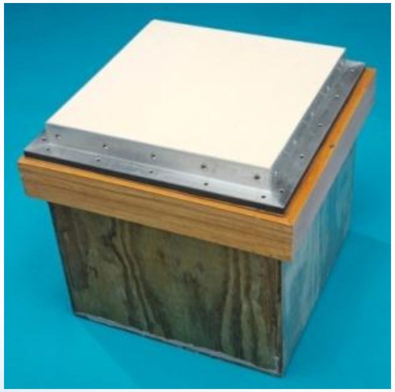
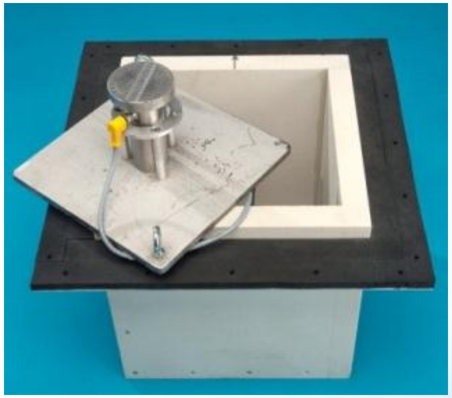
Development and installation of an infrasonic wake vortex detection system at Newport News International Airport

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Outline

- Background of Infrasonic Work
- Development of an Infrasonic Detection System.
- All-weather Wake Vortex Operational System.
- Field installation at PHF Airport
- Conclusions

Background

Technologies evaluated over last 40 years for mitigation/ avoidance

- Millimeter wave radar
- Sodar (sonic detection and ranging)
- Anemometer-based ground wind lines
- Pulsed and continuous-wave LIDAR
- Electromagnetic radar (NEXARD)
- Opto-acoustic sensors
- Phased-microphone Array

Wake Vortices and Infrasonic Emissions

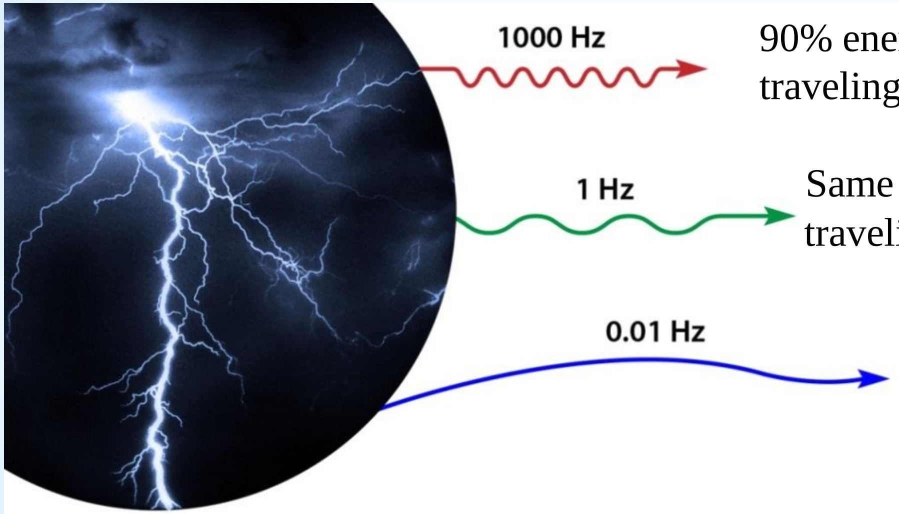
- A vortex-warning detector using infrasonic sensor was first proposed by Bedard (NOAA) in early 1970s for altitude estimate, strength, and spatial extent.

- Later T. M. Georges (NOAA) suggested that as infrasound from aircraft wake vortices travels over relatively long distances and could be useful for wake vortex detection (June 1971).

- Hardin-Wang-Wassaf (2004) suggested that wake vortex detection might be accomplished utilizing infrasonic transducers such as those employed in nuclear test monitoring.

