

Oförstörande provning i kärnkraftens betongkonstruktioner

LTH-projekt från 1995 - 2022

Peter Ulriksen

Avsökningsmetoder



Vid behov av snabb färd framåt
T ex på vägar måste man offra
Upplösning tvärs färdriktningen

Här världens första GSSI
5 kanalsystem byggt för LTH
5 x 500 MHz antenner



När behovet av maximal upplösning är stort måste man ta till en XY-scanner. Upplösningen i horisontalled är i princip hur liten som helst, till priset av att det tar lång tid att genomföra mätningen.

En lämplig upplösning har visat sig vara 1 cm mellan mätpunkterna.



1997

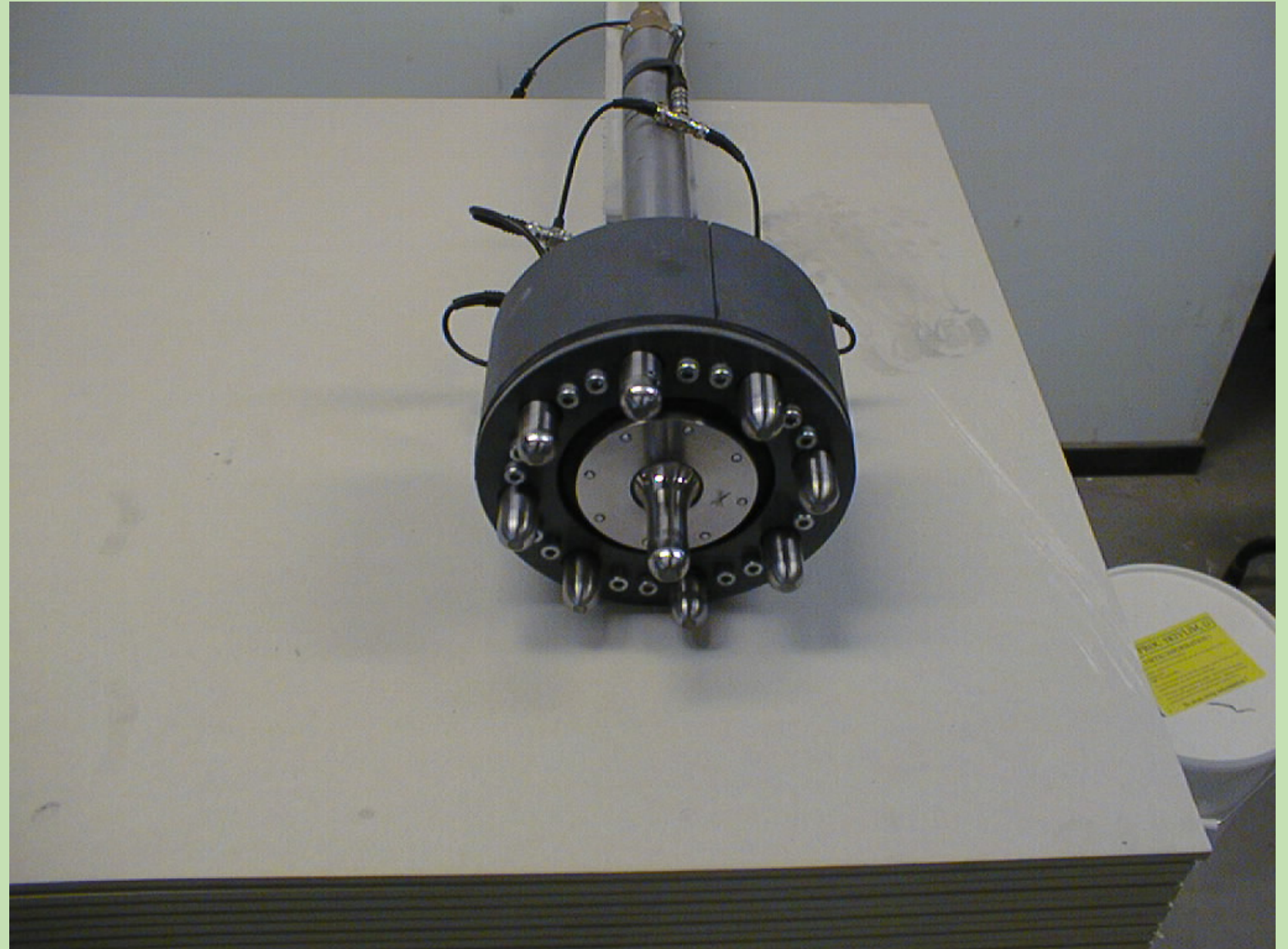
Automatisk avsökning av betongkonstruktioner med utrustning baserad på mekaniska vågor

Elforsk Rapport 1997:23 - Peter Ulriksen, Ulrika Wiberg



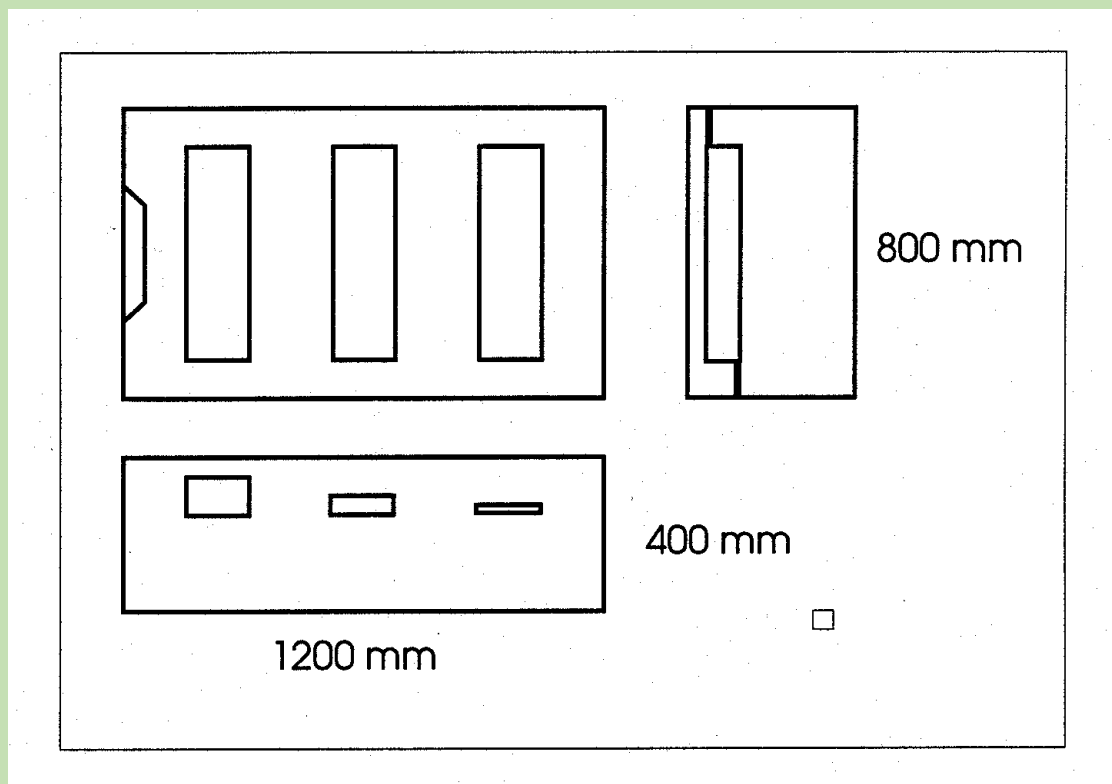
Center point
is piezo actuator

8 accelerometers
connected in
parallell



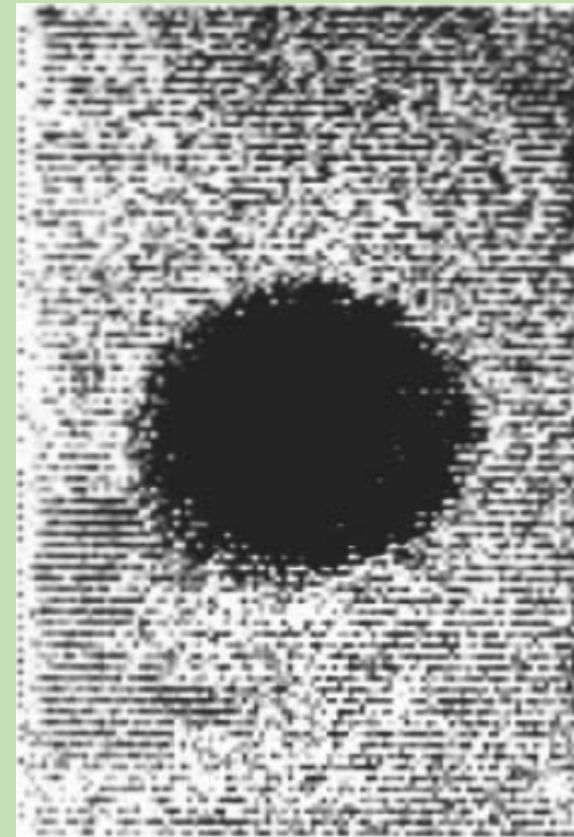
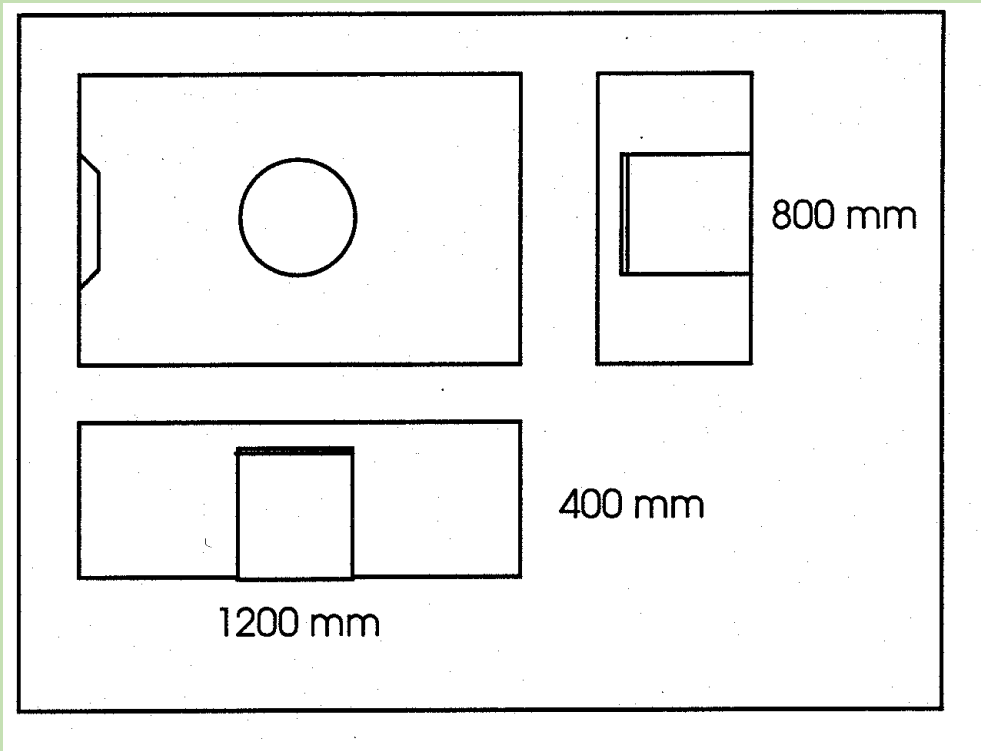


Three foam concrete blocks





A cylinder with a movable piston



2010

Litteraturstudier och test av oförstörande provningsmetoder (OFP) med möjliga tillämpningar på kärnkraftens betongkonstruktioner

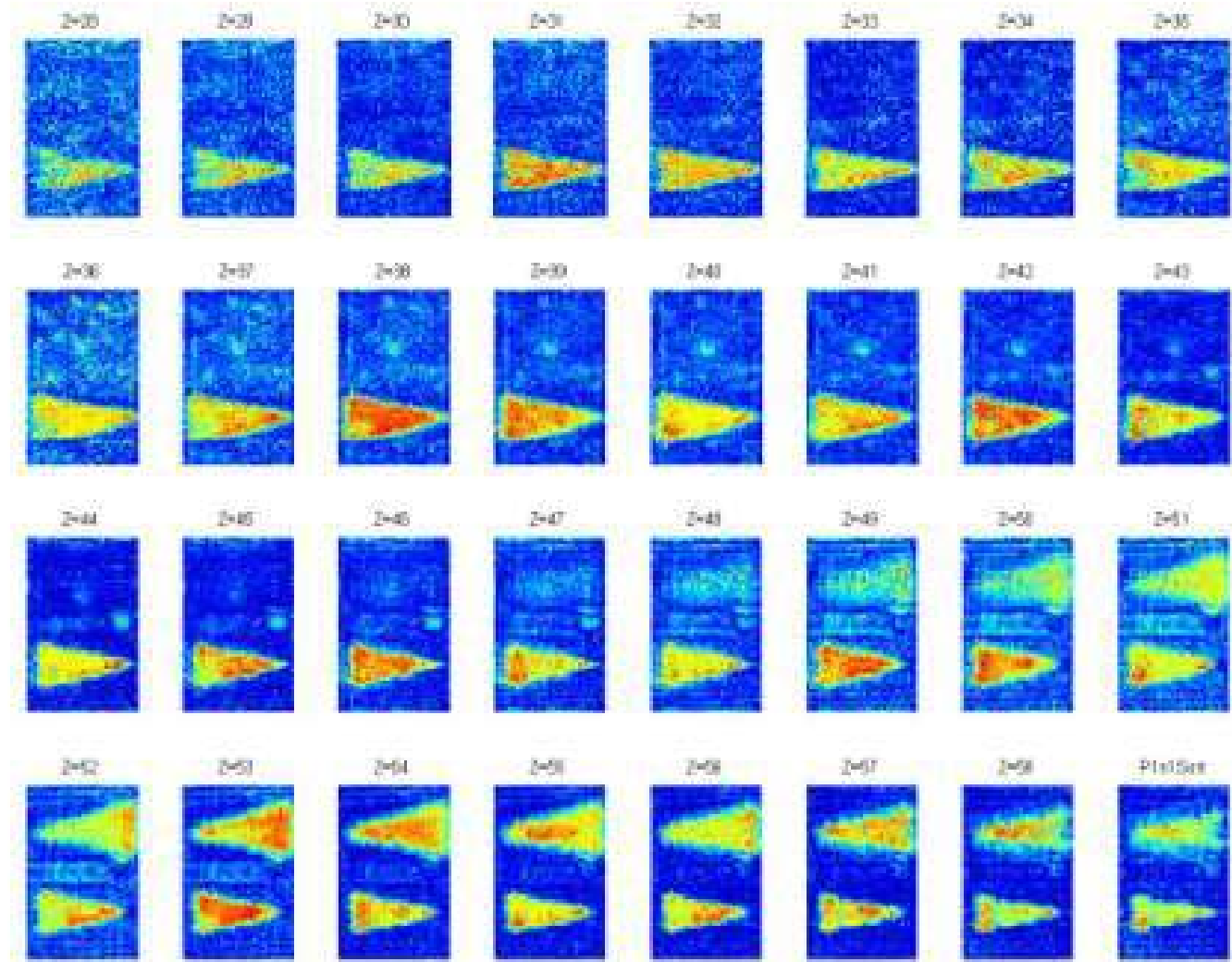
Elforsk Rapport 2010:85 - Peter Ulriksen

