Ultrasound in Medicine

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The course contains the fundamentals of the ultrasound in medical imaging including physical nature of ultrasonic waves propagating in tissue like materials and ultrasonic sources used. Properties of isotropic media will be described. The basic parameters like impedance, energy, intensity and radiation pressure will be addressed. Next we will discuss the reflection and refraction, attenuation, absorption and scattering. Field calculation will be explained on the basis of Rayleigh-Sommerfeld diffraction equations, Rayleigh integral and impulse response will be discussed. The important part of ultrasonic imaging is related to the different transducers - linear, phase arrays and specific beam forming including synthetic apertures. Contrast agents and nonlinear acoustic based on KZK equation will be considered. The course is dedicated to the students being interested in medical imaging and bioengineering.

Main topics:

1. Introduction
2. Physics of ultrasounds: wave equations, Helmholtz equation, solutions to the wave equation, reflections, pulse functions, attenuation, dispersion.
3. Different scanning ultrasonic pulses: bandpass signals, reflections, scattering, scattering statistical properties, speckle noise.
4. 2D imaging: Fresnel and Fraunhofer approximations, derivation of the point spread function, Huygens' principle, wave propagation - diffraction (focusing), as in optics.
5. Basic of the ultrasonic transducers: flat and focused transducers – O'Neil's formula.
6. Array systems: linear, convex and phase arrays. Anatomy of the ultrasonic beam beamforming, dynamic focusing, sampling – side lobes and grating patterns.
7. Ultrasonography scanning systems: block diagrams and signal analysis.
8. Synthetic apertures: basic theory and designs.
9. Encoded ultrasonography: resolution/penetration, linear frequency modulation – chirp, Barker codes, Golay codes, compression in time and frequency domain.
10. FPGA based novel ultrasonic systems.
11. Introduction to nonlinear ultrasonography: nonlinear wave propagation, harmonic imaging, pulse inversion imaging.
12. Contrast agents in ultrasonographic imaging.
13. Doppler blood flow measurements: continuous wave CW Doppler, pulse wave PW Doppler, blood flow spectrum analysis, color coded flow mapping, Power Doppler

The total number of lecture hours: 30, laboratory exercises: 6 hours, self-teaching: 80, direct tutoring and consultations: 20 hours.

ECTS Points: 5