SALZGITTER MANNESMANN FORSCHUNG

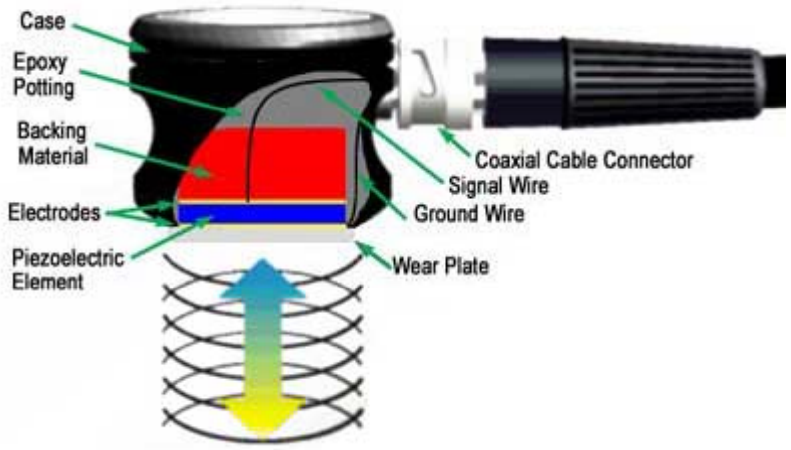
Ein Unternehmen der Salzgitter Gruppe

Ultrasonic Inspection Techniques

JoinTec Meeting 25th of June 2008

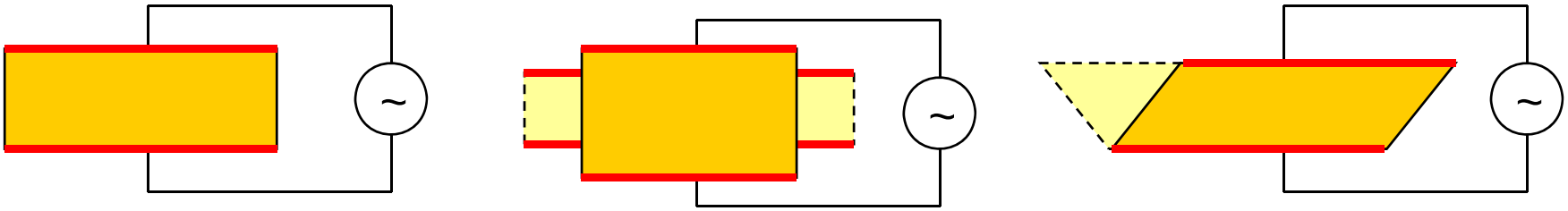
M. Kaack

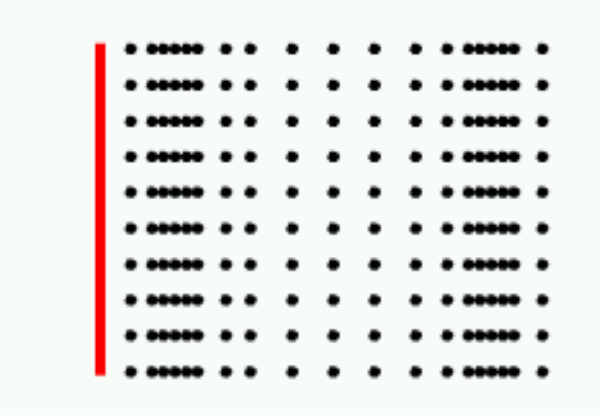
Piezoelectric Transducer Heads



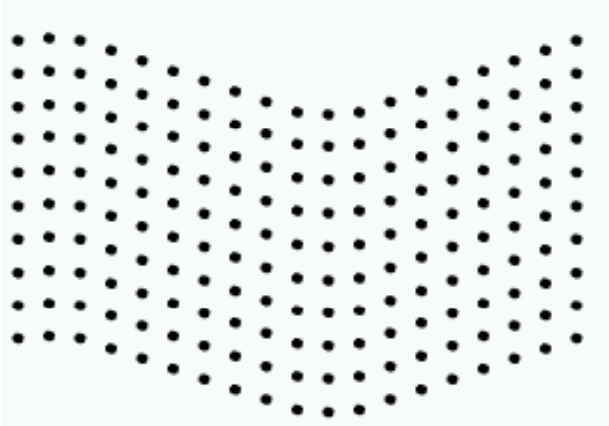
- Ultrasonic heads are equipped with a piezoelectric device (transducer).
- Typical frequencies: 0.5 MHz to 25 MHz
  Typical voltages : a few 100 V
- Depending on orientation longitudinal or transversal waves can be generated.

Wave types





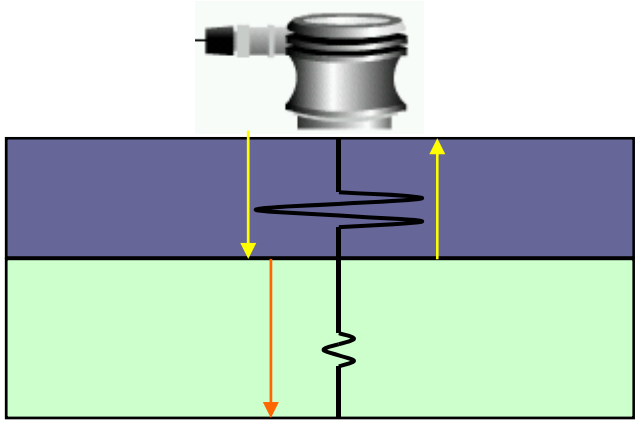
longitudinal wave



transversal wave

- Transversal waves can simply be generated by using an appropriate transducer, but cannot transmitted through water.

Transmission through interfaces



- If both inpedances are almost the same ⇨ R=0
- If both inpedances are very different ⇨ R=1

Acoustic impedance

$$Z = v \cdot \rho$$

Reflection coefficient

$$R = \left(\frac{Z_2 - Z_1}{Z_2 + Z_1} \right)^2$$

V_{air} = 340 m/s ρ_{air} = 0.001 g/cm³

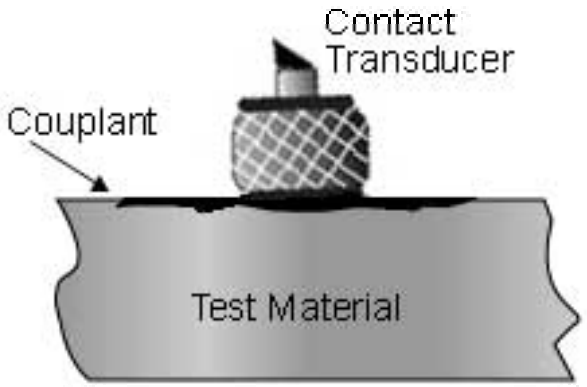
V_{steel} = 5850 m/s ρ_{steel} = 7.89 g/cm³

V_{water} = 1500 m/s ρ_{water} = 1.0 g/cm³

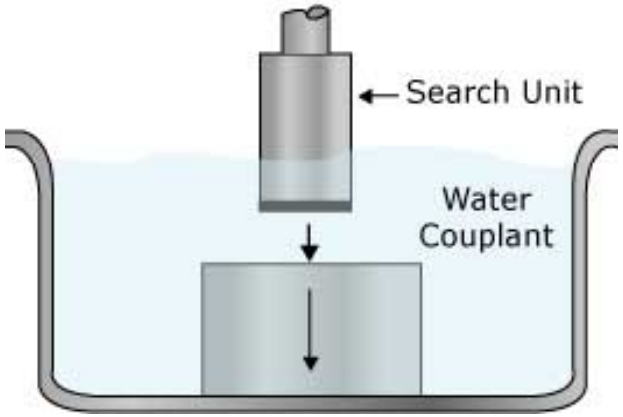
⇨ Water is used as copling medium.

