Universitatea Națională de Știință și Tehnologie Politehnica București
Facultatea de Electronică, Telecomunicații și
Tehnologia Informației

COURSE DESCRIPTION

1. Program identification information

1.1 Higher education institution	**National University of Science and Technology Politehnica Bucharest**
1.2 Faculty	**Electronics, Telecommunications and Information Technology**
1.3 Department	**Electronic Devices, Circuits and Architectures**
1.4 Domain of studies	Electronic Engineering, Telecommunications and Information Technology
1.5 Cycle of studies	Masters
1.6 Programme of studies	Microsystems

2. Date despre disciplină

2.1 Course name (ro) (en)				Microsisteme electromecanice pentru radiofrecventa			
2.2 Course Lecturer				Prof.dr.ing. Dan NECULOIU			
2.3 Instructor for practical activities				Prof.dr.ing. Dan NECULOIU			
2.4 Year of studies	2	2.5 Semester	I	2.6. Evaluation type	E	2.7 Course regime	Ob
2.8 Course type		DA	2.9 Course code	UPB.04.M3.O.03-15		2.10 Tipul de notare	Nota

3. Total estimated time (hours per semester for academic activities)

3.1 Number of hours per week	4	Out of which: 3.2 course	2.00	3.3 seminary/laboratory	2
3.4 Total hours in the curricula	56.00	Out of which: 3.5 course	28	3.6 seminary/laboratory	28
Distribution of time:					hours
Study according to the manual, course support, bibliography and hand notes Supplemental documentation (library, electronic access resources, in the field, etc) Preparation for practical activities, homework, essays, portfolios, etc.					65
Tutoring					0
Examinations					4
Other activities (if any):					0

3.7 Total hours of individual study	69.00
3.8 Total hours per semester	125
3.9 Number of ECTS credit points	5

4. Prerequisites (if applicable) (where applicable)

4.1 Curriculum	Electronic Devices, Microwave, Electronic Circuits, Active Microelectronic Devices Modelling
4.2 Results of learning	Basic knowledge of physics, electronic devices, electronic circuits, modelling, electromagnetic field propagation, transmission lines

5. Necessary conditions for the optimal development of teaching activities (where applicable)

5.1 Course	The classes will be taught in a classroom equipped with an overhead projector and computer and all necessary facilities for on-line teaching.
5.2 Seminary/ Laboratory/Project	Compulsory presence at laboratory classes, according to current PUB regulations. Follow the midterms and final term for the project.The project classes will be held in a classroom equipped with a computer, overhead projector and all necessary facilites for online teaching. Freeware software packages will be used (CST Student Edition, Sonnet Lite). The intermediary and final project deadlines must be respected.

6. General objective *(Reffering to the teachers' intentions for students and to what the students will be thought during the course. It offers an idea on the position of course in the scientific domain, as well as the role it has for the study programme. The course topics, the justification of including the course in the currcula of the study programme, etc. will be described in a general manner)*

The subject is studied in the frame of the „Microsystems” specialization and endeavors to familiarize the students with the main approaches, models and explanatory theories of the radiofrequency and microwave domain area, used to solve practical applications and problems, relevant to the stimulation of the learning process of the students.

The specific thematic of the subject matter consists in the operating principles of microwave micro-electro-mechanical sustems. The students become familiar with the influence of the technological development on the innovation in the field of the course, including the influence of nanotechnologies in the semiconductor layer growth and nanolithography fields.

Following an overview of the propagation on different transmission media, particularly planar transmission lines used in MIC and MMIC, RFMEMS components based on micro-switches with electrostatic actuation will be presented. Electrostatic and mechanical modeling and high-frequency equivalent circuits are described in detail. 3D numerical modeling techniques using electromagnetic simulation software packages are introduced.

Manufacturing technologies using surface micromachining and bulk micromachining are presented in detail. The main applications in the field of microwaves are introduced:high-performance filters and antennas, phase shift circuits and variable attenuators, RFMEMS front-end reception microsystems.

