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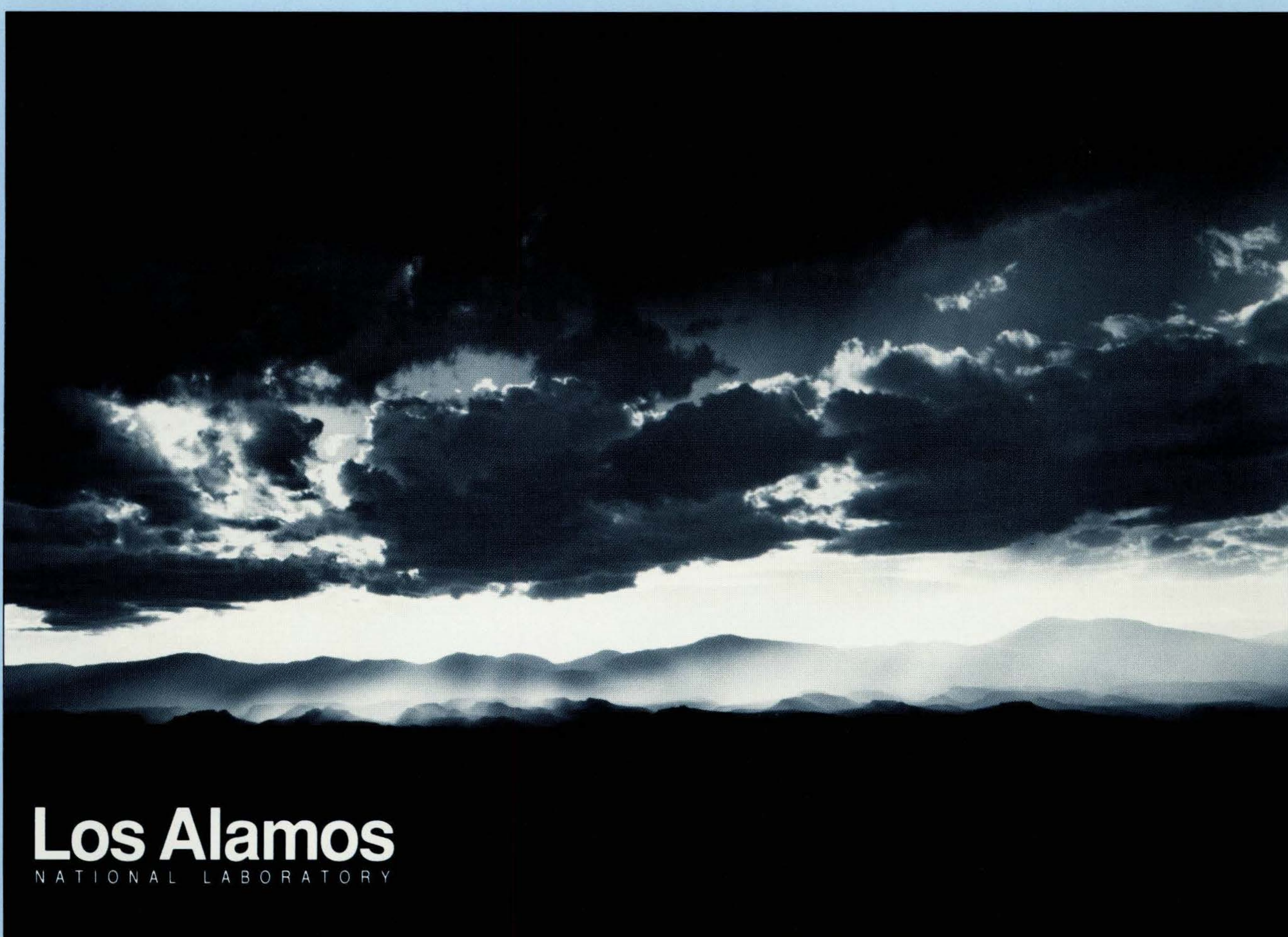
INTEGRATED VERIFICATION EXPERIMENT DATA COLLECTED AS PART OF THE LOS ALAMOS NATIONAL LABORATORY'S SOURCE REGION PROGRAM

