Sound exposure level duration adjustments in UAS rotorcraft noise certification tests

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13. ABSTRACT (Maximum 200 words)
This report documents work done to support the FAA's development of Unmanned Aerial Systems (UAS) noise certification and noise measurement criteria. The report discusses the applicability of the Code of Federal Regulation Title 14, Part 36, Appendix J, section J36.205(b) for UAS noise certification. The duration correction in the Appendix J noise certification standard was developed based on observations of aircraft operations in the 1980s. A noise measurement program conducted on a small UAS vehicle at Stow Massachusetts showed that this vehicle's noise characteristics are not well modeled by the Appendix j duration correction. The report concludes that the Appendix J duration correction should not be used to extrapolate noise measurements at closer distances to the Appendix J fly-over height.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
AREA				
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: volumes greater than 1000 L shall be shown in m^3				
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
oz	ounces	28.35	grams	g
TEMPERATURE (exact degrees)				
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
ILLUMINATION				
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
FORCE and PRESSURE or STRESS				
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
AREA				
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
VOLUME				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
mL	milliliters	0.034	fluid ounces	fl oz
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
g	grams	0.035	ounces	oz
TEMPERATURE (exact degrees)				
°C	Celsius	1.8C+32	Fahrenheit	°F
ILLUMINATION				
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
FORCE and PRESSURE or STRESS				
N	newtons	0.225	poundforce	lbf
kPa	Kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

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We thank Jack Buckley and the other members of the Crow Island Airpark community in Stow, Massachusetts for graciously allowing us to use their airport to test our drones.

The work would not have been possible without the assistance of Bob Samiljan and Jordan Cumper during the field measurements of the UAS.

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List of Abbreviations

Abbreviation	Term
AMA	Academy of Model Aeronautics
CPA	Closest Point of Approach
CFR	Code of Federal Regulations
dB	decibel
dGPS	differential Global Positioning System
FAA	Federal Aviation Administration
GPS	Global Positioning System
Hz	Hertz (unit of frequency)
IGPM	Inverted Ground Plane Microphone
LAmax	Maximum A-weighted noise level
MOP	Microphone on Plate
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NPS	National Park Service
PVT	Position-Velocity-Time
RC	Radio Control
RF	Radio Frequency
RPM	Revolutions per Minute
SBAS	Satellite based augmentation system
SEL	Sound exposure level
sUAS	Small unmanned aerial system
TiSPI	Tiny Space Position Instrumentation
TSPI	Time-Space-Position Information
UAS	Unmanned Aerial System
UAV	Unmanned Aerial Vehicle

Executive Summary

This report documents a flight test conducted at Stow, Massachusetts on a small Unmanned Aerial System (sUAS) vehicle on September 7, 2018. The purpose of the flight test was to determine the applicability on sUAS rotorcraft of the duration correction for altitude found in noise certification standards for manned helicopters. The manned helicopter correction does not explicitly include an altitude range restriction, though the flyover test conditions do restrict the altitude deviations to ±50 feet of altitude.

Data collected during the flight test showed that the manned helicopter duration correction in the certification standards do not adequate capture the effects on changing altitudes on the measured noise levels of the sUAS vehicle. The implication of this finding is that noise certification of sUAS rotorcraft under Appendix J should only be conducted at the Appendix J specified altitude; the duration correction in the standard is not adequate to compensate for lowering the height of the flyover to accommodate quieter vehicles.

Additional research is needed to determine how to accommodate noise certification of quieter sUAS vehicles under Appendix J or a different noise certification standard.

1. Introduction

The Federal Aviation Administration (FAA) expects Unmanned Aerial System (UAS) vehicles to become more prevalent in the National Airspace System (NAS) in the near future (1). Current regulations require that prior to operating in the NAS, aircraft must be certificated to noise standards based on the classification of the vehicle. An exception currently exists for aircraft designed for fire-fighting and agricultural operations. Small UAS (sUAS) – vehicles of 55 lb MTOW and under – which can operate under Code of Federal Regulations (CFR) Title 14, Part 107 are also currently exempt from noise certification. sUAS vehicles which don't operate under Part 107 rules are currently required to be noise certificated.

UAS and sUAS rotorcraft manufacturers that desire to have their vehicles operate in the NAS must currently have those vehicles certificated under CFR Title 14, Part 36, Appendix H or Appendix J. We expect most sUAS manufacturers to pursue Appendix J certification, due to the simpler requirements compared to Appendix H. An issue arises if the sUAS rotorcraft vehicles generate noise levels which are low enough to not permit adequate Sound Exposure Level (SEL) measurements at the prescribed Appendix J height above the ground. This report discusses the implications of attempting to apply the existing altitude correction methods in Appendix J to overcome this issue.

This report is part of a larger FAA effort to adequately protect the environment and people exposed to UAS operations while promoting the growth of the UAS industry (2).

2. Purpose

Aircraft noise certification provides a method of directly comparing noise levels between different aircraft in the same vehicle classification. The current aircraft noise certification tests which are most applicable to UAS vehicles are the CFR Title 14, Part 36, Appendix G methods and procedures (“Appendix G”) for fixed-wing, propeller-driven UAS, and CFR Title 14, Part 36, Appendix J (“Appendix J”) for rotary-wing UAS (3). The rotary-wing certification under Appendix J is the primary focus of this report due to the majority of UAS vehicles currently operating in the United States using rotary-wing propulsion and lift.

