protocols or applications in one/multiple of the areas of communication networks, IT security, mobile netwokrs and wireless communications. They are able to implement the chosen protocols and application, and to test the functionality as well as to evaluate the performance. The students are able to document the project planning and management, the developed software artefacts and to present the project progress and outcomes.

3 Recommended prerequisite for participation

Successfull participation of an lecture of SEEMOO.

4 Form of examination

Module Eccompanying Examination:

- [20-00-0553-pp] (Study Achievement, Written/Oral Examination, Standard BWS)

5 Grading

Module Eccompanying Examination:

- [20-00-0553-pp] (Study Achievement, Written/Oral Examination, Weighting: 100 %)

6 Usability of this module

B.Sc. Informatik
M.Sc. Informatik
M.Sc. Wirtschaftsinformatik
B.Sc. Psychologie in IT
Joint B.A. Informatik
B.Sc. Sportwissenschaft und Informatik
Can be used in other degree programs.

7 Grade bonus compliant to §25 (2)

8 References

	Will be given in project.

Courses

Course Nr. 20-00-0553-pp	**Course name** Secure Mobile Networking Project		
Instructor Prof. Dr.-Ing. Matthias Hollick		**Type** Internship	**SWS** 6

Module name Network, Traffic and Quality Management for Internet Services					
Module Nr. 20-00-0056	**Credit Points** 3 CP	**Workload** 90 h	**Self study** 60 h	**Duration** 1	**Cycle offered** Every 2. Sem.
Language English			**Module owner** Prof. Dr. rer. nat. Eberhard Max Mühlhäuser		

1	**Content** Introduction into management of Internet service provider (ISP-)networks for integrating IP service platforms with their quality and traffic profiles
2	**Learning objectives / Learning Outcomes** Course Content: Demands and measures for ensuring Quality-of-Service (QoS) ?Criteria from the applications & users view (QoE: Quality of Experience) ?IP QoS Architecture: Differentiated & Integrated Services ?QoS support & impact per application in the current IP traffic mix (Video streaming, VoIP, web browsing, downloads, social networking etc.) Quality support for IP services within ISP network infrastructures ?Impact of network and transport layer Routing (OSPF, BGP), Multiprotocol Label Switching (MPLS), TCP incl. failure handling and resilience ?Measurement, monitoring and optimization of IP traffic regarding QoS criteria Quality support in service overlays and on application layer ?Content Delivery Networks (CDN), clouds and Peer-to-Peer networks (P2P) incl. distributed caches, optimization of transport paths, scalability and ?IETF Standardization (CDN Interconnection, ALTO: Appl. Layer Traffic Opt.)
3	**Recommended prerequisite for participation** Prerequisites: Basic knowledge in computer science and Internet applications is required. The courses on Kommunikationsnetze I and II are recommended.
4	**Form of examination** Module Eccompanying Examination: • [20-00-0056-vl] (Technical Examination, Written/Oral Examination, Standard BWS)
5	**Grading** Module Eccompanying Examination: • [20-00-0056-vl] (Technical Examination, Written/Oral Examination, Weighting: 100 %)
6	**Usability of this module**
7	**Grade bonus compliant to §25 (2)**
8	**References** Will be given in lecture.

Courses

Course Nr.	**Course name**		
20-00-0056-vl	Network, traffic and quality management for Internet services		
Instructor		**Type** Lecture	**SWS** 2

Module name Serious Games					
Module Nr. 20-00-0366	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1	**Cycle offered** Every 2. Sem.
Language German and English			**Module owner** Prof. Dr. Bernt Schiele		

