Precursory anomalies of earthquakes on short distance propagation of 40kHz signals

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Abstract

The subionospheric 40kHz standard signal transmitted from Sanwa, Japan (geographic coordinates:36°11' N, 139°51' E) was continuously received at Inubo, Japan (35°42' N, 140° 52' E). The data were analyzed during the period of 2 years from January 1992 to December 1993. The distance from the transmitter to receiver was about 100km. Dominant ground wave over short distance propagation suffers from the influences of the troposphere and Earth's electric conditions. It may be expected that not only a meteorological factor such as rainfall, but also some other factor (like earthquakes), may play a role in the fading (or scintillation) of the received signal (amplitude and phase). The fading in the data has been investigated carefully, and it is found that some fading may be closely associated with earthquakes. Finally, the mechanism of seismo-fading is also discussed.

1. Introduction

The method of subionospheric propagation of VLF/LF navigation transmitters has been suggested as a promising candidate to study earthquake phenomena[1)]. When we receive a signal from such VLF/LF transmitters, the received signal is composed of sky wave and ground wave, their relative importance being dependent on the transmission power, wave frequency, and source-receiver distance. Precursory anomalies on the subionospheric VLF/LF propagation have been found for the Kobe earthquake (Hayakawa et al.[2)]), in which the sky wave is dominant, consisting of many modes. However, in the present case, the propagation distance from the transmitter (40kHz, 1kW) to the observing station is only 100km, as illustrated in Fig.1. Fig.2 illustrates the dependence of wave intensity (ground and sky waves) on distance for the 40kHz transmission (power = 1kW), in which we can understand that the two types of propagation modes are nearly at equal amplitude at the distance of 100km. Of course, the amplitude of ground wave is expected to depend on the ground conductivity. We have already found that the terminator time (in diurnal patterns) (as found by Hayakawa et al. (1996)) have exhibited the effect of earthquakes, but these are not presented here. Then, this paper deals with the fading (or scintillations) in the LF data, and we try to study their occurrence in relation with earthquakes.

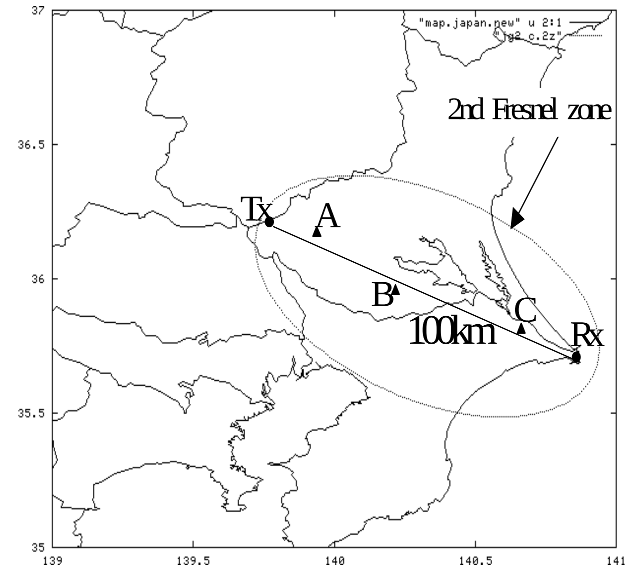

Fig. 1: Location of the transmitter at Sanwa and receiving station at Inubo. The line connecting these two stations is great-circle path, and the dotted line is 2nd Fresnel zone.

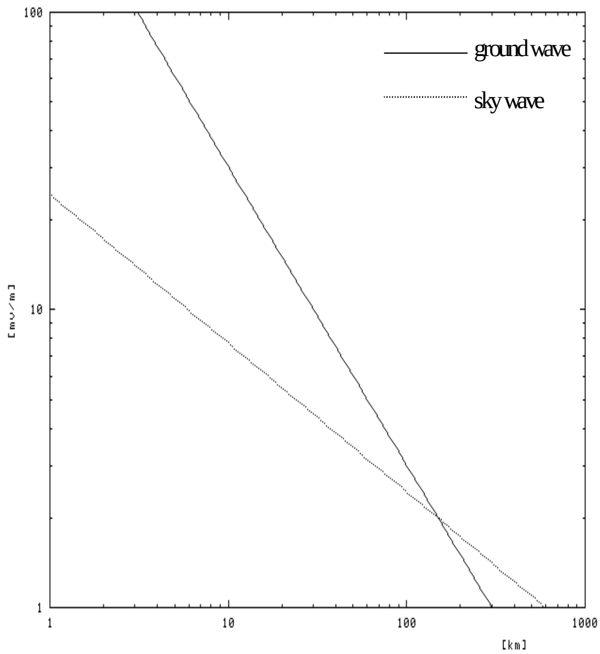

Fig. 2: Dependence on distance of the amplitudes of sky wave and ground wave (40kHz, transmitting power 1kw).

