UltraLab:

Sophisticated Ultrasonic Remote Wave Sensing for Towing Tanks, Basins and Flumes

Jens Hensse, Dr. Torge Rieper, Dr. Malte Schümann

General Acoustics e.K.
Am Kiel-Kanal 1
24106 Kiel
Germany

www.generalacoustics.com
Info@generalacoustics.com

© GENERAL ACOUSTICS, August 2022

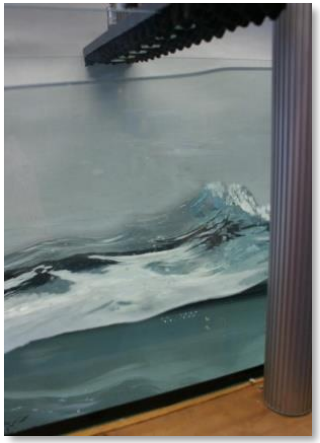
UltraLab: An Overview

What?

- Measuring waves and water levels with high reproducibility
- Wave contours up to breaking waves
- Wave directions

How?

- Cutting edge remote sensing on the basis of airborne ultrasound
- Highly flexible multi-sensor-approach



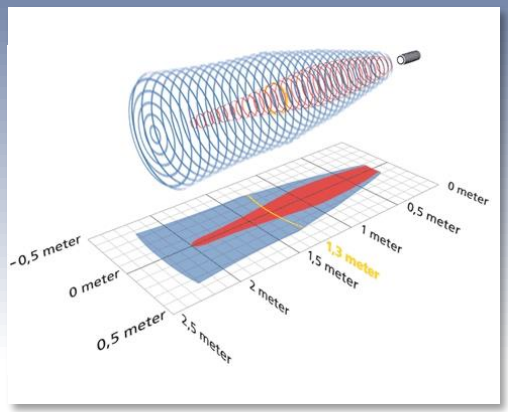
Why UltraLab?

- Calibration-free
- Completely remote
- Pushing the limits of wave sensing technology

© GENERAL ACOUSTICS, August 2022

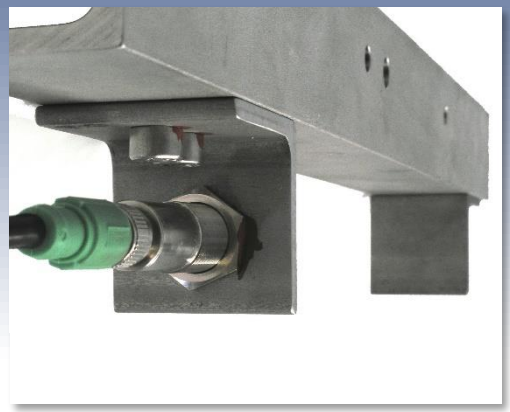
Key Technologies

Narrow Beam Sensor Technology



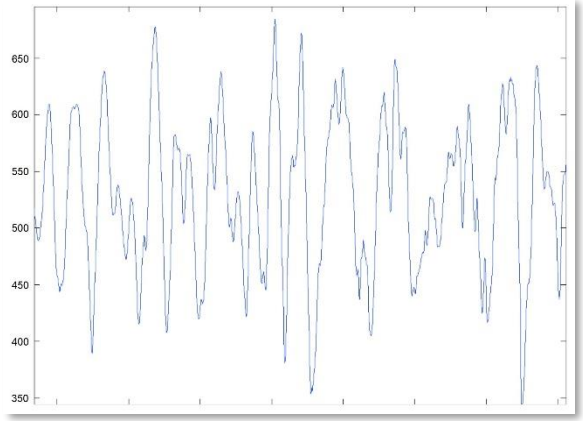
The General Acoustics ultrasonic sensors feature exceptionally narrow beams to accomplish a high spatial resolution.

Reference Measurement



A dedicated speed of sound measurement cancels all influences of temperature and humidity, enabling a fully calibration-free operation.

Exemplary Results – Towed Application



An irregular wave field captured from a carrier moving at 6 m/s (Maritime Institute of the Netherlands (MARIN)

Optional Multiple Sensor Setup

The optional addition of a second and third (only or UltraLab Advanced) receiver to every channel enables towed measurements and the detection of irregular waves.

© GENERAL ACOUSTICS, August 2022

Key Advantages

Remote measurement: No influence on experiment or induced turbulence, no wear

Very high reproducibility: At all times, under all conditions

Easy setup: No water contact, small and lightweight, plug & play, easy to use

Efficient measurement: reliable results, time saving measurement procedure due to calibration-free operation with zero drift

Wide product portfolio: Ready for a wide array of applications, from standard level measurements to highly demanding tasks

Compact and free placeable sensors: Enormous flexibility, can be placed directly next to constructions and models, sensors can be placed next to each other to obtain close line and grid sensor arrays

Multiple sensors concept: Capable of measuring wave directions, extreme wave situations, realization of arrays, no crosstalk of sensors due to synchronization

Multiple channels: Up to 16 channels in one system, 32 or 64 channels by cascading: measuring of 3D wave fields at high resolution

Low cost of ownership: longevity of all components, very low maintenance, flexibilty

UltraLab systems open up new possibilities: measurements of wave fields, breaking waves, extremely steep waves, 3D waves and wave direction. UltraLab gives scientists and researchers a tool to make new investigations possible.

© GENERAL ACOUSTICS, August 2022

Selected UltraLab References

Australia:	Australian Maritime College
Austria:	Schiffbautechnische Versuchsanstalt Vienna
Bulgaria:	Bulgarian Ship Hydrodynamics Centre
Canada:	National Research Council Canada
China:	China University of Geosciences
	Shanghai JiaoTong University
	SSSRI
	Ningbo University
Finland:	VTT
France:	DGA Hydrodynamics, SIREHNA
	ESITC Caen
Germany:	Development Centre for Ship Technology and Transport Systems (DST),
	Technische Universität Braunschweig - Leichtweiß-Institut für Wasserbau
	Schiffbau Versuchsanstalt Potsdam GmbH,
	Hamburgische Schiffbau-Versuchsanstalt GmbH (HSVA),
	Technische Universität Berlin, Hamburg University of Technology
Greece:	National Technical University of Athens
Korea:	Hyundai Heavy Industries Co. Ltd.,
	Korea Research Institute of Ships and Ocean
	Samsung
	Engineering (KRISO, formerly MOERI)
	University of Ulsan
Norway:	Stadt Towing Tank
	SINTEF (formerly MARINTEK)
Singapore:	TCOMS - Technology Centre for Offshore and Marine
Sweden:	SSPA Sweden AB
Netherlands:	Delft University of Technology
	Maritime Research Institute Netherlands (MARIN)
USA:	Webb institute
	Oregon State University Wave Lab
United Kingdom:	University of Glasgow and Strathclyde
	QinetiQ
	University of Southampton

© GENERAL ACOUSTICS, August 2022

The Flagship: UltraLab ULS Advanced

What? Flagship model. Fully digital, highly accurate remote sensing of steep and very fast moving waves with a relative velocity up to 15 m/s

How? The higher sample rate of up to 250 Hz allows for highest spatial and temporal resolution. The UltraLab advanced offers the capability to couple three sensors on every channel enabling the analysis of higher dynamic wave situations.

Why UltraLab? The advanced real time signal processing and the capability to capture highly dynamic wave structures makes this system the ideal choice for applications with a high relative velocity between sensor and dynamic water surface.

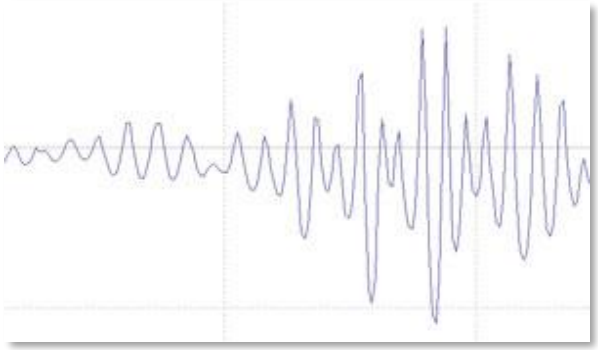
© GENERAL ACOUSTICS, August 2022

The Flexible:
UltraLab ULS HF

What? Fully digital, highly accurate remote sensing of steep and very fast moving waves with 4, 8 or 16 synchronised sensors at 4, 8 or 16 channels.

How? Coupling of two sensors and multiple channels with external channel synchronization and trigger allows for the analysis of wave situations, where a single sensor is not sufficient.

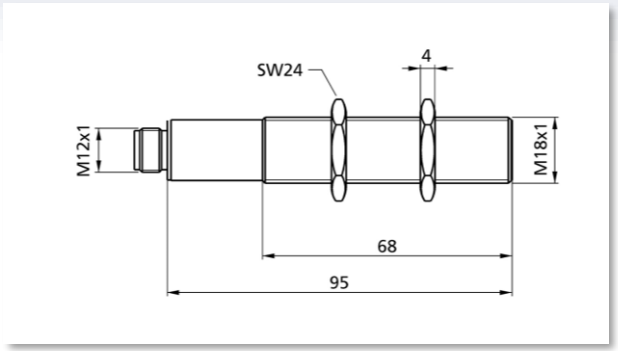
Why UltraLab? Featuring the same UltraLab Advance technology, this system was optimized for more stationary applications.

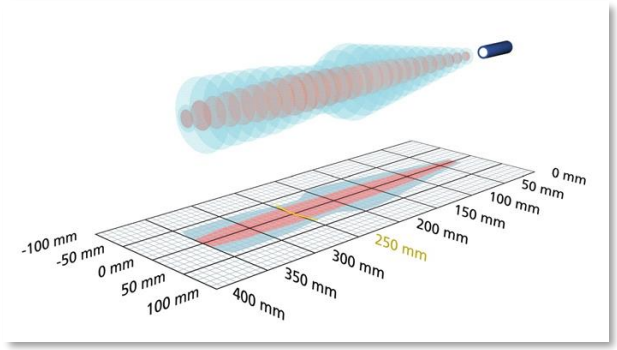


© GENERAL ACOUSTICS, August 2022

UltraLab Sensor USS-02HF

The USS 02-HF sensor is very robust, high quality and smart sensor in a minimized housing for versatile measurements in laboratory applications. The sensor is intended for the use with the General Acoustics UltraLab ULS Advanced and UltraLab ULS HF high precision wave and level measurement systems.



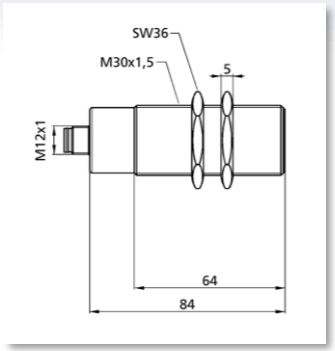


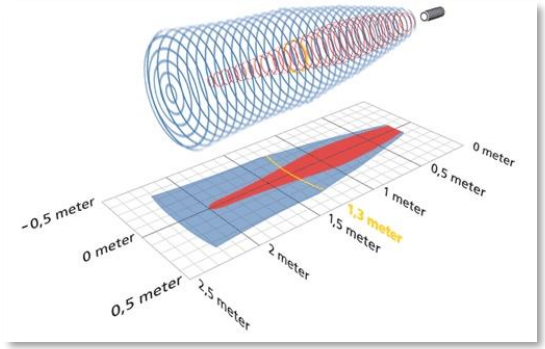
- blind range: 30 mm
- maximum range: 250 mm
- sample rate: up to 100 Hz
- ping frequency: 320 kHz
- resolution: 0.18 mm
- operation temperature: -20 to 70°C
- size: 18 x 105 mm (Ø/L)
- weight: 60 g
- nickel-plated brass housing, IP65
- optional: stainless steel housing
- 10m shielded PUR sensor cable

© GENERAL ACOUSTICS, August 2022

UltraLab Sensor USS-13HF

The USS 13-HF sensor is very robust, high quality sensor for laboratory applications. Its narrow beam angle implies high spatial resolution. The high sensitivity allows measurements of very steep waves and of waves with high dynamics. The USS 13-HF is intended for use with General Acoustics UltraLab ULS Advanced and UltraLab ULS HF high precision wave measurement systems.





