DEPENDENCE OF VLF WAVE ACTIVITY AT SYOWA STATION ON THE DAY OF THE WEEK

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Abstract: In reference to the Sunday decrease of VLF activity observed at Siple Station, VLF wave multi-frequency channel data stored in magnetic computer tapes at Syowa Station have been analyzed for the period from July 1981 to December 1983. Using 2 s sampling data, at 0.75, 1.2 and 2.0 kHz, a minimum for every 10 s is picked up and is then averaged over one hour. From these hourly values for the whole period of analysis, the diurnal variation of the intensity at each frequency for the average of all Sunday data is compared with that drawn for data of the rest of the week (ROW). From this result, we cannot confirm any significant difference on Sunday in comparison with another day of the week.

1. Introduction

It has been considered that the VLF emission activity in the magnetosphere is influenced by the radiation from power lines on the ground. Several such evidences have been found, for example, in the VLF spectra observed at Siple and Roberval Stations (HELLIWELL and KATSUFRAKIS, 1974; HELLIWELL *et al.*, 1975) and world-wide VLF noise distribution at 3.2 and 9.6 kHz observed by Ariel 3 and 4 (BULLOUGH and KAISER, 1979). PARK and MILLER (1979) found that VLF electric field intensity in the frequency range from 2 to 4 kHz observed at Siple Station shows a minimum on Sunday among other days of the week (see Fig. 1) and this week day variation is very much similar to the week day variation of the power consumption in Quebec, Canada, conjugate with Siple Station. From this result, they concluded that VLF emissions observed at Siple Station must have been influenced by the power line radiation from the conjugate northern hemisphere.

On the other hand, THORN and TSURUTANI (1981) pointed out that the VLF wave intensity in the magnetosphere observed by OGO-5 did not show such a Sunday decrease, and such week day variations of VLF wave intensity can be caused by the variation of the absorption through the ionospheric *D* region, and therefore the VLF intensity at Siple is not necessarily reflecting the emission activity in the magnetosphere and power line radiation. Although the above two results appear to be contradictory, the both were real observational results, which have to be rationally explained.

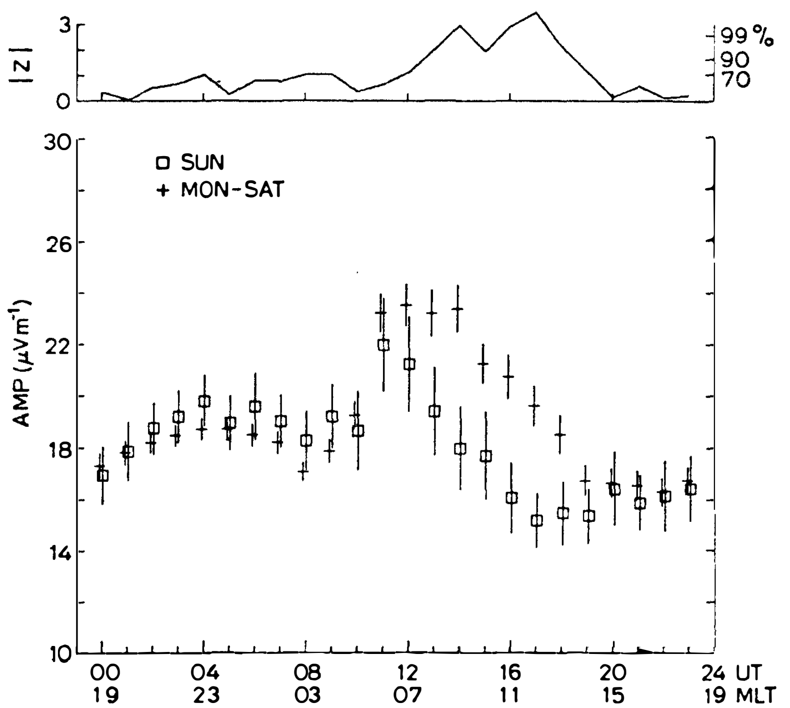


Fig. 1. Daily variations of 2- to 4-kHz wave amplitude showing differences between Sunday and Monday–Saturday. The vertical bars indicate ±1 standard error of the mean. The curve at the top shows the magnitude of the z score, which is related to the confidence level of statistical significance (from PARK and MILLER, 1979).

