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SENSORS AND CERTIFIABLE HYBRID ARCHITECTURES
FOR SAFER AVIATION IN ICING ENVIRONMENT

LILD – Local Ice Layer Detector

An ice layer detection by an inboard sensor

Christian Mendig – German Aerospace Center
Martin Pohl – German Aerospace Center

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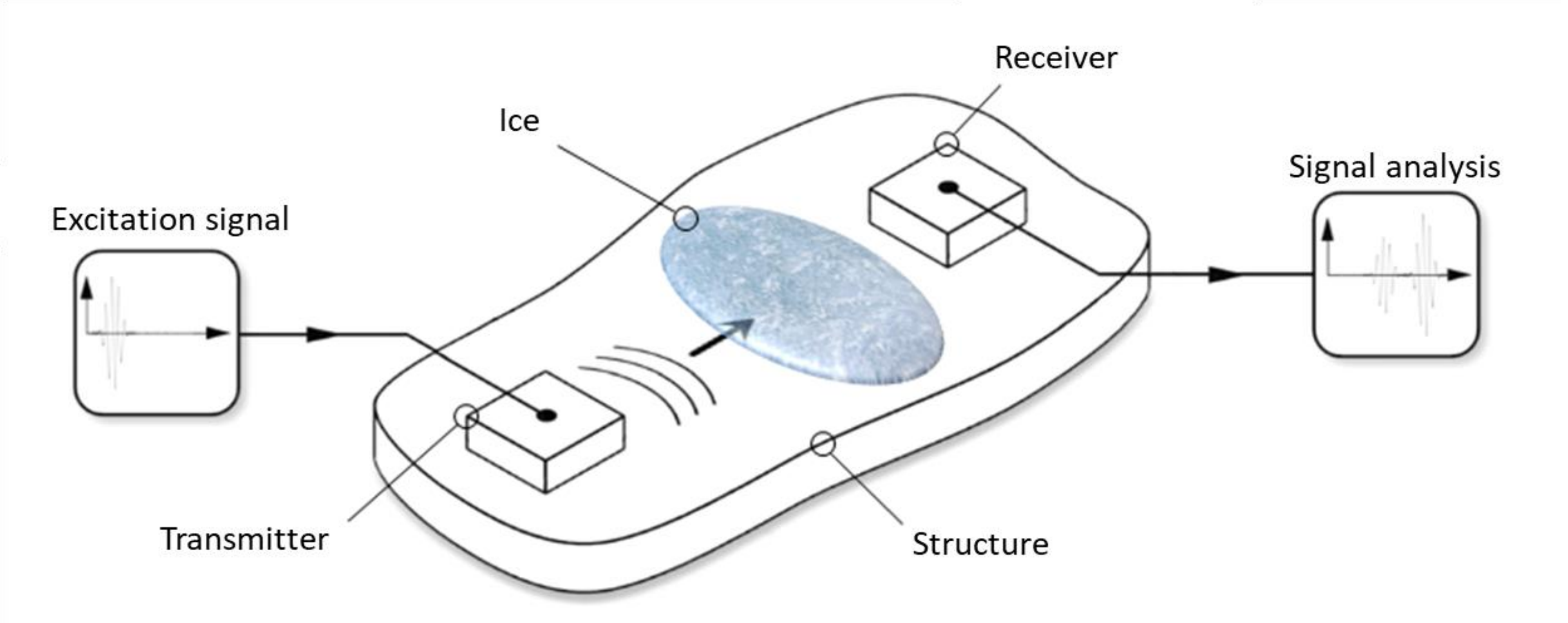
How it works

Transmitter-Receiver-Principle

- Guided ultrasonic wave is excited by an actuator and detected by a receiver

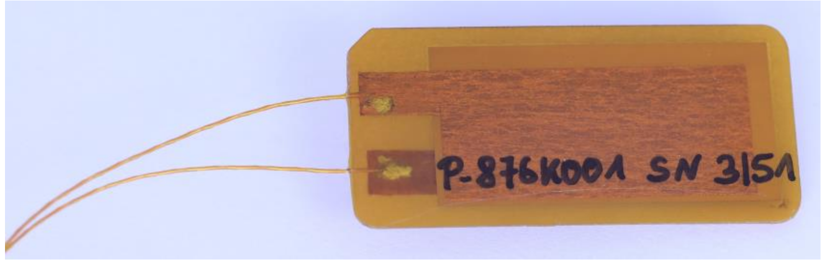


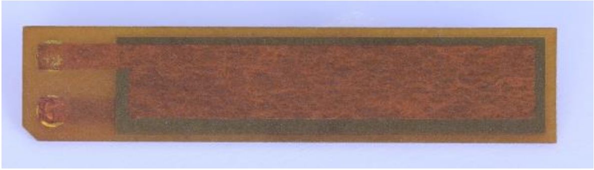
Components of the actuator-sensor- section, derived from [1/Vier and Mendig 2017]