- blind range 200 mm
- maximum range: 1200 mm
- sample rate: up to 100 Hz
- ping frequency: 320 kHz
- resolution: 0.18 mm
- reproducibility: 0,36 mm
- accuracy: < 1 mm
- operation temperature: -25 to 70°C4
- size: 30 x 90 mm (Ø/L)
- weight: 140 g
- nickel-plated brass housing, IP65
- optional: stainless steel housing
- 10m shielded PUR sensor cable

© GENERAL ACOUSTICS, August 2022

UltraLab Sensor USS-25HF

The USS 25-HF sensor is very robust, high quality sensor for laboratory applications. Its very narrow beam angle implies high spatial resolution. The high sensitivity allows measurements of very steep waves and of waves with high dynamics. The USS 25-HF is intended for use with General Acoustics UltraLab ULS Advanced and UltraLab ULS HF high precision wave measurement systems.

- blind range: 200 mm
- maximum range: 2500 mm
- sample rate: up to 50 Hz
- ping frequency: 320 kHz
- resolution: 0.18 mm
- reproducibility: 0.36 mm
- accuracy: < 1 mm
- operation temperature: -25 to 70°C
- size: 110 x 80 mm (Ø/L)
- weight: 440 g (with cable)
- powder coated alloy housing, IP65
- 10m shielded PUR sensor cable

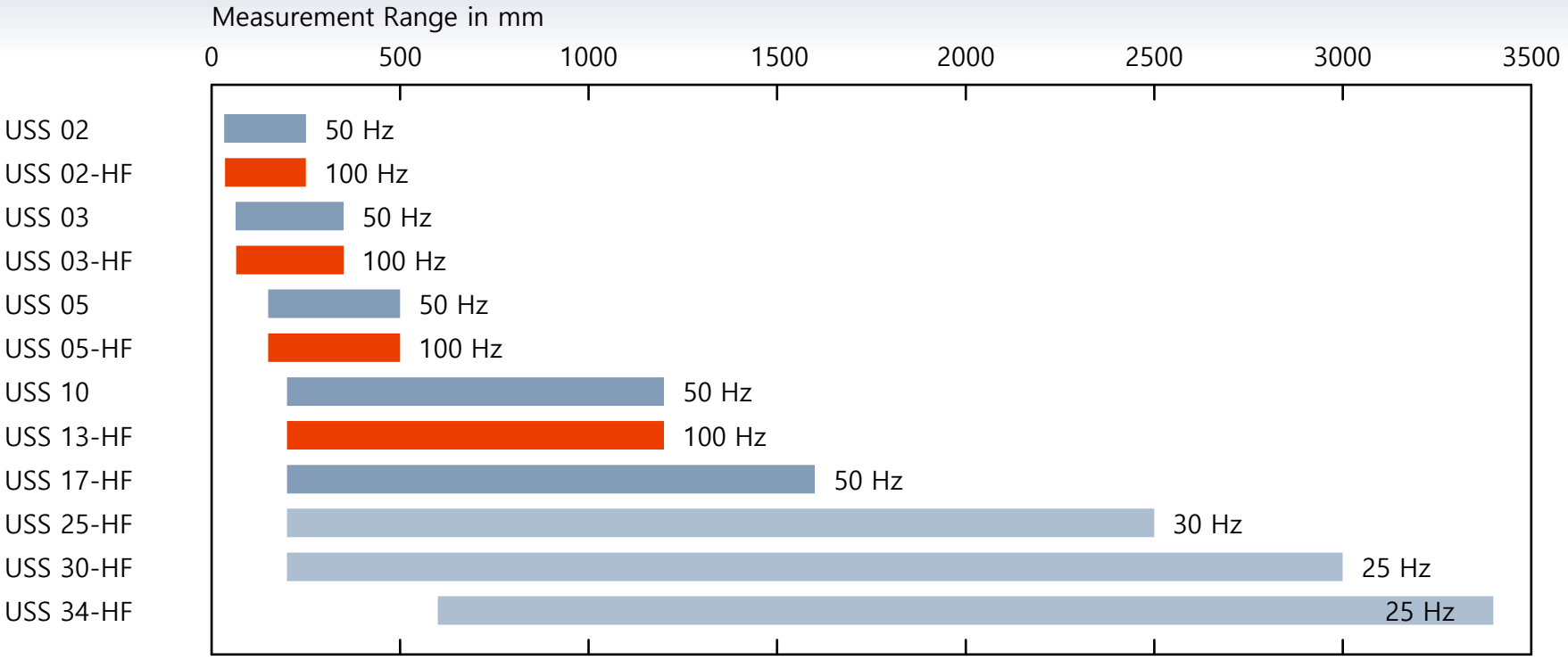
Typical Applications: offshore basins, full scale flumes and wave basins, large scale wave basins

Depending on particular requirements, we offer a wide choice of compatible sensors.

© GENERAL ACOUSTICS, August 2022

UltraLab Sensor Selection

This chart shows the measurement range of all available digital ultrasonic sensors for the digital UltraLab system. The minimum distance is visible (blind range), as well as the maximum distance usable (maximum measurement range). The maximum sample rate is colour-coded and given at the end of every bar. The ultra long range sensors USS 60-HF (max. range: 6000 mm) and USS 10080 (max. range: 10.000 mm) are not depicted here.



© GENERAL ACOUSTICS, August 2022

UltraLab Product Matrix

The UltraLab technology features a highly flexible concept to embed the given sensors in a hardware controller. This enables us to offer a broad array of UltraLab systems tailored for your specific needs and application.

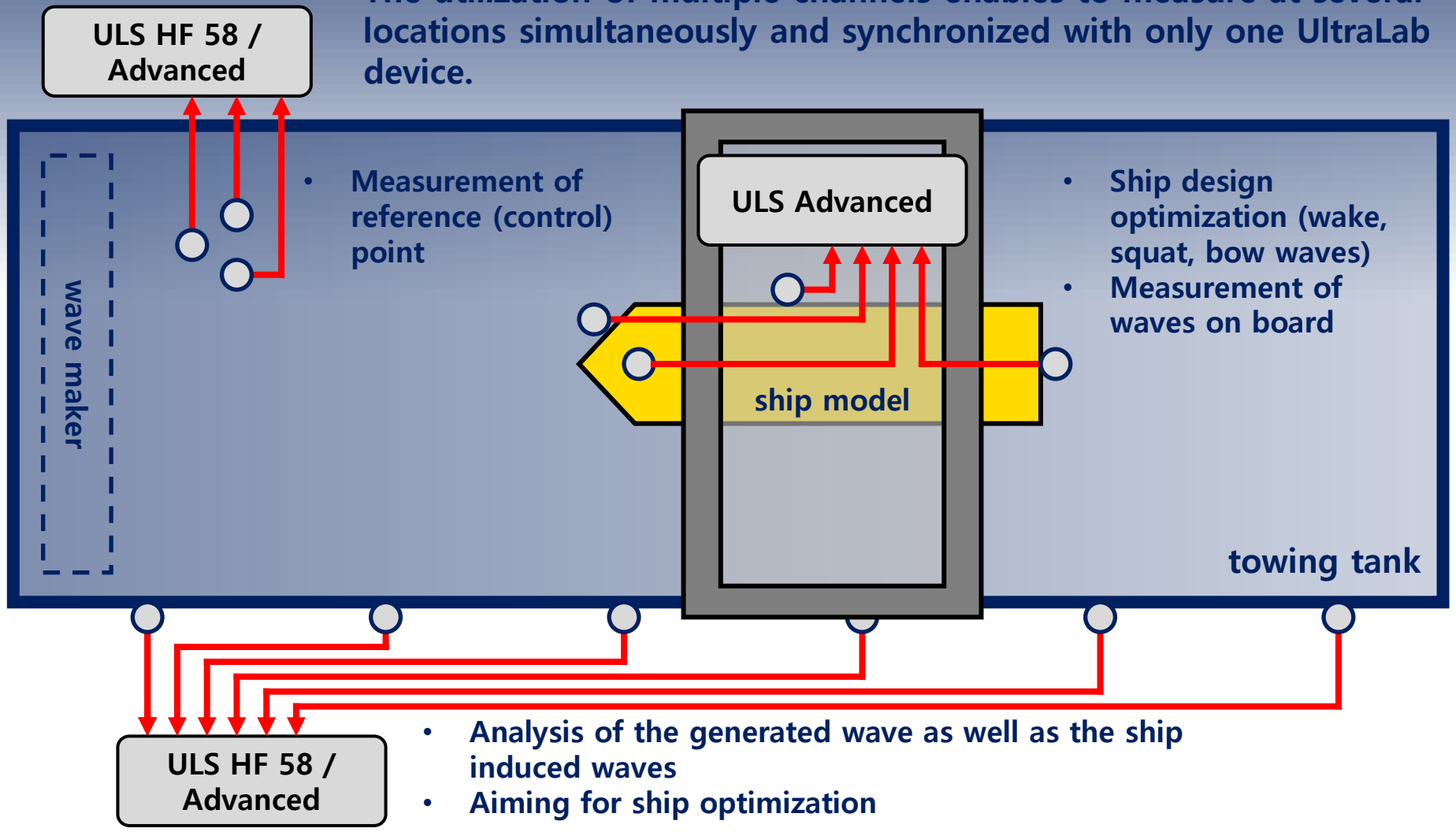
	analogue	digital		
	1 sensor	1 sensor	2 sensors	3 sensors
4 channels	ULS 40D	ULS HF54 ULS HF104	ULS HF54 ULS HF104	ULS Advanced
8 channels	ULS 80D	ULS HF58 ULS HF108	ULS HF58 ULS HF108	ULS Advanced
16 channels		ULS HF516 ULS HF1016	ULS HF516 ULS HF1016	ULS Advanced

- Offering several options regarding:
  - Number of channels
  - Number sensors per channel
  - Sample rate
- Further customization and tailoring towards specific needs possible
- Scheme shows products including options

© GENERAL ACOUSTICS, August 2022

Why Multiple Channels?

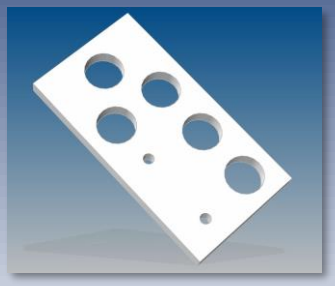
The utilization of multiple channels enables to measure at several locations simultaneously and synchronized with only one UltraLab device.

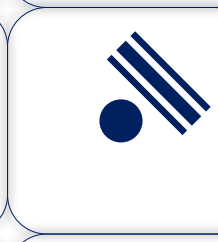


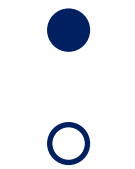
© GENERAL ACOUSTICS, August 2022

Why Multiple Sensors?

The multi sensor approach offers flexible adaption to diverse requirements. Additional receivers enable an enhanced signal input and the detection of wave directions.



	stationary or fixed measurement		towed measurement	
	directional waves	irregular waves	directional waves	irregular waves
moderate waves				
steep waves				
very steep or breaking waves				



© GENERAL ACOUSTICS, August 2022

Which UltraLab for Which Wave Conditions?

With requirements on the measuring task in mind, one can choose a fitting UltraLab directly for the given wave conditions.

	stationary or fixed measurement		towed measurement	
	directional waves	irregular waves	directional waves	irregular waves
moderate waves	ULS 40D / 80D ULS HF5XX	ULS HF5XX	ULS HF54x2 ULS HF58x2	ULS Advanced
steep waves	ULS HF54x2 ULS HF58x2	ULS HF54x2 ULS HF58x2	ULS Advanced	ULS Advanced
very steep or breaking waves	ULS Advanced	ULS Advanced	ULS Advanced	ULS Advanced

More measuring points?