At the Japanese Antarctic Syowa Station, VLF wave intensities in multi-frequency channels have been sampled every 2 s (SATO *et al.*, 1984), and stored in magnetic computer tapes since April 1981. These data are now available in the National Institute of Polar Research. In the present study, we have analyzed these data for about two years, in the similar way as the one PARK and MILLER used, to know whether or not such a Sunday effect is detectable at Syowa Station, which is conjugate of Husafell, Iceland where power consumption is relatively low in comparison with Quebec, Canada.

2. Method of Data Analyses

Among several frequency components observed at Syowa Station, we have paid attention to the frequencies around 2 kHz, to be compared with PARK and MILLER's result. Using 2 s sampling data, a minimum for every 10 s is picked up and is then averaged over one hour to reduce atmospheric interferences. This quantity is treated as the representative intensity of that hour.

From these processed data, the average value for each day is obtained. Figures 2a–2c illustrate the day-to-day variation of each day average for the total period of analysis, from April 1981 to December 1983, for frequencies 0.75, 1.2 and 2.0 kHz, respectively. On some day, the receiver noise level became unusually large due to an artificial noise caused by a dynamo-generator for battery charging at the observing site. Such a noisy day has been omitted in the later analysis, by the criterion that the daily average value exceeds 0.6 times the maximum of the daily average during

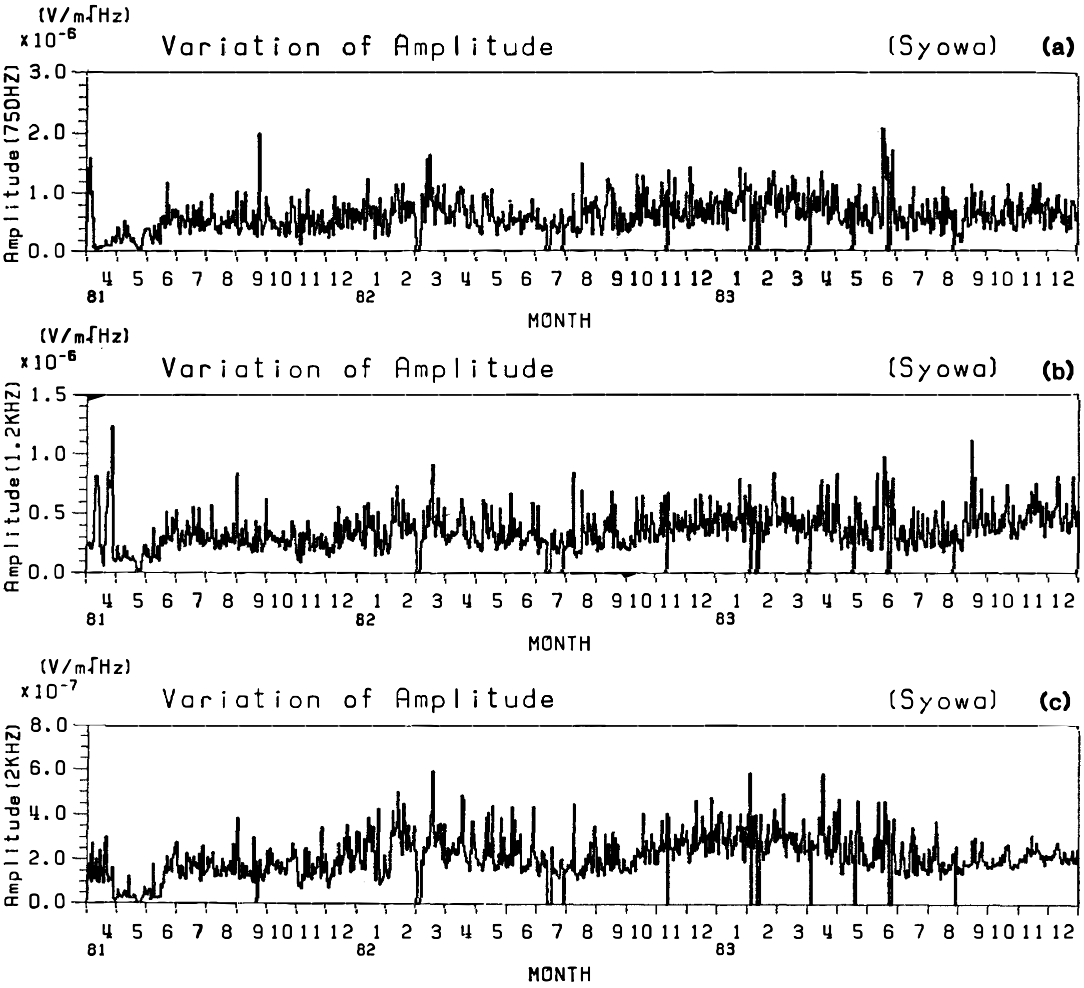


Fig. 2. The day-to-day variation of each day average for the total period of analysis, from April 1981 to December 1983. (a) 0.75 kHz, (b) 1.2 kHz, (c) 2.0 kHz.