Infrasound

(sound at frequencies below 20 Hz)



90% energy of 1000 Hz is absorbed after traveling just 7 km

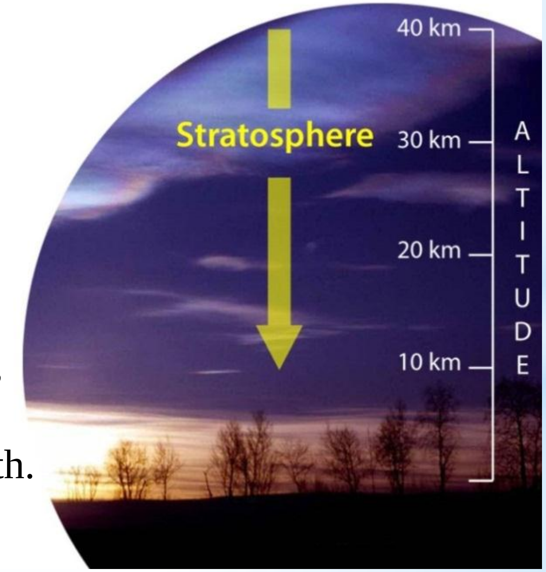
Same energy at 1 Hz is absorbed after traveling 3000 km

Same energy at 0.01 Hz is absorbed after traveling around the Earth's circumference

"Infrasound" *propagates over long distances with little attenuation due to two reasons;*

First, atmospheric absorption is practically negligible at infrasonic frequencies, and

Secondly, there is an acoustic ceiling in the stratosphere, where a positive gradient of the sound pressure with altitude causes reflections of infrasonic rays back to Earth.



Wind Noise Problem

- The atmosphere is inherently noisy.
- Infrasound signals are typically contaminated with wind noise
- Effective wind screening is vital.
- Past methods of screening a microphone from the wind (A low-frequency mechanical filter) used are:
  1) Piped array, 2) Enclosure, 3) A barrier, and 4) An open mesh
- The conventional systems becomes ineffective if wind speed exceeds few meters/sec.

Conventional Infrasonic Detection System

- Need of large “soccer field” type area.
- The soaker hoses require replacement every few months.
- The system become ineffective when wind speed exceeds a few meters per second.

Difficulties to detect Infrasound at Airports

- Airports have noisy environment.
- Due to open field the signals are contaminated with wind noise.
- No compact infrasonic detection systems (suitable for airport environment) were available until recently.
- Non-availability of all-weather system until recently.

Design and Development of an Infrasonic Microphone

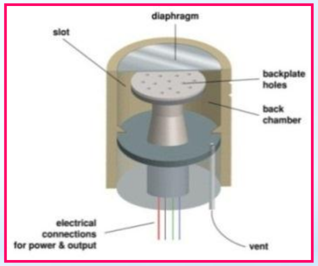
- The performance of any microphone depends upon an electrical and mechanical system of the microphone.

- The function of the mechanical system is to provide damping of the membrane motion.

