Module handbook of the master's program in

Electrical Communication Engineering

at the Dept. of Electrical Engineering/Computer Science

University of Kassel

Status: Summer Semester 2009

Parts highlighted in yellow indicate changes with respect to the previous version of the module handbook i.e., the one published in winter 2008/2009

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1 Course scheme samples

In the following, course scheme samples are listed which serve as examples for selecting modules with a certain overall focus. The foci include

- **Digital Communications**
- **Electromagnetics**
- **Hardware Components for Communication Systems**
- **Microwaves**
- **Mobile Internet**
- **Optoelectronics**
- **OSI Model**
- **Software Components for Communication Systems.**

The samples for a certain focus include **two versions of course schemes**, namely

- one **starting in the summer semester** and
- one **starting in the winter semester**.

Note that neither of these sample versions is mandatory in any way, but both versions rather represent reasonable choices recommended for the corresponding focus. Clearly, each student is free to select other combinations from the modules listed in Sect. 2 complying with the examination rules and corresponding to the individual knowledge in the different areas.

Each course scheme sample contains the corresponding recommended modules which are described in greater detail in Sect. 2. Note that unlike Sect. 2, Sect. 3 contains qualification modules which represent additional mandatory modules in case the examination board grants a conditional admission according to §4 par.(5) of the ECE examination regulation. See Sect. 3 for further details.

1.1 Digital Communications

Course scheme sample with focus on *Digital Communications*						
Start in *summer semester*						
semester	winter semester (WS)/ summer semester (SS)	Credits				
		6	12	18	24	30
1	SS	Digital Communications R1		Mobile Internet R1	Mobile Internet R2	Social Communication NT
2	WS	Digital Communications R2		Digital Communications R3	Digital Communications P1	Mobile Internet R3
3	SS	Digital Communications T1 (Master's Thesis)				

Course scheme sample with focus on *Digital Communications*						
Start in *winter semester*						
semester	winter semester (WS)/ summer semester (SS)	Credits				
		6	12	18	24	30
1	WS	Digital Communications R2		Digital Communications R3	Microwaves R2	Social Communication NT
2	SS	Digital Communications R1		Digital Communications P1	Mobile Internet R1	Mobile Internet R2
3	WS	Digital Communications T1 (Master's Thesis)				

1.2 Electromagnetics

Course scheme sample with focus on *Electromagnetics*						
Start in *summer semester*						
semester	winter semester (WS)/ summer semester (SS)	Credits				
		6	12	18	24	30
1	SS	Hardware Components for Communication Systems R1		Microwaves R1	Optoelectronics R1	Social Communication NT
2	WS	Electromagnetics R1		Electromagnetics P1	Microwaves R2	Digital Communications R3
3	SS	Electromagnetics T1 (Master's Thesis)				

Course scheme sample with focus on *Electromagnetics*						
Start in *winter semester*						
semester	winter semester (WS)/ summer semester (SS)	Credits				
		6	12	18	24	30
1	WS	Electromagnetics R1		Optoelectronics R2		Social Communication NT
2	SS	Hardware Components for Communication Systems R1		Electromagnetics P1	Optoelectronics R1	Microwaves R1
3	WS	Electromagnetics T1 (Master's Thesis)				

1.3 Hardware Components for Communication Systems

Course scheme sample with focus on *Hardware Components for Communication Systems*						
Start in *summer semester*						
semester	winter semester (WS)/ summer semester (SS)	Credits				
		6	12	18	24	30
1	SS	Hardware Components for Communication Systems R1		Microwaves R1	Optoelectronics R1	Social Communication NT
2	WS	Hardware Components for Communication Systems R2		Microwaves P1 *or* Optoelectronics P1	Electromagnetics R1	
3	SS	Microwaves T1 *or* Optoelectronics T1 (Master's Thesis)				

Course scheme sample with focus on *Hardware Components for Communication Systems*						
Start in *winter semester*						
semester	winter semester (WS)/ summer semester (SS)	Credits				
		6	12	18	24	30
1	WS	Hardware Components for Communication Systems R2		Electromagnetics R1		Social Communication NT
2	SS	Hardware Components for Communication Systems R1		Microwaves P1 *or* Optoelectronics P1	Microwaves R1	Optoelectronics R1
3	WS	Microwaves T1 *or* Optoelectronics T1 (Master's Thesis)				

1.4 Microwaves

Course scheme sample with focus on *Microwaves*						
Start in *summer semester*						
semester	winter semester (WS)/ summer semester (SS)	Credits				
		6	12	18	24	30
1	SS	Microwaves R1	Microwaves R3	Digital Communications R1		Social Communication NT
2	WS	Microwaves R2	Microwaves P1	Digital Communications R2		Digital Communications R3
3	SS	Microwaves T1 (Master's Thesis)				

Course scheme sample with focus on *Microwaves*						
Start in *winter semester*						
semester	winter semester (WS)/ summer semester (SS)	Credits				
		6	12	18	24	30
1	WS	Electromagnetics R1		Digital Communications R2		Social Communication NT
2	SS	Microwaves R1	Microwaves R3	Microwaves P1	Digital Communications R1	
3	WS	Microwaves T1 (Master's Thesis)				

1.5 Mobile Internet

Course scheme sample with focus on *Mobile Internet*						
Start in *summer semester*						
semester	winter semester (WS)/ summer semester (SS)	Credits				
		6	12	18	24	30
1	SS	Mobile Internet R1	Mobile Internet R2	Digital Communications R1		Social Communication NT
2	WS	Mobile Internet R3	Mobile Internet P1	Digital Communications R2		Digital Communications R3
3	SS	Mobile Internet T1 (Master's Thesis)				

Course scheme sample with focus on *Mobile Internet*						
Start in *winter semester*						
semester	winter semester (WS)/ summer semester (SS)	Credits				
		6	12	18	24	30
1	WS	Digital Communications R2		Digital Communications R3	Microwaves R2	Social Communication NT
2	SS	Mobile Internet R1	Mobile Internet R2	Mobile Internet P1	Digital Communications R1	
3	WS	Mobile Internet T1 (Master's Thesis)				

1.6 Optoelectronics

Course scheme sample with focus on *Optoelectronics*						
Start in ***summer semester***						
semester	**winter semester (WS)/ summer semester (SS)**	**Credits**				
		6	**12**	**18**	**24**	**30**
1	**SS**	**Optoelectronics R1**	**Hardware Components for Communication Systems R1**		**Microwaves R1**	**Social Communication NT**
2	**WS**	**Optoelectronics R2**		**Optoelectronics P1**	**Hardware Components for Communication Systems R2**	
3	**SS**	**Optoelectronics T1 (Master's Thesis)**				

Course scheme sample with focus on *Optoelectronics*						
Start in ***winter semester***						
semester	**winter semester (WS)/ summer semester (SS)**	**Credits**				
		6	**12**	**18**	**24**	**30**
1	**WS**	**Optoelectronics R2**		**Hardware Components for Communication Systems R2**		**Social Communication NT**
2	**SS**	**Optoelectronics R1**	**Optoelectronics P1**	**Hardware Components for Communication Systems R1**		**Microwaves R1**
3	**WS**	**Optoelectronics T1 (Master's Thesis)**				

1.7 OSI Model

Course scheme sample with focus on *Different Layers of the OSI Model*						
Start in ***summer semester***						
semester	**winter semester (WS)/ summer semester (SS)**	**Credits**				
		6	**12**	**18**	**24**	**30**
1	**SS**	**Mobile Internet R1**	**Microwaves R1**	**Hardware Components for Communication Systems R1**		**Social Communication NT**
2	**WS**	**Mobile Internet R3**	**Microwaves R2**	**Mobile Internet P1**	**Software Components for Communication Systems R2**	
3	**SS**	**Digital Communications T1 *or* Mobile Internet T1 (Master's Thesis)**				

Course scheme sample with focus on *Different Layers of the OSI Model*						
Start in ***winter semester***						
semester	**winter semester (WS)/ summer semester (SS)**	**Credits**				
		6	**12**	**18**	**24**	**30**
1	**WS**	**Software Components for Communication Systems R2**		**Hardware Components for Communication Systems R2**		**Social Communication NT**
2	**SS**	**Mobile Internet R1**	**Mobile Internet R2**	**Mobile Internet P1**	**Digital Communications R2**	
3	**WS**	**Digital Communications T1 *or* Mobile Internet T1 (Master's Thesis)**				

1.8 Software Components for Communication Systems

Course scheme sample with focus on *Software Components for Communication Systems*						
Start in *summer semester*						
semester	winter semester (WS)/ summer semester (SS)	Credits				
		6	12	18	24	30
1	SS	Software Components for Communication Systems R1		Mobile Internet R1	Mobile Internet R2	Social Communication NT
2	WS	Digital Communications R2		Mobile Internet P1	Mobile Internet R3	Digital Communications R3
3	SS	Digital Communications T1 *or* Mobile Internet T1 (Master's Thesis)				

Course scheme sample with focus on *Software Components for Communication Systems*						
Start in *winter semester*						
semester	winter semester (WS)/ summer semester (SS)	Credits				
		6	12	18	24	30
1	WS	Digital Communications R2		Digital Communications R3	Microwaves R2	Social Communication NT
2	SS	Mobile Internet R1	Mobile Internet R2	Mobile Internet P1	Digital Communications R1	
3	WS	Digital Communications T1 *or* Mobile Internet T1 (Master's Thesis)				

2 Modules of the ECE master's program

In this section, all modules which can be selected during the three semesters of the ECE master's program are listed. The modules cover the areas of

- Digital Communications
- Electromagnetics
- Hardware Components for Communication Systems
- Microwaves
- Mobile Internet
- Optoelectronics
- Software Components for Communication Systems.

Within each area, we have the following naming convention: The label of a module, for example *Digital Communications R1*, is made up by the three attributes <AREA TYPE NO>. While AREA and NO denote one of the aforementioned areas and a consecutive numbering, resp., TYPE takes one of the following values:

R **r**egular modules consisting of lectures, exercises, lab trainings and seminars
P **p**roject module
T **t**hesis module (master thesis)
NT **n**on-**t**echnichal module *Social Communication NT1*.

2.1 Digital Communications

Module title	**Digital Communications R1**				
Courses	**Title**	**Type**	**SWS**	**Credits**	**Performance requirements/ Examination**
	Digital Communications III (lec)	lecture	2	4	oral exam (30 minutes)
	Digital Communications III (ex)	exercises	1	1	
	Introduction to Signal Detection and Estimation (lec)	lecture	2	4	oral exam (30 minutes)
	Introduction to Signal Detection and Estimation (ex)	exercises	1	1	
	Simulation of Digital Communication Systems using MATLAB (lab)	lab training	2	2	lab training attendance, programming, oral exam (30 minutes)
Module credits	12				
Language	English				
Held	in summer semester, annually				
Lecturer	Dahlhaus and team				
Responsible(s)	Dahlhaus				
Required qualifications	Knowledge of fundamentals in digital communications				
Workload	120 hours course attendance 240 hours self-study				
Contents	▪ Carrier and timing recovery, signalling in band-limited channels, transmission over linear band-limited channels, intersymbol interference, adaptive equalization, multicarrier transmission ▪ Hypothesis testing, signal detection, Bayesian parameter estimation, maximum-likelihood estimation, iterative schemes based on the expectation-maximization algorithm, signal estimation based on state-space models, Kalman-Bucy filtering, orthogonality principle, Wiener-Kolmogorov filtering ▪ Introduction to MATLAB and its most important commands, simulation of a simple transmission chain, channel coding (convolutional codes), coding gain, channels with multipath propagation, channel models with fading and bit-error rate performance for binary signalling, transmission with orthogonal frequency-division multiplexing (OFDM), interleaving, implementation of an OFDM modem, direct-sequence spread spectrum (DSSS) transmission.				
Literature	▪ J.G. Proakis, *Digital Communications*, McGraw-Hill, 4th ed., ISBN 0-07-118183-0. ▪ H. Vincent Poor, *An Introduction to Signal Detection and Estimation*, Springer, 2nd ed., ISBN 0-387-94173-8 or ISBN 3-540-94173-8. ▪ Papoulis, S. U. Pillai, *Probability, Random Variables, and Stochastic Processes*, McGraw-Hill, 4th ed., ISBN 0071226613. ▪ H.L. van Trees, *Detection, Estimation, and Modulation Theory*, vol. I, New York, NY: John Wiley & Sons, 1968. ▪ A.J. Viterbi, *CDMA - Principles of Spread Spectrum Communications*, Wireless Communications Series, Addison-Wesley, 1995.				
Media	Beamer (presentation), black board (derivations, explanations), paper (exercises), PC based software development (lab training).				
Objectives	▪ Understanding receiver algorithms in the physical layer of real-world communication systems including aspects in the receiver design which characterize the trade-off between implementation effort and achievable performance ▪ Statistical inference in the context of optimum hypothesis testing and signal estimation schemes ▪ Ability to derive optimum signal processing schemes ▪ Understanding approaches for numerical simulation of transceivers in the physical layer of communication systems.				

