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RELATIONSHIP BETWEEN POWER LINE RADIATION AND VLF WAVE ACTIVITIES OBSERVED IN ICELAND

Iwane KIMURA[1,5], Hiroshi HIGUCHI[1]*, Kozo HASHIMOTO[2], Natsuo SATO[3] and Takashi MATSUDO[4]**

[1]*Department of Electrical Engineering II, Kyoto University, Yoshida Honmachi, Sakyo-ku, Kyoto 606*
[2]*Department of Electrical Engineering, Tokyo Denki University, 2, Kanda Nishikicho 2-chome, Chiyoda-ku, Tokyo 101*
[3]*National Institute of Polar Research, 9–10, Kaga 1-chome, Itabashi-ku, Tokyo 173*
[4]*University of Electro-Communications, 5–1, Chofugaoka 1-chome, Chofu-shi, Tokyo 153*
[5]*Institute of Space and Astronautical Science, 6–1, Komaba 4-chome, Meguro-ku, Tokyo 153*

Abstract: Following our previous study on the dependence of VLF emission activity at Syowa Station in Antarctica upon the day of the week, we extended this study with the VLF data in Iceland. All of the data at 0.75, 1.2 and 2.0 kHz observed at Husafell, Isafjördur, and Tjörnes from September 1984 to May 1985 showed no significant weekday dependence of the VLF emission activities, similarly to the data of Syowa Station, except for Tjörnes data at 1.2 kHz with a strong artificial noise on weekdays but not in the weekend. This effect is clearly found statistically as the weekend decrease of VLF signal intensity at 1.2 kHz. It may be due to a power line radiation from the source region which is earlier pointed out by C. G. PARK and T. R. MILLER (J. Geophys. Res., **84**, 943, 1979) using the Siple data. It was also found in Iceland and Syowa data that VLF riser emissions are supposed to be triggered by power line harmonic radiations. It may be suggested that power line harmonic radiation can trigger VLF emissions in the Iceland-Syowa meridian, although no significant weekend decrease of VLF emission activity have been yet statistically detected at these stations.

1. Introduction

According to our previous study, there is no clear dependence of the VLF wave activity at Syowa Station on the day of the week, whereas a significant dependence was found at Siple Station (PARK and MILLER, 1979). Such a dependence, if exists, has been attributed to a possible triggering of VLF emissions in the magnetospheric plasma by power line radiations in the higher harmonic range. The power line harmonic radiations can be assumed to be proportional to the power consumption or line currents on the transmission lines at the conjugate point of Siple.

* Now at NTT.
** Now at KDD Research Laboratory.

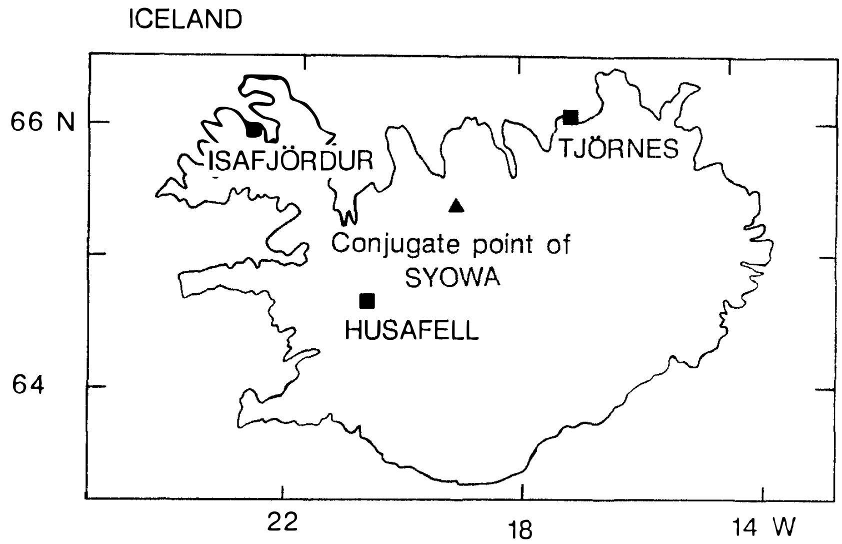

Fig. 1. Three observing stations in Iceland.

The conjugate point of Syowa Station is located in Iceland, where industrial activity is poor. Therefore it may be reasonable even if there is no weekday increase of VLF emission activity at Syowa Station. In connection with this, it is worthwhile to investigate the VLF activity in Iceland. Fortunately, in Iceland, VLF observations have been carried out since 1983 at three stations, Husafell, Isafjördur, and Tjörnes, as shown in Fig. 1. The observed data have been digitized and recorded on magnetic tapes, as done at Syowa Station. The Iceland data are statistically analyzed in the similar way as described in a previous paper (HIGUCHI *et al.*, 1986). The present report describes the result of analyses of Iceland data and some interesting related phenomena.

2. Data Analyses

Similarly to the analyses of Syowa VLF data, multichannel digital data at frequencies of 750 Hz, 1.2 and 2 kHz were used. In order to remove atmospheric effects, the minimum values during every 10 s were picked up. Then one hour average was taken of the above minima, after removing calibration signals and artificial noises. Figure 2 shows the daily average electric field intensities at Husafell at the three frequencies for the whole period of the data analyses, after removing the noise components. In the following, the data from September 17, 1984 to May 31, 1985 are used for the statistical analysis.