The certification methods in Appendix J allow for corrections to measured data during the test to account for expected imperfections in the data collection process. Of particular interest is the duration correction discussed below since this correction potentially allows the operator to fly the vehicle at an altitude other than that prescribed in Appendix J. This altitude allowance is important since small UAS (sUAS) may not have an adequate acoustic signal-to-noise ratio at the prescribed altitude. Deliberately lower the fly-over altitude of the vehicle during the test may beneficially improve the acoustic signal-to-noise ratio, but the altitude deviation may be outside of the expected range where the Appendix J duration correction can be properly applied.

2.1 Duration correction in Appendix J

The duration correction for small helicopter is defined in Appendix J, section 205(b). The section states:

> *The adjustment for off-reference altitude may be approximated from:*
> *<delta>J_1 = 12.5 $\log_{10}(H_T/492)$ dB;*
> *where <delta>J_1 is the quantity in decibels that must be algebraically added to the measured SEL noise level to correct for an off-reference flight path, H_T is the height, in feet, of the test helicopter when directly over the noise measurement point, and the constant (12.5) accounts for the effects on spherical spreading and duration from the off-reference altitude.*

The constant 12.5 factor includes the standard spherical spreading relationship:

$$\Delta_{\text{Spherical}} = 20 \log_{10} (H_T/H_B)$$

In this equation, H_T represents the actual height of the vehicle during the test in units of feet, H_B represents the base height in units of feet, which equals 492 feet for Appendix J tests.

The duration correction is the remaining effect:

$$\Delta_{\text{Duration}} = -7.5 \log_{10}(H_T/H_B)$$

This duration effect is similar to the duration effect equation (B6) in Appendix B of SAE-AIR-1845 (4).

2.2 Duration correction applied to rotorcraft sUAS

The duration correction in SAE-AIR-1845 is explicitly stated to be an empirical adjustment based on experimental results. Past helicopter noise measurements, such as those conducted by Newman (5) and Rickley (6) discuss duration adjustments. These tests were conducted with full sized, crewed helicopters at the normal level over-flight distance of 492 feet. The Newman report states that "it would be unnecessary to develop unique constants for different helicopter models for use in implementing durations correction" (page 67). However, the duration adjustment in the Newman report was only based on speed differences, not altitude. The Rickley report uses a $-10\log_{10}$ relationship between the reference height and closest points of approach during the test; no discussion of the derivation of the relationship is given.

Applying the duration correction developed for crewed helicopters to UAS or sUAS certification flight tests may not be appropriate due to the significantly different heights that may be required during testing.

3. Measurement Setup and Procedures

In order to determine if the Appendix J duration correction adjustment is appropriate for sUAS noise flight tests, we conducted a flight test on a DJI Phantom 3 Advanced sUAS ("DJI"). The flight test was conducted at Crow Island Airpark in Stow, Massachusetts on September 7, 2018. The flight test consisted of a number of level flights over a set of microphones. The passes were conducted at the same ground speed so that only the altitude varied between pass series. Each pass series was flown in alternate opposite directions over the microphones to minimize any effects due to winds.

Two microphone setups were used – an Appendix J setup with a 4 foot pole mounted microphone and an Appendix G setup with an inverted ground plane microphone. The Appendix G setup was added to the test to provide a comparison between the two different certification microphone methods.

3.1 Measurement setup

The equipment set-up for the Appendix J setup is given in section 3.1.1 below. The setup for the ground-plate mounted Appendix G test is similar, other than the placement of the microphone on the ground-plate.

3.1.1 Acoustics

The acoustic instrumentation setup (as diagramed in Figure 1 below), consisted of a Sound Devices 744T audio recorder, Larson Davis 831 sound level meter, G.R.A.S. 40-AD pressure-response microphone, PRM831 pre-amplifier. The microphone/pre-amp combination was setup on a 4 ft. (1.2m) tripod, with the mic angled so the diaphragm to be at grazing incidence with the flight path. Acoustic data from the LD831 and 744T were both time synchronized to UTC using GPS antennas and a MasterClock GPS200A timecode generator. Audio was recorded on the 744T at 24-bit depth, 44.8 kHz sample rate to provide adequate dynamic range and frequency response. Raw audio data can be reprocessed to obtain acoustic metrics not collected on the measurement day. The LD831 sound level meter collected Z-weighted (unweighted) 1/3 octave band data at a 2 Hz sample rate, along with other metrics such as slow A-weighted SPL (LAS).

3.1.2 Meteorology

Continuous meteorological data was collected concurrently with acoustic data using a Vaisala WXT-520 weather sensor, connected via USB to the LD831 sound level meter. Meteorological data included wind speed, wind direction, temperature, and relative humidity, along with averages of those data points for each acoustic "event", and overall averages.

