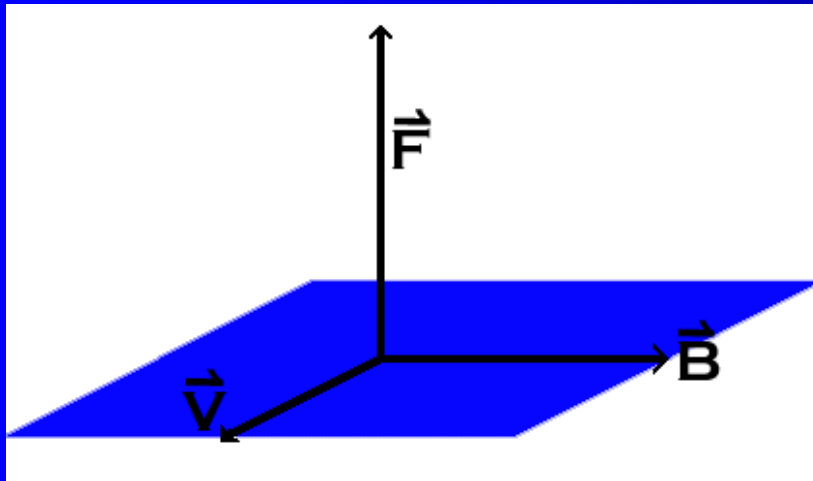


- **NON-CONTACT
ULTRASONIC TESTING USING
EMAT TRANSDUCERS**

Introduction

- EMAT principle
(ElectroMagnetic Acoustic Transducer).



$$\oint \vec{B} \cdot d\vec{l} = \mu_0 I + \mu_0 \epsilon_0 \frac{d\Phi_E}{dt}$$

$$\vec{F} = q(\vec{v} \times \vec{B})$$

Orientation of force vector, magnetic induction and velocity

EMAT – Application Fields

- testing of steel bars and rods
- testing of tubes and pipes
- testing of pressure vessels
- survey testing
- testing on the orbit
- testing of non-metallic products
- measuring of modulus of elasticity
- thickness measuring at high temperatures

Advantages of EMAT

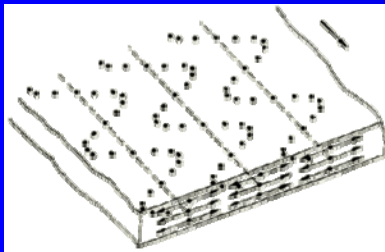
- works without need of contact or liquid coupling
- can work at high temperatures
- enables generation of various wave types
 - SH (shear horizontally polarized)
 - LH (longitudinal horizontally polarized)
 - Rayleigh waves
 - Lamb waves
 - SH plate waves

Disadvantages of EMAT

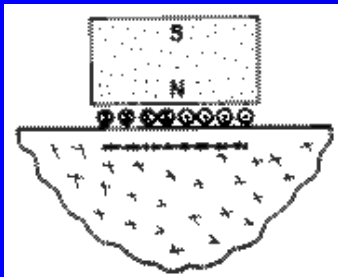
- works only in conductive environment and in ferromagnetic materials
- very weak signal – low SNR
- great force attracting the transducer with permanent magnet to material

Types of US Waves Generated by EMAT

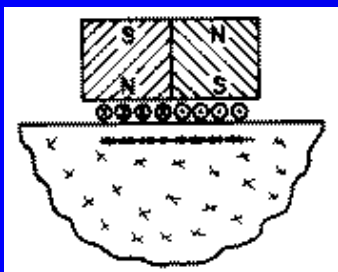
- Shear Wave



- Horizontally polarized shear wave.



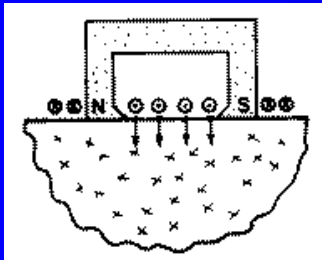
- Spiral coil of EMAT generates radially polarized shear wave, which propagates perpendicularly to the surface.



