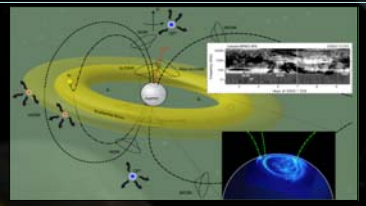
Radio and Plasma Wave Investigations (RPWI) in Japan

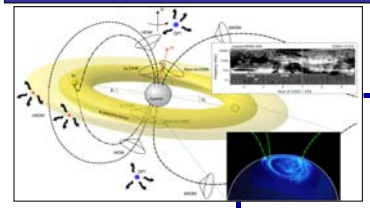
Radio:	first	Direction/Polarization, Subsurface	(80kHz – 45MHz)
Wave:	first	Wave-Particle interaction	(few – 1MHz/20kHz)
E-field:	first	DC E-field measurement	(Langmuir probe)
Plasma:	first	Low-T plasma measurement	(Langmuir probe)



Y. Kasaba (Tohoku Univ.) + RPWI-Japan

(1) Jovian system: Structure & Variation ～Fast rotating Giant magnetosphere～
(2) Jovian system: Energy release ～System filled with energetic particles～
(3) Satellite – Jupiter system ～Electrical coupling of Satellite - Jupiter～
(4) Satellite environment ～Atmosphere, Magnetosphere, and Interiors～

RPWI: Contribution from Japan ---- TEAM



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LATEST Status *(just after **SWT** [Sep @ ESTEC] & **RPWI-Airbus** [Oct @ Uppsala] meetings)*

* **EM1:** Shipment to Europe on 8 Feb 2016
  - Development & Tests in Japan
  - First integration tests with all RPWI

* **'Software-type Wave-Particle Interaction Analyzer' (SWPIA) function** for Ion heating
  with MAG (B-field) & PEP (ion) teams.

* **'Passive SubSurface RADAR (PSSR)' function**
  for the detection of 'ICE – WATER boundary'
  = subsurface ocean surface
  by the reflection of Jovian radiation.

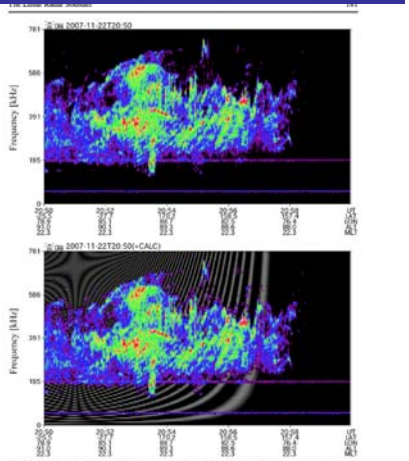
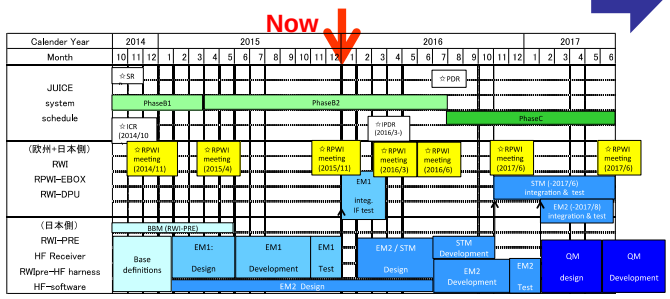


Fig. 22 Spectrogram of AKR with interference patterns. In Panel (b), the AKR spectrogram is superposed on the calculated phase difference between AKRs directly arrived and reflected at the moon surface

4 MHz to 16 MHz based on Cassini plasma wave data. They suggested that CML ranges of Non-Io-A and Non-Io-B DAM gradually became close and merged around 200° in a frequency range below 16 MHz. The event shown in Fig. 24 could be a low-frequency-extended Non-Io A/B DAM based on the CML of occurrence. On the other hand, Jovian DAM emissions have not been detected by LRS probably because the sensitivity is much worse above 15 MHz as shown in Fig. 21, where the noise level of LRS above 15 MHz is higher than ~170 dBm/Wm² Hz due to frequency dependence of antenna impedance and preamplifier input capacitance.

ref. AKR reflection from Lunar surface (Ono et al. 2010)



