Warsaw University of Technology

COURSE OFFERED IN THE DOCTORAL SCHOOL

Code of the course	4606-ES-00000BC-0061	Name of the course	Polish	Synteza filtrów elektrycznych	
			English	Synthesis of electric filters (SoFE)	
Type of the course	Special courses				
Course coordinator	Dr hab. inż. Adam Abramowicz				
Implementing unit	WEiTI	Scientific discipline / disciplines*	information and communication technology, automation, electronic, electrical engineering and space technologies		
Level of education	Doctoral studies	Semester	Winter/~~Summer~~		
Language of the course	English				
Type of assessment:	Graded credit	Number of hours in a semester	45	ECTS credits	3
Minimum number of participants	10	Maximum number of participants	20	Available for students (BSc, MSc)	~~Yes~~/No

Type of classes		Lecture	Auditory classes	Project classes	Laboratory	Seminar
Number of hours	in a week	2	0	1	0	0
	in a semester	30	0	15	0	0

* does not apply to the Researcher's Workshop

1. Prerequisites

Basic knowledge of circuit theory.

2. Course objectives

The aim of this course is to introduce students to the fundamentals of circuit analysis and synthesis if electric filters realized as passive circuits using lumped elements, transmission lines and resonators. Solving practical problems students gain knowledge on filter design.

3. Course content (separate for each type of classes)

Lecture

Frequency characteristics of filters. Transmittance. Amplitude and phase characteristics. Group delay. Conditions of physical realizability. Reaktance transformations. Freqency scaling and normalization. Immitance inverters. Impedance matching in assumed frequency band.

Filter approximations. Introduction to approximation theory. Types of filter characteristics: Butterworth, Chebyshev, elliptic, Gauss, Achiezer-Zolotarev etc.

Reactance circuit synthesis. Foster, Cauer and Darlington methods. Influence of lossy elements. Ladder filters. Computer design of filters.

Lumped element realization of filters. Influence of frequency on lumped elements. Realization of inductances. Losses and filter parameters: bandwidth, group delay. Quality factor of different elements.

Synthesis of direct coupled resonant circuits. Coupled resonant circuits. Magnetic, electric and mixed couplings. Eigenfrequency method.

Realization of filters for LF, RF and microwave frequency range. Microwave resonators and their parameters**.** Transmision lines. Richards transformatin. Microwave immitance inverters. Planar filters (including HTS filters). Diplexers and mutiplexers. Filter banks. Switched filters. Band-stop filters. Multibandthih filters.

Pulse transmission trough filters. Phase correctors. Linear phase filters.

Filters in electronic systems. Influence of filter parameters of receivers and transmitters. Distortions and interference.

Modern trends in filter realization. SAW, BAW, LTCC filters

Project

The project it to design a filter for a given frequency characteristic. The project will be based on analysis and simulation in high frequency structue symulator Microwave Office. The symulator can be used for simulations and optimization of structures consisting of lumped elements, distributed lements (like transmission lines) as well as synthesis of selected filters. Projects will be realized individually or in groups. The results of the projects will be

presented at the end of semester in the form of short presentations (5-10 min.) given in front of all course attendees.
Project examples:

1. Band-stop filter with 10% relative bandwidth at 100 MHz center frequency.
2. Band-pass filter with conatant group delay within 20% relative bandwidth at 500 MHz.
3. Anti-interference filter for 50 Hz.
4. Band-pass filter with two transmission zeroes above passband, center frequency of 1 GHz and relative bandwidth of 3 %.
5. Planar filter with dual mode resonators at 3 GHz.

4. Learning outcomes

	Learning outcomes description	Reference to the learning outcomes of the WUT DS	Learning outcomes verification methods*
Knowledge			
K01	Student has knowledge on filter approximations	SD_W2, SD_W3	Results of the test and project
K02	Student has knowledge on lowpass prototype filters and frequency transformations	SD_W2, SD_W3	Results of the test and project
K03	Student has knowledge on filter realizations at different freuency bands	SD_W2, SD_W3	Results of the test and project
K04	Student has knwoledge on properties of real lumped elements, transmission lines and resonator used in filters	SD_W2, SD_W3	Results of the test and project
K05	Student has knowledge on synthesis and design methods of electric filters	SD_W2, SD_W3	Results of the test and project
Skills			
S01	Student is capable to analyze and synthesize lumped element filters	SD_U1	Results of the written test and project evaluation
S02	Student is capable to design filters in different frequency bands	SD_U1, SD_U5	Results of the written test and project evaluation
S03	Student knows how to use „Microwave Office”	SD_U1	Project evaluation
Social competences			
SC01	The exchange of experiences and effective practice in team work	SD_K1, SD_K4	Results of the project evaluation
SC02	Experience in making a presentation in front of the audience and defending the presented results	SD_K1	Result of the presentation evaluation

*Allowed learning outcomes verification methods: exam; oral exam; written test; oral test; project evaluation; report evaluation; presentation evaluation; active participation during classes; homework; tests

5. Assessment criteria

After the middle of the semester the test concerning filter theory will be held. Last classes will be devoted to presentations of projects. The test The final result will be a sum of the test result and the project result. Na końcu semestru istnieje możliwość poprawy kolokwium. During the course up to 100 point can be scored. The test can

bring up to 40 points. The score for the project is up to 50 point. The remaining 10 points can be scored for the project presentation and for being active. To get course credit for satisfactory grade a student should score at least 50 points.
Grading scale:
<50 points.: grade 2
50-59 points: grade 3
60-69 points.: grade 3,5
70-79 points: grade 4
80-89 points: grade 4,5
90-100 points: grade 5

6. Literature

Basic References:
[1] Temes G. C., Mitry S. K. (red.): *Teoria i projektowanie filtrów*, WNT, Warszawa 1978.
[2] Matthaei G. L., Young L., Jones E. M. T.: *Microwave filters impedance matching networks and coupling structures*, McGraw–Hill, New York 1964
[3] Bellert S. T.: *Zarys teorii syntezy liniowych układów elektrycznych*, Wydawnictwa Politechniki Warszawskiej, Warszawa 1964.
[4] Izydorczyk J., Konopacki J.: *Filtry analogowe i cyfrowe*, Wydawnictwo Pracowni Komputerowej Jacka Skalmierskiego, Katowice 2003.
[5] Abramowicz A.: *Filtry mikrofalowe w systemach radiokomunikacyjnych*, OWPW, Warszawa 2008
[6] Dobrowolski J.: *Technika wielkich częstotliwości*, Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa 2001
Additional references for RF filters:
[1] Hunter I: *Theory and Design of Microwave Filters*, IEE Electromagnetic Waves Series, 2001
[2] Cameron R. J., Kudsia Ch. M., Mansour R.: *Microwave Filters for Communication Systems*, Wiley 2018
[3] Jia-Sheng Hong: *Microstrip Filters for RF / Microwave Applications*, Wiley 2011

7. PhD student's workload necessary to achieve the learning outcomes**

No.	Description	Number of hours
1	Hours of scheduled instruction given by the academic teacher in the classroom	45
2	Hours of consultations with the academic teacher, exams, tests, etc.	5
3	Amount of time devoted to the preparation for classes, preparation of presentations, reports, projects, homework	30
4	Amount of time devoted to the preparation for exams, test, assessments	10
	Total number of hours	**90**
	ECTS credits	**3**

** 1 ECTS = 25-30 hours of the PhD students work (2 ECTS = 60 hours; 4 ECTS = 110 hours, etc.)