Figure 3 illustrates the amplitude histogram at the three frequencies. The abscissa indicates the electric field intensity and the ordinate the occurrence frequency at each level of the field intensity. These represent a typical shape of histograms similar to that shown in PARK and MILLER's paper. Such a check is made to confirm that the characteristic of the original data to be used are qualitatively similar to those of Siple.

As the next step, we examined the dependence of the hourly averaged field intensities upon the day of the week. A number of all data points is about 230 for each hour

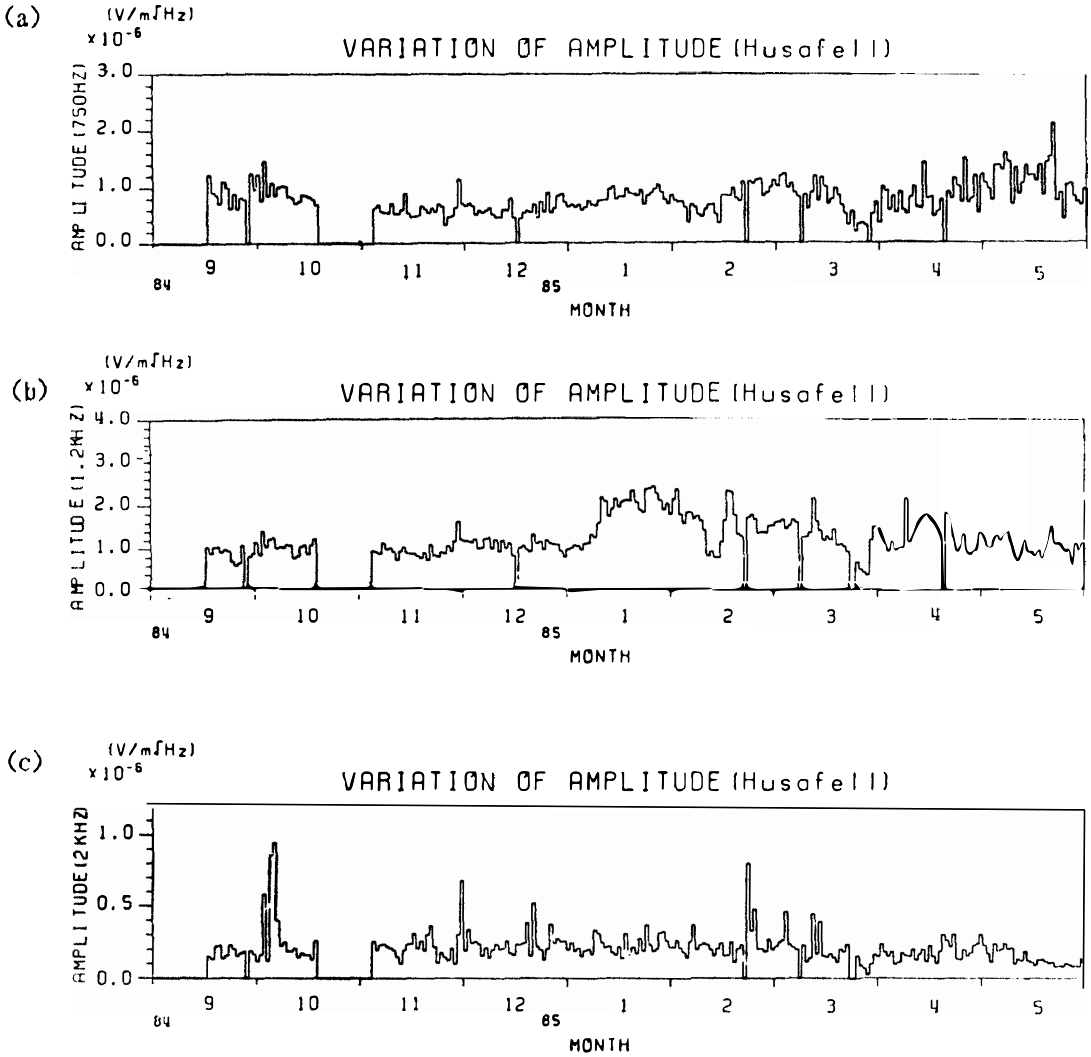

Fig. 2. Day-to-day variation of averaged electric field intensity on each day at Husafell. (a) 750 Hz, (b) 1.2 kHz, and (c) 2.0 kHz.