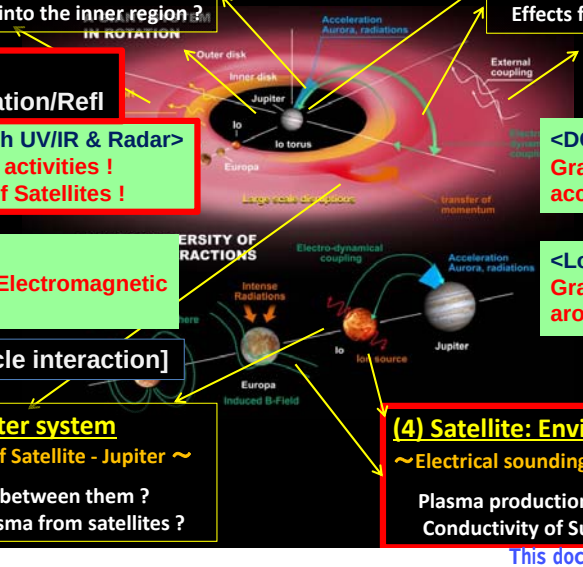
Radio and Plasma Wave Investigations (RPWI)

(2) Jovian system: Energy
～System filled with Relativistic particles～
Particle accelerations along the field lines ?
MEV accerelation by Wave ?
Injection of plasmas into the inner region ?

(1) Jovian system: Structure
Fast rotating Giant magnetosphere～
MIT Couplings ?
Retraction of rot. Energy to outside?
Effects from outside? SW / EUV

first Direction/Polarization/Refl ection !
<Radio: Remote with UV/IR & Radar>
Global high-Energy activities !
Remote sounding of Satellites !

first detection !
<DC E-field: In-situ>
Grasp the plasma motion & acceleration E-field !



<Wave: In-situ>
Direct detection of Electromagnetic energy exchanges !

[first Wave-Particle interaction]

<Low-T plasmas: In-situ>
Grasp the plasmas around/from satellites !

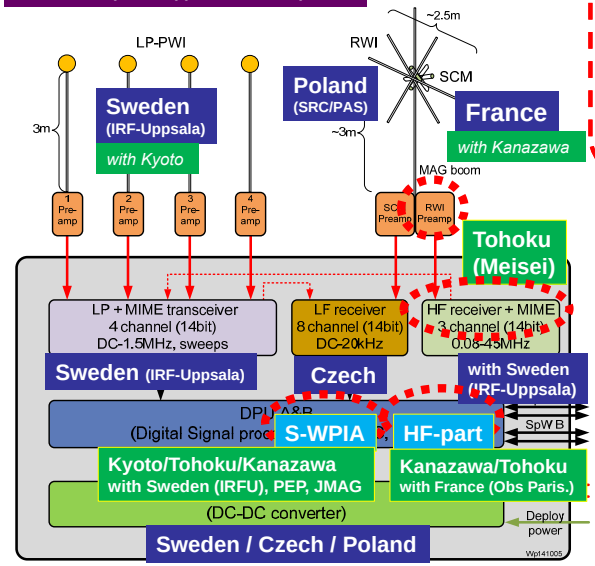
first detection !

(3) Satellite – Jupiter system
～Electrical coupling of Satellite - Jupiter～
Current connections between them ?
Enhancement by plasma from satellites ?

(4) Satellite: Environment & Surface
～Electrical sounding of Atmosphere / Interior～
Plasma production: Volcano, Water, … ?
Conductivity of Surface & Subsurface ?

Radio and Plasma Wave Investigations (RPWI)

[PI] Jan-Erik Wahlund
(IRF – Uppsala, Sweden)



<Remote sensing: Radio>

[HF-System]

* Ex3(80kHz – 45MHz)

first Direction & Polarization →
Remote sensing of Plasma with IR/UV/ENA
Surface & subsurface with Radar & submm

<In-situ: Waves, DC E-field, Low-T plasma>

[LF-System]

* Ex3 & Bx3 (few – 20kHz)
* Wave-Particle correction

[LP-System]

