Planar X-Ray Imaging - I: Basics (1)

Sketch the basic imaging setup.

How is X radiation generated?

What are typical values for tube voltage and photon energy?

Which types of electron-target interaction are relevant?

Explain the anode-heel effect.

How is unfiltered bremsstrahlung distributed over frequency?

Sketch the spectral distribution of diagnostic X radiation qualitatively.

Which parameters determine the efficiency of X-ray tubes?

What are desirable properties of the anode target material? Give an example.

Describe the function of the cathode.

How is the current density determined?

What are suitable cathode materials?

What is the relevance of the focal spot?

How does diagnostic X radiation interact with tissue?

Which phenomena are responsible for attenuation?

Explain the photoelectric effect.

What is a "K-edge"?

What is "Compton-Scattering" and "Rayleigh-Scattering"?

Explain the beam hardening effect.

Which parameters determine the exposure of an X-ray image?

Sketch the basic diagram of an X-ray generator.

Which methods for tube switching do you know?

For given tube limits, how can wrong exposures be prevented?

What is "kerma"?

2. Planar X-Ray Imaging - II: Detectors (1)

Explain X-ray detection by screen-film systems.

What is the "optical density"?

Sketch a densitometric curve (Schwärzungskurve) qualitatively.

Discuss the pro's and con's of a steep curve.

What are selection criteria for luminescent materials?

What is the influence of the screen thickness?

Explain the principle of computed radiography (CR).

What is X-ray fluoroscopy?

Sketch and explain the detection chain.

Describe the basic build-up and operating principle of an XRII.

Which material is often used for the entrance screen, and how is it matched to typical X radiation?

How is it matched to the photo cathode?

What is "vignetting"?

Describe the principle of flat panel solid state detectors.

What is an often used scintillator, and what are its relevant properties?

Describe the effects of scatter on the X-ray image quality.

What is a typical percentage of scatter in diagnostic X-ray imaging?

What is its effect on image contrast?

Sketch an ASG, and identify the relevant components.

Explain the ASG "Selectivity".

How does an ASG improve contrast?

Sketch the basic geometry of planar X-ray imaging.

Identify the relevant components, and derive the magnification.

What are purpose and principle of dual energy X-ray imaging?

Which physical properties can be detected by new x-ray imaging systems?

What is the advantage of phase contrast imaging?

3. Image Quality and System Analysis (1)

What is a (2D) LSI system?

How is transmission over an LSI system described?

Give eigenfunctions, and derive transfer function (and Fourier transform).

What are the parameters specifying a 2D sine wave?

What are OTF and MTF?

How can the MTF of an X-ray imaging system be measured?

What is the "pre-sampling MTF"?

How can it be measured?

What is a discrete-space 2D LSI system?

(Explain and write down the 2D discrete convolution.)

(Write down and explain the 2D discrete-space Fourier transform.)

How is the number of X-ray quanta generated by the X-ray tube distributed? Why?

How are mean value and variance of a Poisson distribution related?

What are the major factors determining the mean number of X-ray quanta generated?

Describe the SNR at input and output of an efficiency stage.

What does "noise-equivalent quanta" mean?

How is the influence of SNR on detail perception evaluated in X-ray imaging?

Sketch a detector diagram including an efficiency stage, an LSI system, and noise sources.

For a homogeneous exposure, describe the spectrum of the incoming quantum noise, and how it changes when passing through the system.

Derive the input SNR for a low-amplitude sinusoid of given frequency, which is superimposed to homogeneous signal.

What is the output signal of the detector?

What is the NPS at the output?

How is the frequency-resolved DQE of a detector system defined?

What is the relevance of the DQE as an imaging quality criterion, especially compared to the MTF? Which factors influence the DQE of an XRII/CCD-system?

Sketch qualitatively.

4. Computed Tomography (1)

What is the aim of CT?

Which quantity is measured?

In which units is it represented?

Describe the imaging principle.

Explain "sinogram" and "Radon transform".

Sketch CT scanners of 1st - 4th generation.

Explain "Multislice" and "resolution - speed - trade-off"

What is X-ray tube focus switching?

How are the projections detected?

Derive the Fourier slice theorem, and explain its relevance for CT imaging.

Describe the Fourier reconstruction approach.

What are its practical shortcomings?

(Describe the principle and the different steps of FBP.)

Which data are filtered?

What is the mathematically "ideal" filter?

Why can't it be realized?

How are filters practically realized?

How are they discretized? Give examples.

Describe the discrete implementation of FBP, and the interpolation of projections.

How can FBP be extended to fan-beam geometries?

Describe helical CT, multislice CT, and cone-beam CT.

What are typical CT imaging artifacts?

How do they usually appear in the reconstructed images?

Explain partial volume artifacts.

Sketch the scatter geometry and antiscatter-grids?

Explain CT detector developments.

What are the new CT trends?

Sketch the main idea of iterative reconstruction.

What is meant by "dual kV" and energy resolving CT?

5. Magnetic Resonance Imaging (1)

Describe the principle of MRI.

Sketch the main components of an MR System.

Which safety related issues can be attributed to these subsystems?

What are preventative measures for safety in MR?

What are the two dominant designs and how are the main components arranged in the two main system types?

When (approx) was MRI established as a clinical modality?

Can you mention typical system parameters?

What are typical quantities measured in MR?

Which two standard contrast types are used in MR imaging, what is the underlying mechanism, and why do they produce different image types?

