Memorandum

U.S. Department
Of Transportation

**Research and
Innovative Technology
Administration**

Subject: HAARP Diesel Engine-Generator Noise Study: Phase 2
Addendum to January 4, 2005 Letter Report

Date: February 11, 2008

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Reply to
Attn. of: RTV-4F

To: Paul Valihura (RTV-4E)

CC: Gregg Fleming (RTV-4F)

1. Introduction

This document is an addendum to the January 2005 letter report "HAARP Diesel Engine-Generator(s) Noise Study", which presented the results and corresponding analysis of an outdoor noise measurement program conducted by the John A. Volpe National Transportation Systems Center's Acoustic Facility (Volpe Center) at the United States Air Force's High Frequency Active Auroral Research Program antenna array (HAARP) in Gakona, AK from September 27th through 30th, 2004. Specifically, the noise generated by the on-site diesel engine powering the HAARP antenna array was investigated in this study. This power plant consists of a single diesel engine driving a generator inside the main HAARP facility building, with the cooling and exhaust mounted on opposite sides of the building. As part of the original analysis, the measured noise levels were extrapolated to account for the noise generated by five simultaneously operating engine-generator pairs, in anticipation of a future expansion of the HAARP power plant.

Since that time, the HAARP power plant was expanded to include four main engine-generator pairs (with the corresponding cooling and exhaust systems) and one backup engine-generator pair. Additionally, the exhaust for the one engine in the 2004 campaign was changed to exhaust vertically rather than to the side. This adjustment made all of the engines exhaust in the same direction. A second outdoor noise measurement program was conducted on September 20th, 2007 by the Volpe Center at the HAARP facility, in order to evaluate the noise produced by the recently expanded power plant. The three main goals of this second measurement program and analysis is to measure the current noise levels generated by the HAARP power plant, to compare those noise levels to the applicable federal regulations, and to confirm or refute the estimated noise levels presented in the January 2005 letter report. The results and corresponding documentation of that second measurement program are presented in this letter report.

The acoustic team, consisting of Eric Boeker and Dr. Paul Valihura of the Volpe Center, performed noise measurements at three locations around the power plant installation to characterize the current noise levels of the HAARP power plant, and at a fourth location on the edge of the USAF facility to evaluate the HAARP-generated noise levels at the closest neighboring piece of private property. Five 5-minute-long samples representing the maximum engine-generator loading (resulting in the maximum expected noise levels from the power plant) were broadcast by the HAARP antenna array on September 20th, 2007; and 1-second, A-weighted equivalent sound pressure levels (1-second L_{Aeq}) and 1/3-Octave, Un-weighted spectral data were measured at all measurement locations.

This memorandum is broken up into five sections. First, the overall purpose of the noise study is presented. Second, the results and the compliance criteria for the applicable standards and regulations from the January 2005 letter report are summarized. Next, the measurement methodology used to collect the HAARP noise data is presented, including short descriptions of the measurement site, microphone locations, measurement equipment, and the data collection procedure utilized during the measurement program. In section five, a brief overview of the data processing effort is presented, consisting of acoustic data processing procedures, verification of data quality, and the calculation of the noise metrics. The noise data are then analyzed for compliance with the applicable standards and regulations. The final section of this memorandum consists of a presentation of results, conclusions and recommendations.

2. Purpose

This study was performed to validate the conclusions of the 1993 Environmental Impact Statement for the HAARP project that the noise generated would be less than a significant level of impact. In 2004-2005, a noise measurement study was conducted to evaluate the noise levels emitted from the HAARP power plant consisting of a single engine-generator pair, and to estimate the sound levels emitted from a potential power plant consisting of five simultaneously operating engine-generators. The purpose of this study is to characterize the noise levels from the current HAARP power plant consisting of four main engine-generator pairs (with the corresponding cooling and exhaust systems), to and compare those estimated sound levels with the findings of the initial study and the applicable regulations. This study will quantify the noise output from the HAARP diesel engine-generator(s), and based on existing impact criteria determine if the resulting noise levels are negatively impacting areas outside of and neighboring the HAARP facility.

3. Summary of Results and Noise Impact Compliance Criteria from the January 2005 Report

3.1. Results from the January 2005 Report

The September 2004 noise measurements of the HAARP power plant containing a single engine-generator produced a variety of different noise results. The following noise metrics were of the most interest to the analysis:

- The 30-minute-long, A-weight equivalent sound pressure levels, $L_{Aeq\ 30min}$, for each 50 m microphone;
- The average $L_{Aeq\ 30min}$ across all of the 50 m microphones;
- The estimated average day-night sound pressure level L_{dn} across all of the 50 m microphones, based on noise levels generated by the power plant, if it operated at full-load for a 24-hour-long period;
- The $L_{Aeq\ 20min}$, L_{dn} and the level exceeded 90% of the measurement interval, L_{90}, for Mic 9[1];
- The average L_{dn} value estimated out to 3200 m (2 miles) from the HAARP facility[2] based on an empirically determined drop-off rate;
- The average L_{dn} value estimated out to 3200 m and extrapolated to account for noise levels from an expanded HAARP power plant consisting of five identical diesel engine-generators operating at full power simultaneously inside the same installation; and
- The background noise measured at the HAARP facility during non-operational hours.

These results are reprinted in Table 8 through Table 13 in Appendix A.

It is important to note that the original analysis was done under the assumption that the HAARP power plant would operate five engine-generator pairs simultaneously. However, it turns out that practical operational procedures have been put into place that allow for up to four simultaneously operating engine-generator pairs; always setting aside one engine-generator as a backup. Therefore, the average L_{dn} value representing five identical diesel engine-generators in Table 12 were recalculated to account for an expanded HAARP power plant consisting of four identical diesel engine-generators operating simultaneously. These recalculated results are presented in Table 14 in Appendix A. The extrapolated results for Mic 9 and the average across Mics 1 through 8 were also recalculated, and presented in Table 15.

[1] The $L_{Aeq\ 20min}$ metric was used for Mic 9 instead of the $L_{Aeq\ 30min}$ metric, because only 20 minutes of noise data was measured in this study, during which there was no background noise interference.
[2] The distance of 3200 m (2 miles) represents the current nearest private residence to the HAARP facility.

3.2. Noise Impact Compliance Criteria

Although there are no common standards or regulations that directly govern the noise levels generated by the HAARP power plant (i.e., noise from a diesel engine-generator facility), several different federal regulations and standards were considered for use in the HAARP noise study. These criteria were chosen, because they best suited different characteristics of the noise generated by the HAARP power plant: EPA/FRA (stationary locomotive noise from a facility), FAA (noise from a facility), HUD (exterior noise in communities from HUD actions), and FTA (noise from a facility, taking into account background noise). These regulations are summarized below in Table 1.

Table 1. Standards and Regulations considered the HAARP Noise Measurement Study

Agency	Regulation	Metric	Measurement Location	Compliance Level
EPA, FRA	40 CFR Part 201.11, 49 CFR Part 210 Appendix A	L_{90}	Nearest neighboring residence, or receiving property	≤ 65 dB(A) + 2 dB tolerance (which effectively means ≤ 67 dB(A))
FAA	14 CFR Part 150.21	L_{dn}	Receiving property	≤ 65 dB(A)
HUD	**24 CFR Part 51.101**	**L_{dn}**	**Receiving property**	**≤ 65 dB(A)**
FTA	"Transit Noise and Vibration Impact Assessment" report (DOT-T-95-16)	L_{dn}	Receiving property	≤ Ambient Noise Level (in dB(A)) + 10 dB, if the ambient noise < 43 dB(A)

These four criteria and an analysis of the HAARP noise data according to these criteria were presented to the U.S. Air Force for their consideration. Upon further consultation, the U.S. Air Force decided upon the HUD regulation as the noise compliance criterion for the analysis of the noise generated by the HAARP power plant.

