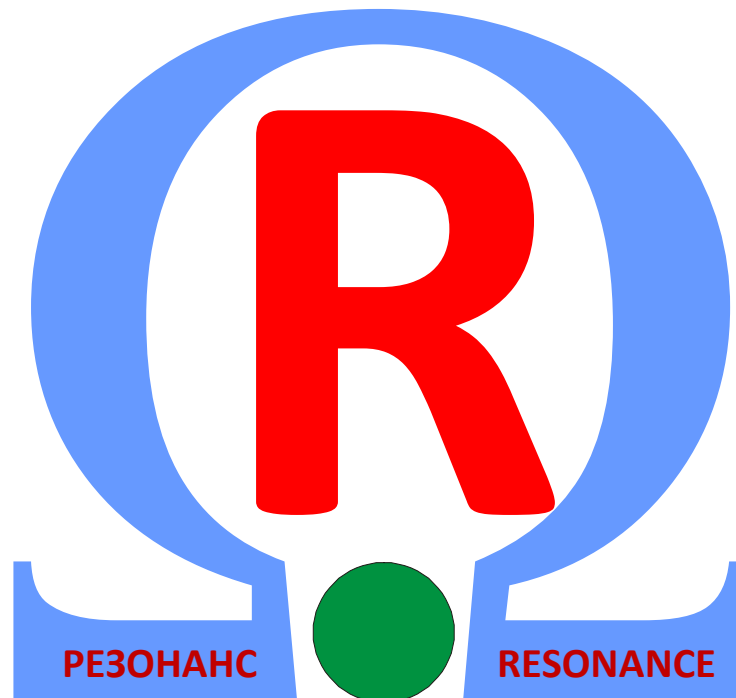


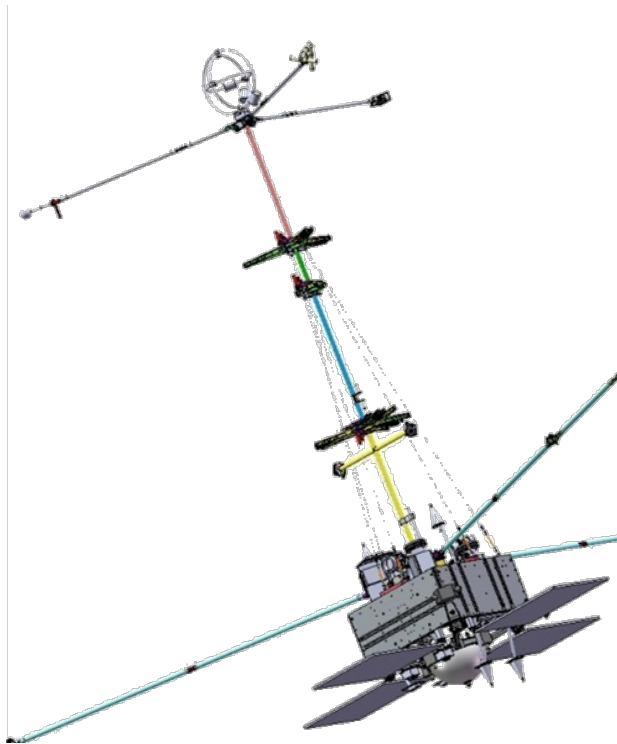
# RESONANCE

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

*Anatoly Petrukovich and Resonance team*



## Resonance



To be launched in 2014

2011: Engineering models delivery

### Inner magnetospheric mission

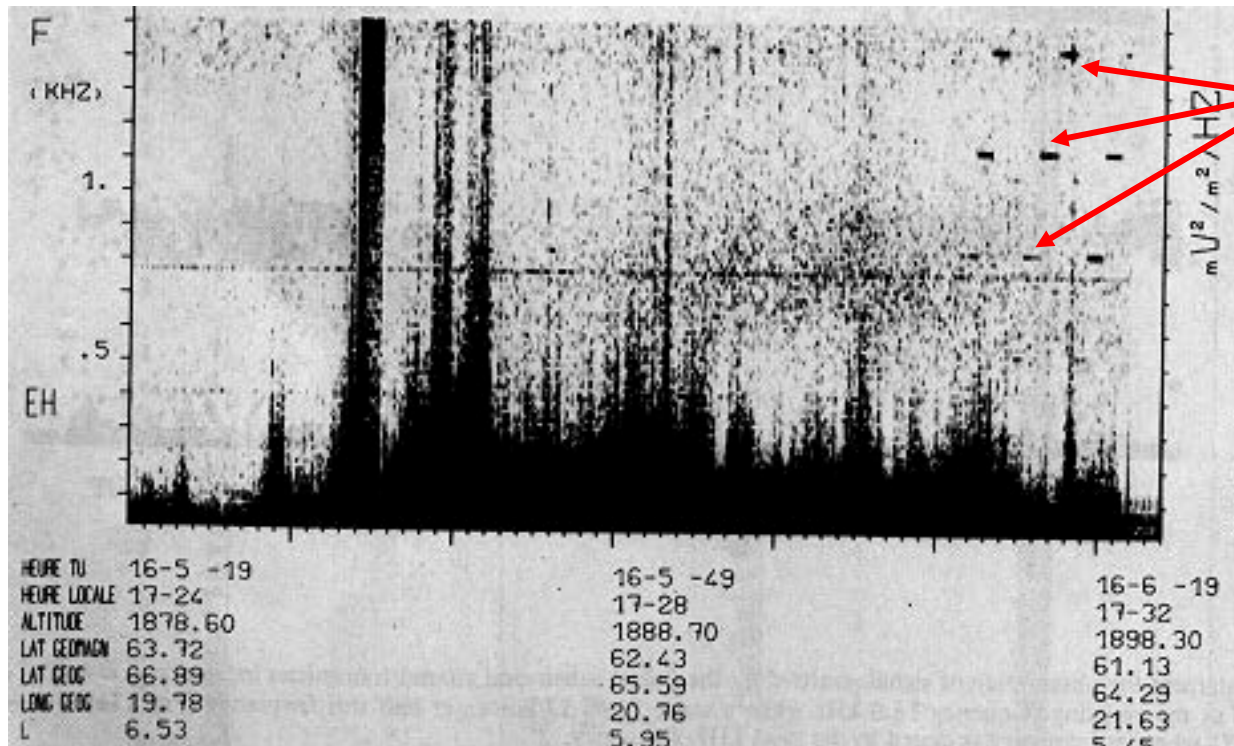
- **Space weather**  
Ring current, outer radiation belt, plasmasphere
- **Resonant wave-particle interactions**  
Magnetospheric cyclotron maser
- **Auroral region acceleration**  
Small-scale active zones, precipitation
- **Two pairs of spacecraft**
- **Magneto-synchronous orbit**