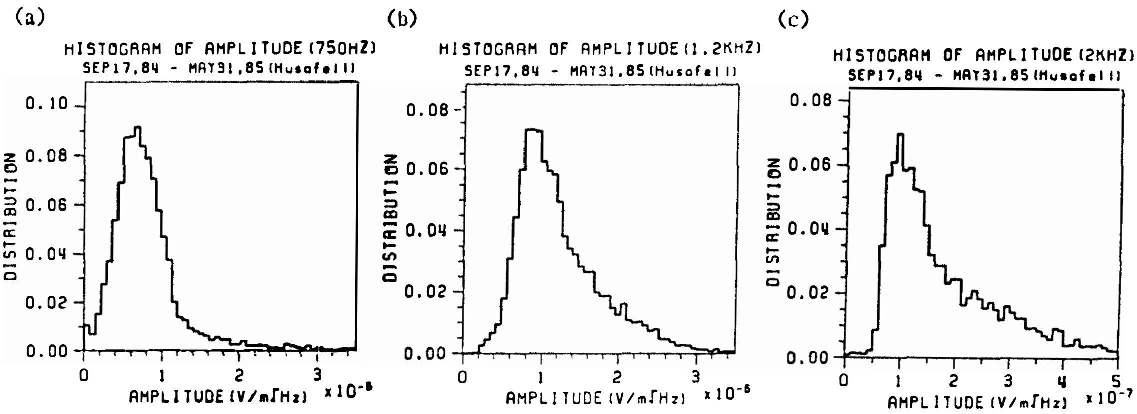

Fig. 3. Histogram of electric field intensity at Husafell. (a) 750 Hz, (b) 1.2 kHz, and (c) 2.0 kHz.

of the day, and about 33 points are available for each day of the week. Since, from Fig. 2, the emission occurrence of each frequency component does not show any noticeable seasonal variation; the numbers of emission events can be regarded enough for statistics. From the hourly values on all Sundays of the whole observation period, we calculate an average daily variation of the emission occurrence for Sunday. Similar daily variation curves can be drawn for comparison, for the rest of the days of the week (ROW).

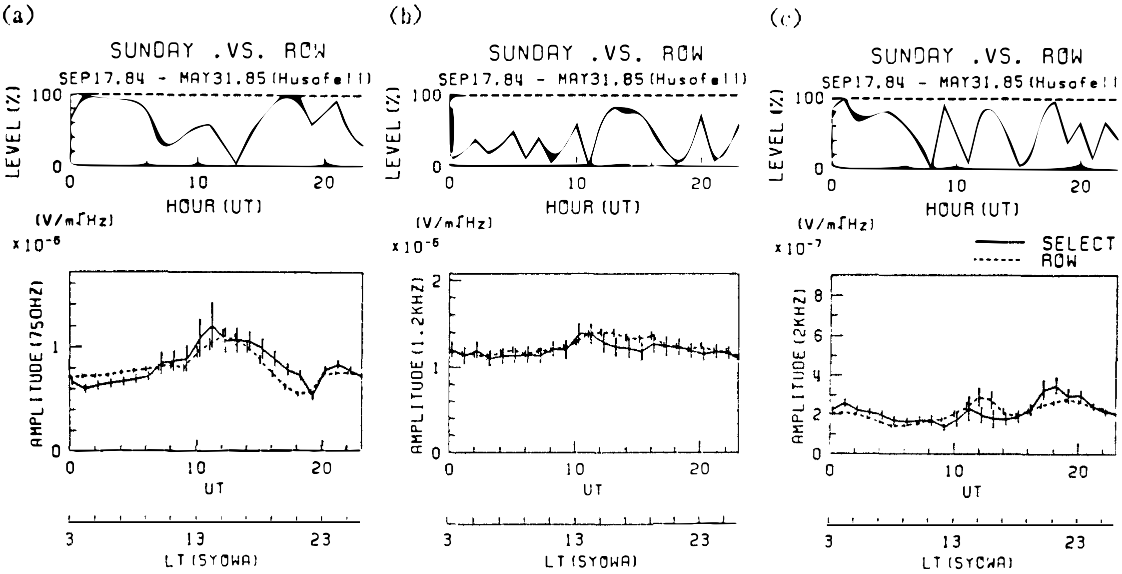

Fig. 4. Averaged daily variation of electric field intensity at Husafell, on Sunday and the rest of the week (ROW). (a) 750 Hz, (b) 1.2 kHz, and (c) 2.0 kHz.

In Fig. 4a, the solid line shows the daily variation of the signal intensities at 750 Hz on Sunday as a function of UT and the local time of Syowa. For the rest days of the week (ROW) the averaged daily variation is shown by a dotted line in the same figure for comparison. The vertical bars on the curves indicate the ranges of the standard deviation at every hour. At the top of the figure, the reliability (HIGUCHI *et al.*, 1986) of the difference of the two daily variation curves is indicated by % for the range of 0 to 100%. Figures 4b and 4c are for the emissions at frequencies 1.2 and 2.0 kHz on Sundays and ROW.

In these figures, there is no case where the reliability of the emission intensity difference between Sundays and ROW exceeds 99% during the working hours. It means that there is no meaningful effect of power line harmonic radiation on the VLF activity observed on the ground, especially at Husafell.

In each panel of Fig. 5, each day of the week is selected and the daily variation of 750 Hz activity on that day is compared with that of ROW. On Monday, Thursday and Saturday, the activity during the day time is rather lower than that of ROW, the tendency being similar to that deduced from the result at Siple. But all these days are not always non-working day. Similarly, at frequencies of 1.2 and 2 kHz, no particular weekend effect is seen, similarly to the results at Syowa Station (HIGUCHI *et al.*, 1986).

