LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

MGH INSTITUTE OF HEALTH PROFESSIONS
A graduate school founded by Massachusetts General Hospital

Real-world ambulatory monitoring of vocal behavior

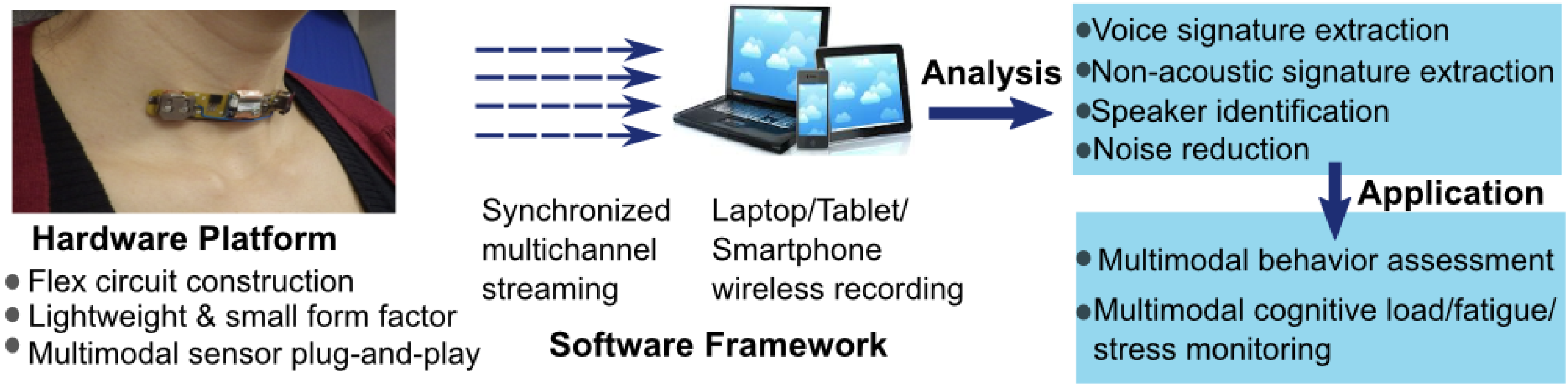
Daryush D. Mehta, Ph.D.
Center for Laryngeal Surgery and Voice - Massachusetts General Hospital/MIT Lincoln Laboratory

Patrick Chwalek, Thomas Quatieri, Sc.D., Laura Brattain, Ph.D. – MIT Lincoln Laboratory

INTERSPEECH Tutorial 2017
August 20, 2017

This material is based upon work supported under Air Force Contract No. FA8721-05-C-0002 and/or FA8702-15-D-0001. Any opinions, findings, conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the U.S. Air Force.

