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Intraoperative differentiation of normal and edematous brain tissue from meningioma by quantitative sonography

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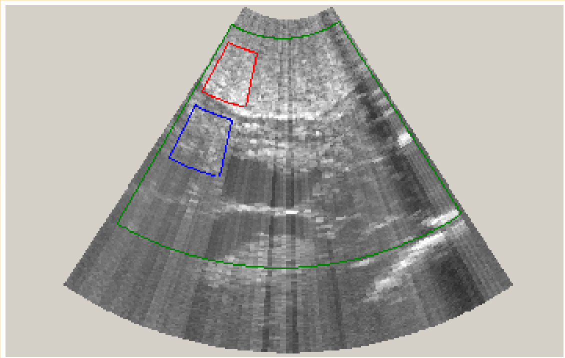
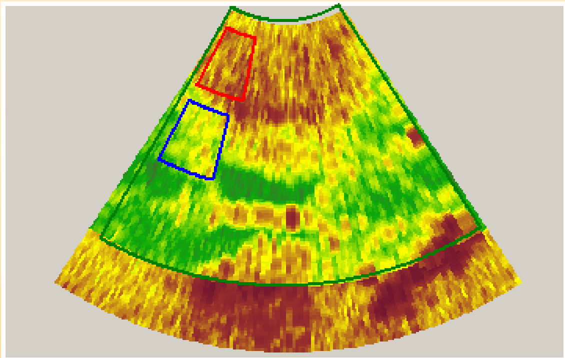
Topics

- Motivation
- Data acquisition
- Parameter extraction
- Results
- Conclusions and Summary





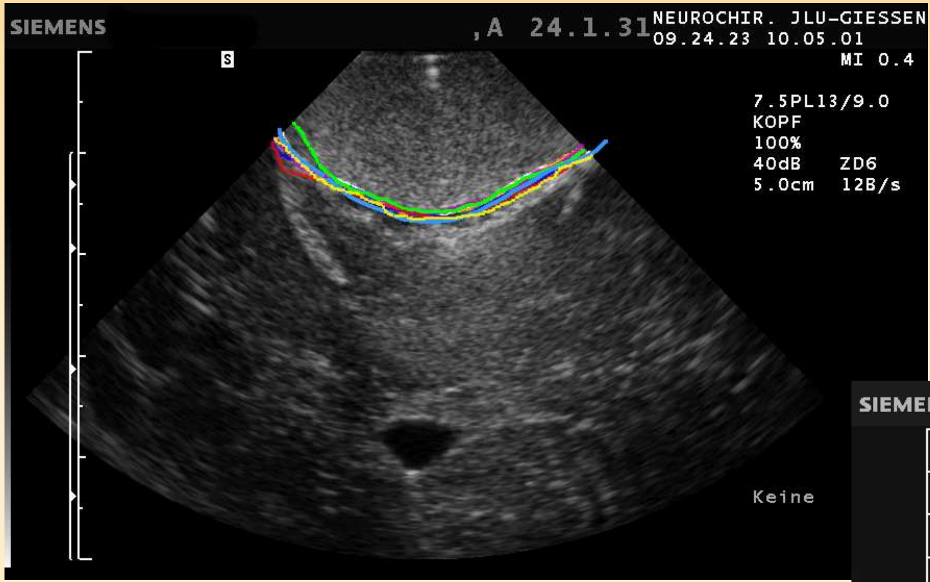
Motivation

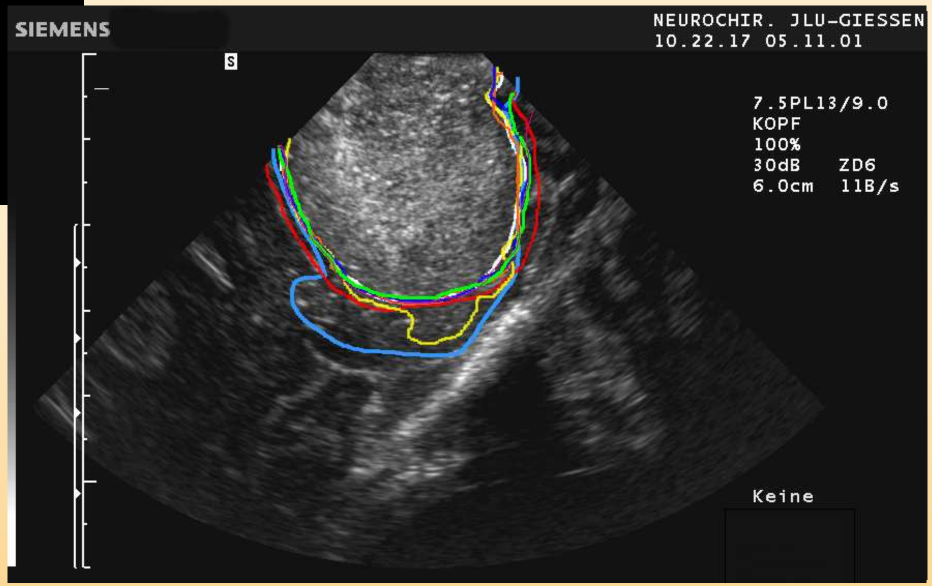
Goals of intraoperative ultrasonography in neurosurgery:

- **localization**
- **resection control**
- **navigation of burr hole procedures and endoscopes, neuronavigation**
- **neurovascular examinations**
- **quantitative sonography and parametric imaging**

?

Interpretation of sonographic images





courtesy of A. Jödicke, Neuro-surgical Clinic, Justus-Liebig-University, Giessen, Germany

Parametric imaging

Conventional B-mode – contrast depends on <u>echo amplitude</u>

- morphology
- biometry (distance, area, volume, angle)
- qualitative access of texture

Parametric image – contrast generated by <u>tissue specific parameters</u>

- tissue state and function
- quantitative data
- morphology

Parametric imaging: tissue specific parameters

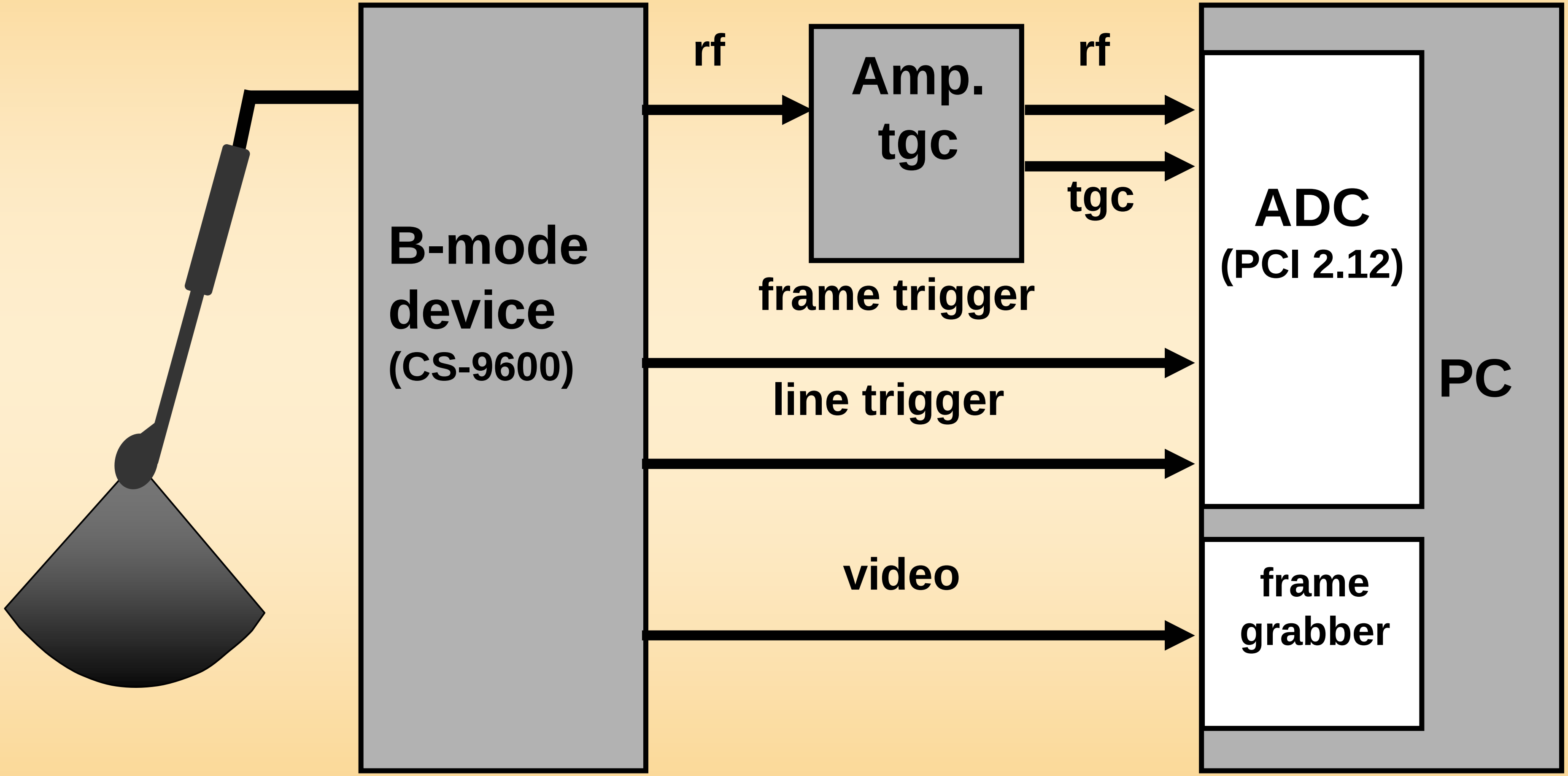
➲ texture parameters:

