# Module description

## Master study program

## Space Sciences and Technologies - Sensing, Processing, Communication (Space - ST)

University of Bremen
Faculty 1 Physics/ Electrical Engineering

June 1, 2018

The module description is used for the orientation of the students. It is not an official legislative basis. It is essential to use the official valid examination rules.

We try to keep the module description updated but modification with respect to personnel and content can occur.

**Änderungshistorie**

| Datum | Version | Art der Änderung |
|---|---|---|
| 26.09.2017 | 170926_Modulhandbuch_Space-ST.pdf (SK) | Modulplan, VAKs, Seitenzahlen |
| 26.01.2018 | 180126_Modulhandbuch_Space-ST.pdf (SK) | Module title updated “Atmospheric Chemistry Modeling”; Module “Engineering Ethics” added |
| 13.02.2018 | 180213 | Elective module “Fascination Space” added |
| 23.05.2018<br>01.06.2018 | 180523 (SK)<br>180601 (SK) | Elective module “Practical Data Analysis with Python” added, examination forms for several modules adjusted |

**Contents**

## Overview

## 1. Mandatory Modules

### 1.1 Foundations (30 CP):

Atmospheric Physics (6 CP)
Communication Technologies (6 CP)
Control Theory I (3 CP)
Inverse Methods and Data Analysis (6 CP)
Science and Exploration Missions (3 CP)
Space Electronics (6 CP)

### 1.2 Remote Sensing and Communication (24 CP):

Atmospheric Spectroscopy (3 CP)
Channel Coding I (3 CP)
Communication Networks for Space (3 CP)
Digital Image Processing (3 CP)
Geodesy and Gravity (3 CP)
Sensors and Measurement Systems (3 CP)
Space Lab (6 CP)

### 1.3 Project (12 CP)

### 1.4 Master Thesis (30 CP)

## 2. Specialization Subjects

Students choose one out of two specialization subjects - “Physics for Space Observation” or “Information Technologies for Space”

### 2.1 Physics for Space Observation (12 CP)

Atmospheric Aerosols (3 CP)

Atmospheric Chemistry Modeling (3 CP)

Remote Sensing of the Ocean and Cryosphere (6 CP)

### 2.2 Information Technologies for Space (12 CP)

Architectures and Design Methodologies of Integrated Digital Systems (4 CP)

RF Frontend Devices and Circuits (4 CP)

Microfluidic Devices (4 CP)

### 2.3 Electives (12 CP)

Students choose elective courses at a total of 12 CP

Antennas (3 CP)

Biogeochemistry (3 CP)

Dynamics 1 (6 CP)

Integrated Circuits (3 CP)

On-Board Data Handling (3 CP)

Remote Sensing of Polar Atmosphere (3 CP)

Statistics and Error Analysis (3 CP)

Wireless Communications (3 CP)

## Module Plan “Space-ST”

| Semester | Pflichtbereich (Compulsory Modules) + Modul Masterarbeit (inkl. Kolloquium) insgesamt 96 CP | | | Project (12 CP) | Wahlpflichtbereich (Compulsory Elective Modules, 12 CP) | | Wahlbereich (Elective Modules, 12 CP) | | ∑ 120 Ver-teilung CP/Semester |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | „Physics for Space Observation” (PSO) (Specialization) | „Information Technologies for Space“ (ITS) (Specialization) | PSO | ITS | |
| 1 | **Foundations (30 CP)** | | | | | | | | 30 |
| | Inverse Methods and Data Analysis, 6 CP | Control Theory I, 3 CP | Space Electronics, 6 CP | | | | | | |
| | Science and Exploration Missions, 3 CP | Atmospheric Physics, 6 CP | Communication Technologies, 6 CP | | | | | | |
| 2 | **Remote Sensing and Communication (24 CP)** | | | | Remote Sensing of Ocean and Cryosphere, 6 CP | RF Frontend Devices and Circuits, 4 CP | Elective Course, 9 CP | Elective Course, 3CP | 30 |
| | Channel Coding I, 3 CP | Sensors and Measurement Systems, 3 CP | Digital Image Processing, 3 CP | | | Architectures and Design Methodologies of Integrated Digital Systems, 4 CP | | | |
| | | Space Lab, 3 CP | Atmospheric Spectroscopy, 3 CP | | | Microfluidic Devices, 4 CP | | | |
| 3 | Communication Networks for Space, 3 CP | Space Lab, 3 CP(Part II) | | Project, 12 CP | Atmospheric Chemistry Modeling, 3 CP | | Elective Course, 3CP | Elective Course, 9 CP | 30 |
| | Geodesy and Gravity, 3 CP | | | | Atmospheric Aerosols, 3 CP | | | | |
| 4 | Master Thesis, 30 CP | | | | | | | | 30 |

CP = Credit Points

# 1. Compulsory Modules

Abbreviations

L: Lecture

EC: Exercises

SL: Study achievement (Studienleistung)

PL: Examination achievements (Prüfungsleistung)

Oral/Written examinations are examination achievements (PL)

Exercises are study achievements (SL)

## 1.1 Foundations (30 CP)

| | |
|---|---|
| **Code no.** | 01-03-AtPhy-V |
| **Module title /** | Atmospheric Physics |
| **Assignment to study programmes** | Compulsory for MSc Space Sciences and Technologies<br>Compulsory for MSc Environmental Physics<br>Optional compulsory for MSc Physik<br>Optional compulsory for MSc Marine Geosciences<br>Optional compulsory for MSc Technomathematik<br>Optional compulsory for MSc Physical Geography: Environmental History |
| **Requirements for participation** | None |
| **Content** | History of the earth's atmosphere, atmospheric composition, radiation in atmosphere, physical laws, description of radiation and atmospheric radiation transport;<br>Climate change;<br>Atmospheric thermodynamics and hydrological cycle;<br>Aerosols and cloud physics;<br>Introduction into atmospheric dynamics |
| **Learning outcome** | Students have background knowledge in Basics physics of the atmosphere |
| **Workload /**<br>**credit points** | 6 CP, 180 h<br>• presence (L + EC): 56 h (4 SWH x 14 weeks)<br>• preparation, learning + exercises: 56 h (4 SWH x 14 weeks)<br>• preparation for exam: 68 h |
| **Course language** | English |
| **Responsible for the module, lecturers /**<br>**Module assignment** | Prof. Dr. John P. Burrows<br>Module section / Foundations |
| **Compulsory / optional** | Compulsory |
| **Offered frequency** | Annually / winter semester |
| **Duration / semester** | 1 semester / winter semester (1st academic year) |
| **ECTS** | 6 CP |
| **Semester Weekly Hours** | 4 SWS (4 semester weekly hours (SWH) / 2x lecture (L) + 2x exercise classes (EC)) |
| **Course and examination performance, type of exam** | Partial exam<br>Examination performance: Written exam/oral exam (will be announced by the respective lecturer)<br>Course performance: Successful assessment of exercise classes |
| **Literature** | • Houghton, J.T., The physics of atmospheres, Cambridge University Press, 1977, ISBN 0 521 29656 0.<br>• Wallace, John M. and Peter V. Hobbs, Atmospheric Science, An Introductory Survey, Academic Press, 2nd Edition 2005, ISBN 0-12-732951-x |

| | |
|---|---|
| **Code no.** | 01-03-ComT-V |
| **Module title /** | Communication Technologies |
| **Assignment to study programmes** | Compulsory for MSc Space Sciences and Technologies<br>Optional compulsory for MSc CMM<br>Compulsory for MSc CIT<br>Optional/compulsory for MSc Elektrotechnik und Informationstechnik<br>Optional compulsory for MSc System Engineering |
| **Requirements for participation** | Basics of communications technologies, stochastic (digital) signal processing, system theory |
| **Content** | • Introduction: Stochastic Processes<br>• Digital Baseband Transmission: Spectra of Data Signals, Cyclostationary autocorrelation function<br>• Digital Modulation: Nonlinear Modulation Methods (FSK, MSK, CPSK), spectral characteristics<br>• Receiver Technologies: Coherent Demodulation, Carrier Synchronization, Non-coherent Demodulation, Optimum Receiver for AGN-Channel<br>• Mobile Radio Channel: Frequency and time selectivity, multipath propagation<br>• Equalization: Linear equalization (T- /T/2-, Decision Feedback) Non-linear MAP/ML-Equalization, Viterbi-Equalizer |
| **Learning outcome** | As outcome, the students should be able to:<br>• Explain the important prerequisites for digital signal transfer<br>• Apply expertise in by using non-linear modulation methods<br>• Explain coherent and non-coherent demodulation<br>• Explain concepts of MAP und ML-designs for wireless transmissions.<br>• Apply the Viterbi-Algorithm on distorted modulation signals. Develop simulation models using Matlab |
| **Workload /**<br>**credit points** | 6 CP, 180 h<br>• presence (L + EC): 56 h (4 SWH x 14 weeks)<br>• preparation, learning + exercises: 56 h (4 SWH x 14 weeks)<br>• preparation for exam: 68 h |
| **Course language** | English |
| **Responsible for the module, lecturers /**<br>**Module assignment** | Prof. Dr.-Ing. Armin Dekorsy<br>Module section / Space Communication Technology |
| **Compulsory / optional** | Compulsory |
| **Offered frequency** | Annually / winter semester |
| **Duration / semester** | 1 semester / winter semester (1st academic year) |
| **ECTS** | 6 CP |
| **Semester Weekly Hours** | (4 semester weekly hours (SWH) / 2x lecture (L) + 2x exercise classes (EC)) |
| **Course and examination performance, type of exam** | Module exam<br>Examination performance: Written exam |
| **Literature** | • J. Proakis: Digital Transmission<br>• Kammeyer: Nachrichtenübertragung |