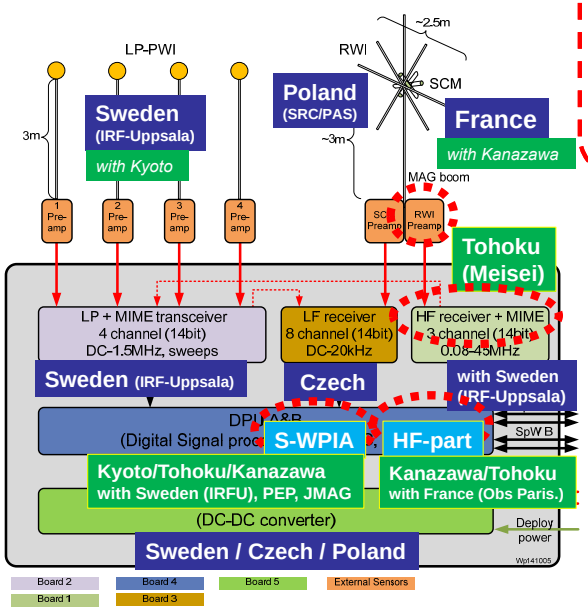
* Electron / Ion (Langmuir probe)

first Wave-Particle interaction
first DC-E field detection
first low-T plasma detection

Sweden (x2), Austria (x1) Czech(x1), France (x4), Japan (x6+α), USA (x5), Poland (x1), UK (x2)

RPWI: Contribution from Japan

[Co-PI] Y. Kasaba (Tohoku Univ.)



<Remote sensing: Radio>

[HF-System]

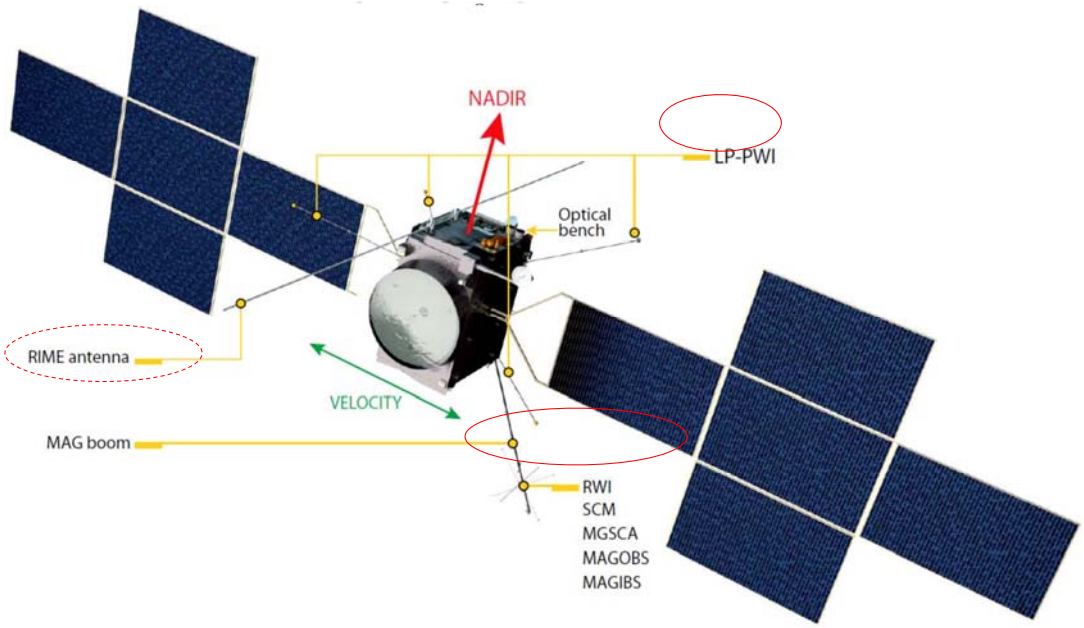
* Preamp (Tohoku/Meisei)
* HF – Receiver (Tohoku/Meisei + IRF-Uppsala)
* DPU: HF - Software (Tohoku/Kanazawa)

<In-situ: Wave, DC-field, Low-T plasma>

[LF & LP-System]

* Software-type WPIA (Tohoku/Kyoto/Kanazawa)
* Contribution to design: E/B sensor, Langmuir Probe (Kyoto/Kanazawa/Tohoku)

