MARINE MAMMAL ACOUSTIC AND BEHAVIORAL MONITORING FOR THE MONTEREY BAY NATIONAL MARINE SANCTUARY FIREWORKS DISPLAY 4 JULY 2007

Contract No.

Prepared for:

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August 4, 2007

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1 INTRODUCTION

Recently, public interest has focused on the possible affects of human made sound sources on the behavior, health and population trends of marine mammals (Fair and Becker, 2000; Romano et al., 2004; Cox et al., 2006; Nowacek et al., 2007). Generally, long term effects to pinnipeds only occur with chronic sound sources or disturbances (Allen et al. 1988) but infrequent disturbances may cause animals to flush from the haul-out but they do not abandon the area permanently (Thorson et al., 2000).

The Monterey Bay National Marine Sanctuary (MBNMS) was issued an Incidental Harassment Authorization (IHA) from the National Marine Fisheries Service to incidentally disturb small numbers of marine mammals (NMFS, 2006). That IHA requires the MBNMS to conduct behavioral observations of marine mammals in the area of the Monterey Harbor and to collect acoustic information on the source characteristics of the sound produced by the fireworks display.

1.1 California Sea Lions

Status—The California sea lion (*Zalophus californianus*) is not listed under the ESA, and the U.S. Stock, some of which occurs in the SOCAL Range Complex, is not considered a strategic stock under the Marine Mammal Protection Act. The U.S. Stock has increased from the early 1900s to the present; the counts of pups increased at an annual rate of 5.4% between 1975 and 2001 (Carretta et al., 2005). The minimum population estimate of the U.S. Stock is 237,000 (Carretta et al., 2005).

Distribution—Nearly all of the U.S. Stock (more than 95%) breeds and gives birth to pups on San Miguel, San Nicolas, and Santa Barbara islands. Smaller numbers of pups are born on San Clemente Island, the Farallon Islands, and Año Nuevo Island (Lowry et al., 1992).

The distribution and habitat use of California sea lions vary with the sex of the animals and their reproductive phase. Adult males haul out on land to defend territories and breed from mid-to-late May until late July. Individual males remain on territories for 27–45 days without going to sea to feed. During August and September, after the mating season, the adult males migrate northward to feeding areas as far away as Washington (Puget Sound) and British Columbia (Lowry et al., 1992). They remain there until spring (March–May), when they migrate back to the breeding colonies.

The distribution of immature California sea lions is less well known, but some make northward migrations that are shorter in length than the migrations of adult males (Huber, 1991) and may haul out at sites along the California coasts. However, most immature seals are presumed to remain near the rookeries (Lowry et al., 1992). Adult females remain near the rookeries throughout the year. Most births occur from mid-June to mid-July (peak in late June).

Acoustics—In-air, California sea lions make incessant, raucous barking sounds; these have most of their energy at less than 2 kHz (Richardson et al., 1995). The male barks have most of their energy at less than 1 kHz (Schusterman et al., 1967). Males vary both the number and rhythm of their barks depending on the social context; the barks appear to control the movements and other behavior patterns of nearby conspecifics (Schusterman, 1977). Females produce barks, squeals, belches, and growls in the frequency range of 0.25 to 5 kHz, while pups make bleating sounds at 0.25 to 6 kHz (Richardson et al., 1995). California sea lions produce two types of underwater sounds: clicks (or short-duration sound pulses) and barks (Schusterman et al., 1966, 1967; Schusterman and Baillet, 1969). All underwater sounds have most of their energy below 4 kHz (Schusterman et al., 1967).

The range of maximal sensitivity underwater is between 1 and 28 kHz (Schusterman et al., 1972). Functional underwater high frequency hearing limits are between 35 and 40 kHz, with peak sensitivities from 15 to 30 kHz (Schusterman et al., 1972). The California sea lion shows relatively poor hearing at frequencies below 1,000 Hz (Kastak and Schusterman, 1998). Peak sensitivities in air are shifted to lower frequencies; the effective upper hearing limit is approximately 36 kHz (Schusterman, 1974). The best range of sound detection is from 2 to 16 kHz (Schusterman, 1974).

Kastak and Schusterman (2002) determined that hearing sensitivity generally worsens with depth—hearing thresholds were lower in shallow water, except at the highest frequency tested (35 kHz), where this trend was reversed. Octave band noise levels of 65 to 70 dB produced an average TTS of 4.9 dB in the California sea lion (Kastak et al., 1999). enter frequencies were 1,000 Hz for corresponding threshold testing at 1,00 Hz and 2,000 Hz for threshold testing at 2,000 Hz; the duration of exposure was 20 min.

1.2 PACIFIC HARBOR SEALS

Status—The harbor seal (*Phoca vitulina richardii*) is not listed under the ESA, and the California Stock is not considered depleted or strategic under the MMPA. The California population has increased from the mid-1960s to the mid-1990s, although the rate of increase may have slowed during the 1990s (Hanan, 1996). The minimum population estimate of the California Stock is 25,720 (Carretta, 2005).

Distribution—Harbor seals are considered abundant throughout most of their range from Baja California to the eastern Aleutian Islands. They generally favor sandy, cobble, and gravel beaches (Stewart and Yochem, 1994), and most haul out on the mainland (Carretta et al., 2005).

Peak numbers of harbor seals haul out on land during late May to early June, which coincides with the peak of their molt. When at sea during May and June (and March to May for breeding females), they generally remain in the vicinity of haul-out sites and forage close to shore in relatively shallow waters. Nursing of pups begins in late February, and pups start to become weaned in May. Breeding occurs between late March and early May. Harbor seals are found in the Monterey Bay area throughout the year (Carretta et al., 2000).

Acoustics—Harbor seals produce a variety of airborne vocalizations including snorts, snarls, and belching sounds (Bigg, 1981). Adult males produce low frequency vocalizations underwater during the breeding season (Hanggi and Schusterman, 1994; Van Parijs et al., 2003). Male harbor seals produce communication sounds in the frequency range of 100 to 1,000 Hz (Richardson et al, 1995).

The harbor seal hears almost equally well in air and underwater (Kastak and Schusterman, 1998). Harbor seals hear best at frequencies from 1 to 180 kHz; the peak hearing sensitivity is at 32 kHz in water and 12 kHz in air (Terhune and Turnball, 1995; Kastak and Schusterman, 1998; Wolski et al., 2003). Kastak and Schusterman (1996) observed a TTS of 8 dB at 100 Hz, with complete recovery approximately one week following exposure. Kastak et al. (1999) determined that underwater noise of moderate intensity (65 to 75 dB source level) and duration (20 to 22 min) is sufficient to induce TTS in harbor seals.

1.3 SOUTHERN SEA OTTERS

Status—The southern sea otter (*Enhydra lutris*) is listed as threatened under the ESA and the California Stock is, therefore, considered depleted under the MMPA. If the restrictions on the use of gill and trammel nets in areas inhabited by southern sea otters were lifted, the southern sea otter population would be designated as a strategic stock as defined by the MMPA (USFWS, 1995 in Carretta et al., 2005). The southern population increased at an average annual rate of 5–7 percent between 1983 and 1994. As the population has increased, its range has also expanded. The sea otter falls under the regulatory oversight of the USFWS.

Distribution—Except during 1976–1983, the southern population increased steadily since it received protection in 1911. The southern sea otter's primary range is restricted to the coastal area of central California, from Point Año Nuevo to south of Point Conception (Orr and Helm, 1989; USFWS, 1996, 2005), plus a small translocated population around San Nicolas Island that diminished to about 17 by 1995, which was not considered viable because the population size was too small (Ralls et al., 1995; USFWS, 1996). Sea otters prefer rocky shorelines with kelp beds and waters about 66 ft (20 m) deep (USFWS, 1996). Few sea otters venture beyond 5,200 ft (1,600 m) from shore, and most remain within 1,600 ft (500 m) (Estes and Jameson, 1988). They require a high intake of energy to satisfy their metabolic requirements. Most sea otters in California tend to be

active at night and rest in the middle of the day (Ralls and Siniff, 1990), but there is extensive variation in the activity of individuals both among and within age and sex classes (Ralls et al., 1995).

Acoustic—Sea otter vocalizations are considered to be most suitable for shortrange communication among individuals (McShane et al., 1995). Airborne sounds include screams; whines or whistles; hisses; deep-throated snarls or growls; soft cooing sounds; grunts; and barks (Kenyon, 1975; McShane et al., 1995). The high-pitched, piercing scream of a pup can be heard from distances of greater than 1 km (McShane et al., 1995). In-air mother-pup contact vocalizations have most of their energy at 3 to 5 kHz, but there are higher harmonics (McShane et al. 1995; Richardson et al., 1995). There is no hearing data available for this species (Ketten, 1998).

2 METHODS

2.1 VISUAL OBSERVATIONS

Counts of marine mammals were conducted by a National Marine Fisheries Service approved marine mammal observer, using high quality binoculars (e.g. 10x42 power Zeiss) during daytime observations or when there is sufficient ambient light. Night vision goggles (ITT 5000) were used during night time hours. Observations were made from a Monterey Bay National Marine Sanctuary vessel (P/B Shark Cat) and the observer was approximately 2.5 meters above the water.

Counts were be made approximately every hour beginning at 16:27 Pacific Daylight Time on 4 July 2007 and continued through 23:05. Counts were concentrated along the jetty where the majority of sea lions were hauled out (Figure 2-1). Sea lions were also counted along the U.S. Coast Guard pier and on several buoys in the harbor. Harbor seal were hauled out exposed rocks on the west end of the harbor (Figure 2-1). Sea otters were seen moving through out the harbor or just outside of the jetty (Figure 2-1). For each count the time, area observed, the species present, group composition when possible (age class and gender), general behavior (e.g. resting, interacting), and other disturbances (vessels, aircraft etc.) were recorded. Environmental conditions were also recorded and included air temperature, tide, wind speed and swell height (outside of the harbor).

At the time the fireworks began, observations were being made at the inside (southern side) of the jetty near the USCG pier where most of the sea lions had been observed. The response of pinnipeds to the fireworks (head lifts, flush or movements), behavior in the water (milling, interacting with con-specifics, swimming or leaving the area) and the time to return to the haul-out, if animals flush, were recorded. Counts were continued for 1.5 hours after the fireworks ended. Counts were made on the following day (5 July) from 08:10 to 09:12 PDT.

Figure 2-1. Map of the Monterey Harbor area including the marine mammal haul-out sites and areas of sea otter sightings.

2.2 Acoustic Recordings

Noise is often defined as unwanted or annoying sound that is typically associated with human activity. Most sound is not a single frequency, but rather a mixture of frequencies, with each frequency differing in sound level.

The amplitude of sound is described in a unit called the decibel (dB). Decibels are measured on a logarithmic scale as the range of sound pressures encountered by human ears is very broad, from the approximate human threshold of hearing 0.00002 Pascal's (Pa) to the approximate human threshold of pain at 200 Pa (a 10 million fold range). The dB scale simplifies this range of sound pressures to a scale of 0 to 140 dB and allows the measurement of sound to be more easily understood. Although not exactly analogous, the decibel scale is similar to the commonly used earthquake Richter scale. As such, a 120 dB sound is not twice the amplitude of a 60 dB sound, but a 1,000 fold increase. In most cases, adding two identical sound sources will increase the decibel level by three dB (100 dB plus 100 dB equals 103 dB).

Noise sources can be continuous (constant noise from traffic or refrigeration units) or transient (passing noise from an aircraft overflight or an explosion). Noise sources can also have a broad range of frequency content (pitch) which can be rather nondescript, such as noise from traffic, or can be very specific and readily identifiable, such as a whistle or a car alarm.

2.3 ACOUSTIC WEIGHTING

There are two weighting filters commonly used in acoustical analysis: A-weighting and C-weighting (Figure 2-2). There is also an unweighted or flat sound measurement, through which the sound is analyzed without any filtering. A-weighting is a standard filter used in acoustics that approximates human hearing. C-weighting approximates human response to loud, usually transient sounds, such as a sonic boom or gunshot. The figure shows how much more A-weighting reduces the low frequency sound compared to C-weighting. For example, using an A-weighted filter, a sound at 20 Hz would be reduced about 50 dB from the unweighted sound, while with C-weighting the 20 Hz sound is only reduced about 6 dB.

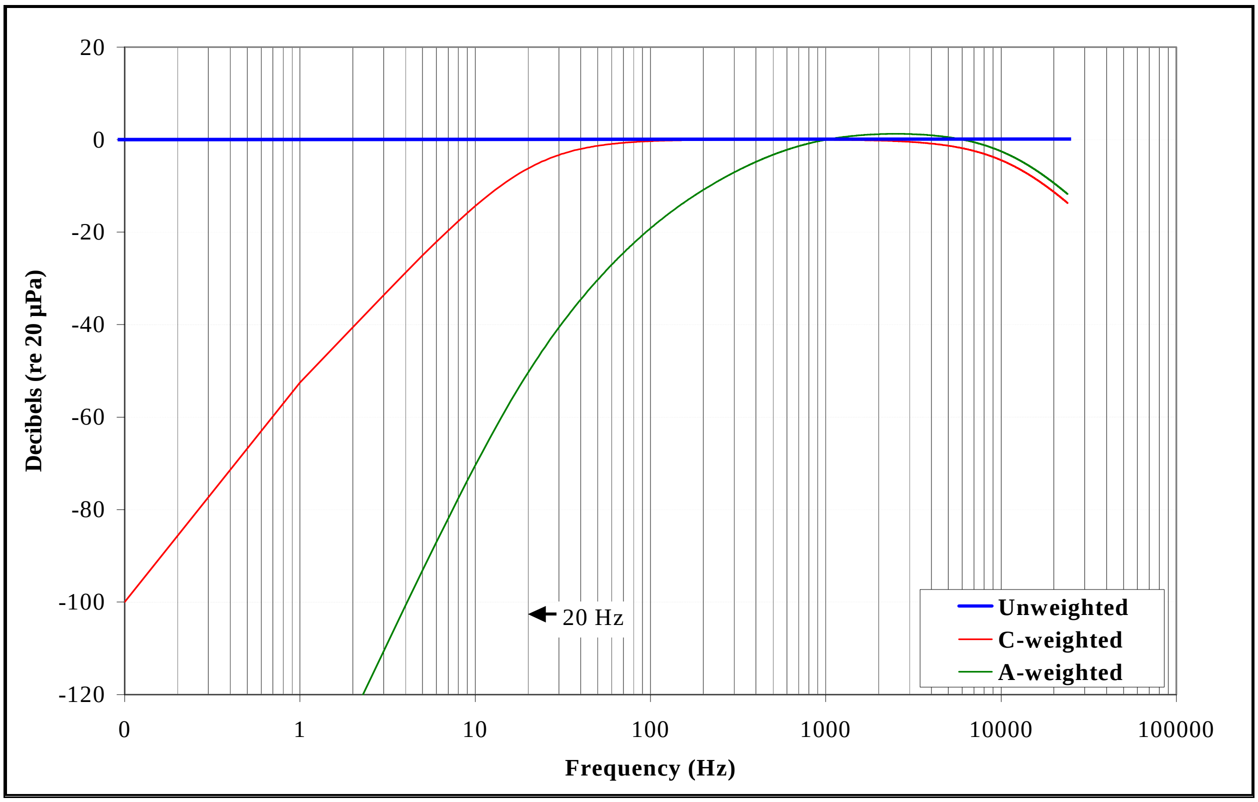

Figure 2-2. Plot of the A-weighted and C-weighted acoustical filters.

2.4 ACOUSTIC METRICS

There are many methods for quantifying noise, depending on the type of noise and potential impacts.

One useful noise metric is the one-hour average sound level, Leq or sometimes abbreviated as L_{eq1H}. The 1 hour Leq can be thought of in terms of *equivalent* sound; that is, if a 1 hour Leq is 45.3 dB, this is what would be measured if a sound measurement device were placed in a sound field of 45.3 dB for one hour. However, this is not what happens during real sound measurements. When a 1 hour Leq level of 45.3 dB is measured, the sound level has fluctuated above and below 45.3 dB, but the *average* during that hour is 45.3 dB. The 1 hour Leq is usually A-weighted unless specified otherwise. The Leq measurements can also be specified for other time periods such as 8 or 24-hour periods.

The most common acoustical metrics used to describe transient noises, such as an sonic booms or explosions, are sound exposure level (SEL), maximum fast sound level (Lmax), peak level (Peak), and unweighted Peak Level.

The sound exposure level is the total sound energy in a sound event *if that event could be compressed into one second.* In essence, SEL is an average sound level that is condensed into one second. This provides a normalized metric. SEL can be reported with A-weighting or other weightings such as unweighted or C-weighted.

The Peak sound level is the greatest instantaneous sound level reached during a sound event. Peak levels can also have various frequency weightings applied to them. Peak levels, though useful in some cases, can often be misleading. It can occur that a single peak in a complex waveform can be substantially greater than the majority of a sound event. Peak levels should always be presented along with one or more of the metrics described above to better describe the sound event. Unweighted peak sound level is simply the Peak sound level with no frequency weighting applied.

The Maximum Fast Sound Level Lmax, usually with A-weighting applied, is the greatest sound level reached during a sound event with a time weighting applied during the calculation. The time weighting causes the sound levels to be influenced by sounds that most recently occurred. The "fast" refers to specific exponential moving average time weighting with a time constant of 1/8 of a second. As this metric does not average the sound over a period of time like the Leq measurements it is a good indicator of the loudest level the sound reaches.

Examples of A-weighted noise levels for various common noise sources are shown in Table 2-1.

Table 2-1. Comparative A-Weighted Sound Levels. Modified from U.S. Department of Transportation, 1980

Noise Level A-weighted dB	Common Noise Levels	
	Indoor	**Outdoor**
100 - 110	Rock band inside New York subway	Jet flyover at 304 meters
90 - 100	Food blender at one meter	Gas lawnmower at one meter
80 - 90	Garbage disposal at one meter	Diesel truck at 15 meters Noisy urban daytime
70 - 80	Shouting at one meter Vacuum cleaner at three meters	Gas lawnmower at 30 meters
60 - 70	Normal speech at one meter	Commercial area heavy traffic at 100 meters
50 - 60	Large business office Dishwasher next room	
40 - 50	Small theater (background) Large conference room (background)	Quiet urban nighttime
30 - 40	Library (background)	Quiet suburban nighttime
20 - 30	Bedroom at night	Quiet rural nighttime
10 - 20	Broadcast and recording studio (background)	
0 – 10	Threshold of hearing	

2.5 Acoustic Equipment and Setup

We used two types of independent systems to monitor the sound environment and to measure the fireworks show noise. We made measurements at the east end of the USCG pier (N 36.60884^{o}, W 121.89129^{o}). This was approximately 800 m to the barge where the fireworks were launched

The first system consisted of a TEAC (TEAC America, Montebello, CA) model RD-120T digital audio tape (DAT) recorder and a high quality Bruel and Kjaer (Bruel and Kjaer, Irvine, CA) type 4193 microphone with a type UC0211 low frequency adapter, type 2669 pre-amplifier and type 5935 power supply (2-3). This system is linear over a wide range of frequencies, and is especially tailored

for recording the low frequency sound associated with impulsive noise such as explosions and sonic booms.

Figure 2-3. DAT system used to record the noise for digital post processing.

The microphone was designed by the manufacturer to have a low frequency cut-off (-3.0 decibels [dB]) at 0.015 Hertz (Hz). This DAT system records the noise digitally to tape, which allows for detailed post-analysis of the frequency content, and the calculation of other acoustical metrics. Using Maxell (Maxell Corp. of America, San Diego, CA) HS4/90 DAT tapes, the DAT system will record for just over three hours, providing ample time to record the fireworks show. The digital data was directly downloaded from the DAT recorder to a computer using TEAC QuikVu software and hardware. The waveforms were then analyzed using custom routines programmed in MatLab (The MathWorks, Natick, MA), a technical computing language.

The second system used for acoustic monitoring was the Larson-Davis (Larson-Davis, Provo, UT) model 820 Type 1 (an acoustical accuracy standard) sound level meter (SLM) (2-4). The SLM measures specific sound events that exceed a minimum sound level, background noise levels, and ambient noise levels. It does not make an actual recording of sound like the DAT recorder, but computes acoustic metrics used to describe specific events and the surrounding sound environment. For all sound monitoring using this system, the SLM was set to begin measurements of sound events when the sound exceeded a level of 70 dB and was set to stop calculating when the sound level drops 6.0 dB below the trigger level of 70 dB. This is called the hysteresis value, and in this case, it is at 64 dB.

Figure 2-4. The Larson Davis model 820 integrating SLM used to measure the background sound environment and fireworks show.

Both the DAT and SLM microphones were mounted 1.2 meters (m) above the ground atop a single tripod. The microphones were covered by extra large windballs (18 cm diameter) and mounted in a short length of weatherproofing PVC. These systems were calibrated prior to launch using a Bruel and Kjaer sound level calibrator type 4220 (123.8 dB calibration tone at 250 Hz).

3 RESULTS

3.1 Fireworks Display

Below is a description of the pyrotechnic effects used by Pyro Spectaculars for the 2007 Monterey Independence Day Fireworks Display. Typically used salute detonations were not performed during the show as the company Pyro Spectaculars was addressing past concerns about wildlife disturbance.

Main body of the show

- 4” shell diameter - quantity ~200
- 5” shell diameter - quantity ~100
- 6” shell diameter - quantity ~60
- 8” shell diameter - quantity ~10
- 10” shell diameter - quantity 2

Grand Finale

- 2.5” shell diameter - bombardment - quantity ~75
- 3” shell diameter - bombardment - quantity ~50
- 3” shell diameter -finale - quantity ~250
- 4” shell diameter -finale - quantity ~60
- 5” shell diameter -finale - quantity ~5
- 6” shell diameter -finale - quantity ~5

In addition approximately 1100 pyrotechnic devices were fired for a total of ~ 1900 total devices.

It is estimated the travel time from the point of launch to the point of detonation is was approximately 2 to 5 seconds. The aerial shells detonate at altitudes between 200 and 1000 feet above sea level. The larger 10-inch to 12-inch diameter shells detonate at the high end of the altitude range (i.e. 800 - 1000 feet). As an estimate the altitude of detonation is 100 feet per inch in shell diameter.

3.2 Visual Observations

Conditions were optimal for observations, clear with only light winds. Due to all the activity in the area and proximity to piers and roads the area was well lighted for nighttime observations and night vision binoculars worked well with the extra light.

3.2.1 California Sea Lions

California sea lions were the most numerous of the marine mammal species with up to 291 sea lions observed. Most sea lions were yearlings or juveniles (2-4 years old). Two sub adult males (approximately 5-6 years old) were also observed and appeared to be practicing holding a water territory. With the exception of the sub adult males which show the beginning of the male only sagital crest (high forehead) it is difficult to determine the gender of yearling or juvenile sea lions.

Most sea lions were hauled out on both sides of the jetty just east of the USCG dock. The number of sea lions was steady until approximately 20:45 when several boats passed by the end of the jetty and shot off their own fireworks causing a number of sea lions to enter the water (Table 3-1).

At the beginning of the fireworks display there were only six sea lions hauled out at the end of the USCG pier. By the fourth fireworks detonation the last of the sea lions had entered the water. The fireworks ended at 21:37 but the first sea lion did not haul out until 21:55. The first sea lion to return was a sub adult male that had been at the end of the jetty. Only four sea lions had hauled out, all at the end of the jetty with the sub adult male, by the time observations were ended at 23:05.

On 5 July two counts were made of the sea lions along the jetty and USCG pier. Both counts were higher than the previous day (Table 3-1).

One sea lion yearling was observed prior to the fireworks that had been tagged (yellow tag) and branded (# 8687 on the left side) on San Miguel Island, Ca. Two yearling sea lions with yellow tags were observed the day after the fireworks but the side with the brand could not be seen to record the brand number.

Table 3-1. Summary of the observations of California sea lions and environmental conditions.

Time	Area	Sea Lions	Behavior	Comment	Tide (m)	Wind (m/s)	Air Temp (°C)
4 July							
16:27-16:56	Jetty - South	141	90% Resting	Still light	1.2 ↓	6.0	10.4
	Jetty - North	89	90 % Resting	Still light			
	Under Pier	10	All Resting	Still light			
Total		**240**					
19:40-20:18	Jetty - South	133	90% Resting	Still light	0.8 ↓	4.0	10.1
	Jetty - North	115	90 % Resting	Still light			
	Under Pier	10	All Resting	Still light			
Total		**258**					
20:18-20:45	Jetty - South	103	90% Resting	Losing light	0.8 ↑	4.0	9.9
	Jetty - North	59	25 % Resting- at least 17 in water	Group at end of jetty is flushed by a boat			
	Under Pier	10	All Resting	Losing light			
Total		**172**					
21:16	Under Pier	6	All resting – 1st fireworks – on the 4th fireworks the rest flush	Almost dark	0.9 ↑	3.0	9.9
21:37	End of Jetty		End of fireworks		0.9 ↑	3.0	9.9
21:55	End of Jetty		1st sea lion returns at end of jetty	Only the sub adult male is back	1.0 ↑	3.0	9.8
22:19	End of Jetty	3	At the end of the jetty		1.0 ↑	3.0	9.8
22:30	End of Jetty	4	At the end of the jetty		1.1 ↑	3.0	9.7
5 July							
08:10-08:37	Jetty - South	128			0.0 ↓	3.1	10.1
	Jetty - North	111					
	Under Pier	52					
Total		**291**					
08:38-0902	Jetty - South	126			0.0 ↓	3.1	10.1
	Jetty - North	108					
	Under Pier	48					
Total		**282**					

3.2.2 Pacific Harbor Seals

Harbor seals were hauled out on exposed rocks just offshore of the western end of the harbor (Figure 2-1). With the tide up to 0.8 meters only a few harbor seals were hauled out (Table 3-2). Observations at the time the fireworks began were conducted by the sea lion haul out site at the jetty therefore no observations were made of the harbor seals. At 70 minutes after the end of the fireworks there were no harbor seals hauled out.

On the day after the fireworks and with a lower tide (0.8 vs. 0.0 meters) there were 31 harbor seals hauled out at the west end of the harbor (Table 3-2).

Table 3-2. Summary of the observations of harbor seals and environmental conditions.

Time	**Area**	**Harbor Seals**	**Behavior**	**Comment**	**Tide (m)**	**Wind (m/s)**	**Air Temp (°C)**
4 July							
18:50	West Harbor	8	Resting 1 in water	Still light	0.9 ↓	4.1	10.2
20:00	West Harbor	8	Resting	Still light	0.8 ↓	4.0	10.1
20:38	West Harbor	6	Resting 2 in water	Losing light	0.8 ↑	4.0	9.9
22:47	West Harbor	0		Dark	1.1 ↑	3.0	9.7
5 July							
09:00	West Harbor	31	Resting		0.0 ↓	3.1	10.1

3.2.3 Southern Sea Otters

Most sea otters were observed foraging or resting through out the harbor and along the jetty (Figure 2-1). Sixteen sea otter observations were made on 4 and 5 July but it is not known if the same sea otters were seen more than once. The exception was one tagged sea otter that was seen on both 4 and 5 July. Observations were primarily for hauled out harbor seals and sea lions but as the observation boat moved between the haul out areas sea otter observations were recorded.

3.3 ACOUSTIC MEASUREMENTS

The SLMs measured the sound environment 330 minutes and ran for 6 hours. Average ambient sound levels (Leq1h) prior to and after the fireworks display ranged from 58.8 to 59 dB. The loudest hour containing the fireworks show was measured at 72.9 dB, 13 to 14.9 dB greater than the ambient measurements (Figure 3-1).

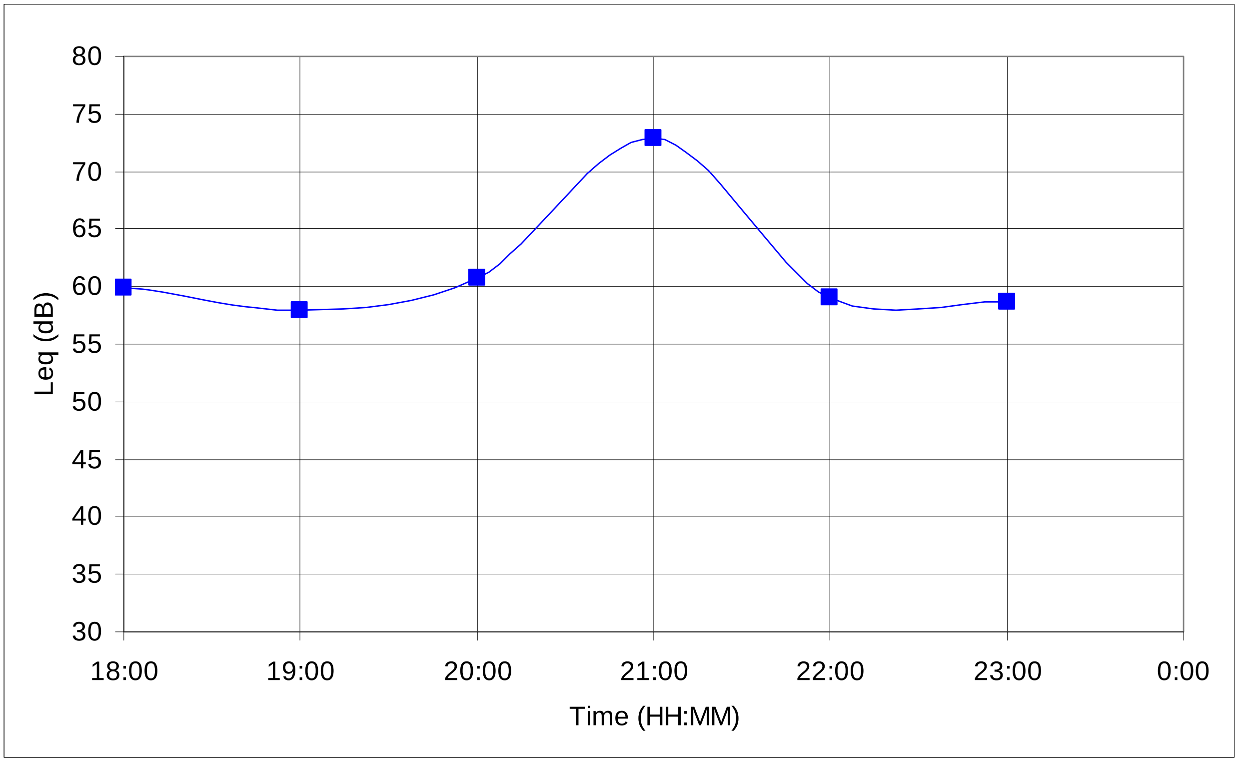

Figure 3-1. Sound levels (Leq1h) prior to and after the fireworks display ranged from 58.8 to 59 dB.

The loudest sound (Unweighted peak) from the SLM was recorded at 21:19:04 and was measured to be 132.2 dB (Figure 3-2). Most of the unweighted peaks were registered on the SLM during the period of 21:15:00 to 21:40:00 (Figure 3-3 and 3-4).

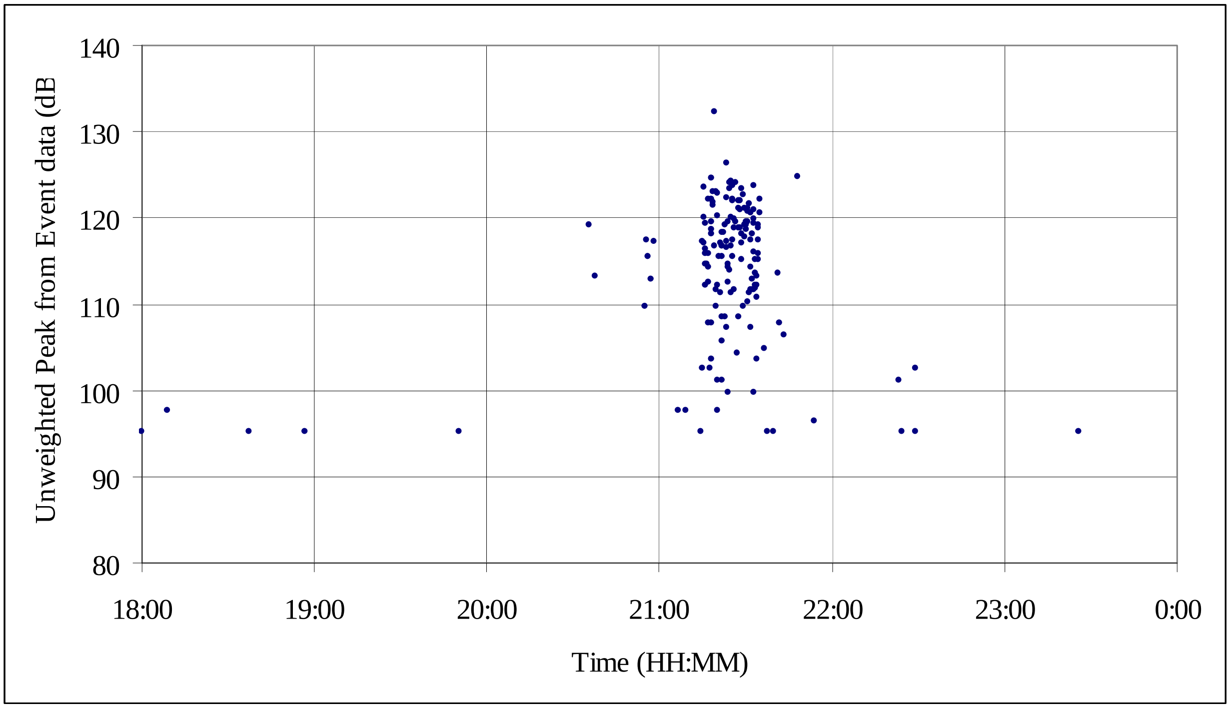

Figure 3-2. Unweighted Peak measurements from SLM Event data.

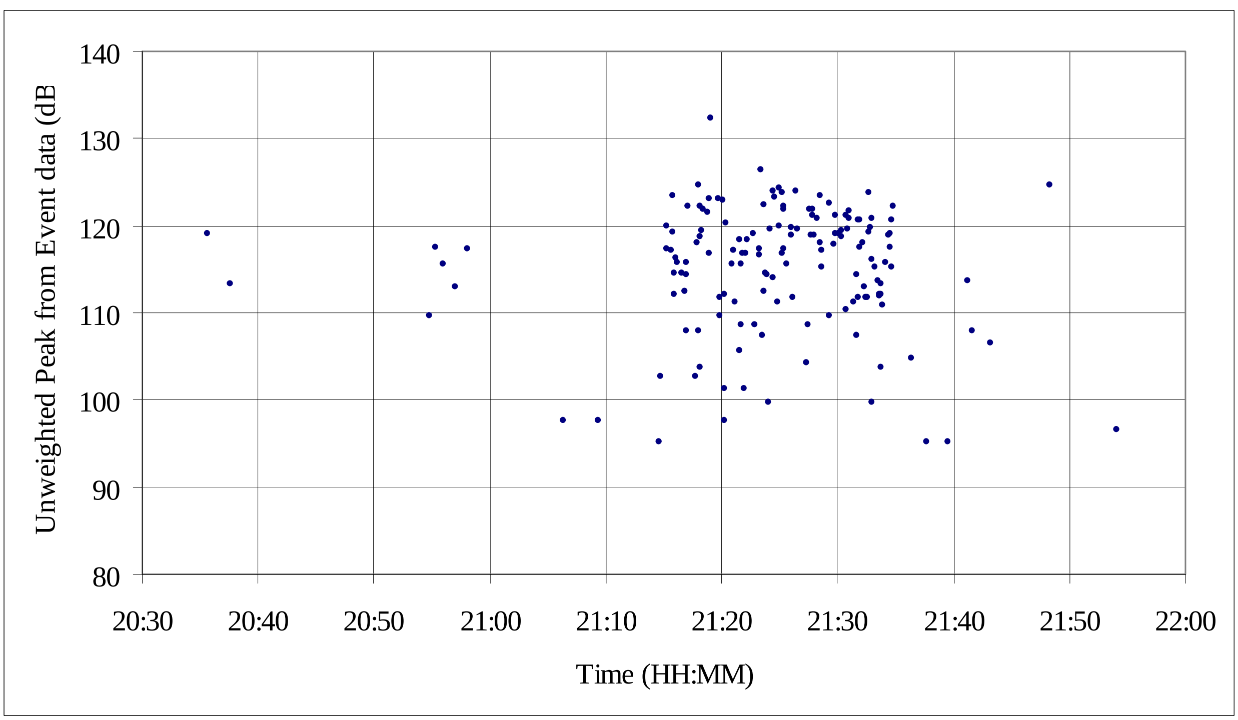

Figure 3-3. Unweighted Peak measurements from SLM Event data from 20:30 to 22:00.