| | |
|---|---|
| **Code no.** | 01-03-CTh1-V |
| **Module title /** | Control Theory I |
| **Assignment to study programmes** | Compulsory for MSc Space Sciences and Technologies<br>Optional compulsory for MSc CMM<br>Optional compulsory for MSc CIT |
| **Requirements for participation** | Knowledge about basics of control (bode diagrams, nyquist plots, nyquist stability criterion, PID controller design) |
| **Content** | Introduction to the definition and features of state variables, State space description of linear systems, Normal forms, Coordinate transformation, General solution of a linear state space equation, Lyapunov stability, Controllability and observability, Concept of state space control, Steady-state accuracy of state space controllers, Observer, Controller design by pole placement, Riccati controller design, Falb-Wolovitch controller design. |
| **Learning outcome** | Students have background knowledge in understanding and handling of state space methodology, design of state space controllers with different methods, observer design |
| **Workload /**<br>**credit points** | 3 CP, 90 h<br>• presence (L + EC): 28 h (2 SWH x 14 weeks)<br>• preparation, learning + exercises: 42 h (3 SWH x 14 weeks)<br>• preparation for exam: 20 h |
| **Course language** | English |
| **Responsible for the module, lecturers /**<br>**Module assignment** | Prof. Dr.-Ing. Kai Michels<br>Module section / Introduction to Space Systems |
| **Compulsory / optional** | Compulsory |
| **Offered frequency** | Annually / winter semester |
| **Duration / semester** | 1 semester / winter semester (1st academic year) |
| **ECTS** | 3 CP |
| **Semester Weekly Hours** | (2 semester weekly hours (SWH) / 1x lecture (L) + 1x exercise classes (EC)) |
| **Course and examination performance, type of exam** | Module exam<br>Examination performance: Written or oral exam depending on the number of participants |
| **Literature** | • K. Michels, Control Engineering, Script, Norman S. Nise: Control Systems Engineering.<br>• Norman S. Nise: Control Systems Engineering |

| | |
|---|---|
| **Code no.** | 01-03-IMDA-V |
| **Module title /** | Inverse Methods and Data Analysis |
| **Assignment to study programmes** | Compulsory for MSc Space Sciences and Technologies<br>Compulsory for MSc Environmental Physics<br>Optional compulsory for MSc Physik<br>Optional compulsory for MSc Marine Geosciences<br>Optional compulsory for MSc Technomathematik |
| **Requirements for participation** | None |
| **Content** | Error analysis and statistics, techniques for the optimal solution of under and over determined systems of linear equations including methods for calculating variances and covariances of the solutions, concepts of resolution and methods to calculate them, practical examples and applications to test data sets from oceanography, image processing and atmospheric remote sensing |
| **Learning outcome** | Students are competent to identify linear inverse methods |
| **Workload /**<br>**credit points** | 6 CP, 180 h<br>• presence (L + EC): 56 h (4 SWH x 14 weeks)<br>• preparation, learning + exercises: 56 h (4 SWH x 14 weeks)<br>• preparation for exam: 68 h |
| **Course language** | English |
| **Responsible for the module, lecturers /**<br>**Module assignment** | Prof. Dr. Reiner Schlitzer, Prof. Dr. Emily King<br>Module section / Optimization |
| **Compulsory / optional** | Compulsory |
| **Offered frequency** | Annually / winter semester |
| **Duration / semester** | 1 semester / winter semester (1st academic year) |
| **ECTS** | 6 CP |
| **Semester Weekly Hours** | 4 SWS (4 semester weekly hours (SWH) / 2x lecture (L) + 2x exercise classes (EC)) |
| **Course and examination performance, type of exam** | Partial exam<br>Examination performance: Written exam/oral exam (will be announced by the respective lecturer)<br>Course performance: Successful assessment of exercise classes |
| **Literature** | Will be announced in the respective course. |

| | |
|---|---|
| **Code no.** | 01-03-SEM-V |
| **Module title /** | Science and Exploration Missions |
| **Assignment to study programmes** | Compulsory for MSc Space Sciences and Technologies<br>Optional compulsory for MSc Physik |
| **Requirements for participation** | Basic courses in Physics on mechanics, electrodynamics, quantum mechanics |
| **Content** | Introduction of completed and planned space missions,<br>Examples are (i) Gravity Probe A for testing the gravitational redshift, (ii) Gravity Probe B for testing the gravitomagnetic Schiff effect, (iii) Cassini for Saturn exploration and testing the gravitational time delay, (iv) Pioneer for planetary exploration and testing the gravitational field in the Solar system, (v) MICROSCOPE for testing the Equivalence Principle, (vi) LISA for searching for gravitational waves and the technology mission LISA pathfinder, (vii) GRACE and GRACE-FO for satellite based geodesy, (viii) ACES on the ISS for testing relativity and establishing space-based metrology, (ix) further missions testing Special and General Relativity using quantum optics, (x) asteroid and comet missions HAYABUSA and Rosetta.<br>For each mission the requirements on the payload technology, the spacecraft technology, and on the mission scenario will be derived. |
| **Learning outcome** | Participants are able to discuss science cases for space and exploration missions, measurement schemes and payload as well as technology requirements on payload and mission. |
| **Workload /**<br>**credit points** | 3 CP, 90 h<br>• presence (L + EC): 28 h (2 SWH x 14 weeks)<br>• preparation, learning + exercises: 42 h (3 SWH x 14 weeks)<br>• preparation for exam: 20 h |
| **Course language** | English |
| **Responsible for the module, lecturers /**<br>**Module assignment** | Prof. Dr. Claus Lämmerzahl<br>Module section / Introduction to Space Systems |
| **Compulsory / optional** | Compulsory |
| **Offered frequency** | Annually / winter semester |
| **Duration / semester** | 1 semester / winter semester (1st academic year) |
| **ECTS** | 3 CP |
| **Semester Weekly Hours** | (2 semester weekly hours (SWH) / 1x lecture (L) + 1x exercise classes (EC)) |
| **Course and examination performance, type of exam** | Partial exam<br>Examination performance: Written exam/oral exam (will be announced by the respective lecturer), graded<br>Course performance: Successful assessment of exercise classes, not graded |
| **Literature** | • H. Dittus, C. Lämmerzahl, S. Turyshev (Editors): Lasers, Clocks and Drag-Free Control - Exploration of Relativistic Gravity in Space, Astrophysics and Space Science Library, Vol. 349 (Springer Verlag, Berlin and Heidelberg 2008), ISBN 978-3-540-34376-9, ISSN 0067-0057.<br>• C. Lämmerzahl and H. Dittus: Fundamental physics in space: A guide to present projects, Annalen der Physik 11, 95 (2002). |

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|---|---|
| **Code no.** | 01-03-SpEl-V |
| **Module title /** | Space Electronics |
| **Assignment to study programmes** | Compulsory for MSc Space Sciences and Technologies |
| **Requirements for participation** | Basic knowledge of semiconductors, analog and digital circuit |
| **Content** | • Radiation environments<br>• MOS Device and radiation<br>• Circuit Reliability basics<br>• Single event effects on analog and digital circuits, memories<br>• Displacement damage (DD) effects<br>• Radiation hard device technologies and circuit design<br>• Noise<br>• gm/Id Method<br>• Mismatch<br>• two pole opamps (OTA)<br>• feedback |
| **Learning outcome** | After this course, students are able to:<br>• describe and characterize noise in electronics circuits<br>• apply the gm/Id sizing method to design amplifier circuits for advance CMOS technologies<br>• deal with process variations and mismatch<br>• understand the frequency behaviour of amplifier circuits<br>• understand and size compensation networks<br>• use feedback to modify circuit characteristics.<br>• understand the impact of radiation on the behavior of circuits<br>• design radiation hard circuits |
| **Workload / credit points** | 6 CP, 180 h<br>• presence (L + EC): 56 h (4 SWH x 14 weeks)<br>• preparation, learning + exercises: 56 h (4 SWH x 14 weeks)<br>• preparation for exam: 68 h |
| **Course language** | English |
| **Responsible for the module, lecturers / Module assignment** | Prof. Dr.-Ing. Steffen Paul<br>Module section / Space Electronics |
| **Compulsory / optional** | Compulsory |
| **Offered frequency** | Annually / winter semester |
| **Duration / semester** | 1 semester / winter semester (1st academic year) |
| **ECTS** | 6 CP |
| **Semester Weekly Hours** | (4 semester weekly hours (SWH) / 2x lecture (L) + 1 seminar + 1x exercise classes (EC)) |
| **Course and examination performance, type of exam** | Partial exam<br>Examination performance: Written exam/oral exam (will be announced by the respective lecturer), graded<br>Course performance: Successful assessment of exercise classes, not graded |
| **Literature** | Will be announced in the respective course. |

