Whistling Like a Bat – Part II:

An Update on the Development of an Ultrasonic Whistle to Deter Bats From Wind Turbines

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ULTRASOUND AS DETERRENT

- Attenuates quickly in the atmosphere
- Birds and large mammals (including people!) can't hear it
- Bats avoid "noisy" environments when foraging
- Bats can learn to avoid toxic moths which emit ultrasonic warning clicks

UMass Amherst

The Bat Whistle Team

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Michael Smotherman

PROJECT TASKS

Task 1: Characterize bat avoidance responses to ultrasound regimes

Task 2: Design initial biomimetic prototype

Task 3: Develop series of prototype whistles operating over range of frequencies

Task 4: Test prototype whistle series on bats in laboratory

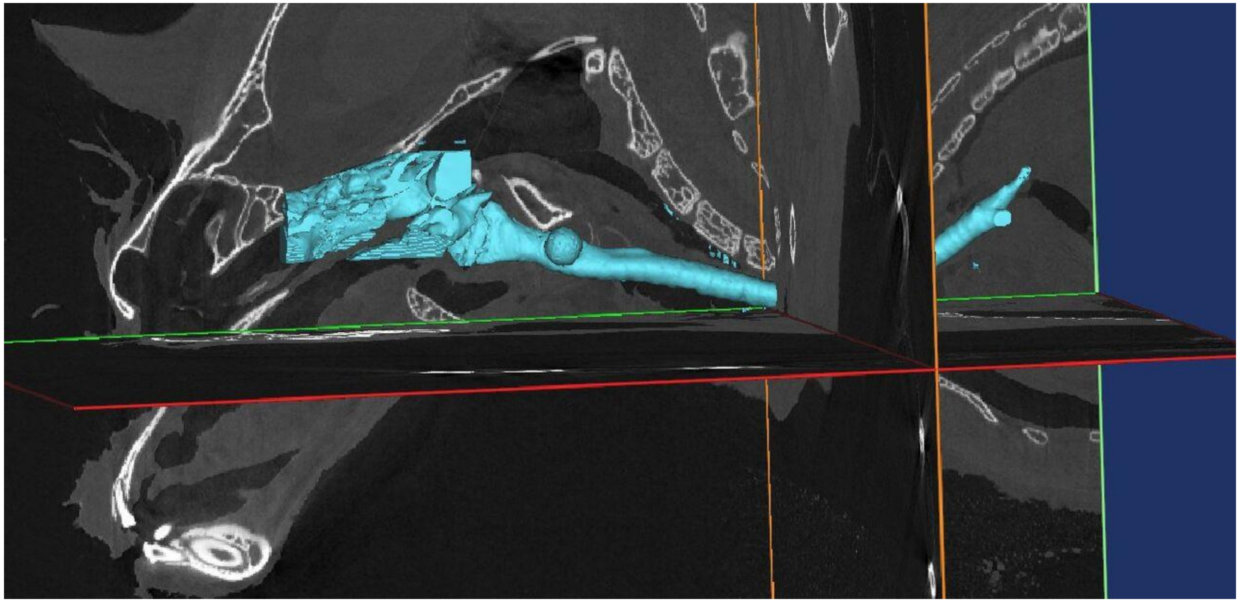
Task 5: Test prototype whistles on wind turbine

Obtained candidate biological models

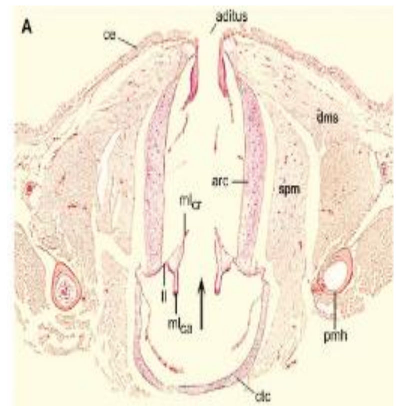
Horseshoe bat

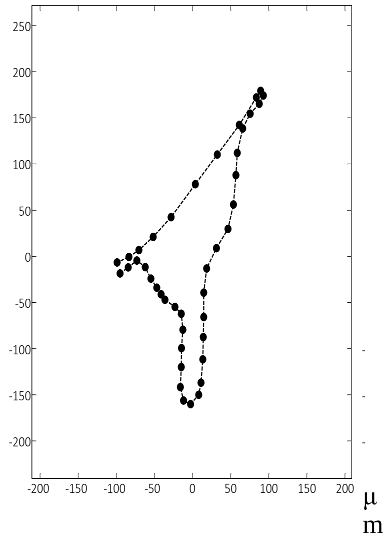
Concave eared torrent frog

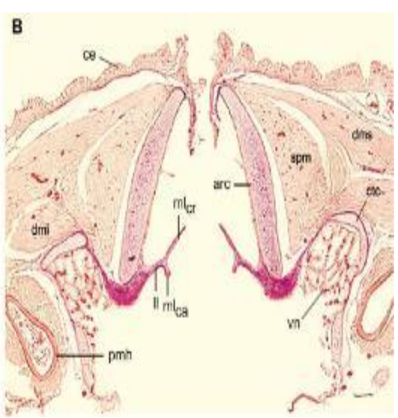
Conducted a literature review of biological structures that produce ultrasound and produced 3-D scans of the larynx of Greater Horseshoe Bats.

