PROCEEDINGS OF ISAP '92, SAPPORO, JAPAN

TRIGGERING CHORUS EMISSIONS FROM WAVELETS IN THE HISS BAND IN THE OUTER MAGNETOSPHERE

Masashi HAYAKAWA[1], Katsumi HATTORI[2], Dominique LAGOUTTE[3], Michel PARROT[3] and Francois LEFEUVRE[3]

1.The University of Electro-Communications, 1-5-1 Chofugaoka, Chofu, Tokyo 182, Japan.
2.Solar-Terrestrial Environment Laboratory, Nagoya University, 3-13 Honohara, Toyokawa, Aich 442, Japan.
3.Laboratoire de Physique et Chimie de l'Environnement, CNRS, Orleans Cedex 2, France.

Abstract

The satellite and ground VLF/ELF data have indicated that magnetospheric discrete chorus emission is often accompanied by a background hiss, and the purpose of this paper is to investigate the association between hiss and chorus and to present detailed experimental findings on the cause and effect relationship between them. The present study is based on the detailed spectral analyses and direction finding measurements for events with simultaneous occurrence of hiss and chorus observed on Geos-1 satellite in the outer magnetosphere. The observational facts might lead us to conclude that a wavelet existing near the upper edge of the hiss band is able to generate a chorus emission through coherent wave-particle interaction in the outer magnetosphere as in the case of active VLF wave injection experiments. On the basis of this conclusion, we discuss the generation mechanism of hiss-triggered chorus.

1. Introduction

Natural magnetospheric VLF/ELF emissions are known to be classified into two different types; (1) unstructured hiss and (2) structured and discrete emissions collectively called "chorus" (e.g. [1][2][3]). However, the fundamental problems such as whether those two types of emissions are essentially different or not and the link between hiss and chorus, are still unsolved and further investigation is required. As the stimulus to trigger a chorus emission, two hypotheses which seem to be in contradiction with each other, have been proposed. The first one is hiss which has so far been considered to be very incoherent and turbulent because the ground and satellite VLF/ELF measurements have indicated that chorus is often accompanied by a background of hiss[4][5][6]. The second one is power line harmonic radiation which is monochromatic and coherent in nature[7][8]. In order to investigate whether these two hypotheses are contradict with each other, we have carried out extensive study for VLF/ELF emission data including both hiss and chorus observed on GEOS1 on the basis of the sophisticated signal analyses and direction finding[9][10][11] and the present paper reports on the results.

2. Experimental results on the link between hiss and chorus

Hattori et al. [9][10][11] have carried out the detailed analyses for VLF/ELF waveform data observed onboard Geos1 satellite. Four events have been treated; one is a VLF event on July 21, 1977 (near equatorial observation at geomagnetic latitude 6.8-8.5^{o}), another event on 2 December, 1977 at a higher latitude of 24-23^{o}, an ELF event on 19 Nov. 1977 (off-equatorial observation at around 20^{o}, and an event of hiss on June 20, 1977. High resolution spectral analysis and direction finding measurements have been performed. The following observational findings mainly based on the equatorial event are noticed and they are very important to study the role of hiss in triggering a chorus emission. (1)It has been reconfirmed that each chorus element is very likely to be originated from the underlying hiss such that each chorus element is asymptotic to the hiss band and that the df/dt at the foot of each chorus is nearly zero(see Fig.1). The frequency drift rate of chorus elements near the equator is about 0.7kHz/s, as is observed so far. (2)The intensity and occurrence of chorus emissions are found to be closely correlated with the underlying hiss band. When the intensity of the underlying hiss exceeds a threshold value of a few $m\gamma/\sqrt{Hz}$, the excitation of chorus emissions is extremely enhanced. (3)It have been established that hiss is, on some occasions, very random and incoherent as has long been considered, but that some parts of hiss exhibit some structures or wavelets(see Fig.2). We can identify wavelets at the foot of some chorus elements which can be considered to be causative to the relevant chorus emissions(Fig.2). These wavelets are seen only in the case of natural hiss, but not in the white noise generated by a noise generator. As for the ELF event, the duration of wavelets to trigger a chorus element is longer than those in the VLF case. And the intensity of wavelets is considerably smaller than those in the VLF case. In Fig.3, we have plotted the relationship between the intensity(Bw) of wavelets and their duration(T) for the former near-equatorial VLF event and dark dots indicate that such wavelets are found to trigger a chorus emission. Two examples of wavelets from ELF event are indicated by ELF. The threshold values of wavelets for triggering a chorus emission are given by the products of the intensity and the duration. (4)The most important new direction finding fact about the association between hiss and chorus is that same azimuthal angle values are obtained for hiss and chorus, which indicates that both phenomena of hiss and chorus come from the same source region. (5) The polar angles for some chorus elements exhibit a tendency to increase with increasing frequency, but other chorus elements have no definite relationship between polar angle and frequency. Finally, we can conclude that a coherent wavelet exsiting at the upper edge of the hiss band is reasonable for triggering a chorus through coherent wave-particle interaction as in the active VLF experiment.