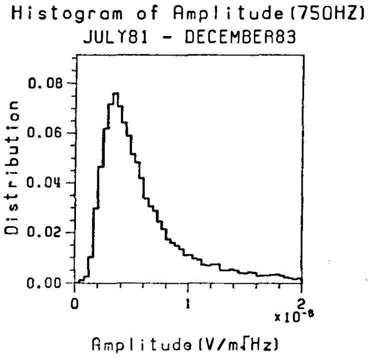
the whole period for three frequencies, 0.75, 1.2 and 2.0 kHz. Such data are not plotted in Fig. 2.

Moreover, continuation of the data with those after this period is not always satisfactory, due to unknown reason, for the period from April to June 1981 in Fig. 2. Therefore, we did not use the data of this period. Conclusively the final data used for the following analysis are of the period from July 1981 to December 1983.

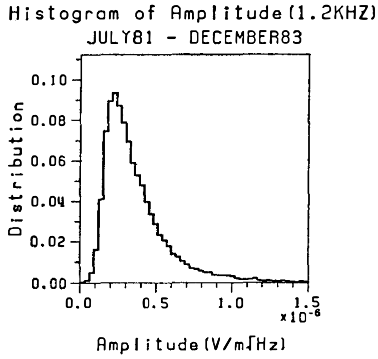
The total number of data points being representative of each hour is about 21000. For each hour of the day and for each day of the week the number of data points is around 125. Among 125, the number for *Kp* index less than or equal to 2 is about 40 and that for *Kp* index larger than 2+ is 85. These numbers can be considered as large samples for statistics.

In order to check the characteristics of our data, the occurrence frequencies at 0.75, 1.2 and 2.0 kHz are plotted against the electric field intensities, as shown in the histogram of Figs. 3a–3c. It is noted that the histogram for 2.0 kHz is very similar to that for the same frequency observed at Siple Station (PARK and MILLER, 1979).

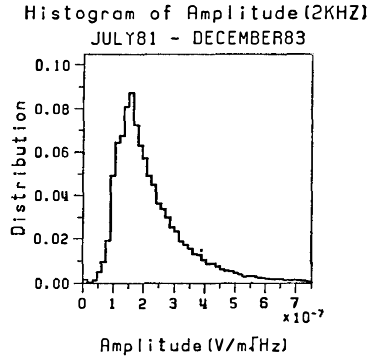
During the whole period of interest, we consider two populations, the hourly



(a) 0.75 kHz.



(b) 1.2 kHz.



(c) 2.0 kHz.

Fig. 3. Histogram of VLF electric field intensities.

values of the VLF noise intensity at fixed frequency on one day of the week and those on the rest of the week. We then need to know whether or not the difference between the sample means of the above two sets of populations is statistically significant. In this case, the size of each population must be sufficiently large. Actually the number of sample data for one day of the week is enough for this statistical analysis as mentioned previously.

Now we represent the sample averages and the sample variances by M_1 and M_2 and σ_1 and σ_2, respectively. The number of samples of each population is N_1 and N_2 respectively. In such a case, the hypothesis $M_1=M_2$ can be abandoned with a significance level of 99 %, when the value