Construction
of test object
for
delamination
studies

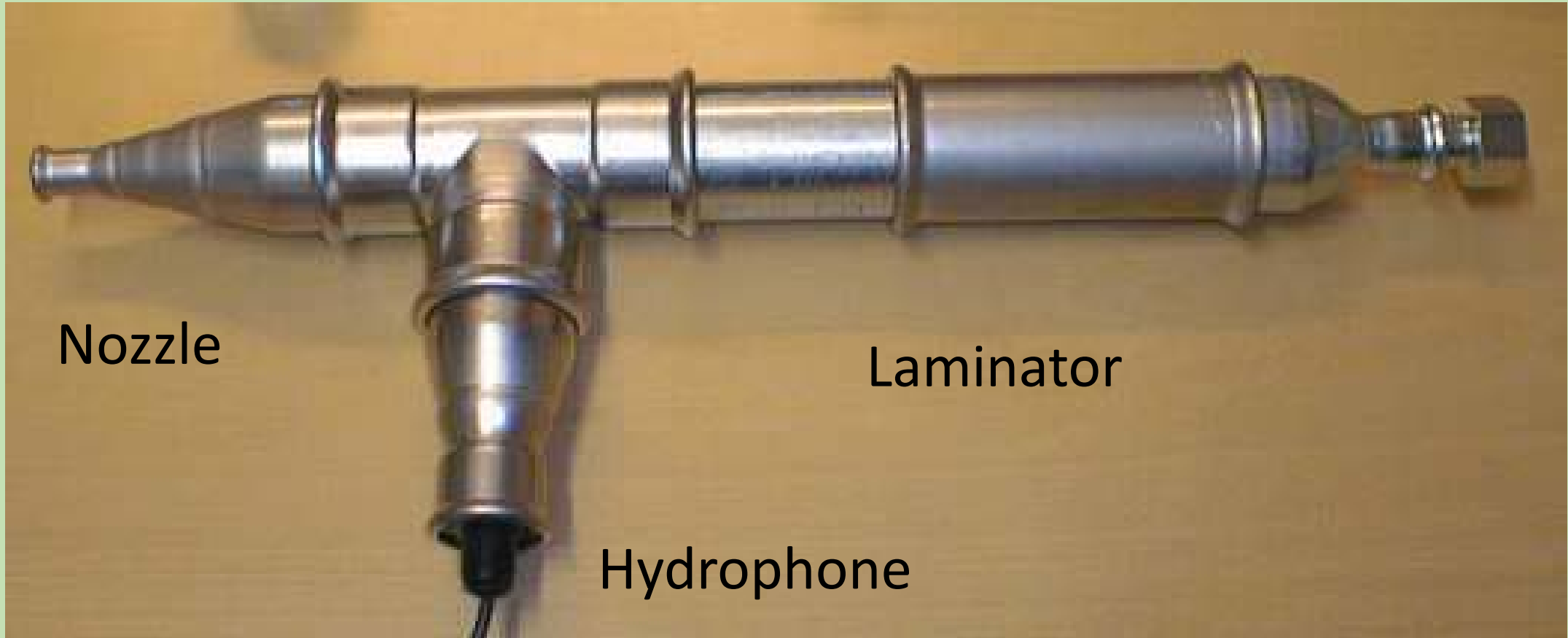


55 kHz Shear wave

Depth slices



Water Jet Device

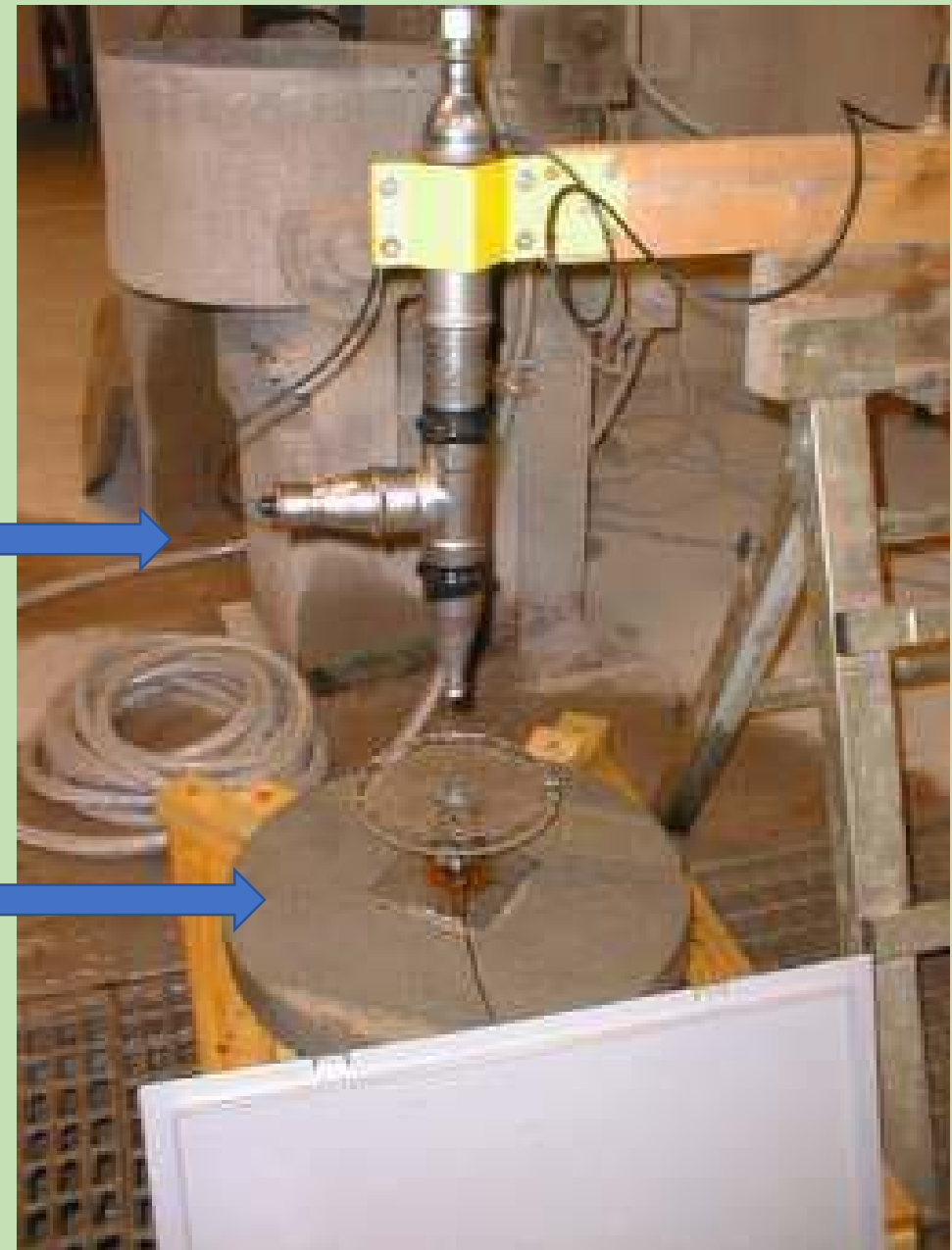


Water jet experiment

Hydrophone



Vibrator



2011

*Impulsresponsmätningars beroende av sprickdjup
Elforsk Rapport 2011:11 - Peter Ulriksen*

To what depth can a delamination be measured?

Point impedance is defined as

$$Z(f) = F(f)/v(f)$$

where

f= Frequency (Hz)

F= Force (N)

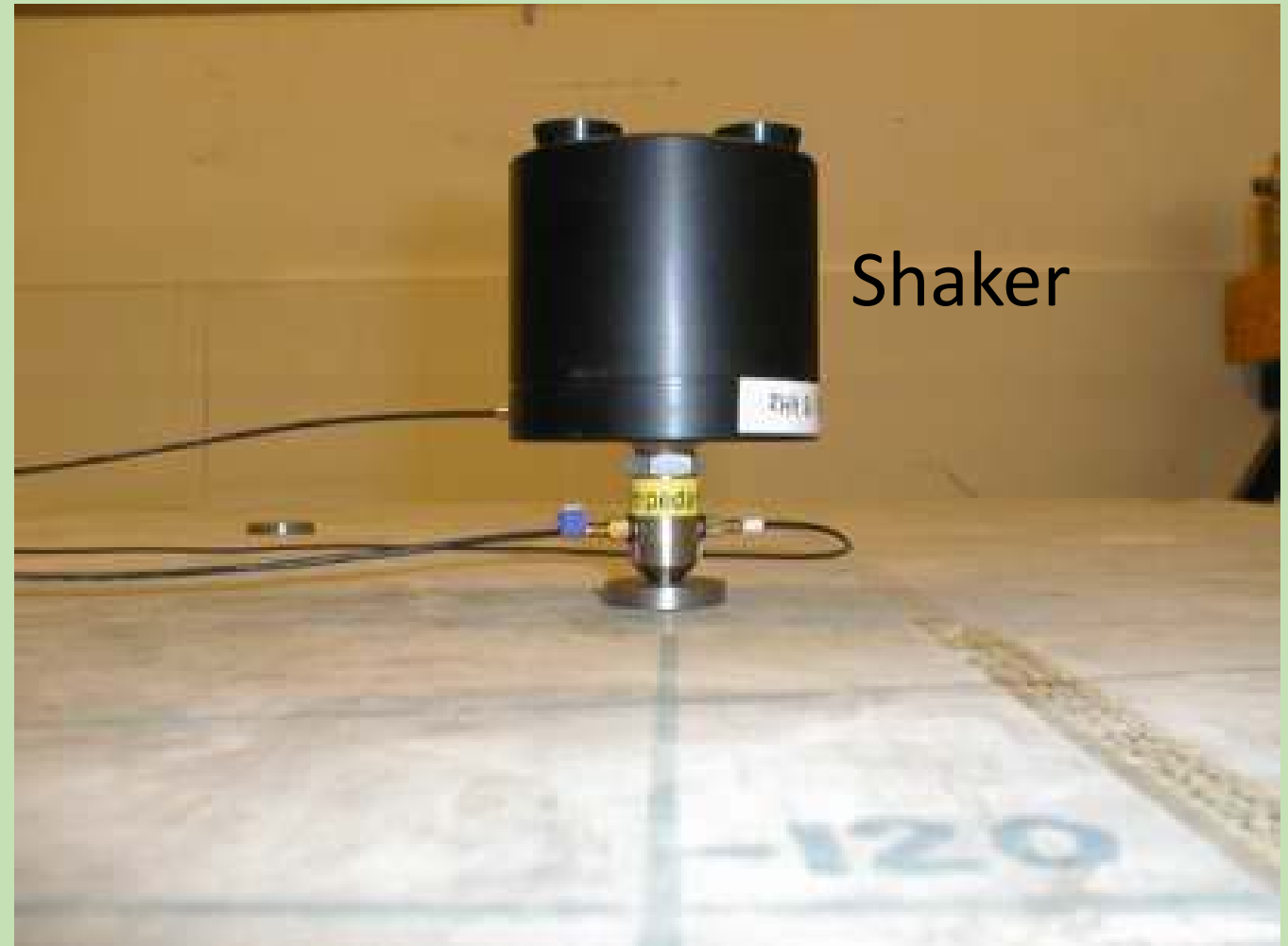
v= velocity (m/s)

Mobility is the inverse of impedance

Impedance head I

- Force transducer
- Accelerometer

To get impedance acceleration must be integrated to velocity, which introduces Errors.



Membrane resonance

$$f_0 = 0.47 \cdot \sqrt{\frac{E}{\rho \cdot (1 - \nu^2)}} \cdot \frac{h}{d^2}$$

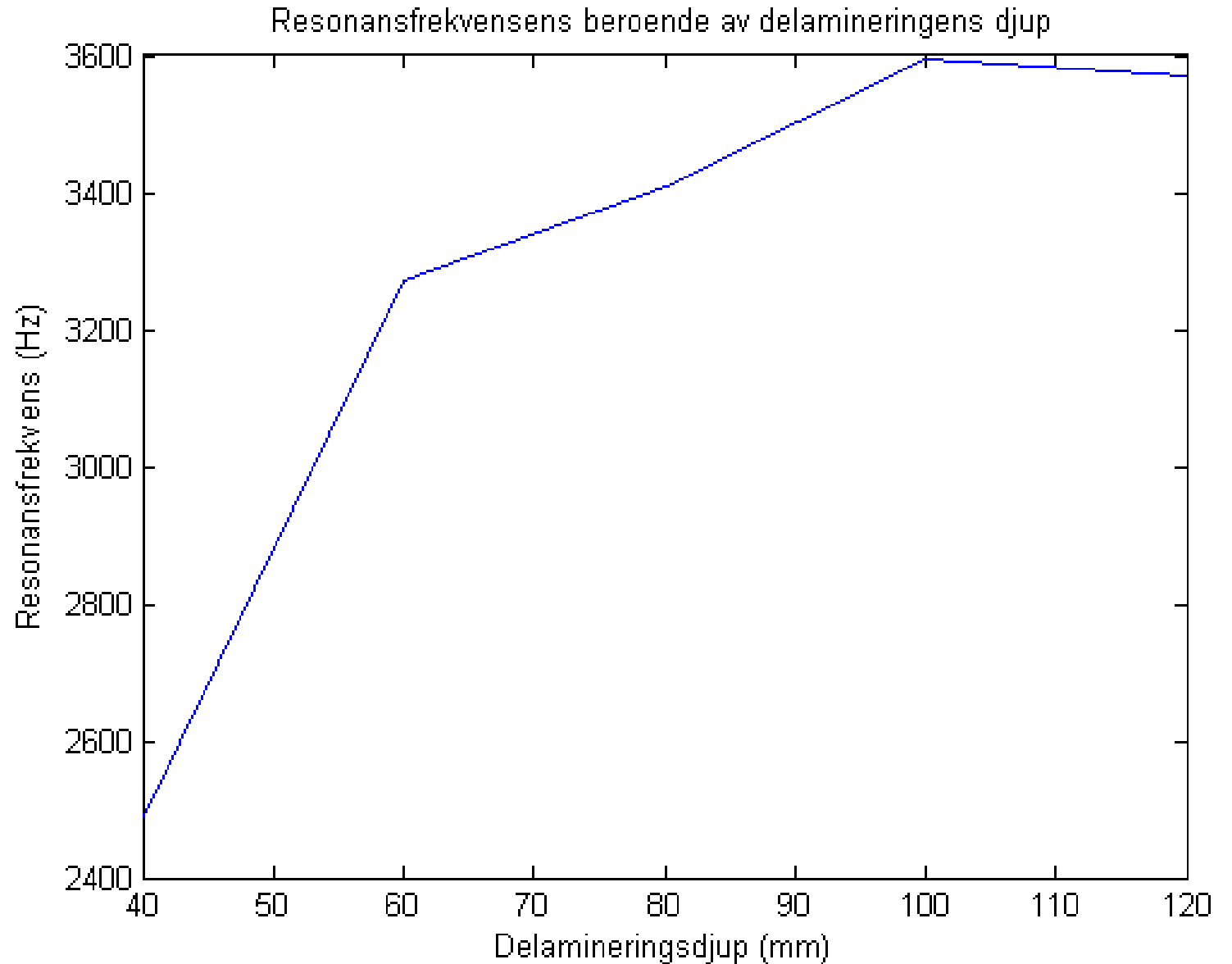
h=membrane thickness

d=membrane diameter

A thicker sheet of concrete is stiffer thus higher resonance frequency.

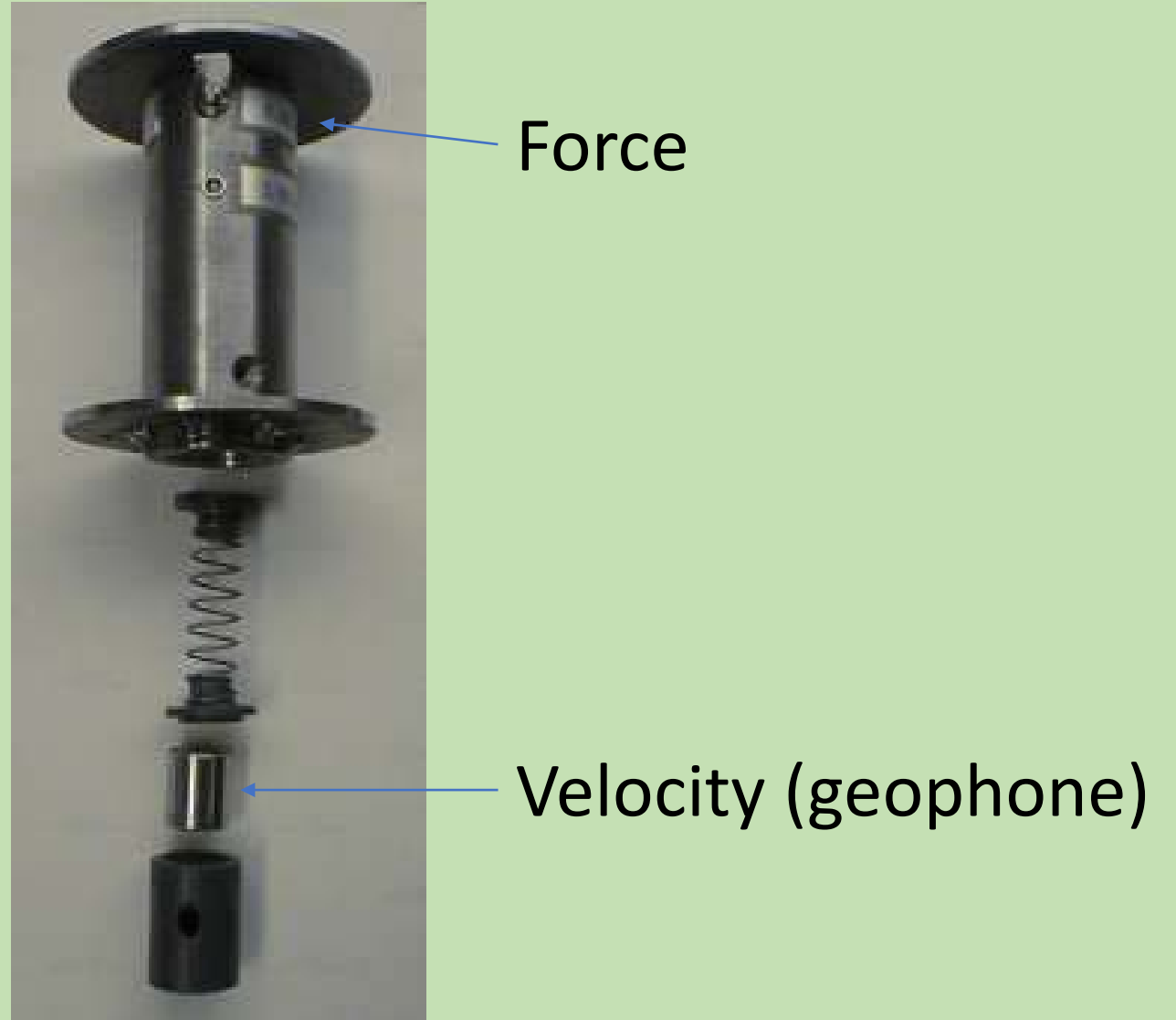
It is not a standing wave, which would do the opposite

Possible depth
80-100 mm

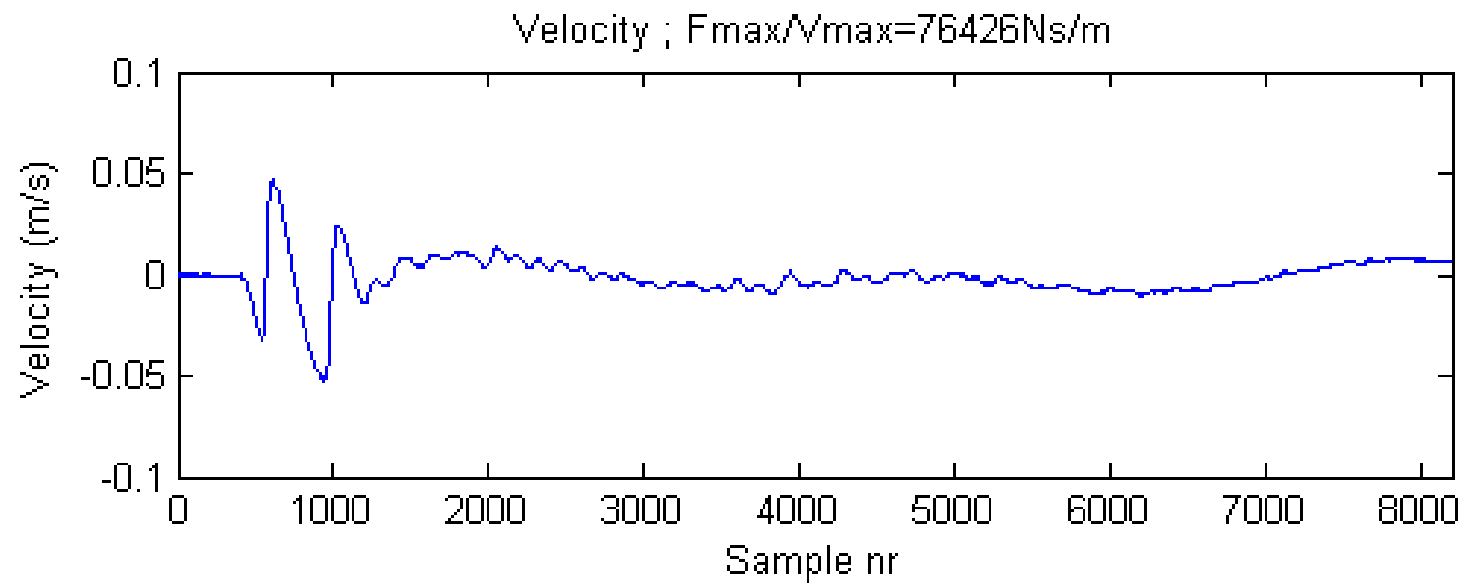
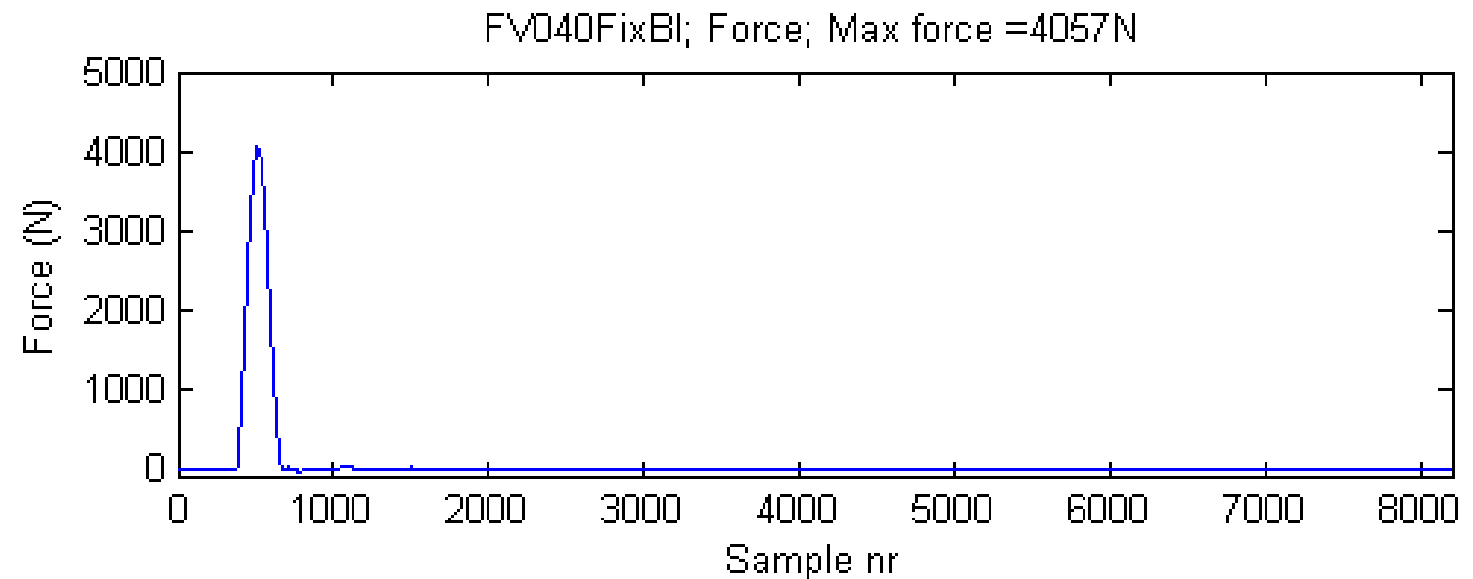


