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DIURNAL VARIATIONS OF RESONANT FREQUENCIES IN THE EARTH-IONOSPHERE CAVITY

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Abstract

Diurnal variations of resonant peak frequencies in the earth-ionosphere cavity were obtained for the first three modes of the electric vertical and horizontal NS and EW components through a year from February, 1967 to January, 1968. The result shows a different variation pattern for each component. There are frequency decreases in the morning and in the evening for the vertical and NS components. It would be preferable for the EW component to show that frequency increases exist at around corresponding times in the morning and in the evening. Diurnal amplitude ranges from 0.1 to 0.8 Hz.

1. Introduction

Balser and Wagner [1962] investigated diurnal variations of peak frequencies of the earth-ionosphere cavity resonances for the electric vertical component by digital analysis. They obtained different variation patterns for the first four modes respectively. For the fundamental mode they showed a sharp frequency drop at 08h-10h local time, a higher value around 14h and a smaller decrease in the evening. Madden and Thompson [1965] used different surface impedances at different points of the earth's surface with a proper ionospheric conductivity model to solve the equations of transmission lines which substitute Maxwell's equations, and obtained a diurnal variation of first mode frequency of the Schumann resonances and showed it in close agreement with the observations made by Balser and Wagner.

Stefant [1963] investigated the diurnal variation of the resonant frequencies of the magnetic component but the diurnal variations given in his paper have no definite pattern, and he stated that the variation is not due to local change of the ionospheric conductivity such as sunrise or sunset effects. On the other hand the effects of a high altitude nuclear explosion on resonant frequencies was reported by Gendrin and Stefant [1962]. They showed simultaneous lowering of the resonant frequencies of the first four modes of the magnetic component at 0900 GMT on July 9, 1962, the time of the explosion. Frequency drops were as much as 0.5 Hz to 0.7 Hz for every mode. They attributed this effect to intense ionization in the lower ionospheric layer. Thus decreased reflection height results in large ionospheric loss for ELF waves, and hence resonant frequencies decreased. The same effect was observed by Balser and Wagner [1963] with regard to the decrease of the first mode frequency.

It is rather difficult to obtain exact peak frequencies of the resonances because the "Q" values of the existing earth ionosphere cavity are too low to get a smooth power spectrum of noises. It is also difficult to obtain diurnal variations of the resonant frequency bacause the variation range of the frequency is normally expected to be as little as a few tenth Hz within a day.

In the present investigation we used data of three electric components for one year from February, 1967 to January, 1968 to get the diurnal variations of peak frequencies.

2. Observations and Analyses

Details of the observations and analyses are described in other papers (Ogawa, Tanaka, Miura and Yasuhara [1966], Ogawa, Tanaka and Yasuhara [1968]) so that only brief description is given here. The electric vertical component of the natural electromagnetic noises was observed in Kyoto (location: 35°01'N, 135°47'E) by using a ball antenna, and the two orthogonal horizontal components, NS and EW, were observed at Aso (location: 32°53'N, 131°01'E) by using ground antennas of 300 meters in length. Noise signals recorded on FM magnetic data recorders were played back at a speed 40 times higher than that of the original recording and were fed into the sound spectrograph. Thus the original frequencies are converted from 4-40 Hz to 160-1,600 Hz, for the vertical component and from 3-30 Hz to 120-1,200 Hz for the horizontal components respectively.

Power spectra of natural noises for four and a half minutes of each hour were obtained for each component. Peak frequencies were then read for the first three modes. Only data where the shape of the spectrum around the peak is smooth enough to be able to read the peak frequency. In the sonagram noise frequency of 60 Hz from the nearby commertial power line, which was picked up by the antenna, is accurate enough to be used for a frequency reference. It is situated 90 mm from the zero mark in the original sonagram paper, and the frequency is read as 0.67 Hz/mm. The reading accuracy may be ± 0.2 mm, which results in a frequency accuracy of ± 0.13 Hz.