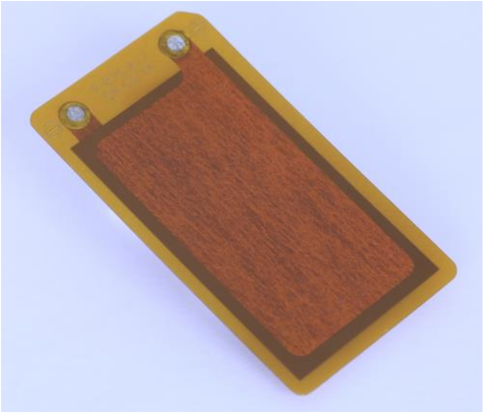
- Interaction of the wave with the observed structure and an ice layer
- Analysis of the receiver output signal considering such as amplitude level or time of flight (group velocity)

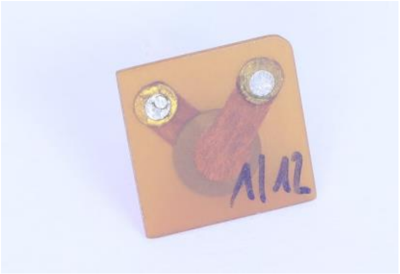
Transmitter ? Receiver ?

- Piezo ceramics are used in both cases





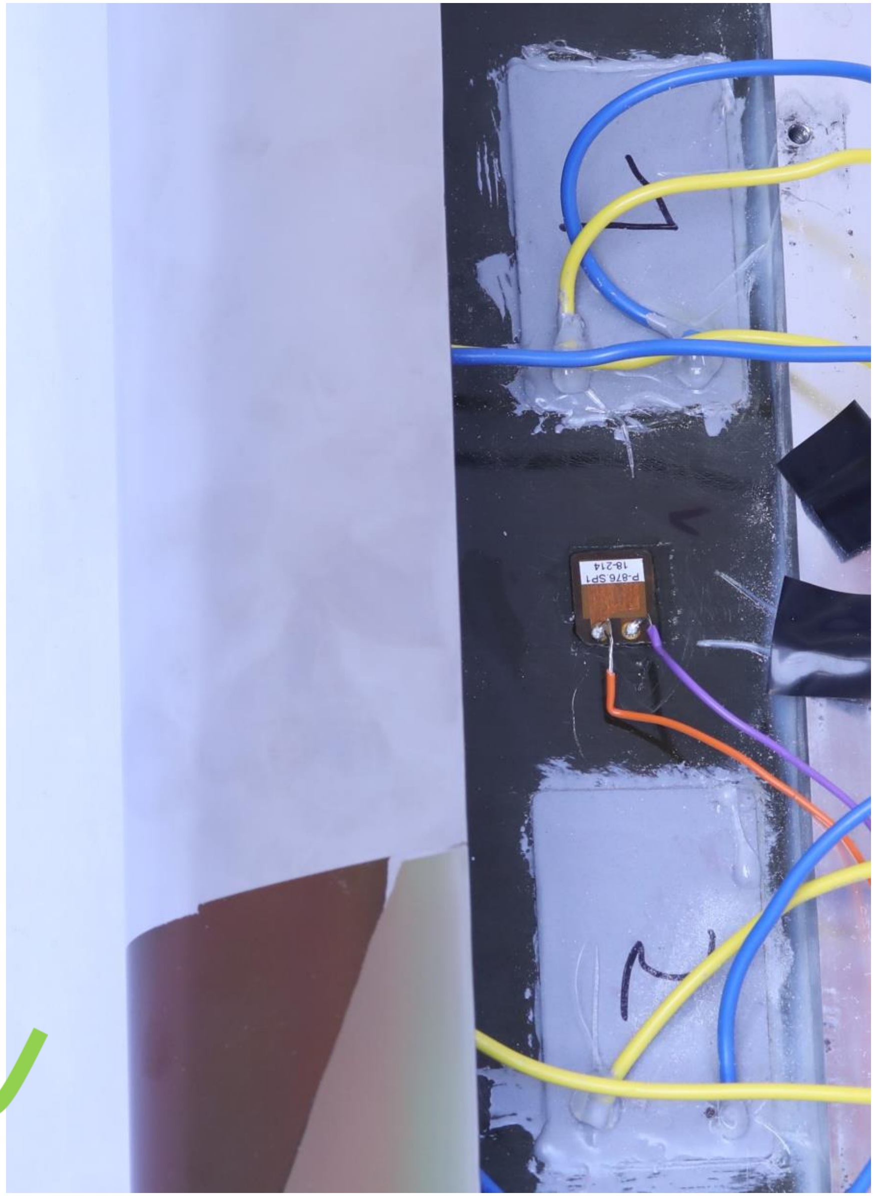




- Piezo ceramics can act as an actuator and as a sensor
- Dimensions determine the useable excitation frequency range
- The bendability of the piezo ceramics allows the mounting on bended structures like slats, stabilizers …

Mounting …

- Piezo ceramics are mounted with an adhesive and protected against moisture (adhesive and moisture protection was investigated in SENS4ICE)
- Test of 15 adhesives in a temperature range of -27 °C to 110 °C (no detaching)
- Test with moisture protection in a water bath for 100 hours.
- Piezo ceramics were actuated during the tests
  → Adhesive and moisture protection for flight test is ok