APPENDIX D:

IONOSPHERIC MEASUREMENTS FOR IVEs

T. Joseph Fitzgerald, Robert C. Carlos, and Paul E. Argo

LOS ALAMOS SOURCE REGION PROGRAM



Photograph: by Chris J. Lindberg

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Contents

Abstract

As part of the integrated verification experiments (IVE), we deployed a network of hf ionospheric sounders to detect the effects of acoustic waves generated by surface ground motion following underground nuclear tests at the Nevada Test Site. The network sampled up to four geographic locations in the ionosphere from almost directly overhead of the surface ground zero out to a horizontal range of 60 km. We present sample results for four of the IVEs: Misty Echo, Texarkana, Mineral Quarry, and Bexar.

1 Introduction

This appendix presents a description of the ionospheric measurements conducted for the integrated verification experiments (IVE) and a sample of the results for the following events: Misty Echo, Texarkana, Mineral Quarry, and Bexar. Because of other commitments ionospheric measurements for the following events could not be obtained: Tulia, Contact, Hornitos, Bullion, and Junction. Experimental difficulties prevented any data acquisition on two events: Amarillo and Metropolis. No ionospheric disturbance was detected for the Ingot event for reasons discussed below. Ionospheric measurements were obtained for several non-IVE events during the same time period but these will not be discussed here.

Ionospheric detection of UGTs relies on the generation of an acoustic wave by surface ground motion following the explosion and propagation of the acoustic wave to high altitudes above GZ where its interaction with the natural ionospheric plasma produces electron density changes. In the detection technique employed for the IVEs, we broadcast highly stable radio tones in the high frequency band, about 3 MHz; the frequency is chosen so that the radio signal is reflected in the ionosphere at an altitude of about 100 km. Any disturbance to the electron density at the reflection level, such as that produced by the acoustic waves following a UGT, will alter the radio signal and thus allows the detection and categorization of the acoustic source.

Our technique is called bistatic radio propagation, that is, a transmitter at one location broadcasts to a receiver at a far enough distance so that direct propagation (ground wave) is highly reduced compared to ionospheric propagation (sky wave). The sensitive region for detecting acoustic disturbances is above the geographic midpoint of the path between transmitter and receiver. For the IVEs we employed two transmitter locations, one at Tonopah Test Range (TTR) and the other at the EPA Farm in Area 15 of the NTS; we also employed two receiver locations, one near Well 5e in Area 5 of the NTS and the other at Indian Springs AFB (ISP). The map in Figure 1 shows that these locations give sensitive regions over Area 19, Area 12, and Area 3 where most Los Alamos events are conducted. Table 1 lists the paths used for the four experiments for which we present results. We detected the high frequency radio signals with Racal 6790GM receivers operated in cw mode which produced a low-passed audio signal at a frequency between 20 to 50 Hz which were digitized and stored. In the analysis presented here, we performed a digital complex demodulation and decimation of the signal to derive time series of the complex amplitudes of the received signals in a $\pm 5\ Hz$ frequency band. The power spectra of these time series presented below show variations of the detected signal versus frequency relative to the nominal transmitted radio frequency.

In general we broadcasted two frequencies from each transmitter location; the two frequencies were chosen so that they reflected from sufficiently separated altitudes to allow time delay discrimination of the acoustic waves. Moreover, we employed a spatial array of antennas at the receive locations so that we could conduct interferometry and array processing of the disturbances. The arrays are illustrated in Figure 1.