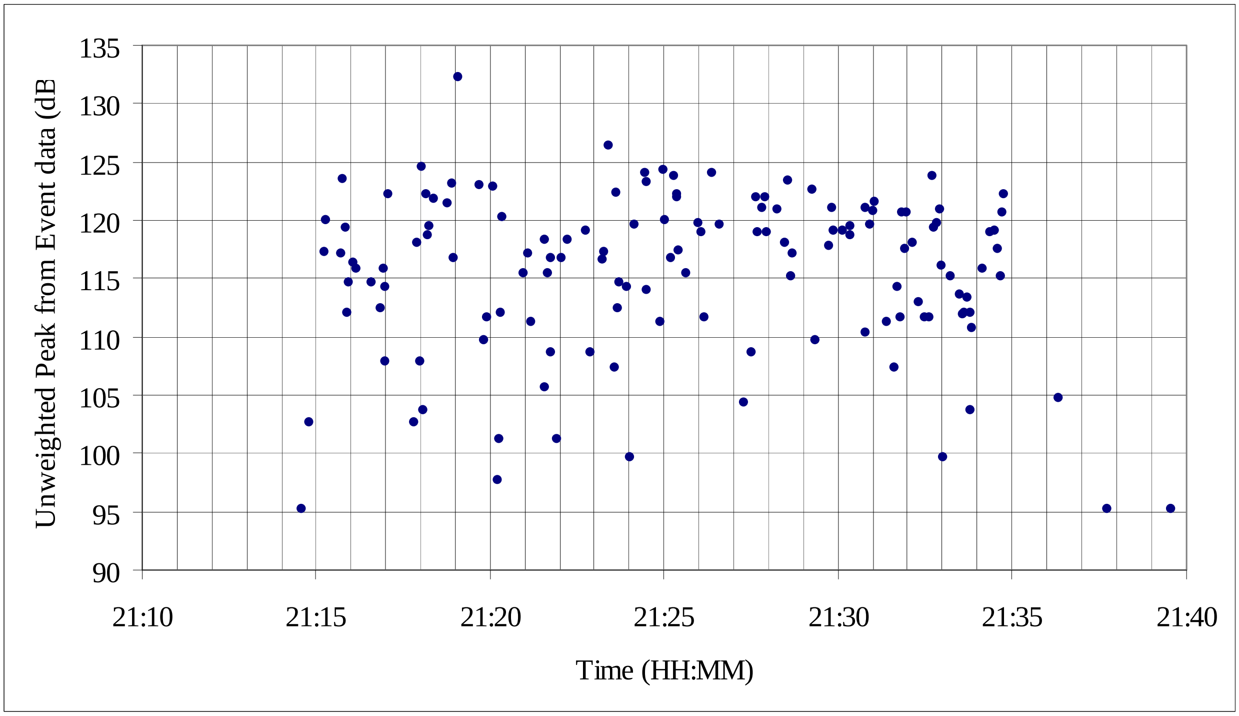

Figure 3-4. Unweighted Peak measurements from SLM Event data from 21:10 to 21:40.

The Unweighted peak threshold of the SLM was triggered 165 times. 145 of the 165 events (88%) were registered between 21:14 and 21:35 and were associated with the detonation of the fireworks (Figure 3-4). Most of the events that exceeded the peak threshold had unweighted peak measurements in the 112 to 124 dB range (Figure 3-3).

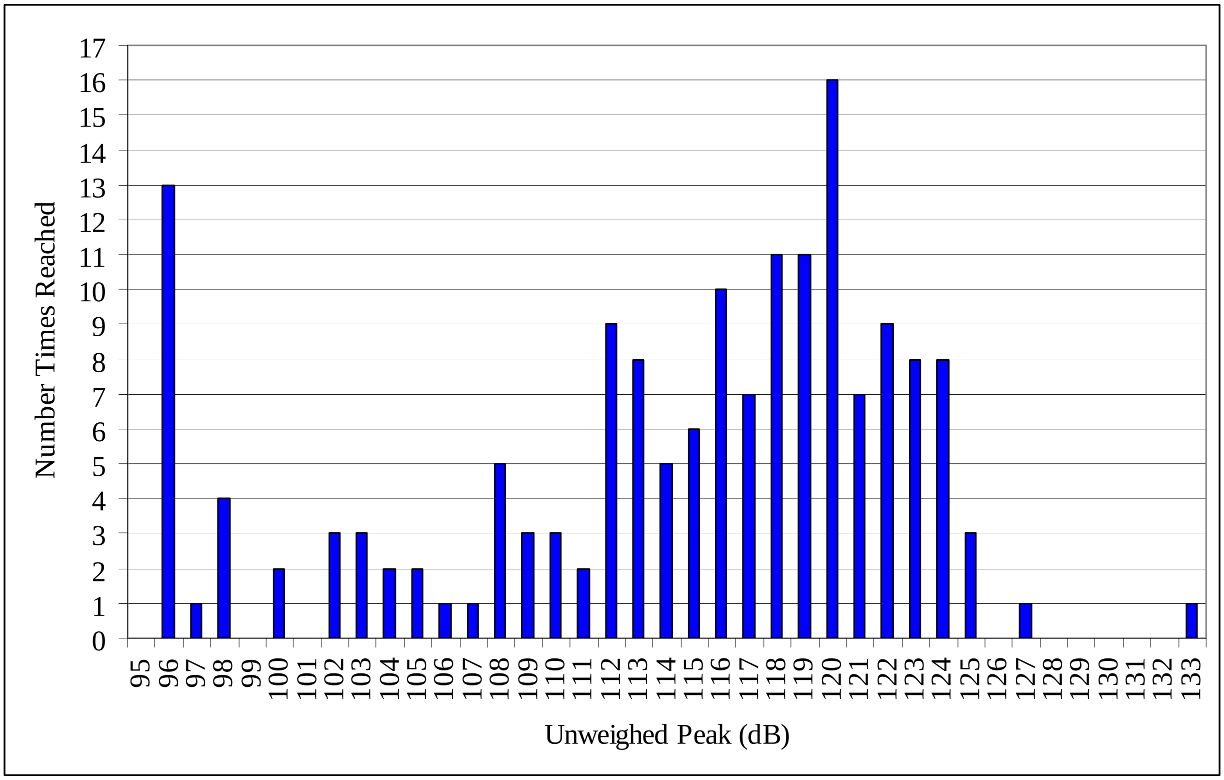

Figure 3-5. Histogram of Unweighted peak threshold triggers.

The duration of the events ranged from 1 to 41.9 seconds with the latter associated with the grand finale. 90% of the events had durations of 3 seconds or less. A-weighted Leq's ranged from 67.9 to 92.9 dB. Other metrics from the SLM event data is summarized in Table 3-3. Complete event data is listed in Appendix A.

Table 3-3. Summary of event data from the LD820 SLM

	Duration (seconds)	A-weighted Leq (dB)	A-weighted SEL (dB)	A-weighted Lmax (dB)	A-weighted Peak (dB)	Unweighted Peak (dB)
Maximum	41.9	92.9	102.9	105.5	130.9	132.3
Minimum	1	67.9	68.7	71	82	95.2

The DAT recorder collected additional information allowing for more detailed information on the noise generated from the fireworks show. Figure 3-6 shows the percentage of time sounds fell within stratified frequency intervals (octave band). Most of the sound energy was in the lowest frequency bin of 0 to 125 Hz. Although the frequency content of the detonations and explosions spread up to 20+ kHz most of the sound energy was low frequency.

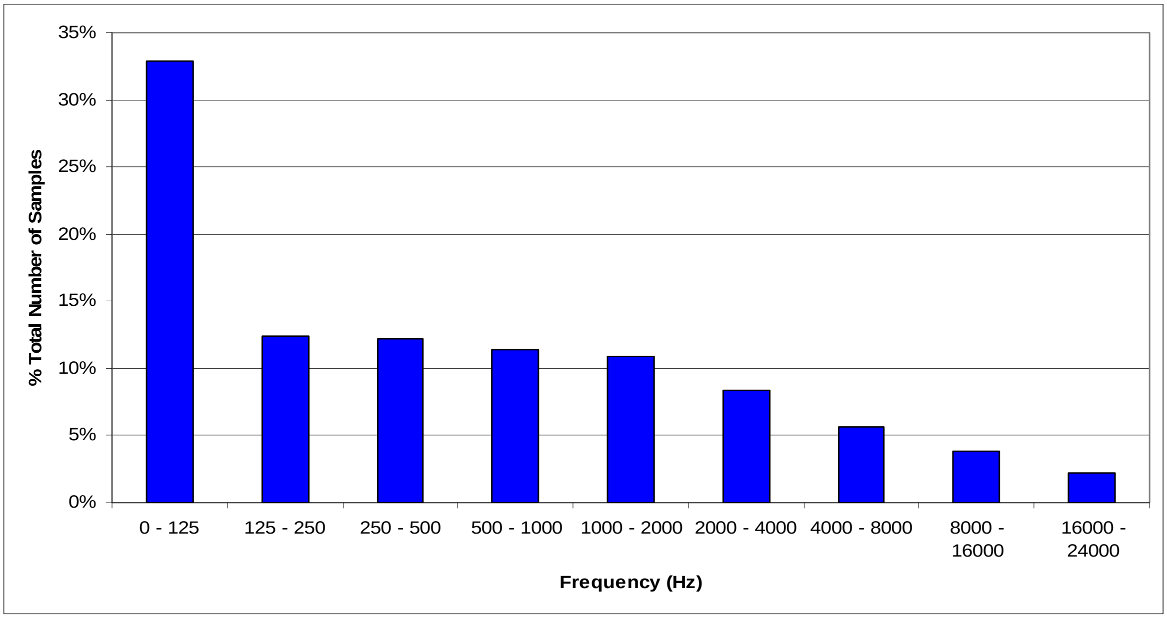

Figure 3-6. Histogram of percentage of time sounds fell within octave frequency intervals.

Sound power levels from the DAT recording ranged from approximately 70 dB to 120 dB throughout the show (Figure 3-7). Data from seconds 316 to 323 were removed due to transients as a result of changes in gain settings on the charge amplifier.

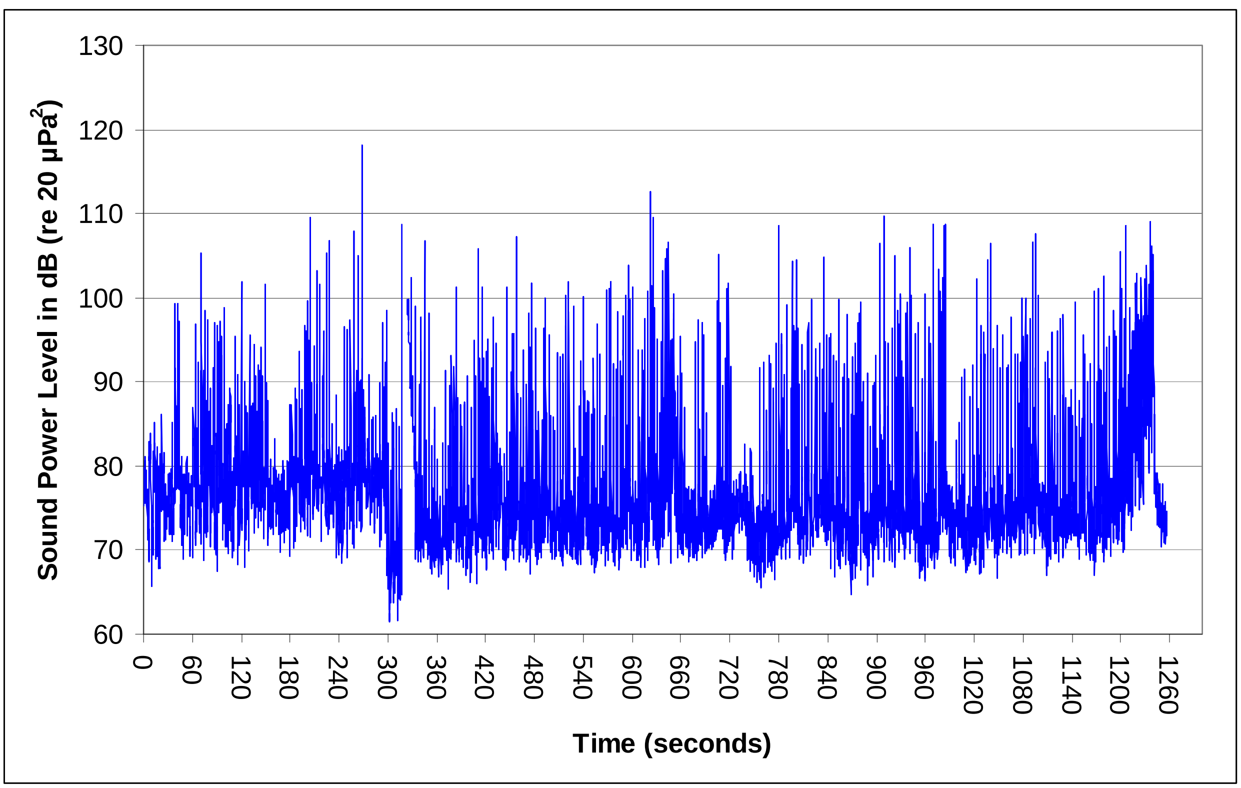

Figure 3-7. Unweighted sound power levels with respect to time from 21:14:00 to 21:35:00.

The spectrogram showed most of the sound energy is lower frequency but individual firework explosions have spectral content reaching up above 20 kHz. Spectrograms with 1 minute intervals were generated to show a high level of detail in the magnitude of the spectral content of firework detonations including crackles and whistles, lower frequency transients associated with the launch of the fireworks, sea lion vocalizations, and aircraft over flights (Figure 3-8 and Figure 3-9). The transients associated with the launch of the fireworks were observed to be lower in frequency, have slower rise times and are estimated to have unweighted peaks in the 1.5 to 5 Pa (97 to 107 dB) range. The spectrograms for the whole show and in 1 minute intervals are in Appendix A.

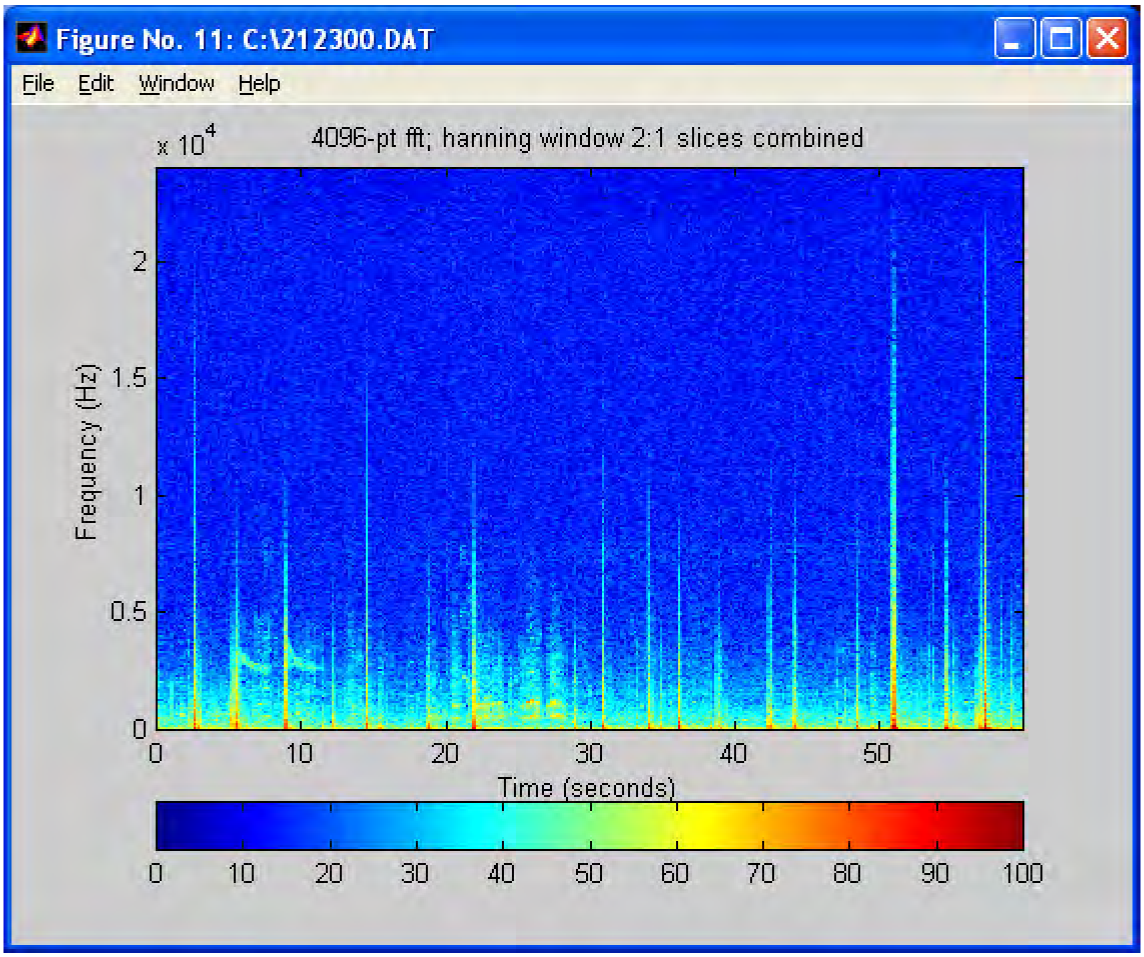

Figure 3-8. Spectrogram 21:23:00 to 21:24:00 illustrating whistles (seconds 6 to 8 and 9 to 11) following the firework explosions.

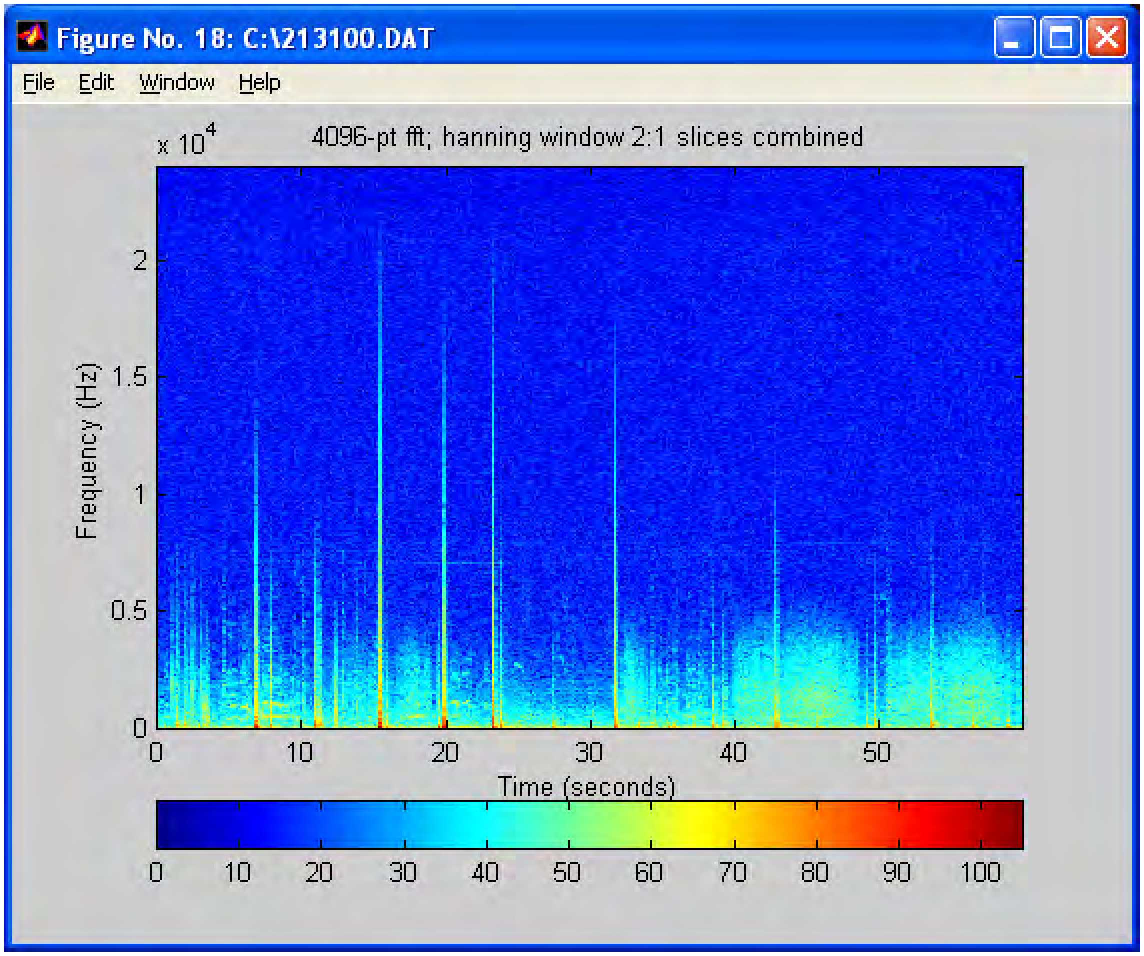

Figure 3-9. Spectrogram 21:31:00 to 21:32:00 illustrating explosions with crackling noise after the firework (seconds 43 to 48 and 53 to 60).

The fireworks explosions were consistent in rate throughout most of the show and increased significantly for the grand finale (Figure 3-10). For the first half of the grand finale multiple whistles were observed (Figure 3-10 seconds 10 to 30).

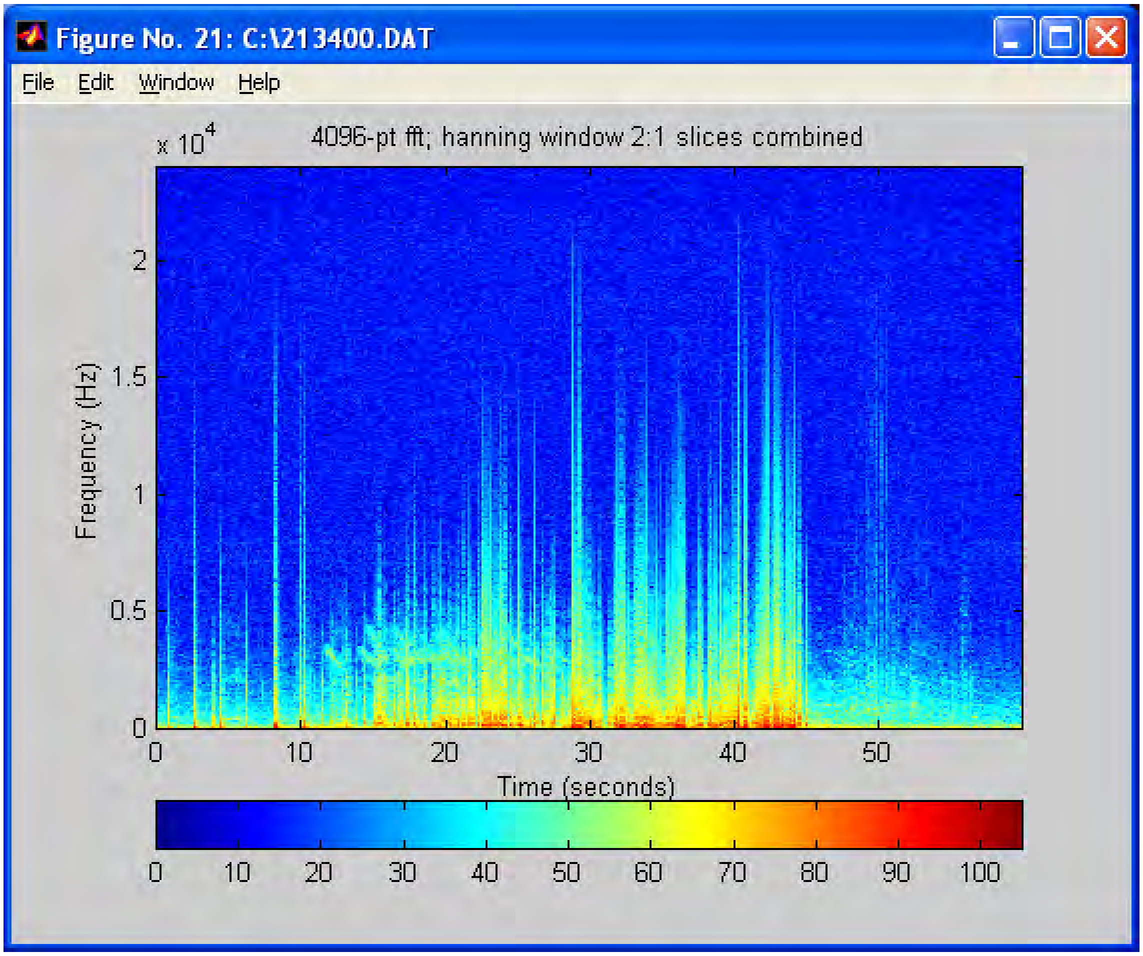

Figure 3-10. Spectrogram 21:34:00 to 21:35:00 of the grand finale.

The 10 inch shells were the largest aerial effects in the show. One was fired off near the beginning of the show at approximately 21:18:28 (Figure 3-11). The peak overpressure was 133.9 dB as measured by the DAT recording and correlated well with the SLM data with a peak overpressure of 132.3 dB. The other at the very end of the grand finale did not have as large a peak overpressure. According to Pyro Spectaculars, they were different fireworks and therefore it is not expected they would have the same peak overpressure as the explosion is dependent on content of the fireworks other physical characteristics and methodology of construction. The Unweighted SEL was measured to be 105.0 dB. Other unweighted and weighted metrics for the 10 inch explosion are contained in Table 3-4.

Table 3-4. Metrics from the DAT recording

			Unweighted				C-weighted			A-weighted		
Firework Description	**Time**	**Duration (sec)**	**RMS Value**	**SEL (dB)**	**Leq (dB)**	**Peak (dB)**	**RMS Value**	**SEL (dB)**	**Leq (dB)**	**RMS Value**	**SEL (dB)**	**Leq (dB)**
10 inch	21:18:28	1.0	3.5	105.0	104.9	133.9	2.9	103.2	103.1	0.6	89.4	89.3
8 inch	21:19:29	1.0	1.3	96.5	96.5	123.4	1.1	94.9	94.9	0.4	86.6	86.6
8 inch	21:15:11	1.0	1.1	94.5	94.5	124.0	0.9	92.7	92.7	0.2	80.9	80.9
8 inch	21:22:49	0.7	0.7	90.1	91.1	127.0	0.6	88.7	89.7	0.2	77.3	78.2
single with crackles	21:15:21	4.0	0.2	86.4	80.4	115.7	0.1	83.5	77.4	0.1	78.6	72.5
single with crackles	21:31:31	2.2	0.7	93.9	90.3	119.0	0.6	93.5	89.9	0.2	85.3	81.7
single with whistle	21:33:00	3.0	0.1	81.0	76.2	112.4	0.1	79.0	74.1	0.0	72.2	67.3
grand finale	21:34:00	c	1.1	111.4	94.5	122.7	1.0	110.9	93.9	0.4	103.1	86.1

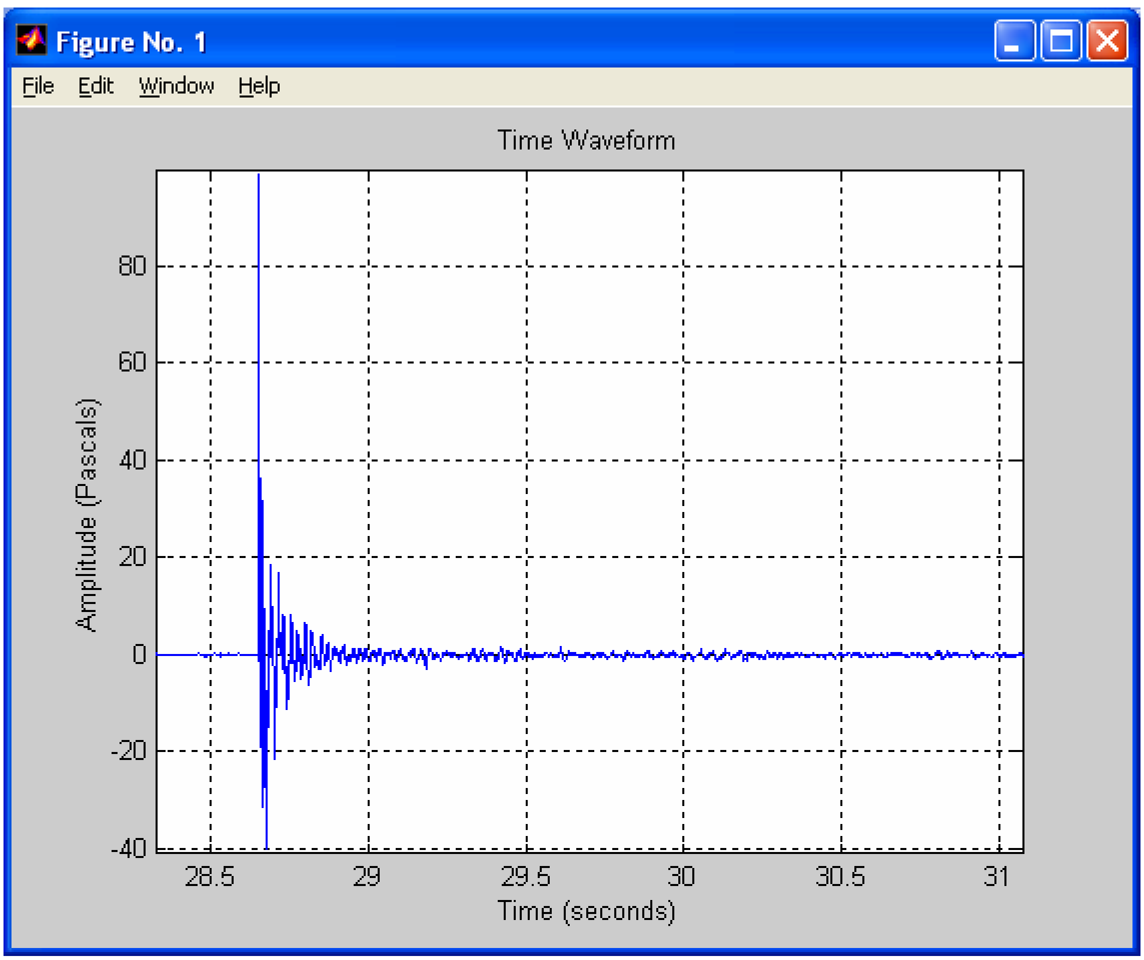

Figure 3-11. Time waveform of the 10 inch firework explosion.

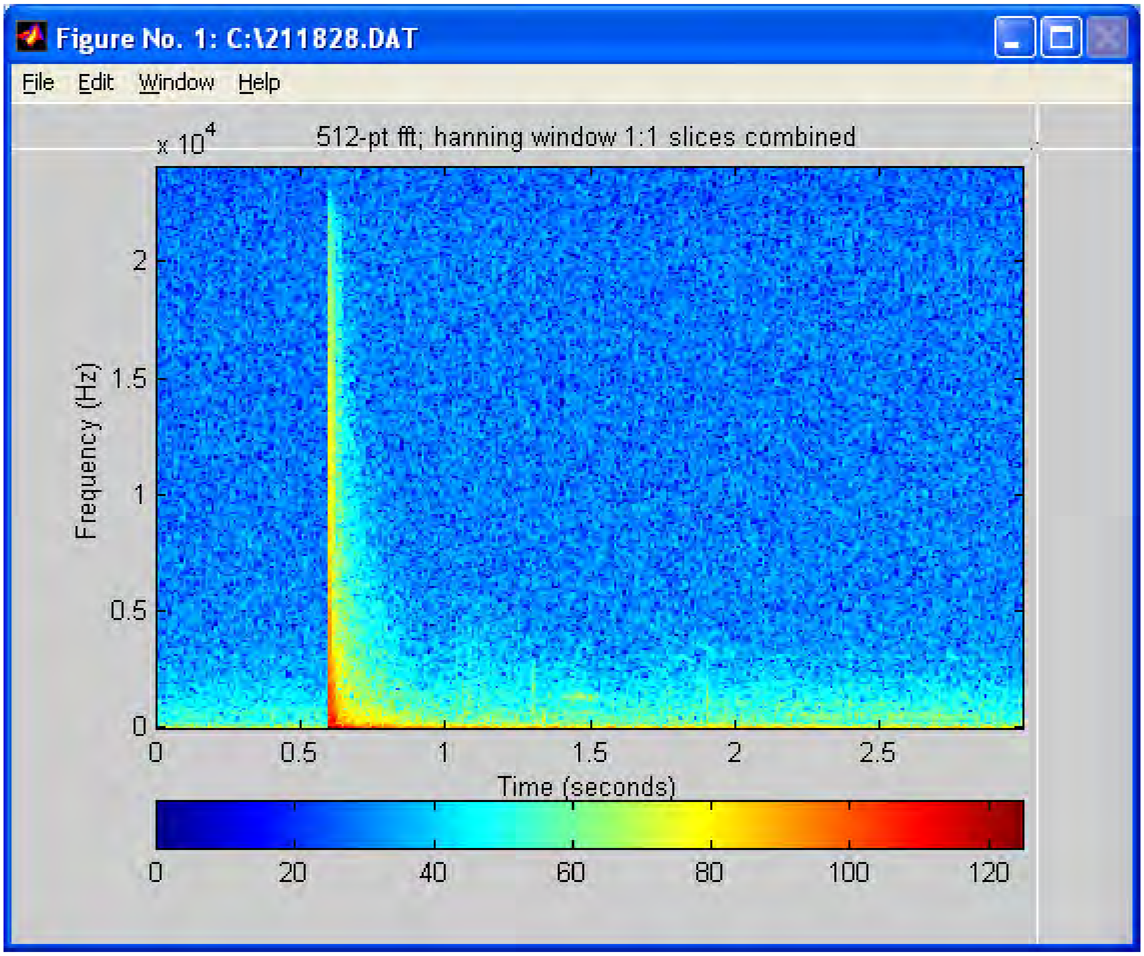

Figure 3-12. Spectrogram of the 10 inch firework explosion. Note: the time scale does not correlate with the other figures associated with this specific firework.

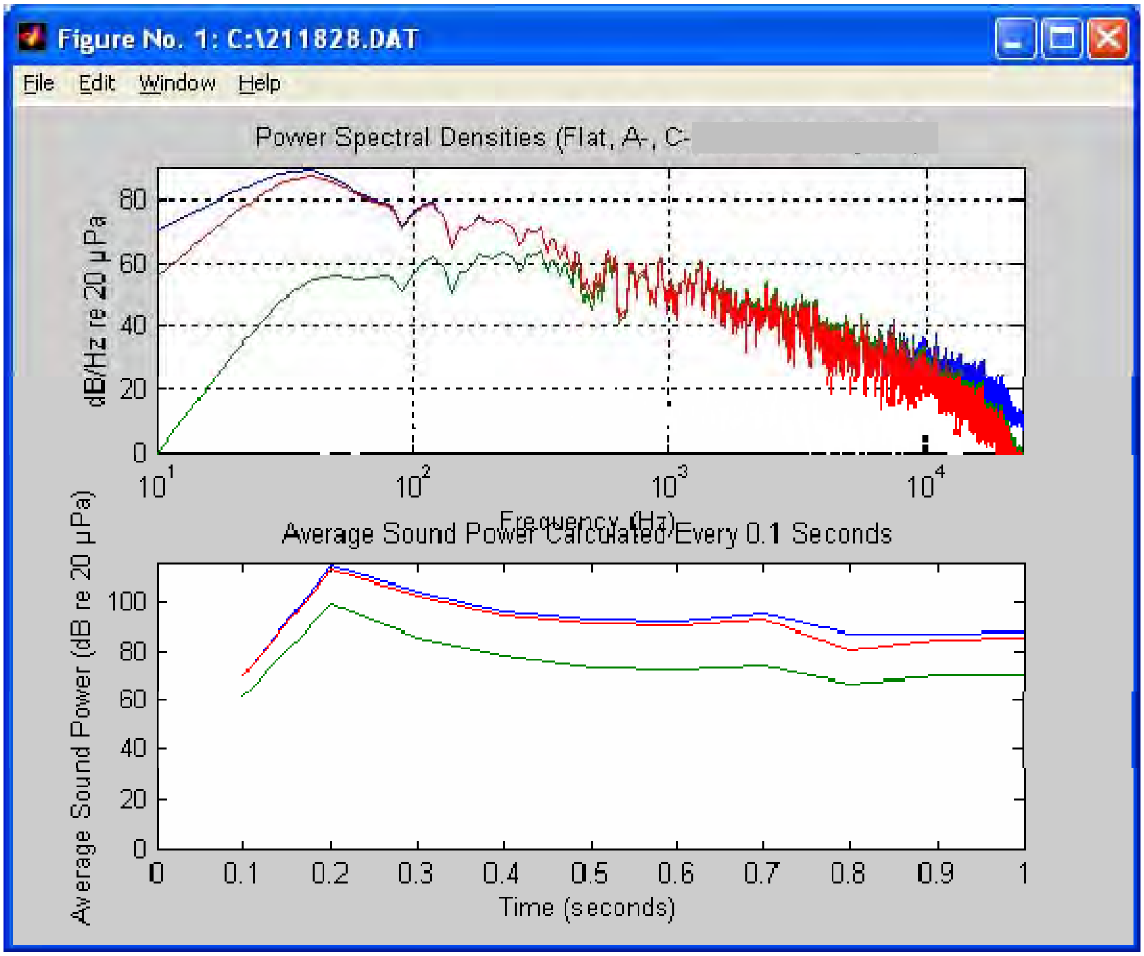

Figure 3-13. Power spectral density and sound power levels for the 10 inch firework explosion.

The second loudest peak was likely from an 8 inch shell at 21:22:49. This had similar frequency content as the 10 inch shell (Figure 3-14) and similar spectrogram profile (Figure 3-15) but the peak overpressure was 6.9 dB down from the 133.9 of the 10 inch shell. The SLM measured this peak to be 126.4 dB compared to the 126.7 dB as recorded by the DAT. Two other waveforms assumed to be 8 inch shells were analyzed and metrics reported in Table 3-4. Unweighted peak overpressures for the 8 inch shells are estimated to be in the 123.4 to 127.0 dB range and unweighted SELs in the 90 to 96 dB range.