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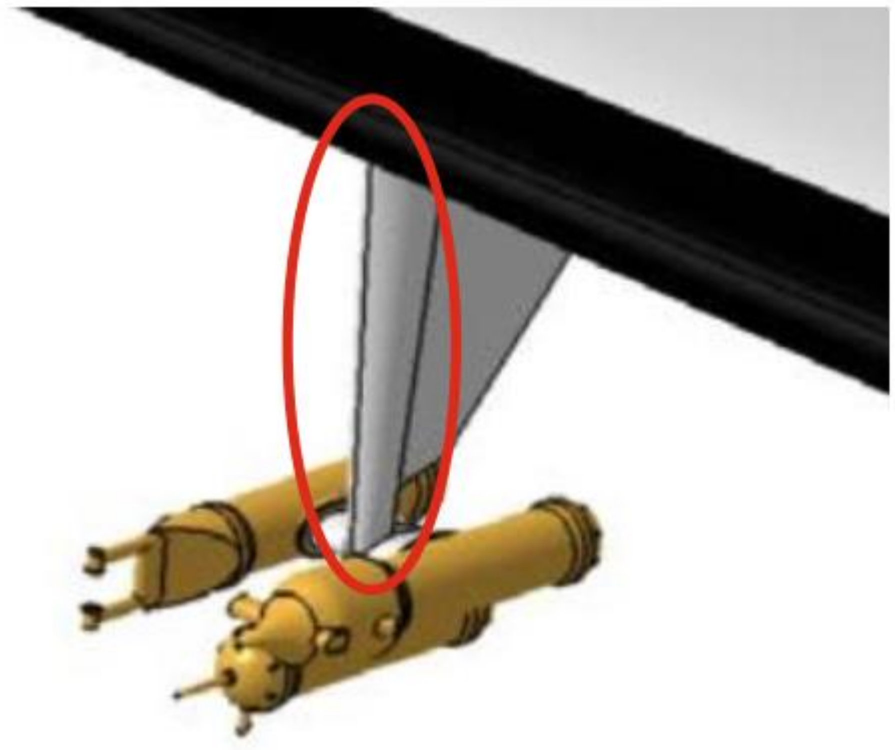
Where we want do place it

... inside a Pylon (SAFIRE ATR42)



- Structure is exposed to icing conditions ✓
- Current and data connector available ✓