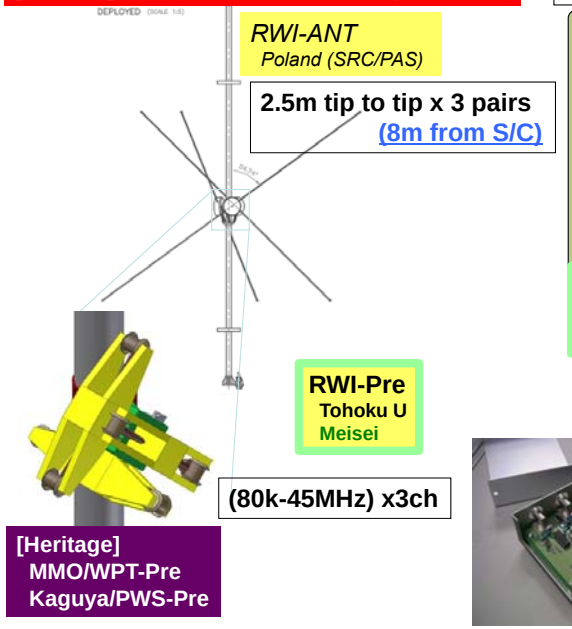
[Science]
Hokkaido, Hakodate FU, Tohoku, Nagoya, Toyama PU, Kanazawa, Fukui IT, Kyoto, Kouchi NCT, RIKEN



RPWI: Contribution from Japan ---- H/W

[Critical] Radiation, Low-T, Long herness

(80k-45MHz) x3ch



RPWI: Contribution from Japan ---- H/W

High Radiation (Mrad ??)

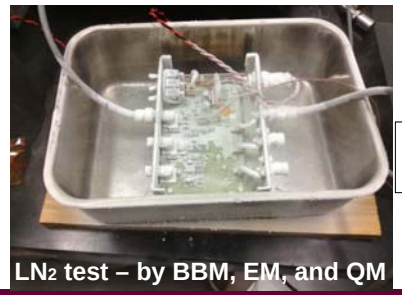
"Al 3.0mm + Ta 1.3mm"
→ <100krad

Long Harness (10.5m for 50MHz)

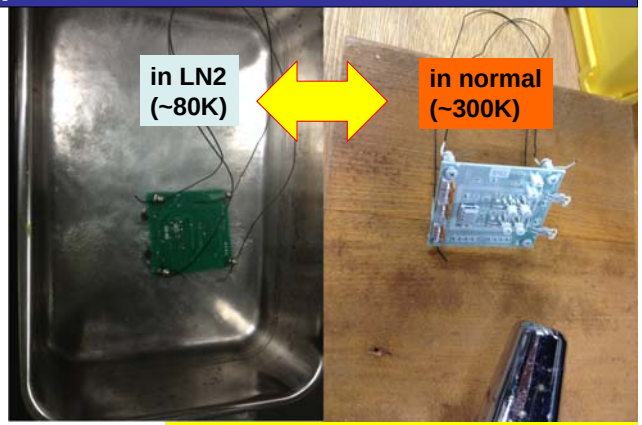
- To be tested in Nov. - Dec.

Low Temperature (30-40 K ??)

- LN_2 (-77K) test
  → Ok above 45K!
- Low-TEMP chamber
  → in TU & Meisei



LN_2 test – by BBM, EM, and QM



LN_2 low temperature Shock-cycle test
'300K <> 80K' x 20 (BBM#4, Sep 2015)

LN_2 low temperature function and performance test (BBM#2, 2013)

Thermal Vacuum Test: +120 ~ -150degC (BBM#4, 2015)

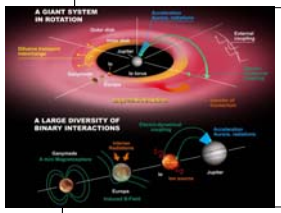
[DPU: Software-type Wave Particle Interaction Analyzer (SWPIA)]

[Heritage] ERG/S-WPIA

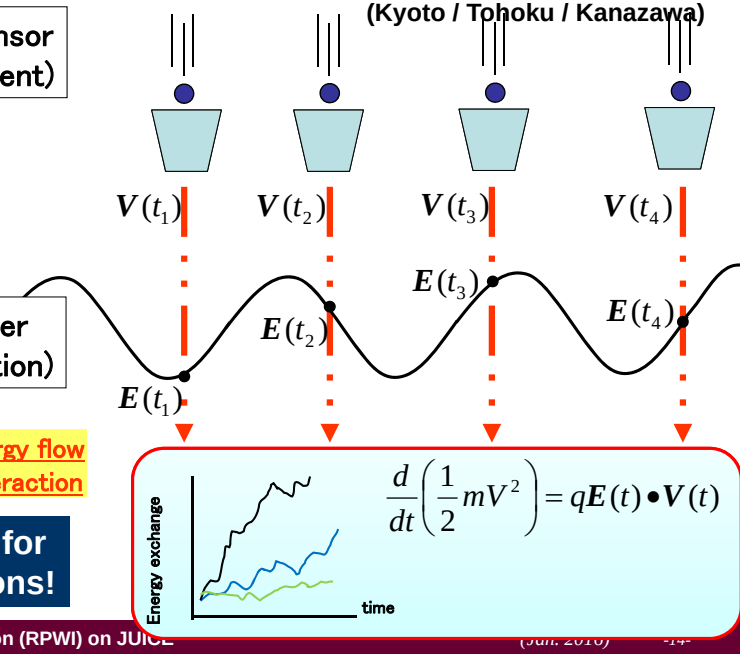
JUI-IRFU-RPWI-TN-026_i1.0_Wave_Particle_Interaction_Analyzer