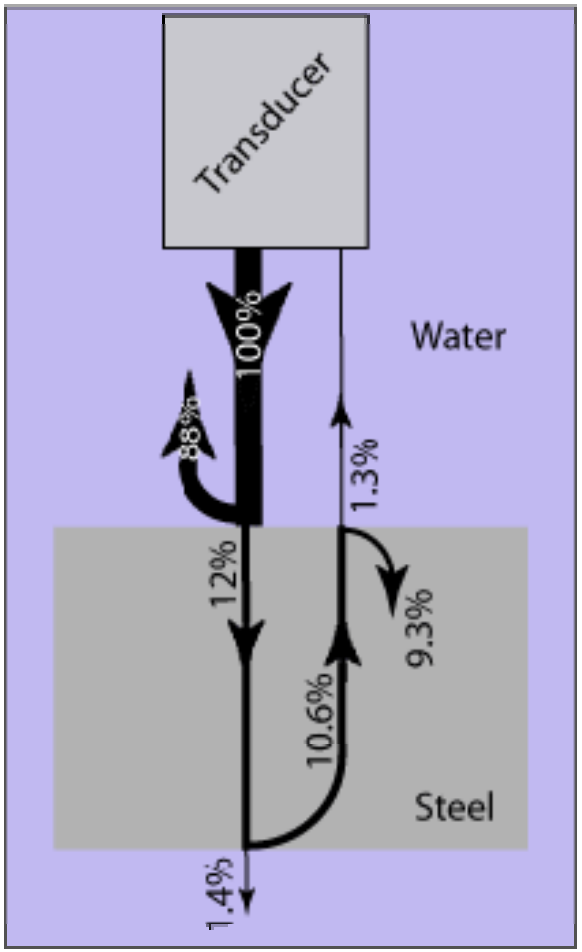
Transducer coupling

Coupling by oil or grease

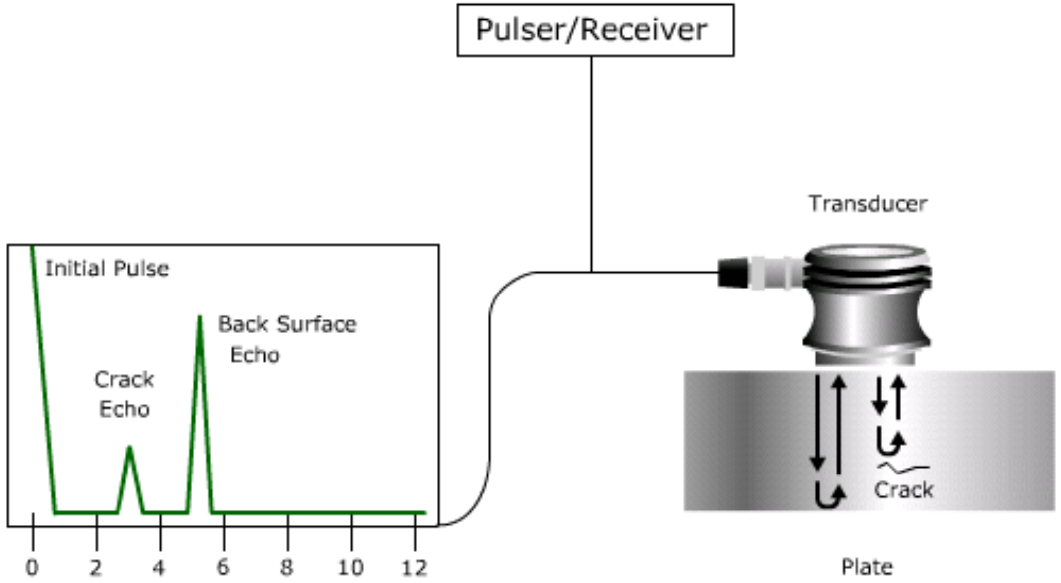


Immersion technique

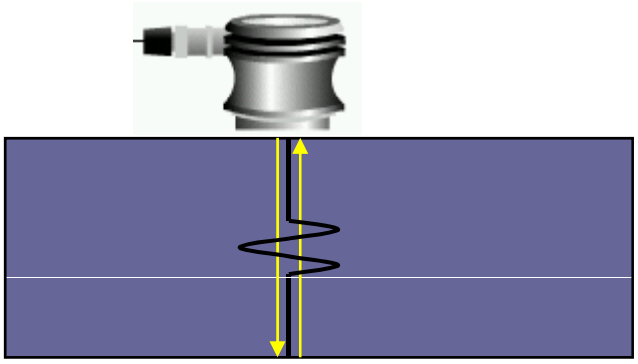


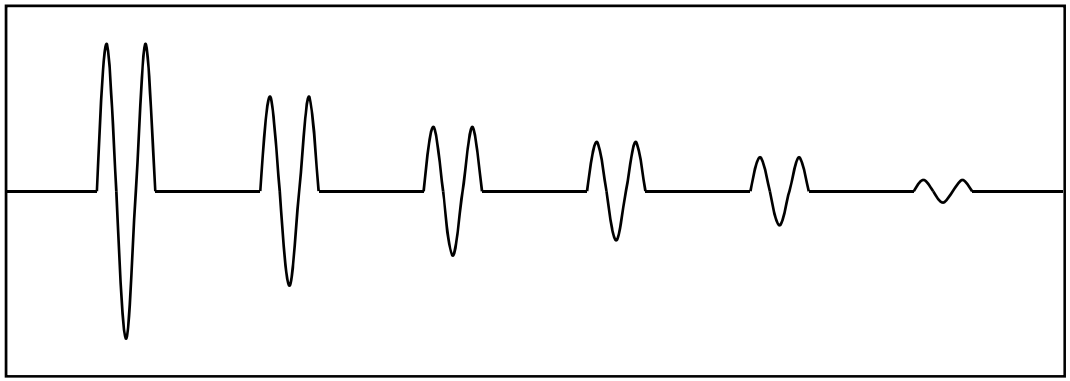


Perpendicular Inspection

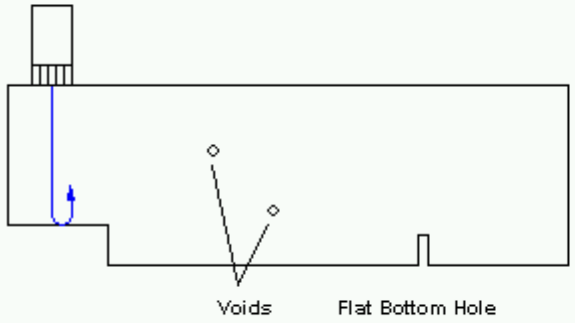


- Ultrasonic wave runs several times through the sample.
- Wave is attenuated.