Impedance head 2 (LTH)

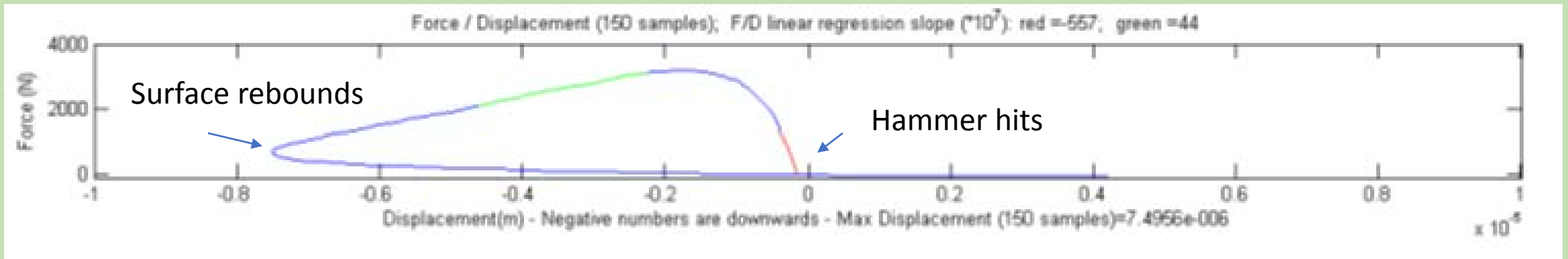
Velocity is measured directly



180 mm depth
to delamination



Spring constant is best measured in the green part of the curve



Force vs displacement by integrated velocity

Instrumenterad bomknackning

Elforsk Rapport 2012:09 - Peter Ulriksen

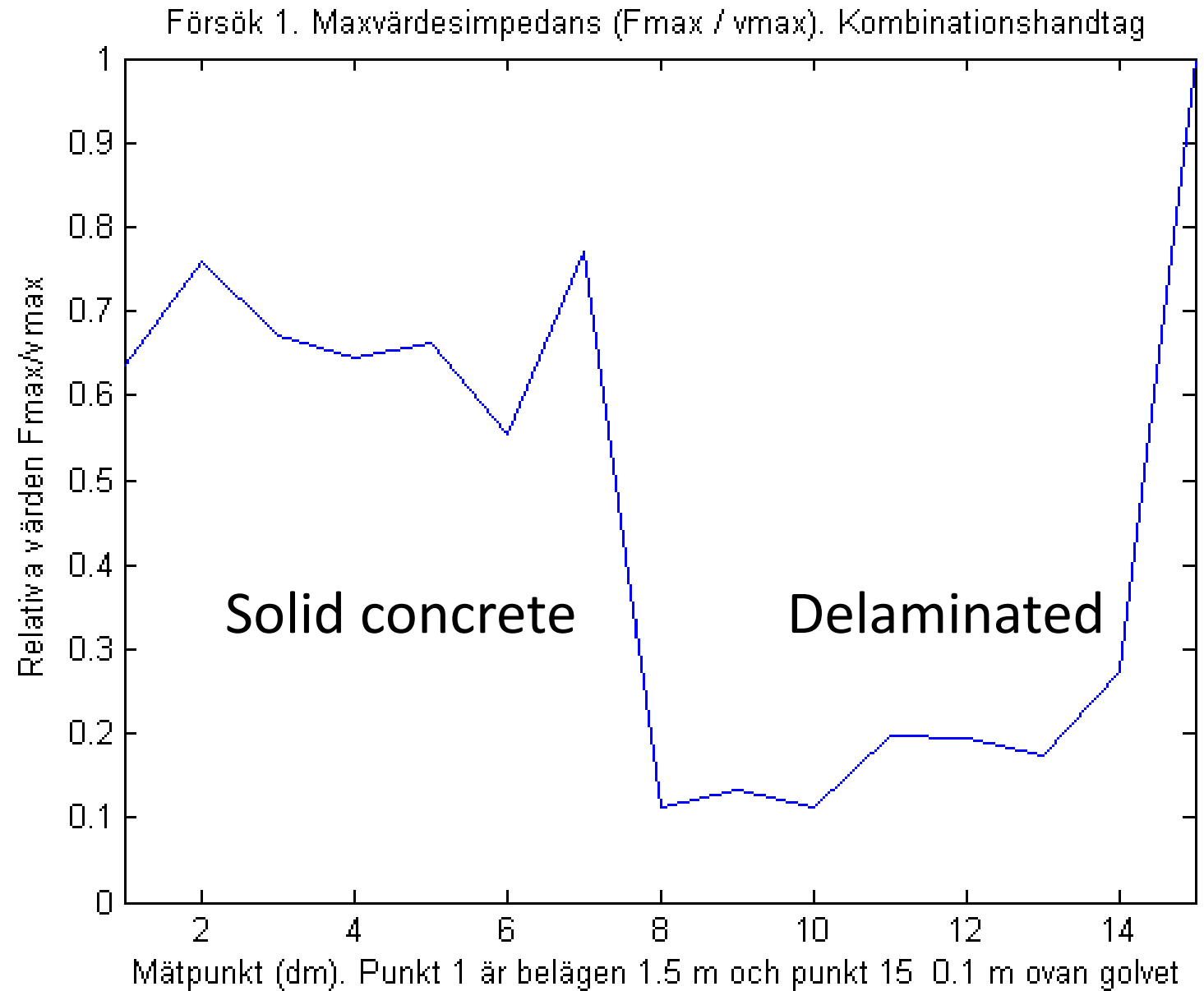
Tests in Ringhals

Dead blow hammer

Force and velocity
recorded at wall -
sound recorded
in air

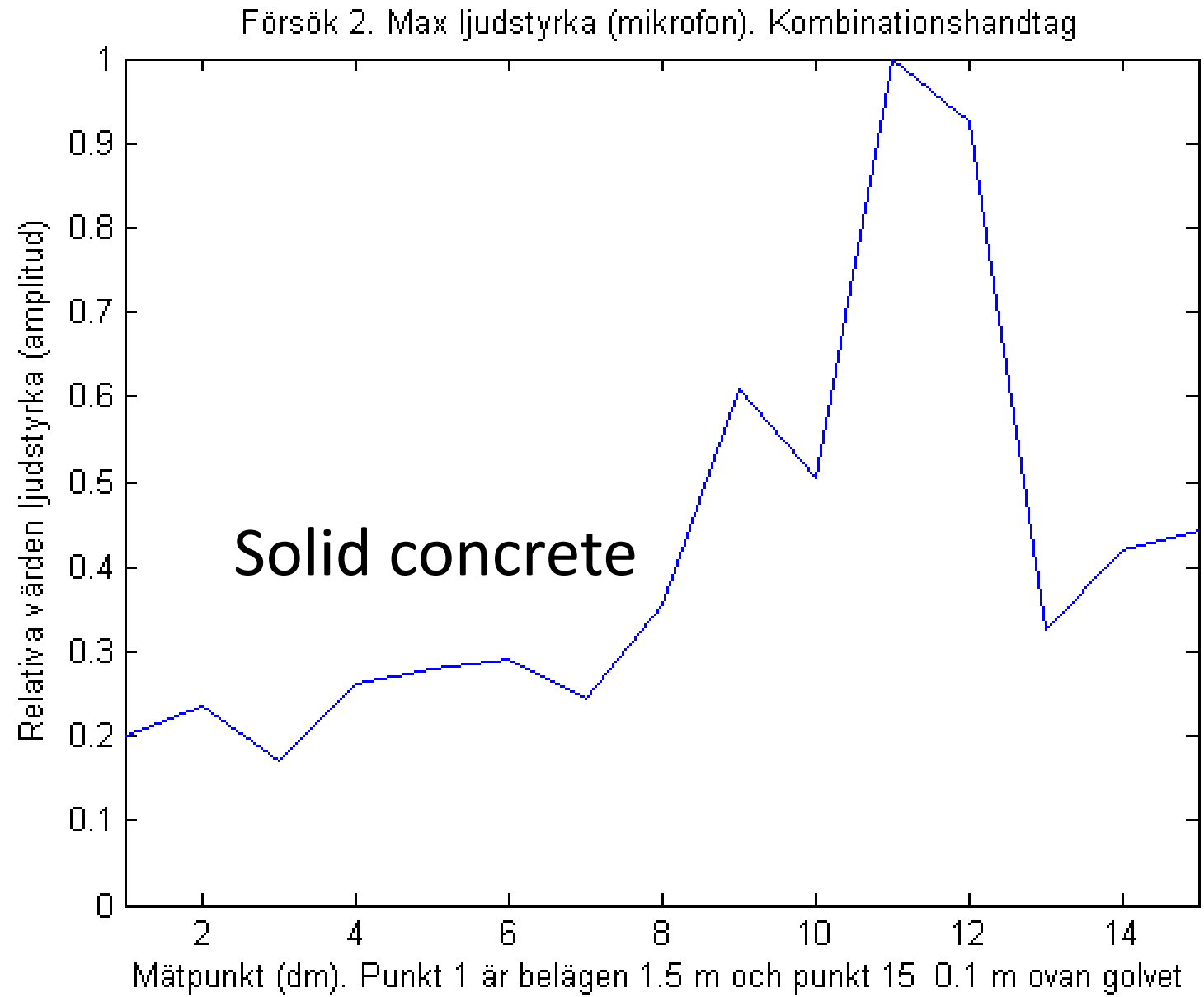


Vertical profile



Vertical profile

Microphone
amplitude

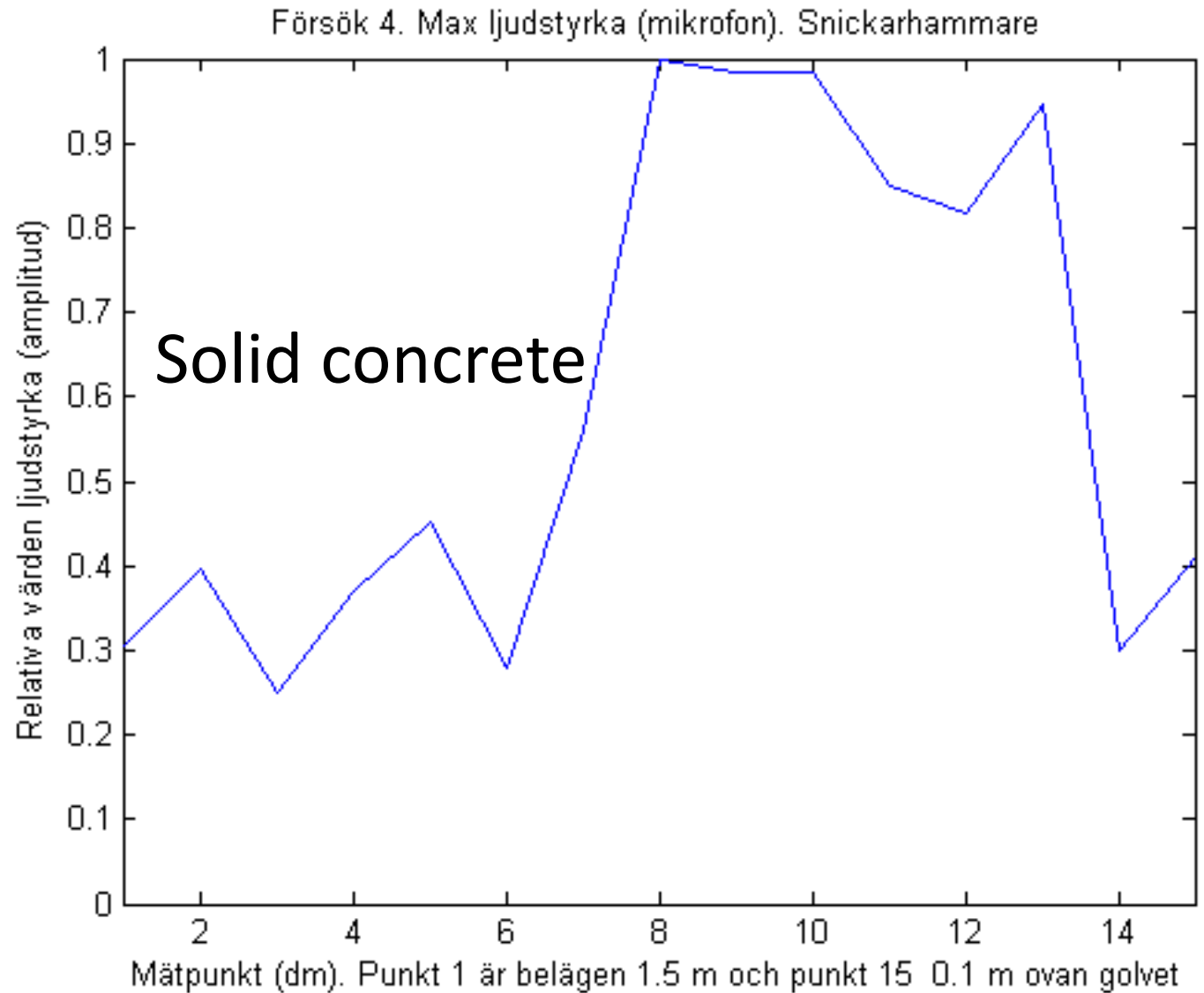


Carpenters hammer and microphone
Simple – no cables
But no calculations possible
Still objective data

Vertical
profile

Carpenters
hammer

Microphone
amplitude



Projektorstyrd avsökning och dokumentation

Energiforsk Rapport 2015:162 - Peter Ulriksen, Peter Jonsson

4 corners are
initially
identified



Test area
2 x 1 m

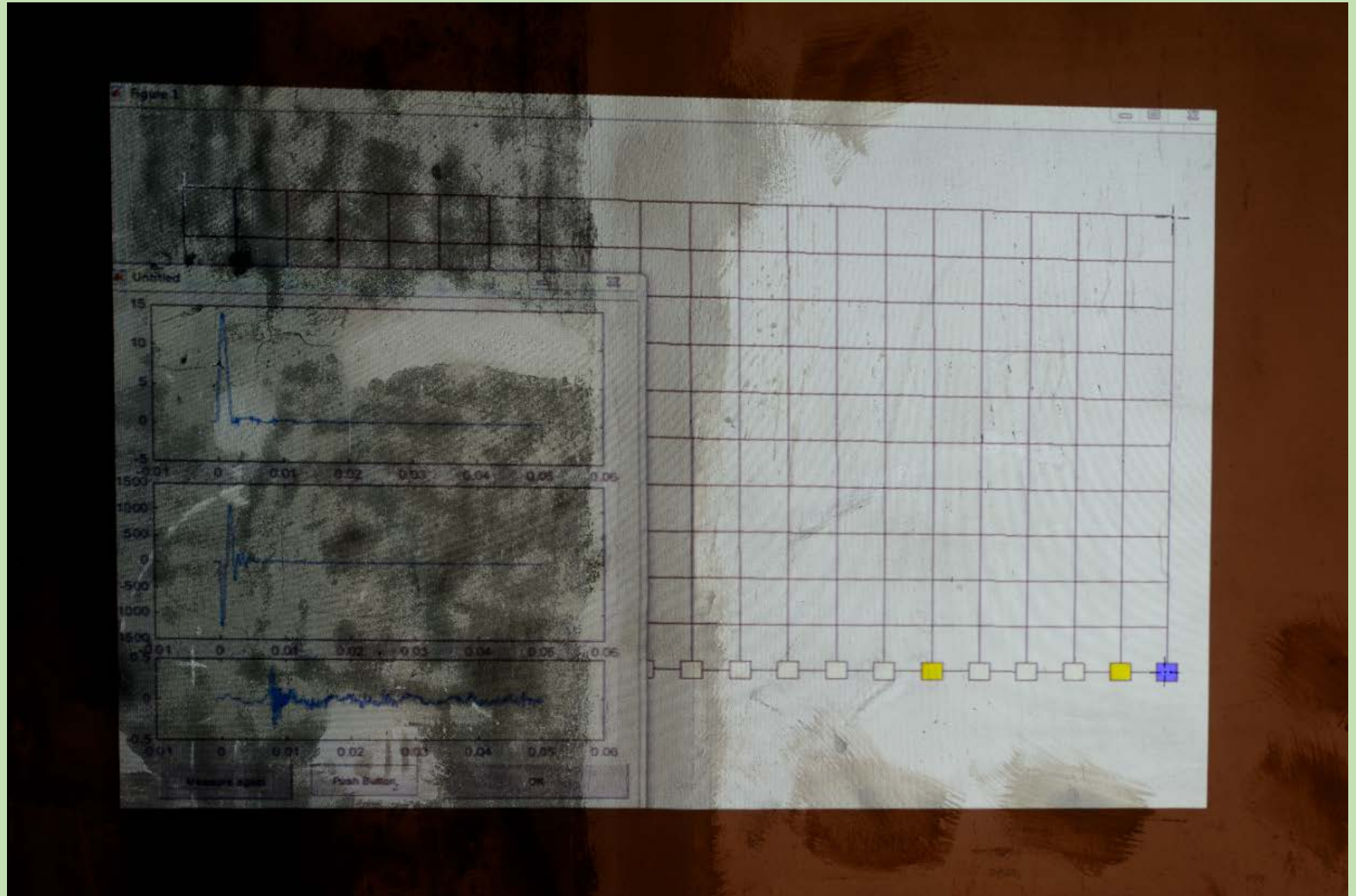
Zebra-pattern is
probably
a consequence
of two pixelized
data: projection
and photograph