- Configuration of EMAT for plane polarized shear wave, which propagates perpendicularly to the surface.

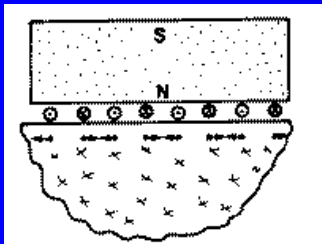
Types of US Waves Generated by EMAT

● Longitudinal Wave

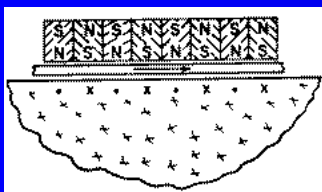


- Magnetic field oriented parallel to the surface for generation of longitudinally polarized wave, which propagates perpendicularly to the surface.

● Rayleigh and Lamb Waves



- Meander coil in this configuration enables generation of longitudinal, shear, Rayleigh, Lamb wave, plate wave, which propagates under an angle.



- Periodic magnetic field enables generation of planar or angled horizontally polarized shear wave or plate wave.

Generator for EMAT

Basic parameters of the developed generator:

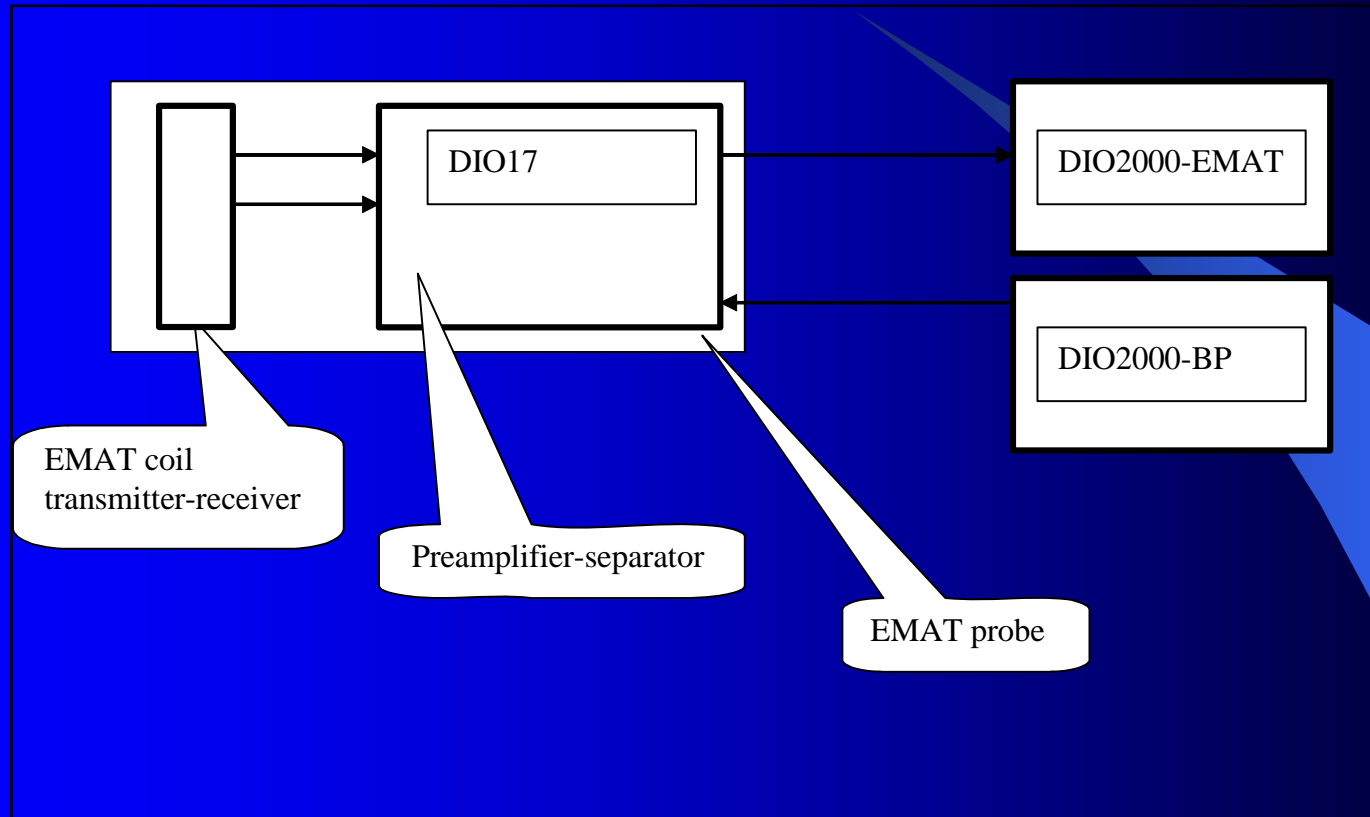
- Voltage	900 V
- Leading edge time	6 ns
- Current	30 A – 160 A
- Output pulse power	27 kW – 150 kW
- Number of output pulses	1 to 20

