PROPAGATION OF WHISTLER WAVES TRAPPED IN A NARROW DENSITY TROUGH

H. Sugai, K. Ido, H. Niki, S. Takeda

PROPAGATION OF WHISTLER WAVES TRAPPED IN A NARROW DENSITY TROUGH

H. Sugai, K. Ido, H. Niki and S. Takeda.

Department of Electrical Engineering, Nagoya University, Nagoya Japan.

Abstract: Whistler waves are observed to be trapped in the narrow density trough of width $2d \lesssim \lambda_{//}$ (parallel wave length). The phase and amplitude profile of ducted whistlers is measured along and across the trough. The experimental results are in good agreement with the recent trapping theory.

Ducted propagation of whistler waves has been widely recognized as a mechanism guiding the wave energy along lines of magnetic field in geomagnetosphers[1]. In the field-aligned density trough or hump ('duct'), whistlers are trapped somewhat in the manner of a metalic waveguide. The conventional ray theory[1] cannot be applied to the narrow duct ($2d \lesssim \lambda_{//}$). The recent theory[2] solving the eigenvalue problem has predicted that whistler waves are trapped even in the narrow density trough.

In this paper we present laboratory experiments of whistler wave trapping in the narrow density trough. The details of plasma device has already been reported elsewhere[3]. The experiment is performed in an afterglow plasma of density $n \simeq 7 \times 10^{11}$ cm^{-3} and electron temperature $kT_e = 0.3 - 0.8$ eV, under the magnetic field $B_0 = 100 - 200$ G. The field-aligned density trough is artificially produced in the novel fashion where the depth and the width of the duct can be controlled arbitrally. Whistler waves of frequency $\omega/2\pi = 100 - 500$ MHz are excited with an electric dipole antenna. The rf power applied to the exciter antenna is so small that the wave nonlinearity and the electron heating due to antenna actions[4] is excluded.

While the wave energy flow diverges in the uniform density profile, the narrow density trough

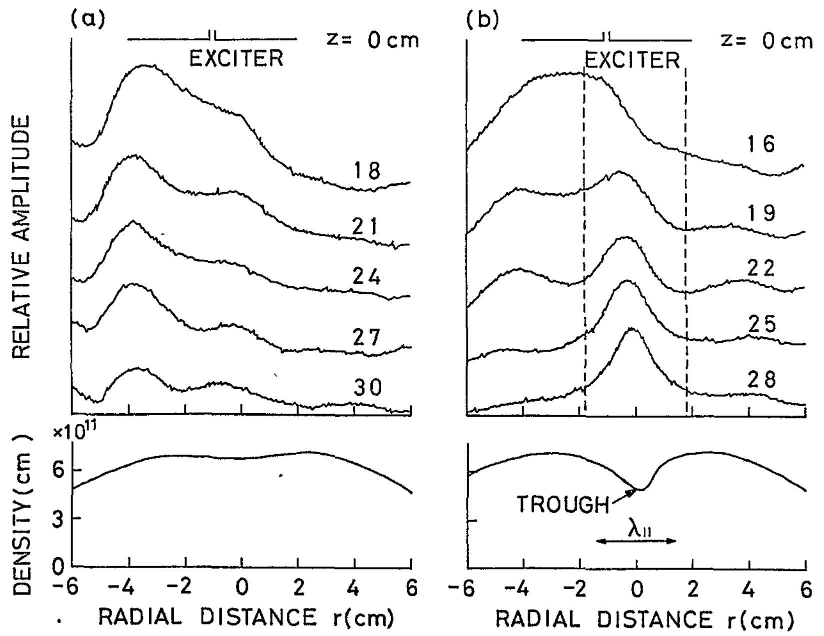

Fig.1. Relative wave amplitudes across B_0 at different axial distances from the exciter antenna, together with the density profiles in the absence (a) and the presence (b) of the narrow density trough. $\omega/\Omega = 0.70$, $\Omega/2\pi = 508$ MHz.

confines the wave which does not broaden with increasing distance from the exciter. Figure 1 displays a comparison of the wave amplitude profiles across B_0, in the absence [Fig.1(a)] and in the presence [Fig.1(b)] of the density trough. The perfectly ducted mode is established at $z \gtrsim 25$ cm, while the effect of radiation broadenning from the exciter antenna cannot be neglected for $z \lesssim 15$ cm.