The basic principles of RFMEMS with volume and bulk acoustic waves are presented, with an opening towards filtering and propagation applications

All these topics contribute to the transmission/creation of a general overview for the students regarding the methodological and procedural landmarks of the field and represent a solid starting point for the development of skills in new fields (for example 6G technologies, which imply an increase in operating frequencies up to the millimeter wave range, 30 – 300 GHz).

7. Competences *(Proven capacity to use knowledge, aptitudes and personal, social and/or methodological abilities in work or study situations and for personal and proffesional growth. They refflect the empolyers requirements.)*

Specific Competences	Demonstrates basic and advanced knowledge in the field of „Microsystems" operating in the frequency range 1 – 300 GHz. Uses the appropriate knowledge, methods and software tools for the implementation of engineering solutions in the field. Identifies solutions for a specific task. The student will acquire the following skills: C1. Use of the fundamental elements regarding the operation, modeling, design and applications of microwave and millimeter wave micro-electro-mechanical systems. C2. Knowledge of the structure, operation and modeling of solid-state semiconductor devices and ability to identify the main circuit applications. C3. Knowledge of the structure and modeling of planar transmission lines used in integrated microwave circuits. C4. Use of advanced software tools for the electromagnetic simulation of planar circuit passive blocks. C5. Design of RFMEMS using advanced analytical and numerical techniques. C6. Modeling of high-frequency piezoelectric devices. C7. Oral and written communication in Romanian: use of field specific scientific vocabulary for efficient written and oral communication C8. Oral and written communication in a foreign language (English): demonstrates an understanding of the field specific vocabulary, as well as the fact that part of the English terms are included in the DEX.
Transversal (General) Competences	CT1. Adapting to new technologies, professional and personal development, through continuous learning by using printed documentation sources, specialized software tools and electronic resources in Romanian and English. CT2. Teamwork and efficient communication through coordinated effort with others for medium level problem solving, particularly in the on-line environment CT3. The ability to think in scientific terms, to independently search and analyze data, as well as form and present conclusions/identify solutions. CT4. Analysis and synthesis capacity: can present in a synthetic way the acquired knowledge, as a result of a systematic analysis process, according to the project presentations. CT5. Respects the academic ethic principles: during their documentation activities the student correctly cites the bibliographic sources used in the reports of the various project stages.

8. Learning outcomes *(Synthetic descriptions for what a student will be capable of doing or showing at the completion of a course. The learning outcomes reflect the student's acomplishments and to a lesser extent the teachers' intentions. The learning outcomes inform the students of what is expected from them with respect to performance and to obtain the desired grades and ECTS points. They are defined in concise terms, using verbs similar to the examples below and indicate what will be required for evaluation. The learning outcomes will be formulated so that the correlation with the competences defined in section 7 is highlighted.)*

Knowledge	*The result of knowledge aquisition through learning. The knowledge represents the totality of facts, priciples, theories and practices for a given work or study field. They can be theoretical and/or factual.* • The development of the field is marked by the harmonious interweaving of technological development with the invention of new devices (for example those based on different fields of physics: mechanical, electrostatic, electromagnetic, piezoelectric) and advanced modeling including that based on numerical techniques (favored by the increase in system performance calculation and the implementation of advanced software packages). • The field-specific notions assimilated by students combine the knowledge related to microwave devices (principles of operation, modeling, characterization) with those related to the propagation on planar transmission lines and the propagation of bulk and surface acoustic waves.
Skills	*The capacity to apply the knowledge and use the know-how for completing tasks and solving problems. The skills are described as being cognitive (requiring the use of logical, intuitive and creative thinking) or practical (implying manual dexterity and the use of methods, materials, tools and intrumentation).* • Graduates of this discipline can select relevant information not only for electro-mechanical microwave microsystems, but also for devices based on the piezoelectric effect for the generation of acoustic waves. • Graduates are encouraged to use specific principles in order to apply very high frequency microsystems. • Graduates are encouraged to work productively in a team, deepening some concepts and project themes. • Graduates must write scientific reports and are encouraged to present their achievements in public sessions in front of their colleagues. • Graduates are encouraged to develop project themes within the research activities for the dissertation and to experimentally verify identified solutions. • Graduates of this discipline are encouraged to solve practical applications, in course exercises or individual homework assignments. • Identifies solutions and develops project resolution plans. Formulate conclusions based on the results obtained.