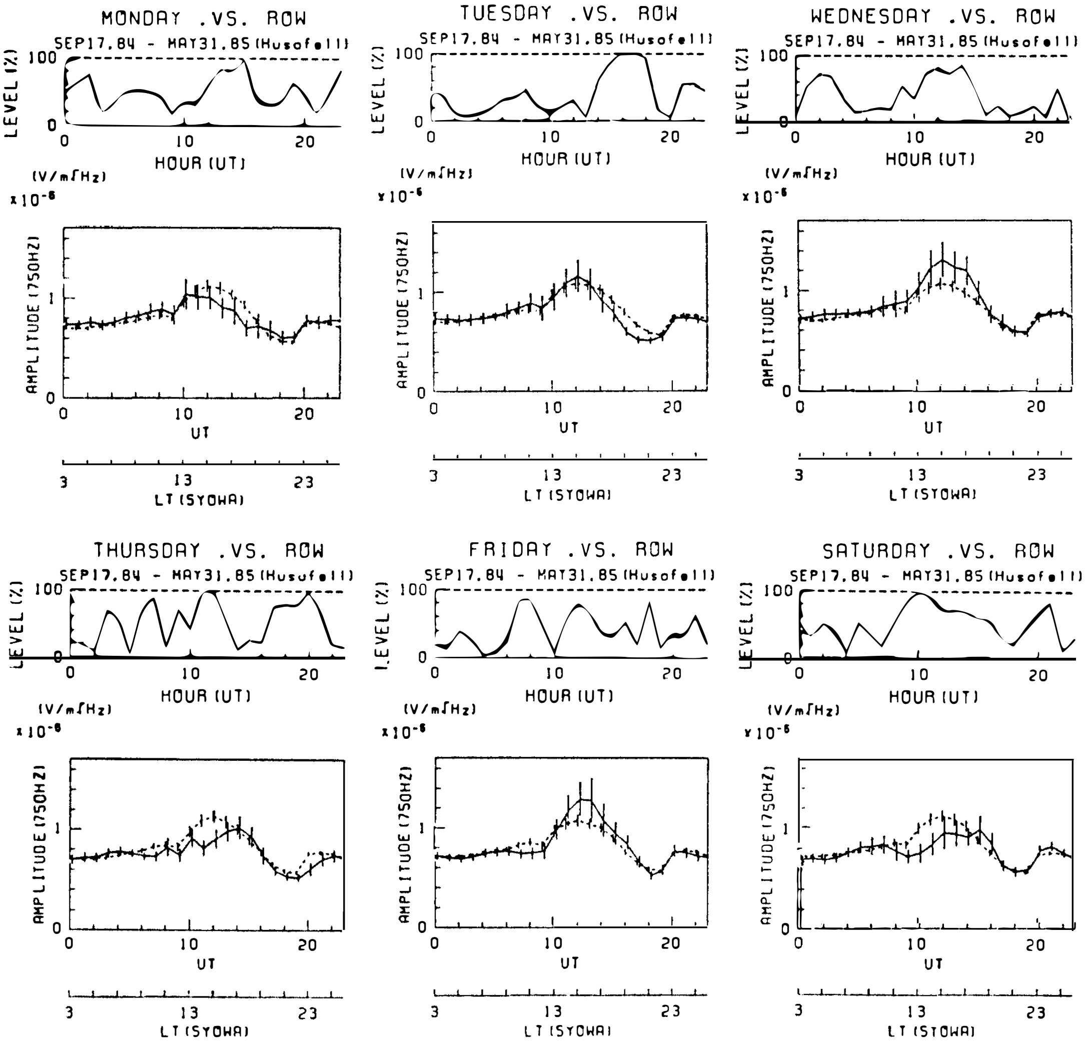

Fig. 5. Averaged daily variation of electric filed intensity at a frequency of 750 Hz at Husafell, on each day of the week and on ROW.

The VLF data observed at Isafjördur and Tjörnes, at the same three frequencies, were subjected to the similar statistical analysis, which showed a result similar to the above mentioned Husafell data, except for Saturday and Sunday at Tjörnes at 1.2 kHz, as shown in Fig. 6. On these weekend days, the VLF activity at 1.2 kHz is significantly lower especially during the daytime, with the reliability over 99%. At 750 Hz and 2 kHz, such a tendency is not noticeable. In order to investigate a cause of the weekend effects, VLF wide band dynamic spectra at Tjörnes are examined; Fig. 7a is the spectrum commonly observed on weekdays, whereas Fig. 7b is that on Saturday and Sunday. It is clearly shown that several strong line spectra are almost continuously seen on weekdays around 1.2 kHz. These line spectra appear to be an artificial noise that might be either directly generated by power consuming machines in a local area or power line harmonic radiations propagating from a distant place.

These facts show that in general the weekend decrease of VLF activity is not detectable in Iceland as well as in Syowa, but the ground based VLF activity at Tjörnes