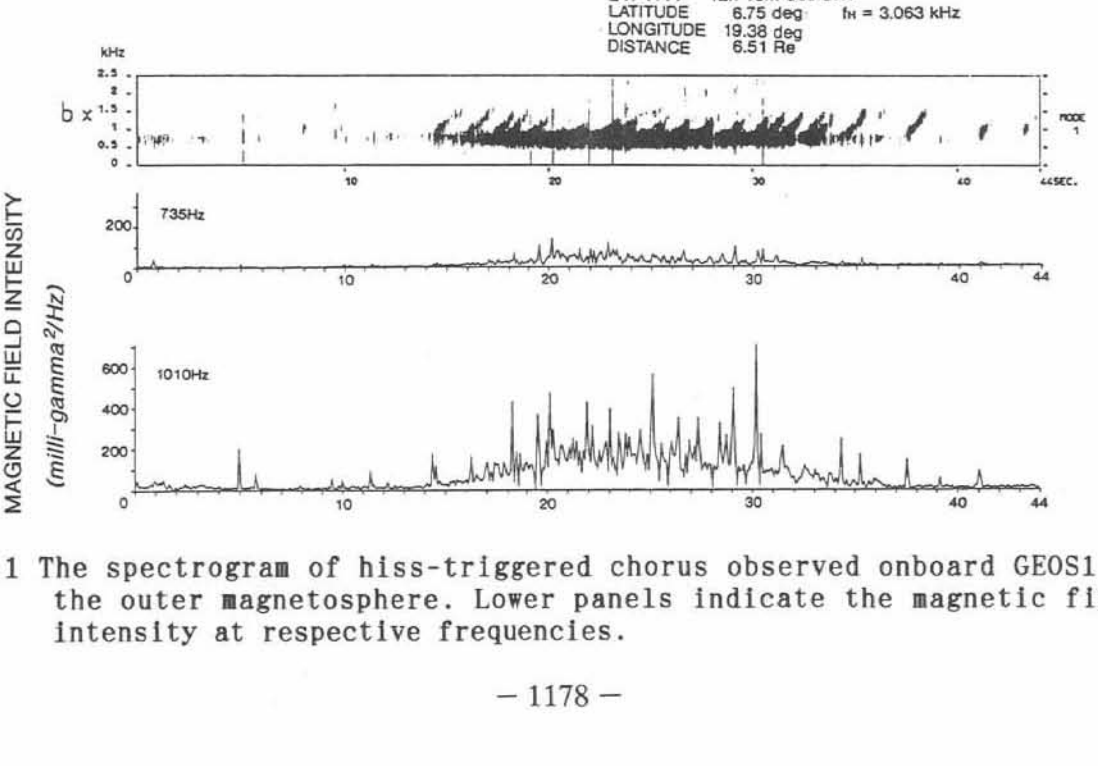

Fig.1 The spectrogram of hiss-triggered chorus observed onboard GEOS1 in the outer magnetosphere. Lower panels indicate the magnetic field intensity at respective frequencies.