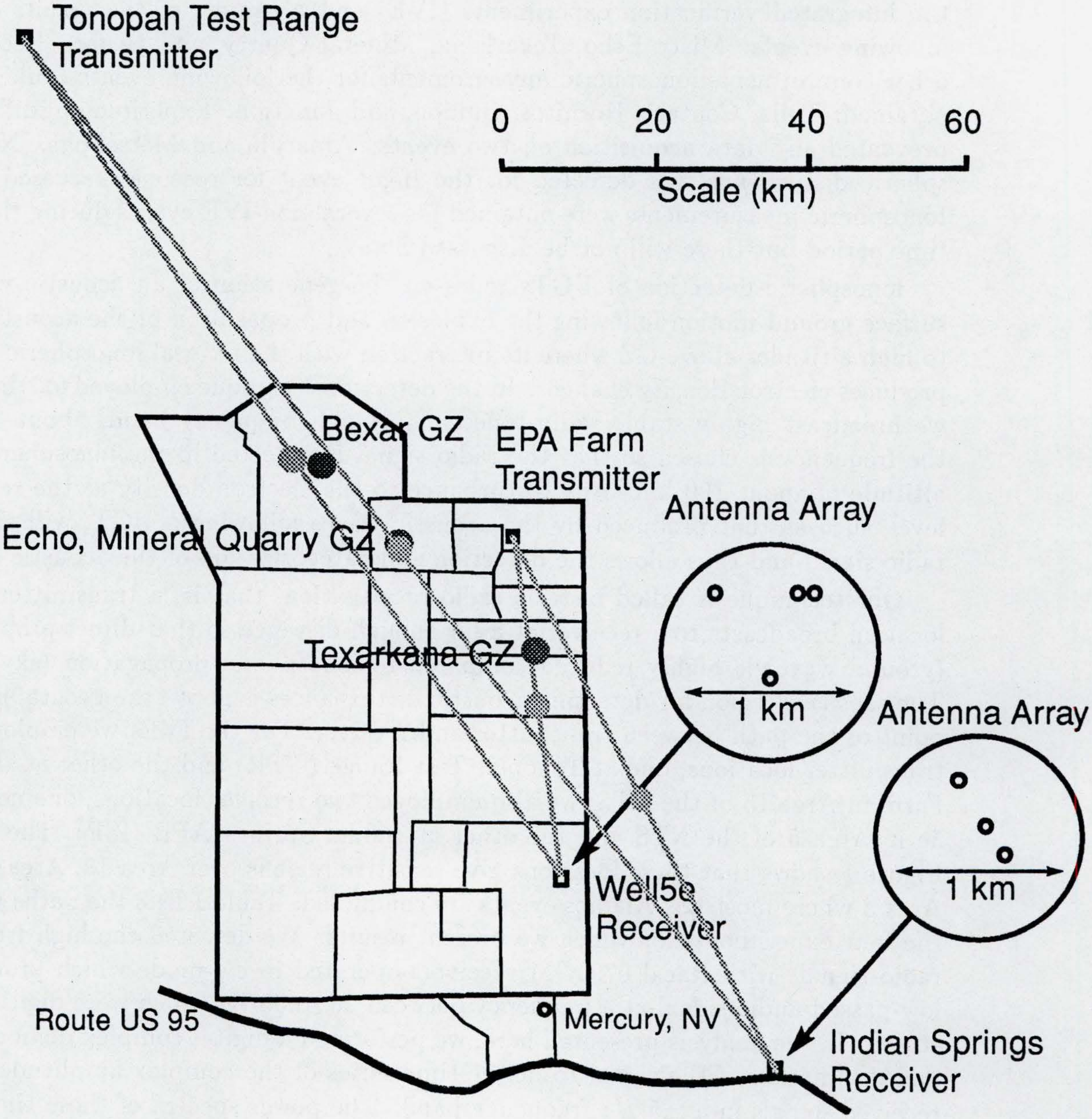

Figure 1: Location of transmit and receive stations used for ionospheric measurements for IVEs. Dark-filled circles indicate locations of surface ground zero; light-filled circles indicate mid-paths between transmitters and receivers.