Competences to be acquired	▪ Research and development in the area of digital transmission systems, signal processing (e.g. transceivers, image processing), statistical inference (e.g. quality management) and simulation of communication systems (e.g. telecommunications) ▪ Design of terminals and base stations, in particular for wireless communications based on multicarrier transmission ▪ Operation and maintenance of devices in production processes.

<table>
<tr><td>Module title</td><td colspan="5">Digital Communications R2</td></tr>
<tr><td rowspan="6">Courses</td><td>Title</td><td>Type</td><td>SWS</td><td>Credits</td><td>Performance requirements/ Examination</td></tr>
<tr><td>Digital Communications IV (lec)</td><td>lecture</td><td>2</td><td>4</td><td>oral exam (30 minutes)</td></tr>
<tr><td>Mobile Radio (lec)</td><td>lecture</td><td>2</td><td>4</td><td rowspan="2">oral exam (30 minutes)</td></tr>
<tr><td>Mobile Radio (ex</td><td>exercises</td><td>1</td><td>1</td></tr>
<tr><td>Signal Processing in Wireless Communications (sem)</td><td>seminar</td><td>2</td><td>3</td><td>seminar attendance, presentation and oral exam (20 minutes)</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>Module credits</td><td colspan="5">12</td></tr>
<tr><td>Language</td><td colspan="5">English</td></tr>
<tr><td>Held</td><td colspan="5">in winter semester, annually</td></tr>
<tr><td>Lecturer</td><td colspan="5">Dahlhaus and team</td></tr>
<tr><td>Responsible(s)</td><td colspan="5">Dahlhaus</td></tr>
<tr><td>Required qualifications</td><td colspan="5">Knowledge of fundamentals in digital and wireless communications</td></tr>
<tr><td>Workload</td><td colspan="5">105 hours course attendance
255 hours self-study</td></tr>
<tr><td>Contents</td><td colspan="5">▪ Multichannel and multicarrier transmission, orthogonal frequency-division multiplexing (OFDM), spread spectrum (direct sequence, frequency hopping), PN sequences, transmission over fading multipath channels, channel coding for multipath channels, multiple-input multiple-output (MIMO) transmission, multiuser detection, code-division multiple access (CDMA) and random access
▪ Deterministic and stochastic description of mobile radio channels, time-variant linear systems, probability density functions of complex amplitudes in fading channels, characterization of noise and interference, diversity, multichannel signalling and linear combining, spread spectrum signalling, hypothesis testing with minimum probability of error, sufficient statistics, conventional detection, near-far problem, joint detection, detection in asynchronous CDMA systems, synchronisation with phase-locked loops (PLLs) and delay-locked loops (DLLs), demodulation in UMTS with wideband CDMA (uplink and downlink), overview of UMTS
▪ Overview of existing wireless communication systems, basics in the characterization of wireless channels and signal processing in wireless transceivers, channel modelling, signal processing at the transmitter with/without channel coding for different wireless systems, selected topics from signal processing (e.g. radio frequency identification (RFID)), short-range radio, satellite communications, radio broadcast with analog modulation, Wireless Personal Area Networks (WPANs), Wireless Local Area Networks (WLANs), cellular radio of second (2G), third generation (3G) and systems beyond 3G, software tools for research and development, standardization bodies and research trends in the area of signal processing in wireless communication systems.</td></tr>
<tr><td>Literature</td><td colspan="5">▪ J.G. Proakis, Digital Communications, McGraw-Hill, 4th ed., ISBN 0-07-118183-0.
▪ Papoulis, S. U. Pillai, Probability, Random Variables, and Stochastic Processes, McGraw-Hill, 4th ed., ISBN 0071226613.
▪ W.C.Y. Lee, Mobile Communications Engineering, New York: McGraw-Hill, 2nd ed., 1998.
▪ H.L. van Trees, Detection, Estimation, and Modulation Theory, vol. I, New York, NY: John Wiley & Sons, 1968.
▪ S.Verdu, Multiuser Detection, Cambridge University Press, ISBN 0-521-59373-5, 1998.
▪ A.J. Viterbi, CDMA - Principles of Spread Spectrum Communications, Wireless Communications Series, Addison-Wesley, 1995.
▪ Additional papers to be handed out according to seminar topics.</td></tr>
<tr><td>Media</td><td colspan="5">Beamer (lecture, seminar), black board (derivations, explanations), paper (exercises).</td></tr>
<tr><td>Objectives</td><td colspan="5">▪ Detailed understanding of schemes in the physical layer of digital communication systems
▪ Understanding the channel characterization, interference phenomena and signal processing in advanced wireless and mobile radio systems</td></tr>
</table>

	▪ Introduction to scientific work ▪ Literature and internet based investigation to understand advanced topics in signal processing ▪ Presentation of a scientific topic in a seminar.
Competences to be acquired	▪ Research and development in the area of signal processing for wireless and wired digital communication systems ▪ Operation and maintenance of devices in communication systems ▪ Consulting in the area of information technology.

<table>
<tr><td>Module title</td><td colspan="5">Digital Communications R3</td></tr>
<tr><td rowspan="3">Courses</td><td>Title</td><td>Type</td><td>SWS</td><td>Credits</td><td>Performance requirements/ Examination</td></tr>
<tr><td>Digital Communications II (lec)</td><td>lecture</td><td>3</td><td>5</td><td rowspan="2">oral exam (30 minutes)</td></tr>
<tr><td>Digital Communications II (ex)</td><td>exercises</td><td>1</td><td>1</td></tr>
<tr><td>Module credits</td><td colspan="5">6</td></tr>
<tr><td>Language</td><td colspan="5">English</td></tr>
<tr><td>Held</td><td colspan="5">in winter semester, annually</td></tr>
<tr><td>Lecturer</td><td colspan="5">Dahlhaus and team</td></tr>
<tr><td>Responsible(s)</td><td colspan="5">Dahlhaus</td></tr>
<tr><td>Required qualifications</td><td colspan="5">Knowledge of fundamentals in digital communications</td></tr>
<tr><td>Workload</td><td colspan="5">60 hours course attendance
120 hours self-study</td></tr>
<tr><td>Contents</td><td colspan="5">▪ Fundamentals in information theory, entropy, mutual information
▪ Typical sequences and Shannon capacity for the discrete memoryless channel
▪ Channel coding: block codes, cyclic block codes, systematic form
▪ Soft and hard decisions and performance; interleaving and code concatenation
▪ Convolutional codes: tree and state diagrams, transfer function, distance properties; the Viterbi algorithm
▪ Source coding: fixed-length and variable-length codes, Huffman coding; the Lempel-Ziv algorithm; coding for analog sources, rate-distortion function; pulse-code modulation; delta-modulation, model-based source coding, linear predictive coding (LPC)</td></tr>
<tr><td>Literature</td><td colspan="5">▪ T. Cover and J.A. Thomas, Elements of Information Theory, 2nd ed., Wiley, ISBN: 978-0-471-24195-9
▪ J.G. Proakis, Digital Communications, McGraw-Hill, 4th ed., ISBN 0-07-118183-0.
▪ Papoulis, S. U. Pillai, Probability, Random Variables, and Stochastic Processes, McGraw-Hill, 4th ed., ISBN 0071226613.</td></tr>
<tr><td>Media</td><td colspan="5">Beamer (presentation), black board (derivations, explanations), paper (exercises).</td></tr>
<tr><td>Objectives</td><td colspan="5">▪ Understanding fundamentals in communications related aspects of information theory
▪ Ability to design source and channel coding schemes and implement them efficiently in software
▪ Detailed understanding of schemes in the physical layer of digital communication systems.</td></tr>
<tr><td>Competences to be acquired</td><td colspan="5">▪ Research and development in source and channel coding
▪ Research and development in the area of signal processing for wireless and wired digital communication systems.</td></tr>
</table>

Module title	**Digital Communications P1**				
Courses	**Title**	**Type**	**SWS**	**Credits**	**Performance requirements/ Examination**
	Digital Communications Project Work	project	4	6	Report and presentation
Module credits	6				
Language	English				
Held	in summer and winter semesters, topics on demand anytime				
Lecturer	Dahlhaus and team				
Responsible(s)	Dahlhaus				
Required qualifications	Knowledge of fundamentals in digital communications				
Workload	60 hours course attendance 120 hours self-study				
Contents	▪ Schemes in the physical and medium access control layers of the OSI model for wired/wireless communication systems ▪ Topics of digital communications.				
Literature	▪ J.G. Proakis, *Digital Communications*, McGraw-Hill, 4th ed., ISBN 0-07-118183-0. ▪ H. Vincent Poor, *An Introduction to Signal Detection and Estimation*, Springer, 2nd ed., ISBN 0-387-94173-8 or ISBN 3-540-94173-8. ▪ Papoulis, S. U. Pillai, *Probability, Random Variables, and Stochastic Processes*, McGraw-Hill, 4th ed., ISBN 0071226613. ▪ H.L. van Trees, *Detection, Estimation, and Modulation Theory*, vol. I, New York, NY: John Wiley & Sons, 1968. ▪ Additional papers/references according to project topics.				
Media	PC based software development and/or hardware development (project work), beamer (presentation of results), report (electronic form and hard copy).				
Objectives	▪ Application of knowledge acquired in the area of digital communications to a specific technical/scientific problem ▪ Solving a problem individually or in a team ▪ Writing of a report and presentation of results.				
Competences to be acquired	▪ Literature and internet based investigation ▪ Structured approach for solving a problem ▪ Independent scientific work ▪ Ability to work in a team and to exchange ideas ▪ Presentation in the framework of a project.				