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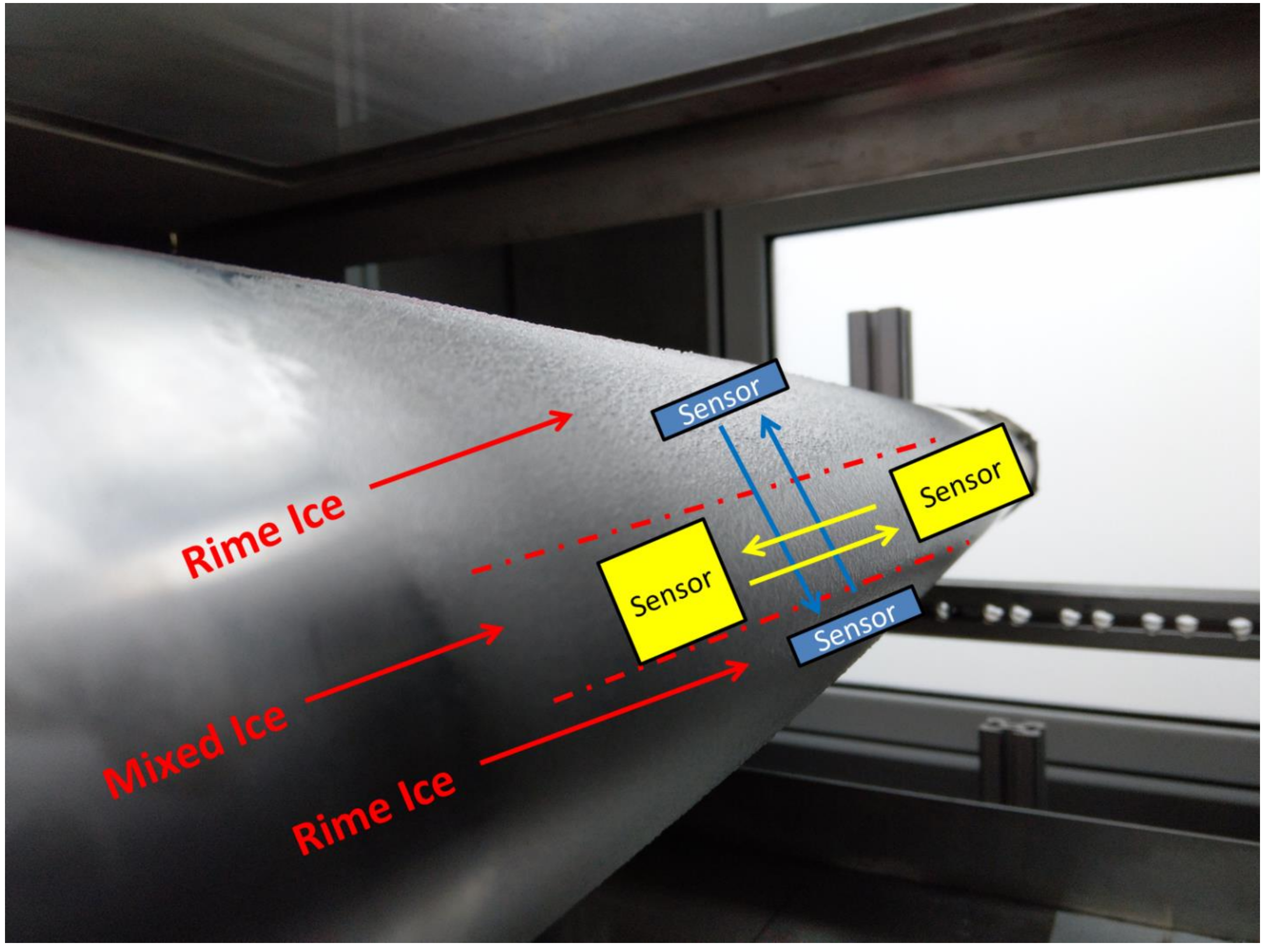
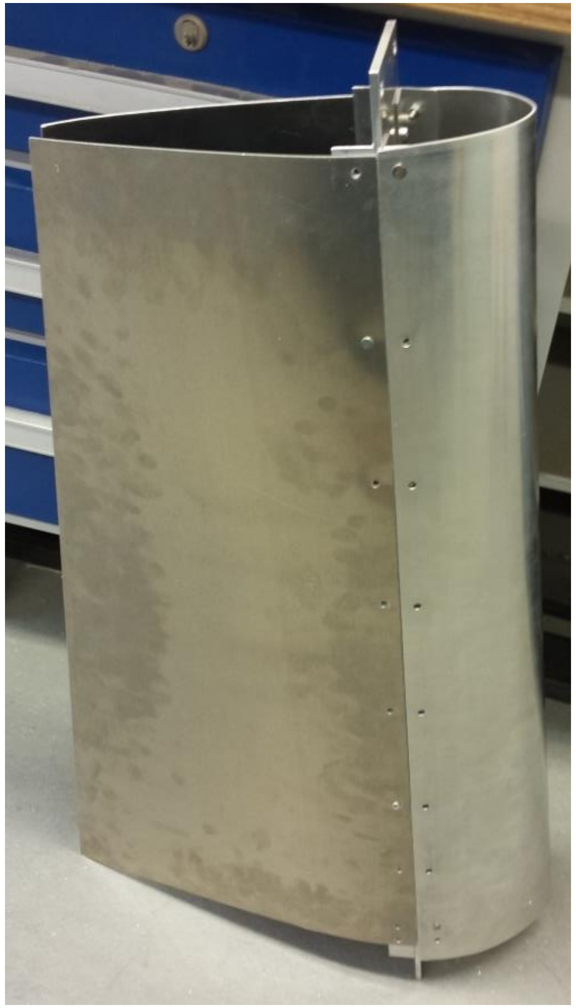
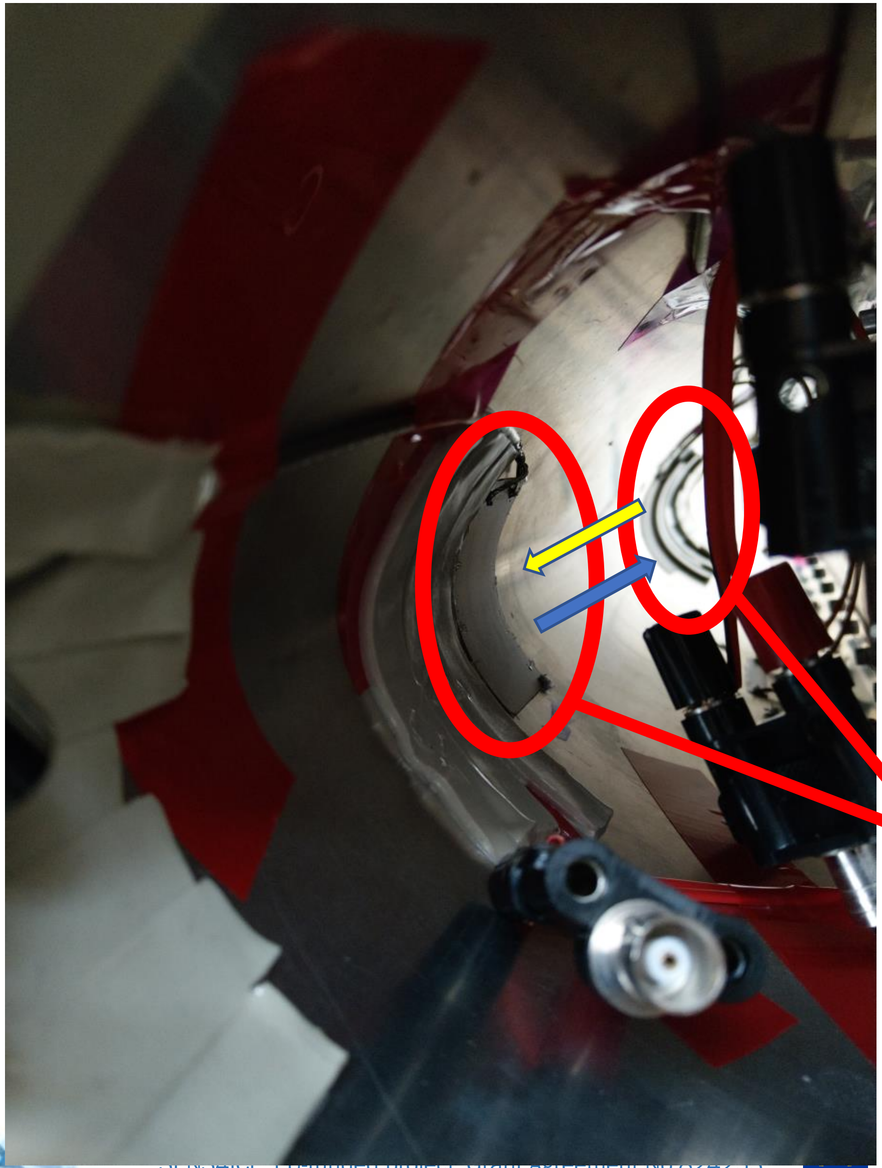
Some results