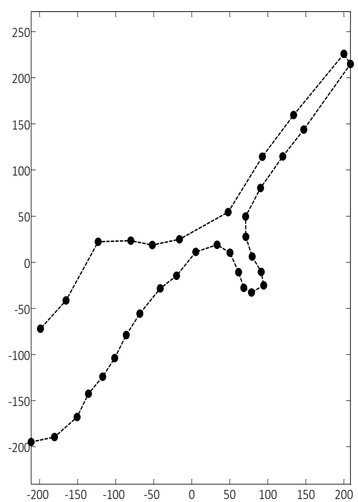


Flexible Silicone Rubber Casting

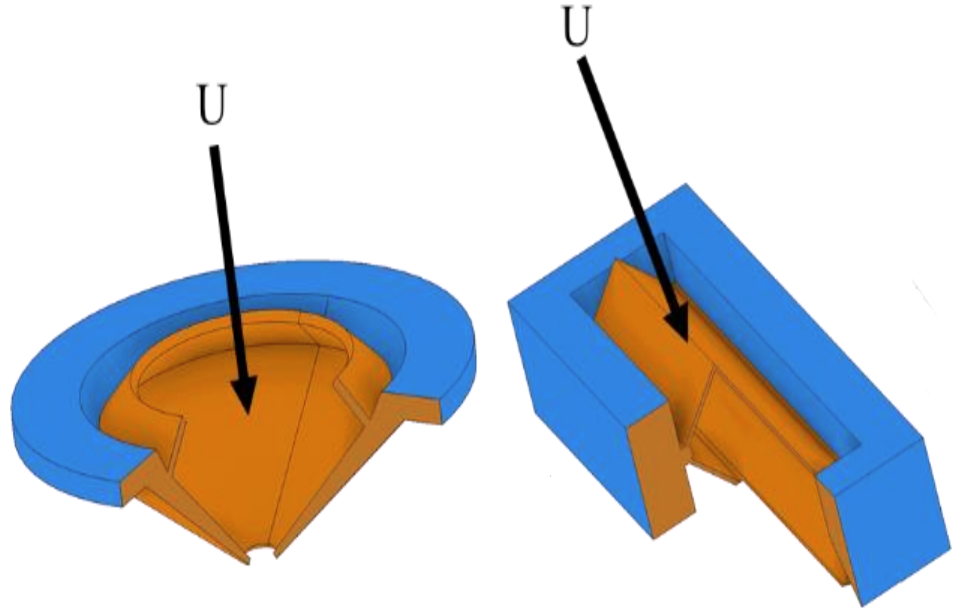






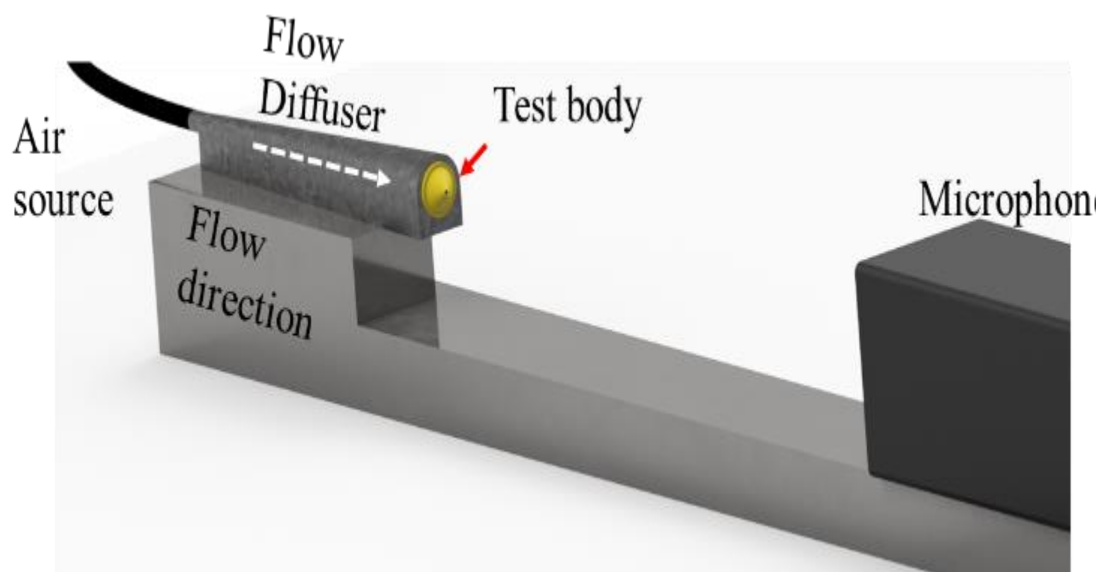


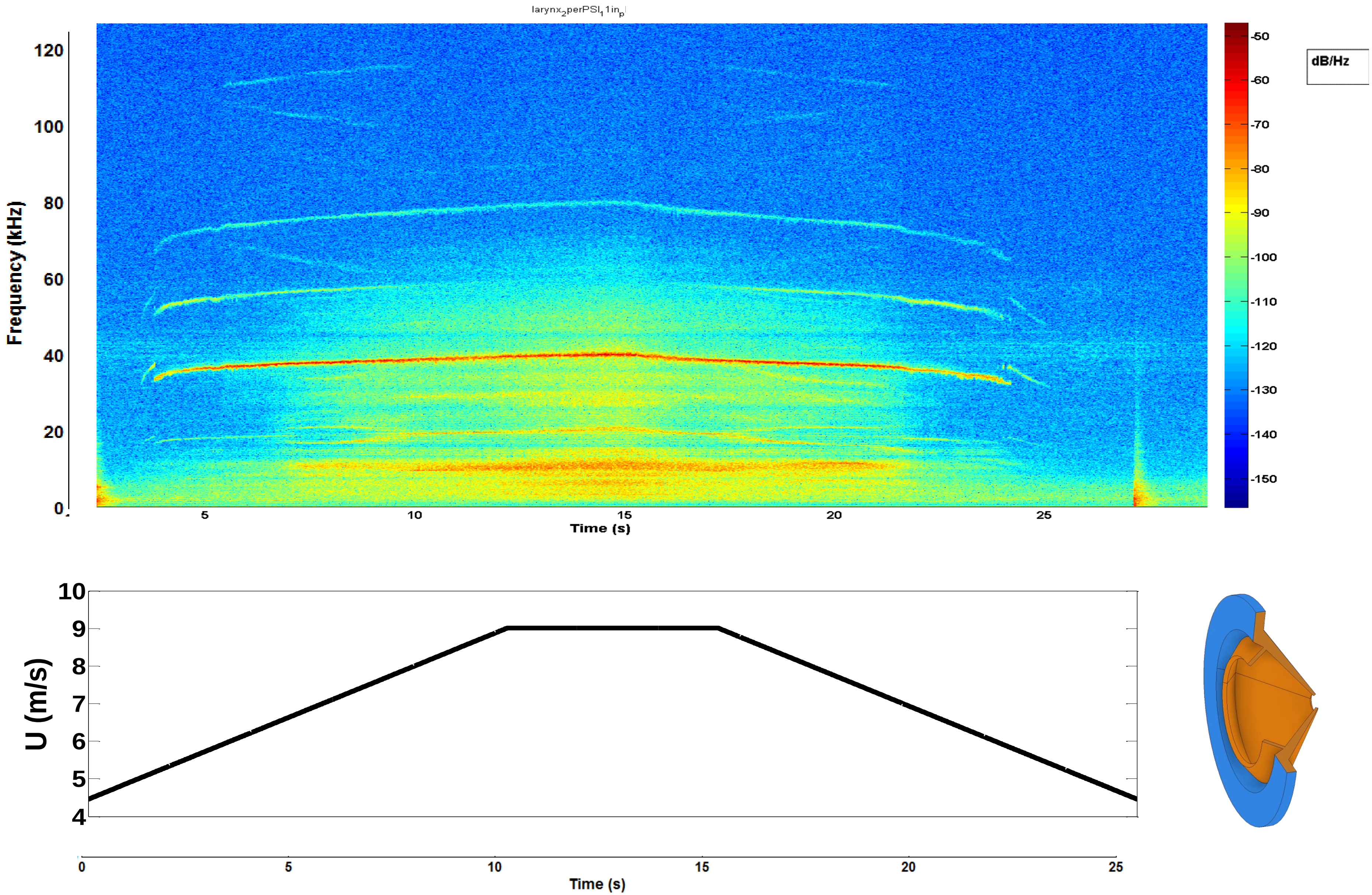
Suthers *et al.* 2006



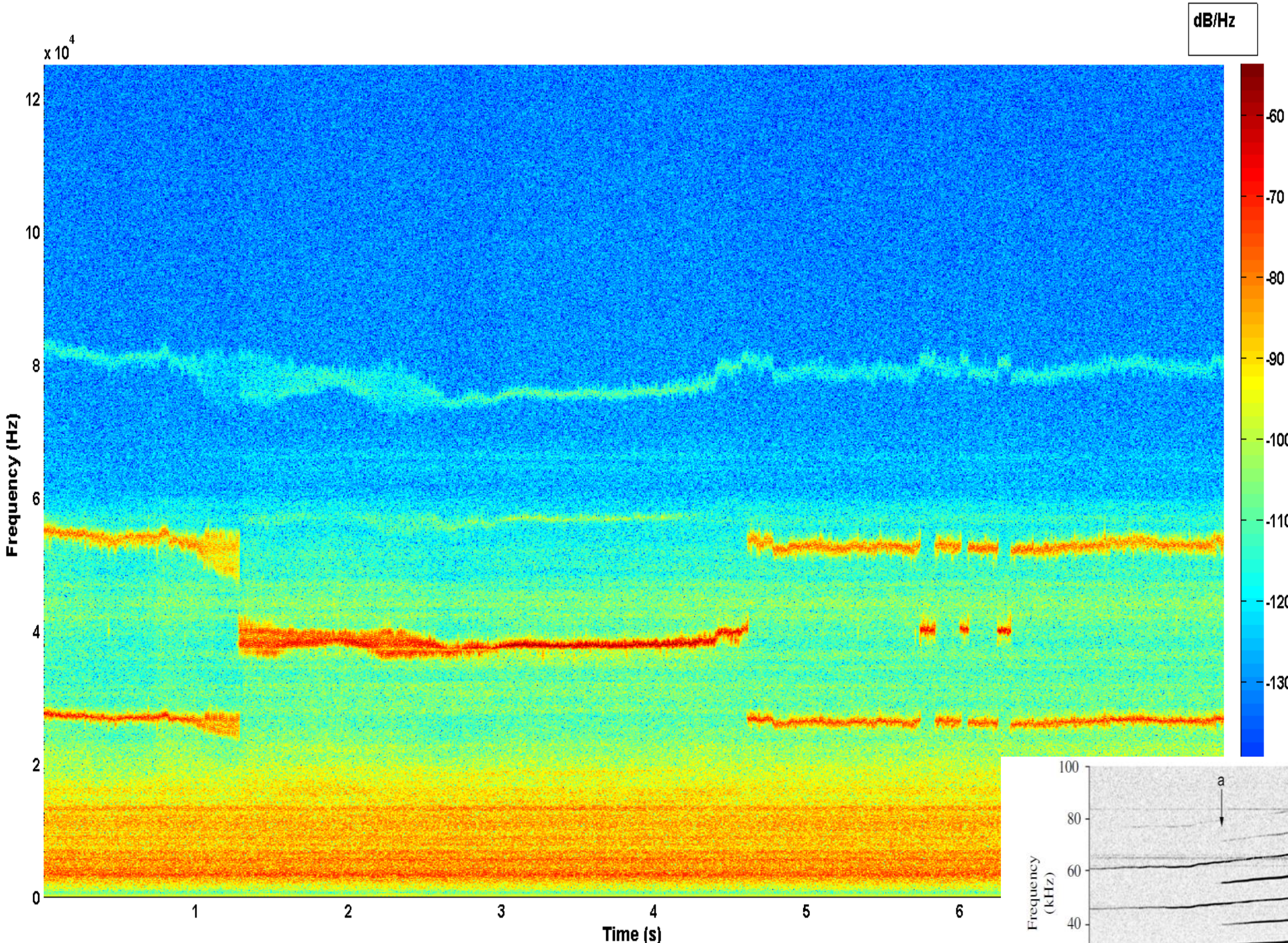
a. Revolved

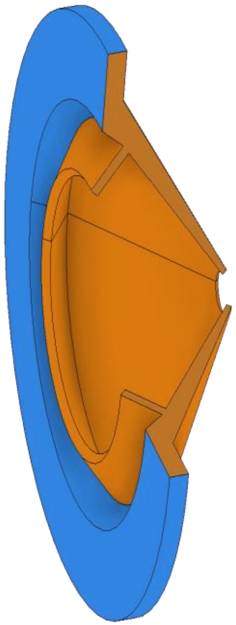
b. Uniform





Frequency (kHz)
Time (s)
dB/Hz
U (m/s)
Time (s)





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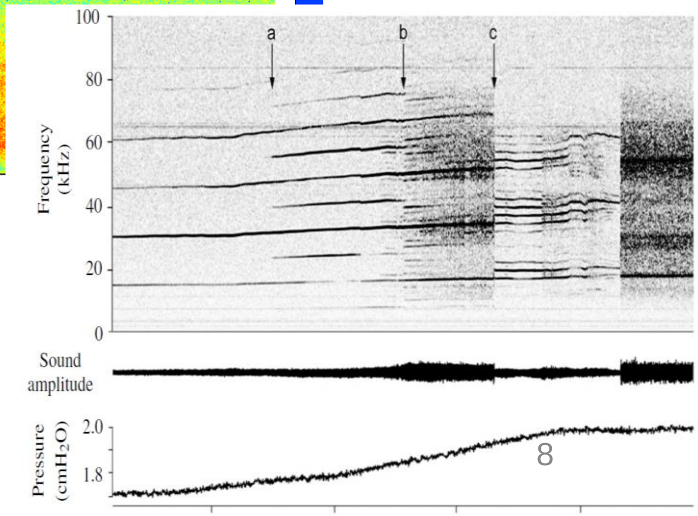
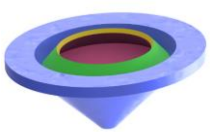


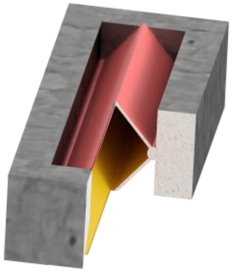
Flexible outlet restriction at 14.7 m/s (constant flow pressure)

Developed a prototype whistle that produced ultrasound frequencies of 40, 60, 80 and 120 kHz. Tested a flexible output on the whistle and observed frequency jumps (modulation) as seen in a bat larynx.