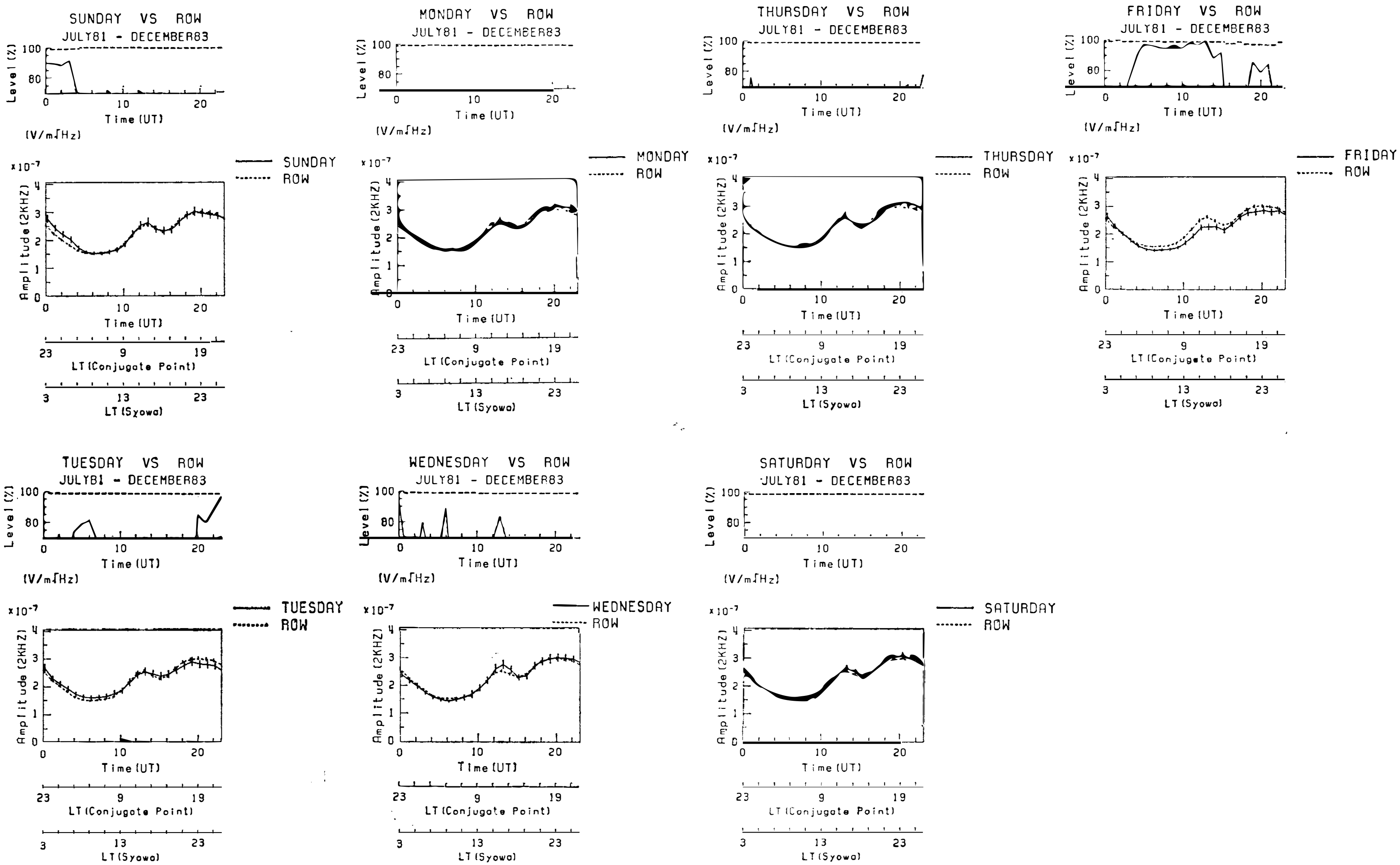
$$t=\frac{M_1-M_2}{(\sigma_1^2/N_1+\sigma_2^2/N_2)^{1/2}},$$

is larger than 2.58.