1	**Content** Introduction to the topic of “”Serious Games"": scientific and technical foundations, application areas and trends. Individual lectures include: * Introduction to Serious Games * Game Development, Game Design * Game Technology, Tools and Engines * Personalization and Adaptation * Interactive Digital Storytelling * Authoring and Content Generation * Multiplayer Games * Game Interfaces and Sensor Technology * Effects, Affects and User Experience * Mobile Games * Serious Games Application Domains and Best Practice Examples The exercise consists of theoretical and practical parts. Students are taught how to use a Game Engine.
2	**Learning objectives / Learning Outcomes** After successfully completing this course the students are able to explain the concept of “Serious Games” and can transfer it to different application domains (like education or health). They can describe the general approach for developing computer games and can apply basic principles of game design, personalisation / adaptation and interactive digital storytelling. Aside from that students are able to sketch out other current research questions regarding Serious Games as well as their solutions.
3	**Recommended prerequisite for participation**
4	**Form of examination** Module Eccompanying Examination: • [20-00-0366-iv] (Technical Examination, Written/Oral Examination, Standard BWS)
5	**Grading** Module Eccompanying Examination: • [20-00-0366-iv] (Technical Examination, Written/Oral Examination, Weighting: 100 %)
6	**Usability of this module** B.Sc. Informatik M.Sc. Informatik B.Sc. Computational Engineering M.Sc. Computational Engineering M.Sc. Wirtschaftsinformatik B.Sc. Psychologie in IT Joint B.A. Informatik B.Sc. Sportwissenschaft und Informatik M.Sc. Sportwissenschaft und Informatik Can be used in other degree programs.
7	**Grade bonus compliant to §25 (2)** In dieser Vorlesung findet eine Anrechnung von vorlesungsbegleitenden Leistungen statt, die lt. §25 (2) der 5. Novelle der APB und den vom FB 20 am 30.3.2017 beschlossenen Anrechnungsregeln zu einer Notenverbesserung um bis zu 1.0 führen kann.
8	**References**

	Will be given in lecture.

Courses			
	Course Nr. 20-00-0366-iv	**Course name** Serious Games	
	Instructor	**Type** Integrated Course	**SWS** 4

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 Grade bonus compliant to §25 (2)

8 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. Boris Koldehofe, M.Sc. Ralf Kundel		Lecture	2
Course Nr.	**Course name**		
18-sm-2280-ue	Software Defined Networking		
Instructor		**Type**	**SWS**
Prof. Dr. Boris Koldehofe, M.Sc. Ralf Kundel		Practice	2

Module name TK3: Ubiquitous / Mobile Computing					
Module Nr. 20-00-0120	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1	**Cycle offered** Every 2. Sem.
Language German			**Module owner** Prof. Dr. rer. nat. Eberhard Max Mühlhäuser		

1	**Content** Objectives: - Knowledge of technical basics of the mobile communication - Knowledge of important challenges of the Ubiquitous Computing - Methodic knowledge about current approaches to these challenges Course Content: - Introduction to Ubiquitous Computing - Mobile Communication - Internet of Things: RFID and Smart Items - Service Discovery & Cloudlets - Context- and Location-aware Computing - Human Computer Interaction - Privacy and Trust in Ubiquitous Computing
2	**Learning objectives / Learning Outcomes** After successfully attending the course, students are familiar with the technical basis of mobile communication. They understand the fundamental challenge of ubiquitous computing. They know current approaches to solve these challenges. They are able to apply their knowledge to build ubiquitous computing systems.
3	**Recommended prerequisite for participation** Computer Netzwerke and Distributed Systems
4	**Form of examination** Module Eccompanying Examination: • [20-00-0120-iv] (Technical Examination, Written/Oral Examination, Standard BWS)
5	**Grading** Module Eccompanying Examination: • [20-00-0120-iv] (Technical Examination, Written/Oral Examination, Weighting: 100 %)
6	**Usability of this module** B.Sc. Informatik M.Sc. Informatik M.Sc. Wirtschaftsinformatik B.Sc. Psychologie in IT Joint B.A. Informatik B.Sc. Sportwissenschaft und Informatik M.Sc. Sportwissenschaft und Informatik May be used in other degree programs.
7	**Grade bonus compliant to §25 (2)** In dieser Vorlesung findet eine Anrechnung von vorlesungsbegleitenden Leistungen statt, die lt. §25 (2) der 5. Novelle der APB und den vom FB 20 am 30.3.2017 beschlossenen Anrechnungsregeln zu einer Notenverbesserung um bis zu 1.0 führen kann.
8	**References**

Literature recommendations will be updated regularly, an example might be:
A Primary Literature:
Handbook of Research: Ubiquitous Computing Technology for Real Time Enterprises edited by Prof. Dr. Max Mühlhäuser, Dr. Iryna Gurevych, 2008, Information Science Reference, ISBN-10: 1599048329
B Secondary Literature:
1. F. Adelstein, S. Gupta et al.: Fundamentals of Mobile & Pervasive Computing McGraw Hill 2004,
2. Stefan Poslad: Ubiquitous Computing, Wiley 2009, ISBN 978-0-470-03560-3
3. Kapitel Mobilkommunikation: M. Sauter: Grundkurs Mobile Kommunikationssysteme: UMTS, HSDPA und LTE, GSM, GPRS und Wireless LAN; Vieweg-Teubner Studium 2010
4. J. Krumm (Ed.): Ubiquitous Computing Fundamentals, CRC Press 2010
D. Cook, S. Das (Ed.): Smart Environments, Wiley 2005