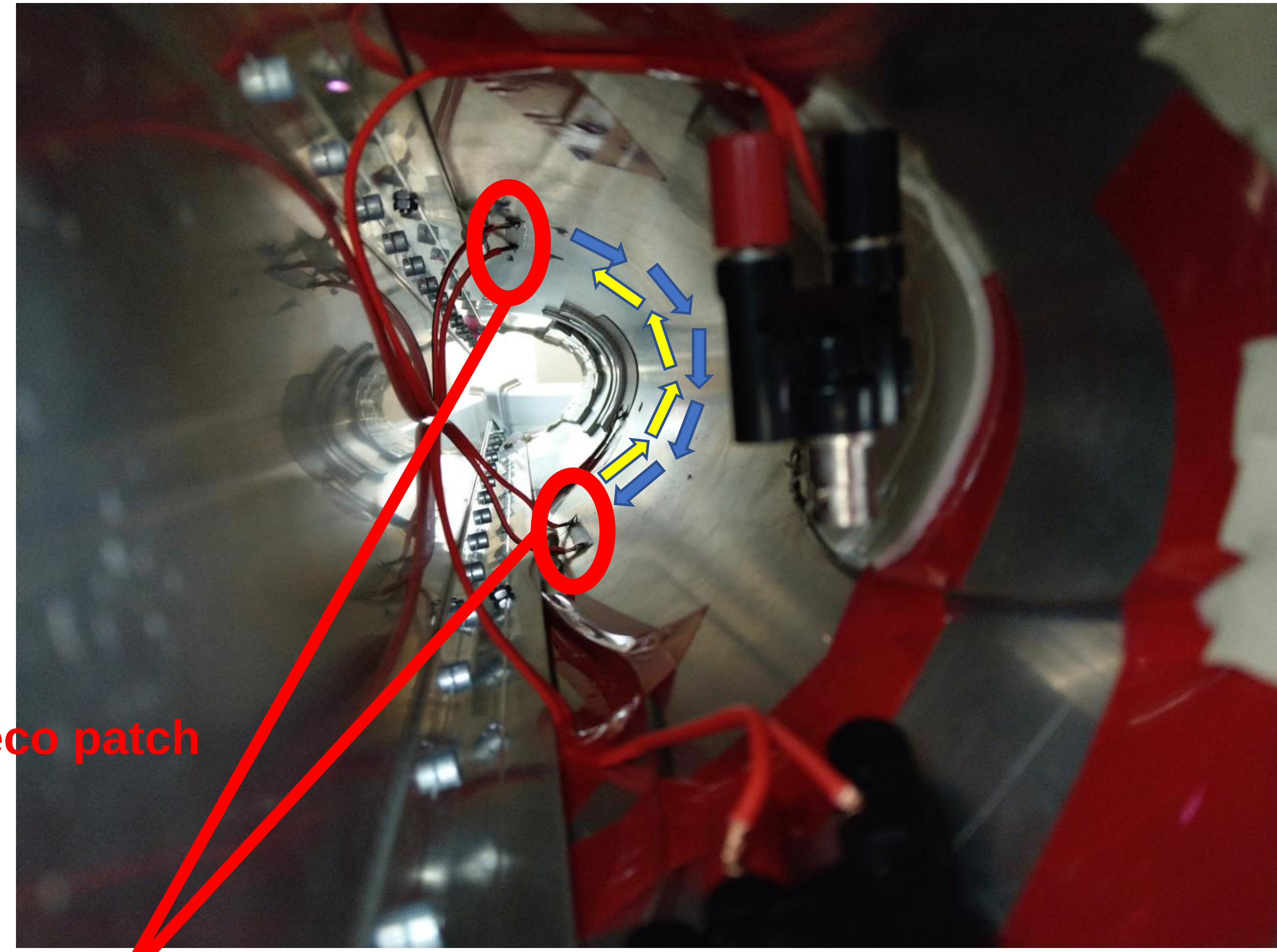
Pylon in the De-Icing Test Stand





Pylon in the De-Icing Test Stand

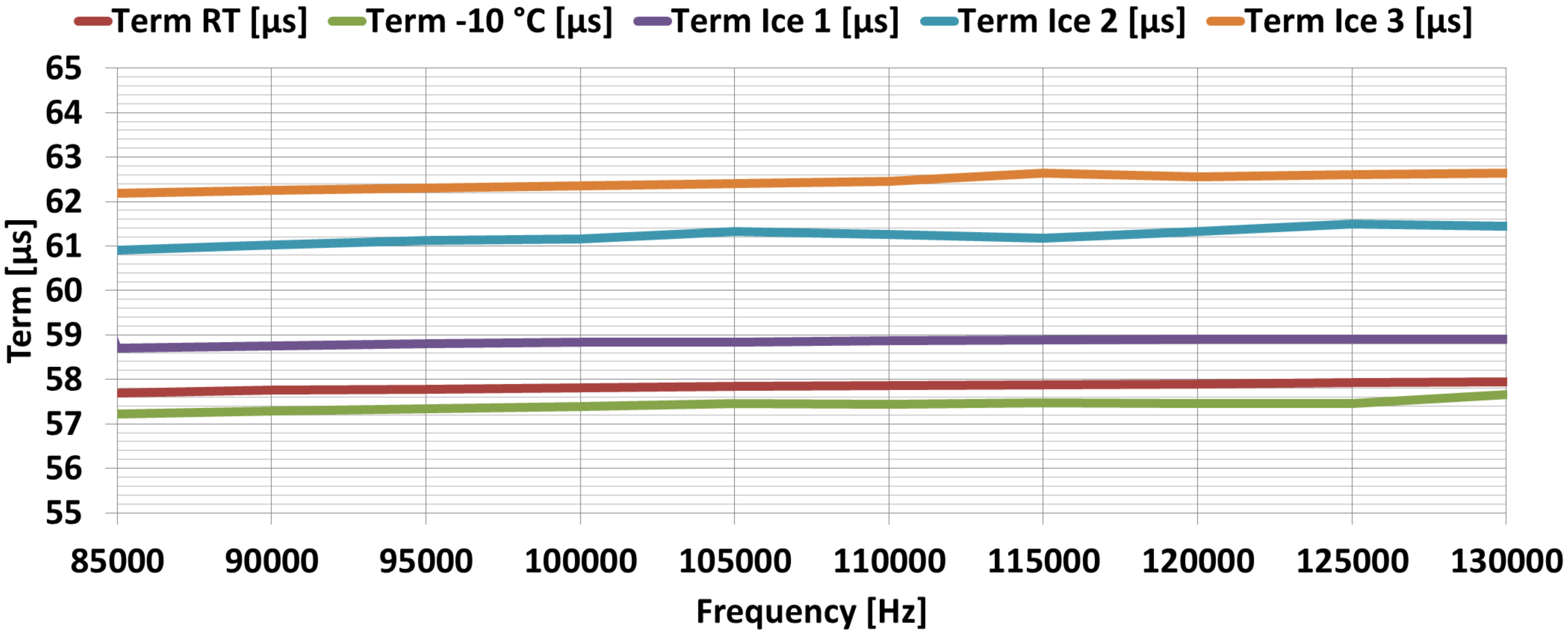




Flexible pieco patch

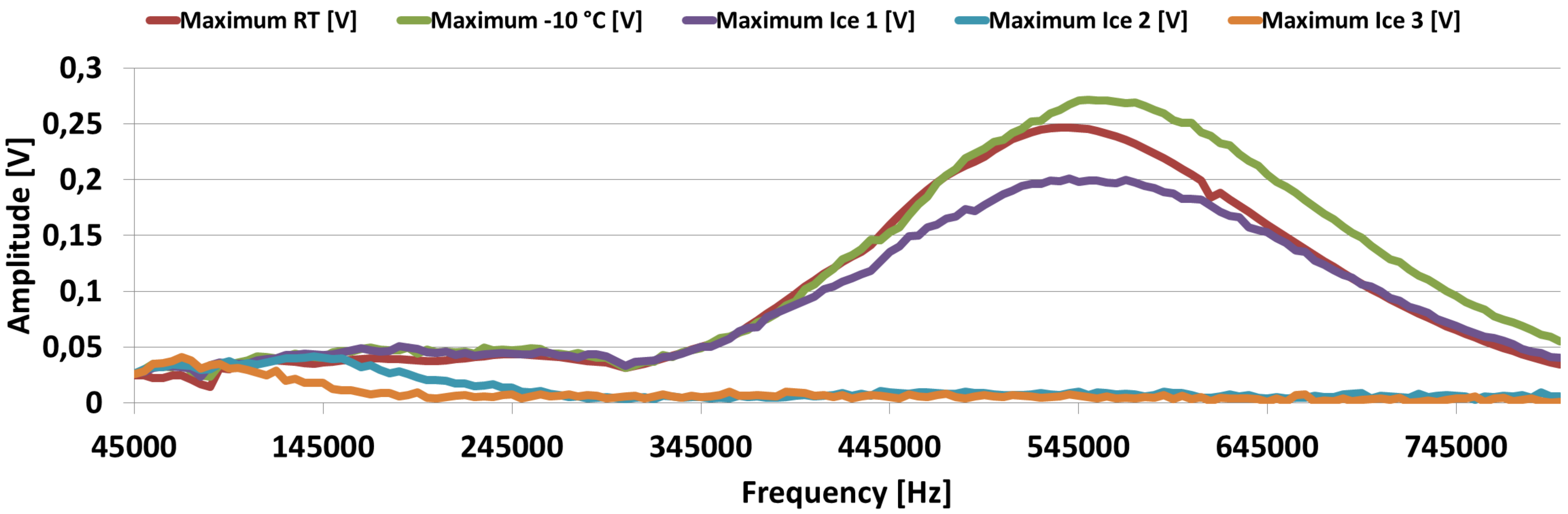
Flexible pieco patch

Measurement Results