4. Measurement Methodology

4.1. HAARP Measurement Site and Microphone Locations

The HAARP power plant consists of five EMD Model 20-645-E4 diesel locomotive engines driving a Baylor Model G855VRV-362 generator inside a building, with the cooling and exhaust mounted on opposite sides of the building. A muffler is used on the exhaust, and there is a horizontally mounted fan operating with the cooling system. The facility employees reported that the cooling fans had a noticeable, high frequency component, whereas the exhaust system has a noticeable, low frequency component. The nearest residence is approximately 3200 m (2 miles) away, and approximately 250 m (820 ft) from the closest edge of the building is the Tok Cutoff Highway and nearest neighboring piece of private property.

In September 2004, the noise measurements took place in eight locations that were 50 m (164 ft) from the power plant portion of the HAARP building and equidistant from each other at 45 degree increments, two additional microphones to measure drop-off rate, and a final measurement microphone was setup at the turnoff from the Tok Cutoff Highway onto the HAARP access road. Although this method provided a comprehensive approach, the data analysis showed that a smaller number of measurement positions could be used to measure and analyze the noise from the HAARP power plant. In addition, several changes to the HAARP facility, such as the addition of an equipment garage and altering the directionality of the exhaust ports (see Figure 1), made noise measurements at several of the previous microphone positions impossible, impractical or unnecessary[3].

Figure 1. Recent Changes at HAARP: Equipment Garage (left) and Exhaust Ports (right)

[3] This was especially relevant for Microphone locations 5 and 6a from the 2004 study.

Therefore, an abbreviated number of microphone locations were used in the second HAARP noise measurement study. Noise measurements were made at the two loudest microphone locations from the 2004 study:

- 50 m from the cooling fans (Mic 1); and
- 100 m from the exhaust ports (Mic 6b).

The following additional noise measurement locations were also used:

- 200 m from the exhaust ports (Mic 6c); and
- On the east shoulder of the Tok Cutoff Highway across from the HAARP access road (Mic 9a).

These microphone locations are presented in relation to the HAARP building and the surrounding area in Figure 2 and Figure 3, and their exact GPS coordinates are presented in Table 18 in Appendix B.[4]

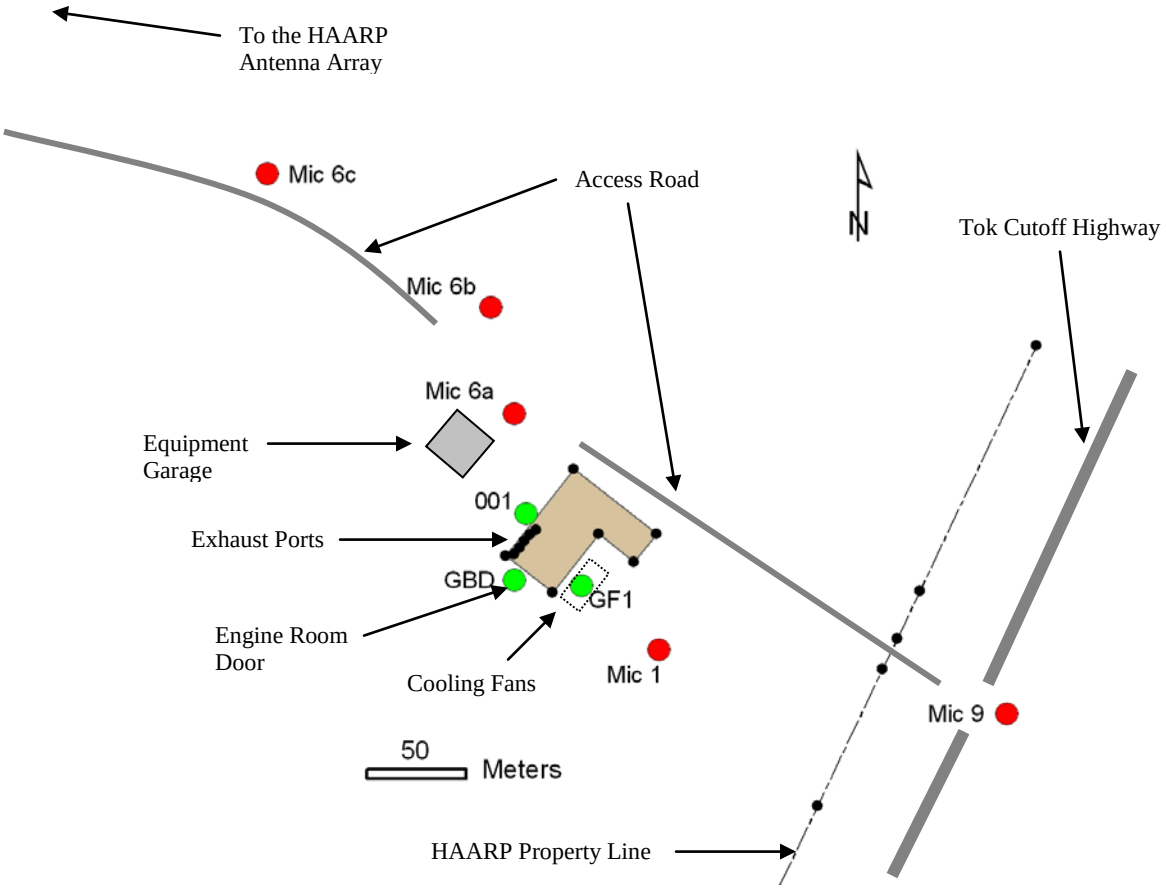

Figure 2. HAARP Building and Noise Measurement Positions

[4] Although exact distance between the HAARP power plant and the measurement locations were desired, the measurement site was limited by the physical constrains of the HAARP site, including buildings, terrain and foliage. However, the potential "worst case" error in noise level between the microphone distances in Appendix B and those list above were estimated according to $20*\log_{10}(d1/d2)$. At each microphone, these distance errors were found to be smaller than the allowable uncertainty of the noise measurement equipment. Therefore, the approximate measurement distances were deemed acceptable.

Figure 3. Microphone Locations (clockwise from top left): Mic 1, Mic 6b, Mic 9a, and Mic 6c.

4.2. Measurement Equipment

For this noise measurement study, Larson-Davis model 824 Integrating Sound Level Meters/Real Time Analyzers (LD-824) were deployed at all of the measurement positions, These analyzers were setup in accordance with the procedures and settings presented in the January 2005 report. All the acoustic instrumentation conformed to the corresponding American National Standards Institute (ANSI) and International Electrotechnical Commission (IEC) standards.

Meteorological data were collected by the HAARP facility's in-house weather station. All of the measurement positions were identified using a hand-held GPS receiver by the HAARP personnel.

4.3. Data Collection

For the most part, noise data were collected for this study in accordance with the procedures presented in the January 2005 letter report. The changes in HAARP power plant operation and noise measurement procedures from those listed in that report are documented below:

- Noise measurements took place during daytime hours on September 20th, 2007. To account for increased traffic on the Tok Cutoff Highway and on the HAARP property during daytime hours, observers logged noise intrusions at Microphone positions 6c and 9a during each noise event. These logged intrusions were then accounted for during data processing.
- A steady-state, full loading (80% load, or full load) on the four engine-generators pairs in the HAARP power plant was the noise source for the noise measurement.
- The acoustic instrumentation collected noise data over the five consecutive 5-minute long full-load signals. Since the HAARP facility often operates with the doors to the engine room open in the summer, noise data were measured with the doors closed (Events 1-3) and open (Events 4-5).
- On several instances, HAARP had to stop operation due to aircraft operating in the vicinity. These instances were logged as noise intrusions and accounted for during data processing.