<table>
<tr><td>Module title</td><td colspan="5">Digital Communications T1</td></tr>
<tr><td rowspan="2">Courses</td><td>Title</td><td>Type</td><td>SWS</td><td>Credits</td><td>Performance requirements/ Examination</td></tr>
<tr><td>Digital Communications Master Thesis</td><td>master thesis</td><td>20</td><td>30</td><td>Report and presentation</td></tr>
<tr><td>Module credits</td><td colspan="5">30</td></tr>
<tr><td>Language</td><td colspan="5">English</td></tr>
<tr><td>Held</td><td colspan="5">in summer and winter semesters, topics on demand anytime</td></tr>
<tr><td>Lecturer</td><td colspan="5">Dahlhaus and team</td></tr>
<tr><td>Responsible(s)</td><td colspan="5">Dahlhaus</td></tr>
<tr><td>Required qualifications</td><td colspan="5">▪ Knowledge of fundamentals in digital communications
▪ Proof of fulfilled admission requirements for the Master thesis according to the ECE examination regulation</td></tr>
<tr><td>Workload</td><td colspan="5">300 hours course attendance
600 hours self-study</td></tr>
<tr><td>Contents</td><td colspan="5">▪ Schemes in the physical and medium access control layers of the OSI model for wired/wireless communication systems
▪ Topics of digital communications.</td></tr>
<tr><td>Literature</td><td colspan="5">▪ J.G. Proakis, Digital Communications, McGraw-Hill, 4th ed., ISBN 0-07-118183-0.
▪ H. Vincent Poor, An Introduction to Signal Detection and Estimation, Springer, 2nd ed., ISBN 0-387-94173-8 or ISBN 3-540-94173-8.
▪ Papoulis, S. U. Pillai, Probability, Random Variables, and Stochastic Processes, McGraw-Hill, 4th ed., ISBN 0071226613.
▪ H.L. van Trees, Detection, Estimation, and Modulation Theory, vol. I, New York, NY: John Wiley & Sons, 1968.
▪ Additional papers/references according to thesis topics.</td></tr>
<tr><td>Media</td><td colspan="5">PC based software development and/or hardware development (project work), beamer (presentation of results), report (electronic form and hard copy).</td></tr>
<tr><td>Objectives</td><td colspan="5">▪ Independent scientific approach to solve a problem in the physical and medium access control layers of the OSI model for wired/wireless communication systems and related topics
▪ Writing of a report and presentation of results in a colloquium.</td></tr>
<tr><td>Competences to be acquired</td><td colspan="5">▪ Literature and internet based investigation
▪ Independent scientific work
▪ Compilation of a report, preparation of a talk and presentation of scientific results.</td></tr>
</table>

2.2 Electromagnetics

<table>
<tr><td>Module title</td><td colspan="5">Electromagnetics R1</td></tr>
<tr><td rowspan="7">Courses</td><td>Title</td><td>Type</td><td>SWS</td><td>Credits</td><td>Performance requirements/ Examination</td></tr>
<tr><td>Electromagnetic Field Theory II (lec)</td><td>lecture</td><td>2</td><td>3</td><td rowspan="2">oral exam (30 minutes)</td></tr>
<tr><td>Electromagnetic Field Theory II (ex)</td><td>exercises</td><td>1</td><td>1</td></tr>
<tr><td>Inverse Problems and Imaging (lec)</td><td>lecture</td><td>2</td><td>3</td><td rowspan="2">oral exam (30 minutes)</td></tr>
<tr><td>Inverse Problems and Imaging (ex)</td><td>exercises</td><td>1</td><td>1</td></tr>
<tr><td>Numerical Methods in Electromagnetic Field Theory I (lec)</td><td>lecture</td><td>2</td><td>3</td><td rowspan="2">oral exam (30 minutes)</td></tr>
<tr><td>Numerical Methods in Electromagnetic Field Theory I (lec)</td><td>exercises</td><td>1</td><td>1</td></tr>
<tr><td>Module credits</td><td colspan="5">12</td></tr>
<tr><td>Language</td><td colspan="5">English</td></tr>
<tr><td>Held</td><td colspan="5">in winter semester, annually</td></tr>
<tr><td>Lecturer</td><td colspan="5">Witzigmann and team</td></tr>
<tr><td>Responsible(s)</td><td colspan="5">Witzigmann</td></tr>
<tr><td>Required qualifications</td><td colspan="5">Mathematical foundations in electromagnetic field theory</td></tr>
<tr><td>Workload</td><td colspan="5">135 hours course attendance
225 hours self-study</td></tr>
<tr><td>Contents</td><td colspan="5">▪ Maxwell’s equations, equations describing electromagnetic properties of matter, continuity and boundary conditions, plane waves, Fresnel reflexion, Hertzian dipole, antenna parameters, electromagnetic formulation of Huygens’ principle
▪ Representation of scalar and electromagnetic diffraction fields using integrals, Born’s approximation, physical optics, diffraction tomography, synthetic aperture radar
▪ Integral equations EFIT, MFIE, method of moments, finite elements, finite differences, finite integration approach.</td></tr>
<tr><td>Literature</td><td colspan="5">▪ A.T. de Hoop, Handbook of Radiation and Scattering of Waves, Academic Press, London 1995
▪ C.A. Balanis, Advanced Engineering Electromagnetics, John Wiley & Sons, New York 1989
▪ W.C. Chew, J.-M. Jin, E. Michielssen, J. Song, Fast and Efficient Algorithms in Computational Electromagnetics, Artech House, Boston, 2001.</td></tr>
<tr><td>Media</td><td colspan="5">Beamer (presentation), black board (derivations, explanations), paper (exercises), PC based software development (exercises).</td></tr>
<tr><td>Objectives</td><td colspan="5">▪ Understanding the physical and mathematical background of Maxwell’s equations, ability to derive basic solutions (plane wave, Hertzian dipole), understanding radiation, propagation and diffraction of electromagnetic waves
▪ Understanding diffraction and inverse diffraction and linearization and ability to derive and implement corresponding algorithms
▪ Understanding different mathematical approaches to numerical methods and ability to derive and implement corresponding algorithms.</td></tr>
<tr><td>Competences to be acquired</td><td colspan="5">▪ Research and development in the area of analysis and numerical approaches for electromagnetic waves with respect to radiation, diffraction and use of these phenomena for imaging (radar)
▪ Implementation of algorithms on a PC
▪ Interpretation and evaluation of numerical results.</td></tr>
</table>

Module title	**Electromagnetics P1**				
Courses	**Title**	**Type**	**SWS**	**Credits**	**Performance requirements/ Examination**
	Electromagnetics Project Work	project	4	6	Report and presentation
Module credits	6				
Language	English				
Held	in summer and winter semesters, topics on demand anytime				
Lecturer	Witzigmann and team				
Responsible(s)	Witzigmann				
Required qualifications	Knowledge of fundamentals in electromagnetic field theory				
Workload	60 hours course attendance 120 hours self-study				
Contents	▪ Analysis of a problem (project task) in the area of field theory ▪ Structured approach to the solution.				
Literature	Scientific papers/books according to project topics.				
Media	PC based software development and/or hardware development (project work), beamer (presentation of results), report (electronic form and hard copy).				
Objectives	▪ Application of knowledge acquired in the area of field theory to a specific technical/scientific problem ▪ Solving a problem individually or in a team ▪ Writing of a report and presentation of results.				
Competences to be acquired	▪ Literature and internet based investigation ▪ Structured approach for solving a problem ▪ Independent scientific work ▪ Ability to work in a team and to exchange ideas ▪ Presentation in the framework of a project.				

Module title	**Electromagnetics T1**				
Courses	**Title**	**Type**	**SWS**	**Credits**	**Performance requirements/ Examination**
	Electromagnetics Master Thesis	master thesis	20	30	Report and presentation
Module credits	30				
Language	English				
Held	in summer and winter semesters, topics on demand anytime				
Lecturer	Witzigmann and team				
Responsible(s)	Witzigmann				
Required qualifications	▪ Knowledge of fundamentals in field theory ▪ Proof of fulfilled admission requirements for the Master thesis according to the ECE examination regulation				
Workload	300 hours course attendance 600 hours self-study				
Contents	▪ Theoretic and practical problems in the area of wave propagation ▪ Theoretic and practical inverse problems in the area of acoustic and electromagnetic fields ▪ Non-destructive testing and remote sensing.				
Literature	▪ Langenberg, *Skriptum Elektromagnetische Feldtheorie*, Kassel 2000 (in German) ▪ Marklein, *Numerische Modellierung von Wellenausbreitungsproblemen im Zeitbereich*, Dissertation, Kassel, 1998, (in German) ▪ Hollins C. Chen, *Theory of Electromagnetic Waves*, McGraw Hill 1983 ▪ Additional papers/references according to thesis topics.				
Media	PC based software development and/or hardware development, beamer (presentation of results), report (electronic form and hard copy).				
Objectives	▪ Independent scientific approach to solve a field theoretical problem and related topics ▪ Writing of a report and presentation of results in a colloquium.				
Competences to be acquired	▪ Literature and internet based investigation ▪ Independent scientific work ▪ Compilation of a report, preparation of a talk and presentation of scientific results.				

2.3 Hardware Components for Communication Systems

<table>
<tr><td>Module title</td><td colspan="5">Hardware Components for Communication Systems R1</td></tr>
<tr><td rowspan="5">Courses</td><td>Title</td><td>Type</td><td>SWS</td><td>Credits</td><td>Performance requirements/ Examination</td></tr>
<tr><td>Optical Communications (lec)</td><td>lecture</td><td>2</td><td>3</td><td>oral exam (30 minutes)</td></tr>
<tr><td>Optical Communications (sem)</td><td>seminar</td><td>2</td><td>3</td><td>seminar attendance, presentation and oral exam (20 minutes)</td></tr>
<tr><td>Microsystem technology (lec)</td><td>lecture</td><td>2</td><td>3</td><td>oral exam (30 minutes)</td></tr>
<tr><td>Technology of electronic and optoelectronic devices (lec)</td><td>lecture</td><td>2</td><td>3</td><td>oral exam (30 minutes)</td></tr>
<tr><td>Module credits</td><td colspan="5">12</td></tr>
<tr><td>Language</td><td colspan="5">English</td></tr>
<tr><td>Held</td><td colspan="5">in summer semester, annually</td></tr>
<tr><td>Lecturer</td><td colspan="5">Bangert, Hillmer and teams</td></tr>
<tr><td>Responsible(s)</td><td colspan="5">Bangert</td></tr>
<tr><td>Required qualifications</td><td colspan="5">▪ Fundamentals in digital and analog communications
▪ Basic knowledge on semiconductor devices (transistor, laser diode, LED, photo diode), material science and optics.</td></tr>
<tr><td>Workload</td><td colspan="5">120 hours course attendance
240 hours self-study</td></tr>
<tr><td>Contents</td><td colspan="5">▪ Fundamentals of fibre-optic transmission
▪ Fibre-To-The-X (FTTX), all-optical transmission systems
▪ Single and multimode fibres, dispersion shifted and dispersion compensating fibres
▪ Coherent detection in fibre optics
▪ Wavelength division multiplexing
▪ Wavelength division multiple access
▪ Optical amplifiers and switches
▪ Single-mode fibre systems: optical backbones, cable TV, local area networks
▪ Topics in optical communications and optical communication systems
▪ Introduction to modern fabrication processes, technology of fibers, wave guides, lasers
▪ Crystal growth: semiconductor wafers, thin layer epitaxy
▪ Lithography: optical, X-ray, electron-beam, ion-beam, EUVL, nano imprint
▪ Plasma processing and vacuum technology
▪ Deposition techniques: evaporation, sputtering, plasma assisted techniques
▪ Dry and wet-chemical etching and clean room technology
▪ Fabrication technology of electronic devices (planar transistor, electronic integrated chips), optoelectronic devices (semiconductor lasers, gratings) and micro-opto-electro-mechanical systems (MOEMS)
▪ Introduction to micromachining, microsystem techniques, miniaturization, packaging and nanotechnology
▪ Reasons for miniaturization and integration, types of micromachining
▪ Sensors and actuators
▪ Large variety of MEMS and MOEMS examples: membranes, springs, resonator elements, cantilevers, valves, manipulation elements, gripping tools, light modulators, optical switches, beam splitters, projection displays, micro optical bench, data distribution, micromachined tunable filters and lasers,
▪ Displays: micromachined (micromirror) displays, laser display technology, vacuum-electronics
▪ Lab tour in the clean room.</td></tr>
<tr><td>Literature</td><td colspan="5">▪ A. Bangert, Optical Communications, Lecture Notes, 2008.
▪ J.-P. Laude, DWDM: Fundamentals, Components and Applications, Artech-House, 2002.
▪ W. Goralski, Optical Networking & WDM, McGraw-Hill, 2001
▪ G. Cancellieri (ed.), Single-Mode Optical Fiber Measurement: Characterization and Sensing, Artech-House, 1993.</td></tr>
</table>

	▪ R. Williams, *Modern GaAs Processing Methods*, Artech House Inc., ISBN 0-89006-343-5, 1990. ▪ W. Menz, J.Mohr and O. Paul, *Microsystem Technology*, VCH-Verlag, 2001. ▪ K. Iga, S. Kinoshita, *Process technology for semiconductor lasers*, Springer, Series in Material Science 30, 1996. ▪ B. Bhushan (Editor), *Springer Handbook of Nanotechnology*, Springer, 2004. ▪ Additional papers to be handed out according to seminar topics.
Media	Beamer (lecture and seminar presentations), black board (derivations, explanations), paper (exercises).
Objectives	▪ Understanding the fundamentals in optical communication systems ▪ Ability to understand design guidelines for optical components to be used in optical communications ▪ Understanding the fundamentals in micromachining, micro-opto-electro-mechanical systems (MOEMS) and optical MOEMS ▪ Understanding the fundamentals of semiconductor technology including specific processes, schemes and required instrumentation ▪ Methodology, interdisciplinary aspects, future perspectives and market trends ▪ Finding solutions using interdisciplinary analogies ▪ Establishing synergies between engineering disciplines and natural sciences ▪ Introduction to the 21st century as the "century of photonics and nano technology".
Competences to be acquired	▪ Research and development in optical broadband communications ▪ Design of optical communication systems for broadcast and transport ▪ Knowledge in micromachining, devices, thin layer and clean room technologies ▪ Methodology in specialized miniaturization schemes and integration of electronic and optoelectronic devices and systems ▪ Knowledge of design, fabrication and use of nanoelectronic, (opto-)electronic and micromachined devices.