- **The influence of the temperature has to measured and the signal has to be corrected**
- **We work on two different types of temperature measurement inside the sensor**

Measurement Results



- Usabel frequency range is given by the piezo ceramics, the adhesive and the structure
- In this frequency range we look for a high sensitivity against an ice layer.
- We improved the algorithm of the term calculation to work with small amplitude levels

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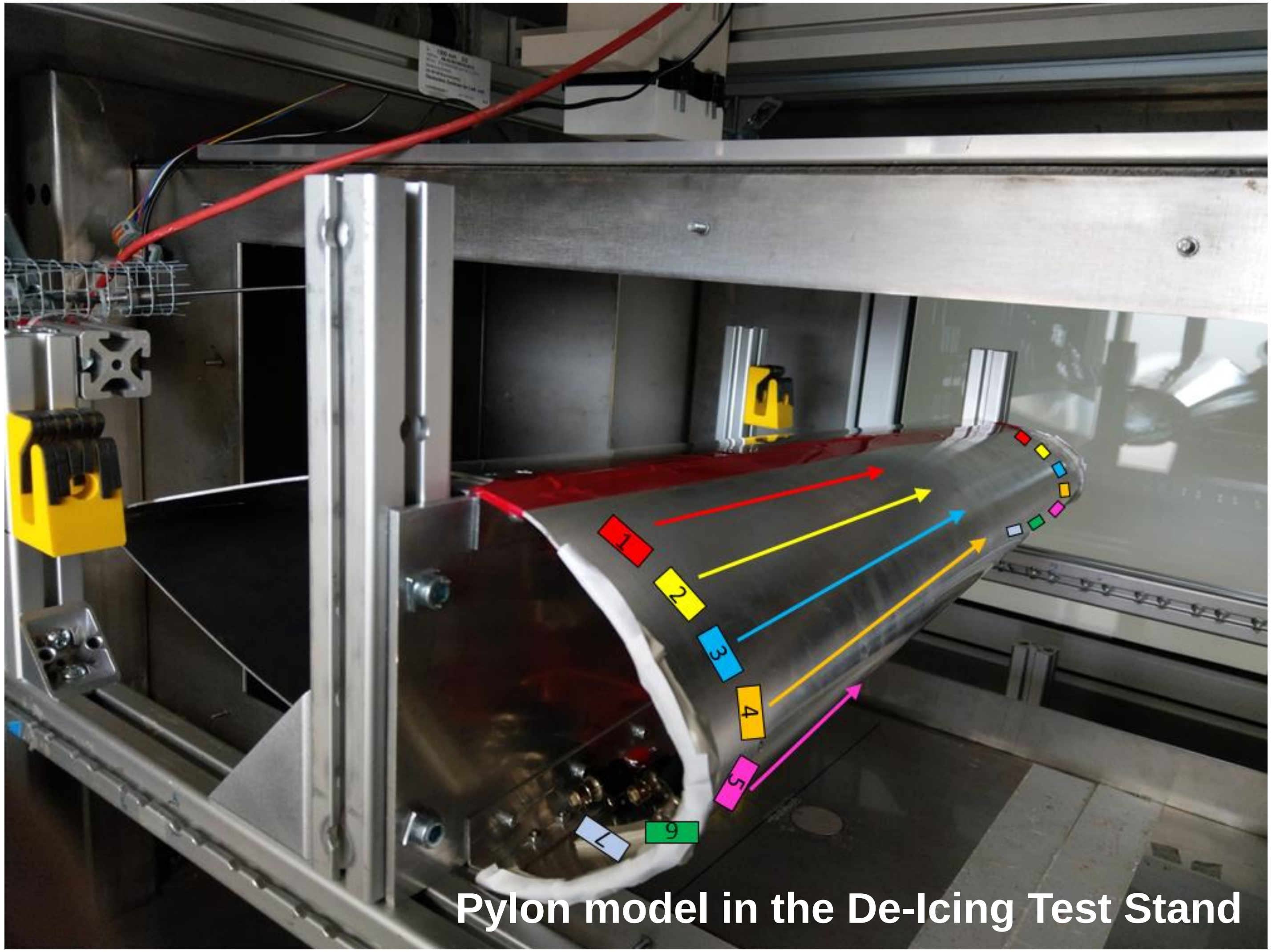
What about Appendix C and Appendix O ?

