Hybrid concept for a forefield reconnaissance system for melting probes capable of moving through terrestrial and extraterrestrial cryospheres

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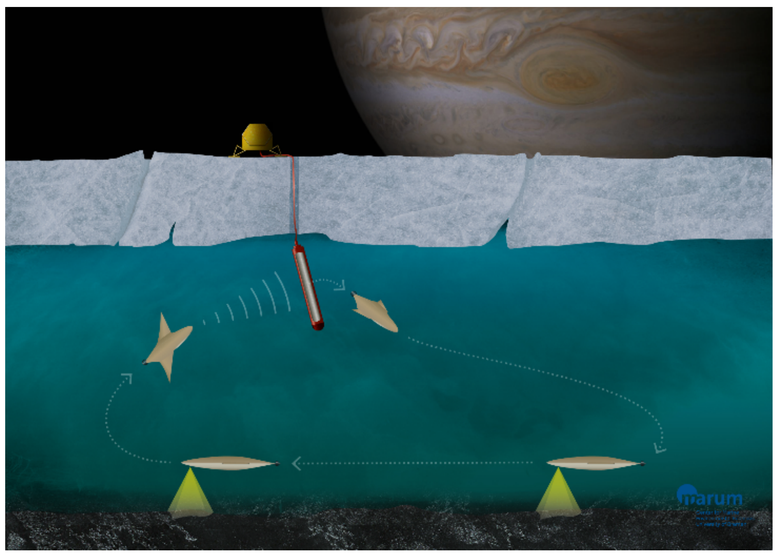
TRIPLE



The TRIPLE project line by the German Space Agency at DLR aims to develop technologies for a potential Europa mission to explore its subsurface oceans and search for extraterrestrial life.

The system consists of three main parts:

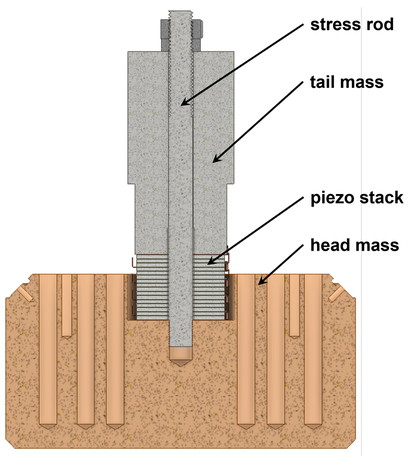
1) **Melting Probe:** The melting probe carries the nanoAUV through the ice to the subglacial water reservoir. Powerful trajectory planning and a forefield reconnaissance system are mandatory for safe arrival.

2) **nanoAUV:** A small autonomous underwater vehicle designed to explore the subglacial water reservoir.

3) **AstroBioLab:** Instruments for analyzing samples taken by the nanoAUV.

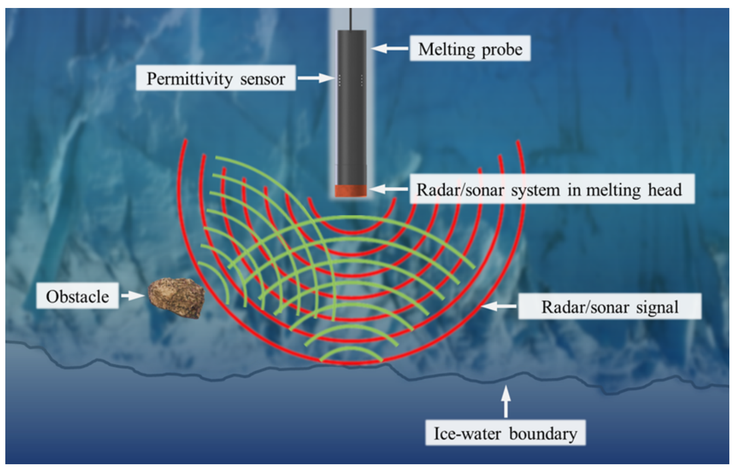
Acoustic FRS (AC-FRS)

The sonar uses a Tonpilz style acoustic transducer to emit signals into the ice and record reflections from obstacles in front of the probe.



A Tonpilz consists of a stack of piezoelectric discs clamped between two masses. To install the sonar directly at the tip of the probe the melting head acts as the head mass for the transducer.
The piezo stack is driven by an AC voltage so that the resulting periodic deformation of the piezo discs generates the acoustic signal. As signal shapes Baker codes and frequency sweeps with an operational frequency band between 1-50 kHz are used. This reduces the attenuation of the signals in ice.

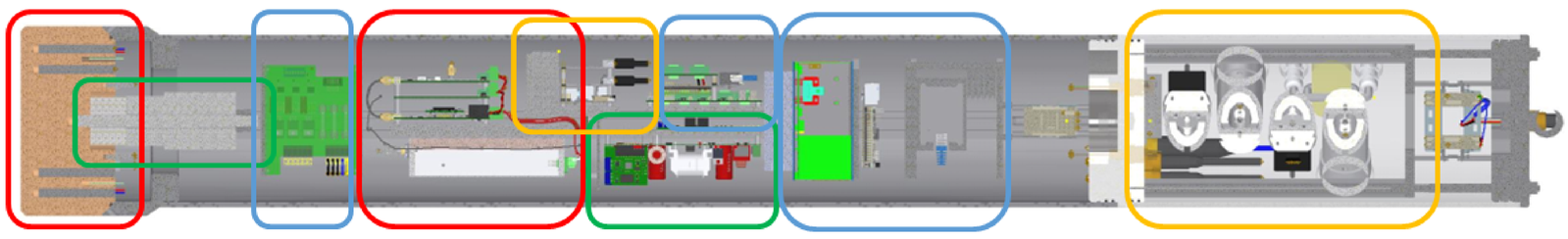
TRIPLE-FRS



In TRIPLE-FRS a hybrid forefield reconnaissance system (FRS) for melting probes based on a combination of radar and sonar systems is developed. This system is essential for the localization of obstacles in the melting trajectory and for detecting the ice-water boundary.

