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Project "Resonance": main scientific objectives and the experiment design

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Abstract

We discuss the main scientific objectives of the space mission "Resonance" which is to be launched in 2013 for studying the wave-particle interactions in the inner magnetosphere as related to the origin of different types of electromagnetic emissions and the formation of radiation belts and ring current. We outline the state of the art in these studies and consider how the planned orbits and instruments onboard the Resonance spacecraft constellation will help in pursuing the yet unsolved problems of the inner-magnetosphere dynamics.

1. Introduction

The "Resonance" project has primarily been designed for studying the processes of wave-particle interactions in the inner magnetosphere [1]. The main problems which formed the core of this planned mission are (i) the origin of discrete electromagnetic emissions in the ELF/VLF and ULF ranges, (ii) the interrelationship of the discrete and noise-like emissions, and (iii) the influence of these waves on the energetic charged particles, i.e., the ring current and radiation belts. The important role of cold plasma distribution in the wave-particle interactions has made the cold-plasma dynamics another, equally important, problem for the project.

Since the project has been proposed, many interesting and important results have been obtained in studies of the mentioned problems. In this report, we discuss the scientific program of the Resonance project in view of those recent achievements.

2. Scientific objectives

Here, we list recent results in studying the topics of the "Resonance" project and review the importance of the project objectives.

VLF chorus and hiss. Spacecraft data have been fruitfully used to reveal chorus properties [2], and theory and simulations of chorus emissions have been developed [3–5]. Chorus has been proposed as an alternative source of plasmaspheric hiss [6]. "Resonance" should provide high-resolution energetic-particle data to resolve the problem of free-energy source of chorus and chorus interrelationship with hiss. ELF-VLF wave data in several components in the vicinity of chorus generation region to reveal the dominant mode of propagation of chorus.

Pc1 waves. Some new properties of electromagnetic ion-cyclotron emissions (e.g., a finite size of their source region, $\pm 11^\circ$ near the magnetic equator), have been obtained from observations [7]. Mechanisms of pearl-type emissions were discussed but not finally understood [8]. "Resonance" data should help in revealing the cause and consequences in the interrelationship between Pc1 waves and flux-tube oscillations (Pc4–5), in measuring the waves reflected from the ionosphere, and in resolving the mechanisms which form the main spectral features in this frequency range, such as pearls and IPDP.

Radiation belts. The role of chorus emissions in the acceleration of energetic electrons to relativistic energies was demonstrated observationally [9] and investigated theoretically [10]. The great impact of the discrete spectrum of chorus emissions in the acceleration efficiency has been demonstrated [11–13]. "Resonance" can quantify the efficiency of electron-acceleration and precipitation related to noise-like and discrete emissions.

Ring current/plasmasphere interface. Precipitation of energetic ions from the ring current due to the resonant interactions with ion cyclotron waves was studied experimentally [14–16] and theoretically [17, 18]. "Resonance" measurements should help in further understanding the relationship between the plasmasphere and ring-current dynamics, including the subauroral electric-field penetration issues.

Auroral kilometric radiation. Waveguide properties of AKR have recently been revealed [19]. "Resonance" will operate in the auroral region and contribute to better understanding of AKR generation and propagation, as well as auroral acceleration processes.

3. Spacecraft

A special orbit called magnetosynchronous orbit, has been suggested for the Resonance spacecraft [1]. The spacecraft at such an orbit will spend a long time in one specific flux tube. This kind of orbit can be especially convenient for detailed studies of the processes that develop in a specific magnetic-flux tube, such as generation of waves propagating nearly parallel to the magnetic field and field-aligned motion of both energetic charged particles and background plasma.

The planned spacecraft constellation comprises two pairs of satellites which will enter the same flux tube at different locations. The distance between the pairs will be about 30000 to 40000 km, and the distance within a pair will be varied from several tens to several thousands of km. This configuration should allow us to study the relationship between smaller- and larger-scale processes and cover a wide range of important spatial scales during a mission.

The instruments onboard the spacecraft include electromagnetic-field sensors for a wide range of frequencies, charged-particle detectors for energy ranges from tens of eV to several MeV, and thermal-plasma probes. We hope to achieve a high resolution for energetic particle measurements both in phase space and in time, which can be especially important to understand the wave-particle interaction dynamics.

4. Active experiments

The flux tube in which the spacecraft will spend a long time can be conjugated with a chosen ground-based facility such as, e.g., HAARP heater. It provides an opportunity to organize coordinated active experiments with a very long interval of observations of the phenomena induced in the magnetosphere by the ionospheric heating. Of special interest can be the propagation of ELF/VLF and ULF waves excited by the modulated heating, nonlinear interaction of such waves with energetic charged particles [20], and formation of artificial density ducts [21–23] which can influence both wave propagation and wave-particle interactions.

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