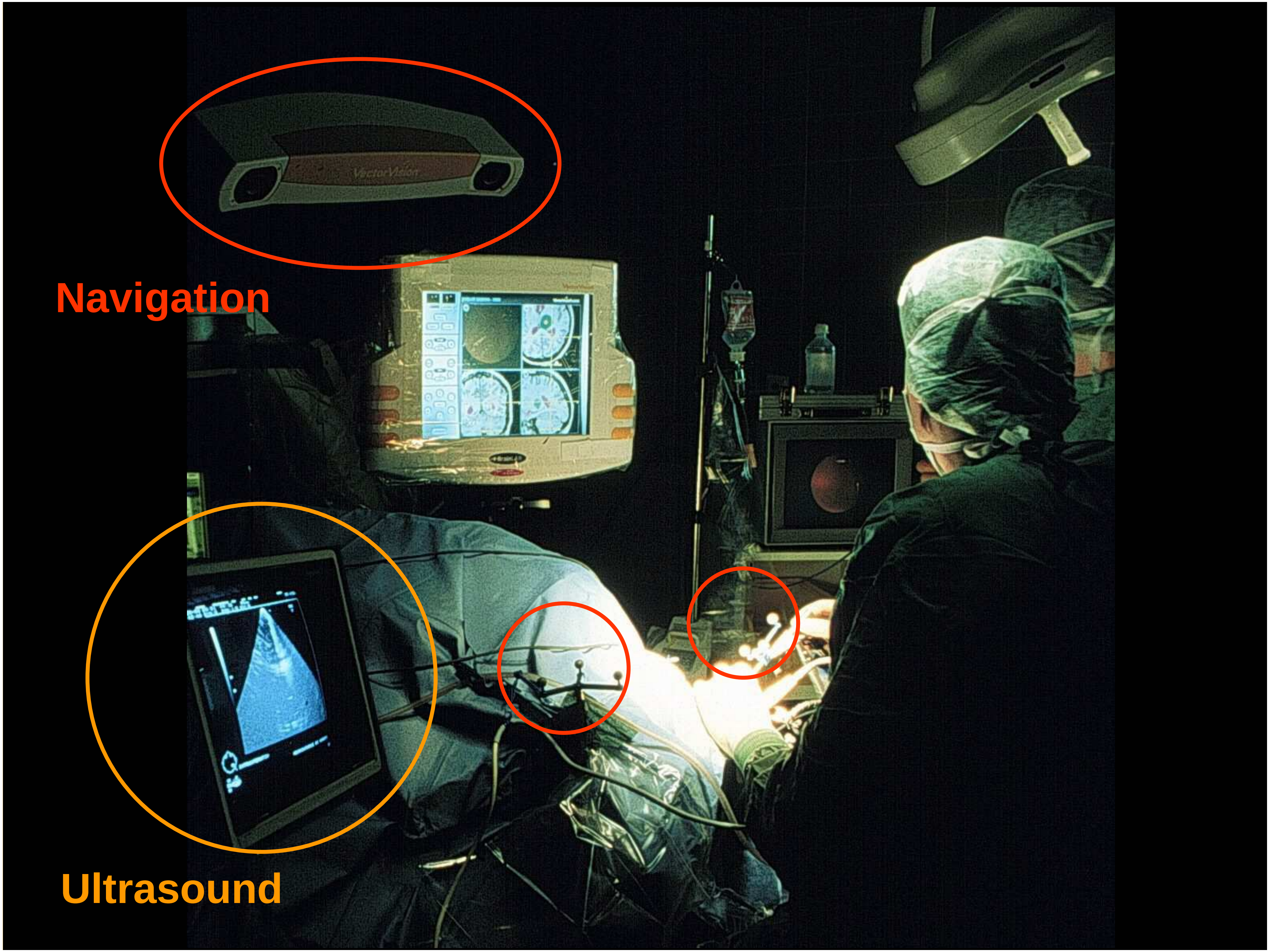
- **1st order statistics**
  (gray value histogram characteristics):
  mean, standard deviation, skew, curvature, ...
- **2nd order statistics**
  (relation of pixels to the neighborhood):
  co-occurrence-parameter, image patterns, fractal dimension, …

➲ spectral parameters:

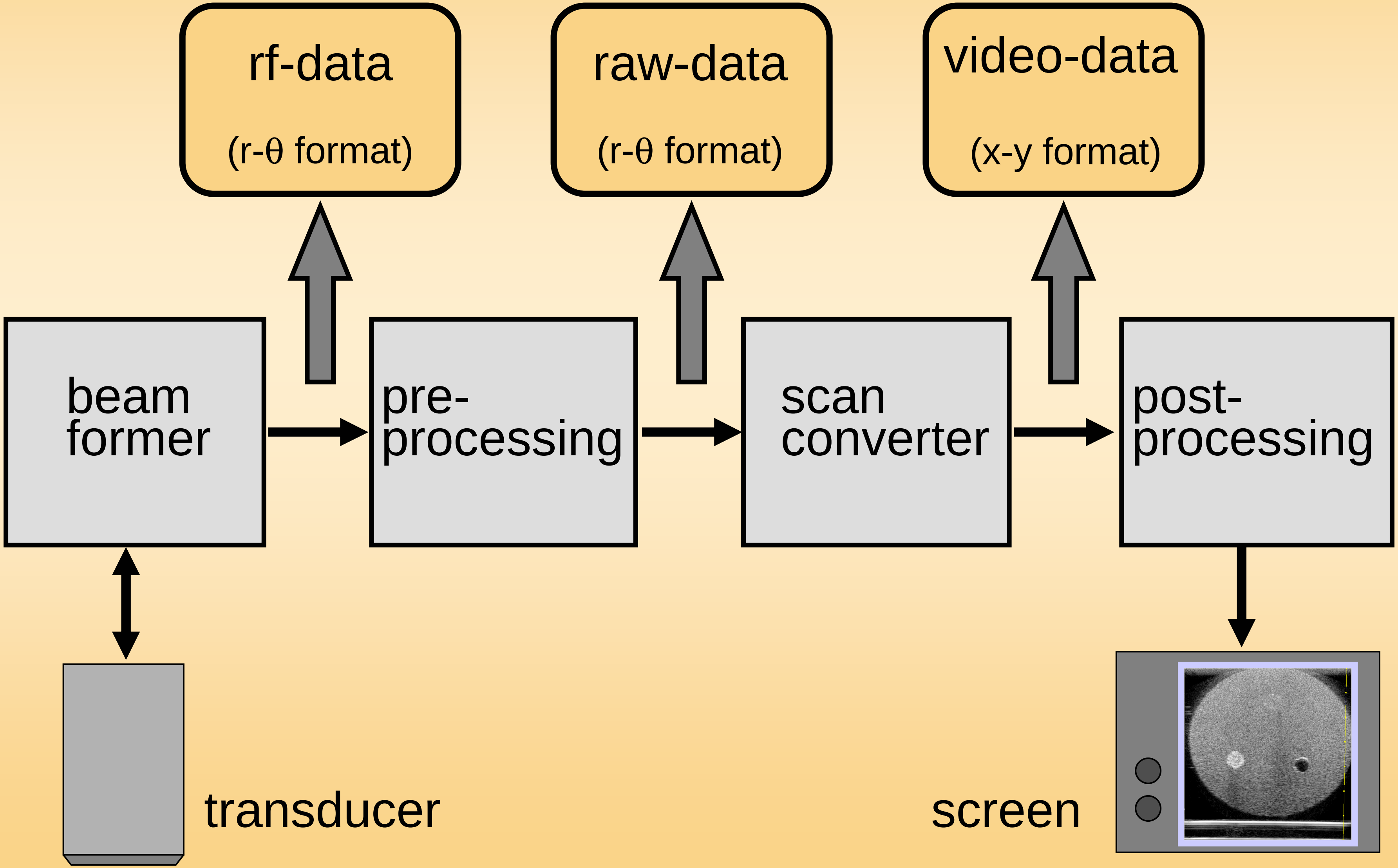
- **attenuation**
- **backscatter**
- **IBC**
- **IOA**
- **…**