## 1.2 Remote Sensing and Communication (24 CP)

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|---|---|
| **Code no.** | 01-03-AtSp-V |
| **Module title /** | Atmospheric Spectroscopy |
| **Assignment to study programmes** | Compulsory for MSc Space Sciences and Technologies<br>Optional for MSc Environmental Physics<br>Optional compulsory for MSc Marine Geosciences<br>Optional compulsory for MSc Technomathematik |
| **Requirements for participation** | None |
| **Content** | Prisms and grating spectrometers, Fourier-Transform-Spectroscopy, transitions, rotational spectra, vibrational spectra, rotational-vibrational spectra, remote sensing methods |
| **Learning outcome** | The students have background knowledge in basics of spectroscopy, understanding and interpretation of measured spectra with regard to the structure of the molecules as well as basics of the FTIR-spectroscopy, understanding of remote sensing methods. |
| **Workload /**<br>**credit points** | 3 CP, 90 h<br>• presence (L + EC): 28 h (2 SWH x 14 weeks)<br>• preparation, learning + exercises: 28 h (2 SWH x 14 weeks)<br>• preparation for exam: 34 h |
| **Course language** | English |
| **Responsible for the module, lecturers /**<br>**Module assignment** | Prof. Dr. Justus Notholt<br>Module section / Remote Sensing and Communication |
| **Compulsory / optional** | Compulsory |
| **Offered frequency** | Annually / summer semester |
| **Duration / semester** | 1 semester / summer semester (1st academic year) |
| **ECTS** | 3 CP |
| **Semester Weekly Hours** | (2 semester weekly hours (SWH) /<br>1,5x lecture (L) + 0,5x exercise classes (EC)) |
| **Course and examination performance, type of exam** | Partial exam<br>Examination performance: Written exam/oral exam (will be announced by the respective lecturer), graded<br>Course performance: Successful assessment of exercise classes and/or successful writing of an essay, not graded |
| **Literature** | Will be announced in the respective course. |

| | |
|---|---|
| **Code no.** | 01-03-CCod1-V |
| **Module title /** | Channel Coding I |
| **Assignment to study programmes** | Compulsory for MSc Space Sciences and Technologies<br>Optional compulsory for MSc CIT<br>Optional compulsory for MSc Elektrotechnik und Informationstechnik |
| **Requirements for participation** | Basics of communication technology and digital signal processing |
| **Content** | 1) Basic Concepts and channel models<br>2) Information theory<br>3) Linear block codes:<br>a. Generator and parity check matrix<br>b. Standard array and syndrome decoding<br>c. Examples (SPC, Hamming, Simplex),<br>d. Cyclic Codes (description by polynomials),<br>e. Examples (CRC, BCH, Reed-Solomon),<br>4) Convolutional codes:<br>a. Encoder structure and graphical representations<br>b. Viterbi decoding<br>c. Code properties |
| **Learning outcome** | Channel Coding I is a one semester course. The aim is to provide a basic understanding how channel coding works and to present the most important code families. Moreover, results obtained from information theory show the ultimate limits theoretically achievable with optimal codes. After this course, the students should be able to:<br>• Explain the principle of channel coding<br>• Explain the ultimate limits from information theory<br>• Perform encoding and decoding for linear block and convolutional codes<br>• Grade the performance of different codes |
| **Workload /**<br>**credit points** | 3 CP, 90 h<br>• presence (L + EC): 42 h (3 SWH x 14 weeks)<br>• preparation, learning + exercises: 28 h (2 SWH x 14 weeks)<br>• preparation for exam:20 h |
| **Course language** | English |
| **Responsible for the module, lecturers /**<br>**Module assignment** | Dr.-Ing. Dirk Wübben<br>Module section / Remote Sensing and Communication |
| **Compulsory / optional** | Compulsory |
| **Offered frequency** | Annually / summer semester |
| **Duration / semester** | 1 semester / summer semester (1st academic year) |
| **ECTS** | 3 CP |
| **Semester Weekly Hours** | (3 semester weekly hours (SWH) / 2x lecture (L) + 1x exercise classes (EC)) |
| **Course and examination performance, type of exam** | Module exam<br>Examination performance: Written exam |
| **Literature** | • Neubauer, A., J. Freudenberger, V. Kühn: Coding Theory: Algorithms, Architectures and Applications.<br>• Lin, S., D. J. Costello, Jr.: Error Control Coding: Fundamentals and Applications.<br>• Moreira, J. C., P.G. Farr: Essentials of Error-Control. |

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|---|---|
| **Code no.** | 01-03-CNS-V |
| **Module title /** | Communication Networks for Space |
| **Assignment to study programmes** | Compulsory for MSc Space Sciences and Technologies<br>Compulsory for MSc CIT (under the title Communication Networks Systems)<br>Optional compulsory for MSc CMM (under the title Communication Networks Systems) |
| **Requirements for participation** | None |
| **Content** | Distributed Systems, ISO/OSI 7 Layer Reference Model for Open Communication, Formal Specification Methods for Protocols (SDL), Data Link Layer, Network Layer, Transport Layer, Application Oriented Layers, Local Area Networks, Wide Area Networks, Network Control: (virtual) connections, Routing, Addressing, Flow Control, System Examples: TCP/IP, ISDN / B-ISDN / ATM, Wireless Networks, Performance Analysis |
| **Learning outcome** | The participants are able to describe exemplary systems of communication networks, name and explain the layers of a communication network, know the basic technologies used for communication protocols, know basic error handling mechanisms for communication protocols. |
| **Workload /**<br>**credit points** | 3 CP, 90 h<br>• presence (L + EC): 42 h (3 SWH x 14 weeks)<br>• preparation, learning + exercises: 28 h (2 SWH x 14 weeks)<br>• preparation for exam:20 h |
| **Course language** | English |
| **Responsible for the module, lecturers /**<br>**Module assignment** | Prof. Dr. Anna Förster<br>Module section / Remote Sensing and Communication |
| **Compulsory / optional** | Compulsory |
| **Offered frequency** | Annually / winter semester |
| **Duration / semester** | 1 semester / winter semester (2nd academic year) |
| **ECTS** | 3 CP |
| **Semester Weekly Hours** | (3 semester weekly hours (SWH) /<br>2x lecture (L) + 1x exercise classes (EC)) |
| **Course and examination performance, type of exam** | Partial exam<br>Examination performance: Project presentation graded<br>Course performance: Successful assessment of homework assignments and a successful work on a project, not graded presentation. |
| **Literature** | • Walrand, J.: Communication Networks, A first course, WCB/McGraw-Hill 1998, ISBN 0-256-17404-0.<br>• Tanenbaum, A.S.: Computer Networks, Prentice Hall 1996, ISBN 0-13 349945-6 (and newer editions).<br>• Ross/Kurose, Computer Networking: A Top Down Approach, 4th ed., Addison-Wesley, July 2007. |

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|---|---|
| **Code no.** | 01-03-DIP-V |
| **Module title /** | Digital Image Processing |
| **Assignment to study programmes** | Compulsory for MSc Space Sciences and Technologies<br>Optional for MSc Environmental Physics<br>Optional compulsory for MSc Marine Geosciences<br>Optional compulsory for MSc Technomathematik |
| **Requirements for participation** | None |
| **Content** | • Digital image, sampling<br>• Image enhancement using filters<br>• Image analysis methods using segmentation, feature extraction and classification<br>• Fourier transformation of digital image, linear filters in spatial and frequency domains<br>• Data compression |
| **Learning outcome** | Students know the fundamentals of digital image processing. |
| **Workload /**<br>**credit points** | 3 CP, 90 h<br>• presence (L + EC): 28 h (2 SWH x 14 weeks)<br>• preparation, learning + exercises: 28 h (2 SWH x 14 weeks)<br>• preparation for exam: 34 h |
| **Course language** | English |
| **Responsible for the module, lecturers /**<br>**Module assignment** | Dr. Christian Melsheimer, Dr. Gunnar Spreen<br>Module section / Remote Sensing and Communication |
| **Compulsory / optional** | Compulsory |
| **Offered frequency** | Annually / summer semester |
| **Duration / semester** | 1 semester / summer semester (1st academic year) |
| **ECTS** | 3 CP |
| **Semester Weekly Hours** | (2 semester weekly hours (SWH) /<br>1,5x lecture (L) + 0,5x exercise classes (EC)) |
| **Course and examination performance, type of exam** | Partial exam<br>Examination performance: Written exam/oral exam (will be announced by the respective lecturer), graded.<br>Course performance: Successful assessment of exercise classes and/or successful writing of an essay, not graded |
| **Literature** | Will be announced in the respective course. |