Get an UltraLab with 8 or 16 channels for measurements at multiple locations.

Higher sample rate is key for higher dynamics.

Choose our ULS 108 for 100 Hz or ULS Advanced for optional up to 250 Hz.

The ULS 40D and ULS 80D combine analogue sensors with advanced digital processing.

© GENERAL ACOUSTICS, August 2022

Customized Systems

Based on the decision of a number of channels and sensors per channel an UltraLab system can be further customized to precisely fit customer requirements.

Our options include:

- A wide array of sensors can be chosen suiting for different measuring ranges and wave resolutions
- Enhanced sample rate of 100 Hz for Ultralab HF104, HF108 and HF1016, or up to 250 Hz for UltraLab Advanced for highly dynamic situations
- Rugged housing for full scale and field applications: UltraLab Advanced Field
- Precise synchronization of multiple UltraLab systems for even more measuring locations
- Fast analogue output for auxiliary control applications
- PTP-synchronization to link multiple UltraLab controllers with full synchronization
- Raw data output for highly demanding scientific applications
- Highly resolving radar sensors for highest sample rates at large measuring distances
- Customized measuring ranges
- ...

© GENERAL ACOUSTICS, August 2022

Detailed Specifications

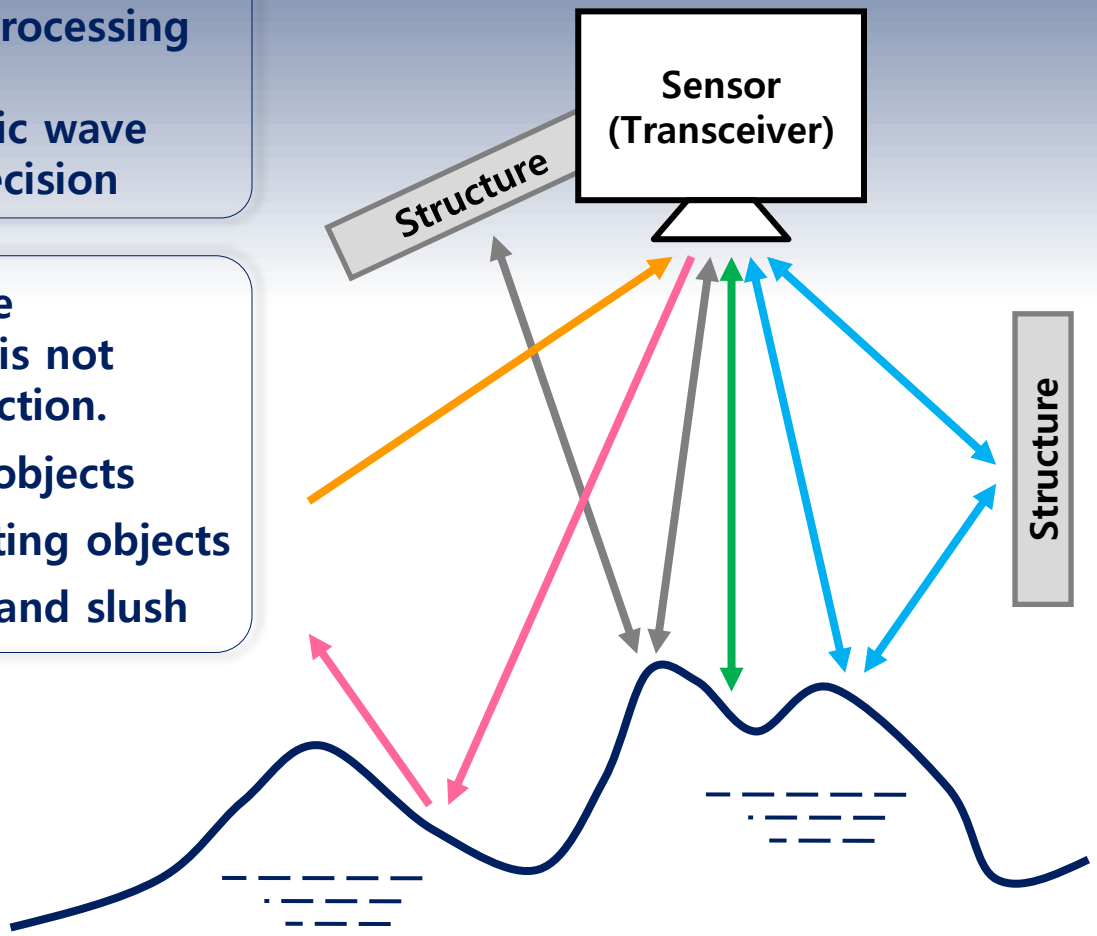
	UltraLab ULS 40D / 80D	UltraLab ULS HF 5XX	UltraLab ULS HF 10XX	UltraLab ULS Advanced
Application				
capabilities	analysis of water surfaces with lower dynamics	analysis of turbulent processes and steep and breaking wave at low to moderate speeds		highest performance, analysis of very turbulent waters, very steep and breaking waves, white water, at very high speeds
relative maximum speed (sensor to wave)	up to 2 - 4 m/s (depending on wave parameter)	up to 6 m/s (depending on wave parameter)		up to 15 m/s
Resolution	up to 180 µm	up to 180 µm		
Repeatability in mm	up to 0.36 µm	up to 0.36 µm		
Sample rate	10 to 75 Hz, depending on sensor	50 or 25 Hz, switchable	100 or 50 Hz, switchable	100 or 50 Hz, switchable, 250 Hz on request
Technical specs				
Type	analogue	digital, each controller is factory configured to take 2 different sensor models		
Number of channels	4 or 8	4, 8 or 16	8 or 16	4, 8 or 16
Number of sensors per channel	1	1 or 2	1 or 2	up to 3
ranges (blind zone / full scale)	3 cm / 25 cm up to 50 cm / 600 cm			
standard / maximum sensor cable length	10 m / 200 m	10 m / 15 m		
sensor size (diameter / length)	30 / 100 mm, 80 / 120 mm	18 / 90 mm, 30 / 100 mm		
sound velocity calibration	internal temperature compensation (2-point calibration if needed)	calibration-free with continuous sound velocity measurement and automatic calibration with the additional REF-300i sensor or: fixed sound velocity set-up		
Signal processing and data				
data output	analogue 0-10 V (BNC-sockets) optional digital RS232/LAN/SD-card	digital RS232, optional LAN/Ethernet optional analogue 0-10 V (BNC-sockets)		RS232 and LAN/ Ethernet optional analogue 0-10 V (BNC-sockets)
data acquisition / software	Windows UltraLab software / Remote control of controller via UltraLab software			
lost echo suppression	no	yes (based on wave theory)		
fault- and multiple echo cancellation	basic	highly sophisticated		

Types of Echoes

multiple joined sensors
+
highly sophisticated data processing
=
analysis of highly dynamic wave situations with high precision

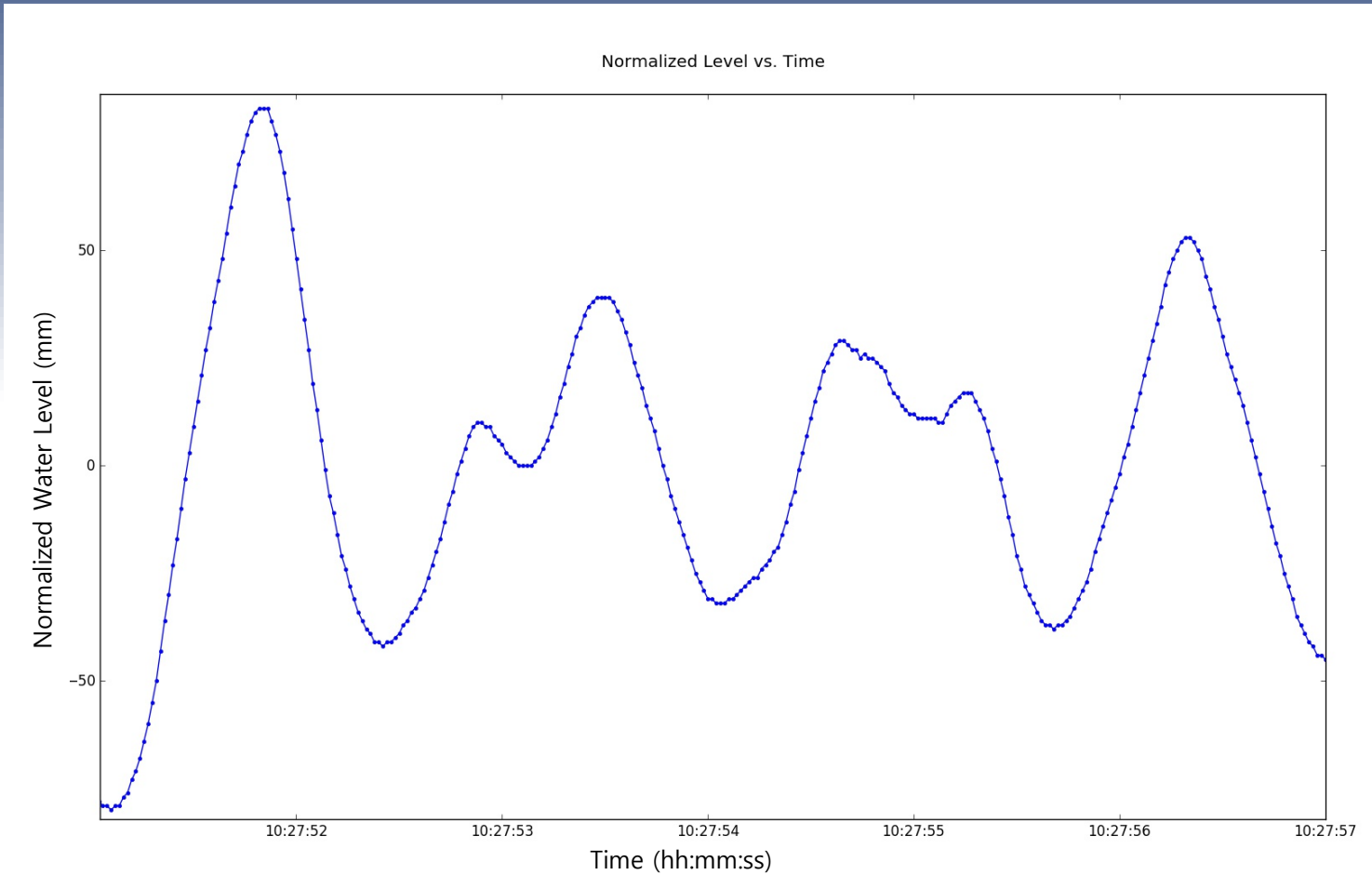
Since ALL received echoes are evaluated, the measurement is not limited to water surface detection.