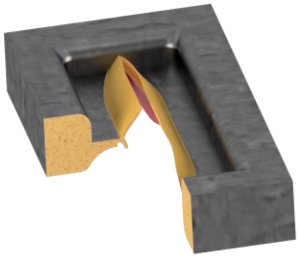
a. Revolved larynx



b. Axially mirrored



c. Axially asymmetric



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Test prototype whistle series on bats in laboratory

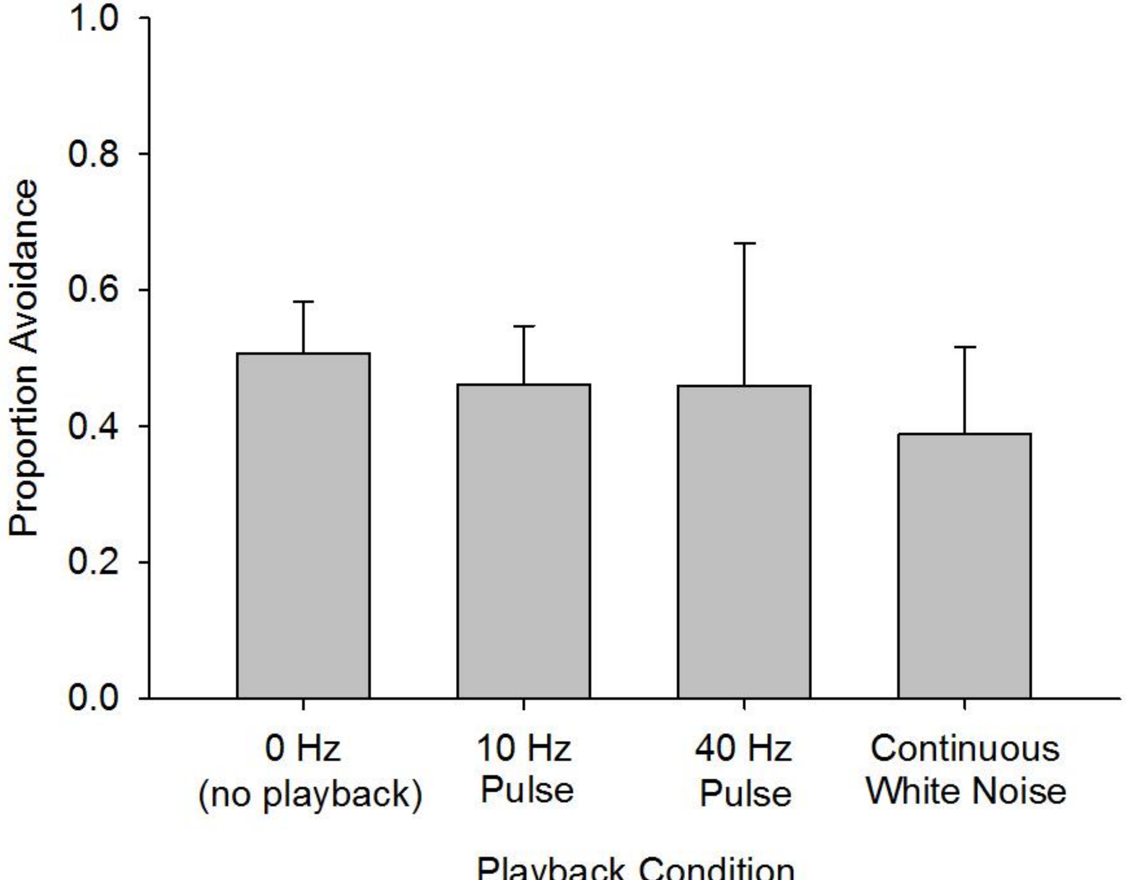
Mexican Free-tailed Bat

Tri-colored Bat

Three Assays

- Y-Maze - Bats given a choice to fly down either of two sides of a divided tunnel. One side had a continuous acoustic stimulus playing while the other was quiet. We measured the % flights down both sides.
- Perching Assay – Bats are released into a room with smooth walls and ceiling . They cannot easily perch anywhere except on two feeding platforms at opposite sides of room, making this essentially a *two-alternative forced choice assay*. Both perches have a speaker. During trials, one of the speakers is ON, and we count how many times the bats land on either perch (stimulus vs quiet perch).
- Turning Assay - Bats fly down an open tunnel. Their approach triggers a stimulus playback (PB) from either of two speakers positioned on opposite sides of tunnel. We assess whether the PB altered flight paths by recording which direction bat turned in response to PB (towards or away from PB speaker).

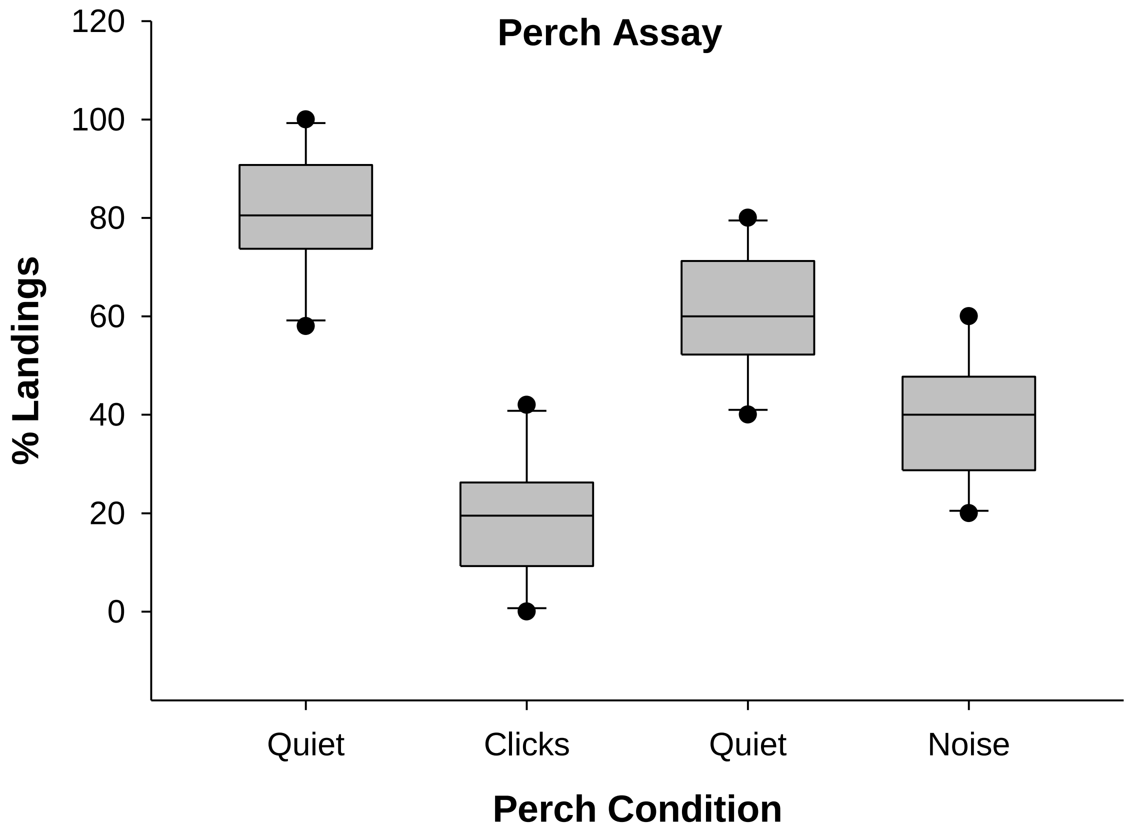
Y-Maze Assay



- Sample Size: 6 bats, 20 flights per bat.

- Results: No statistically significant effect of any stimulus on flight path choice.

Perching Assay



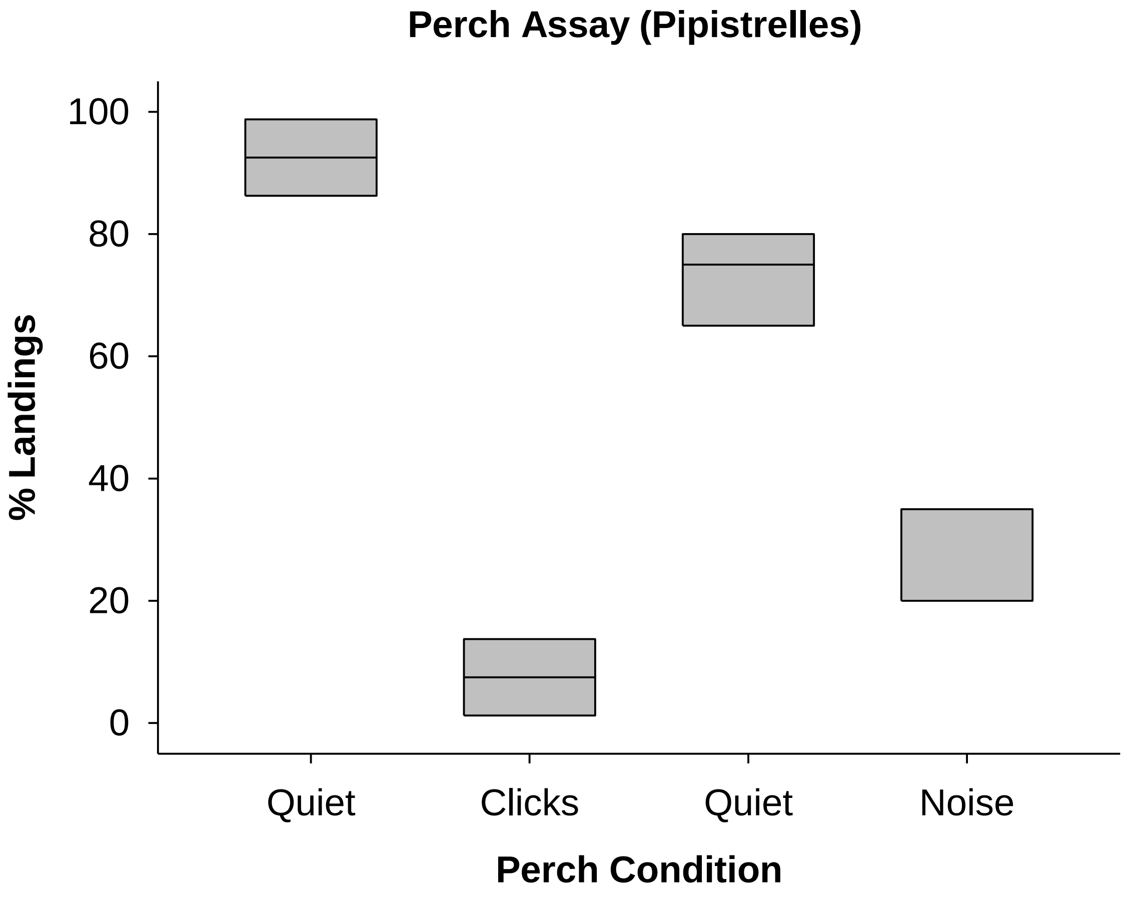
Sample Size: 10 bats, >10 landings per trial.

<u>Experiment 1</u>: Bats chose between quiet perch and perch with broadband clicks.
<u>Experiment 2</u>: Bats chose between quiet perch and perch with continuous white noise.