First point
indicated LL

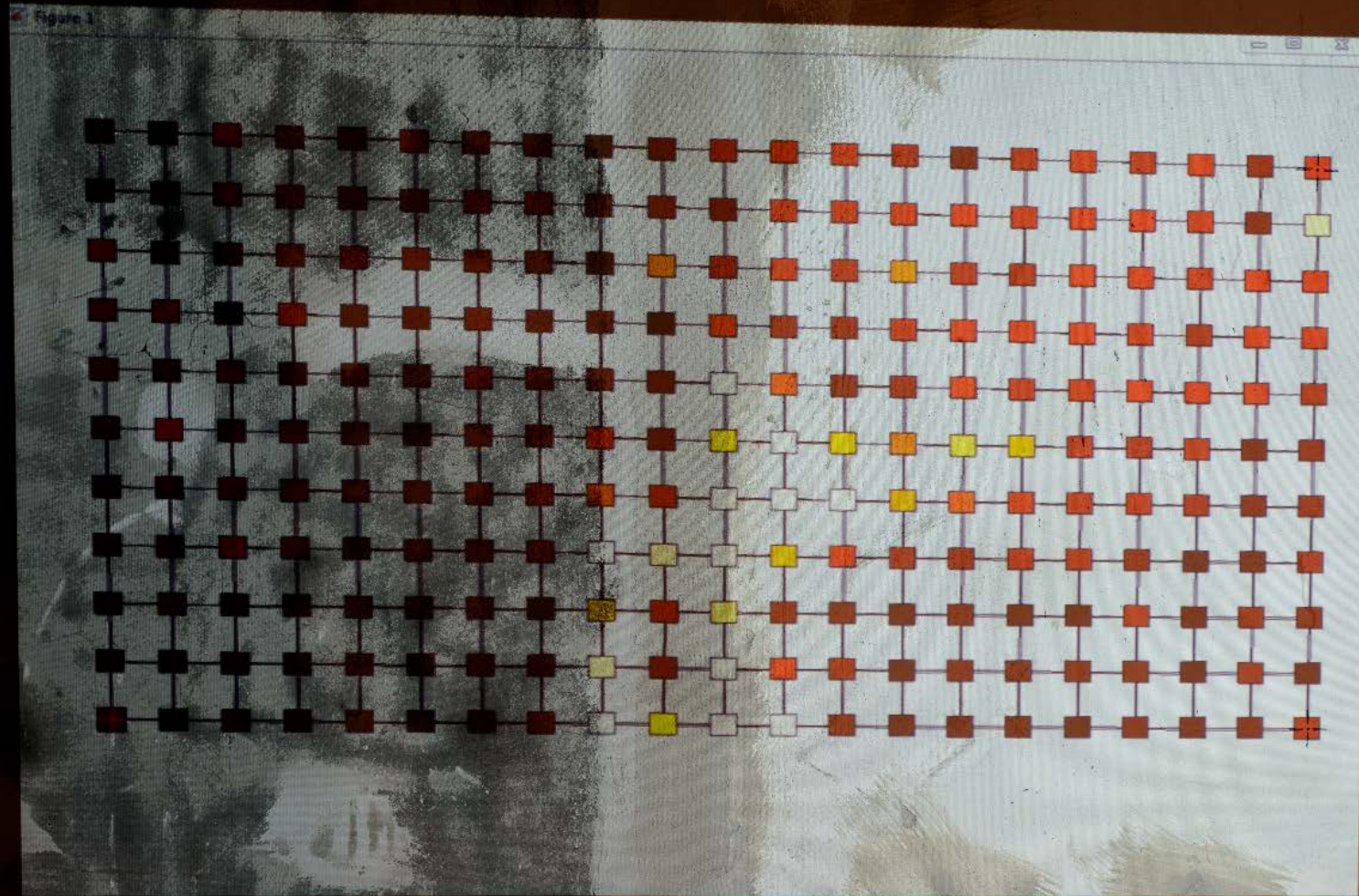


Recorded signal feedback

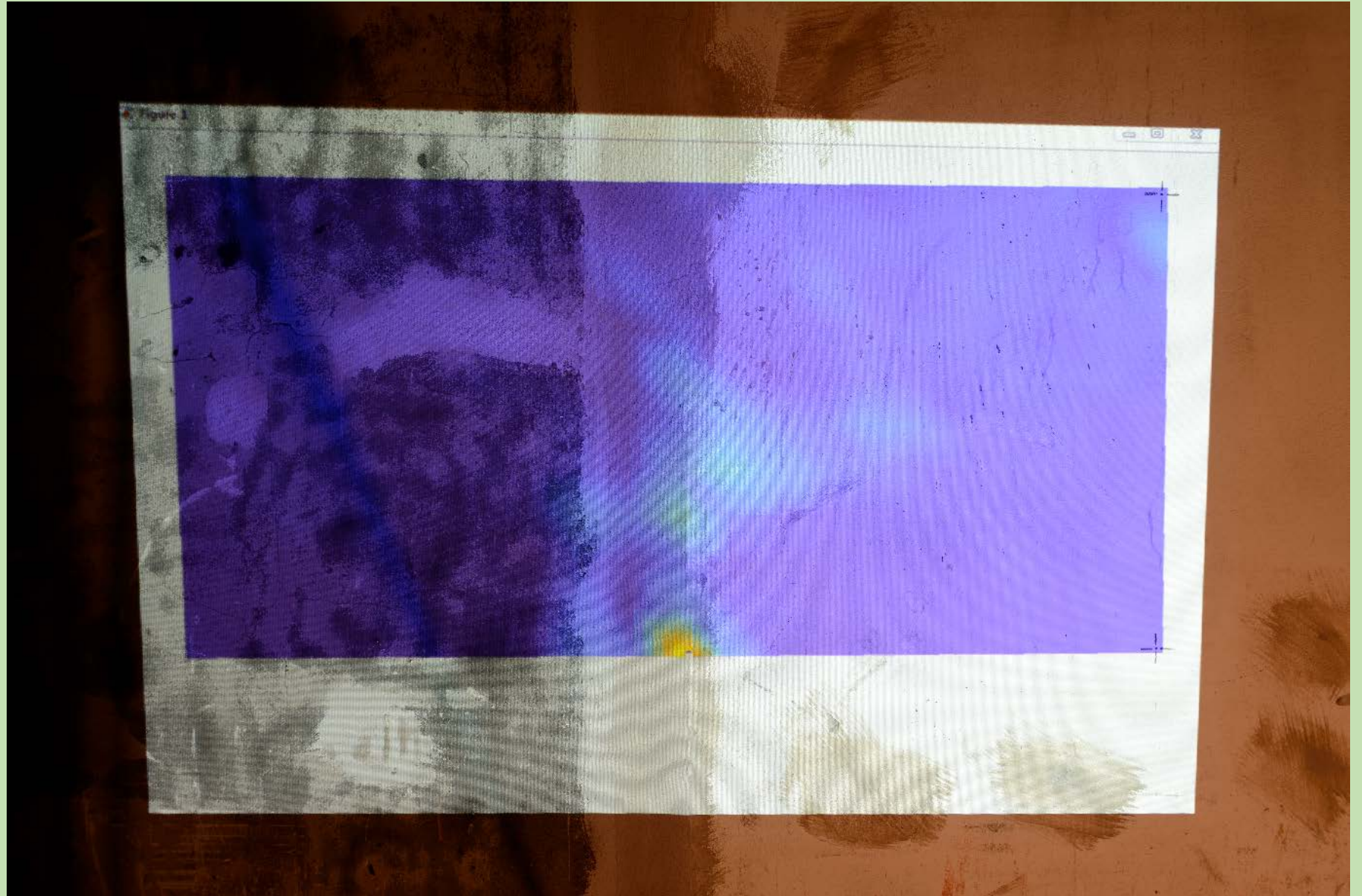


All points
measured

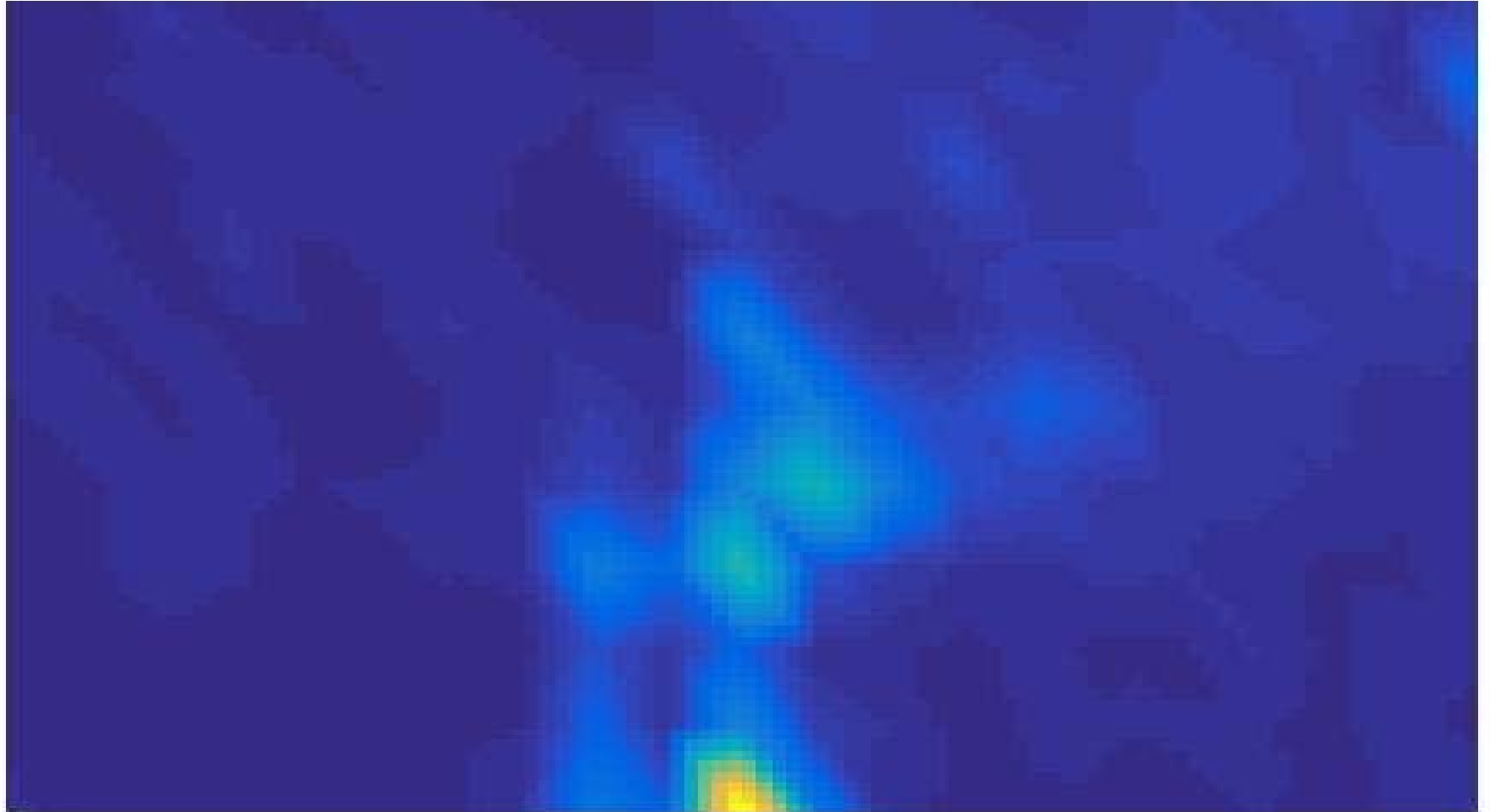
Preliminary
color map



Interpolated
data
projected to
the object



Documentation
image



Projection of
parallell lines
reveals surface
topography

”Structured light”



Ultraljudsmetod för att detektera korrosion i tätplåt i reaktorinneslutningar

Energiforsk Rapport 2016:246 - Peter Ulriksen

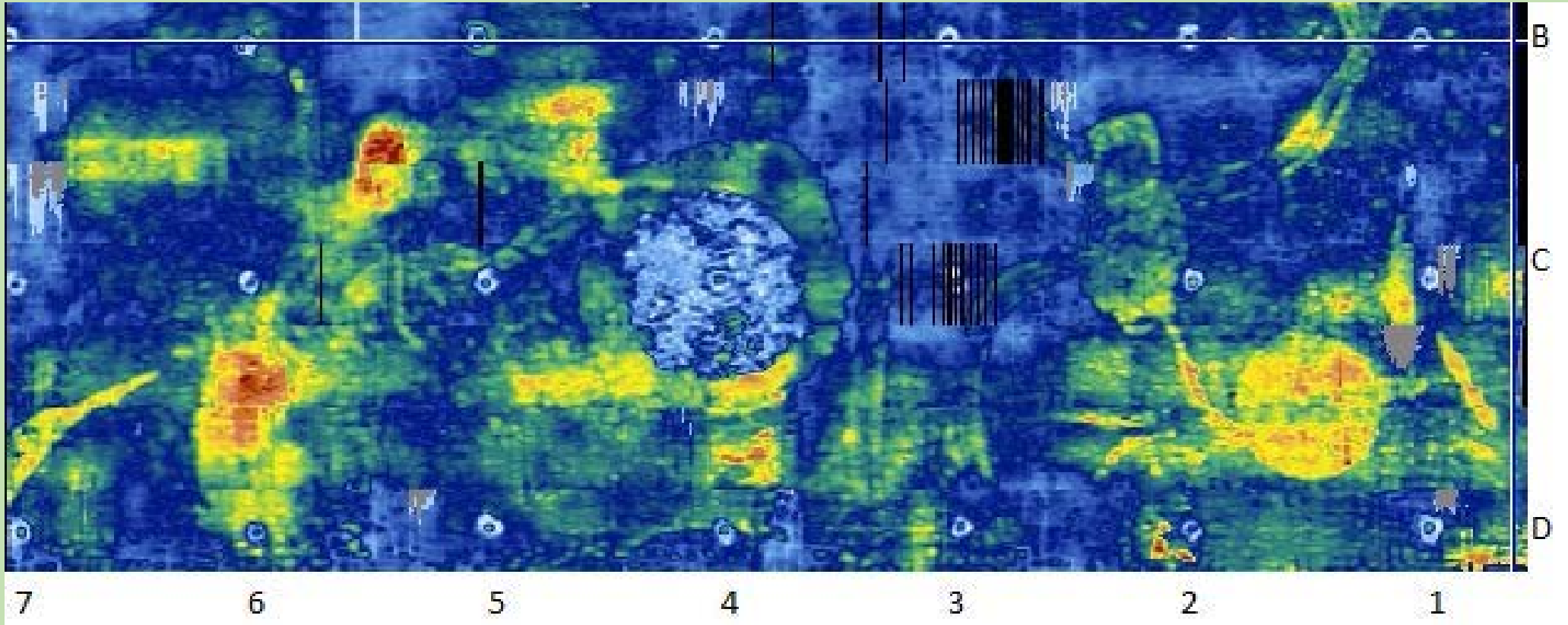
The ACCEPPT liner mock-up
before painting

ACCEPPT studied NPP with an
inside, surface mounted liner

The purpose was to measure
through the liner to see if
what was on the backside
could be imaged.



