

NATIONAL TRANSPORTATION SAFETY BOARD
Vehicle Recorder Division
Washington, DC 20594

July 17, 2015

SOUND SPECTRUM STUDY

Specialist's Report
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1. EVENT

Location:	Open Water
Date:	September 5, 2014
Aircraft:	Socata TBM700
Registration:	N900KN
NTSB Number:	ERA14LA424

2. SUMMARY

On September 5, 2014, about 1410 eastern daylight time (EDT), a Socata TBM700 (marketed as TBM900), N900KN, impacted open water near the coast of northeast Jamaica. The commercial pilot/owner and his passenger were fatally injured. An instrument flight rules flight plan was filed for the planned flight that originated from Greater Rochester International Airport (ROC), Rochester, New York at 0826 and destined for Naples Municipal Airport (APF), Naples, Florida. The personal flight was conducted under the provisions of 14 *Code of Federal Regulations* Part 91.

A sound spectrum study was performed based on audio obtained from an air traffic control (ATC) recording and examined the pilot's speech throughout the flight for symptoms of hypoxia¹.

3. SOUND SPECTRUM STUDY

3.1. Description of Audio File

The National Transportation Safety Board (NTSB) Vehicle Recorder Division received a file that contained radio transmissions from air traffic controllers, the accident aircraft, and other non-pertinent aircraft. The file was sampled at 8,000 kHz in waveform (*.wav) format and was 42 minutes and 59 seconds in length. The last transmission from the pilot was heard 6 minutes and 47 seconds into the recording; therefore, the remainder of the audio file was not used in this report.

¹ Hypoxia refers to a condition of low oxygen.

3.2. Overview of Study

The NTSB has conducted speech analysis and the effects of hypoxia in prior accidents. For example, in a prior accident involving a Piper PA-31-T1, the pilot advised ATC that he had lost cabin pressurization and needed an immediate descent. About 20 seconds later he was cleared to 25,000 feet, then 15 seconds later to 15,000 feet. Shortly after the pilot acknowledged the lower altitudes, the radio communications deteriorated to microphone clicks with no carrier. (NTSB, 1998, LAX98FA260)

Additionally, the NTSB was asked to perform voice analysis by the Australian Transportation Safety Board (ATSB), in which a pilot of a Beech Super King Air 200 was communicating to ATC and was known to have experienced hypobaric hypoxia. (ATSB 199902928)

The analysis provided to the ATSB contained quantitative and qualitative observations based on transmissions made by the pilot as the flight went on. The NTSB examined the following quantitative measurements of the pilot:

- Response time² (seconds)
- Time between finishing speaking and finishing keying microphone (seconds)
- Speaking rate (syllables/second)
- Fundamental frequency (Hertz)

This report seeks to replicate the methodology performed by the NTSB in its assistance to the ATSB in 199902928. Additionally, some qualitative observances are noted in the ATC audio recording, such as audible breathing, and completeness of response.

4. Quantitative Data

This study evaluated the following aspects of speech that are consistent with symptoms of hypoxia based on prior reports; pilot response time, microphone release, speaking rate, and voice fundamental frequency. The pilot produced 12 total transmissions during the 6 minutes and 47 seconds.

4.1. Pilot Response Time

² After ATC finished their transmission to the time it took the pilot to respond.

The first three transmissions were initiated from the pilot and thus have no response time.

The pilot's response was calculated by the amount of time it took the pilot to respond to the ATC. Table 1 provides the response time of 9 transmissions:

Table 1. Response time of pilot to ATC.

Microphone Transmission	Time of ATC end of transmission (mm:ss.n)	Time of beginning pilot transmission (mm:ss.n)	Difference (seconds)
4	02:16.305	02:17.038	0.733
5	02:36.642	02:37.131	0.489
6	02:49.318	02:50.131	0.813
7	03:00.845	03:01.573	0.728
8	04:46.481	04:46.975	0.494
9	05:19.834	05:20.936	1.096
10	05:35.473	05:35.879	0.406
11	06:12.821	06:15.037	2.216
12	06:45.519	06:46.929	1.41

Transmission 8 was initially given by the controller to the pilot at 04:39.166 and repeated at 04:46.481, the controller was finally answered at 04:46.975; potentially skewing the response time.

