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Kilometric Continuum and its Propagation Characteristics Observed with Multiple Satellites

K. Hashimoto[1], J. L. Green[2], R. R. Anderson[3], and H. Matsumoto[1]

[1]*RISH, Kyoto University*
[2]*NASA/GSFC, USA*
[3]*University of Iowa, USA*

Kilometric continuum radiation is the high frequency extension of escaping continuum emissions in the frequency range from 100 kHz to 800 kHz first identified with the GEOTAIL and has been observed with various satellites. An example of CRRES observations reveals a possibility that kilometric continuum has been radiated as a wide beam emission contrary to the continuum theory. The IMAGE and GEOTAIL simultaneous observations have indicated another new evidence of a very broad emission cone.

1. Introduction

Kilometric continuum radiation was first identified in the Sweep Frequency Analyzer (SFA) data of the GEOTAIL Plasma Wave Instrument (PWI) [1] as the high frequency extension of escaping continuum emissions in the frequency range from 100 kHz to 800 kHz[2]. It consists of from a few to many narrow-band emissions that are observed mainly near the magnetic equator. The other emissions most frequently encountered in this range are Auroral Kilometric Radiation (AKR) and Type III solar radio bursts. The kilometric continuum frequency spectra are composed of discrete components like escaping continuum, and its intensities are usually much weaker than AKR but are similar to those of escaping continuum [3] as shown in Figure 1.

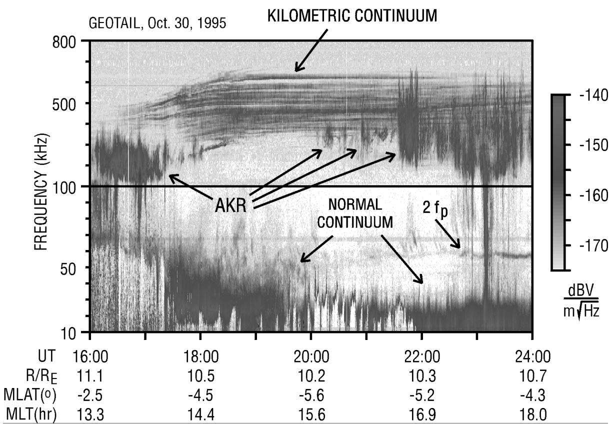

Fig. 1. Kilometric Continuum [2].

The source mechanism is expected to be the mode conversion of electrostatic waves into electromagnetic waves near the plasma frequency [4]. The CRRES satellite [5] had a quasi-equatorial orbit and observed much kilometric continuum including source regions inside the plasmapause. An interesting spectral structure observed by CRRES is examined to test the linear mode conversion theory [4,6].

The IMAGE Radio Plasma Imager (RPI) observations [7] have indicated that kilometric continuum radiation is generated at the equatorial plasmapause within a notch region of the plasmasphere [8]. A simultaneous kilometric continuum observation by GEOTAIL and IMAGE is also examined and it indicates a wide beam emission contrary to Jone's beaming theory.

2. Propagation of kilometric continuum

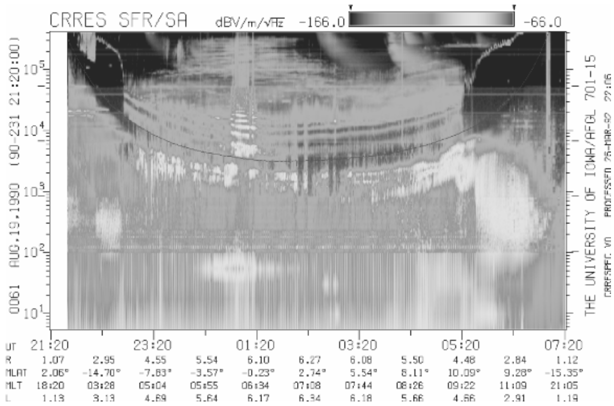

Fig. 2. CRRES observations on August 19, 1990. A notch-like structure is seen 2200-2220 UT. Note the structure of the narrow band emissions above 100 kHz from 2320-0300.