Courses

Course Nr.	**Course name**		
20-00-0120-iv	TK3: Ubiquitous / Mobile Computing		
Instructor		**Type** Integrated Course	**SWS** 4

Module name					
Ubiquitous computing in business processes					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
20-00-0121	3 CP	90 h	60 h	1	Every 2. Sem.
Language			**Module owner**		
German and English			Prof. Dr. rer. nat. Eberhard Max Mühlhäuser		

1	**Content** - Learning how state-of-the-art ubiquitous computing technologies can be utilized in enterprise business processes and in the context of smart city services - Identifying technologies' economic potential for business processes and in the context of smart cities - Understanding underlying technologies, their benefits, challenges, and corresponding business cases - Technologies considered will be RFID technology and its integration with business processes, other smart items (e.g., smart shelfs), etc. - Demonstration of how integration works between the real world and the virtual world as it is represented in enterprise software systems today - Hands-on experience and live demonstrations
2	**Learning objectives / Learning Outcomes** After participation in this course, students will have aquired knowledge about implications of ubiquitous computing on business to business processes and in the context of smart city services in conjunction with basic concepts.
3	**Recommended prerequisite for participation**
4	**Form of examination** Module Eccompanying Examination: • [20-00-0121-vl] (Technical Examination, Written/Oral Examination, Standard BWS)
5	**Grading** Module Eccompanying Examination: • [20-00-0121-vl] (Technical Examination, Written/Oral Examination, Weighting: 100 %)
6	**Usability of this module** B.Sc. Informatik M.Sc. Informatik M.Sc. Wirtschaftsinformatik B.Sc. Psychologie in IT Joint B.A. Informatik B.Sc. Sportwissenschaft und Informatik M.Sc. Sportwissenschaft und Informatik May be used in other degree programs.
7	**Grade bonus compliant to §25 (2)**
8	**References** - Mühlhäuser, M.; Gurevych, I. (Eds.): Ubiquitous Computing Technology for Real Time Enterprises Information Science Reference, Dezember, 2007 - Finkenzeller, K: RFID-Handbuch. Grundlagen und praktische Anwendungen von Transpondern, kontaktlosen Chipkarten und NFC. Hanser Fachbuch; Auflage: 5., aktual. u. erw. Aufl. (1. Oktober 2008) - Fleisch, E.; Mattern, F. (Hrsg.): Das Internet der Dinge: Ubiquitous Computing und RFID in der Praxis, Springer, Berlin, Heidelberg, New York 2005 - Österle, H.; Fleisch, E.; Alt, R.: Business Networking – Shaping Collaboration between Enterprises, Springer - Callaway, E.H.: Wireless Sensor Networks: Architectures and Protocols, Auerbach Publications

Courses

	Course Nr.	Course name		
	20-00-0121-vl	Ubiquitous computing in business processes		
	Instructor		**Type**	**SWS**
			Lecture	2

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.-Ing. Anja Klein		

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	**Grade bonus compliant to §25 (2)**			
8	**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. 18-kp-2110-vl	**Course name** Machine Learning in Information and Communication Technology (ICT)		
	Instructor Prof. Dr. techn. Heinz Köppl, Prof. Dr.-Ing. Anja Klein, Prof. Dr.-Ing. Abdelhak Zoubir, Prof. Dr.-Ing. Marius Pesavento		**Type** Lecture	**SWS** 2
	Course Nr. 18-kp-2110-pr	**Course name** Machine Learning in Information and Communication Technology (ICT) Lab		
	Instructor Prof. Dr. techn. Heinz Köppl, Prof. Dr.-Ing. Anja Klein, Prof. Dr.-Ing. Abdelhak Zoubir, Prof. Dr.-Ing. Marius Pesavento		**Type** Internship	**SWS** 1
	Course Nr. 18-kp-2110-ue	**Course name** Machine Learning in Information and Communication Technology (ICT)		
	Instructor Prof. Dr. techn. Heinz Köppl, Prof. Dr.-Ing. Anja Klein, Prof. Dr.-Ing. Abdelhak Zoubir, Prof. Dr.-Ing. Marius Pesavento		**Type** Practice	**SWS** 1