We use different signal transmission paths



Pylon model in the De-Icing Test Stand

- Appendix C:
  - Ice will be on the leading edge
- Appendix O:
  - Ice will be additionally further back on the pylon
- <u>Differentiation between both conditions is done by using different signals paths</u>

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What to consider when using it

Every material has it`s own mechanical propertys

- Output signal depends on the mechanical properties of the ice and the observed structure

TABLE I. MATERIAL PROPERTIES USED FOR THE ANALYSIS.

Material	Density (g/cm^3)	Young's Modulus (GPa)	Poisson's Ratio	Lame Constant (λ)	Lame Constant (μ)
Glaze Ice	0.9	8.3	0.351	7.24	3.07
Rime Ice	0.6	2.5	0.282	1.26	0.975
Mixed Ice	0.8	6.3	0.326	4.45	2.38
Aluminum	2.7	70.3	0.345	55.27	25.95

Mechanical properties of different ice types [2/Gao and Rose 2009]

- Mechanical properties of aluminum and cfrp also vary ($E_{Al} \approx 70$ Gpa, $E_{CFRP} \approx 300$ Gpa)

- A design and pretests are necessary for every structure

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What should be kept in mind

Key Facts

- Detects ice layers of small thickness
- No influence on aerodynamics (no additional drag)
- Can indicate icing at unprotected areas
- Allows conclusions of the icing conditions (C or O) by the choice of the application place

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What are our next steps

Next steps ...

- Test of respone time under given icing conditions in Q1/2021 in the TUBS icing wind tunnel

Case	Condition	Droplet Distribution	Droplets above 100microns	Droplets above 500microns	Aircraft True Airspeed		Static Temp.		Altitude	Mach. No.	Total Temp.		MVD	LWC	Response Time	App. O Discrimination Time	FZRA Discrimination Time
[-]	[-]	[-]	[%]	[%]	[knots]	[m/s]	[deg. C]	[deg. F]	[feet]	[-]	[deg. C]	[deg. F]	[microns]	$[g/m^3]$	[s]	[s]	[s]
1	LW-C CM	Dv99 < 100	0%	0%	78	40,0	-20	-4	0	0,125	-19,2	-2,6	15	0,3	40	-	-
2	LW-C CM	Dv99 < 100	0%	0%	78	40,0	-10	14	0	0,123	-9,2	15,4	20	0,42	24	-	-
3	LW-C CM	Dv99 < 100	0%	0%	78	40,0	-10	14	0	0,123	-9,2	15,4	15	0,6	20	-	-
4	LW-C CM	Dv9															-
5	LW-C CM	Dv9															-
6	LW-C CM	Dv9															-
7	LW-C CM	Dv99 < 100	0%	0%	78	40,0	-1	30,2	0	0,121	-0,2	31,6	23	0,54	133	-	-
8	LW-C CM	Dv99 < 100	0%	0%	78	40,0	-1	30,2	0	0,121	-0,2	31,6	15	0,86	118	-	-
9	LW-C CM	Dv99 < 100	0%	0%	78	40,0	-5	23	0	0,122	-4,2	24,4	22	0,44	22	-	-
10	LW-C CM	Dv99 < 100	0%	0%	78	40,0	-5	23	0	0,122	-4,2	24,4	32	0,24	36	-	-

!! Many thanks for dedicating your time !!

- Distinguish between App C and App O conditions by analyzing different transmission paths of the waves.
- Tests with de-icing fluids (AMS 1424 and AMS 1428)

This project has received funding from European Union's Horizon 2020 research and innovation programme under grant agreement n° 824253.

Visit our website: www.sens4ice-project.eu

List of references

[1] Leonard Johannes Vier und Christian Mendig (2017) *Automatisierte Klar- und Mischeiserzeugung und der Einfluss beider Eisarten auf die Ausbreitung geführter Wellen.* Masterarbeit. DLR-internal report. DLR-IB-FA-BS-2017-68, 161 S.

[2] Huidong Gao and Joseph L. Rose (2009) Ice Detection and Classification on an Aircraft Wing with Ultrasonic Shear Horizontal Guided Waves. IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency control, vol. 56, no. 2, February 2009