TigerShark UAS
Level Flyover Noise Measurements

Final Report – 18 July 2016

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Prepared for: **Federal Aviation Administration**
Office of Environment & Energy
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1. Introduction

FAA's Office of Environment and Energy (AEE) is supporting the FAA Unmanned Aircraft Systems (UAS) Integration Office to ensure the safe, efficient, and timely integration of UAS into the United States' National Airspace System (NAS). In order to fulfill this mission, the FAA is developing UAS standards, procedures, and regulatory products. The primary control over aircraft source noise is the noise certification process, which is the responsibility of AEE within the FAA.

This document describes the TigerShark UAS level flyover noise measurements that were performed at Griffiss International Airport, Rome NY, on May 17 2016.

2. Test Aircraft

Airplane information to be reported under Section G36.109(g)

Tiger Shark is a medium weight UAS. It is powered by a Herbrandsen 372 engine with 31" x 18" blade propeller. Maximum Takeoff Weight is 397 lbs.

Table 1: UAS specifications

Type	NASC TigerShark
Model	Block 3
Serial numbers (if any)	052 N1730X
Modifications that would affect the noise characteristics	None
Engine performance	32 hp / 8,000 rpm 2 blades 6,500 rpm with 31" X 18" prop.
Maximum takeoff weight (lbs.)	397

3. Measurement Site

Acoustical considerations in selecting the measurement site location included the following:

- To minimize the effect of altitude on aircraft performance, the elevation of the measurement site should be below 2,000 feet above mean sea level (AMSL);
- To lessen the risk of external acoustic contamination, a measurement site should have a relatively quiet ambient environment with very few daily aircraft operations; and
- To eliminate the need of acoustic corrections due to terrain undulations, the measurement site should have a long stretch of flat terrain near the test runway, where a centerline and sideline microphone can be placed

Test Site Name: NY Griffiss UAS Test Site
Airport Name: Griffiss International Airport, Rome NY (KRME)

Table 2: Points of Contact

Contact	Phone	Email
Raymond Young	(702) 525-1562	ryoung@nuair.org

4. Instrumentation

4.1. Acoustic System

The MSU acoustic system (Bruel & Kjaer) consists of:

- Two 2250-G4 Hand-held Analyzers (figure 1) with Sound Level Meter, Frequency Analysis, Enhanced Logging and Sound Recording Software (Qty: 2). Characteristics of the Type 4189 microphone:
  - Sensitivity: 50mV/Pa
  - Frequency: 6.3Hz . 20 kHz
  - Dynamic Range: 14.6 . 146 dB
  - Temperature: .30 to +150^0 C (.22 to +302^0 F)
  - Polarization: Prepolarized
- One Sound Calibrator Class 1 and LS, 94 and 114 dB, 1 kHz
- Two 1/2" Pressure-field Microphones, 3 Hz to 20 kHz, 200V Polarization (Qty: 2). Characteristics of the Type 4192 microphone:
  - Sensitivity: 12.5mV/Pa
  - Frequency: 3.15 Hz . 20 kHz
  - Dynamic Range: 19 . 162 dB
  - Temperature: .30 to +300^0 C (.22 to +572^0 F)
  - Polarization: 200V
- One laptop to acquire and post-process the data;
- 2 tripods.

Figure 1. 2250-G4 B&K Analyzer

4.2. Meteorological System

Wind speed and direction, relative humidity, air temperature, and barometric pressure at specified time intervals (typically, in the orders of seconds) were collected by the Volpe

team. However, the meteorological data were collected by Volpe only during the takeoff noise measurements. For the level flyover measurements, approximate values for wind speed, average temperature and humidity were collected from the internet, which are included in section 5.

4.3. Global Positioning System

The time-space position information of the test aircraft during the takeoff and flyover noise certification tests was provided by NASC. The global positioning system (GPS) was used as the primary aircraft guidance and tracking system during measurements.

5. Measurements Procedures

The tests were performed as follows:

- Three level flyovers in each direction for two separate flight altitudes (i.e., 12 total runs).
- Flight altitudes are: 200 feet and 400 feet (NASC tram could not perform flights at 50 and 100 ft – as originally planned – because of some flight safety issues: tall trees were present in the area).
- During the measurements, the wind speed was below 2 m/s, the averaged temperature varied between 45 and 50 F, and the humidity varied between 68% and 70%.

Calibration of the microphones

The microphones were calibrated using the following procedure:

- Mount the B&K 4231 calibrator on the microphone. Activate the calibrator with a sine wave signal of 94 decibels (dB) at 1 kHz. Calibrate the microphones to this reference signal. After calibration, record one minute of the calibration signal and note levels indicated on the log sheets.
- Apply a microphone simulator to the preamp to measure the system noise floor and ensure no outside interference is present. Apply a +20 dB gain to raise the sensitivity of the meter to help identify any anomalous signals. Record one minute of the noise floor and note levels indicated on the log sheets.
- Reinsert the microphone and reapply the calibrator to verify that the analyzer reads the same initial calibration reading performed in Step 1. Record another minute of the calibration signal and note levels indicated on the log sheets.

Number of measurements:

3 level flyovers in each direction for each flight altitude, i.e. 12 total runs:
Flight altitudes are: 200 ft and 400 ft

Figures 2 and 3 show a front and a top view of the measurement setup, while figure 4 shows an example of a flight path. One microphone was positioned under the flight path, while the other one was positioned at 50 feet from the first in the lateral direction. Both of them were places at 4 feet from the ground.

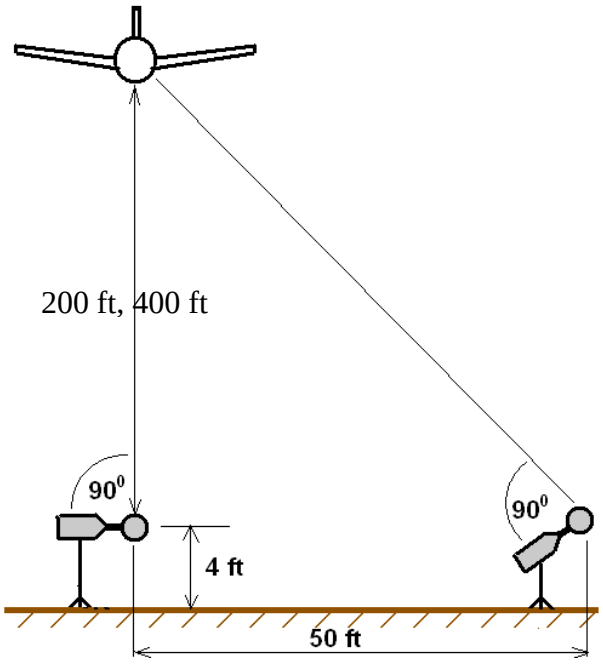

Figure 2. View from the front – Level flyover

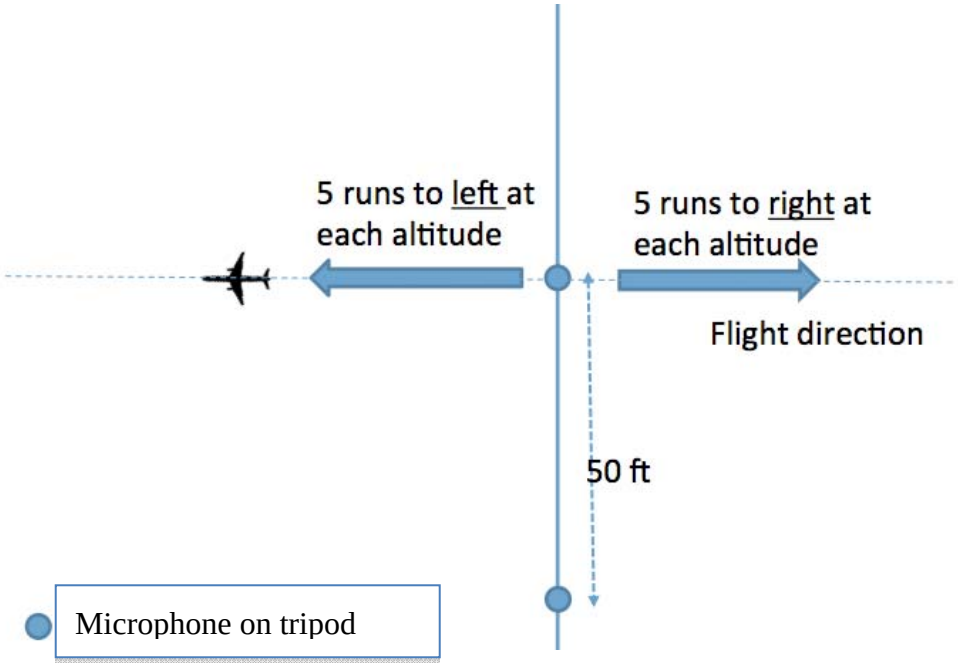

Figure 3. View from the top – Level flyover

Figure 4. Test site (red dot represents the location of the microphones)

6. Data Analysis

Field elevation: 503.7 ft
Sound level meter #1 location: 43^0 13.223' N 75^0 23.283' W
Sound level meter #2 location: 43^0 13.219' N 75^0 23.293' W

The NASC team was not able to fly the UAS at 50 and 100 feet because of flight safety issues (trees were present in close proximity to the measurement site). Next table lists the heights, headings, rotational speed of the engine and the maximum noise attained at the two microphones. More data about the collected noise are included in the appendix B.

