LETTER TO THE EDITOR

**Worldwide Simultaneity of Occurrence of a Q-type ELF Burst
in the Schumann Resonance Frequency Range**

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For the past ten years a number of workers have investigated naturally occurring ELF electromagnetic noises from different points of interest. Many recorded examples of noise waveforms have been exhibited in their papers (Schumann and König, 1954; Hepburn, 1957; Tepley, 1959, 1961; Balser and Wagner, 1960; Polk and Fitchen, 1962; Sao, Jindo, and Yamashita, 1963; Rycroft and Wormell, 1964; Hughes, 1964; Ogawa, Tanaka, Miura, and Yasuhara, 1966; Ogawa, Tanaka, Miura, and Owaki, 1966). Ogawa, Tanaka, Miura, and Yasuhara (1966) have classified the vertical electric component of these ELF noises, which were observed using a "ball antenna", into three categories; ELF flashes, ELF bursts, and "ELF continuous". ELF flashes probably originate from a kind of lightning discharge within a distance of about 1,000 km, and show a simple damped waveform. ELF bursts have two categories; N- and Q-types. N-type bursts have preceding VLF components and the source distances have been estimated to be in the range from 2,500 km to 5,000 km. The origin of N-type bursts may also be lightning discharges. Q-type bursts have no VLF components, and their amplitudes are rather larger than N-type bursts. The frequency of occurrence of Q-type bursts is found to be larger than that of N-type bursts, provided counting is restricted to bursts with amplitudes of over $400 \mu\text{V/m}$. Q-type bursts occur more frequently in the daytime than in the nighttime, as has already been pointed out by Polk (1964), and Keefe, Polk, and König (1964). "ELF continuous" comprises the background noise, and the daily variation of its mean amplitude is quite similar to the daily variation of world thunderstorm activity.

Most ELF noises originate with lightning discharges from thunderstorms over the world. The origin of the Q-type bursts, however, is not clearly understood. A point of interest in attempting to understand the origin of ELF noises is the geographical extent of their simultaneous occurrence and the change of their waveforms with distance. Keefe, Polk, and König (1964) investigated the simultaneity of the occurrences of ELF noises at Kingston (lat. $41^{\circ}30'$ North, long. $71^{\circ}32'$ West), Rhode Island, U.S.A., and Brannenburg (lat. $47^{\circ}26'$ North, long. $12^{\circ}03'$ East), Germany, and they found rather poor simultaneity of the occurrences. Considering the sensitivities of the instruments used by them they might have measured both ELF flashes and ELF bursts. As described above, ELF flashes and N-type ELF bursts originate rather near to the observation sites, and would not simultaneously be observed at both stations.

Galejs (1965) quoted two horizontal magnetic field components observed simultaneously

in Canada and in Antarctica (Lokken, 1964, private communication) and showed the existence of a good correlation between occurrences of the high intensity ELF noise bursts observed at three sites.

On May 8, 1966 at 08 h 01 m 37.6 s UT a large, beautiful damped oscillation of about 7.8 Hz was recorded at Kyoto on vertical electric-field component (Ogawa, Tanaka, Miura, and Yasuhara, 1966). The corresponding oscillation was also recorded at Aso on both the vertical electric-field component, and NS and EW components of earth current. The oscillation is not preceded by higher component than some hundred Hz. It apparently falls into the previously defined category of a Q-type burst. Inquiries regarding the simultaneous occurrence of this oscillation were made at seventeen institutions over the world. It was found that simultaneous observations were made at three of those stations: Palo Alto, Kauai, and Kerguelen Island. Location of these measuring stations is indicated on a world map in Fig. 1. In Table 1 are given geographic and geomagnetic coordinates of the five stations, and local onset time, measured components, peak-to-peak amplitudes, and frequencies of the oscillation. The recorded oscillations are reproduced in Figs. 2, 3, 4, 5, and 6 for Kyoto, Aso, Palo Alto, Kauai, and Kerguelen Island respectively. It is interesting to see the very similar waveforms recorded at the stations.

As is shown in Fig. 7 the onset times of the oscillation coincide with each other within the accuracy of measurement, but there seems a tendency of the onset time to start first at Kerguelen Island, then move toward Palo Alto.

The amplitude of the oscillation is much larger than those of natural ELF noises which excite the earth-ionosphere cavity resonances. The peak-to-peak amplitude at Palo Alto is about twice as large as at Kerguelen Island. As the impulsive responses of the recorders are, however, different at both stations, we should not pay too much attention to these values.