3. Theoretical considerations for chorus emissions from a wavelet in the hiss band

Chorus emissions are considered to be generated by the Electron-Cycrotron Instability around the magnetic equator. Therefore, based on the direction finding results, we have performed 3-dimensional inverse ray tracing computations to find out the ray paths and wave normal angles in the source region of chorus emissions. Ray tracing computational results indicate that the generartion angles occupy the range between the Gendrin angle and the oblique resonance angle in the equatorial region for the equatorial VLF event as indicated in Fig.4. In this figure, circle, triangle and box show the wave normal of hiss-triggered chorus in the source region, together with the Gengrin angle and oblique resonance angle.chorus. Those results suggest that chorus emissions are generated at the wave normal angle very oblique to the megnetic field.

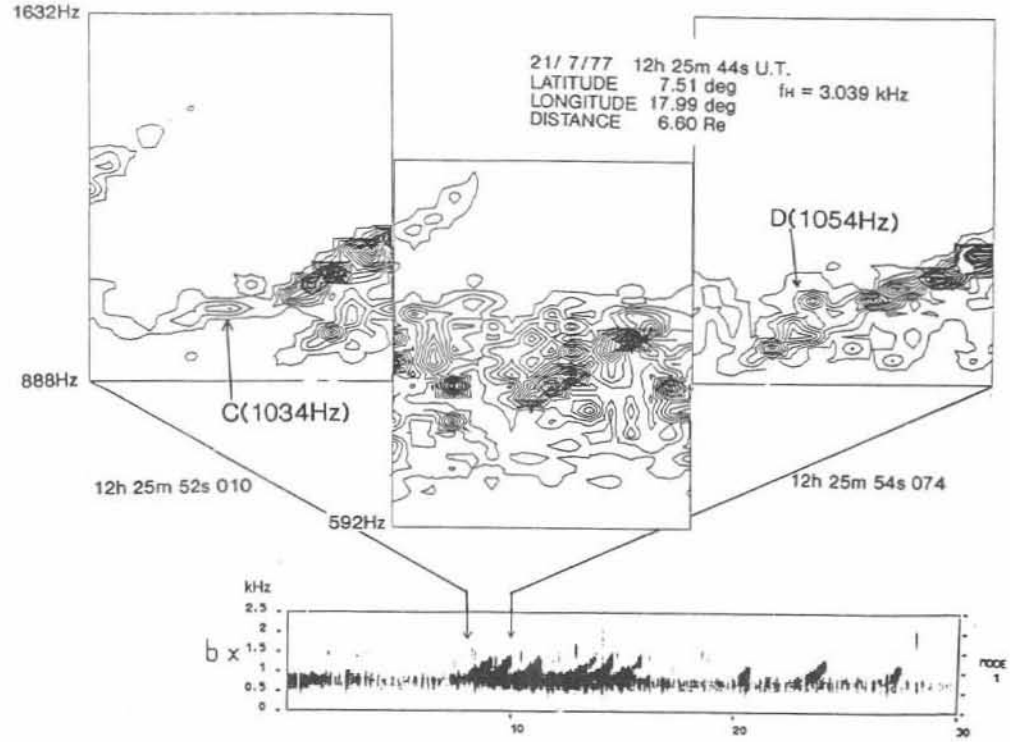

Fig.2 The intensity contour map. C and D are wavelets to be considered to be origins of the relevant chorus.

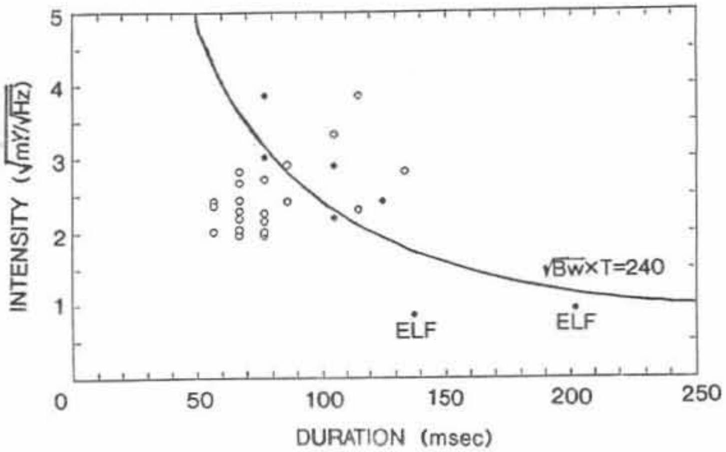

Fig.3 The relationship between the intensity($\sqrt{Bw}$) of wave let and their duration(T)