Table 3

Event	Test height (feet)	Heading	RPM	Microphone #1		Microphone #2	
				LASmax	LCpeak	LASmax	LCpeak
1	200	150^0	4000	76.41	94.16	75.04	92.49
2	300	150^0	6700	87.71	103.86	88.94	105.38
3	230	150^0	6800	92.35	107.57	91.44	107.81
4	200	330^0	6800	90.62	106.28	91.86	110.59
5	200	330^0	6700	91.27	106.19	90.75	107.75
6	200	330^0	6700	90.18	104.32	91	108.32
7	400	330^0	6600	83.27	96.44	85.19	100.9
8	480	330^0	6700	82.17	96.89	85.07	100.67
9	440	330^0	6600	84.77	99.37	85.77	103.27
10	440	150^0	6800	84.06	98.64	86.16	103.29
11	450	150^0	6800	84.26	98.71	85.58	100.04

12	470	150^0	6800	82.92	97.52	83.77	98.79

Figures 5-12 show time histories of LAFmax, LAFmin, LCpeak and LAeq, while figures 13-16 show spectra history of LZeq (for several instances in time) for all cases. The gray vertical bands in the time history plots (figures 5-12) represent the instant in time corresponding to the maximum values, when the UAS was in the closest proximity to the sound level meater. The definitions of LAFmax, LAFmin, LCpeak, LAeq, and LZeq are given in the appendix.

-The maximum LAeq for the level flight at 200 m perceived by microphone # 1 was 92.8 dB, while for the microphone # 2 it was 84.6 dB (the corresponding LCpeak levels were 110.6 dB and 98.7 dB, respectively).
-The maximum LAeq for the level flight at 400 m perceived by microphone # 1 was 87.5 dB, while for the microphone # 2 it was 84.6 dB (the corresponding LCpeak levels were 107.6 dB and 103.3 dB, respectively).

Spectra plots for LZeq in figures 13-16 show that the peak frequency is approximately 1000 Hz. All spectra plots show a spike around frequency 100 Hz, which corresponds to the first harmonic tone of the propeller (some of the plots also show a couple of multiple tones).

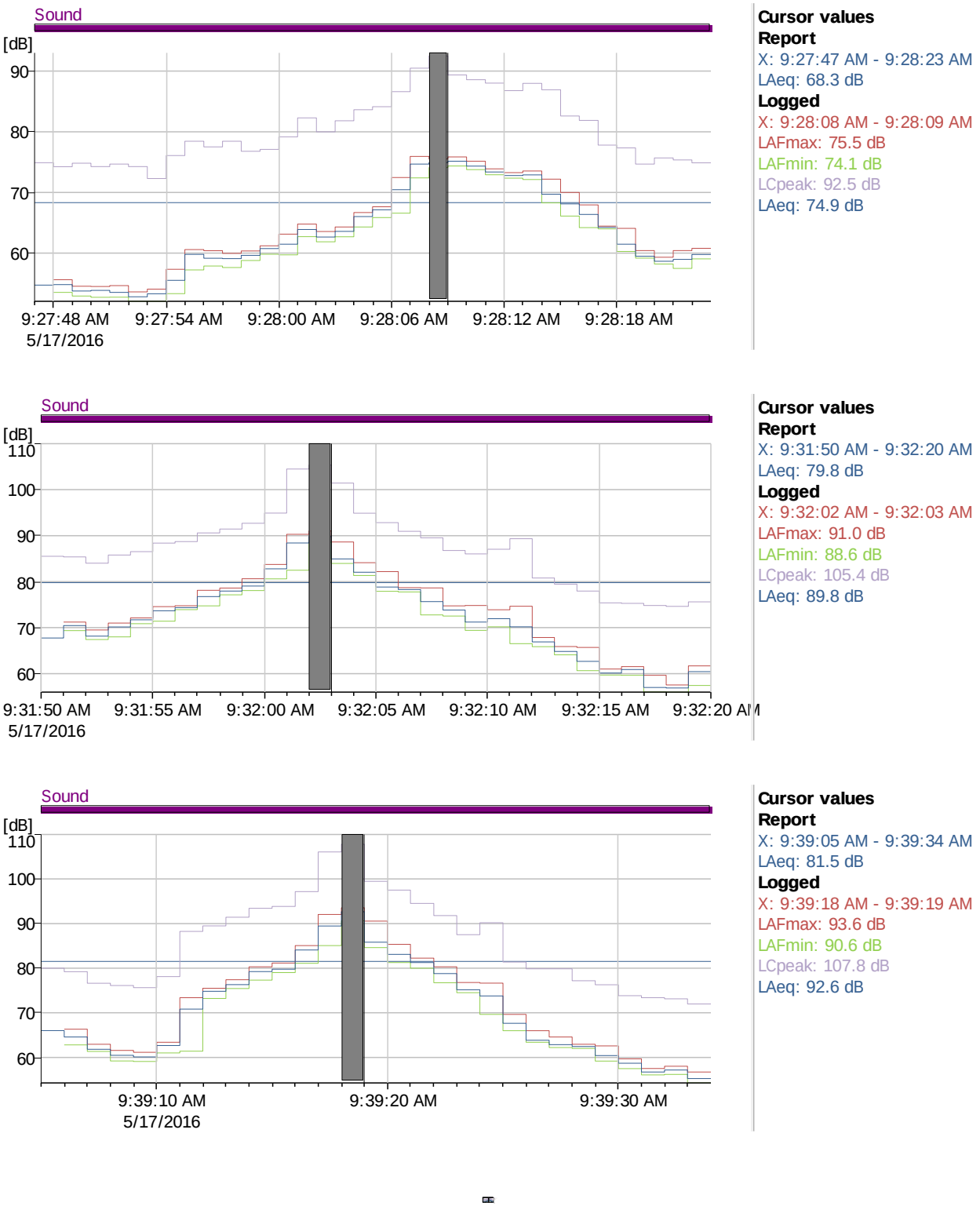

Figure 5. Time histories of LAFmax, LAFmin, LCpeak and LAeq for the level flight at 200 feet (150^0 direction); microphone #1; events 1, 2 and 3 in table 3.