Data acquisition

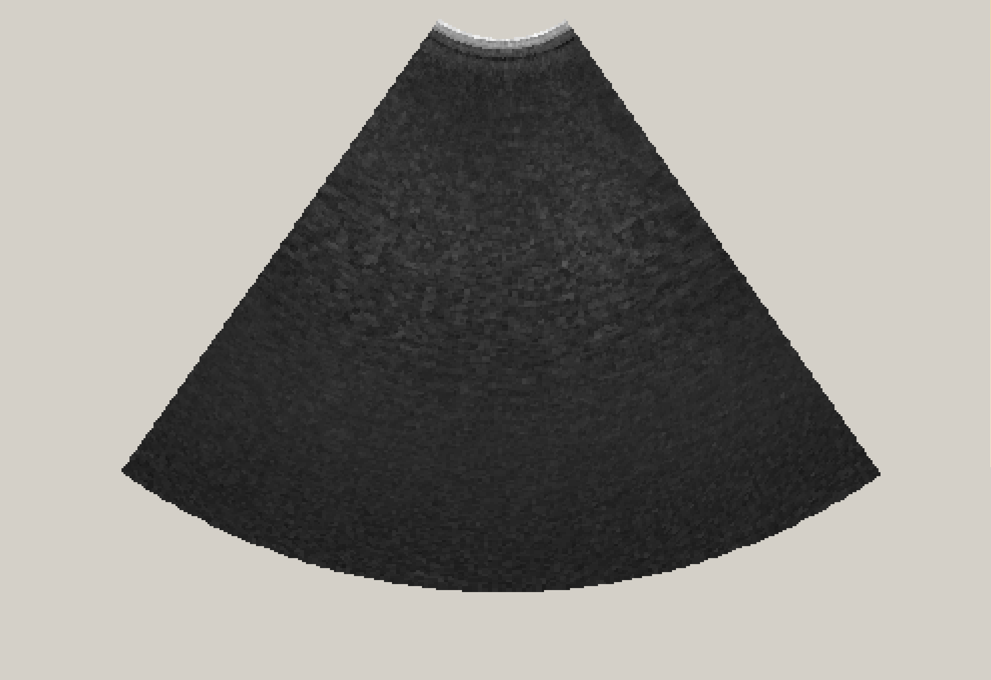



VectorVision
Navigation
Ultrasound

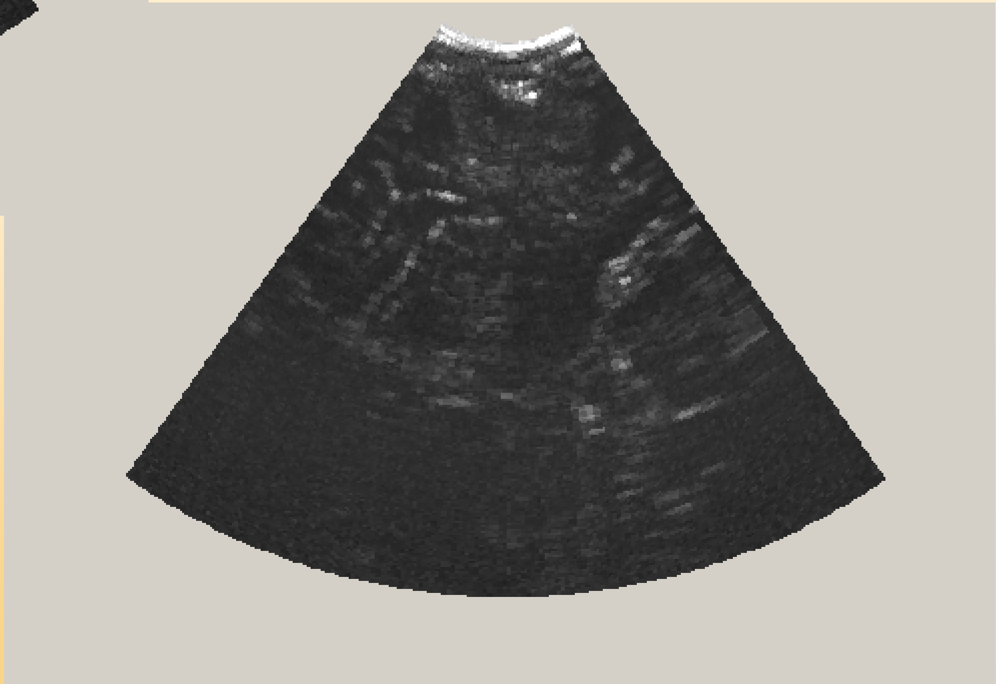
Overview: Ultrasound-Echo-Data



B-mode image (reconstructed from rf data)



phantom



brain tissue

Ultrasound – Tissue interaction

Main effects dependent on frequency:

absorption

app. 60 – 70 %

Intensity loss due to relaxation processes
(macro-) molecular level

scattering

app. 30 – 40 %

Size:	Shape:	Distribution:
specular	isotropic	scatterer density
ka(↓)	quasi-cylindrical	regular
Rayleigh	quasi-planar	non-regular

attenuation $\alpha(f) = \alpha_a(f) + \alpha_s(f)$

Model of the signal path

$$A(s,f) = A_0(f)\, W_{S/E}(f)\, T_0^2\, e^{-2\alpha_0(f)s_0}\, D(s,f)\, H(s,f)\, E(s,f)\, V_{TGC}(s,f)$$

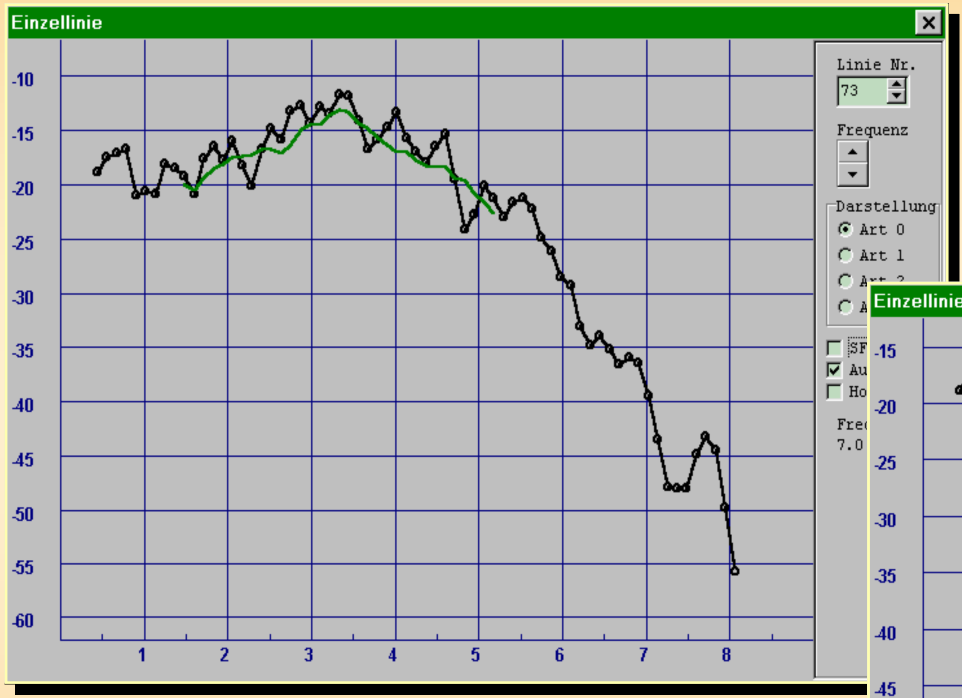
Transmitted signal ($A_0(f)$)

intermediate tissue ($e^{-2\alpha_0(f)s_0}$)