Event	WL5-EPA	WL5-TTR	ISP-EPA	ISP-TTR
Misty Echo				•
Texarkana	•			
Mineral Quarry				•
Bexar	•	•	•	•

Table 1: Paths deployed for IVE experiments.

We briefly describe for each of the four IVE events for which a disturbance was detected these parameters: the transmitter-receiver paths; the radio frequencies employed; a summary of the results; and sample power spectra versus time. The Ingot event for which no disturbance was detected took place so early in the morning that the ionosphere was in a nighttime condition; the acoustic waves would have dissipated before reaching the 300 km reflection altitude of our hf signals.

2 Misty Echo

For this tunnel event we employed transmitters at Tonopah Test Range operating at 3.70 and 3.75 MHz and receivers at Indian Springs AFB. In the absence of ionosonde data of electron density content versus altitude, we must rely on models of electron density which predict that these frequencies reflected in the E layer of the ionosphere at an altitude of about 100 km. Figure 2 shows the power spectra versus time for one set of data; although the signal to noise ratio for this data set was poor a disturbance beginning at 340 s after the explosion is evident. This delay corresponds to acoustic propagation to the E layer.

3 Texarkana

For this Area 7 event we employed transmitters at the EPA Farm operating at 2.90 and 3.30 MHz and receivers at Well5e. Ionosonde data obtained at Well5e shows that the radio frequencies reflected in the E layer of the ionosphere at an altitude of about 100 km. Figure 3 shows the power spectra versus time for one set of data between 250 and 500 s after the event; a prolonged disturbance beginning at 335 s after the explosion is evident.

4 Mineral Quarry

For this tunnel event we employed transmitters at Tonopah Test Range and receivers at Indian Springs AFB. The radio frequencies were chosen to have reflected in the E layer of the ionosphere at an altitude of about 100 km. Figure 4 shows the power spectra versus time for one set of data; a disturbance beginning at 320 s after the explosion is evident.

5 Bexar

For this Area 19 event we employed all stations to obtain four reflection points ranging from almost directly overhead to 60 km distance. The operating frequencies were 3.82 and 3.92 MHz; ionosonde data obtained at Well5e shows that the radio frequencies reflected in the E layer of the ionosphere at an altitude of about 100 km. Figure 5 shows the power spectra versus time for one set of data; there is a disturbance beginning at 310 s after the explosion.