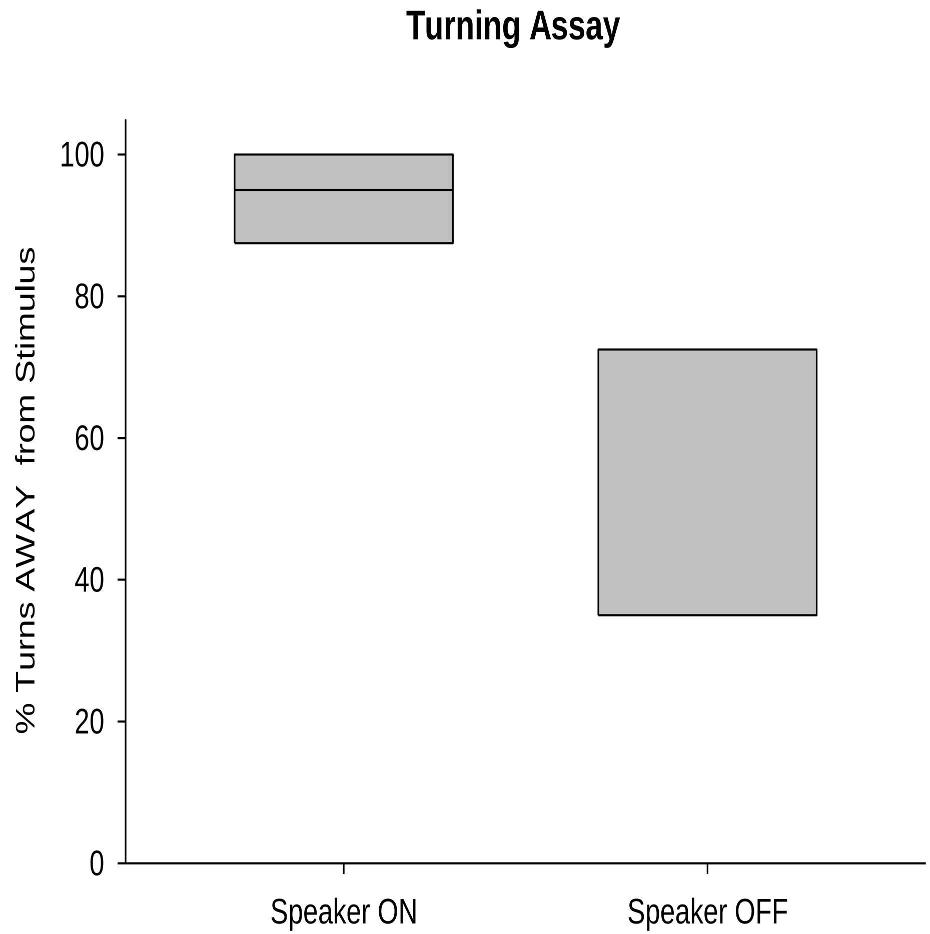
Perimyotis subflavus: n=8

ANOVA, P<0.001

Given the choice between a quiet landing platform and a noisy platform, the pipistrelles almost always landed on the quiet platform. Both clicks and broadband noise had significant effects.



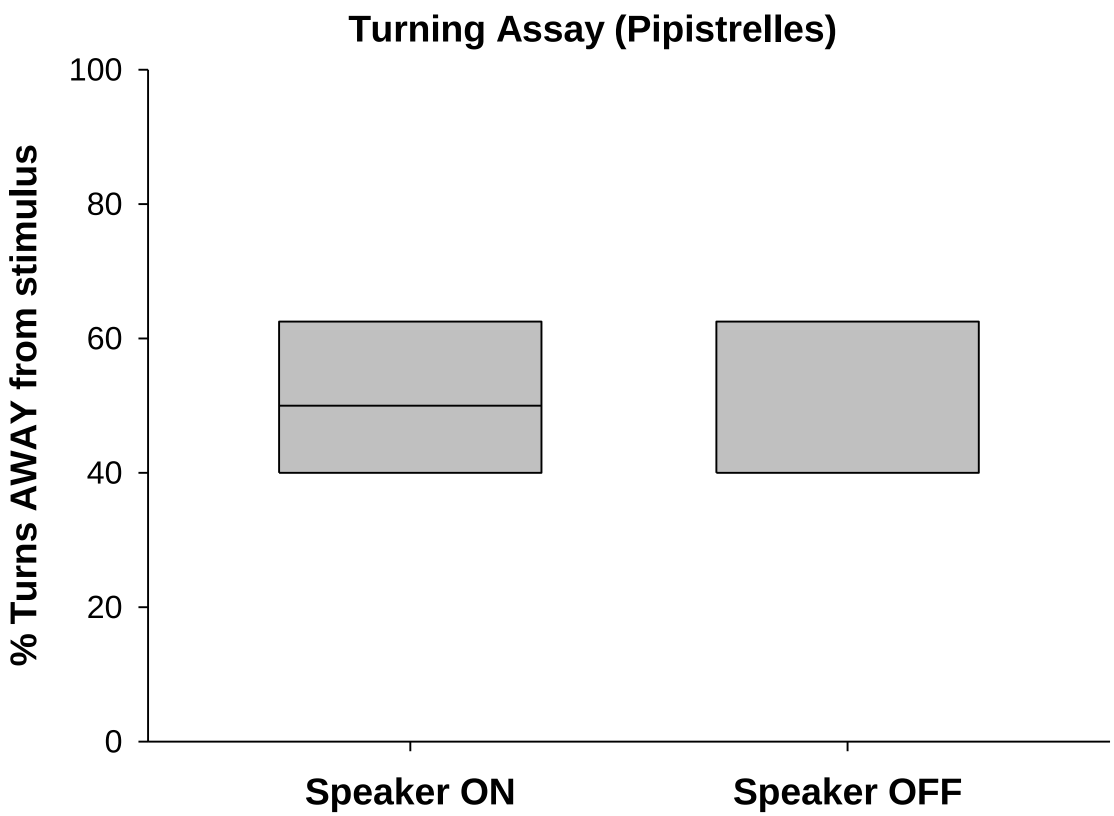
Turning Assay



Conclusions: Stimulus side positively correlated with direction of turn. This assay works well and seems most appropriate for testing whether the proposed device can alter flight paths in the wild.

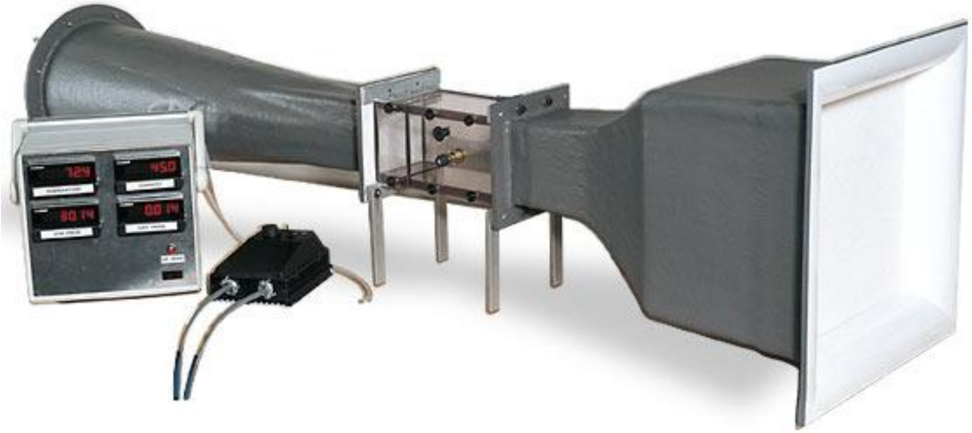
Perimyotis subflavus: n=5, 20 flights per bat; ANOVA, P = 0.815

These flights were done with wild, untrained bats because we cannot keep pipistrelles in the lab for more than two days at a time. Still, most of the bats would fly back and forth in our flight tunnel, and 5 of 8 bats completed enough trials to allow for a statistical test. The pipistrelles flew more slowly than the free-tailed bats and could even hover in place or reverse directions. This impacted the results because the pipistrelles did not seem to respond reflexively to the pulse-triggered stimulus in the same way the fast-flying free-tailed bats did. This doesn't mean they didn't hear it or failed to localize the source, only that they did not perceive the speaker as posing an imminent threat.