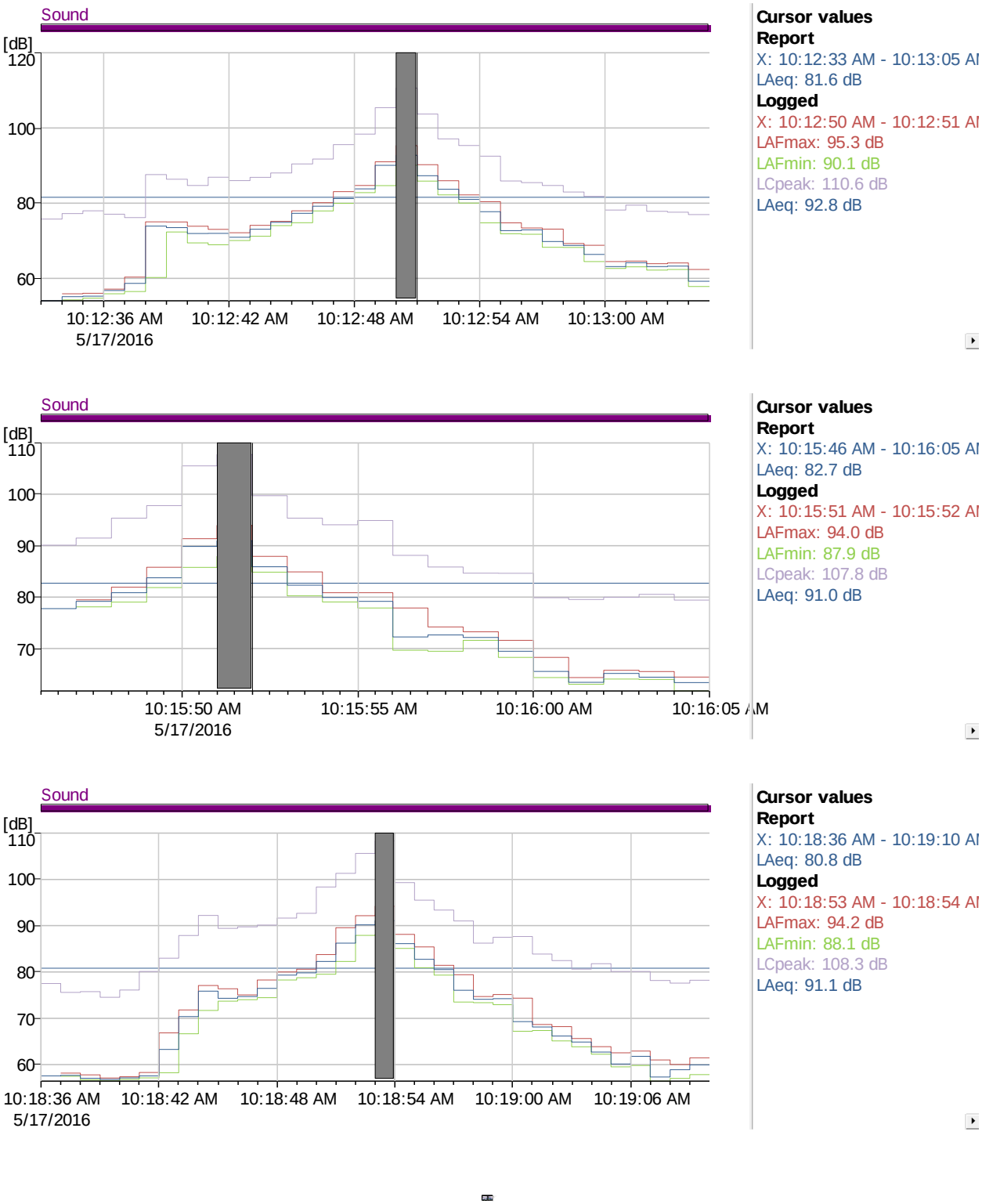

Figure 6. Time histories of LAFmax, LAFmin, LCpeak and LAeq for the level flight at 200 feet (330^0 direction); microphone #1; events 4, 5 and 6 in table 3.

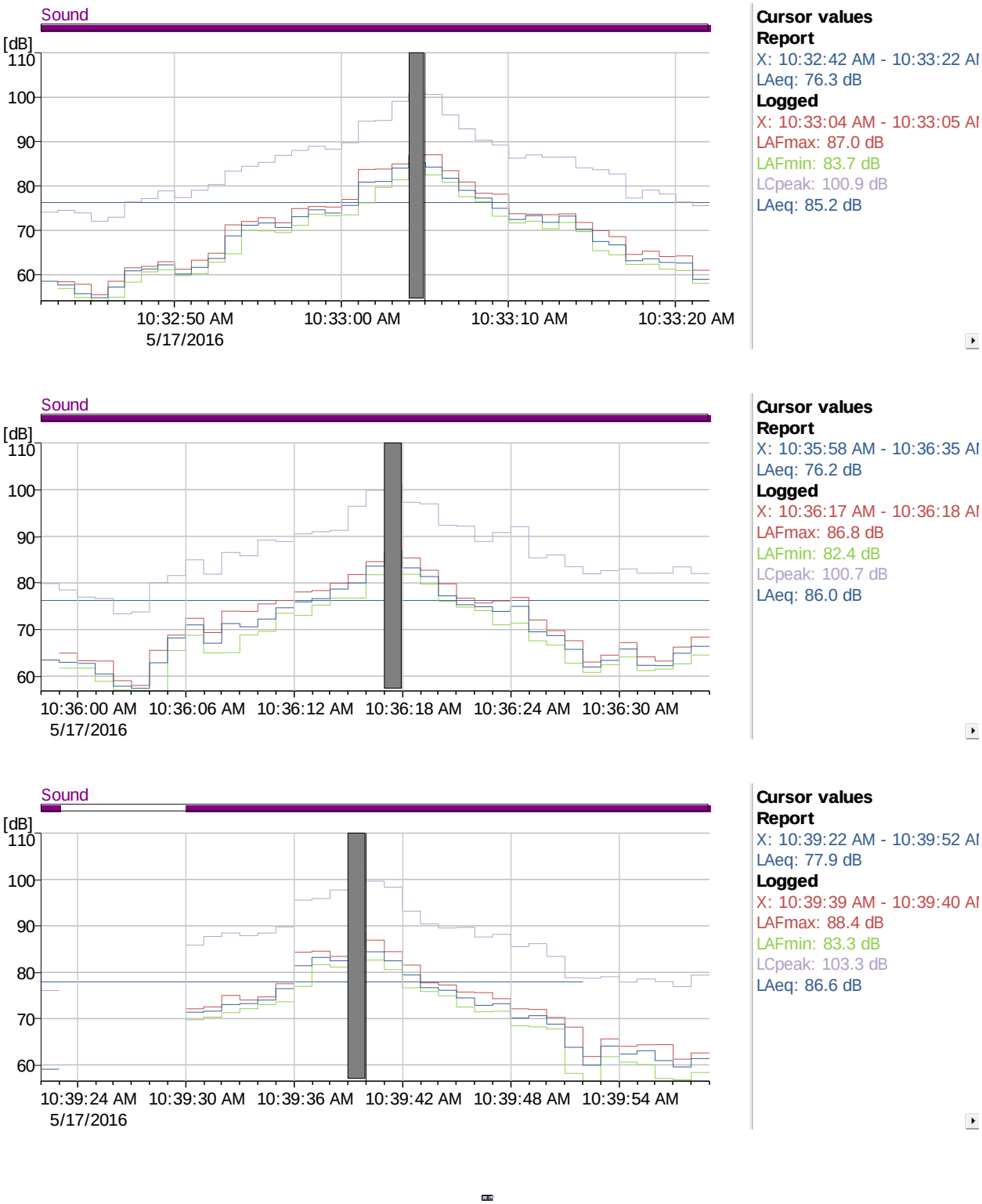

Figure 7. Time histories of LAFmax, LAFmin, LCpeak and LAeq for the level flight at 400 feet (330^0 direction); microphone #2; events 1, 2 and 3 in table 3.

