SPECTRAL FEATURES IN AURORAL KILOMETRIC RADIATION

M. Y. Boudjada*, V. N. Kuril'chik†, H. O. Rucker*, D. F. Vogl*, and E. Kaufmann‡

Abstract

We report on the occurrence probability of auroral kilometric radiation (AKR) events based on data of the INTERBALL/AKR–X experiment. This experiment consists of six channels covering the frequency range from 100 kHz to 1.5 MHz. The multichannel is connected to a loop antenna used for performing electromagnetic measurements. In the AKR registrations we distinguish two different structures: continuum and bursty emissions. We use the observed spectra as a criterion to separate between the two types which appear smooth in the case of the continuum and bursty in the case of bursty emission. Taking into consideration the occurrence of each type of structure, we can note that: (a) the continuum seems to be associated to the late evening sector of the Earth magnetosphere when the bursty is related to the early morning sector and (b) the appearance of the AKR continuum is clearly anti–correlated to the occurrence of AKR bursty emission. The analysis of the observation conditions enables to show that the hollow cone associated to the AKR emission has different geometric configurations with regard to the satellite positions. We compare our results to the Viking observations and we derive the propagation mode of the bursty and continuum AKR emission.

1 Introduction

The auroral kilometric radiation (AKR) is an intense electromagnetic emission originating high above the auroral regions and is associated with discrete auroral arcs. This emission is observed in the frequency range from 50 to 700 kHz with a peak intensity around 200 kHz [Gurnett, 1978]. The average power radiated from Earth by AKR has been estimated to be 10^7–10^8 Watts [Gallagher and Gurnett, 1979]. The spectrum has upper and lower cutoff frequencies which fluctuate over a wide range on a time scale of tens of minutes.

*Space Research Institute, Austrian Academy of Sciences, Schmiedlstrasse 6, A–8042 Graz, Austria
†Sternberg Astronomical Institute, Moscow State University, 119899 Moscow, Russia
‡Institute for Geophysics, Astrophysics and Meteorology, University of Graz, Halbärthgasse 1, A–8010 Graz, Austria

AKR is emitted in discrete bursts lasting only a few seconds or less. The dominant mode of the free propagating AKR waves is the R–X mode and is usually accompanied by L–O mode waves at a factor of 10 to 100 lower amplitudes [Kaiser et al., 1978; Mellot et al., 1984]. This auroral emission consists of extraordinary–mode waves emitted near the electron cyclotron frequency, approximately perpendicular to the Earth's magnetic field. AKR is believed to be generated by the Doppler–shifted cyclotron resonance instability [Wu and Lee, 1979], and it originates in a plasma cavity which extends from 1.3 to at least 3.3 Earth radii at 70° invariant magnetic latitude [Calvert, 1981].

2 AKR–X experiment

The INTERBALL–1 (Tail probe) satellite was launched on August 3, 1995 over the Northern polar region. The spacecraft orbit is highly eccentric (eccentricity of about 0.93) with a 62.8° inclination, an apogee of 31 R_E geocentric, a perigee altitude of 796.7 km and an orbital period of 91.7 hours. We use the observed spectra as a criterion to separate between the two types which appear smooth in the case of the continuum and bursty in the case of bursty emission. It is important to note that in this study we only take into consideration the event where the separation between the two types is clearly evident. During the considered period (from August 4 through December 31, 1995) the auroral kilometric radiation is continuously observed. The occurrence probability in magnetic local time (MLT) shows two maxima for each type of structure.

3 Observations

3.1 AKR bursty events

From the AKR–X experiment data observed from August to December 1995, we select the bursty AKR emission which corresponds to 42% of the total AKR events. It is characterized by a frequency bandwidth larger than 300 kHz and an occurrence duration from few minutes up to several hours (and days). This emission has a variable intensity with regard to the background level from -14 dB and up to -12 dB with a signal/noise ratio of about 10^3.

The bursty emission has an occurrence probability in MLT with two maxima, 22 MLT and 03 MLT, mainly related to the early morning sector of the magnetosphere. Table 1 summarizes the activity of AKR bursty emission which seems to be important before and after the equinox, i.e. 27% and 42% for September and October, respectively. After this period the AKR burst activity decreases in particular close to the solstice. On the other hand, the satellite magnetic latitude of the AKR bursty events, on average, is found to decrease from 42° to 34° (end of October) and increases to 47° in the end of the year. The maximum intensity level seems to be independent on the occurrence of the AKR bursty emission.