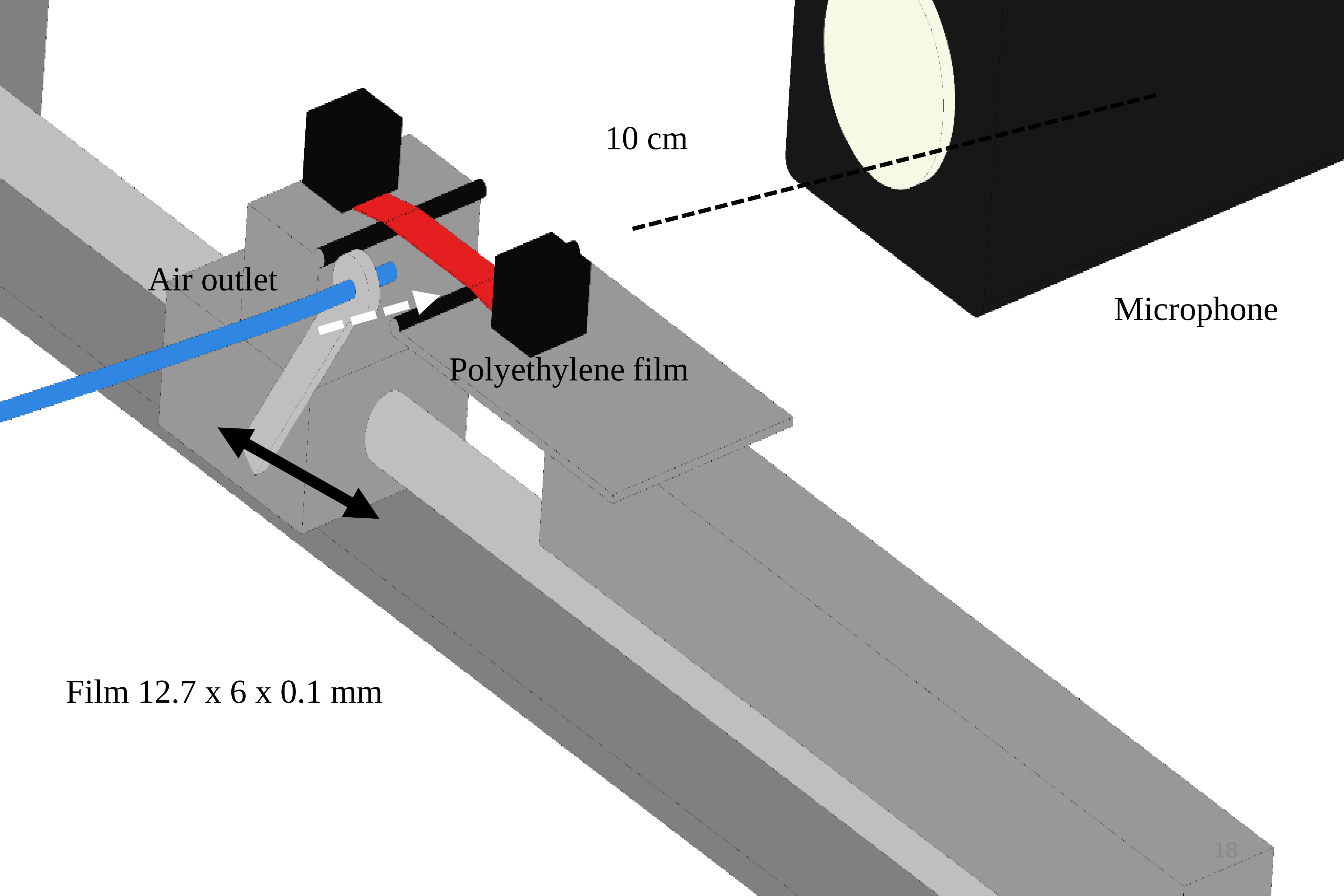




Design initial biomimetic prototype

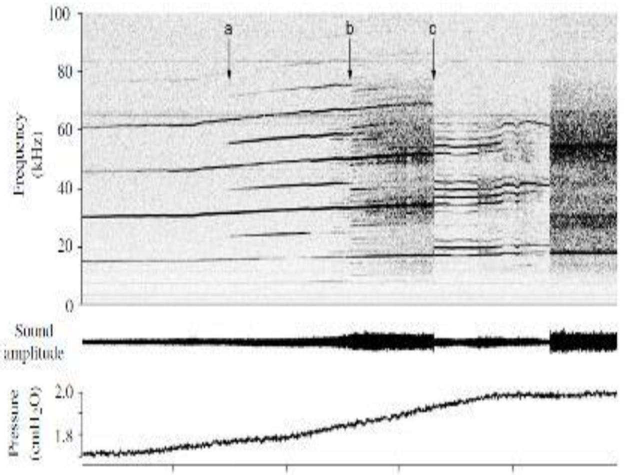


How does tension influence higher harmonics and frequency-modulation?

