CORRELATIONS OF AKR INDEX WITH $K_p$ AND $Dst$ INDICES

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Abstract: After initial observations of Auroral Kilometric Radiation (AKR), their associations with substorms had been intensively investigated during 1970's. Herein we extend these studies and propose a new index available for substorm studies, named the AKR index. We define the AKR index by the power flux of AKR normalized to a reference distance from the Earth. The AKR index is found to show good correlations with $K_p$ and $Dst$ indices for weak magnetic disturbances. The AKR index tends to saturate for moderate and severe disturbance.

1. Introduction

The GEOTAIL Plasma Wave Instrument (PWI) (Matsumoto et al., 1994) has observed a variety of plasma waves including Auroral Kilometric Radiation (AKR). Various studies so far have discussed the time-dependent AKR emissions associated with magnetospheric substorms. Gurnett (1974) and Kaiser and Alexander (1977) pointed out a close relation between AKR and auroral electrojet (AE) index. In spite of their successful results, the association of AKR emissions with magnetospheric substorms has not been explicitly studied since them. Generally, empirical evidence has suggested that a sudden enhancement of AKR could be a clear signature of substorm onsets. Murata et al. (1995) defined substorm onsets using AKR sudden enhancements. However, the relation between the AKR sudden onsets and the magnetospheric substorm onsets identified by other signatures such as Pi 2 pulsation has been still unclear. In this paper we propose a new index called the AKR index for use in substorm studies, to examine the relationship between this index with other two indices, $K_p$ and $Dst$ indices.

2. Definition of AKR Index

Figure 1 represents a dynamic spectrum (0–800 kHz) of AKR and other plasma waves observed by GEOTAIL. The GEOTAIL/PWI team has observed the AKR with the Sweep Frequency Analyzer (SFA). The frequency sweep time is 8 s, so we obtain the 8 s value of AKR power flux.

We define the AKR index by the power flux of the observed AKR normalized to
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a reference distance from the Earth. In formatting the AKR index we remove the dependence on the satellite position. We first apply the following normalization equation to the observed signals:

\[ E_0 = E(r) \frac{r}{r_0} \frac{V}{m/\sqrt{\text{Hz}}} \]  

(1)

where \( r \) is the distance from the Earth to the spacecraft, \( E(r) \) and \( E_0 \) represent the amplitude of the observed and normalized electric field of AKR respectively, and the suffix 0 denotes the parameter at the reference distance \( (r_0 = 25 \text{ RE \ in \ the \ present \ study}) \). Then we integrate the normalized power flux over the frequency from 50 kHz \((=f_i)\) to 800 kHz \((=f_o)\):

\[ \frac{\int_{f_i}^{f_o} E^2 \, df}{f_o - f_i} \frac{V^2}{m^2/\text{Hz}} \]  

(2)

We define the AKR index \( e \) by the logarithmic AKR power flux \((\text{dBV/m/}\sqrt{\text{Hz}})\). The noise level of the SFA detector onboard GEOTAIL is about \(-180 \text{ dBV/m/}\sqrt{\text{Hz}}\). When GEOTAIL is located at the largest apogee, the noise level becomes \(-160 \text{ dBV/m/}\sqrt{\text{Hz}}\) after the normalization with eq. (1). We exclude signals smaller than \(-160 \text{ dBV/m/}\sqrt{\text{Hz}}\) from the integration in eq. (2).

The present frequency range (between 50 kHz and 800 kHz) is reasonable since most of the AKR power fluxes appear in this frequency range. In this range, however, we occasionally observe TYPE III solar bursts (Fig. 1). Thus, at strong TYPE III solar burst periods, the AKR index is contaminated by solar bursts.

3. AKR Index Correlated with Kp and Dst Indices

Our attempt is to prove that the AKR index is a useful index. One of the greatest interests is the result of its comparisons with Kp and Dst indices. The latter two indices are frequently referred to in the study for a long-term activity of the magnetosphere. Note that the Kp index is usually provided every three hours and
Fig. 2. Correlation of AKR index with Kp index statistically averaged over one year (from January 1993 to December 1993). The vertical line at each Kp value represents the standard deviation of logarithmic AKR index value. The straight line in the figure represents the least square fit calculated from the plots for Kp less than 4. This line is given as $\varepsilon = -151.0 + 5.65 \text{Kp}$.