Wireless, dual-channel voice monitor on flex circuit

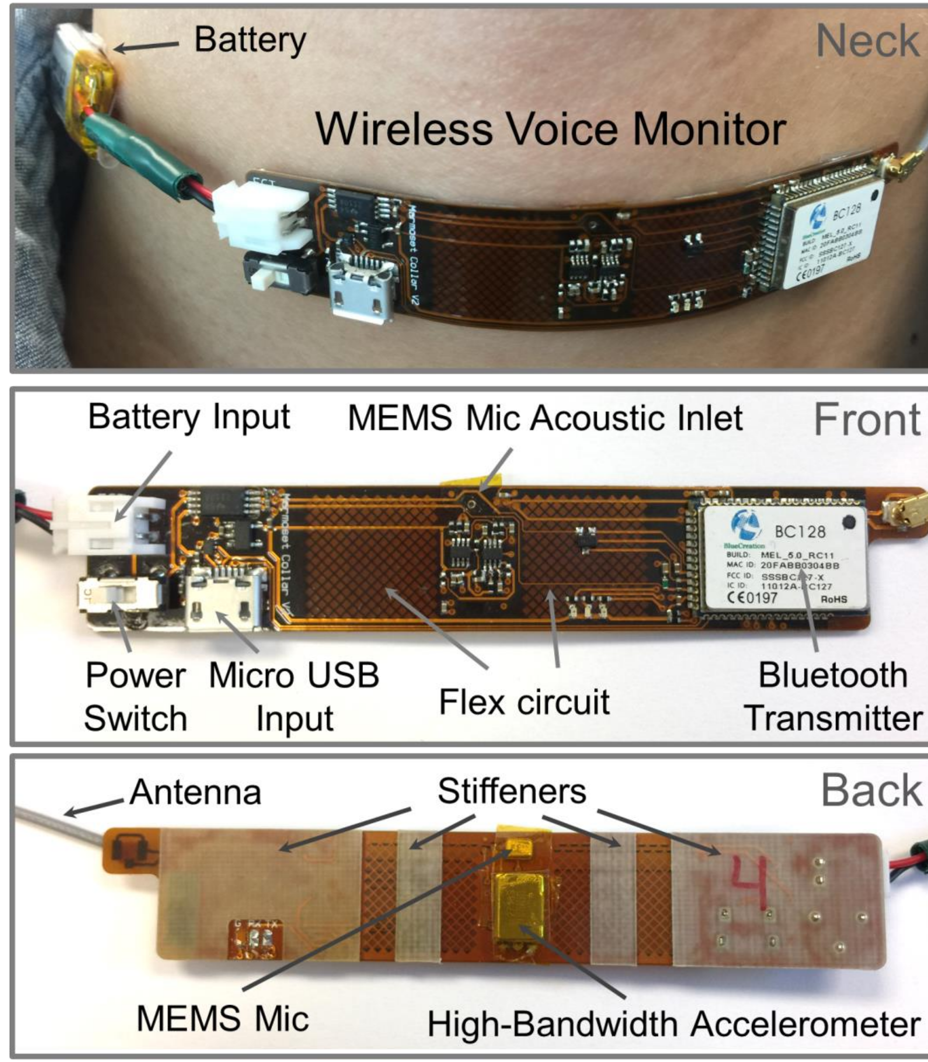


Feature	Specification
Sample rate	44.1 kHz (per channel)
Resolution	16 bits
Bandwidth	ACC: 0–5 kHz, MIC: 0–15 kHz
Power consumption	50 mW (transmitting), 18 mW (standby)
Battery life	Up to 8 hours (110 mAh battery)
Weight	4.0 g (12.5 g with 110mAh battery)
Size	Transmitter: 68 mm x 14.5 mm x 5 mm Receiver: 59 mm x 25 mm x 10 mm
Wireless protocol	Bluetooth 4.0

MGH collaboration with MIT Lincoln Laboratory

Wireless, dual-channel voice monitor on flex circuit

Smartphone or
dedicated receiver



Two sensors

- **Single-axis, high-bandwidth accelerometer** (BU-27135, Knowles Electronics, Itasca, IL) placed just above the collarbone and attached to the neck skin
- **Omnidirectional MEMS microphone** (SPA2410LR5H-B, Knowles Electronics) housed adjacent to the accelerometer.

Study design

Four adult participants (two male, two female) wore the wireless voice monitor inside an acoustically treated sound booth that contained loudspeakers that allowed for the **simulation of ambient acoustic stimuli** at varying calibrated sound pressure levels. Each participant performed the following speech tasks:

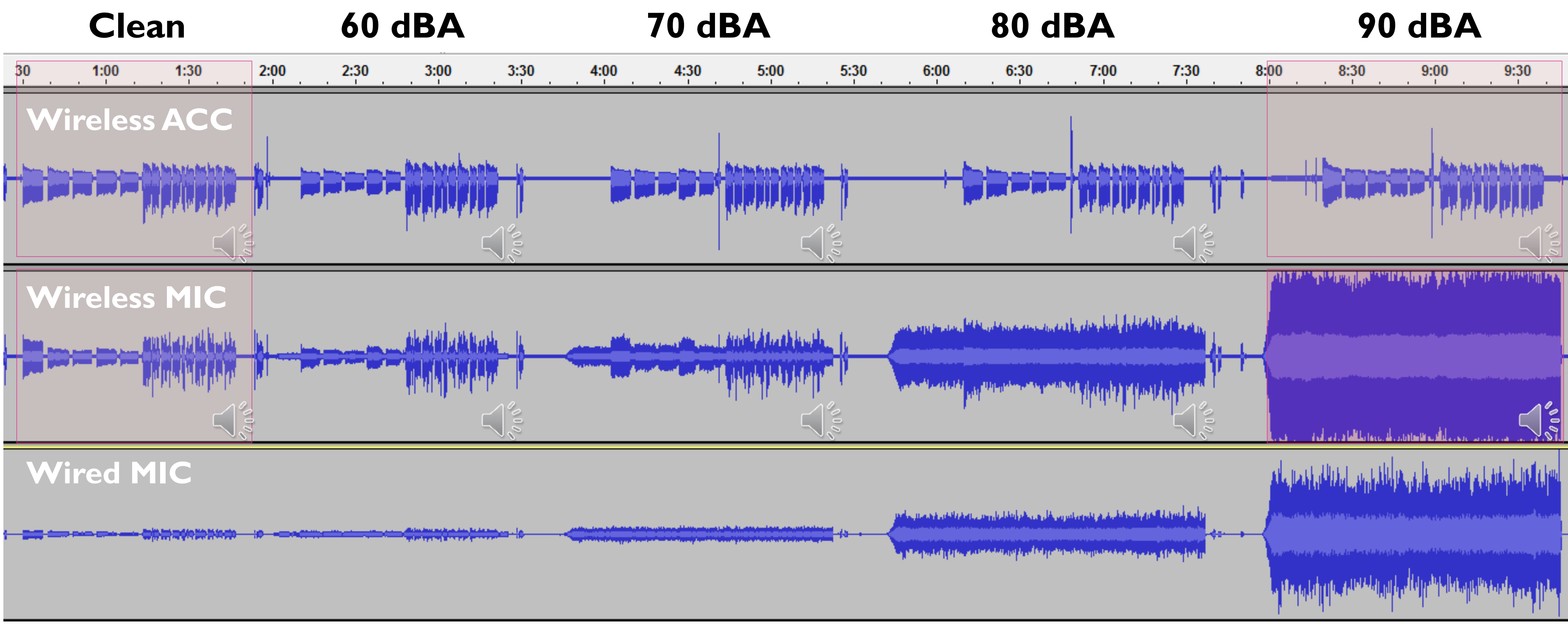
1) /a/ vowel starting at a loud intensity and gradually decreasing to a soft level
2) Phonetically balanced Rainbow Passage

Four different levels of the same background noise stimulus (helicopter rotors):

1) Quiet – 26 dBA
2) Mild – 43 dBA
3) Moderate – 54 dBA
4) Loud – 66 dBA

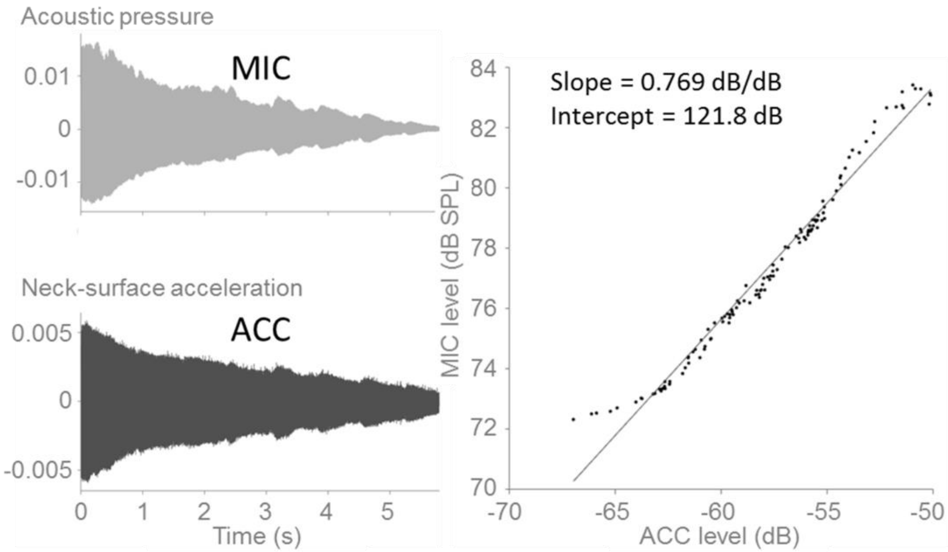
Robustness of accelerometer to ambient noise