Similarly, Transmission 9 was followed by static mic noise presumably from the accident aircraft; the command was repeated in transmission 10 and answered successfully by the pilot.

4.2. Pilot Microphone Release Time

The microphone release time was calculated from the time the pilot was finished speaking, to the end of the transmission where only static or ambient noise was prevalent. Table 2 provides the response time of 9 transmissions:

Table 2. Microphone release time following end of speaking.

Microphone Transmission	Time pilot finished speaking (mm:ss.n)	Time mic was released (mm:ss.n)	Difference (seconds)
2	01:10.011	01:10.257	0.246
3	02:13.706	02:14.343	0.637
4	02:23.791	02:24.174	0.383
5	02:39.809	02:39.959	0.150

Microphone Transmission	Time pilot finished speaking (mm:ss.n)	Time mic was released (mm:ss.n)	Difference (seconds)
6	02:51.957	02:52.296	0.339
7	03:03.356	03:03.779	0.423
8	04:48.828	04:53.215	4.387
9	05:20.949	05:23.339	2.390
10	05:37.857	05:38.535	0.678
11	06:16.643	06:17.400	0.757
12	06:49.307	06:51.942	2.635

4.3. Pilot Speaking Rate

The pilot's speaking rate was established by taking the syllables spoken divided by the time it took to articulate a word with silent pauses or fillers (such as uhhs or umms) discounted. The speaking rate was then averaged into two groups: before and after the 8th microphone transmission. The pilot's speaking rate was calculated at 6.1 syllables per second with no change before or after.

4.4. Pilot Voice Fundamental Frequency

A speech signal can be broken down into its formant frequencies, which are resonance frequencies³ that are the most prominent frequency bands in a speech signal. Typically a segment of speech can be broken down into the fundamental frequency (f0) and the next four formats (f1, f2, f3, f4).

The fundamental frequency is the lowest frequency of a signal and is a property of interest because it is the most consistent formant for speech. Studies have shown that fundamental frequency increases in times of heightened psychological stress or excitement (Brenner, 1994).

For the purposes of this report, the fundamental frequency of the pilot's voice was determined using spectrogram software. The pilot voiced his call sign to ATC, "Nine-Hundred-Kilo-November" (900KN), 9 times throughout the audio recording and was used as a baseline for analysis. Table 3 provides the fundamental frequency of the 9 radioed call signs.

Table 3. Fundamental Frequency of radioed call sign.

Time (mm:ss.n)	f0 Max (Hz)	f0 Min (Hz)	f0 Average (Hz)
00:31.8	140.31	95.51	114.01
01:07.5	113.31	93.216	101.35

³ Resonance implies a synchronous vibration of a neighboring object. In this case the vocal tract.

Time (mm:ss.n)	f0 Max (Hz)	f0 Min (Hz)	f0 Average (Hz)
02:12.3	141.08	110.27	126.98
02:38.7	121.79	79.43	94.58
03:02.3	109.46	63.79	93.75
04:47.8	125.40	84.37	102.40
05:36.7	126.96	65.85	102.88
6:15.9	138.25	79.94	107.70
6:48.2	119.97	88.40	106.88

Figure 1 is a spectrograph⁴ of the voiced call sign '900KN' in microphone transmission one. The fundamental frequency is shown on the bottom with its successive formants shown in red (f1), green (f2), blue (f3), and yellow (f4).