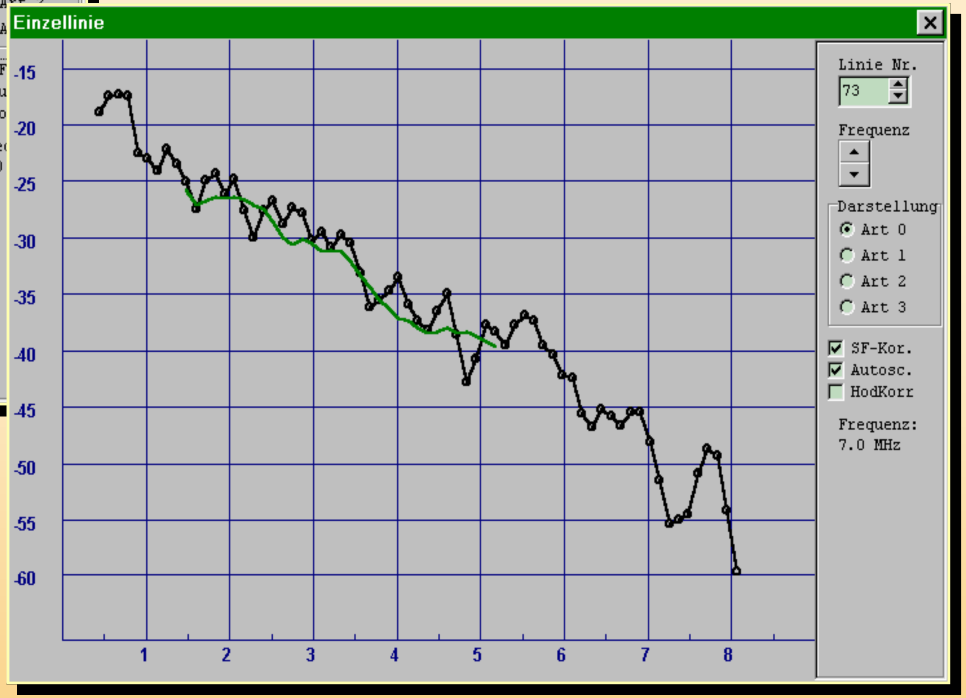
sound field function ($D(s,f)$, $E(s,f)$)

s....... depth
f .... frequency
α_0...... attenuation of intermediate tissue
s_0....... length of intermediate tissue
$W_{S/E}$... electro acoustic properties of the probe
T_0...... transmission coefficient of the probe-tissue interface
D....... diffraction function „transmitting“
E....... diffraction function „receiving“
H....... tissue characteristics
V_{TGC}... time-gain-compensation

Soundfield correction



without correction
overestimated amplitudes
in focal zone

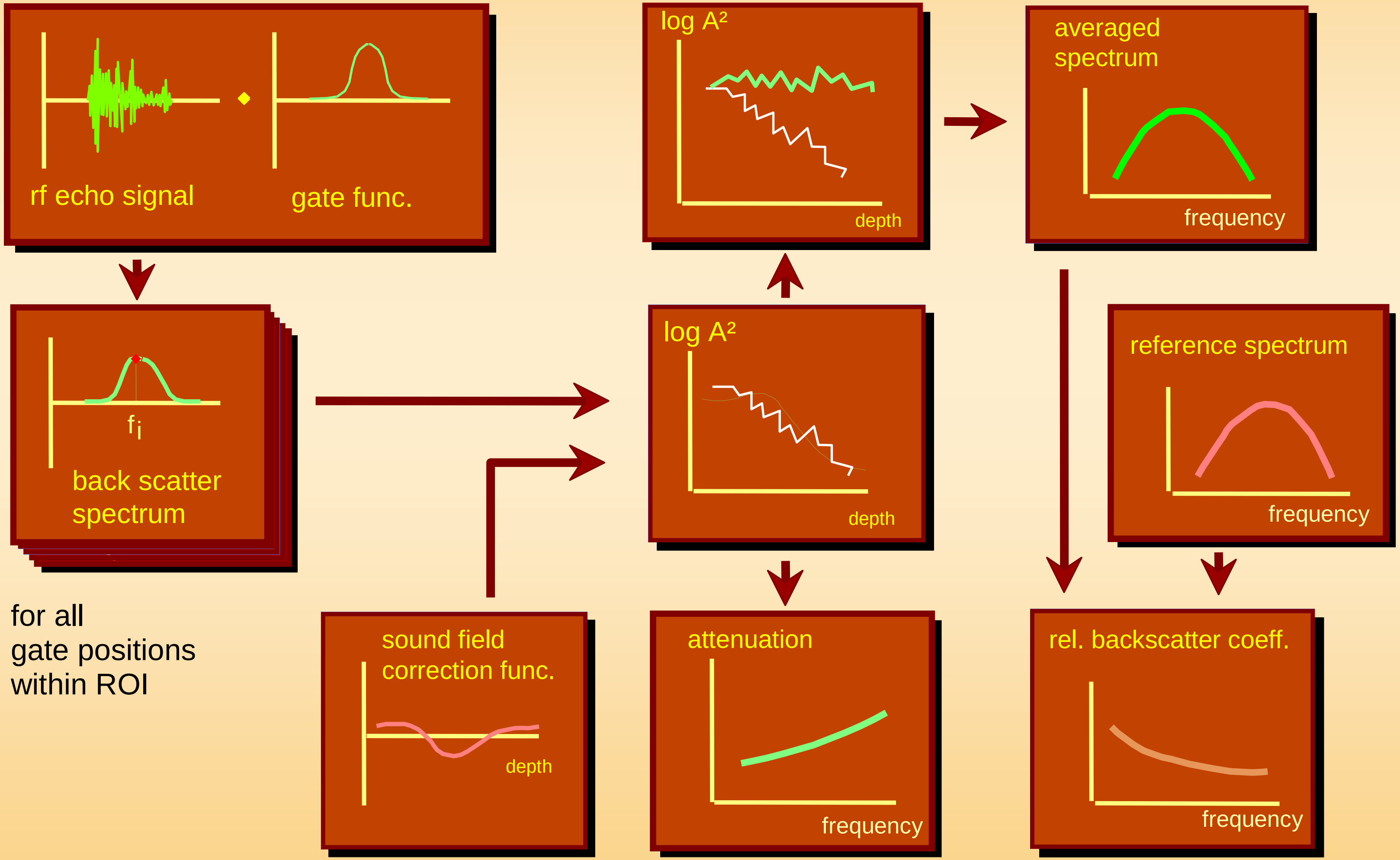


with correction
constant slope of amplitudes
(linear in dB)

