CONTINUUM RADIATION OBSERVED BY GEOTAIL IN THE DISTANT MAGNETOTAIL

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1. Introduction

Terrestrial Continuum Radiation (CR) has been widely observed by many spacecraft in the magnetosphere. The CR is detected in the wide frequency range from 5 to 100 kHz, and is believed to be generated at the geomagnetic equator of the plasmapause over the 4–14 local time (LT) zone [*Gurnett and Shaw*, 1973; *Gurnett*, 1975]. The spectrum of the CR usually consists of diffuse, almost continuous structures. However, *Gurnett and Shaw* [1973] have identified a banded harmonic structure in the CR spectrum near the generation region. They have also found the two distinct lower cutoff frequnecies; one corresponding to the L-O mode cutoff frequency (same as the local plasma frequency (f_p)), and another the R-X mode cutoff frequency ($f_{R=0}$). This suggests that the CR propagates in both the L-O and R-X modes.

Gurnett [1975] classified the CR into lower-frequency trapped components (5∼20 kHz) and higher-frequency escaping components (20∼100 kHz). The trapped component, called magnetosheath trapped CR (MSCR) [*Nagano et al.*, 1994], is "trapped" within the magnetosphere, being reflected at the magnetopause. On the other hand, the escaping components above the plasma frequency in the solar wind propagate freely out of the magnetosphere, often with a banded harmonic structure. These types of CR are believed to be generated through a linear mode conversion from an electrostatic wave near the upper hybrid frequency (f_{UHR}) in a large density gradient perpendicular to the geomagnetic field [*Jones*, 1976] at the plasmapause. The frequency range of the CR indicates the electron density at the plasmapause, where f_{UHR} is close to f_p.

On the other hand, the CR has been observed by ISEE-3 and GEOTAIL spacecraft in the distant magnetotail region [*Coroniti et al.*, 1984; *Nagano et al.*, 1994]. *Nagano et al.* [1994] have shown that the CR at frequencies extending down to 1 kHz was observed along with an electron cyclotron harmonic (ECH) wave in the Lobe region, and suggested that such a low frequency CR, called "Lobe Trapped CR" (LTCR), is generated from the ECH wave near the plasma sheet boundary layer (PSBL). However, the source regions and the generation mechanism for the LTCR have not been identified yet.

In this paper, we try to identify the source region of the LTCR by a statistical analysis using a large number of plasma wave data obtained by GEOTAIL from September 1992 to October 1994. Furthermore, we compare the spectral characteristics of the LTCR with those of the MSCR generated at plasmapause, and discuss the posibility of the LTCR generation in the distant tail.

2. Continuum Radiation observed by GEOTAIL

The data set used in our statistical analysis is obtained with Sweep Frequency Analyzer (SFA) of the Plasma Wave Instrument (PWI) onboard GEOTAIL [*Matsumoto et al.*, 1994]. SFA has five wave receivers and measures overall wave amplitudes in the frequency range from 24 to 800 kHz. On the other hand, detailed spectra of the LTCR are obtained with Wave Form Capture (WFC) of PWI. The WFC can capture the wave forms of two electric and three magnetic components from 10 Hz to 4 kHz. We can analyze detailed frequency-time structures of the LTCR in the distant tail region.

PWI is connected to the two kinds of electric sensors and a tri-axial search coil. Two set of long dipole antennas with a length of 100m tip-to-tip are extended perpendicularly to the GEOTAIL spin axis. They are wire and probe antennas termed “WANT” and “PANT,” respectively. The magnetic sensors are mounted on a mast with the length of 6 m from the spacecraft body.