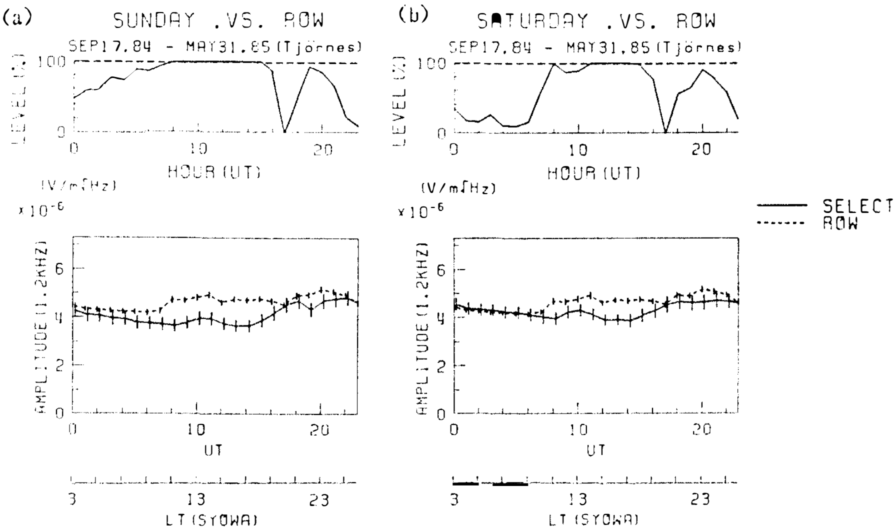

Fig. 6. Weekend-day decrease of electric field intensity at a frequency of 1.2 kHz at Tjörnes, as compared with that on ROW.

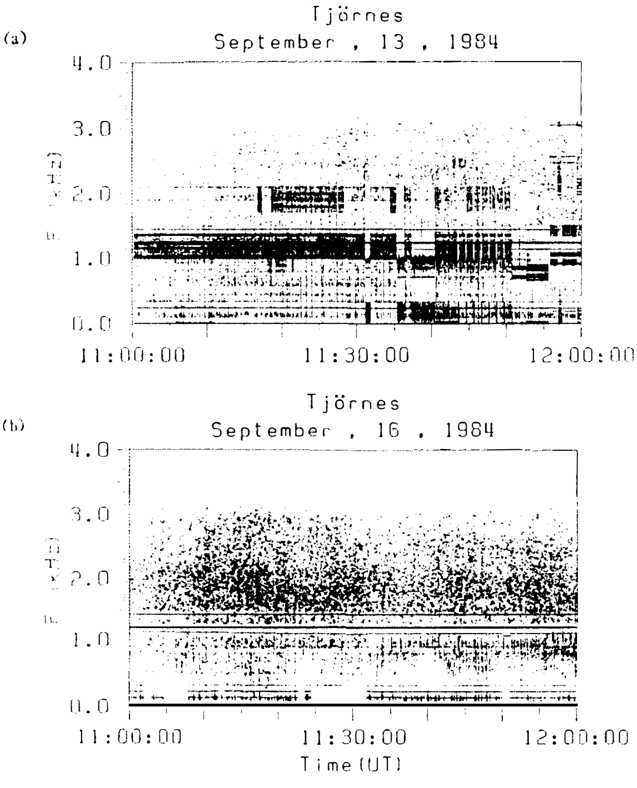

Fig. 7. VLF wide band spectra at Tjörnes on a weekday (a) and during the weekend (b).

has shown an apparent decrease of artificial noise on the weekend days that might be related with a decrease of power consumption at some place in the vicinity of Tjörnes. Therefore the characteristics of VLF emission activity obtained at Tjörnes may indicate the weekend decrease in power line harmonic radiation as a source. Such a characteristic should be detected also at a conjugate point of Siple, if the Sunday decrease found on Siple is attributable to the harmonic radiation from power lines around the conjugate area of Siple.

3. Discussion

As mentioned in the previous section, it is statistically found that there is no significant weekday dependence on the VLF emission activity at both sides of the geomagnetic conjugate points, Syowa and Husafell. A similar tendency was also seen for two other Iceland stations, Tjörnes and Isafjördur.

On the other hand, we have looked at individual wide band data over a longer period than that used for the previous statistical analysis. We have found then an event observed on August 21, 1985 at the three Iceland stations as well as at Syowa Station in Antarctica, in which riser and hook emissions appeared to be triggered by power line harmonic radiations. Figure 8 illustrates a part of spectra starting from 1710: 00 UT for Husafell and Tjörnes stations. The event continued from 1654 until 1730 UT.

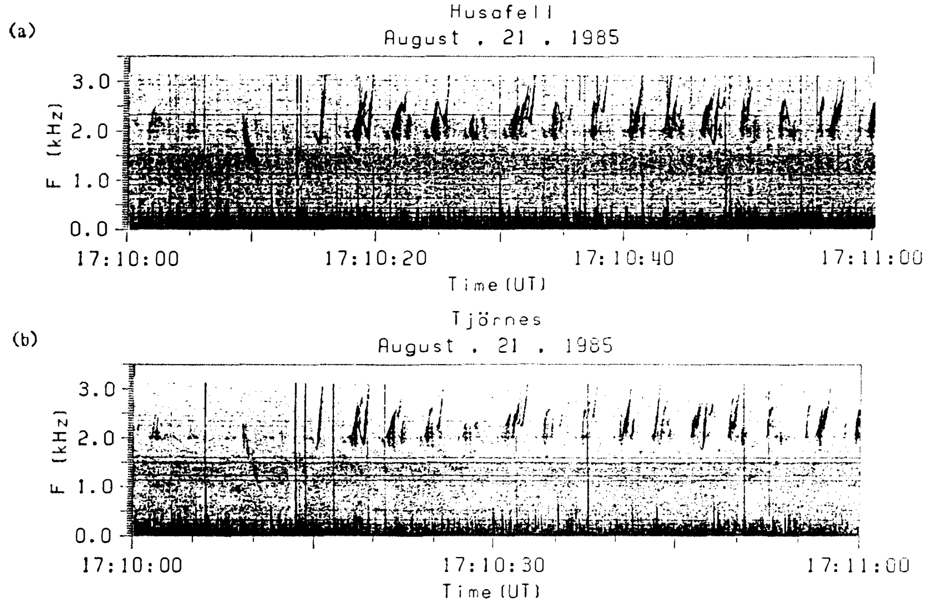

Fig. 8. VLF emissions, which appear to be triggered by power line harmonic radiations, observed at Husafell (a) and Tjörnes (b) on August 21, 1985.