Estimation of sound field correction functions

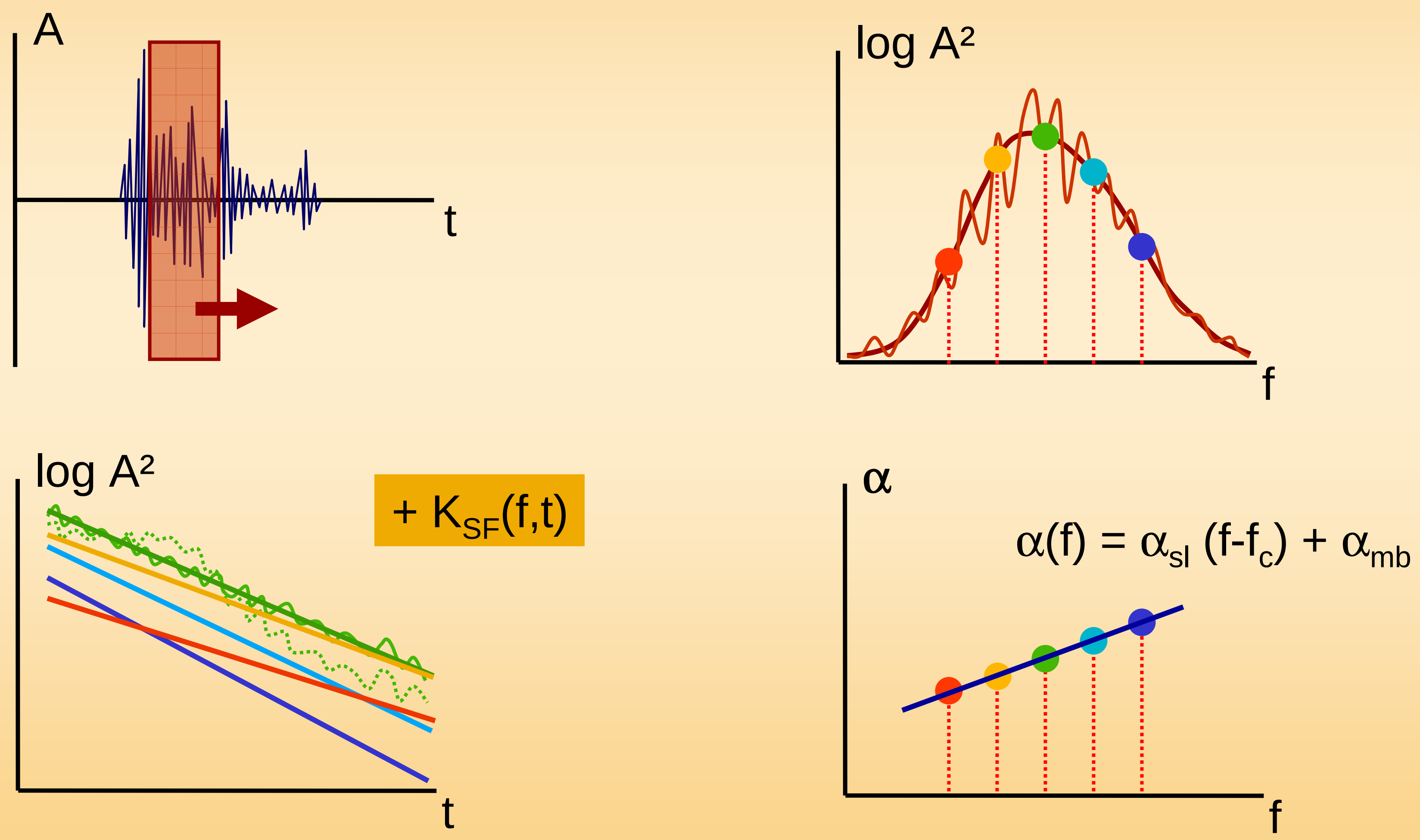
- **calculation (spatial impulse response - Field II)**
- **hydrophone**
- **plane reflector**
- **thin wire or point reflector**
- **tissue mimicking phantom**
- **normal tissue**

