ON THE OBSERVATION AND GENERATION MECHANISM OF HISS-TRIGGERED CHORUS IN THE OUTER MAGNETOSPHERE

K.Hattori[1], M.Hayakawa[1)3)], S.Shimakura[2], M.Parrot[3], and F.Lefeuvre[3]

1) Research Institute of Atmospherics, Nagoya University, Toyokawa, Japan
2) Department of Electrical Engineering, Chiba University, Chiba, Japan
3) Laboratoire de Physique et Chimie de l'Environnement, Orleans, France

ABSTRACT

The characteristics of hiss-triggered chorus in the outer magnetosphere have been investigated on the basis of the detailed analyses of wave spectra, direction finding results and the fine structures of the hiss band, and then we have presented their generation mechanism.

1. Introduction

VLF/ELF emissions are one of the most popular wave phenomena in the magnetosphere, and they are classified into the two types; (1) hiss (Helliwell,1965; Hayakawa et al., 1986) characterized by a continuous band-limited white noise and (2) chorus exhibiting a coherent, discrete emission (Hayakawa et al., 1984). A controversy exists whether those two types of VLF emissions are essentially different or not. The satellite and ground observations have frequently indicated their coexistence in the form of the chorus supposed to be triggered from the hiss(so-called hiss-triggered chorus). These hiss-triggered chorus events have been investigated in details in the present paper. The main emphasis of the analyses is placed on the wave spectra, direction finding measurement and fine structures within the hiss band, and then based on these results, we present how a chorus is generated from the hiss band.

2. Wave characteristics of hiss-triggered chorus and the wave normals of the hiss and chorus

Fig.1 illustrates an example of hiss-triggered chorus events observed near the equatorial plane ($\Lambda \sim 7°$) on GEOS-1 satellite at 12h15m U.T. on 21st July, 1977 (L value=6.5-6.7, L.T. $\sim$13h). A lot of chorus are found to appear from the upper edge of the hiss band, and the intensity of chorus elements is

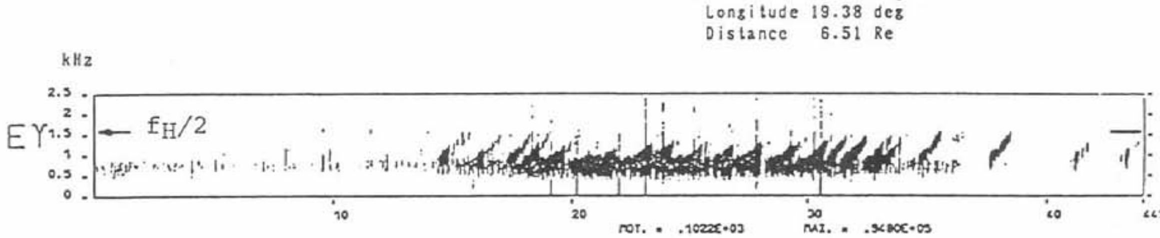


Fig.1 An example of hiss-triggered chorus observed near the equatorial plane on GEOS-1.

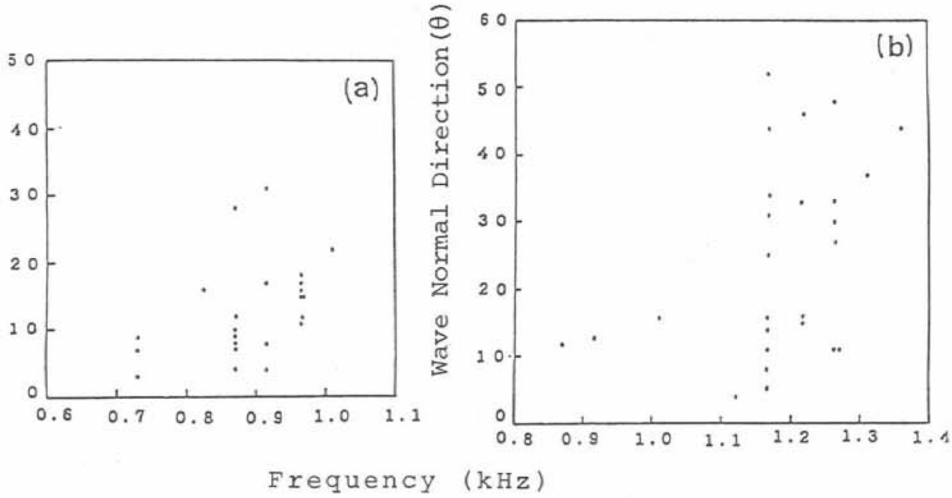


Fig.2 The wave normal directions of the hiss(a) and chorus(b) components of hiss-triggered chorus events.

obvious to be stronger than that of the hiss. Also, the spectrum of each chorus element at the beginning is asymptotic to the hiss band. Considering these together, we can conclude that hiss is the cause and chorus is the consequence. Fig.1 shows that the df/dt of chorus is, in linear fit, about 0.7kHz/s, which seems to be typical for natural chorus at the relevant L values and L.T.s(Burtis and Helliwell, 1976). When the hiss intensity becomes smaller by one order of magnitude, we find no chorus triggering.