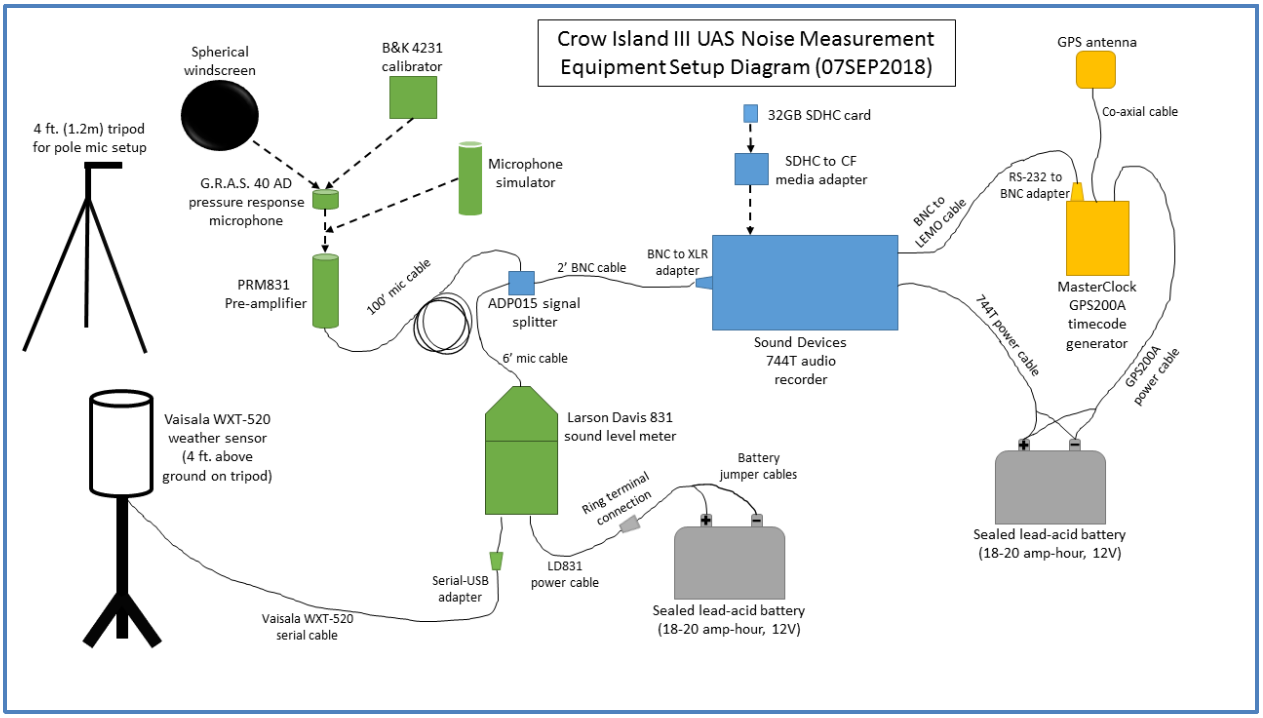

Figure 1. Sample equipment setup during flight test

Figure 2 below shows a photograph of the two microphones in place at Crow Island Airpark. The view in the photograph is looking east along the runway. The different altitude series were conducted in alternating east-west passes over the microphones.

Figure 2. Microphones at Crow Island Airpark

3.2 Measurement procedures

The DJI operates with the ability to fly completely autonomously; however, the built-in DJI control system did not allow the setting of both waypoint position information and altitude information for autonomous flight, so a 3rd-party application which allowed for pre-defined waypoints and altitudes was used for flight control. The microphones were setup between the eastern and western waypoints, with the intention that the waypoints were far enough away from the microphones so that the DJI would be in stable flight (i.e. the acceleration up to cruising speed was complete) at the 10 dB down points before the microphone along the flight path. The DJI uses the rotor thrust to decelerate from cruise speed, so the vehicle's noise signature during both acceleration and deceleration is not the same as the cruise mode noise.

The DJI recorded position and altitude information during the measurements. This internally recorded data was used to determine the DJI's position during post-processing. The DJI did carry a Volpe-developed dGPS tracking system during the test, but several of the flight test series were not recorded by the Volpe system. Because of the data drop-outs from the Volpe tracking system, those data were not used.

4. Summary of measured data

This section of the report presents a summary of the data collected during the flight test with the Appendix J set-up. Each sub-section discusses the data collected in a particular series of the flight test. Appendix B provides additional data.

4.1 25 foot series

The flight test series with 25 foot nominal heights over the ground was conducted in two separate groups of passes. Table 1 below presents a summary of the data collected during this series. Passes 1 through 5 were flown starting at about 10:45 am local time. Passes 6 through 10 were flown at about 12:30 pm local time. We considered the first group of passes to be adequate, but we had remaining battery power in the DJI at the end of the flight test and elected to repeat what we considered the most difficult set of passes due to their close proximity to the microphones.

Table 1. Summary of data from 25 foot overflight series for pole-mounted microphone

Pass	Direction of pass	Slant range (feet)	LAMax	SEL
1	East	19.0	66.2	69.1
2	West	21.4	66.1	69.0
3	East	24.7	66.2	69.0
4	West	25.6	65.9	68.8
5	East	27.2	65.8	69.1
6	East	21.4	66.8	69.8
7	West	25.7	66.0	69.0
8	East	27.7	67.5	70.4
9	West	25.4	65.9	69.0
10	East	26.8	67.6	70.4

4.2 50 foot series

The flight test series with 50 foot nominal altitudes over the ground was also conducted in two separate groups of passes. Table 2 below presents a summary of the data collected during this series. Passes 1 through 5 were flown starting at about 11:00 am local time. Passes 6 through 10 were done at about 11:20 pm local time. We considered the first group of passes to be possibly contaminated by extraneous ambient noise, so we repeated the 50 foot runs after the completion of the 100 foot series when ambient noise levels were lower. Examination of the data shows there is little difference between the two groups, so we consider both groups of data to be equally representative; both groups were included in the analysis.

Table 2. Summary of data from 50 foot overflight series for pole-mounted microphone

Pass	Direction of pass	Slant range (feet)	LAMax	SEL
1	East	44.9	61.8	66.1
2	West	44.5	61.4	65.6
3	East	46.5	61.8	65.9
4	West	45.7	61.2	65.6
5	East	47.7	61.5	65.6
6	East	40.6	61.8	66.2
7	West	38.7	61.8	66.0
8	East	37.2	62.1	66.2
9	West	39.6	62.3	66.2
10	East	42.7	62.3	66.1

4.3 100 foot series

The flight test series with 100 foot nominal altitudes over the ground was conducted in a single group of passes. Table 3 below presents a summary of the data collected during this series. Passes 1 through 6 were flown starting at about 11:10 am local time. No issues were noted during this series.

