Microwave Engineering Group

TECHNISCHE UNIVERSITÄT WIEN
Vienna University of Technology

Characterization of electromagnetic-anisotropic materials

Holger Arthaber

Vienna University of Technology
Institute of Electrodynamics, Microwave and Circuit Engineering

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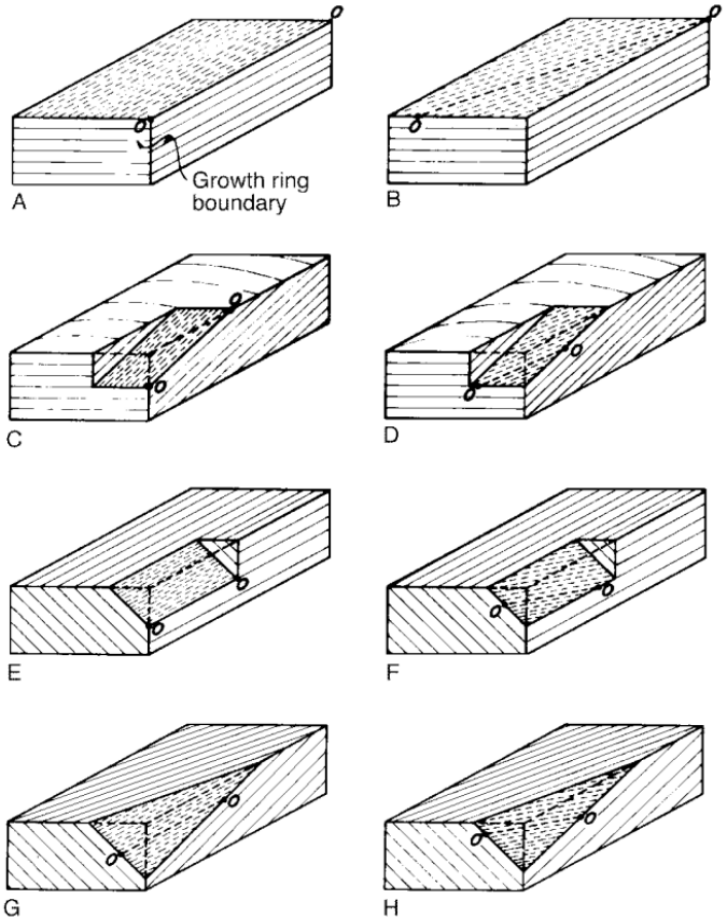
Contents

- Problem
- Measurement Setup Evolution
- Inverse Problem
- Results
- Conclusion

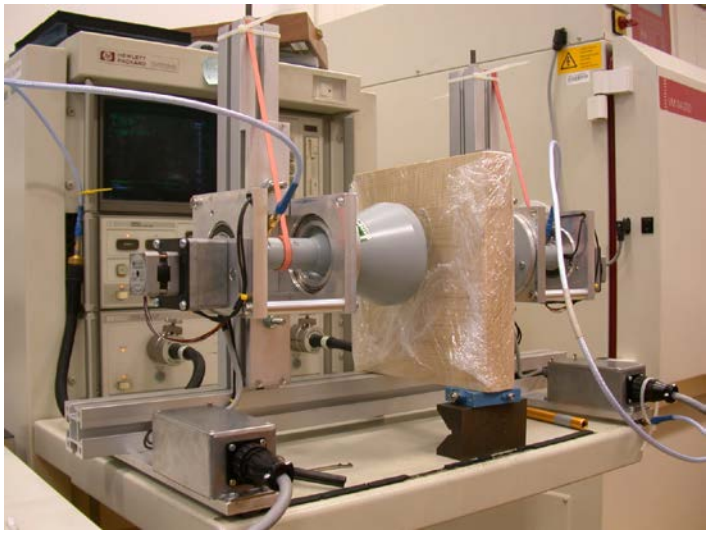
Problem

- Measuring 3D orientation of grain angle in wooden boards
- Why?
  - Strength strongly varies along fiber and perpendicular to fiber
  - surface inspection does not give required information
- Chosen approach:
  - X-band transmission measurement
  - Dual-polarized TX/RX
  - Model fitting of measurement to determine grain orientation

