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COMPUTER EXPERIMENTS FOR INTERACTIONS OF INHOMOGENEOUS PLASMA AND HF ELECTROMAGNETIC WAVES ON IONOSPHERIC HEATING EXPERIMENTS (EXTENDED ABSTRACT)

Hiroko UEDA[1], Yoshiharu OMURA[2] and Hiroshi MATSUMOTO[2]

[1]*Department of Electrical and Electronics Engineering, Chiba University, 1-33, Yayoi-cho, Inage-ku, Chiba 263*

[2]*Radio Atmospheric Science Center, Kyoto University, Uji 611*

We investigate direct conversion (DC) process (ANTANI *et al*., 1991) of an obliquely propagating L-O mode electromagnetic pump wave into upper hybrid (UH) waves by small-scale density irregularities whose scale length perpendicular to the geomagnetic field is comparable to or much less than the pump wave length. The process of the excitation of UH waves seems to be essential in explaining some of the feature of the stimulated electromagnetic emissions (SEE), which are observed in the ionospheric heating experiments (LEYSER *et al*., 1989; GOODMAN *et al*., 1993). The SEE has been observed only during L-O mode pumping in narrow ranges of the pump frequency, near the several multiples of the electron cyclotron frequency. In addition, it grows on the same time scale as thermally generated field aligned density irregularities giving rise to high-frequency backscatter (HEDBERG *et al*., 1983). The process may also be related to UH waves generally observed by satellites around the ionospheric and magnetospheric regions with small-scale density irregularities.

The WKB approximation, common for analysis of wave propagation in inhomogeneous plasmas, can not be applied to such a case of small-scale irregularities. Therefore we carried out two-dimensional electromagnetic particle simulations to study the conversion process under the effect of the irregularities.

Figure 1 shows the typical ionospheric heating situation schematically. A high-power electromagnetic pump wave with a frequency ω_0 and a wave number k_0, is vertically launched into the ionospheric F region. The incident wave passes through the upper hybrid resonance layer where $\omega_0 \simeq \omega_{UH} = \sqrt{\Pi_e^2 + \Omega_e^2}$ a few kilometers below the reflection layer, where ω_{UH}, Π_e, and Ω_e are the UH frequency, the local plasma frequency, and the electron cyclotron frequency, respectively. Analytical studies pointed out that the pump wave is able to beat with zero-frequency field aligned density irregularity, with large wavenumber k_n perpendicular to the external magnetic field, to directly convert into high frequency electrostatic waves if the following resonant conditions are satisfied;

$$\omega_0 = \omega + \omega_n,$$
$$\boldsymbol{k}_0 = \boldsymbol{k} + \boldsymbol{k}_n,$$

where ω and $\boldsymbol{k}$ are frequency and wave number of the excited wave. And also the

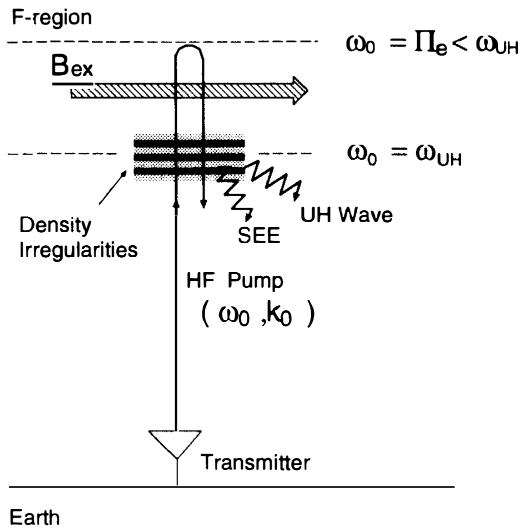

Fig. 1. Schematic of the typical ionospheric heating situation.

following conditions are assumed; $k_n \simeq k_{n\perp} = k_n$, $|k_{0\perp}| \ll |k_n|$, $|k_{n\parallel} \ll |k_{0\perp}|$, and $\omega_n \simeq 0$.

An initial profile of simulation plane is shown in Fig. 2. We have set up a obliquely propagating plane wave whose wave number perpendicular to the geomagnetic field $k_{0\perp}$ is much larger than that in the parallel direction $k_{0\parallel}$, and a coherent perpendicular density irregularity of the wave number k_n, here $k_{0\perp} \ll k_n$. The frequency of the pump wave is assumed to be equal to the upper hybrid frequency, *i.e.*, the density irregularity is quasi-static.