## Heating effects in the magnetosphere - 1

Study of EM waves:

- VLF/ELF demodulated emission (Getmantsev effect)
- emission, stimulated by ionospheric heating (EMIC)

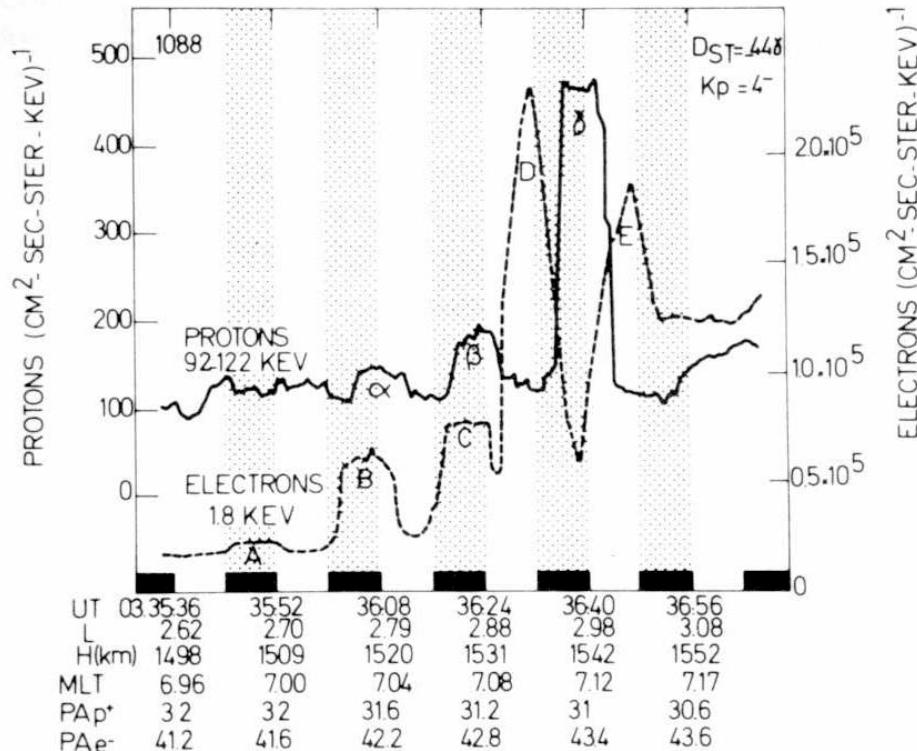
Previous results from ARCAD-3 satellite



Demodulated emission  
above Tromso  
heating facility

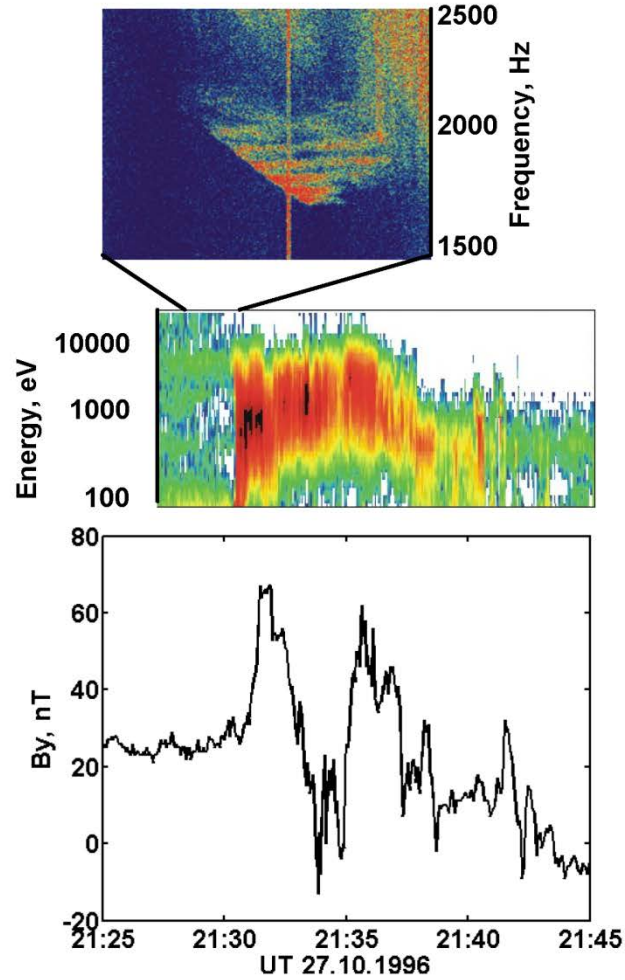
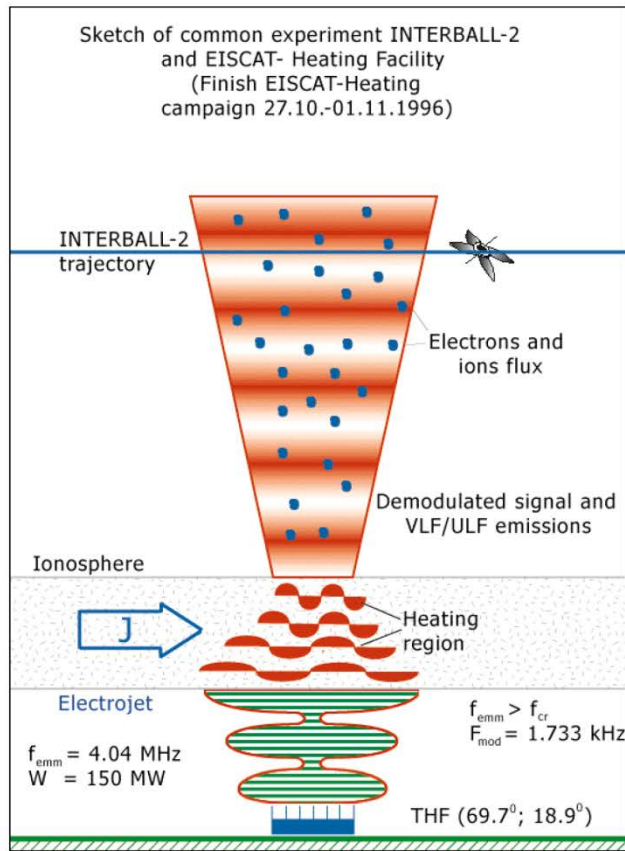
## Heating effects in the magnetosphere - 2