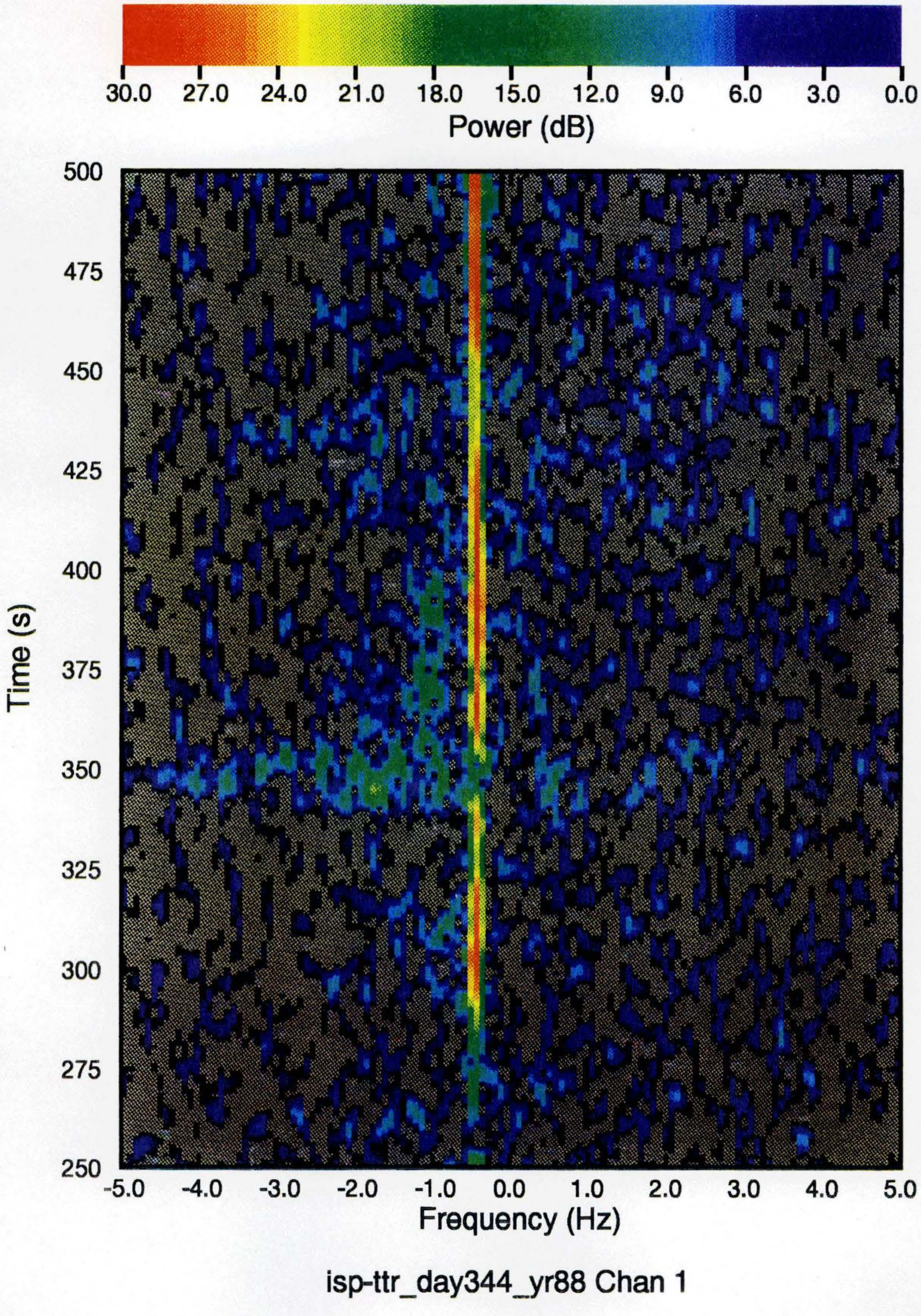

Figure 2: Power spectrum of cw transmission between the Tonopah Test Range and Indian Springs versus time in seconds after the detonation of the Misty Echo event. The plot shows spectral power coded according to the scale at the top at a given Doppler shift between 250 and 500 s after the detonation of the UGT. A disturbance associated with the UGT occurred between 340 and 400 s.