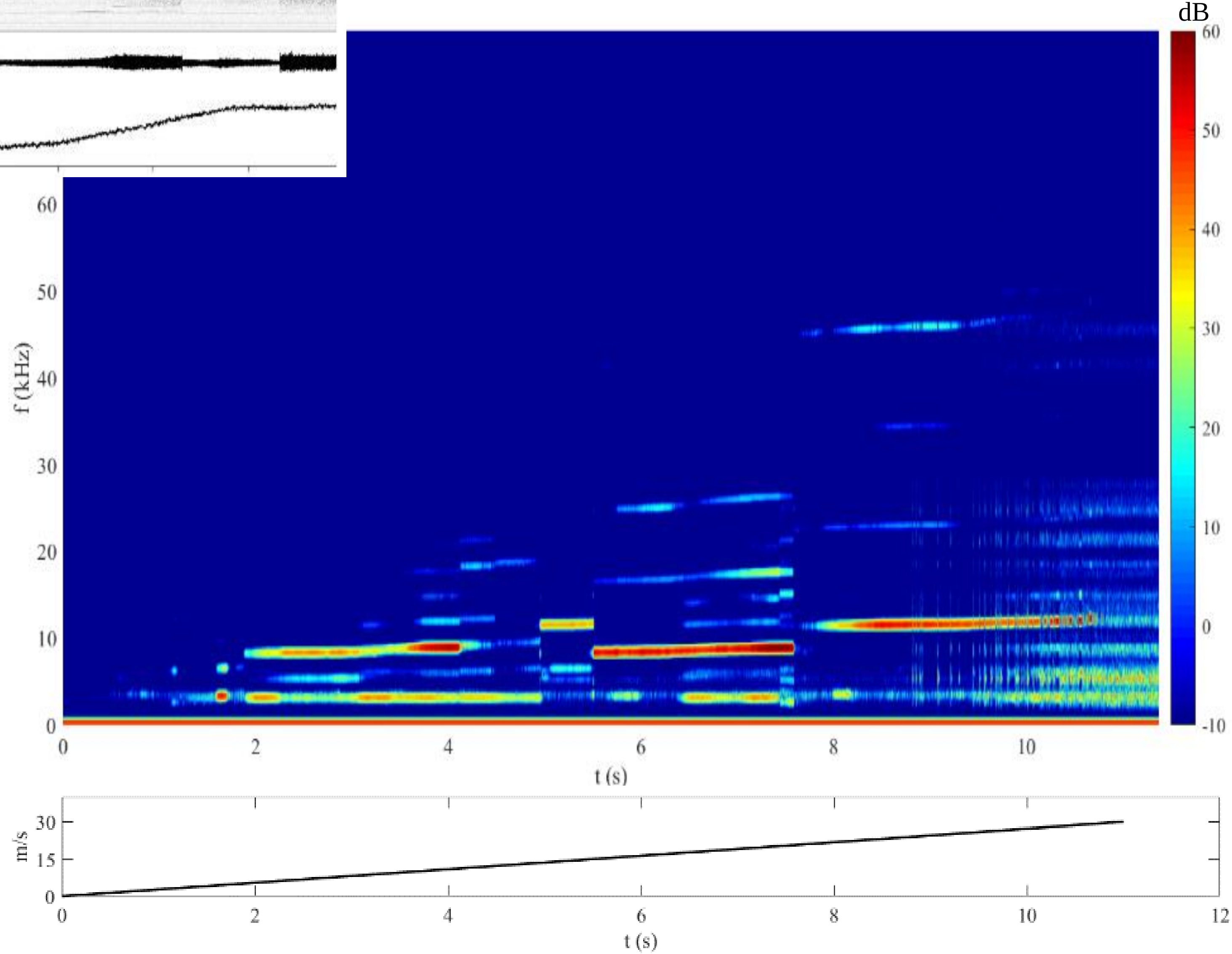


Similar frequency jumps are observed for excised larynx

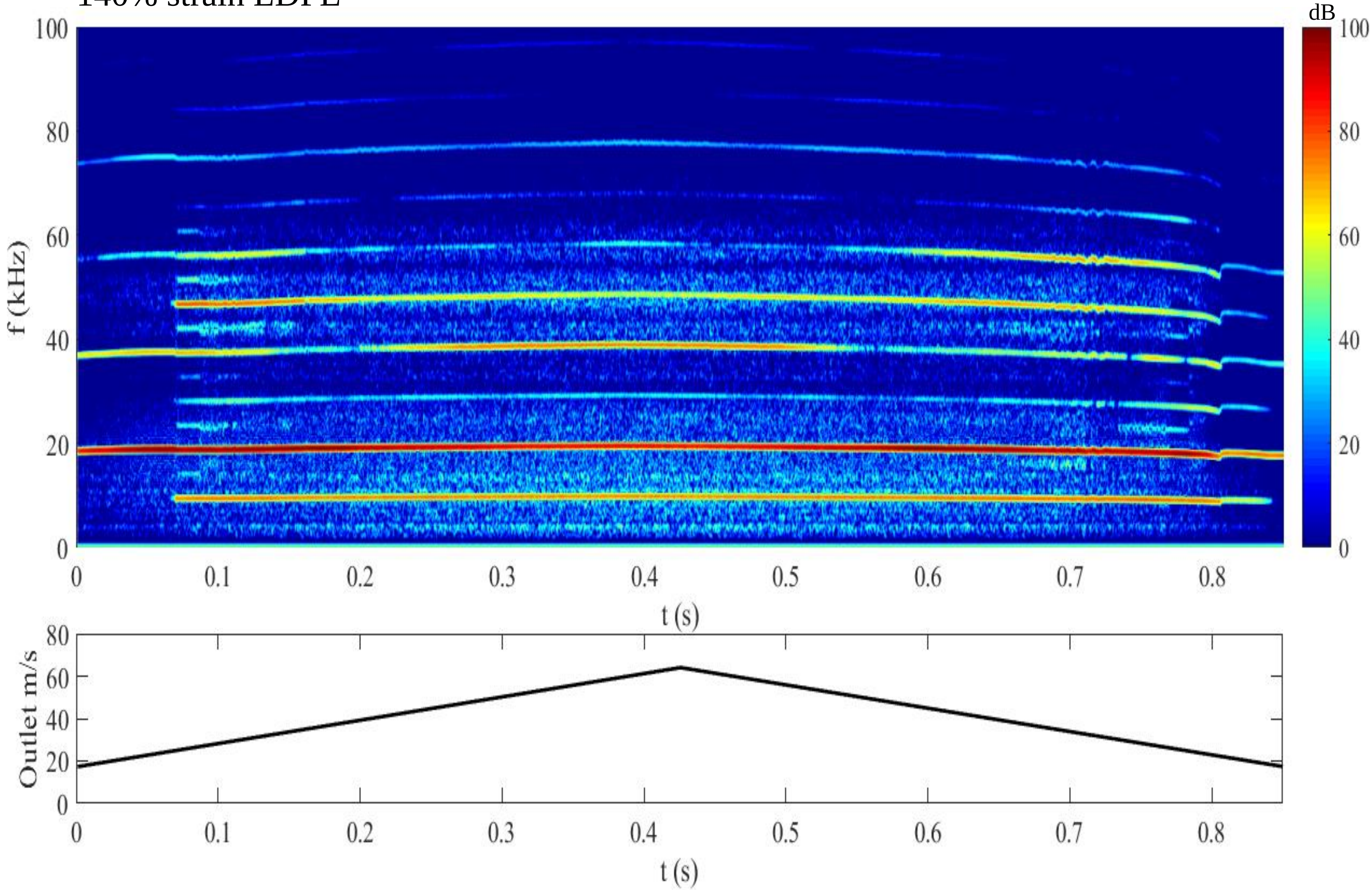
15% strain: velocity ramp 0-30 m/s



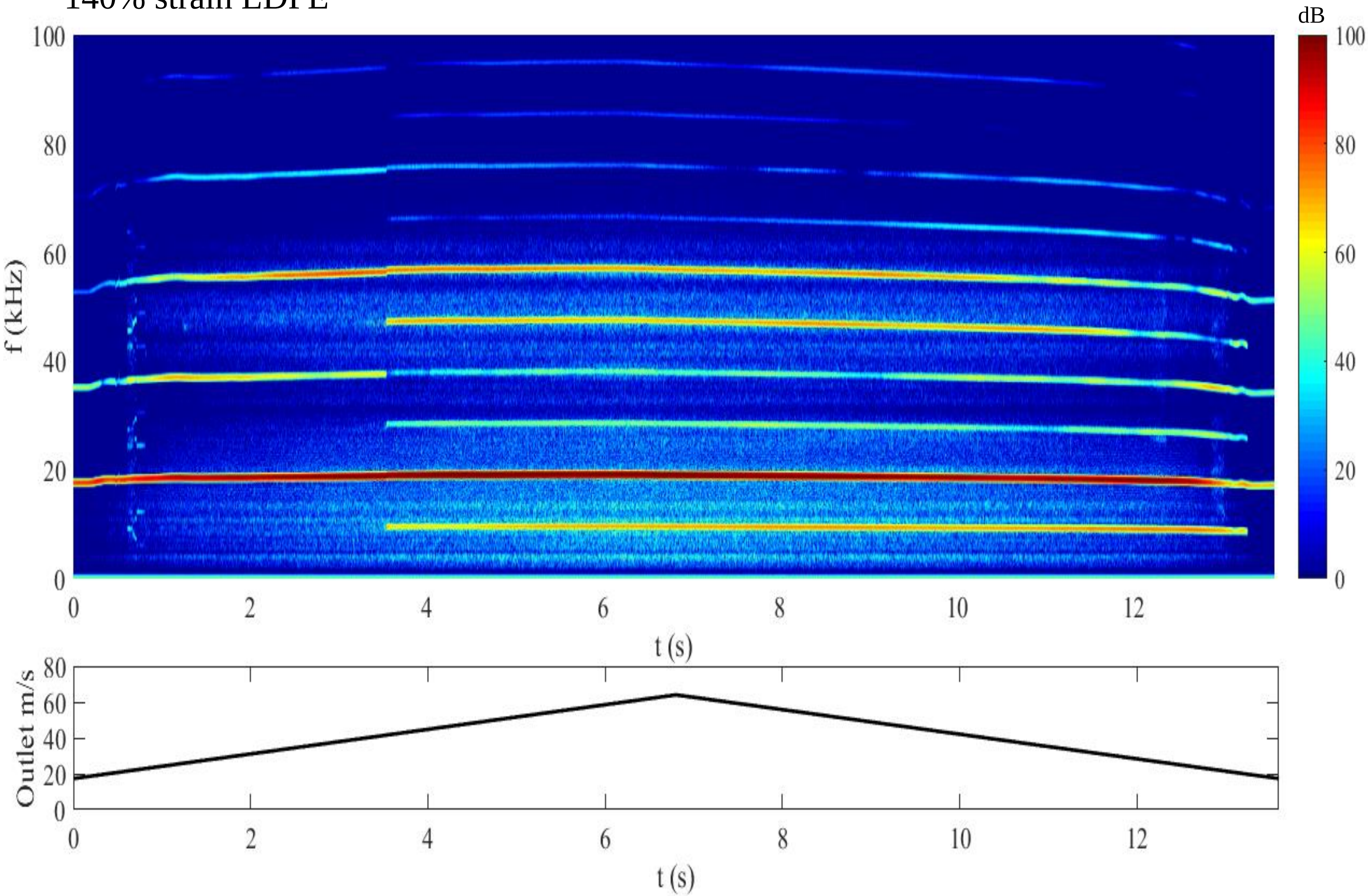
Suthers *et al.* 2006



With a directly impinging jet with transient velocity, higher harmonics are observed
140% strain LDPE

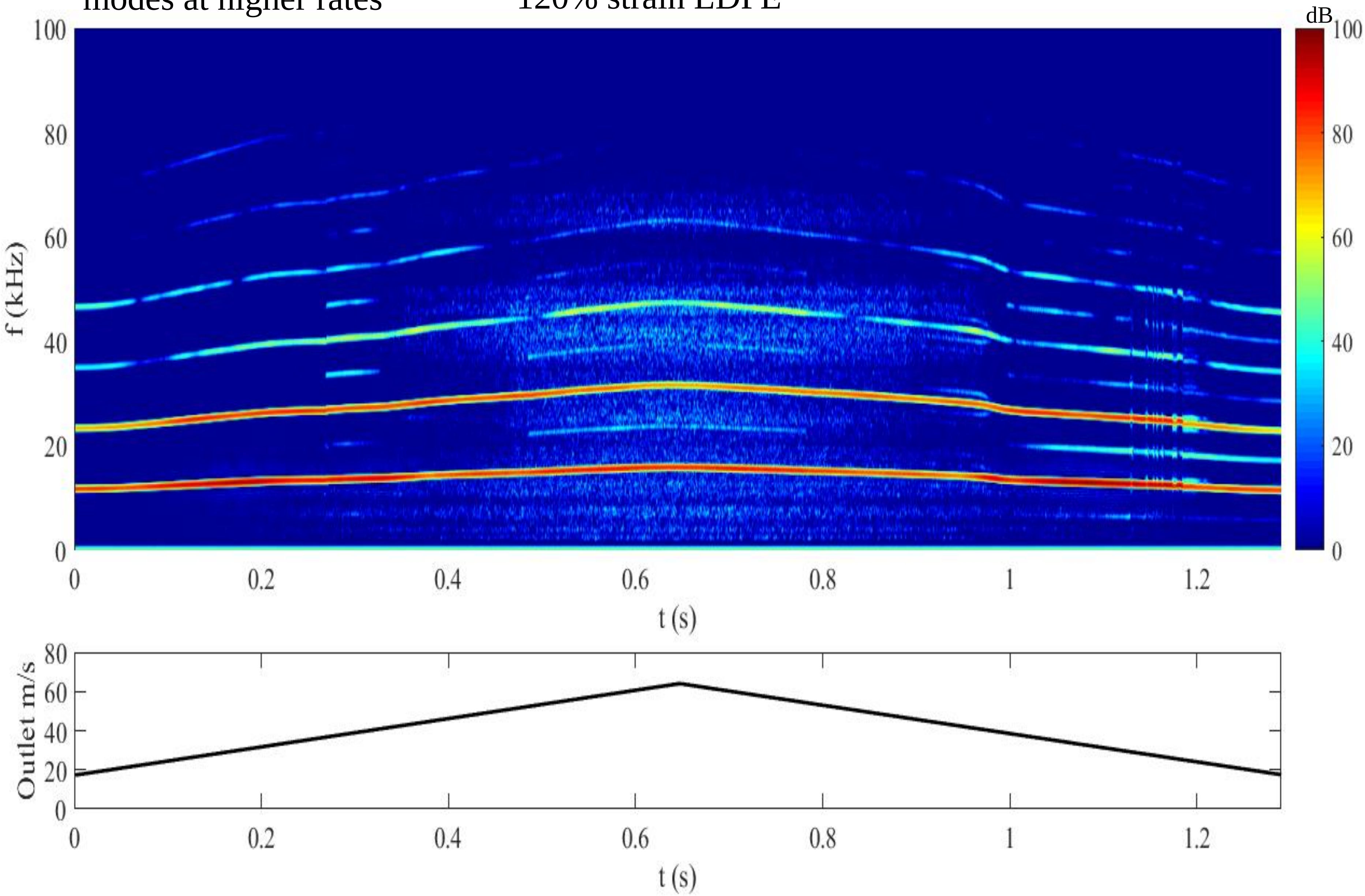


On a longer timescale, frequency jumping occurs within the harmonics
140% strain LDPE

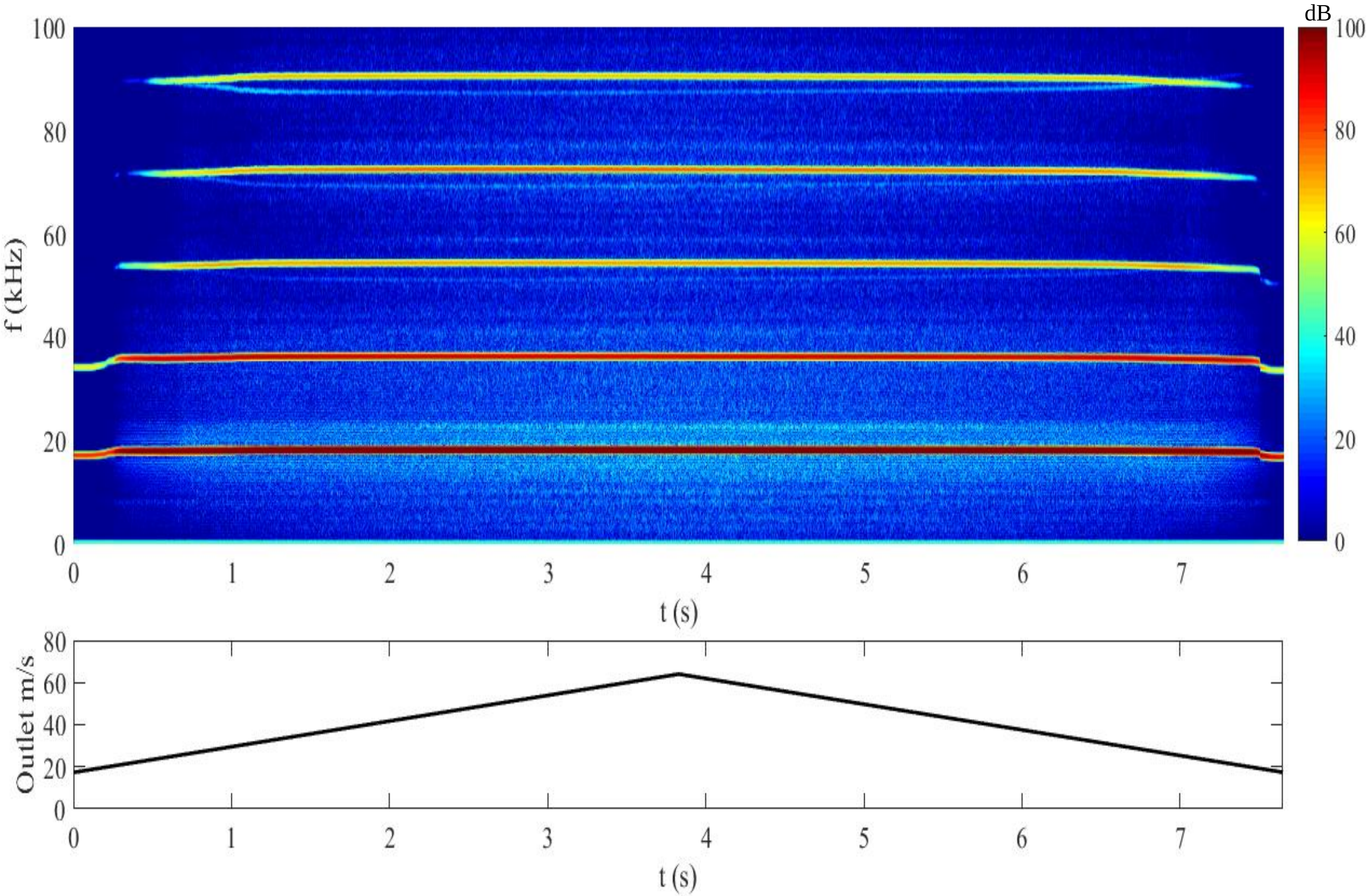


At low strain, frequency jumps are possible for lower velocities and dominated by plate modes at higher rates