| | |
|---|---|
| **Code no.** | 01-03-GG-V |
| **Module title /** | Geodesy and Gravity |
| **Assignment to study programmes** | Compulsory for MSc Space Sciences and Technologies |
| **Requirements for participation** | None |
| **Content** | Classical geodesy<br>• Repetition of Newtonian gravitational theory<br>• Multipole moments of the Earth and the gravitational field of the Earth<br>• Definition of the geoid on the rotating Earth<br>• Equation of motion for satellites<br>• Calculation of satellite orbits<br>• Description of orbits for satellite formation flight and extraction of the gravitational field<br>Relativistic geodesy<br>• Elements of relativistic gravity theory<br>• Post-Newtonian solution for the gravitational field of the Earth<br>• Definition of the geoid<br>• Clocks in the gravitational field: clock geodesy<br>• Relativistic satellite orbits, basic effects |
| **Learning outcome** | The students will have knowledge of notions of nonrelativistic gravity theory, knowledge of basic notions of geodesy, an understanding of methods to measure the gravitational fields, knowledge of basic principles of relativistic gravity and an understanding of clock geodesy |
| **Workload /**<br>**credit points** | 3 CP, 90 h<br>• presence (L + EC): 42 h (3 SWH x 14 weeks)<br>• preparation, learning + exercises: 28 h (2 SWH x 14 weeks)<br>• preparation for exam: 20 h |
| **Course language** | English |
| **Responsible for the module, lecturers /**<br>**Module assignment** | Prof. Dr. Claus Lämmerzahl<br>Module section / Remote Sensing and Communication |
| **Compulsory / optional** | Compulsory |
| **Offered frequency** | Annually / winter semester |
| **Duration / semester** | 1 semester / winter semester (2nd academic year) |
| **ECTS** | 3 CP |
| **Semester Weekly Hours** | (3 semester weekly hours (SWH) /<br>2x lecture (L) + 1x exercise classes (EC)) |
| **Course and examination performance, type of exam** | Partial exam<br>Examination performance: Written exam/oral exam (will be announced by the respective lecturer), graded.<br>Course performance: Successful assessment of exercise classes and/or successful writing of an essay, not graded |
| **Literature** | Will be announced in the respective course. |

| | |
|---|---|
| **Code no.** | 01-03-SMS-V |
| **Module title /** | Sensors and Measurement Systems |
| **Assignment to study programmes** | Compulsory for MSc Space Sciences and Technologies<br>Optional compulsory for MSc CIT<br>Optional compulsory for MSc CMM<br>Optional compulsory for MSc Elektrotechnik und Informationstechnik |
| **Requirements for participation** | Basics of electrical engineering and electrical measurement |
| **Content** | • Basics of Sensors<br>• Thermal Sensors<br>• Sensor Technology<br>• Force and Pressure Sensors<br>• Inertial Sensors<br>• Magnetic Sensors<br>• Flow Sensors |
| **Learning outcome** | The students know how to name and explain important sensors, apply characterization parameters for sensors, choose sensors for a given application and apply them, analyze sensor systems, understand micromachining technologies for sensors |
| **Workload /**<br>**credit points** | 3 CP, 90 h<br>• presence (L + EC): 28 h (2 SWH x 14 weeks)<br>• preparation, learning + exercises: 42 h (3 SWH x 14 weeks)<br>• preparation for exam: 20 h |
| **Course language** | English |
| **Responsible for the module, lecturers /**<br>**Module assignment** | Prof. Dr. Walter Lang<br>Module section / Remote Sensing and Communication |
| **Compulsory / optional** | Compulsory |
| **Offered frequency** | Annually / summer semester |
| **Duration / semester** | 1 semester / summer semester (1st academic year) |
| **ECTS** | 3 CP |
| **Semester Weekly Hours** | Sensors and Measurement Systems (2 semester weekly hours (SWH) / 1,5x lecture (L) + 0,5x exercise classes (EC) in the clean room) |
| **Course and examination performance, type of exam** | Module exam<br>Examination performance: Written exam |
| **Literature** | • Sinclair: Sensors and Transducers.<br>• J. Bentley: Principles of measurement systems. |

| | |
|---|---|
| **Code no.** | 01-03-LSPA-V |
| **Module title /** | Space Lab |
| **Assignment to study programmes** | Compulsory for MSc Space Sciences and Technologies |
| **Requirements for participation** | None |
| **Content** | Measurements of meteorological quantities, atmospheric trace gases, ocean currents, environmental radioactivity, absorption cross-sections, measurements of Embedded Systems and Communications. |
| **Learning outcome** | Participants know the basics of measurement techniques in Space Sciences and Technologies. |
| **Workload /**<br>**credit points** | 6 CP, 180 h<br>• presence (L): 18 h (6 SWH x 3 weeks)<br>• presence (Lab): 24 h (6 SWH x 4 weeks)<br>• preparation, report: 84 h (12 SWH x 7 weeks)<br>• preparation for exam: 54 h |
| **Course language** | English |
| **Responsible for the module, lecturers /**<br>**Module assignment** | PD Dr. Annette Ladstätter-Weißenmayer, Dr. A. Richter, Prof. Dr.-Ing. A. Garcia-Ortiz, Prof. Dr.-Ing. St. Paul, Prof. Dr.-Ing. A. Dekorsy, Prof. Dr.-Ing. A. Förster, Prof. Dr. J. Burrows, Prof. Dr. J. Notholt, Prof. Dr. M. Rhein<br>Module section / Remote Sensing and Communication |
| **Compulsory / optional** | Compulsory |
| **Offered frequency** | Semesterly |
| **Duration / semester** | 2 semesters / summer semester (1st academic year), winter semester (2nd academic year) |
| **ECTS** | 6 CP |
| **Semester Weekly Hours** | (8 laboratory (Lab) + 1 lecture (L)) |
| **Course and examination performance, type of exam** | Partial exam<br>Examination performance: Oral exam<br>Course performance: Successful experiments with accepted reports |
| **Literature** | Will be announced in the respective course. |

## 1.3 Project (12 CP)

| | |
|---|---|
| **Code no.** | 01-03-PrSpa |
| **Module title /** | Project |
| **Assignment to study programmes** | Compulsory for MSc Space Sciences and Technologies |
| **Requirements for participation** | None |
| **Content** | The content is related to the respective area of research of the project.<br>Working in the laboratories of the Institute of Environmental Physics / Electrical Engineering / AWI<br>Individual instruction (practical training)<br>Preparation of a thesis paper on a possible research project which - as a rule - should be closely related to the subsequent Master's Thesis. |
| **Learning outcome** | The students should be able to transfer a scientific problem/question into an experimental and/or theoretical study, should develop successful strategies for the planning and conducting of scientific studies and should be able to summarize and present preliminary scientific results in a thesis paper. |
| **Workload /**<br>**credit points** | 12 CP, 360 h |
| **Course language** | English |
| **Responsible for the module, lecturers /**<br>**Module assignment** | Prof. Dr. John P. Burrows, Prof. Dr. Justus Notholt, Prof. Dr. Monika Rhein, PD Dr. Annette Ladstätter-Weißenmayer, Prof. Dr.-Ing.Dr.-Ing. Steffen Paul, Prof. Dr. Alberto Garcia-Ortiz, Prof. Dr. Kai Michels, Prof. Dr. Walter Lang, Prof. Dr.-Ing.Dr.-Ing. Martin Schneider, Prof. Dr. Anna Förster as well as further university lecturers of the IUP (Institute of Environmental Physics) / AWI (Alfred Wegener Institute for Polar and Marine Research) depending on the area of research<br>Module section / Project |
| **Compulsory / optional** | Compulsory |
| **Offered frequency** | Annually / winter semester |
| **Duration / semester** | 1 semester / winter semester (2nd academic year) |
| **ECTS** | 12 CP |
| **Semester Weekly Hours** | (12 CP, 360 h) |
| **Course and examination performance, type of exam** | Module examination<br>• Successful assessment of the project<br>Thesis paper on research project which can be conducted within the context of the Master's Thesis. |
| **Literature** | Will be announced in the respective course. |

## 1.4 Master Thesis (30 CP)

| | |
|---|---|
| **Code no.** | 01-03-ThsSpa |
| **Module title /** | Master Thesis (incl. colloquium) |
| **Assignment to study programmes** | Compulsory for MSc Space Sciences and Technologies |
| **Requirements for participation** | Required for the application for the Master's Thesis is the passing of all the mandatory exams of the module sections "Compulsory", "Compulsory Elective" and the module "project". |
| **Content** | The content is related to the respective area of research of the project.<br>Working in the laboratories of the Institute of Environmental Physics / Electrical Engineering / AWI<br>Individual instruction (practical training)<br>Preparation of a thesis paper on a possible research project which - as a rule - should be closely related to the subsequent Master's Thesis. |
| **Learning outcome** | The students should be able to transfer a scientific problem/question into an experimental and/or theoretical study, should develop successful strategies for the planning and conducting of scientific studies and should be able to summarize and present preliminary scientific results in a thesis paper. |
| **Workload /**<br>**credit points** | 30 CP, 900 h |
| **Course language** | English |
| **Responsible for the module, lecturers /**<br>**Module assignment** | Prof. Dr. John P. Burrows, Prof. Dr. Justus Notholt, Prof. Dr. Monika Rhein, PD Dr. Annette Ladstätter-Weißenmayer, Prof. Dr.-Ing. Steffen Paul, Prof. Dr. Alberto Garcia-Ortiz, Prof. Dr. Kai Michels, Prof. Dr. Walter Lang, Prof. Dr.-Ing. Martin Schneider, Prof. Dr. Anna Förster as well as further university lecturers of the IUP (Institute of Environmental Physics) / AWI (Alfred-Wegener-Institute for Polar and Marine Research) depending on the area of research<br>Module section / Master Thesis and Colloquium |
| **Compulsory / optional** | Compulsory |
| **Offered frequency** | Annually / summer semester |
| **Duration / semester** | 1 semester / summer semester (2nd academic year) |
| **ECTS** | 30 CP |
| **Semester Weekly Hours** | (30 CP, 900 h) |
| **Course and examination performance, type of exam** | Module examination<br>• Successful assessment of the Master's Thesis<br>• Successful colloquium to the Master's Thesis<br>Credit points for the finale module are granted on the basis of the marks for the Master's Thesis (75%) and the colloquium (25%). |
| **Literature** | Will be announced in the respective course. |

## 2. Specialization Subjects

One specialization subject has to be selected out of “Physics for Space Observation” or “Information Technologies for Space”.