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

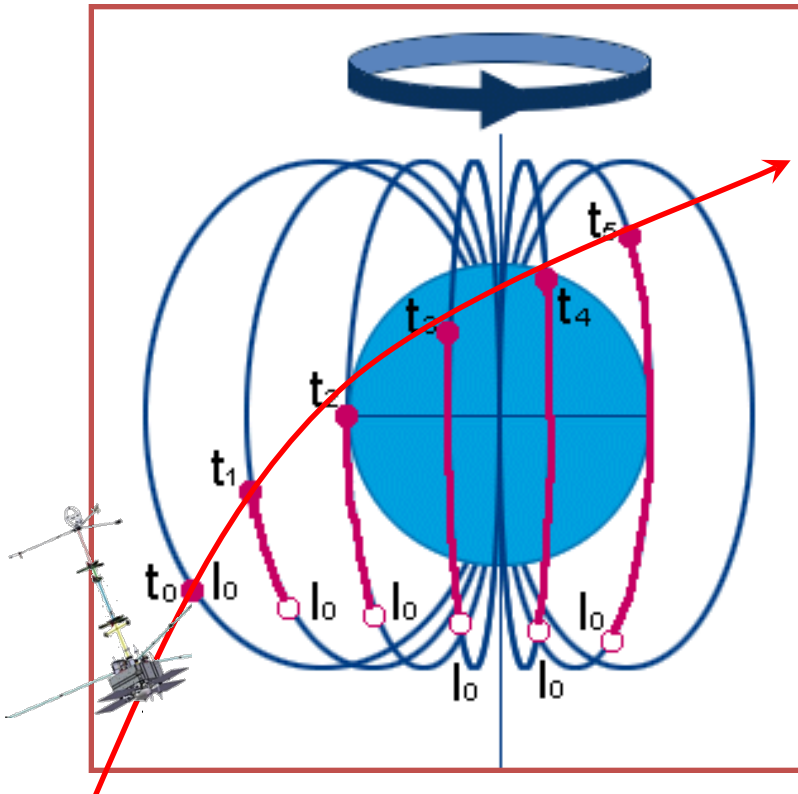
### Magnetosynchronous orbits

Apogee:  $\sim 28\,000$  km,

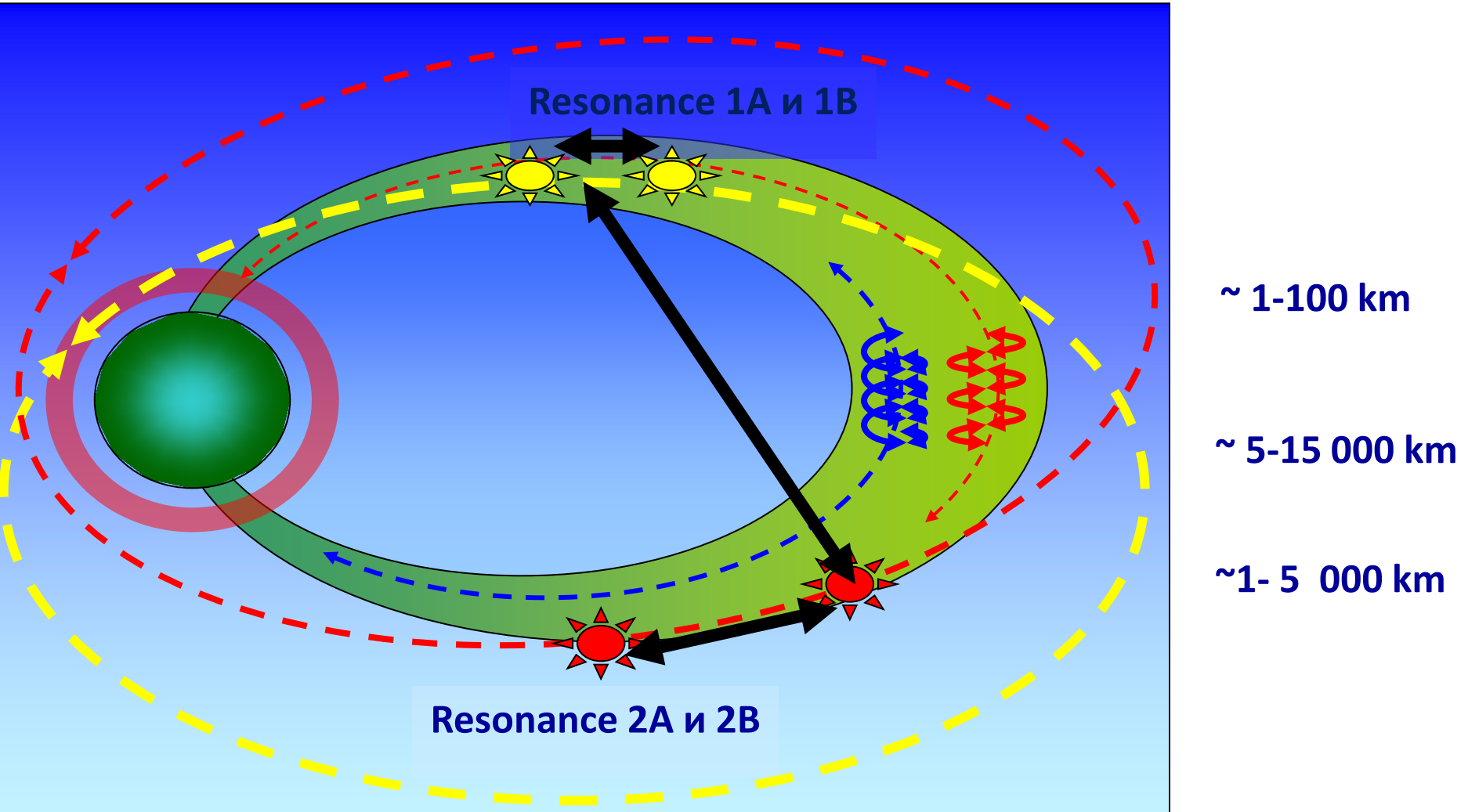