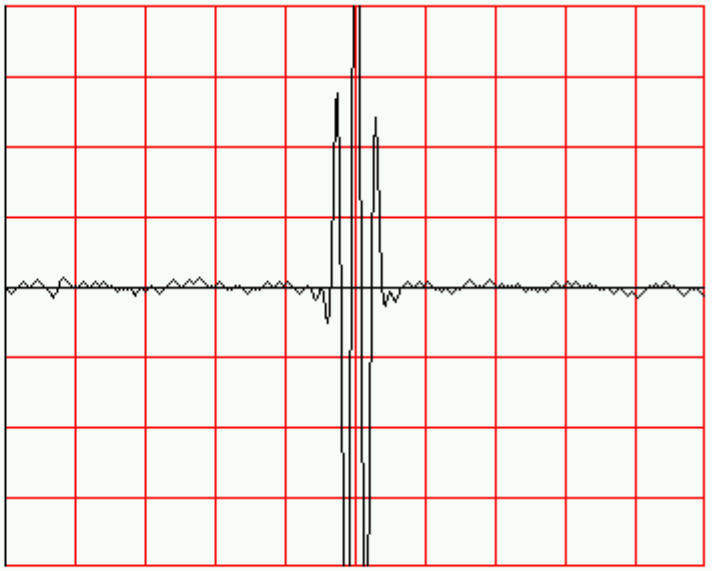


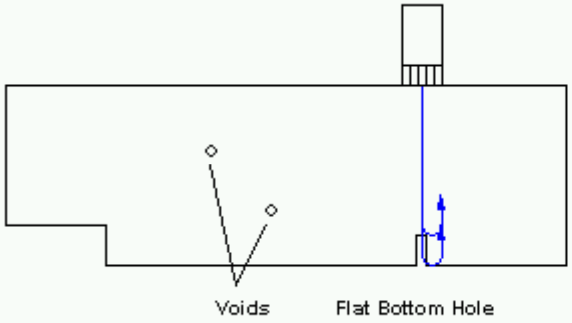


Perpendicular Inspection: WT measurement

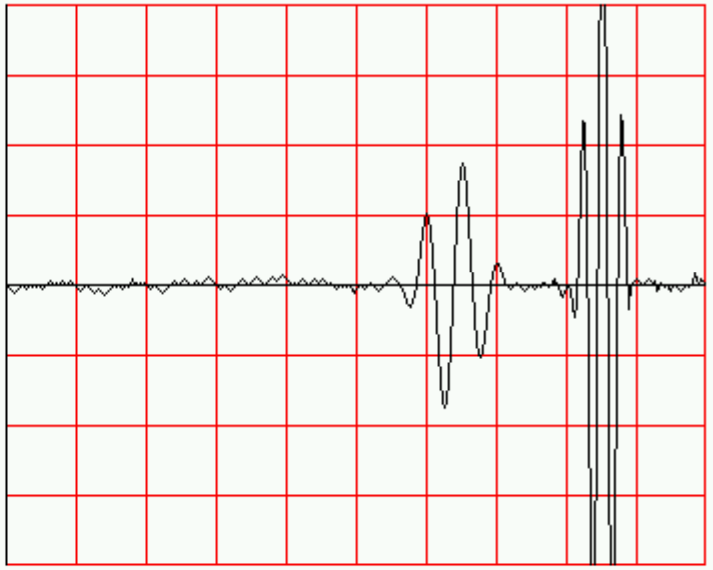


Stainless Steel Block

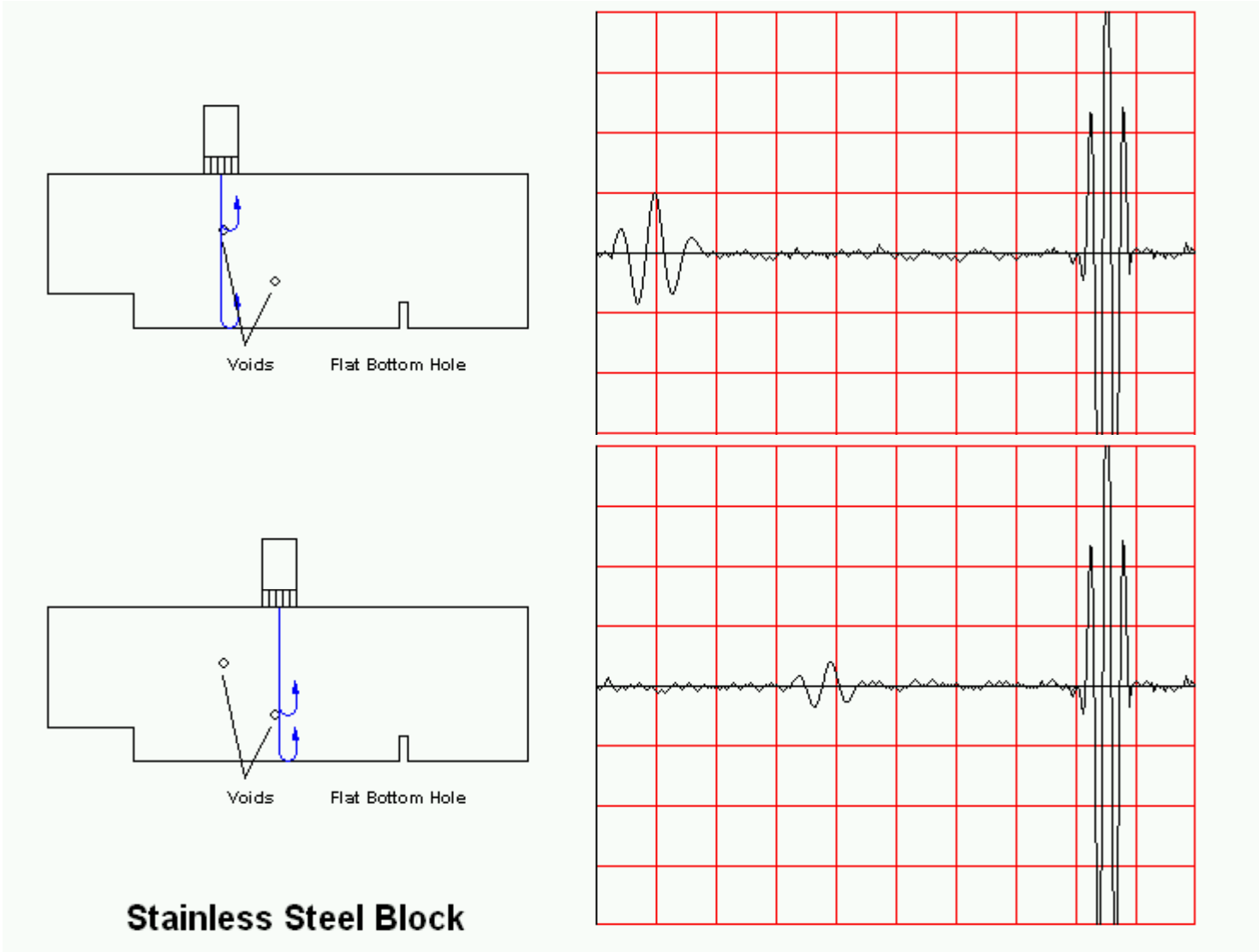




Stainless Steel Block

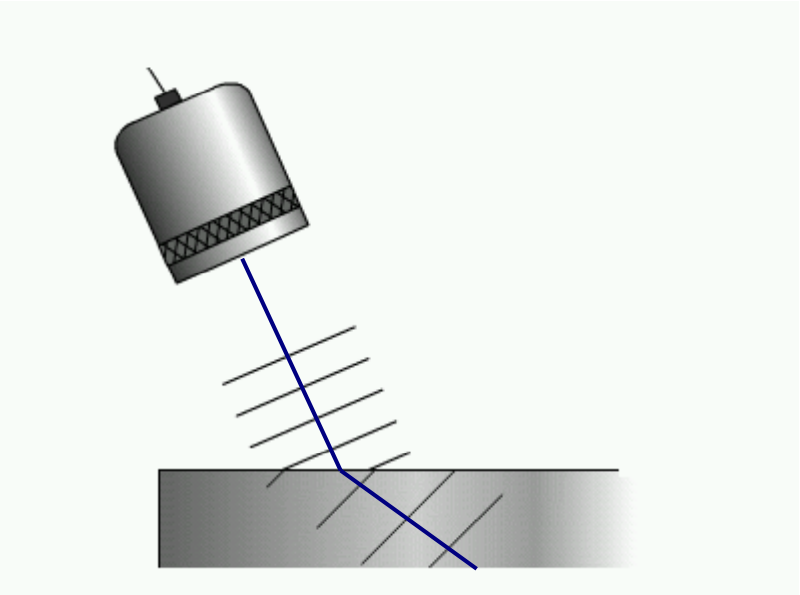


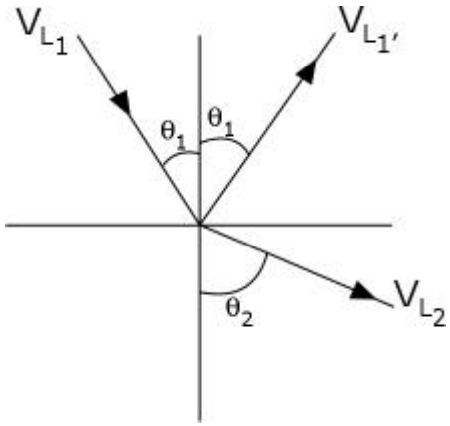
Perpendicular Inspection: defect detection



Oblique Incidence

- If an acoustic wave passes the interface under an oblique angle it is refracted according to Snell's law.

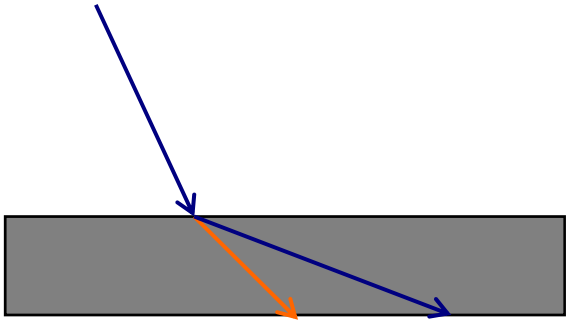


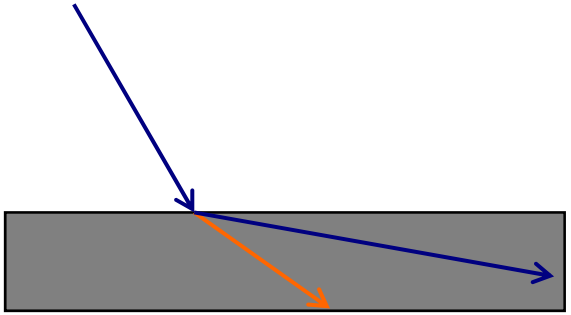


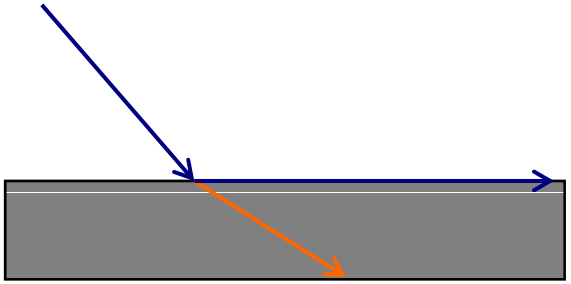
$$\frac{\sin\theta_1}{V_{L_1}} = \frac{\sin\theta_2}{V_{L_2}}$$

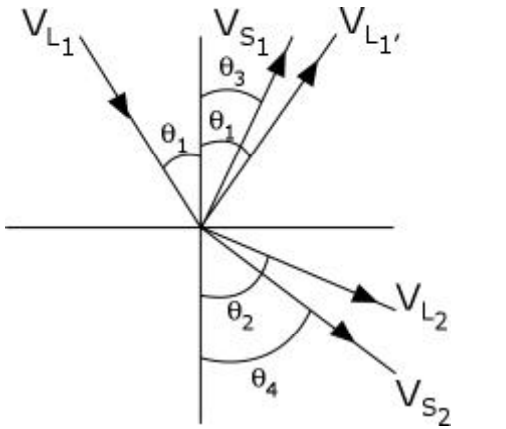
- The situation is similar to optics.
- But here Mode Conversion can take place.

