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A Technical Note

Audible pedestrian traffic signals: Part 2. Analysis of sounds emitted

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Abstract—This project evaluated audible pedestrian traffic signals from three perspectives: 1) the patterns of use and the impact of these signals on pedestrian travel; 2) the physical characteristics of the sound emitted by these devices; and, 3) the detection of their emitted sounds in the presence of various traffic noise levels. This paper, the second of three companion articles (2, 3), examines the sounds emitted by the Nagoya/Traconex audible traffic signal, the unit most commonly found in the western United States and almost exclusively in California. The sounds emitted by the north-south and east-west Traconex audible signals were analyzed for their loudness, directionality, frequency spectrum, and temporal characteristics using standard engineering tools including an anechoic chamber, sound level meters, spectrum analyzers, and signal analyzers.

Key words: *audible pedestrian traffic signals, elderly, signaling devices, sonogram, sound dispersion, sound intensity, spectral analysis of sounds, visually impaired.*

INTRODUCTION

In a companion paper (2), the prevalence and impact of audible traffic signals were described. The second phase of this project characterized the sounds emitted by Nagoya/Traconex Audible Pedestrian Traffic Signals (APTS) using standard engineering instruments such as sound meters, frequency analyzers, high fidelity recorder, and an anechoic chamber. As illustrated in **Figure 1**, the Nagoya/Traconex signal is a self-contained, bell-shaped, and weatherproofed unit that attaches via brackets directly to the pedestrian crosswalk signal box. The analysis of sounds from these audible signals consisted of three parts: 1) a spectral analysis of the sounds emitted by the device based on field recordings and anechoic chamber tests; 2) the sound intensity level reaching a pedestrian at an intersection with the Nayoya/Traconex device; and, 3) the directionality of the emitted sound.

The technical analysis focused on the Nagoya/Traconex audible traffic signal for several reasons. First, such units were available to the project for extended testing (3) from Traconex, the manufacturer under license from Nagoya Electric Works of Japan. Second, such units are exclusively used at many intersections in many California cities so that multiple field inspections of installed units and field recordings of their emitted sounds were possible. Third, the analysis of sounds from these devices could be related to their impact (2) on the traffic accident data available from the California Highway Patrol.

METHOD

Recordings of the audible pedestrian traffic signal (APTS) were made at three intersections in San Diego, CA, where audible pedestrian traffic signals had been installed. A high fidelity portable cassette recorder (SONY PMD221) made recordings of the sounds for both directions of travel, north-south and east-west, in December of 1987, during the mid-morning hours of 9:30-11:00 a.m., and during the evening traffic rush hours of 4:00-6:00 p.m. The intersections studied were Mission Boulevard and West Mission

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Figure 1.
The Nagoya/Traconex audible pedestrian traffic signal installation for the north-south and east-west directions of travel.

Bay Drive, College Avenue and El Cajon Boulevard, and College Avenue and Montezuma Road. The overall level of traffic noise at these locations was also measured using a hand-held, calibrated sound level meter (Bruel & Kjaer Type 2226).

Sounds from Nagoya/Traconex audible signals

The Nagoya/Traconex audible pedestrian traffic signals emit an electronic "cuckoo" sound for the north-south direction of travel and an electronic "chirp" sound for the east-west direction of travel. The units are designed to emit their respective sounds continuously during the WALK phase of the traffic signal cycle. The APTS emit no sound during the flashing or steady DON'T WALK phases.

The manufacturer (4) lists the following specifications for its north-south "cuckoo" sound: 1) two frequencies are combined to produce the cuckoo sound; 2) the duration of this sound is 0.6 s $\pm$ 20 percent; 3) the frequency base is 1100 Hz $\pm$ 20 percent; and, 4) the frequency deviation is + 120 Hz $\pm$ 20 percent. Specifications for the east-west "chirp" sound are as follows: 1) a continuous frequency variation to produce the chirp sound; 2) the chirp lasting

0.2 s ± 20 percent; 3) a frequency base of 2800 Hz ± 20 percent; and, 4) a frequency deviation of 800 Hz ± 20 percent.

The output for both units is specified to be 90 dB sound pressure level (SPL, re; 20 μ Pa) at 1 m and self-switching between one of two adjustable output levels depending on the ambient noise level. The power requirement of the equipment is 115 AC ± 15 percent, 60 Hz, 3 W.