Perigee:  $\sim 500$  km,

Period:  $\sim 8$  hours

Inclination:  $+63.4^\circ$  and  $-63.4^\circ$



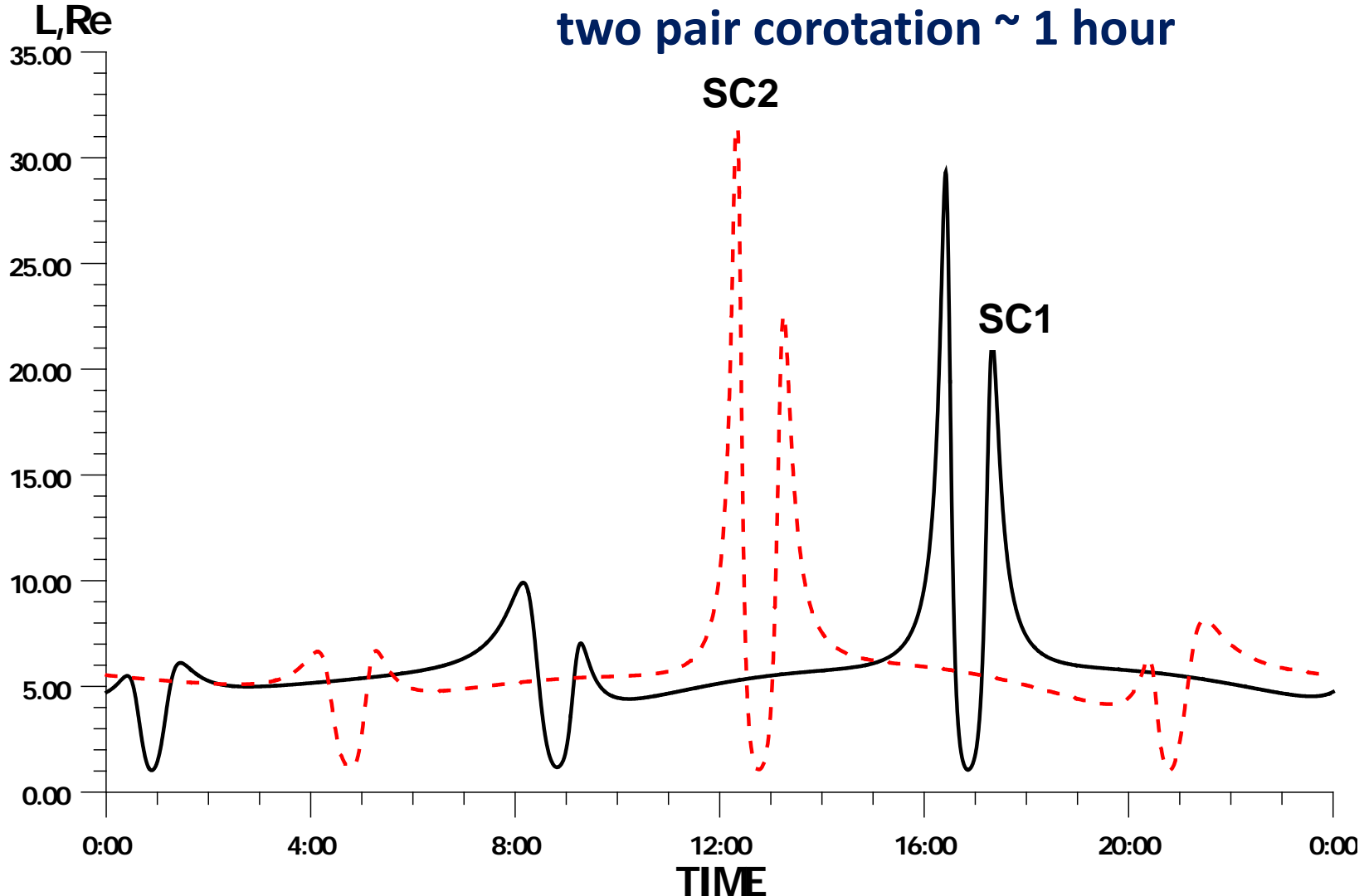
### Separation strategy with four spacecraft