<table>
<tr><td>Module title</td><td colspan="5">Hardware Components for Communication Systems R2</td></tr>
<tr><td rowspan="6">Courses</td><td>Title</td><td>Type</td><td>SWS</td><td>Credits</td><td>Performance requirements/ Examination</td></tr>
<tr><td>Optoelectronic devices (lec)</td><td>lecture</td><td>3</td><td>4</td><td rowspan="2">oral exam (30 minutes)</td></tr>
<tr><td>Optoelectronic devices (ex)</td><td>exercises</td><td>1</td><td>2</td></tr>
<tr><td>Optoelectronics I (lab)</td><td>lab training</td><td>2</td><td>2</td><td>written report on simulated data</td></tr>
<tr><td>Semiconductor memories (lec)</td><td>lecture</td><td>2</td><td>3</td><td rowspan="2">oral exam (30 minutes)</td></tr>
<tr><td>Semiconductor memories (ex)</td><td>exercises</td><td>1</td><td>1</td></tr>
<tr><td>Module credits</td><td colspan="5">12</td></tr>
<tr><td>Language</td><td colspan="5">English</td></tr>
<tr><td>Held</td><td colspan="5">in winter semester, annually</td></tr>
<tr><td>Lecturer</td><td colspan="5">Hillmer and team</td></tr>
<tr><td>Responsible(s)</td><td colspan="5">Hillmer</td></tr>
<tr><td>Required qualifications</td><td colspan="5">Basic knowledge on semiconductor devices, material science</td></tr>
<tr><td>Workload</td><td colspan="5">135 hours course attendance
225 hours self-study</td></tr>
<tr><td>Contents</td><td colspan="5">▪ Introduction into ray- and quantum optics
▪ Refractive index, polarization, interference, diffraction, coherence
▪ Material properties of glass: dispersion, absorption
▪ Optical waveguiding, detailed introduction into dispersion and absorption
▪ Interferometers (Michelson, Fabry-Pérot, Mach-Zehnder)
▪ Optical multilayer structures (e.g. DBR mirrors)
▪ Introduction to lasers, LEDs, photo diodes and solar cells
▪ Simulation of active and passive optical devices (e.g. Fabry-Pérot interferometers, VCSELs)
▪ Introduction to semiconductor memories
▪ Different types of semiconductor memories
▪ Understanding MOSFET as a main element of memory cell
▪ Process technology for semiconductor memories
▪ Simulation and modeling of semiconductor memories
▪ Advanced topics in semiconductor memories
▪ Future semiconductor memories.</td></tr>
<tr><td>Literature</td><td colspan="5">▪ J. Gowar, Optical Communication Systems, 2nd ed., Prentice Hall, 1993.
▪ K. Iga, S. Kinoshita, Process technology for semiconductor lasers, Springer, Series in Material Science 30, 1996.
▪ S.L. Chuang, Physics of Optoelectronic Devices, John Wiley & Sons, New York, 1995.
▪ B. Mroziewicz, M. Bugajski and W. Nakwaski, Physics of semiconductor lasers, North-Holland, Amsterdam, 1991.
▪ K. Sharma, Advanced Semiconductor Memories: Architectures, Designs and Applications, NJ, Wiley & Sons, 2002
▪ Y. Taur and T.K. Ning, Fundamental of Modern VLSI Devices, UK, Cambridge University Press, 1998.</td></tr>
<tr><td>Media</td><td colspan="5">Beamer (lecture), black board (derivations, explanations), paper (exercises).</td></tr>
<tr><td>Objectives</td><td colspan="5">▪ To learn basic principles of optoelectronic devices and systems, structure and operating principles of optoelectronic components
▪ To learn the huge application potential of optoelectronic devices and photonic tools
▪ The engineer should learn to solve problems using interdisciplinary analogies.
▪ To understand the successful solutions of nature as a promising approach for an advanced working engineer.
▪ Introduction to scientific working. The engineer learns how to interprete data from model calculations and how to compare experimental and theoretical results and to</td></tr>
</table>

	conclude methodology ▪ Understanding the fundamentals in semiconductor memories ▪ Understanding the limits of fabrication processes ▪ Gaining requisite knowledge for being initiated into the practical tasks and projects of industry and research in the area of semiconductor memories, especially DRAM technology.
Competences to be acquired	▪ Understanding the complex interaction of electronic, thermal and optical phenomena in laser diodes. ▪ Sustainable knowledge in operation and application of optoelectronic devices ▪ Research and development in the area of optoelectronic components ▪ Research and development in the area of semiconductor memories and semiconductor process technology.

2.4 Microwaves

<table>
<tr><th>Module title</th><th colspan="5">Microwaves R1</th></tr>
<tr><td rowspan="4">Courses</td><td>Title</td><td>Type</td><td>SWS</td><td>Credits</td><td>Performance requirements/ Examination</td></tr>
<tr><td>Microwaves and Millimeter Waves I (lec)</td><td>lecture</td><td>2</td><td>3</td><td rowspan="2">written exam (2 hours)</td></tr>
<tr><td>Microwaves and Millimeter Waves I (ex)</td><td>exercises</td><td>1</td><td>1</td></tr>
<tr><td>Microwaves and Millimeter Waves I (lab)</td><td>lab training</td><td>2</td><td>2</td><td>lab training attendance and conductance of experiments</td></tr>
<tr><td>Module credits</td><td colspan="5">6</td></tr>
<tr><td>Language</td><td colspan="5">English</td></tr>
<tr><td>Held</td><td colspan="5">in summer semester, annually</td></tr>
<tr><td>Lecturer</td><td colspan="5">Bangert and team</td></tr>
<tr><td>Responsible(s)</td><td colspan="5">Bangert</td></tr>
<tr><td>Required qualifications</td><td colspan="5">Knowledge of fundamentals in microwave technology</td></tr>
<tr><td>Workload</td><td colspan="5">75 hours course attendance
105 hours self-study</td></tr>
<tr><td>Contents</td><td colspan="5">▪ Theory of microwave networks, n-ports, signal flow diagrams
▪ Microwave devices, measurement of S-parameters, hetero structure components, microwave field-effect transistors (FETs), Shockley’s model, 2-region model, saturation model, FET-equivalent network
▪ Linear amplifiers and oscillators
▪ Introduction to microwave measurement instruments, measurement of parameters of microwave components (lab).</td></tr>
<tr><td>Literature</td><td colspan="5">▪ G. Kompa, Practical Microstrip Design and Applications, Artech House, 2006
▪ G. Kompa, Lecture Notes (in German)
▪ H. Brand, Schaltungslehre linearer Mikrowellennetze, S. Hirzel Verlag, 1970 (in German)
▪ Notes on lab training.</td></tr>
<tr><td>Media</td><td colspan="5">Beamer (presentation), black board (derivations, explanations), paper (exercises), experiments (lab training).</td></tr>
<tr><td>Objectives</td><td colspan="5">▪ Knowing the basics and applications of microwave circuit theory and the operation principles of technically relevant microwave devices
▪ Ability to design linear microwave networks (e.g. linear amplifier, linear oscillator)
▪ Understanding schemes for characterizing microwave devices based on measurements (lab training).</td></tr>
<tr><td>Competences to be acquired</td><td colspan="5">▪ Use of instruments for microwave measurements
▪ Analysis and synthesis of linear microwave systems
▪ Research and development in the design of microwave components.</td></tr>
</table>

<table>
<tr><td>Module title</td><td colspan="5">Microwaves R2</td></tr>
<tr><td rowspan="4">Courses</td><td>Title</td><td>Type</td><td>SWS</td><td>Credits</td><td>Performance requirements/ Examination</td></tr>
<tr><td>Microwaves and Millimeter Waves II (lec)</td><td>lecture</td><td>2</td><td>3</td><td rowspan="2">oral exam (30 minutes)</td></tr>
<tr><td>Microwaves and Millimeter Waves II (ex)</td><td>exercises</td><td>1</td><td>1</td></tr>
<tr><td>Microwaves and Millimeter Waves II (lab)</td><td>lab training</td><td>2</td><td>2</td><td>lab training attendance and conductance of experiments</td></tr>
<tr><td>Module credits</td><td colspan="5">6</td></tr>
<tr><td>Language</td><td colspan="5">English</td></tr>
<tr><td>Held</td><td colspan="5">in winter semester, annually</td></tr>
<tr><td>Lecturer</td><td colspan="5">Bangert and team</td></tr>
<tr><td>Responsible(s)</td><td colspan="5">Bangert</td></tr>
<tr><td>Required qualifications</td><td colspan="5">▪ Attendance of module Microwaves R1 or comparable knowledge and skills
▪ Knowledge of vector algebra and vector analysis.</td></tr>
<tr><td>Workload</td><td colspan="5">75 hours course attendance
105 hours self-study</td></tr>
<tr><td>Contents</td><td colspan="5">▪ Definitions and survey of wave guide structures
▪ Transmission line theory and describing equations, reflection coefficient, input impedance, Maxwell’s equations, decoupling of Maxwell’s equations, electro-dynamic potential
▪ Classification of field modes on wave guides
▪ Field-theoretical analysis of hollow and dielectric wave guides (optical fibre)
▪ Transmission line resonators and wave guide cavities (frequency stabilized oscillators)
▪ Antennas.</td></tr>
<tr><td>Literature</td><td colspan="5">▪ R.E. Collin, Foundations for Microwave Engineering, McGraw-Hill, 1992
▪ David M. Pozar, Microwave Engineering, 3rd ed., Wiley, 2005
▪ Notes on lab training.</td></tr>
<tr><td>Media</td><td colspan="5">Beamer (presentation), black board (derivations, explanations), paper (exercises), experiments (lab training).</td></tr>
<tr><td>Objectives</td><td colspan="5">▪ Understanding the electrical and transmission properties of different types of microwave guides and resonators together with applications
▪ Ability to calculate parameters of microwave guides based on the complete set of Maxwell’s equations.</td></tr>
<tr><td>Competences to be acquired</td><td colspan="5">▪ Research and development in the area of microwave components
▪ Characterization and modelling of microwave components based on measurements
▪ Design of microwave networks.</td></tr>
</table>

<table>
<tr><td>Module title</td><td colspan="5">Microwaves R3</td></tr>
<tr><td rowspan="4">Courses</td><td>Title</td><td>Type</td><td>SWS</td><td>Credits</td><td>Performance requirements/ Examination</td></tr>
<tr><td>Microwave Integrated Circuits II (lec)</td><td>lecture</td><td>2</td><td>3</td><td rowspan="2">oral exam (30 minutes)</td></tr>
<tr><td>Microwave Integrated Circuits II (ex)</td><td>exercises</td><td>1</td><td>1</td></tr>
<tr><td>Microwave Integrated Circuits II (sem)</td><td>seminar</td><td>2</td><td>2</td><td>seminar attendance and presentation</td></tr>
<tr><td>Module credits</td><td colspan="5">6</td></tr>
<tr><td>Language</td><td colspan="5">English</td></tr>
<tr><td>Held</td><td colspan="5">in summer semester, annually</td></tr>
<tr><td>Lecturer</td><td colspan="5">Bangert and team</td></tr>
<tr><td>Responsible(s)</td><td colspan="5">Bangert</td></tr>
<tr><td>Required qualifications</td><td colspan="5">▪ Attendance of module Microwaves Q1 or comparable knowledge and skills
▪ Knowledge of vector algebra and vector analysis.</td></tr>
<tr><td>Workload</td><td colspan="5">75 hours course attendance
105 hours self-study</td></tr>
<tr><td>Contents</td><td colspan="5">▪ III-V-Semiconductor devices
▪ Classification of FET models, Shockley’s model
▪ Extraction of model parameters
▪ Fundamentals of non-linear FET modelling
▪ Large-scale signal description of devices
▪ Non-linear circuit design (power amplifiers).</td></tr>
<tr><td>Literature</td><td colspan="5">▪ G. Kompa, Lecture Notes
▪ R.E. Collin, Foundations for Microwave Engineering, McGraw-Hill, 1992
▪ David M. Pozar, Microwave Engineering, 3rd ed., Wiley, 2005
▪ Additional papers to be handed out according to seminar topics.</td></tr>
<tr><td>Media</td><td colspan="5">Beamer (lecture and seminar presentations), black board (derivations, explanations), paper (exercises).</td></tr>
<tr><td>Objectives</td><td colspan="5">Ability to design non-linear microwave circuits.</td></tr>
<tr><td>Competences to be acquired</td><td colspan="5">▪ Research and development in the area of microwave components
▪ Design of microwave components for base stations (broadband power amplifiers).</td></tr>
</table>