Instrumentation for EMAT Signal Processing

Basic characteristics of the ultrasonic channel:

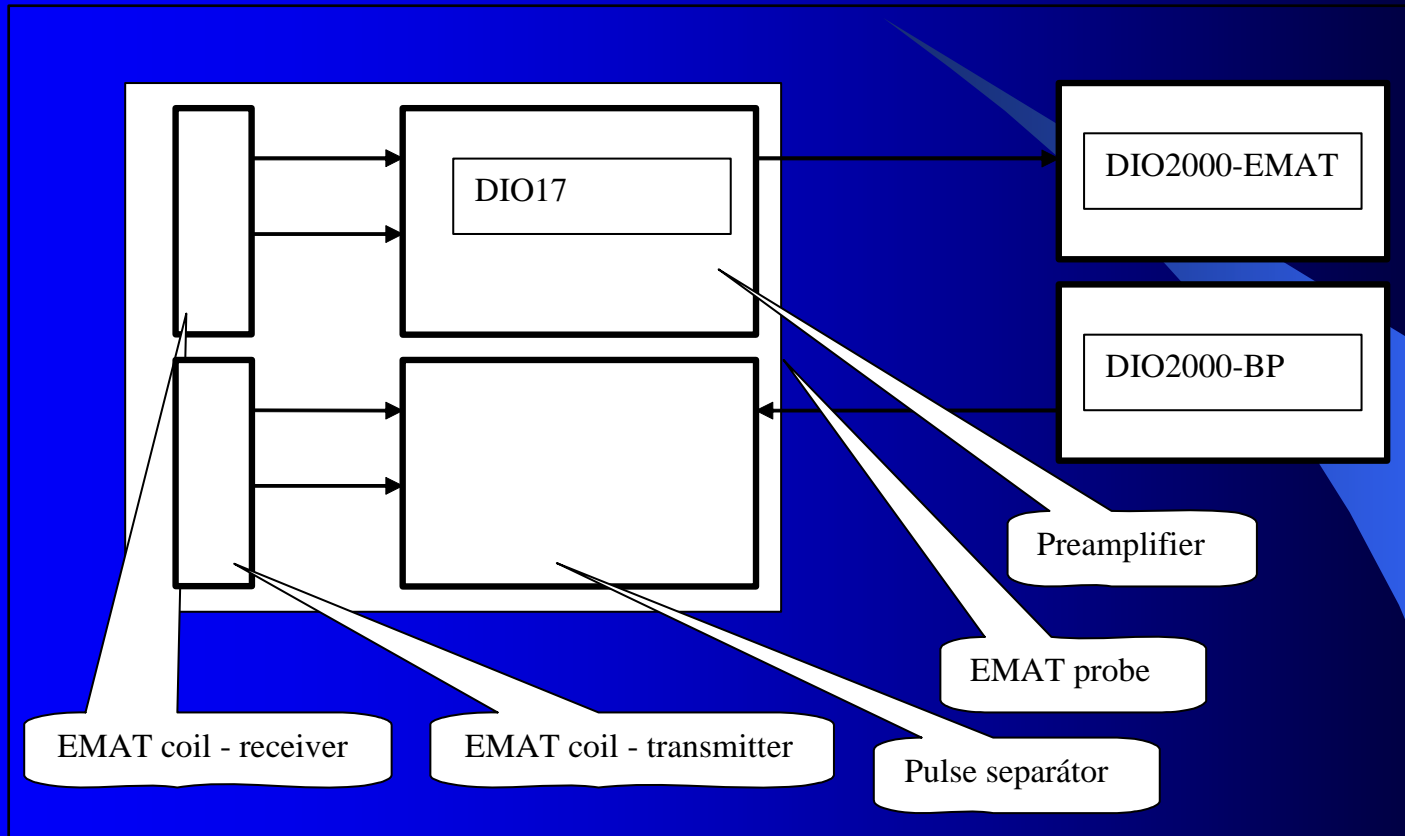
- adjustable pulse repetition rate;
- adjustable gain and frequency band filters;
- digital signal processing DSP (digital filters, averaging and other functions);
- three monitor gates with adjustable threshold level;
- measuring of echo amplitudes, mean, relative and absolute echo position and its graphic presentation;
- 2 analog outputs (amplitude and time) for C-scan;
- automatically refreshable freeze mode, freezing of maximum values;
- external and internal synchronization with adjustable time shift;
- external power pulse generator can be connected to each channel;
- transducers with internal dynamically excited preamplifier can be connected.