Table 3. Summary of data from 100 foot overflight series for pole-mounted microphone

Pass	Direction of pass	Slant range (feet)	LAMax	SEL
1	East	87.2	57.2	63.4
2	West	89.8	55.7	62.0
3	East	90.5	57.5	63.5
4	West	96.4	56.2	62.0
5	East	93.8	57.0	63.0
6	West	96.6	57.0	63.8

4.4 200 foot series

The flight test series with 200 foot nominal altitudes over the ground was conducted in a single group of passes. Table 4 below presents a summary of the data collected during this series. Passes 1 through 5 were flown starting at about noon local time. Prior to beginning this series, the west and east waypoints defining the autonomous track were moved farther to the west and east, respectively, to ensure that the DJI could accelerate and decelerate at the beginning and ending of each pass without influencing the noise measured during the cruise portion of the flight. Moving the waypoints farther from the microphones also ensured that the 10 dB down points were adequately captured. Note that we also ran a nominal 400 foot series, but the noise levels of the DJI did not rise to 10 dB above the ambient for the measurement by the Appendix J pole-mounted microphone; the Sound Exposure Levels measured by the Appendix G ground-plate microphone *did* reach above the ambient by 10 dB.

Table 4. Summary of data from 200 foot overflight series for pole-mounted microphone

Pass	Direction of pass	Slant range (feet)	LAMax	SEL
1	East	186.4	52.8	61.1
2	West	186.1	51.4	60.3
3	East	187.7	52.5	60.7
4	West	189.3	51.0	59.5
5	East	188.8	52.3	60.3

Figure 3 below presents the slant distance and the Sound Exposure Levels for the data in Table 1 through Table 4. The slant distances shown here are the distances from the pole-mounted microphone to the reported position of the DJI at its closest point of approach to the microphone. This differs slightly from the Appendix J definition of the distances used in the duration correction. The Appendix J definition uses the reported altitude of the vehicle above the ground, not the slant distance of the vehicle to the microphone. For the Appendix J test, ignoring the influence of the microphone height on the pole is reasonable, since the altitude of the vehicle is two orders of magnitude greater than the microphone height. For this duration test, however, the lowest series of overflights was conducted at nominal altitudes of 25 feet; Table 1 shows the lowest pass at about 19 feet, which is only a factor of about fiver greater than the microphone height. At these relatively close distances, the slant range was considered more meaningful than the altitude.

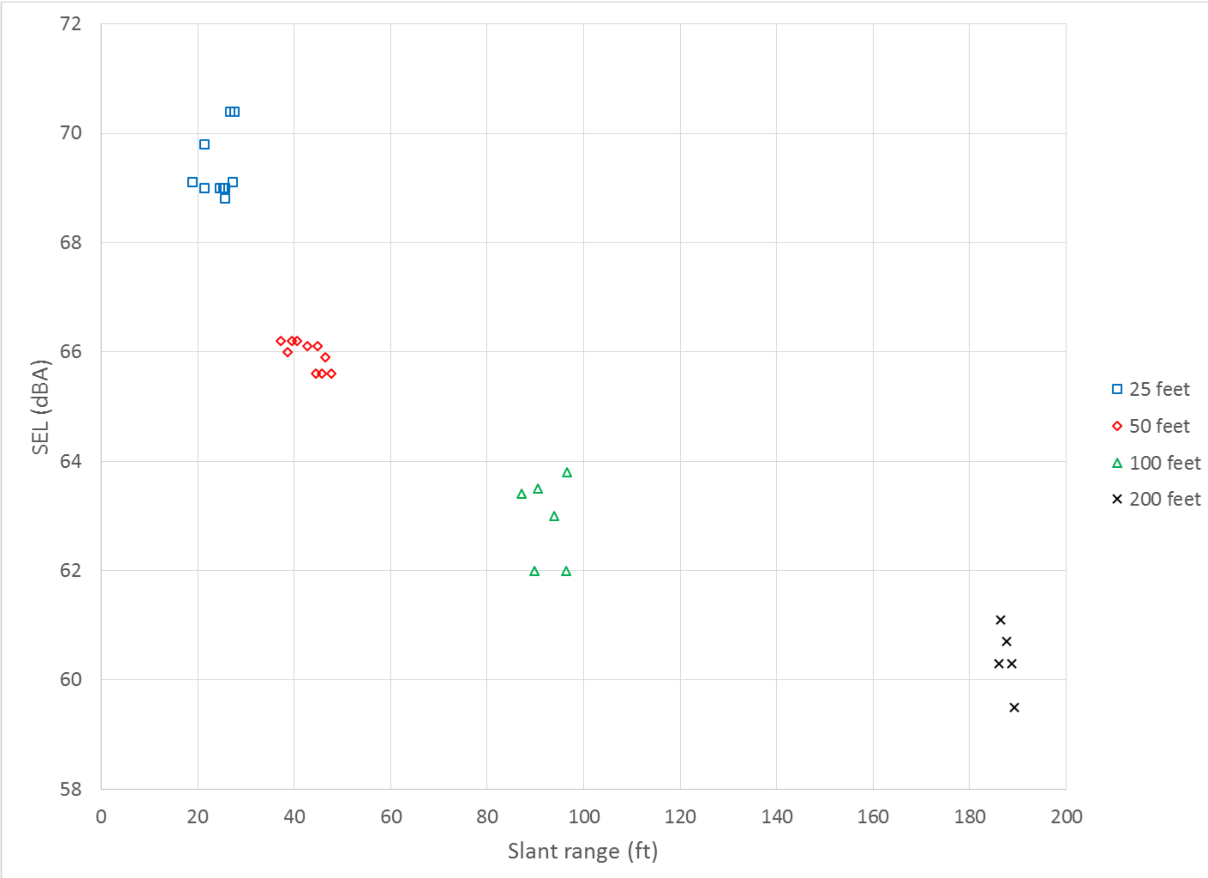

Figure 3. Sound exposure levels for DJI Phantom 3 in cruise flight measured by pole-mounted microphone

4.5 Pole-mounted and ground-plate comparison

The data for the Appendix G ground plate microphone are given in Appendix A in a format similar to the tables above. A summary graphic showing the differences in the measured noise levels of the two systems is given in Figure 4 below.