Table 1: Occurrence of the AKR bursty emission observed from 08th August, 1995 to 31st December, 1995.

Period of observations	Day of Year	Structure	Occurrence	Magnetic Local Time	Magnetic Latitude
04/08 to 31/08	216-243	Burst	19%	05:00 MLT	42 °
01/09 to 30/09	244-273	Burst	27%	02:30 MLT	39 °
01/10 to 31/10	274-303	Burst	42%	04:30 MLT	34 °
01/11 to 30/11	304-334	Burst	7%	01:30 MLT	40 °
01/12 to 31/12	335-365	Burst	3%	23:00 MLT	47 °

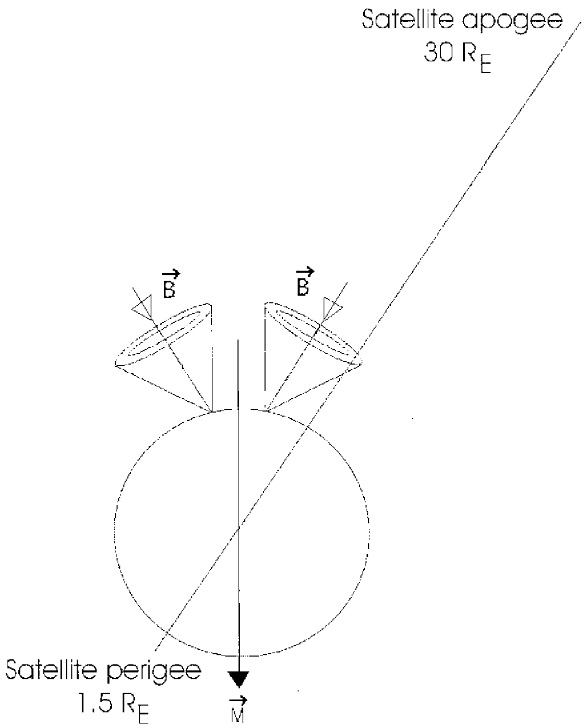

Figure 1: Observational geometrical conditions before and close to the autumn solstice.

3.2 AKR continuum events

As for the AKR bursty emission, the AKR continuum events were observed from August to December 1995. Those events have a frequency bandwidth of less than 200 kHz and an occurrence duration of about one to five hours. The intensity is found two or three orders of magnitude less than the AKR bursty emission with a signal–to–noise ratio of about 10^2.

Table 2: Occurrence of the AKR continuum emission observed from 08th, August, 1995 to 31st, December, 1995.

Period of observations	Day of Year	Structure	Occurrence	Magnetic Local Time	Magnetic Latitude
04/08 to 31/08	216-243	Contin.	4%	06:30 MLT	32 °
01/09 to 30/09	244-273	Contin.	1%	05:30 MLT	36 °
01/10 to 31/10	274-303	Contin.	10%	00:00 MLT	38 °
01/11 to 30/11	304-334	Contin.	28%	23:00 MLT	38 °
01/12 to 31/12	335-365	Contin.	57%	22:00 MLT	34 °

The occurrence distribution of the continuum events in magnetic local time seems to be related to the evening sector of the magnetosphere. In Table 2 we note the presence of two maxima, at 22 MLT and 01 MLT, observed few weeks before and close to the winter solstice. In the beginning the continuum activity is observed in the late morning sector (06:30 MLT) on August 10, 1995, shifted to the early morning sector (0:00 MLT) on November 1, 1995 and appeared in the late evening on December 24, 1995. The satellite magnetic latitude of the AKR continuum emission is found to increase, from August to the end of October, and decrease up to 20° magnetic latitude on December 24, 1995.