Instrumentation for EMAT Signal Processing



Preamplifier EMAT for Single Transducer

Instrumentation for EMAT Signal Processing



Preamplifier EMAT for Dual Transducer

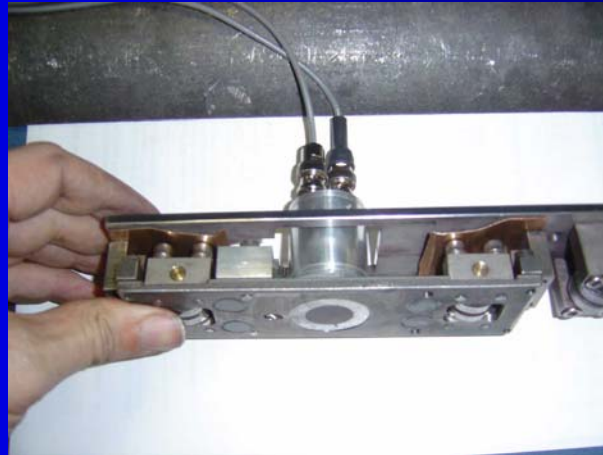
Software DIO 2000

- is intended for control of ultrasonic units, database and signals display;
- individual activation and deactivation of each channel;
- A-scan of ultrasonic signals for each channel can be displayed in one or more windows and by groups;
- graphic display of the measured values process, depending on time or space co-ordinates;
- process of measured and calculated values;
- B-scan and its combinations, combined values from several channels, statistics, minimum values, maximum values etc.;
- outputs for automated marking;
- maximum possible number of channels up to 64.

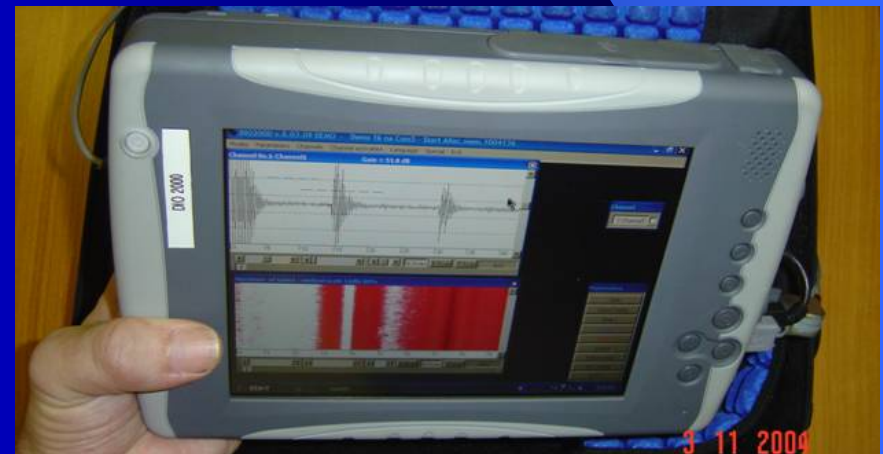
EMAT – Parameters for Thickness Measurement