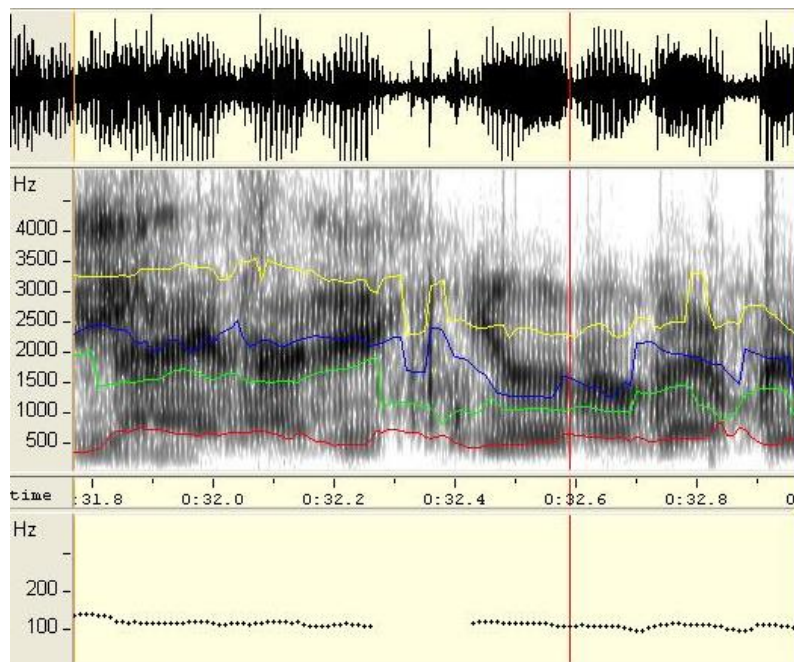


Figure 1. Spectrograph of radioed call sign with formants overlaid.

Figure 2 compares the spectrograph of 'Kilo November' for transmission 9 and 2. In transmission 2, a stop delineating each syllable is shown in orange where in transmission 9, the boundary is less clear and the spectrograph appears to be joined consistent with slurring.

⁴ A spectrograph is a graphical representation of audio with time vs frequency in the x and y domain, and intensity represented as color.

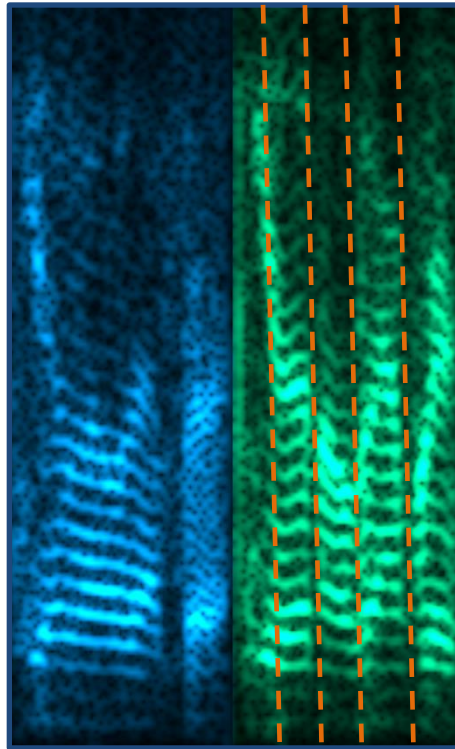


Figure 2. Spectrograph of 'Kilo November' during transmission 9 (left) vs transmission 2 (right).

4.5. Conclusion

The study showed the following symptoms consistent with hypoxia:

- A consistent fundamental frequency was shown in the spectrograph analysis throughout the audio clip with exception to microphone transmission 3.
- The microphone release time drastically increased after microphone transmission 8, which was roughly 2 minutes and 30 seconds after transmission 3 when the pilot indicated, "something was not correct" to ATC. In addition, pilot response time increased noticeably after this.
- Slurring of the speech became noticeably more prevalent, following transmission 9, with spectrograph analysis of the consonant 'k' in 'kilo', virtually missing from the pilot's speech. Audible breathing was heard during prolonged microphone keying in transmissions 8, 10, and 11.

The study showed the following symptoms inconsistent with hypoxia:

Previous studies have shown that the pilot's speaking rate decreased as hypoxia develops; however, the pilot appeared to maintain a consistent speaking rate in this case.