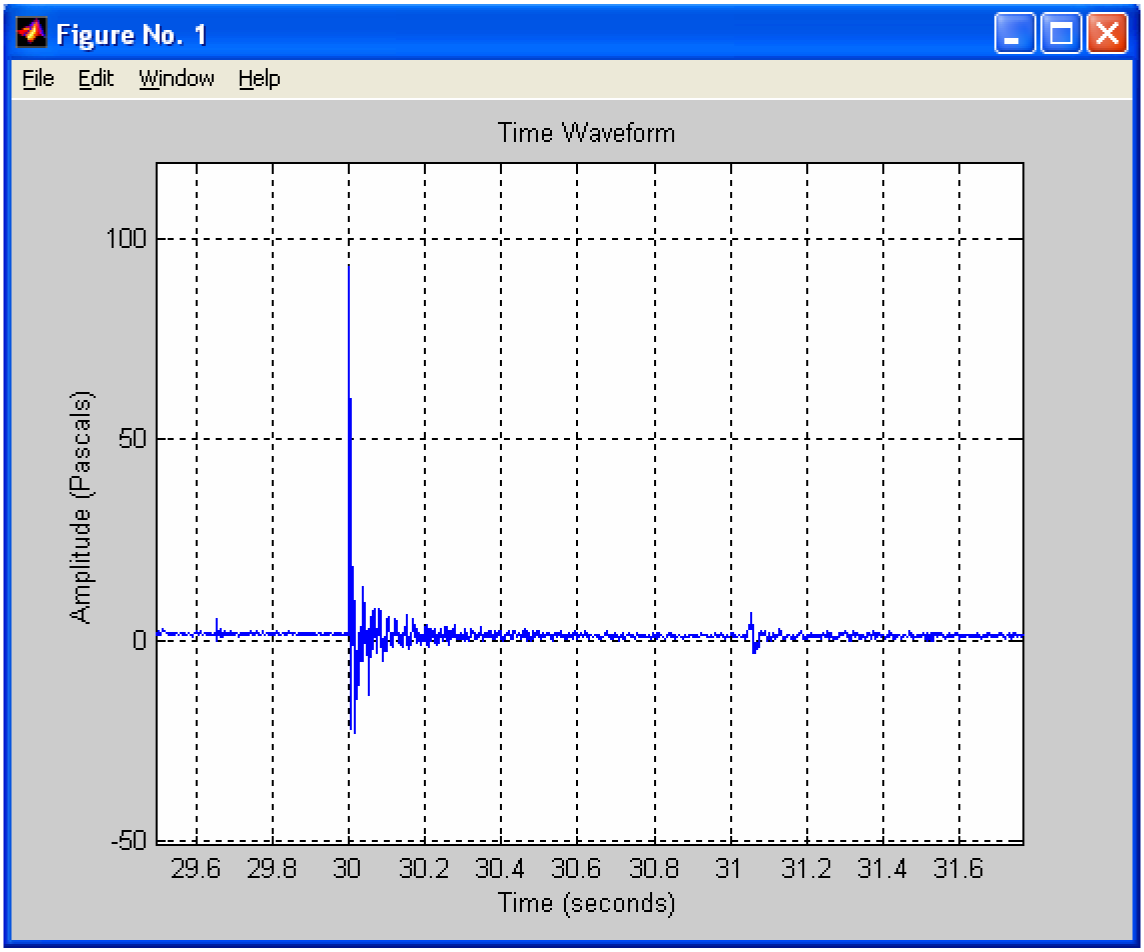

Figure 3-14. Time waveform of the 8 inch firework explosion.

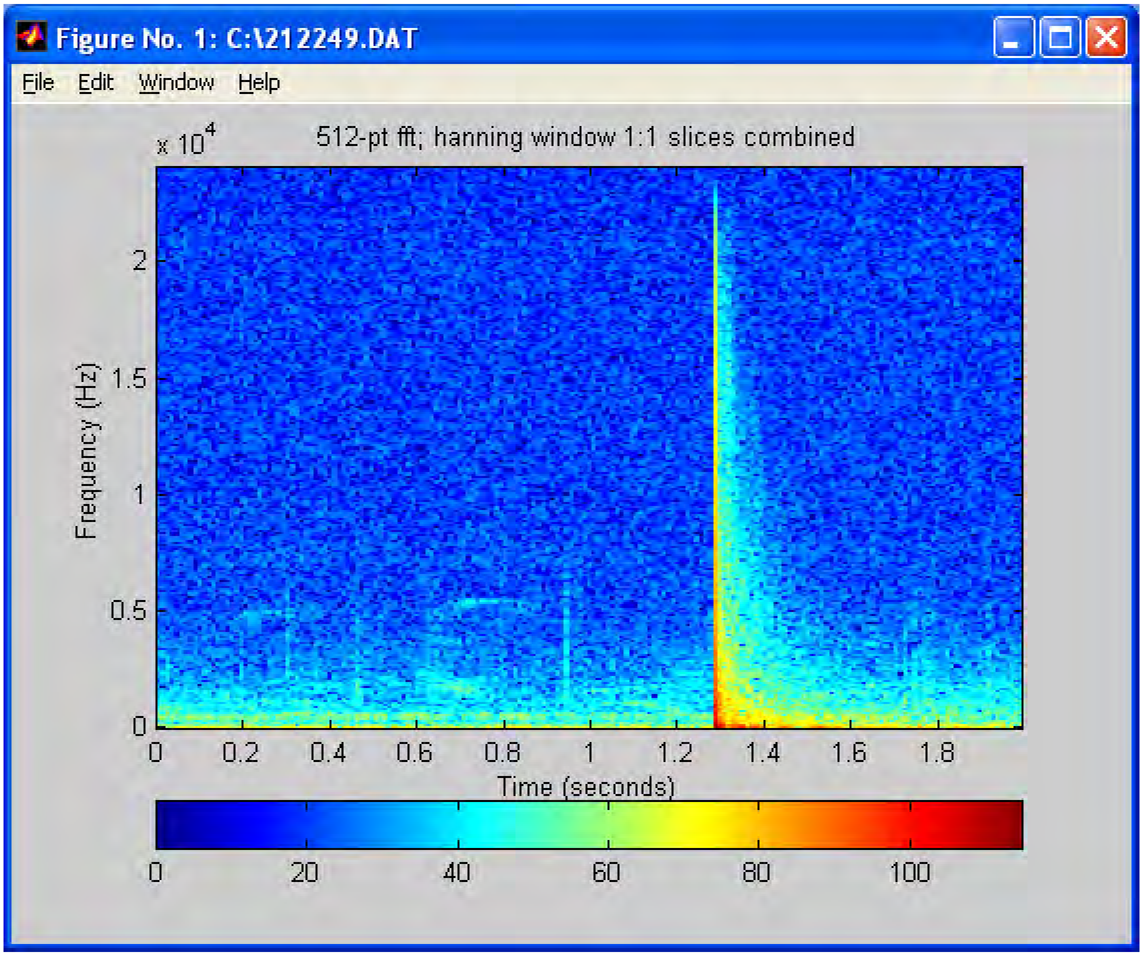

Figure 3-15. Spectrogram of the 8 inch firework explosion. Note the time scale does not correlate with the other figures associated with this specific firework.

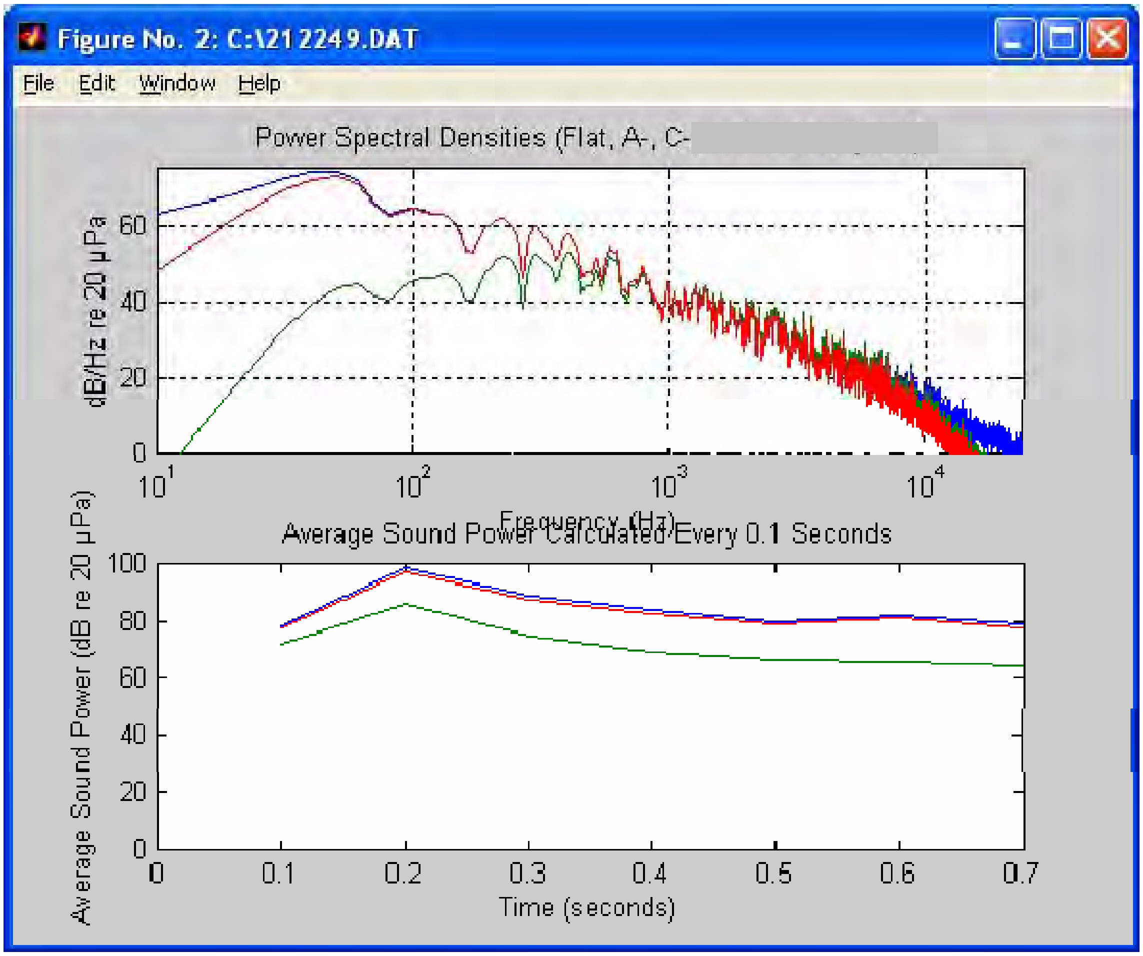

Figure 3-16. Power spectral density and sound power levels for the 8 inch firework explosion.

Single explosions with sparkles or crackles were similar in shape to the 10 and 8 inch shell explosions but were followed by crackling noise that lasted for up to 5 seconds afterwards (Figure 3-17). The spectrogram clearly shows the increased sound energy up to approximately 5 kHz from the crackling noise (Figure 3-18).

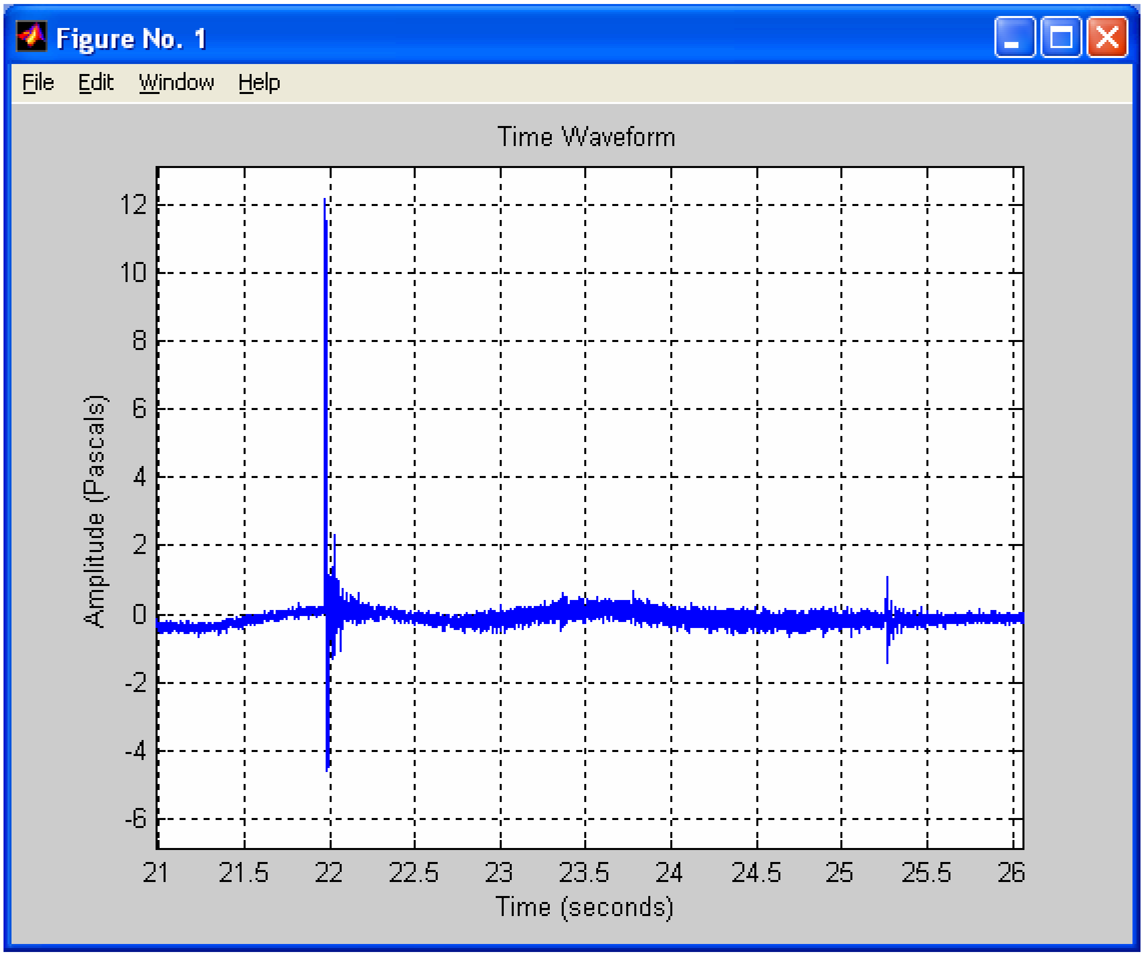

Figure 3-17. Time waveform of a single explosion with crackles 21:15:21.

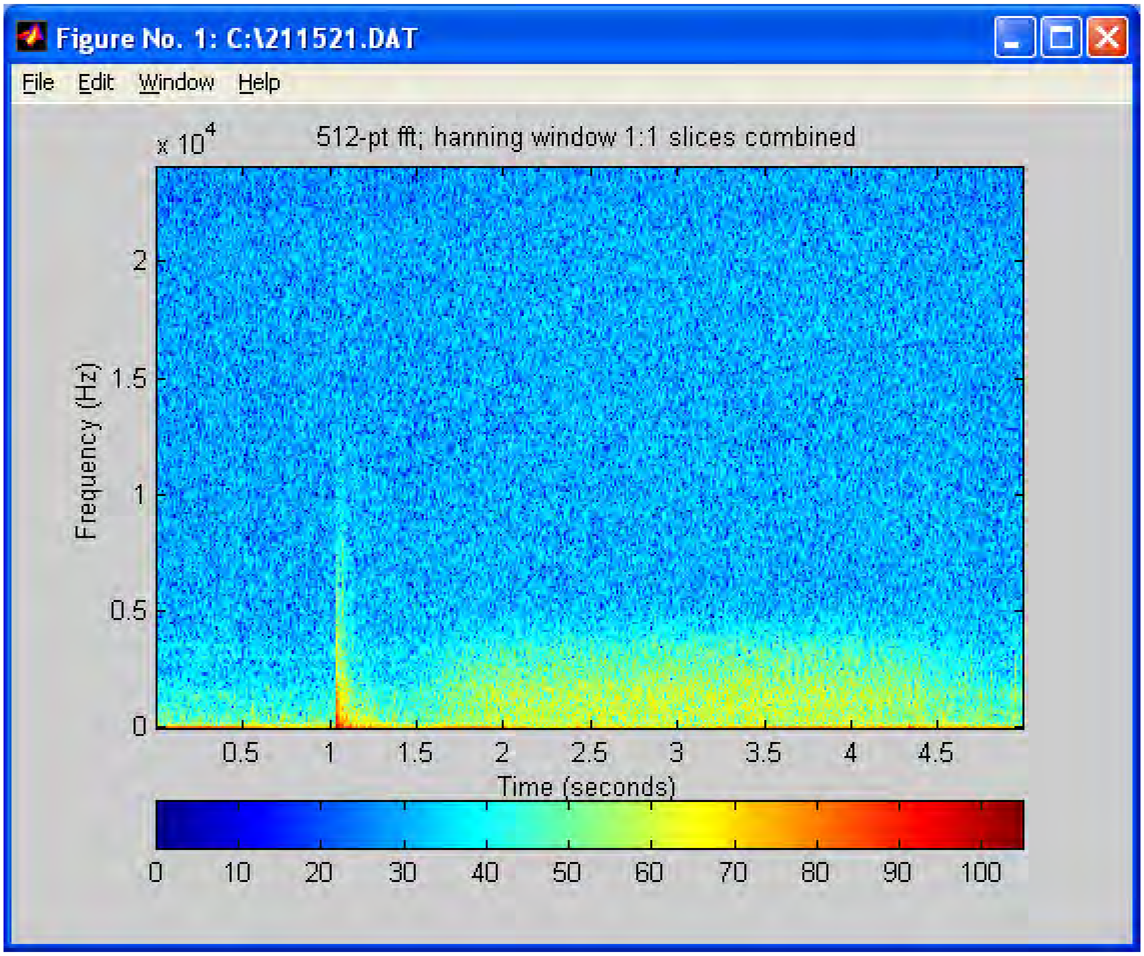

Figure 3-18. Spectrogram of the firework explosion and subsequent crackling noise. Note the time scale does not correlate with the other figures associated with this specific firework.

The spectral content of this firework explosion and subsequent crackling noise has higher levels in the 1000 to 5000 kHz range as is evident in the power spectral density measurements (Figure 3-19). One other waveform was analyzed with crackling noise and summarized metrics are reported in Table 3-4. Unweighted peak levels were in the 115 to 119 dB range and unweighted SELs in the 86 to 94 dB range.

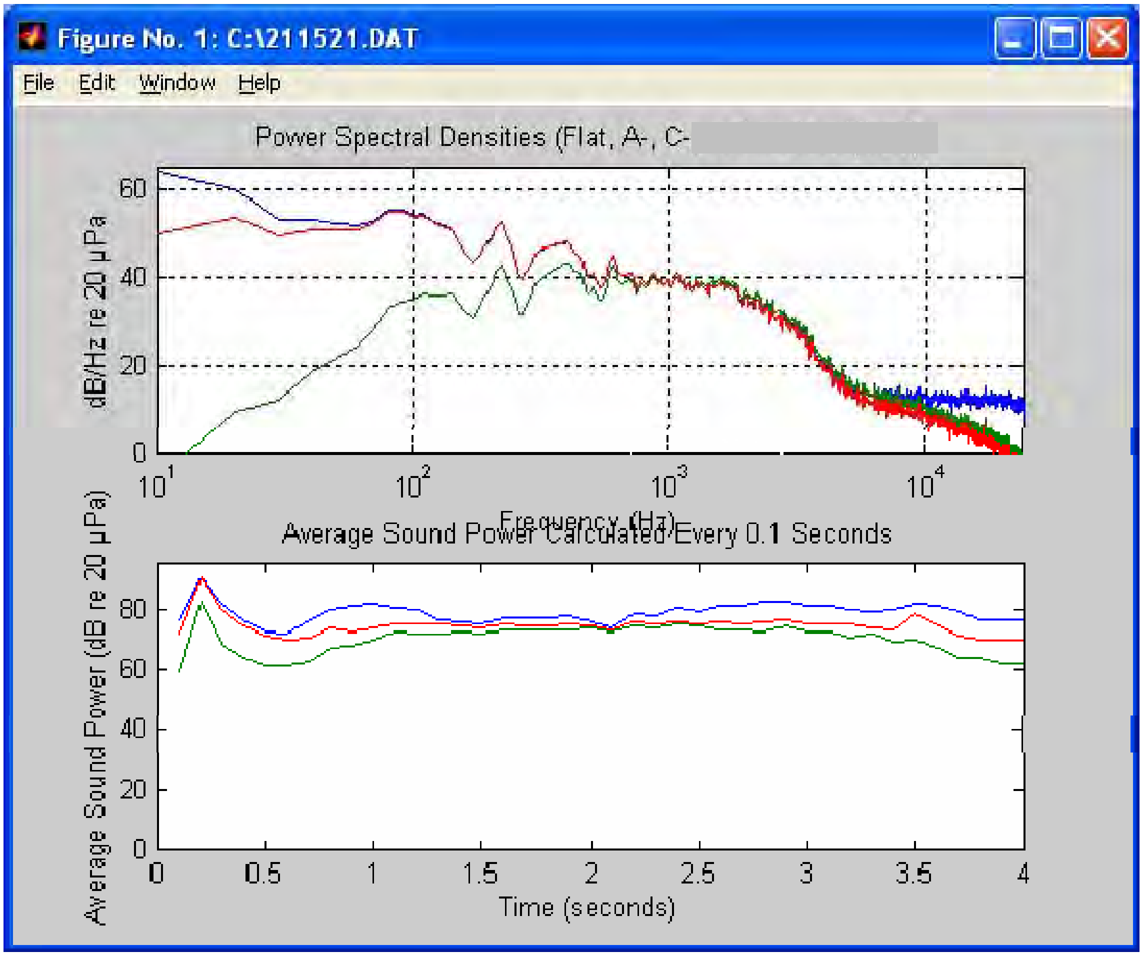

Figure 3-19. Power spectral density and sound power levels for the firework explosion with crackling noise.

Single explosions with whistles (Figure 3-20) were the most easily identifiable due to their tonal whistles following the fireworks detonation. The frequency content of the whistle drops from approximately 4 kHz to 2.5 kHz over a period of ~3 seconds (Figure 3-21). Sea lion vocalizations were clearly evident throughout the fireworks show and can be seen in the spectrogram at 3 seconds and ~4.5 seconds.

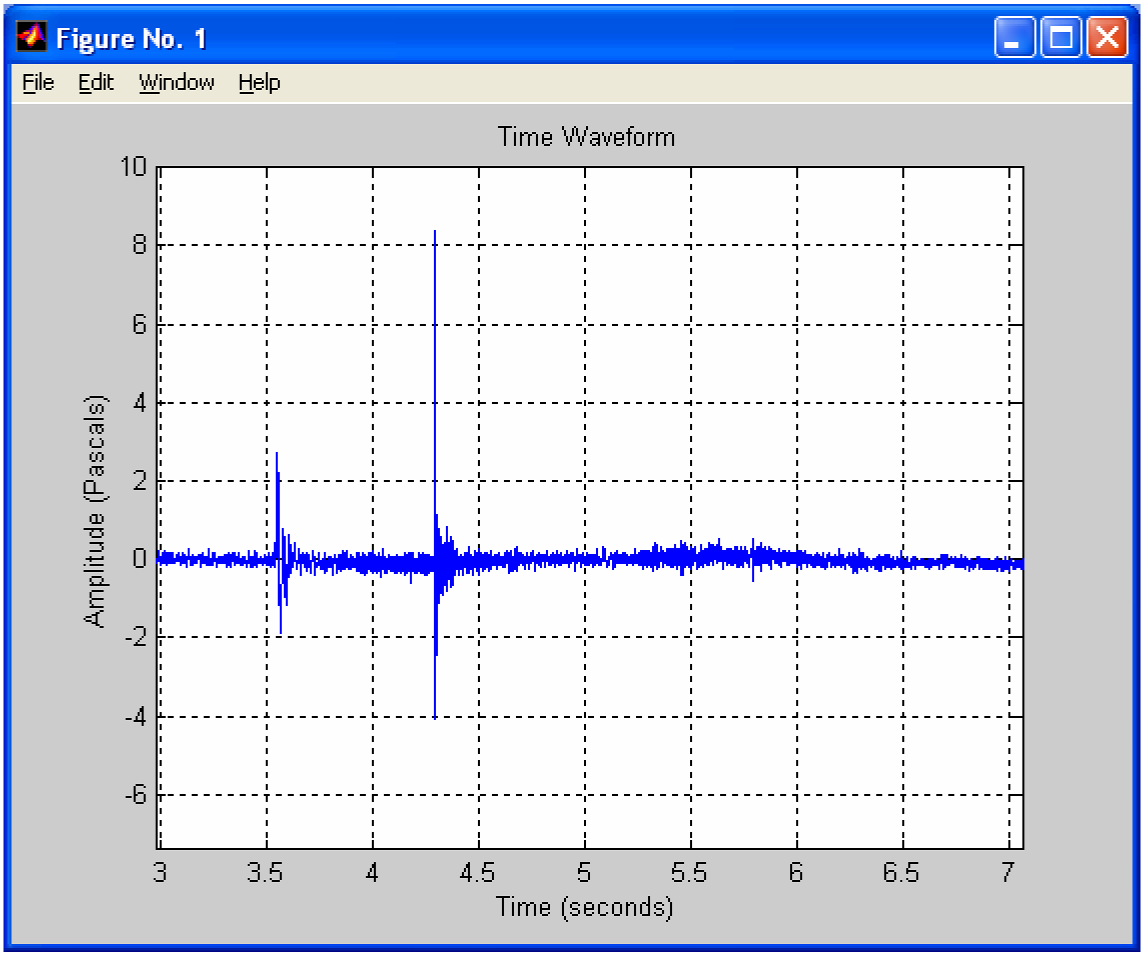

Figure 3-20. Time waveform for single explosions with whistles. The peak at 3.5 seconds is the launch noise for the firework and the explosion occurs at approximately 0.8 seconds later at 4.3 seconds.

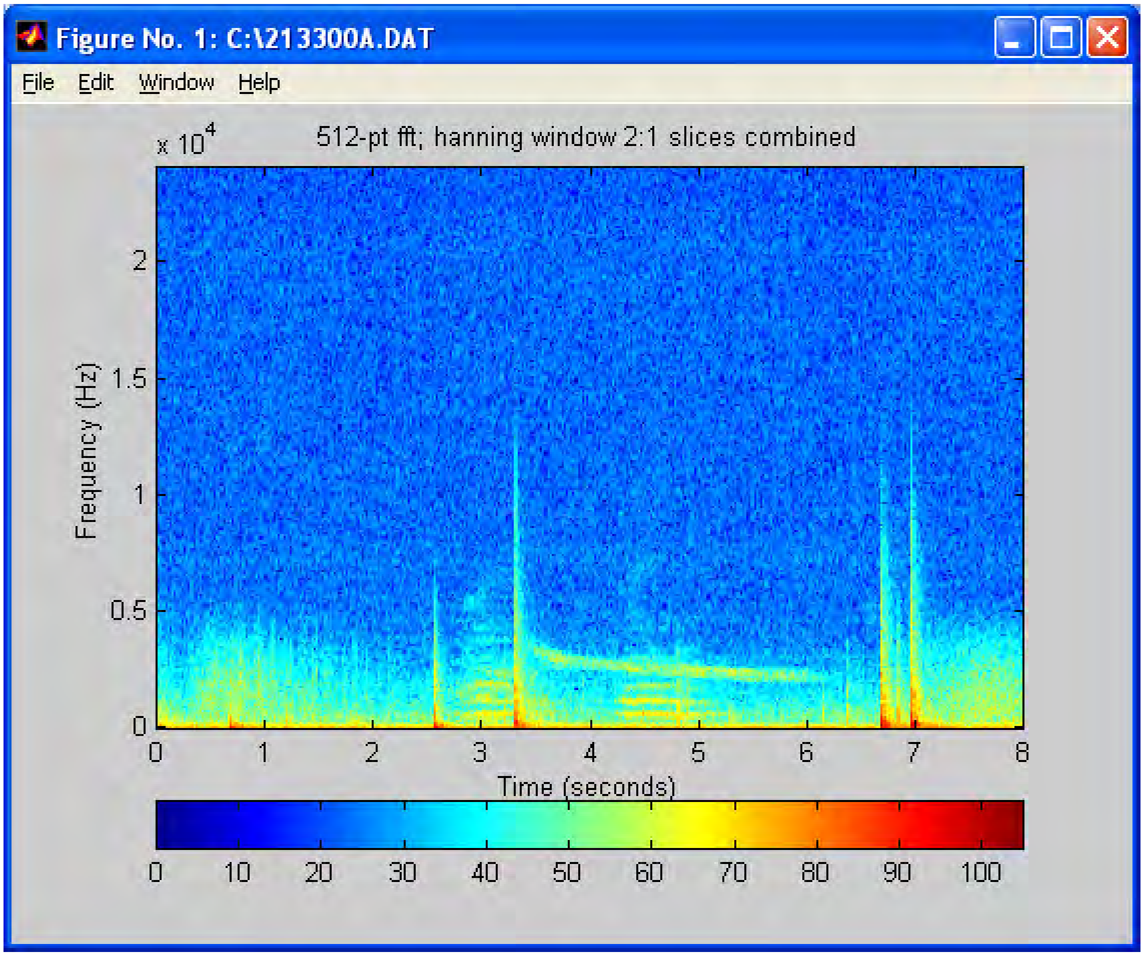

Figure 3-21. Spectrogram of a detonation followed by 4 kHz to 2.5 kHz whistling that lasts approximately 3 seconds. The peak at 3.5 seconds is the launch noise for the firework and the explosion occurs at approximately 0.8 seconds later at 4.3 seconds.

The spectral content of this firework explosion and subsequent whistling noise produces higher levels and harmonics at 640, 1250 and 2500 Hz (Figure 3-22) compared to the other fireworks. Unweighted peak levels were measured at 112.4 and the unweighted SEL was measured to be 81 dB. Other summarized metrics are reported in Table 3-4.

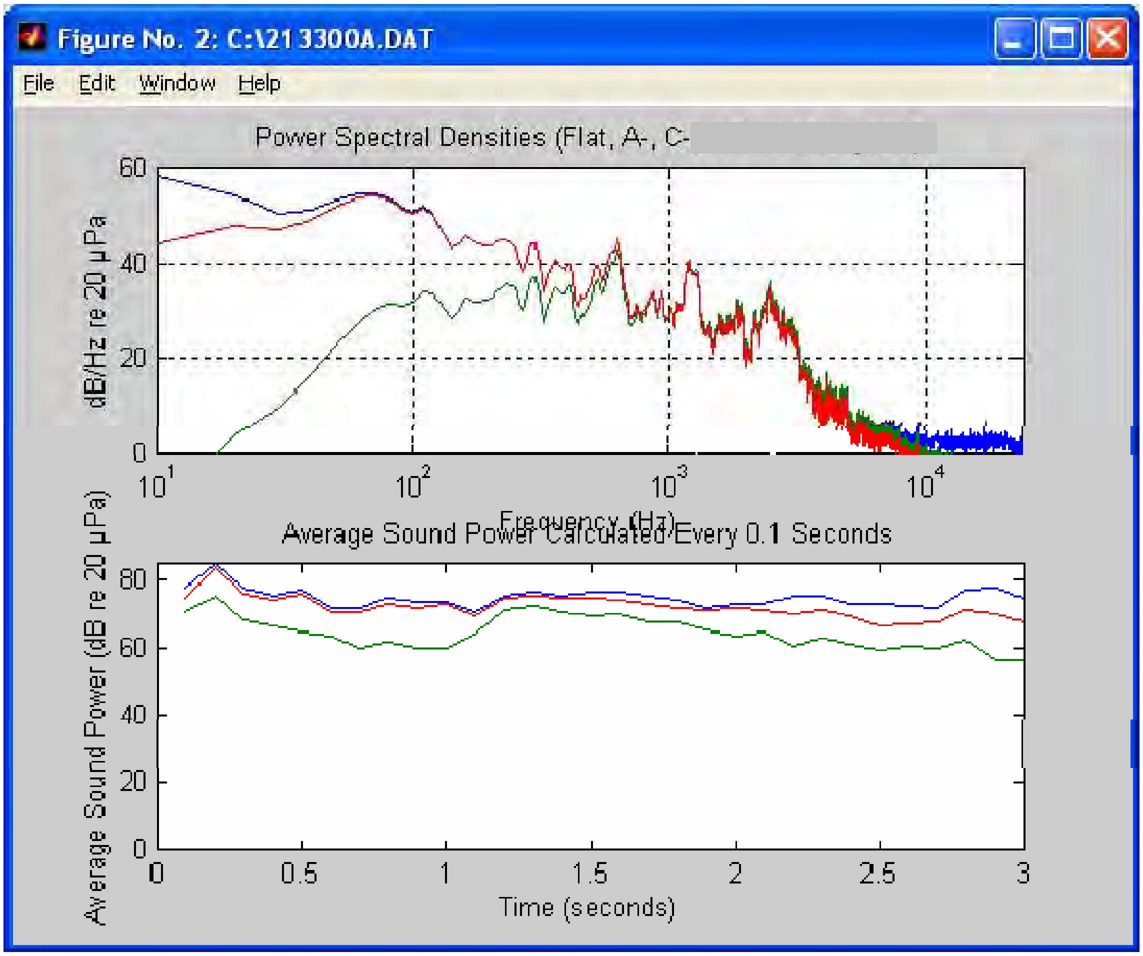

Figure 3-22. Power spectral density and sound power level for the explosion and whistling.

The grand finale contained almost 25% of the fireworks for the whole show. The magnitude of the quantity is clearly evident in the time waveform (Figure 3-23). One 10 inch shell was apparently launched during this time period but the loudest peak measured did not exceed 28 Pascals (123 dB). The unweighted SEL for the grand finale was measured to be 111.4 dB and had an unweighted Leq of 94.5 dB. Additional metrics are reported in Table 3-4.

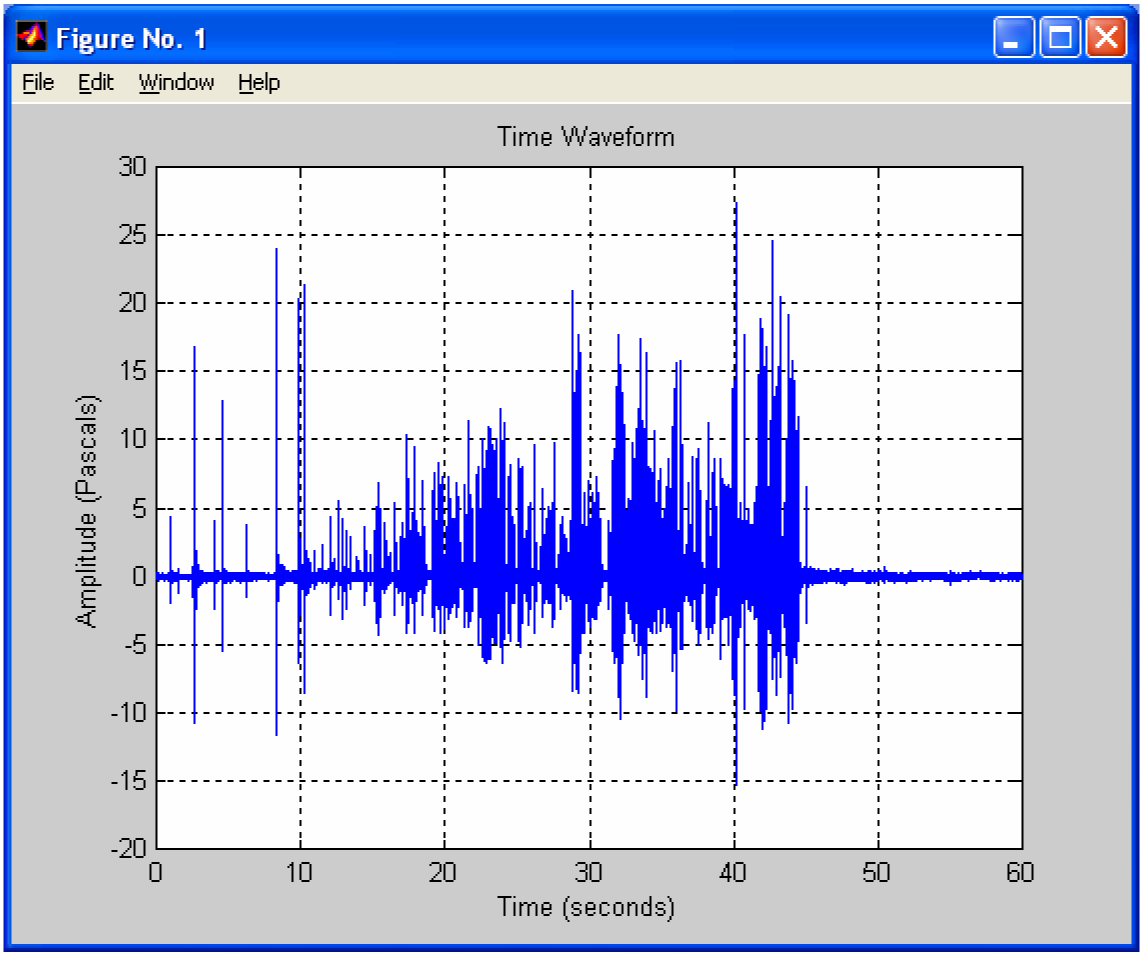

Figure 3-23. Time waveform of the grand finale.