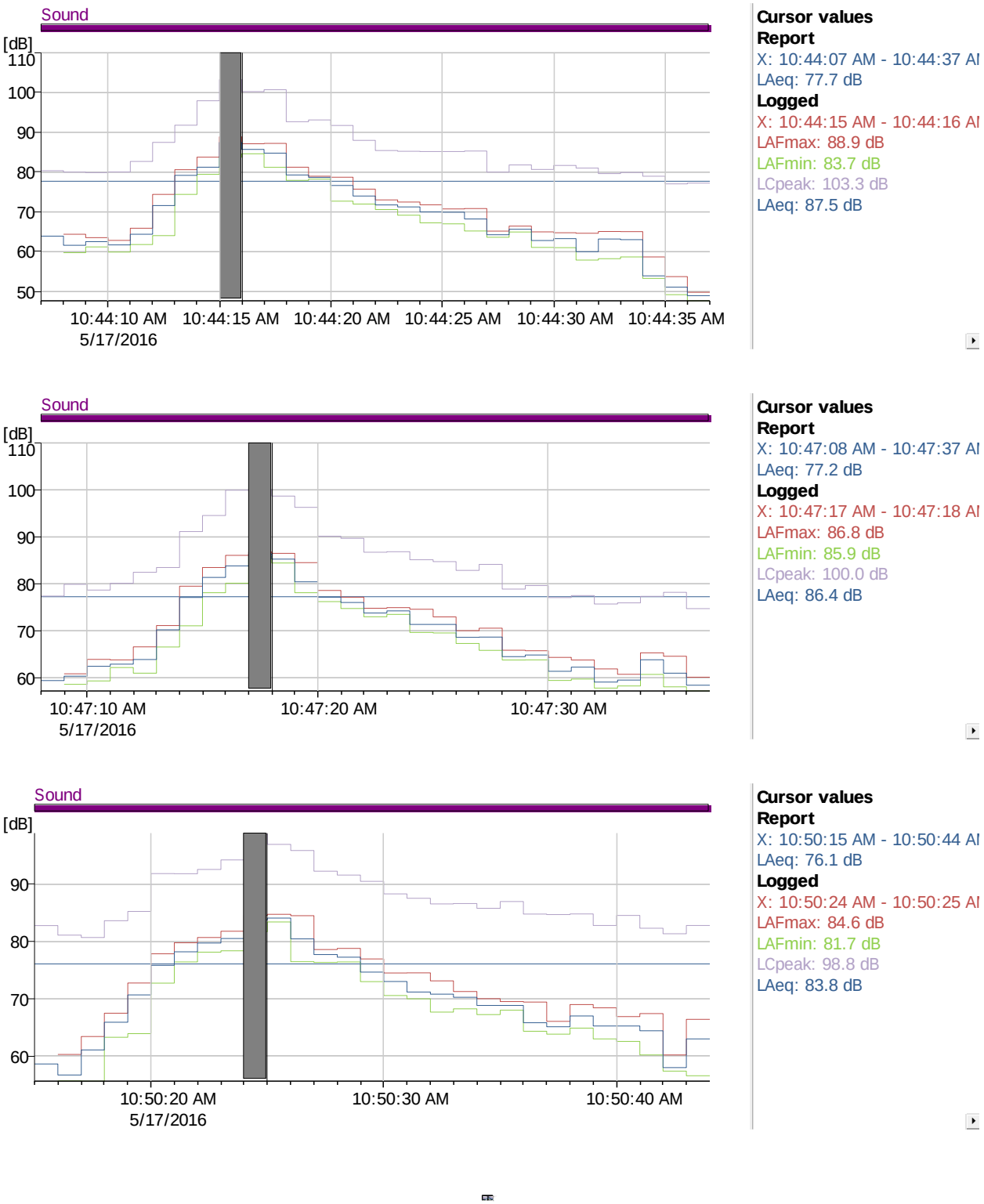

Figure 8. Time histories of LAFmax, LAFmin, LCpeak and LAeq for the level flight at 200 feet (150^0 direction); microphone #2; events 4, 5 and 6 in table 3.

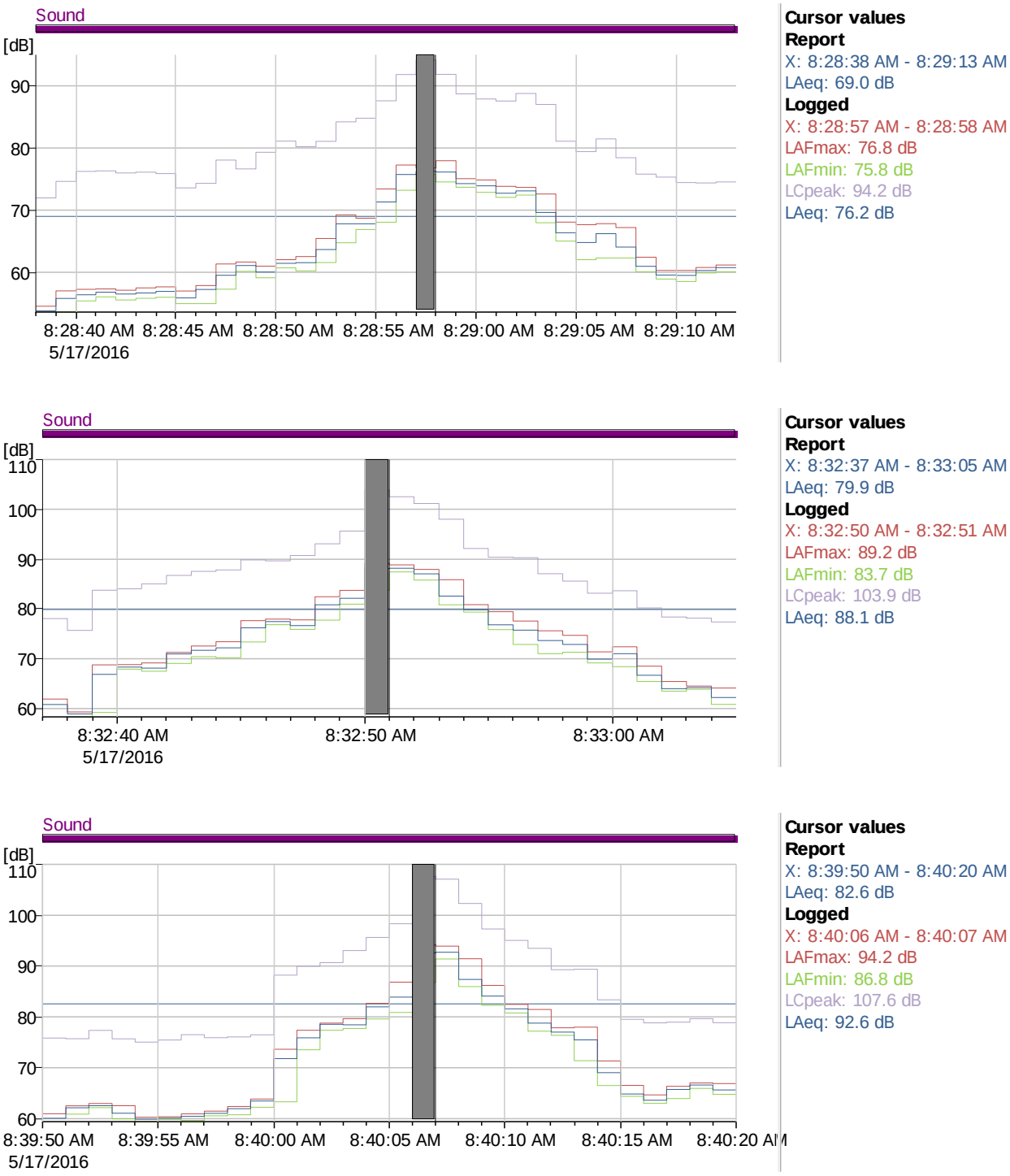

Figure 9. Time histories of LAFmax, LAFmin, LCpeak and LAeq for the level flight at 400 feet (150^0 direction); microphone #1; events 7, 8 and 9 in table 3.

