NATIONAL TRANSPORTATION SAFETY BOARD
Vehicle Recorder Division
Washington, D.C. 20594

October 30, 2017

Onboard Video Sound Spectrum

Specialist's Study Report
by Bill Tuccio, Ph.D.

1. EVENT

Location:	San Juan, Puerto Rico
Date:	July 4, 2017
Aircraft:	Piper PA-28-180
Registration:	N9427J
Operator:	Horizon Aviation
NTSB Number:	ERA17LA227

On July 4, 2017, at 1721 Atlantic daylight time, a Piper PA28-180, N9427J, operated by Horizon Aviation, was substantially damaged when it impacted the San Antonio Canal shortly after takeoff from Fernando Luis Ribas Dominicci Airport (SIG), San Juan, Puerto Rico. The private pilot and three passengers were not injured. Visual meteorological conditions prevailed, and no flight plan was filed for the local personal flight, which was conducted under the provisions of 14 *Code of Federal Regulations* Part 91.

2. DETAILS OF STUDY

The purpose of this study was to determine propeller revolutions per minute (RPM) from an onboard video and audio recording.[1]

2.1. Background

Audible sound is composed of multiple frequencies. Using software based upon mathematical transformations, it is possible to visualize these component frequencies. In a propeller powered aircraft, Smith (1989)[2] published the following relationship for a 2-bladed propeller:

$$RPM = BPF * 60 / 2 \qquad \text{(equation 1)}$$

where BPF is blade passage frequency, 60 converts from seconds to minutes, and 2 is a factor for the number of propeller blades. Any given recorded sound may have multiple harmonics of the fundamental frequency; the BPF is generally the fundamental frequency and is of the greatest amplitude. When conducting a forensic conversion from frequency

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[1] See the Witness and Onboard Video Specialist's Factual Report in the public docket for this investigation.

[2] Smith, M. (1989). "Aircraft Noise." Cambridge University Press.

to RPM, identification of the proper harmonic is accomplished by comparing converted values to expected values during known periods of operation.

2.1.1. Limitations

The ability to measure frequencies in the sound spectrum is limited by a number of factors, ultimately limited by the resolution of the display. When measuring a frequency on the sound spectrum frequency line, it was possible to select a frequency with a precision of approximately 3 Hz, equating to about 90 RPM. Accordingly, RPM measures are +/- 45 RPM.

In some cases it is possible to identify engine speed based on sound frequencies related to cylinder firing; the benefit of such a method would be to further validate the propeller BPF method. The large number of harmonics in this case precluded the use of the cylinder-based method.

2.1.2. Results

Figure 1 shows the sound spectrum during the recording. The assumed BPF is annotated, as are possible harmonics.

Figure 1. Sound spectrum during recording.

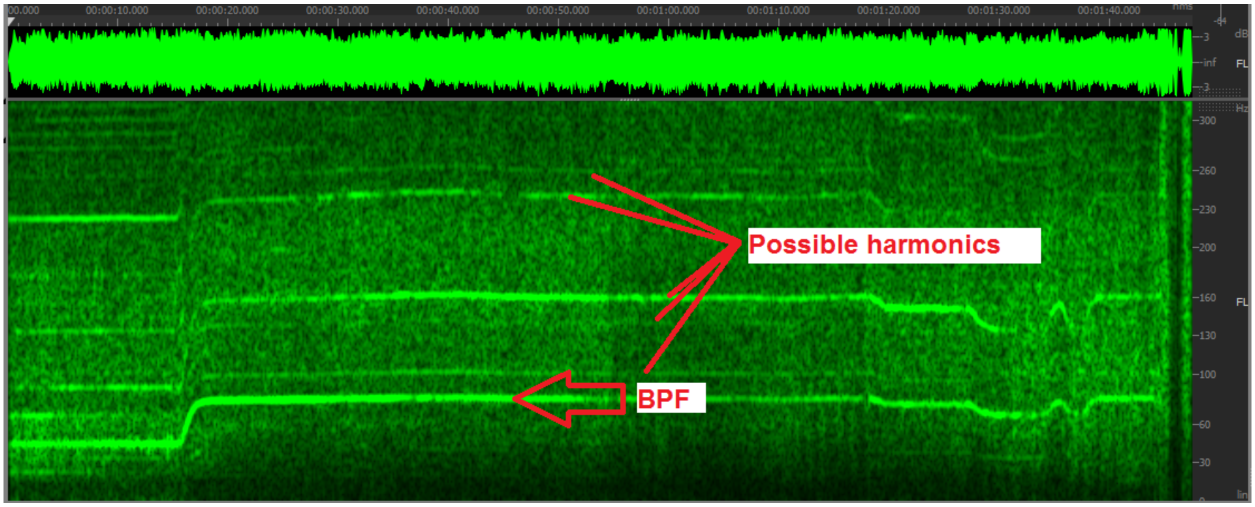

Figure 2 shows the same sound spectrum image, annotated with measurement points. Values for the measurement points are detailed in table 1. All times are in onboard video elapsed time. Trial conversions of the “BPF” annotated frequency trace (figure 1) created expected RPM values; accordingly, this trace was used as the BPF to convert to RPM.