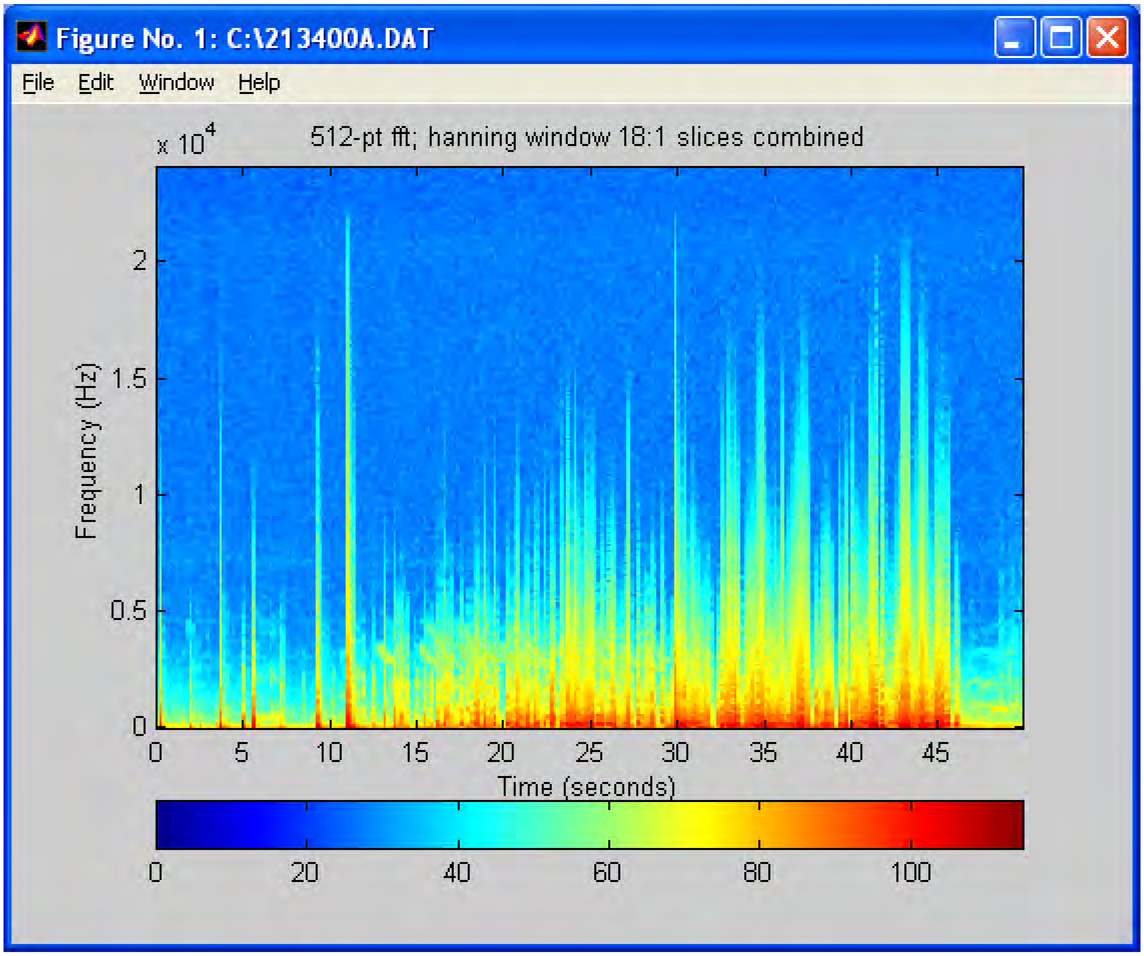

Figure 3-24. Spectrogram of the grand finale.

Sound power levels steadily increased with the increasing number of firework detonations (Figure 3-25).

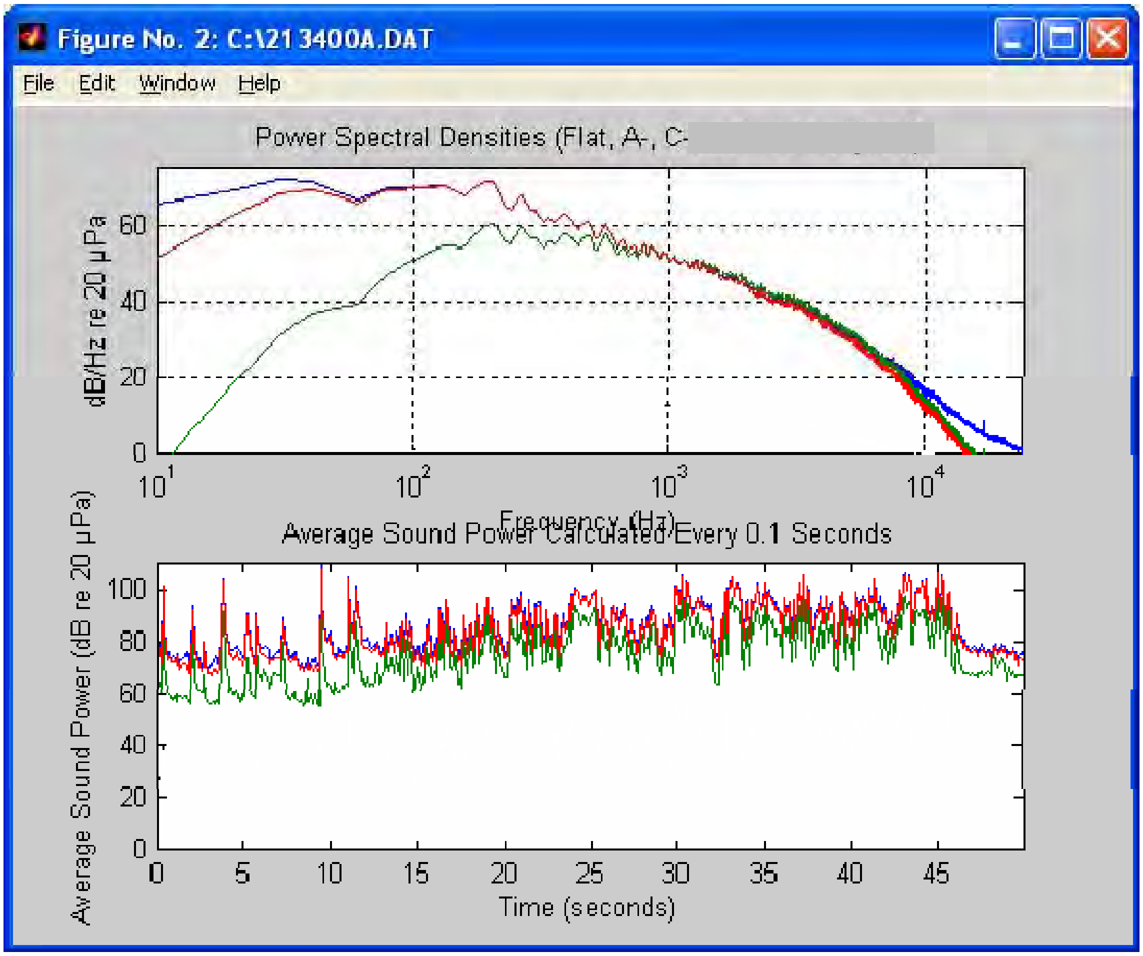

Figure 3-25. Power spectral density and sound power for the grand finale.

4 DISCUSSION

4.1 Visual Observations

4.1.1 California Sea Lions

Most sea lions had left the haul-out by the time the fireworks display had begun due to boat traffic near the jetty and smaller fireworks/firecrackers being used. The few remaining sea lions, 2-3 year olds, were under the Coast Guard pier and all entered the water by the fourth fireworks detonation. All instances of sea lions entering the water that were observed were relatively slow and it appeared no sea lions were injured.

Only a few animals had returned to haul-out on the jetty and interestingly the first was a sub-adult male that seem to practicing holding a territory. Once the male hauled out then several other sea lions hauled out near him but this was the only area where sea lions returned before observations were ended for the night. The sea lions at the Coast Guard jetty seem well acclimated to humans, both those on the western edge of the jetty and the boats or kayakers passing by the jetty. The prolonged disturbance of private party fireworks and the official fireworks display probably increased the time the sea lions spent in the water in contrast to short term disturbances (sonic boom or ship passing to closely). Despite the disturbance of the 4^{th} of July celebration, the sea lions continue to use the jetty to haul out and the fireworks display only caused a short term disruption in behavior.

4.1.2 Pacific Harbor Seals

We did not directly observed the harbor seals during the fireworks display but assume that they likely entered the water with the first several detonations. The harbor seals did not haul-out again during the post fireworks display monitoring. Harbor seals were hauled out in greater numbers the next morning although the higher numbers could be a result of the lower tide level allowing more haul-out area.

Similar to the sea lions in this area, harbor seals are more acclimated to human presence than harbor seals in many other areas. Despite the disturbance of the 4^{th} of July celebration, the harbor seals continue to use the rocks on the western end of the harbor to haul out and the fireworks display only caused a short term disruption in behavior.

4.1.3 Southern Sea Otters

We did not directly observe sea otters during the fireworks display but we did observe them in the harbor shortly after the display ended. We assume that at least some of the sea otters that were observed during the post fireworks display monitoring were the same ones observed in the harbor just prior to the fireworks. Despite the disturbance of the 4^{th} of July celebration, the sea otters continue to use the harbor to feed and rest in and the fireworks display only caused a short term disruption in behavior.

4.2 Acoustic Monitoring

Firework detonations including crackles and whistles, lower frequency transients associated with the launch of the fireworks, sea lion vocalizations, and aircraft over flights were measured. Most of the sound energy from the fireworks is low frequency but the explosions have spectral content reaching up above 20 kHz. The explosions have unweighted peaks ranging from 112 to 133.9 dB but most have unweighted peaks in the 112 to 124 dB range. The loudest explosion was from the 10 inch shell which had an unweighted peak of 133.9 dB and unweighted SEL of 105.0 dB. Several 8 inch

shells were measured to have unweighted peaks ~8.5 to 14.9 dB less than the 10 inch shell measurements and had unweighted SELs in the 90 to 96.5 dB range. The transients associated with the launch of the fireworks were observed to be lower in frequency, have slower rise times and have unweighted peaks estimated to in the 1.5 to 5 Pa (97 to 107 dB) range. The loudest hour containing the fireworks show was measured at 72.9 dB, 13 to 14.9 dB greater than the ambient measurements before and after the show.

5 ACKNOWLEDGEMENTS

Thanks to Scott Kathey for facilitation of monitoring activities and information collection, Pyro Spectaculars for fireworks and show information and Jon Francine for supporting physical acoustics measurements.

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APPENDIX A

LD820 SLM EVENT DATA

Time	Duration	A-weighted	A-weighted	A-weighted	A-weighted	Unweighted
HH:MM:SS	(seconds)	Leq (dB)	SEL (dB)	Lmax (dB)	Peak (dB)	Peak (dB)
21:14:01	1.4	71.5	73.1	73.4	84.5	
21:14:03	1.5	71.9	73.7	74.7	85.2	
21:14:34	1.1	68.4	68.7	71	89.8	95.2
21:14:47	1.7	70.3	72.5	75.4	98	102.6
21:15:14	2.1	80.7	83.9	88	115	117.3
21:15:17	2.5	83.2	87.2	90	119.1	120
21:15:37	1.7	68.2	70.4	71.4	82.8	
21:15:42	1.5	80	81.8	89.3	112.5	117.1
21:15:46	2	84.7	87.8	94.5	121.1	123.5
21:15:51	1	83.3	83.3	90.1	117.3	119.3
21:15:53	1.6	74.1	76.1	82.9	105.2	112.1
21:15:57	3.8	75.4	81.2	86.2	107.8	114.6
21:16:05	4.2	78.3	84.5	87.4	112.6	116.3
21:16:10	2.9	76.6	81.3	88.5	107.8	115.8
21:16:35	1	81.9	81.9	89.8	112.1	114.6
21:16:51	4.4	75.4	81.8	84.8	109.2	112.5
21:16:56	1	80.1	80.2	87.5	112.2	115.8
21:16:58	1.8	75.4	78	81.1	104.7	107.9
21:17:00	1.8	78	80.7	85.8	109.1	114.3
21:17:04	1.1	84.6	85	92.5	119.8	122.2
21:17:49	2.4	69.9	73.7	73.8	94.6	102.6
21:17:55	1	81.6	81.8	89	112.3	118.1
21:17:59	1.6	78.9	80.8	84.6	106.2	107.9
21:18:01	1.4	86.1	87.5	94.6	124.3	124.6
21:18:06	1.6	74.3	76.2	81	100.3	103.7
21:18:09	1.1	84.6	85	92.6	121.5	122.2
21:18:12	1	82.3	82.3	89.9	116.3	118.7
21:18:16	1.7	81	83.2	90.5	116.3	119.5
21:18:24	1.1	84.2	84.7	92.3	121.1	121.8
21:18:47	1	83.5	83.7	90.8	120.8	121.5
21:18:54	1.1	86	86.6	94.4	121.9	123.1
21:18:58	1.1	80.3	80.5	88	111.2	116.8
21:19:04	3	92.9	97.6	105.5	130.9	132.3
21:19:42	1.1	86.3	86.7	94.5	121.9	123
21:19:50	1.2	76.6	77.4	82.2	105.8	109.7
21:19:54	1.3	77.3	78.4	84.1	106.3	111.7
21:20:06	1.3	84.1	85.4	92.5	118.3	122.9
21:20:12	1.2	69.8	70.8	74.1	93.4	97.7
21:20:15	1.5	70.1	71.9	72.5	90.3	101.2
21:20:18	1.1	76.7	77.1	84.6	109.3	112.1
21:20:22	1.1	83.1	83.4	91	112.1	120.3
21:20:58	1.8	77.3	79.8	86.6	112.9	115.5
21:21:06	1.4	79.7	81.1	88.5	115.7	117.1
21:21:10	1.2	77.1	77.9	83.4	106.9	111.3
21:21:33	1	84	84	91.1	117.3	118.3
21:21:35	1.2	69.7	70.6	75.4	100.4	105.7
21:21:39	1.1	77.3	77.7	85	105.2	115.5
21:21:44	1.8	74	76.6	80.8	102.7	108.6
21:21:46	7.6	77	85.8	87.3	113.4	116.8

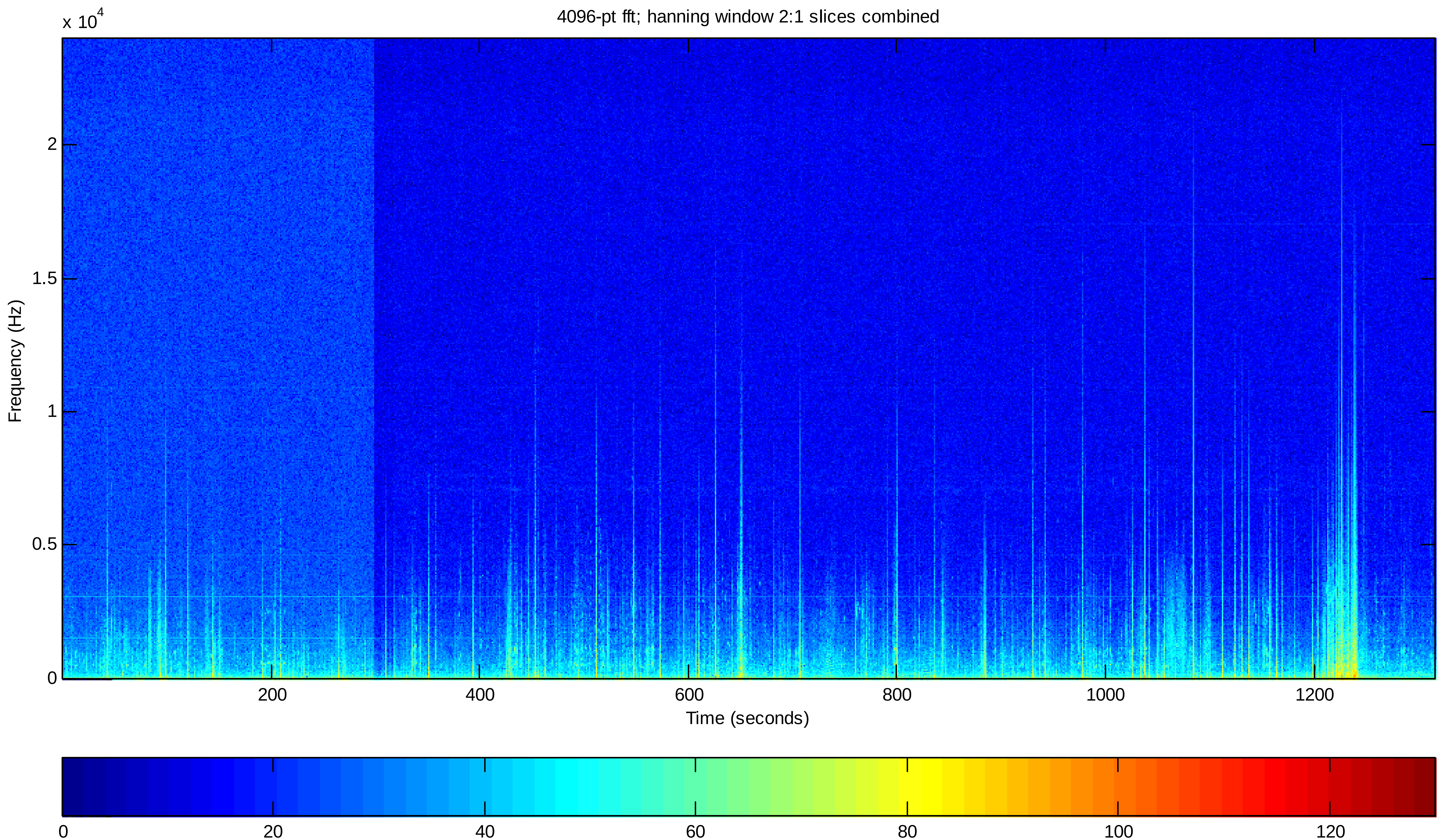
Time HH:MM:SS	Duration (seconds)	A-weighted Leq (dB)	A-weighted SEL (dB)	A-weighted Lmax (dB)	A-weighted Peak (dB)	Unweighted Peak (dB)
21:21:54	3.2	76	80.9	80	99.1	101.2
21:22:03	1	80.3	80.4	87.6	115.2	116.8
21:22:14	1	81.9	82	89.5	105.8	118.3
21:22:46	6.4	76.3	84.4	89.4	115.7	119.1
21:22:53	2.5	72.2	76.1	81.3	102.3	108.6
21:23:02	1.3	67.9	69	71.5	87.2	
21:23:14	2.1	76.3	79.4	86.4	115.7	116.6
21:23:17	2.8	77.6	82.1	88.8	114.4	117.3
21:23:24	1.2	88.1	89	96.3	126.1	126.4
21:23:34	1.7	74.5	76.8	81	102.6	107.3
21:23:37	1.1	85.5	85.9	93.5	120.9	122.4
21:23:40	1.5	78	79.6	85.5	110.6	112.5
21:23:44	1.7	75.8	78.2	85.4	112.7	114.6
21:23:57	2.4	77	80.8	86.6	110.6	114.3
21:24:01	1.1	74.8	75	79.3	89.8	
21:24:02	1.2	72.1	72.9	75.6	88.1	99.7
21:24:09	1.2	81.6	82.4	90	118.9	119.6
21:24:26	1.5	86.7	88.5	94.9	122.7	124
21:24:29	1	77.9	78	85.4	108.9	114
21:24:31	2	85.7	88.6	95.6	121.4	123.3
21:24:53	1	75.6	75.7	82.4	106.8	111.3
21:24:59	1.9	86.3	89.1	96.6	122.2	124.3
21:25:02	2.5	81.1	85.1	90.1	113.9	120
21:25:13	1	80.9	81.1	88.4	114.4	116.8
21:25:16	1.6	83.6	85.6	92.9	123.6	123.8
21:25:21	1.1	85.2	85.5	93.2	121.2	121.9
21:25:22	2.5	81.6	85.6	93.2	120.6	122.2
21:25:25	8.8	83.3	92.7	91.6	116.2	117.4
21:25:37	1.2	80	80.7	87.7	115.1	115.5
21:25:59	1	83.6	83.6	91.2	116.4	119.8
21:26:04	1	82.7	82.8	90.1	112.9	118.9
21:26:09	1.7	73.6	76	82.4	106.7	111.7
21:26:22	5.9	81.5	89.2	94.9	120.8	124
21:26:36	1.5	82.4	84.3	91.5	118.8	119.6
21:27:17	1.1	70.1	70.6	75.1	100.9	104.3
21:27:30	1.2	74.7	75.3	80.7	106.3	108.6
21:27:39	1	84.8	84.9	92.6	115.2	121.9
21:27:42	1.1	81.8	82.2	89.7	115.4	118.9
21:27:48	1	84	84.1	91	114.2	121.1
21:27:54	2.9	80.9	85.5	92.1	121.2	121.9
21:27:57	1.5	81	82.8	89.6	115.9	118.9
21:28:15	1.1	84.7	85.1	92.7	115.9	120.9
21:28:28	1.9	82.1	84.9	90.2	114.9	118.1
21:28:33	1.5	83.2	85	92.4	122.8	123.4
21:28:39	2.9	75.9	80.5	85.7	114.4	115.2
21:28:42	1.7	80.4	82.7	88.5	112.3	117.1
21:29:16	4.2	82.6	88.8	93.2	120.7	122.6
21:29:20	1.8	77.3	79.9	83.3	105.4	109.7
21:29:43	1.2	81.8	82.7	90.2	105.9	117.8

21:29:49	1.7	83.1	85.3	92.7	118.4	121.1
21:29:53	1.2	82	82.8	90.2	115.2	119.1
Time HH:MM:SS	Duration (seconds)	A-weighted Leq (dB)	A-weighted SEL (dB)	A-weighted Lmax (dB)	A-weighted Peak (dB)	Unweighted Peak (dB)
21:30:07	2.3	83	86.7	90.4	115.5	119.1
21:30:20	1	83.3	83.3	91	115.8	118.7
21:30:22	1.2	83	84	90.9	113.7	119.5
21:30:46	1.5	74.5	76.3	82.6	106.2	110.3
21:30:48	1	85	85.2	92.5	118.8	121.1
21:30:56	1.1	83.4	83.7	91.2	117.5	119.6
21:31:00	1.1	84.4	84.8	92.3	117.8	120.8
21:31:02	3.2	83.4	88.4	93	120.5	121.6
21:31:07	1.3	71.9	73.2	77.6	86.9	
21:31:16	1.2	69.7	70.6	72	85.2	
21:31:17	1.2	75.7	76.7	79.2	89.7	
21:31:19	1.2	70.1	70.8	72.9	84.4	
21:31:22	1	68.8	68.9	72.1	82	
21:31:24	1	78	78	83.2	110.3	111.3
21:31:37	1.4	74.2	75.6	80.3	103.3	107.3
21:31:43	2.2	77.8	81.3	87.1	113.5	114.3
21:31:47	1.1	79	79.5	85.1	108.9	111.7
21:31:51	1.1	84.2	84.4	91.5	118.7	120.6
21:31:55	1.7	79.3	81.5	89	116	117.5
21:31:59	1.3	84.3	85.6	91.8	119.8	120.6
21:32:08	2	78	81	88.6	117.5	118.1
21:32:19	5.4	72	79.3	84.2	109.2	112.9
21:32:29	4.9	71.5	78.4	83	109.2	111.7
21:32:37	1.5	74.3	76.1	80	103.9	111.7
21:32:42	1.2	86.7	87.4	95.1	123.4	123.8
21:32:45	1.5	81.5	83.3	90.6	115.8	119.3
21:32:51	1.6	82.4	84.3	91.5	118.8	119.8
21:32:55	1.5	82.9	84.5	92.1	119.4	120.9
21:32:57	1.9	78.1	81	87.4	112.4	116.1
21:33:00	1.1	70.3	70.9	73.7	98.4	99.7
21:33:14	1.1	80.8	81.1	87.5	112.5	115.2
21:33:29	1.2	79.7	80.4	85.7	112.7	113.6
21:33:36	1.4	75.9	77.5	84.1	108.4	111.9
21:33:38	1.6	75.3	77.3	84.4	109.5	112.1
21:33:40	1.1	69.5	69.8	72.3	84.9	
21:33:42	1.8	79.2	81.6	86.9	112.3	113.3
21:33:47	1.2	76.4	77.2	84.1	109.4	112.1
21:33:49	1.3	71.8	73	76.3	96.8	103.7
21:33:50	5.8	75.2	82.8	83.6	108	110.8
21:34:10	1.5	82.1	83.8	88.4	113.2	115.8
21:34:22	1.7	79.9	82.2	89.3	117.5	118.9
21:34:29	1.1	83.3	83.7	90.9	115	119.1
21:34:35	1.3	82.1	83.3	89	116.8	117.5
21:34:40	2.2	76.2	79.5	86.6	110.5	115.2
21:34:44	1.1	84.4	84.6	92.4	119.3	120.6
21:34:46	41.9	86.7	102.9	97.5	121.9	122.2

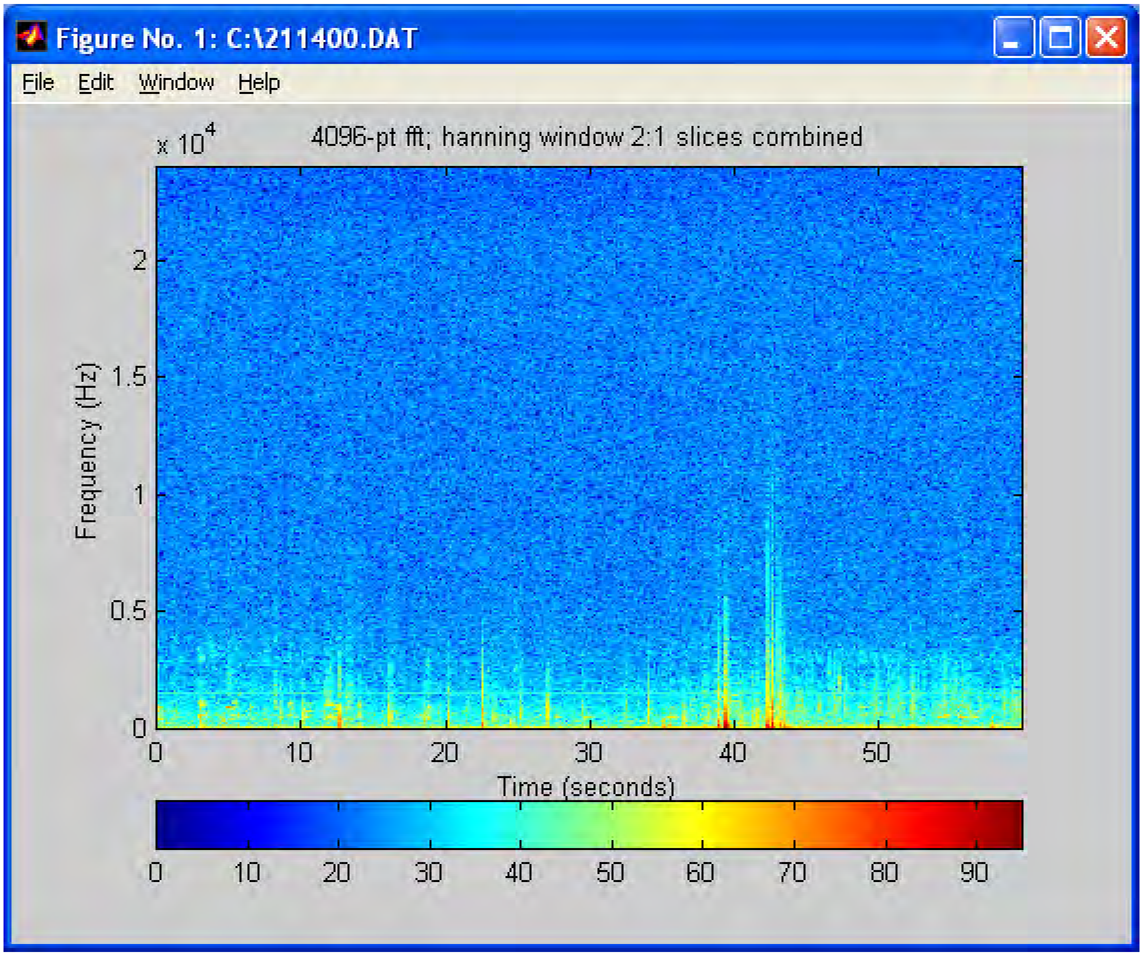
SPECTOGRAMS

TIME WAVEFORMS

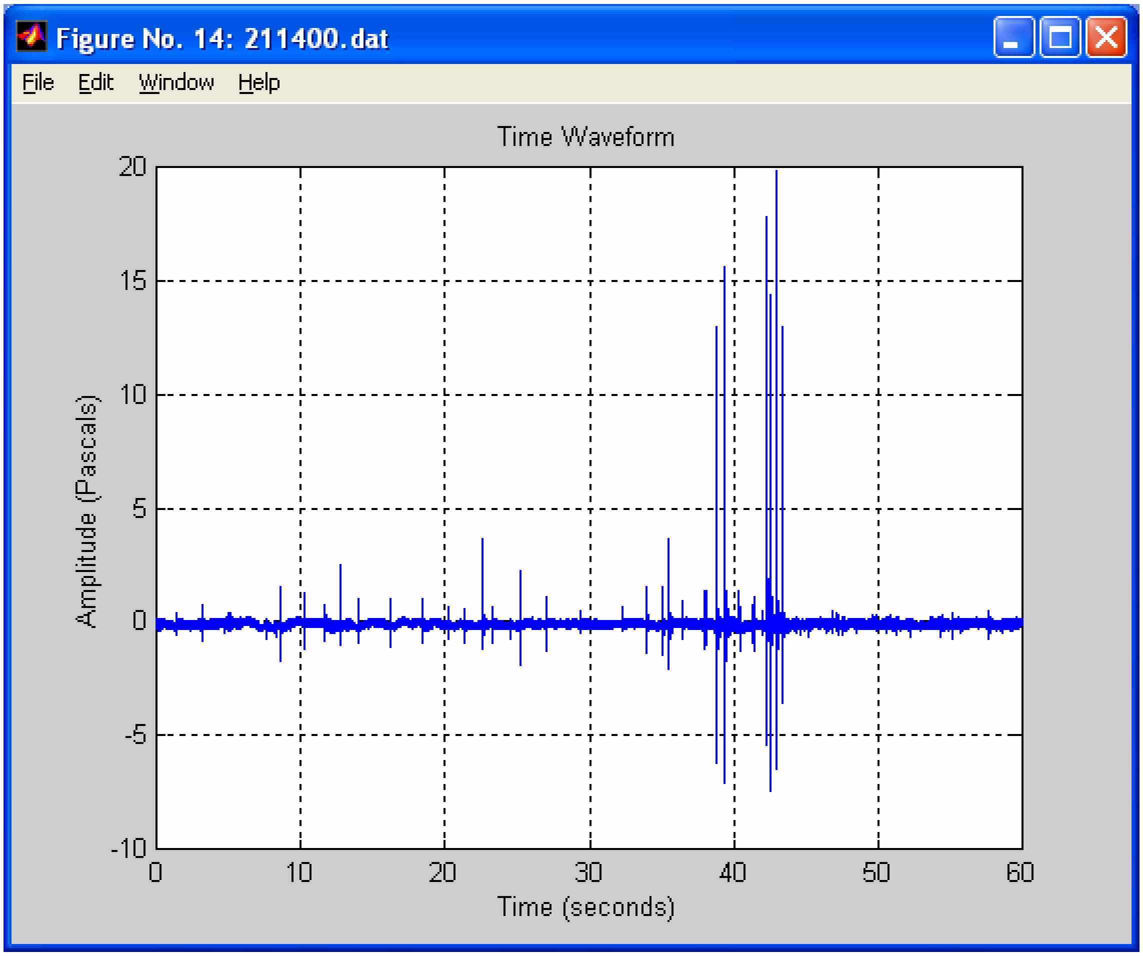
NOTES


4096-pt fft; hanning window 2:1 slices combined
x 10^4
Frequency (Hz)
0
0.5
1
1.5
2
200
400
600
800
1000
1200
Time (seconds)
0
20
40
60
80
100
120

Notes: 21:14:00 to 21:15:00
Minimal noise (sea lion barking) and extraneous fireworks were clearly audible before the show.
21:14:39 approximate start time of show with the two sets of firework detonations that resulted in seagull screams.
21:15:00 firework crackling can be heard.

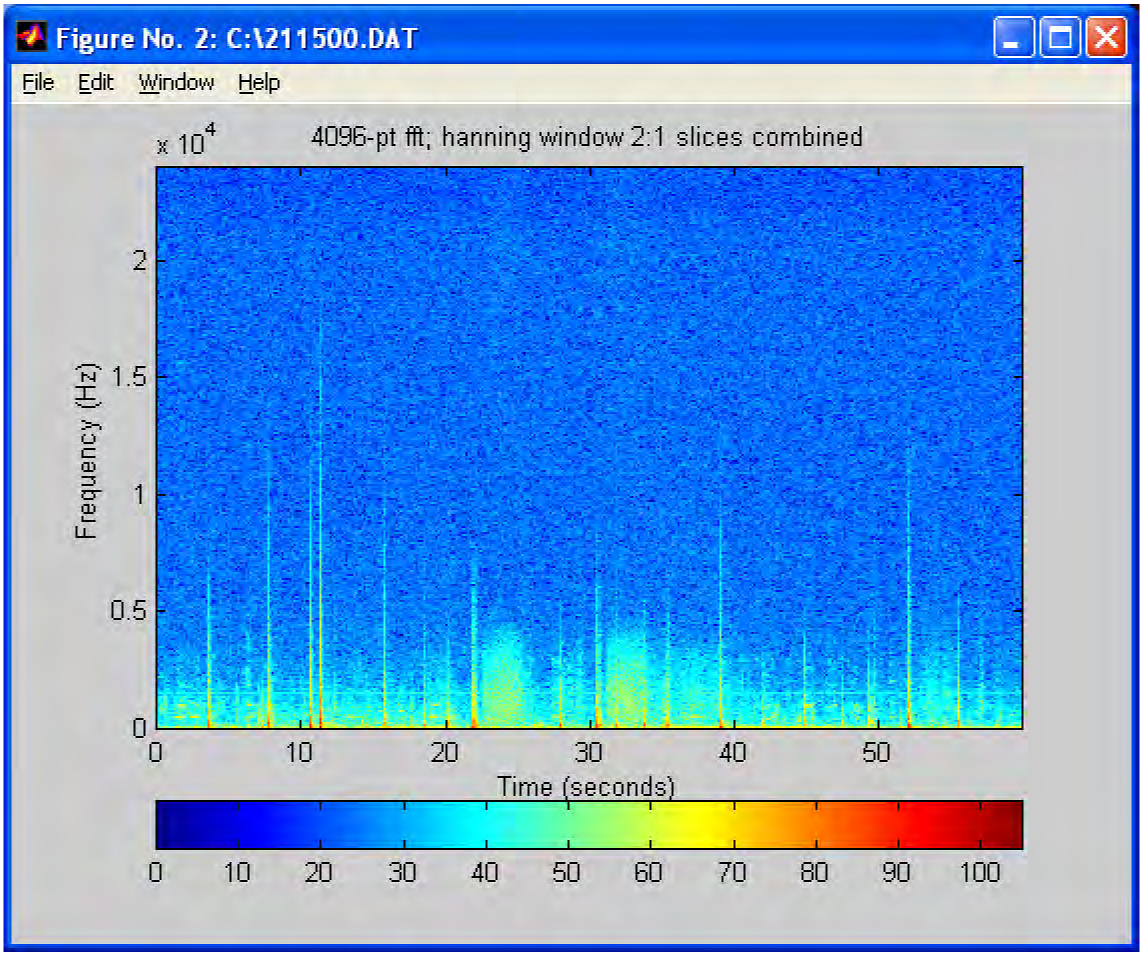


Spectrogram 21:14:00 to 21:15:00.

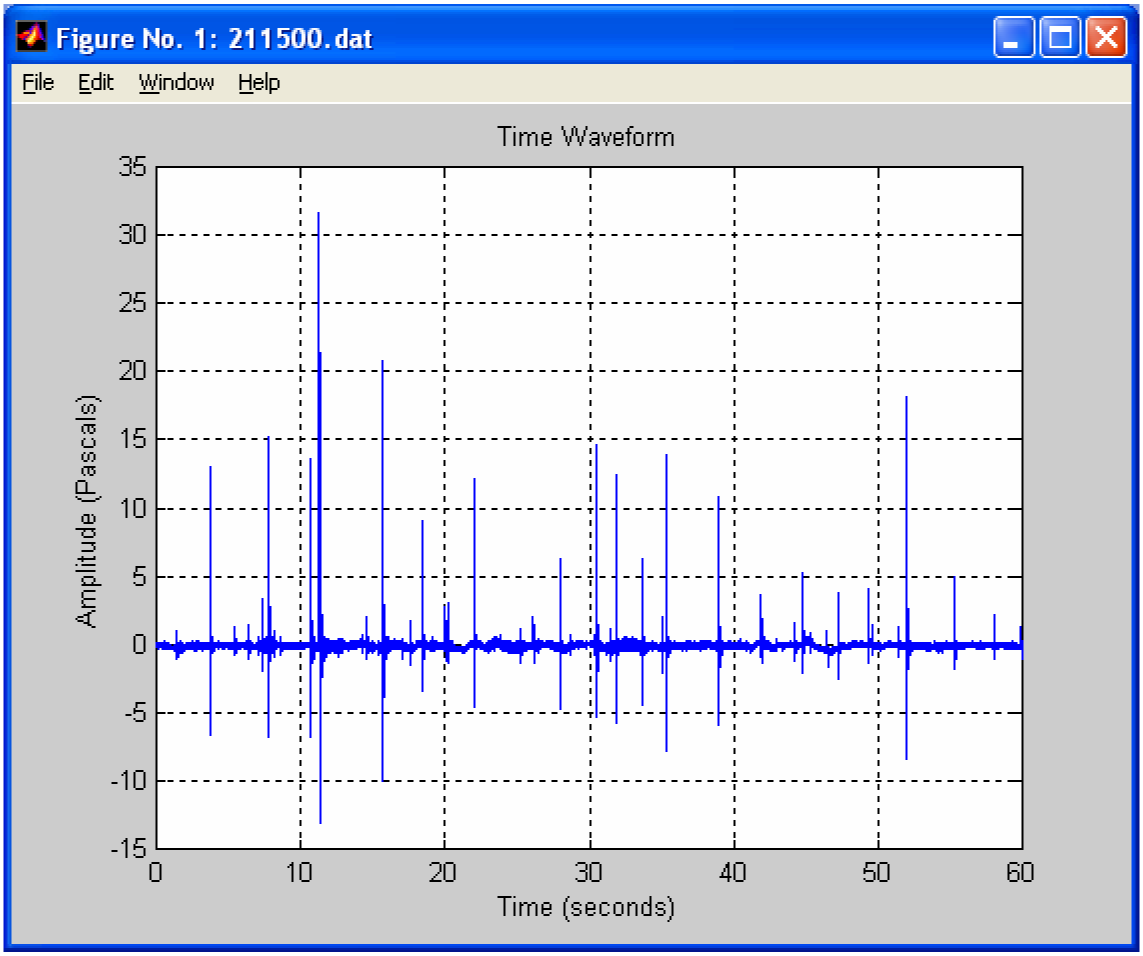


Time waveform 21:14:00 to 21:15:00

Notes: 21:15:00 to 21:16:00
21:15:10 louder detonations were observed that was likely an 8 inch shell.
21:15:11 louder detonation is assumed to be a 6 in shell.
21:15:22 single explosions had clearly audible crackling afterwards
21:15:30 single explosions had clearly audible crackling afterwards.