120% strain LDPE



At 180% strain the response is fully plate modes, without frequency jumping or hysteresis



Whistle Design Conclusions

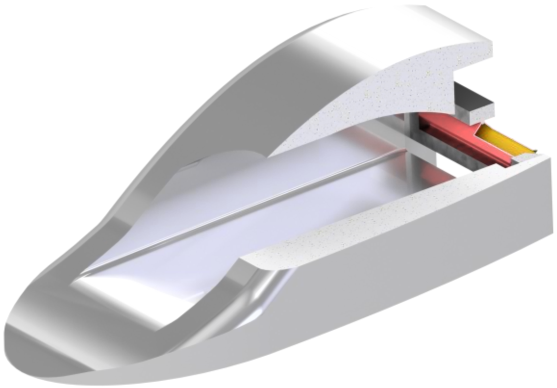
Complexity of larynx geometry can be reduced to a tensioned film in flow

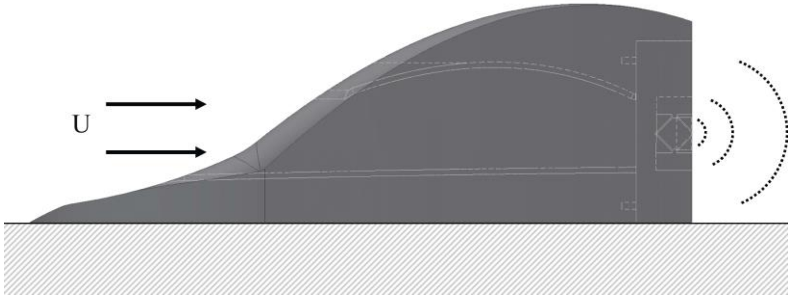
Device produced ultrasound using flow-induced oscillations, at frequency range and power desired

Tension effective at controlling harmonics and frequency

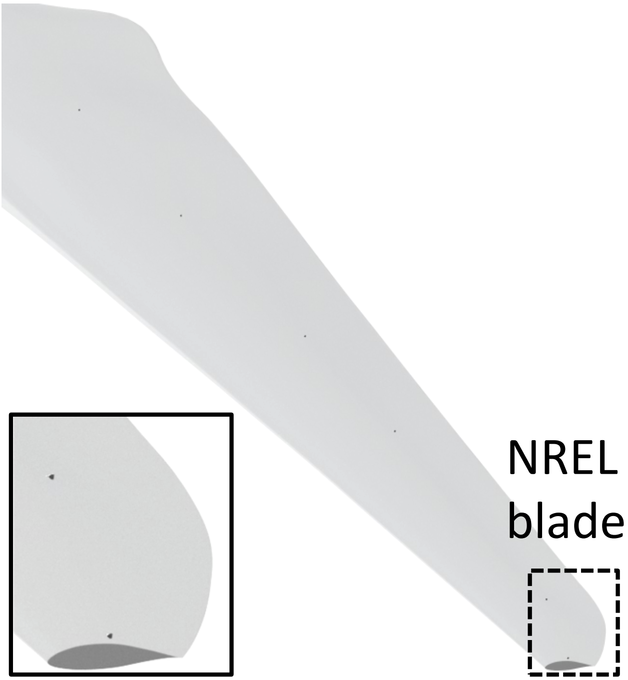
95 dB peak at 10 cm: corresponds to 61 dB at 5 m

Aerodynamic and acoustic aspects of deterrent placement



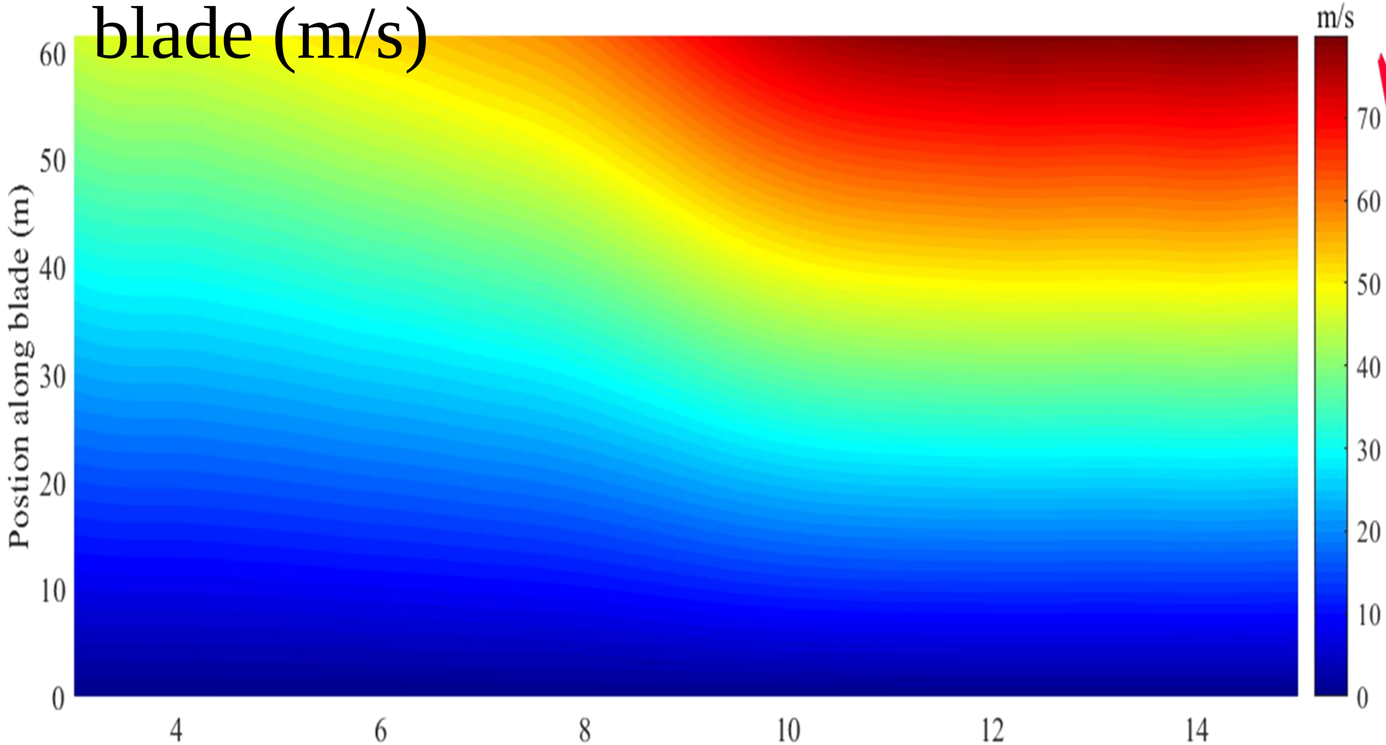


Housing for Ultrasonic Whistle

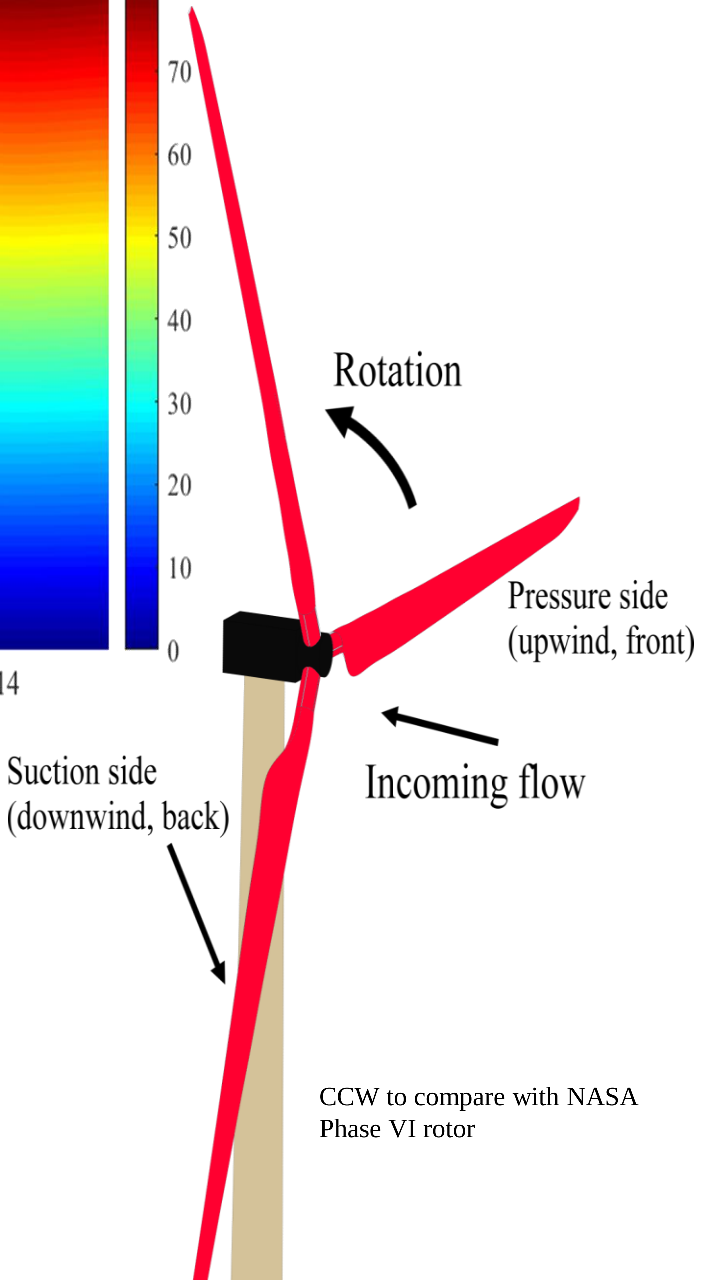


NREL 5 MW reference blade (62 m)

Local velocity along the length of a rotating NREL 5MW blade (m/s)