As expected, the Appendix J pole-mounted microphone measures lower noise levels than the Appendix G ground plate microphone. This is due to the pole microphone experiencing some destructive interference between the direct and ground-reflected sound, while the ground plate microphone experiences the direct and reflected sound as always in phase except at very high frequencies.

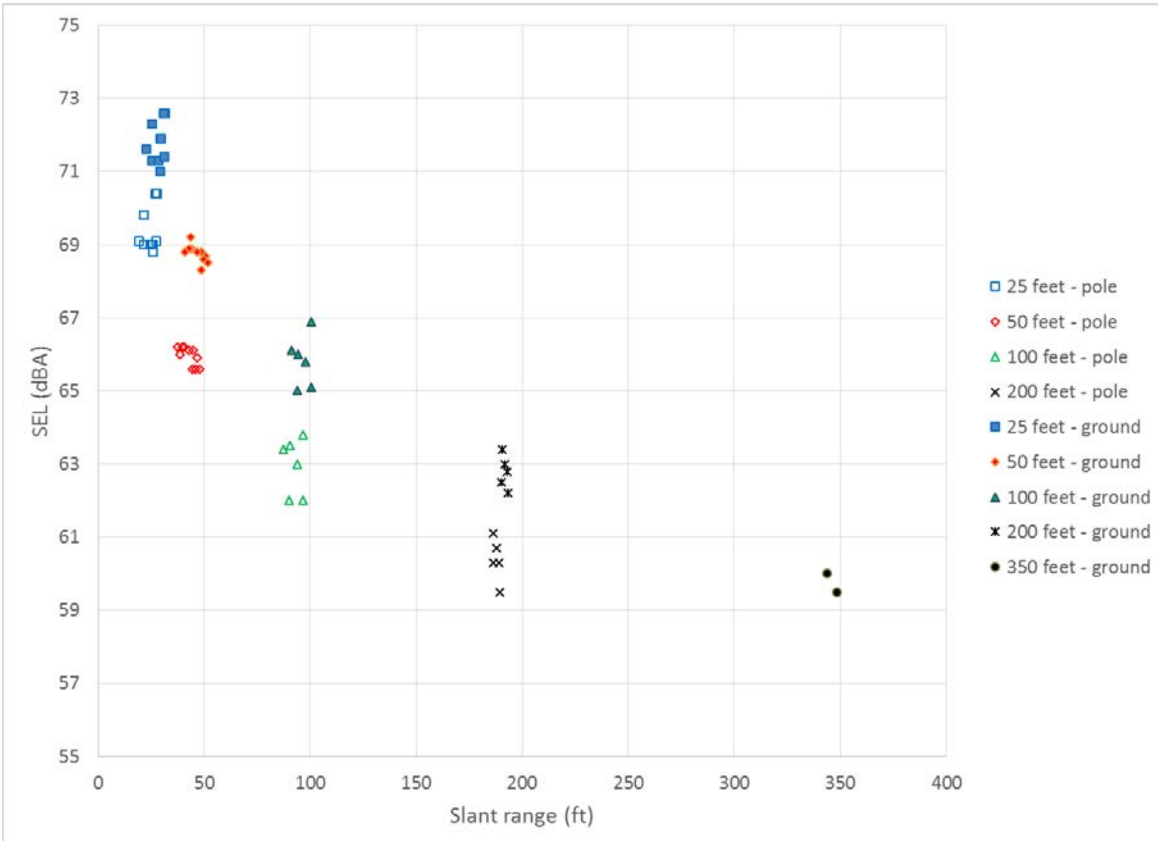

Figure 4. Sound exposure levels for DJI Phantom 3 in cruise flight measured by both microphone systems

5. Results and next steps

The data presented in section 4 allows a comparison of the measured data and the Appendix J altitude correction. In Figure 5 below, the average Sound Exposure Level measured by the Appendix J pole-mounted microphone for each of the flight series is presented along with the curve representing the Appendix J altitude correction for the higher altitudes. Note that the altitude correction includes both the spherical spreading term and the duration correction. The Appendix J altitude correction based on the 25 foot nominal SEL is plotted as a dashed blue line starting at the average nominal 25 foot measurement point and extending to the 200 foot slant range line. The Appendix J altitude correction based on the 50 foot nominal SEL is plotted as a dashed red line starting at the average nominal 50 foot measurement point and extending to the 200 foot slant range line. The Appendix J altitude correction based on the 100 foot nominal SEL is plotted as a dashed green line starting at the average nominal 100 foot measurement point and extending to the 200 foot slant range line. The nominal 25 foot measurement adequately captures the SEL measured at the nominal 50 foot flyover height, but under-predicts the noise at the 100 and 200 flyover heights. The nominal 50 foot flyover measurement under-predicts both the 100 and the 200 flyover heights. The nominal 100 foot flyover measurement under-predicts the 200 foot fly-over height.