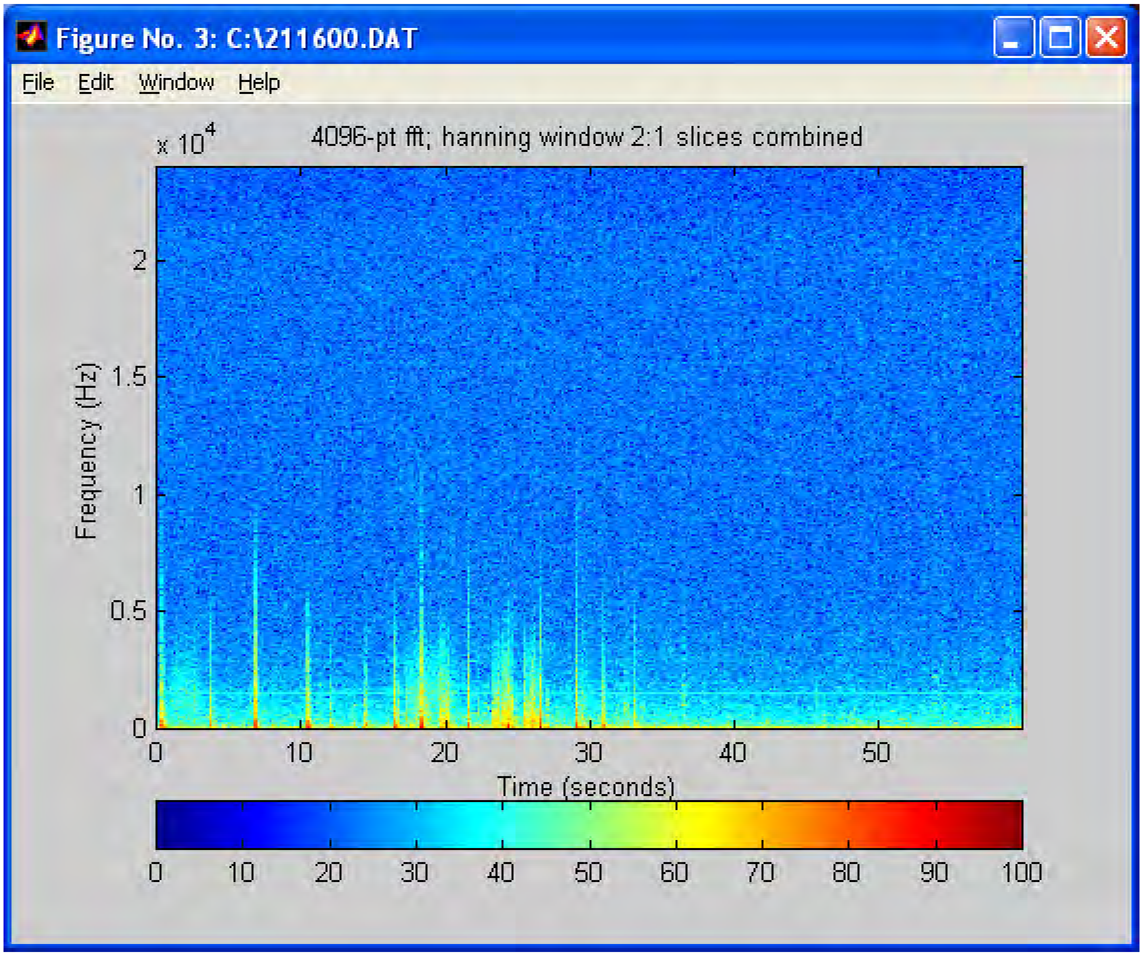


Spectrogram 21:15:00 to 21:16:00

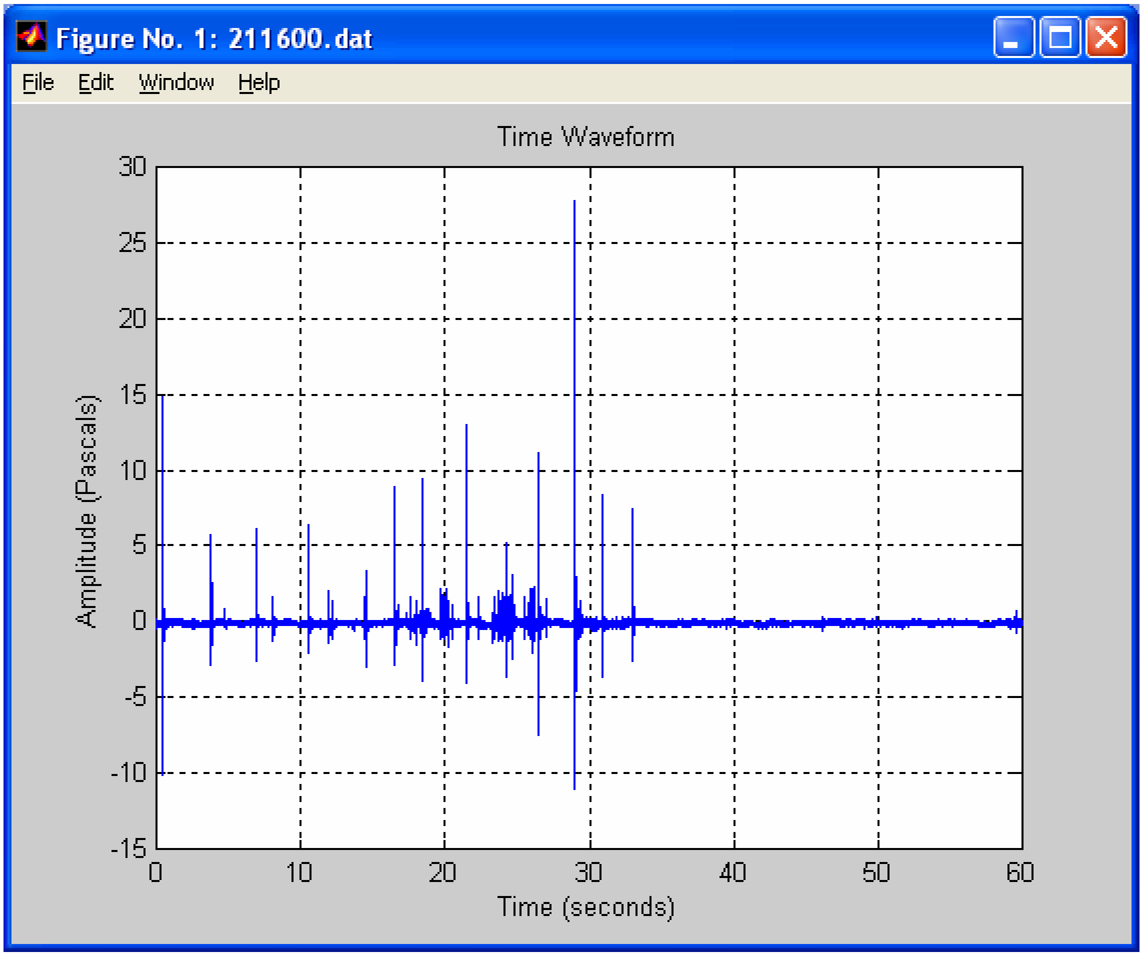


Time waveform 21:15:00 to 21:16:00

Notes: 21:16:00 to 21:17:00. Crackling observed at 21:16:00 and 17. 21:16:24-28 multiple explosions were heard. A louder explosion was heard at 21:16:28. This is likely an 8 inch shell. 21:16:35 to 21:16:59 quiet.

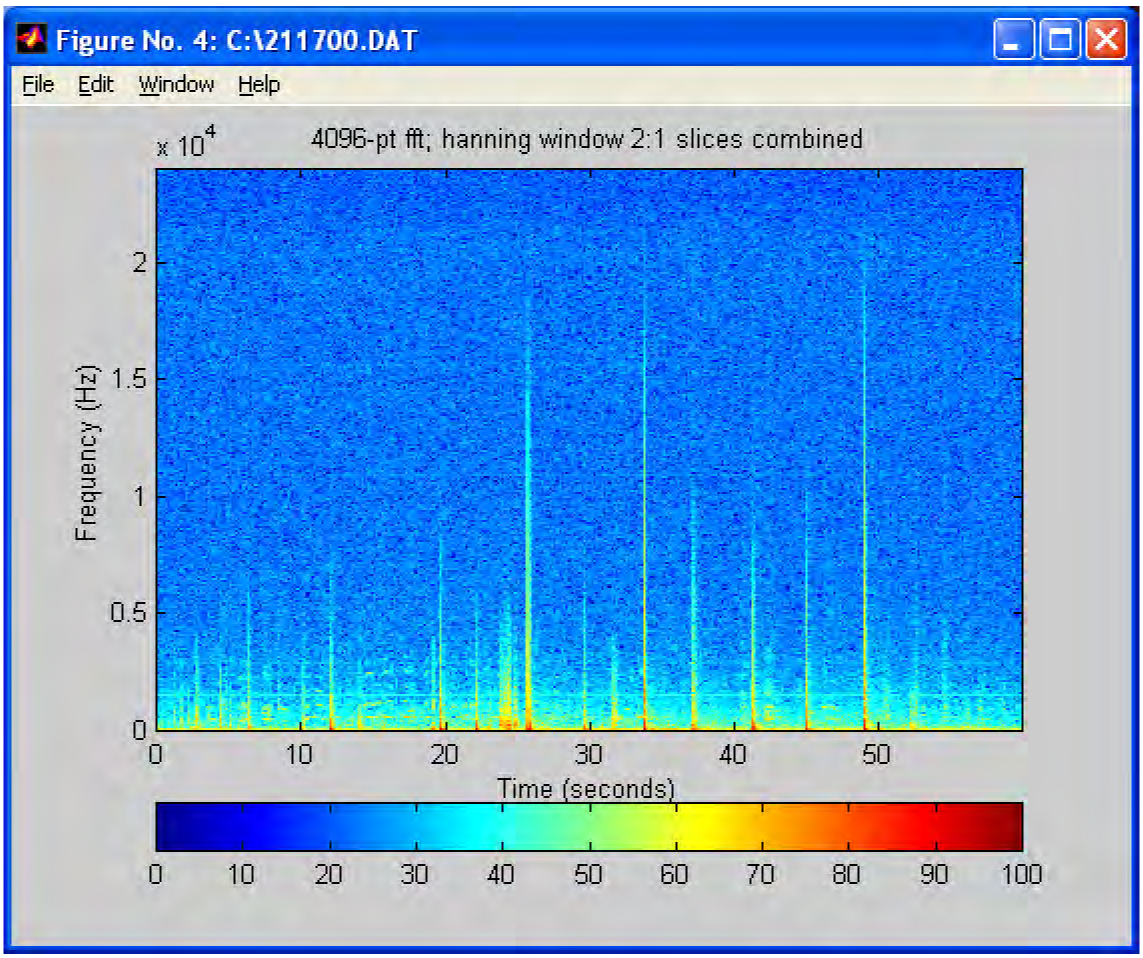


Spectrogram 21:16:00 to 21:17:00

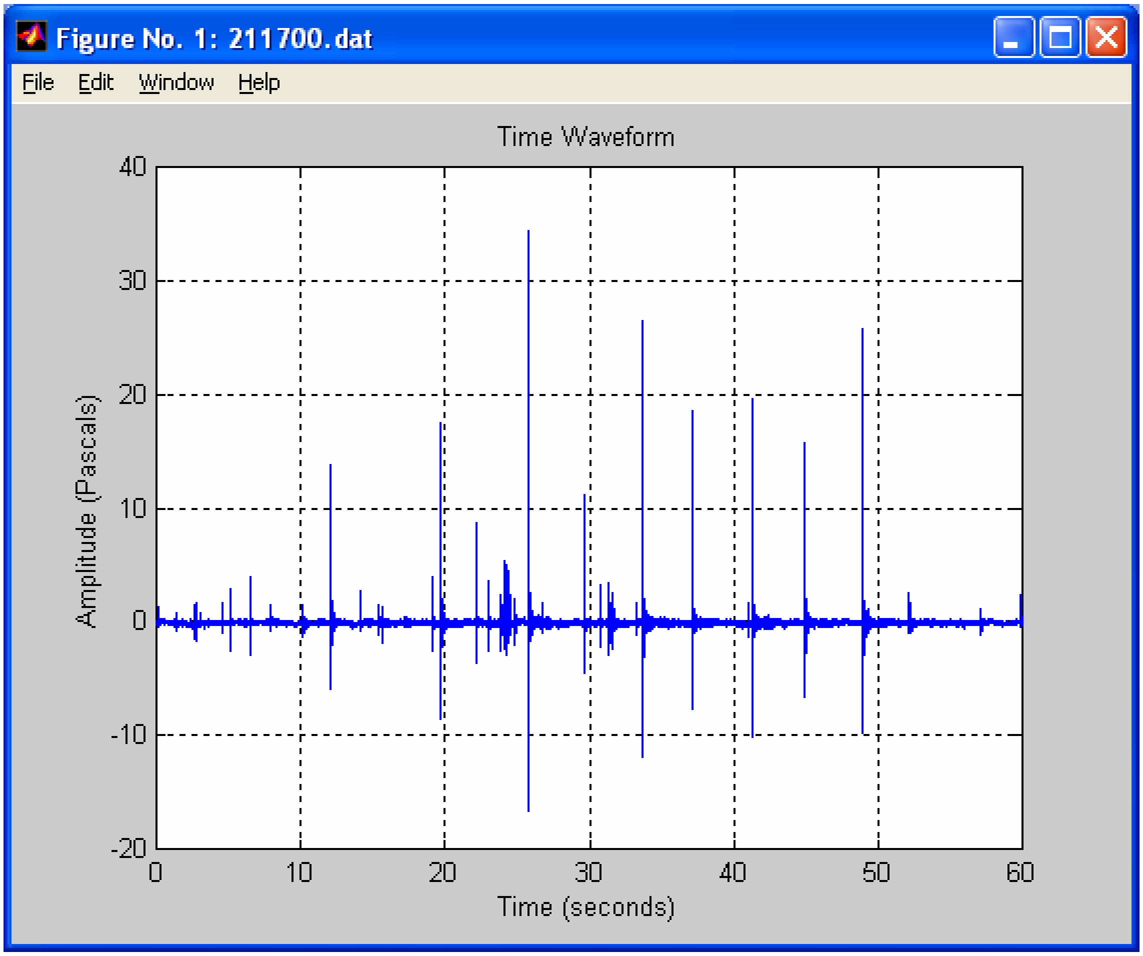


Time waveform 21:16:00 to 21:17:00

Notes: 21:17:00 to 21:18:00
21:17:12 louder single explosion
21:17:20 louder explosion
21:17:23-24 multiple explosions
21:17:26 louder single explosion
21:17:31 -32 multiple explosions
21:17:33 louder single explosion
21:17:37 louder single explosion
21:17:41 louder single explosion
21:17:45 louder single explosion
21:17:48 louder single explosion

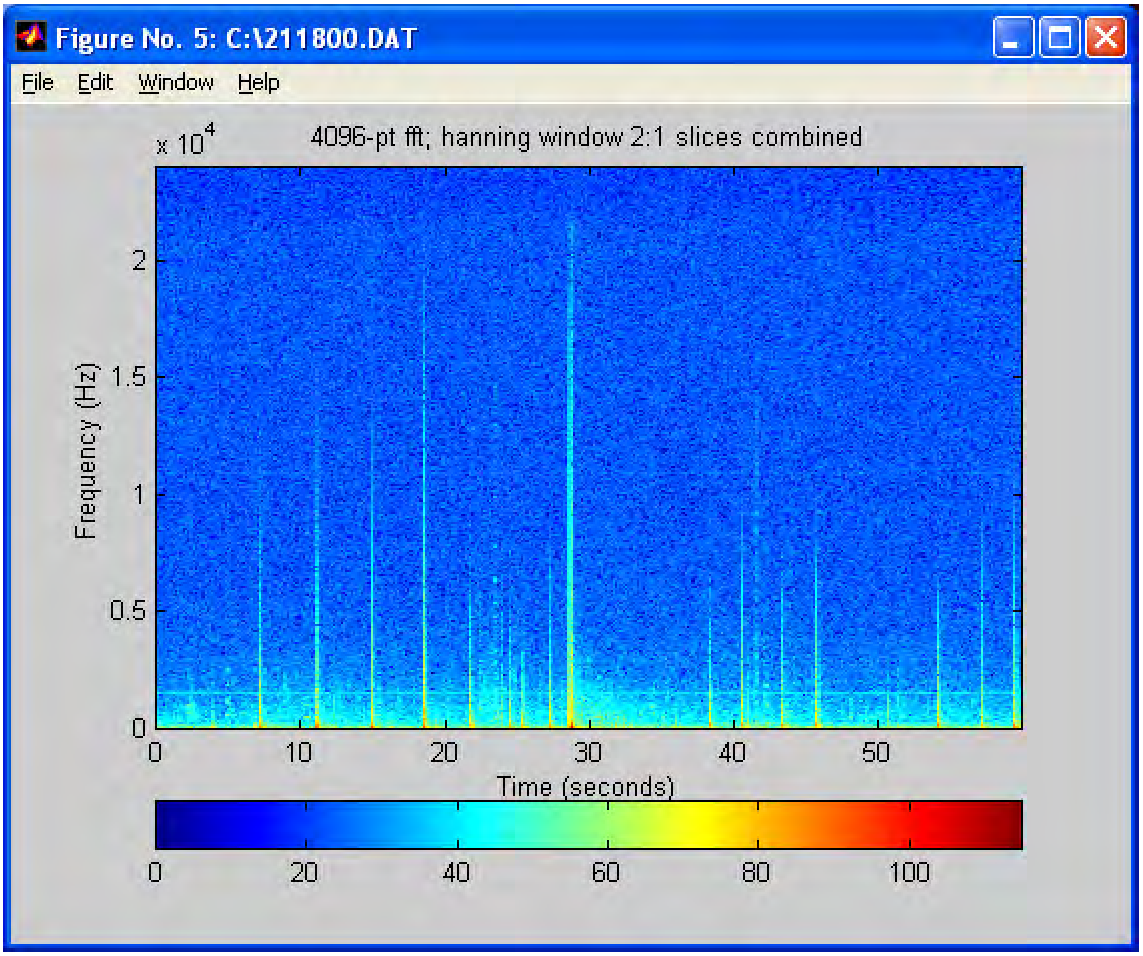


Spectrogram 21:17:00 to 21:18:00

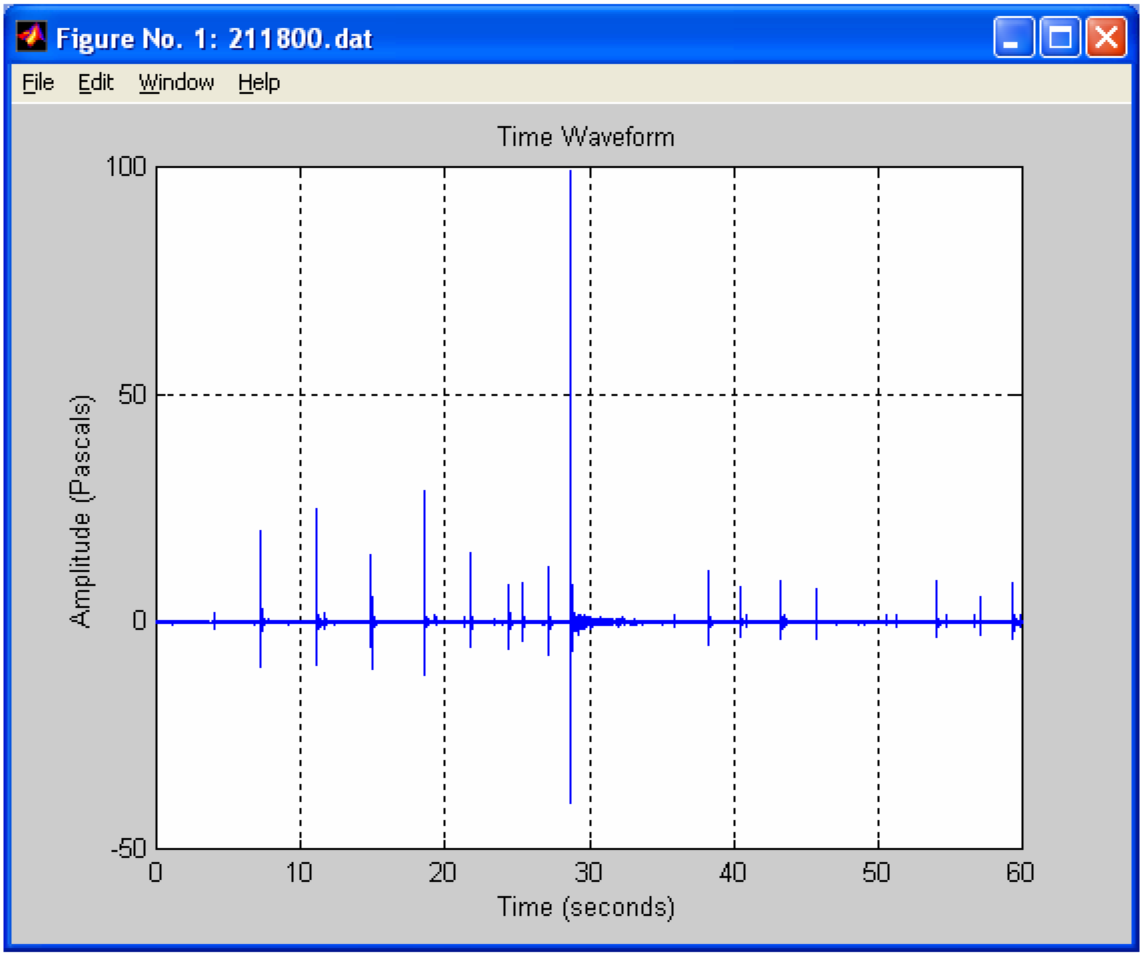


Time waveform 21:17:00 to 21:18:00

Notes: 21:18:00 to 21:19:00
21:18:06 single explosion
21:18:11 single explosion
21:18:14 single explosion
21:18:18 single explosion
21:18:21 single explosion
21:18:28 louder single explosion
21:18:30-59 smaller explosions

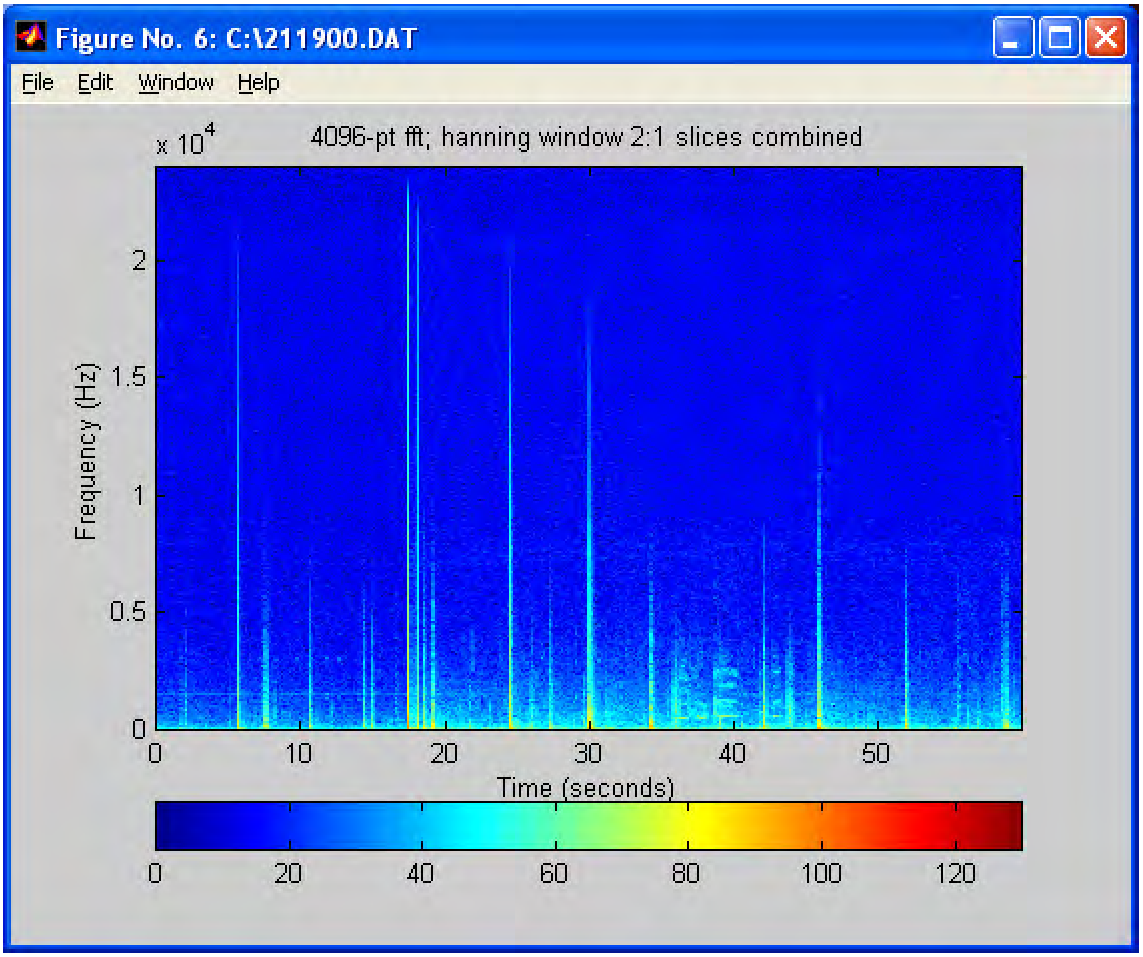


Spectrogram 21:18:00 to 21:19:00

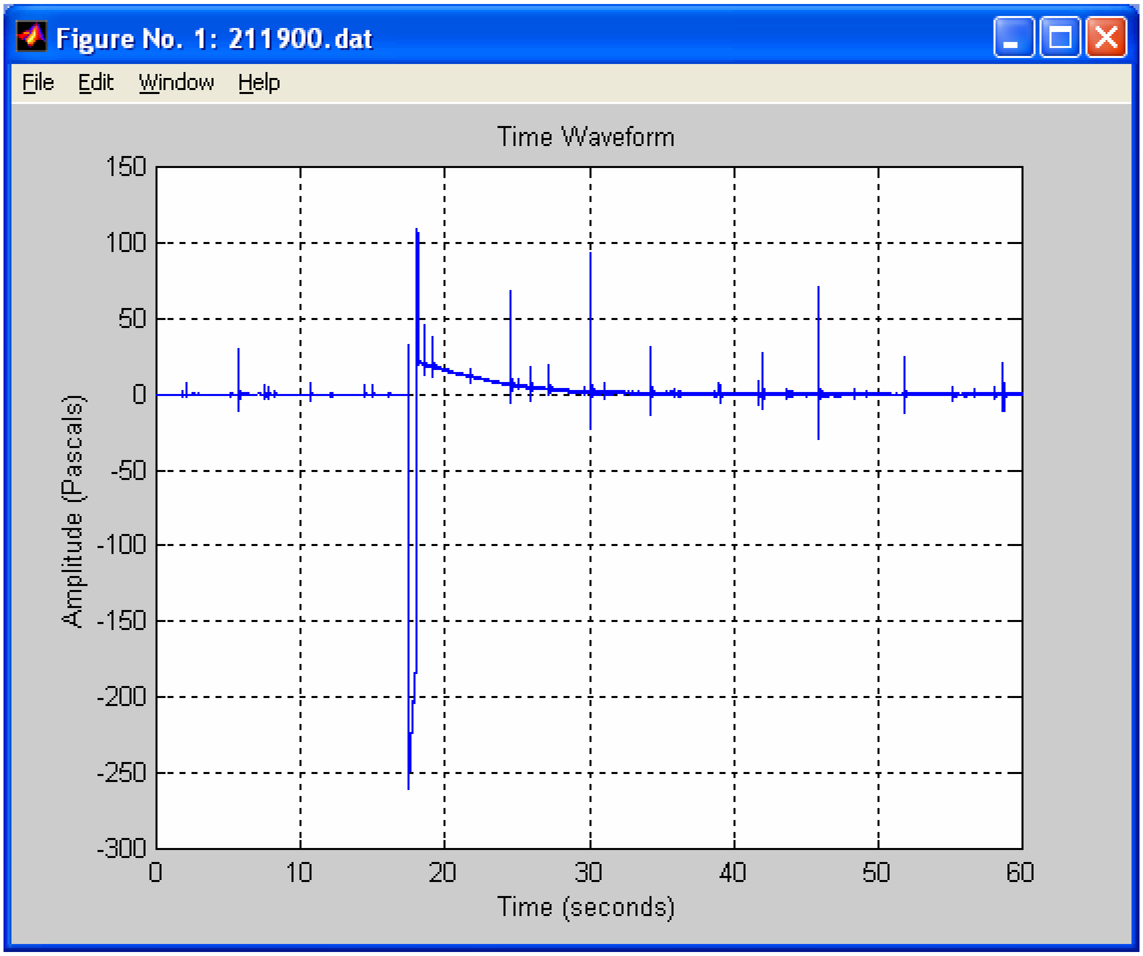


Time waveform 21:18:00 to 21:19:00

Notes: 21:19:00 to 21:20:00
21:19:06 explosion
21:19: 17-28 charge amplifier gain change +10 dB causes bad data through 28.
21:19:25 explosion
21:19:30 explosion
21:19:35 explosion with crackles
21:19:36 to 45 clearly audible and visible sea lion vocalizations.
21:19:45 explosion

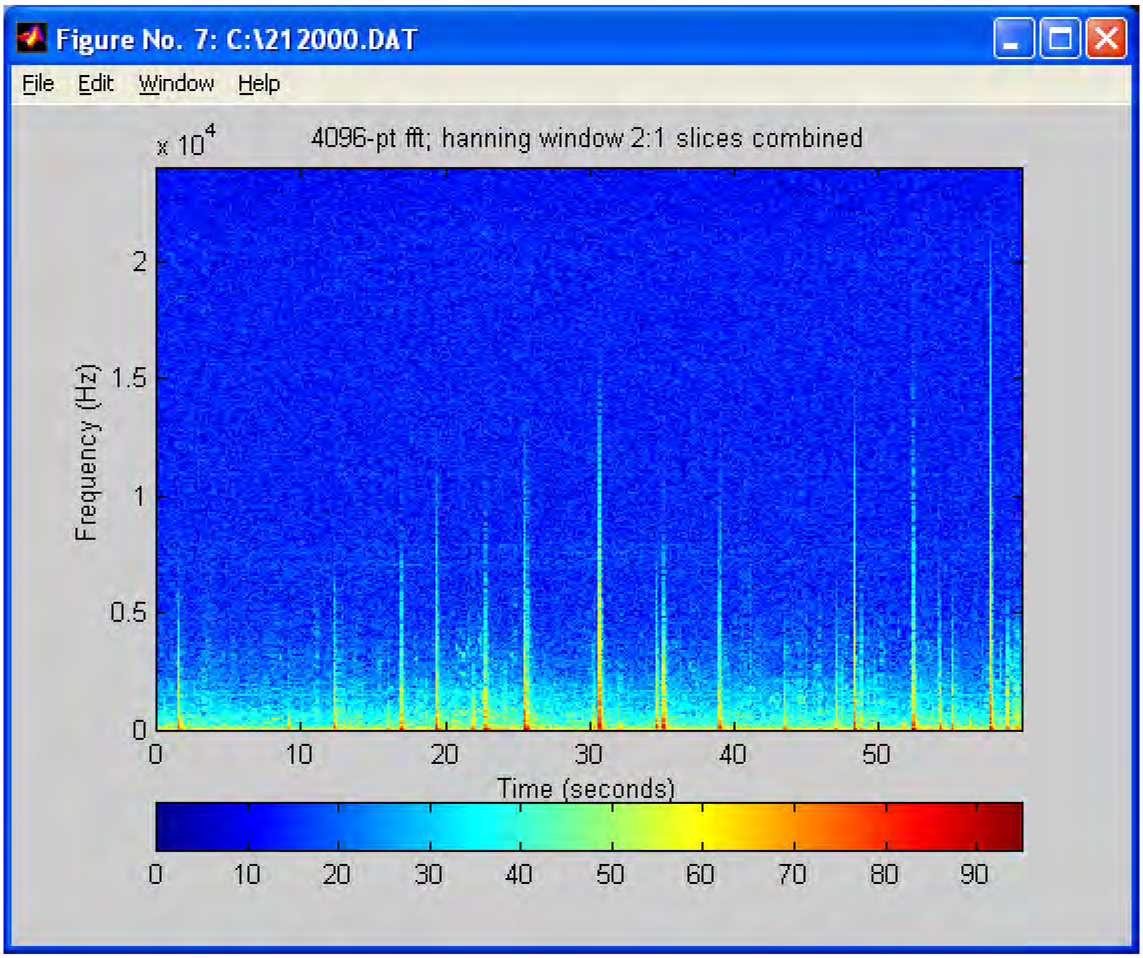


Spectrogram 21:19:00 to 21:20:00

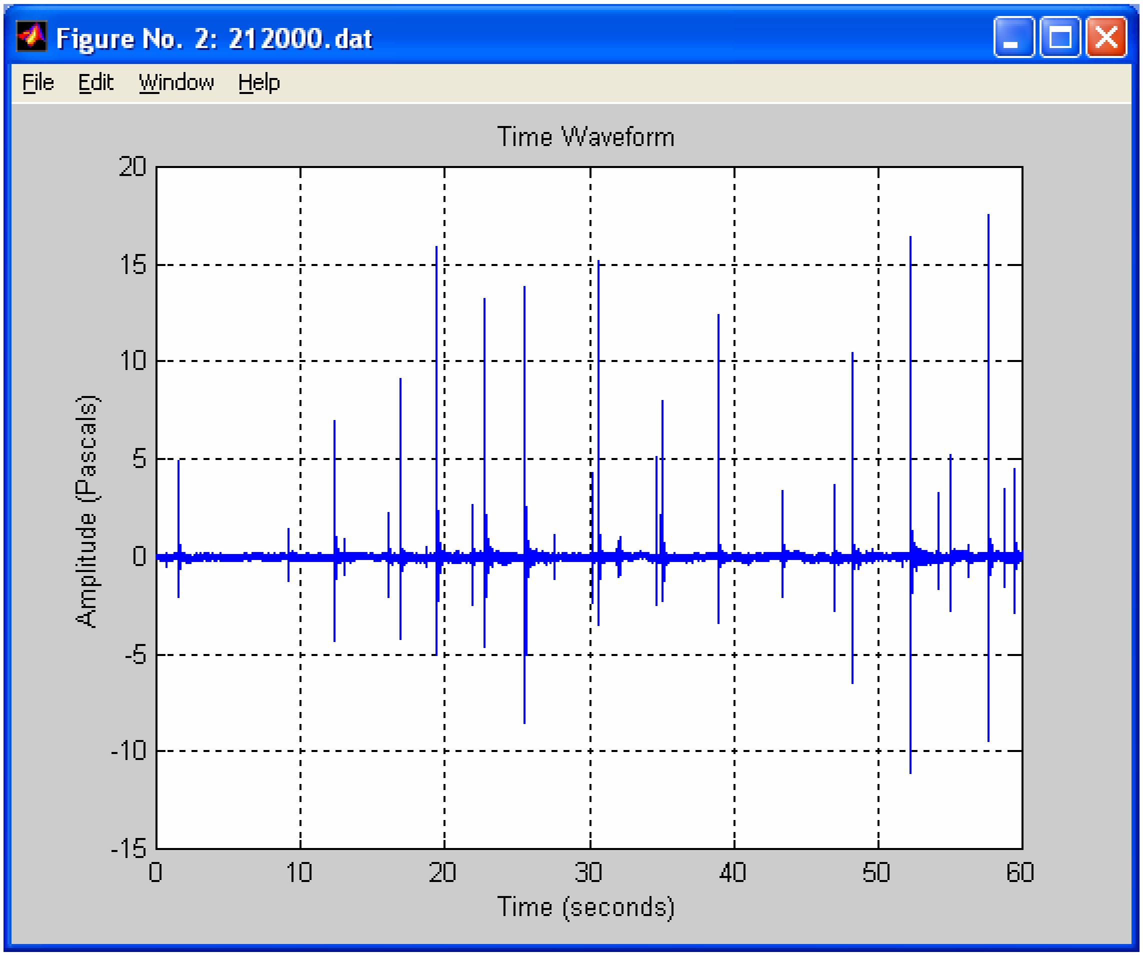


Time waveform 21:19:00 to 21:20:00

Notes: 21:20:00 to 21:21:00
21:20:12 single loud explosion
21:20:17 single loud explosion
21:20:19 single louder explosion, kids screaming through 21:20:24
21:20:22 single louder explosion
21:20:25 single louder explosion
21:20:30 single shaper explosions
21:20:31 doubles explosions
21:20:38 single louder explosion
21:20:48 single louder explosion
21:20:52 single louder explosion