Oblique Incidence









$$\frac{\sin\theta_1}{V_{L_1}} = \frac{\sin\theta_2}{V_{L_2}} = \frac{\sin\theta_3}{V_{S_1}} = \frac{\sin\theta_4}{V_{S_2}}$$

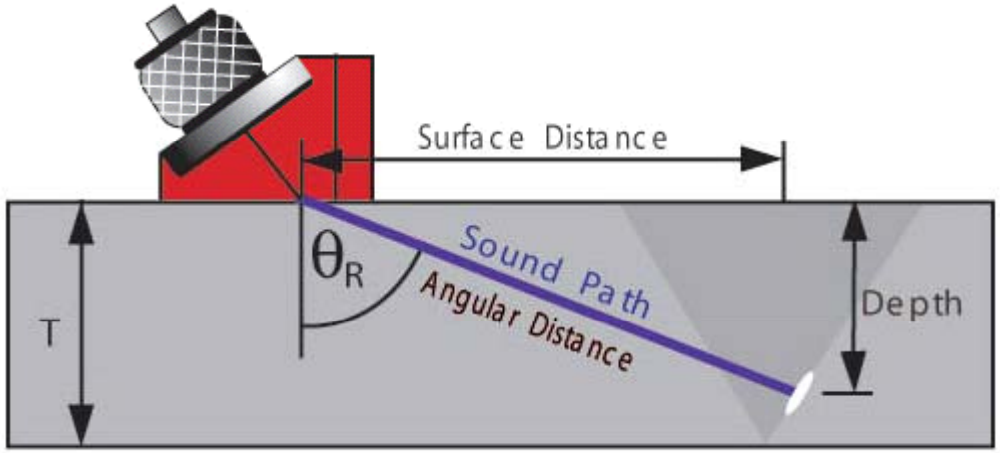
Long and trans wave are possible and have different sound velocities.

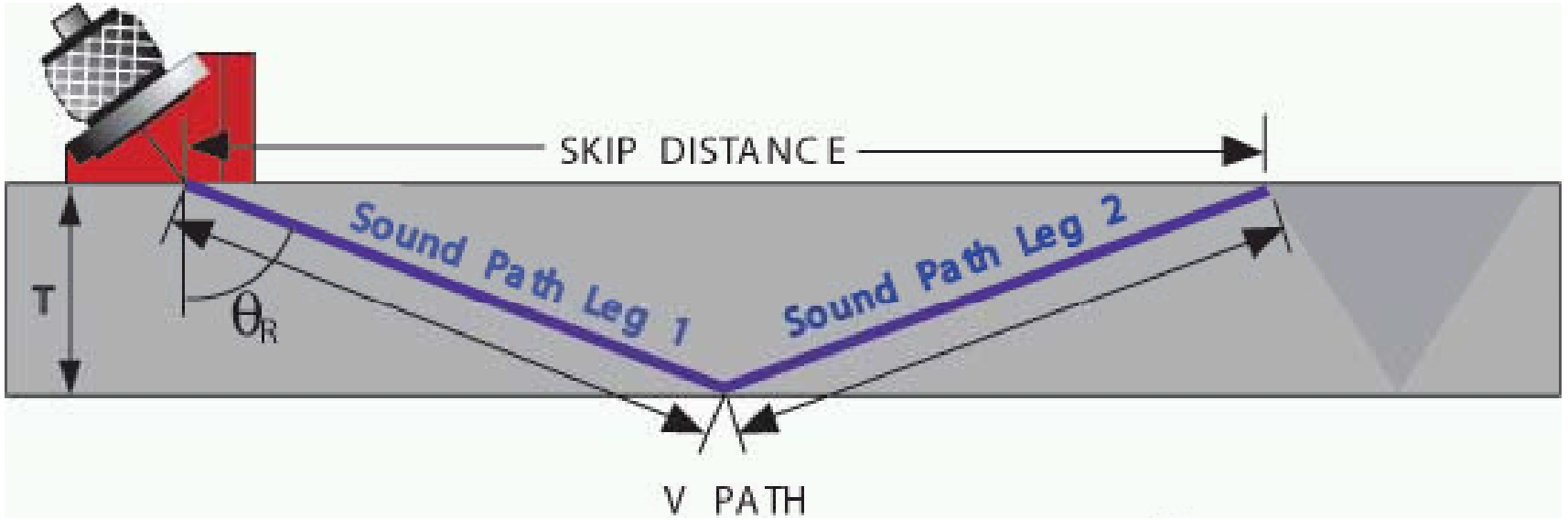
$$v_L = 5900\,m/s$$

$$v_T = 3200\,m/s$$

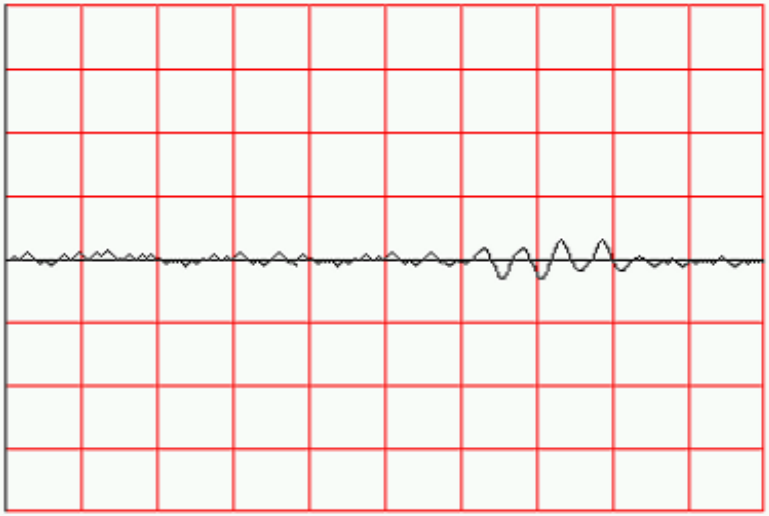
- Increasing the angle of incidence leads to only transversal wave.
- Situation used for weld inspection!