- Dead zone: 15 μ s
- Measuring range: 0,8 mm – 150 mm
- Distance probe to material: 1 to 2 mm !!!
- Protective layer thickness: 0,5 mm
- Protective layer material: corundum plate
- Probe type: shear wave
- Probe frequency: 2 – 7 MHz

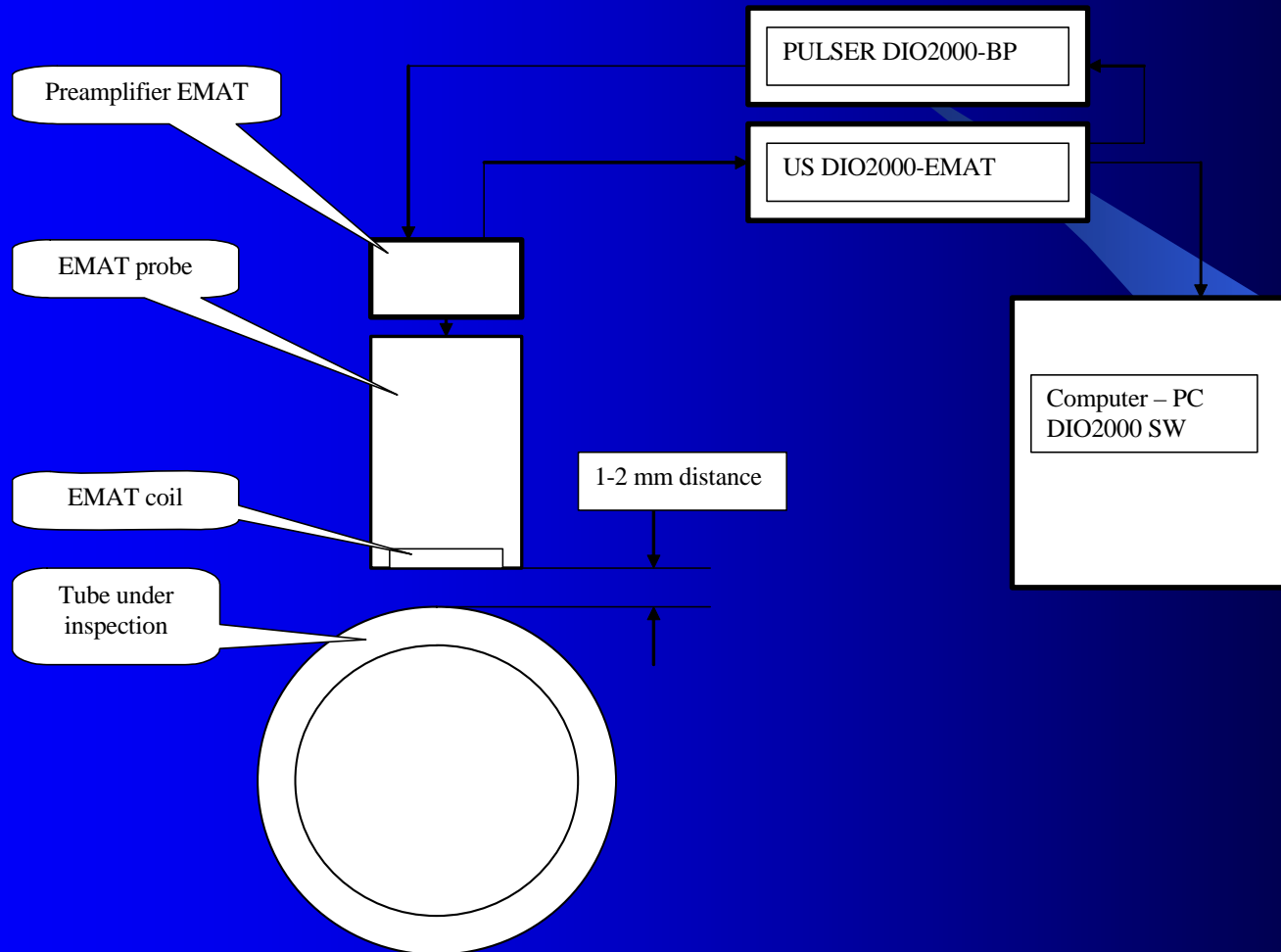
EMAT Probes



Hand Instruments for Ultrasonic Testing



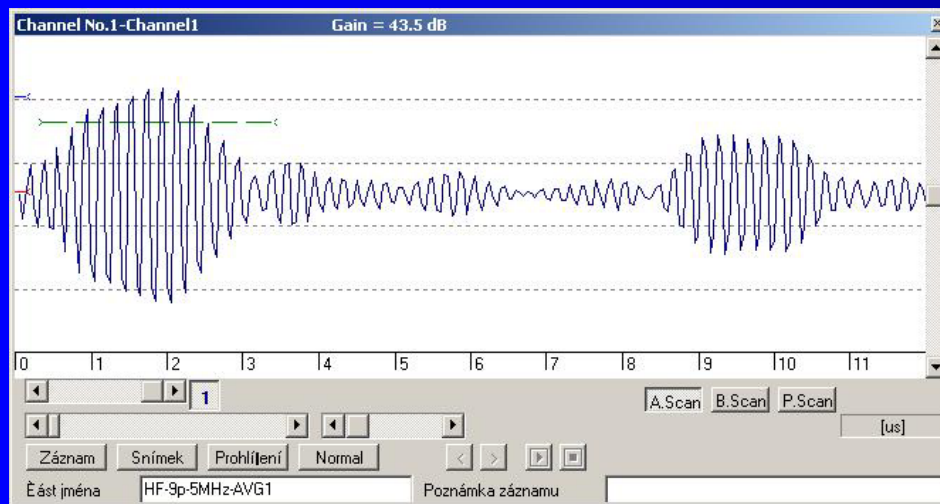
Automated Measuring System



Results of Signal Characteristics and Spectrum Measurements