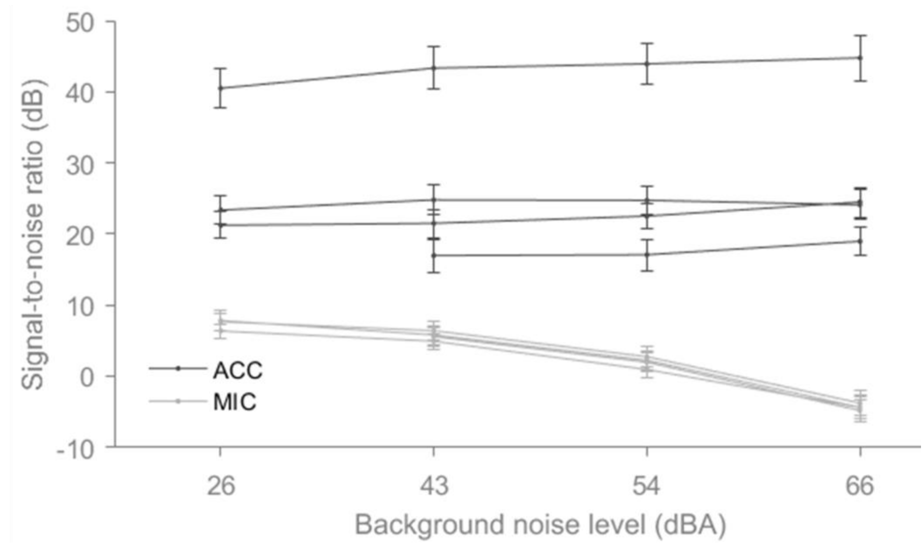
Background noise level



MGH collaboration with MIT Lincoln Laboratory

Robustness of accelerometer to ambient noise





Participant-specific calibration of accelerometer (ACC) signal level to microphone (MIC) sound pressure level using the loud-to-soft vowel task

Comparison of signal-to-noise ratio (SNR) of the ACC and MIC signals for the Rainbow Passage. Error bars: ± 1 std. dev

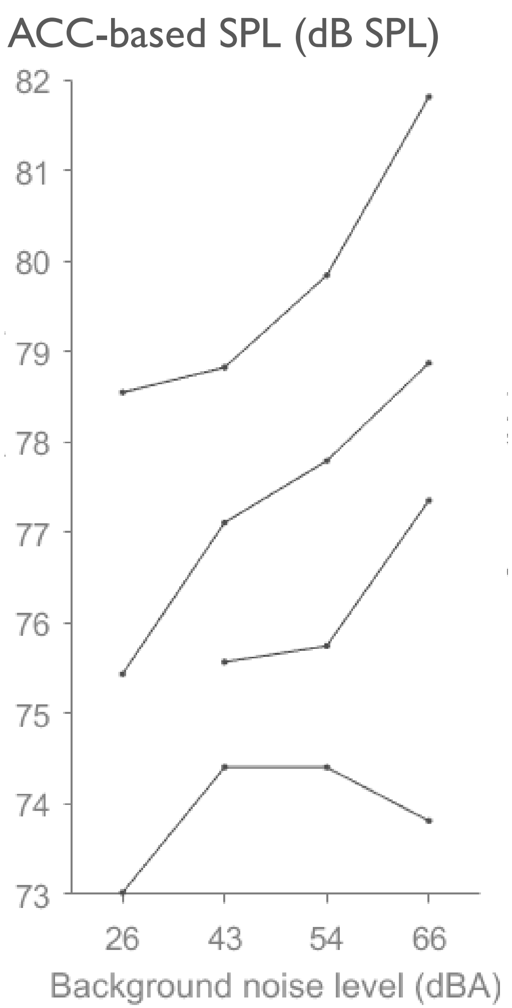
Monitoring environmental sound levels and the Lombard effect