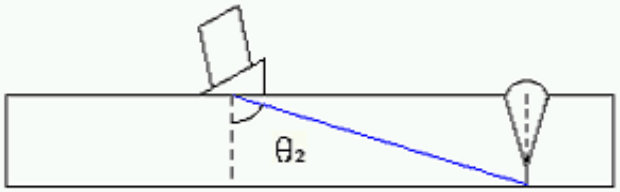
Wedge transduer heads

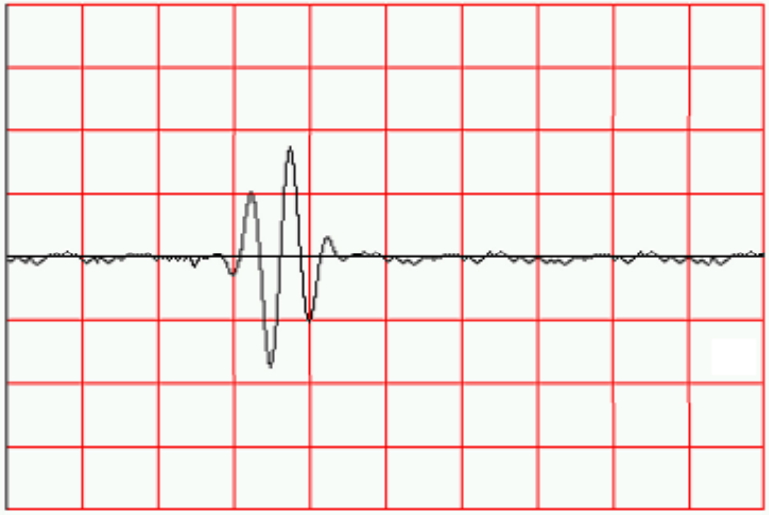




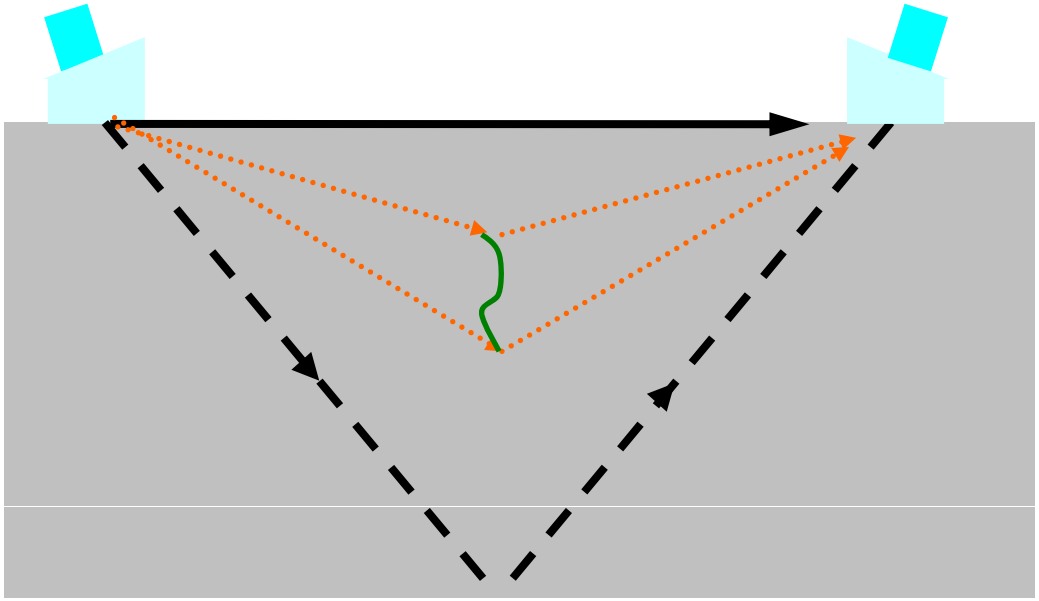
Oblique Incidence Defect Detection





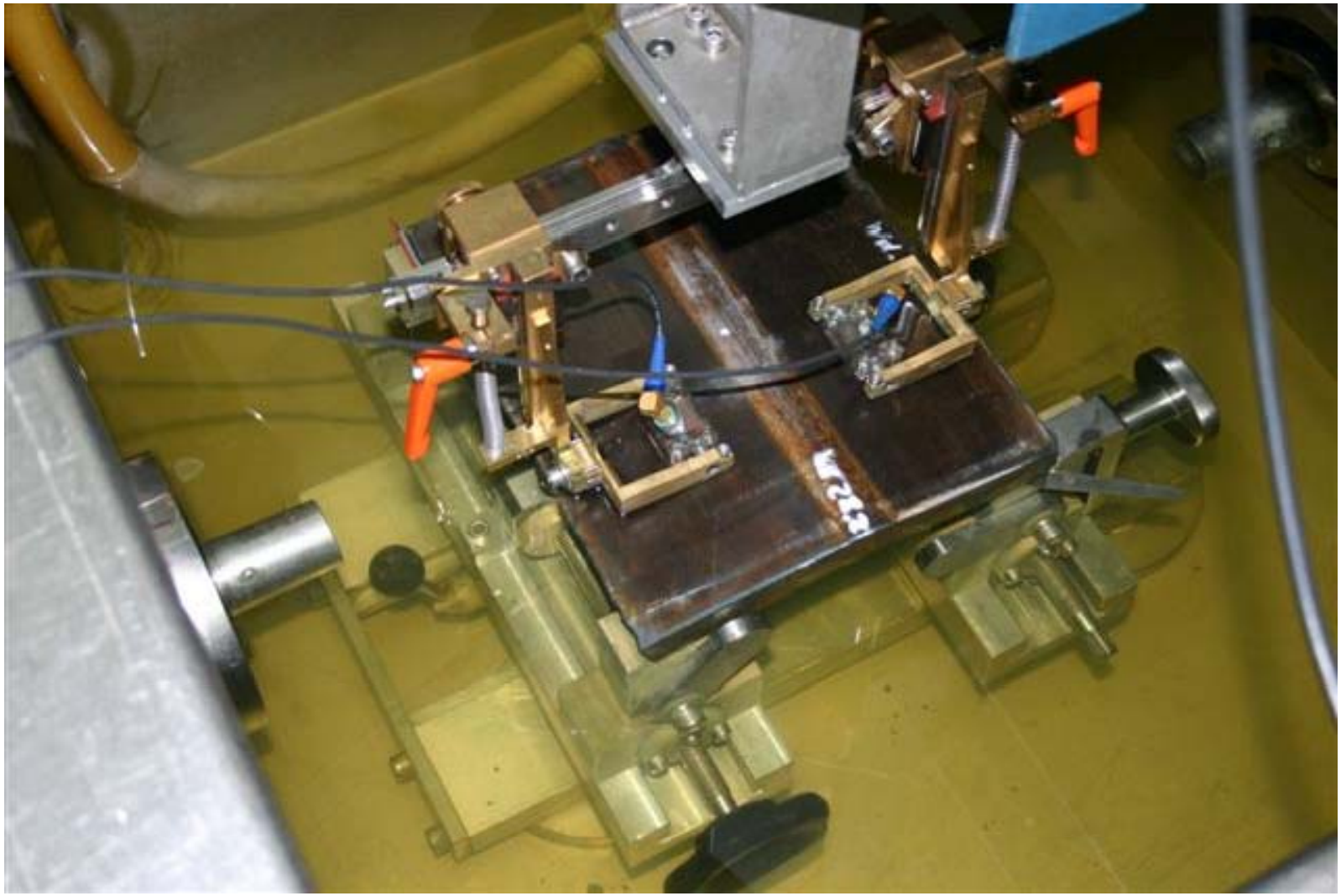


Time of Flight Diffraction TOFD



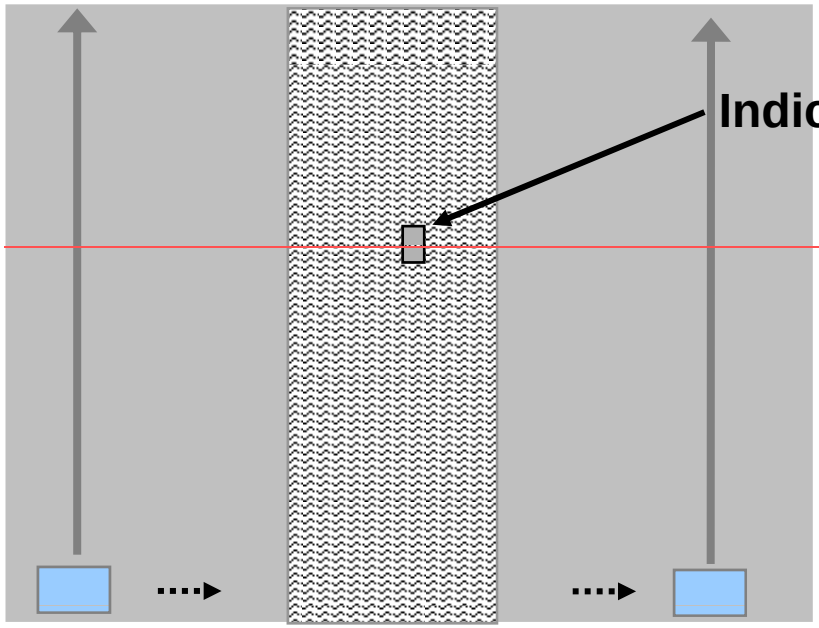
- Transducer heads with wide opening angle are used and mounted in a fixed distance.
- Crack tips give an diffracted signal that is well detectable when comparing it to the neighbourhood.

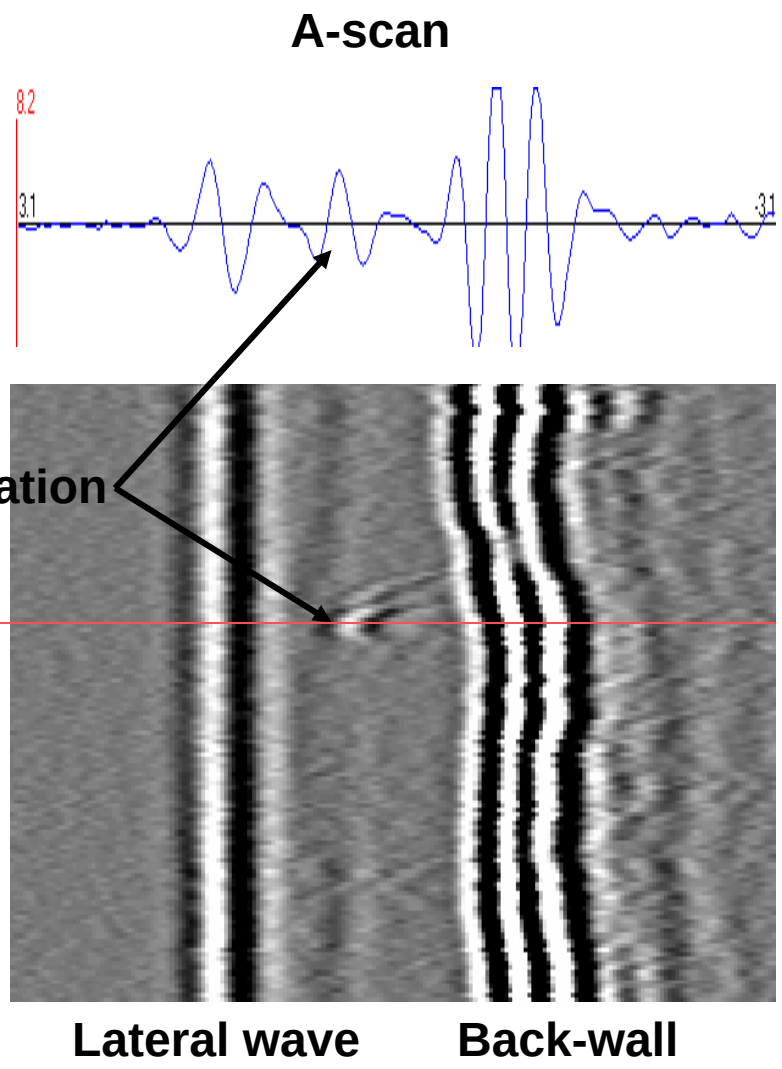
Time of Flight Diffraction TOFD



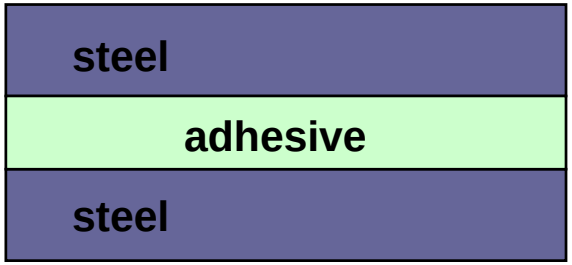
Time of Flight Diffraction TOFD

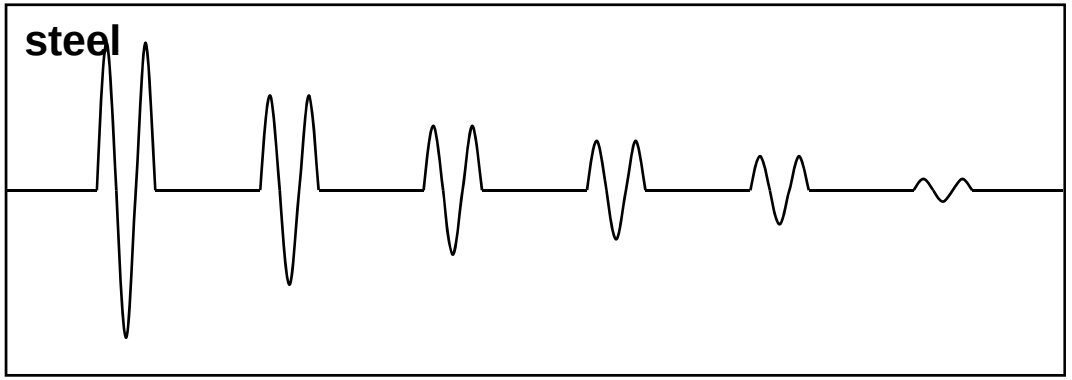
- TOFD is typically used for the inspection of girth welds.
- Evaluation mainly by visual inspection.