- After the HAARP power plant had been powered-down and all of the associated noises from the HAARP facility had subsided, background noise measurements were conducted. These measurements occurred roughly two hours following the power plant noise measurements due to inclement weather.

5. Data Processing

5.1. Acoustic Data Processing Procedures and Verification of Data Quality

For each measurement system, the initial and final calibration, the electronic noise floor, and the background noise measurements were investigated. The initial and final calibration measurements were compared to see if any calibration drift had occurred, and needed to be accounted for. In all cases, the calibration drift was less than 0.2 dB(A) over the course of the measurements, so no calibration adjustments needed to be implemented[5]. This is a good indicator that the noise instrumentation performed properly over the course of the noise measurements, even under the severe temperature and meteorological conditions.

The electronic noise floor data measured by each sound level meter was also investigated. All electronic noise floor measurements were below 20 dB(A) and steady in level over time, so the effects of electromagnetic interference (especially from the HAARP array) on the noise instrumentation during the course of the noise measurements were considered to be negligible.

Once the calibration and electronic noise floor data had been checked and verified, the noise data could be processed. These data were correlated with the observer log sheets, which indicated the start and stop times of each noise event, and the start and stop time of each interference event. The noise data for each microphone corresponding to the HAARP full-load broadcasts (five 5-minute-long broadcasts) were separated out from the rest of the data for processing purposes. These data blocks were further processed to remove the interference events from the HAARP noise event[6]. Once the interference events were removed, any data sets that did not include a minimum of 5-minutes of valid noise data were considered incomplete. From these processed, valid noise data, the metrics were calculated according to the methods presented in the January 2005 letter report. The metrics associated with each five-minute data block are presented in Appendix B.[7]

To further verify data quality, the background noise data were also collected at all of the HAARP noise measurement positions[8]. The average background noise level was determined to be of 35.1 dB(A). Unlike the September 2004 background noise levels, the average background noise level includes background noise from Mic 9a, because its background noise levels were not significantly different from those measured closer to the HAARP power plant. The background noise data is presented in Appendix B. These background noise levels were all more than 10 dB below the measured noise levels from the HAARP power plant (evaluating each $L_{Aeq\ 5min}$ data block), and could therefore be ignored according to criteria presented in ISO 6190 and ANSI 12.8-1998.

5.2. Calculation of Metrics and Presentation of Data

After the noise data were processed, the desired noise metrics were calculated. For data reduction purposes, the A-weighted equivalent sound pressure level for each 5-minute-long data block at each measurement system, $L_{Aeq\ 5min,}$

[5] The manufacturer' specified accuracy for the model 4231 calibrator is 0.3 dB.

[6] Observer loggers were not present at all four microphones. Data collected from microphones without complete observer logs were subject to additional data processing, in order to accurately define and remove interference events. Since these interference events were much louder than the noise generated by the HARRP power plant (over 20 dB in most instances), the interference peaks were easily identified in the data sets and correlated with the observer logs from the manned microphone positions. 30-second-long L_{Aeq}s were calculated before and after (but not including) the perceived interference peak. Each interference event was then defined as when the noise data became louder than the corresponding 30-second-long L_{Aeq} plus two standard deviations.

[7] Due to the large number of interference events at Mic 9a attributed to traffic on the Tok Cutoff Highway, only three 5-minute-long data blocks went into the metric calculations for the Mic 9a data.

[8] It is important to note that these background noise levels were collected over a short period of time during the day in late autumn. Longer background noise measurements (as well as multiple background noise measurements) could have better characterized the ambient noise levels surrounding the HAARP facility. Furthermore, the background noise could have substantial variation from day to night and from season to season. Regardless, time and weather conditions did not allow for extensive background noise measurements, so the background noise levels used in this study were based on the best available data

and the corresponding, un-weighted 1/3-Octave spectrum were calculated according to the methodology presented in the January 2005 letter report. The $L_{Aeq\ 5min}$ metrics are presented in Appendix B, along with the maximum and minimum sound pressure levels and standard deviation across each data block. The associated spectral data are presented in Figure 4. Although separate noise measurements were made with the engine room door opened and closed, there were not significant differences between the noise levels (and spectra) from these separate measurements. Furthermore, the noise data at each microphone showed very little variation from one event to the next, and that repeatability from event to the next indicated that the HAARP engine-generator was very stable under full-load operation. Therefore, the data sets were combined, and the 30-minute-long, A-weight equivalent sound pressure levels, $L_{Aeq\ 30min}$, were then mathematically derived for each microphone from the corresponding valid $L_{Aeq\ 5min}$ values. The resultant $L_{Aeq,\ 30min}$ values are presented below in Table 2.

Table 2. The $L_{Aeq\ 30min}$ Values at Each Measurement Location

Microphone	Approximate Distance from HAARP (m)	$L_{Aeq\ 30min}$ Levels [dB(A)]
Mic 1	50	72.8
Mic 6a (estimated)	*50*	*68.0*
Mic 6b	100	62.7
Mic 6c	200	59.7
Mic 9a	200	57.1

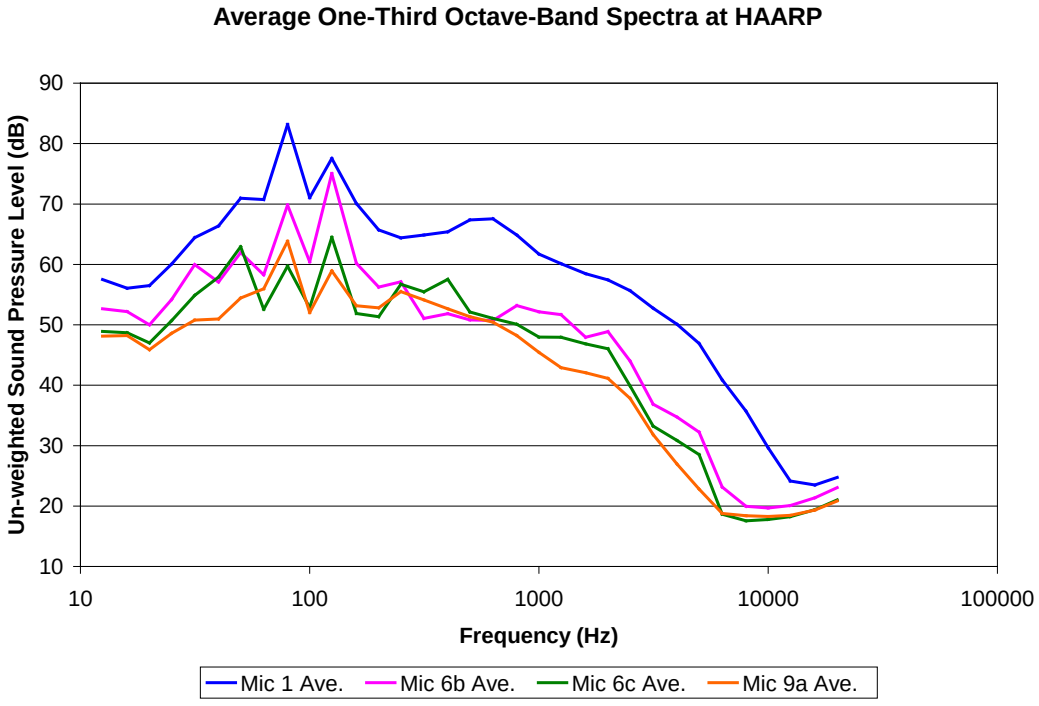

Figure 4. Average, Un-weighted One-Third Octave-Band Spectra at Each Measurement Location

As discussed in Section 4.2, there was not enough room to setup a microphone at 50 m from the HAARP installation along Mic Line 6, because of the new equipment garage. Therefore, the sound levels at 50m in Mic Line 6 had to be estimated. This was done by calculating an average drop-off rate per double of distance for the HAARP site, 5.5

dB[9], and applying it to the measured $L_{Aeq\ 5min}$ values for Mic 6b at 100 m (see Appendices B). The estimated $L_{Aeq\ 30min}$ at 50 m for Mic Line 6 was then calculated, and is also presented in Table 2. It should be noted that Figure 4 does not include an estimated one-third octave-band frequency spectrum for Mic 6a. It is not appropriate to apply a simple drop-off rate to a one-third octave-band spectrum, as the ground effect varies substantially with frequency.