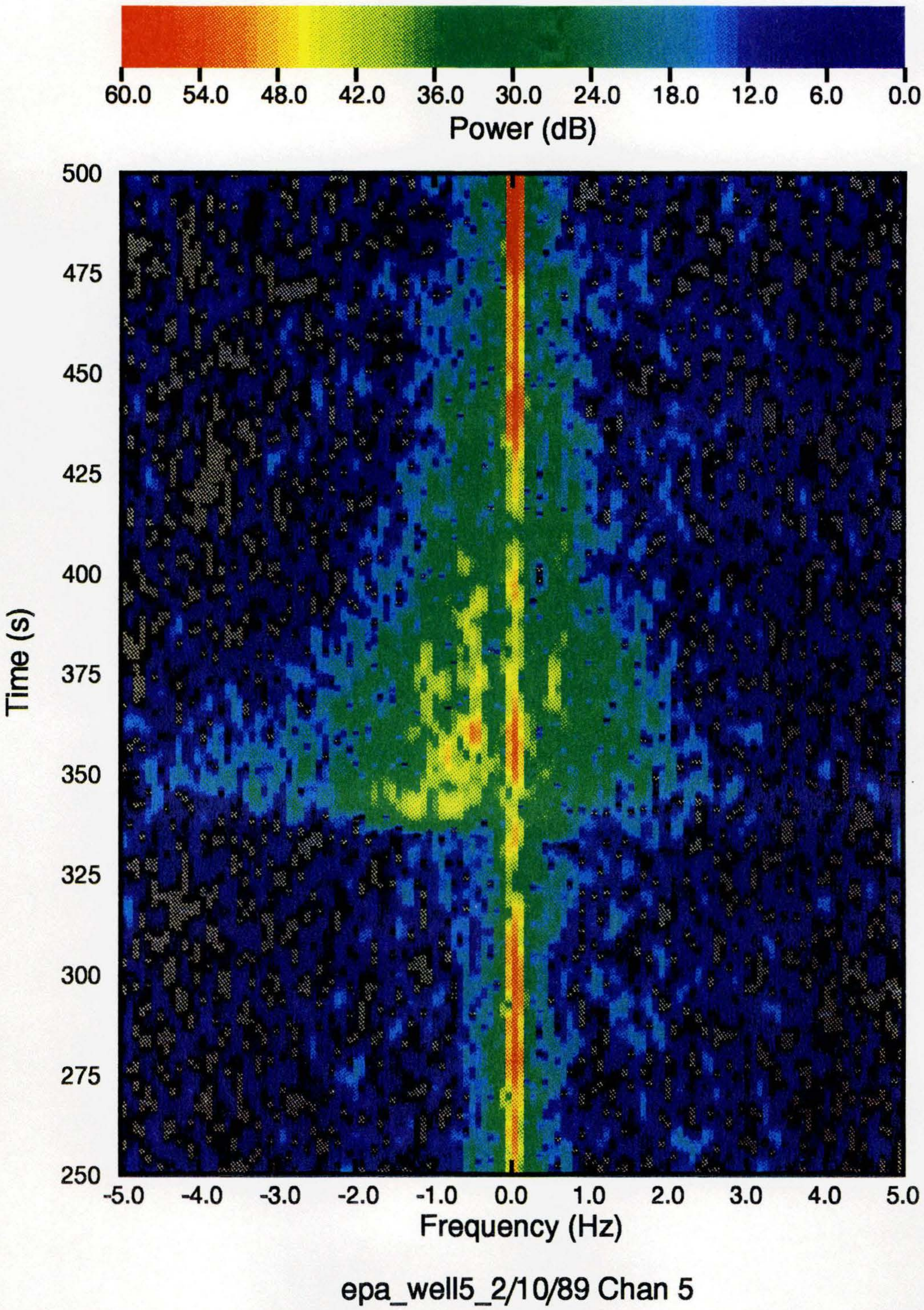

Figure 3: Power spectrum of cw transmission between the EPA Farm and Well 5e versus time in seconds after the detonation of the Texarkana event. The plot shows spectral power coded according to the scale at the top at a given Doppler shift versus time after the detonation of the UGT. A disturbance associated with the UGT occurred between 335 and 500 s.