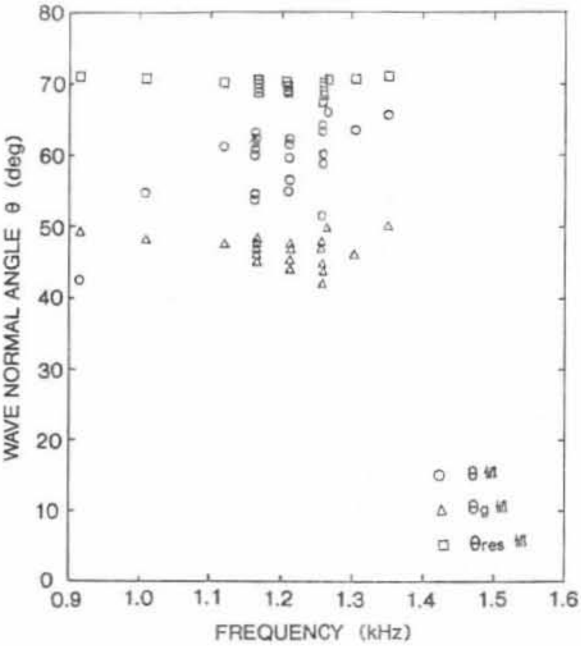

Fig.4 Wave normal angles in the source region by means of the inverse ray tracing computations.

4. Concluding Remarks

We have found out the possibility that chorus emissions are generated by wavelets at the upper edge of the hiss band. That is, a chorus emission is triggered by such a wavelet through a coherent wave-particle interaction just like in the case of active VLF injection experiments[12]. The most important new finding in this paper is found from Fig.3 which shows the presence of a threshold of product of the intensity and the duration of a wavelet for generating chorus from the wavelet in the hiss band. The wavelets above this experimental threshold are able to excite a chorus emission. Another important finding is the suggestion of the oblique instability for chorus emissions in the range of the normalized frequency $0.3<\lambda<0.5$.

References

[1]Helliwell,R.A., Whistlers and Related Ionospheric Phenomena, Stanford Univ., Press, Stanford CA, 1965.

[2]Sazhin,S.S., Natural Radio Emissions in the Earth's Magnetosphere, Nauka, Moscow, 1982.

[3]Hayakawa,M., Y.Yamanaka, M.Parrot and F.Lefeuvre, J.Geophys.Res., 89, 2811, 1984.

[4]Burtis,W.J. and R.A.Helliwell, Planet.Space Sci., 24, 1007, 1976.

[5]Cornilleau-Wehrlin,N., R.Gendrin, F.Lefeuvre, M.Parrot, R.Grard, D.Jones, A.Bahnsen, E.Ungestrup and W.G.Gibbons, Space Sci.Rev., 22, 371, 1978.

[6]Koons,H.C., J.Geophys.Res., 86, 6745, 1981.

[7]Luette,J.P., C.G.Park and R.A.Helliwell, Geophys.Res.Lett., 4, 275, 1977.

[8]Luette,J.P., C.G.Park and R.A.Helliwell, J.Geophys.Res., 84, 2657, 1979.

[9]Hattori,K., M.Hayakawa, S.Shimakura, M.Parrot and F.Lefeuvre, Proc.Natl Inst.Polar Res., Symp. on Upper Atmosphere Phys., 2, 84, 1989.

[10]Hattori,K., M.Hayakawa, D.Lagoutte, M.Parrot and F.Lefeuvre, ibid, 4, 20, 1991.

[11]Hattori,K., M.Hayakawa, D.Lagoutte, M.Parrot and F.lefeuvre, Planet.Space Sci., 39, 1465, 1991.

[12]Helliwell,R.A., D.L.Carpenter, U.S.Inan and J.P.Katusfrakis, J.Geophys.Res., 91, 4381, 1986.