## 2.1 Physics for Space Observation (12 CP)

| | |
|---|---|
| **Code no.** | 01-03-AtA-V |
| **Module title /** | Atmospheric Aerosols |
| **Assignment to study programmes** | Compulsory for MSc Space Sciences and Technologies<br>Optional compulsory for MSc Marine Geosciences<br>Optional compulsory for MSc Technomathematik |
| **Requirements for participation** | None |
| **Content** | Description of atmospheric aerosols, their composition and measuring methods. Introduction to radiative transfer in the troposphere with emphasis on aerosols and clouds. |
| **Learning outcome** | Students have an advanced knowledge of the atmosphere and light scattering. |
| **Workload /<br>credit points** | 3 CP, 90 h<br>• presence (L + EC): 28 h (2 SWH x 14 weeks)<br>• preparation, learning + exercises: 28 h (2 SWH x 14 weeks)<br>• preparation for exam: 34 h |
| **Course language** | English |
| **Responsible for the module, lecturers /<br>Module assignment** | Dr. Marco Vountas, Dr. Luca Lelli<br>Module section / Specialization Subject – Physics for Space Observation |
| **Compulsory / optional** | Compulsory |
| **Offered frequency** | Annually / winter semester |
| **Duration / semester** | 1 semester / winter semester (2nd academic year) |
| **ECTS** | 3 CP |
| **Semester Weekly Hours** | (2 semester weekly hours (SWH) / 1,5x lecture (L) + 0,5x exercise classes (EC)) |
| **Course and examination performance, type of exam** | Partial exam<br>Examination performance: Written exam/oral exam (will be announced by the respective lecturer)<br>Course performance: Successful assessment of exercise classes and/or successful writing of an essay |
| **Literature** | Will be announced in the respective course. |

| | |
|---|---|
| **Code no.** | 01-03-AtCM1-V |
| **Module title /** | Atmospheric Chemistry Modeling |
| **Assignment to study programmes** | Compulsory for MSc Space Sciences and Technologies<br>Optional compulsory for MSc Marine Geosciences<br>Optional compulsory for MSc Technomathematik |
| **Requirements for participation** | None |
| **Content** | • Concept of chemistry transport models<br>• Atmospheric Chemical Composition/Processes<br>• Model equations and numerical approaches focusing on the:<br>  ○ formulation of atmospheric rates<br>  ○ numerical methods for chemical systems<br>• Surface fluxes/emissions<br>• Observations and model evaluations<br>• Inverse modeling for atmospheric chemistry |
| **Learning outcome** | Participants will have the chance to:<br>Get a theoretical overview of the concepts of numerical atmospheric chemistry modelling, to review fundamentals of atmospheric chemistry and physics, to formulate model equations and numerical (differential) approaches for various systems focusing on atmospheric chemistry mechanisms and to assess the role of chemistry transport models as components of the atmospheric observing system. Concepts of inverse modelling will be also presented. |
| **Workload /**<br>**credit points** | 3 CP, 90 h<br>• presence (L + EC): 28 h (2 SWH x 14 weeks)<br>• preparation, learning + exercises: 42 h (3 SWH x 14 weeks)<br>• preparation for exam: 20 h |
| **Course language** | English |
| **Responsible for the module, lecturers /**<br>**Module assignment** | Prof. Dr. Mihalis Vrekoussis<br>Module section / Specialization Subject – Physics for Space Observation |
| **Compulsory / optional** | Compulsory |
| **Offered frequency** | Annually / winter semester |
| **Duration / semester** | 1 semester / winter semester (2nd academic year) |
| **ECTS** | 3 CP |
| **Semester Weekly Hours** | (2 semester weekly hours (SWH) / 1,5x lecture (L) + 0,5x exercise classes (EC)) |
| **Course and examination performance, type of exam** | Partial exam<br>Examination performance: Written exam/oral exam (will be announced by the respective lecturer)<br>Course performance: Successful assessment of exercise classes and/or successful writing of an essay |
| **Literature** | • Modeling Methods for Marine Science: David M. Glover, William J. Jenkins, Scott C. Doney.<br>• Numerical Recipes: William H. Press, Saul Teukolsky, William T. Vetterling und Brian P. Flannery.<br>• Further references will be provided at the start of the course. |

| | |
|---|---|
| **Code no.** | 01-04-RSOC-V |
| **Module title /** | Remote Sensing of the Ocean and Cryosphere |
| **Assignment to study programmes** | Compulsory for MSc Space Sciences and Technologies<br>Optional compulsory for MSc Marine Geosciences<br>Optional compulsory for MSc Technomathematik |
| **Requirements for participation** | None |
| **Content** | Error analysis and statistics, techniques for the optimal solution of under and over determined systems of linear equations including methods for calculating variances and covariances of the solutions, concepts of resolution and methods to calculate them, practical examples and applications to test data sets from oceanography, image processing and atmospheric remote sensing |
| **Learning outcome** | Students have background knowledge in basics and application of remote sensing of sea ice extent and thickness, sea surface height, winds over the ocean, waves, ocean bottom, surface temperature and salinity, ocean color and other remote sensing applications for ocean and cryosphere. |
| **Workload /**<br>**credit points** | 6 CP, 180 h<br>• presence (L + EC): 56 h (4 SWH x 14 weeks)<br>• preparation, learning + exercises: 56 h (4 SWH x 14 weeks)<br>• preparation for exam: 68 h |
| **Course language** | English |
| **Responsible for the module, lecturers /**<br>**Module assignment** | Prof. Dr. Monika Rhein, Prof. Dr. Astrid Bracher, Dr. Georg Heygster, Dr. Gunnar Spreen, Prof. Dr. Christian Haas, Prof. Dr. Ben Marzeion<br>Module section / Specialization Subject – Physics for Space Observation |
| **Compulsory / optional** | Compulsory |
| **Offered frequency** | Annually /summer semester |
| **Duration / semester** | 1 semester / summer semester (1st academic year) |
| **ECTS** | 6 CP |
| **Semester Weekly Hours** | (4 semester weekly hours (SWH) / 2x lecture (L) + 2x exercise classes (EC)) |
| **Course and examination performance, type of exam** | Partial exam<br>Examination performance: Written exam/oral exam (will be announced by the respective lecturer), graded<br>Course performance: Successful assessment of exercise classes, not graded |
| **Literature** | Will be announced in the respective course. |

## 2.2 Information Technologies for Space (12 CP)

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|---|---|
| **Code no.** | 01-03-DIDS-V |
| **Module title /** | Architectures and Design Methodologies of Integrated Digital Systems |
| **Assignment to study programmes** | Compulsory for MSc Space Sciences and Technologies<br>Compulsory for MSc CMM<br>Elective for MSc CIT<br>Optional compulsory for MSc Elektrotechnik und Informationstechnik |
| **Requirements for participation** | None |
| **Content** | • Design tools and abstractions levels<br>• Physical design, Floorplanning and placement, Routing and wire estimation, DRC and LVS<br>• Design-for-Test, Scan-based design, Boundary scan, BIST Test-architectures for SoCs<br>• Test-generation and error diagnosis, ATPG, Fault simulation |
| **Learning outcome** | The students will learn the design methodologies, theoretical algorithms, and tools used for the development of microelectronic integrated systems, as well as the strategies regarding their practical implementation with industrial CAD tools. The students will be able to implement a complex microelectronic integrated digital guarantying its correctness and testability. |
| **Workload /**<br>**credit points** | 4 CP, 120 h<br>• presence (L + EC): 42 h (3 SWH x 14 weeks)<br>• preparation, learning + exercises: 42 h (3 SWH x 14 weeks)<br>• preparation for exam: 36 h |
| **Course language** | English |
| **Responsible for the module, lecturers /**<br>**Module assignment** | Prof. Dr.-Ing. Alberto García-Ortiz<br>Module section / Specialization Subject – Information Technologies for Space |
| **Compulsory / optional** | Compulsory |
| **Offered frequency** | Annually / summer semester |
| **Duration / semester** | 1 semester / summer semester (1st academic year) |
| **ECTS** | 4 CP |
| **Semester Weekly Hours** | (3 semester weekly hours (SWH) / 2x lecture (L) + 1x exercise classes (EC)) |
| **Course and examination performance, type of exam** | Module exam<br>Examination performance: Written or oral exam |
| **Literature** | • J.M. Rabaey, A. Chandrakasan, B. Nikolic, Digital Integrated Circuits – A Design Perspective, ISBN-10_9788120322578<br>• Michael John Sebastian Smith, Application-Specific Integrated Circuits, Addison-Wesley Publishing Company ISBN 0-201-50022-1 |

