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Unique Features of VLF Noise Triggered in the Magnetosphere by Morse-Code Dots from NAA

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A study of 1963 VLF data from Eights, Antarctica, verified that triggering of artificial magnetospheric noise by Morse-code dots at 14.7 kHz occurs rarely by comparison to triggering by dashes. In the few cases (~0.3% of all runs) when dots were found to trigger noise, this occurred during strong triggering by dashes. On spectrograms, the dot-produced noises were in each case of a simple falling-tone form.

Previous research on VLF magnetospheric noise triggered by fixed-frequency transmitters indicated a strong dependence of noise occurrence on the duration of the transmitted signal. Morse-code dashes, ~150 msec long, were found to produce the bulk of events observed at ground stations, whereas dots, ~50 msec long, were found to trigger only rarely [*Helliwell et al.*, 1964; *Kimura*, 1967]. To verify the dot-dash relationship, the author recently examined spectrographic records from 43 active periods of artificially stimulated emissions (ASE). The noises were produced by NAA at 14.7 kHz (10^6 watts, Cutler, Maine, $L \sim 3.2$) and were observed in the conjugate region at Eights, Antarctica ($L \sim 4$). The study indeed verified the low production of noise by dots, and showed that whenever dots do trigger, the noise produced has a simple and distinctive spectral form.

In a previous study of Eights data by the author, a visual examination was made of 35-mm spectral records representing hourly 2-min broadband recordings in May–August 1963. In this study, 235 of 1625 recording intervals (~15%) were found to contain NAA-produced ASE. I. Kimura (personal communication), in studying several blocks of this same data, found that all cases tentatively containing triggering by dots also involved strong triggering by dashes. A careful re-examination of 43 of the most active runs was therefore made, and identifiable triggering by dots was found in only 4 of these. Triggering by dots therefore occurred in ~4/1625 or 0.3% of all runs, in ~4/235 or 1.7% of all runs containing ASE, and in ~4/43 or 9% of all periods of 'strong' triggering by dashes. The original findings of *Helliwell et al.* [1964] on the rarity of triggering by dots were strongly confirmed.

Three of the four known examples of ASE triggering by dots and of what is meant by 'strong' triggering by dashes are shown in Figure 1. Northern-hemisphere records of frequency 14–18 kHz versus time show the transmitted schedule of NAA at 14.7 kHz. The corresponding Eights records (12–18 kHz) are immediately below. Each northern-hemisphere record is shown with a time delay sufficient to make the noises received at Eights lie approximately below the associated sequence of transmitted dots and dashes. The time shifts, of the order of 1 sec, are indicated by arrows above the northern-hemisphere records. (It is known from other work that the time between keying of a dash and the observation of an ASE in the conjugate hemisphere is approximately equal to the whistler-mode travel time over the path [*Helliwell et al.*, 1964].)

The distinctive spectral form of noises triggered by dots is illustrated particularly well by the bottom pair of panels of Figure 1. Before $t \sim 1.4$ sec, dashes are regularly transmitted (cf. SES record), and the triggering is extremely complex, with many overlapping rising and falling tones. Then from $t \sim 1.4$ sec until $t \sim 3.3$ sec, dots only are keyed, and there is a series of falling tones, each apparently associated with a single dot of the transmitted schedule. After $t \sim 3.3$ sec, triggering by dashes again dominates the activity. Roughly similar patterns appear on the other two pairs of panels, although