3. Dependence of VLF Emissions on the Day of the Week

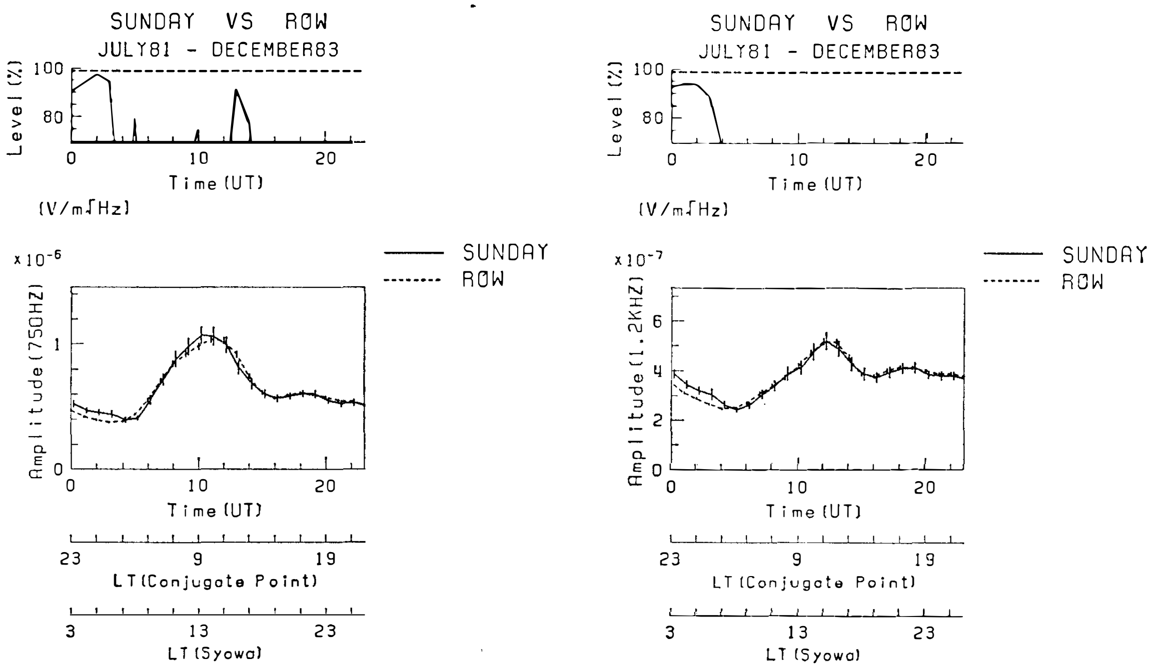
In order to check whether or not statistical features similar to those obtained by PARK and MILLER (1979) are also found in the data observed at Syowa Station, diurnal variations of averaged electric field intensity are illustrated at selected frequencies on a day of the week using all available processed data taken over the period as mentioned previously. In Fig. 4a, for example, the solid line represents the diurnal variation of the intensity at 2.0 kHz for the average of all Sunday data, and the dashed line represents that for the rest of the week (ROW). In the similar way, the Monday, Tuesday, Wednesday, Thursday, Friday, and Saturday averages are respectively compared with the ROW. The vertical bars indicate the ranges of the standard deviation at every hour. At the top of each figure, the reliability of the difference of the two lines is indicated by % for the range of 70–100 %. If the reliability curve exceeds the 99 % line, the difference is plausible with a reliability of 99 %. Figures 4b and 4c are for those at frequencies 0.75 and 1.2 kHz on Sunday as compared with the ROW.

In these figures, there is no case where the reliability of the difference between the intensity on one particular day of the week and that on the ROW exceeds 99 %.



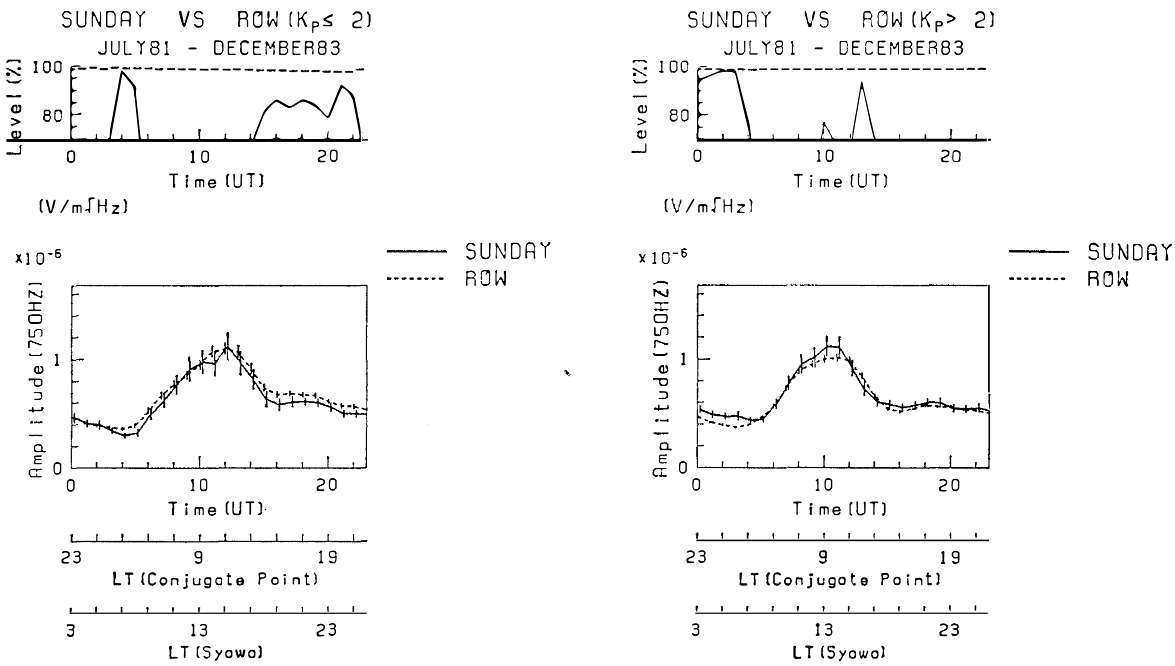
SUNDAY VS ROW
JULY81 - DECEMBER83
MONDAY VS ROW
JULY81 - DECEMBER83
THURSDAY VS ROW
JULY81 - DECEMBER83
FRIDAY VS ROW
JULY81 - DECEMBER83
TUESDAY VS ROW
JULY81 - DECEMBER83
WEDNESDAY VS ROW
JULY81 - DECEMBER83
SATURDAY VS ROW
JULY81 - DECEMBER83
Level (%)
Time (UT)
(V/m√Hz)
×10⁻⁷
Amplitude (2KHZ)
SUNDAY
MONDAY
TUESDAY
WEDNESDAY
THURSDAY
FRIDAY
SATURDAY
ROW
LT (Conjugate Point)
LT (Syowa)