- detection and of floating objects
- size determination of floating objects
- measurement of ice floes and slush



© GENERAL ACOUSTICS, August 2022

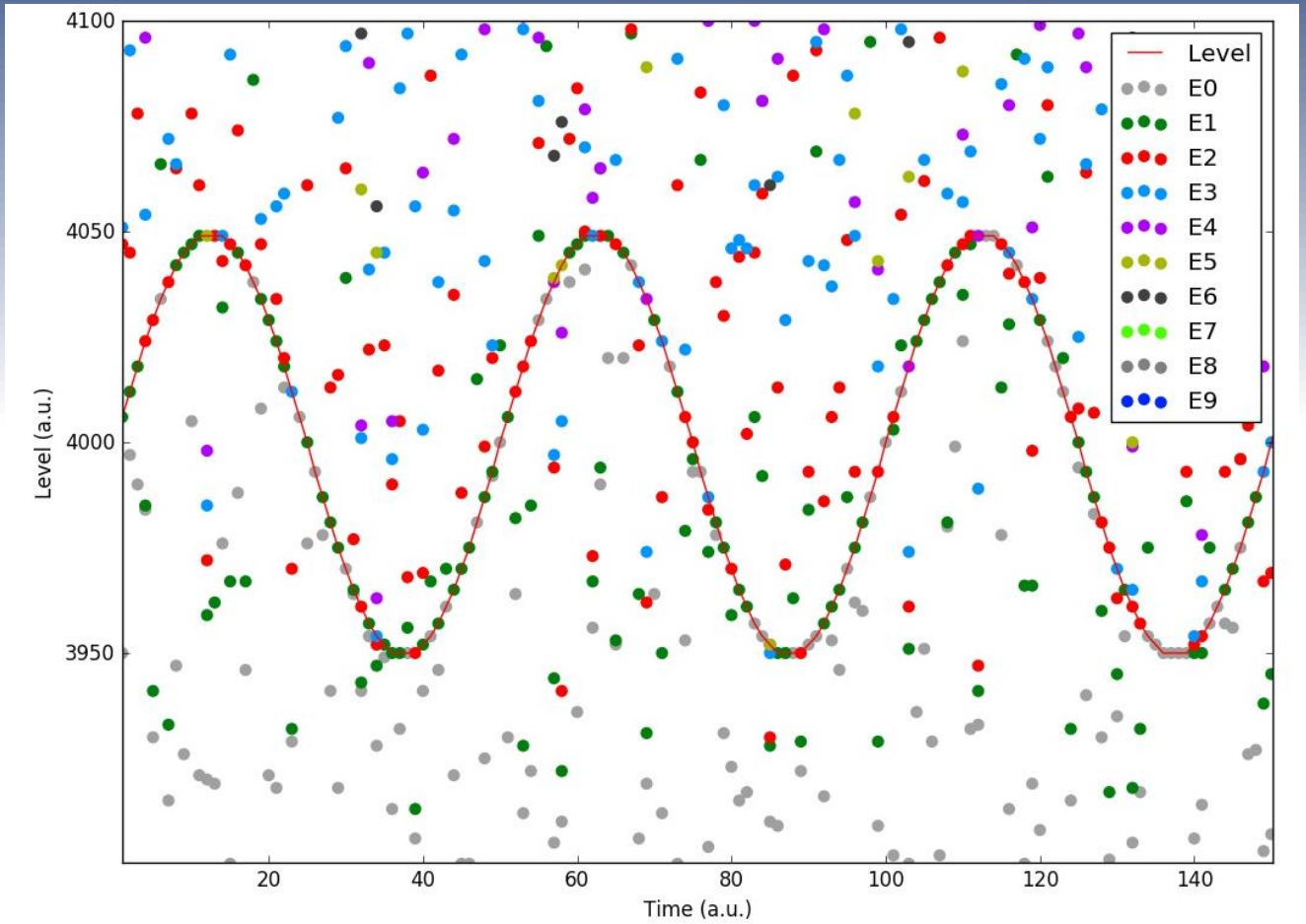
A Typical Measurement



- **Capturing every detail of an irregular wave (1 Hz, 200 mm peak to peak)**
- **High resolution due to high sample rate (50 Hz, 250 Hz optional)**

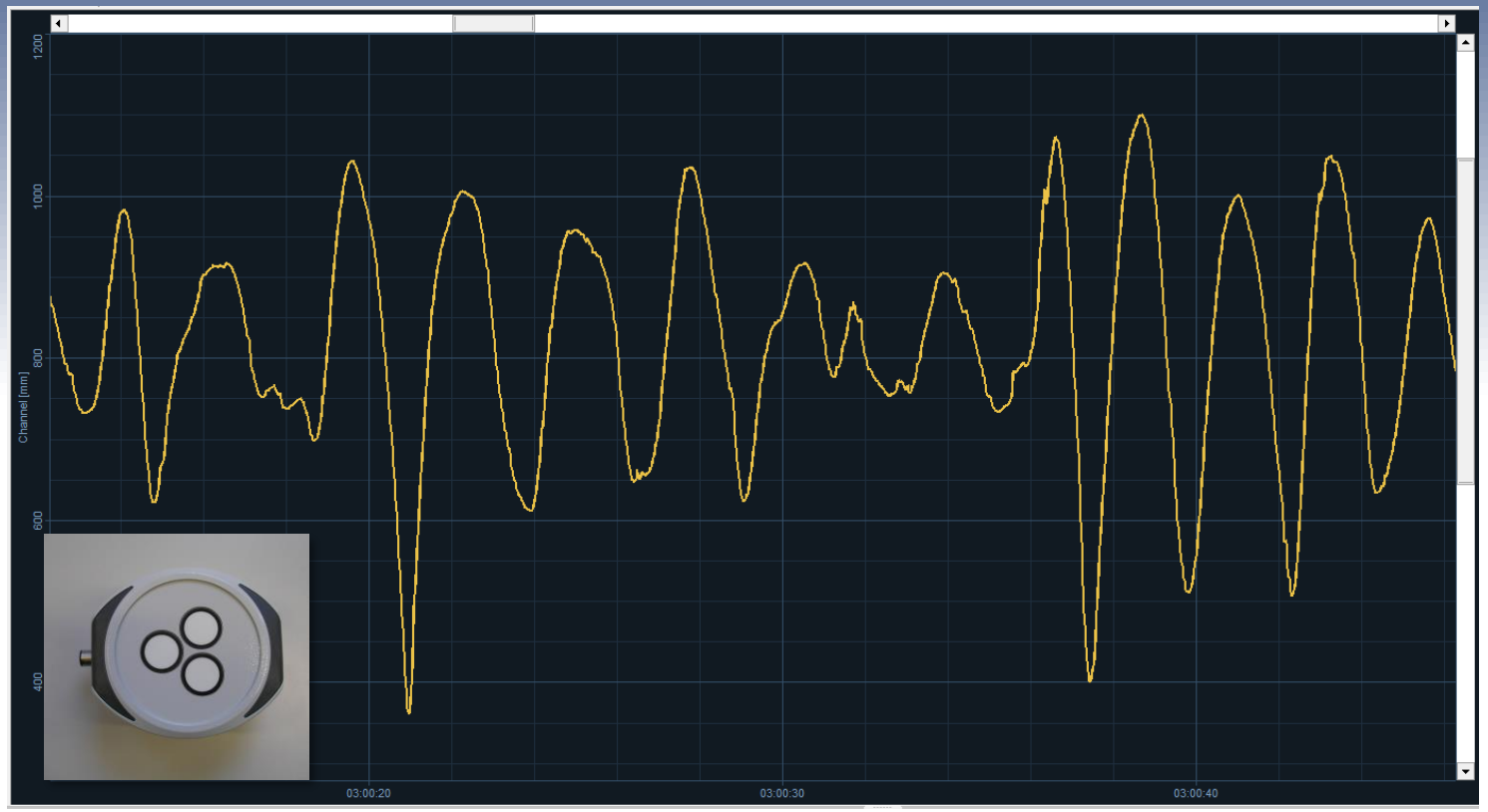
© GENERAL ACOUSTICS, August 2022

Sophisticated Evaluation with Simulated False Echoes



- Worst case simulation with extreme false echoes shows robustness of our own sophisticated integrated processing algorithms
- distinguishing the real echoes with high reliability, providing clear results

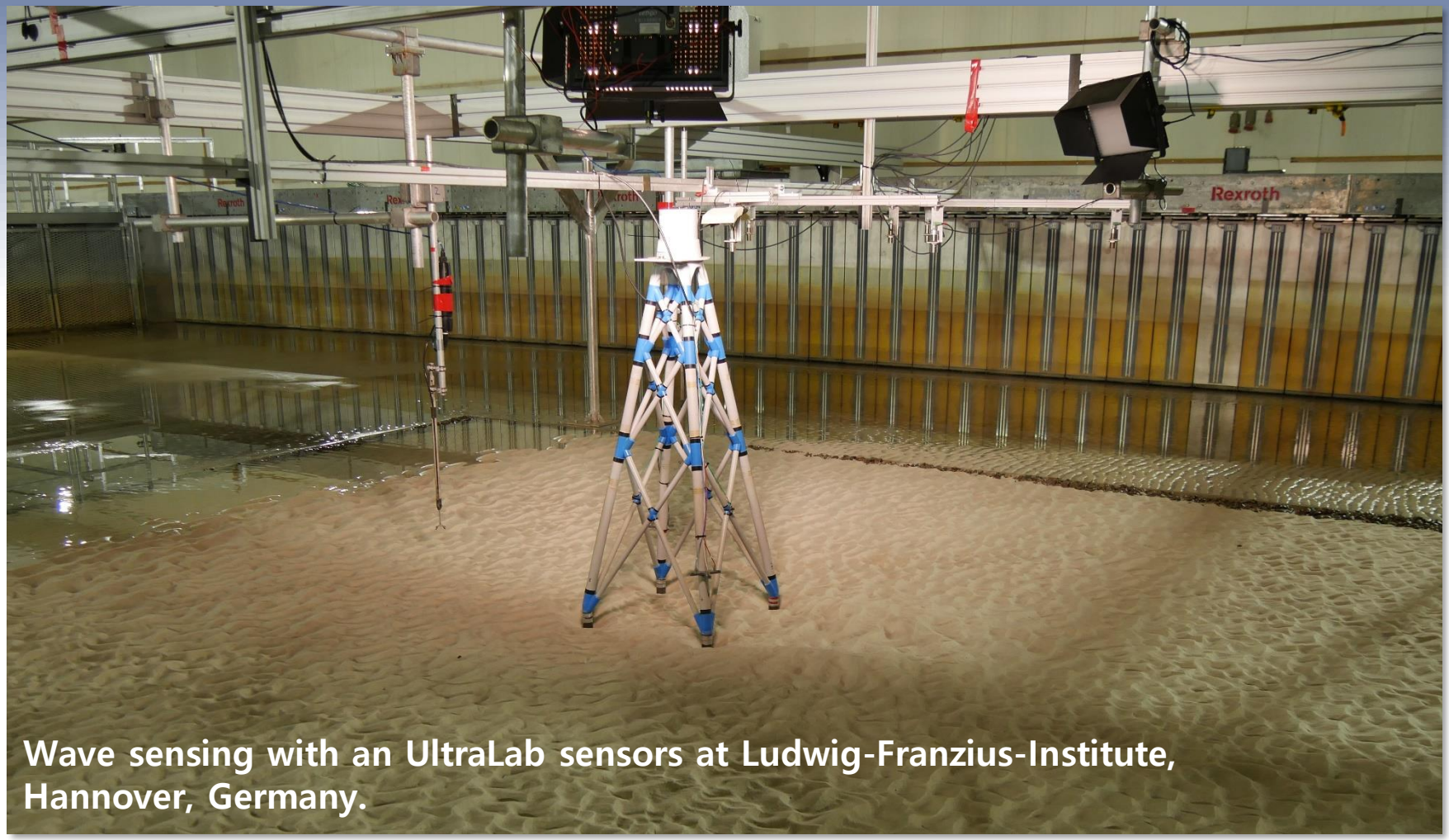
Steep Wave Measurements



- Example of real steep wave measurements
  (2 s with 700 mm peak to peak, Bretschneider Spectra)
- Captured with an UltraLab Sensor USS-25HF
- Screenshot from the UltraLab software: for controlling the hardware, capturing data, visualization and replay