The average $L_{Aeq\ 30min}$ across all of the 50 m microphones was then calculated, using energy-averaging as specified by ISO 6190. This average was based on the noise levels measured at Mic 1 and estimated at Mic 6a, which represent the loudest noise levels around the HAARP power plant as presented in the January 2005 letter report. L_{dn} values were also calculated based on the average $L_{Aeq\ 30min}$ making the assumption that those levels would be constant over a 24 hour period. Although, the HAARP facility will probably never broadcast a full load signal for 24 hours straight, these estimated L_{dn} values represent the loudest expected day-night sound levels that could be generated by the HAARP power plant. The average $L_{Aeq\ 30min}$ and L_{dn} values were presented in Table 3.

Table 3. HAARP Average Metrics at 50 m

Microphone	Metrics	Ave. Level [dB(A)]
Average	Ave. $L_{Aeq\ 30min}$	71.1
Average	Ave. L_{dn}	77.5

The $L_{Aeq\ 30min}$ and L_{dn} metrics were also calculated for Mic 9a, since this microphone location represented the closest potential residence to the HAARP power plant. These values are all presented in Table 4.

Table 4. HAARP Metrics at Mic 9a

Microphone	Metrics	Ave. Level [dB(A)]
Mic 9a	$L_{Aeq\ 30min}$	57.1
Mic 9a	L_{dn}	63.5

In much the same manner as the Mic 6a results were estimated at 50m, the average drop-off rate was applied to the average $L_{Aeq\ 30min}$, in order to estimate noise levels at distances further away from the HAARP facility. This was a rough estimate based on the average drop-off rates observed on two Mic Lines at the HAARP facility. Long distance propagation effects, such as meteorological effects, were not considered. This presents a conservative prediction of noise levels that might be observed at various distances from the HAARP power plant[10]. These noise levels were estimated out to a distance of 3200 m (2 miles) from the HAARP facility, in order to account for the current nearest private residence. These results were then used to estimate average L_{dn} values out to 3200 m, which are used to determine compliance with the applicable regulations, and are discussed further in Section 6. They are presented in Table 5 (and later in Figure 9).

[9] Like in the 2005 report, the average drop-off rate presented in this report is the average of the drop-off rates from two different pairs of microphone locations: the drop-off between Mic 1(50 m) and Mic 9a (200 m), and the drop-off between Mic 6b (100 m) and Mic 6c (200 m). .

[10] When evaluating sound propagation, meteorological effects, ground effects, terrain blockage, scattering from foliage, and other propagation effects have a much more prominent impact on sound level degradation over long distances, than they do over short distances. By applying the measured short-distance drop-off rate to long distance sound level estimations, the likelihood of over-predicting estimated sound levels increases. These sound level estimations incorporate limited effects from meteorology and terrain, and are considered conservative.

Table 5. HAARP Noise Levels Estimated out to 3200 m from the Facility

Distance (m)	Ave. L_{dn} for 4 Engines [dB(A)]
50	77.5
100	72.0
200	66.5
400	61.1
800	55.6
1600	50.2
3200	44.7

6. Analysis

The analysis of the noise levels produced by the HAARP diesel engine-generators consist of a comparison between the measured noise levels from the current HAARP power plant and the extrapolated noise levels from the January 2005 letter report.

The average $L_{Aeq\ 30min}$ level for the HAARP facility at 50 m was 71.1 dB(A), and the corresponding, average L_{dn} was 77.5 dB(A). These are both 4.7 dB louder than the levels estimated from the January 2005 report (see Table 15). This difference may be attributed to two main factors. First, the current average $L_{Aeq\ 30min}$ and average L_{dn} for the HAARP facility were based on measurements at the loudest two microphone locations, whereas the results in the 2005 report were based on an average across eight different microphone locations with noise levels spanning a 24 dB range. Therefore, the current average noise levels are biased high by the omission of the quieter noise measurement positions, representing the "worst case" noise levels[11]. They may be considered conservative estimations of expected noise impacts.

Second, the changes made to the HAARP power plant since the 2004 study (raised directional exhaust ports, full antenna array loading, possible operational changes, etc.) could have directly impacted noise levels. One example of such a change can be seen in Figure 5, which shows that the newly raised engine exhaust ports are now visible from Mic 1 and Mic 9a, where the shorter exhaust stack was shielded by the HAARP main building from the property line in 2004. These changes in the characteristics of the noise generated by the HAARP power plant may be observed by comparing the average one-third octave-band noise spectra at several microphone positions common to both the 2004 and 2007 noise studies. These spectra at Mic 1, Mic 5/6b and Mic9/9a are presented in Figure 6, Figure 7 and Figure 8, respectively.[12] The spectra in these figures were normalized to 70 dB at 1,000 Hz in order to directly compare their frequency content and relative amplitude.

[11] For comparison purposes, the average $L_{Aeq\ 30min}$ from the 2004 study was recalculated using only the noise levels from the loudest measurement positions, Mics 1 and 6a. The recalculated average $L_{Aeq\ 30min}$ was 63.8 dB, which is 3.4 dB louder than the average $L_{Aeq\ 30min}$ presented in the January 2005 report that included contributions from Mics 1 through 8.

[12] Spectral data could not be compared at Mic 6b, because no spectral data were collected on Mic Line 6 during the 2004 study. Therefore, the Mic 6b spectral data from the 2007 study were compared with the Mic 5 spectral data from the 2004 study, since both microphone locations were on the exhaust port side of the HAARP power plant.