<table>
<tr><td>Module title</td><td colspan="5">Microwaves P1</td></tr>
<tr><td rowspan="2">Courses</td><td>Title</td><td>Type</td><td>SWS</td><td>Credits</td><td>Performance requirements/ Examination</td></tr>
<tr><td>Microwaves Project Work</td><td>project</td><td>4</td><td>6</td><td>Report and presentation</td></tr>
<tr><td>Module credits</td><td colspan="5">6</td></tr>
<tr><td>Language</td><td colspan="5">English</td></tr>
<tr><td>Held</td><td colspan="5">in summer and winter semesters, topics on demand anytime</td></tr>
<tr><td>Lecturer</td><td colspan="5">Bangert and team</td></tr>
<tr><td>Responsible(s)</td><td colspan="5">Bangert</td></tr>
<tr><td>Required qualifications</td><td colspan="5">Knowledge of fundamentals in microwave components</td></tr>
<tr><td>Workload</td><td colspan="5">60 hours course attendance
120 hours self-study</td></tr>
<tr><td>Contents</td><td colspan="5">▪ Analysis of a problem according to project description
▪ Structured approach to the solution.</td></tr>
<tr><td>Literature</td><td colspan="5">Scientific papers/books according to project topics.</td></tr>
<tr><td>Media</td><td colspan="5">PC based software development and/or hardware development (project work), beamer (presentation of results), report (electronic form and hard copy).</td></tr>
<tr><td>Objectives</td><td colspan="5">▪ Application of knowledge acquired in the area of microwave components to a specific technical/scientific problem
▪ Solving a problem individually or in a team
▪ Writing of a report and presentation of results.</td></tr>
<tr><td>Competences to be acquired</td><td colspan="5">▪ Literature and internet based investigation
▪ Structured approach for solving a problem
▪ Independent scientific work
▪ Ability to work in a team and to exchange ideas
▪ Presentation in the framework of a project.</td></tr>
</table>

Module title	**Microwaves T1**				
Courses	**Title**	**Type**	**SWS**	**Credits**	**Performance requirements/ Examination**
	Microwave Master Thesis	master thesis	20	30	Report and presentation
Module credits	30				
Language	English				
Held	in summer and winter semesters, topics on demand anytime				
Lecturer	Bangert and team				
Responsible(s)	Bangert				
Required qualifications	▪ Knowledge of fundamentals in microwave components ▪ Proof of fulfilled admission requirements for the Master thesis according to the ECE examination regulation				
Workload	300 hours course attendance 600 hours self-study				
Contents	▪ Computer-aided circuit design ▪ Device modelling ▪ Microwave measurement approaches and instrumentation ▪ Radar sensors ▪ Topics in high frequency technology.				
Literature	▪ R.E. Collin, *Foundations for Microwave Engineering*, McGraw-Hill, 1992 ▪ G. Kompa, *Lecture Notes HF-Sensorik*, (in German) ▪ G. Kompa, *Practical Microstrip Design and Applications*, Artech House, 2006 ▪ Additional papers to be handed out according to thesis topics.				
Media	PC based software development and/or hardware development, beamer (presentation of results), report (electronic form and hard copy).				
Objectives	▪ Independent scientific approach to solve a problem in microwave technology and related topics ▪ Writing of a report and presentation of results in a colloquium.				
Competences to be acquired	▪ Literature and internet based investigation ▪ Independent scientific work ▪ Compilation of a report, preparation of a talk and presentation of scientific results.				

2.5 Mobile Internet

Module title	**Mobile Internet R1**				
Courses	**Title**	**Type**	**SWS**	**Credits**	**Performance requirements/ Examination**
	Introduction to Communication II (lec)	lecture	2	3	written exam (2 hours)
	Introduction to Communication II (ex)	exercises	1	1	
	Introduction to Communication II (lab)	lab training	1	2	lab training attendance and conductance of experiments
Module credits	6				
Language	English				
Held	in summer semester, annually				
Lecturer	David and team				
Responsible(s)	David				
Required qualifications	Knowledge of contents of the course *Introduction to Communication I* or comparable knowledge and skills				
Workload	60 hours course attendance 120 hours self-study				
Contents	▪ Mobile communication: theoretical basics, present systems and applications (mobile radio channel, GSM services, GSM system, UMTS, WAP) ▪ Other services like MMS, pervasive computing and ubiquitous systems including practical experiments with real products ▪ Measurements of mobile radio channels.				
Literature	▪ Kurose/Ross, *Computer Networks*, Addison Wesley, 2nd edition ▪ Douglas E. Comer, *Internetworking with TCP/IP*, Prentice Hall, 4th edition ▪ Dimitri Bertsekas, Robert Gallager, *Data networks*, Prentice Hall, 1992 ▪ Andrew S. Tanenbaum, *Computer Networks*, Prentice Hall, 1996, last edition ▪ Klaus David und Thorsten Benkner, *Digitale Mobilfunksysteme*, B.G. Teubner, 1996 (in German) ▪ Harri Holma und Antti Toskala, *WCDMA for UMTS*, Wiley, 2002.				
Media	Beamer (presentation), black board (derivations, explanations), paper (exercises), PC based software development (lab training).				
Objectives	▪ Understanding the mobile radio channel, mobile radio systems and services ▪ Understanding the interaction of individual components in mobile radio systems.				
Competences to be acquired	▪ Research and development in the area of mobile internet ▪ Ability to use mobile radio measurement equipment.				

<table>
<tr><td>Module title</td><td colspan="5">Mobile Internet R2</td></tr>
<tr><td rowspan="4">Courses</td><td>Title</td><td>Type</td><td>SWS</td><td>Credits</td><td>Performance requirements/ Examination</td></tr>
<tr><td>Communication Technologies I (lec)</td><td>lecture</td><td>2</td><td>3</td><td rowspan="2">written exam (2 hours)
or
oral exam (30 minutes)</td></tr>
<tr><td>Communication Technologies I (ex)</td><td>exercises</td><td>1</td><td>1</td></tr>
<tr><td>Communication Technologies I (lab)</td><td>lab training</td><td>1</td><td>2</td><td>lab training attendance and conductance of experiments</td></tr>
<tr><td>Module credits</td><td colspan="5">6</td></tr>
<tr><td>Language</td><td colspan="5">English</td></tr>
<tr><td>Held</td><td colspan="5">in summer semester, annually</td></tr>
<tr><td>Lecturer</td><td colspan="5">David and team</td></tr>
<tr><td>Responsible(s)</td><td colspan="5">David</td></tr>
<tr><td>Required qualifications</td><td colspan="5">Knowledge of contents of the course Introduction to Communication I or comparable knowledge and skills</td></tr>
<tr><td>Workload</td><td colspan="5">60 hours course attendance
120 hours self-study</td></tr>
<tr><td>Contents</td><td colspan="5">▪ Advanced and recent topics in the area of networks and applications (IPv6, QoS, Voice over IP, traffic theory, distributed systems)
▪ Firewalls, file/print/web server.</td></tr>
<tr><td>Literature</td><td colspan="5">▪ Kurose/Ross, Computer Networks, Addison Wesley, 2nd edition
▪ Douglas E. Comer, Internetworking with TCP/IP, Prentice Hall, 4th edition
▪ Dimitri Bertsekas, Robert Gallager, Data networks, Prentice Hall, 1992
▪ Andrew S. Tanenbaum, Computer Networks, Prentice Hall, 1996, last edition
▪ Klaus David und Thorsten Benkner, Digitale Mobilfunksysteme, B.G. Teubner, 1996 (in German)
▪ Harri Holma und Antti Toskala, WCDMA for UMTS, Wiley, 2002.</td></tr>
<tr><td>Media</td><td colspan="5">Beamer (presentation), black board (derivations, explanations), paper (exercises), PC based software development (lab training).</td></tr>
<tr><td>Objectives</td><td colspan="5">Understanding internet applications, services and protocols.</td></tr>
<tr><td>Competences to be acquired</td><td colspan="5">▪ Research and development in the area of mobile internet
▪ Ability to design schemes for server based services in networks.</td></tr>
</table>

<table>
<tr><td>Module title</td><td colspan="5">Mobile Internet R3</td></tr>
<tr><td rowspan="4">Courses</td><td>Title</td><td>Type</td><td>SWS</td><td>Credits</td><td>Performance requirements/ Examination</td></tr>
<tr><td>Communication Technologies II (lec)</td><td>lecture</td><td>2</td><td>3</td><td rowspan="2">written exam (2 hours)
or
oral exam (30 minutes)</td></tr>
<tr><td>Communication Technologies II (ex)</td><td>exercises</td><td>1</td><td>1</td></tr>
<tr><td>Communication Technologies II (lab)</td><td>lab training</td><td>1</td><td>2</td><td>lab training attendance and conductance of experiments,
oral exam (30 minutes)</td></tr>
<tr><td>Module credits</td><td colspan="5">6</td></tr>
<tr><td>Language</td><td colspan="5">English</td></tr>
<tr><td>Held</td><td colspan="5">in winter semester, annually</td></tr>
<tr><td>Lecturer</td><td colspan="5">David and team</td></tr>
<tr><td>Responsible(s)</td><td colspan="5">David</td></tr>
<tr><td>Required qualifications</td><td colspan="5">Knowledge of contents of the module Mobile Internet R1 or comparable knowledge and skills</td></tr>
<tr><td>Workload</td><td colspan="5">60 hours course attendance
120 hours self-study</td></tr>
<tr><td>Contents</td><td colspan="5">▪ Mobile distributed systems, middleware, pervasive computing, context awareness
▪ Basic configuration, cryptography, transmission range, data rates for WLANs and Bluetooth systems.</td></tr>
<tr><td>Literature</td><td colspan="5">▪ Kurose/Ross, Computer Networks, Addison Wesley, 2nd edition
▪ Douglas E. Comer, Internetworking with TCP/IP, Prentice Hall, 4th edition
▪ Dimitri Bertsekas, Robert Gallager, Data networks, Prentice Hall, 1992
▪ Andrew S. Tanenbaum, Computer Networks, Prentice Hall, 1996, last edition
▪ Uwe Hansmann, Lothar Merk, Martin S. Nicklous, and Thomas Stober, Pervasive Computing, 2nd edition, Springer 2003
▪ R. Chow and T. Johnson, Distributed Operating Systems & Algorithms, Addison Wesley, 1998.</td></tr>
<tr><td>Media</td><td colspan="5">Beamer (presentation), black board (derivations, explanations), paper (exercises), PC based software development (lab training).</td></tr>
<tr><td>Objectives</td><td colspan="5">▪ Knowing advanced and recent topics in the area of mobile networks and applications including pervasive computing
▪ Understanding the potentials and limitations of wireless based services.</td></tr>
<tr><td>Competences to be acquired</td><td colspan="5">Research and development in the area of mobile internet</td></tr>
</table>

Module title	**Mobile Internet P1**				
Courses	**Title**	**Type**	**SWS**	**Credits**	**Performance requirements/ Examination**
	Mobile Internet Project Work	project	4	6	Report and presentation
Module credits	6				
Language	English				
Held	in summer and winter semesters, topics on demand anytime				
Lecturer	David and team				
Responsible(s)	David				
Required qualifications	Knowledge of contents of the course *Introduction to Communication I* and the module *Mobile Internet R1* or comparable knowledge and skills				
Workload	60 hours course attendance 120 hours self-study				
Contents	Mobile internet				
Literature	Scientific papers/books according to project topics.				
Media	PC based software development (project work), beamer (presentation of results), report (electronic form and hard copy).				
Objectives	▪ Solving a problem in the area of mobile internet individually ▪ Writing of a report and presentation of results.				
Competences to be acquired	▪ Literature and internet based investigation ▪ Independent scientific work ▪ Presentation in the framework of a project.				