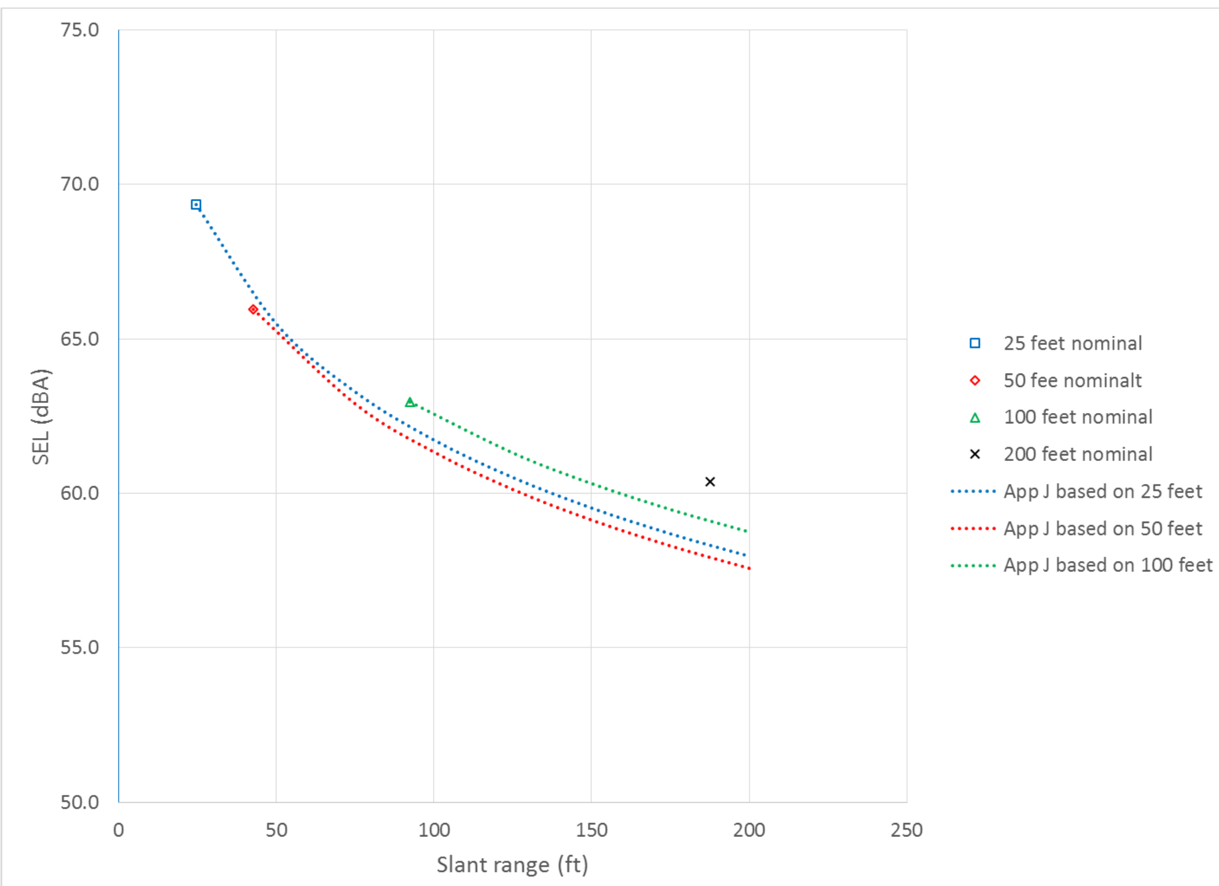

Figure 5. Appendix J duration adjustments applied to different cruise altitudes

Assuming that the spherical spreading correction is correct, then the difference between the measurements and the predicted SEL is due to the duration correction. The Appendix J duration correction appears to not adequately capture the effects of fly the UAS at significantly different heights over the microphone. The Appendix J standard allows a 50 foot deviation from the nominal flight path altitude of 492 feet [J36.105(b)(2)]; because the Appendix J duration adjustment functions shown in Figure 5 above do not appear to represent the measured data, Appendix J adjustments may not adequately capture duration effects due to altitude changes. The duration correction should not be used for large adjustments of fly-over altitudes. The ability of the 25 foot flyover measurement to accurately predict the 50 foot fly-over measurement suggests that the Appendix J duration adjustment may work well for small corrections in altitude, which is the correction's intended purpose.

This flight test was only conducted on a single sUAS. Additional testing should be done on other sUAS and UAS to determine the limits of the duration adjustment. While a duration adjustment for this single UAS can be determined from the data collected in this test, the authors believe doing so for one UAS would be counter-productive to the solution of developing a general duration adjustment for all sUAS.

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Appendix A: Ground Plate data

The noise levels measured by the Appendix G ground plate microphone system are presented here in the same format as the Appendix J pole-mounted microphone data presented in section 4.

Table 5. Summary of data from 25 foot overflight series for ground-plate microphone

Pass	Direction of pass	Slant range (feet)	LAMax	SEL
1	East	22.6	67.3	71.6
2	West	25.5	68.4	71.3
3	East	28.5	68.5	71.3
4	West	29.3	68.0	71.0
5	East	31.1	68.3	71.4
6	East	25.3	69.3	72.3
7	West	29.2	66.7	71.9
8	East	31.4	69.8	72.6
9	West	29.6	69.0	71.9
10	East	30.8	69.5	72.6

Table 6. Summary of data from 50 foot overflight series for pole-mounted microphone

Pass	Direction of pass	Slant range (feet)	LAMax	SEL
1	East	48.6	64.4	68.8
2	West	48.5	64.1	68.3
3	East	50.4	64.6	68.7
4	West	49.8	64.5	68.6
5	East	51.7	64.4	68.5
6	East	44.1	64.6	68.9
7	West	42.8	65.0	68.9
8	East	40.8	64.9	68.8
9	West	43.7	65.3	69.2
10	East	46.5	64.7	68.8