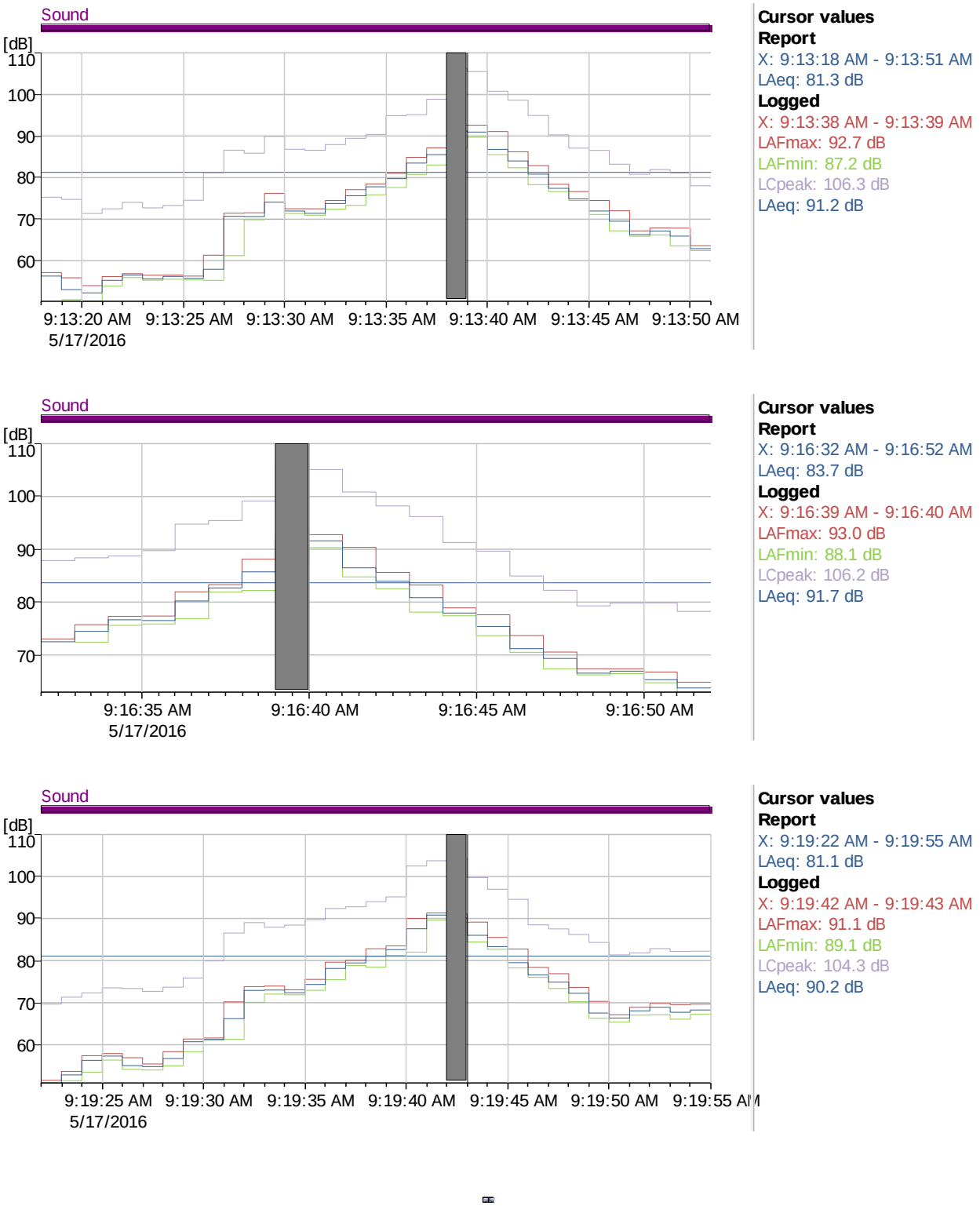

Figure 10. Time histories of LAFmax, LAFmin, LCpeak and LAeq for the level flight at 400 feet (330^0 direction); microphone #1; events 10, 11 and 12 in table 3.

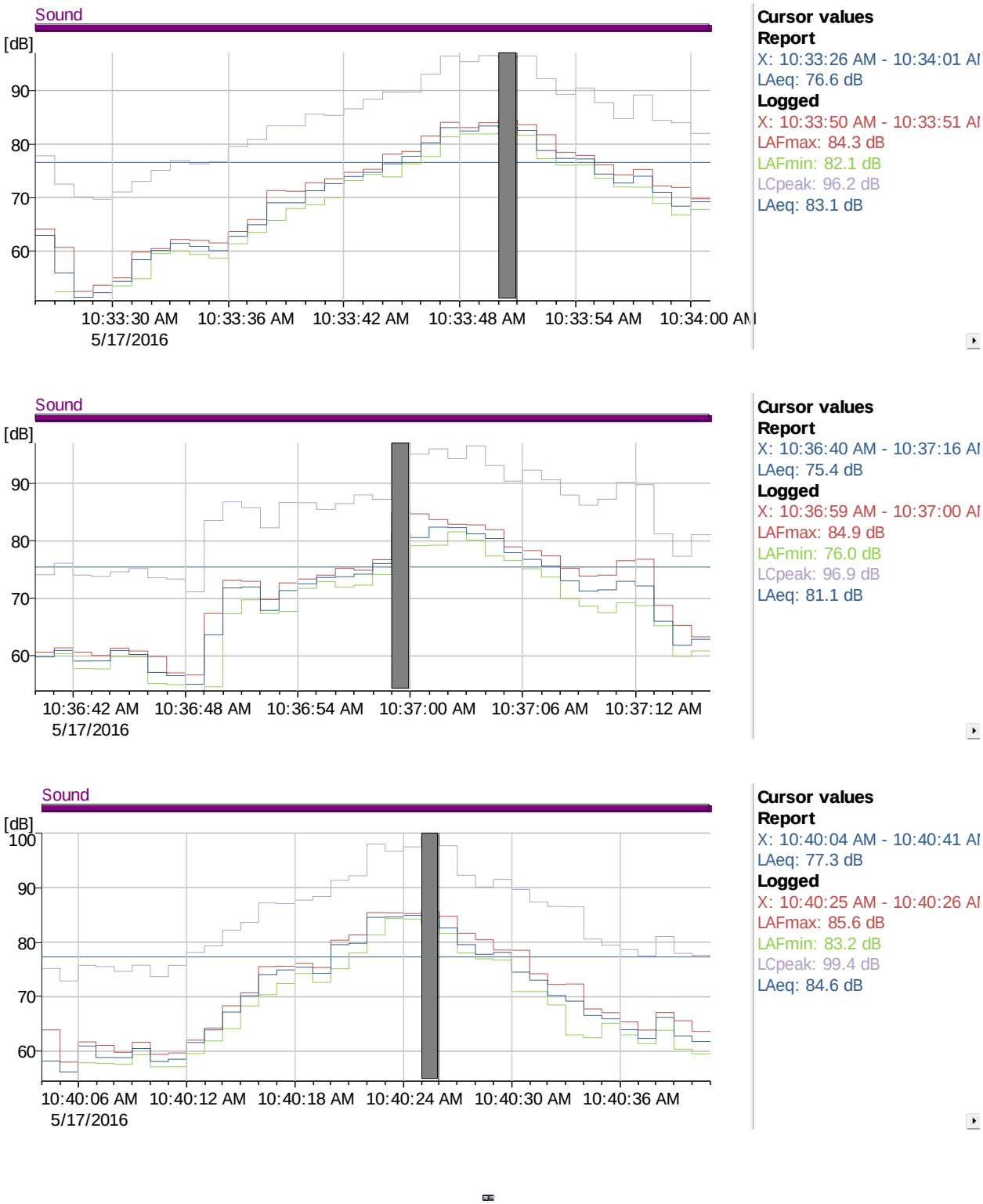

Figure 11. Time histories of LAFmax, LAFmin, LCpeak and LAeq for the level flight at 400 feet (330^0 direction); microphone #2; events 7, 8 and 9 in table 3.