Figure 1(a) shows an example of the dynamic spectrum of the electric field obtained by Sweep Frequency Analyzer (SFA), when GEOTAIL is located at about 91 R_E tailward from the Earth in the Lobe region on January 26, 1993. The horizontal axis is the universal time (UT) and the vertical axis is the frequency. The MSCR is observed for almost all the time in the frequency range from 7 to 30 kHz, while The LTCR is observed from 13:15 UT to 13:43 UT, 14:00 UT to 14:13 UT, and 14:16 UT to 15:00 UT in the frequency range from 800 Hz to 4 kHz. Figure 1(b) shows the spectrum averaged over 1 minute at 14:30. In this case, the LTCR is well separated from the MSCR and the amplitude of the LTCR is larger than that of the MSCR.

3. Statistical Analysis of the LTCR Source Region

In this section we perform a statistical analysis of the LTCR intensities to identify its possible source regions. The data set for the statistical analysis is obtained by SFA from September 1992 to October 1994. In Figures 2(a) and (b) the observed locations of the LTCR and the MSCR, respectively, during these two years are plotted on the ecliptic plane in the GSM’ coordinate system (the GSM’ coordinate system modified with the actual solar wind flow direction). The MSCR are widely observed in magnetosphere, while the LTCR are observed mainly in the distant magnetotail.

In the statistical analysis the intensities of the LTCR are averaged over every 64 seconds between the lower and upper cutoff frequencies, which are obtained from the maximum and minimum, respectively, of intensity change with frequency (dE/df) with the 3-point Lagrangian interpolation scheme. For the case of the MSCR, the intesities are averaged in the similar way.

The source region can be estimated by comparing the intensities of the LTCR with those of the MSCR. In the past studies, the source regions of the MSCR and the escaping CR were determined by examining the spatial distribution of the intensities of these waves [*Gurnett*, 1975]. Figure 3(a) shows the variation of the intensity ratio between the LTCR and the MSCR, $\beta = \mathrm{E_{LTCR}/E_{MSCR}}$, versus $\mathrm{E_{LTCR}}$, where $\mathrm{E_{LTCR}}$ and $\mathrm{E_{MSCR}}$ are the intensities of the LTCR and the MSCR, respectively. We can see that as the intensity of the LTCR becomes large, the β becomes gradually large. This result indicates that the intensities of the LTCR become larger than those of the MSCR when GEOTAIL comes close to the source region of the LTCR. The spatial distributions of the LTCR for $\beta > 0$, corresponding to $\mathrm{E_{LTCR}}$ becomes larger than the average MSCR intensity of -153 dBV/m/$\sqrt{\mathrm{Hz}}$, are shown in Figures 3(b)$\sim$(d). The percentage of occurence of such “source regions of the LTCR” becomes high in the spatial region from 30 R_E to 100 R_E in $\mathrm{X_{GSM'}}$, and the source region of LTCR scarcely exists in the distant tail region ($X_{GSM'}$ <-150) as shown in Figure 3(b). It should be noted that the percentage of occurance is extremely high at $X_{GSM'} = -125\mathrm{R_E}$. Furthermore, the source regions of the LTCR concentrate at the southward near PSBL and the North mantle region as shown in Figure 3(d).

4. Wave Form Analysis of the LTCR

The detailed spectral structure of the LTCR can be analyzed with WFC data. The LTCR is classified into three types by their frequency-time structures as shown in Figures 4(a)$\sim$(c), which show the dynamic spectra of electric field components between 0 and 4 kHz over 8 seconds. The LTCR shown in Figure 4(a) has a banded harmonic structure of an electrostatic (n+1/2) ECH wave, where the spacing between the harmonics (indicated by the horizontal solid lines) coincides with the locally observed electron cyclotron frequency. Such a spectral structure should possibly be observed near the LTCR source region. In Figures 4(b) and (c), the two distinct lower cutoff frequencies can be confirmed. The lower and upper ones correspond to the local plasma frequency (f_p) and the R-X mode cutoff frequency ($f_{R=0}$) [cf. *Nagano, et al.*, 1994]. In this case the intensities of the LTCR become constant above those cutoffs, so that they seem to be the mixture of the CR waves generated at different frequencies at different locations.