Module name Radar Techniques					
Module Nr. 18-jk-2040	**Credit Points** 3 CP	**Workload** 90 h	**Self study** 60 h	**Duration** 1	**Cycle offered** WiSe
Language German			**Module owner** Prof. Dr.-Ing. Rolf Jakoby		

1	**Content** First, there will be an introduction of different radar techniques, describing their concepts and principles, their applications and the operating frequency ranges. In a historical survey, the radar ranges and propagation effects will be dealt with. In the second part, various primary and secondary radar techniques will be investigated in detail, including specific techniques of radar signal processing and -analysis.
2	**Learning objectives / Learning Outcomes** Students will know about concepts and principles to detect objects as well as to determine the angular position and range of objects. They learn about the functional principles of various radar systems, including signal processing. They will understand the major physical propagation effects.
3	**Recommended prerequisite for participation** Fundamentals of Communications, Microwave Engineering I
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 Wi-ETiT
7	**Grade bonus compliant to §25 (2)**
8	**References** Slides, Latest Publications and Books

Courses

	Course Nr. 18-jk-2040-vl	**Course name** Radar Techniques		
	Instructor Dr.-Ing. Holger Maune		**Type** Lecture	**SWS** 2

Module name					
Relativistic Electrodynamics					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
18-kb-2020	5 CP	150 h	90 h	1	WiSe
Language			**Module owner**		
German and English			Prof. Dr.-Ing. Harald Klingbeil		

1	**Content** Basics of tensor analysis (tensor fields, transformation behavior, invariance, Ricci calculus, covariant derivative, differential operators), Lorentz transform, fundamental relativistic effects (time dilation, length contraction, Doppler effect), covariant form of Maxwell's equations, induction law from relativistic point of view, relation to relativistic mechanics, four-vectors and four-tensors, electromagnetic energy-momentum tensor and Maxwell's stress tensor, applications of relativistic electrodynamics
2	**Learning objectives / Learning Outcomes** The students understand the basic ideas of Special Relativity and are familiar with the scientific vocabulary. They are able to derive and interpret fundamental formulas, and they are familiar with the mathematical tools. The students understand the concept of covariance and a coordinate-free description of physical theories. They are able to quantitatively compute electromagnetic phenomena in the context of Special Relativity.
3	**Recommended prerequisite for participation** Recommended: "Grundlagen der Elektrodynamik" (18-dg-1010)
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**
7	**Grade bonus compliant to §25 (2)**
8	**References** Lecture slides are offered for download. Further references are given in the lecture.

Courses

	Course Nr. 18-kb-2020-vl	**Course name** Relativistic Electrodynamics		
	Instructor Prof. Dr.-Ing. Harald Klingbeil		**Type** Lecture	**SWS** 2
	Course Nr. 18-kb-2020-ue	**Course name** Relativistic Electrodynamics		
	Instructor Prof. Dr.-Ing. Harald Klingbeil		**Type** Practice	**SWS** 2

Module name Multimedia Communications Seminar II					
Module Nr. 18-sm-2090	**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. 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 Grade bonus compliant to §25 (2)

8 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

3.5.3 Laboratories

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	**Grade bonus compliant to §25 (2)**
8	**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**
Prof. Dr.-Ing. Ralf Steinmetz, Dr. Ing. Björn Richerzhagen, M.Sc. Florian Jomrich		Internship	3

Module name					
Lab Exercise on Secure Mobile Networking					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
20-00-0552	6 CP	180 h	120 h	1	Every 2. Sem.
Language			**Module owner**		
German and English			Prof. Dr. rer. nat. Karsten Weihe		