| | |
|---|---|
| **Code no.** | 01-03-MiD-V |
| **Module title /** | Microfluidic Devices |
| **Assignment to study programmes** | Compulsory for MSc Space Sciences and Technologies<br>Optional compulsory for MSc CIT<br>Optional compulsory for MSc CMM<br>Optional compulsory for MSc Elektrotechnik und Informationstechnik |
| **Requirements for participation** | Knowledge of microtechnology. This can be acquired by:<br>the course on “Introduction to Micro Technology” by M. Vellekoop, or the course “Sensors and Measurement Systems” by W. Lang, or studying a textbook such as “Introduction to Microfabrication” (S. Franssila) |
| **Content** | • Contents, Organisation, Introduction Basics of microfluidics<br>• Flow control: valves and pumps<br>• Sensors and analysis in µfluidic devices<br>• Examples of µfluidic devices<br>• Technology for µfluidic devices |
| **Learning outcome** | In this class, an overview is given of the developments in the area of microfluidic devices from the early start (where especially silicon integrated valves and pumps where investigated) to the lab-on-a-chip devices of today. The functionality of the sensors and actuators, the technologies applied, and the design of fluidic chips will be discussed. Some basic fluidics aspects will be presented and a practical (Laborübung) in which COMSOL is used for the simulation of microfluidic elements is included.<br>Practical: “Introduction to COMSOL based fluidic simulations” (Dr. S. van den Driesche).After this course, you should be able to:<br>• understand the basics of microfluidics<br>• understand and explain the functioning of microfluidic devices<br>• apply characterization parameters for (elements of) microfluidic devices<br>• understand fabrication technologies for microfluidic devices |
| **Workload /**<br>**credit points** | 4 CP, 120 h<br>• presence (L + EC): 42 h (3 SWH x 14 weeks)<br>• preparation, learning + exercises: 42 h (3 SWH x 14 weeks)<br>• preparation for exam: 36 h |
| **Course language** | English |
| **Responsible for the module, lecturers /**<br>**Module assignment** | Prof. Dr.-Ing. Michael Vellekoop<br>Module section / Specialization Subject – Information Technologies for Space Engineering |
| **Compulsory / optional** | Compulsory |
| **Offered frequency** | Annually / summer semester |
| **Duration / semester** | 1 semester / summer semester (1st academic year) |
| **ECTS** | 4 CP |
| **Semester Weekly Hours** | (3 semester weekly hours (SWH) / 2x lecture (L) + 1x exercise classes (EC)) |
| **Course and examination performance, type of exam** | Module exam<br>Examination performance: Written exam |
| **Literature** | • M. Koch, A. Evans, A. Brunnschweiler, Microfluidic Technology and Applications, RSP.<br>• H. Bruus, Theoretical Microfluidics, Oxford University Press |

| | |
|---|---|
| **Code no.** | 01-03-RFC-V |
| **Module title /** | RF Frontend Devices and Circuits |
| **Assignment to study programmes** | Compulsory for MSc Space Sciences and Technologies<br>Optional compulsory for MSc CIT<br>Optional compulsory for MSc Elektrotechnik und Informationstechnik |
| **Requirements for participation** | Basic system and communication theory |
| **Content** | • Two-port circuits<br>• Noise in electronic circuits<br>• Fundamentals of non-linear devices<br>• RF devices<br>• RF circuits and frontends |
| **Learning outcome** | The students have to know the fundamental working principles of analogue RF frontend devices and circuits that are the main building blocks of fixed and mobile devices for wireless communications (GSM, WLAN, UMTS, RFID, etc.) as well as for sensors like radar sensors.<br>They should understand the basic principles of RF devices like amplifiers, mixers, oscillators, PLL's, and frequency synthesizers. The fundamentals of two-port circuits, electronic noise, and effects of non-linearities are addressed at first. Based on these theoretical parts students should be able to discuss the pros and cons of different RF frontend architectures and to design first basic analogue RF frontend circuits. |
| **Workload /**<br>**credit points** | 4 CP, 120 h<br>• presence (L + EC): 42 h (3 SWH x 14 weeks)<br>• preparation, learning + exercises: 42 h (3 SWH x 14 weeks)<br>• preparation for exam: 36 h |
| **Course language** | English |
| **Responsible for the module, lecturers /**<br>**Module assignment** | Prof. Dr.-Ing. Martin Schneider<br>Module section / Specialization Subject – Information Technologies for Space Engineering |
| **Compulsory / optional** | Compulsory |
| **Offered frequency** | Annually / summer semester |
| **Duration / semester** | 1 semester / summer semester (1st academic year) |
| **ECTS** | 4 CP |
| **Semester Weekly Hours** | (3 semester weekly hours (SWH) / 2x lecture (L) + 1x exercise classes (EC)) |
| **Course and examination performance, type of exam** | Module exam<br>Examination performance: Written exam |
| **Literature** | • Ulrich L. Rohde, David P. Newkirk, "RF/Microwave Circuit Design for Wireless Applications" John Wiley & Sons, 2000.<br>• David M. Pozar, "Microwave Engineering," John Wiley & Sons, third edition, 2005.<br>• David M. Pozar, "Microwave and RF Design of Wireless Systems," New York, NY: Wiley, 2001.<br>• J. Laskar, B. Matinpour, S. Chakraborty, "Modern Receiver Front-Ends: Systems, Circuits, and Integration," Hoboken, NJ: Wiley-Interscience, 2004.<br>• B. Razavi, "RF Microelectronics," Upper Saddle River, NJ, Prentice Hall, 1st edition, 1998. |

## 2.3 Elective Modules (12 CP)

Elective Courses have to be selected from the following modules:

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|---|---|
| **Code no.** | 01-03-Ant-V |
| **Module title /** | Antennas |
| **Assignment to study programmes** | MSc Space-ST - Wahlfach<br>MSc Elektrotechnik und Informationstechnik – Pflicht/ Wahpflichtlfach<br>MSc CIT – Pflichtfach<br>MSc Wirtschaftsingenieurswesen – Pflichtfach |
| **Requirements for participation** | Electrodynamics |
| **Content** | • Fields and wave in free space based on Maxwell's equations<br>• Fundamentals of antennas<br>• Hertz Dipole amd magnetic dipole<br>• linear antennas, half wave length dipole<br>• antenna arrays<br>• aperture antennas<br>• Calculation of microstrip patch antennas<br>• presentation and discussion of realization examples |
| **Learning outcome** | After this course, the students know how<br>• to explain the working principle of antennas<br>• to decide which kind of antennas suits a certain application at a certain frequency<br>• to apply the method of electrodynamic potentials for solving antenna problems<br>• to explain and to apply the method of equivalent sources for calculating aperture antennas |
| **Workload / credit points** | 3 CP, 90 h<br>• Presence (L + EC): 42 h (3 SWH x 14 weeks)<br>• Preparation, learning and exercises: 28 h (2 h/week x 14 weeks)<br>• Preparation for exam: 20 h |
| **Course language** | English |
| **Responsible for the module, lecturers / Module assignment** | Prof. Dr.- Ing. Martin Schneider |
| **Compulsory / optional** | Optional |
| **Offered frequency** | Annually / winter semester |
| **Duration / semester** | 1 semester / 2nd academic year |
| **ECTS** | 3 CP |
| **Semester Weekly Hours** | 3 semester weekly hours (SWH)<br>2x lecture (L) + 1x exercise classes (EC)) |
| **Course and examination performance, type of exam** | Module exam (MP) / written examination (120 minutes) |
| **Literature** | • C. A. Balanis, ”Antenna Theory ”, John Wiley & Sons, 3rd Edition, 2005<br>• J. D. Kraus, ”Antennas For All Applications”, McGraw-Hill, 3rd Edition, 2002 |

| | |
|---|---|
| **Code no.** | 01-03-BGC-V |
| **Module title /** | Biogeochemistry |
| **Assignment to study programmes** | Optional for MSc Space Sciences and Technologies<br>Optional compulsory for MSc Physik<br>Optional compulsory for MSc Marine Geosciences<br>Optional compulsory for MSc Technomathematik |
| **Requirements for participation** | None |
| **Content** | Global biochemical cycles of elements, important biophysical processes in atmosphere and ocean, carbon-, methane-, nitrogen and water cycle, greenhouse gases |
| **Learning outcome** | The participants will have an advanced understanding of the chemical physical, geological and biological processes and reactions that govern the composition of the natural environment (including the biosphere, the cryosphere, the hydrosphere, the pedosphere, the atmosphere and the lithosphere). |
| **Workload /**<br>**credit points** | 3 CP, 90 h<br>• presence (L + EC): 28 h (2 SWH x 14 weeks)<br>• preparation, learning + exercises: 28 h (2 SWH x 14 weeks)<br>• preparation for exam: 34 h |
| **Course language** | English |
| **Responsible for the module, lecturers /**<br>**Module assignment** | PD. Dr. Annette Ladstätter-Weißenmayer<br>Module section / Elective Courses |
| **Compulsory / optional** | Optional |
| **Offered frequency** | Annually / summer semester |
| **Duration / semester** | 1 semester / summer semester (1st academic year) |
| **ECTS** | 3 CP |
| **Semester Weekly Hours** | (2 semester weekly hours (SWH) /<br>1x lecture (L) + 1x exercise classes (EC)) |
| **Course and examination performance, type of exam** | Partial exam<br>Examination performance: Written exam/oral exam (will be announced by the respective lecturer)<br>Course performance: Successful assessment of example classes and/or successful writing of an essay |
| **Literature** | Will be announced in the respective course. |