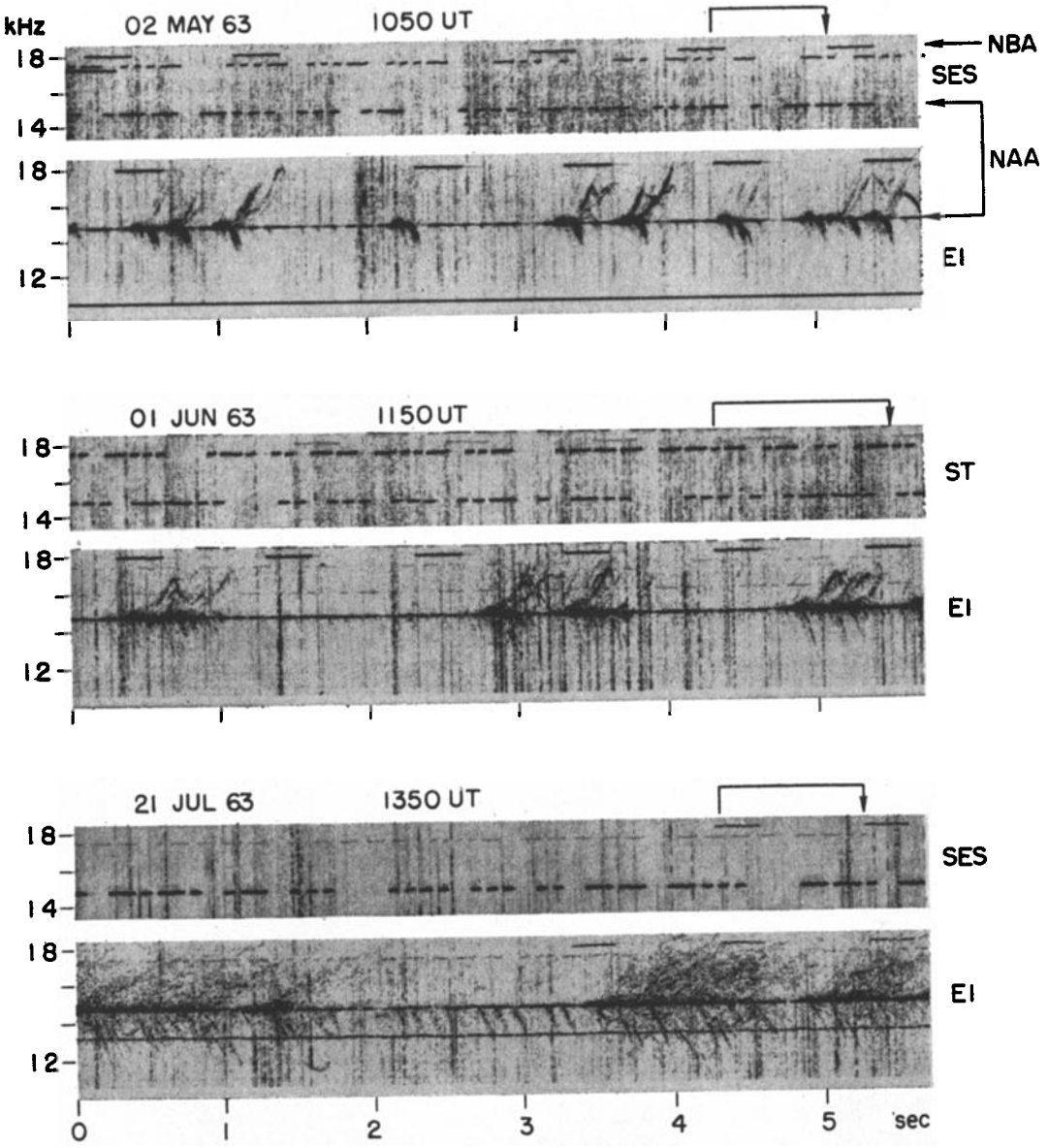

Fig. 1. Frequency-time records illustrating strong triggering of VLF magnetospheric noise by Morse-code dashes and the characteristic falling-tone spectrum of noises triggered by Morse-code dots. Three cases are illustrated, with northern-hemisphere records from Suffield Experimental Station (SES) and Stanford (ST) compared with the corresponding records of noises observed at Eights, Antarctica. In each case the northern-hemisphere display of the transmitted schedule of NAA at 14.7 kHz is shown with a time delay sufficient to make the noises received at Eights lie approximately below the associated sequence of transmitted dots and dashes. The time shifts are indicated by arrows.

the dot-associated falling tones are of much more limited duration in these cases. The greater length and intensity of the dot-associated noises on the bottom panel may be related to the correspondingly greater complexity of the dash-produced forms there.

The restriction of triggering by dots to periods of very active dash-associated activity makes the problem of dot-noise identification difficult. The dash noises are often complex and of longer duration than the ~150 msec transmitted pulse. Single dashes in Figure 1 appear to produce several falling as well as rising tones, thus tending to mask any dot noises that might be produced. To avoid this masking effect, it is necessary to select Morse-code words in which dots and dashes are clearly separated, as was done in the cases illustrated.

In the present study it has been verified that triggering by dots occurs rarely. When dots were found to trigger, this occurred during strong triggering by dashes involving both rising and falling noise forms. The dot-produced noises were in each case of a simple falling-tone form, in contrast to the rising characteristic found by *Kimura* [1967] to be the most common form of dash-produced ASE. (Kimura classified the noises according to the categories of falling tones, rising tones, combinations of these, and other various effects, finding rising tones to occur in 64% of the cases studied.)

The dot-noise form is similar to the short falling tone occasionally observed at the end of the ~1-sec Omega pulses observed at Eights. This type of noise, produced at 10.2 kHz by the 100-watt transmitter at Forest Port, New York, is also rare by comparison to NAA dash-produced ASE [*Kimura,* 1968].

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