Examples of the frequency time pattern of observed noises and the power spectra are given in Fig. 1 and in Fig. 2 respectively for the vertical component. Hourly values read from these spectra were normalized to the daily mean value

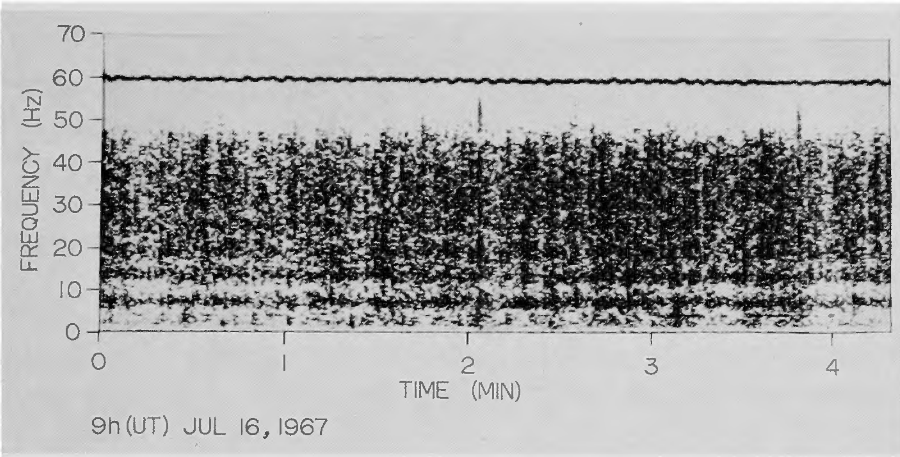

Fig. 1. An example of the sonagram showing the Schumann resonance frequency time display. Signals were observed by the use of a ball antenna in Kyoto during a period from 0859 to 0905 UT, July 16, 1967. 60 Hz noise is from the nearby commertial power line. The wavy pattern of the 60 Hz noise was produced during the data processing.

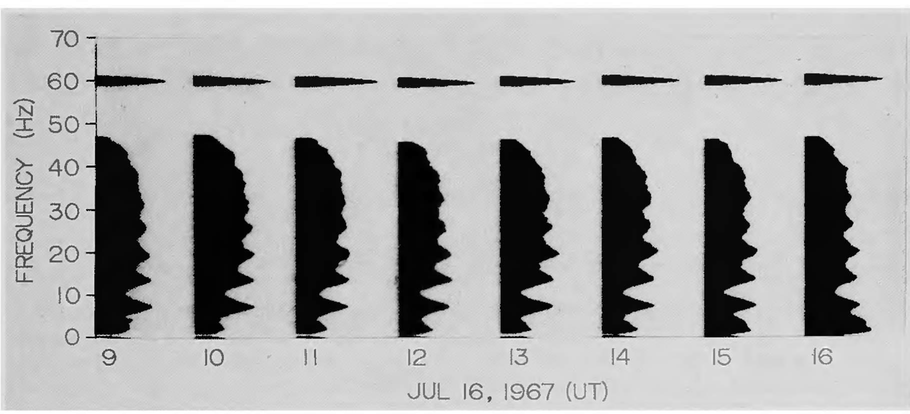

Fig. 2. An example of the sonagram showing the Schumann resonance power spectra which were obtained by integrating four and a half minutes signals shown in Fig. 1 as an example. The amplitude reads relative power as 1 db/mm on the original sonagram paper. 60 Hz noise is used as a frequency reference.

of that day and mean diurnal variations for a week of each month were obtained, so that the resultant frequency error may be less than ± 0.06 Hz.

3. Results and discussions

The diurnal variation curves of each month are shown in Fig. 3 for the first three modes of electric vertical (VT) and horizontal NS and EW components from February, 1967 to January, 1968. The June and November data of NS component were so disturbed by some artificial or electrostatic noises that no