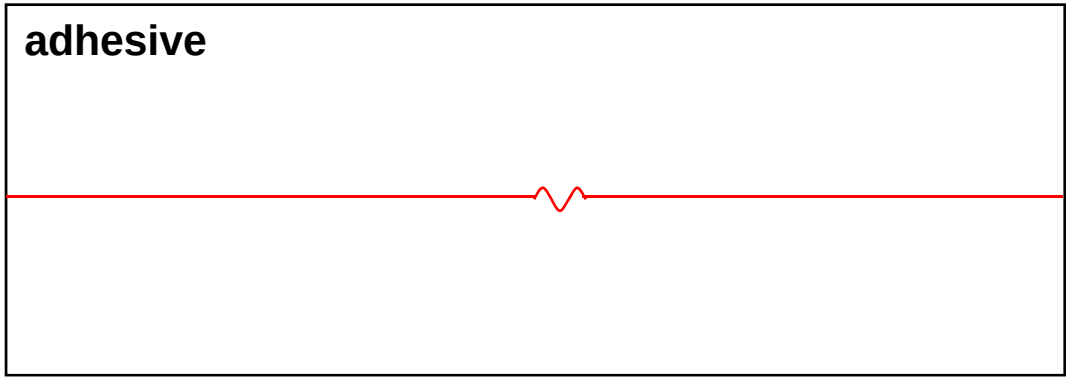


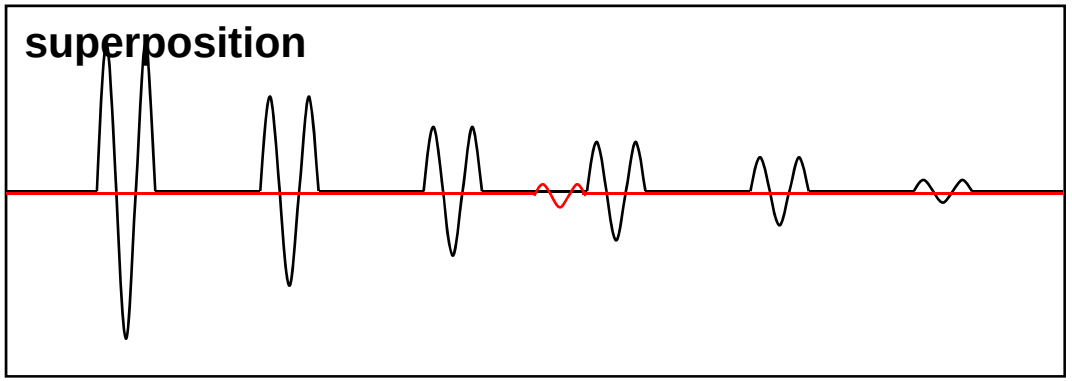


Inspection of adhesive joints









- High attenuation in adhesive layer.
- Superposition is difficult to interpret.
- Only weak joint gives no particular reflection.
- Solution: nonlinear effects

nonlinear effects

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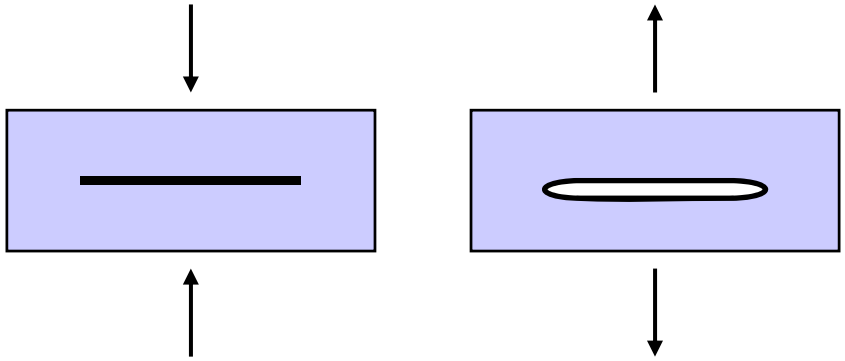
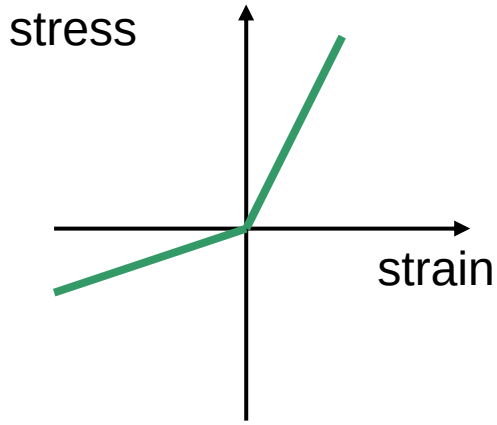
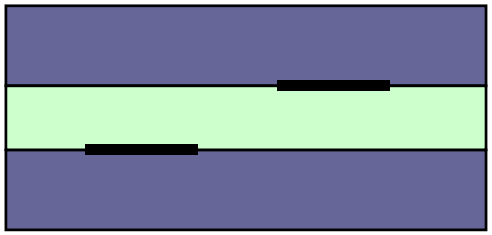
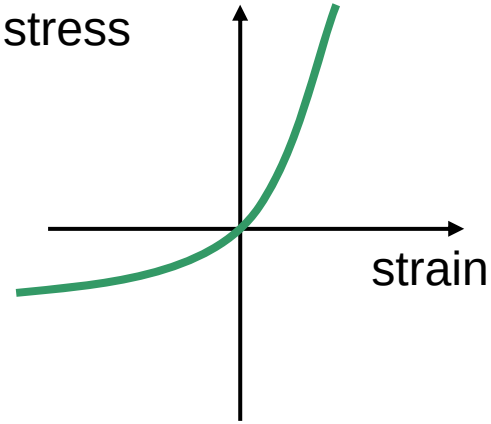
Fatigue cracks