The weatherproof, bell-shaped units are 16.5 cm (6.5 in) high and 13.3 cm (5.25 in) in diameter and weigh 1.4 kg (3 lbs). They are attached by brackets to the signal box holding the pedestrian traffic signal light (**Figure 1**) and wired in parallel to the WALK or green light indicators. Thus a typical 4-way intersection would have eight pedestrian signal boxes and eight audible signals.

The audible signal equipment used for the laboratory measurements were new Nagoya/Traconex units supplied to the project by the importer, Traconex, Inc. The field measurements and recordings were made on units that were installed on traffic signal poles and that had been in use for about 3 to 4 years.

Field measurements

Physical inspections of the Nagoya/Traconex audible traffic signals installed in various locations throughout San Diego revealed the following:

- The audible traffic signal units were usually mounted on traffic signal poles and attached to their respective walk signals. This location usually meant that the units were 2.5 to 3 m (8 to 10 ft) away from the ears of a typical pedestrian standing on the corner waiting to cross the intersection.
- The north-south signal emitted a *longer* cuckoo sound pattern that repeated a minimum of *four* times during the WALK portion of the light cycle.
- The east-west signal emitted a *shorter* chirp sound pattern that repeated a minimum of *seven* times during the WALK portion of the light cycle.

The field recordings and field sound meter measurements revealed the following:

- The sound intensity directly in front of the device (3 cm away) was 105-110 dBA SPL (A weighted).
- The traffic noise at these intersections varied between 55 dBA and 85 dBA SPL.
- The audible traffic signals momentarily increased their sound outputs by approximately 5 dB (as claimed by the manufacturer) when the traffic noise was extra loud (over 80 dBA SPL), such as with the passing of a diesel truck or bus.

Spectral analysis of field recordings

Using a high fidelity portable cassette recorder (SONY PMD221), the sounds emitted by audible traffic signals were recorded from where a pedestrian would stand while waiting to cross the intersection. Subsequent spectral analysis of the recorded sounds using a Scientific Atlanta SD300 signal analyzer and the Digital Sona-Graph (Model 7800) by Kay Elemetrics Corporation, Pine Brook, NJ, revealed the following:

- The sonograms for both the north-south and east-west signals, recorded from where a pedestrian would stand while waiting for the corresponding traffic light to signal its WALK message, are shown in **Figure 2** and **Figure 3** respectively. The horizontal axis represents time (100 ms per major division) while the vertical axis represents sound level intensity (5 dB per division) or frequency (500 Hz per division). The top trace in the figures shows that the emitted sound was 4 to 5 dB above the background noise level.
- A frequency analysis of the cuckoo sound from the north-south signal (**Figure 2**) shows major frequency peaks at approximately 950, 1950, 2875, 3825, and 4725 Hz. This sound pattern lasts about 400 ms, repeats once every 1.5 s, and has a characteristic sound of an electronic "cuckoo" produced by incrementally changing from one frequency to another (1250 Hz to 950 Hz) with harmonics as high as 6000 Hz.
- A frequency analysis of the chirp sound from the east-west signal (**Figure 3**) shows major frequency peaks at approximately 2100 and 6300 Hz. The east-west chirp signal has a continuous variation in frequency fundamentals from 2600 to 1500 Hz with harmonics up to 7000 Hz. This sound pattern lasts about 140 ms and repeats at 1 s intervals.
- Spectral analysis of the traffic noise revealed wide-band noise with frequency components from 6 Hz to 7000 Hz with most of the acoustic energy below 1000 Hz.

Laboratory measurements of the sound intensity patterns

Careful and multiple laboratory measurements of the sound intensity and sound directionality of the new Nagoya/Traconex units were made inside an anechoic chamber located on the San Diego State University campus. A calibrated cardioid microphone was placed 1 m away from the signal and oriented from +90 to −90 degrees in 30-degree increments about the main axis (0 degrees) of the sound source. The sound intensities (in dB SPL, re: 20 μ Pa) of the north-south and east-west audible sig-