Responsability and autonomy	*The student's capacity to autonomously and responsably apply their knowledge and skills.* • The students are encouraged to select and analyze bibliographic references pertinent to the subject matter • The students are encouraged to follow the academic ethic guidelines by accurately citing the references used in the project reports. • The students are encouraged to demonstrate their receptivity to new learning settings, including on-line, by being invited and involved in presenting their original rezults in student sessions and conferences. • The students are encouraged to collaborate with their colleagues and their tutors. • The students are encouraged to demonstrate autonomy in organizing their learning framework or problem solving approach, in the frame of the project HomeWorks. • The students are encouraged to show social responsibility by actively participating in the student social life and academic community. • The students are encouraged to promote new solutions, corresponding to the field of study, by providing papers and being encouraged to continue their work in the frame of a Master Thesis. • The students are encouraged to acknowledge the value of their contribution in the field of engineering by identifying sustainable solutions for existing social and economical problems (social responsibility). • The students are encouraged to analyze the technological impact of the proposed solutions in their field on the environment for durable development. • The students are encouraged to demonstrate management skills for real life scenarios such a time management for collaborative work.

9. Teaching techniques *(Student centric techniques will be considered. The means for students to participate in defining their own study path, the identification of eventual fallbacks and the remedial measures that will be adopted in those cases will be described.)*

Starting from the analysis of the learning characteristics of the students and their specific needs, the teaching process will explore teaching methods based on exposition (lecture), as well as conversation-interactive methods based on learning models using direct and indirect exploration of reality (experiment, demonstration, modeling), and also action based methods, such as exercise, practical activities and problem solving.

During the teaching activities, lectures based on Power Point presentations or animations will be used. These will be provided to students. Each lecture will begin with a recap of the previous lectures, particularly the last one.

The presentations use images and diagrams, making the information easy to understand and assimilate.

This subject covers information and practical activities meant to assist the students in their learning endeavors and development of optimal collaboration and communication relationships in an environment promoting learning by discovery.

Active listening and assertive communication skills will be practiced, as well as feedback mechanisms, as means of behavioral regulation in diverse situations and adapting the pedagogical endeavor to student learning requirements.

10. Contents

COURSE

Chapter	Content	No. hours
1	Introduction. The RFMEMS field. RFMEMS advantages. RFMEMS materials. Microsensors and microactuators for MEMS.	2
2	RFMEMS fabrication. Metallic and dielectric thin film deposition. Photolithography. Volume micromachining (etch techniques, wet etching, dry etching). Surface micromachining. Technologic steps for dielectric membranes fabrication.	4
3	RFMEMS design basics. Introduction. Mechanic microstructures modelling (Static and dynamic modelling; High frequency equivalent circuit models; Electromagnetic modelling). Membrane supported RFMEMS modelling. Nonlinear design of RFMEMS.	4
4	RFMEMS switches. Introduction. Classification and integration with planar transmission lines. Basic parameters of switches. Switches with resistive contact. Switches with capacitive contacts. Electromechanical design of RFMEMS switches. Electromagnetic design of switches.	6
5	Micromachined filters and antennas. Basic principles. Membrane supported coupled lines filter design. Reconfigurable filters. Double folded slot antennas. Yagi-Uda antennas. Reconfigurable antennas. Future development directions.	4
6	RFMEMS microsystems. Introduction. Basics of the receiving microsystems design. Double folded slot antenna receiver fabricated by silicon micromachining. Double folded slot antenna receiver fabricated by GaAs micromachining. Passive imaging mm-wave sensor. RFMEMS phase shifters.	4
7	Piezoelectric RFMEMS devices. Basic principles. FBAR devices for microwave applications. SAW devices fabricated using nanolithography. Piezoelectric filters and sensors.	4
	Total:	