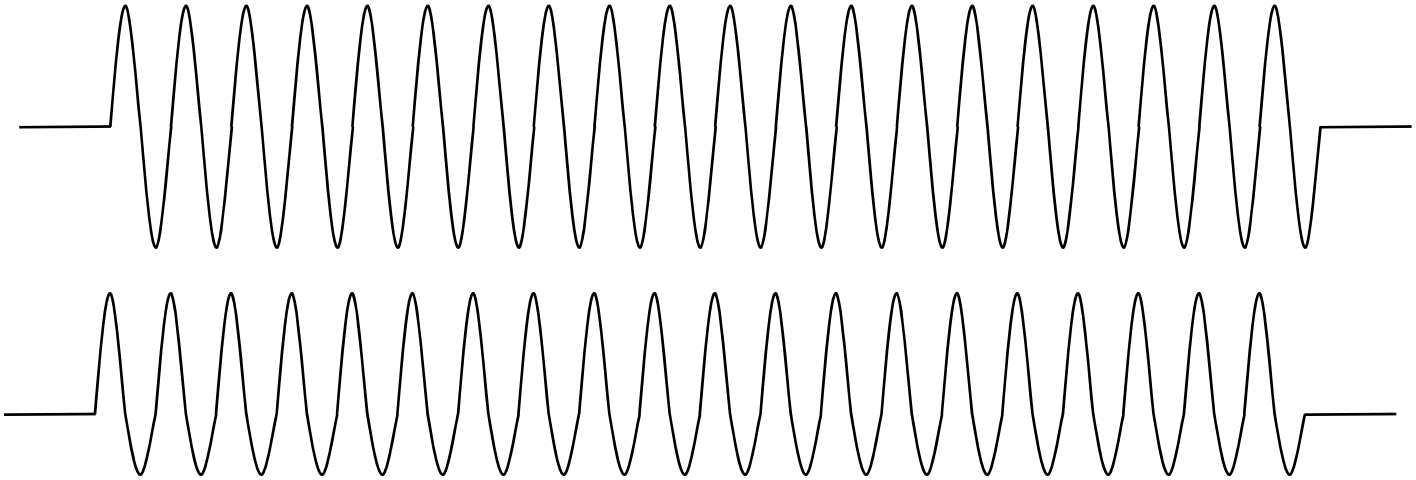
Adhesive joints

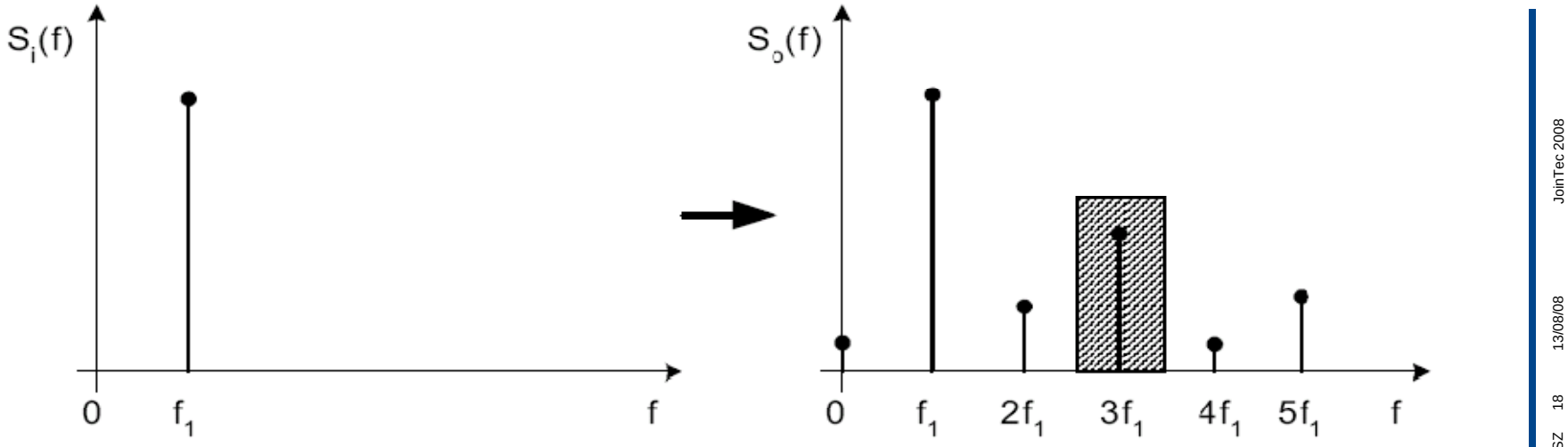




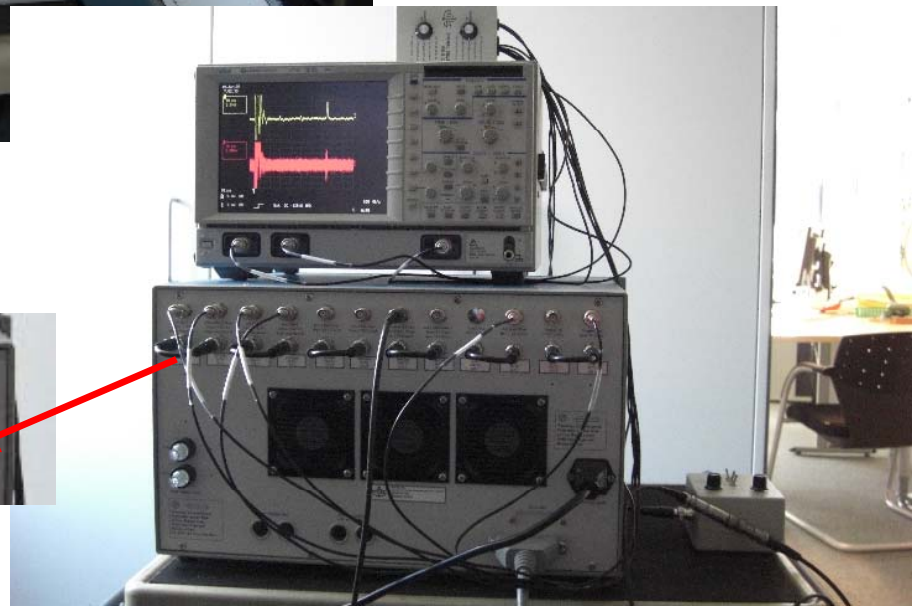
- weak joints
- air filled voids

Effects on Ultrasound

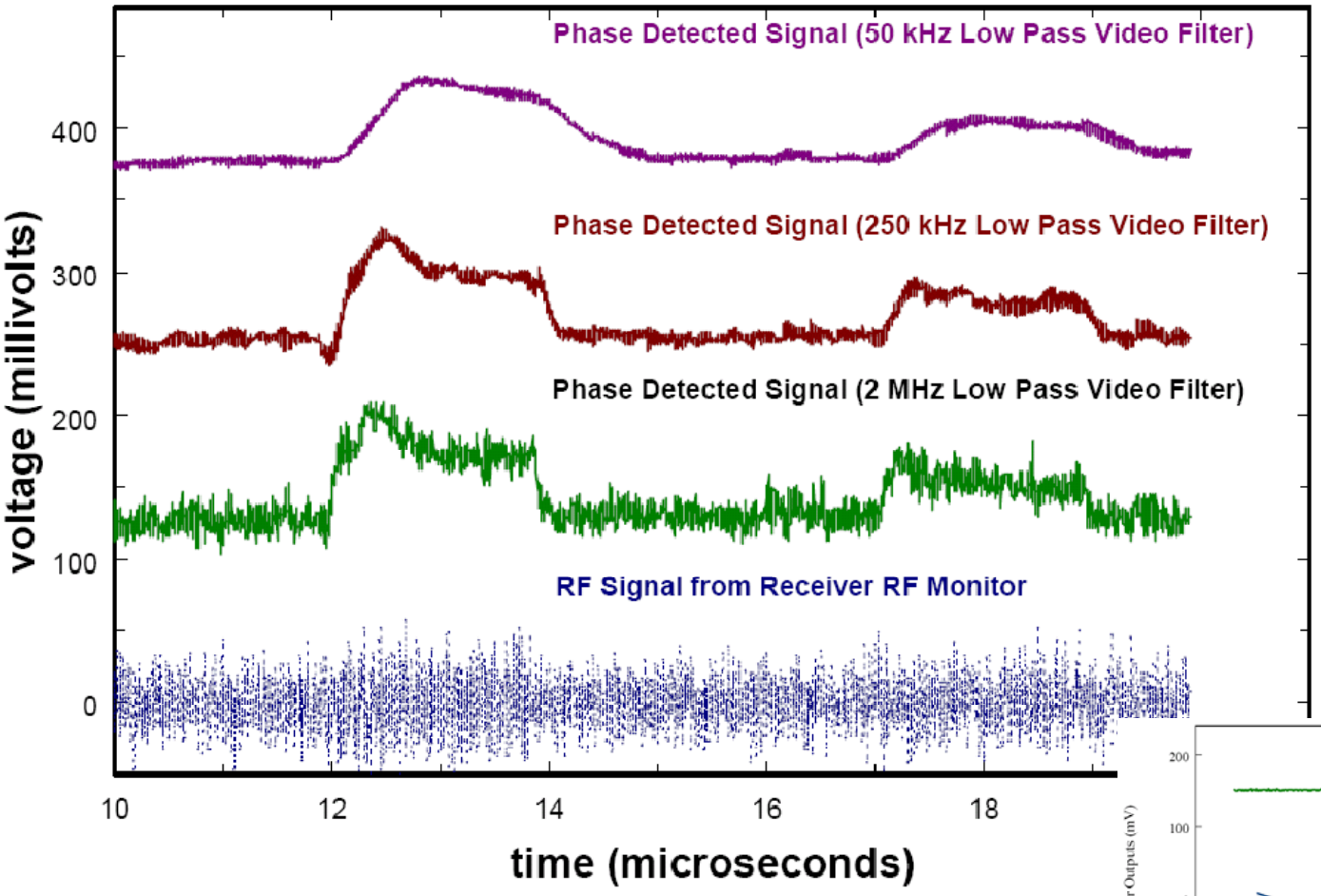


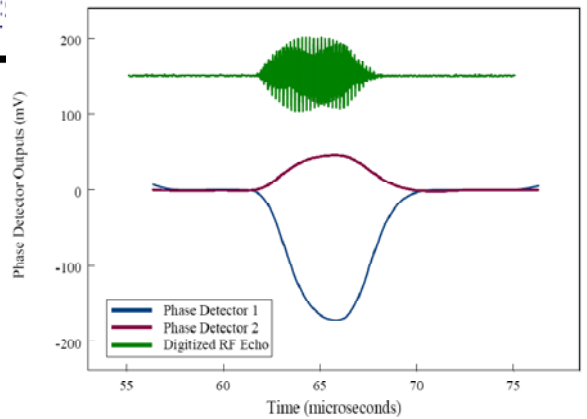


The RITEC SNAP