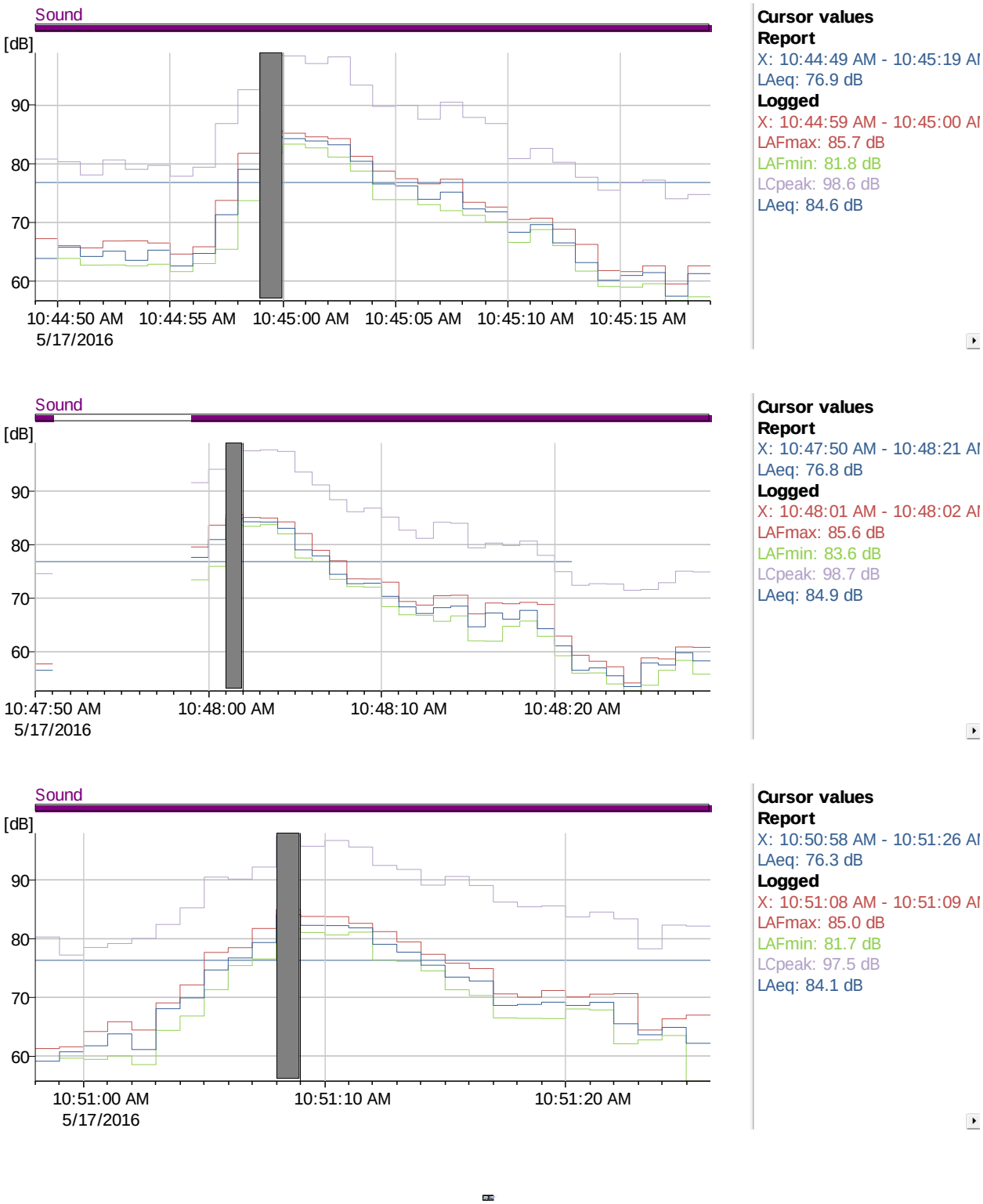

Figure 12. Time histories of LAFmax, LAFmin, LCpeak and LAeq for the level flight at 400 feet (150^0 direction); microphone #2; events 10, 11 and 12 in table 3.

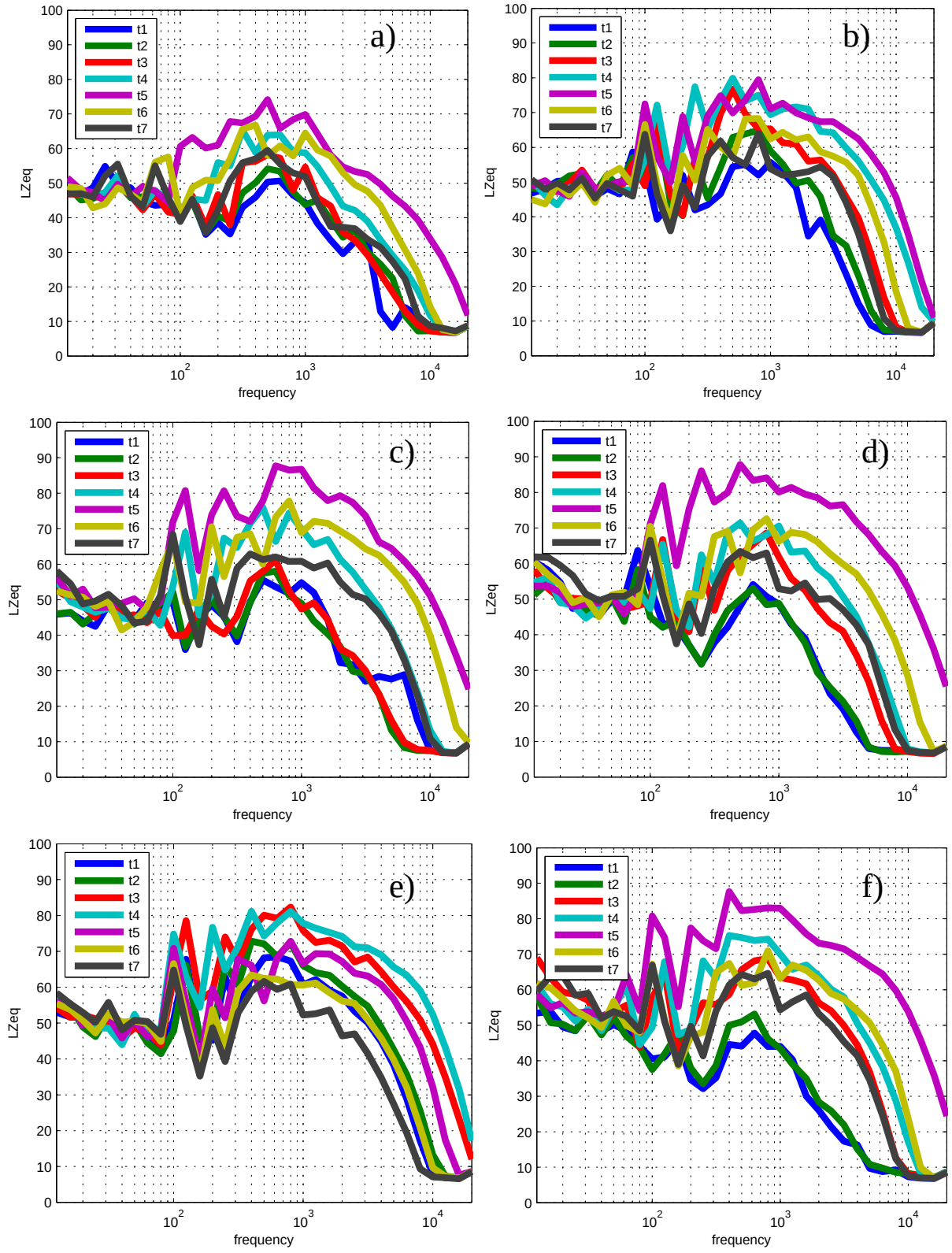

Figure 13. Spectra of LZeq for the level flight at 200 feet, for different times and for microphone #1: a) event 1; b) event 2; c) event 3; d) event 4; e) event 5; f) event 6 (see table 3). In the legend, t1, t2, t3, t4, t5, t6 and t7 represent different times, 5 seconds apart from each other.