Resulting signal had been principally affected by:

- pulser setting 1-9 pulses,
- setting of analog input circuits,
- consecutive DSP processing in real time,
- reflected signal of the transducer in P-E mode.



HF EMAT signal at 5 MHz frequency and 8 transmitted pulses produces energy aggregation with dominant energy matching with transmitted frequency.

Results of Measurements

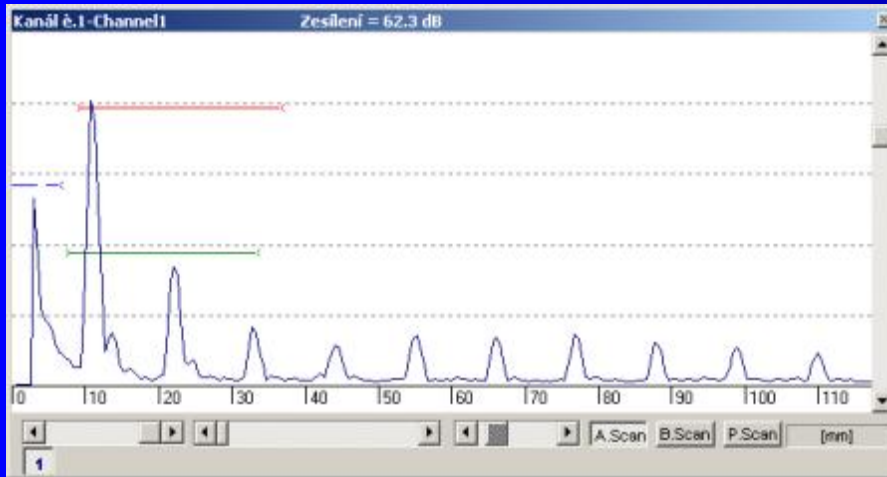


Plate thickness 10 mm,
steel.