2. Observational Results

The total number of fading phenomena with duration of over ten minutes was 151 during the whole observation period, and that of earthquakes that we selected was 30 with a criterion of Ms $\geqq$ 4.0, within 2nd Fresnel zone. We show an example of the relationship between fadings and earthquakes in Fig.3. At the same time we examine the rain precipitation at three spots on the propagation path, Shimotuma (A in Fig.1), Ryuugasaki (B in Fig.1), and Tounosyou (C in Fig.1) in order to examine the association with precipitation. As for the earthquakes, there were recorded four earthquakes on 5 May, 23 July, 10 Sep. and 1 Nov. during these eight months, but it was recognized that fading occurs for less than 10 days around the day of earthquakes. In addition, it was suggested that fading might be related to weather factor, in particular rainfall.

So the fading which took place on that day when the precipitation was observed at least a little at those three spots, is considered to be due to the rainfall effect, so that such a fading was removed from the analysis. We show the result in Fig.4. The first glance at this figure may suggest that the fading phenomena (indicated by a box on the time axis) are closely related with the large earthquakes. Four large earthquakes are indicated by vertical lines, whose magnitude is greater than 4.0. These earthquakes in May, July, and October are found to accompany the fading effect, and mainly they take place before the quakes (especially for May, July and October earthquakes). We have to comment on the earthquakes in September. As is seen from Fig.3, there are a lot of rainfall before this earthquake, so that all of the fading phenomena are removed because we had rainfall simultaneously (even though some of fadings are due to the seismic effect). Fig.5 illustrates the superimposed epoch analysis, in which the full line (without the rainfall influence) may indicate the precursory effect of earthquakes.

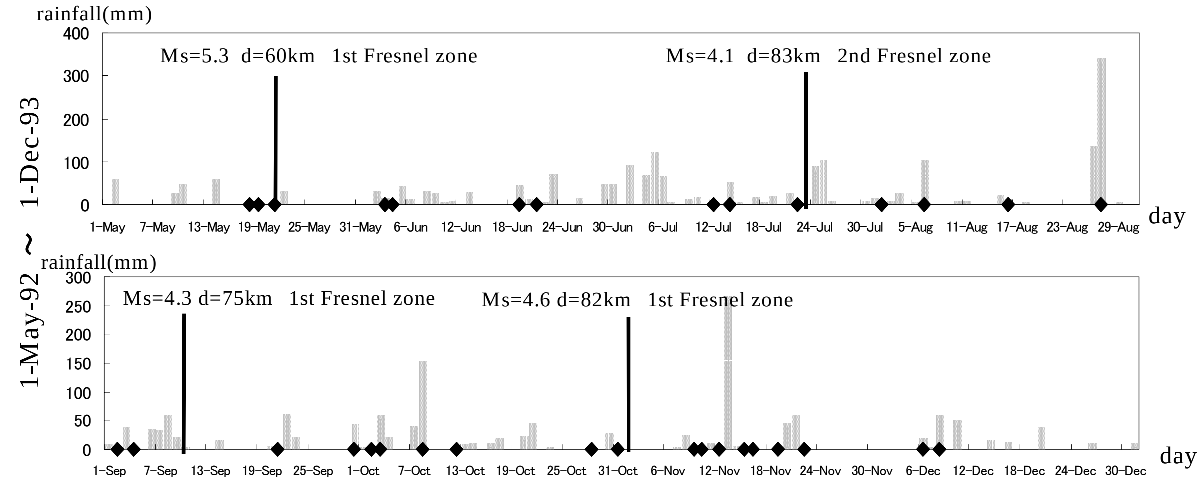

Fig. 3: Correlation plots of earthquakes, fadings and total rainfalls. The period is 8 months from 1 May, 92 to 1 Dec, 93. The Ms and depth of each earthquake are indicated, together with its location in terms of Fresnel zone.