Table 7. Summary of data from 100 foot overflight series for pole-mounted microphone

Pass	Direction of pass	Slant range (feet)	LAMax	SEL
1	East	91.2	60.0	66.1
2	West	93.8	59.3	65.0
3	East	94.4	60.2	66.0
4	West	100.5	59.7	65.1
5	East	97.7	60.0	65.8
6	West	100.6	59.8	66.9

Table 8. Summary of data from 200 foot overflight series for pole-mounted microphone

Pass	Direction of pass	Slant range (feet)	LAMax	SEL
1	East	190.4	55.3	63.4
2	West	190.2	55.1	62.5
3	East	191.7	55.5	63.0
4	West	193.4	54.6	62.2
5	East	192.8	55.1	62.8

Table 9. Summary of data from 350 foot overflight series for pole-mounted microphone

Pass	Direction of pass	Slant range (feet)	LAMax	SEL
1	East	348.3	50.3	59.5
2	West	343.7	50.3	60.0

Appendix B: Summary data

The data for the pole-mounted and ground-plate microphones for each pass are summarized in the tables below. Each table also contains a comparison of the measured SEL between the two systems, and a projection to the Appendix J fly-over height (492 feet) using the Appendix J altitude correction. The equation used for the projection to the Appendix J height is:

$$\mathrm{SEL}_{\mathrm{Projected}} = \mathrm{SEL} + 12.5\,\log_{10}(\mathrm{CPA}/492)$$

Figure 6 shows the individuals passes projected to the standard Appendix J height of 492 feet for the pole-mounted microphone and the ground-plate microphone data.

Table 10. Pole microphone system summary

Nominal Pass Height (feet)	Pass ID number	Time @ LAS Max	CPA (feet)	Laeq @ Max (dB)	LAS Max (dB)	SEL (dB)	SEL diff from Ground Plate	SEL projected to 492’
25	1	14:44:16	19	67.6	66.2	69.1	-2.5	51.4
	2	14:44:37	21.4	67.6	66.1	69	-2.3	52.0
	3	14:45:00	24.7	68.6	66.2	69	-2.3	52.8
	4	14:45:21	25.6	68.8	65.9	68.8	-2.2	52.8
	5	14:45:43	27.2	68.3	65.8	69.1	-2.3	53.4
	6	16:27:11	21.4	70	66.8	69.8	-2.5	52.8
	7	16:27:33	25.7	67.9	66	69	-2.9	53.0
	8	16:27:55	27.7	68.8	67.5	70.4	-2.2	54.8
	9	16:28:16	25.4	69.2	65.9	69	-2.9	52.9
	10	16:28:39	26.8	70.7	67.6	70.4	-2.2	54.6
50	1	14:59:36	44.9	63.3	61.8	66.1	-2.7	53.1
	2	14:59:58	44.5	62.4	61.4	65.6	-2.7	52.6
	3	15:00:20	46.5	63	61.8	65.9	-2.8	53.1
	4	15:00:42	45.7	61.1	61.2	65.6	-3	52.7
	5	15:01:03	47.7	63.4	61.5	65.6	-2.9	52.9
	6	15:22:58	40.6	62.2	61.8	66.2	-2.7	52.7
	7	15:23:19	38.7	63.5	61.8	66	-2.9	52.2
	8	15:23:41	37.2	62.2	62.1	66.2	-2.6	52.2
	9	15:24:03	39.6	64.1	62.3	66.2	-3	52.5
	10	15:24:25	42.7	63.4	62.3	66.1	-2.7	52.8
100	1	15:09:37	87.2	57.4	57.2	63.4	-2.7	54.0
	2	15:09:58	89.8	56.2	55.7	62	-3	52.8
	3	15:10:21	90.5	57.9	57.5	63.5	-2.5	54.3
	4	15:10:42	96.4	56.7	56.2	62	-3.1	53.2
	5	15:11:05	93.8	57.8	57	63	-2.8	54.0
	6	15:11:27	96.6	57.9	57	63.8	-3.1	55.0
200	1	16:01:22	186.4	53.2	52.8	61.1	-2.3	55.8
	2	16:01:52	186.1	52.2	51.4	60.3	-2.2	55.0
	3	16:02:22	187.7	52.7	52.5	60.7	-2.3	55.5
	4	16:02:53	189.3	50.9	51	59.5	-2.7	54.3
	5	16:03:22	188.8	52.7	52.3	60.3	-2.5	55.1