| | |
|---|---|
| **Code no.** | 01-03-Dyn1-V |
| **Module title /** | Dynamics I |
| **Assignment to study programmes** | Optional for MSc Space Sciences and Technologies<br>Compulsory for MSc Environmental Physics<br>Optional compulsory for MSc Physik<br>Optional compulsory for MSc Marine Geosciences<br>Optional compulsory for MSc Technomathematik |
| **Requirements for participation** | None |
| **Content** | Governing equations, basic conservation laws, balances, elementary applications of the basic equations, circulation and vorticity, planetary boundary layer, Rossby waves |
| **Learning outcome** | The students will have an understanding of the basic dynamical processes in atmosphere and ocean; earning how to interpret physical equations physically |
| **Workload /**<br>**credit points** | 6 CP, 180 h<br>• presence (L + EC): 56 h (4 SWH x 14 weeks)<br>• preparation, learning + exercises: 56 h (2 h x 14 weeks)<br>• preparation for exam: 68 h |
| **Course language** | English |
| **Responsible for the module, lecturers /**<br>**Module assignment** | Prof. Dr. Thomas Jung<br>Module section / Elective Courses |
| **Compulsory / optional** | Optional |
| **Offered frequency** | Annually / winter semester |
| **Duration / semester** | 1 semester / winter semester (2nd academic year) |
| **ECTS** | 6 CP |
| **Semester Weekly Hours** | (4 semester weekly hours (SWH) / 2x lecture (L) + 2x exercise classes (EC)) |
| **Course and examination performance, type of exam** | Partial exam<br>Examination performance: Written exam/oral exam (will be announced by the respective lecturer)<br>Course performance: Successful assessment of exercise classes |
| **Literature** | Will be announced in the respective course. |

| | |
|---|---|
| **Code no.** | 01-03-EngE-V |
| **Module title /** | Engineering Ethics |
| **Assignment to study programmes** | Optional for MSc Space Sciences and Technologies<br>Optional for MSc ET/IT |
| **Requirements for participation** | None |
| **Content** | • Basic moral concepts<br>• Basic moral theories and values and their rationale<br>• Codes of Ethics (examples from Associations and Agencies)<br>• Case Studies from engineering<br>• Professional ideals, social and environmental responsibility |
| **Learning outcome** | After the course the students will be able to<br>• discuss and apply professional codes of ethics<br>• distinguish normative from descriptive judgements<br>• describe basic norms, values and ethical theories<br>• determine conditions of responsibility<br>• apply norms and theories to concrete cases in engineering and identify ethical issues at different stages |
| **Workload /**<br>**credit points** | Total working hours: 90 h<br>• presence (L ): 28 h (2 h x 14 weeks)<br>• preparation and follow-up: 28 h (2 SWH x 14 weeks)<br>• preparation for exam: 34 h |
| **Course language** | English |
| **Responsible for the module, lecturers /**<br>**Module assignment** | Prof. Dr. Dagmar Borchers, M.A. Björn Haferkamp<br>Module section / Elective Courses |
| **Compulsory / optional** | Optional |
| **Offered frequency** | Annually / summer semester |
| **Duration / semester** | 1 semester (1st or 2nd academic year) |
| **ECTS** | 3 CP |
| **Semester Weekly Hours** | 2 semester weekly hours |
| **Course and examination performance, type of exam** | Module exam<br>Examination performance: written summary and oral exam (will be announced by the lecturer) |
| **Literature** | Will be announced in the respective course |

| | |
|---|---|
| **Code no.** | 01-03-RingSp-V |
| **Module title /** | Fascination Space – On the scientific and practical use of astronautics |
| **Assignment to study programmes** | Optional for MSc Space Sciences and Technologies |
| **Requirements for participation** | None |
| **Content** | • Asteroids - impact risk and mitigation options<br>• What do satellites tell us about the earth climate?<br>• Glancing towards the edge of the universe: James Webb & Hubble<br>• Satellite geodesy<br>• Gravity waves in space<br>• Mathematics in space<br>• and others<br>The contents of this seminar series might be slightly adjusted in the course of the term. |
| **Learning outcome** | The students will learn about science missions in space, in particular the science case, the mission scenario and the technological challenges. Furthermore, they gain an understanding of how certain aspects of space research are transferred into everyday life and practical use. And they will get an overview on past, current and future space missions. |
| **Workload /**<br>**credit points** | 3 CP, 90 h<br>• presence (L ): 14 h (2 SWH x 7 weeks)<br>• follow-up and protocols: 14 h (2 SWH x 7 weeks)<br>• preparation of a seminar talk and an essay: 62 h |
| **Course language** | English |
| **Responsible for the module, lecturers /**<br>**Module assignment** | Prof. Dr. Claus Lämmerzahl, PD Dr. Annette Ladstätter-Weißenmayer<br>Experts from the field of space research and applications serve as guest lecturers.<br>Module section / Elective Courses |
| **Compulsory / optional** | Optional |
| **Offered frequency** | Annually / summer semester |
| **Duration / semester** | 1 semester / summer semester (1st or 3rd academic year) |
| **ECTS** | 3 CP |
| **Semester Weekly Hours** | 2 semester hours every other week |
| **Course and examination performance, type of exam** | Study performances: A report/protocol of every lecture, one essay |
| **Literature** | • will be announced at the beginning of the semester |

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|---|---|
| **Code no.** | 01-03-InS-V |
| **Module title** | Integrated Circuits |
| **Assignment to study programmes** | Optional for MSc Space Sciences and Technologies<br>Compulsory / optional compulsory for MSc Elektrotechnik und Informationstechnik<br>Compulsory for MSc Systems Engineering<br>Compulsory for MSc Electrical Engineer with Management<br>Optional for MSc CIT<br>Compulsory for MSc CMM |
| **Requirements for participation** | Basics of electrical engineering and analog integrated circuits |
| **Content** | • Noise<br>• gm/Id Method<br>• Mismatch<br>• two pole opamps (OTA)<br>• feedback |
| **Learning outcome** | After this course, students are able to:<br>• describe and characterize noise in electronics circuits<br>• apply the gm/Id sizing method to design amplifier circuits for advance CMOS technologies<br>• deal with process variations and mismatch<br>• understand the frequency behaviour of amplifier circuits<br>• understand and size compensation networks<br>• use feedback to modify circuit characteristics. |
| **Workload** | Total working hours: 90 h<br>• Presence (L + EC): 42 h ( 3 SWH x 14 weeks)<br>• Preparation, learning and exercises: 14h (1 h/week x 14 weeks)<br>• Preparation for exam: 34 h |
| **Course language** | English |
| **Responsible for the module, lecturers** | Prof. Dr.-Ing. Steffen Paul |
| **Compulsory / optional** | Optional |
| **Offered frequency** | Annually, winter semester |
| **Duration/ semester** | 1 Semester/ 1st semester |
| **ECTS** | 3 CP |
| **SWH** | 3 SWS (2 SWS Vorlesung & 1 SWS Übung) |
| **Course and examination performance / type of exam** | Module Exam (MP) / oral examination (30 minutes) |
| **Literature** | • T. Carusone: Analog integrated circuit design.<br>• W. Sansen: Analog Design essentials. |

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|---|---|
| **Code no.** | 04-M30-CEM-SFI-1 |
| **Module title /** | On-Board Data Handling |
| **Assignment to study programmes** | Optional for MSc Space Sciences and Technologies |
| **Requirements for participation** | Basics of electrical engineering and analog integrated circuits |
| **Content** | On-Board Data Handling (OBDH) includes all aspects from payload data processing to mission critical control tasks. The OBDH system can in principle be considered as an embedded system that is subject to strong requirements with respect to reliability and availability in harsh environments with minimal or no maintenance.<br>The lecture considers various aspects from general mission scenarios and their impact on the OBDH system, examples for typical architecture, techniques for Failure Detection Isolation and Recovery (FDIR) and approaches for guaranteeing functional correctness of the hardware and/or software. Relevant standards are introduced.<br>A coarse table of contents reads as follows:<br>• Mission scenarios and implications on the OBDH system<br>• Tasks for OBDH<br>• Standards for space applications<br>• Architectures for OBDH system considered as embedded systems<br>• Hardware and software solutions<br>• Functional correctness |
| **Learning outcome** | The students should be able to explain typical scenarios for space missions, to understand and derive mission-specific requirements for the On-Board Data Handling (OBDH) system, to explain relevant standards, to explain and justify typical test approaches for OBDH systems, to understanding approaches for Failure Detection Isolation and Recovery (FDIR) and to have the ability to specify an OBDH system. |
| **Workload /**<br>**credit points** | 3 CP, 90 h<br>• presence (L + EC): 42 h (3 SWH x 14 weeks) in the clean room<br>• preparation, learning + exercises: 28 h (2 SWH x 14 weeks)<br>• preparation for exam: 20 h |
| **Course language** | English |
| **Responsible for the module, lecturers /**<br>**Module assignment** | Prof. Dr. Claus Braxmaier, Dr. Fank Dannemann<br>Module section / Elective Courses |
| **Compulsory / optional** | Optional |
| **Offered frequency** | Annually / summer semester |
| **Duration / semester** | 1 semester / summer semester (1st academic year) |
| **ECTS** | 3 CP |
| **Semester Weekly Hours** | (3 semester weekly hours (SWH) /<br>2x lecture (L) + 1x exercise classes (EC)) |
| **Course and examination performance, type of exam** | Module exam<br>Examination performance: Oral exam |
| **Literature** | A list of references will be given in the lecture |