Principle of parameter estimation

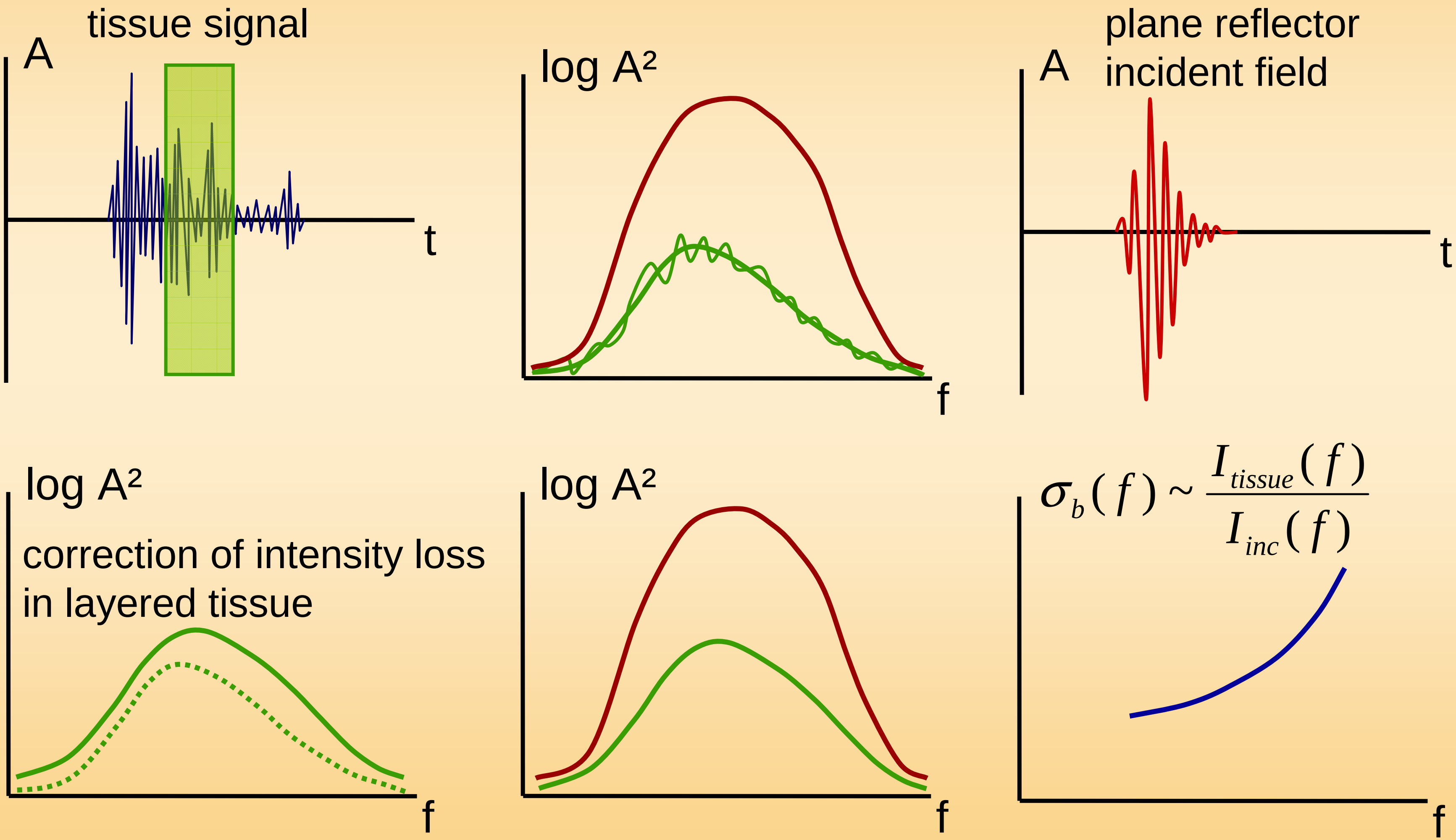


for all
gate positions
within ROI

Multi narrow band method

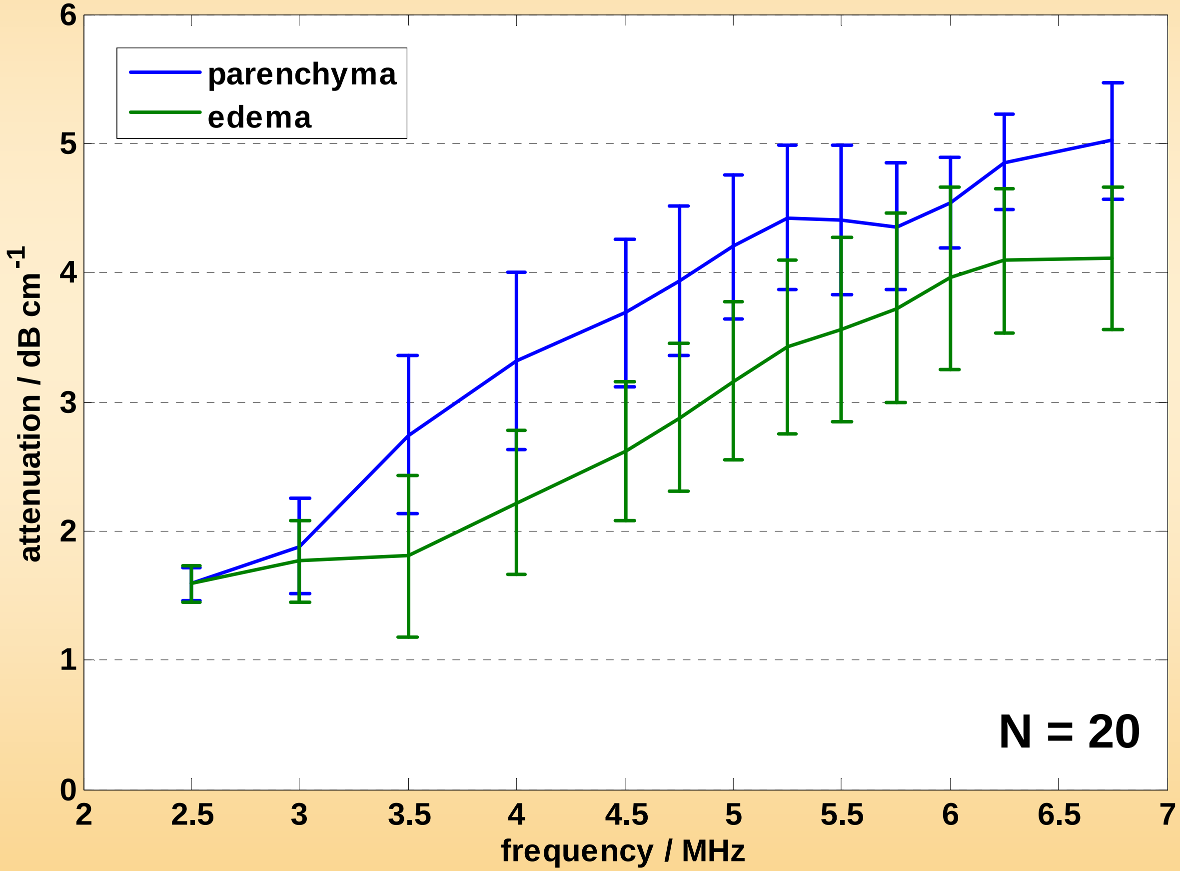


Backscatter coefficient

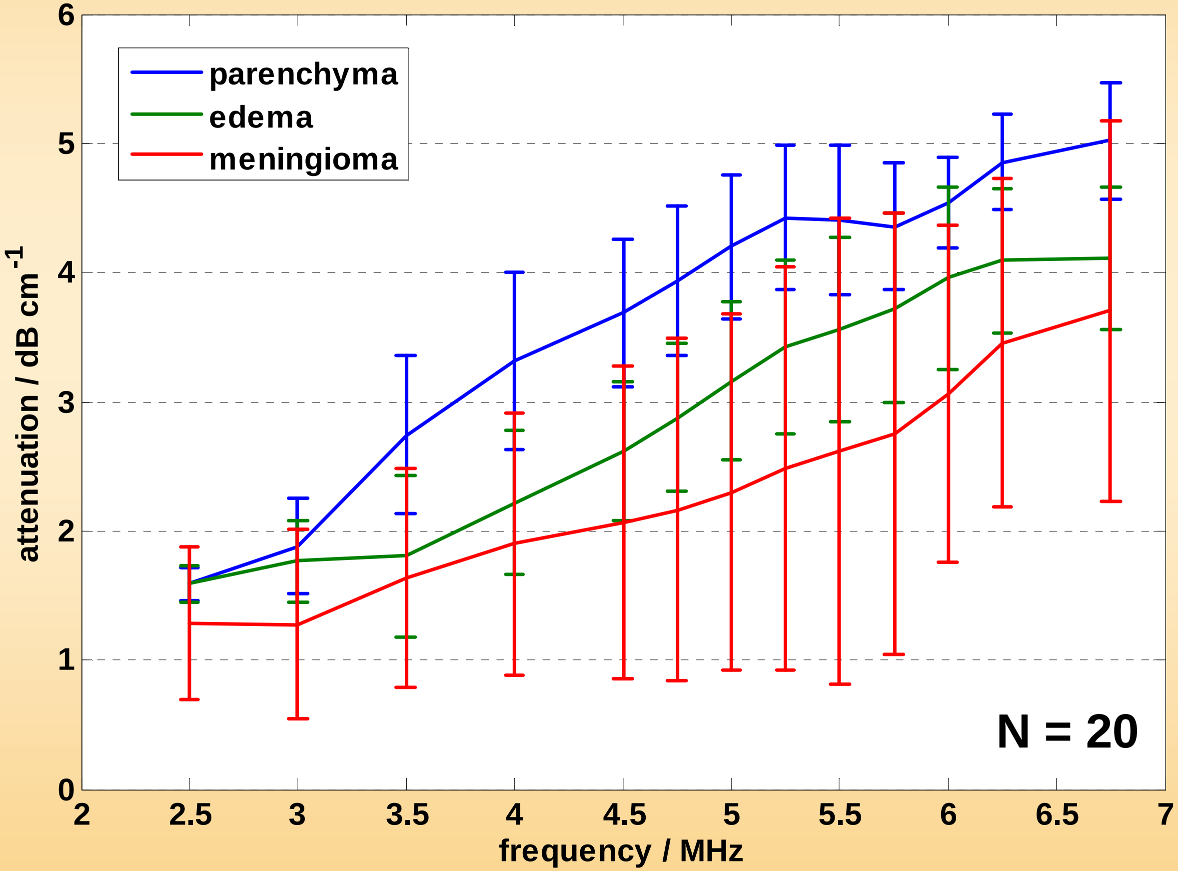


$$\sigma_b(f) \sim \frac{I_{tissue}(f)}{I_{inc}(f)}$$