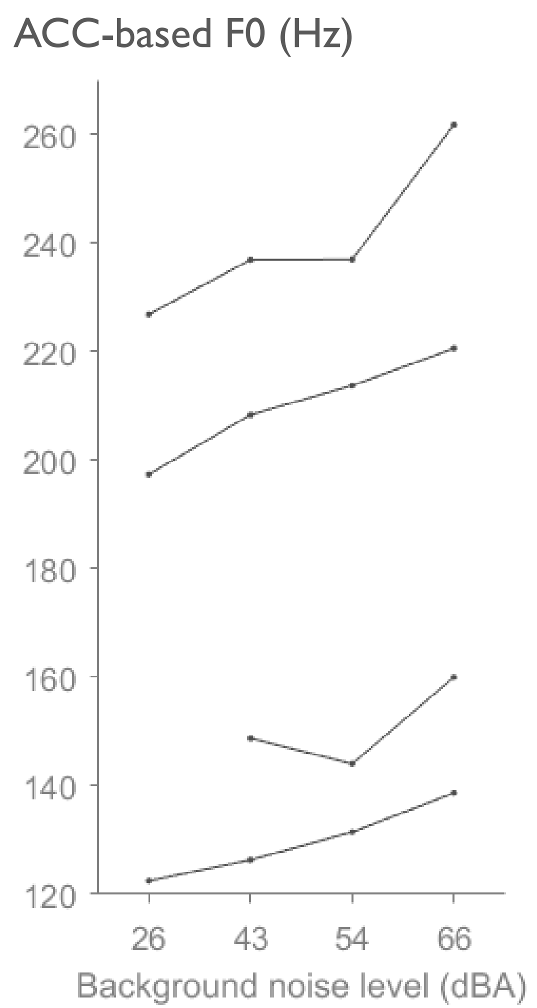
<u>Personal noise dosimeters</u>

- Place on shoulder near ear
- A-, C-, Z-weighted response
- Lightweight (36 g)
- Class 2 SLM (1% resolution, ±10% accuracy)
- Estimate Lombard speech properties—vocal compensation to background level