Figure 5 shows the polarization hodograms of the LTCR shown in Figure 4(b) in the frequency range (a) from 1.7 kHz to 1.75 kHz, and (b) form 2.1 kHz to 2.15 kHz, respectively. We can confirm that the components of the LTCR between $f_{R=0}$ and f_p shows the polarization of L-O mode as in Figure 5(a). On the other hand, the polarization above $f > f_{R=0}$ in Figure 5(b) shows the hybrid mode of L-O and R-X mode. Such characteristics are the same as those of the MSCR. Thus, the LTCR can be generated in the distant tail region by the same generation mechanism for the MSCR.

5. Conclusions

The statistical analysis shows the averaged distribution of the LTCR source regions. The source regions of the LTCR widely distributes over the distant tail region, and concentrates at the southward of the transition region between Lobe and PSBL. The results also indicates another possibility that the source region may exist in high latitude of mantle region, which is transition region from Lobe to magnetosheath.

The wave form analysis shows that the spectral structures and polarization of the LTCR are same as those of the MSCR generated near the plasmapause. This suggests that the LTCR is generated in the distant tail regions via a similar process to generate the MSCR near the plasmapause.

In the future we will discuss the possibility of generation of the LTCR in such distant tail regions by investigating the relationship among wave activities, plasma conditions, and geomagnetic activities.

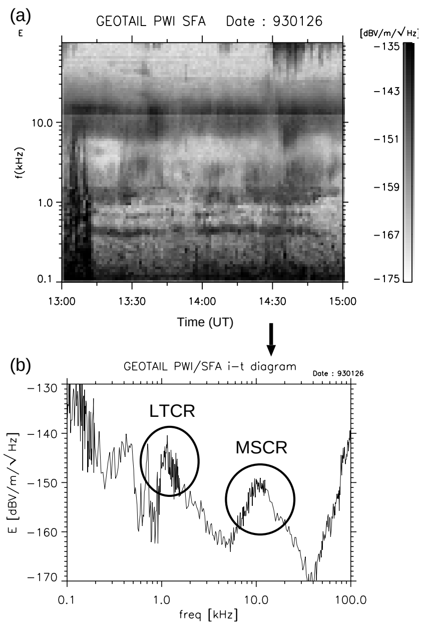

Figure 1 : An example of Lobe Trapped CR observed by the SFA from 13:00 to 15:00 UT on January 26, 1993

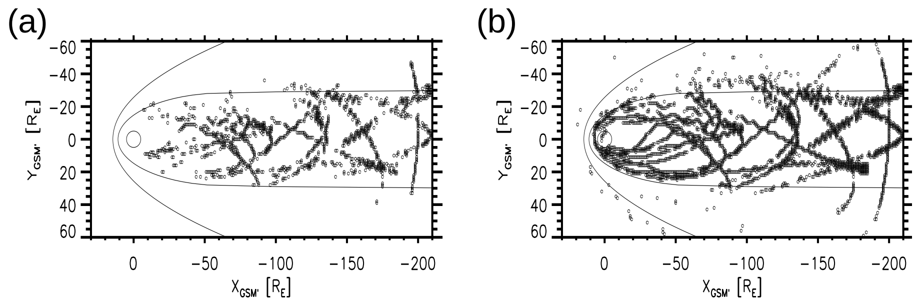

Figure 2 : The observed locations of (a) Lobe Trapped CR and (b) Magnetosphere Trapped CR, from September 1992 to October 1994 in the GSM' coordinate system

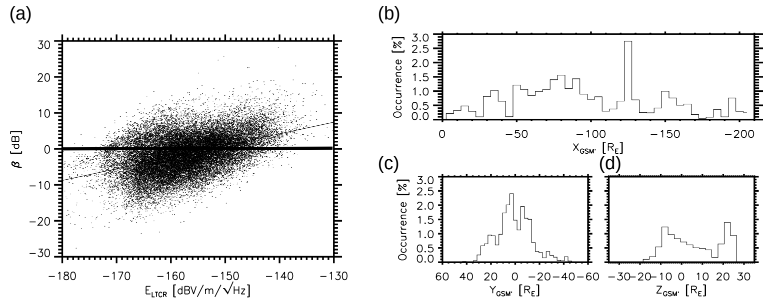

Figure 3 : (a) Correlation between the intensities of Lobe Trapped CR and the those of MS Trapped CR