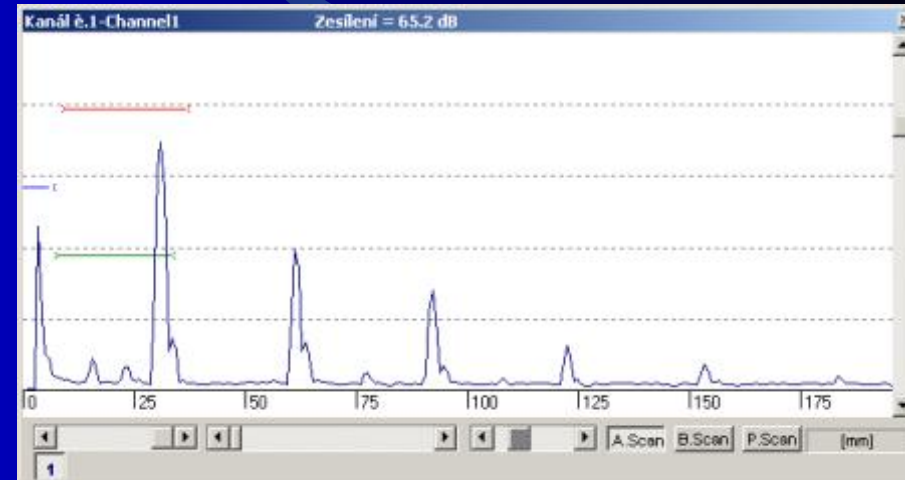


Plate thickness 30 mm,
steel.

Results of Measurements

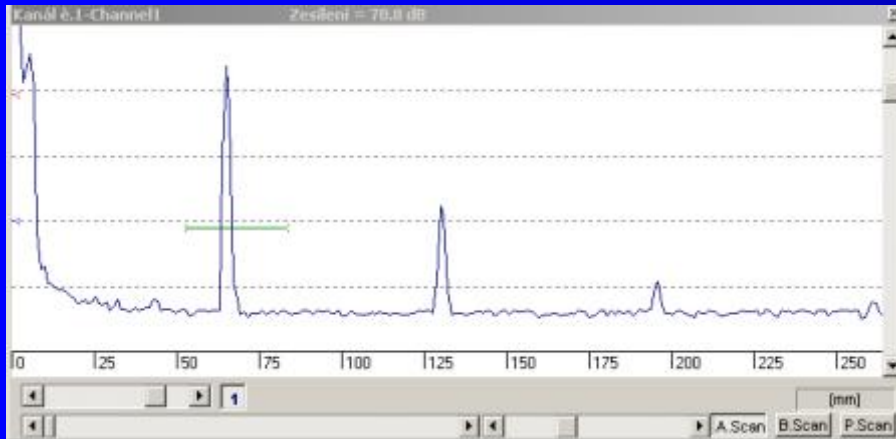


Plate thickness 60 mm,
aluminium.

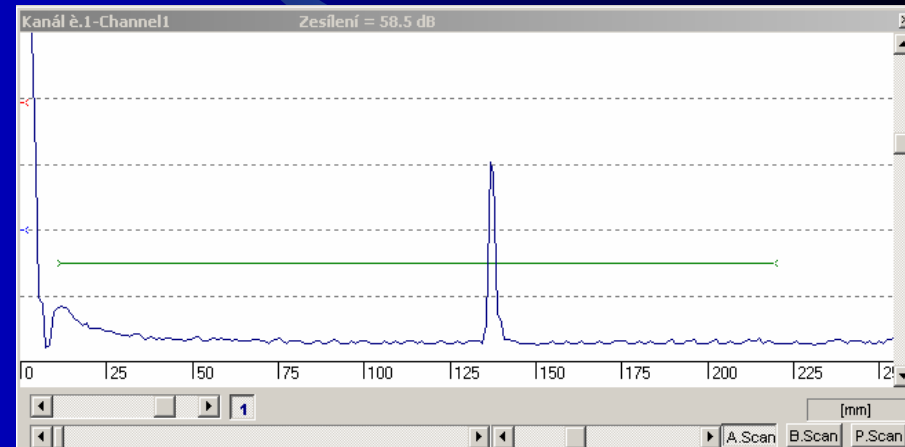


Plate thickness 135 mm,
steel.