Can you give approx. values for T1 and T2 in tissue?

Describe the precession of a magnetic pegtop in a static external magnetic field.

What are "gyromagnetic ratio" and "Lamor-frequency"?

How can the Lamor-frequency be made dependent on the z-coordinate?

Explain the "flipping" of a classical magnetic pegtop by a rotating external magnetic field at resonance.

Which signal is picked up by antenna coils for MRI?

Sketch the receiver principle.

Quantum mechanical view: (What are the quantum mechanical properties of angular momentum and magnetic dipole moment of proton spins?)

Which states are possible in a static external magnetic field, and how are they populated in thermal equilibrium?

How is an externally observable macroscopic magnetization generated?

What happens in a transversal magnetic field at resonance?

How are longitudinal and transversal magnetization influenced?

Describe spin-lattice relaxation and spin-spin relaxation.

What is meant by "free induction decay" and "inversion recovery"?

Which phenomena influence the observed decay of transversal magnetization?

What do the Bloch equations describe?

(Write down the basic Bloch equation (relating the change of the magnetic dipole moment, the dipole moment itself, and the external magnetic field).)

(Describe the relaxation processes after a short transversal pulse.)

Explain the concept and need for "rephasing" and the two basic principles of achieving this.

Sketch the saturation recovery and inversion recovery pulse sequences together with the relaxation processes.

Sketch and explain spin echo sequences and gradient echo sequences.

What are the repetition time TR and the echo time TE?

Describe the principles of slice selection in tomographic reconstruction.

How are the x- and y-coordinates encoded?

What is k-space?

How can a slice be reconstructed?

What is the role of field gradients?

Which system parameters need to be adjusted (and to what typical level) for (T1, T2, PD) weighted MRI for saturation recovery?

Why do B1 shading effects occur (and why are they stronger at higher B0 field strengths)?

What can be done about that?

6. Imaging in Nuclear Medicine (1)

What is the goal of nuclear imaging?

Name the two basic imaging principles in NM.

What are radiopharmaceuticals and what do you do with them?

Describe the relevant properties of atom nuclei.

What are isotopes?

Why are certain nuclei unstable and what happens then?

Which types of radiation are emitted in radioactive decay, what are typical speeds, energies?

Describe the law governing radioactive decay, and explain "half life".

Give examples of clinical radionuclides.

Why are they not found in nature?

How can they be produced?

Describe what happens in a scintillation detector.

What quantity is measured?

Describe planar scintigraphy.

Why is a collimator needed in scintigraphy and SPECT?

Which geometrical properties define collimator resolution and what are the design conflicts?

Give some approximate values for typical collimator resolution.

How can the detection of scattered quanta be reduced?

What is the principle of the Anger-camera?

Sketch and describe the principle of SPECT

Typical Resolution?

Why are elliptic orbits used?

Why would you use more than one camera, and why not more than 2 or 3?

What are the main Imaging error sources in SPECT?

Why is attenuation correction needed?

Sketch and describe a PET setup.

Which particles are emitted by the decaying radionuclides, and what radiation is measured?

Which typical half lives do the isotopes have in PET?

Can you indicate approximate injected activity for a PET study?

Which type of detectors are used?

How are images reconstructed conceptually?

Why are no collimators necessary?

Which mechanisms lead to Imaging errors?

Why is attenuation correction needed and how can this be performed?

7. Medical Ultrasound Imaging (1)

Physics of sound wave:

Describe the velocity of vibrating particles in materials!

Which is the analogue of the acoustic intensity compared with the electrical physics?

What is the reason of the application of ultrasound gel?

Dilemma of ultrasound signal:

What is the reason of the dilemma of ultrasound signal?

How is the trade-off resolution solutions?

Explain "Reflection" and "Transmission" and what does it mean in practical imaging?

Sketch an ultrasound system with the signal path.

What is the specialty of the amplifier and why is this necessary?

Ultrasound transducer:

Describe the piezoelectric effect of certain ferroelectric ionic crystals!

Echo pulse:

How to determine both the axial and lateral resolution of echo pulse method?

How to realize the beam forming phased array and how does it work?

Noise and artifacts:

How many types and describe each of them?

How to improve images when artifacts are visible (different artifacts)?

Imaging modes:

How many types and how does it work?

Doppler effect:

How can be the Doppler frequency shift derived?

Describe roughly through the wave characters the functionality of the PW Doppler!

How is the principle of color Doppler effect?

3D imaging:

Describe the acquisition technique for 3D US imaging?

8. Optical Coherence Tomography

Describe or sketch the basic principle of an optical interferometer.

How is a cross sectional image obtained in OCT?

Why is OCT especially useful in ophthalmology (eye diagnosis)?

Which two basic issues in optical access to the eye are overcome by OCT?

Can you mention typical wavelengths for OCT?

Speed and resolution? over the three generations?

Which technology jumps enabled these steps?

9. Clinical applications and Trends

What are the main pro´s and con´s of each imaging modality?

Compare Modality A with Modality B [choose: XR, CT, US, MR, PET, OCT] by the following parameter [choose: Spatial Resolution x,y,z, 2D/3D, Time resolution, Radiation exposure/Safety, Contrast mechanisms, main artifacts]

Which Imaging Modalities are typically used for which clinical question?

Name examples for multimodality Imaging devices.

Give a few examples of current clinical trends and innovations in medical imaging.