Fig. 4. (a) 2.0 kHz.



(b) 0.75 kHz. *(c) 1.2 kHz.*

Fig. 4. Dependence of VLF emissions on the day of the week (see text).



(a) $Kp \leq 2$. *(b) $Kp > 2$.*

Fig. 5. Kp dependence of VLF emission activity at 0.75 kHz (see text).

It means that there is no meaningful difference between Sunday and the other days of the week.

We then investigate the *Kp* dependence of the above characteristics. Figure 5 shows the diurnal variation of VLF intensity at 0.75 kHz on Sunday and that on the

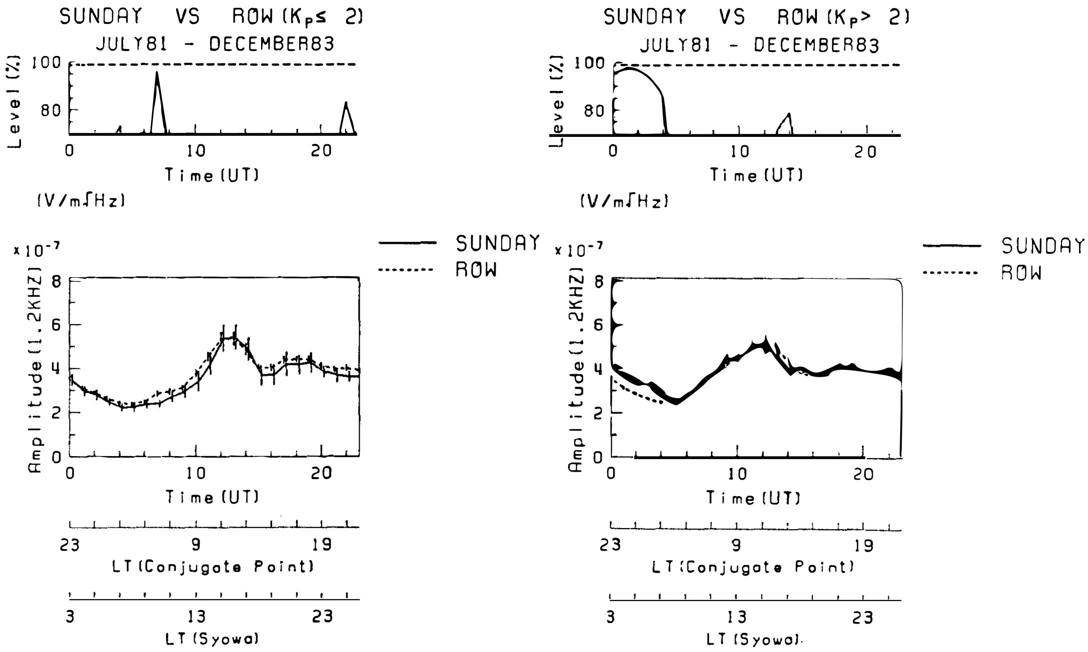


Fig. 6. Kp dependence of VLF emission activity at 1.2 kHz (same as Fig. 5).