© GENERAL ACOUSTICS, August 2022

Example Applications and References

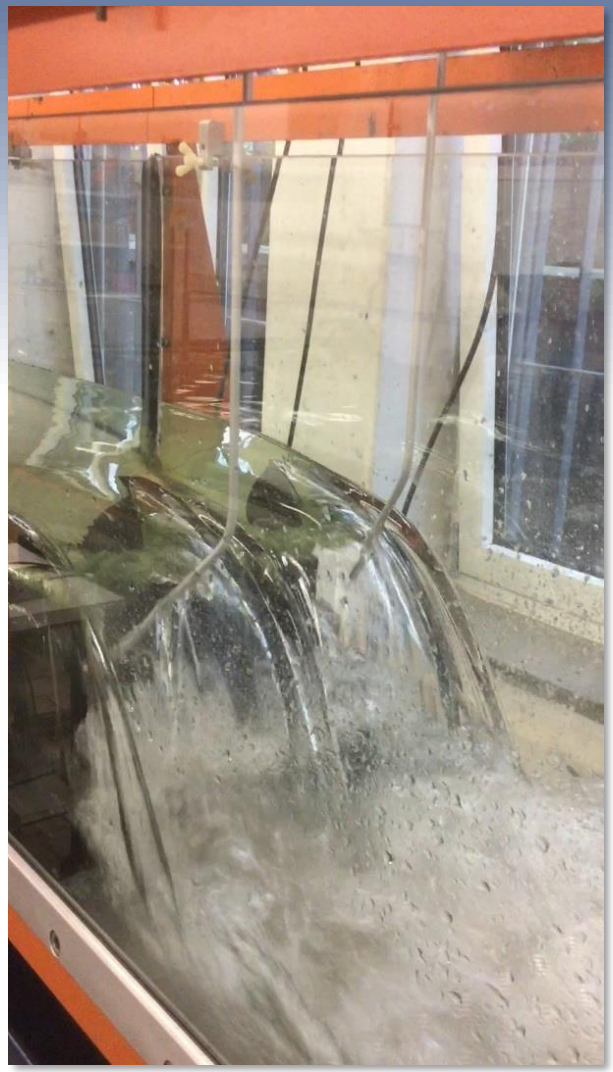


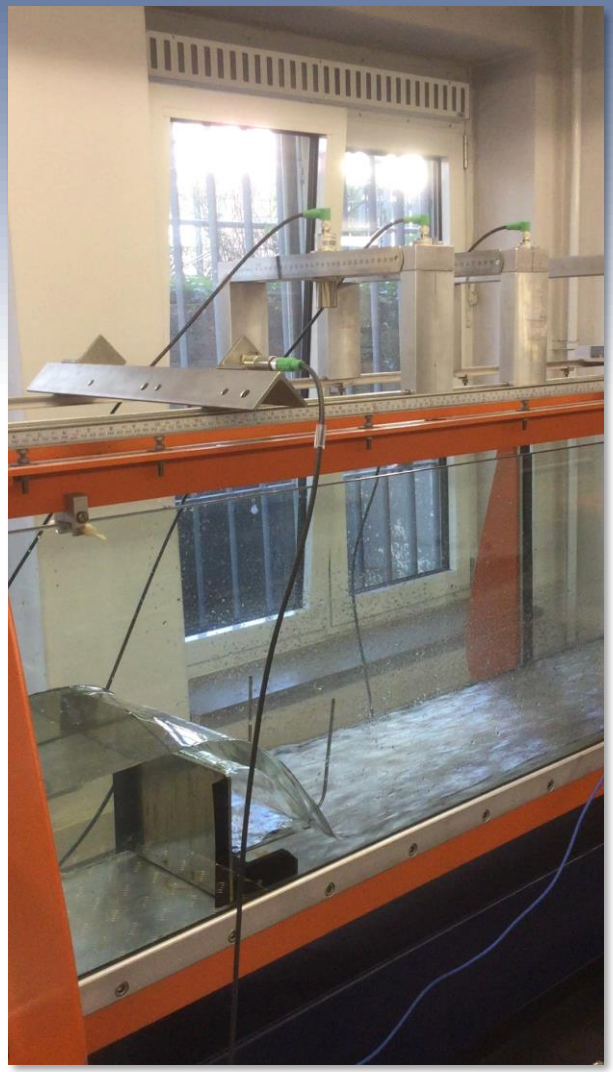
Wave sensing with an UltraLab sensors at Ludwig-Franzius-Institute, Hannover, Germany.

Example Applications and References

Wave sensing with an UltraLab HF108 and USS 02/HF sensors at National Technical University of Athens

Example Applications and References





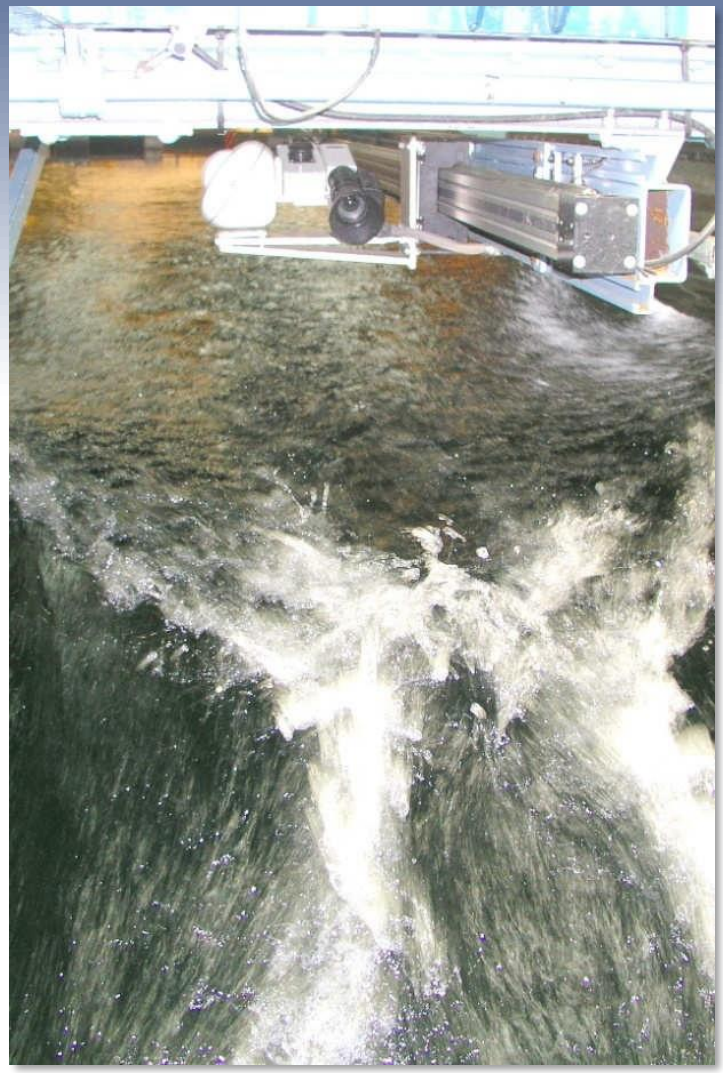
Analysis of highly dynamic shooting water at a flume in Mainz, Germany with an UltraLab

© GENERAL ACOUSTICS, August 2022

Example Applications and References

UltraLab USS sensors mounted on a traverse crossbeam to span a large basin with multiple sensors. (left)

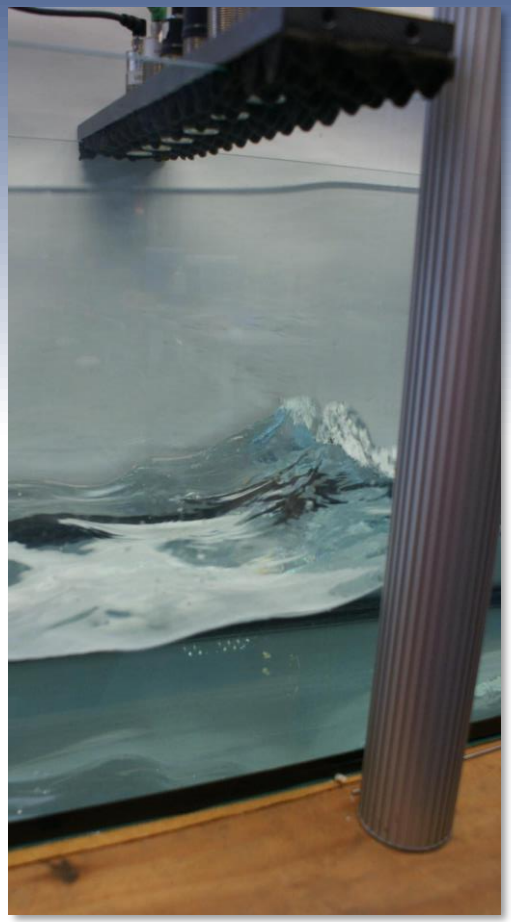
Analysis of highly dynamic water and wave situations at a flume at the RWTH Aachen University, Germany. (left)

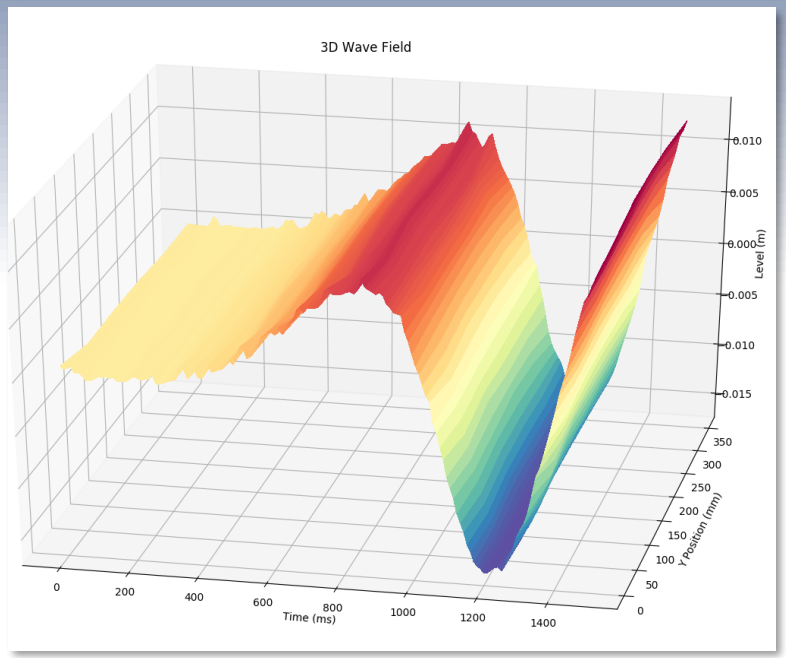


Beam-mounted USS sensors to evaluate white water situations. (right)

© GENERAL ACOUSTICS, August 2022

Example Applications and References



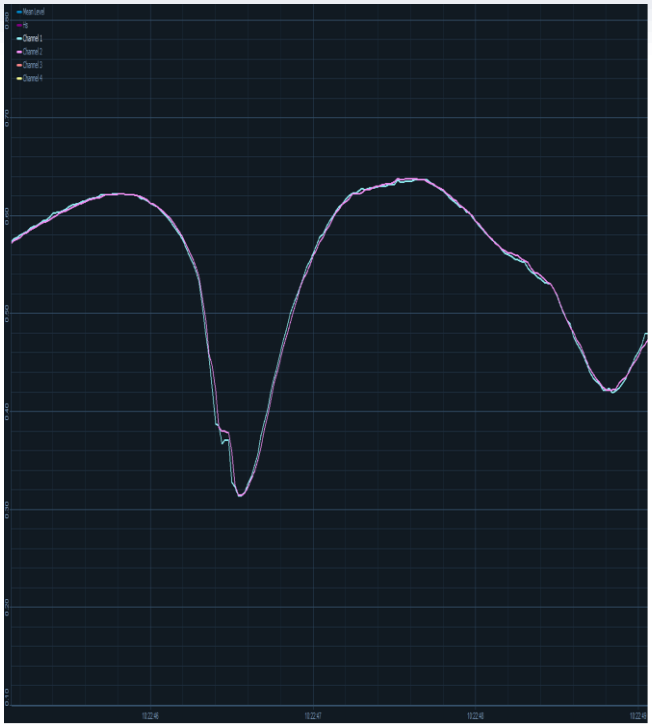


A sensor array of six sensors enables a two dimensional measurement of a complete wave, plus time dimension. Captured with an UltraLab HF 58.