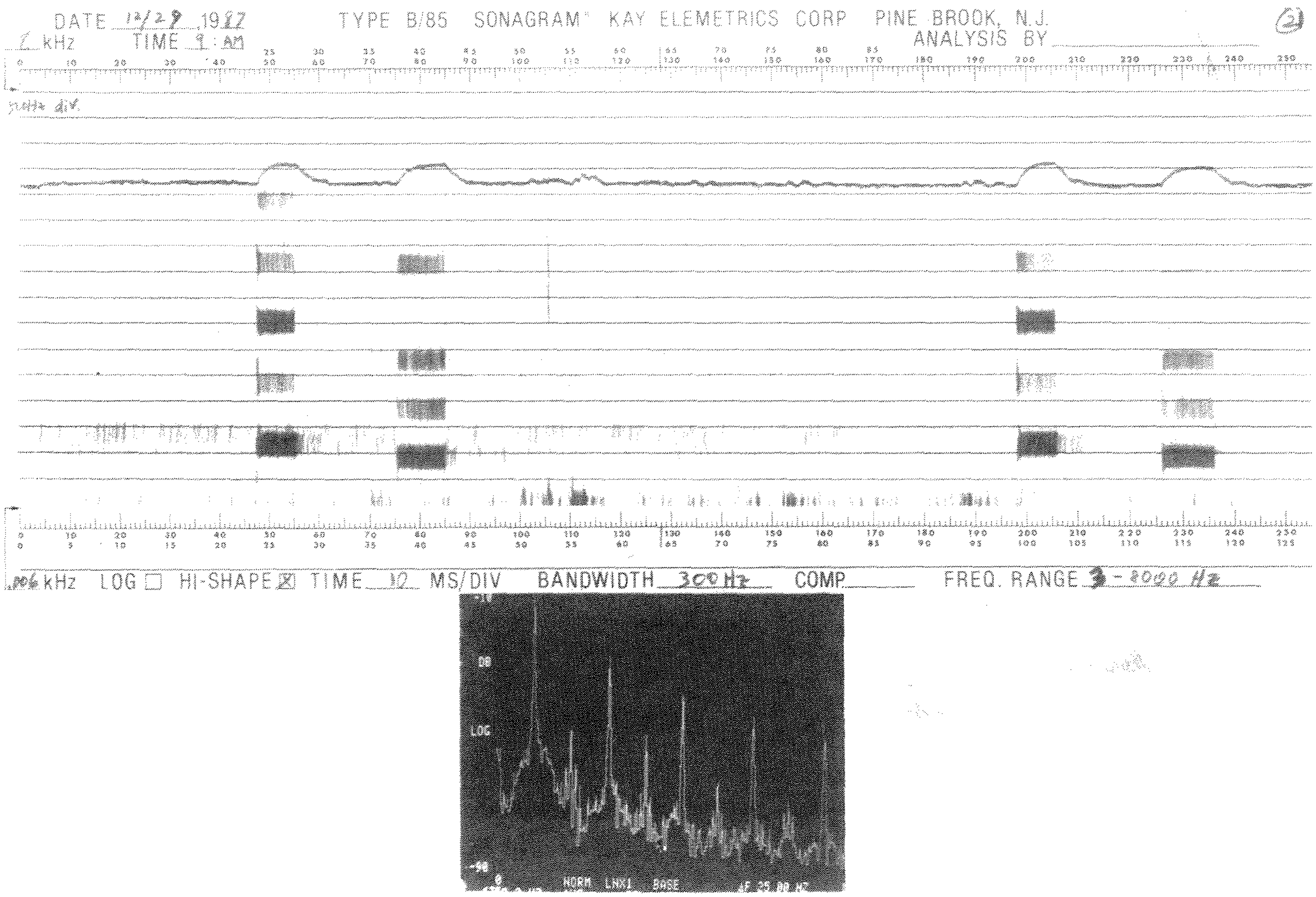

Figure 2.
Sonogram (above) and frequency spectrum (below) of the north-south "cuckoo" sound. The horizontal scale is 10 ms per division, and the vertical scale is 500 Hz (or 5 dB) per division.

nals were measured with their volume controls at the center (or medium) and maximum settings.

With the volume control of the north-south cuckoo signal set at the *center* position of its adjustments range, the output sound intensity varied from 76 dB at 0 degrees (straight ahead) to 70 dB at ± 90 degrees (**Figure 4**). When the volume control of the north-south cuckoo signal was set for *maximum* output, the signal's sound intensity at 0 degrees surprisingly stayed the same (76 dB). However, the sound intensity exhibited slightly less directionality, showing a drop of just 2 dB at the ± 90 degree extremes.

With the volume control of the east-west chirp signal set at the *center* position of its adjustment range, the output sound intensity varied from 71 dB to 0 degrees to 59 dB at ± 90 degrees (**Figure 5**). With the volume control of the east-west chirp signal set for *maximum* output, the signal's sounds intensity increased noticeably (about 6 dB). The chirp's intensity was 77 dB at 0 degrees and 65 dB at ± 90 degrees.

