RECENT MEASUREMENTS AND MODELING OF ELF/VLF RADIO NOISE

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ABSTRACT

As we have pointed out at preceding URSI General Assemblies, there have been many studies made of specific wave phenomena in the ELF/VLF range (5 Hz to 30 kHz), but there has been a lack of measurements of the important statistical quantities that define ELF/VLF radio noise in a communication context. In an effort to provide these quantities, the STAR Laboratory at Stanford University has been conducting a global survey of ELF/VLF radio noise, with measurement systems installed at eight different locations around the world [1]. This paper reports on recent progress in the derivation of new noise statistics and noise parameters as well as the development of new and improved noise models (Fig. 1 shows an example of clustering in ELF/VLF noise for which a new noise model is developed). Examples illustrating the distinctive modal propagation of ELF/VLF noise during nighttime conditions are presented. In addition, recent measurements of the ultra-low frequency (ULF; frequencies less than 5 Hz) magnetic field produced by thunderstorms are presented, which suggest (1) the existence of correlations between ULF and ELF/VLF radio noise, and (2) that thunderstorms may help stimulate ULF geomagnetic pulsations.

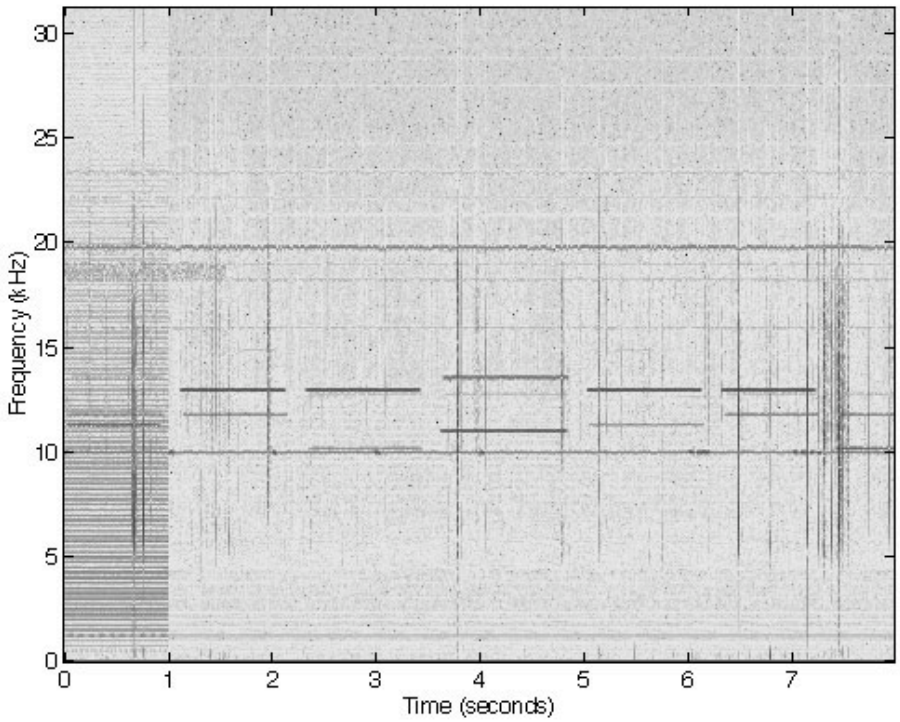

Fig. 1. Arrival Heights VLF spectrogram, 08 May 1995, at 16:05 UTC. The vertical lines are sferics, and a distinctive cluster (or multiple clusters) of these sferics can be seen occurring just after the seven second time mark. The first 1 second of the interval of data shown includes a calibration signal. The horizontal lines all represent man-made signals of various kinds.

ELF/VLF NOISE MODELING

A new clustering Poisson model is developed that accurately characterizes the interarrival times of ELF/VLF sferics [2]. According to this model, the sources of the noise are clusters of impulses with independent and identically distributed waveforms (an example of the naturally-occurring clustering can be seen in Fig. 1). Cluster occurrence is a spatial and temporal Poisson process with source distribution independent of direction and time. The impulses within clusters are defined as variable length Poisson processes. The model is justified by the physical properties of lightning and it is verified by comparing its predicted impulse interarrival distributions to those of measured atmospheric radio noise. Given the accuracy to which the predicted distributions fit the actual data, the Clustering Poisson model proves to be a strong candidate for characterizing the clustering of sferics in atmospheric noise.