1	**Content** The Lab Exercise on Secure Mobile Networking covers the applied software development as well as hardware-software development. Topic areas covered are communication networks, IT security, mobile networks and wireless communications as well as the combination of these. Goal is the solving of a given problem by implementation in software or hardware/software in a team. Course contents: - Solving of a problem in the area of communication networks, IT security, mobile networks and wireless communications - Survey on solution alternatives and discussion of pros and cons - Conception of a software architecture or a combined hardware-software architecture - Software/hardware design for the target platform - Prototypical realization on the target platform - Evaluation of the system with respect to performance aspects - Documentation of the implemented solution
2	**Learning objectives / Learning Outcomes** After successfully attending the course, students have aquired the ability to solve problems in the area of secure mobile networking using software technology. The students have gained insight into the design/implementation of complex protocols or applications in one/multiple of the areas of communication networks, IT security, mobile netwokrs and wireless communications. They are able to implement the chosen protocols and application, and to test the functionality as well as to evaluate the performance. Students are able to document the developed software artefacts and to present the project progress and outcomes.
3	**Recommended prerequisite for participation** Successfull participation in an lecture of SEEMOO.
4	**Form of examination** Module Eccompanying Examination: • [20-00-0552-pr] (Study Achievement, Written/Oral Examination, Standard BWS)
5	**Grading** Module Eccompanying Examination: • [20-00-0552-pr] (Study Achievement, Written/Oral Examination, Weighting: 100 %)
6	**Usability of this module** B.Sc. Informatik M.Sc. Informatik M.Sc. Wirtschaftsinformatik B.Sc. Psychologie in IT Joint B.A. Informatik B.Sc. Sportwissenschaft und Informatik Can be used in other degree programs.
7	**Grade bonus compliant to §25 (2)**
8	**References** Will be given in lab.
Courses	

	Course Nr.	Course name		
	20-00-0552-pr	Secure Mobile Networking Lab		
	Instructor		**Type**	**SWS**
	Prof. Dr.-Ing. Matthias Hollick		Internship	4

Module name Visual Computing Lab					
Module Nr. 20-00-0418	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1	**Cycle offered** Every 2. Sem.
Language German and English			**Module owner** Prof. Dr. Bernt Schiele		

1	**Content** Students work in this lab on selected topics in the area of visual computing. Project results will be presented in a talk at the end of the course. The specific topics addressed in the lab change every semester and should be discussed directly with one of the instructors.
2	**Learning objectives / Learning Outcomes** After successful completion of this course, the students will be able to independently analyze and solve a problem in the area of visual computing and to evaluate the results.
3	**Recommended prerequisite for participation** Practical programming skills, e.g. Java, C++ Basic knowledge or interest within Visual Computing Participation in one basic lecture within Visiual Computing
4	**Form of examination** Module Eccompanying Examination: • [20-00-0418-pr] (Study Achievement, Written/Oral Examination, Standard BWS)
5	**Grading** Module Eccompanying Examination: • [20-00-0418-pr] (Study Achievement, Written/Oral Examination, Weighting: 100 %)
6	**Usability of this module** B.Sc. Informatik M.Sc. Informatik B.Sc. Computational Engineering M.Sc. Computational Engineering M.Sc. Wirtschaftsinformatik B.Sc. Psychologie in IT Joint B.A. Informatik B.Sc. Sportwissenschaft und Informatik M.Sc. Sportwissenschaft und Informatik Can be used in other degree programs.
7	**Grade bonus compliant to §25 (2)**
8	**References** Will be announced in course.

Courses

Course Nr. 20-00-0418-pr	**Course name** Lab Visual Computing		
Instructor		**Type** Internship	**SWS** 4

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	**Grade bonus compliant to §25 (2)**
8	**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, M.Sc. Florian Jomrich		Internship	6

Module name					
Project on Secure Mobile Networking					
Module Nr.	**Credit Points**	**Workload**	**Self study**	**Duration**	**Cycle offered**
20-00-0553	9 CP	270 h	180 h	1	Every 2. Sem.
Language			**Module owner**		
German and English			Prof. Dr. rer. nat. Karsten Weihe		

1 Content

The Project on Secure Mobile Networking covers the applied software development as well as hardware-software development. Topic areas covered are communication networks, IT security, mobile netwokrs and wireless communications as well as the combination of these. Goal is to independently carry out a development project in a team.

Course contents:

- Independent solving of a development project in the area of communication networks, IT security, mobile netwokrs and wireless communications
- Project planning and project management
- Survey on solution alternatives and discussion of pros and cons
- Conception of a software architecture or a combined hardware-software architecture
- Software/hardware design for the target platform
- Prototypical realization on the target platform
- Evaluation of the system with respect to performance aspects
- Documentation of the implemented solution as well as extensive documentation of the project management

2 Learning objectives / Learning Outcomes

After successfully attending the course, students have aquired the ability to solve complex problems in the area of secure mobile networking using software technology. To this end, the students are able to independently define, manage and carrry out a project.