© GENERAL ACOUSTICS, August 2022

Example Applications and References

Example of a measurement capturing a breaking freak wave at the University in Hannover. Captured with UltraLab HF58 with two USS13 sensors



Data corresponding to the picture above: Two separate sensors providing two almost identical signals only slightly delayed due to their slightly different position

© GENERAL ACOUSTICS, August 2022

Example Applications and References

Measurement of dynamic water level at the ship stern at the Maritime Research Institute Netherlands (MARIN)

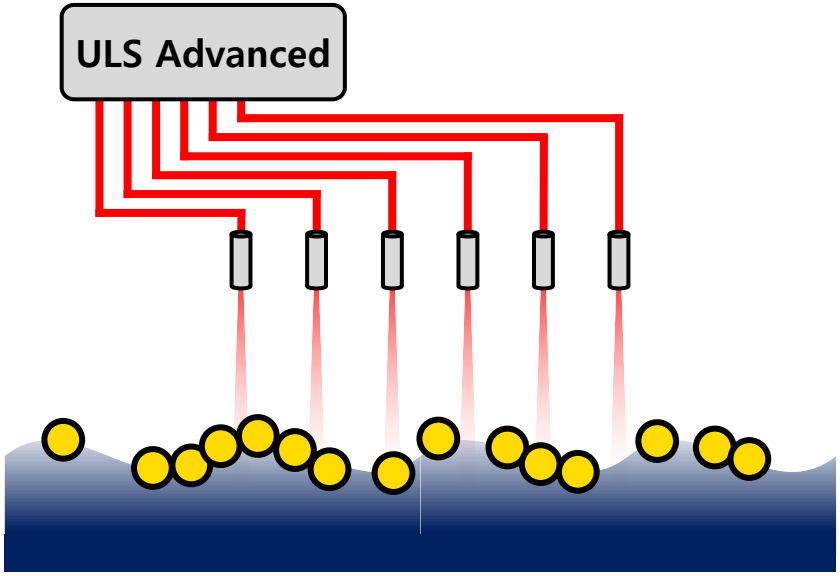
Example Applications and References

Detection and analysis of green water on ship deck at the Ship Model Basin SVA Potsdam, Germany

Evaluation of Floating Objects and Ice

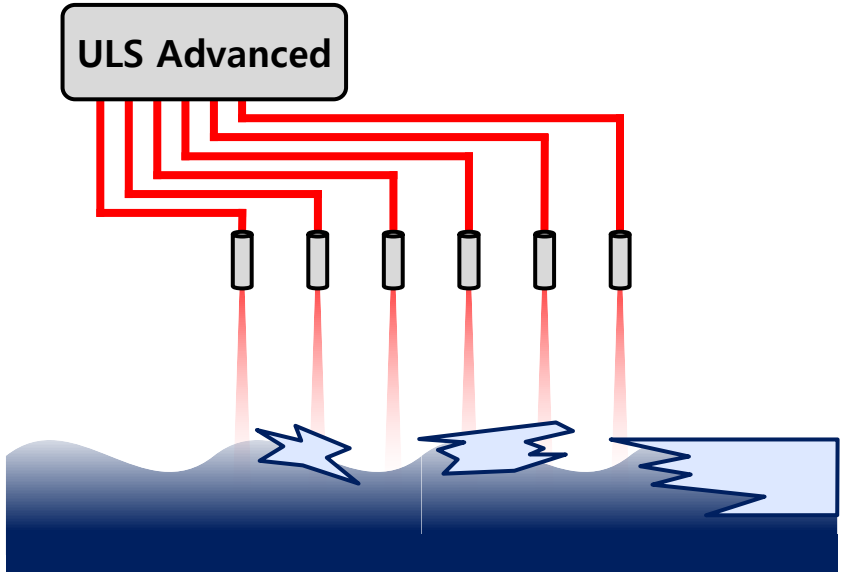
Measurement of floating objects

The ultrasonic measurement is not limited to water surfaces. Since alle received echoes are evaluated, echoes from floating objects can be processed as well. This enables and determination of location and size of floating objects with same precision as with the water surface at post processing.



Application in ice tanks

Since floating objects can be evaluated precisely, UltraLab can be utilized for numerous applications in ice water tanks, evaluating moving ice surfaces, ice floes and slush utilizing a specialized signal processing. The technology is fully suited for deployment in cold, moist and salty environment.

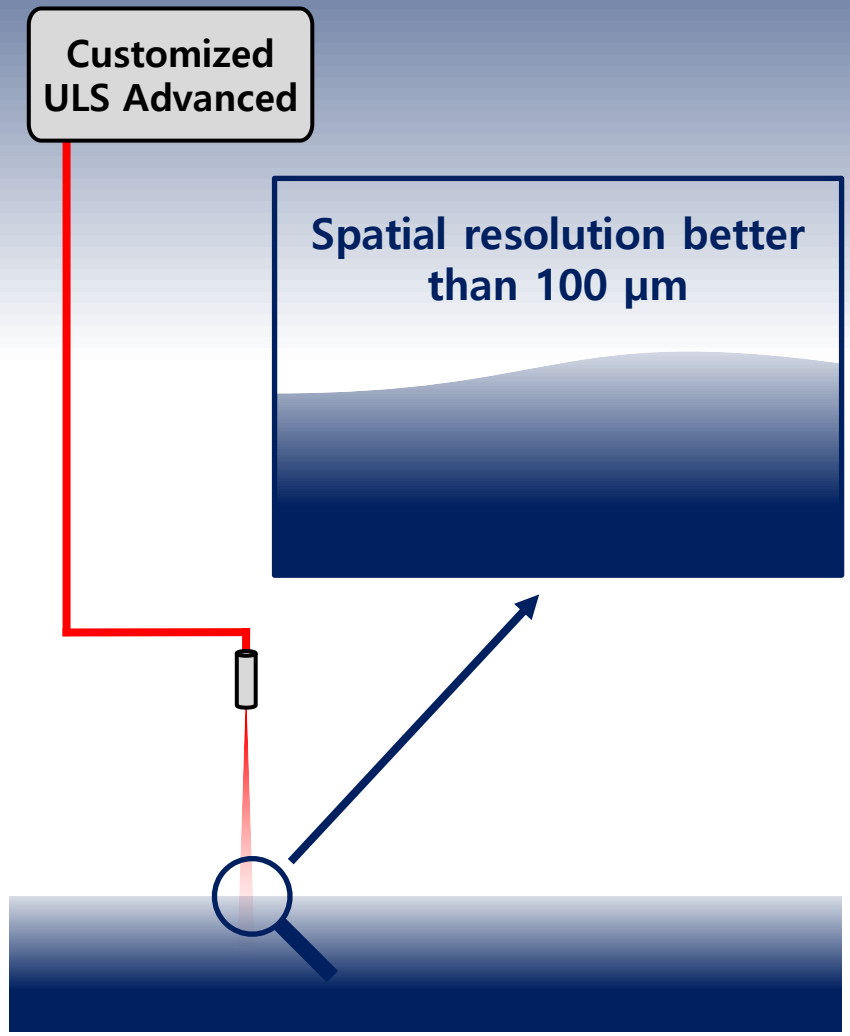


© GENERAL ACOUSTICS, August 2022

Calm Water Surfaces with Extremely High Resolution

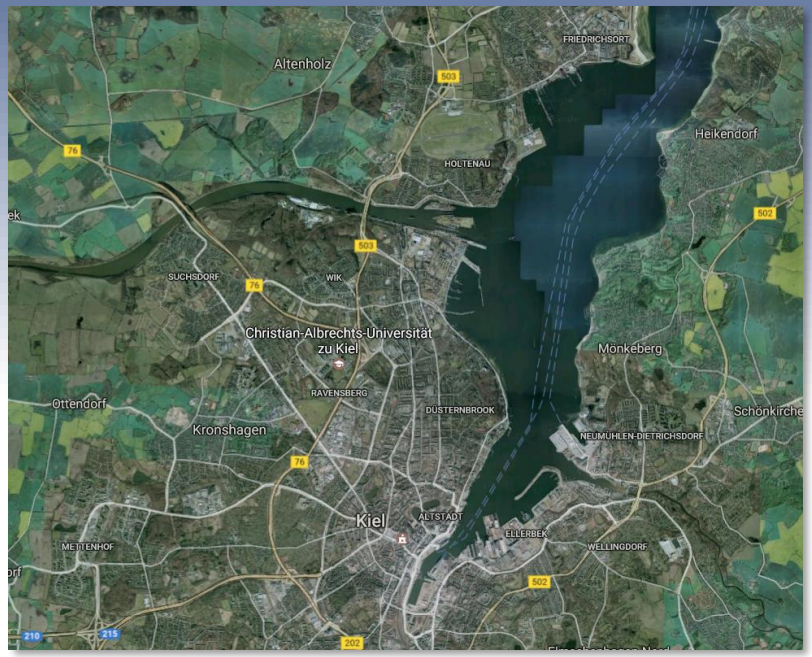
To obtain a quality control benchmark for the non agitated water surfaces at calmest situations, a measurement of the water surface with an extreme resolution and precision can be conducted. This verification of calm water status can be utilized to enhance reproducibility of other measurements in facility or to define a steady state starting point for these measurements.

The extremely high resolution of better than 100 µm is obtained by oversampling, the utilization of highest ping rates and highest applicable ultrasound frequency. A customized UltraLab controller with one ore multiple highest resolving short range sensors is needed.



© GENERAL ACOUSTICS, August 2022

Wave Direction Measurements at the Kiel Canal

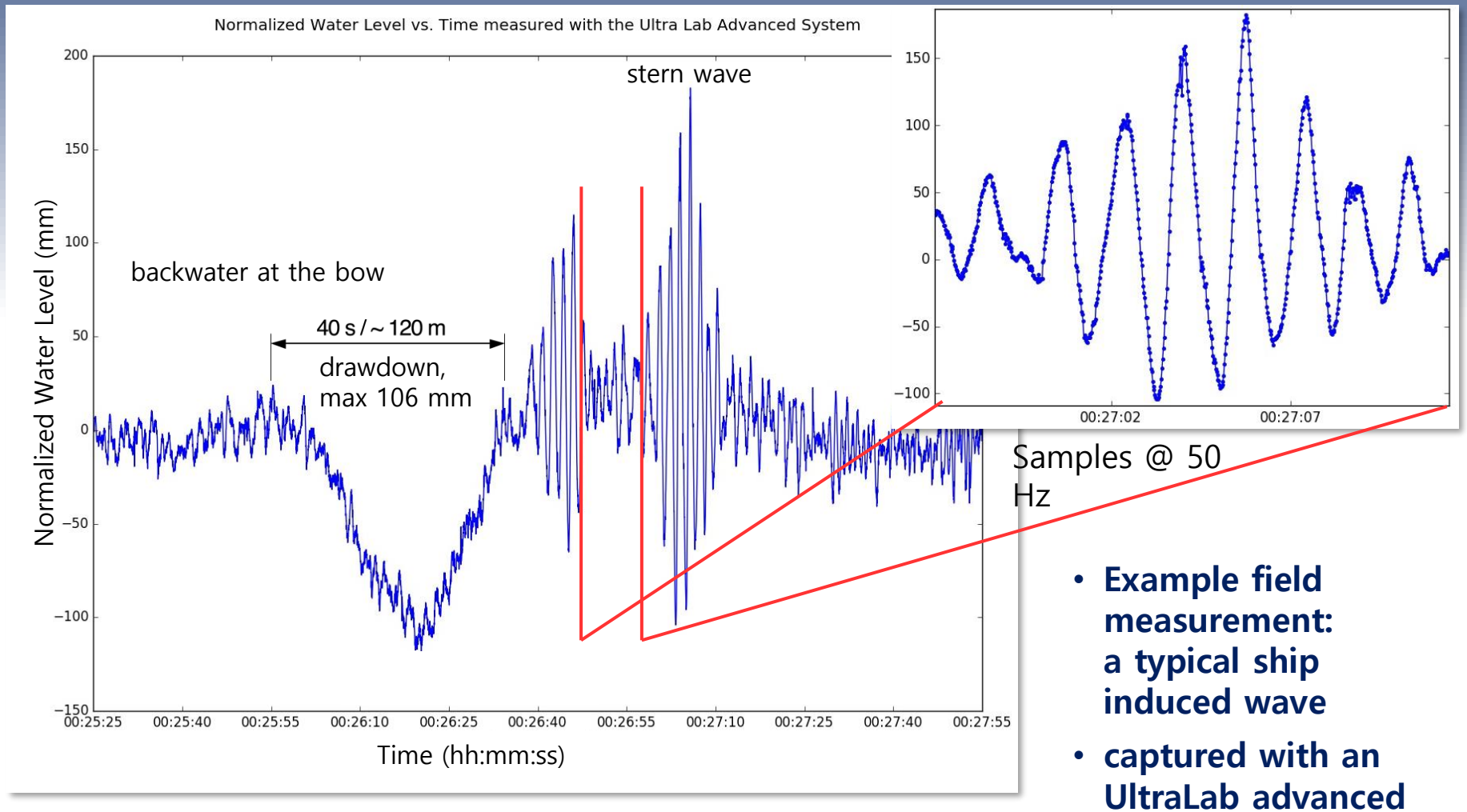


Providing our UltraLab Advance with a rugged housing enables high precision remote sensing outdoors:

UltraLab Advance Field

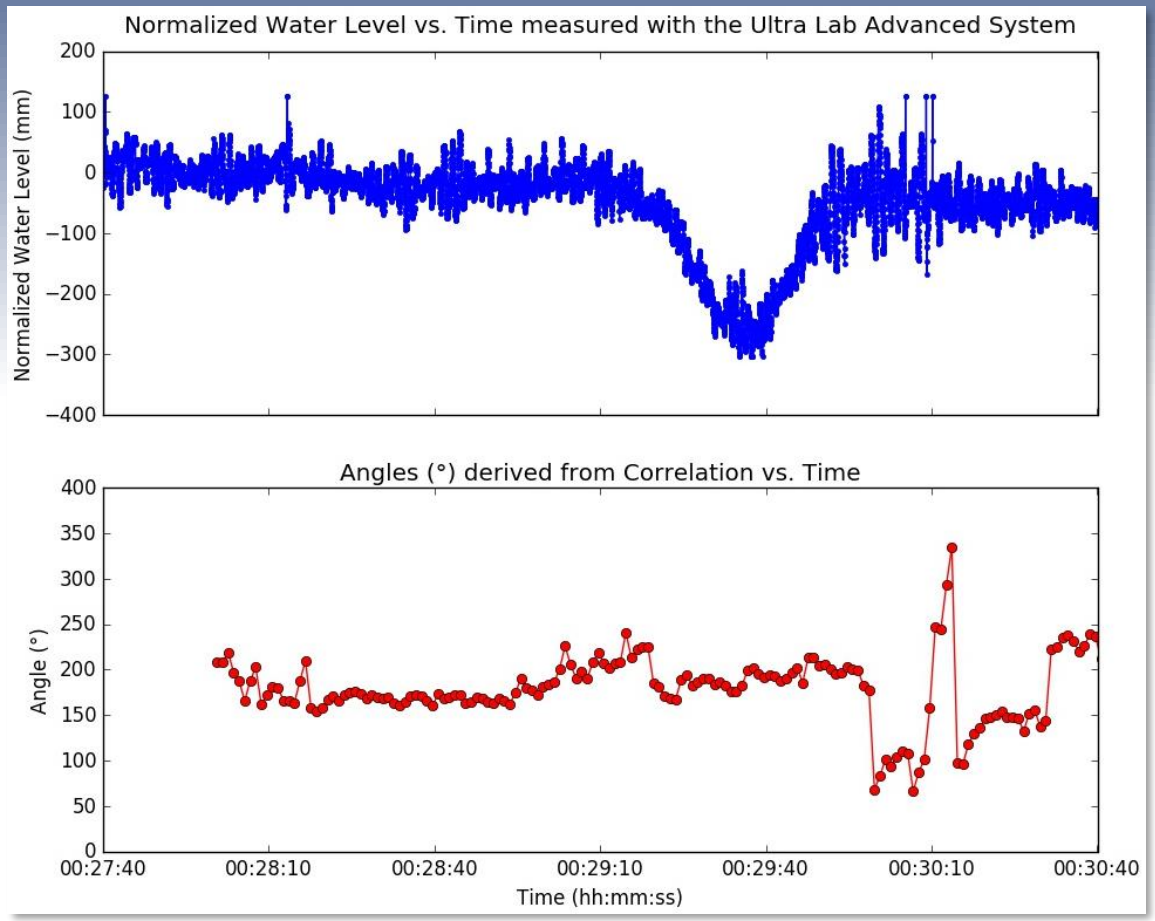
© GENERAL ACOUSTICS, August 2022

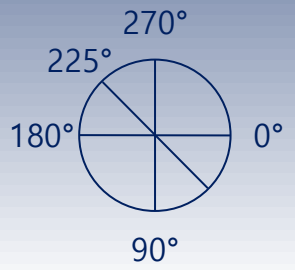
Example: A Ship Induced Wave

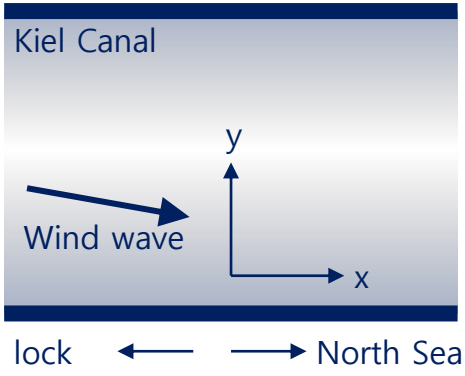


- **Example field measurement: a typical ship induced wave**
- **captured with an UltraLab advanced field**

Wave Direction Measurements



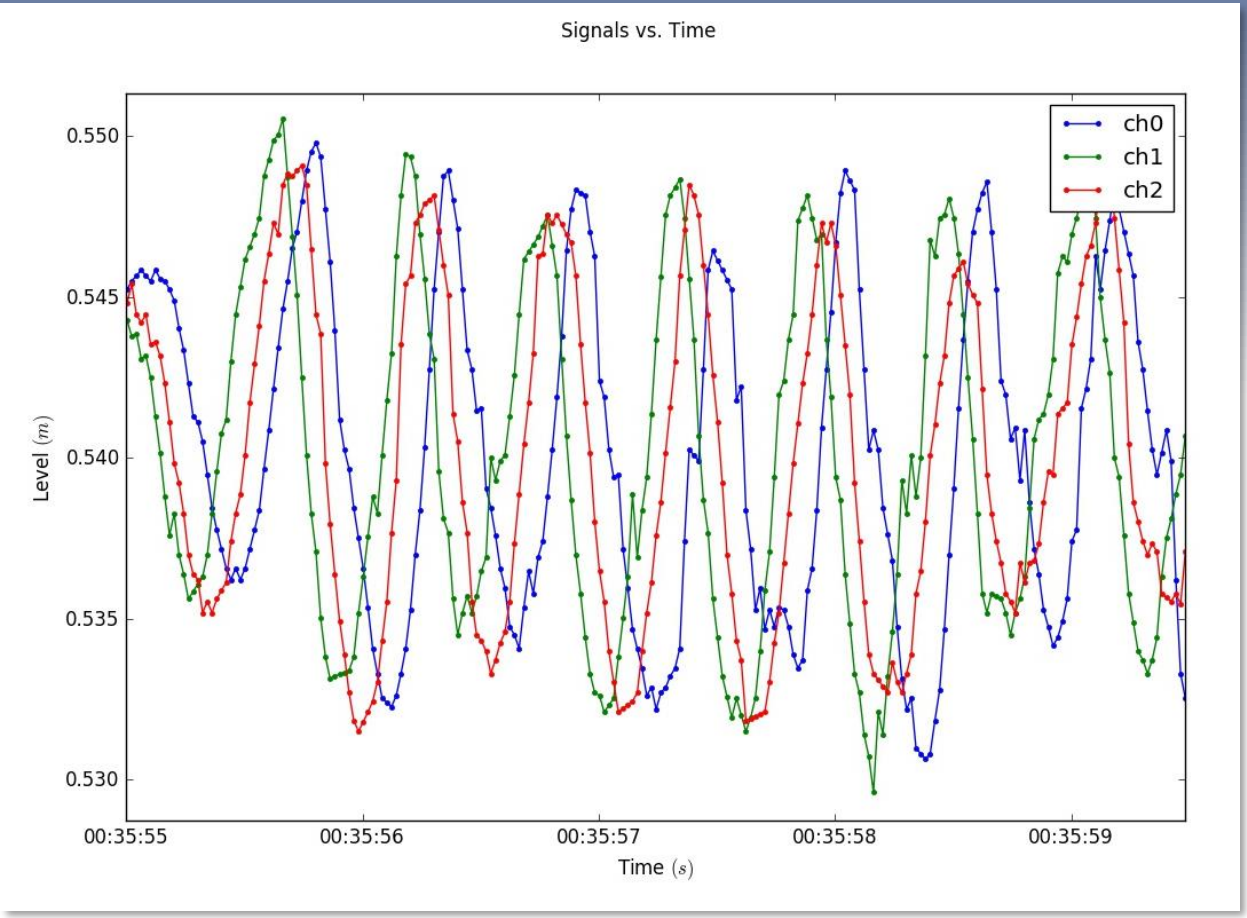




- **Graphs plotting water level and waves (blue) and wave direction (red)**
- **Superposition of Wind and ship induced waves visible**
- **Results show the passing of a ship and the induced ship waves**

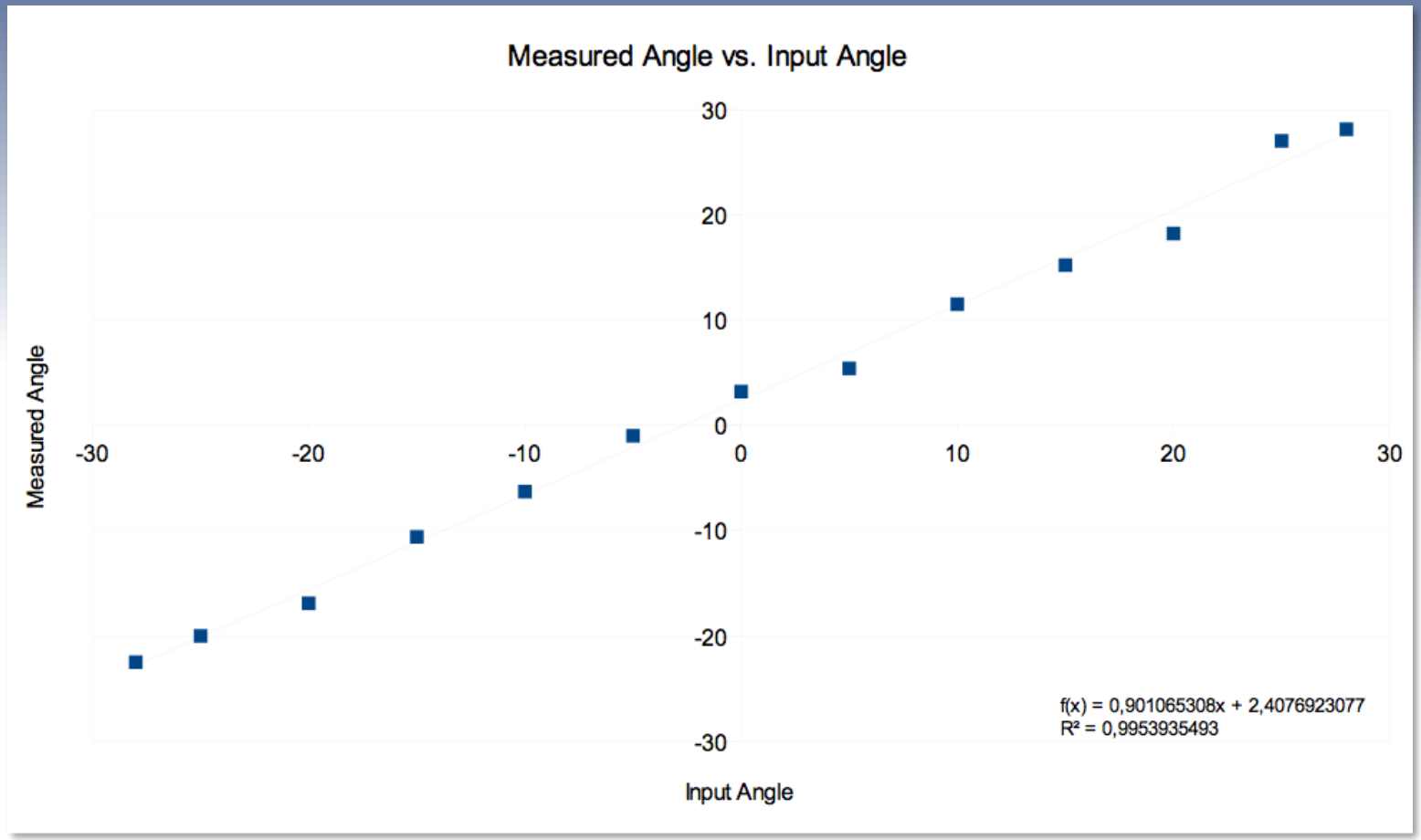
© GENERAL ACOUSTICS, August 2022

Calculating Wave Directions



- **Utilizing three triangularly arranged sensors**
- **Phase shift between the sensors signals enables the calculation of the wave direction**