More expanded spectra are shown in Fig. 9, in which starting frequencies of risers or hooks appear to be 2.0 kHz or to coincide with one of the line structures, 50 or 100 Hz apart one another. These lines are coincident with power line harmonics of 50 Hz. In order to check this tendency more carefully, we read the frequency of each of the line structures and plotted the occurrence frequency of the difference between the read frequency and higher harmonics of 50 Hz. Figure 10 illustrates the results for different time intervals of data obtained at Husafell and Tjörnes. On the other hand a

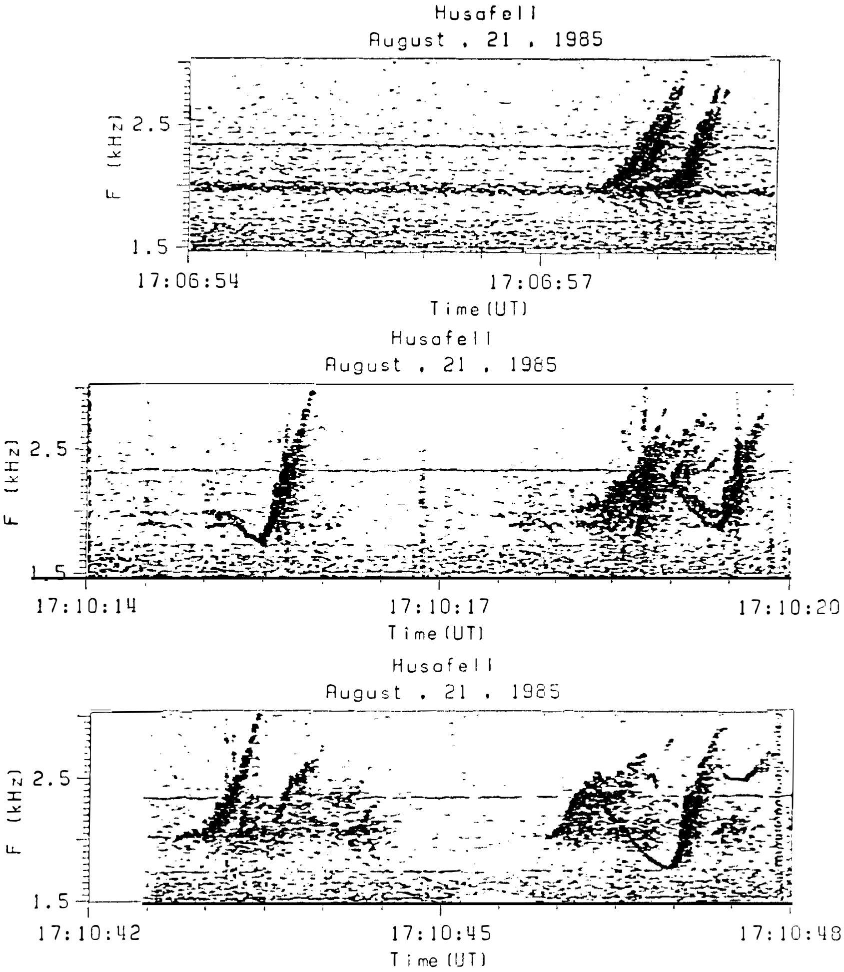

Fig. 9. Expanded spectra of the August 21, 1985 event, observed at Husafell.

similar analysis was made for the difference between the read frequency and higher harmonics of 60 Hz for all the data shown in Fig. 10 and the results are shown in Fig. 11. By comparing these two Figures, it is clear that the line structures observable at Husafell and Tjörnes are much more coincident with the higher harmonics of 50 Hz than those of 60 Hz. In Fig. 10, however, the line frequencies appear to be not exactly higher harmonics of 50 Hz but are deviated by several tens of Hz at the frequency of 2 kHz. But this deviation may be ascribable to a slight difference in recording and playback tape-speeds and/or to a fluctuation in frequency of the commercial AC power supply system. Taking account of the fact that the power line frequency in European zone including Iceland is 50 Hz, the harmonic line structures seen on the VLF spectra observed in Iceland can, therefore, be power line harmonic radiations and the emissions observed on August 21, 1985, are possibly related with these harmonic line radiations. In this event, at Syowa Station which is conjugate with Husafell, similar emissions were observed at the same time, so it is sure that some components of these emissions were echoing between the Iceland zone and the Antarctic Syowa zone.