(Kyoto / Tohoku / Kanazawa)

Plasma particle sensor (Plasma measurement)



Plasma wave receiver (Waveform observation)

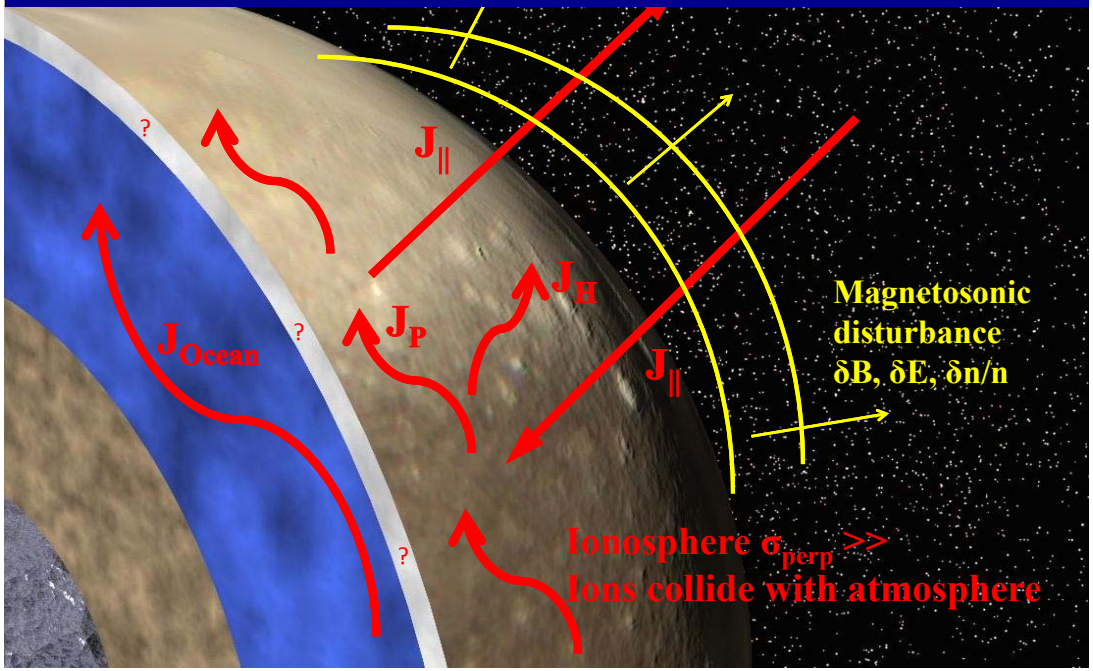


Direct measurement of energy flow by Wave – Electron/Ion interaction

It is larger demand for the low-TLM missions!

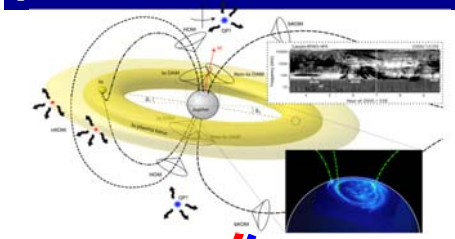
[DPU: Passive SubSurface Radar (PSSR)]

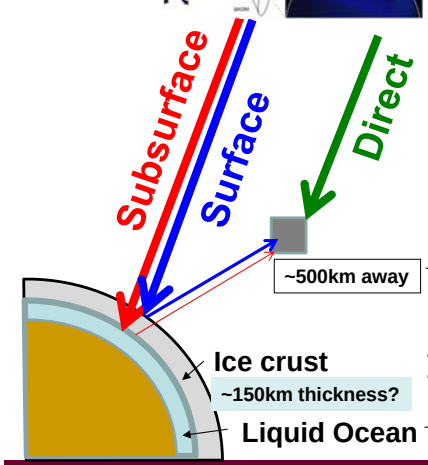
JUI-IRFU-RPWI-TN-026_i1.0_Passive_Subsurface_Radar