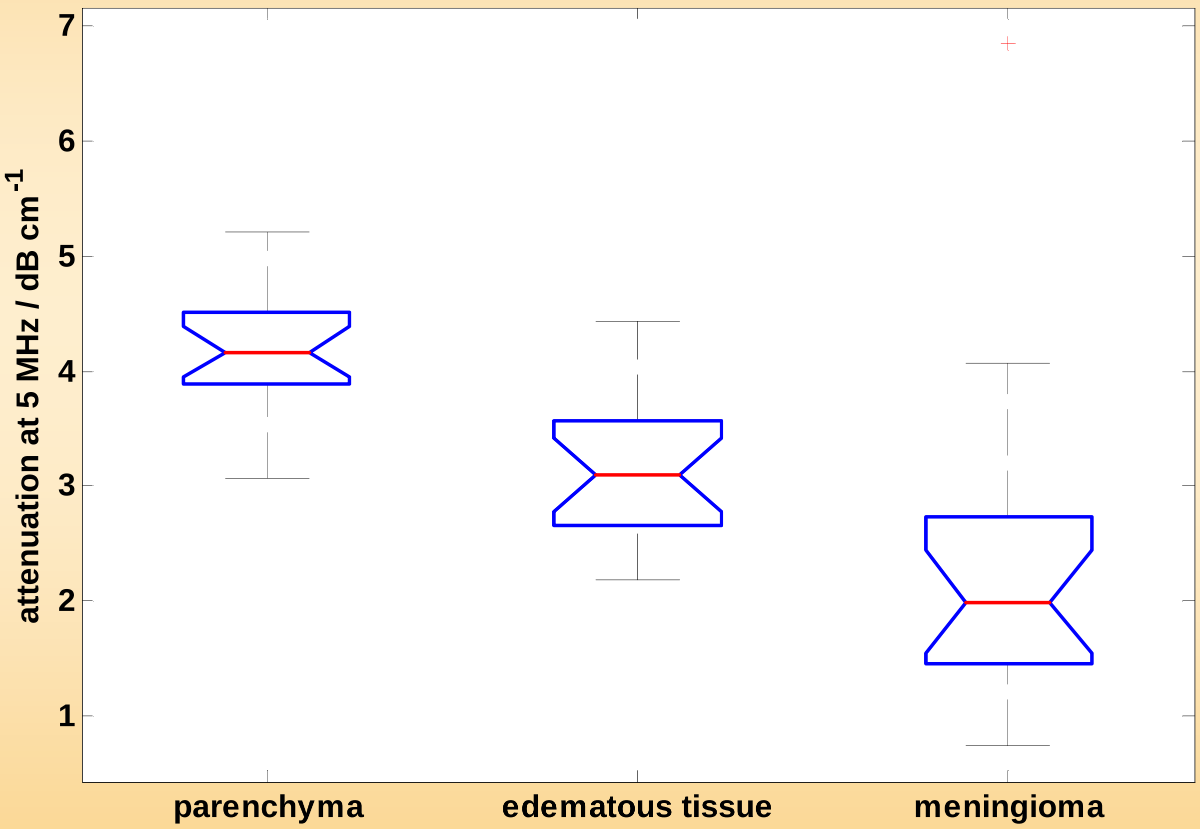
Frequency dependent attenuation



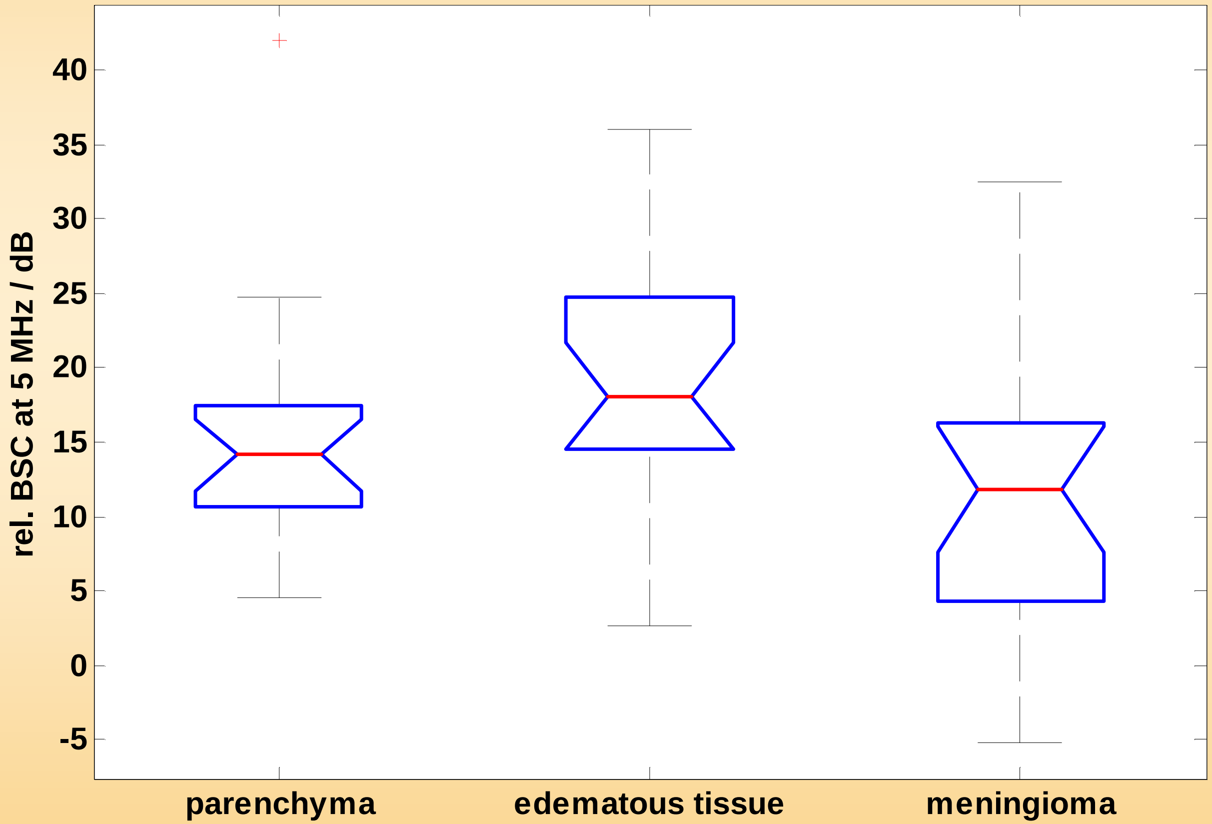
Frequency dependent attenuation



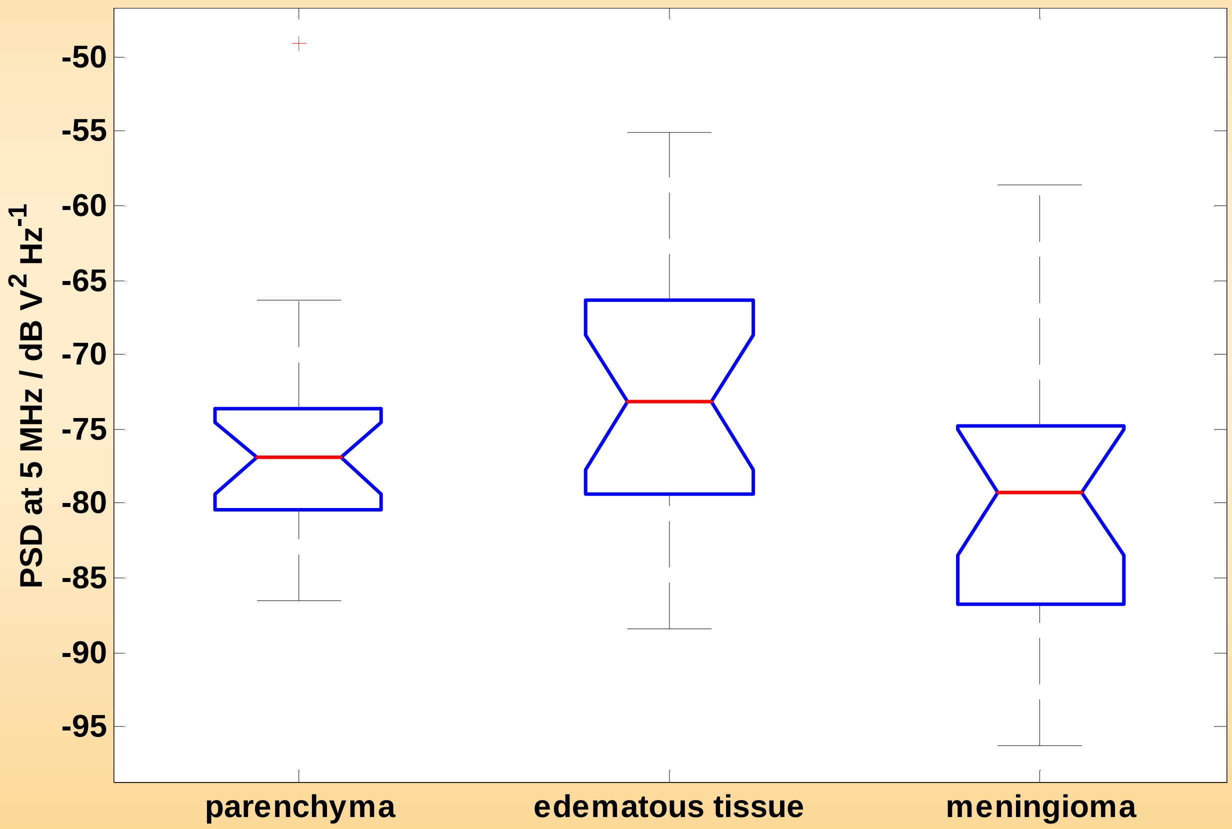
Attenuation at 5 MHz



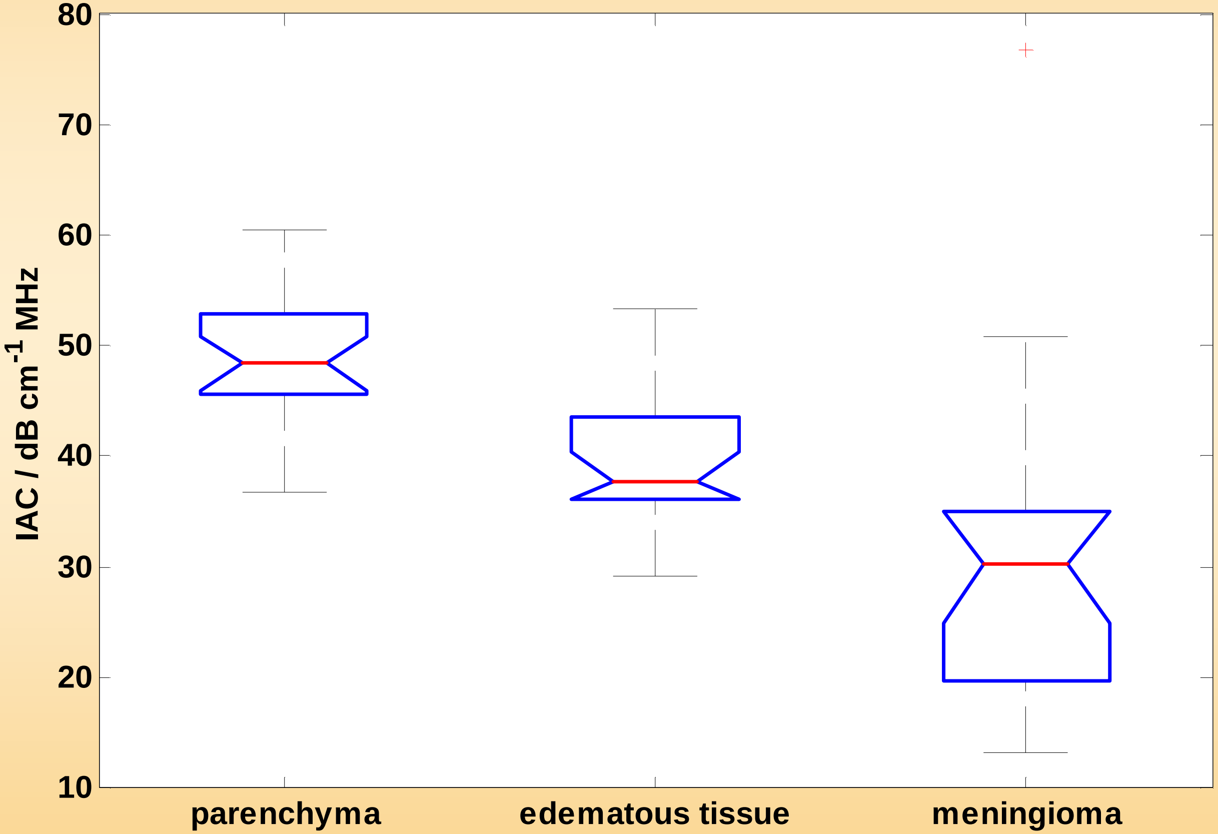
Relative backscatter coefficient (5 MHz)