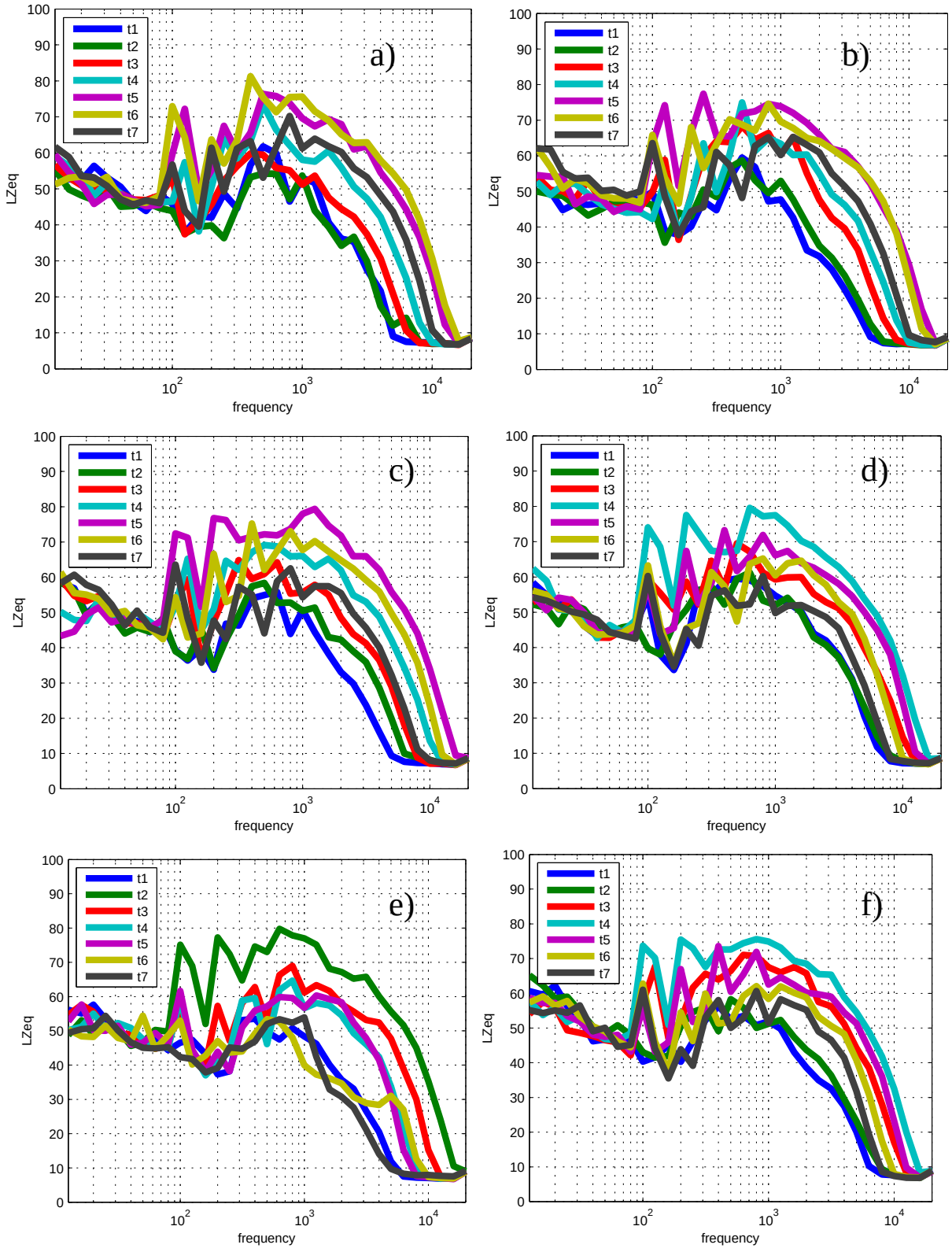

Figure 14. Spectra of LZeq for the level flight at 400 feet, for different times and for microphone #1: a) event 7; b) event 8; c) event 9; d) event 10; e) event 11; f) event 12 (see table 3). In the legend, t1, t2, t3, t4, t5, t6 and t7 represent different times, 5 seconds apart from each other.

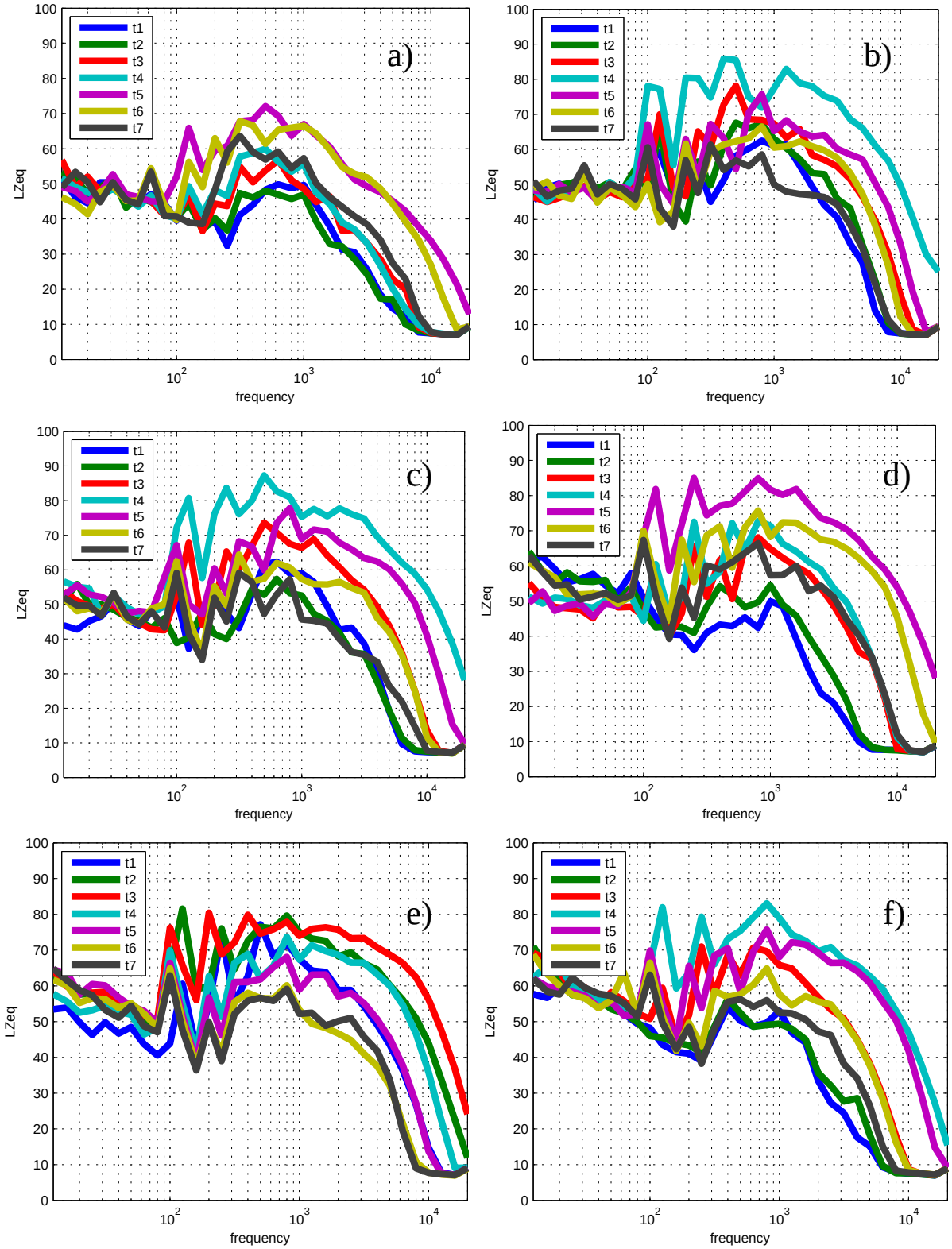

Figure 15. Spectra of LZeq for the level flight at 200 feet, for different times and for microphone #2: a) event 1; b) event 2; c) event 3; d) event 4; e) event 5; f) event 6 (see table 3). In the legend, t1, t2, t3, t4, t5, t6 and t7 represent different times, 5 seconds apart from each other.

