THEORY OF GENERATION MECHANISM OF THE PLANETARY RADIO EMISSIONS

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Extended Abstract [1]

The Earth and Jupiter are wellknown as radio planets that are emitting very intense and coherent radio wave emissions, i.e. the auroral kilometric radiation (AKR), Jovian decametric (JDR), hectometric (JHR) and kilometric (JKR) radiations. The kilometric radiation from Saturn (SKR) has also been investigated using observational results by Voyager spacecraft.

The theories for interpreting the generation mechanism of radio emissions from planets can be categorized in direct generation and conversion processes; the conversion processes are also divided into nonlinear and linear processes. Some of these results are summarized in Tables 1 and 2. In the present paper, we emphasize the importance of conversion processes. This is justified when we consider that the source mechanism due to the Landau interaction process between beams and plasma favors the generation of plasma waves in a frequency range from $f_p < f < f_{UHR}$, where f_p and f_{UHR} are the plasma and upper hybrid frequencies, because a wide range of the beam energy can be used for the generation of waves in a very narrow frequency range around the upper hybrid frequency. Conversion processes of the hybrid mode waves in a frequency range $f_p < f < f_{UHR}$ into the escaping mode of radio waves are basically depending on the two types of inhomogeneous properties of the plasma or the beam. The first is the inhomogeneity of the plasma density distribution while the second is the inhomogeneity of the energy distribution of precipitating particles.

For the cases $f_p \ll f_c$ which can be applicable to the source media of the coherent bursts of planetary emissions, the conversion rate of radio waves into the escaping mode has been studied. The dispersion relation of plasma waves of the escaping mode is characterized by the proximity (see Figure 1) between the Z–mode and L–O mode waves and there is also only a very small gap in $\omega - k$ space between the Z–mode and the R–X mode waves. This closeness of the dispersion relations leads to an effective conversion of energy from the Z–mode to the escape mode of the radio waves.

We have calculated the conversion rate for the following three cases of conversion (see Fig. 1):

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[1]Because of the absence of the author this paper was presented by S. J. Bauer

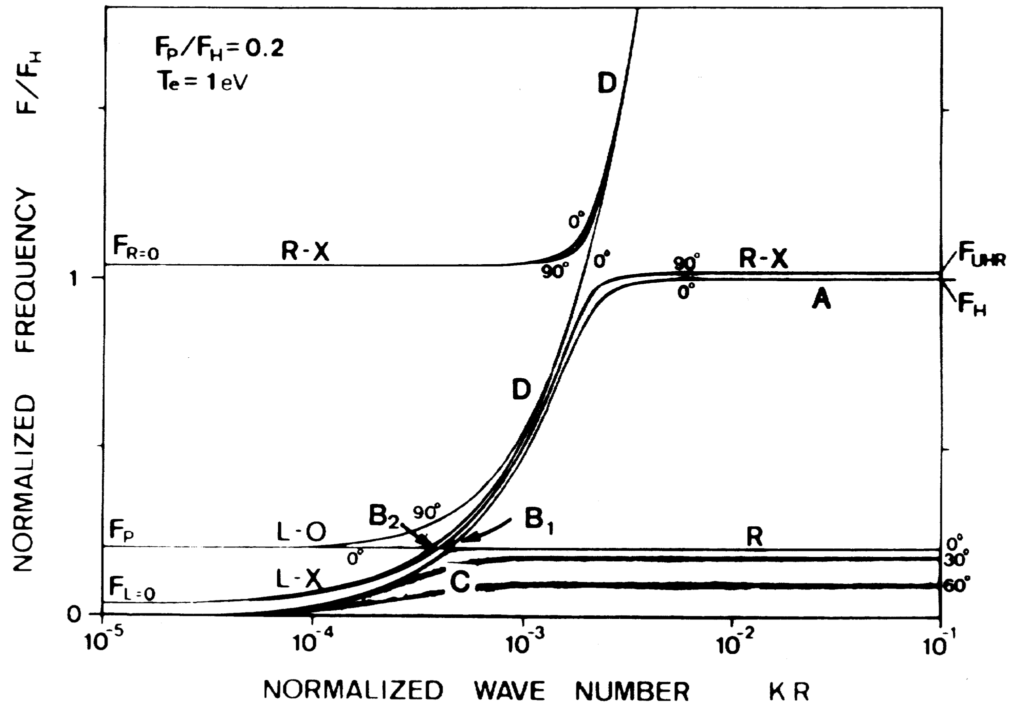

Figure 1: Dispersion curves ($\omega - k$ diagram) of the plasma waves for the condition $f_p/f_H = 0.2$ where f_p and f_H are the plasma and electron cyclotron frequencies. The frequency is normalized by the electron cyclotron frequency f_H, and the wave number k is normalized by the electron cyclotron radius R. Curve C corresponds to the whistler mode; plasma waves are generated at A on branch 0°. Conversion process I takes place between B1 and B2; conversion process II near D at $f/f_H \leq 0.5$, and conversion process III between R–X and D branches in the upper part of the diagram.