5 MHz Roto Array image through the visible liner



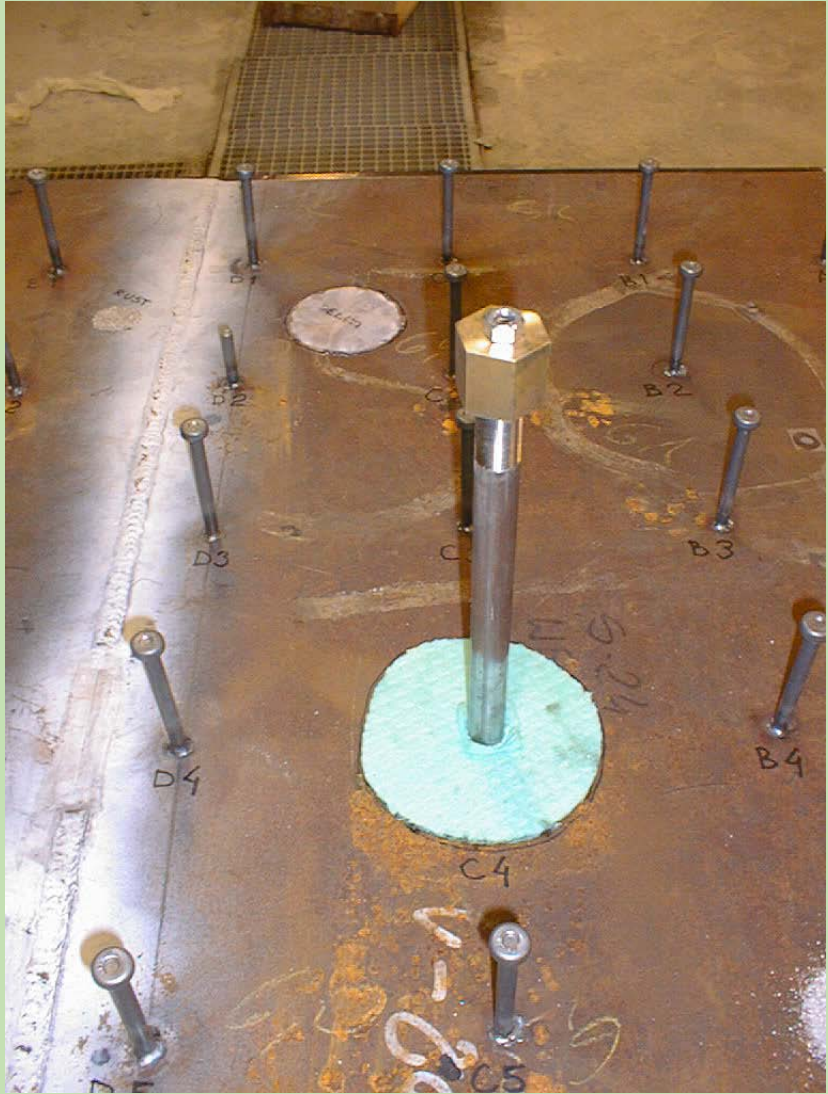
Roto Array

5 MHz

64 sensors

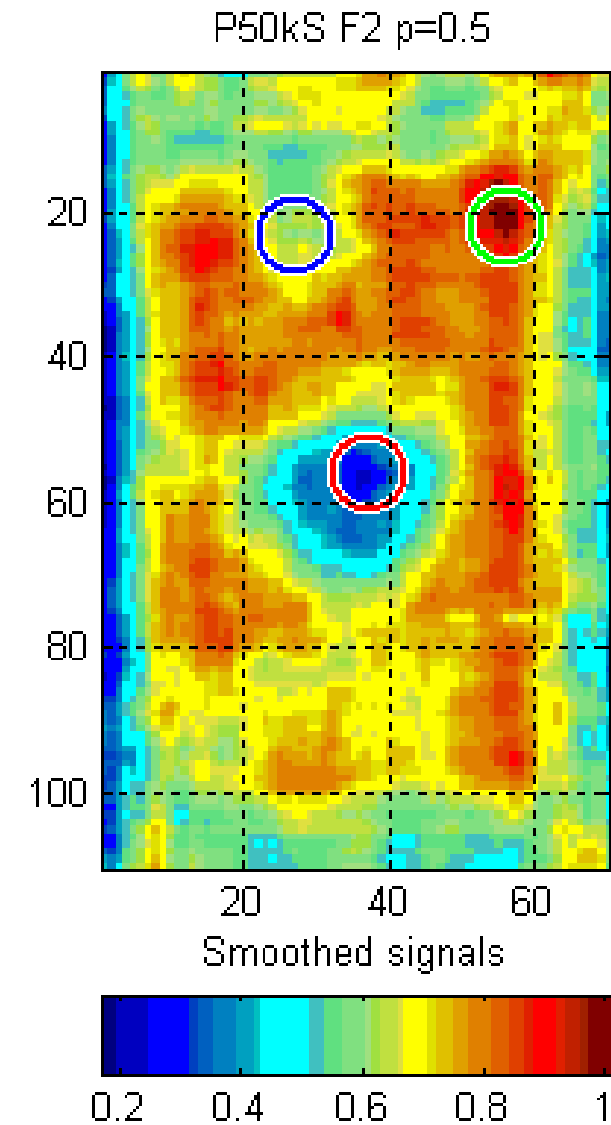
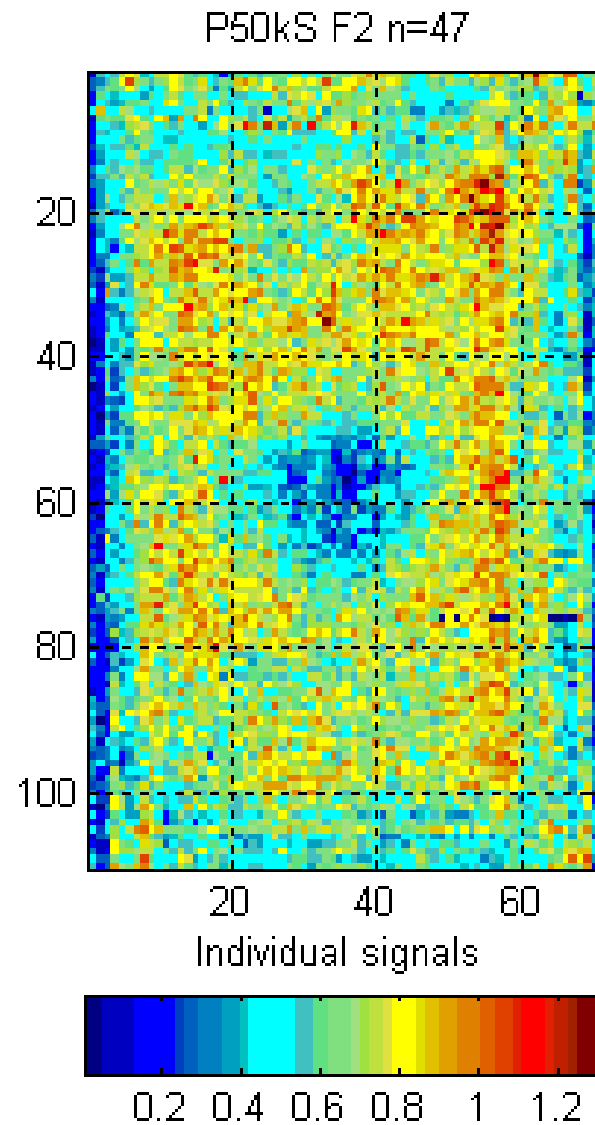


Concrete side of the liner Simulated defects



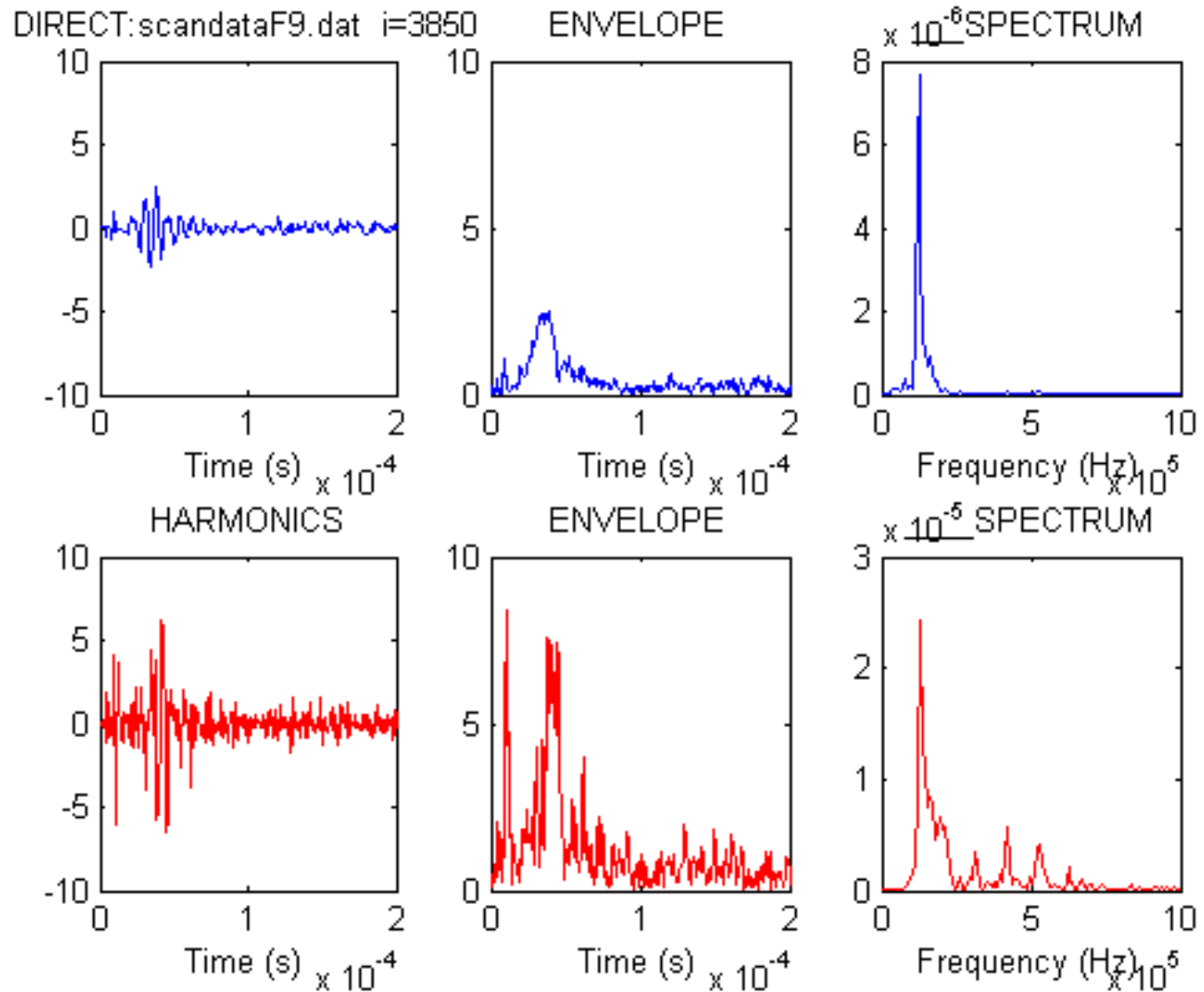
Same object surveyed
from the concrete side
55 kHz A1220 US.

Unfiltered echo
Depth slice 47



Echo from the
central area
(Wettex)
Red circle

Highpass filtered
echo reveals
overtones –
may be due to
non-linearity



Ultraljudsmetod för att detektera korrosion i tätplåt i reaktorinneslutningar , Etapp 2

No success
with
accelerated
corrosion

Found on
scrapyard



1200x800x700 mm

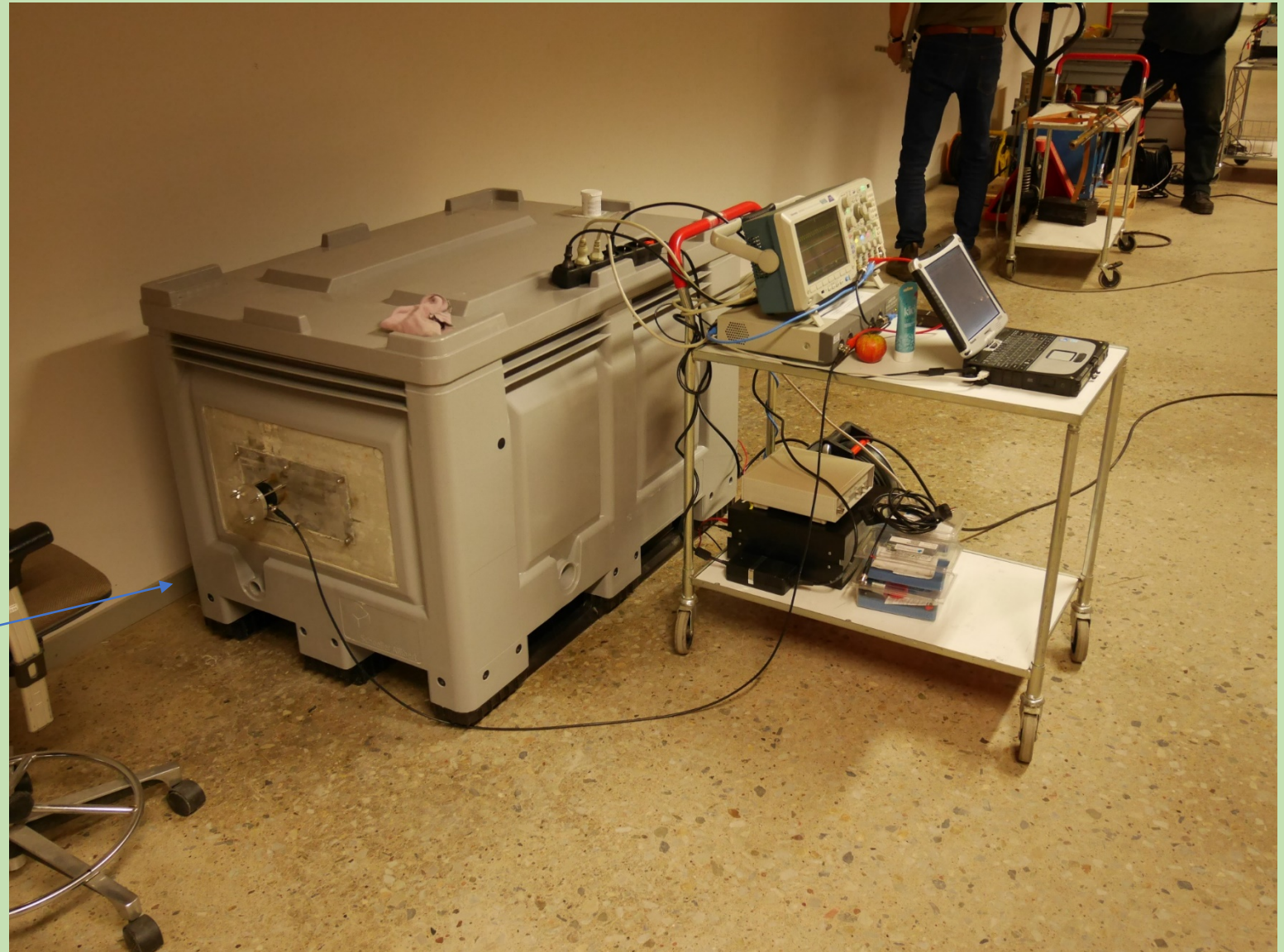
Construction of the
main mock-up



Measurements in
time domain
and in
frequency domain

Straight through
receiver

Aluminium plates was a
misstake



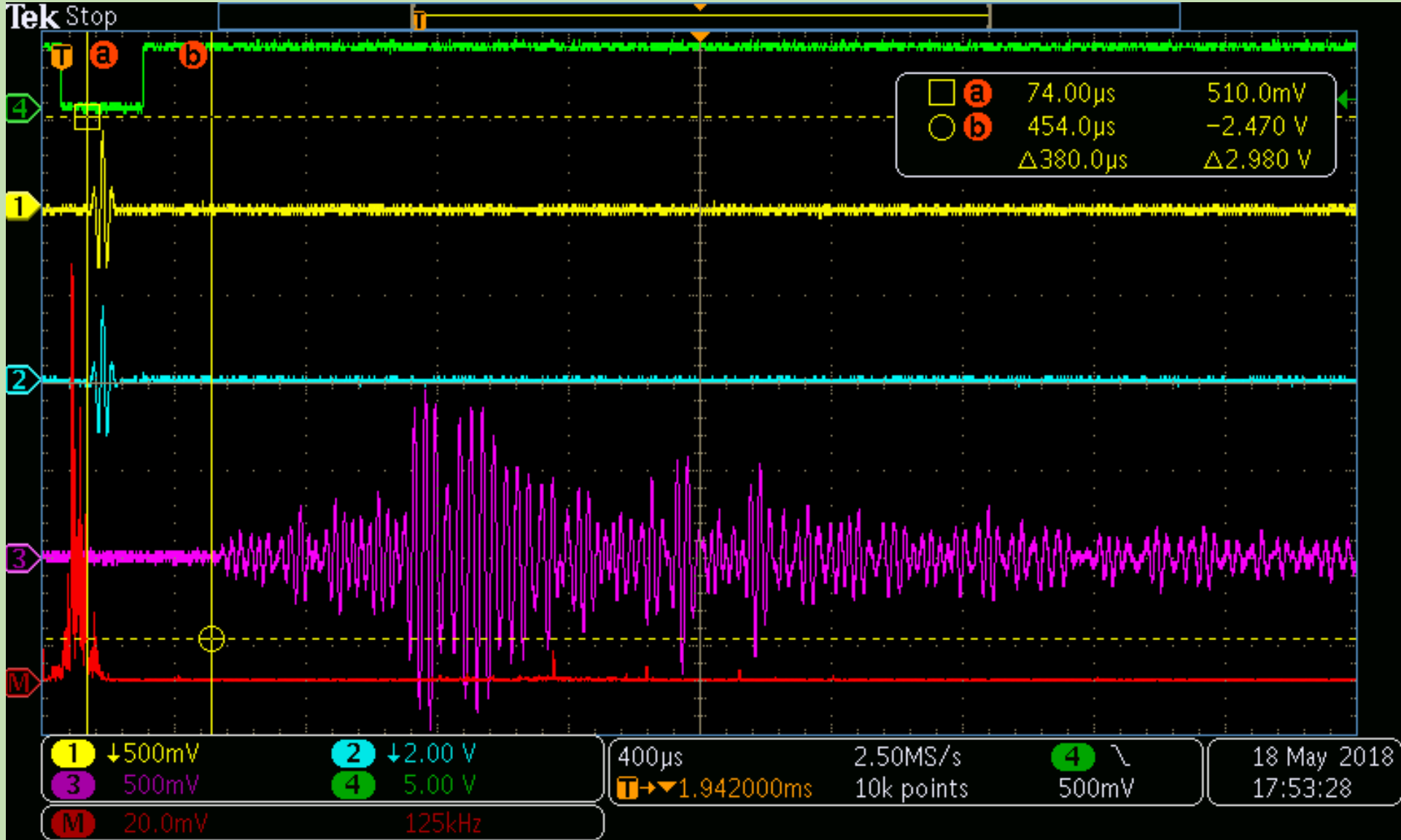
AWG gate

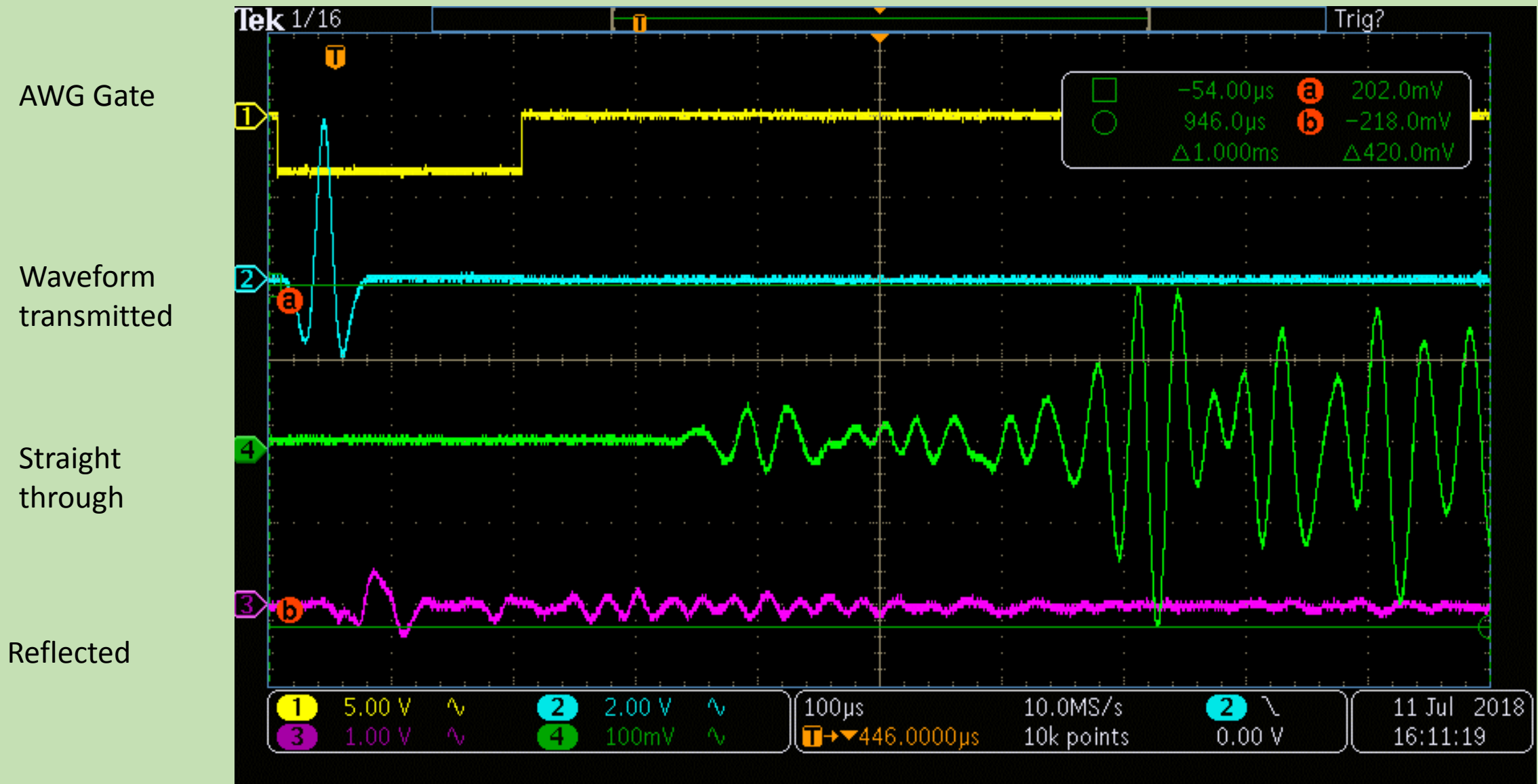
AWG signal

Power Tx signal

Straight through

Spectrum





Test object 2: Three states of corrosion

Not shown are:

Test object 3:
Pieces of wood

Test object 4:
A leather glove

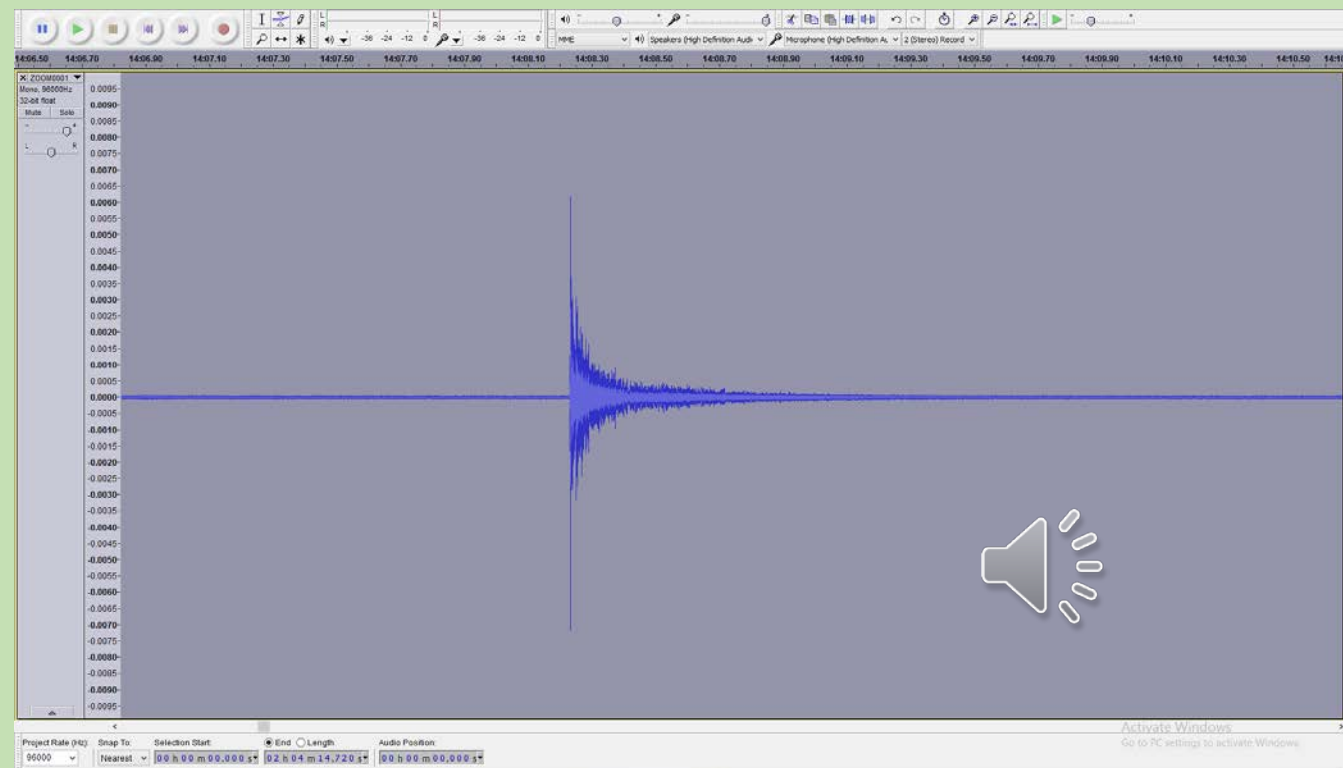


Test av förekomst av akustiska emissioner vid trycktest i fransk reaktorinneslutning

Existerar akustiska emissioner under trycktest i reaktorinneslutningar?



Inspelningsutrustning
60 h. *Upptryckning.*



En luftburen *akustisk emission* under
period med statiskt tryck
vid ett trycktest i reaktorinneslutning

Localisation of click sounds in LTH reverberant room using a tetrahedron array

**Data measured and provided by Peter Ulriksen,
Professor at Lund University**

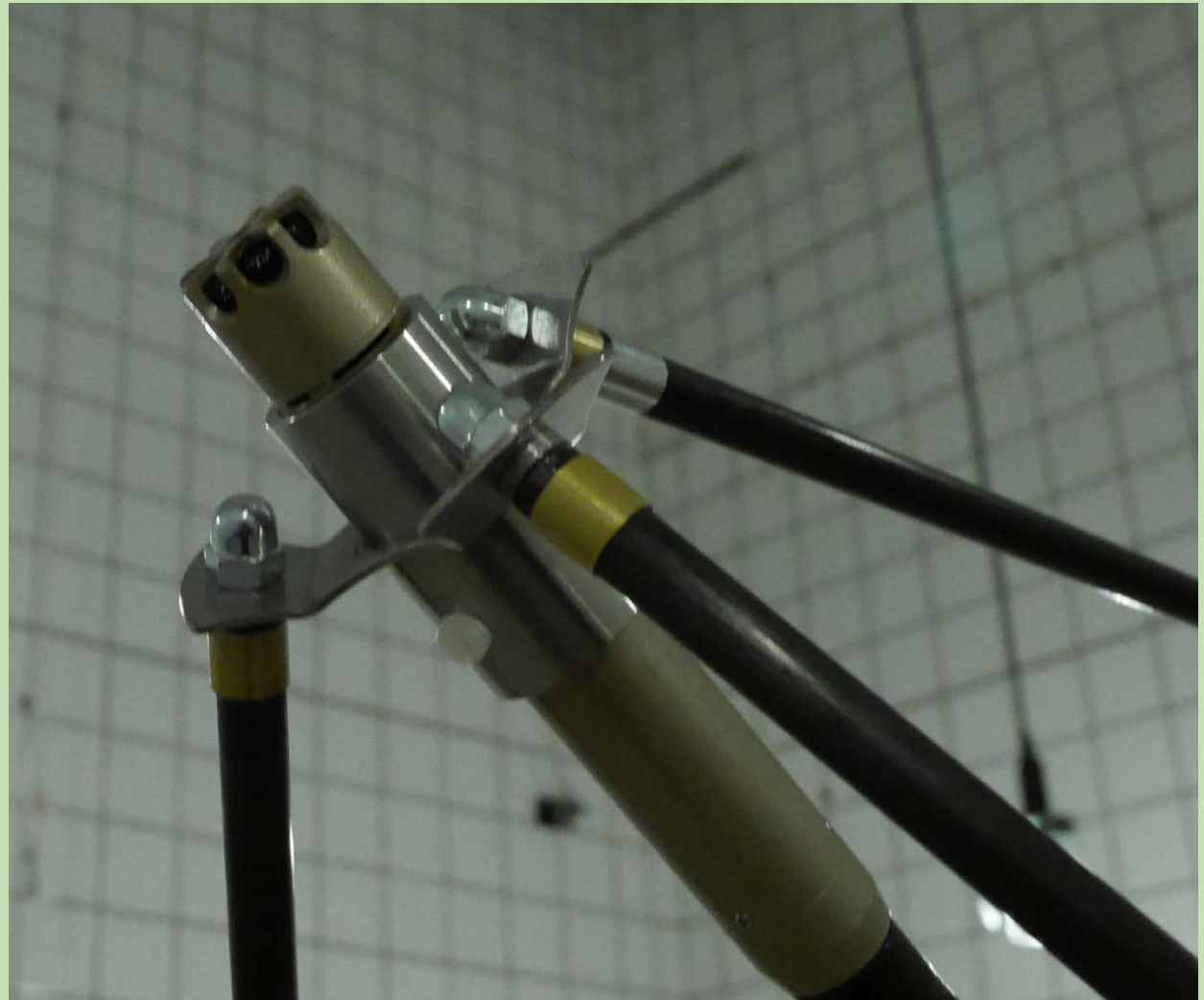
K. Haddad

14th of March, 2016

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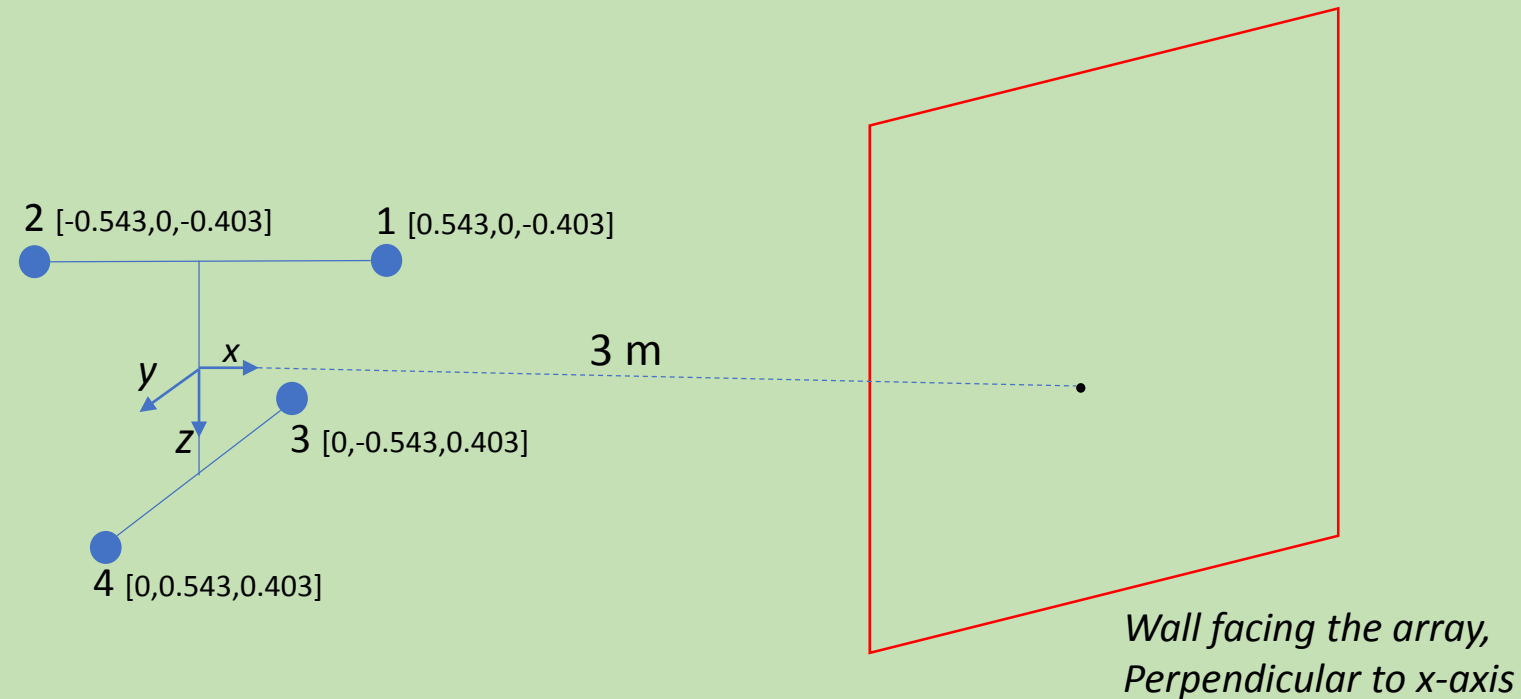
Oförstörande provning i
kärnkraftens betongkonstruktioner
Energiforsk 221121

4-channel tetrahedral acoustic array built by LTH



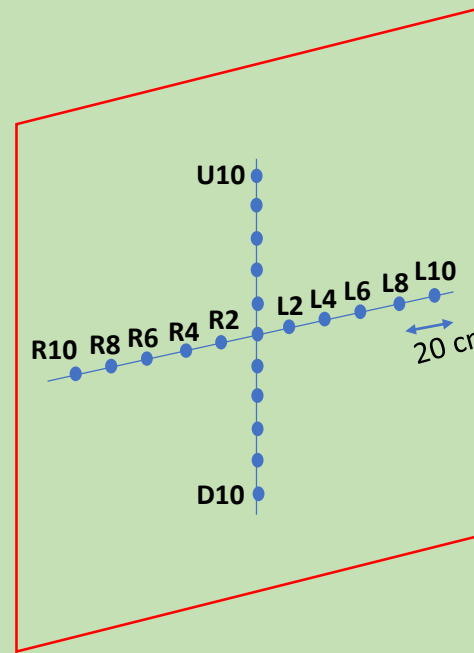
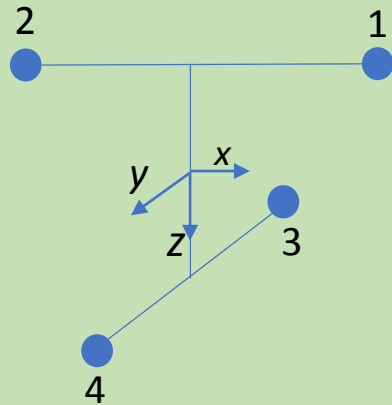
Localisation of click sounds in LTH reverberant room using a Tetrahedron array

- Setup



Localisation of click sounds in reverberant room using a Tetrahedron array

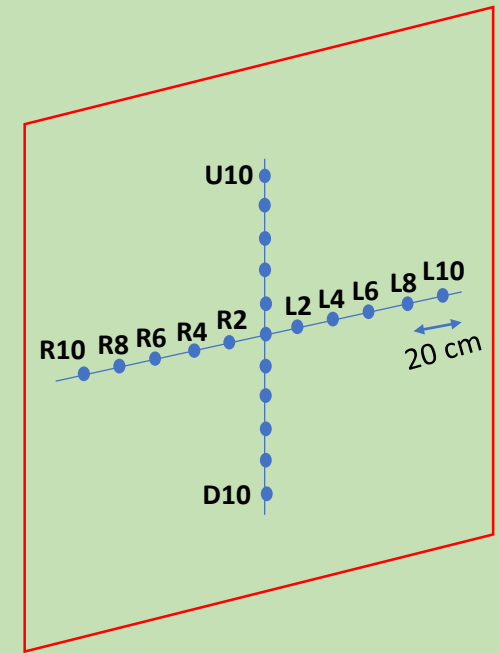
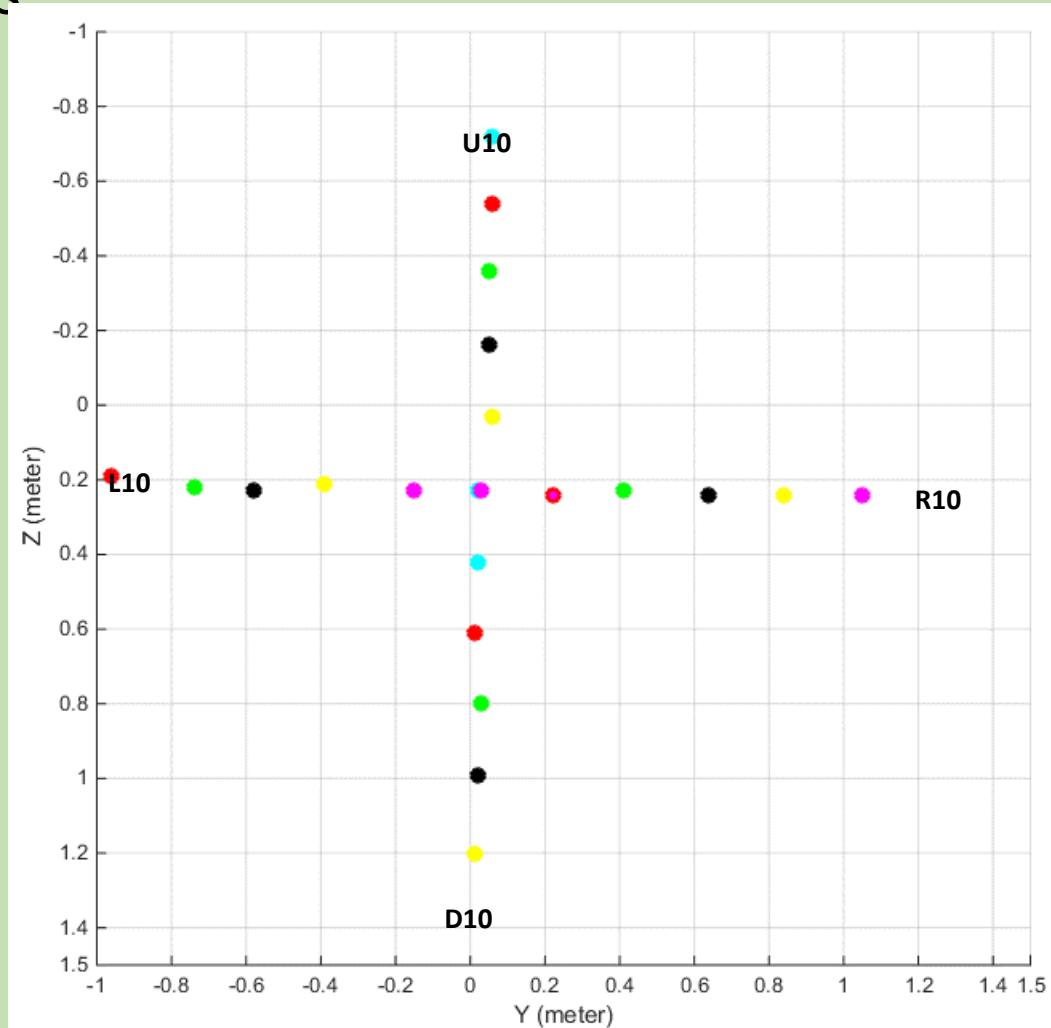
- Events (Processed only Gain 5)



*Wall facing the array,
Perpendicular to x-axis*

Localisation of click sounds in reverberant room using a Tetrahedron array

- Results



ACOUSTIC EMISSION DETECTION AND SOURCE DIRECTION FINDING IN THE RINGHALS 2 REACTOR CONTAINMENT DURING PRESSURE TEST

RAPPORT BET 178 / KCU52178

PETER ULRIKSEN - TEKNISK GEOLOGI LUNDS TEKNISKA HÖGSKOLA

KARIM HADDAD - BRÜEL&KJAER SOUND AND VIBRATION MEASUREMENT A/S

JOHANNA SPÅLS - RINGHALS NUCLEAR POWER PLANT

Tetrahederformad mikrofonarray

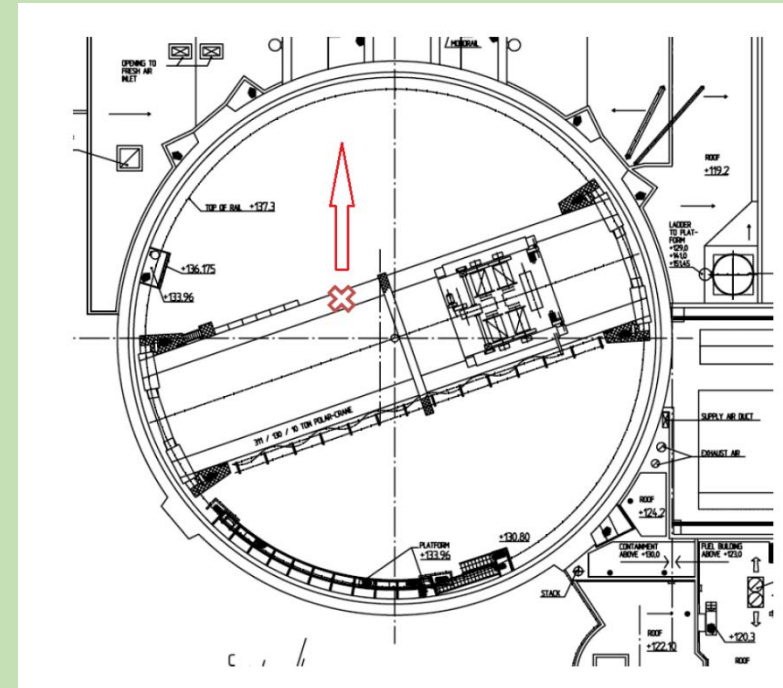
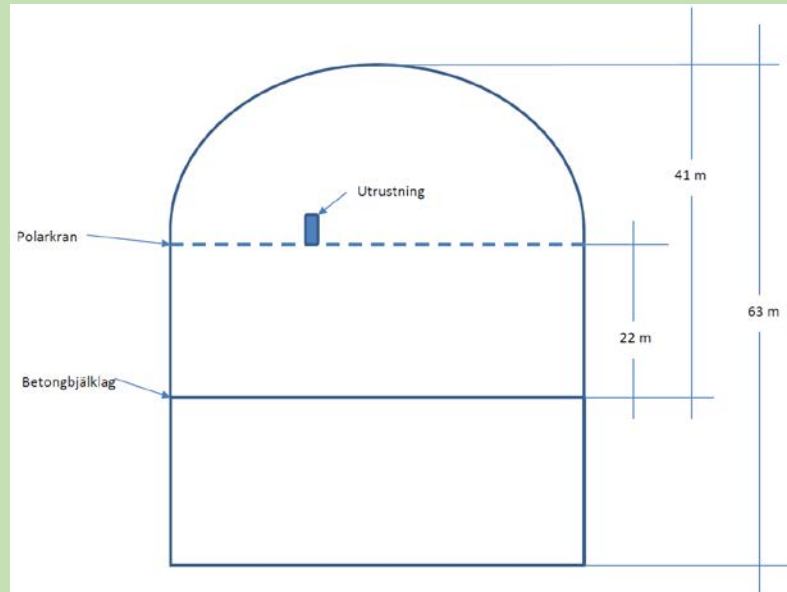