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|---|---|
| **Code no.** | 01-03-PDAP-V |
| **Module title /** | Practical Data Analysis with Python |
| **Assignment to study programmes** | Optional for MSc Space Sciences and Technologies<br>Optional for MSc Environmental Physics<br>Optional for MSc Physik<br>Optional for MSc Marine Geosciences |
| **Requirements for participation** | None |
| **Content** | The course will touch on the following subjects:<br>• "But this worked yesterday, before I made some changes ..." or: An introduction to version control<br>• Getting started: How to setup your own computer for data analysis in Python.<br>• Hands-on introduction to the Python scientific ecosystem: Arrays and mathematical operations, using NumPy.<br>• Labeled arrays or how to intuitively work with data, using Pandas and xarray.<br>• Reading and writing data in common file formats.<br>• Making both meaningful and beautiful plots, using matplotlib.<br>• Statistical analysis in Python using the SciPy and Statsmodels packages.<br>• Parameter estimation / regression using SciPy<br>• An overview of the most common special-topic libraries for the research areas covered by the students' study programmes.<br>• Working with geoscientific data and plotting maps, using Cartopy and Shapely.<br>• Other data analysis tasks needed by the students for their study program, upon demand. |
| **Learning outcome** | Upon successful completion of this course, the student will be able to work with scientific data using the Python scientific programming ecosystem, including the whole scientific data lifecycle (reading data, statistical analysis, plotting, storing results), following modern scientific programming best practices (e.g., version control, reproducibility, documentation, …). |
| **Workload /**<br>**credit points** | 3 CP, 90 h<br>• presence (L + EC): 28 h (2 SWH x 14 weeks)<br>• preparation, learning + exercises: 26 h (2 SWH x 13 weeks)<br>• preparation for exam: 36 h |
| **Course language** | English |
| **Responsible for the module, lecturers /**<br>**Module assignment** | Dr. Andreas Hilboll |
| **Compulsory / optional** | Optional |
| **Offered frequency** | Annually / summer semester |
| **Duration / semester** | 1 semester / summer semester (1st academic year) |
| **ECTS** | 3 CP |
| **Semester Weekly Hours** | (2 semester weekly hours (SWH) /<br>1x lecture (L) + 1x exercise classes (EC)) |
| **Course and examination performance, type of exam** | Partial exam<br>Examination performance: Two graded homework projects<br>Course performance: Successful assessment of example classes and/or successful writing of an essay |
| **Literature** | VanderPlas, Jake: Python Data Science Handbook, O'Reilly, 2016 (freely available online at https://jakevdp.github.io/PythonDataScienceHandbook/) |

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|---|---|
| **Code no.** | 01-03-RSPA-V |
| **Module title /** | Remote Sensing of Polar Atmosphere |
| **Assignment to study programmes** | Optional for MSc Space Sciences and Technologies |
| **Requirements for participation** | None |
| **Content** | Introduction in methods of measurements means instruments and retrieval for polar atmosphere. |
| **Learning outcome** | The students will have basic understanding of remote sensing of polar atmosphere. |
| **Workload / credit points** | 3 CP, 90 h<br>• presence (L + EC): 42 h (3 SWH x 14 weeks)<br>• preparation, learning + exercises: 28 h (2 SWH x 14 weeks)<br>• preparation for exam: 20 h |
| **Course language** | English |
| **Responsible for the module, lecturers / Module assignment** | Prof. Dr. Christian Haas<br>Module section / Elective Courses |
| **Compulsory / optional** | Optional |
| **Offered frequency** | Annually / winter semester |
| **Duration / semester** | 1 semester / winter semester (2nd academic year) |
| **ECTS** | 3 CP |
| **Semester Weekly Hours** | (3 semester weekly hours (SWH) /<br>2x lecture (L) + 1x exercise classes (EC)) |
| **Course and examination performance, type of exam** | Partial exam<br>Examination performance: Written exam/oral exam (will be announced by the respective lecturer), graded.<br>Course performance: Successful assessment of exercise classes and/or successful writing of an essay, not graded |
| **Literature** | Will be announced in the respective course. |

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|---|---|
| **Code no.** | 01-03-StEA-V |
| **Module title /** | Statistics and Error Analysis |
| **Assignment to study programmes** | Optional for MSc Space Sciences and Technologies<br>Optional for MSc Environmental Physics<br>Optional compulsory for MSc Physik<br>Optional compulsory for MSc Marine Geosciences<br>Optional compulsory for MSc Technomathematik |
| **Requirements for participation** | None |
| **Content** | Random variables, probability, density and distribution functions, expectation values, covariance and correlation, error propagation, statistical tests |
| **Learning outcome** | The participants have knowledge about statistics, error calculation and data analysis. |
| **Workload /**<br>**credit points** | 3 CP, 90 h<br>• presence (L + EC): 28 h (2 SWH x 14 weeks)<br>• preparation, learning + exercises: 28 h (2 SWH x 14 weeks)<br>• preparation for exam: 34 h |
| **Course language** | English |
| **Responsible for the module, lecturers /**<br>**Module assignment** | Prof. Dr. Reiner Schlitzer<br>Module section / Elective Courses |
| **Compulsory / optional** | Optional |
| **Offered frequency** | Annually / summer semester |
| **Duration / semester** | 1 semester / summer semester (1st academic year) |
| **ECTS** | 3 CP |
| **Semester Weekly Hours** | (3 semester weekly hours (SWH) /<br>2x lecture (L) + 1x exercise classes (EC)) |
| **Course and examination performance, type of exam** | Partial exam<br>Examination performance: Written exam/oral exam (will be announced by the respective lecturer)<br>Course performance: Successful assessment of example classes and/or successful writing of an essay |
| **Literature** | Will be announced in the respective course. |

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|---|---|
| **Code no.** | 01-03-WCom-V |
| **Module title /** | Wireless Communications |
| **Assignment to study programmes** | Optional for MSc Space Sciences and Technologies<br>Compulsory for MSc CIT<br>Compulsory for MSc IKT Optional compulsory for MSc. ME/KT<br>Optional for MSc CMM |
| **Requirements for participation** | Basics of communications technologies, stochastic (digital) signal processing, system theory |
| **Content** | • Mobile Radio Channels: Power Delay Profile, Doppler Spectrum, Jakes-Spectrum, Channel Modelling, Rayleigh-Fading/Rician Channels<br>• Multi-Carrier Transmission: Basics, Ambiguity-Function, F/T-Grid, Principles of CP-OFDM, Detectors for CP-OFDM, PAPR/Crest Factor, Out-of-Band radiation, LTE<br>• CDMA: Principles, spreading sequence design system models, Single-User Machted Filter Bank, Rake Receiver, Multi-User Detection (MF, LS, MMSE), Radio System principles<br>• MIMO: Principles and system model, spatial duplexing, BLAST |
| **Learning outcome** | After this course, the students will have a basic knowledge on wireless communications with the ability to design modern communication systems. In particular, they should be able to:<br>• Model mobile radio channels, apply their expertise to perform analysis of digital wireless transmission<br>• Apply knowledge on the design of modern solutions for mobiles (OFDM, CDMA, MIMO).<br>• Combine existing Matlab-Modules for the simulation of mobile communication systems. |
| **Workload /**<br>**credit points** | 3 CP, 90 h<br>• presence (L + EC): 42 h (3 SWH x 14 weeks)<br>• preparation, learning + exercises: 28 h (2 SWH x 14 weeks)<br>• preparation for exam: 20 h |
| **Course language** | English |
| **Responsible for the module, lecturers /**<br>**Module assignment** | Prof. Dr.-Ing. A. Dekorsy<br>Module section / Elective Courses |
| **Compulsory / optional** | Optional |
| **Offered frequency** | Annually / summer semester |
| **Duration / semester** | 1 semester / summer semester (1st academic year) |
| **ECTS** | 3 CP |
| **Semester Weekly Hours** | (3 semester weekly hours (SWH) /<br>2x lecture (L) + 1x exercise classes (EC)) |
| **Course and examination performance, type of exam** | Module exam<br>Examination performance: Written exam |
| **Literature** | • David Tse, Pramond Viswanath: Fundamentals of Wireless Communications.<br>• J. Proakis: Digital Transmission<br>• Goldsmith: Wireless Communications<br>• Paulraj, Nabar, Gore: Introduction to Space-Time Wireless Communications. |