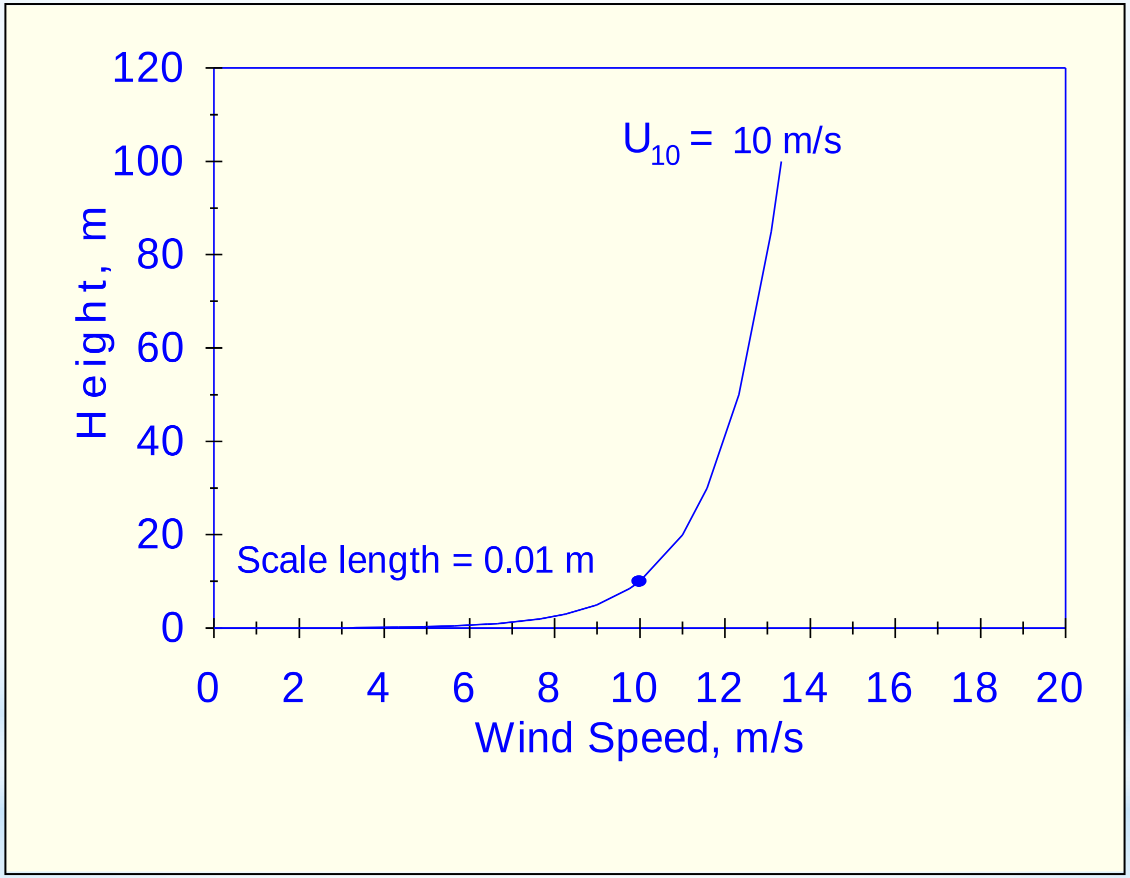
- The back chamber serves as a reservoir for the air flow through the openings in the back-plate.

- Electret-based technology offers the lowest possible background noise, as Johnson noise generated is minimized.

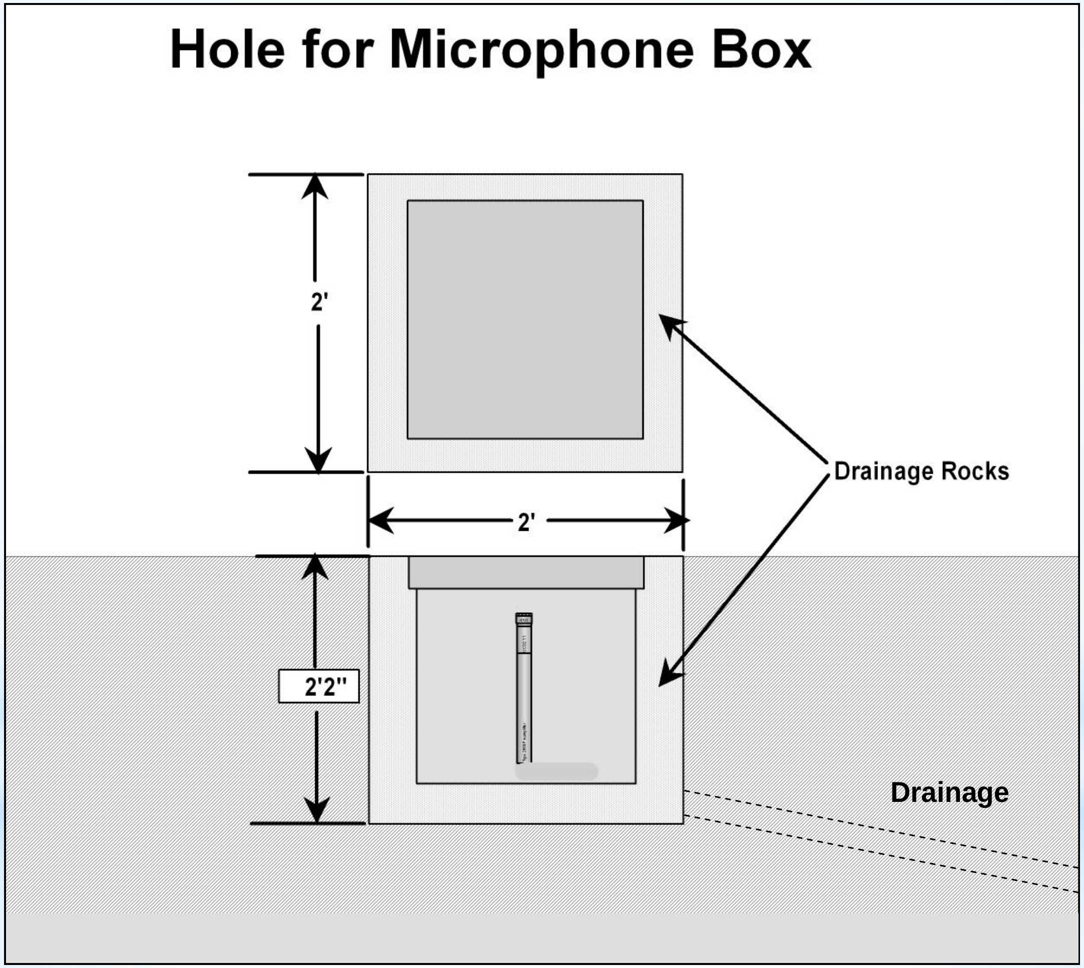
- The microphone was built by PCB Piezotronics under contract to NASA Langley Research Center.