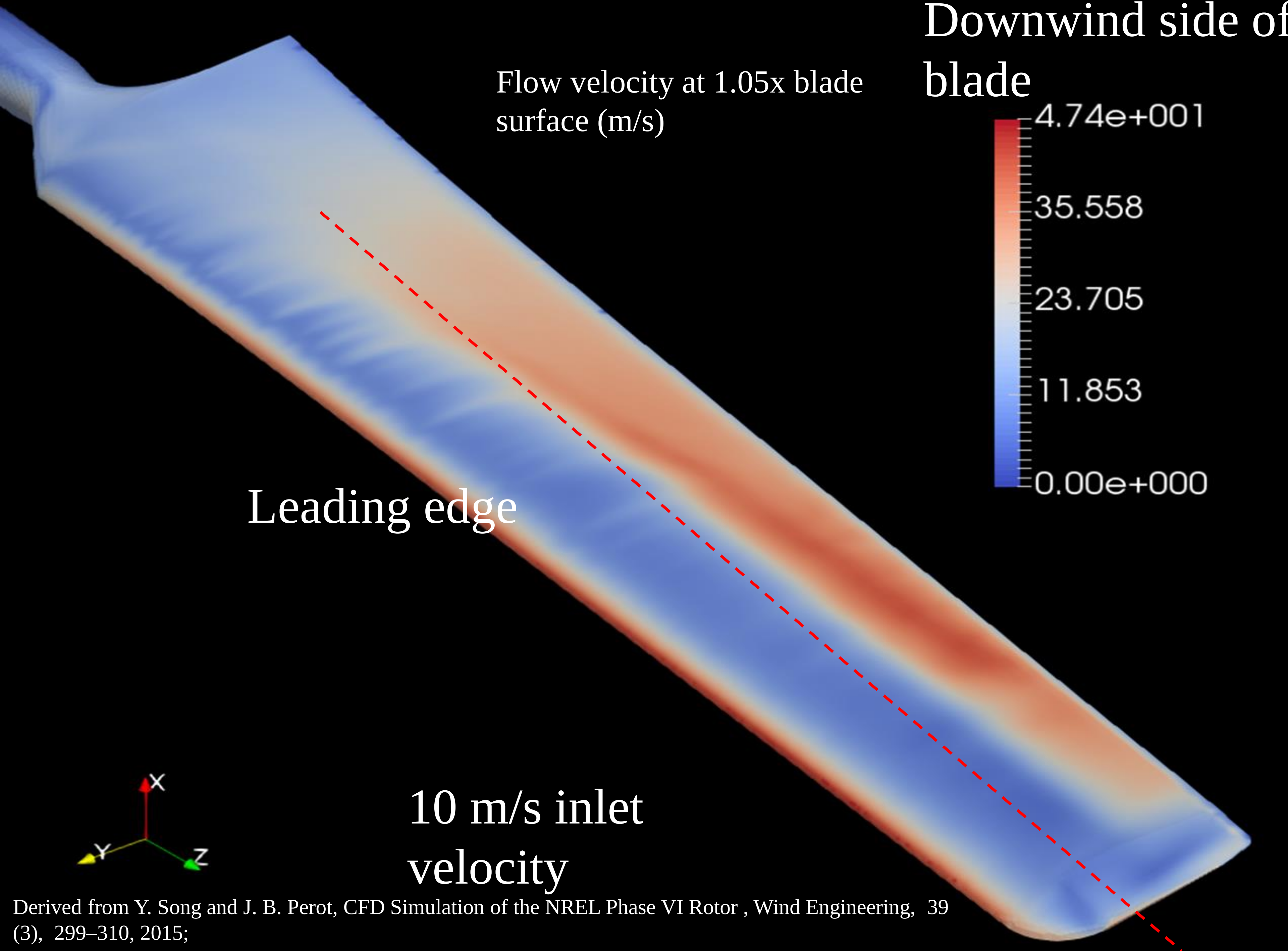
Incoming flow * (m/s)



CCW to compare with NASA Phase VI rotor

* Derived from Jonkman, J.M., Butterfield, S., Musial, W., "Definition of a 5-MW reference wind turbine for offshore system development," National Renewable Energy Laboratory Colorado, 2009

Downwind side of blade



Derived from Y. Song and J. B. Perot, CFD Simulation of the NREL Phase VI Rotor , Wind Engineering, 39 (3), 299–310, 2015;

Low-speed flow characteristics

For low velocities (5 m/s) flow remains well attached

Device placement unlikely to be issue anywhere on blade

Flow separation largest issue with device placement

Let us study 10 m/s case: best matches experimental data (Fig b.)

Y. Song and J. B. Perot, CFD Simulation of the NREL Phase VI Rotor , Wind Engineering, 39 (3), 299–310, 2015;

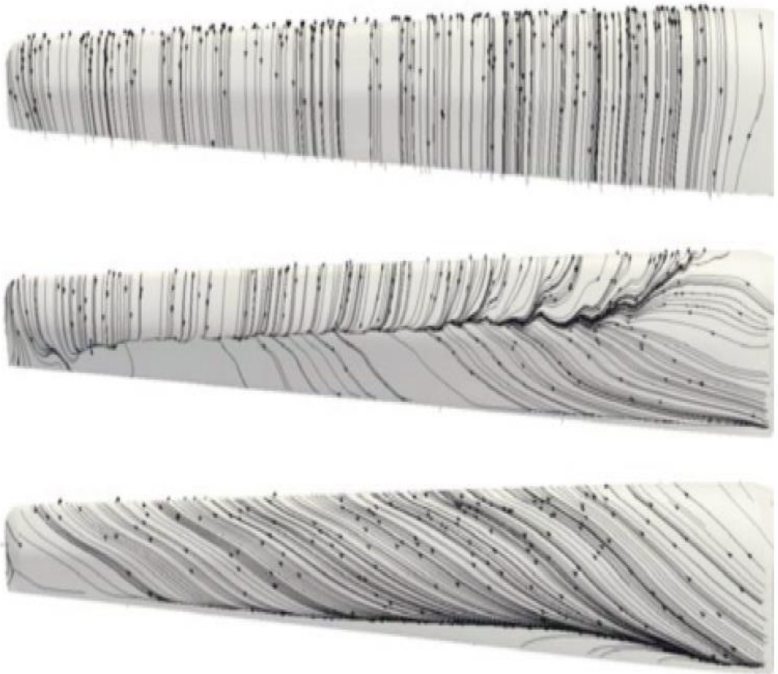


Figure a. Surface streamlines for incoming flow of 5, 10, 21 m/s

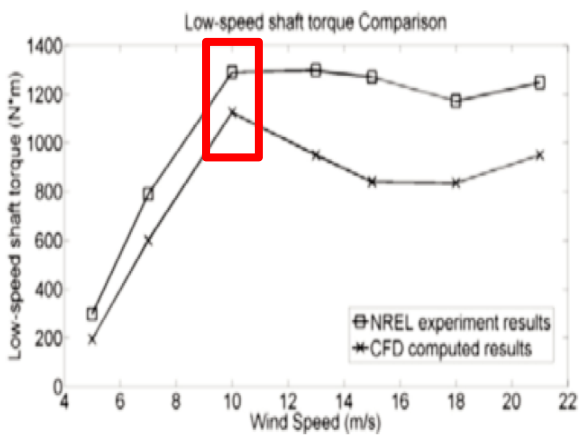
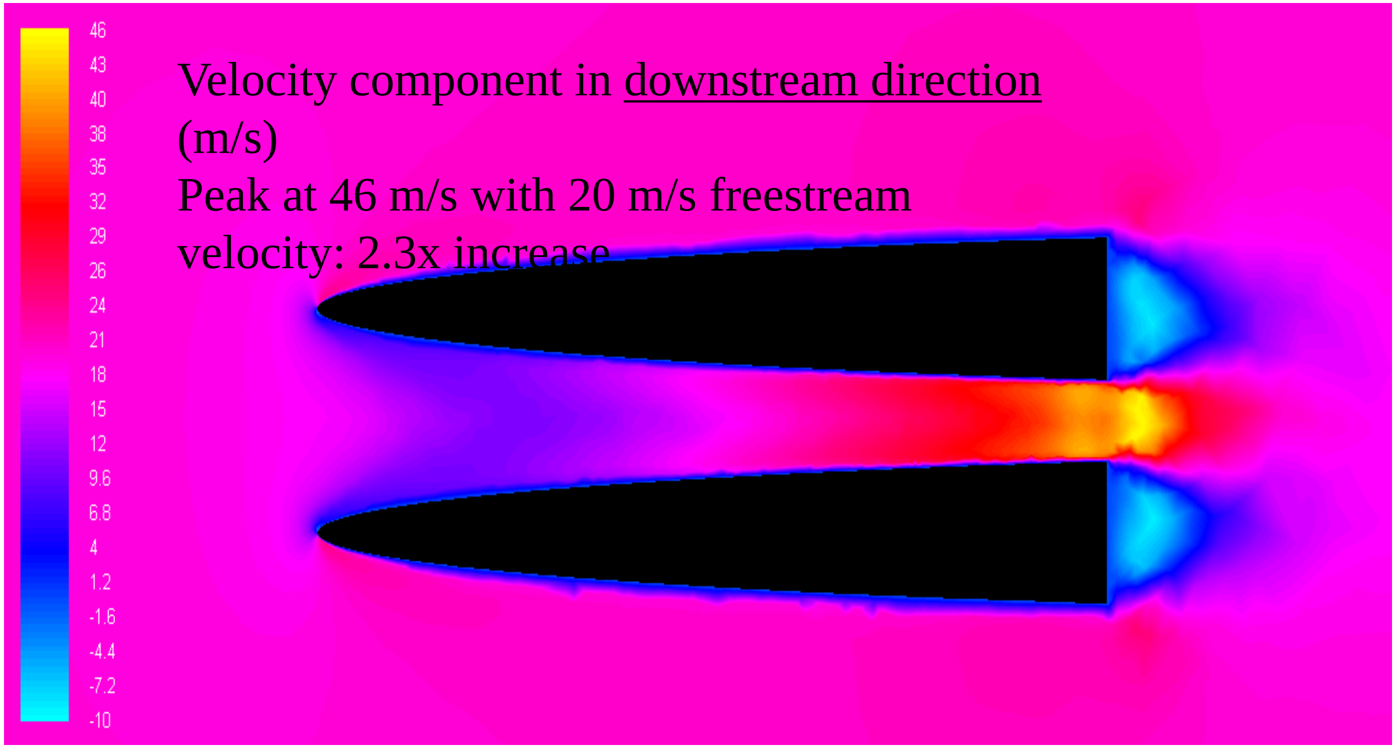


Figure b. Validation of CFD runs with experimental data

Flow Concentrator



Deterrent Placement Conclusions

Industrial-scale turbine blade has local velocity magnitude appropriate for current device requirements

Exact velocity profile is installation dependent

Cord-wise velocity reductions can be compensated for using flow concentrator

Flow separation avoidable by placement closer to leading edge or on upwind side of blade

Current peak acoustic output appropriate for arrayed deployment along blade

Ongoing Work

- Testing of Whistle Sounds on Bats in the Laboratory and Field
- Recording Sounds of Whistles Attached to Actual Turbine Blade


Thank you!