Figure 5. Raised Exhaust Ports at HAARP: View from Mic 1 (left) and View from Mic 9a (right)

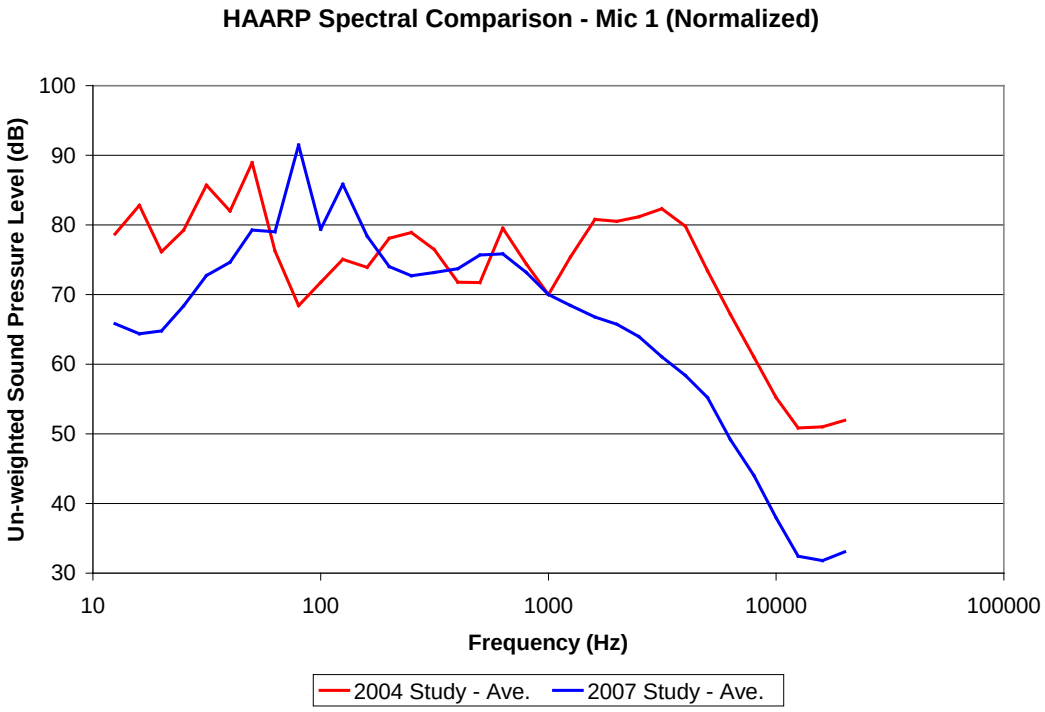

Figure 6. Frequency Comparison between the 2004 Noise Data and the 2007 Noise Data at Mic 1

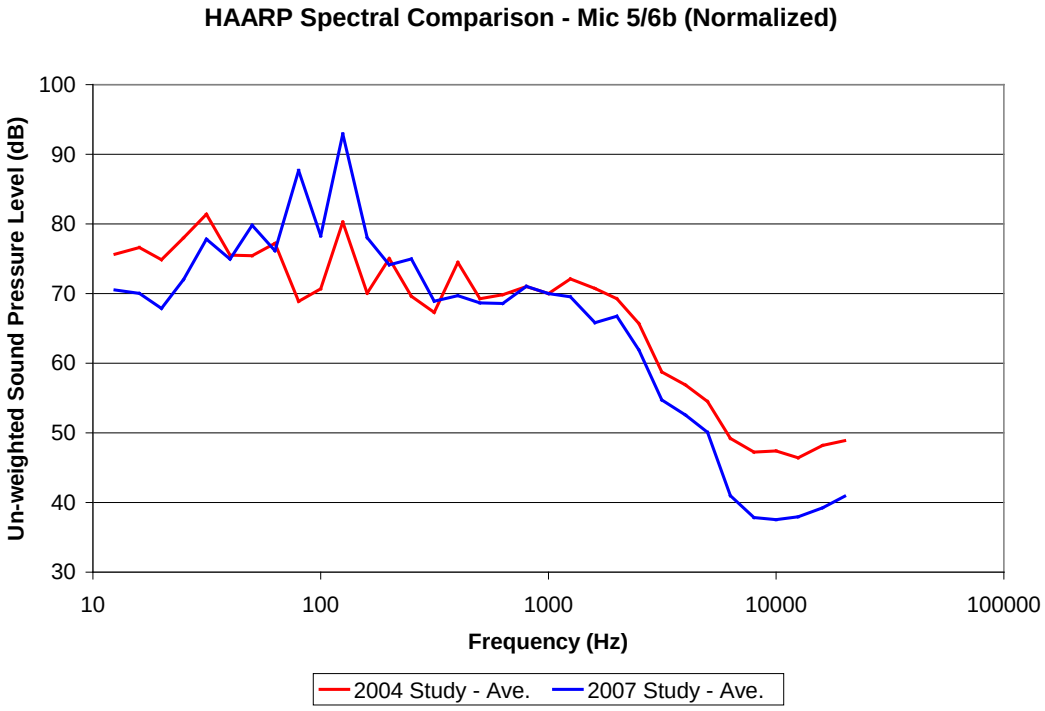

Figure 7. Frequency Comparison between the 2004 Noise Data and the 2007 Noise Data at Mic 5/6b

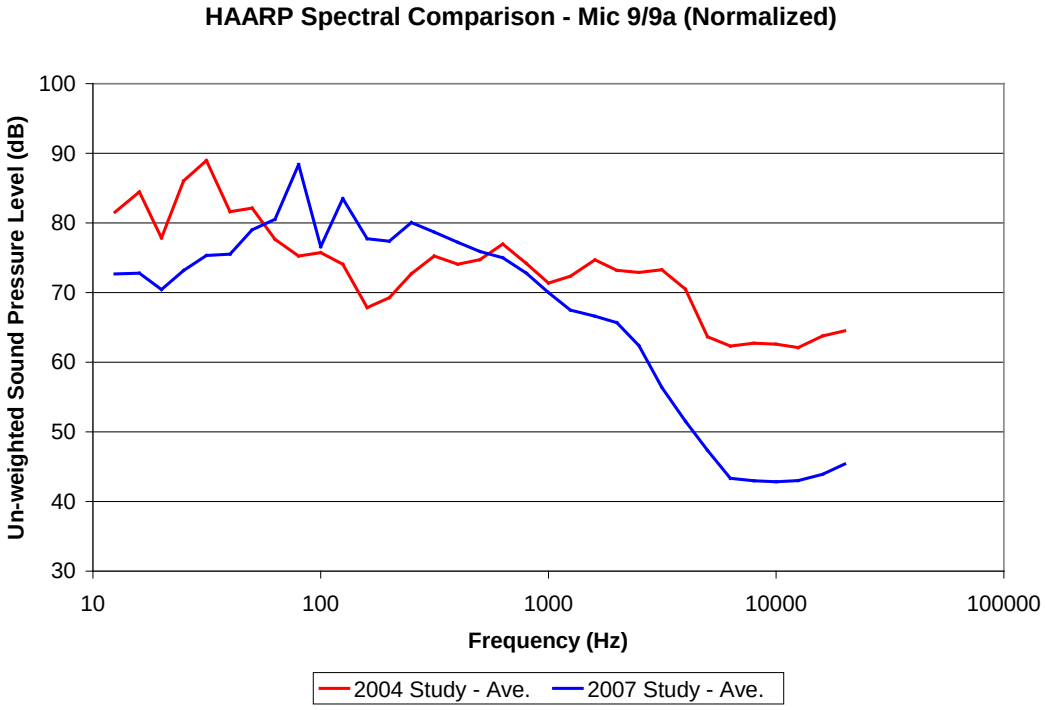

Figure 8. Frequency Comparison between the 2004 Noise Data and the 2007 Noise Data at Mic 9/9a

New tonal components were observed in the spectral data measured at these positions. While the Mic 1 average spectra showed peaks at 50 and 630 Hz rising as much as 10 dB higher than their neighboring 1/3-Octave bands, as well as a broader peak spanning from 1.6 kHz to 4 kHz in 2004, the current spectra does not have these peaks, and instead showed dominant peaks at 60 and 125 Hz rising as much as 10 dB higher than their neighboring 1/3-Octave bands, (see Figure 6). Mic 5 showed smaller peaks (around 5 to 7 dB) at 125 and 400 Hz in 2004, but the addition of an 80 Hz peak and a larger 125 Hz peak were observed in 2007 (see Figure 7). Additional changes were also observed at Mic 9a, including the emergence of peaks at 80 and 125 Hz (see Figure 8).[13] In general, these peaks should correspond to engine, generator and cooling fan operational parameters (blade speed, etc.), but this operational information was not collected on-site. Specifically, the 125 Hz peak was only observed at Mic 5 in 2004 (the exhaust port side of the HAARP facility), but was observed at all microphone locations in 2007; indicating that all microphone locations are now exposed to engine exhaust noise. An 80 Hz peak was also observed at all microphone locations, and may be attributed to engine exhaust noise, as well.