The $Dst$ every one hour.

Figure 2 indicates the $AKR$ index vs. $Kp$ index plots for one year (from January 1993 to December 1993). We used three-hour average of the $AKR$ index for the direct comparison with the $Kp$ index. The vertical lines are the standard deviations of the $AKR$ index at each $Kp$ value. The $AKR$ index is proportional to the $Kp$ index when the $Kp$ is smaller than 4. The straight line in the figure represents the least square fit calculated from the plots for $Kp < 4$. This line is given as $\varepsilon = -151.0 + 5.65 \text{Kp}$ where $\varepsilon$ represents the $AKR$ index. When the $Kp$ is greater than 4, however, we find no strong dependence of the $AKR$ index on the $Kp$ index.

Figure 3 shows scatter plots of the $AKR$ index against the $Dst$ index during the same interval as in Fig. 2. We again find a linear relation between the $AKR$ and $Dst$ indices when the $Dst$ value is between is $-50$ and 0. (Note that the $Dst$ becomes greater as the geomagnetic disturbance becomes smaller.) At severe ($Dst < -50$) or weak ($Dst > 0$) disturbance period, we see no strong dependence of $AKR$ on the $Dst$ index. This reminds us of the similar tendency between the $AKR$ and the $Kp$ index in Fig. 2.

It is notable that the value of the $AKR$ index at the turnover points in Fig. 2 ($Kp = 4$) and in Fig. 3 ($Dst = -50$) are about $-132 \text{ dBV/m/Hz}$. These coincidences remind us of the studies by Voots et al. (1977) and Gallagher and D'Angeolo (1981). Voots et al. pointed out in their statistical study that two different stages exist in the correlation between the $AKR$ power flux and the $AE$ index. Gallagher and D'Angeolo investigated the correlation of $AKR$ power flux with a variety of the solar wind parameters. They found that the solar wind velocity shows a good parallelism with the $AKR$ power and is divided into two levels. The
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Fig. 3. Correlation of AKR index with Dst index statistically averaged over one year (from January 1993 to December 1993). The vertical line at each Dst value represents the standard deviation of logarithmic AKR index value.

4. Summary and Discussions

The close relationship between Auroral Kilometric Radiation (AKR) and magnetospheric substorms has been pointed out in its early studies (e.g., Gurnett, 1974). Even though Gurnett demonstrated “AKR as an indicator available for substorm studies”, AKR has rarely been used practically as an index. AKR is observed by GEOTAIL for most of the time in the magnetotail, and the upper frequency limit of the intense AKR is usually lower than 800 kHz (Gurnett, 1991), which is the upper frequency of the SFA. These conditions enabled us to propose the AKR index as a new practical index.

We defined the AKR index by the AKR power flux normalized to a certain distance (25 RE) from the Earth. In order to demonstrate the utility of the AKR index for substorm studies, we compared the AKR index with Kp and Dst indices. At the low geomagnetic activity period, the AKR index shows a linear relationship with the geomagnetic indices of Kp and Dst. These useful results imply a straightforward adequacy of AKR index as a substitute for the geomagnetic indices.

The Kp index becomes greater and the Dst index becomes smaller during high activity periods, whereas the AKR index tends to saturate contrary to the linear relationship at the low activity period. AKR is excited with the growth of the turnover points in the both studies coincide each other (the AKR power at the turnover point is \(-132\) dBV/m/Hz if normalized to \(r=25\) RE from the Earth). Taking account of these results, Gallagher and D'Angelo concluded that the solar wind velocity controls both AKR emissions and geomagnetic activities. The present result shows a good agreement with their conclusions.
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electron cyclotron maser instability resonanced with the electrons precipitating into the auroral region. These electrons come from the tail plasma sheet and are accelerated in the inverted-V potential (Gurnett, 1974; Benson and Calvert, 1979). The inverted-V potential is believed to be formed through wave-particle interactions with precipitating electrons. Thus, the growth of the potential is saturated when a large amount of particles precipitate at the severe disturbance period. This possibly causes the saturation of the AKR index at the high activity period. We need further investigations of the saturation process through the direct comparison between the AKR index and particle precipitations observed in the ionosphere.

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References


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