The transverse profiles of wave amplitudes show the exponential decay outside the trough. The transverse decay length Λ is plotted in Fig.2, as a function of the frequency normalized by the electron cyclotron frequency Ω. The solid line in Fig.2 indicates the theoretical curve obtained in the sharp boundary model[2] The experimental values of Λ become minimum around the critical frequency ω_c.

The wave length as well as the wave amplitude is modified in the presence of the density trough. The measured dispersion relations of the ducted modes well agree with the theoretical ones, as shown in Fig.3.

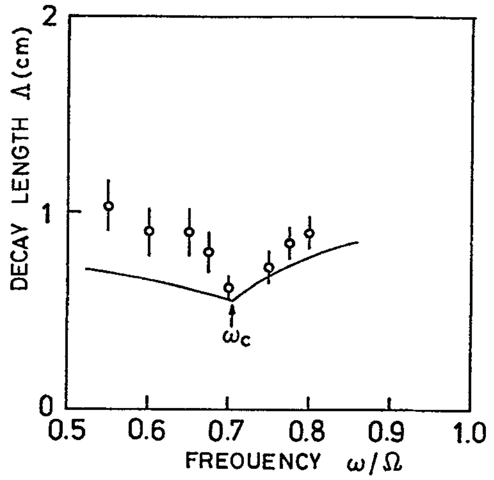

Fig.2. Experimental points and theoretical line of the transverse decay length Λ as a function of the normalized frequency ω/Ω. The density depression rate δ = 33 %, and 2d = 1.4 cm.

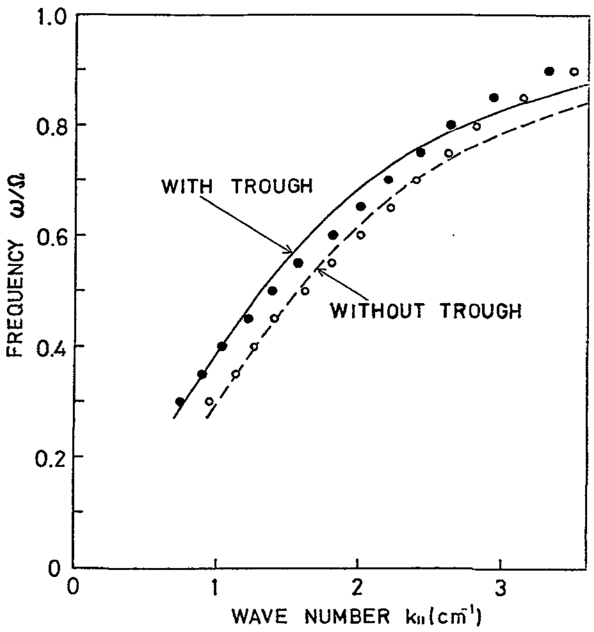

Fig.3. Comparisor of the whistler wave dispersion relations in a uniform plasma and in a narrow density trough. Solid line and closed circles correspond to the case with the trough, and dashed line and open circles indicate the case without the trough. $n_1 = 6.9 \times 10^{11}$ cm^{-3}, $\Omega/2\pi$ = 508 MHz, δ = 30 %, and 2d = 1.4 cm.

References

1. R.A. Helliwell, Whistlers and Related Ionospheric Phenomena (Stanford Univ., Stanford, Calif., 1965).
2. K. Mima, G. Morales, Y.C. Lee, and B.D. Fried, Research Report of Institute for Fusion Theory, Hiroshima University (1978), Hiroshima, Japan.
3. H. Sugai, M. Sato, K. Ido, and S. Takeda, J. Phys. Soc. Japan 44, 1953 (1978).
4. H. Sugai, M. Maruyama, M. Sato, and S. Takeda, Phys. Fluids 21, 690 (1978).