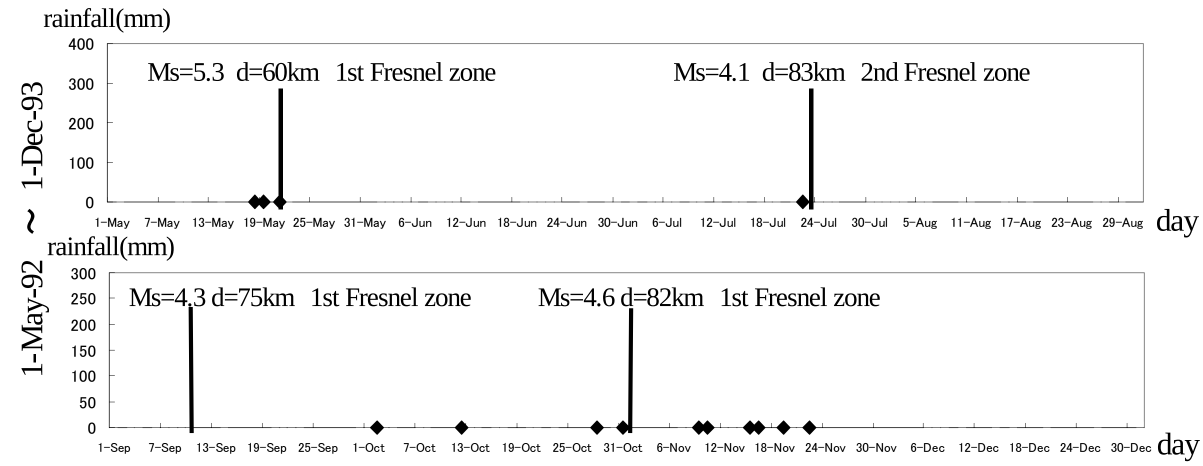

Fig. 4: Correlative plots of earthquakes and fading phenomena excluding the influence of precipitation.

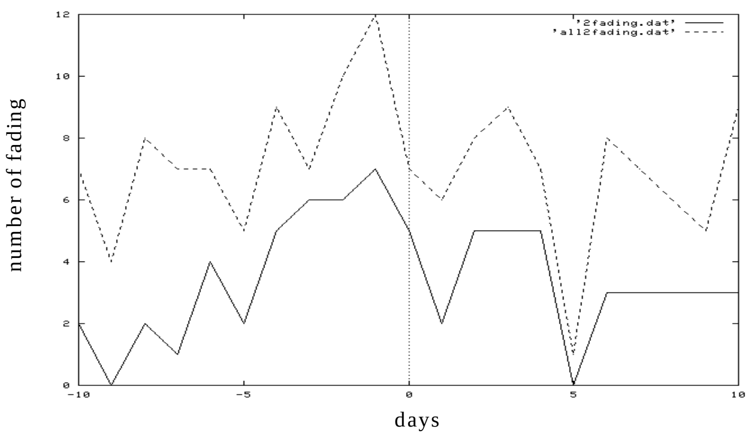

Fig. 5: Superimposed epoch analysis. The dotted line refers to all fadings, which the full line, to the fadings without the influence of rainfall. Both of those have a maximum a few days before an earthquake day, (0).

4. Discussion

The wave data we analyzed in this paper are considered to be due to the ground wave, which depends on the electric conductivity of the earth, etc. It is said that before an earthquake, the electric conductivity of the Earth changes by several hundred times as compared with the pre-quake condition. We think that a sudden change in those electricity constants has caused such a fading effect. The ground wave electric field E is as follows:

$$E = \frac{E_0 \lambda \{\varepsilon_s^{\ 2} + (60\sigma\lambda)\}}{\pi d \sqrt{(\varepsilon_s - 1)^2 + (60\sigma\lambda)^2}} \quad [\mathrm{mV/m}]$$

E_0 is the field in free space, λ, wavelength =7.5[km], d, distance of signal path = 100[km], σ, Earth's conductivity, and ε_s, permeability. Fig.6 shows the electric field of ground wave, in which we show how the electric field changes with the change in conductivity. In this calculation we used two conductivities for propagation over sea (σ =4[S/m], ε_s=80), and dry ground (σ =0.0005[S/m], ε_s=4), and shows the relation between the reception distance and field intensity. It is understood that about 40% change in electric field intensity is expected at the distance of 100km. It is indicated that fading taking place around earthquakes can be accounted for by the change of this field intensity.

The fading amplitude can be explained by this kind of change in conductivity, but we have to explore the fluctuation mechanism how we observe the fast fluctuation of fading. This should be studied in future.

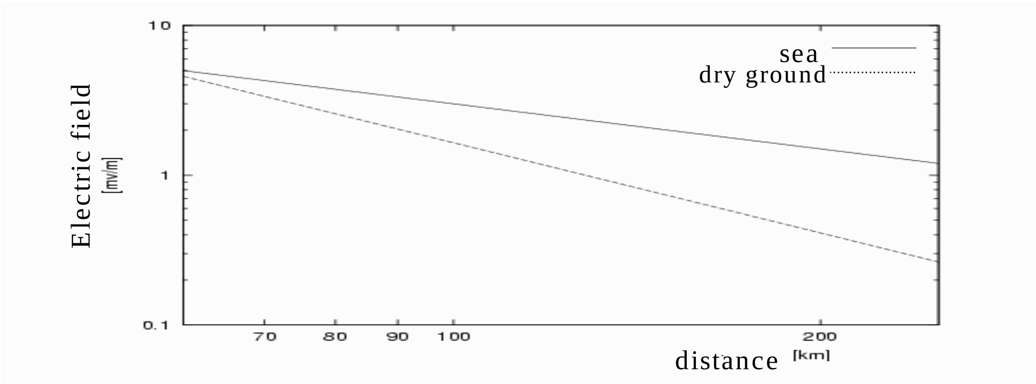

Fig. 6: Dependence on distance of electric field of the ground wave. The full line refers to the case of sea, while the dotted line, dry ground.

References

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