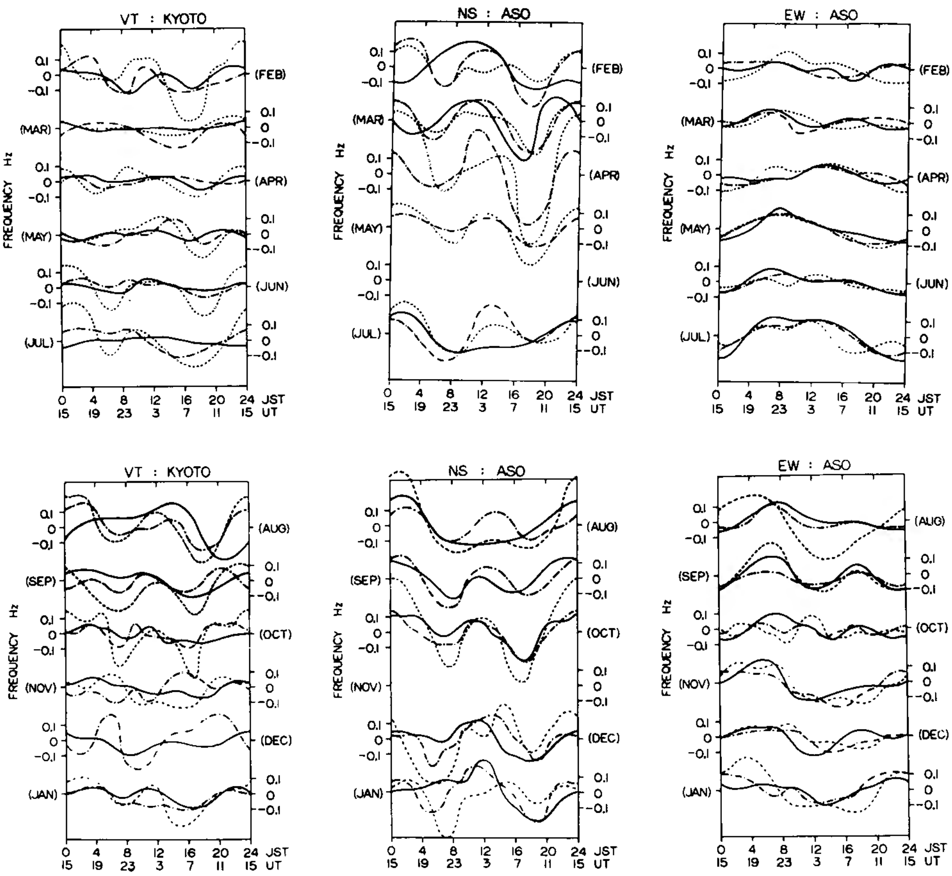

Fig. 3. Diurnal variations of the peak frequencies of the lowest three modes of the Schumann resonances for electric vertical (VT) and horizontal NS and EW components from February, 1967 to January, 1968. The solid, broken and dotted curves give the fundamental, second and third modes respectively.

curve could be deduced. For the same reason it was impossible to obtain data for the first mode curves of April and May for the NS component and third mode curves of December for the vertical component and of September for the NS component. The vertical and NS components have a similar variation pattern; there are frequency decreases in the morning and in the evening. Diurnal amplitude ranges from 0.1 to 0.8 Hz which exceeds the experimental accuracy. On the other hand, the variation pattern for the EW component, is completely different from those of the vertical and NS components. It would be preferable to see frequency increases at around times which correspond to those of the vertical and NS components, i. e., in the morning and in the evening. The fact that the diurnal variation pattern of the resonant frequency differes from the other component is rather surprising. This result has been deduced by statistical treatment of noises through noise spectra, over a period of some few minutes. On the other hand, however, it is reported by Ogawa et al. [1967] that an individual noise burst has the same feature of resonant frequency as the present result.

The average diurnal variation of the peak frequencies observed by Balser and Wagner [1962] in Massachusetts during February 1962 was interpreted for the fundamental mode in terms of the relative location of noise source and observer with analyses of an electrical transmission network by Madden and Thompson [1965] and with calculation of the surface impedance by Large and Wait [1968]. The result of the present experiment of the peak frequencies may be interpreted by more than one location of noise sources, that is, different noise sources have separate affects on NS and EW components. This is, however, not too realistic because in an investigation of peak power made by Ogawa, Tanaka and Yasuhara [1968] they assumed the relative thunderstorm activity which is mainly contributed by Asian, African and American thunderstorms, and obtained fairly good agreement between experimental and theoretical results.

Another interpretation of the present diurnal variation of peak frequencies may be due to anisotropic propagation of ELF waves with the anisotropic conductivity profile of ionosphere. For this interpretation it will be necessary to take the transient effect of the ELF waves with more realistic ionospheric models into consideration.

The peak frequencies were found to vary month by month, which will be discussed elsewhere in future. The average peak frequencies over a period from February, 1967 to January, 1968 were 7.69, 14.1 and 20.3 Hz for the first, second and third modes of the vertical component, and were 7.71, 14.1 and 20.4 Hz for the corresponding modes of the EW component.

Acknowledgments

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