The determination of wave normal directions of the causative hiss and resultant chorus has been performed on the basis of simultaneous multiple field components, and the corresponding result is given in Fig.2. The hiss is found to be propagating approximately along the magnetic field, and the wave normals of chorus make angles widely distributed from 0° to 60°.

Whether hiss is completely incoherent or not, is a big problem (Helliwell et al., 1986), and we have investigated the fine structure within the hiss band by means of the sophisticated spectral analyses. We have found that there are occasionally several monochromatic coherent wavelets with duration of a few tens of ms (Tsuji ey al., 1989). These coherent wavelets seem to play an important role in phase-bunching the electrons (Koons, 1981).

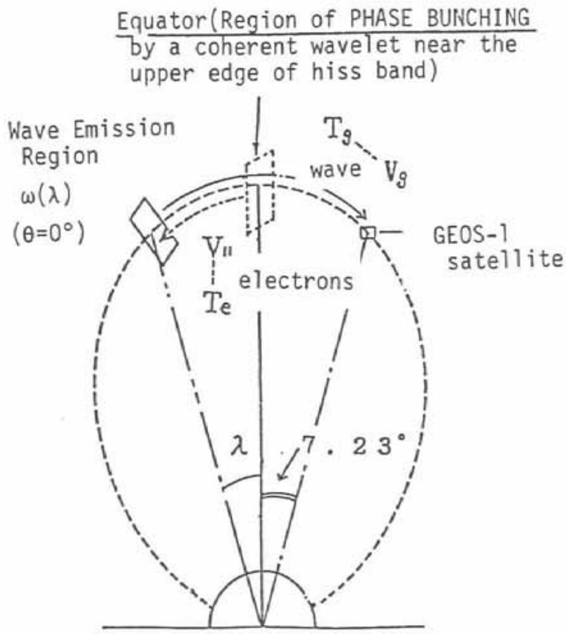


Fig.3 The proposed generation model of hiss-triggered chorus.

3. Generation mechanism of hiss-triggered chorus

Fig.3 gives a schematic illustration how a chorus is generated from the hiss. Two steps are involved in this model. As the first step, such coherent wavelets near the upper edge of the hiss band phase-bunch the electrons at the geomagnetic equator. Then, the next step is that those phase-bunched electrons travel away from the equator, radiating a coherent wave due to the cyclotron resonance. By using the measured hiss intensity, we have evaluated the phase-bunching time (Tb), and wave-particle interaction time (Tr), and it is found that the phase bunching is very possible by the intense wavelets in the hiss band. Fig.4 indicates the df/dt theoretically calculated on the assumption that the coherent wave is generated with $\theta=0°$ and of the two different kinds of propagation (ducted and non-ducted). The df/dt for non-ducted one is about 0.8kHz/s, is nearly identical with the observed value.

The important quantity θ is discussed here. Fig.5 indicates the θ value at the satellite in the case of non-ducted propagation after $\theta=0°$ generation. The value of θ greater than 35° are expected from the ray-tracing study, which is in sharp contrast with the observed result in Fig.2. In order to solve this discrepancy, there are three possibilities;(1) an extent in L value of generation region, (2) the emission angle is not