The students have gained insight into the design/implementation of complex protocols or applications in one/multiple of the areas of communication networks, IT security, mobile netwokrs and wireless communications. They are able to implement the chosen protocols and application, and to test the functionality as well as to evaluate the performance. The students are able to document the project planning and management, the developed software artefacts and to present the project progress and outcomes.

3 Recommended prerequisite for participation

Successfull participation of an lecture of SEEMOO.

4 Form of examination

Module Eccompanying Examination:

- [20-00-0553-pp] (Study Achievement, Written/Oral Examination, Standard BWS)

5 Grading

Module Eccompanying Examination:

- [20-00-0553-pp] (Study Achievement, Written/Oral Examination, Weighting: 100 %)

6 Usability of this module

B.Sc. Informatik
M.Sc. Informatik
M.Sc. Wirtschaftsinformatik
B.Sc. Psychologie in IT
Joint B.A. Informatik
B.Sc. Sportwissenschaft und Informatik
Can be used in other degree programs.

7 Grade bonus compliant to §25 (2)

8 References

	Will be given in project.

Courses			
Course Nr. 20-00-0553-pp	**Course name** Secure Mobile Networking Project		
Instructor Prof. Dr.-Ing. Matthias Hollick		**Type** Internship	**SWS** 6

3.6 IT in Engineering, Computer Science, Mathematics and Physics

All modules not already listed in this document and offered by Dept. (FB) 4–13 or 16–20.

4 Studium Generale

4.1 Business Administration

Module name Introduction to Business Administration					
Module Nr. 01-10-1028/f	**Credit Points** 3 CP	**Workload** 90 h	**Self study** 60 h	**Duration** 1	**Cycle offered** Every Sem.
Language German			**Module owner** Prof. Dr. rer. pol. Dirk Schiereck		
1	**Content** This course serves as an introduction into studies of business administration for students of other siences. The course will provide a broad spectrum of knowledge from the “birth” of business administration as an university science field until its fragmentation into many specialized disciplines. Core topics will include basics of business administration (definitions and German legal forms), some Marketing concepts, introduction into Production Management (business process optimization and quality management), basic knowledge of organisational and personnel related topics, fundamental concepts of finance and investment as well as internal and external reporting standards.				
2	**Learning objectives / Learning Outcomes** The couse encourages students who have not been confronted with business studies before to think economicially. Furthermore, it should enable students to better understand actions of managers and corporations in general. After the course students are able to • comprehend the development in the history of business administration, • apply essential marketing concepts, • use fundamental methods in production management, • economically valuate investment alternatives and • understand important interrelations in financial accounting.				
3	**Recommended prerequisite for participation** None				
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Written/Oral Examination, Standard Grading System)				
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Written/Oral Examination, Weighting: 100 %)				
6	**Usability of this module**				
7	**Grade bonus compliant to §25 (2)**				
8	**References** Thommen, J.-P. & Achleitner, A.-K. (2006): Allgemeine Betriebswirtschaftslehre, 5. Aufl., Wiesbaden. Domschke, W. & Scholl, A. (2008): Grundlagen der Betriebswirtschaftslehre, 3. Aufl., Heidelberg. Further literature will be announced in the lecture.				

Courses				
	Course Nr. 01-10-0000-vl	**Course name** Introduction to Business Administration		
	Instructor		**Type** Lecture	**SWS** 2
	Course Nr. 01-10-0000-tt	**Course name**		
	Instructor Prof. Dr. rer. pol. Dirk Schiereck		**Type** Tutorial	**SWS** 0

Module name Introduction to Economics (V)					
Module Nr. 01-60-1042/f	**Credit Points** 3 CP	**Workload** 90 h	**Self study** 60 h	**Duration** 1	**Cycle offered** Every Sem.
Language German and English			**Module owner** Prof. Dr. rer. pol. Michael Neugart		

1	**Content** • Economic modeling • Supply and demand • Elasticities • Consumer and producer rent • Opportunity costs • Marginal analysis • Cost theory • Utility maximization • Macroeconomic aggregates • Long-run growth • Aggregate supply and aggregate demand
2	**Learning objectives / Learning Outcomes** Students are introduced to the principles of economics and their application to selected fields of interest.
3	**Recommended prerequisite for participation** None
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Written/Oral Examination, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Written/Oral Examination, Weighting: 100 %)
6	**Usability of this module** none
7	**Grade bonus compliant to §25 (2)**
8	**References** to be announced in course.