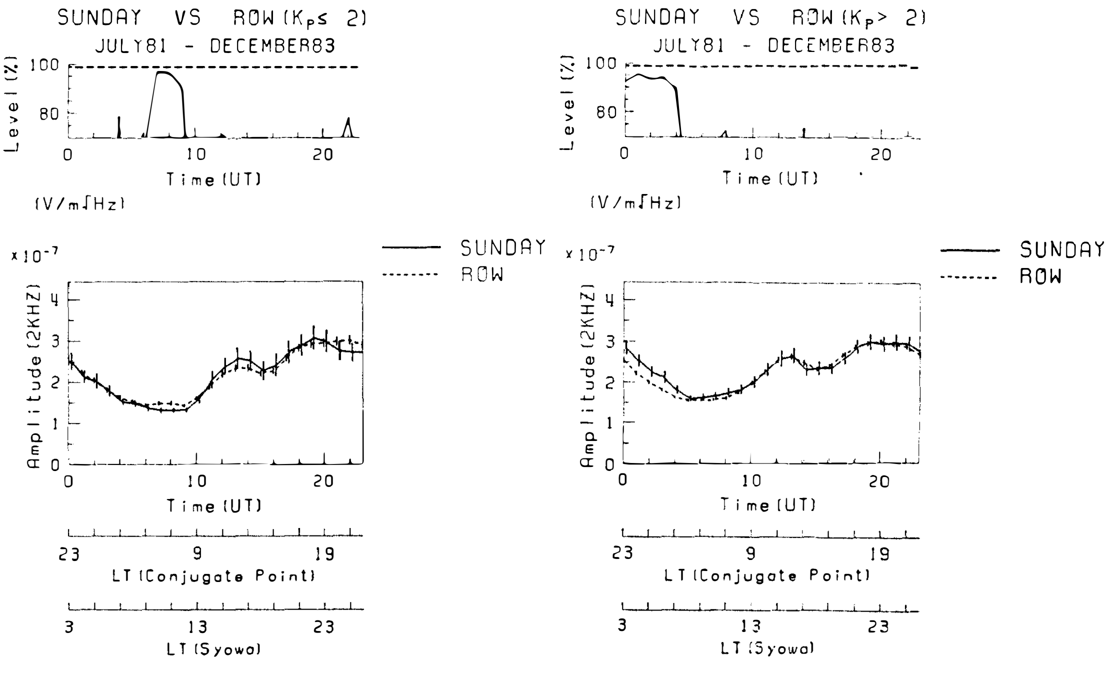


Fig. 7. Kp dependence of VLF emission activity at 2.0 kHz (same as Fig. 5).

ROW for $Kp \leq 2$ and $Kp > 2$. Figures 6 and 7 represent those for 1.2 and 2.0 kHz, respectively. For these statistics, we cannot see any significant difference on Sunday in comparison with another day of the week.

4. Discussion and Conclusion

As mentioned in the previous section, the Sunday decreases found in Siple's VLF data (PARK and MILLER, 1979) are not found in Syowa's VLF data in the frequency range from 0.75 to 2 kHz. In this respect, we have to take into account the difference in conditions around the areas, Roberval and Husafell, which are magnetically conjugate of Siple and Syowa Stations. According to PARK and MILLER, the state of Quebec, in which Roberval is located, is one of industrial regions in Canada, where power consumption is relatively high and day-to-day variation of the power consumption shows a minimum on Sunday. They claimed for these reasons, that power line harmonic radiation from the power transmission lines, which is of a minimum intensity, influences the VLF emission intensity in the magnetosphere by wave-particle interactions. On the other hand, Husafell is located in a less industrial region in Iceland and in Europe. Therefore, it is not contradictory, even if there is no Sunday decrease phenomenon at Syowa Station.

The above-mentioned analysis was simply based on the digital data stored on magnetic tapes. We have also looked at some sample dynamic spectra processed from the wideband data observed at Syowa Station. However, we seldom find any line structure in the spectra, like power line harmonics as well as local interferences. It is partly because the location of VLF observing point at Syowa Station is sufficiently far from Syowa Station and may be because power line radiation phenomena or magnetospheric line emissions (MATTHEWS and YEARBY, 1981) are less active around Syowa Station.

Acknowledgments

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