## Three sample orbits:

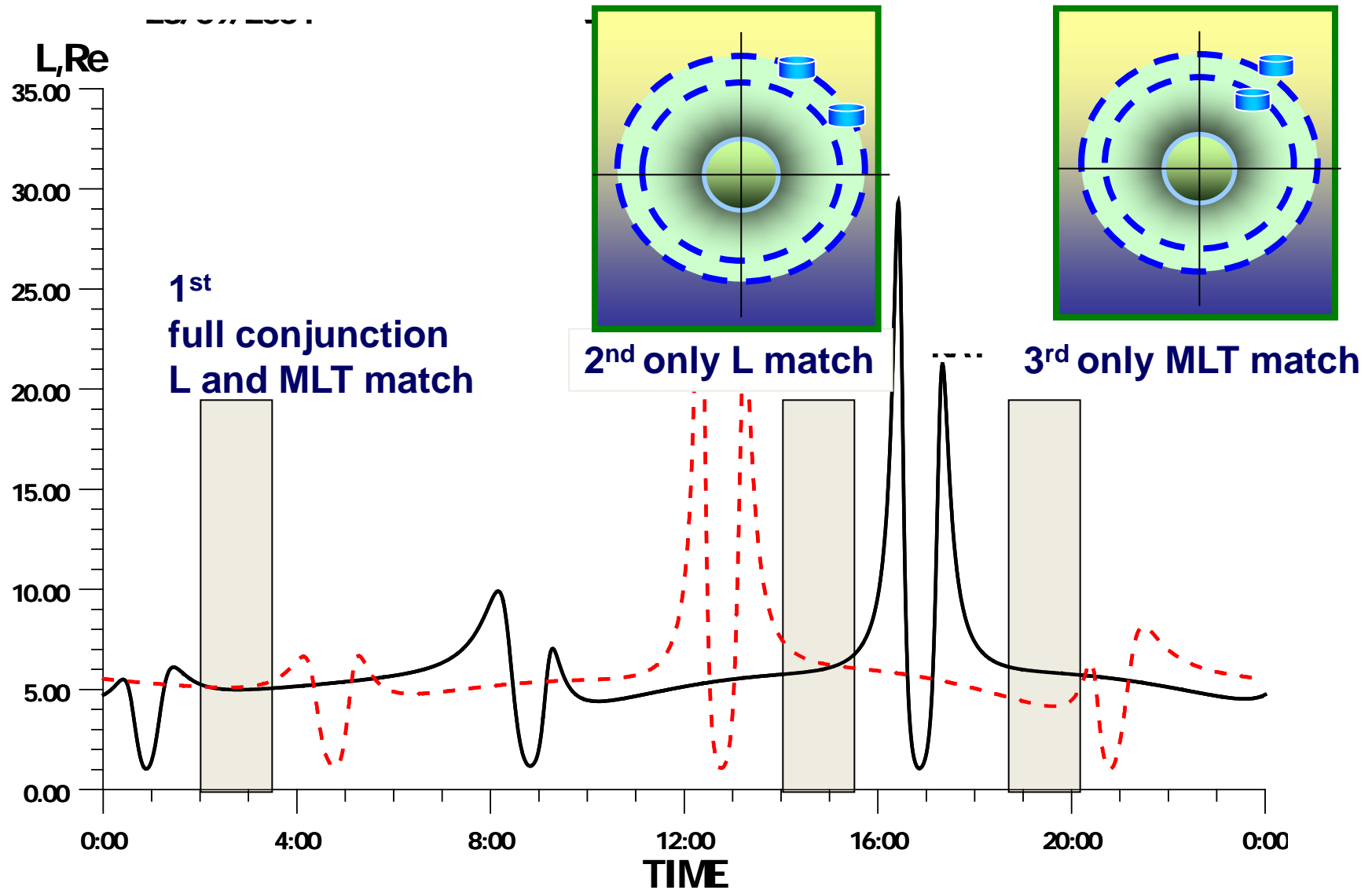
single pair corotation up to 3 hours

two pair corotation ~ 1 hour

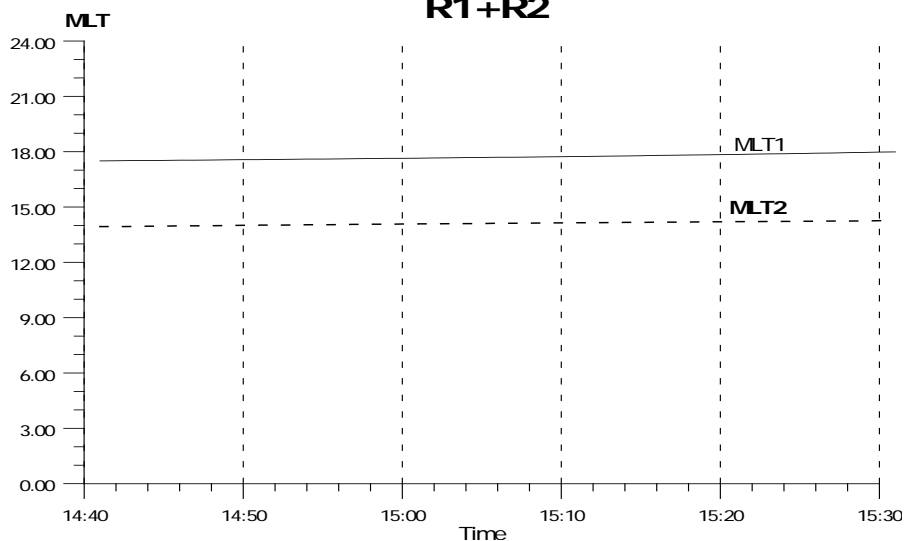