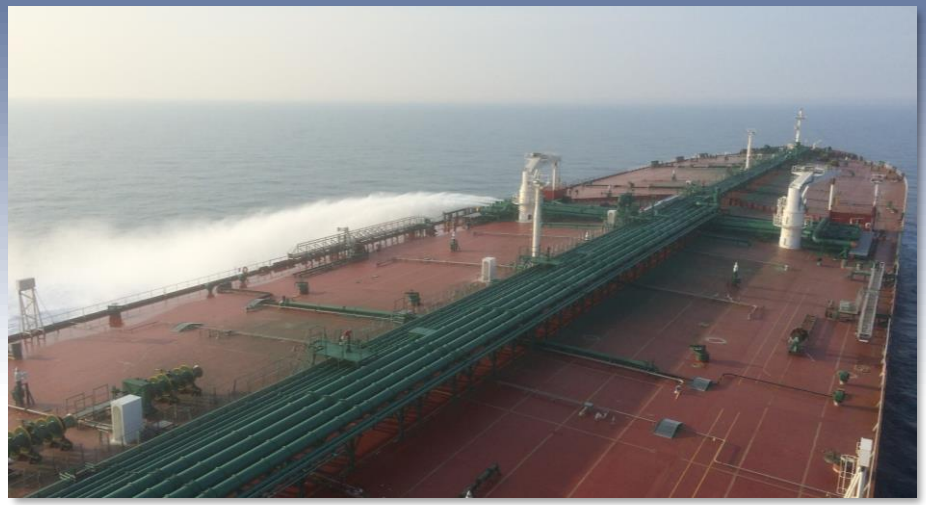
Proof of Accuracy of Wave Direction Measurements



- Proof of accuracy of wave direction measurement at lab
- Same regular directional wave, triple sensor setup, once with rotated orientation
- Regression shows high quality of wave direction measurement

© GENERAL ACOUSTICS, August 2022

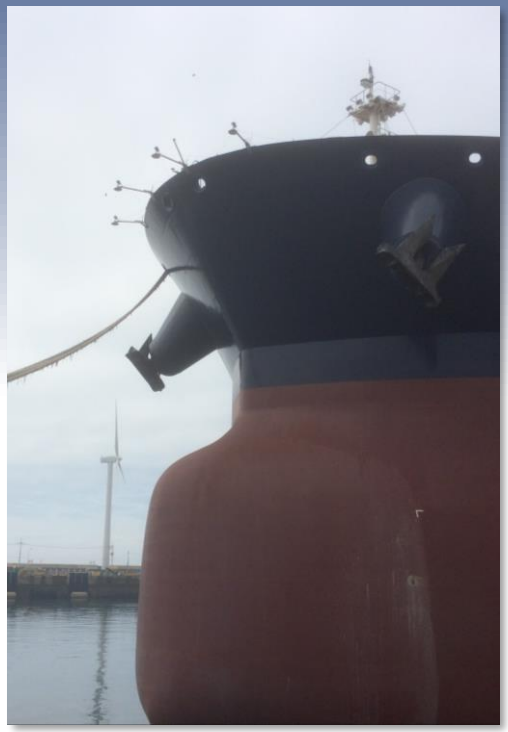
Directional Wave Measurements from Moving Vessels

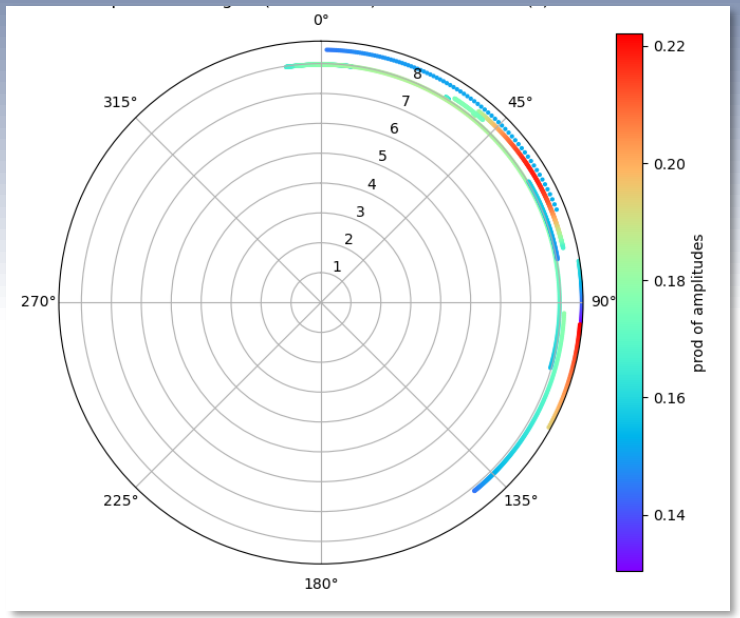


- Utilizing UltraLab Advanced Field for ship mounted measurements
- High performance radar sensors for longer measuring ranges
- With Hyundai Heavy Industries, South Korea

© GENERAL ACOUSTICS, August 2022

Directional Wave Measurements from Moving Vessels

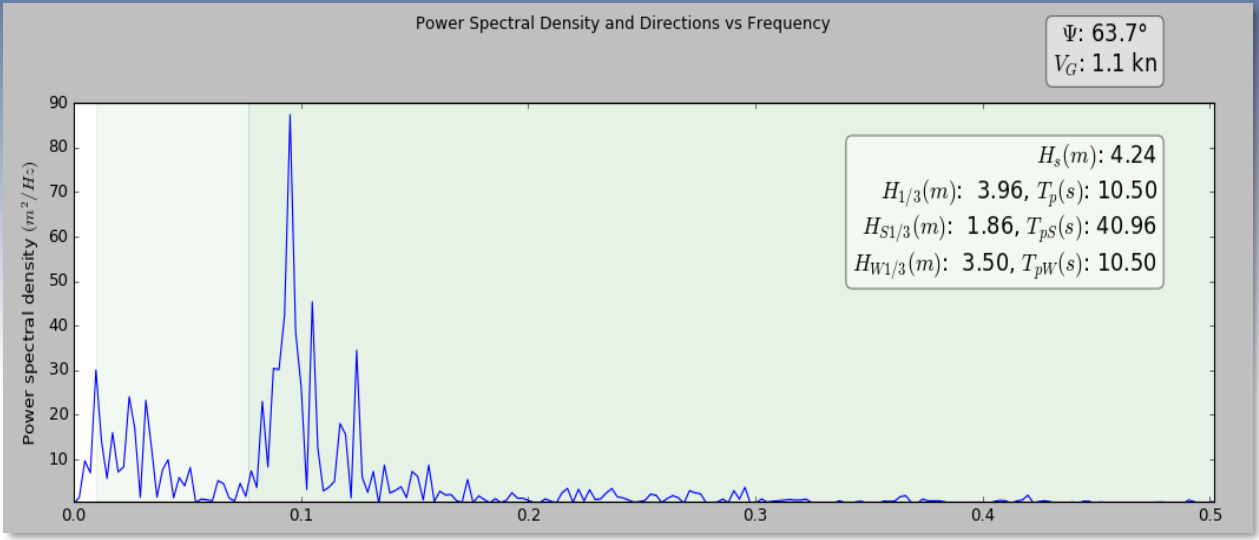




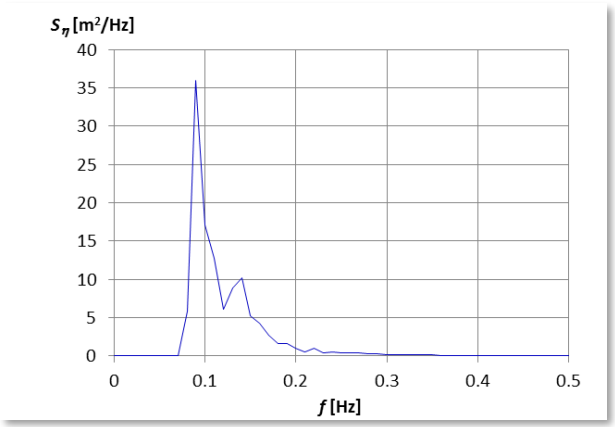
- Utilizing a UltraLab Advanced Field system with radar sensors
- Taking into account speed and motion correction (with GPS, gyro, motion, acceleration)
- Results show the spectrum of wave directions captured with this system
- Visible superposition of different wave directions (sea state)
- With Hyundai Heavy Industries, South Korea

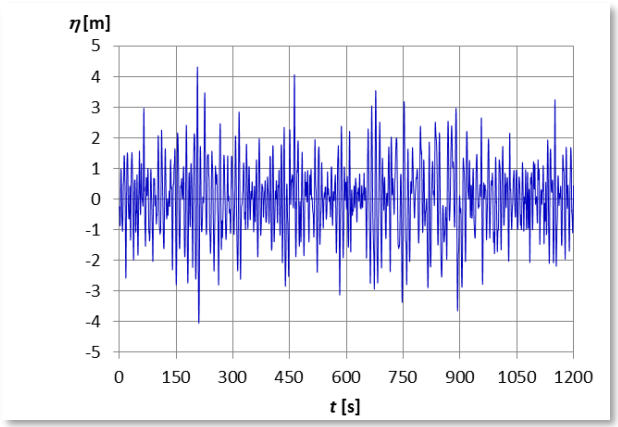
© GENERAL ACOUSTICS, August 2022

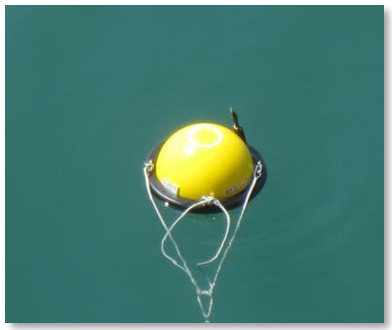
Wave Spectra Captured with UltraLab Advanced



- The same wave spectrum captured with UltraLab Advanced (above) and captured with a wave buoy (below)
- With DNV / Hyundai Heavy Industries, South Korea







Further Example Applications

- Analysis of Wave topping in large basins
- Measurement of steep and breaking waves, also from the moving carriage (even at 20m/s) (sensors mounted on the carriage or at various positions in the test area)
- Wake & white water (sensors mounted on model or carriage)
- Water & waves & squat at the sides of the vessel (sensors mounted on model or carriage)
- Water on board (sensors mounted on model or carriage)
- Water level and wave action in moon-pools (sensors mounted on model)
- Ship induced waves (sensors mounted at various positions in the test area)

© GENERAL ACOUSTICS, August 2022