In the simulations, we have confirmed the excitation of UH wave under satisfying the matching condition. Figures 3a and b show the electron density distribution and x component of electric field (E_x) in the simulation plane at time $t = 1.28/\Omega_e$. The E_x component is obviously modulated in x direction with the wave number corresponding to the density irregularity, while E_y and E_z components are not affected. The E_x component necessarily oscillates with the same frequency as the pump wave, so that the electrostatic

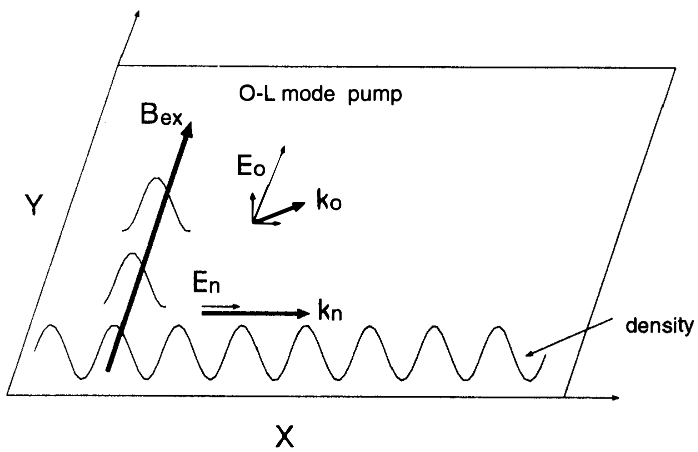

Fig. 2. Model of computer experiments.

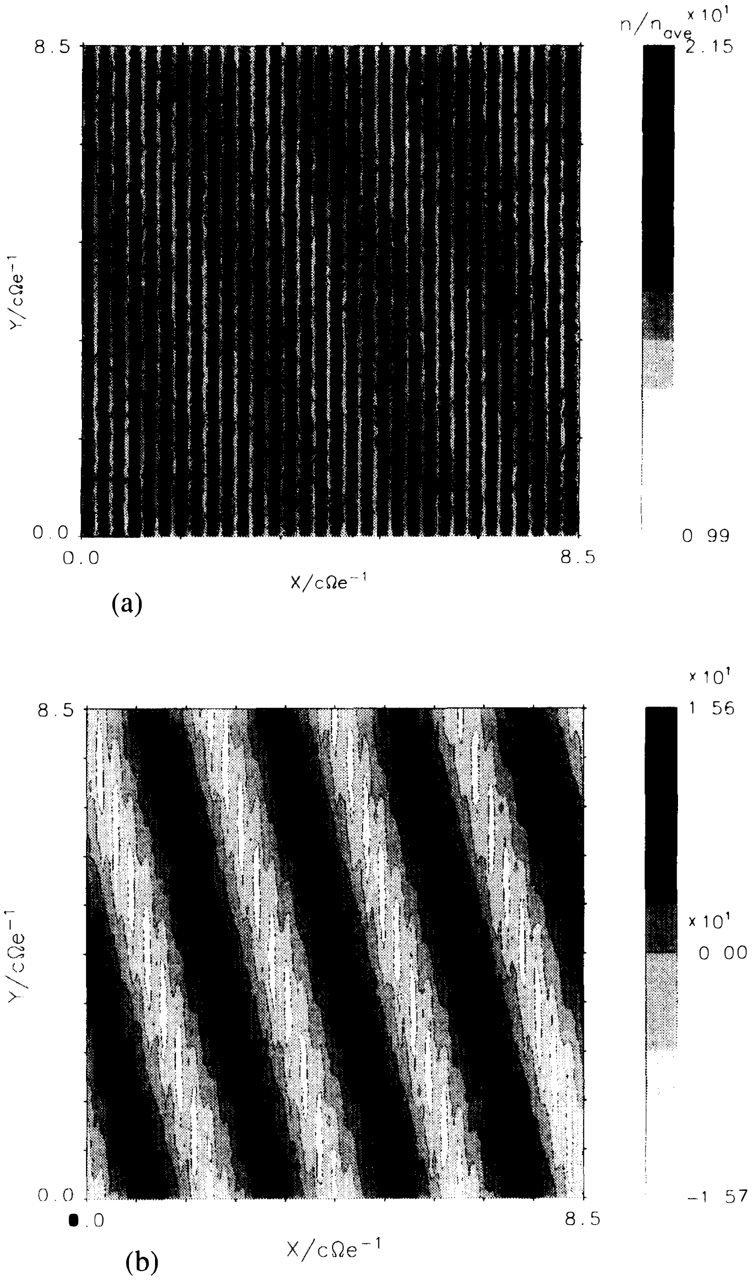

Fig. 3. Distribution of (a) the electron density, (b) E_x component at $t = 2.28/\Omega_e$.

wave oscilating with the UH frequency with the perpendicular wave number k_n is excited. Physical picture of this process can be described as follows. The L-O mode pump induces oscillatory electron drift. This induced electron velocity beats with the density irregularities in the x direction. The interaction results in a source current which acts as a radiating antenna for the UH wave.

The energy conversion of the UH wave from the pump is considered to depend on degree of the irregularity, scale length of the irregularity relative to the pump wave length, propagation angle of the pump wave to the geomagnetic field, and the pump frequency as compared with cyclotron frequency. We will discuss the feature of the UH wave excitation process in terms of the above-mentioned parameters.

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