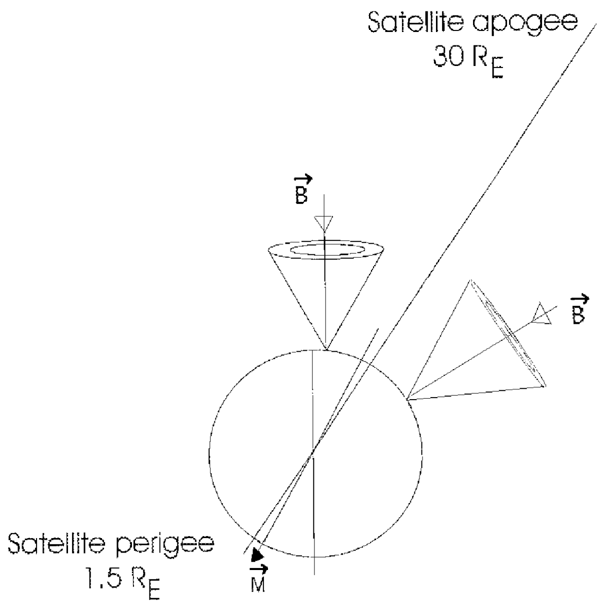

Figure 2: Observational geometrical conditions before and close to the winter solstice.

4 Discussion and conclusion

The analysis of the auroral kilometric radiation observed by INTERBALL–1 satellite allows us to characterise the observational features of the AKR bursty and continuum emissions. It appears that the seasonal effect could be responsible for the increase of the continuum occurrence. We also note that the anti–correlation of bursty and continuum emission is due to geometrical configurations of the source and the satellite positions. As it is well known the radiating diagram of the cyclotron maser instability [Wu and Lee, 1979] is a hollow cone. According to the Viking observations [de Feraudy et al., 1988; Louarn and Le Queau, 1996] when the satellite was close to the source region, the inner part of the hollow cone is associated to the X–mode when the external part is related to the O–mode.

We show in Figures 1 and 2 the geometrical conditions of the satellite's position with regard to the hollow cone for the two sub–periods: before and after the equinox of the autumn (Figure 1) and before and close to the solstice of the winter (Figure 2). Taking into consideration the Viking results, it appears that the X–mode could be related to the AKR bursty structure emitted from the inner part of the hollow cone which intersects the main part of the satellite orbits. When the O–mode is associated to the AKR continuum structure radiated from the external part of the hollow cone, this radiation intersects the main part of the satellite orbits before and close to the winter solstices periods.

Fundamental questions emerge from our investigation:

a) Which part of the loss cone distribution generates the smooth and the bursty structures?
b) Is there a possibility to check the mode propagation of the continuum and bursty emission?

Future investigations should allow us to answer to these questions using observations of the Geotail/PWS experiment which covers the same frequency band (few kHz and up to 800 kHz). We also attempt to increase the period of study, from five months to one year, which enables a better analysis of AKR occurrence and its relationship to the seasonal effect.

Acknowledgements: V. Kuril'chik thanks the Austrian Academy of Sciences for financial support during his visit to the Space Research Institute, Graz (Austria).

References

Calvert, W., The auroral plasma cavity, *Geophys. Res. Lett.*, **8**, 919, 1981.

De Feraudy, H., A. Bahnsen, and M. Jespersen, Observations of nightside and dayside auroral kilometric radiation with Viking, in *Planetary Radio Emissions II*, edited by H. O. Rucker, S. J. Bauer, and B. M. Pedersen, Austrian Academy of Sciences Press, Vienna, 41–60, 1988.

Gallagher, D. L., and D. A. Gurnett, Auroral kilometric radiation: Time averaged source position, *J. Geophys. Res.*, **84**, 6501, 1979.

Gurnett, D. A., Electromagnetic plasma wave emissions from the auroral field lines, *J. Geomag. Geoelectricity*, **30**, 257, 1978.

Kaiser, M. L., J. K. Alexander, A. C. Ridle, J. B. Pearce, and J. Warwick, Direct measurements by Voyager–1 and –2 of the polarization of terrestrial kilometric radiation, *Geophys. Res. Lett.*, **5**, 857, 1978.

Louarn, P., and D. Le Queau, Generation of the Auroral Kilometric Radiation in plasma cavities: I. Experimental study, *Planet. Space Sci.*, **44**, 199, 1996.

Mellot, M. M., W. Calvert, R. L. Huff, D. A. Gurnett, and S. D. Shawhan, DE–1 observations of ordinary mode and extraordinary mode auroral kilometric radiation, *Geophys. Res. Lett.*, **11**, 1188, 1984.

Wu, C. S., and H. K. Lee, A theory of the terrestrial kilometric radiation, *Astrophys. J.*, **230**, 621, 1979.