Courses

Course Nr. 01-60-0000-vl	**Course name** Introduction to Economics	
Instructor	**Type** Lecture	**SWS** 2

4.2 Languages

4.2.1 German Language Modules

Module name German Basic Course I					
Module Nr. 41-11-0112	**Credit Points** 3 CP	**Workload** 90 h	**Self study** 60 h	**Duration** 1	**Cycle offered** Every Sem.
Language German			**Module owner** M.A. Britta Friedmann		
1	**Content**				
2	**Learning objectives / Learning Outcomes**				
3	**Recommended prerequisite for participation**				
4	**Form of examination** Module Eccompanying Examination: • [41-11-0110-ku] (Study Achievement, Study Archievment, Duration: 90 min, Standard BWS)				
5	**Grading** Module Eccompanying Examination: • [41-11-0110-ku] (Study Achievement, Study Archievment, Weighting: 100 %)				
6	**Usability of this module**				
7	**Grade bonus compliant to §25 (2)**				
8	**References**				
Courses					
	Course Nr. 41-11-0110-ku	**Course name** German Basic Course I			
	Instructor		**Type** Course	**SWS** 2	

Module name German Basic Course I - Participation only					
Module Nr. 41-11-0114	**Credit Points** 0 CP	**Workload** 0 h	**Self study** 0 h	**Duration** 1	**Cycle offered** Every Sem.
Language German			**Module owner** M.A. Britta Friedmann		

1	**Content**
2	**Learning objectives / Learning Outcomes**
3	**Recommended prerequisite for participation**
4	**Form of examination** Module Eccompanying Examination: • [41-11-0110-ku] (Study Achievement, null, BWS b/nb)
5	**Grading** Module Eccompanying Examination: • [41-11-0110-ku] (Study Achievement, null, Weighting: 100 %)
6	**Usability of this module**
7	**Grade bonus compliant to §25 (2)**
8	**References**

Courses

	Course Nr. 41-11-0110-ku	**Course name** German Basic Course I	
	Instructor	**Type** Course	**SWS** 2

Module name German Basic Course II/III					
Module Nr. 41-11-0122	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1	**Cycle offered** Every Sem.
Language German			**Module owner** M.A. Britta Friedmann		

1	**Content**
2	**Learning objectives / Learning Outcomes**
3	**Recommended prerequisite for participation**
4	**Form of examination** Module Eccompanying Examination: • [41-11-0120-ku] (Study Achievement, Study Archievment, Duration: 90 min, Standard BWS)
5	**Grading** Module Eccompanying Examination: • [41-11-0120-ku] (Study Achievement, Study Archievment, Weighting: 100 %)
6	**Usability of this module**
7	**Grade bonus compliant to §25 (2)**
8	**References**

Courses

	Course Nr. 41-11-0120-ku	**Course name** German Basic Course II/III		
	Instructor		**Type** Course	**SWS** 4

Module name German Basic Course II/III - Participation only					
Module Nr. 41-11-0124	**Credit Points** 0 CP	**Workload** 0 h	**Self study** 0 h	**Duration** 1	**Cycle offered** Every Sem.
Language German			**Module owner** M.A. Britta Friedmann		

1	**Content**
2	**Learning objectives / Learning Outcomes**
3	**Recommended prerequisite for participation**
4	**Form of examination** Module Eccompanying Examination: • [41-11-0120-ku] (Study Achievement, null, BWS b/nb)
5	**Grading** Module Eccompanying Examination: • [41-11-0120-ku] (Study Achievement, null, Weighting: 100 %)
6	**Usability of this module**
7	**Grade bonus compliant to §25 (2)**
8	**References**

Courses

	Course Nr. 41-11-0120-ku	**Course name** German Basic Course II/III	
	Instructor	**Type** Course	**SWS** 4

Module name German Basic Course IV/V					
Module Nr. 41-11-0132	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1	**Cycle offered** Every Sem.
Language German			**Module owner** M.A. Britta Friedmann		