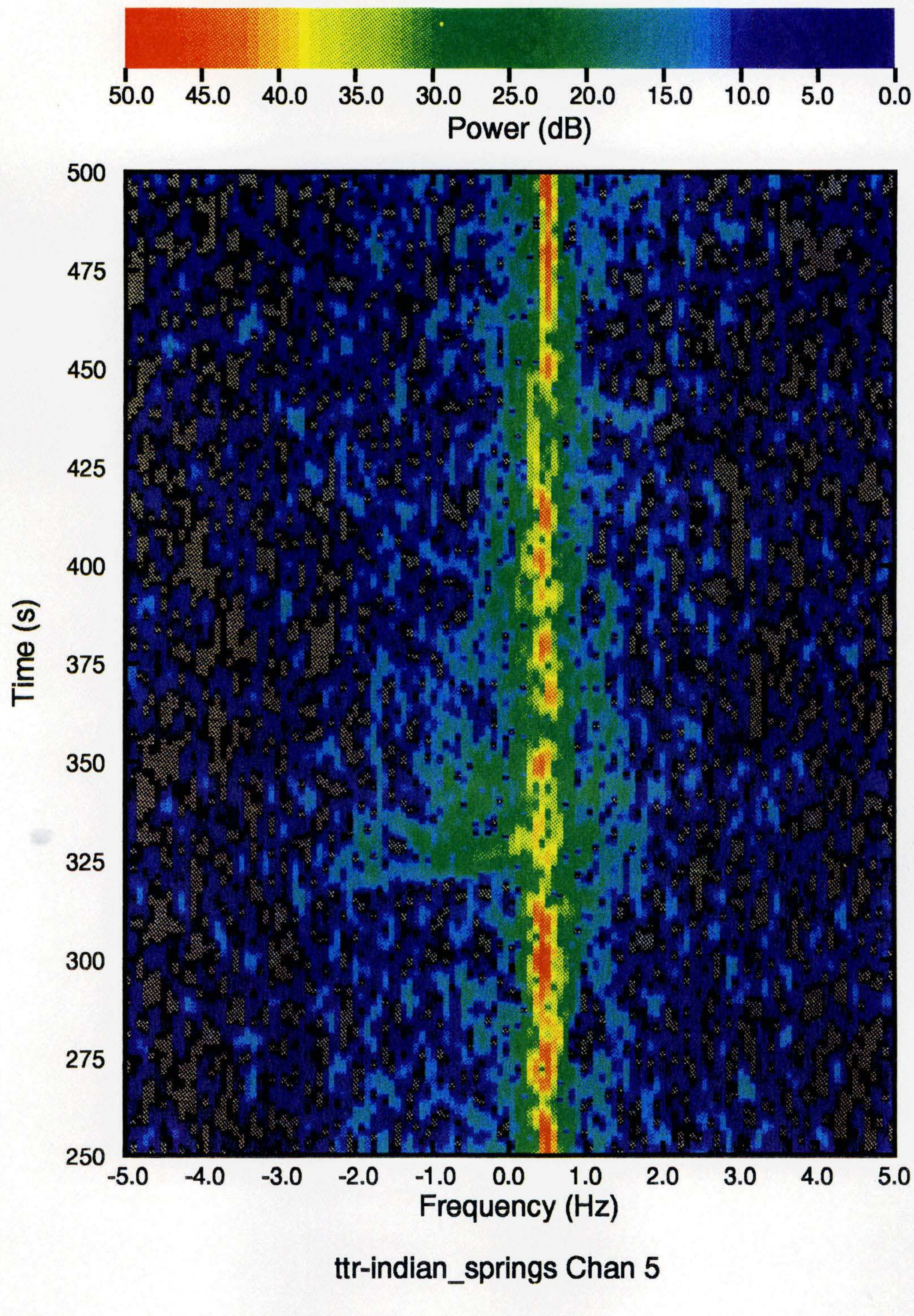

Figure 4: Power spectrum of cw transmission between the Tonopah Test Range and Indian Springs versus time in seconds after the detonation of the Mineral Quarry event. The plot shows spectral power coded according to the scale at the top at a given Doppler shift between 250 and 500 s after the detonation of the UGT. A disturbance associated with the UGT occurred between 320 and 360 s.