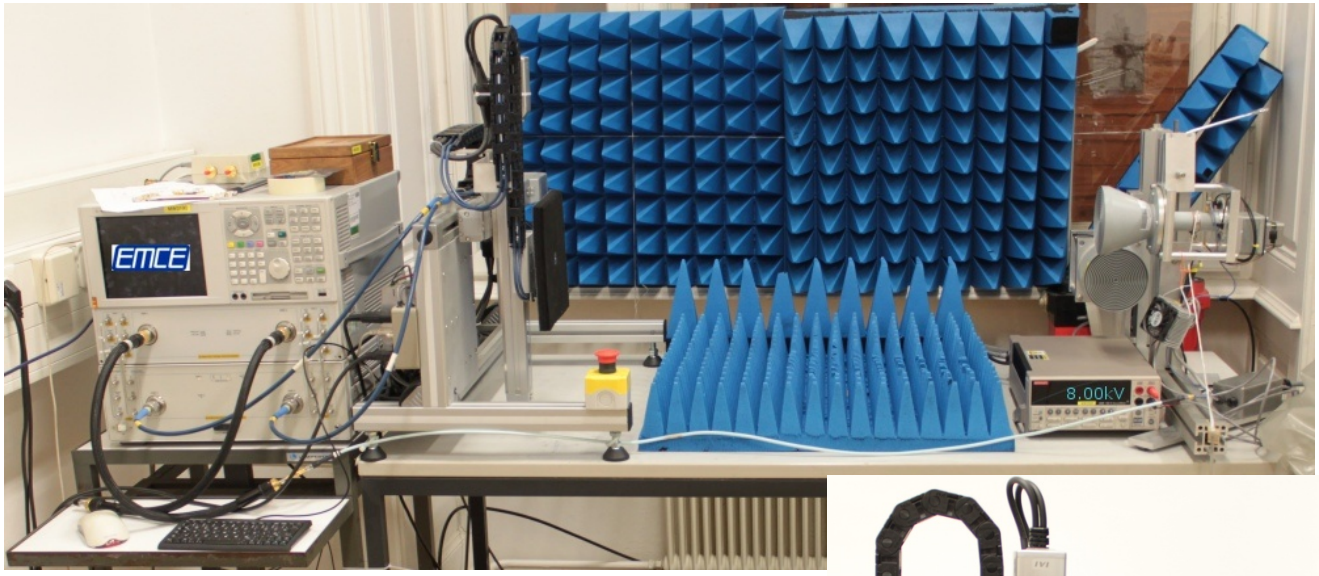


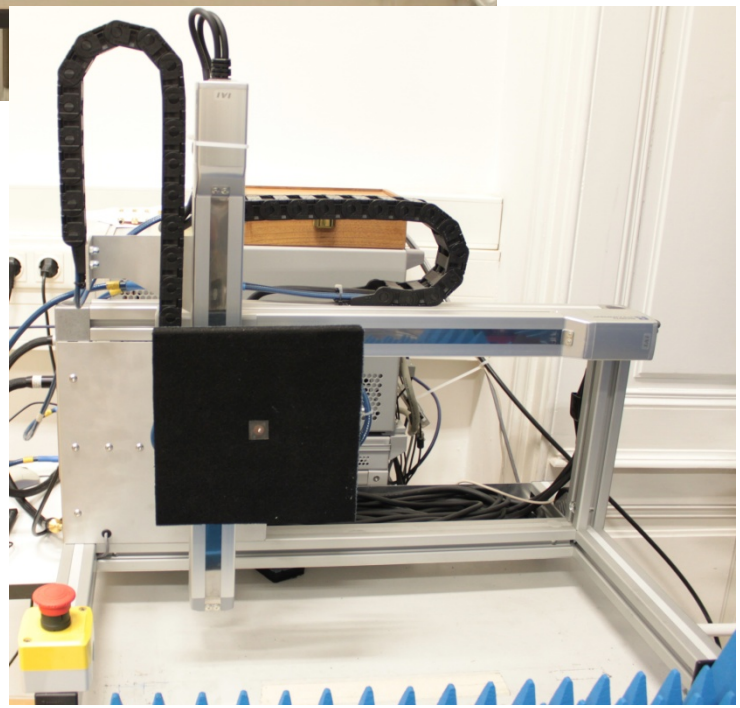
Measurement Setup Evolution

- Phase 1: First tests…



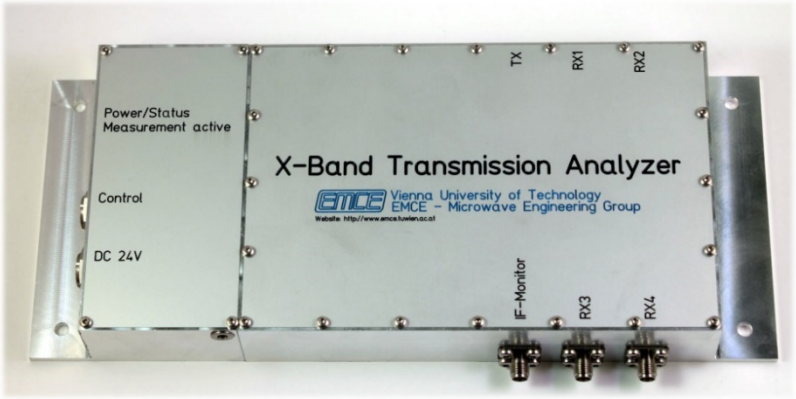
- Phase 2: X/Y-scanner (electro-mechanical)