ELF/VLF RADIOWAVE PROPAGATION

ELF/VLF radio noise measurements made during the night and day are compared for the frequency range 500 Hz and 5.0 kHz and the first three propagation modes are found to produce distinctive changes in the nighttime data (see Figure 2). The cutoff frequencies for the modes are typically well defined and the noise amplitudes between the cutoff frequencies often show unusual oscillatory behavior that is ascribed to interference between adjacent modes [3].

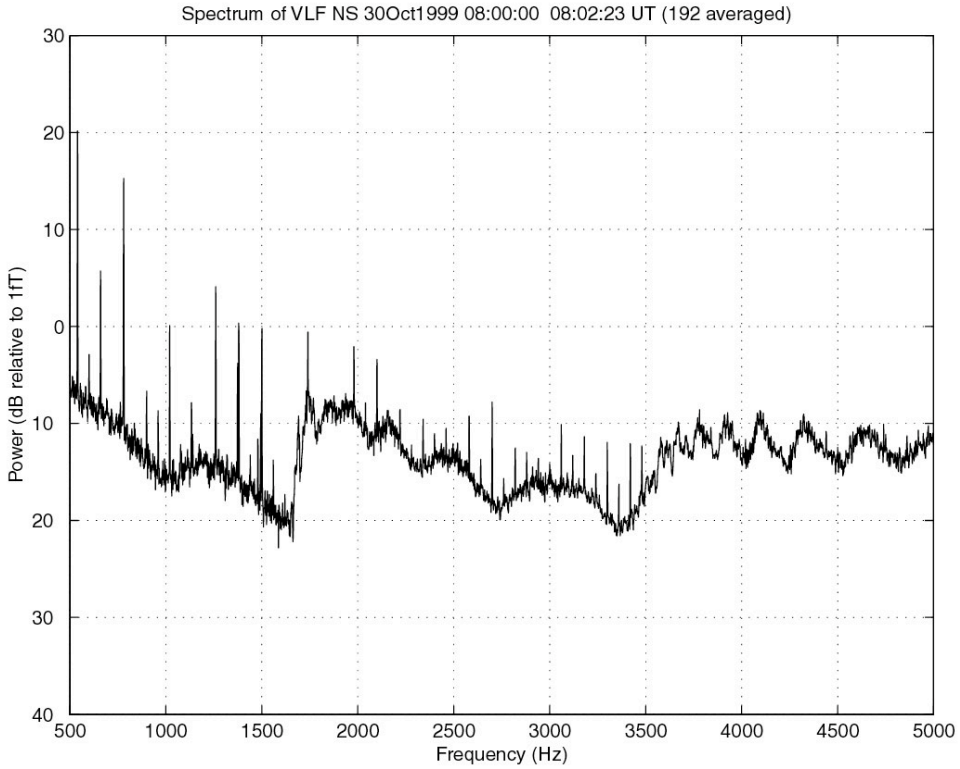

Fig. 2. Measured spectrum of the ELF/VLF noise occurring at Stanford, California, during the night on October 30, 1999, 08:00 UT (00:00 local; the NS field component of the noise is plotted). Transitions between modes can be clearly seen at around 1700 Hz and 3600 Hz.

ULF & ELF/VLF RADIOWAVE CORRELATIONS

Measurements of ultra-low frequency (ULF; frequencies less than 5 Hz) magnetic field fluctuations near isolated thunderstorms show that thunderstorms are powerful sources of ULF magnetic fluctuations with the potential to produce geomagnetic pulsations at distant locations (Fig. 3). Given that thunderstorms are also the source of most if not all of the sferics comprising the major part of natural ELF/VLF radio noise, these measurements suggest that there must be correlations between ULF magnetic fluctuations and ELF/VLF radio noise [4, 5].