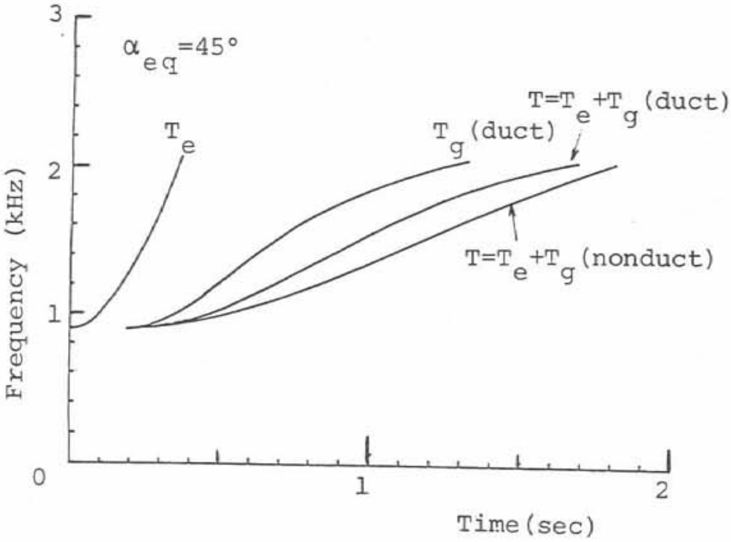
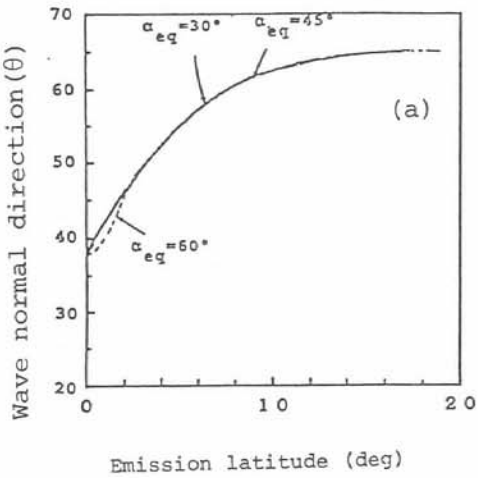


Fig.4 The dynamic spectra of chorus elements predicted from the theoretical considerations.



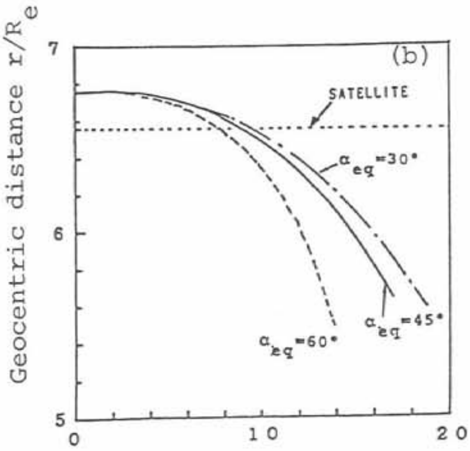


Fig.5 The wave normal (a) and the geocentic distance (b) at the satellite, predicted from the ray tracing study.

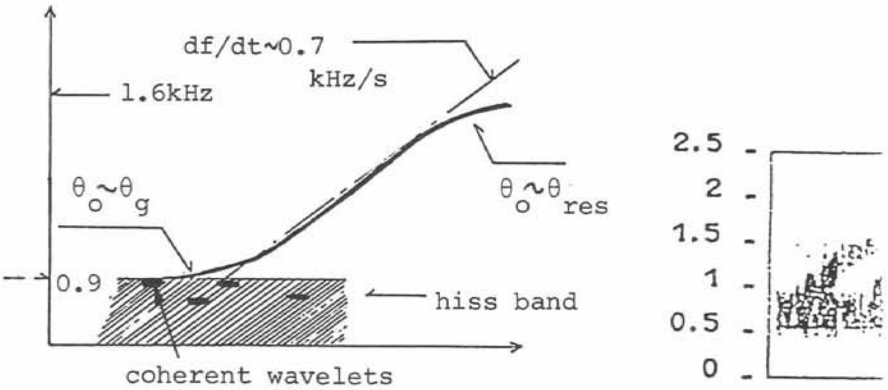


Fig.6
The final physical implication on the mechanism of hiss-triggered chorus.

exactly θ =0° and (3) a combination of the ducted and non ducted propagation modes. For these three factors, the same computations have been performed, and the final conclusion is as follows. The overall feature in Fig.2 can be satisfactorily interpreted in terms of the generation of oblique waves in the emission region. The initial θ around the starting frequency of a chorus is nearly θg (Gendrin angle)(this possibility was inferred by Goldstein and Tsurutani(1984)) and it increases to θres(oblique resonance angle) toward higher frequency component of the chorus. This important finding has been supported by the inverse ray-tracings based on the observed direction finding data at the satellite.

4. Conclusion

The coherent wavelets within the hiss band are found to be able to phase-bunch the electrons at the equator, and these bunched electrons radiates a coherent wave with oblique wave normal (θg to θres) due to the coherent cyclotron instability while they travel away from the equator.

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