Module title	**Mobile Internet T1**				
Courses	**Title**	**Type**	**SWS**	**Credits**	**Performance requirements/ Examination**
	Mobile Internet Master Thesis	master thesis	20	30	Report and presentation
Module credits	30				
Language	English				
Held	in summer and winter semesters, topics on demand anytime				
Lecturer	David and team				
Responsible(s)	David				
Required qualifications	▪ Knowledge of contents of the modules *Mobile Internet R1, Mobile Internet R2* and *Mobile Internet R3* or comparable knowledge and skills ▪ Proof of fulfilled admission requirements for the Master thesis according to the ECE examination regulation				
Workload	300 hours course attendance 600 hours self-study				
Contents	Topics from the area of mobile internet.				
Literature	Papers according to thesis topics.				
Media	PC based software development, beamer (presentation of results), report (electronic form and hard copy).				
Objectives	▪ Independent scientific approach to solve a problem in the area of mobile internet ▪ Writing of a report and presentation of results in a colloquium.				
Competences to be acquired	▪ Literature and internet based investigation ▪ Independent scientific work ▪ Compilation of a report, preparation of a talk and presentation of scientific results.				

2.6 Optoelectronics

<table>
<tr><td>Module title</td><td colspan="5">Optoelectronics R1</td></tr>
<tr><td rowspan="3">Courses</td><td>Title</td><td>Type</td><td>SWS</td><td>Credits</td><td>Performance requirements/ Examination</td></tr>
<tr><td>Microsystem technology (lec)</td><td>lecture</td><td>2</td><td>3</td><td>oral exam (30 minutes)</td></tr>
<tr><td>Technology of electronic and optoelectronic devices (lec)</td><td>lecture</td><td>2</td><td>3</td><td>oral exam (30 minutes)</td></tr>
<tr><td>Module credits</td><td colspan="5">6</td></tr>
<tr><td>Language</td><td colspan="5">English</td></tr>
<tr><td>Held</td><td colspan="5">in summer semester, annually</td></tr>
<tr><td>Lecturer</td><td colspan="5">Hillmer and team</td></tr>
<tr><td>Responsible(s)</td><td colspan="5">Hillmer</td></tr>
<tr><td>Required qualifications</td><td colspan="5">Basic knowledge on semiconductor devices (transistor, laser diode, LED, photo diode), material science and optics</td></tr>
<tr><td>Workload</td><td colspan="5">60 hours course attendance
120 hours self-study</td></tr>
<tr><td>Contents</td><td colspan="5">▪ Introduction to modern fabrication processes, technology of fibers, wave guides, lasers
▪ Crystal growth: semiconductor wafers, thin layer epitaxy
▪ Lithography: optical, X-ray, electron-beam, ion-beam, EUVL, nano imprint
▪ Plasma processing and vacuum technology
▪ Deposition techniques: evaporation, sputtering, plasma assisted techniques
▪ Dry and wet-chemical etching and clean room technology
▪ Fabrication technology of electronic devices (planar transistor, electronic integrated chips), optoelectronic devices (semiconductor lasers, gratings) and micro-opto-electro-mechanical systems (MOEMS)
▪ Introduction to micromachining, microsystem techniques, miniaturization, packaging and nanotechnology
▪ Reasons for miniaturization and integration, types of micromachining
▪ Sensors and actuators
▪ Large variety of MEMS and MOEMS examples: membranes, springs, resonator elements, cantilevers, valves, manipulation elements, gripping tools, light modulators, optical switches, beam splitters, projection displays, micro optical bench, data distribution, micromachined tunable filters and lasers,
▪ Displays: micromachined (micromirror) displays, laser display technology, vacuum-electronics
▪ Lab tour in the clean room.</td></tr>
<tr><td>Literature</td><td colspan="5">▪ R. Williams, Modern GaAs Processing Methods, Artech House Inc., ISBN 0-89006-343-5, 1990.
▪ W. Menz, J.Mohr and O. Paul, Microsystem Technology, VCH-Verlag, 2001.
▪ K. Iga, S. Kinoshita, Process technology for semiconductor lasers, Springer, Series in Material Science 30, 1996.
▪ B. Bhushan (Editor), Springer Handbook of Nanotechnology, Springer, 2004.</td></tr>
<tr><td>Media</td><td colspan="5">Beamer (presentation), black board (derivations, explanations), paper (exercises).</td></tr>
<tr><td>Objectives</td><td colspan="5">▪ Understanding the fundamentals in micromachining, micro-opto-electro-mechanical systems (MOEMS) and optical MOEMS
▪ Understanding the fundamentals of semiconductor technology including specific processes, schemes and required instrumentation
▪ Methodology, interdisciplinary aspects, future perspectives and market trends
▪ Finding solutions using interdisciplinary analogies
▪ Establishing synergies between engineering disciplines and natural sciences
▪ Introduction to the 21st century as the “century of photonics and nano technology”.</td></tr>
<tr><td>Competences to be acquired</td><td colspan="5">▪ Knowledge in micromachining, devices, thin layer and clean room technologies
▪ Methodology in specialized miniaturization schemes and integration of electronic and optoelectronic devices and systems
▪ Knowledge of design, fabrication and use of nanoelectronic, (opto-)electronic and micromachined devices</td></tr>
</table>

<table>
<tr><td>Module title</td><td colspan="5">Optoelectronics R2</td></tr>
<tr><td rowspan="5">Courses</td><td>Title</td><td>Type</td><td>SWS</td><td>Credits</td><td>Performance requirements/ Examination</td></tr>
<tr><td>Semiconductor lasers (lec)</td><td>lecture</td><td>3</td><td>5</td><td rowspan="2">oral exam (30 minutes)</td></tr>
<tr><td>Semiconductor lasers (ex)</td><td>exercises</td><td>1</td><td>2</td></tr>
<tr><td>Optoelectronics II (lab)</td><td>lab training</td><td>2</td><td>2</td><td>written report on measured data</td></tr>
<tr><td>Optoelectronics II (sem)</td><td>seminar</td><td>3</td><td>3</td><td>seminar attendance and presentation</td></tr>
<tr><td>Module credits</td><td colspan="5">12</td></tr>
<tr><td>Language</td><td colspan="5">English</td></tr>
<tr><td>Held</td><td colspan="5">in winter semester, annually</td></tr>
<tr><td>Lecturer</td><td colspan="5">Hillmer and team</td></tr>
<tr><td>Responsible(s)</td><td colspan="5">Hillmer</td></tr>
<tr><td>Required qualifications</td><td colspan="5">Basic knowledge on semiconductor devices, material science, optoelectronics</td></tr>
<tr><td>Workload</td><td colspan="5">120 hours course attendance
240 hours self-study</td></tr>
<tr><td>Contents</td><td colspan="5">▪ Diffractive elements: 1-, 2- and 3-dimensional gratings, Fresnel lenses and photonic crystals
▪ Lasers: gain, rate equations, DFB gratings, spectra, ultrafast lasers, tunable lasers, chirped gratings, microdisc lasers, quantum cascade lasers, DBR mirrors for vertical cavity lasers, VCSELs, blue semiconductor lasers
▪ Light processing: switches, splitters, amplifiers, combiners, multiplexers, demultiplexers, beam transformers
▪ Optical communication systems: WDM, TDM
▪ Experimental modules such as DFB laser diodes, sample stages, optical spectrum analyzers and PC will be assembled to measure laser spectra as a function of injection current and temperature
▪ Measured are: spectral shift of different modes of diode lasers with varying injection current and temperature, light power-versus-current characteristics, T_o.
▪ Evaluation, interpretation, documentation and presentation of the measured data.
▪ Specific advanced topics in optoelectronics (seminar).</td></tr>
<tr><td>Literature</td><td colspan="5">▪ J. Gowar, Optical Communication Systems, 2nd ed., Prentice Hall, 1993.
▪ K. Iga, S. Kinoshita, Process technology for semiconductor lasers, Springer, Series in Material Science 30, 1996.
▪ S.L. Chuang, Physics of Optoelectronic Devices, Wiley & Sons, New York, 1995.
▪ F. Träger (Editor), Springer Handbook of Lasers and Optics, Springer, 2007.</td></tr>
<tr><td>Media</td><td colspan="5">Beamer (presentation), black board (derivations, explanations), paper (exercises), measurement instrumentation (lab).</td></tr>
<tr><td>Objectives</td><td colspan="5">▪ To learn basic principles of optoelectronic devices and systems, structure and operating principles of optoelectronic components
▪ To learn the huge application potential of optoelectronic devices and photonic tools
▪ The engineer should learn to solve problems using interdisciplinary analogies.
▪ To understand the successful solutions of nature as a promising approach for an advanced working engineer.
▪ To learn presentation techniques and to obtain presentation practice.
▪ To learn to structure a talk to optimize the transfer of essentials to the audience.
▪ Introduction to scientific working. The engineer learns how to analyze measured data and how to compare experimental and theoretical results and inferences.
▪ To learn to efficiently apply different set-up components for optical characterization.</td></tr>
<tr><td>Competences to be acquired</td><td colspan="5">▪ Deep knowledge of the complex interaction of electronic, thermal and optical phenomena in laser diodes.
▪ Knowledge of design methodology
▪ Experimental and theoretical know-how on optoelectronic devices
▪ Knowledge in design, operation and application of optoelectronic devices
▪ Presentation techniques, optimum use of tools.</td></tr>
</table>

Module title	Optoelectronics P1				
Courses	**Title**	**Type**	**SWS**	**Credits**	**Performance requirements/ Examination**
	Optoelectronics Project Work	project	4	6	Report and presentation
Module credits	6				
Language	English				
Held	in summer and winter semesters, topics on demand anytime				
Lecturer	Hillmer and team				
Responsible(s)	Hillmer				
Required qualifications	Profound knowledge in optoelectronics				
Workload	60 hours course attendance 120 hours self-study				
Contents	▪ Theoretical model calculation using advanced software tools on problems at the research front ▪ Example: calculation of laser spectra with the goal to optimize and design an advanced VCSEL with complex coupling (real and imaginary part in refractive index). This is done for a novel hybrid structure combining inorganic and organic materials ▪ Variation of basic parameters, like Δn, measurements and evaluation of different characteristics ▪ The simulations are defined according to general and actual problems in optoelectronics and are related to research topics of the working group.				
Literature	Scientific papers/books according to project topics.				
Media	Beamer (presentation of results), report (electronic form and hard copy).				
Objectives	▪ Practice in theoretical model calculations. The engineer should learn to understand basics and fundamental interaction of effects by a variation of geometric and material parameters. ▪ The student will learn how to design advanced photonic devices. ▪ Introduction to scientific work. The engineer learns how to analyze and to interpret calculated theoretical data. ▪ To structure the analyzed data and parameter series in such a way that the uninvolved reader can understand and follow the argumentation. ▪ Methodology of project organization and project management, team work.				
Competences to be acquired	▪ To create new or modify existing models according to the given problem. ▪ To analyze data series with respect to the given problem. ▪ To experience synergies in knowledge during the comparison and analysis of theoretical and experimental data. ▪ Introduction into appropriate scientific working.				