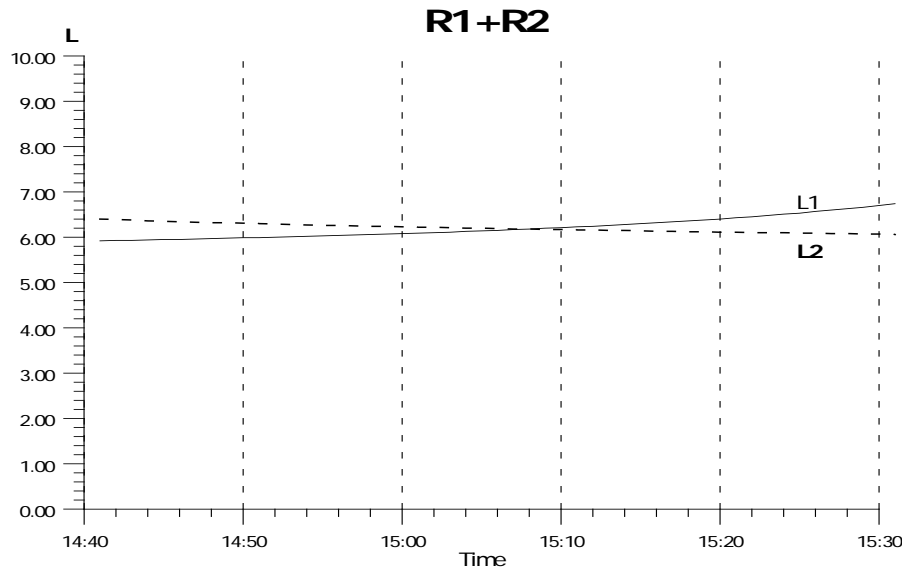




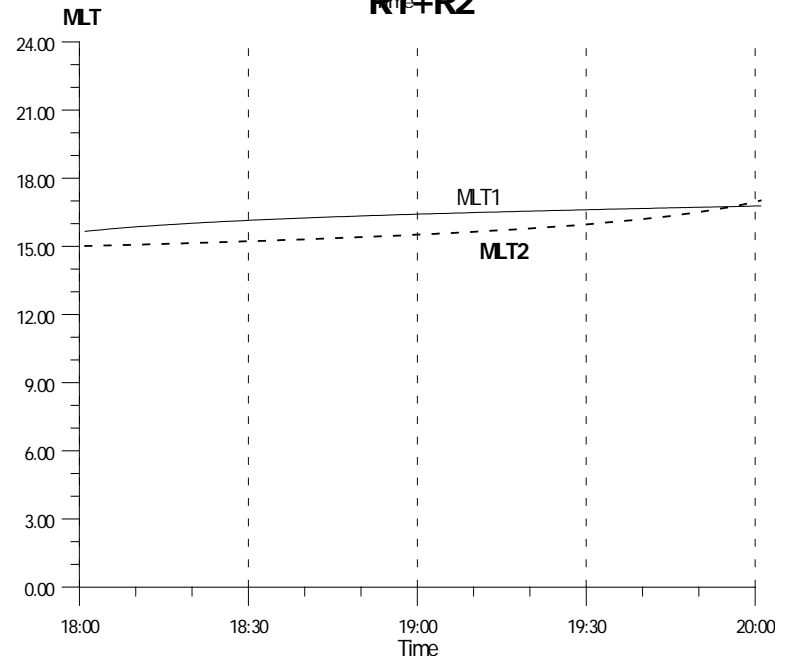
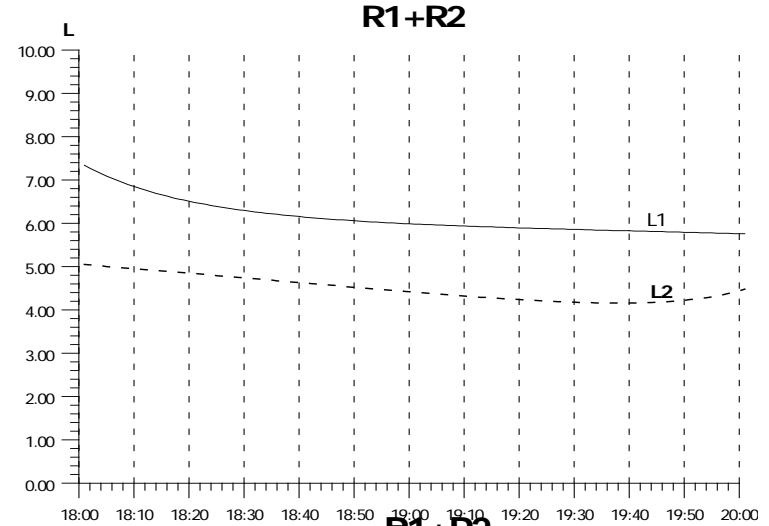
## Three sample orbits