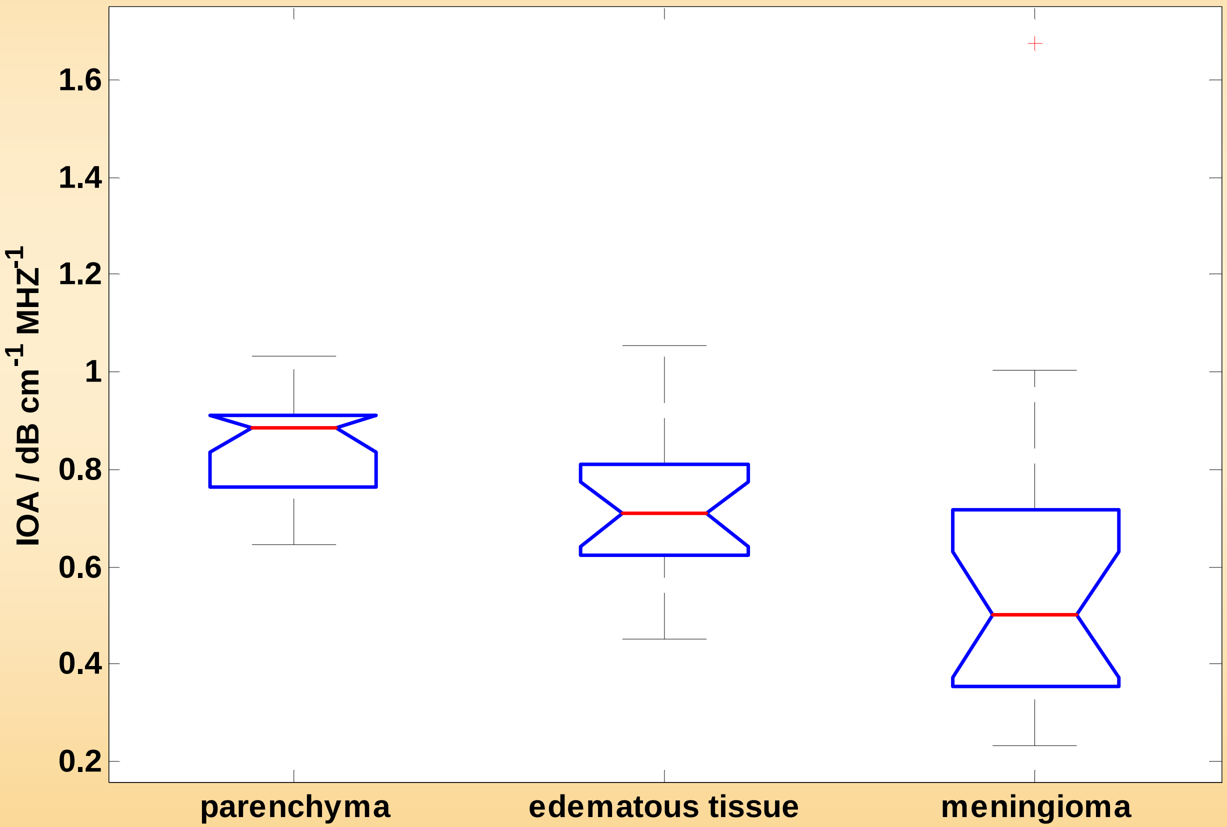
Power spectral density (5 MHz)



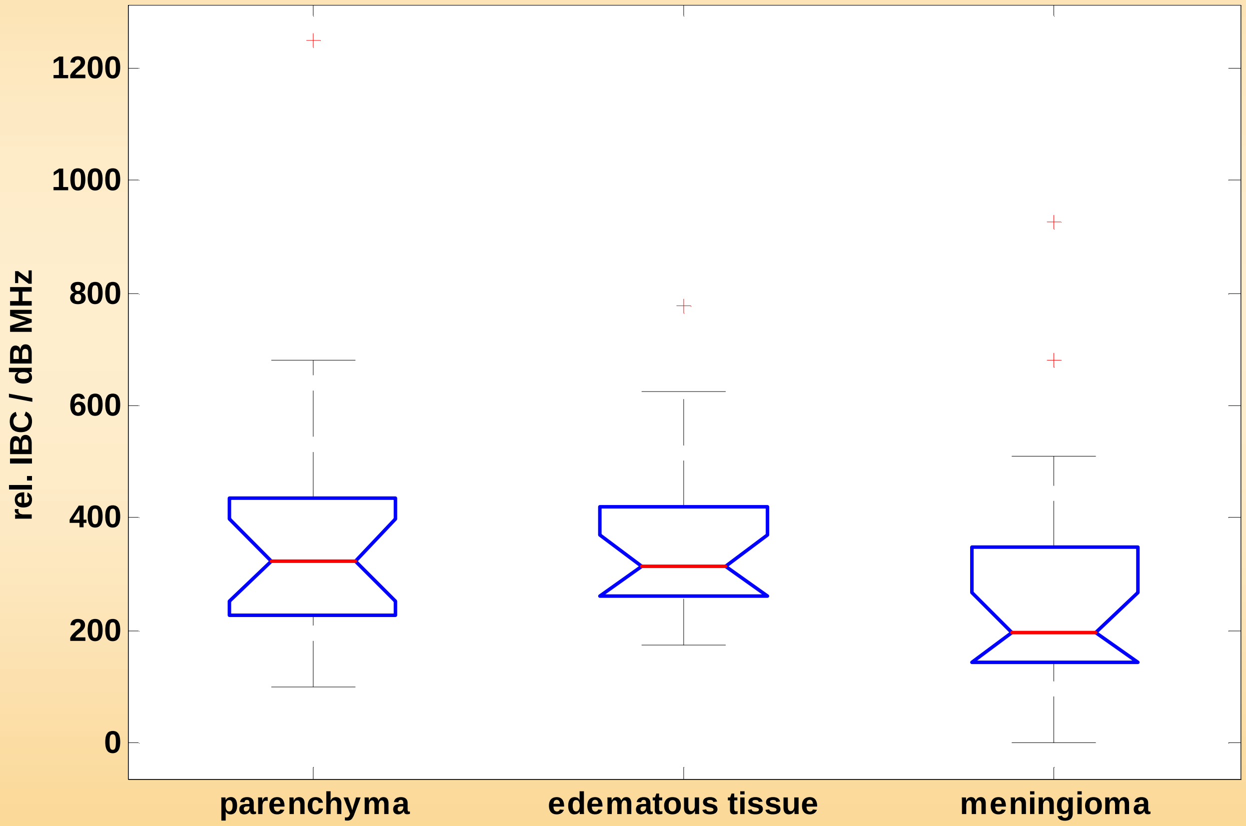
Integrated attenuation coefficient



Slope of attenuation



Relative integrated backscatter coefficient



Conclusions

- **Significant differences for all attenuation parameters**
  (e.g. attenuation at 5.0 MHz
  normal brain vs. edema: *P* = .00002
  normal brain vs. meningioma: *P* = .000004
  edema vs. meningioma: *P* = .002
- **Backscatter parameters allow significant differentiation between:**
  - edema and meningioma
  (at low frequencies and at the probe's center frequency)
  - normal brain tissue and meningioma
  (at low frequencies)
- **Normal brain is not significantly distinguishable from edema by backscatter parameters**

Perspectives

- analysis of additional tumor types
- analysis of tumors with infiltrating character

Summary

- Meningioma was used as a basic model due to its clearly definable margins
- Spectral analysis of intraoperatively acquired rf-data was able to significantly differentiate among normal brain, edematous tissue, and meningioma
- This could form the basis for intraoperative tissue characterization, thus allowing a more precise definition of tumor borders and improve attempts of radical resection