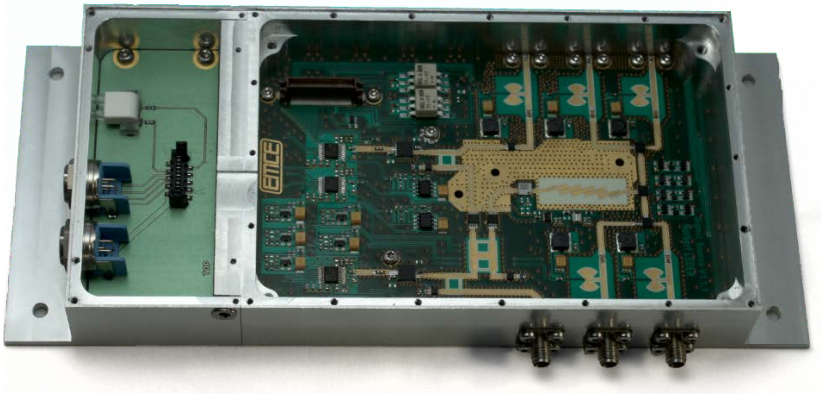


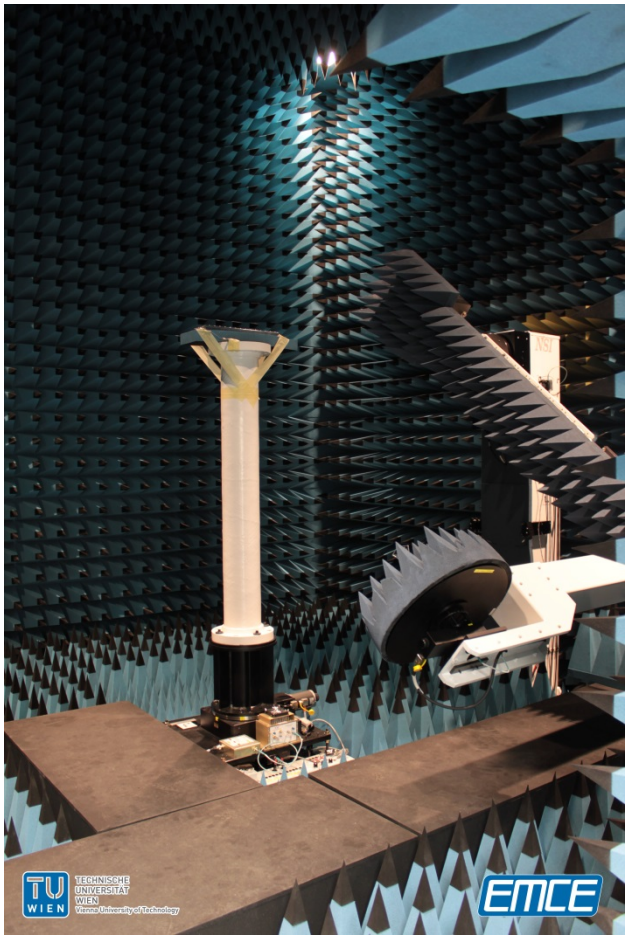


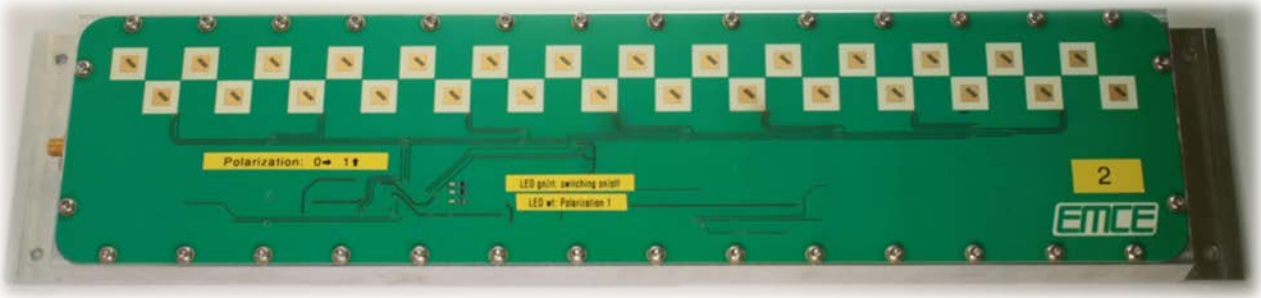
Measurement Setup Evolution

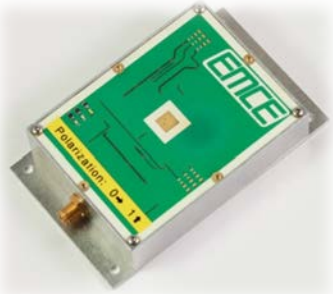
- Phase 3: industrial prototype





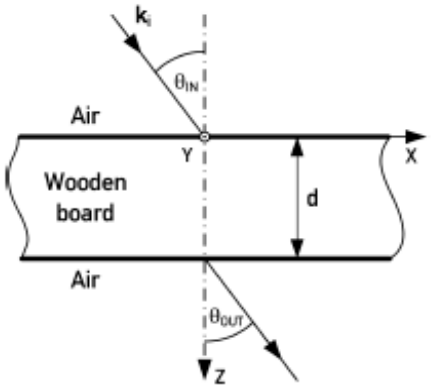






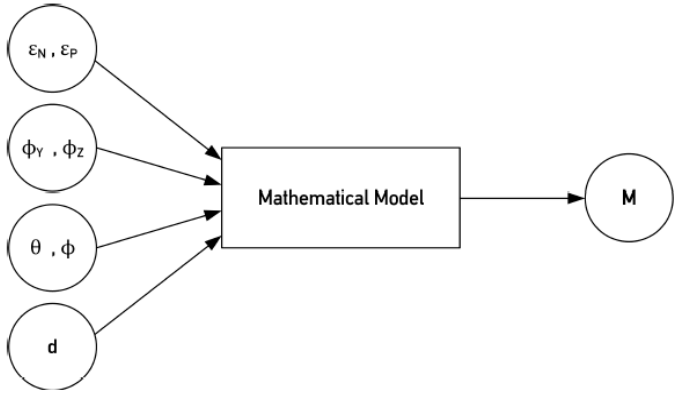
Inverse Problem

- Transmission through anisotropic (birefringent) media results in polarization ‚distortion'
- Transmission coefficients can be calculated by Berreman-method



$$\epsilon_r = \begin{pmatrix} \epsilon_{xx} & \epsilon_{xy} & \epsilon_{xz} \\ \epsilon_{yx} & \epsilon_{yy} & \epsilon_{yz} \\ \epsilon_{zx} & \epsilon_{zy} & \epsilon_{zz} \end{pmatrix} \Rightarrow \mathbf{J}_T = \begin{pmatrix} t_{pp} & t_{ps} \\ t_{sp} & t_{ss} \end{pmatrix}$$