## 2<sup>nd</sup> case: L match



## 3<sup>rd</sup> case: MLT match

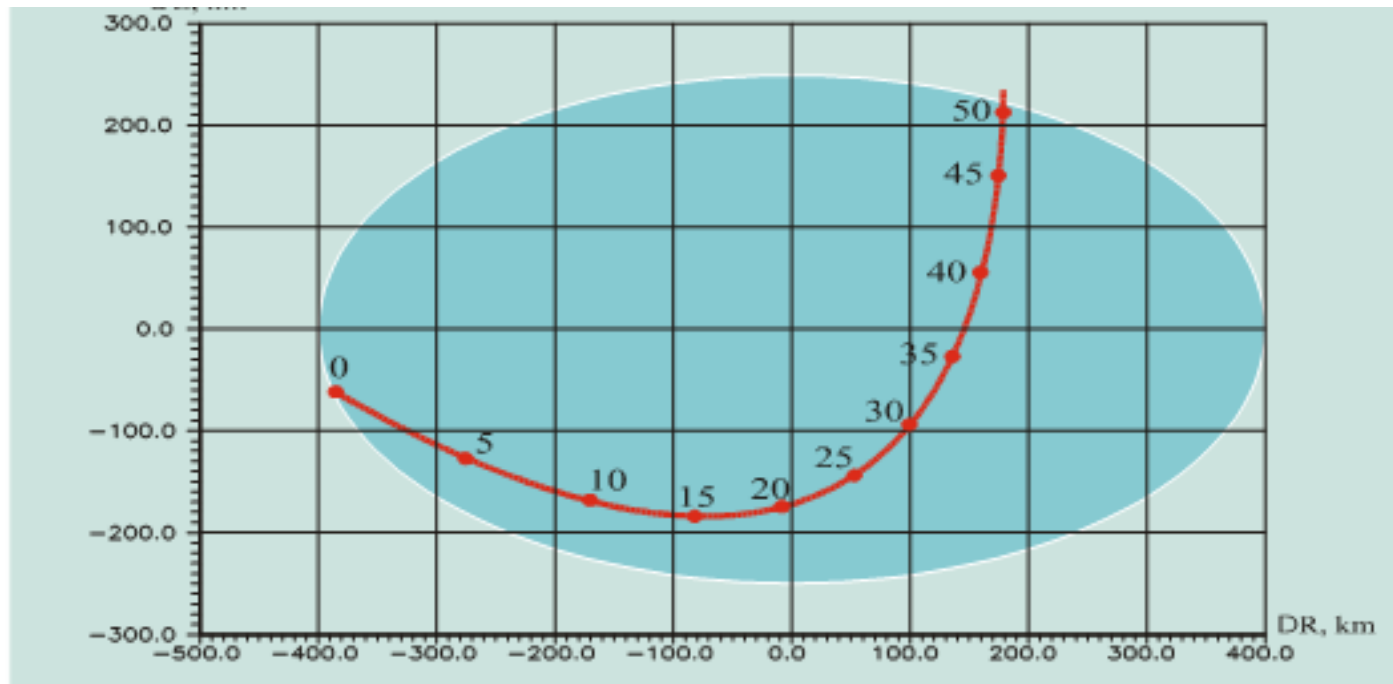


## How conjugacy with HAARP is defined

Required accuracy of conjugacy depends on physical processes of interest

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

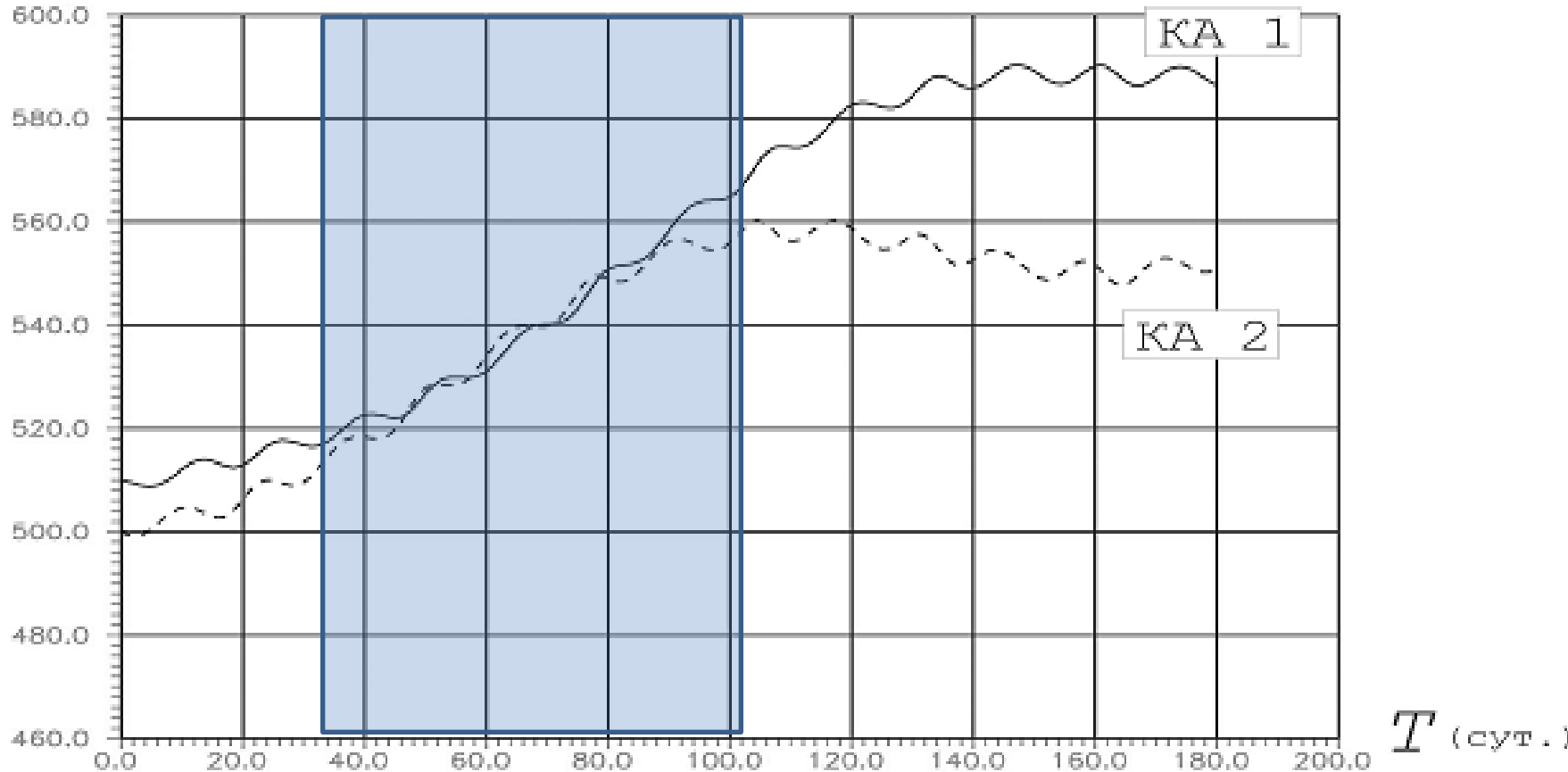
**Far zone:** spacecraft map to 100-km spot in ionosphere above HAARP



