Characteristics of Jovian Low-Frequency Radio Emissions during the Cassini and Voyager Flyby of Jupiter

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Abstract

In chapter 1, we give an overview of Jovian decametric (DAM) and hectometric (HOM) radio emissions from both observational and theoretical points of view, specify the attenuation lanes associated with Jovian HOM emissions, review the summary of Imai et al. (2011a), and describe the target of this thesis. Jupiter's DAM and HOM radiations originate from interactions between the magnetospheric plasma and the strong magnetic field of Jupiter. They are still not clearly understood due to their complex phenomenology and limited observation conditions. We have analyzed the HOM/DAM structure by investigating statistical properties of the Jovian DAM and HOM radio emissions based on Cassini and Voyager observations below 16 MHz. As taking advantage of the Cassini polarization capability, we have also extended the analysis of rotationally well-defined lowered intensity and flanked enhancement properties associated with Jovian HOM attenuation lanes. Moreover, we survey the origin of Jovian HOM attenuation lanes by performing ray-tracing computations in a more realistic magnetic and plasma environment at Jupiter. Because the radio propagation is strongly affected by the Jovian magnetosphere system, these observational and theoretical considerations centralized through this thesis work lead to a better understanding of Jupiter's radio and plasma physics.

Chapter 2 specifies the descriptions of the spacecraft observations, data analysis methods, and statistical results. The radio wave data used here were taken during the Jupiter flyby of the Cassini and Voyager spacecraft. We state the method of how to deduce the HOM polarization by using Cassini data, and the rotation based averaging method being applicable to the identification of Jovian DAM and HOM within interference. Our main findings are that (1) the features of non-Io-B show similar trends in longitude from 10 to 16 MHz for both Cassini and combined Voyager 1 and 2 data, but the different behaviors of non-Io-A and -C are presented, (2) the moon Io clearly influences the radio emissions above 4 MHz around 90° and 250° Io phase,

(3) the occurrence probability of the HOM emissions are separated into right- and left-hand polarization senses, and (4) the attenuation lanes play an important role in not only reducing specific regions of occurrence probability, but also in intensifying the occurrence probability of the HOM emissions next to the attenuated regions.

The theoretical models of the magnetic field and plasma density at Jupiter and the ray tracing technique are given in chapter 3. The Jovian magnetosphere and global plasma models used in this study are reviewed. More importantly, the reproduction of the diffusive equilibrium model at Jupiter is emphasized for the study of the HOM ray propagation. Finally, the basics of ray tracing technique based on the Haselgrove's equations in polar coordinate are spelled out in this chapter.

Chapter 4 shows the results of the comprehensive ray-tracing computations for the HOM attenuation lanes using Cassini Jupiter encounter data. We test the origin of the lanes as refraction from either Case (i) enhanced density in a magnetic flux shell at L-value = 5.7 or Case (ii) the Io plasma torus itself or both. The modeling includes a bi-kappa diffusive Io plasma torus model and magnetic flux shell model in addition to Jupiter's global magnetic and plasma models. Our survey assumed emission frequencies of 0.5-3.0 MHz with a cone half-angle β from 40°-90° for northern hemisphere radio emission and of 90°-130° for southern hemisphere radio emission in the continuous radio source longitudes of polar regions. Our main results are that (1) Case (i) is better for producing the attenuation lanes than Case (ii), (2) the attenuation lanes are seen for all cone half-angles but the major HOM beaming is confined within $50° \leq \beta \leq 60°$ and $120° \leq \beta \leq 130°$ for northern and southern hemisphere radio emissions, respectively, (3) a reasonable enhanced density is, in addition to specific latitude-dependent density from the diffusive equilibrium model, found to be 100 cm^{-3} with the breadth of the density enhancement across the flux shell, 5.0 Io radii, and (4) the ray tracing computations easily reproduce the frequency widths of the attenuation lanes but the enhanced rate of the computed attenuation lanes is sensitive to only the breadth of the magnetic flux shell model.

In chapter 5, we summarize the new findings of our statistical DAM/HOM structure based on the Cassini and Voyager spacecraft, and of the Jovian HOM attenuation lanes compared with the Cassini polarization and the ray-tracing results. Theses new results of the spacecraft observations and ray-tracing yield the benefits of not only enhancing our understanding of Jovian low-frequency radio emissions, but also reinforcing our knowledge of the microscopic plasma profile around Jupiter's polar regions, which have not been explored by any *in situ* spacecraft yet.