Figure 2. Sound spectrum, annotated with measurements.

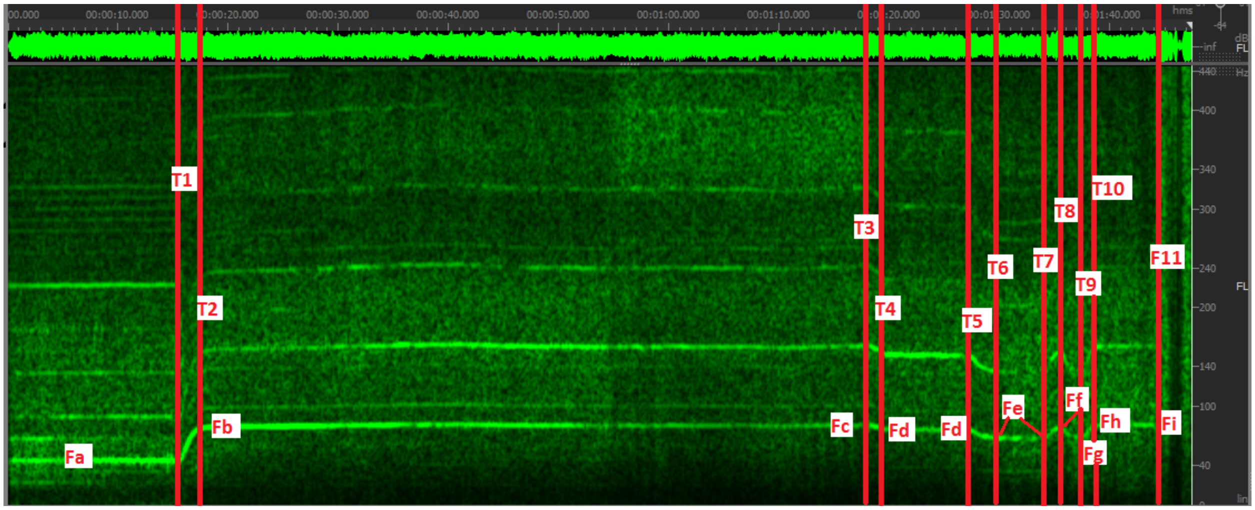

Table 1. Time and frequency measures with computed RPM.

Time (secs)	Figure Time Code	Measured Frequency	Frequency (Hertz)	RPM
15.2	T1	44.8	Fa	1,344
18.9	T2	79.5	Fb	2,385
77.5	T3	81.7	Fc	2,451
79.8	T4	75.5	Fd	2,265
87.1	T5	75.5	Fd	2,265
90.1	T6	66.0	Fe	1,980
93.9	T7	66.0	Fe	1,980
95.5	T8	76.4	Ff	2,292
97.1	T9	65.0	Fg	1,950
98.4	T10	79.1	Fh	2,373
104.5	T11	81.7	Fi	2,451

2.2. Discussion

These conclusions incorporate factual information from the *Witness and Onboard Video Specialist's Factual Report*.

Prior to 15.2 seconds (T1), the engine was operating at 1,344 RPM, as the airplane was entering the runway but had not yet started its takeoff.

At 18.9 seconds (T2), the engine was operating at 2,385 RPM, and the airplane had commenced its takeoff roll.

At 77.5 seconds (T3), the engine RPM had increased slightly to 2,451 RPM, as the airplane had climbed above the departure end of the runway.

At 79.8 seconds (T4), the engine RPM decreased to 2,265 RPM; this occurred about as the airplane had banked slightly right.

Between 79.8 seconds (T4) and 87.1 seconds (T5), the engine RPM remained steady at 2,265 RPM.

By 90.1 seconds (T6), the engine RPM decreased to 1,980 RPM; shortly after this reduction the airplane began to bank left.

Between 90.1 seconds (T6) and 93.9 seconds (T7), the engine RPM remained steady at 1,980 RPM; by this point the airplane had started to descend and was still banking left.

At 95.5 seconds (T8), the RPM momentarily increased to 2,292 RPM.

At 98.4 seconds (T9), the RPM momentarily decreased to 1,950 RPM.

From 98.4 seconds (T10) until just before impact at 104.5 (T11), the RPM was stable between 2,373 to 3,451 RPM.

2.3. Conclusions

After takeoff, there was a reduction in RPM, and then an increase in RPM towards the end of the recording. The reasons for the RPM changes could not be determined from this study.