From this example, it is concluded that emissions are triggered at the Syowa-Iceland meridian by power line harmonic radiations, but such an event is a very rare

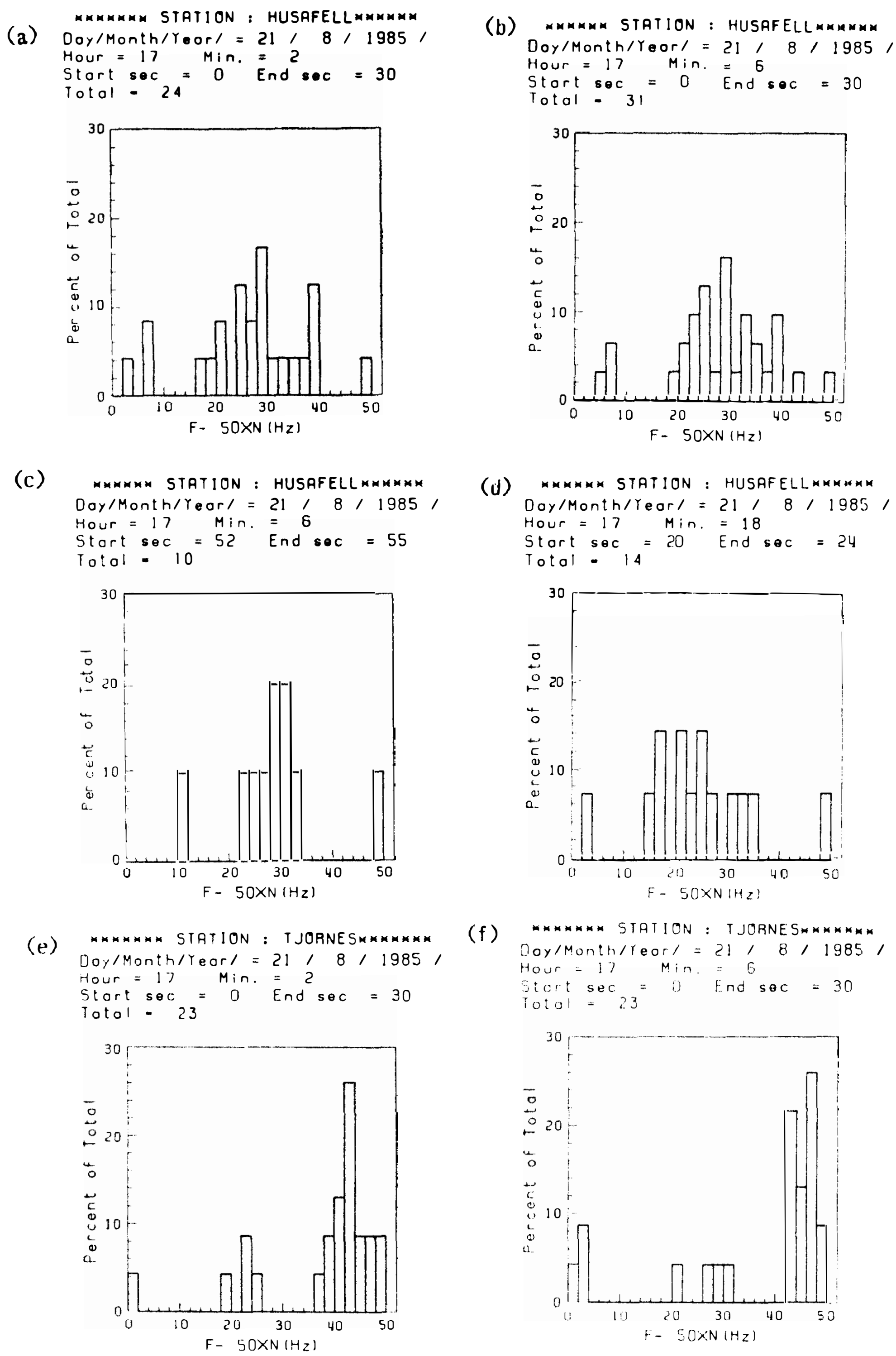

Fig. 10. Deviation in frequency of the harmonic line structures in the VLF spectra below 2 kHz, observed at Husafell and Tjörnes, from the higher harmonics of 50 Hz.

case so that we could not find any statistical weekend decrease of VLF activity both at Syowa Station and at three stations in Iceland. The weekend decrease observed