SUMMARY

The field recordings and anechoic chamber tests of the Nagoya/Traconex audible pedestrian traffic signals revealed the following:

- Sound chamber evaluations of the Nagoya/Traconex audible pedestrian traffic signal indicate that the sound emitted by the north-south unit was less directional than the sound emitted by the east-west unit. However, their sound patterns (**Figure 4** and **Figure 5**) were not so highly directional that precise aiming of the units during field installations would be necessary.

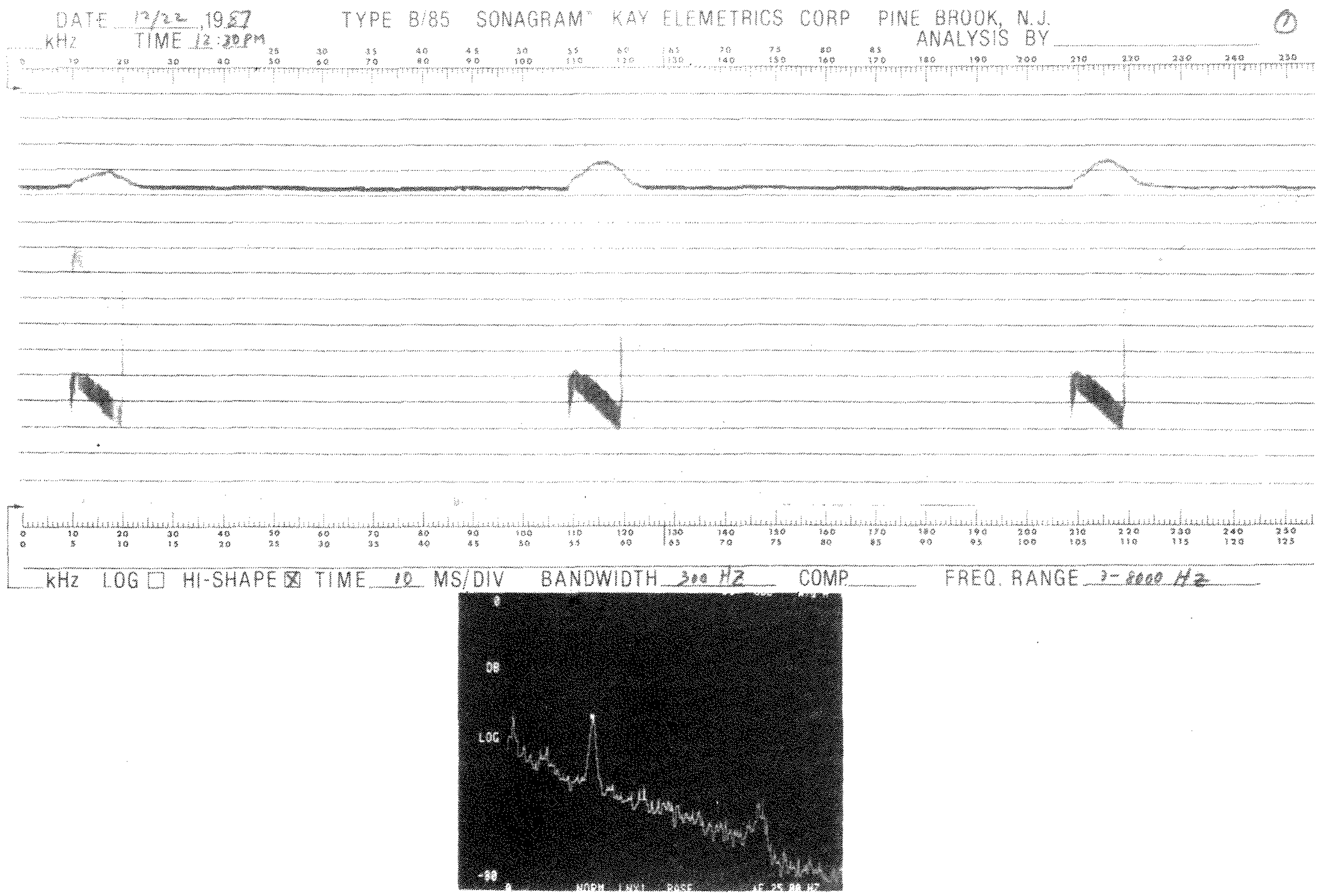

Figure 3.
Sonogram (above) and frequency spectrum (below) of the east-west "chirp" sound. The horizontal scale is 10 ms per division, and the vertical scale is 500 Hz (or 5 dB) per division.