<table>
<tr><td>Module title</td><td colspan="5">Optoelectronics T1</td></tr>
<tr><td rowspan="2">Courses</td><td>Title</td><td>Type</td><td>SWS</td><td>Credits</td><td>Performance requirements/ Examination</td></tr>
<tr><td>Optoelectronics Master Thesis</td><td>master thesis</td><td>20</td><td>30</td><td>Report and presentation</td></tr>
<tr><td>Module credits</td><td colspan="5">30</td></tr>
<tr><td>Language</td><td colspan="5">English</td></tr>
<tr><td>Held</td><td colspan="5">in summer and winter semesters, topics on demand anytime</td></tr>
<tr><td>Lecturer</td><td colspan="5">Hillmer and team</td></tr>
<tr><td>Responsible(s)</td><td colspan="5">Hillmer</td></tr>
<tr><td>Required qualifications</td><td colspan="5">▪ Profound knowledge in optoelectronics
▪ Proof of fulfilled admission requirements for the Master thesis according to the ECE examination regulation</td></tr>
<tr><td>Workload</td><td colspan="5">300 hours course attendance
600 hours self-study</td></tr>
<tr><td>Contents</td><td colspan="5">▪ Independent scientific work on a problem in photonics and related areas like design, technological fabrication in the clean room, characterization of optoelectronic devices or systems, nanotechnology and micromachining
▪ The students are working on problems which have a pronounced application potential, partly in an consortium including industry.
▪ The students are encouraged to create spin-off companies based on their own work.</td></tr>
<tr><td>Literature</td><td colspan="5">Papers according to thesis topics.</td></tr>
<tr><td>Media</td><td colspan="5">PC based software development and/or hardware development, instruments for measurements and experiments, beamer (presentation of results), report (electronic form and hard copy).</td></tr>
<tr><td>Objectives</td><td colspan="5">▪ Creating models for a given problem
▪ To obtain practice in experimental work (technology or characterization) or theoretical model calculations
▪ Analyzing and interpreting of measured data
▪ Comparison of own results to actual literature
▪ Writing of a report and presentation of results in a colloquium
▪ Team work and efficient in projects.</td></tr>
<tr><td>Competences to be acquired</td><td colspan="5">▪ Experience in practical clean room technology
▪ Profound knowledge in theoretical model calculations
▪ Independent scientific work
▪ Compilation of a report, preparation of a talk and presentation of scientific results.</td></tr>
</table>

2.7 Social Communication

<table>
<tr><td>Module title</td><td colspan="5">Social Communication NT1</td></tr>
<tr><td rowspan="2">Courses</td><td>Title</td><td>Type</td><td>SWS</td><td>Credits</td><td>Performance requirements/ Examination</td></tr>
<tr><td>German Language Course (sem)</td><td>seminar</td><td>7</td><td>6</td><td>seminar attendance,
exams: written (2 hours) and oral (30 minutes)</td></tr>
<tr><td>Module credits</td><td colspan="5">6</td></tr>
<tr><td>Language</td><td colspan="5">English and German</td></tr>
<tr><td>Held</td><td colspan="5">in summer and winter semesters, semi-annually</td></tr>
<tr><td>Lecturer</td><td colspan="5">Dialog-Institut</td></tr>
<tr><td>Responsible(s)</td><td colspan="5">B. Warnke-Kilian</td></tr>
<tr><td>Required qualifications</td><td colspan="5">Admission requirements for the ECE program fulfilled according to the examination regulation</td></tr>
<tr><td>Workload</td><td colspan="5">105 hours course attendance
75 hours self-study</td></tr>
<tr><td>Contents</td><td colspan="5">▪ Orientation in the city, working day, study, professional every day life
▪ Food, eating habits, body, health, disease
▪ Sports, leisure, clubs
▪ Accomodation, flat hunting, furnishing
▪ Study, school, education, looking for a job, application
▪ Daily routine, curriculum vitae
▪ Shopping, magazines, consumption, environment protection
▪ Parties and celebrations, ritual, meetings
▪ Seasons, weather, travelling
▪ Culture, politics and society
▪ Relations, feelings, habits, behaviour.</td></tr>
<tr><td>Literature</td><td colspan="5">▪ Tangram, Deutsch als Fremdsprache, Lehrwerk für die Grundstufe, Max Hueber Verlag
▪ Themen, Hueber Verlag
▪ Eurolingua, Deutsch als Fremdsprache, Cornelsen Verlag.</td></tr>
<tr><td>Media</td><td colspan="5">Beamer and black board (explanations), internet based search (computer), paper (exercises), films, DVDs.</td></tr>
<tr><td>Objectives</td><td colspan="5">General topics:
▪ Social integration
▪ Knowing basic German language expressions up to level A2
▪ Using the language in everyday situations.
Objectives in terms of levels of the Common European Reference Framework (Gemeinsamer Europäischer Referenzrahmen, GERR):
A1 The student is able to
▪ understand usual expressions with immediate meaning (own person, family, shopping, working, schedule, displays, brochures, simple announcements, use of public transport)
▪ communicate in simple standard situations, enquire about and obtain information about familiar things and exchange information (looking for a way, accomodation, present activity, apologize if absent).
▪ understand and use familiar every-day expressions for satisfying concrete needs
▪ introduce herself/himself/others and ask questions about a person, e.g. about their living conditions, and answer corresponding questions
▪ communicate on a simple level, if the conversational partner speaks slowly and distinctly and assist in case of a misunderstanding.
A2 The student is able to
▪ speak about her/his person, the job, the environment and elementary needs on a basic level
▪ describe his living conditions and understand short simple messages
▪ write simple texts and letters, read and understand and have brief chats in German
▪ understand main topics of oral and written texts (in the context of familiar situations at work, administration, school, leisure and radio/TV reports on latest news,</td></tr>
</table>

	profession and interests).
Competences to be acquired	▪ Soft skills: learning and study techniques, learning experience and problem solving as well as inter-cultural competence, scientific language ▪ Elementary and independent use of German language ▪ Communication competence ▪ Inter-cultural competence ▪ Social competence.

2.8 Software Components for Communication Systems

<table>
<tr><td>Module title</td><td colspan="5">Software Components for Communication Systems R1</td></tr>
<tr><td rowspan="5">Courses</td><td>Title</td><td>Type</td><td>SWS</td><td>Credits</td><td>Performance requirements/ Examination</td></tr>
<tr><td>Java Code Camp – Context Awareness (lec)</td><td>lecture</td><td>4</td><td>5</td><td>oral exam (30 minutes)</td></tr>
<tr><td>Communication Technologies I (lec)</td><td>lecture</td><td>2</td><td>3</td><td rowspan="2">written exam (2 hours)
or
oral exam (30 minutes)</td></tr>
<tr><td>Communication Technologies I (ex)</td><td>exercises</td><td>1</td><td>1</td></tr>
<tr><td>Medium Access Control Protocols in Wireless Communications (sem)</td><td>seminar</td><td>2</td><td>3</td><td>seminar attendance, presentation and oral exam (20 minutes)</td></tr>
<tr><td>Module credits</td><td colspan="5">12</td></tr>
<tr><td>Language</td><td colspan="5">English</td></tr>
<tr><td>Held</td><td colspan="5">in summer semester, annually</td></tr>
<tr><td>Lecturer</td><td colspan="5">Dahlhaus/David and teams</td></tr>
<tr><td>Responsible(s)</td><td colspan="5">Dahlhaus</td></tr>
<tr><td>Required qualifications</td><td colspan="5">▪ Knowledge of fundamentals in digital communications
▪ Knowledge of contents of the course Introduction to Communication I or comparable knowledge and skills.</td></tr>
<tr><td>Workload</td><td colspan="5">135 hours course attendance
225 hours self-study</td></tr>
<tr><td>Contents</td><td colspan="5">▪ Advanced and recent topics in the area of networks and applications (IPv6, QoS, Voice over IP, traffic theory, distributed systems)
▪ Firewalls, file/print/web server
▪ Medium access control in wireless communication systems.</td></tr>
<tr><td>Literature</td><td colspan="5">▪ Kurose/Ross, Computer Networks, Addison Wesley, 2nd edition
▪ Douglas E. Comer, Internetworking with TCP/IP, Prentice Hall, 4th edition
▪ Dimitri Bertsekas, Robert Gallager, Data networks, Prentice Hall, 1992
▪ Andrew S. Tanenbaum, Computer Networks, Prentice Hall, 1996, last edition
▪ Klaus David und Thorsten Benkner, Digitale Mobilfunksysteme, B.G. Teubner, 1996 (in German)
▪ Harri Holma und Antti Toskala, WCDMA for UMTS, Wiley, 2002
▪ Additional papers to be handed out according to seminar topics.</td></tr>
<tr><td>Media</td><td colspan="5">Beamer (lecture, seminar), black board (derivations, explanations), paper (exercises).</td></tr>
<tr><td>Objectives</td><td colspan="5">▪ Understanding internet applications, services and protocols
▪ Literature and internet based investigation on a topic from medium access control in wireless communication systems
▪ Introduction to scientific work in the field of medium access control in wireless transmission systems
▪ Presentation of a scientific topic in a seminar.</td></tr>
<tr><td>Competences to be acquired</td><td colspan="5">▪ Operation and maintenance of devices in communication systems
▪ Research and development in the area of mobile internet
▪ Ability to design schemes for server based services in networks
▪ Consulting in the area of information technology.</td></tr>
</table>

<table>
<tr><td>Module title</td><td colspan="5">Software Components for Communication Systems R2</td></tr>
<tr><td rowspan="5">Courses</td><td>Title</td><td>Type</td><td>SWS</td><td>Credits</td><td>Performance requirements/ Examination</td></tr>
<tr><td>Digital Communications IV (lec)</td><td>lecture</td><td>2</td><td>4</td><td>oral exam (30 minutes)</td></tr>
<tr><td>Digital Communications II (lec)</td><td>lecture</td><td>3</td><td>5</td><td rowspan="2">oral exam (30 minutes)</td></tr>
<tr><td>Digital Communications II (ex)</td><td>exercises</td><td>1</td><td>1</td></tr>
<tr><td>Simulation of Digital Communication Systems using MATLAB (lab)</td><td>lab training</td><td>2</td><td>2</td><td>lab training attendance, programming, oral exam (30 minutes)</td></tr>
<tr><td>Module credits</td><td colspan="5">12</td></tr>
<tr><td>Language</td><td colspan="5">English</td></tr>
<tr><td>Held</td><td colspan="5">in winter semester, annually</td></tr>
<tr><td>Lecturer</td><td colspan="5">Dahlhaus and team</td></tr>
<tr><td>Responsible(s)</td><td colspan="5">Dahlhaus</td></tr>
<tr><td>Required qualifications</td><td colspan="5">Knowledge of fundamentals in digital communications</td></tr>
<tr><td>Workload</td><td colspan="5">120 hours course attendance
240 hours self-study</td></tr>
<tr><td>Contents</td><td colspan="5">▪ Fundamentals in information theory, entropy, mutual information; typical sequences and Shannon capacity for the discrete memoryless channel; channel coding: block codes, cyclic block codes, systematic form; soft and hard decision and performance; interleaving and code concatenation; convolutional codes: tree and state diagrams, transfer function, distance properties; the Viterbi algorithm; source coding: fixed-length and variable-length codes, Huffman coding; the Lempel-Ziv algorithm; coding for analog sources, rate-distortion function; pulse-code modulation; delta-modulation, model-based source coding, linear predictive coding (LPC)
▪ Multichannel and multicarrier transmission, orthogonal frequency-division multiplexing (OFDM), spread spectrum (direct sequence, frequency hopping), PN sequences, transmission over fading multipath channels, channel coding for multipath channels, multiple-input multiple-output (MIMO) transmission, multiuser detection, code-division multiple access (CDMA) and random access
▪ Introduction to MATLAB and its most important commands, simulation of a simple transmission chain, channel coding (convolutional codes), coding gain, channels with multipath propagation, channel models with fading and bit-error rate performance for binary signalling, transmission with orthogonal frequency-division multiplexing (OFDM), interleaving, implementation of an OFDM modem, direct-sequence spread spectrum (DSSS) transmission.</td></tr>
<tr><td>Literature</td><td colspan="5">▪ T. Cover and J.A. Thomas, Elements of Information Theory, 2nd ed., Wiley, ISBN: 978-0-471-24195-9
▪ J.G. Proakis, Digital Communications, McGraw-Hill, 4th ed., ISBN 0-07-118183-0.
▪ Papoulis, S. U. Pillai, Probability, Random Variables, and Stochastic Processes, McGraw-Hill, 4th ed., ISBN 0071226613.
▪ A.J. Viterbi, CDMA - Principles of Spread Spectrum Communications, Wireless Communications Series, Addison-Wesley, 1995.</td></tr>
<tr><td>Media</td><td colspan="5">Beamer (lecture), black board (derivations, explanations), paper (exercises).</td></tr>
<tr><td>Objectives</td><td colspan="5">▪ Understanding fundamentals in communications related aspects of information theory
▪ Ability to design source and channel coding schemes and implement them efficiently in software
▪ Detailed understanding of schemes in the physical layer of digital communication systems
▪ Understanding approaches for numerical simulation of transceivers in the physical layer of communication systems.</td></tr>
<tr><td>Competences to be acquired</td><td colspan="5">▪ Research and development in source and channel coding
▪ Research and development in the area of signal processing for wireless and wired digital communication systems</td></tr>
</table>

	▪ Operation and maintenance of devices in communication systems ▪ Consulting in the area of information technology.