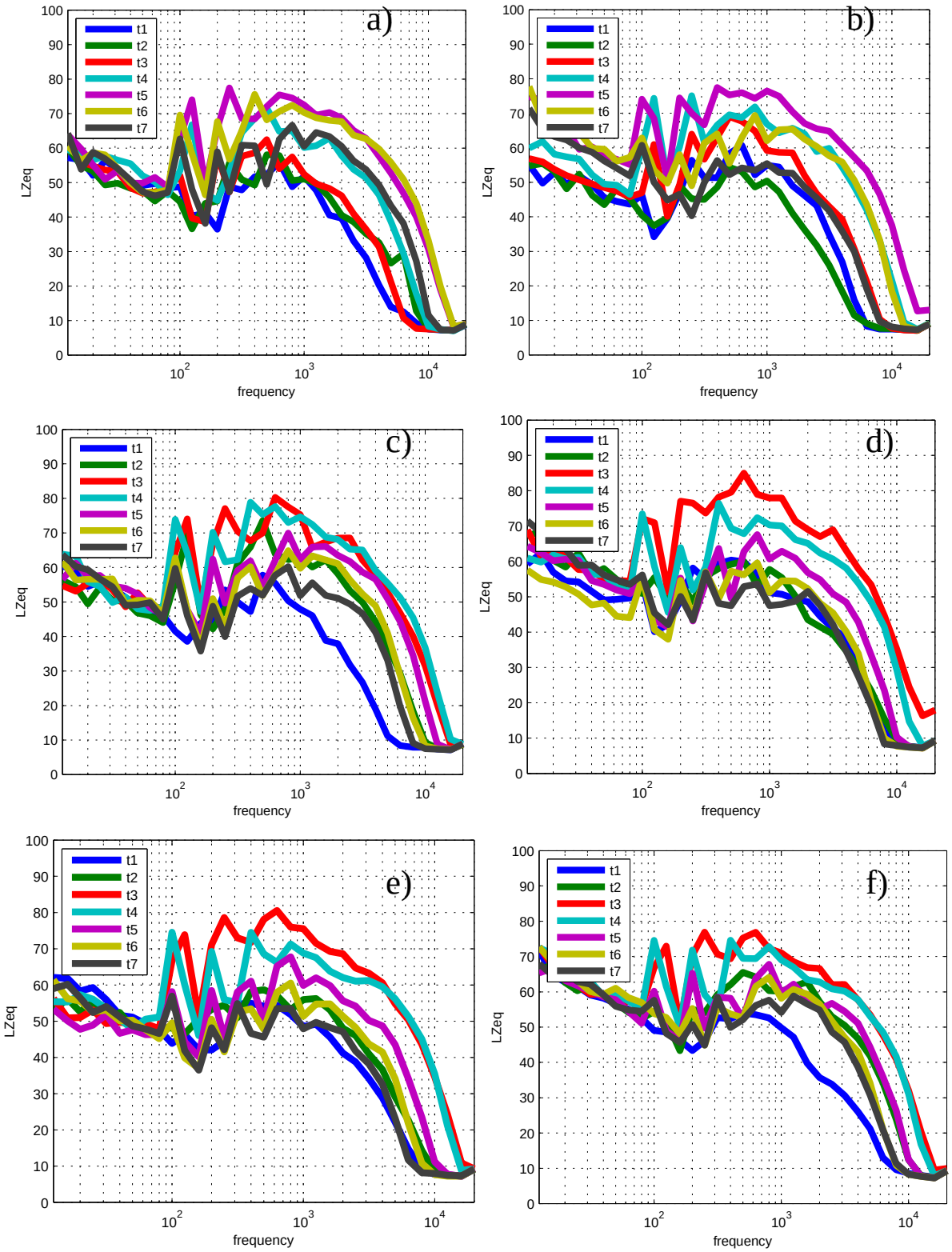

Figure 16. Spectra of LZeq for the level flight at 400 feet, for different times and for microphone #2: a) event 7; b) event 8; c) event 9; d) event 10; e) event 11; f) event 12 (see table 3). In the legend, t1, t2, t3, t4, t5, t6 and t7 represent different times, 5 seconds apart from each other.

Appendix A

LAeq : A-weighted, equivalent sound level. A widely used noise parameter describing a sound level with the same Energy content as the varying acoustic signal measured

LAFmax : A-weighted, Fast, Maximum, Sound Level.

LAFmin : A-weighted, Fast, Minimum, Sound Level.

LASmax : A-weighted, Slow, Maximum, Sound Level.

LASmin : A-weighted, Slow, Minimum, Sound Level.

LCpeak : C-weighted, Peak, Sound Level.

A-weighting : the A-weighting filter covers the full audio range - 20 Hz to 20 kHz and the shape is similar to the response of the human ear at the lower levels - see the Equal Loudness Contours entry.

C-weighting : a standard frequency weighting for sound level meters, commonly used for higher level measurements and Peak - Sound Pressure Levels. Approximately follows the 100 Phon curve - also written as dB(C) or dBC.

Appendix B

Microphone #1, low altitude (all noise data in dB)

Height	200	300	230	200	200	200
LAFTeq	72.68	84.23	88.17	88	89.07	85.93
LAFmax	77.95	89.21	94.21	92.65	93	91.37
LASmax	76.41	87.71	92.35	90.62	91.27	90.18
LAImax	78.84	89.72	94.86	93.02	93.5	91.73
LCFmax	80.78	91.16	95.41	95.4	95.12	94.3
LCSmax	79.56	90.15	93.62	93.09	93.06	92.61
LCImax	81.62	91.65	96	95.68	95.53	94.62
LAFmin	53.61	58.36	59.43	50.28	62.98	51.44
LASmin	55	59.49	60.17	52.75	64.9	52.09
LAImin	55.05	59.09	59.75	51.72	63.26	51.91
LCFmin	57.88	62.33	62.63	59.13	67.97	58.1
LCSmin	58.93	63.33	63.19	60.85	69.04	58.8
LCImin	59.92	63.01	62.96	60.22	68.19	59.55
LCpeak	94.16	103.86	107.57	106.28	106.19	104.32
LAIeq	69.92	80.62	83.72	82.41	84.77	81.94
LCIeq	72.78	83.06	85.19	84.89	86.65	84.38

LAeq	68.99	79.92	82.57	81.27	83.67	81.07

Microphone #1, high altitude (all noise data in dB)

Height	400	480	440	440	450	470
LAFTeq	79.89	80.01	80.76	81.92	80.5	80.99
LAFmax	84.3	84.86	85.59	85.67	85.61	84.97
LASmax	83.27	82.17	84.77	84.06	84.26	82.92
LAImax	84.84	86.2	86.51	86.18	86.23	85.46
LCFmax	86.46	86.24	87.4	86.97	86.82	86.49
LCSmax	85.44	84.58	86.49	85.9	86.23	85.03
LCImax	86.99	87.39	88.28	87.39	87.22	86.89
LAFmin	50.78	53.94	54.53	56.63	52.68	55.74
LASmin	54.09	55.87	58.04	59.32	54.96	60.03
LAImin	54.05	54.64	57.56	58.68	53.74	60.14
LCFmin	56.61	58.41	58.97	63.07	58.5	63.94
LCSmin	59.3	60.16	61.52	64.09	60.35	64.67
LCImin	59.09	59.9	61.67	63.58	59.98	65.97
LCpeak	96.44	96.89	99.37	98.64	98.71	97.52
LAIeq	77.25	76.9	78.14	77.73	77.6	77.37
LCIeq	79.22	78.92	79.7	79.28	79.26	79.33
LAeq	76.55	75.44	77.29	76.86	76.83	76.31

Microphone #2, low altitude (all noise data in dB)

Height	200	300	230	200	200	200
LAFTeq	71.85	85.14	87.12	88.1	90.18	87.9
LAFmax	75.92	91.02	93.56	95.31	93.95	94.23
LASmax	75.04	88.94	91.44	91.86	90.75	91
LAImax	76.71	91.79	94.17	96.31	94.66	95.03
LCFmax	78.76	92.81	96.47	96.92	95.58	96.17
LCSmax	77.92	91.37	94.68	93.71	92.68	93.16
LCImax	79.56	93.18	96.86	97.73	96.24	96.75
LAFmin	52.06	56	54.29	54.32	61.75	56.45
LASmin	53.02	57.84	56.14	54.41	63.81	56.85
LAImin	53.18	56.85	54.67	54.61	62.59	56.74
LCFmin	56.75	63.35	61.53	62.93	67.13	60.86
LCSmin	57.89	64.02	62.51	64.68	68.58	62.63
LCImin	58.34	63.79	62.21	66.2	68.2	63.57
LCpeak	92.49	105.38	107.81	110.59	107.75	108.32
LAIeq	68.93	80.89	83	84.53	85.29	83.24

LCIeq	71.72	83.24	86.13	86.11	87.07	85.25
LAeq	68.3	79.8	81.53	81.58	82.69	80.79

Microphone #2, high altitude (all noise data in dB)

Height	400	480	440	440	450	470
LAFTeq	80.98	80.68	84.02	82.83	82.06	81.36
LAFmax	87.05	86.84	88.4	88.9	86.78	84.79
LASmax	85.19	85.07	85.77	86.16	85.58	83.77
LAImax	87.58	87.19	89.44	89.47	87.05	85.41
LCFmax	88.91	89.16	90.03	90.6	89.32	88.5
LCSmax	87.23	87.7	87.8	88.84	88.49	87.34
LCImax	89.24	89.65	90.82	91.13	89.56	89.08
LAFmin	54.16	56.86	56.54	47.68	57.19	55.59
LASmin	55.49	58.08	60.41	52.82	59.69	56.97
LAImin	54.5	57.18	60.03	54.73	58.8	57.82
LCFmin	58.99	60.62	63.64	64.14	61.88	66.95
LCSmin	60.35	61.94	65.25	66.58	63.72	68.72
LCImin	59.66	61.64	64.96	67.04	62.74	70.45
LCpeak	100.9	100.67	103.27	103.29	100.04	98.79
LAIeq	77.26	77.25	79.37	79.02	78.06	77.16
LCIeq	79.19	79.93	81.12	81.26	80.77	80.51
LAeq	76.27	76.23	77.91	77.72	77.21	76.08