I) Conversion at the plasma frequency

The energy conversion rate becomes a maximum in this frequency domain when there is an inhomogeneity in the plasma density regardless of the feature of the inhomogeneity itself. The conversion rate can be estimated to be more than 10% of the generated waves solely from Z–mode to the L–O mode waves.

II) Conversion in the frequency range from f_p to f_c

In this frequency range efficient conversion takes place from the Z to the L–O mode. The conversion rate is depending on the feature and extent of the irregularities; the possible values of the conversion rate are in the range from 0.1 to 1%.

III) Conversion near the electron cyclotron frequency

The conversion rate for irregularities in the plasma density distribution is not necessarily larger than for case II, but the conversion rate between the Z–mode and R–X mode waves for an inhomogeneous distribution of precipitating particle velocity becomes extremely large; the conversion rate, in this case becomes almost 100% between the Z–mode and R–X mode. Therefore, the existence of any R–X mode should also be considered as a consequence of mode conversion.

Table 1 Summary of Direct Process Theories of AKR and JDW

Process	Reference	Object	Polarization	Mechanism
		Linear Theories		
Direct process (EM-mode origin)	Ellis[1962,1963,1965]	JDW	R-X	Incoherent cyclotron radiation (helical beam)
	Ellis and McCulloch[1963]	JDW	R-X	
	Fung[1966]	JDW	R-X	Coherent cyclotron radiation
	Frankel[1973]	Continuum radiation	R-X (L-0)	Incoherent gyrosynchrotron radiation (100 keV-1MeV electron)
	Melrose[1976]	AKR and JDW	R-X	Coherent cyclotron interaction by temperature anisotropic electron beams
	Wu and Lee[1979]	AKR	R-X (L-0)	Coherent cyclotron interaction by reflected loss-cone-type electrons
		Nonlinear Theory		
	Palmadesso et al.[1976]	AKR	L-0	Landau interaction of beat waves produced by ion wave turbulence (beam-to-beat waves, beat waves to EM waves

Table 2 Summary of Conversion Mechanism Theories of AKR and JDW

Process	Reference	Object	Polarization	Mechanism
		Linear Mode Conversion		
Conversion process (ES-mode origin)	Oya[1971,1974]	general JDW	L-0 L-0	Conversion of ES waves near f_{UHR} into Z mode waves
	Scarf[1974] Benson[1975]	JDW AKR	L-0 L-0	and Z mode waves into L-0 mode waves at f_p through
	Jones[1976,1977b)	continued AKR JDW	L-0	the inhomogeneity of plasma
	Boswell[1978]	AKR	L-0	Excitation by ion beams
		Nonlinear Conversion		
	Wu et al.[1973]	JDW	R-X	Budden tunneling slow R-X fast R-X
	Smith[1976]	JDW		
	Barbosa[1976]	AKR	R-X (L-0)	Incoherent three-wave coupling $\omega_1=\omega_2\cong\omega_{UHR}$, $\omega_3\cong 2\omega_{UHR}$
	Roux and Pellat[1979]	AKR	R-X (L-0)	Coherent three-wave coupling $\omega_1=\omega_2\cong\omega_{UHR}$, $\omega_3\cong 2\omega_{UHR}$
	Jones[1977a,1978]	AKR JDW	R-X + L-0	Three-wave coupling of Z mode waves $\omega_1\cong\omega_{UHR}$, $\omega_2\cong\omega_{L-0}$ $\omega_3\cong\omega_{UHR}+\omega_{L-0}$
	Galeev and Kranoselskikh[1976] Maggs[1978]	AKR AKR	R-X + L-0	Dipole radiation from Langmuir caviton $\omega=2\omega_{pe}$
	Grabbe et al.[1980]	AKR	R-X	R-X EM waves and electrostatic ion cyclotron waves coupled with beam-generated R-X mode waves