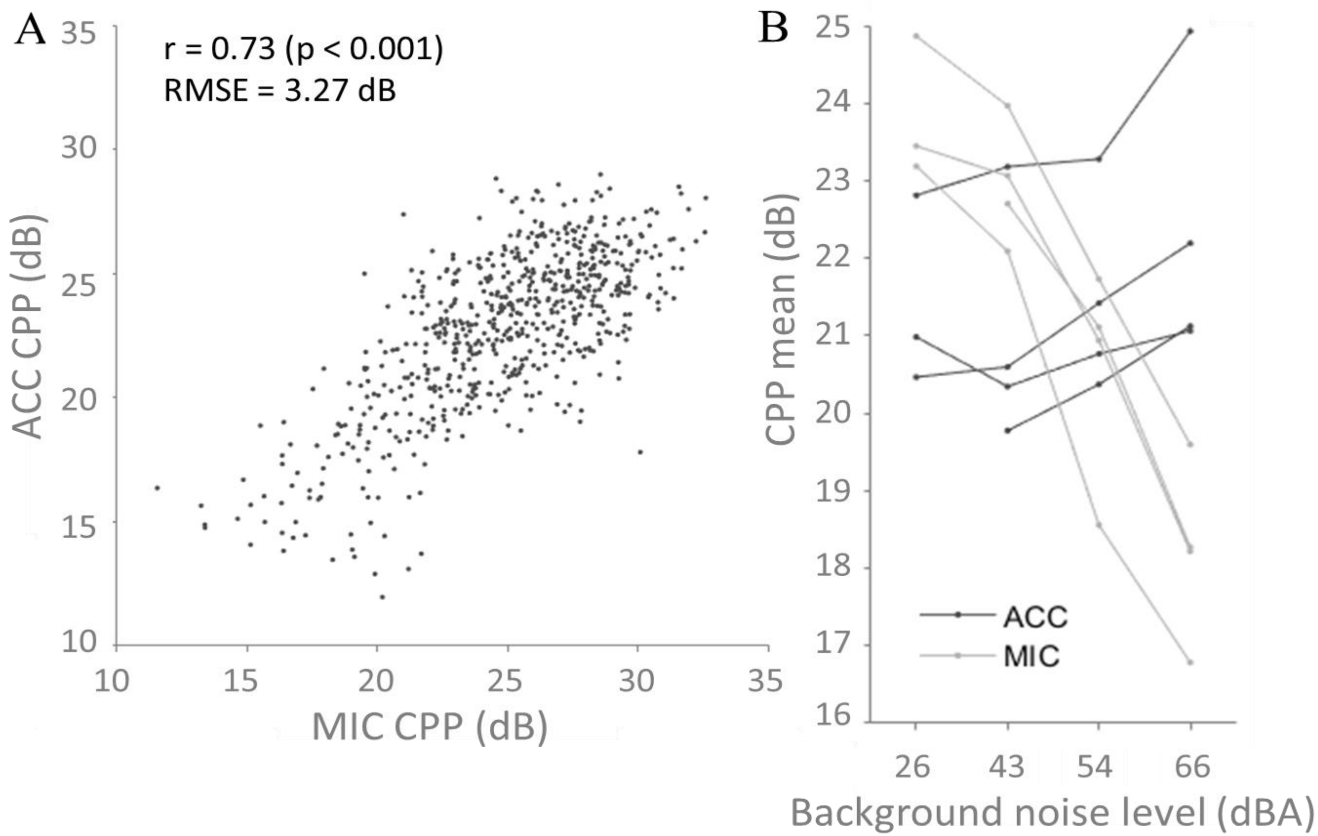
Audio³ soundBadge

Cirrus doseBadge





Monitoring environmental sound levels and the Lombard effect



Mean cepstral peak prominence (CPP) increases

(A) Correlation between frame-level MIC- and ACC-based CPP in quiet

Pearson’s r and root-mean-square error (RMSE) shown

(B) Lombard effect only observed in the ACC signal

Summary

- **Accelerometer (ACC)-based SNR remained stable across all background noise levels** when compared with the decreasing values for MIC-based SNR.

- Estimates of voice SPL may be better obtained using the ACC signal as compared to the MIC signal in naturalistic environments that exhibit varying levels of background acoustic noise

- **Participant-specific SPL mapping required in a quiet setting** to be applied to ACC signal levels in noisy settings.

- **ACC-based estimates of CPP** can act as noise-robust measures of overall voice quality.

Special thanks to Prof. Robert Desimone, Prof. Guoping Feng, and Dr. Charles Jennings at the McGovern Institute for Brain Research at MIT, Dr. Rogier Landman at the MIT/Harvard Broad Institute, and Mr. Kerry Johnson, Mr. Tejash Patel, and Dr. Christopher Smalt at MIT Lincoln Laboratory for their generous support and help.

Discussion

- **Ambulatory tracking of everyday verbal communication** as individual's go about their typical daily activities.

- Efforts to develop a custom wireless solution have been motivated by experience demonstrating that **patient compliance improves when technology is easy to use** and less cumbersome.

- Future device development can also take advantage of the modularity of the system to add **additional sensors and real-time processing of voice features that can provide user biofeedback** via mobile devices such as smartphones and smartwatches.