Table 11. Ground Plate microphone system summary

Nominal Pass Height (feet)	Pass ID number	Time @ LAS Max	CPA (feet)	Laeq @ Max (dB)	LAS Max (dB)	SEL (dB)	SEL diff from Pole mic.	SEL projected to 492’
25	1	14:44:16	22.6	65.2	67.3	71.6	2.5	54.9
	2	14:44:37	25.5	70.8	68.4	71.3	2.3	55.2
	3	14:45:00	28.5	71.1	68.5	71.3	2.3	55.8
	4	14:45:21	29.3	70.9	68.0	71.0	2.2	55.7
	5	14:45:43	31.1	70.8	68.3	71.4	2.3	56.4
	6	16:27:11	25.3	71.1	69.3	72.3	2.5	56.2
	7	16:27:33	29.2	61.9	66.7	71.9	2.9	56.6
	8	16:27:55	31.4	72.5	69.8	72.6	2.2	57.7
	9	16:28:16	29.6	71.1	69.0	71.9	2.9	56.6
	10	16:28:39	30.8	72.2	69.5	72.6	2.2	57.6
50	1	14:59:36	48.6	65.8	64.4	68.8	2.7	56.2
	2	14:59:58	48.5	65.8	64.1	68.3	2.7	55.7
	3	15:00:20	50.4	66.1	64.6	68.7	2.8	56.3
	4	15:00:42	49.8	66.6	64.5	68.6	3.0	56.2
	5	15:01:03	51.7	66.3	64.4	68.5	2.9	56.3
	6	15:22:58	44.1	66.4	64.6	68.9	2.7	55.8
	7	15:23:19	42.8	66.5	65.0	68.9	2.9	55.6
	8	15:23:41	40.8	66.8	64.9	68.8	2.6	55.3
	9	15:24:03	43.7	66.7	65.3	69.2	3.0	56.1
	10	15:24:25	46.5	66.8	64.7	68.8	2.7	56.0
100	1	15:09:37	91.2	60.4	60.0	66.1	2.7	57.0
	2	15:09:58	93.8	59.7	59.3	65.0	3.0	56.0
	3	15:10:21	94.4	60.8	60.2	66.0	2.5	57.0
	4	15:10:42	100.5	60.7	59.7	65.1	3.1	56.5
	5	15:11:05	97.7	60.9	60.0	65.8	2.8	57.0
	6	15:11:27	100.6	60.6	59.8	66.9	3.1	58.3
200	1	16:01:22	190.4	55.7	55.3	63.4	2.3	58.2
	2	16:01:52	190.2	55.9	55.1	62.5	2.2	57.3
	3	16:02:22	191.7	55.9	55.5	63.0	2.3	57.9
	4	16:02:53	193.4	55.5	54.6	62.2	2.7	57.1
	5	16:03:22	192.8	55.5	55.1	62.8	2.5	57.7
350	1	16:14:08	348.3	50.6	50.3	59.5	-	57.6
	2	16:14:37	343.7	50.5	50.3	60.0	-	58.1

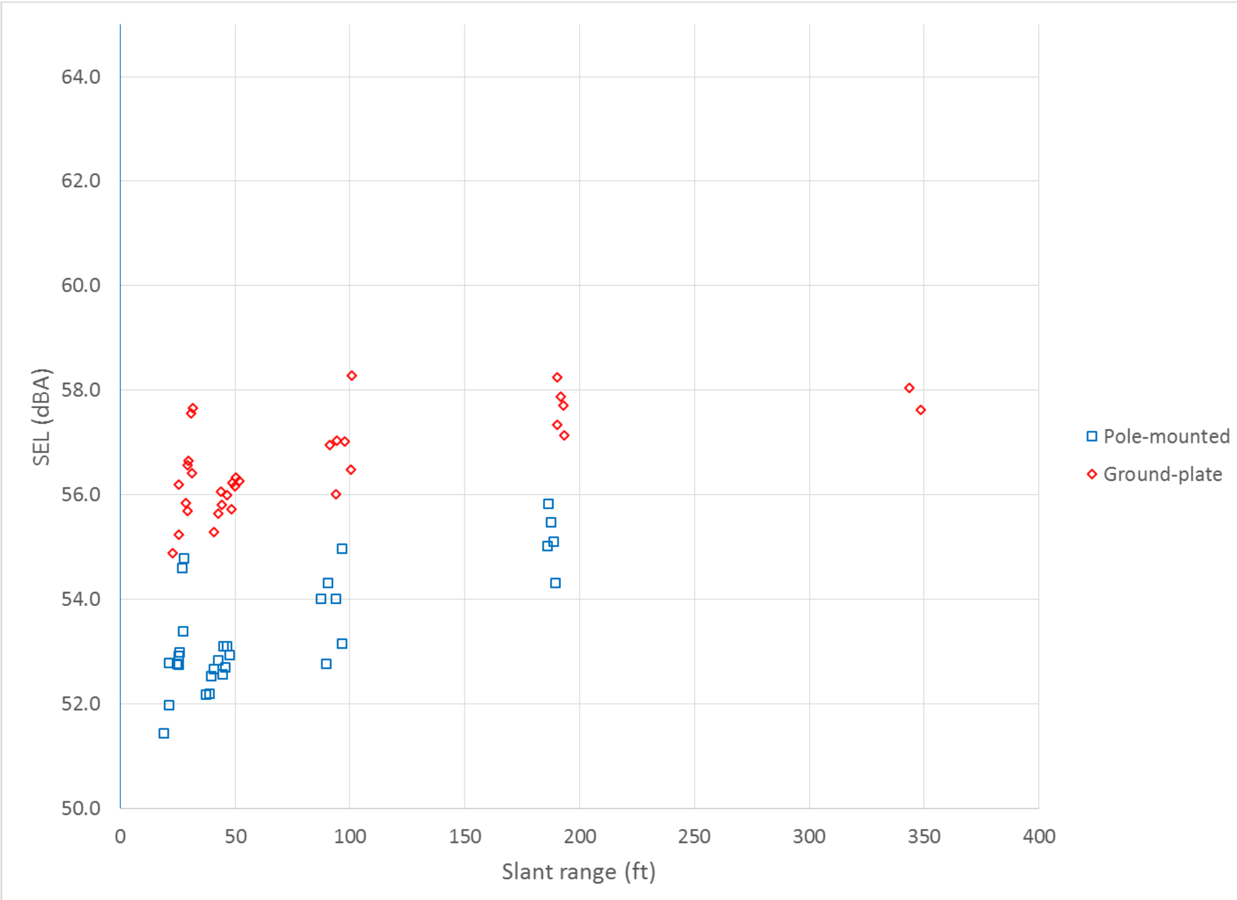

Figure 6. Individual passes projected to Appendix J height

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