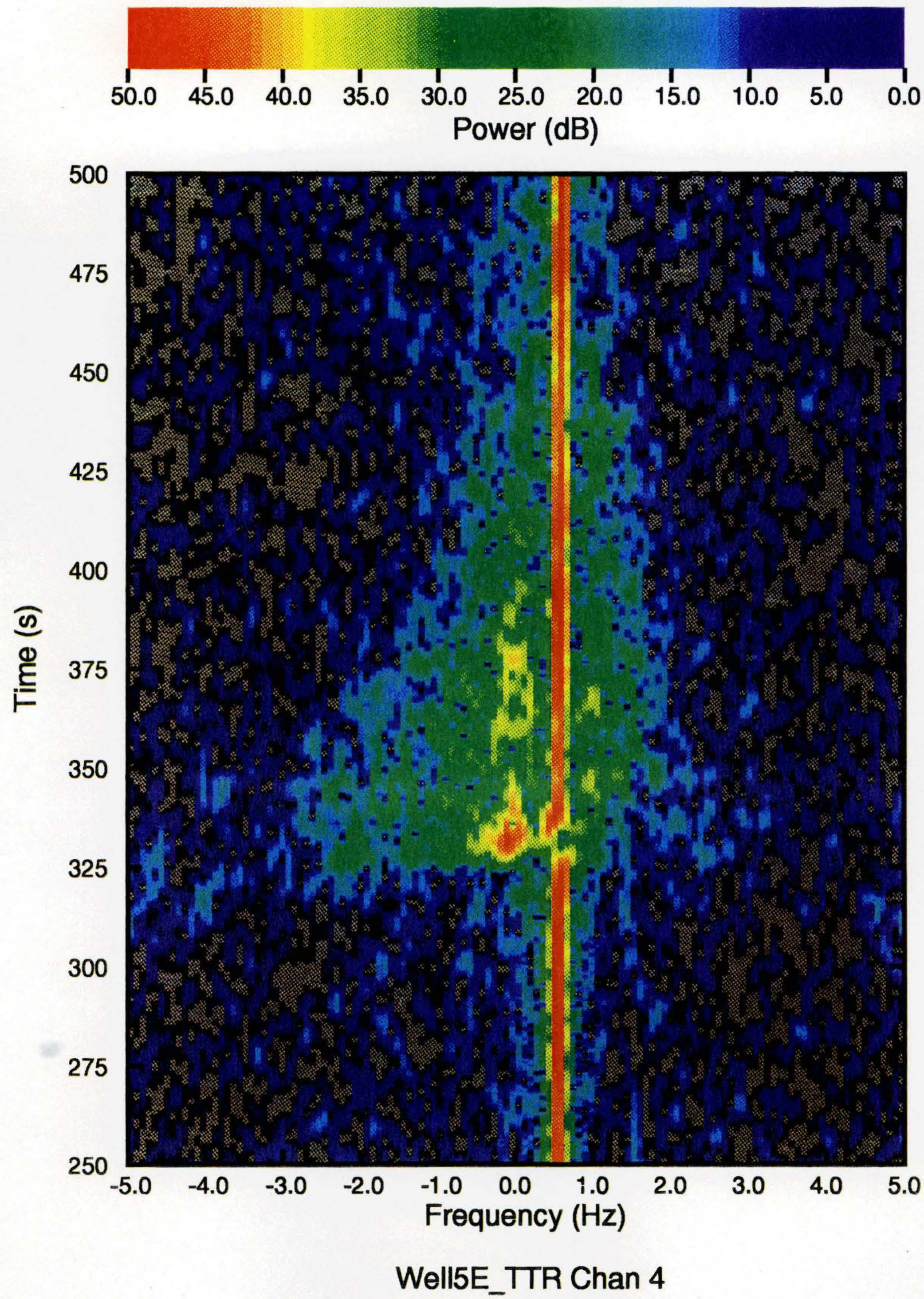

Figure 5: Power spectrum of cw transmission between the Tonopah Test Range and Well 5e versus time in seconds after the detonation of the Bexar event. The plot shows spectral power coded according to the scale at the top at a given Doppler shift versus time after the detonation of the UGT. A disturbance associated with the UGT occurred between 310 and 460 s.

Acknowledgement

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