(b)∼(d) The spatial distribution of source regions for the LTCR

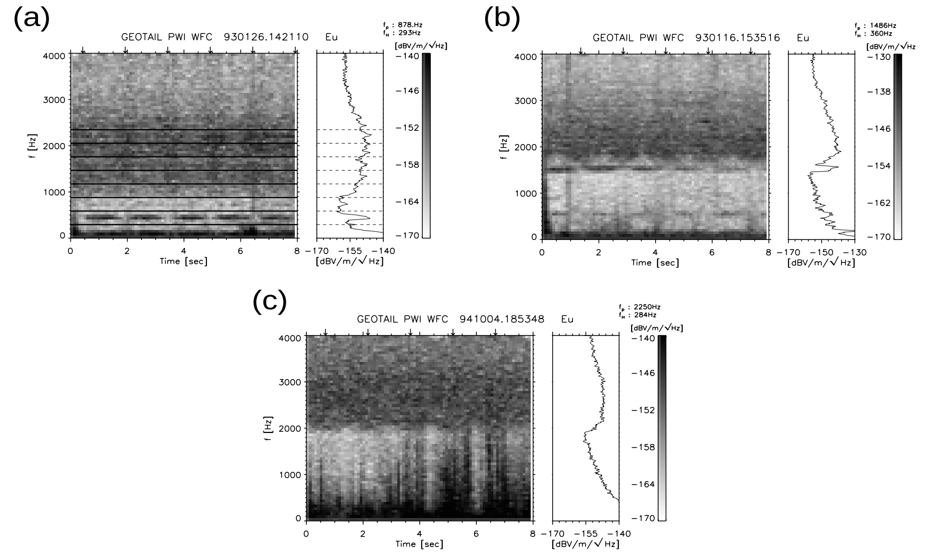

Figure 4 : Dynamic spectra of the LTCR obtained by WFC at (a) 14:21:10 UT on Jan. 26, 1993, (b) 15:35:16 on Jan. 16, 1993, and (c) 18:53:48 on Oct. 4, 1994

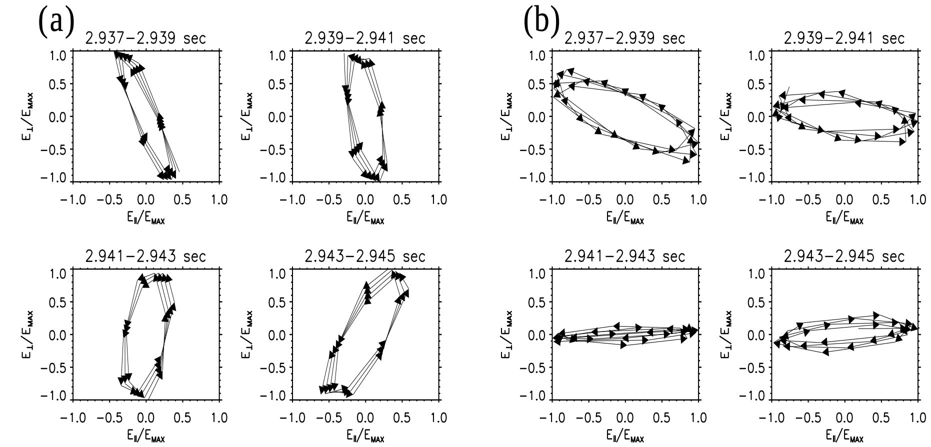

Figure 5 : The polarization of the LTCR at 15:35:16 UT on Jan. 16, 1993.

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