Both radar (RF-FRS) and sonar (AC-FRS) are integrated into the melting head. To determine the phase velocity of the electromagnetic waves a permittivity sensor (PS-FRS) is integrated into the rear part of the melting probe which further provides scientific data about the stratification inside the ice.

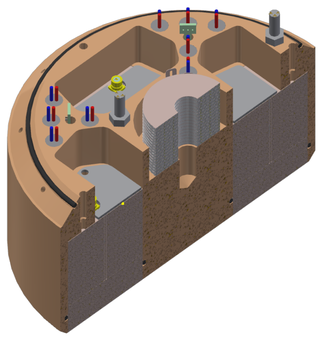
RF-FRS AC-FRS PS-FRS FRS-Mainsystem

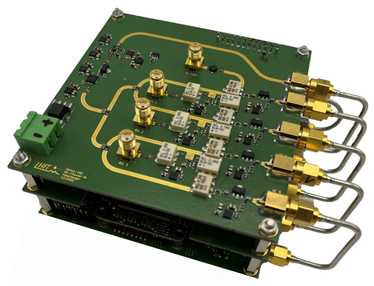


CAD model of the fully integrated 1.5m long FRS-melting probe. All subsystems RF-FRS, AC-FRS, PS-FRS as well as the FRS-Mainsystem, which includes melting control and power supply are marked. The probe is linked to the surface station through a 3-phase 400 V cable situated at the back of the probe, and in addition, it utilizes powerline communication via this same cable.

Radio Frequency FRS (RF-FRS)

The radar is based on a sequential sampling impulse radar system operating at 1.35 GHz, which is a compromise between the antenna size and the penetration depth of the electromagnetic waves.





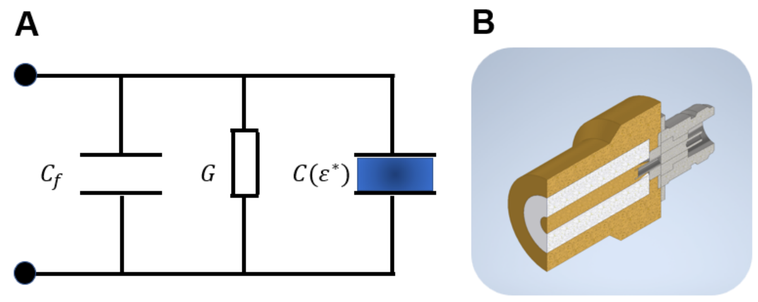
The radar uses one transmitting and three receiving antennas integrated into the melting head. In order to influence the melting process as little as possible, the antennas are made of Aluminum Nitride (AIN) ceramics offering high thermal conductivity.

The radar system employs a custom-designed high-power pulse amplifier that has been optimized to maximize the output power while maintaining the signal integrity.

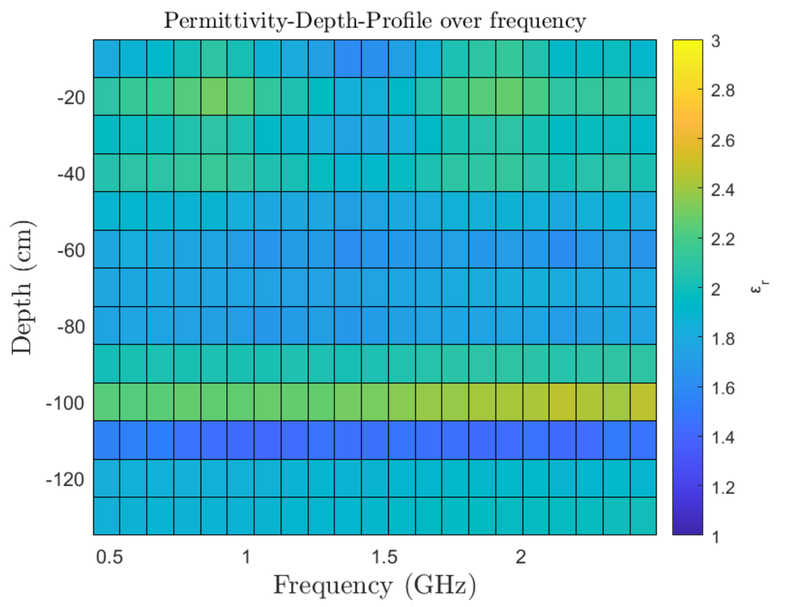
The radar consists of the 3 stacked PCBs:

- Baseband system with signal processing
- Transmitting system
- 3-Channel receiving system

Permittivity-Sensor FRS (PS-FRS)



A Equivalent circuit approximation of the coaxial head: Capacitance C_f, conductivity G and variable capacitance with a dielectric of surrounding media $C(\varepsilon_r^*)$
B CAD model of the impedance-matched coaxial head with dielectric (Teflon) filling used in the integrated FRS-system.



Permittivity profile of the upper parts of the Jungfraufirn glacier, Switzerland, acquired in April 2022.

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