- Similar volume control settings on these units may not yield similar outputs. Therefore, accurate on-site settings of the audible signal's output must be made with the aid of a calibrated sound level meter.
- The east-west chirp sound has much higher frequency components than the north-south cuckoo sound. Thus the east-west chirp probably would be more easily detected than the north-south cuckoo in the presence of the broadband, low frequency traffic noise (3).
- Assuming that the Traconex APTS's maximum sound pressure output would increase about 5-8 dB in the presence of loud environmental noise, the test unit met the factory listed specifications within reasonable manufacturing tolerances.

ACKNOWLEDGMENT

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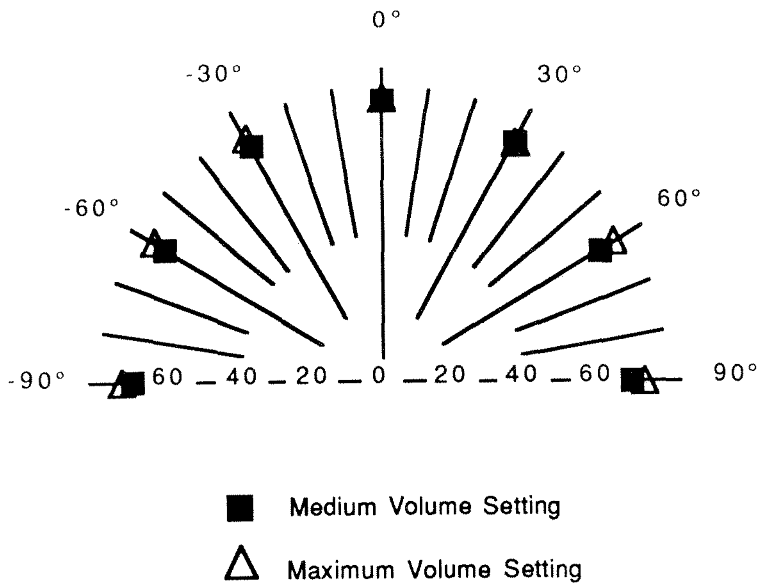
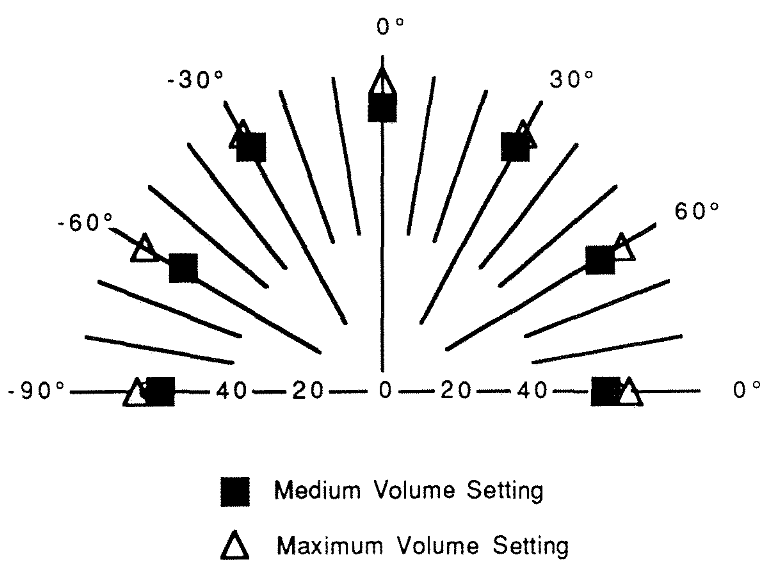
NORTH-SOUTH "CUCKOO" SOUND PATTERNS



Orientation	dB SPL (Med.)	dB SPL (Max.)
-90°	71	74
-60°	72	75
-30°	74	76
0°	76	76
30°	75	75
60°	71	75
90°	70	74

Figure 4.
North-south "cuckoo" sound dispersion patterns at medium and maximum volume settings.

EAST-WEST "CHIRP" SOUND PATTERNS



Orientation	dB SPL (Med.)	dB SPL (Max.)
-90°	59	65
-60°	61	73
-30°	70	74
0°	71	77
30°	70	74
60°	66	73
90°	59	65

Figure 5.
East-west "chirp" sound dispersion patterns at medium and maximum volume settings.