The average frequency of the oscillation was calculated for each station and each component for several periods of the clear oscillation. The average frequencies thus calculated are different from each other component as is shown in Fig. 8. NS component of both the electric and magnetic components has a higher frequency of 7.84 Hz on the average, except at Kauai. The electric vertical component also has a higher frequency. EW component of both the electric and magnetic components has a lower frequency of 7.47 Hz on the average. This fact may be caused by anisotropy of conductivity of the upper boundary of earth-ionosphere wave guide due to the earth's magnetic field.

As the average frequency of the oscillation is just the same as that of the fundamental mode of the Schumann resonance, the phenomenon should have resonated as it propagated between the earth and the ionosphere. Let θ the angular separation between the signal source and the observation site, then the peak intensity of each mode of the Schumann resonances is proportional to $P_n(\cos\theta)$ for the electric vertical component, where P_n is the n th Legendre polynomial, while for the electric horizontal component and the magnetic component it is proportional to $\frac{\partial}{\partial\theta} P_n(\cos\theta)$. For the fundamental mode $P_1(\cos\theta) = \cos\theta$ and $\frac{\partial}{\partial\theta} P_1(\cos\theta) = -\sin\theta$. In the present observation net Palo Alto and Kerguelen are situated

Fig. 1 Location of measuring stations of the event.

Table 1. The coordinates of the stations, and local onset time, measured components, amplitudes, and frequencies of May 8 1966 event

Station	Geographic Latitude	Geographic Longitude	Geomagnetic Latitude	Geomagnetic Longitude	Local Onset Time	Measured Component	Amplitude (peak-to-peak)	Frequency (Hz)
Palo Alto	37°26'N	122°10'W	43.5°N	299.0°E	00 ^h 01 ^m 37.59 ^s ±0.04 ^s	Magnetic NS Magnetic EW	90 mV 120 mV	7.80±0.21 7.47±0.21
Kyoto	35°01'N	135°47'E	24.5°N	202.2°E	17 ^h 01 ^m 37.56 ^s ±0.03 ^s	Electric, Vertical	1.4 mV/m	7.84±0.12
Aso	32°53'N	131°01'E	22.1°N	198.1°E	17 ^h 01 ^m 37.56 ^s	Electric, Vertical Electric NS Electric EW	Scale off Scale off Scale off	7.93±0.12 7.85±0.12 7.52±0.12
Kauai	22°09'N	159°18'W	21.7°N	265.6°E	22 ^h 01 ^m 37.52 ^s ±0.04 ^s	Magnetic NS	70 mV ±10 mV	7.42±0.18
Kerguelen Island	49°19' S	70°10' E	56.5° S	127.8° E	13 ^h 01 ^m 37.49 ^s ±0.06 ^s	Magnetic NS Magnetic EW	65 mV 45 mV	7.78±0.15 7.47±0.15

Fig. 2 Electric vertical component of the event observed at Kyoto.

Fig. 3 Electric vertical and horizontal NS and EW components of the event observed at Aso.

Fig. 4 Magnetic NS and EW components of the event observed at Palo Alto.

Fig. 5 Magnetic NS component of the event observed at Kauai.

Fig. 6 Magnetic NS and EW components of the event observed at Kerguelen Island.

Fig. 7 Distribution of onset time of the event commencing 08 h 01 m UT May 8, 1966.

Fig. 8 Distribution of frequency of the event. Cross marks indicate vertical component, black circles indicate NS component, and white circles indicate EW component.

at almost opposite sides of the globe, and at both stations the 8 Hz oscillations were observed on the magnetic record, not including higher harmonic components. This suggests that the position of the source signal is 90° separated from the both stations: near where Japan is situated. However the 8 Hz oscillations were also clearly observed at Japanese stations on both the *electric vertical* and *horizontal* components simultaneously, and this not only rules out the possibility of generation of the oscillation near Japan but also the other possibility of generation on the opposite side of the world from Japan.

In spite of the half worldwide distribution of location of the measuring stations, the present oscillation shows almost the same waveform not including VLF component, although electromagnetic noises radiated from lightning discharges, which compose most ELF noises, cover a wide frequency range at their origin.

There are therefore certain features of the oscillation which suggest an origin different from a lightning discharge. If this is the case, the question then arises as to where and how

it originated. Did it originate in the ionosphere, for example, or outside the ionosphere? We can not answer these questions at the present time. It is the purpose of this letter to draw attention of worldwide cooperative study to the origin of Q-type ELF bursts.

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