Kilometric continuum radiation was observed by CRRES near the equator on August 19, 1990, as shown in Figure 2, which extends for 10 hours beginning at 21:20 UT. The emissions observed between 2150 and 2210 might be the ones inside a notch. New interesting characteristics of the kilometric continuum are seen above 100 kHz from 2320 UT to 0320 UT while CRRES was well outside the plasmapause. The low frequency normal continuum and the higher frequency kilometric continuum could have different source regions. In fact the small break in the emission spectra around 80 kHz gives one the impression that they are coming from two distinct sources. The durations of the emissions are different for frequencies from 100 to 300 kHz. Below 300 kHz, the durations are longer at lower frequencies. If the durations were limited by a plasma wall like a notch extending in longitude, they would be longer for higher frequencies. Therefore, they could be related to the effect of the beaming.

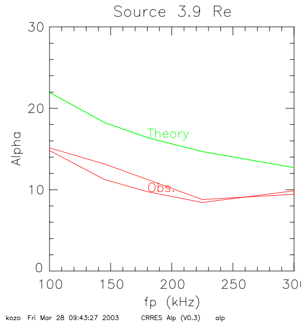

Fig. 3. Comparison between the observations (red) and the theory (green) of the alpha angle as a function of frequency. The positions of the plasmapause is 3.9 Re.

The beaming angle is defined as $\alpha = \tan^{-1}(f_{\mathrm{H}}/f_{\mathrm{p}})$, where f_{H} and f_{p} are the local cyclotron and plasma frequencies, respectively [6]. The angle is estimated from an angle measured from an assumed source position (3.9Re) to the start and end positions for each frequency. Since the radiated frequencies are equal to the plasma frequencies and the cyclotron frequency is assumed to be 14.8 kHz at 3.9 Re based on the dipole model, α can be calculated as shown in Figure 3. The theoretical and observed values are shown. At and below 225 kHz, the observed trends are quite similar and consistent with the theory, but the values are different. The 300 kHz observation in Figure 3 shows higher α and this trend is consistent if its source altitude is lower, which means higher f_{H}. Since the source of the 300 kHz waves are expected to be further inside the plasmapause according to Figure 2 where the local f_{H} is higher, its theoretical α is expected to be larger. These results for our kilometric continuum radiation observations are consistent with the objections to the theory raised by a study of terrestrial continuum radiation [9].

3. Geotail and IMAGE simultaneous observetions

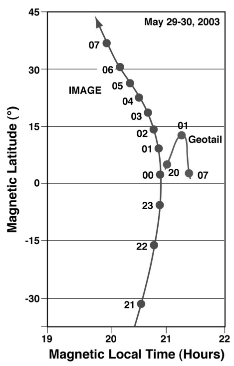

Fig. 4. IMAGE and GEOTAIL orbits on May 29–30, 2003.

The IMAGE RPI and GEOTAIL PWI simultaneously observed kilometric continuum in the frequency range from 400 kHz to 750 kHz. IMAGE moved from the southern hemisphere to 30°N. On the other hand, GEOTAIL moved from 4.4°N to 12.3°N at 01 UT, then 2.4°N as shown in Figure 4. Both satellites observed almost the same spectra in a wide latitude range of more than 30°. The kilometric continuum was received during the disturbed time, especially Kp $>$ 7 from 20 UT to 03 UT. The kilometric continuum with quite good similarity in both spectra including the fine structures can be seen from 21 UT to 06 UT. Their longitudes are close within 10°. These observations are very uncharacteristic of kilometric continuum reported by [2] and [8] due to the wide latitudinal spread of the emission observed by IMAGE RPI. The intensity observed by IMAGE is weaker around 400 kHz after 0430 UT where the satellite is in latitudes higher than 25°. It would be difficult to explain these quite similar spectra by multiple narrow beam sources. This can be rather explained if the sources radiate in wide directions in latitude and both satellites receive the emissions from the same or close sources contrary to the beaming theory.

4. Conclusion

The beaming theory shows a good conversion rate at a beaming angle. *Jones* [10] indicated more precise conversion rate using the full-wave theory. There are, however, no conversion near the equator. On the other hand, the CRRES and IMAGE satellites observed kilometric continuum in wide latitudes including the equator. The beaming theory is not consistent with the present observations since they were ibserved in wide angles including the equator. The theory itself is just an application of Snell's law. The conversion of Z mode waves to O mode waves is basically expected to follow this theory. Since our observations, however, indicated clear objections, new explanation on the propagation of continuum is expected.

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