Equatorial projection of the near zone & trajectory – **50 min**

## Resonance orbit evolution

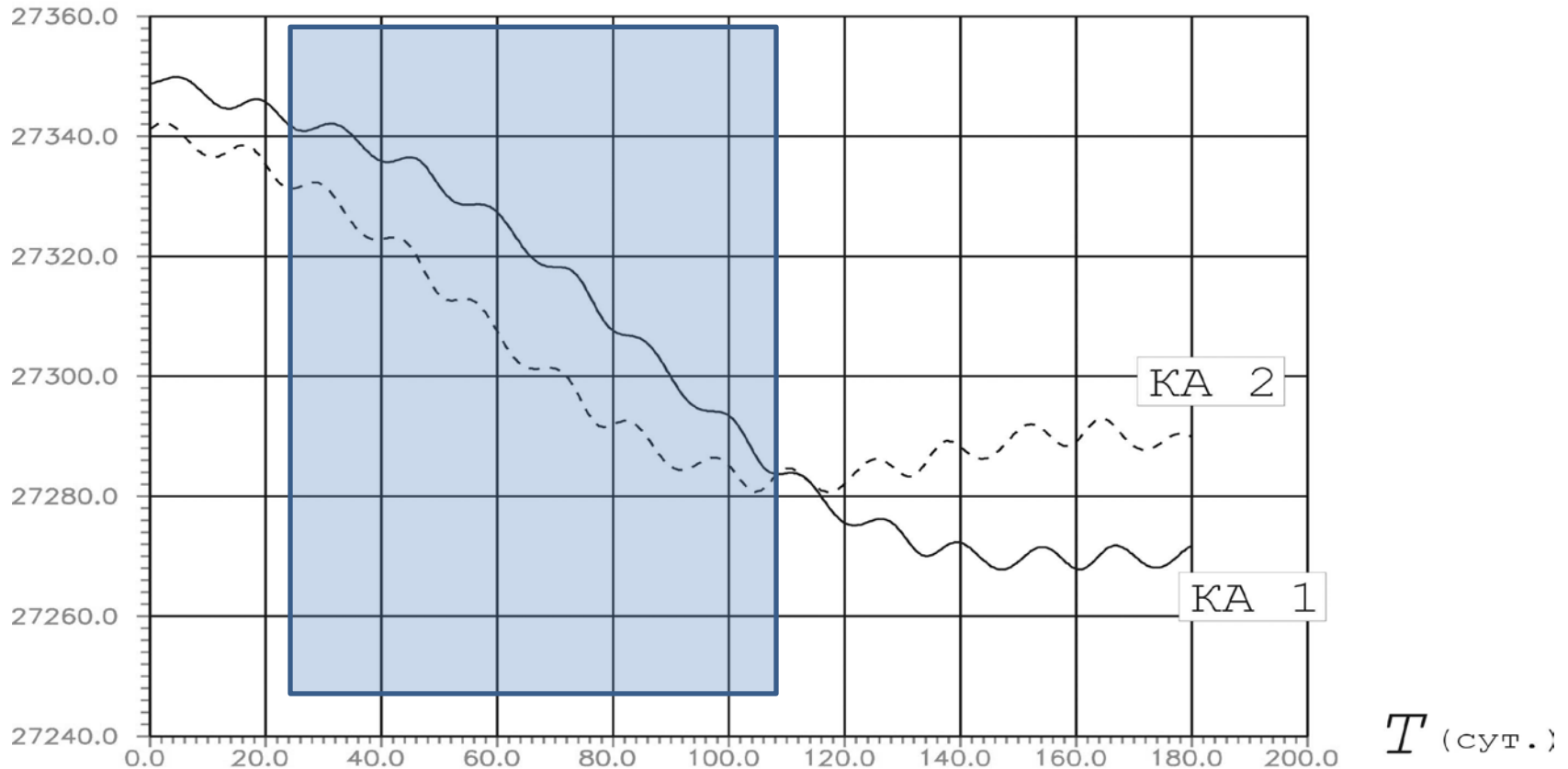
Perigee height, km



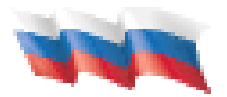
The best period for the first joint operation  
(four satellites in the selected flux tube)  
is 40-110 days after the launch

## Resonance orbit evolution

Apogee height, km



The best period for the first joint operation  
(four satellites in the selected flux tube)  
is 40-110 days after the launch



## 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

### Ground level

Exchange of work schedules

Resonance team is aware of HAARP timetable  
HAARP team is aware of Resonance orbit and schedule

### Extended level

Adjustment of work schedules

A special joint campaign with dedicated HAARP  
and Resonance sessions

### Advanced level

Downlink of real-time Resonance wave measurements  
to HAARP and feedback to HAARP emission

## Scientific collaboration Resonance-HAARP

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