Bibliography:

D.Neculoiu, “Structuri avansate de microunde realizate prin microprelucrare”, Editura Printech, 2005

G.M.Rebeiz, ”RF MEMS: Theory, Design and Technology”, John Wiley & Sons, 2003

H.J. De Los Santos, ”RF MEMS Circuit Design for Wireless Communications”, Artech House, 2002

Ken-ya Hashimoto, “Surface Acoustic Wave Devices in Telecommunications” Springer-Verlag Berlin Heidelberg 2000, Springer, 2000.

A.Qun Liu, "RF MEMS Switches and Integrated Switching Circuits, Springer Science+Business Media, LLC 2010

J.Iannacci, "Practical Guide to RF-MEMS", Wiley-CH, 2013

David Morgan, “Surface Acoustic Wave Filters With Applications to Electronic Communications and Signal Processing”, 2nd Edition, Elsevier, 2007.

LABORATORY		
Crt. no.	**Content**	**No. hours**
1	Basic principles of experimental characterization in the field of microwaves and millimeter waves. Description of basic equipment.	4
2	The Vector Network Analyzer (VNA): SOLT calibration techniques. S parameter measurements	4
3	Experimental characterization of RFMEMS	6

	Total:	14
PROJECT		
Crt. no.	**Content**	**No. hours**
1	Defining the project theme. Configurations of micro-switches for microwaves for different transmission media. Analytical modeling for preliminary design.	6
2	3D numerical modeling techniques for electromagnetic analysis using the CST Microwave Studio package – Student edition	6
3	Report. Presentation, grading	2
	Total:	14

Bibliography:

D.Neculoiu, “Structuri avansate de microunde realizate prin microprelucrare”, Editura Printech, 2005
D.Neculoiu, Al.Muller, “Dispozitive si circuite de microunde – Aplicatii”, Editura Printech, 2001
CST manual de utilizare (2022)

11. Evaluation

Activity type	11.1 Evaluation criteria	11.2 Evaluation methods	11.3 Percentage of final grade
11.4 Course	Basic understanding of main notions and design equations	Multiple choise examination	50
11.5 Seminary/laboratory/project	Lab activity	Grading of the report and active participation	10
	1th project assignment	Grading of the report and presentation	20
	2nd project assignment	Grading of the report and presentation	20
11.6 Passing conditions			
50% from maximum of 100			

12. Corroborate the content of the course with the expectations of representatives of employers and representative professional associations in the field of the program, as well as with the current state of knowledge in the scientific field approached and practices in higher education institutions in the European Higher Education Area (EHEA)

- The high frequency electronics is very important in the field of devices, active and passive circuits and systems with applications in telecommunications, radars, test equipment, sensors, RFID technologies, 4G and 5G equipment etc. By performing the coursework, the students develop problem solving abilities and are able to improve the current state of these fields.

- While developing the materials for this subject, knowledge presented in the literature as well as the tutors own research, published in international peer reviewed journals and conferences were taken into account.

- The course has a similar content to that presented at courses held at prestigious universities from the US and Europe.

The subject provides the students with skills fulfilling employer requirements in the professional fields described above.

Date	Course lecturer	Instructor(s) for practical activities
17.10.2024	Prof.dr.ing. Dan NECULOIU	Prof.dr.ing. Dan NECULOIU

Date of department approval	Head of department
31.10.2024	Prof. Dr. Claudius DAN

Date of approval in the Faculty Council	Dean
01.11.2024	Prof. Dr. Mihnea Udrea