[DPU: Passive SubSurface Radar (PSSR)]

JUI-IRFU-RPWI-TN-026_i1.0_Passive_Subsurface_Radar





Pros

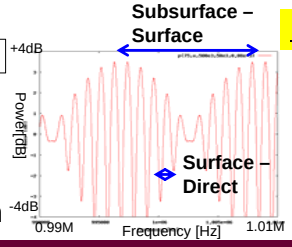
Radio Source: Low-Frequency (& Wide-band) radio waves from Jupiter which continuously emitted.

Less attenuation ($\propto 1/f$) in the subsurface media is expected in ~1MHz.
(Long antenna & PWR is needed if we emit it.)

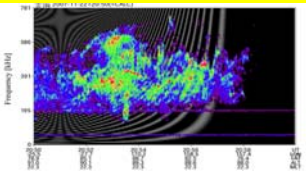
ref. **RIME** = Active Radar @ 9MHz

Cons

Jupiter-side area of the moons only
(Ganymede: 7.15 day orbit around Jupiter)



Lunar case: AKR by Kaguya LRS



<Reflectance> Space(ε_r=1) ⇔Ice(ε_r=3) ⇔ Liquid ocean (ε_r=87)

Surface echo (Space ⇔ Ice)

R_S ~ 0.27

Subsurface echo (Ice ⇔ Ocean)

R_{SS} ~ (1-0.27) x 0.69 x T_{ice}

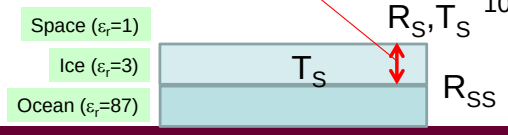
~ 0.50 x T_{ice}

<Transmission in ice ~150 km>

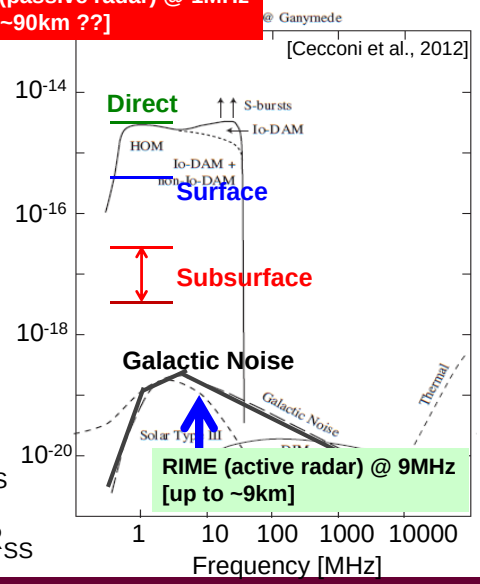
T_{ice} ~ 0.25 – 0.06 @ 50MHz

[$f_{TiO2,FeO}$ = 1 - 10%]

Ice thickness: D>150km
(suggested in prev. studies)
[kivelson et al. 2002; Spohn and Schubert, 2003]



PSSR (passive radar) @ 1MHz [up to ~90km ??]



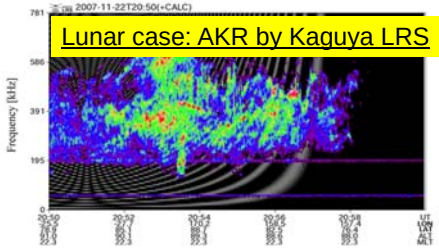
RIME (active radar) @ 9MHz [up to ~9km]

[mode-1]

The ice crust thickness is determined by the interference patterns in the spectrogram of Jovian hectometric radio waves (HOM) directly from Jupiter (direct HOM) and reflected from the top and bottom ends of the ice crust (its echoes).

if the HOM is continuous and coherent in
> 3.3 msec (the 500-km round-trip time between the ice crust and S/C)
in wide-bandwidth.

Lunar case: AKR by Kaguya LRS



[mode-2: Short waveform, one-component]

[mode-3: Full component incl. Direction & Doppler info]

The ice crust thickness is determined by the autocorrelation analysis of the waveforms of direct HOM and its echoes from the ice crust.

if the HOM is
"almost random" or "short coherent burst **< 3.3 msec**".
[This method is like 'RIME with large emission antenna set at Jupiter'.]