Förberedande försök i LTH:s
efterklangsrums (ekorum)



Instruktion för Ringhals mätgrupp

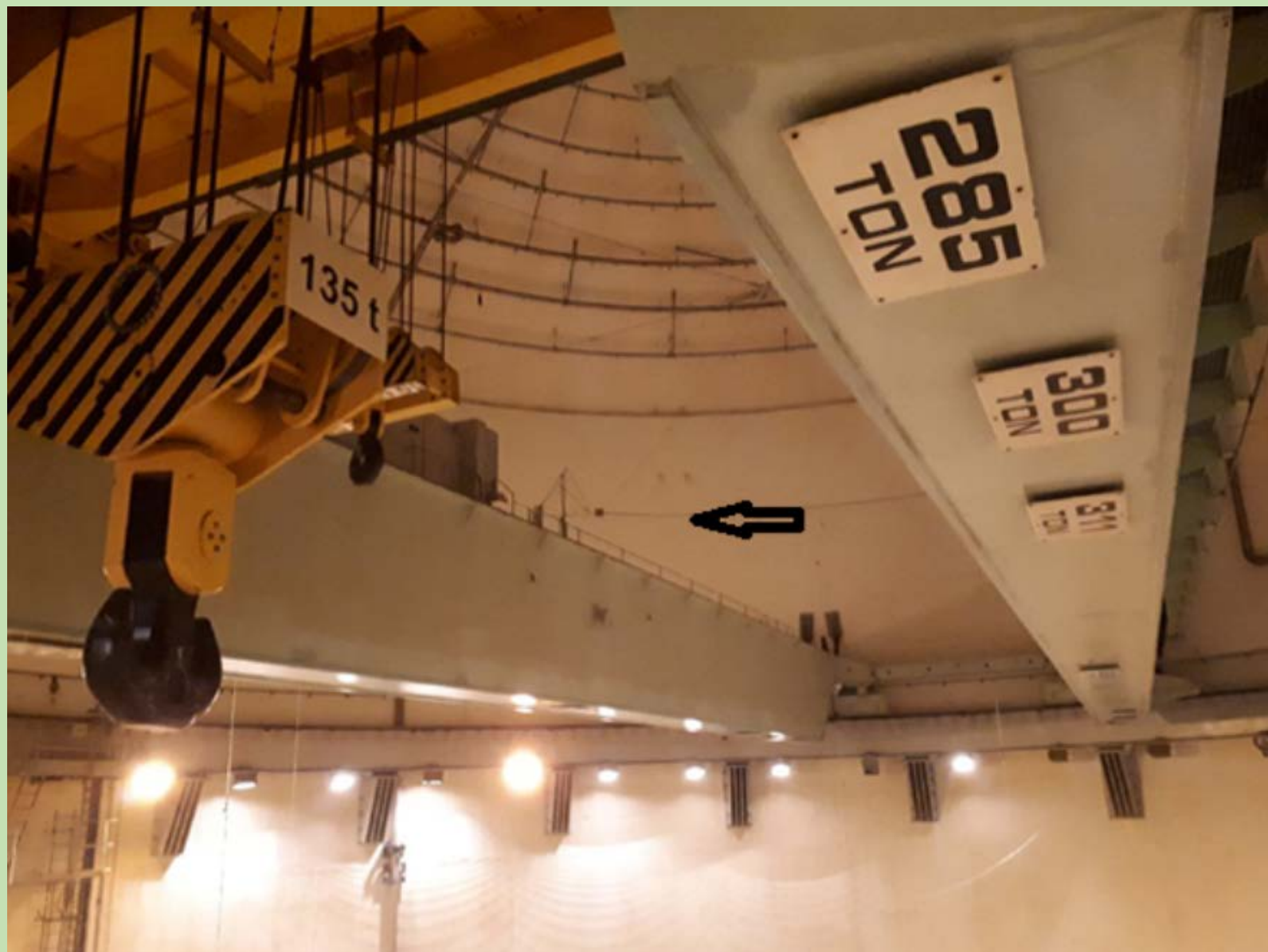
Placering av mikrofonerna på portalkranen



Placering av mikrofonerna på Portalkranen

Utplacering och aktiviering
av mätutrustningen
av Ringhals mätgrupp

Johanna Spåls ledde arbe-
tet på Ringhals

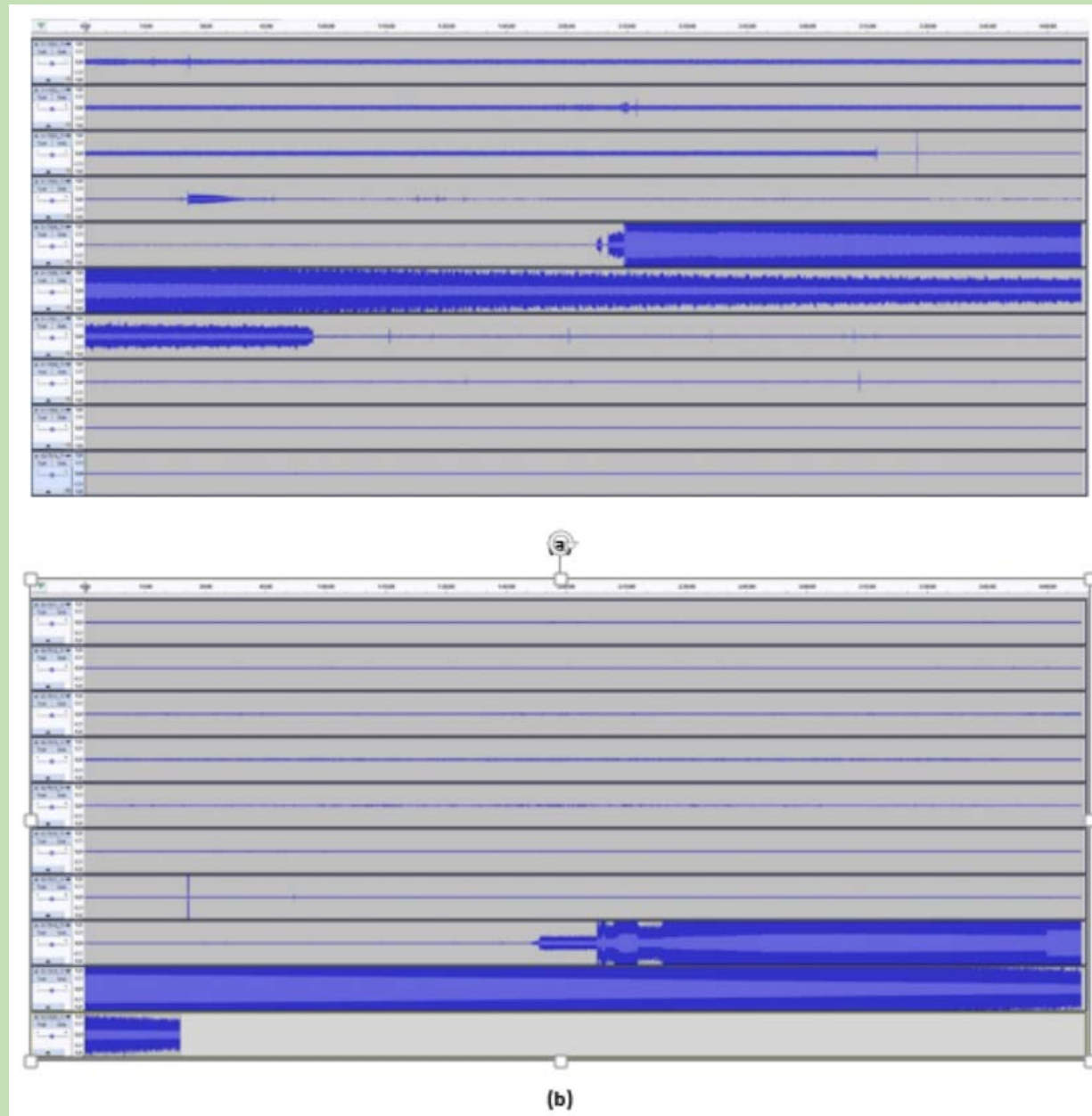


Hela mätperioden

20 epoker om 4 h.

De höga amplituderna registreras när trycket stegras respektive släpps ner.

De relevanta emissionerna sker när trycket är högt.



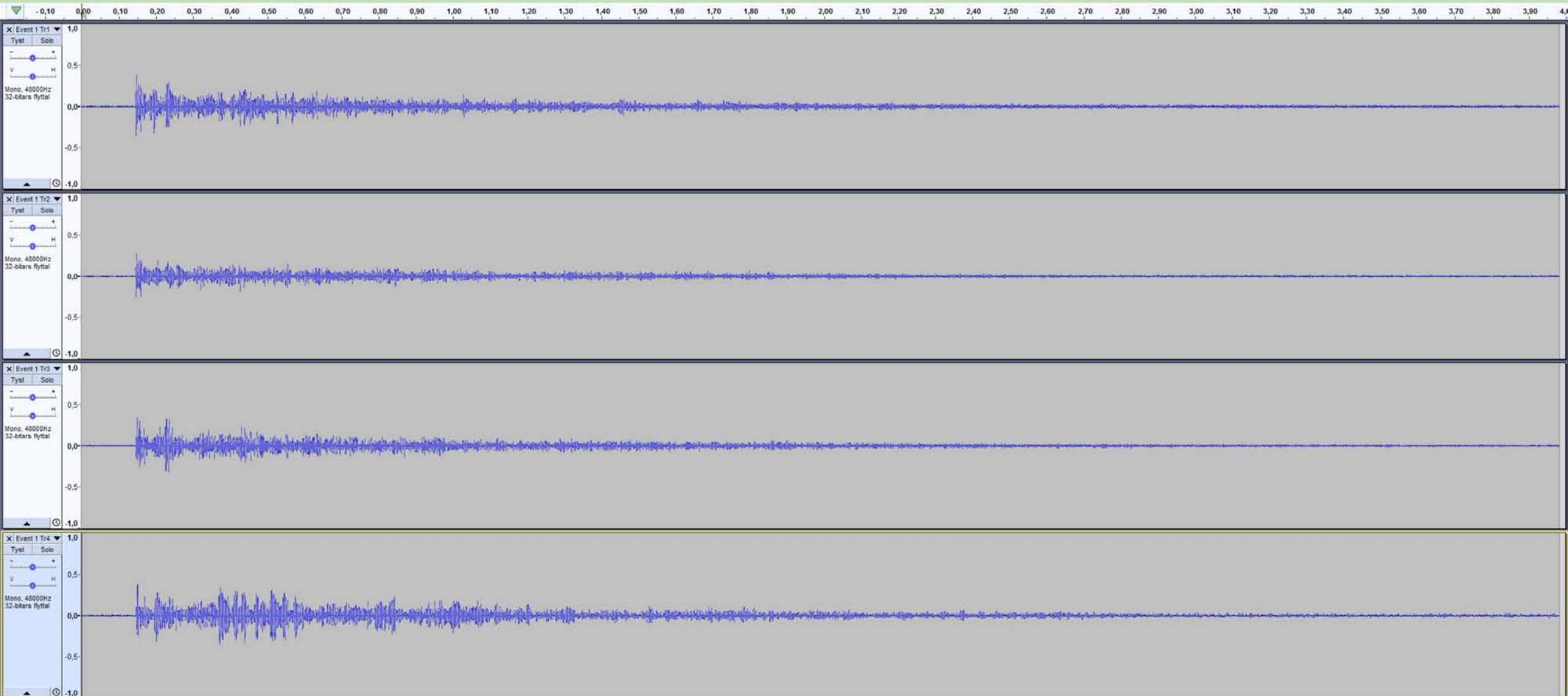
Trycket ökas



Trycket sänks



Inzoomning i händelse 1



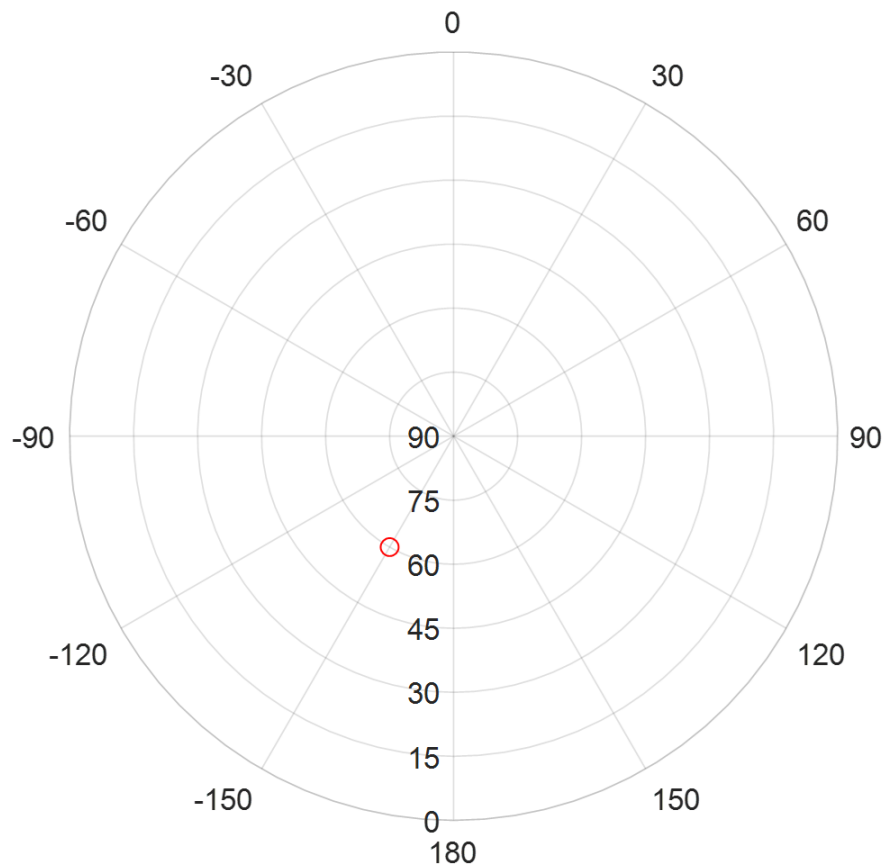
Antal händelser i varje epok (4h)

RATE OF EVENTS IN EACH RELEVANT EPOCH

<u>Epoch 7:</u> 2020-04-01 13:28:00	44 events
<u>Epoch 8:</u> 2020-04-01 17:37	14 events
-	
Epoch 11: 2020-04-02 06:02	6 events
Epoch 12: 2020-04-02 10:11	8 events
Epoch 13: 2020-04-02 14:19	2 events
Epoch 14: 2020-04-02 18:28	2 events
-	
Epoch 17: 2020-04-03 06:53	2 events
Epoch 18: 2020-04-03 11:02	6 events