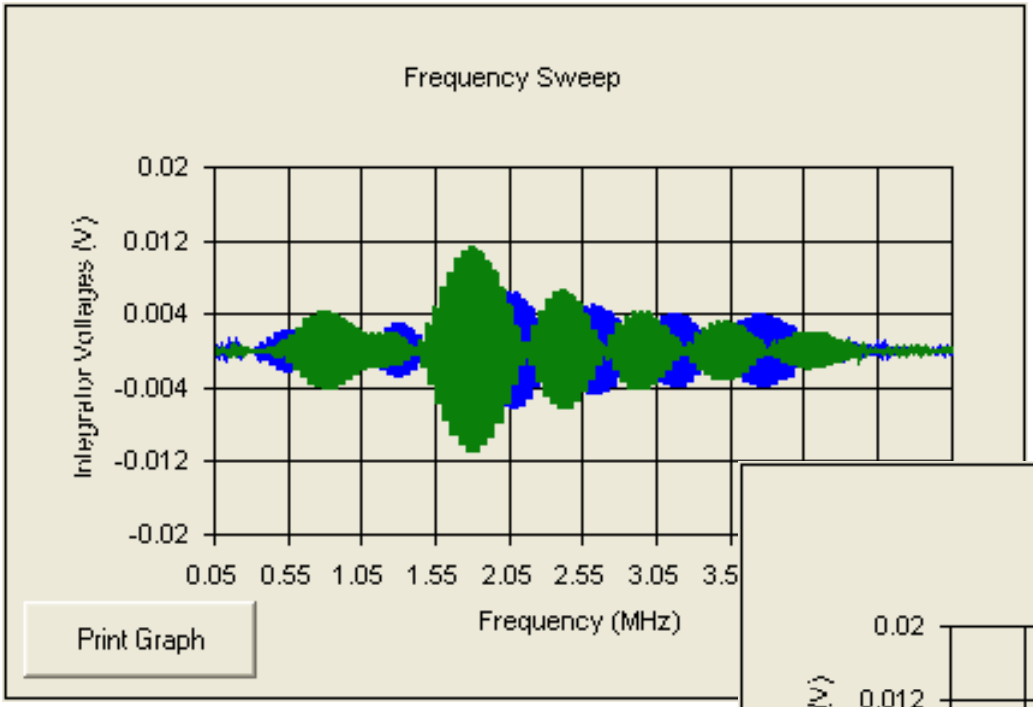
Signalprocessing



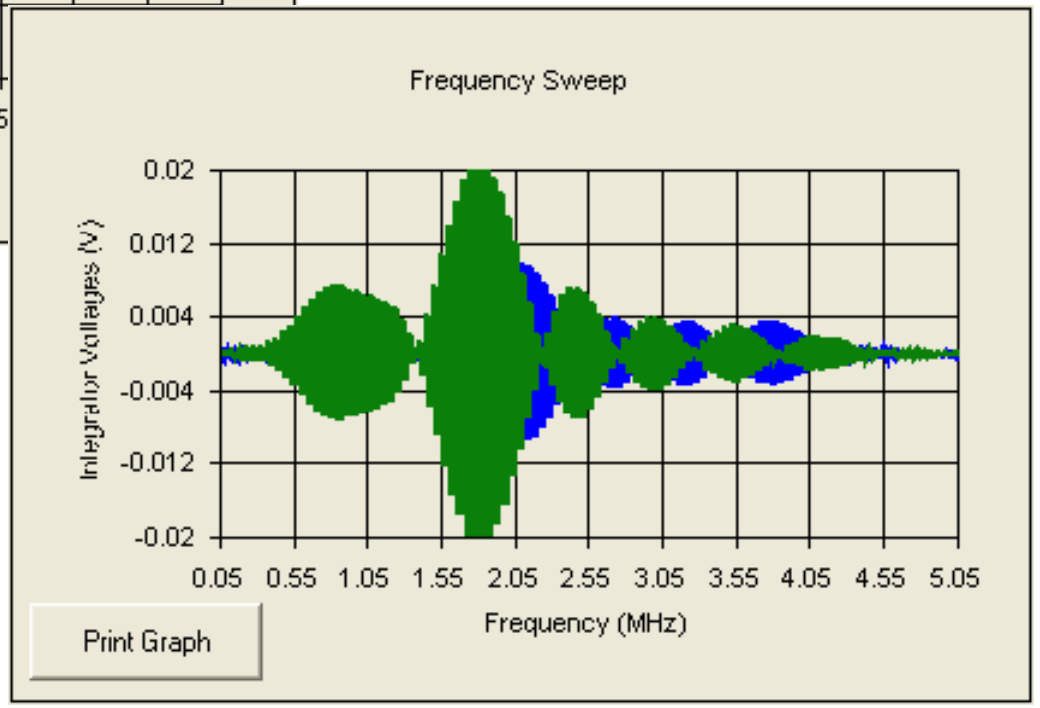


Signalprocessing

Comparison Second Harmonic

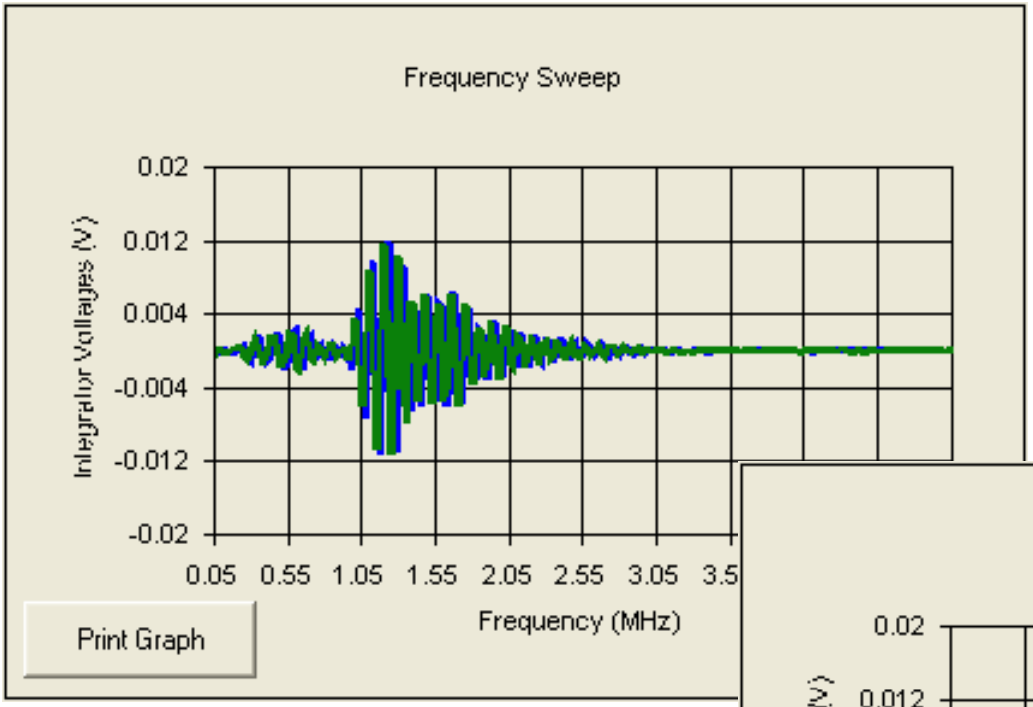


normal joint

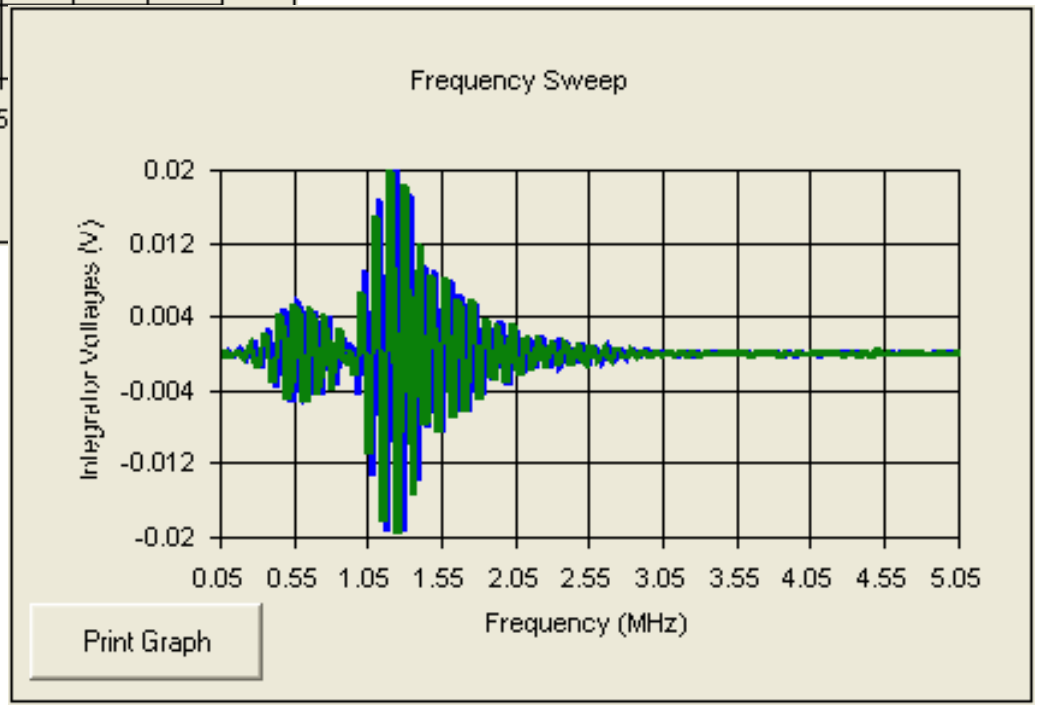


weak joint

Comparison Third Harmonic



normal joint



weak joint