RESONANCE
Project for Studies of Wave-Particle Interactions in the Inner Magnetosphere collaboration with HAARP

Anatoly Petrukovich and Resonance team
Resonance

Inner magnetospheric mission

- Space weather
  Ring current, outer radiation belt, plasmasphere

- Resonant wave-particle interactions
  Magnetospheric cyclotron maser

- Auroral region acceleration
  Small-scale active zones, precipitation

- Two pairs of spacecraft

2011: Engineering models delivery

To be launched in 2014
Study of EM waves:
- VLF/ELF demodulated emission (Getmantsev effect)
- emission, stimulated by ionospheric heating (EMIC)

Previous results from ARCAD-3 satellite

Demodulated emission above Tromso heating facility
Heating effects in the magnetosphere - 2

Stimulated precipitation of energetic particles

Modulation of particle flux as a result of artificial wave and particle interaction
Heating effects in the magnetosphere - 3

Upward particle fluxes and field-aligned currents in auroral zone
Orbit design

Goal: corotation with a flux tube

Magnetosynchronous orbits

Apogee: ~28 000 km,
Perigee: ~ 500 km,
Period: ~ 8 hours
Inclination: +63.4° and -63.4°
Separation strategy with four spacecraft
Three sample orbits:

- Single pair corotation up to 3 hours
- Two pair corotation ~ 1 hour
Three sample orbits

1\textsuperscript{st} full conjunction L and MLT match
2\textsuperscript{nd} only L match
3\textsuperscript{rd} only MLT match

TIME

L, Re
2nd case: L match

3rd case: MLT match

Space Research Institute
How conjugacy with HAARP is defined

Required accuracy of conjugacy depends on physical processes of interest

**Near** zone: spacecraft map to 20-km spot in ionosphere above HAARP

**Far** zone: spacecraft map to 100-km spot in ionosphere above HAARP

Equatorial projection of the near zone & trajectory – **50 min**
The best period for the first joint operation (four satellites in the selected flux tube) is 40-110 days after the launch
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Limitations on conjugacy

Matching two pairs of spacecraft + L shell + HAARP is difficult

- Matching one pair of spacecraft is simpler and more often
- Matching far zone is simpler than near zone
- Magnetospheric variability affects actual mapping
- Natural orbit evolution + launch inaccuracy smear conjugacy

The best time for joint work with HAARP will be 1-4 months after the launch!

HAARP conjunction is at 1 of 3 orbits
  (once per day ~ 1 hour within magnetic corotation interval)
Local time of campaign determined by launch selection
## Variants of collaboration Resonance-HAARP

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<th>Level</th>
<th>Details</th>
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<tbody>
<tr>
<td><strong>Ground level</strong></td>
<td>Exchange of work schedules</td>
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<td></td>
<td>Resonance team is aware of HAARP timetable</td>
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<tr>
<td></td>
<td>HAARP team is aware of Resonance orbit and schedule</td>
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<tr>
<td><strong>Extended level</strong></td>
<td>Adjustment of work schedules</td>
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<td>A special joint campaign with dedicated HAARP and Resonance sessions</td>
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<td><strong>Advanced level</strong></td>
<td>Downlink of real-time Resonance wave measurements to HAARP and feedback to HAARP emission</td>
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Scientific collaboration Resonance-HAARP

- To define scientific goals and specific experiments
- To determine requirements to HAARP and Resonance operation
- To analyze data