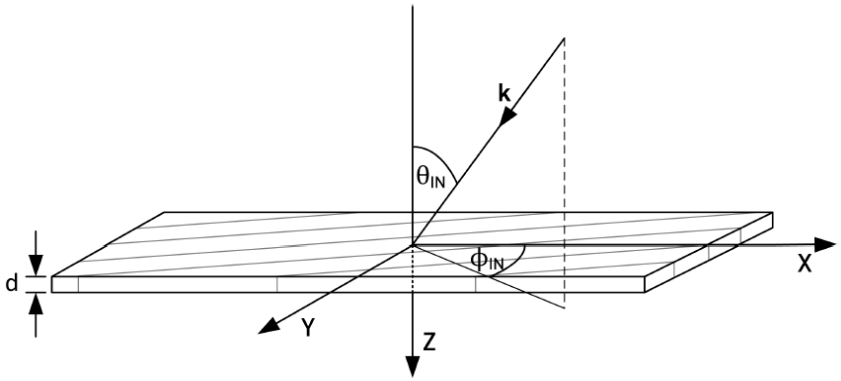
- Inverse problem is tricky:
  - no direct solution possible → fitting
  - no unique solution
  - sensitive to noise



- Consideration of
  - Thickness deviation
  - Non-orthogonal polarization
  - Gain/phase imbalance between h/v polarizations
  - Measurement noise

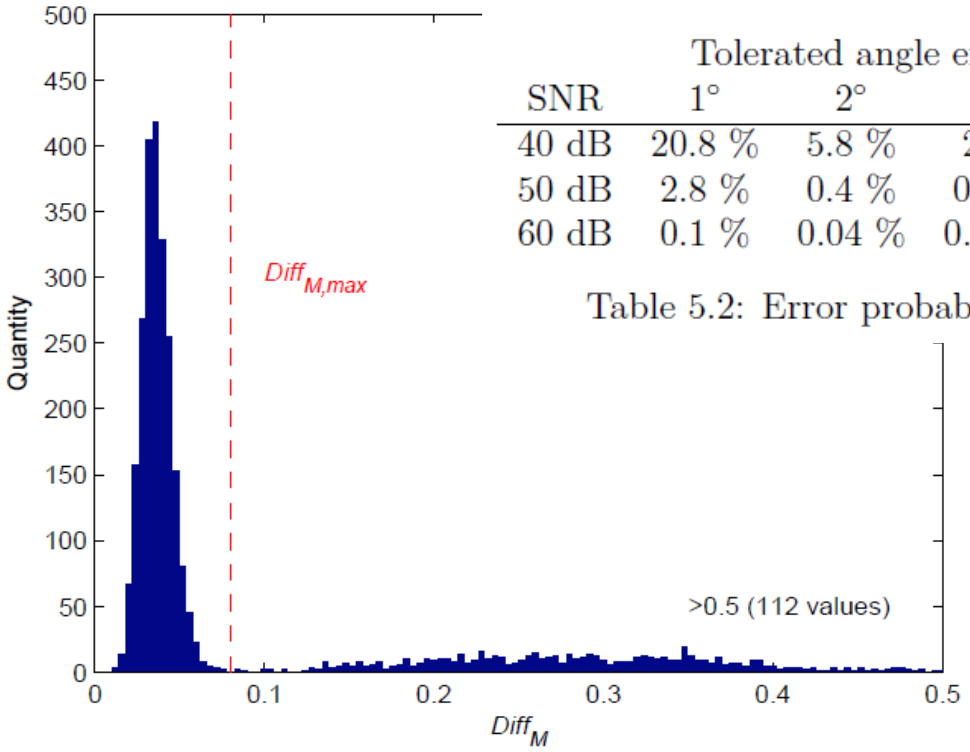
- Variation of all parameters:
  ε_r-tensor, thickness, measurement imperfections

- Measurement of two/three transmissions:
  - phi=0°, theta=45°
  - phi=180°, theta=45°
  - (theta=0°)



Results

- Developed solver estimates confidence of solution, discards „bad“ results, but does not work perfect:



	Tolerated angle error				
SNR	1°	2°	3°	$Diff_{M,max}$	Number of sets
40 dB	20.8 %	5.8 %	2.9 %	0.08	2231
50 dB	2.8 %	0.4 %	0.04 %	0.04	2220
60 dB	0.1 %	0.04 %	0.001 %	0.03	2267

Table 5.2: Error probabilities for different SNR values

- theta=0° measurement allow to determine the projection of the the tensor‘s main axis → redcuction of unknowns
- Consideration of spatial measurement neighbours → close to 0% error rate possible
- Trade-off: error-rate, num.of discarded measurements, precision

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Thank You For Your Attention!

Contact:

Dr. Holger Arthaber

Email: holger.arthaber@tuwien.ac.at, Phone: +43 1 58801 35420

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Gusshausstrasse 25/354

1040 Vienna, Austria