Next, the average L_{dn} level for the current HAARP power plant was extrapolated out to 3200 m (2 miles) and presented along with the average L_{dn} based on the 2004 data extrapolated to account for 4 diesel engine-generators and estimated out to 3200 m (see Figure 9). Along with the estimated noise levels as a function of distance, Figure 9 also illustrates the 65 dB L_{dn} noise impact thresholds from Table 1, along with both the 2004 and 2007 average background noise levels, to illustrate the potential variability in background noise near the HAARP site[14].

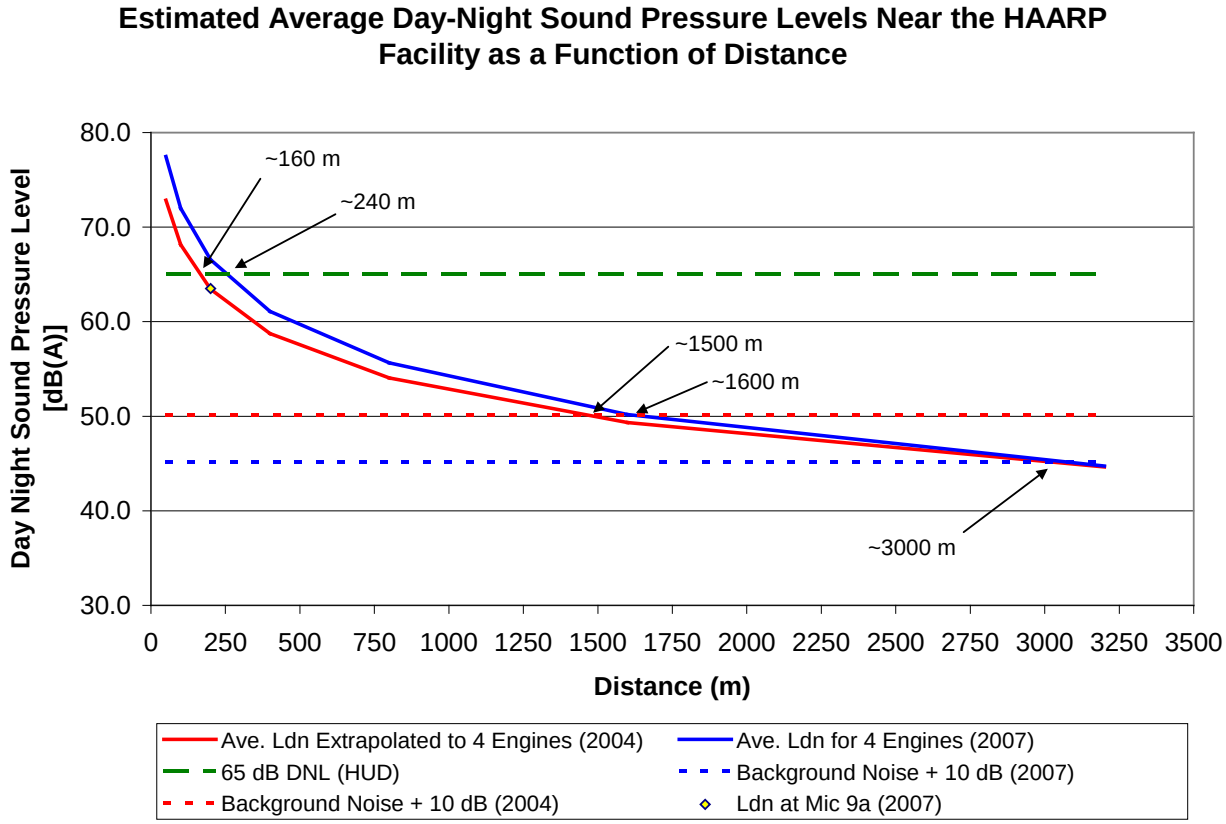

Figure 9. Comparison between Average L_{dn} Estimated out to 3200 m for the Current HAARP Power Plant and for the 2004 Power Plant Data Extrapolated to Account for 4 Engine-Generators

[13] A detailed comparison between the Mic 9a spectral data from 2007 and the Mic 9 spectral data from 2004 was not undertaken, because the later were considered to not be discernable from background noise in the January 2005 report.
[14] The stipulation of "Background Noise + 10 dB" found in the FTA regulations was used in this analysis, because it represents a level where the HAARP power plant noise is discernable from the background noise.

Figure 9 suggests that the L_{dn} due to the HAARP power plant would most likely drop below 65 dB at approximately 240 m (roughly the Tok Cutoff Highway), drop below the 2004 background noise levels plus 10 dB at approximately 1600 m, and drop below the 2007 background noise level plus 10 dB at approximately 3000 m.

Since the average HAARP noise levels were biased by the higher noise levels directed towards the center of the HAARP property, it was not surprising that the estimated average noise levels at 200 m were noticeably higher than the measured noise levels at Mic 9a, which were also approximately 200 m from the HAARP power plant building. This difference was due to (a.) the directionality of the HAARP noise output, and (b.) the lack of long distance propagation effects in the estimated levels, like blocked line-of-site.

It is important to note that the 200 m position represented the closest possible point a residence could be to the HAARP power plant, and that both the measured noise levels (Mic 9a) and the estimated noise levels were very close to the HUD criterion. The measured L_{dn} met the 65 dB criteria, but the estimated L_{dn} exceeded it. Even though these noise levels represent the worst case scenario where that power plant is operating at full load for a straight 24 hours, they are close enough to the criteria to be of concern.

7. Conclusions and Recommendations

Noise data were collected at numerous locations on the HAARP facility, and the resulting noise levels were compared against the estimated noise levels from the January 2005 letter report. In general, the current noise levels were found to be approximately 4-5 dB higher than the previously estimated levels. This difference was attributed to conservative estimations of expected noise impacts (average levels were based on the loudest microphone positions only) and changes to the HAARP power plant since the 2004 study, which altered its noise characteristics.

When considering potential noise impacts, the most applicable data set was collected at Mic 9a. Mic 9a was located approximately 200 m from the HAARP power plant installation and represents the closest piece of private property (field conditions required placement of the equipment within the highway right of way and not actually on private property) adjacent to the HAARP facility, although there is not currently a residential structure on that property. The noise levels for Mic 9a were compared to the noise criterion, in order to determine if the noise levels generated by the current HAARP power plant were in compliance with the applicable criteria should residential development ever be undertaken at this adjacent private property. The results of that comparison are presented below in Table 6.

Table 6. Noise Levels from the Current HAARP Power Plant Compared to the HUD Regulation

Agency Regulation and Guidance[15]	Metric	Compliance Level in dB(A)	Measured Level at Mic 9a in dB(A)	In Compliance (Yes/No)?
HUD	L_{dn}	$\leq$ 65 dB(A)	63.5 dB(A)	Yes

As seen in Table 6, the HAARP power plant is in compliance with the HUD noise criterion, as predicted in the January 2005 letter report. While these noise levels were above the background noise level at Mic 9a, but they should be much quieter than any other potential noise source in the area, such as noise from the Tok Cutoff Highway[16].