3 Qualification modules

If a student does not fulfill the admission requirements for the ECE program, the examination board can grant a conditional admission according to §4 par.(5) of the ECE examination regulation. The condition requires that the student has to earn credits (totalling at most 30 credits) from the modules listed below prior to starting the master thesis.

As in Section 1, the modules cover the areas of

- Digital Communications
- Electromagnetics
- Microwaves
- Optoelectronics.

Within each area, we have the aforementioned naming convention <AREA TYPE NO> such as *Digital Communications Q1*, where, unlike in Section 1, TYPE takes the value **Q** for **q**ualification.

3.1 Digital Communications

<table>
<tr><td>Module title</td><td colspan="5">Digital Communications Q1</td></tr>
<tr><td rowspan="7">Courses</td><td>Title</td><td>Type</td><td>SWS</td><td>Credits</td><td>Performance requirements/ Examination</td></tr>
<tr><td>Digital Communications I (lec)</td><td>lecture</td><td>3</td><td>3</td><td rowspan="2">oral exam (30 minutes)</td></tr>
<tr><td>Digital Communications I (ex)</td><td>exercises</td><td>1</td><td>1</td></tr>
<tr><td>Introduction to Communication I (lec)</td><td>lecture</td><td>2</td><td>3</td><td rowspan="2">written exam (2 hours)
or
oral exam (30 minutes)</td></tr>
<tr><td>Introduction to Communication I (ex)</td><td>exercises</td><td>1</td><td>1</td></tr>
<tr><td>Fundamentals of RF Circuit Design (lec)</td><td>lecture</td><td>2</td><td>3</td><td rowspan="2">written exam (2 hours)</td></tr>
<tr><td>Fundamentals of RF Circuit Design (ex)</td><td>exercises</td><td>1</td><td>1</td></tr>
<tr><td>Module credits</td><td colspan="5">12</td></tr>
<tr><td>Language</td><td colspan="5">English</td></tr>
<tr><td>Held</td><td colspan="5">in winter semester, annually</td></tr>
<tr><td>Lecturer</td><td colspan="5">Dahlhaus/David and teams</td></tr>
<tr><td>Responsible(s)</td><td colspan="5">Dahlhaus</td></tr>
<tr><td>Required qualifications</td><td colspan="5">Knowledge of fundamentals in communications</td></tr>
<tr><td>Workload</td><td colspan="5">135 hours course attendance
225 hours self-study</td></tr>
<tr><td>Contents</td><td colspan="5">▪ Introduction, mathematical models for communication channels, linear systems, basics of probability and random variables, the central limit theorem, Fourier transforms, Shannon-Kotelnikov (sampling) theorem, stochastic processes, stationary processes and linear time-invariant systems, complex baseband representation of bandpass signals, orthogonal expansions of signals, linear digital modulation schemes, optimum receivers for the additive white Gaussian noise channel
▪ Overview of OSI layer model, physical layer (layer 1), passive/active components, data link layer/medium access control (layer 2), network layer (layer 3), transport layer (layer 4), session layer (layer 5), presentation layer (layer 6), application layer (layer 7).
▪ Matching networks, small-scale signal high frequency amplifier, selective amplifiers, oscillators, mixers
▪ Analog modulation schemes: amplitude modulation (AM) and related schemes, frequency modulation (FM) and related schemes; digitale modulation schemes using sinusoidal carrier signals: amplitude/frequency/phase-shift keying (ASK,FSK,PSK); fundamentals of phase-locked loops (PLLs).</td></tr>
<tr><td>Literature</td><td colspan="5">▪ J.G. Proakis, Digital Communications, McGraw-Hill, 4th ed., ISBN 0-07-118183-0.
▪ T. Cover, J.A. Thomas, Elements of Information Theory, 2nd ed., Wiley, ISBN: 978-0-471-24195-9
▪ Kurose/Ross, Computer Networks, Addison Wesley, 2nd ed.
▪ Douglas E. Comer, Internetworking with TCP/IP, Prentice Hall, 4th ed.
▪ Dimitri Bertsekas, Robert Gallager, Data Networks, Prentice Hall, 1992
▪ Andrew S. Tanenbaum, Computer Networks, Prentice Hall, 1996, last edition
▪ Fred Halsall, Data Comm., Computer Networks and Open Systems, 1996, 4th ed.</td></tr>
<tr><td>Media</td><td colspan="5">Beamer (presentation), black board (derivations, explanations), paper (exercises).</td></tr>
</table>

Objectives	▪ Understanding fundamentals in digital communications and statistical signal processing ▪ Understanding the OSI layer model as basis of wired and wireless digital transmission systems ▪ Understanding the operation of transistor circuits and their dimensioning at high frequencies ▪ Understanding of receiver schemes and methods for signal transmission over radio channels.
Competences to be acquired	▪ Development in the area of digital transmission systems ▪ Design of hardware and software components in digital transmission systems ▪ Assessment of analog front-ends.

3.2 Electromagnetics

Module title	**Electromagnetics Q1**				
Courses	**Title**	**Type**	**SWS**	**Credits**	**Performance requirements/ Examination**
	Mathematical Foundations of Electromagnetic Field Theory (lec)	lecture	2	2	oral exam (30 minutes)
	Mathematical Foundations of Electromagnetic Field Theory (ex)	exercises	1	1	
	Electromagnetic Field Theory **I** (lec)	lecture	2	2	written exam (2 hours) or oral exam (30 minutes)
	Electromagnetic Field Theory **I** (ex)	exercises	1	1	
Module credits	6				
Language	English				
Held	in summer semester, annually				
Lecturer	Witzigmann and team				
Responsible(s)	Witzigmann				
Required qualifications	Knowledge of fundamentals in electrical engineering, mathematics and communications				
Workload	90 hours course attendance 90 hours self-study				
Contents	▪ Vector and tensor algebra, vector and tensor analysis, distributions, fundamentals of complex analysis, special functions, Fourier transform, Laplace transform ▪ Coordinate systems, line/surface/volume integrals, fundamental equations of electromagnetic fields and waves: Maxwell's equations and continuum equations in integral and differential forms, equations describing electromagnetic properties of matter, continuity and boundary conditions, Poynting vector ▪ Electrostatic fields: field strength and scalar potential, concept of a point electric charge, electrostatic Green's function, method of mirror charges, separation of variables ▪ Magnetostatic fields: magnetic vector potential, vector Laplace and Poisson equations, Biot-Savart law, magnetic moments, magnetization, magnetic polarisation ▪ Electro-quasistatic fields, magneto-quasistatic fields ▪ Basic considerations of electromagnetic fields.				
Literature	Will be announced during the lecture.				
Media	Beamer (presentation), black board (derivations, explanations), paper (exercises).				
Objectives	▪ Mathematical basics and understanding of fundamental concepts of electromagnetics ▪ Basics of field theory: vector/tensor algebra, vector/tensor analysis, differential equations, Fourier and Laplace transforms ▪ Approaches for calculating static, stationary and slowly time-varying fields ▪ Preparation to learning the theory of electromagnetic fields, antennay, optoelectronics ▪ Preparation to numerical methods of electromagnetic field theory.				
Competences to be acquired	▪ Preparation to research and software development in the area of theory and numerics of fields and waves ▪ Assessment of transmission systems in communications ▪ Basic knowledge for majoring in remote sensing and characterization of scattering fields.				

3.3 Microwaves

Module title	**Microwaves Q1**				
Courses	**Title**	**Type**	**SWS**	**Credits**	**Performance requirements/ Examination**
	Microwave Integrated Circuits I (lec)	lecture	2	3	written exam (2 hours)
	Microwave Integrated Circuits I (ex)	exercises	1	1	
	Microwave Integrated Circuits I (lab)	lab training	2	2	lab training attendance and conductance of experiments
Module credits	6				
Language	English				
Held	in winter semester, annually				
Lecturer	Bangert and team				
Responsible(s)	Bangert				
Required qualifications	▪ Knowledge of fundamentals of high frequency technology ▪ Knowledge of vector algebra and vector analysis.				
Workload	75 hours course attendance 105 hours self-study				
Contents	▪ Methods for designing networks ▪ Survey of striplines ▪ Methods of micro-strip analysis ▪ Dispersion in micro-striplines, dispersion measurements ▪ Planar wave guide models ▪ Micro-strip discontinuities and losses, technology ▪ Introduction to Agilent Advanced Design System (ADS), harmonic analysis, simulation of *S*-parameters in microwave networks, micro-strip resonators and discontinuties.				
Literature	▪ G. Kompa, *Practical Microstrip Design and Applications*, Artech House, 2006 ▪ H. Brand, *Schaltungslehre linearer Mikrowellennetze*, S. Hirzel Verlag, 1970 (in German) ▪ Notes on lab training.				
Media	Beamer (presentation), black board (derivations, explanations), paper (exercises), experiments (lab training).				
Objectives	▪ Understanding schemes for computer-aided design of integrated microwave and millimeter wave circuits ▪ Ability to model the electrical properties of planas lines, line discontinuities and branchings in integrated circuits ▪ Ability to design integrated circuits ▪ Ability to apply commercial design software and to simulate linear and non-linear microwave circuits.				
Competences to be acquired	▪ Research and development in the area of microwave components ▪ Characterization and modeling of microwave components based on measurements ▪ Design of microwave networks.				

3.4 Optoelectronics

Module title	**Optoelectronics Q1**				
Courses	**Title**	**Type**	**SWS**	**Credits**	**Performance requirements/ Examination**
	Optoelectronic devices (lec)	lecture	3	4	oral exam (30 minutes)
	Optoelectronic devices (ex)	exercises	1	2	
Module credits	6				
Language	English				
Held	in winter semester, annually				
Lecturer	Hillmer and team				
Responsible(s)	Hillmer				
Required qualifications	Basic knowledge on electronic semiconductor devices (diodes, transistor), material science				
Workload	60 hours course attendance 120 hours self-study				
Contents	▪ Introduction into optics ▪ Refractive index, polarisation, interference, diffraction, coherence ▪ Material properties of glass; dispersion, absorption ▪ Optical waveguiding ▪ Interferometers ▪ Introduction to lasers, LEDs, photo diodes and solar cells.				
Literature	▪ J. Gowar, *Optical Communication Systems*, 2nd ed., Prentice Hall, 1993. ▪ K. Iga, S. Kinoshita, *Process technology for semiconductor lasers*, Springer, Series in Material Science 30, 1996. ▪ S.L. Chuang, *Physics of Optoelectronic Devices*, John Wiley & Sons, New York, 1995. ▪ F. Träger (Editor), *Springer Handbook of Lasers and Optics*, Springer, 2007.				
Media	Beamer (presentation), black board (derivations, explanations), paper (exercises).				
Objectives	▪ To learn basic principles of optics and basic optoelectronic devices ▪ To understand set-up and operation principles of basic optoelectronic devices ▪ To learn the huge application potential of optoelectronic devices and photonic tools ▪ To learn to calculate basic optoelectronic problems.				
Competences to be acquired	▪ To obtain a rough idea of the complex interaction of electronic, thermal and optical phenomena in laser diodes ▪ Basic knowledge in operation and application of optoelectronic devices.				