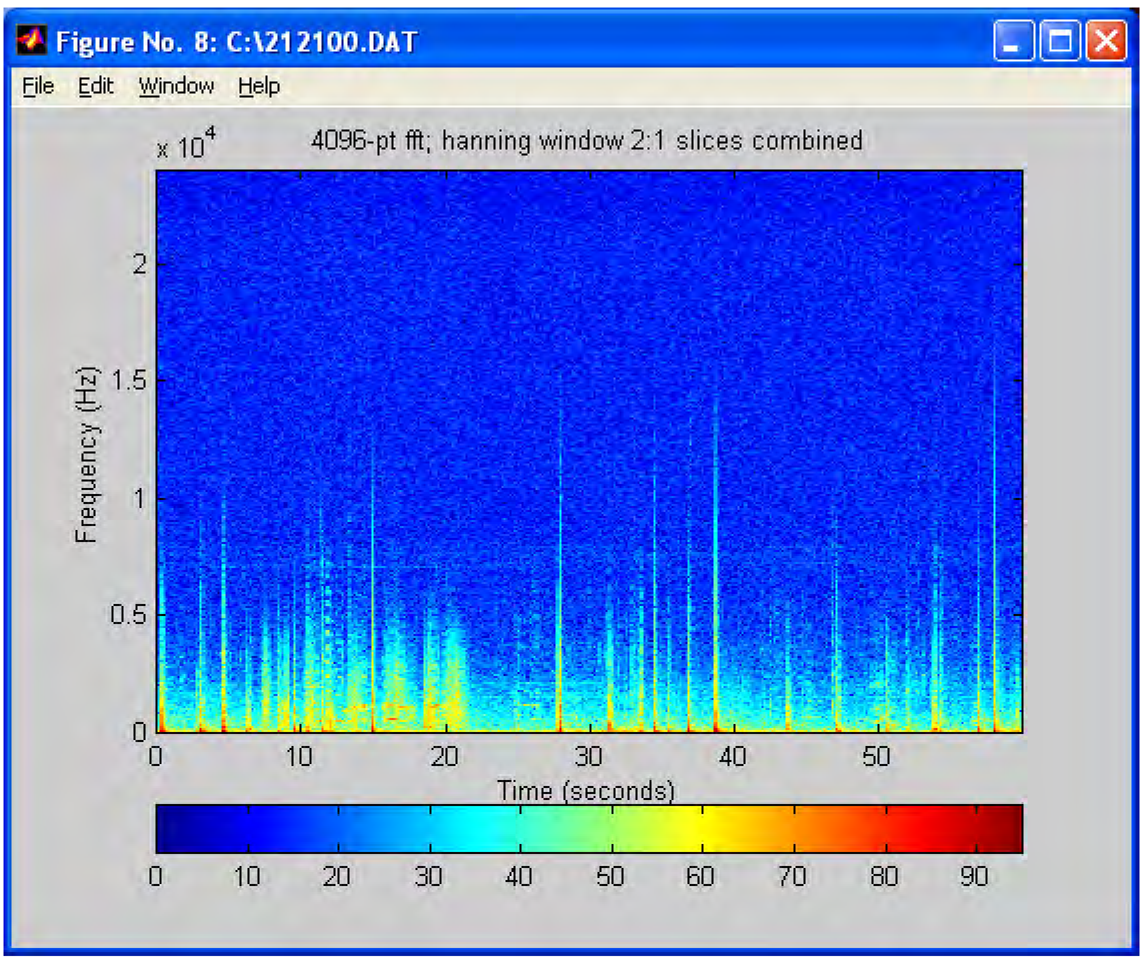


Spectrogram 21:20:00 to 21:21:00

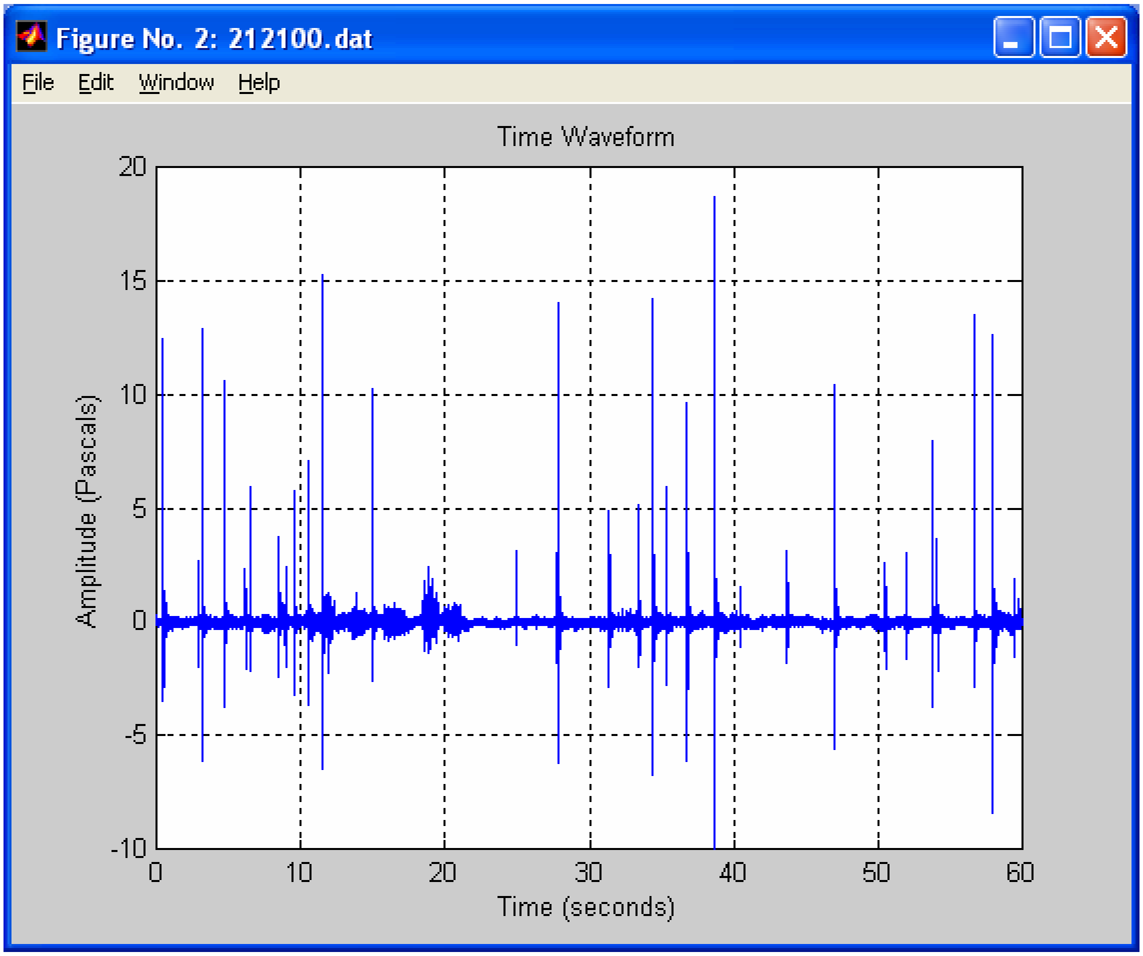


Time waveform 21:20:00 to 21:21:00

Notes: 21:21:00 to 21:22:00.
21:21:01 single explosion
21:21:02 single explosion
21:21:03 single explosion
21:21:04 single explosion
21:21:07 with cracklers
21:21:08 pops
21:21:10 pops and crackles, sea lion vocalization through 21:21:20
21:21:11 kid screaming through 21:21:13
21:21:11 large single explosion
21:21:15 crackles
21:21:19 crackles
21:21:20 popping
21:21:28 large single explosion
21:21:39 larger single explosion
21:21:49 sea lion vocalizations

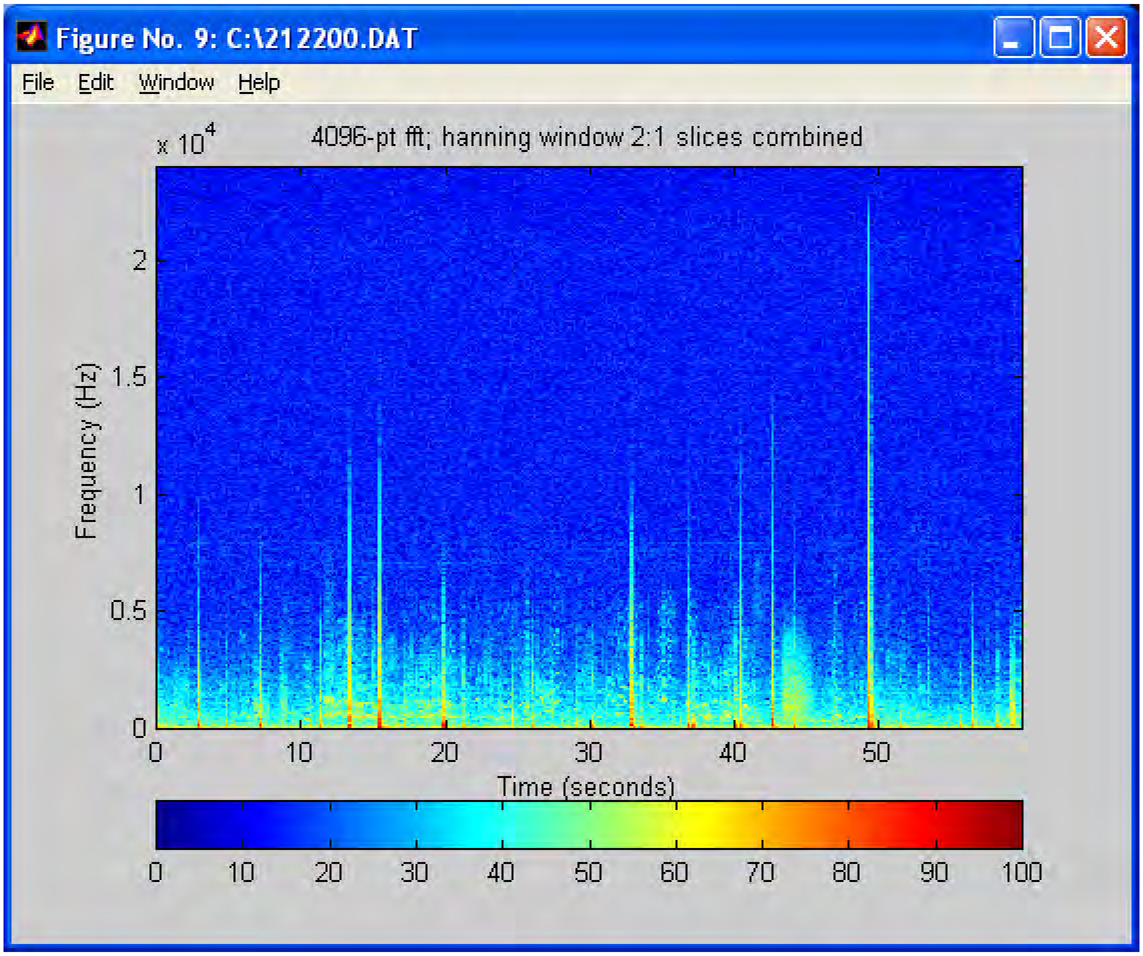


Spectrogram 21:21:00 to 21:22:00

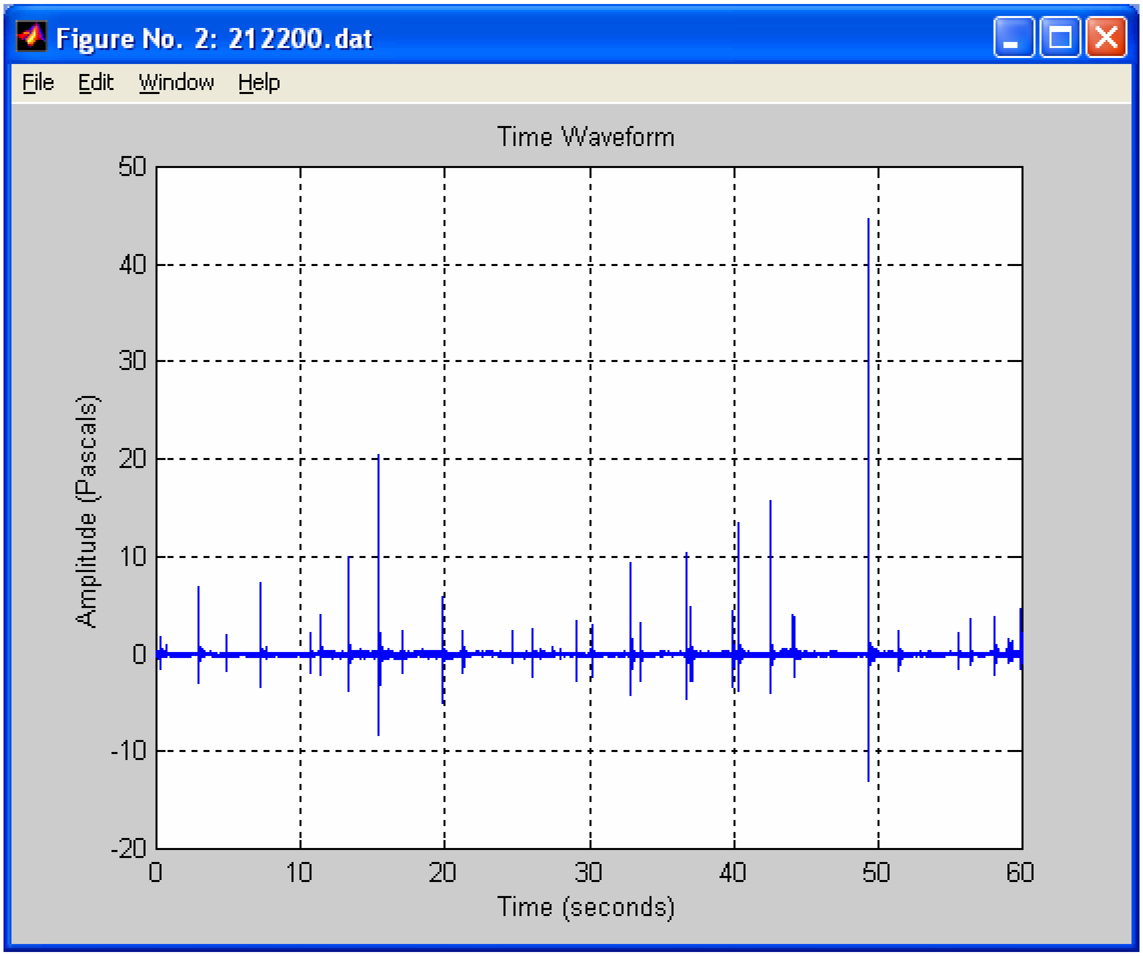


Time waveform 21:21:00 to 21:22:00

Notes: 21:22:00 to 21:23:00
21:22:10 to 24 sea lion vocalizations
21:22:13 single explosions
21:22:15 single explosions
21:22:20 single explosions
21:22:33 single explosions
21:22:42 single explosions with crackles through 21:22:45
21:22:49 very large explosion
21:22:59 crackles

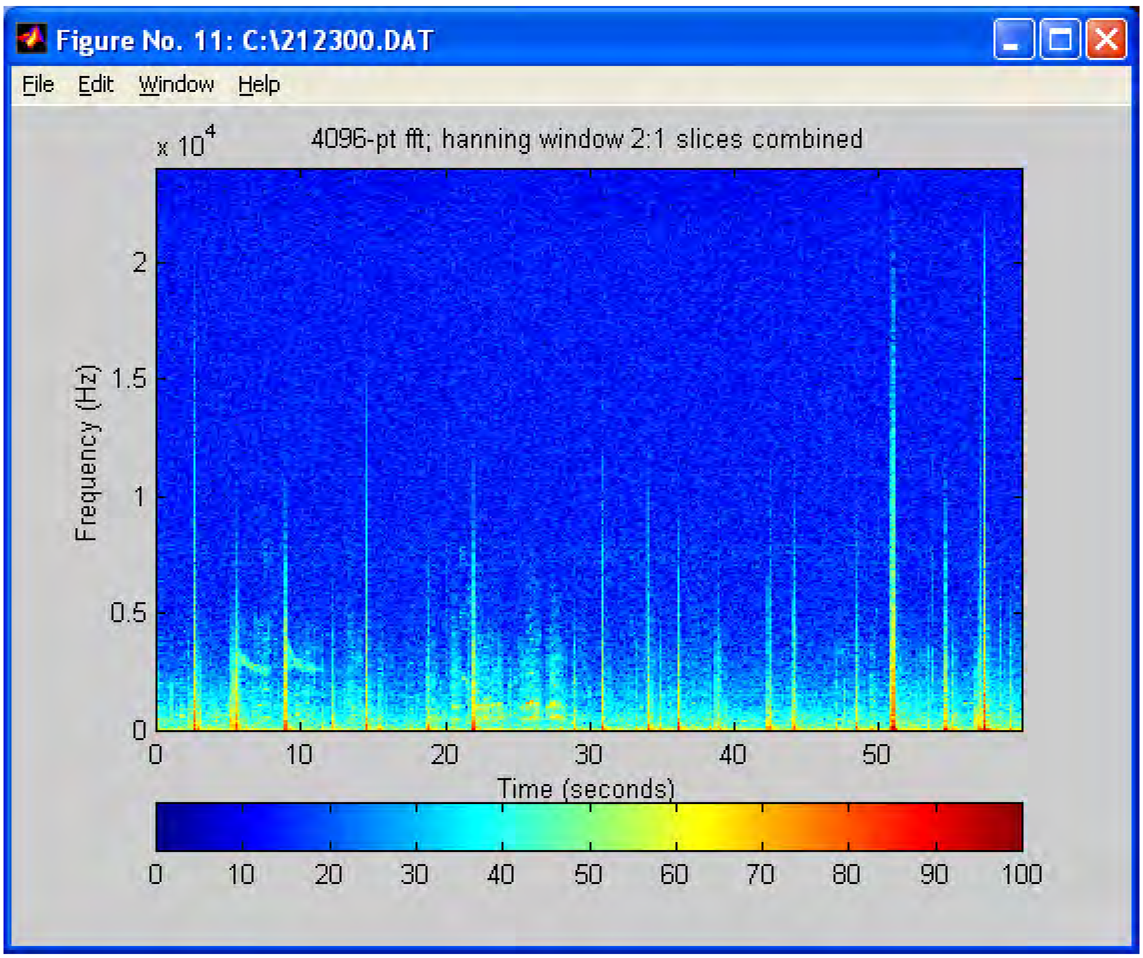


Spectrogram 21:22:00 to 21:23:00

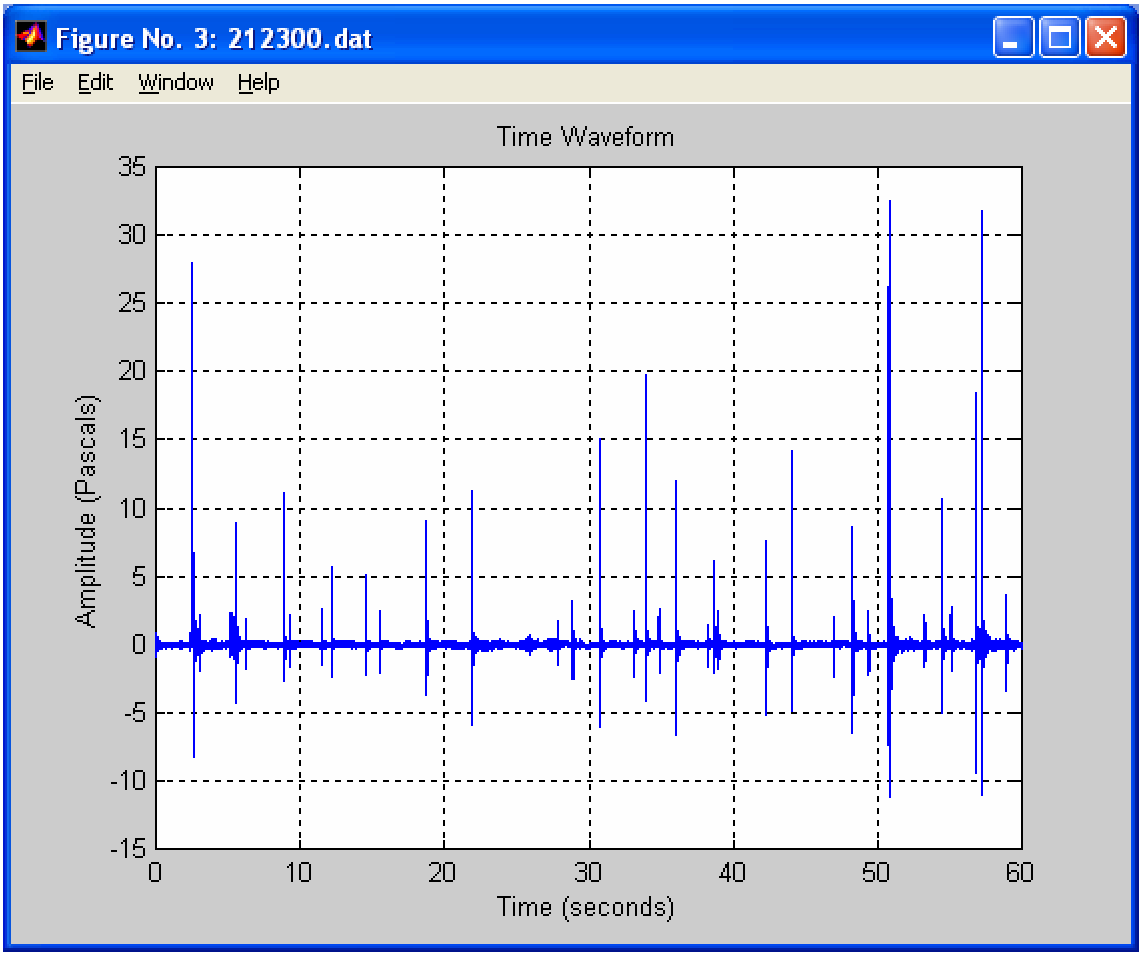


Time waveform 21:22:00 to 21:23:00

Notes: 21:23:00 to 21:24:00.
21:23:00 sea lions audible / human conversation.
21:23:02 loud single explosion
21:23:05 single explosion with whistle
21:23:08 single explosion with whistle
21:23:20 – 29 louder sea lion vocalizations audible and visible.
21:23:22 single explosion
21:23:42 single explosion
21:23:44 single explosion
21:23:48 single explosion
21:23:51 louder double explosion
21:23:56-57 louder double explosion

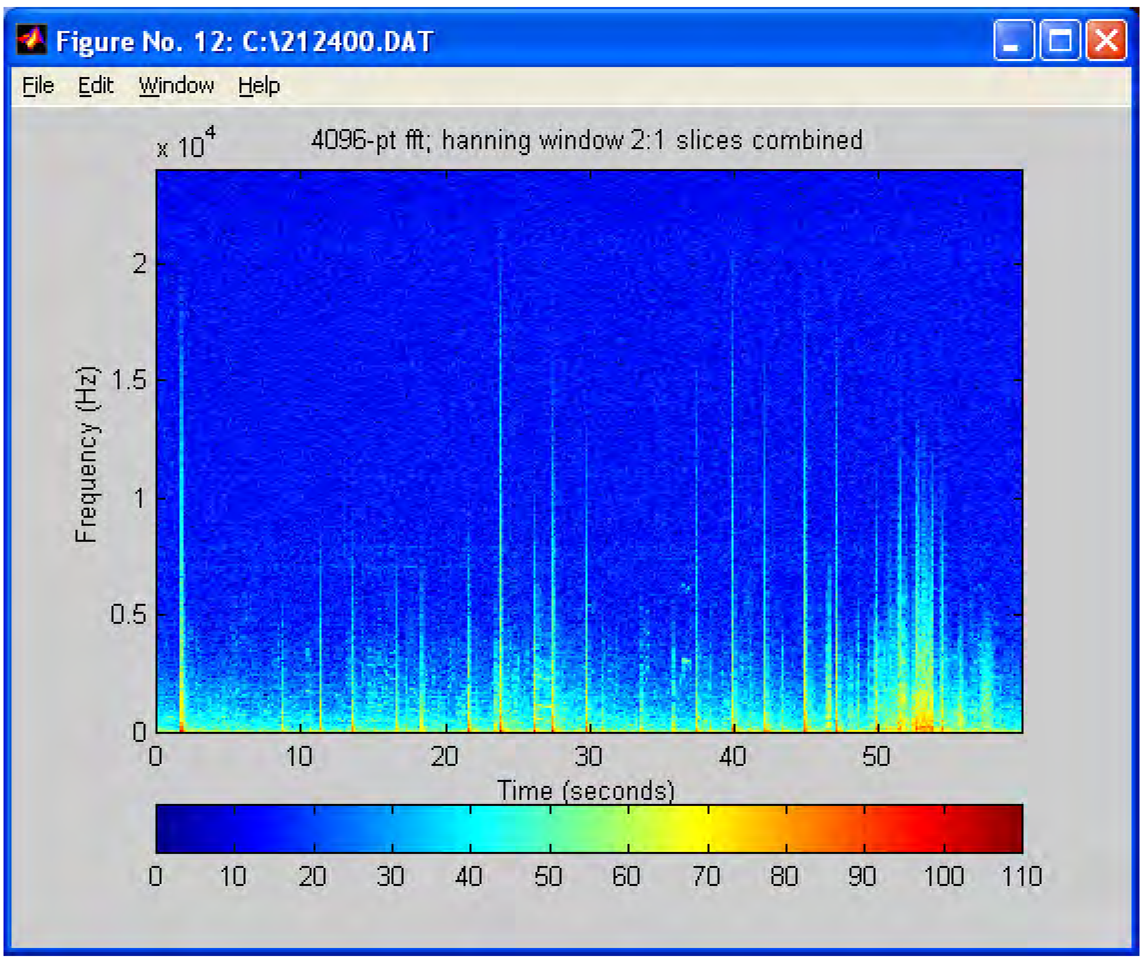


Spectrogram 21:23:00 to 21:24:00

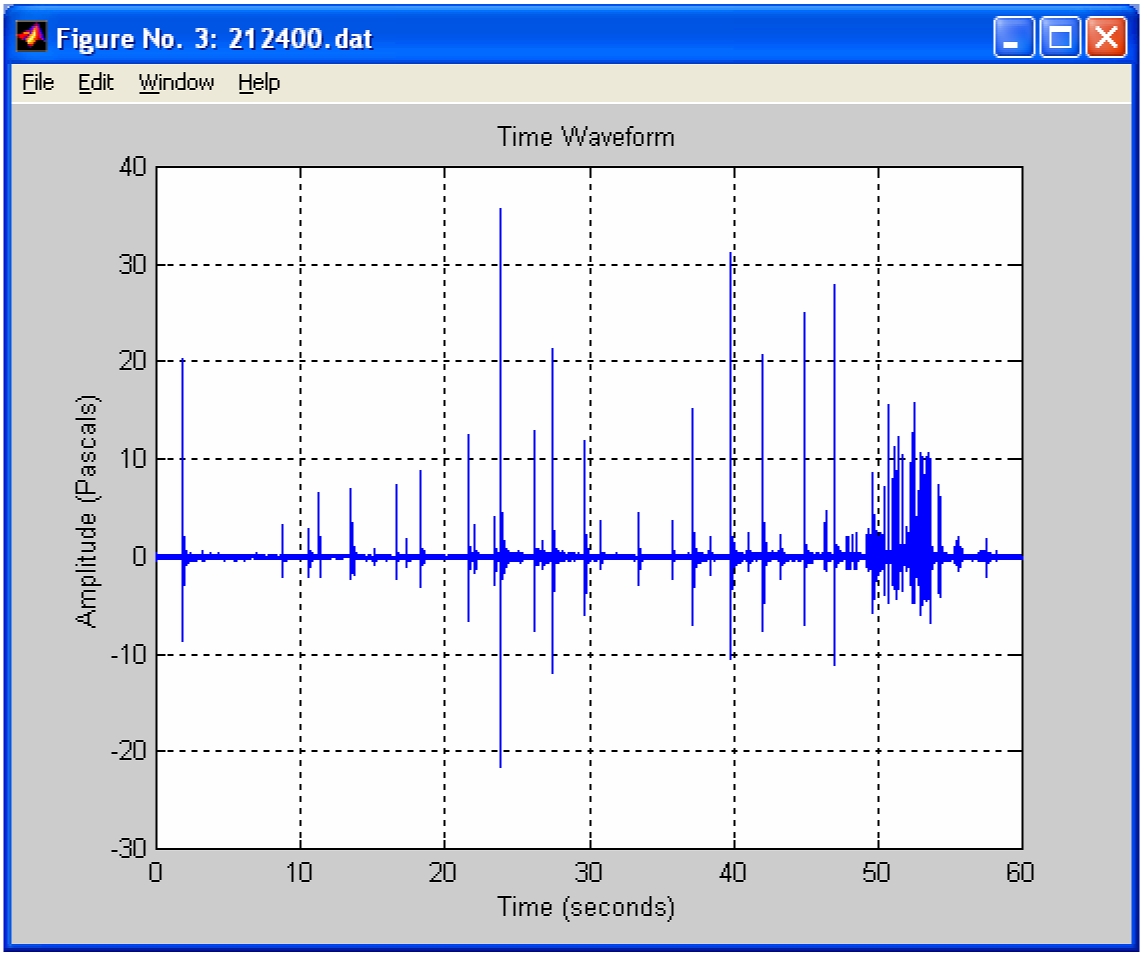


Time waveform 21:23:00 to 21:24:00

Notes: 21:24:00 to 21:25:00
21:24:02 single explosion
21:24:24 single louder explosion
21:24:26 seal lion vocalizations audible
21:24:27 single explosion
21:24:38 launch of fireworks
21:24:39 single explosion
21:24:42 single explosion
21:24:45 single explosion
21:24:46 single explosion
21:24:47-51 multiple launches
21:24: 49-55 multiple explosions with crackle follow

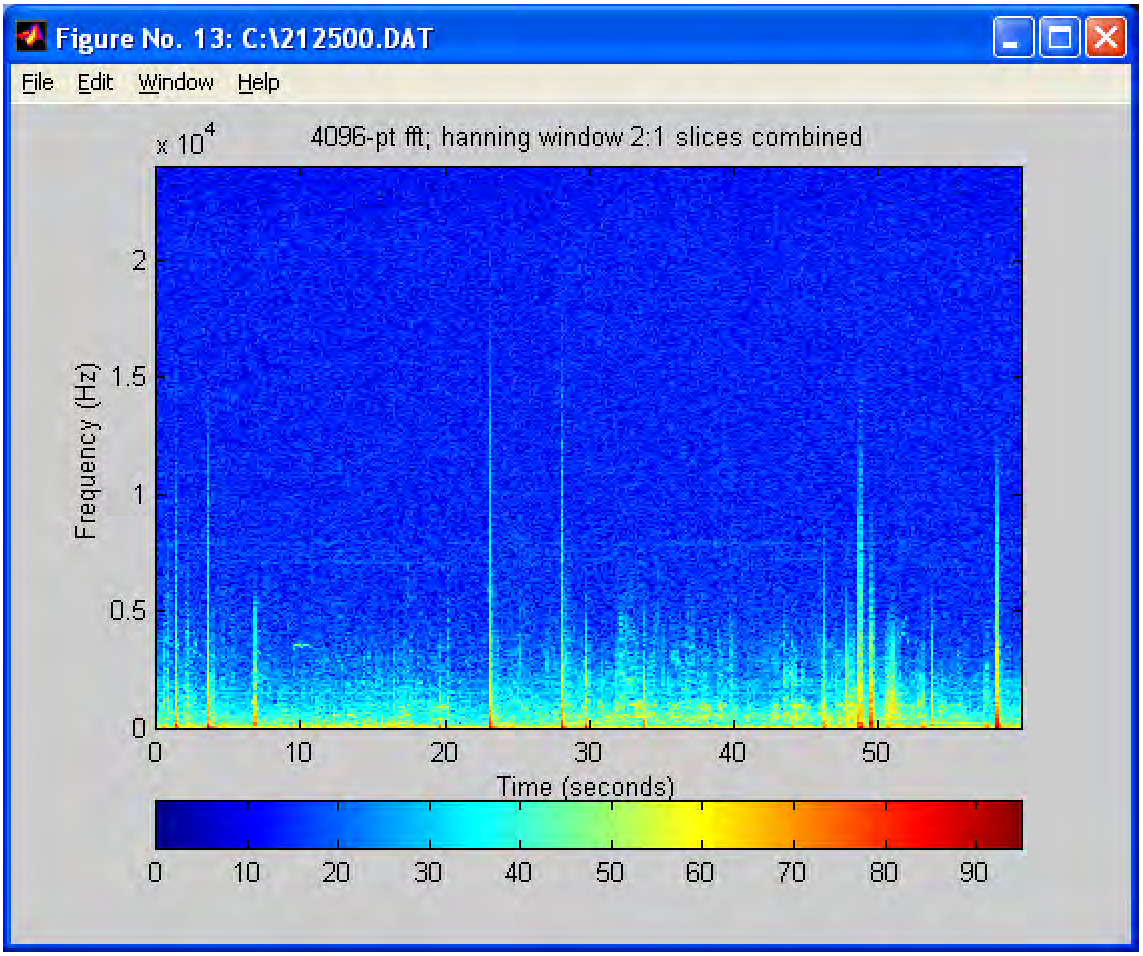


Spectrogram 21:24:00 to 21:25:00

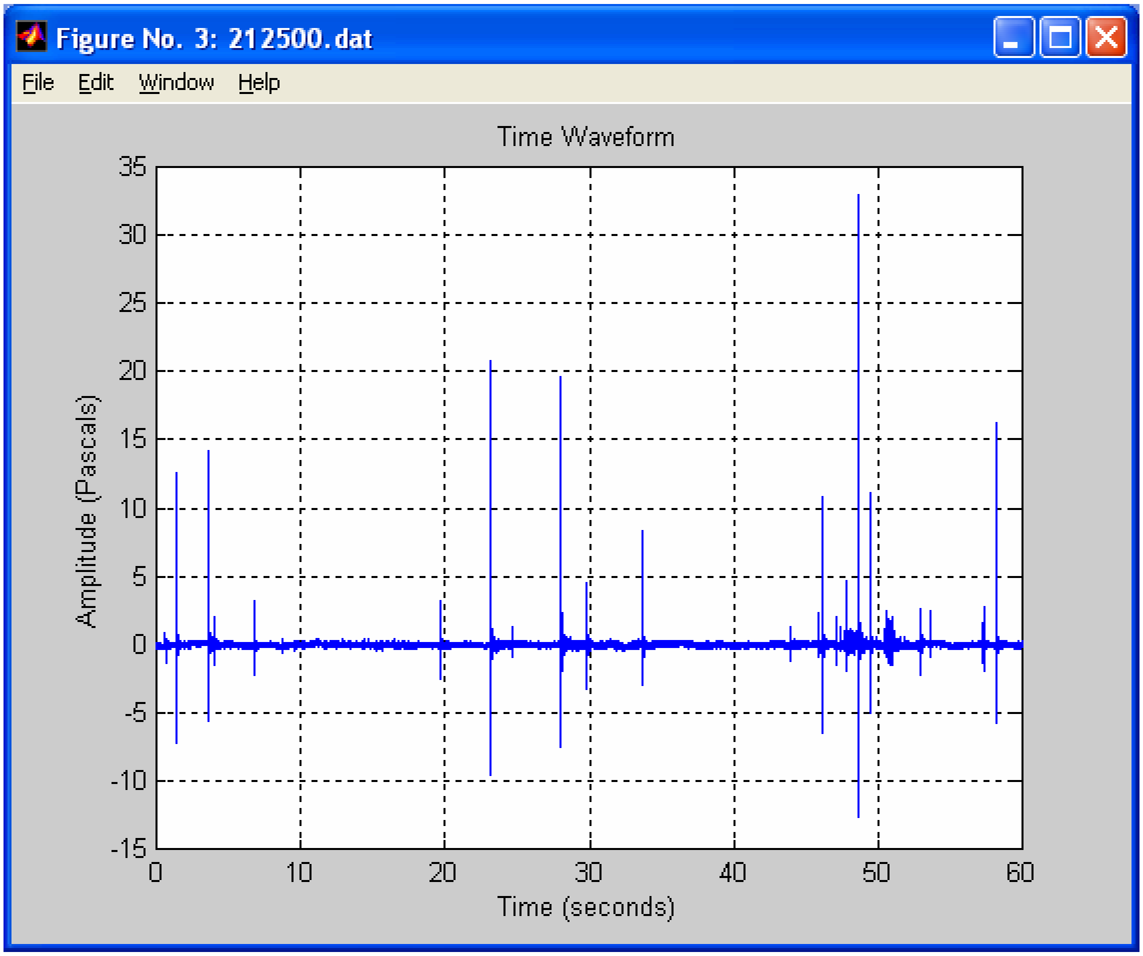


Time waveform 21:24:00 to 21:25:00

Notes: 21:25:00 to 21:26:00
21:25:10 human whistling at ~ 4kHz
21:25:23 single explosion
21:25:28 single explosion
21:25:29 sea lion vocalizations through 55
21:25:23 louder single detonation
21:25:48 crackling and single detonation
21:25:49 crackling and single detonation
21:25:58 single explosion