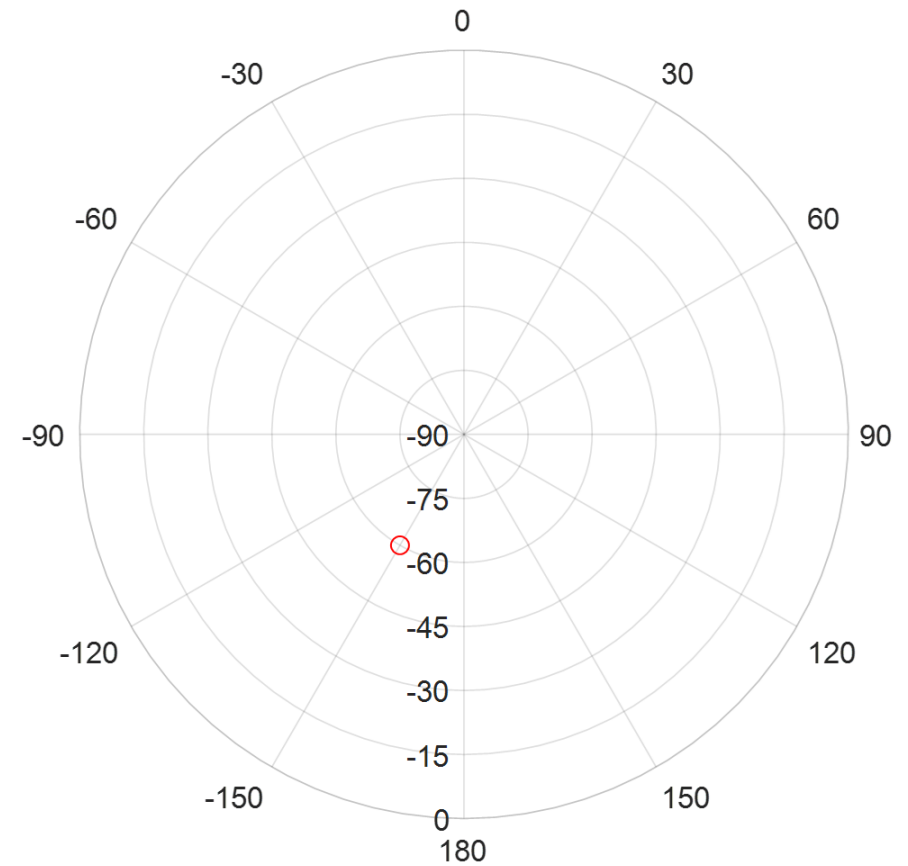
Presentation method

Northern hemisphere Up



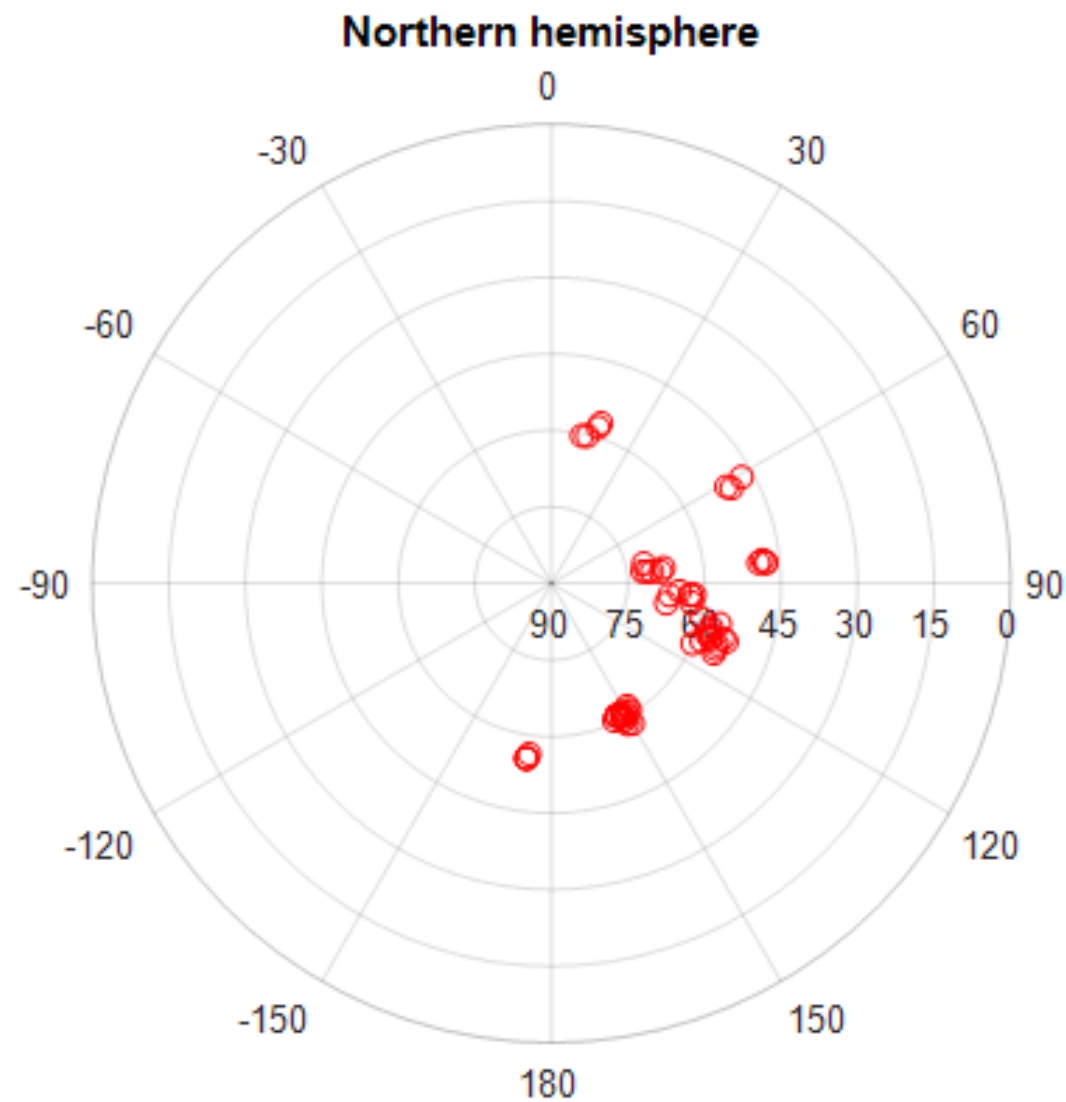
Azimuth: -150 deg
Elevation: 60 deg

Southern hemisphere Down

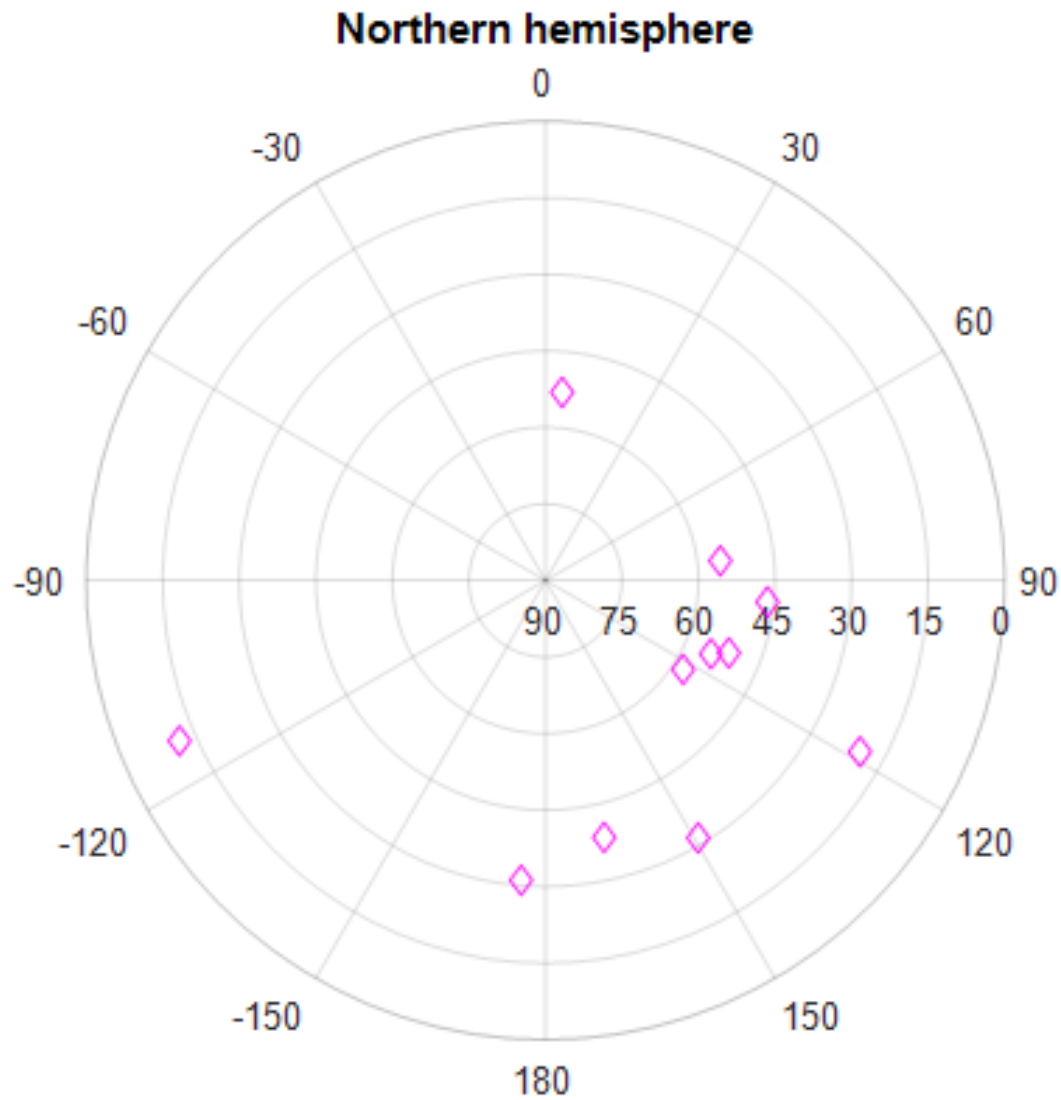


Azimuth: -150 deg
Elevation: -60 deg

Verkliga data (59)
med hög
tillförlitlighet



Verkliga data (11)
med lägre
tillförlitlighet



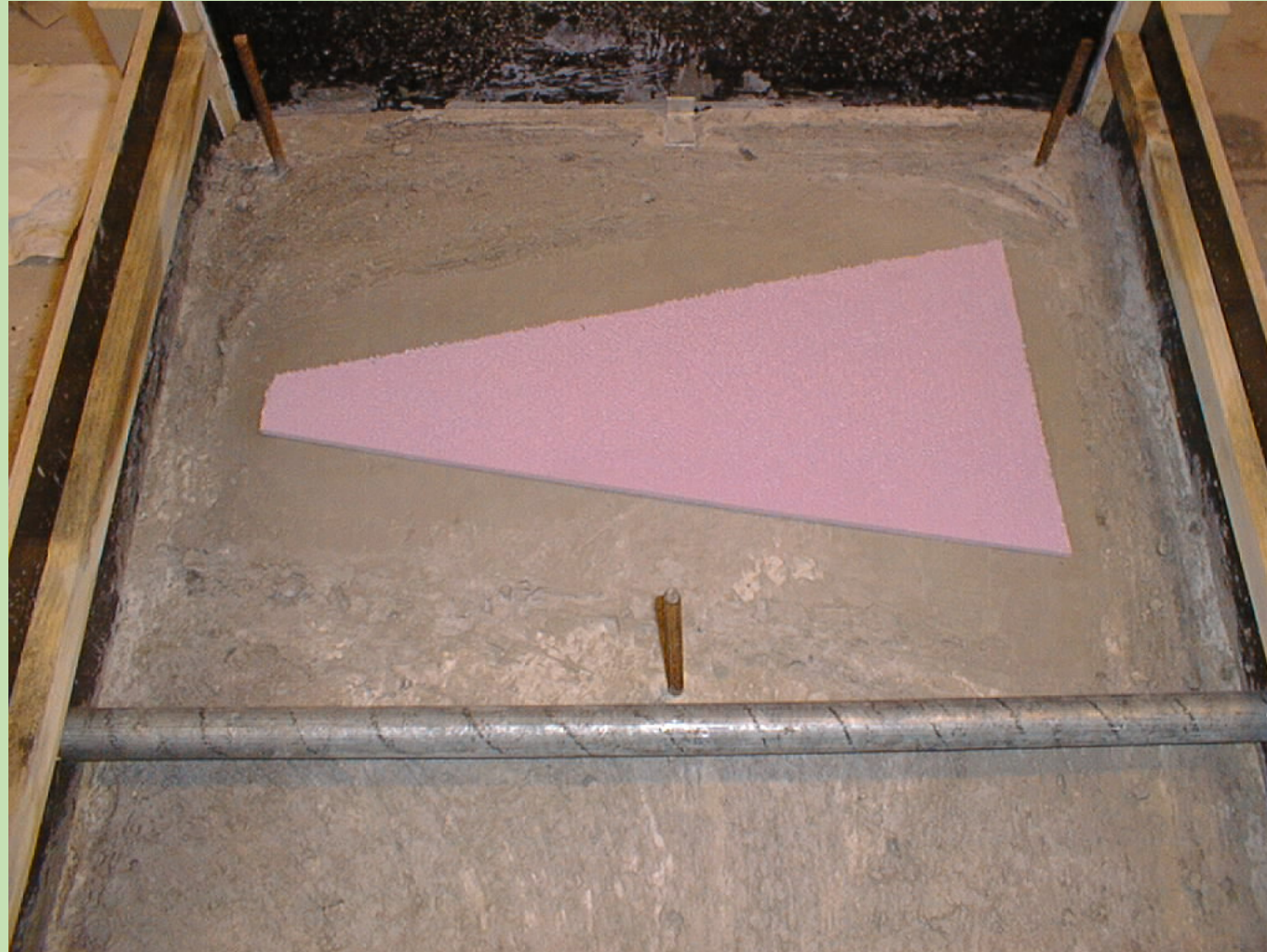
Modern radar för betong

Radar 2 GHz GSSI

CBI testar

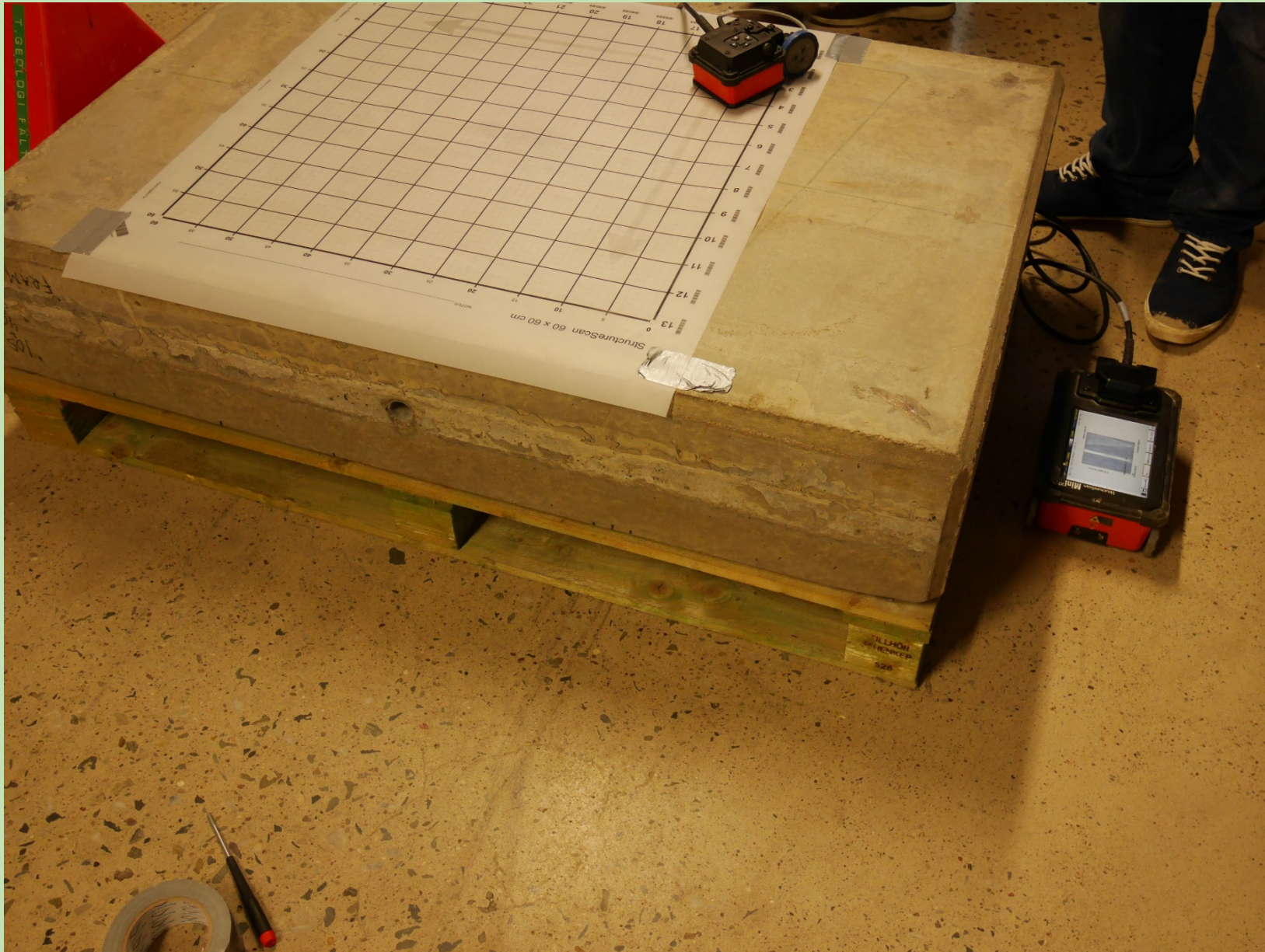


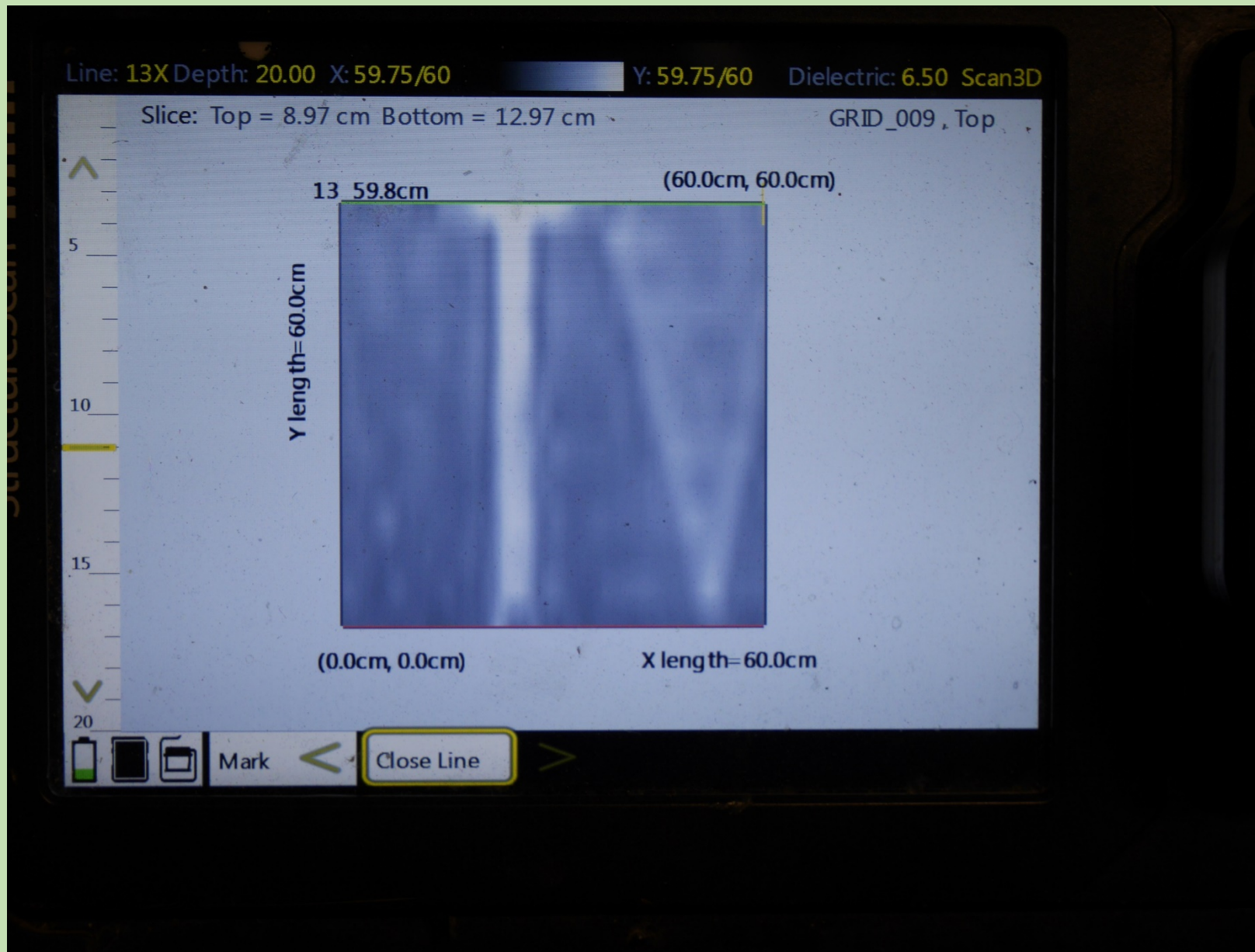
Testobjekt före pågjutning: delaminering i form av frigolitskiva



2 GHz

CBI





Tack för visat intresse