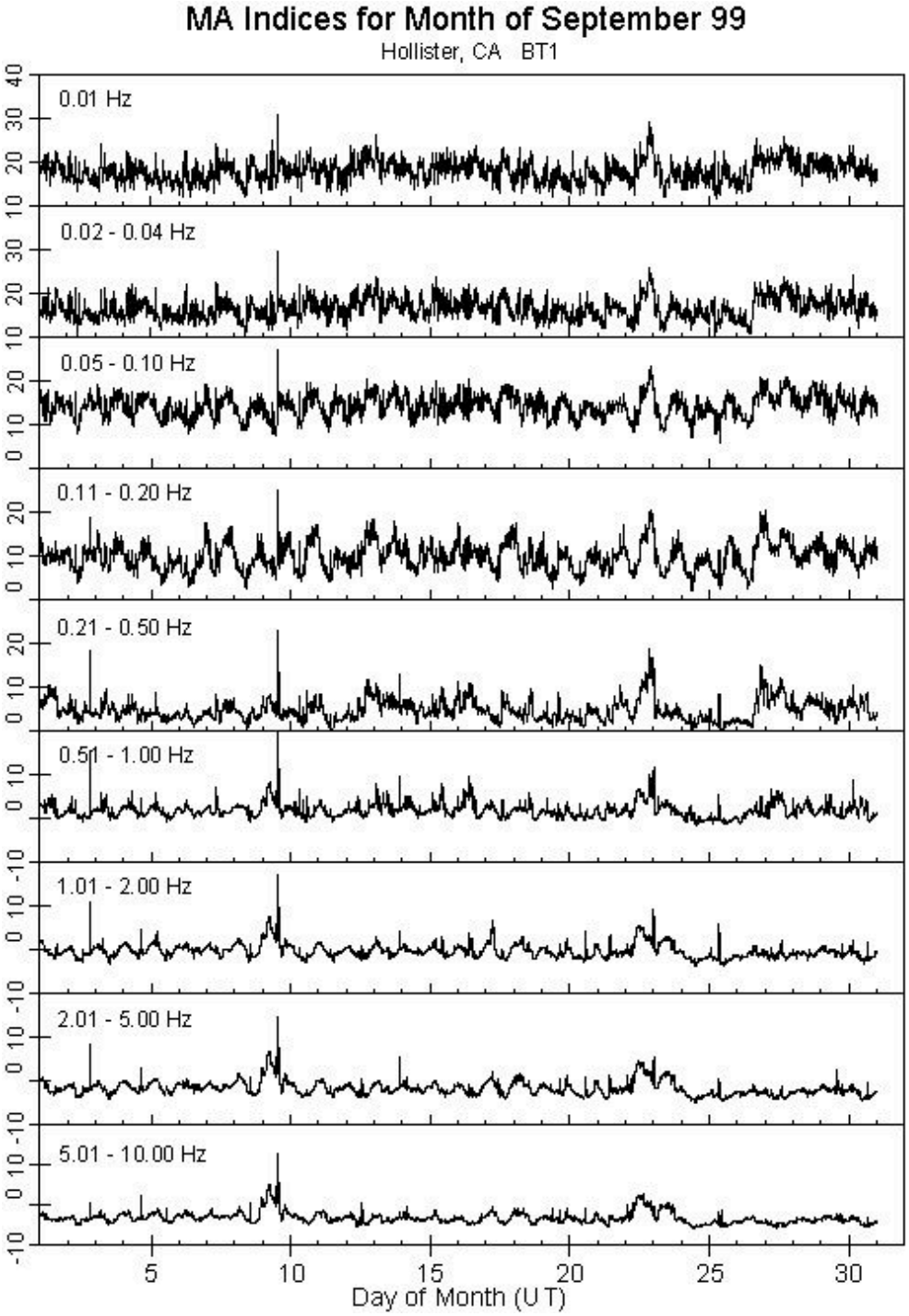

Fig. 3. Geomagnetic activity indices measured during the September 1999 at Hollister, California. Two local, isolated thunderstorms occurred in the vicinity of Hollister during the month. The first of these took place during the interval 8–9 September and the second during the interval 22–23 September. Both thunderstorms produced strong ULF magnetic field changes at Hollister (lightning striking close to the measuring instrument produced the large spikes on the 9th), but there are distinct differences in their frequency characteristics.

REFERENCES

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