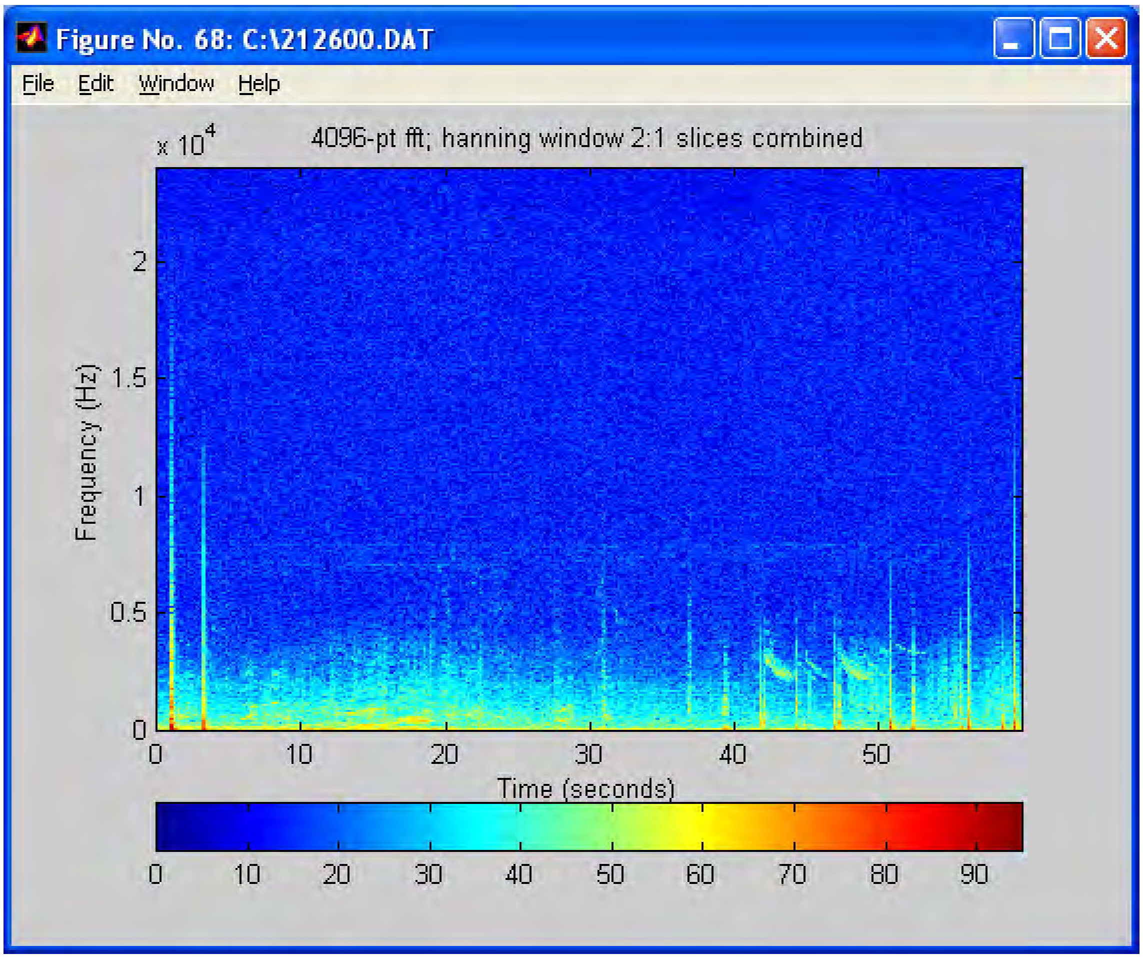


Spectrogram 21:25:00 to 21:26:00

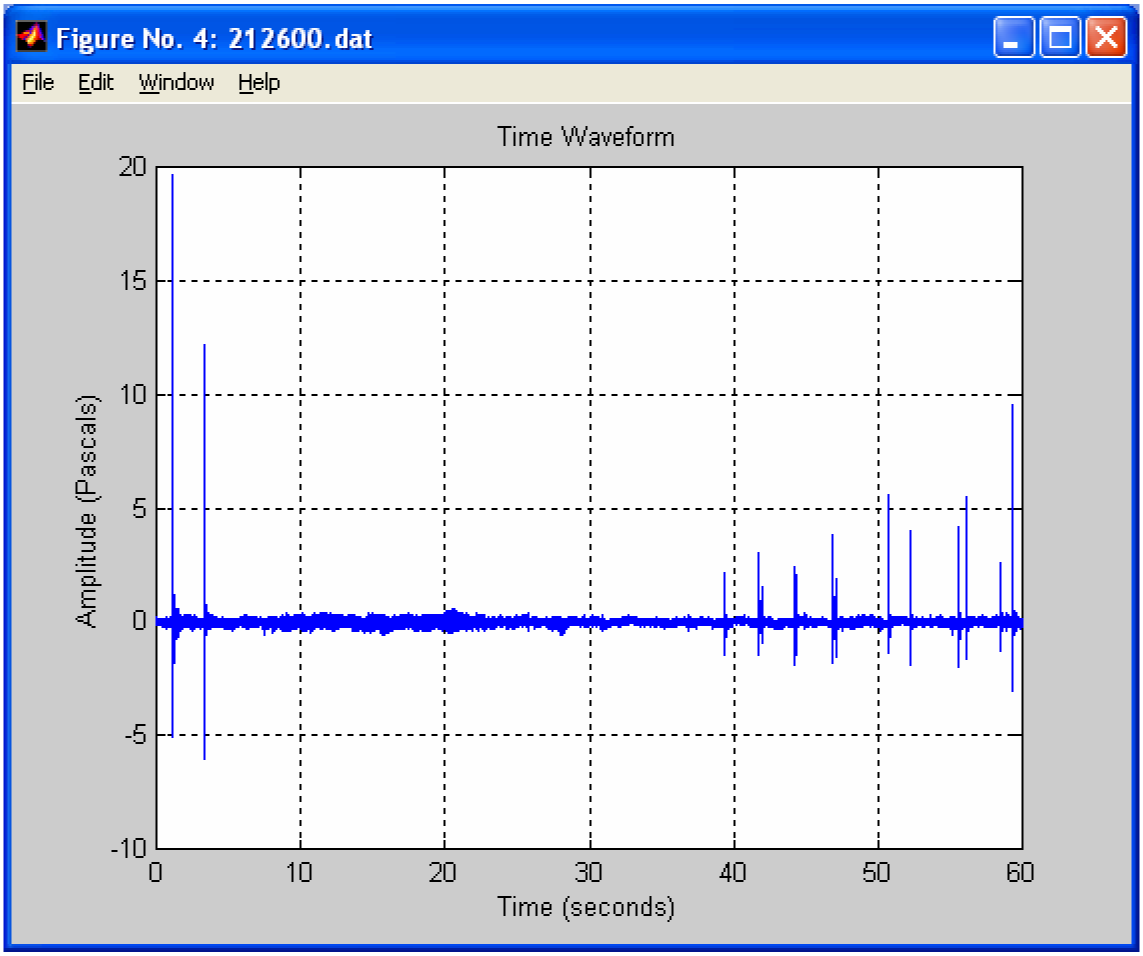


Time waveform 21:25:00 to 21:26:00

Notes 21:26:00 to 21:27:00.
21:26:02 louder single explosion
21:26:04 louder single explosion
21:26:02 fixed wing aircraft audible
21:26:19 closest point of approach of fixed wing aircraft overflight
21:26:28 sea lions audible
21:26:33 plane no longer audible
21:26:36 strange noise
21:26:39 double firing
21:26:41 whistle fireworks through 21:26:50
21:26:44 and 47 double firings followed by whistles

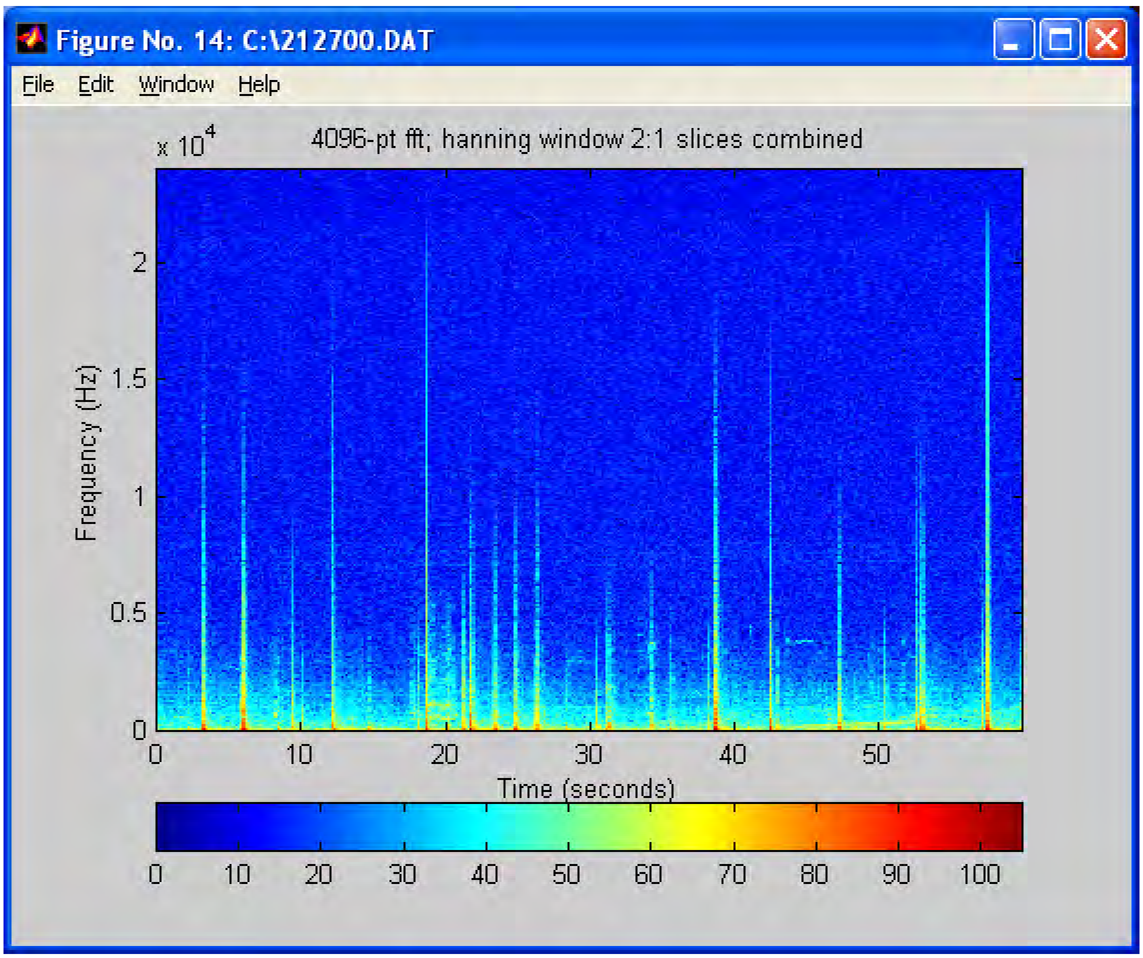


Spectrogram 21:26:00 to 21:27:00

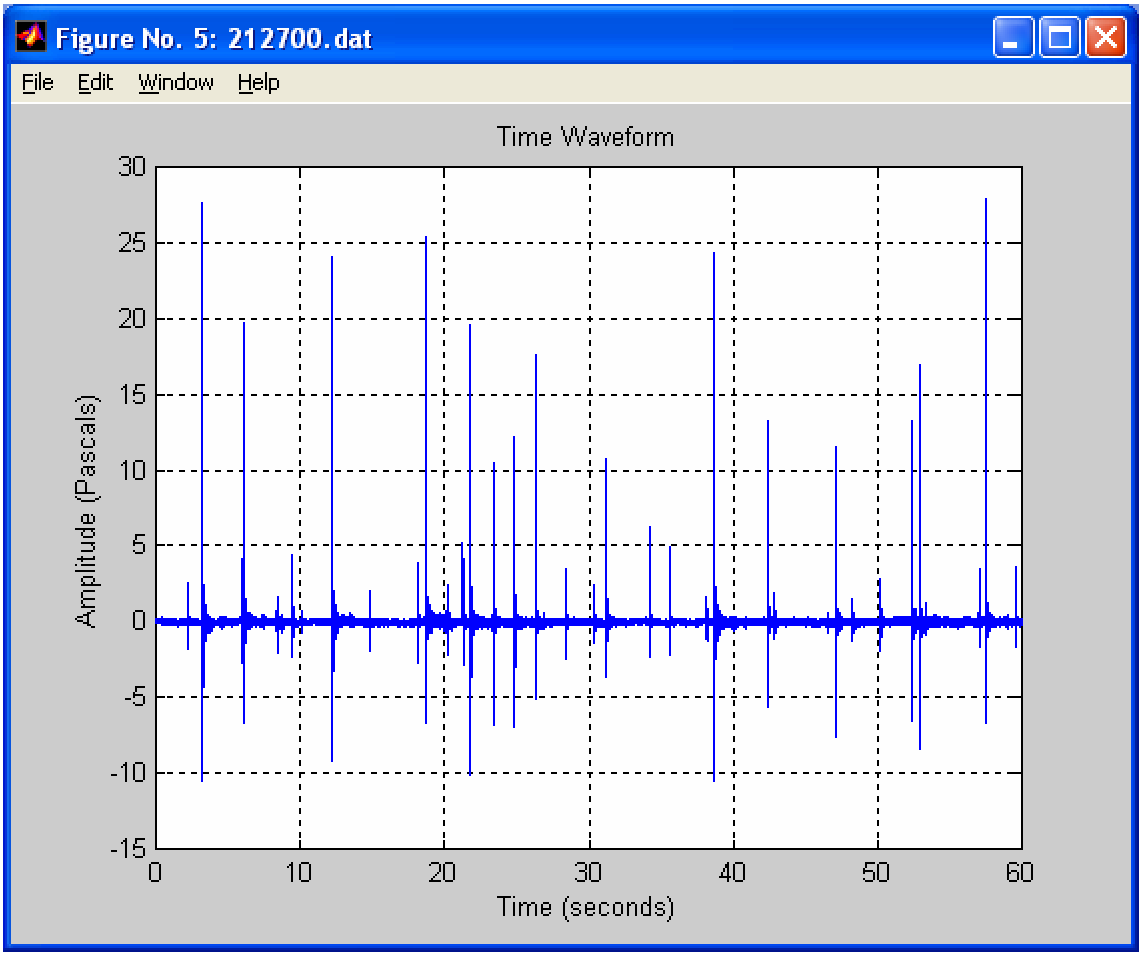


Time waveform 21:26:00 to 21:27:00

Notes: 21:27:00 to 21:28:00
21:27:03 single explosion
21:27:05 single explosion
21:27:06 single explosion
21:27:09 single explosion
21:27:12 single louder explosion
21:27:18 sea lion vocalizations for 2 seconds. Note harmonics in spectrogram
21:27:22 through 27 sequence of 4 fireworks explosions
21:27:28 airplane audible
21:27:52 airplane closest point of approach. Visible in spectrogram.
21:27:38 single louder explosion
21:27:47 single explosion
21:27:52-53 double explosion
21:27:57 single louder explosion

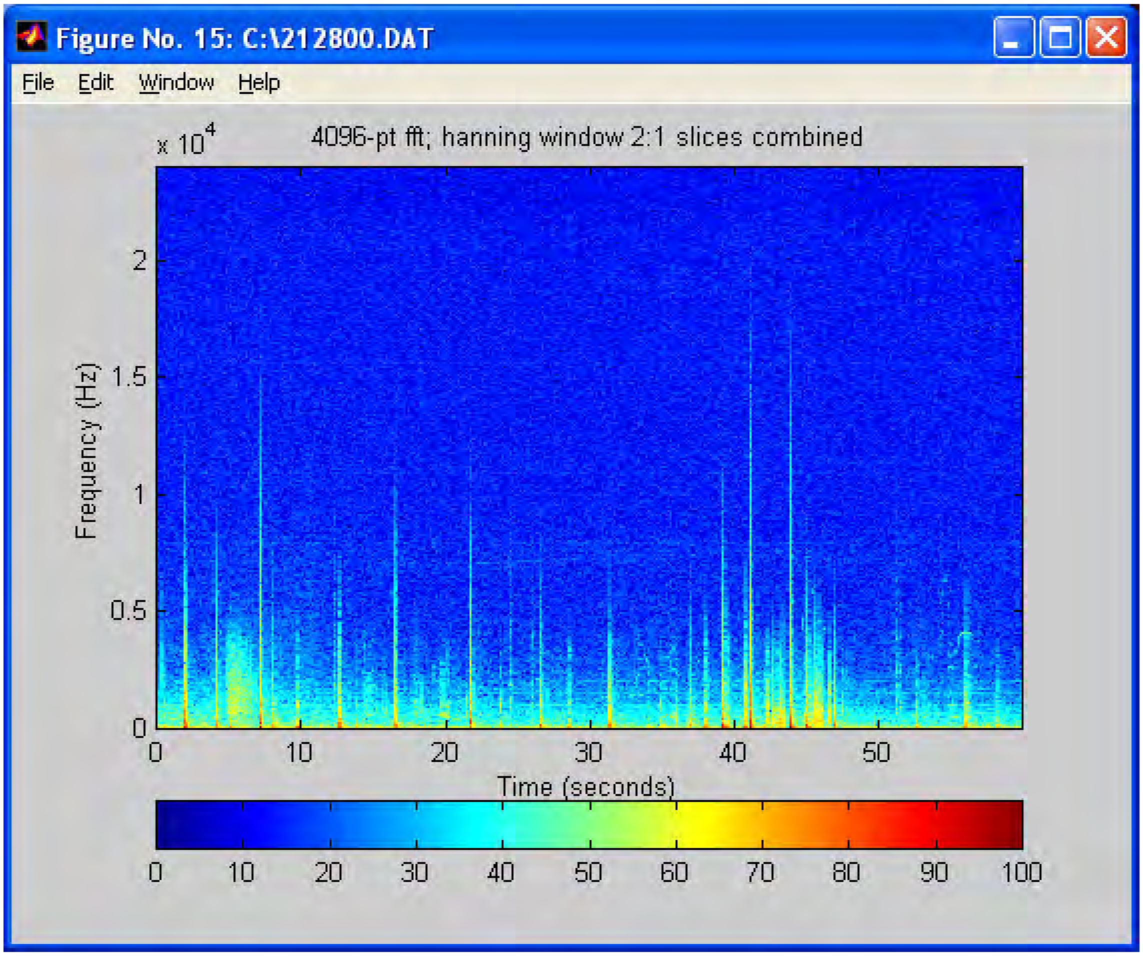


Spectrogram 21:27:00 to 21:28:00

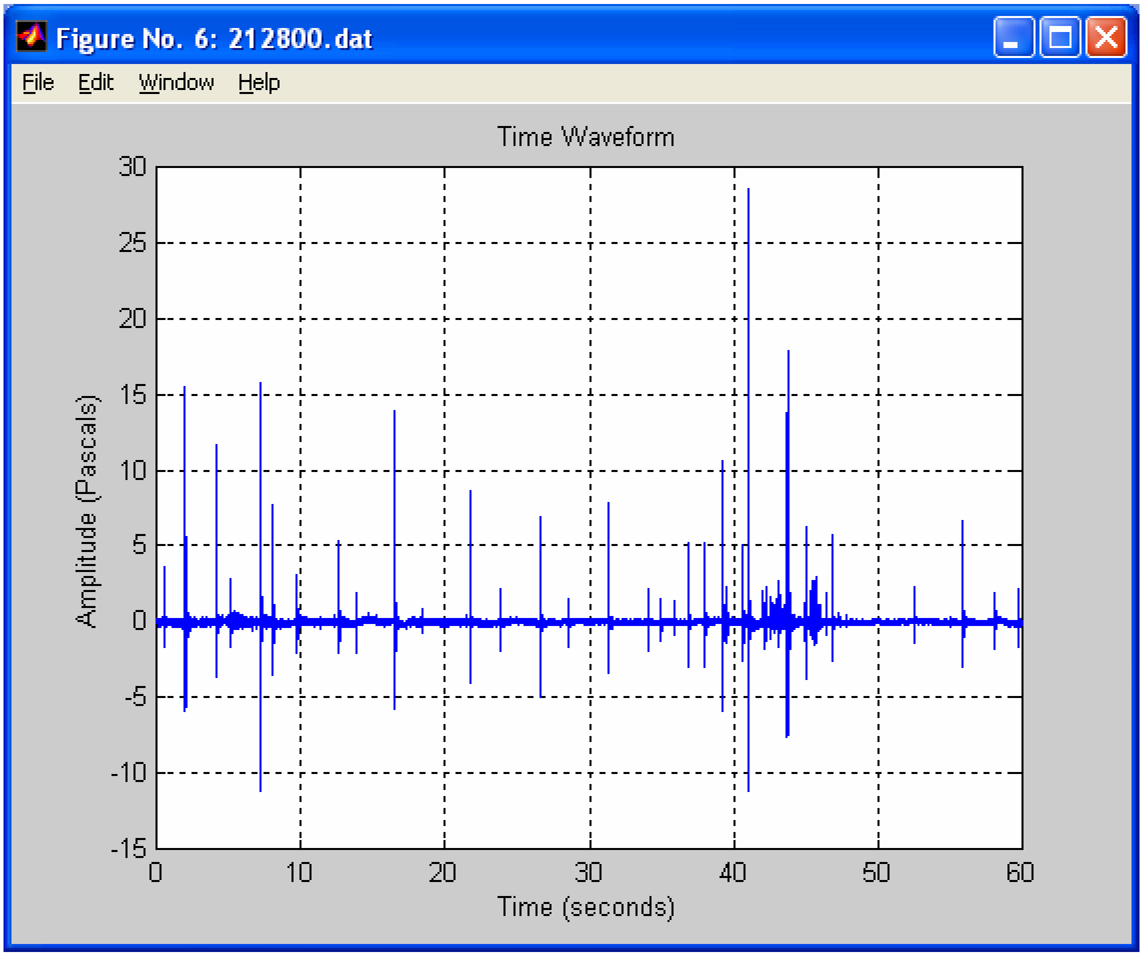


Time waveform 21:27:00 to 21:28:00

Notes: 21:28:00 to 21:29:00 .
21:28:02 - 03 single explosions
21:28:05 single explosion with crackles
21:28:16 single explosion
21:28:18 seal lions audible for ~2 seconds
21:28:31 single smaller explosion
21:28:38 multiple fireworks firings
21:28:39 – 48 multiple explosions with crackling
21:28:55 human ~4 kHz whistle

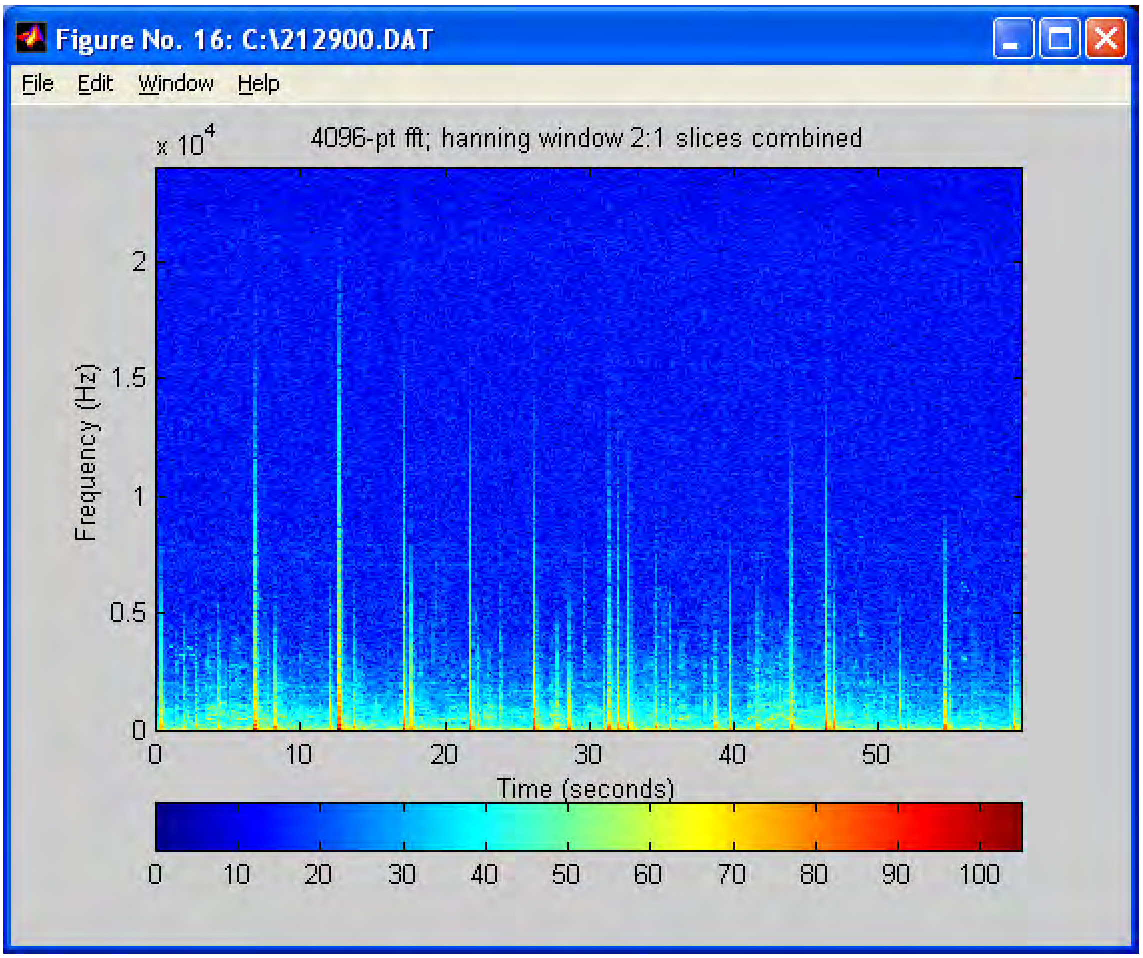


Spectrogram 21:28:00 to 21:29:00

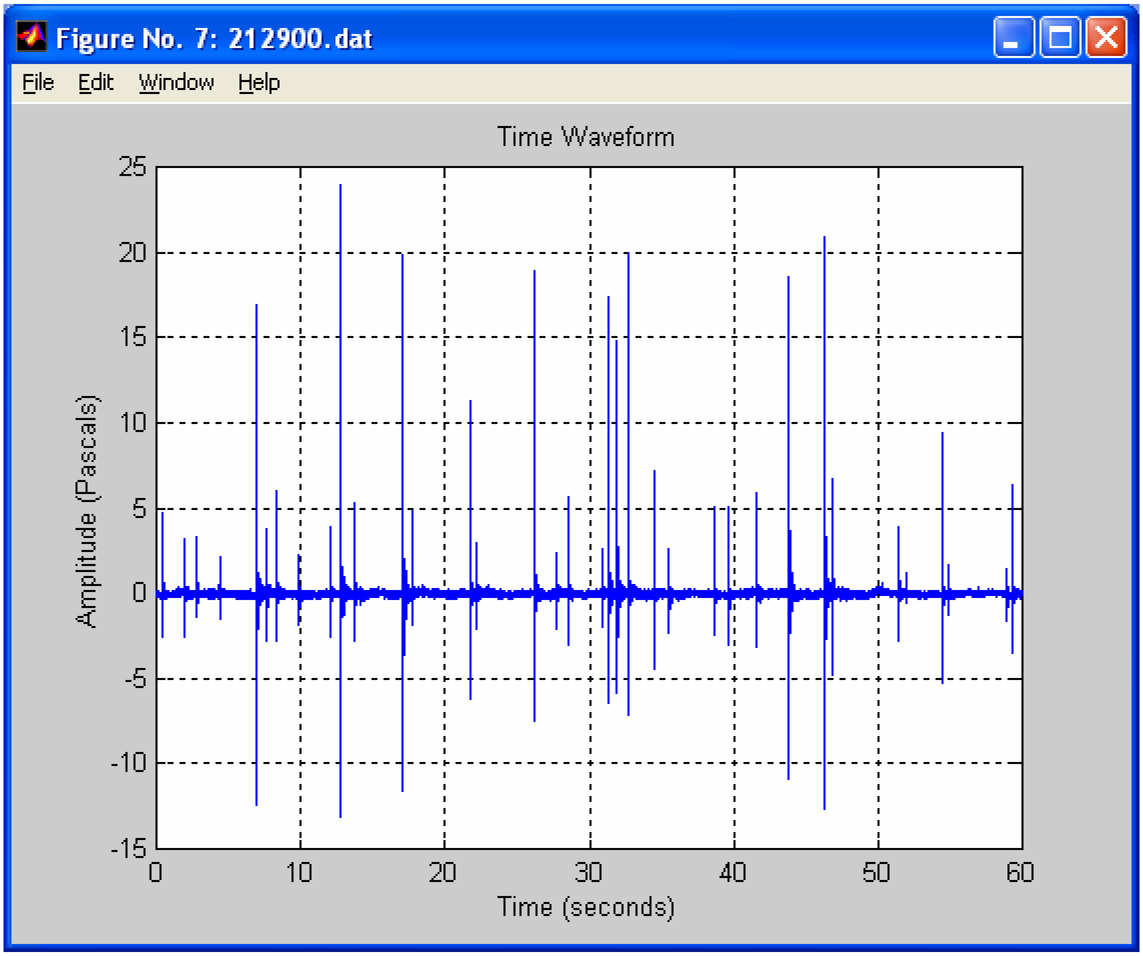


Time waveform 21:28:00 to 21:29:00

Notes: 21:29:00 to 21:30:00
21:29:00 sea lions audible throughout this minute
21:29:01-02 high 4 kHz whistle
21:29:07 louder single explosion
21:29:12 louder single explosion
21:29:17 single explosion
21:29:26-33 mulitple explosions/sequence
21:29:44 single explosion
21:29:45 mulitple explosions
21:29:55 single explosion

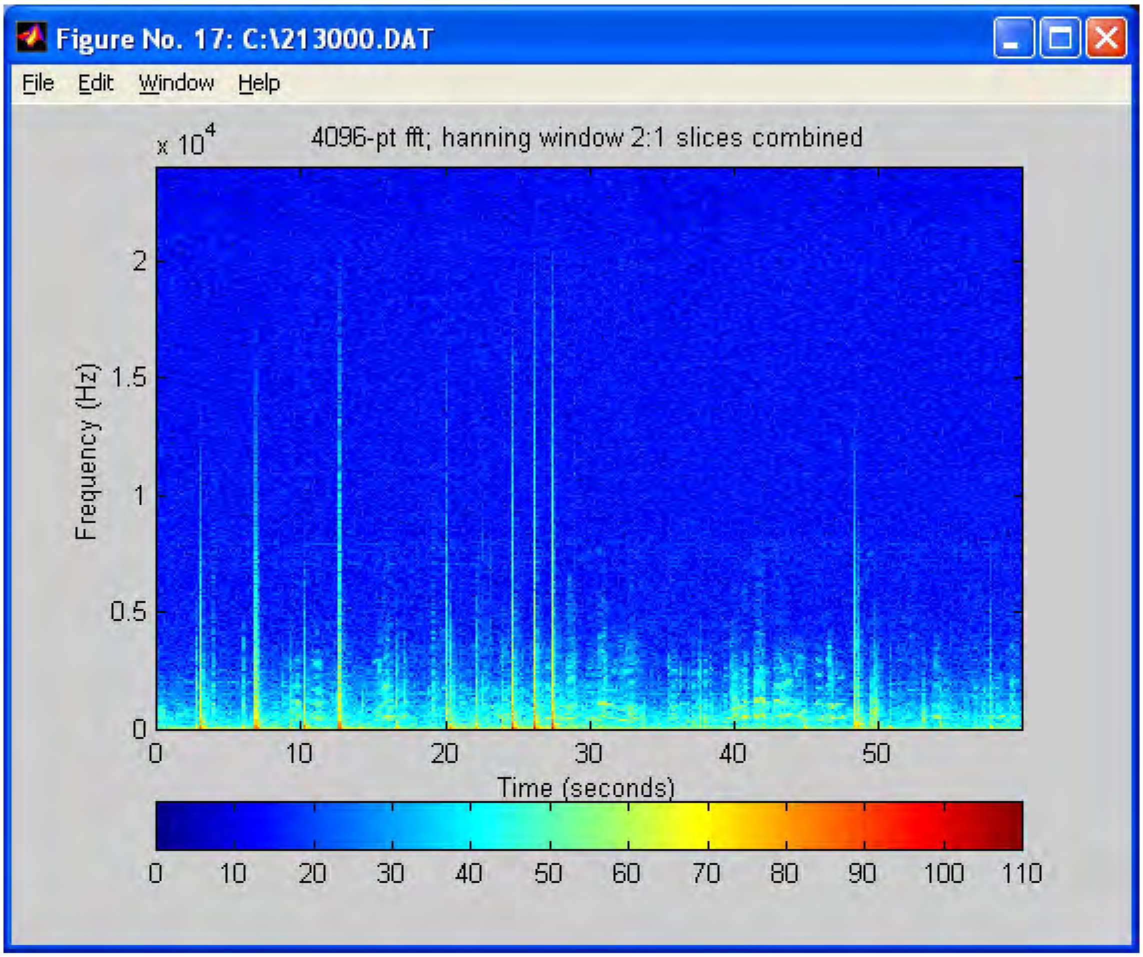


Spectrogram 21:29:00 to 21:30:00

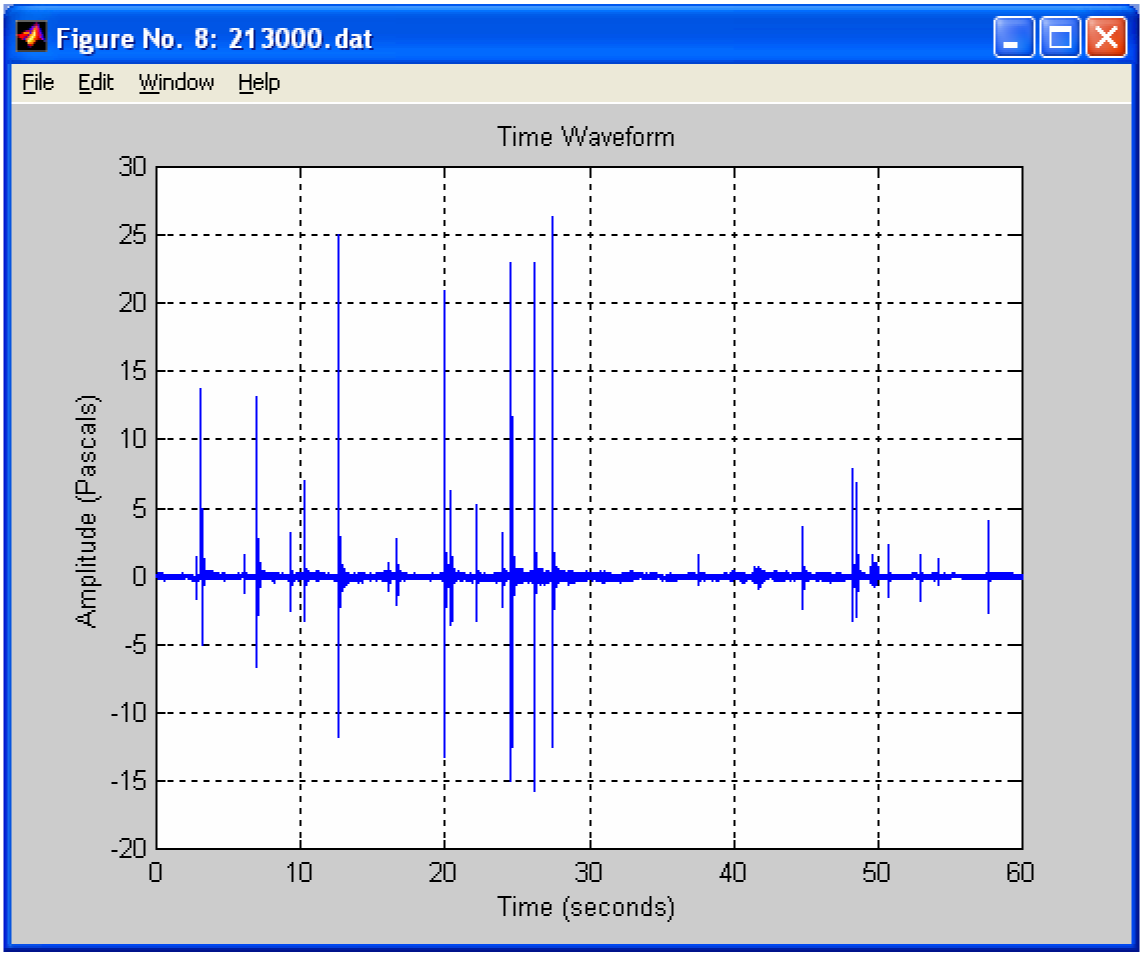


Time waveform 21:29:00 to 21:30:00

Notes: 21:30:00 to 21:31:00 .
21:30:00 sea lions audible throughout recording. See turquoise rhythmic vocalizations 21:30:30 to 21:30:45.
21:30:03 single explosions
21:30:07 single explosions
21:30:13 single explosions
21:30:20 single explosions
21:30:20 3 launches
21:30:25, 26, 27 3 single explosions
21:30:47-48 explosions with a little crackling