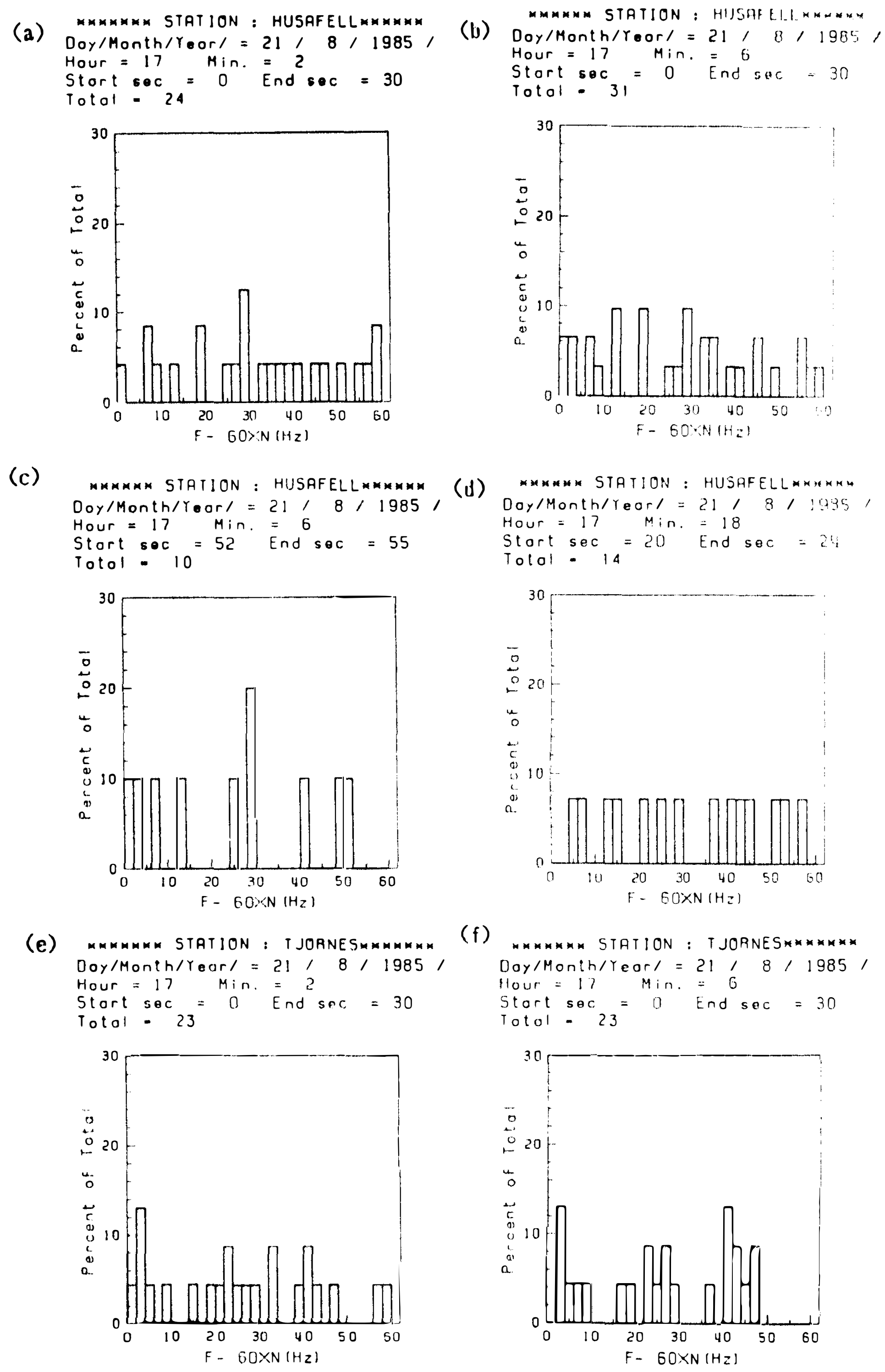

Fig. 11. Deviation in frequency of the harmonic line structures in the VLF spectra below 2 kHz, observed at Husafell and Tjörnes, from the higher harmonics of 60 Hz.

in Tjörnes data at 1.2 kHz mentioned in Section 2 may be an indication of characteristics of power line harmonic radiations at the source site. However there must be a threshold of the source intensity below which the triggering of VLF emissions would not take place in the magnetosphere, and the actual intensity of the harmonic radiation around Iceland might have been below the threshold, for most of the time, except for the August 21 event. The reasoning for this may be based on the fact that there is no large power consumption in Iceland (*i.e.* 0.4 GW in average) and that Iceland is located far from industrial area in U.K. or other European countries. The total power consumptions in U.K., France and Norway, for information, are around 31, 30 and 10 GW respectively.

From our full wave calculation based on multiple reflection within an earth-ionosphere wave guide, the signal intensity at an altitude of 150 km after penetrating through the lower ionosphere is about 30 db less at a distance of 1000 km away from the source than just above the source region. Therefore if the source region for the induced VLF activity in Iceland is located in U.K. or Europe, the power line radiation effect must be much weaker in Iceland-Syowa meridian than the Quebec-Siple meridian, since the total power consumption in Iceland (0.4 GW) is much smaller than Quebec area (around 10 GW).

4. Conclusion

From the statistical analysis of multi-channel VLF data obtained at three Iceland stations at frequencies 0.75, 1.2 and 2.0 kHz, it is found that there is no significant weekend decrease in the daily variation of the signal intensity. This is consistent with the statistical results for Syowa Station's data (HIGUCHI *et al.*, 1986). There is one exceptional result at Tjörnes for the 1.2 kHz data which show a weekend decrease of the signal intensity, but this decrease is found to be ascribable reasonably to an artificial noise around 1.2 kHz which is weak on weekend days.

It was also found that a noteworthy emission event on August 21, 1985 observed at Syowa as well as at the three Iceland stations, to be triggered by power line harmonic radiations around 2 kHz.

These facts together with the Siple results (PARK and MILLER, 1979) can be consistently understood, since the power consumption in Iceland is much lower than Quebec area. Even if the power line harmonic radiations in Iceland may have come from European zone, they are not powerful enough to trigger VLF emissions in the magnetosphere. The event observed on August 21, 1985, at three Iceland stations is rather an exceptional triggered phenomenon. Such a rare case will not influence the global statistical characteristics of VLF emissions.

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