As presented in Section 6, the average noise levels generated by the HAARP power plant were also considered. It was estimated that the L_{dn} from the HAARP power plant would most likely drop below 65 dB at approximately 225 m (roughly the Tok Cutoff Highway), drop below the 2004 background noise levels plus 10 dB at approximately 1600 m, and drop below the 2007 background noise level plus 10 dB at approximately 3000 m (see Figure 9). Therefore, the maximum noise levels from the HAARP power plant are estimated to be in compliance with the HUD

[15] Presented in Table 1.
[16] Highway traffic-based noise level estimates are based on observer logs during the HAARP noise measurement study, as discussed in Section 5.1. They are not based on a highway noise analysis.

criterion within approximately 40 m of the HAARP property line. These compliance results are the same as those predicted in the January 2005 letter report.

It was also noted in Section 6 that new tonal components were observed in the spectral data measured in 2007 when compared with the 2004 data. Of most concern was a 125 Hz peak that was previously only observed on the exhaust port side of the HAARP facility was now observed at all microphone locations in 2007 along with an 80 Hz peak; indicating that all microphone locations are now exposed to engine exhaust noise. Although noise mitigation is not required as a result of this analysis it is possible that some of this exhaust noise could be diverted away from the Tok Cutoff Highway (and the nearest property line) by installing a noise barrier on top of the HAARP power plant's roof between the exhaust stacks and the highway, in order to reflect some of the exhaust noise towards the main HAARP antenna array. Typical barriers could reduce noise levels up to 5 to 10 dB at the closest potential residence, if the line-of-sight between the receiver and the noise source is blocked. If such a noise barrier were to be installed, a follow-up noise measurement study to assess its effectiveness is recommended.

Of particular interest were noise levels at the current, nearest residential structures, approximately 3200 m (2 miles) away from the HAARP Facility. Resources did not allow for direct measurements at this location, but estimates were made based on the measurements that were conducted, along with conservative propagation and plant operational characteristics, as discussed in Section 5.2. The sound level estimated at 3200 m is compared with the applicable noise criteria in Table 7.

Table 7. Estimated Noise Levels from the Existing HAARP Power Plant at a Distance of 3200 m Compared to the Appropriate Standards and Regulations

Agency Regulation and Guidance	Metric	Compliance Level in dB(A)	Estimated Level at 3200 m in dB(A)	In Compliance (Yes/No)?
HUD	L_{dn}	≤ 65 dB(A)	44.7 dB(A)	Yes

As seen above, the HAARP power plant was estimated to be in compliance with the HUD regulation concerning noise levels at the current nearest residential structure. These noise levels will be most likely above the background noise level, but they should be much quieter than any other potential noise source in the area, such as noise from the Tok Cutoff Highway.

This analysis leads to the conclusion that under existing conditions the HAARP facility is in compliance with applicable noise regulations. However, both the measured and estimated noise levels near the Tok Cutoff Highway (Mic 9a, representing the closest possible point a residence could be to the HAARP power plant) were very close to the HUD compliance criterion (the measured L_{dn} met the 65 dB criteria, but the estimated L_{dn} exceeded it). Even though these noise levels represent the worst case scenario where that power plant is operating at full load for a straight 24 hours, they are close enough to the criteria to be of concern. If future private home construction did take place across and immediately adjacent to the Tok Cutoff Highway, noise mitigation may be appropriate. However, it is unlikely that a home would be built adjacent to the highway on a site that is predominately black spruce wetlands and a more traditional location would be much further east on the bluff overlooking the Copper River. Since the current, nearest residential structure to the HAARP facility is approximately 3200 m away, no noise impact is expected from the expanded facility at that location. If any additional changes were made to the HAARP engine-generator, exhaust system (including mufflers) or cooling system designs, a follow-up noise study is recommended, in order to verify that these changes to the HAARP power plant did not result in a violation of applicable noise regulations.

Finally, it is important to note that these estimated noise levels were based on the worst case scenario; 24 hour operation of the HAARP power plant at full loading. Operational planning measures, such as limiting power plant operational time to less than 24 hours a day with the majority of the hours happening during the daytime or operating at less than full loading, should result in noise levels lower than estimated.

Appendix A. Results from the January 2005 Report

The following results are reprinted from the January 2005 letter report "HAARP Diesel Engine-Generator(s) Noise Study."

Table 8. The $L_{Aeq\ 30min}$ Values at Each 50 m Measurement Location (2004 Data)

Microphone	$L_{Aeq\ 30min}$ Levels [dB(A)]
Mic 1	61.9
Mic 2	63.3
Mic 3	56.5
Mic 4b	59.8
Mic 5	55.3
Mic 6a	65.1
Mic 7	49.3
Mic 8	41.2

Table 9. HAARP Average Metrics at 50 m (2004 Data)

Microphone	Metrics	Ave. Level [dB(A)]
Average	Ave. $L_{Aeq\ 30min}$	60.4
Average	Ave. L_{dn}	66.8

Table 10. HAARP Metrics at Mic 9 (2004 Data)

Microphone	Metrics	Ave. Level [dB(A)]
Mic 9	$L_{Aeq\ 20min}$	41.0
Mic 9	L_{dn}	47.4
Mic 9	L_{90}	39.7

Table 11. HAARP Noise Levels Estimated out to 3200 m from the Facility (2004 Data)

Distance (m)	Ave. L_{dn} for 1 Engine (estimate) [dB(A)]
50	66.8
100	62.1
200	57.4
400	52.7
800	48.0
1600	43.3
3200	38.6

Table 12. HAARP Noise Levels Extrapolated to Account for 5 Engine-Generators Estimated out to 3200 m from the Facility (2004 Data)

Distance (m)	Extrapolated Ave. L_{dn} for 5 Engines (estimate) [dB(A)]
50	73.8
100	69.1
200	64.4
400	59.7
800	55.0
1600	50.3
3200	45.6

Table 13. HAARP Background Noise Data (2004 Data)

Microphone	Metrics	Background Noise Level [dB(A)]
Mic 1	Background noise L_{Aeq}	37.9
Mic 5	Background noise L_{Aeq}	38.5
Mic 6a	Background noise L_{Aeq}	37.2
Mic 6b	Background noise L_{Aeq}	38.2
Mic 9	Background noise L_{Aeq}	40.1
Ave.	**Background noise L_{Aeq}** (based on Mics 1, 5 and 6a.)	**37.9**

Table 14. HAARP Noise Levels Extrapolated to Account for 4 Engine-Generators Estimated out to 3200 m from the Facility (2004 Data, recalculated)

Distance (m)	Extrapolated Ave. L_{dn} for 4 Engines (estimate) [dB(A)]
50	72.8
100	68.1
200	63.4
400	58.7
800	54.0
1600	49.3
3200	44.6

Table 15. Select HAARP Metrics Extrapolated to Account for 4 Engine-Generators (2004 Data, recalculated)

Microphone	Extrapolated Ave. Metrics for 4 Engines (estimate) [dB(A)]	Ave. Level [dB(A)]
Ave.	$L_{Aeq\ 30min}$	66.4
Ave.	L_{dn}	72.8
Mic 9	$L_{Aeq\ 30min}$	47.0
Mic 9	L_{dn}	53.4

Appendix B. HAARP Noise Data (including Background Noise) and Position Data from 2007

The processed noise data from the September 2007 HAARP power plant noise measurements are presented below, along with the GPS coordinates of the measurement site.