1	**Content**
2	**Learning objectives / Learning Outcomes**
3	**Recommended prerequisite for participation**
4	**Form of examination** Module Eccompanying Examination: • [41-11-0130-ku] (Study Achievement, Study Archievment, Duration: 90 min, Standard BWS)
5	**Grading** Module Eccompanying Examination: • [41-11-0130-ku] (Study Achievement, Study Archievment, Weighting: 100 %)
6	**Usability of this module**
7	**Grade bonus compliant to §25 (2)**
8	**References**

Courses

Course Nr. 41-11-0130-ku	**Course name** German Basic Course IV/V		
Instructor		**Type** Course	**SWS** 4

Module name German Basic Course IV/V - Participation only					
Module Nr. 41-11-0134	**Credit Points** 0 CP	**Workload** 0 h	**Self study** 0 h	**Duration** 1	**Cycle offered** Every Sem.
Language German			**Module owner** M.A. Britta Friedmann		

1	**Content**
2	**Learning objectives / Learning Outcomes**
3	**Recommended prerequisite for participation**
4	**Form of examination** Module Eccompanying Examination: • [41-11-0130-ku] (Study Achievement, null, BWS b/nb)
5	**Grading** Module Eccompanying Examination: • [41-11-0130-ku] (Study Achievement, null, Weighting: 100 %)
6	**Usability of this module**
7	**Grade bonus compliant to §25 (2)**
8	**References**

Courses

	Course Nr. 41-11-0130-ku	**Course name** German Basic Course IV/V	
	Instructor	**Type** Course	**SWS** 4

Module name German Intensive Basic Course I					
Module Nr. 41-12-0102	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 0 h	**Duration** 1	**Cycle offered** Every Sem.
Language German			**Module owner** M.A. Britta Friedmann		

1	**Content**
2	**Learning objectives / Learning Outcomes**
3	**Recommended prerequisite for participation**
4	**Form of examination** Module Eccompanying Examination: • [41-12-0100-ku] (Study Achievement, Study Archievment, Duration: 90 min, Standard BWS)
5	**Grading** Module Eccompanying Examination: • [41-12-0100-ku] (Study Achievement, Study Archievment, Weighting: 100 %)
6	**Usability of this module**
7	**Grade bonus compliant to §25 (2)**
8	**References**

Courses

	Course Nr. 41-12-0100-ku	**Course name** German Intensive Basic Course I		
	Instructor		**Type** Course	**SWS** 20

Module name German Intensive Basic Course II/III					
Module Nr. 41-12-0122	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 0 h	**Duration** 1	**Cycle offered** Every Sem.
Language German			**Module owner** M.A. Britta Friedmann		

1	**Content**
2	**Learning objectives / Learning Outcomes**
3	**Recommended prerequisite for participation**
4	**Form of examination** Module Eccompanying Examination: • [41-12-0120-ku] (Study Achievement, Study Archievment, Duration: 90 min, Standard BWS)
5	**Grading** Module Eccompanying Examination: • [41-12-0120-ku] (Study Achievement, Study Archievment, Weighting: 100 %)
6	**Usability of this module**
7	**Grade bonus compliant to §25 (2)**
8	**References**

Courses

Course Nr. 41-12-0120-ku	**Course name** German Intensive Basic Course II/III		
Instructor		**Type** Course	**SWS** 20

Module name German Intensive Basic Course IV/V					
Module Nr. 41-12-0132	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 0 h	**Duration** 1	**Cycle offered** Every Sem.
Language German			**Module owner** M.A. Britta Friedmann		

1	**Content**
2	**Learning objectives / Learning Outcomes**
3	**Recommended prerequisite for participation**
4	**Form of examination** Module Eccompanying Examination: • [41-12-0130-ku] (Study Achievement, Study Archievment, Duration: 90 min, Standard BWS)
5	**Grading** Module Eccompanying Examination: • [41-12-0130-ku] (Study Achievement, Study Archievment, Weighting: 100 %)
6	**Usability of this module**
7	**Grade bonus compliant to §25 (2)**
8	**References**

Courses

Course Nr. 41-12-0130-ku	**Course name** German Intensive Basic Course IV/V		
Instructor		**Type** Course	**SWS** 20

4.3 Miscellaneous

All modules for this areas are listed in the external module manual “Studium Generale”.