Results of Measurements

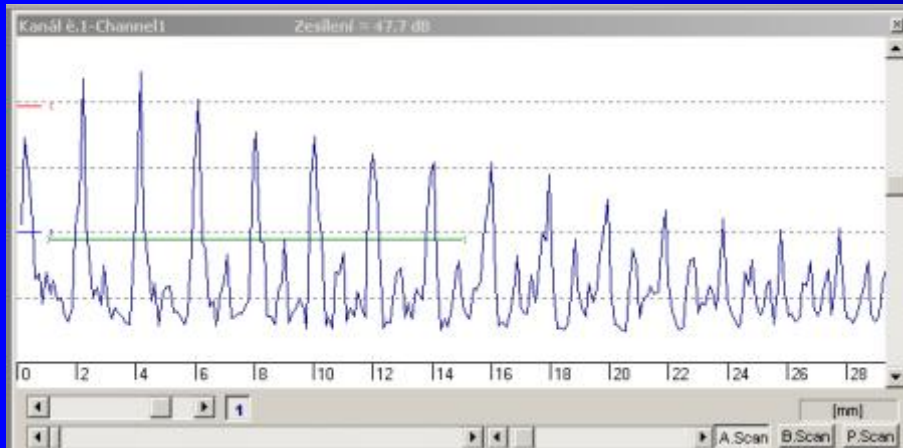
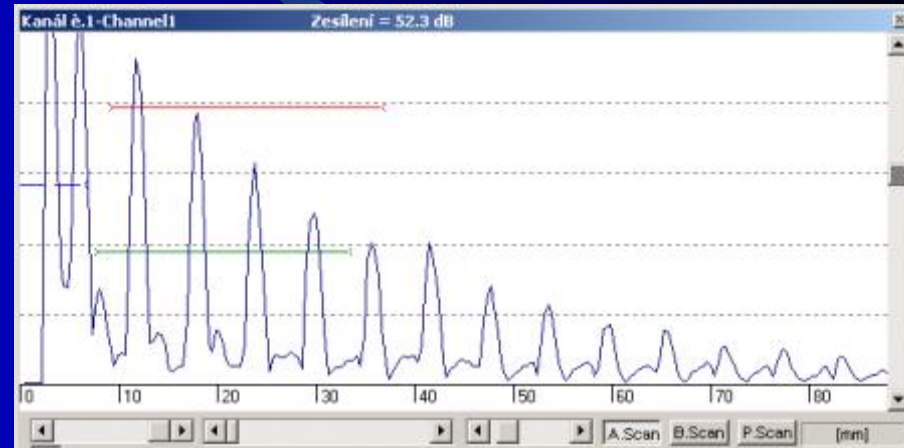


Plate thickness 2 mm,
aluminium.



Tube T 6 mm, 200 mm dia.

OFF-LINE Signal Processing Methods

- Data export is available with different extent of the measuring parameters, up to the clear matrices non/sampled data.
- Saved data are indexed according to the order, or files are marked by the time mark for identification distribution.
- Export of the measured data is available in the following formats:
 - Database PARADOX for programming in DELPHI
 - EXCEL export
 - ASCII file export
 - Binary file export
 - ASCII file in the columns for MATLAB

Results of Development

- Designing the EMAT probes — By optimizing the coil impedance, we have achieved very good signal, even with lead-in cables up to 5 m long.
- Durability tests of probes in real operation — Durability of probes is determined primarily by mechanical destruction by different artifacts on the material under measuring.
- Development of EMAT amplifiers — Amplifiers with power supply from external sources seems to be insufficient from view of noise immunity. We have developed the amplifiers, which are powered dynamically via signal cable.