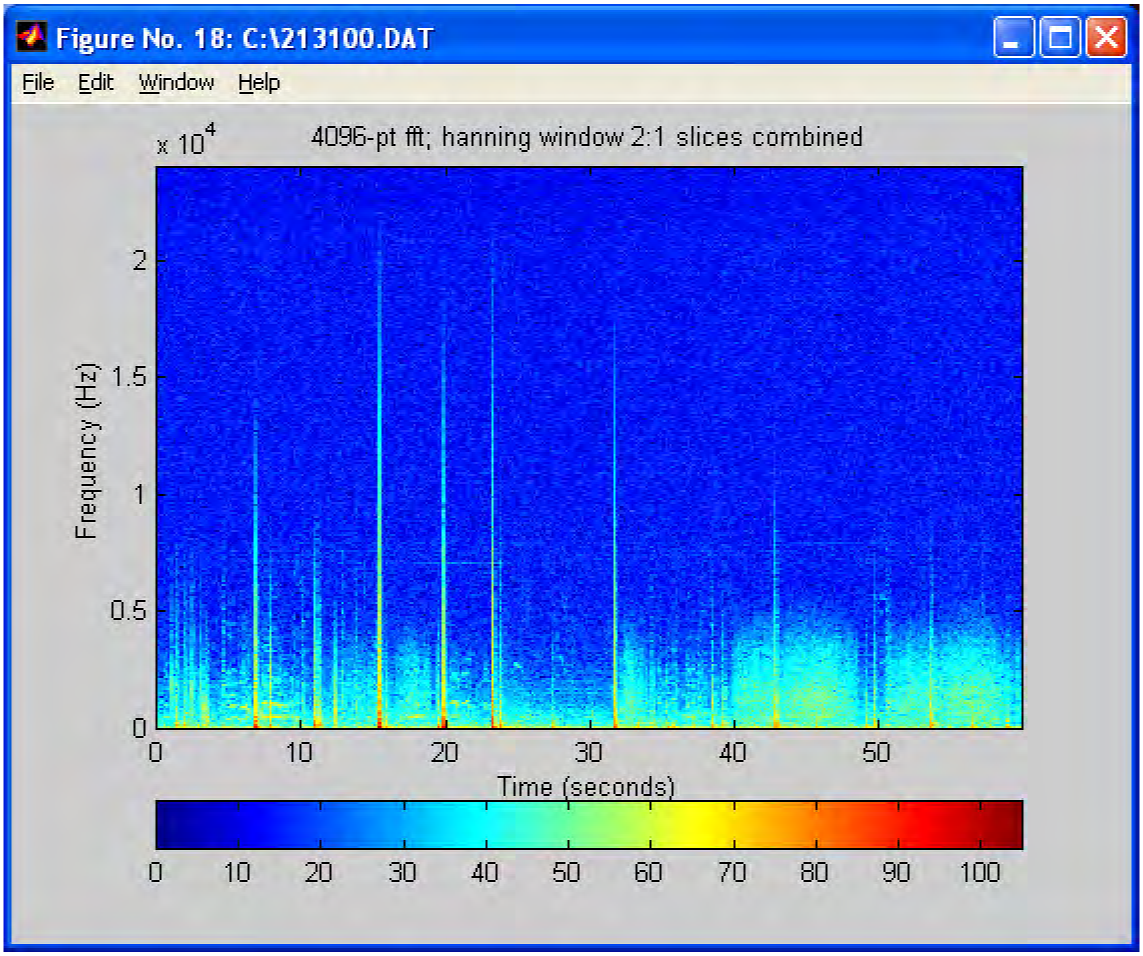


Spectrogram 21:30:00 to 21:31:00

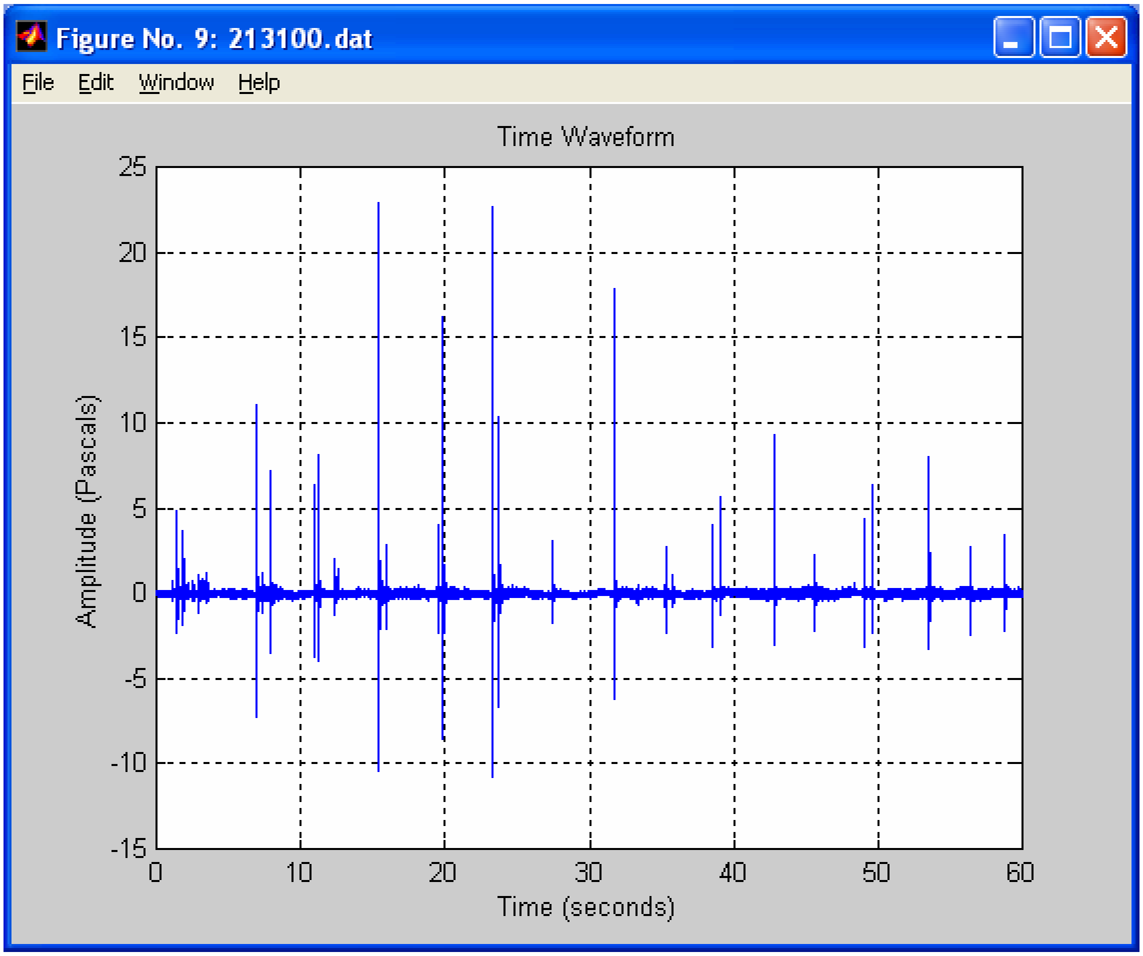


.
Time waveform 21:30:00 to 21:31:00

Notes: 21:31:00 to 21:32:00
21:31:02-05 smaller explosions with crackling
21:31:07-08 strong zalophus vocalizations – see yellow harmonics on spectrogram
21:31: 16-22 strong zalophus vocalizations – see yellow harmonics on spectrogram
21:31:15 single explosion with crackling
21:31:20 single explosion
21:31:23 single explosion
21:31:24 single explosion
21:31:30 – 60 good examples of explosions with lots of crackling.

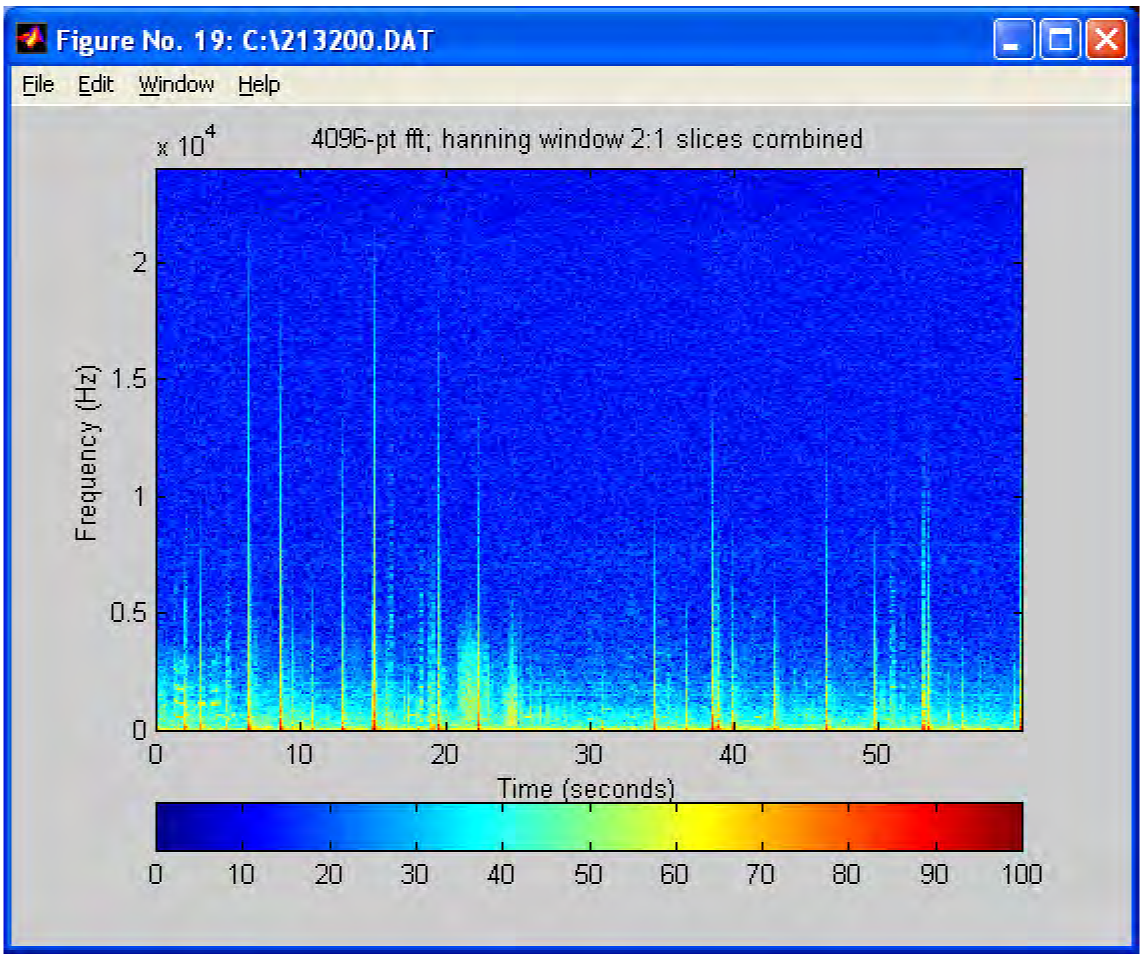


Spectrogram 21:31:00 to 21:32:00

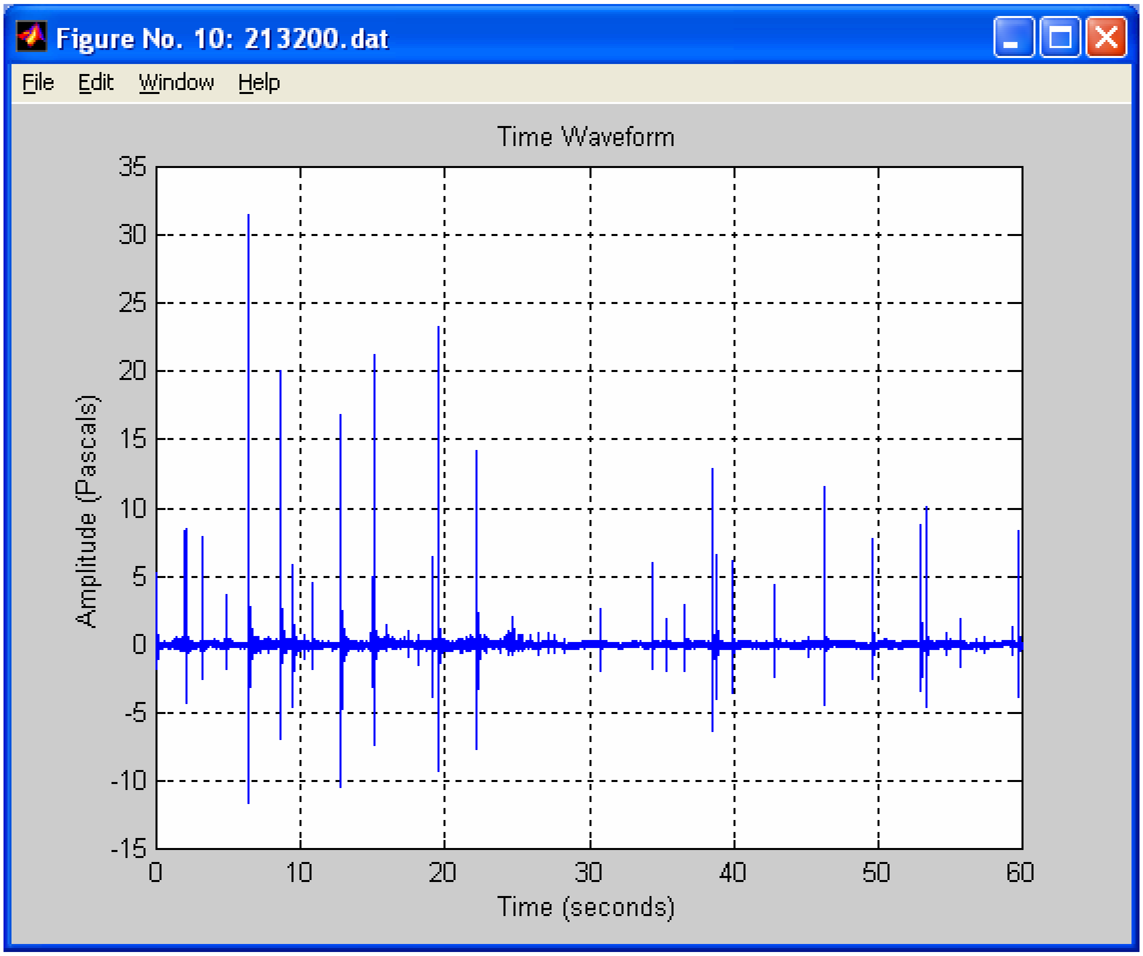


Time waveform 21:31:00 to 21:32:00

Notes: 21:32:00 to 21:33:00
21:32:02-06 good zalophus vocalizations
21:32:06 single louder explosion
21:32:08 single louder explosion
21:32:12 single louder explosion
21:32:15 single louder explosion
21:32:16 single explosion with crackling
21:32:19 single explosion
21:32:20-22 single explosion with crackling
21:32:38 single explosion
21:32:52-53 double explosions

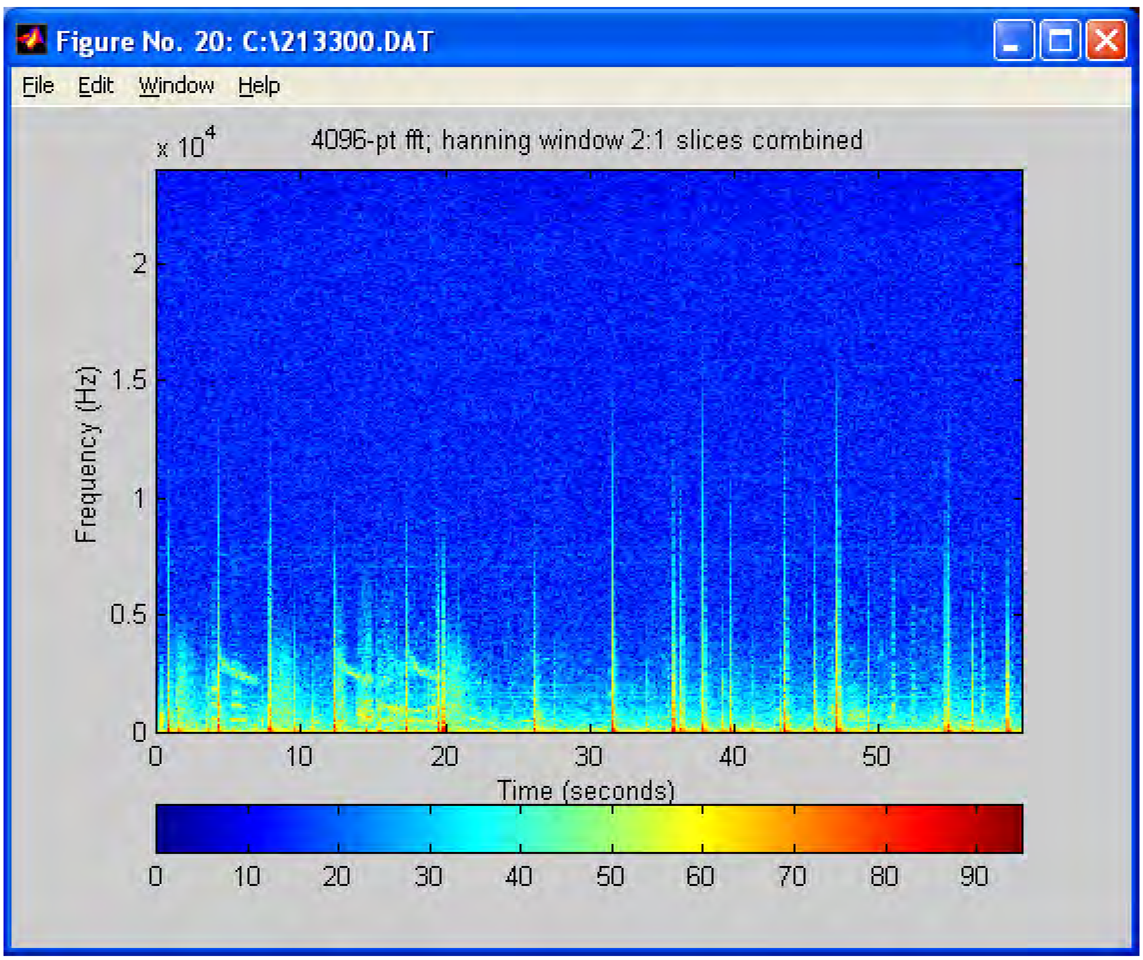


Spectrogram 21:32:00 to 21:33:00

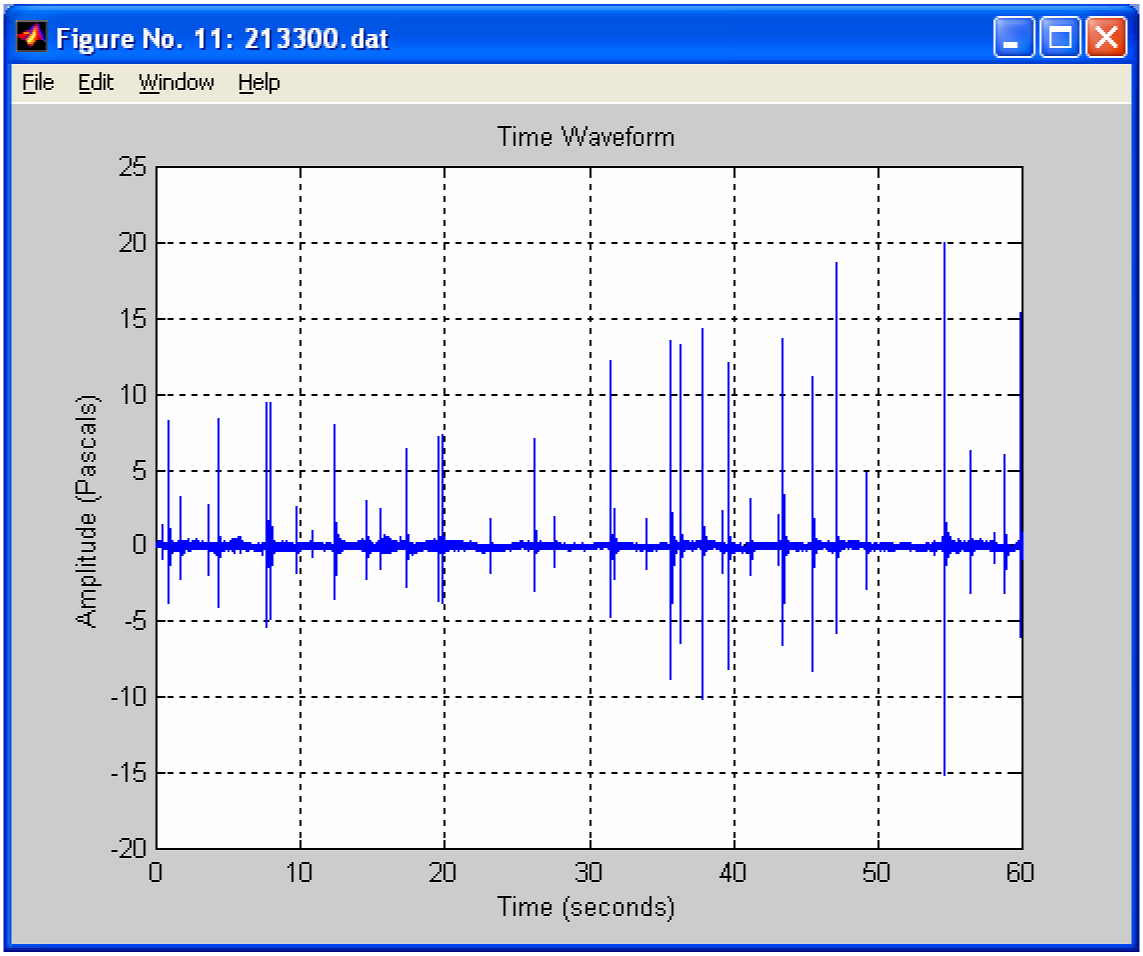


Time waveform 21:32:00 to 21:33:00

Notes:
21:33:01 single explosion with crackles
21:33:05: single explosion with whistles
21:33:08 single explosion
21:33:12 single explosion with whistles
21:33:15-20 good zalophus vocalizations
21:33: 17 single explosion with whistles
21:33:32 single explosion
21:33:35 single explosion
21:33:36 single explosion
21:33:37 single explosion
21:33:39 single explosion
21:33:43 single explosion
21:33:45 single explosion
21:33:47 single explosion
21:33:54 single explosion
21:33:59 single explosion

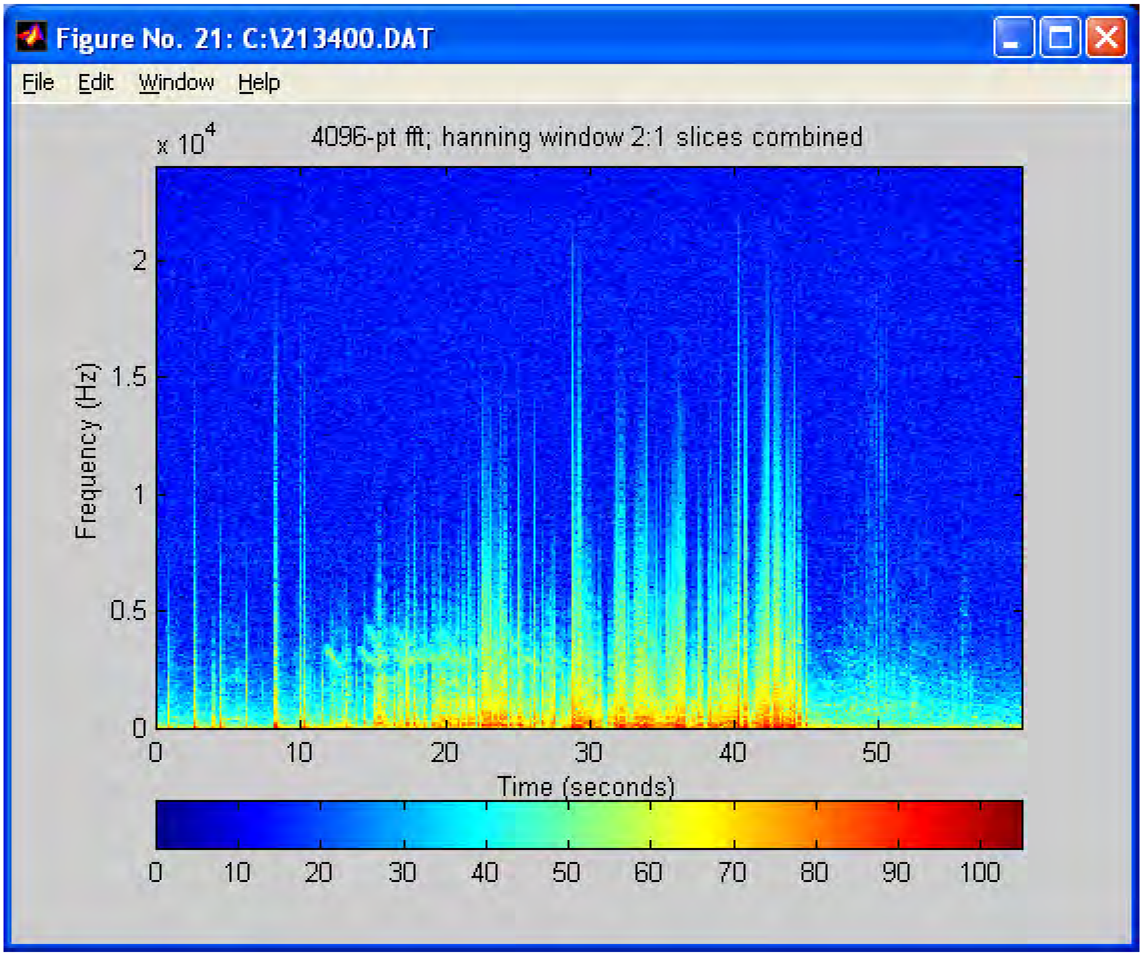


Spectrogram 21:33:00 to 21:34:00

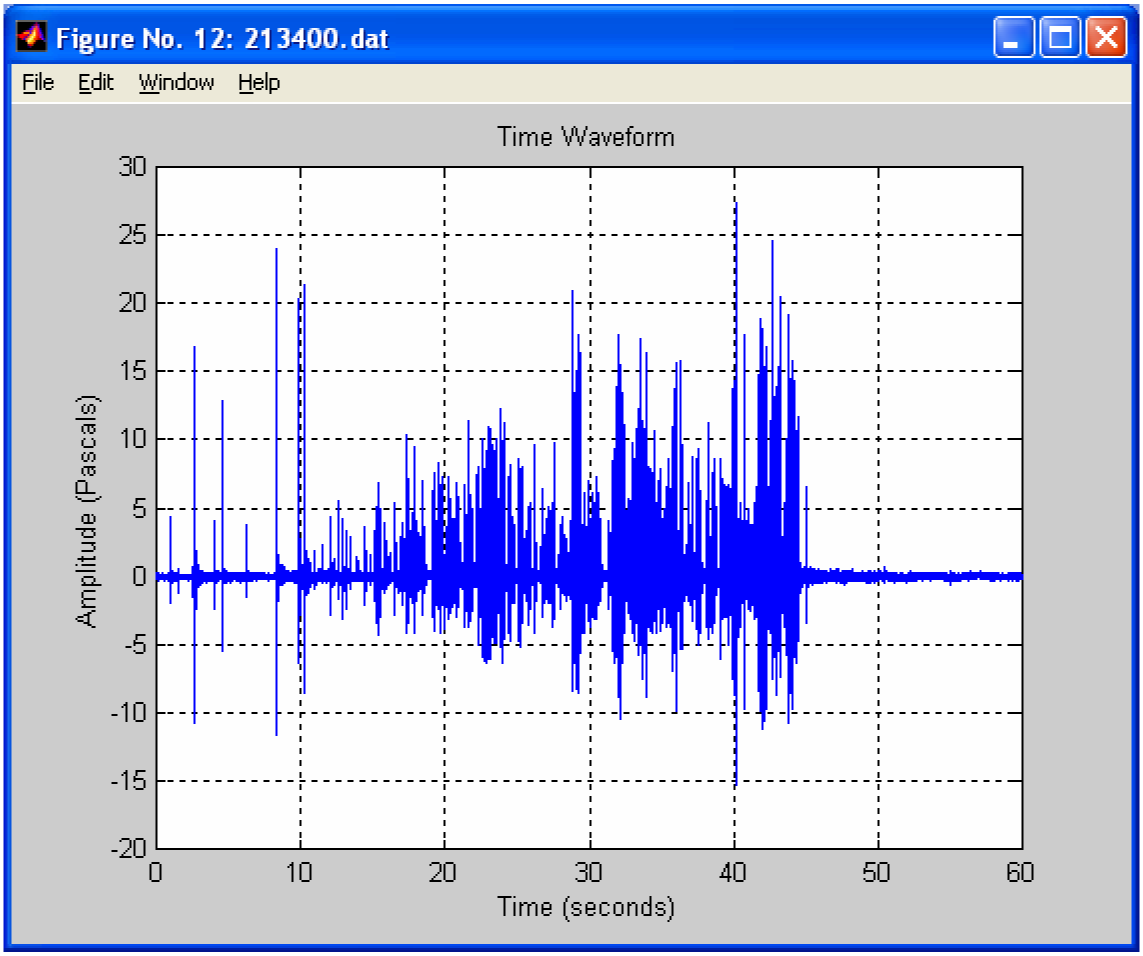


Time waveform 21:33:00 to 21:34:00

Notes: 21:34:00 to 21:35:00
21:34:00 grand finale begins
21:34:10 to 21:34:20 single explosion with whistles in the 3-4kHz region
21:34:45 show ends

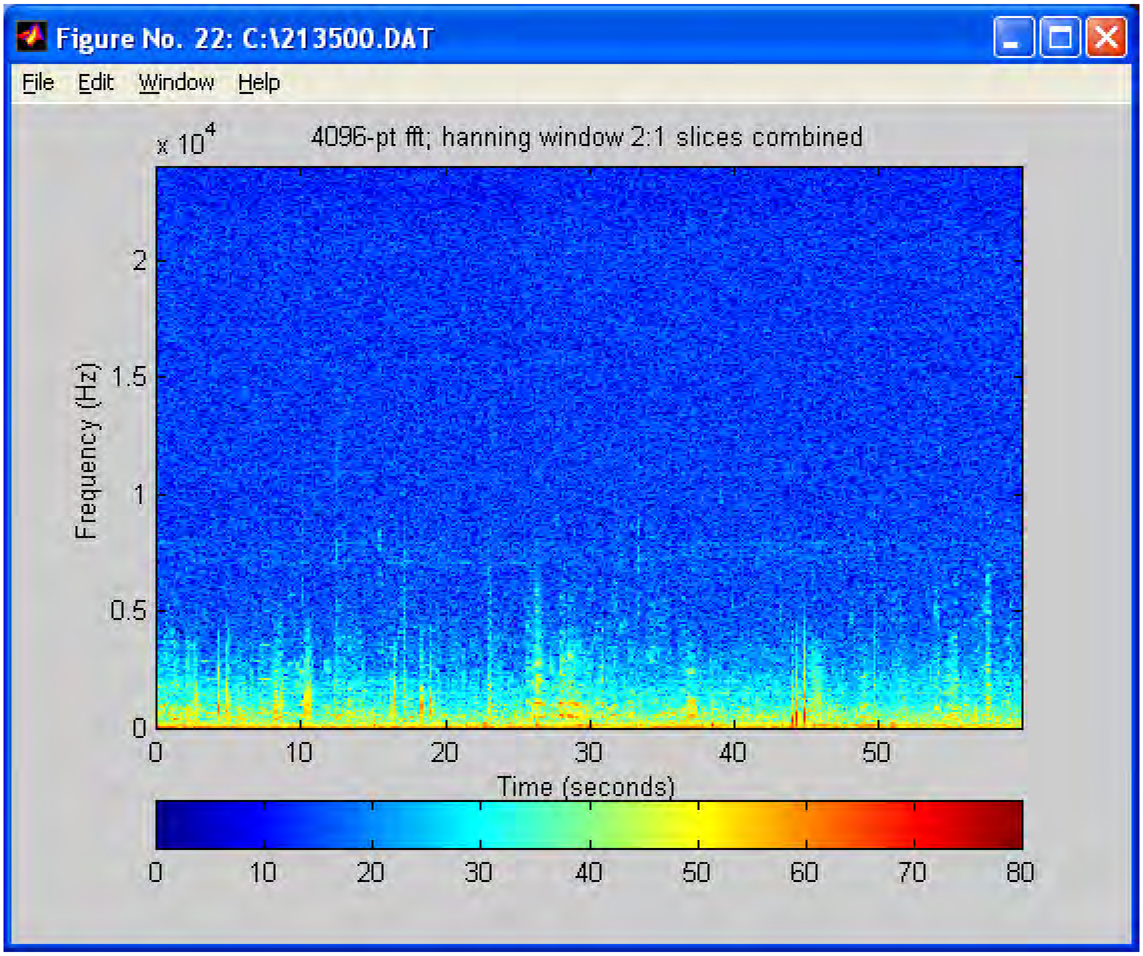


Spectrogram 21:34:00 to 21:35:00

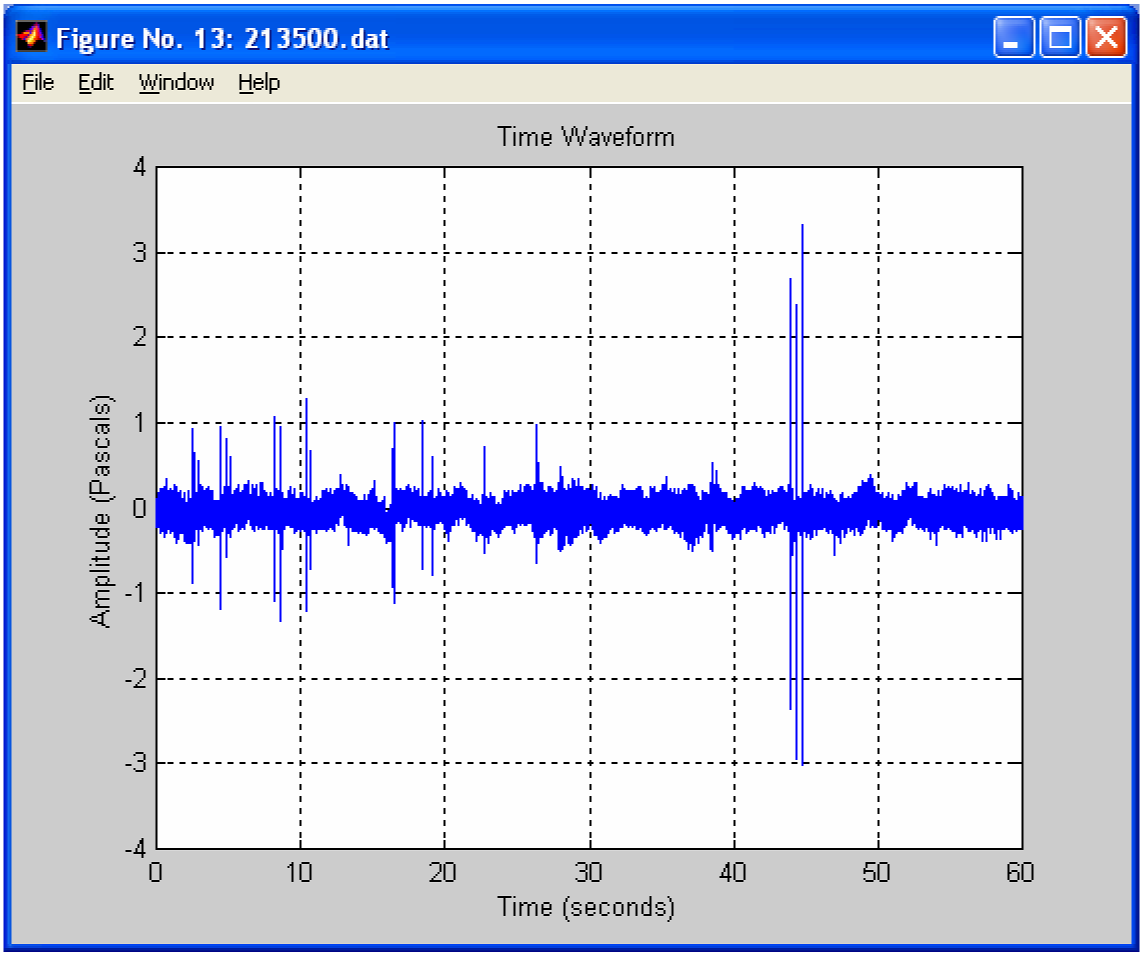


Time waveform 21:34:00 to 21:35:00

Notes: 21:35:00 to 21:36:00
21:35:27-30 good zalophus vocalizations
21:35:44 random fireworks
21:35:55 zalophus vocalizations



Spectrogram 21:35:00 to 21:36:00



Time waveform 21:35:00 to 21:36:00