Table 16. HAARP Noise Data for Each Individual Microphone and Data Block (2007 Data)

Microphone (Location)	Metrics	5-minute-long Data Blocks [dB(A)]				
		1st	2nd	3rd	4th	5th
Mic 1 (50 m)	$L_{Aeq\ 5min}$	73.0	72.8	72.8	72.9	72.7
	Max levels	74.2	74.1	74.1	73.6	73.4
	Min levels	71.4	72.1	72.1	72.2	71.8
	Standard deviations	0.5	0.3	0.3	0.3	0.3
Estimated Mic 6a (50 m)	Mic 6b $L_{Aeq\ 5min}$ with Ave. Drop-Off	67.8	67.9	68.4	68.5	68.2
Mic 6b (100 m)	$L_{Aeq\ 5min}$	62.3	62.5	62.9	63.0	62.7
	Max levels	64.9	65.1	65.1	66.0	65.0
	Min levels	57.5	60.4	60.4	57.0	60.5
	Standard deviations	1.0	0.7	0.7	1.4	0.9
Mic 6c (200 m)	$L_{Aeq\ 5min}$	59.3	59.3	59.2	59.9	60.5
	Max levels	61.8	61.8	61.8	62.9	62.7
	Min levels	55.9	56.5	56.5	57.1	58.5
	Standard deviations	0.9	1.0	1.0	1.1	0.7
Mic 9a (200 m)	$L_{Aeq\ 5min}$	58.1	57.1	N/A	N/A	56.1
	Max levels	64.9	59.6	N/A	N/A	58.5
	Min levels	55.5	54.4	N/A	N/A	51.8
	Standard deviations	1.1	1.1	N/A	N/A	1.4
	L_{10}	59.1	58.6	N/A	N/A	57.3
	L_{99}	55.5	54.9	N/A	N/A	51.9
	L_{90}	56.6	55.7	N/A	N/A	53.8

Table 17. HAARP Background Noise Data (2007 Data)

Microphone	Metrics	Background Noise Level [dB(A)]
Mic 1	$L_{Aeq\ 5min}$	38.4
Mic 6b	$L_{Aeq\ 5min}$	33.5
Mic 6c	$L_{Aeq\ 5min}$	32.0
Mic 9a	$L_{Aeq\ 5min}$	33.6
Ave.	**$L_{Aeq\ 5min}$**	**35.1**

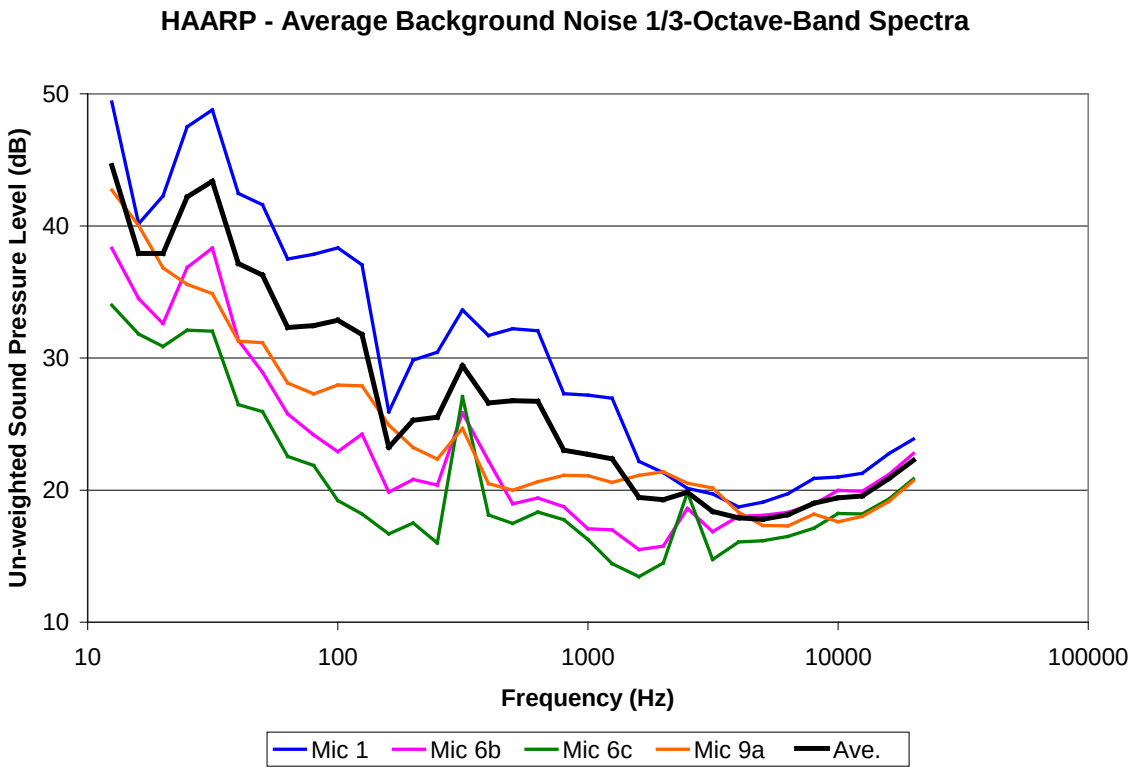

Figure 10. Average, Un-weighted One-Third Octave-Band Background Noise Spectra at Each Measurement Location

Table 18. HAARP Measurement Site Position Data (2007 Data)

Position[17]	Nearest Noise Source	Approximate Position Relative to Nearest Noise Source (m)	GIS Measured Position Relative to Nearest Noise Source (m)	GPS Coordinates	Comments
Mic 1	GF1	50	50.6	N 62°23.462' W 145°07.694	
Mic 6a	001	50	---	N 62°23.527' W 145°07.774'	Microphone Position from 2004 Study
Mic 6b	001	100	105	N 62°23.556' W 145°07.786'	
Mic 6c	001	200	214.7	N 62°23.594' W 145°07.914'	
Mic 9	GF1	200	223.4	N 62°23.442' W 145°07.492'	
GBD	---	---	---	N 62°23.482' W 145°07.777'	Generator Bay over head door
001	---	---	---	N 62°23.500' W 145°07.769'	Corner of generator bay closest to exhaust stack for Generator #1
GF1	---	---	---	N 62°23.480' W 145°07.738'	Generator #1 cooling fan

[17] These positions correspond with those displayed in Figure 2

Table 19. Noise Levels from the Current HAARP Power Plant Compared to the Applicable Federal Standards and Regulations Taken into Consideration

Agency Regulation and Guidance[18]	Metric	Compliance Level in dB(A)	Measured Level at Mic 9a in dB(A)	In Compliance (Yes/No)?
EPA, FRA	L_{90}	≤ 67 dB(A))	55.5 dB(A)	Yes
FAA	L_{dn}	≤ 65 dB(A)	63.5 dB(A)	Yes
HUD	L_{dn}	≤ 65 dB(A)	63.5 dB(A)	Yes
FTA	L_{dn}	≤ 45.1 dB(A)[19]	63.5 dB(A)	**No**

Table 20. Estimated Noise Levels from the Existing HAARP Power Plant at a Distance of 3200 m Compared to the Applicable Federal Standards and Regulations Taken into Consideration

Agency Regulation and Guidance[20]	Metric	Compliance Level in dB(A)	Estimated Level at 3200 m in dB(A)	In Compliance (Yes/No)?
FAA	L_{dn}	≤ 65 dB(A)	44.7 dB(A)	Yes
HUD	L_{dn}	≤ 65 dB(A)	44.7 dB(A)	Yes
FTA	L_{dn}	≤ 45.1 dB(A)	44.7 dB(A)	Yes

[18] Specific Regulations and Policies are presented in Table 1.
[19] The L_{Aeq} of the background noise at Mic 9 was equal to 35.1 dB(A), and the criteria does specify a L_{dn} of less than or equal to the ambient noise level + 10 dB.
[20] Specific Regulations and Policies are presented in Table 1.

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