Vertical profile of horizontal wind

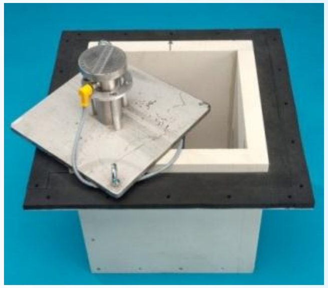


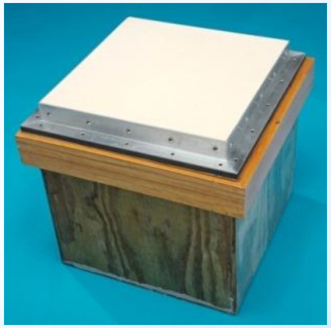
Sub-surface Infrasonic Windscreen



Design and Development of Compact Windscreen

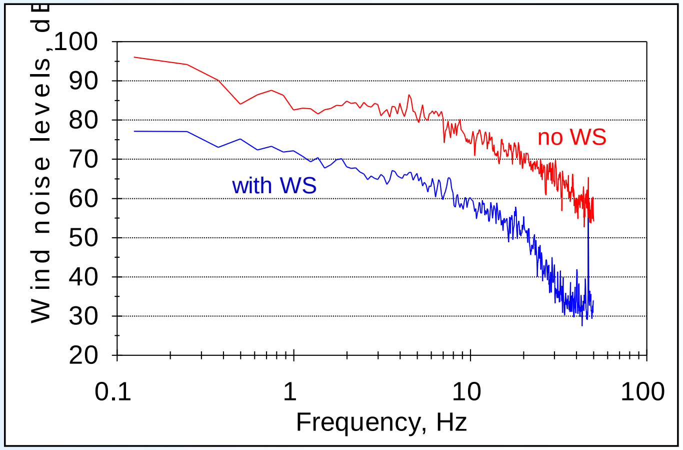
- Low acoustic impedance
- Attenuation of wind-generated noise
- Transmission of infrasonic signal
- No water retention



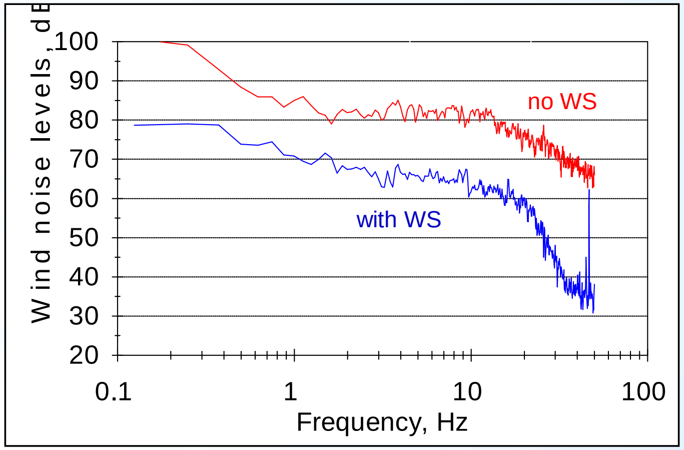


Wind Noise Reduction

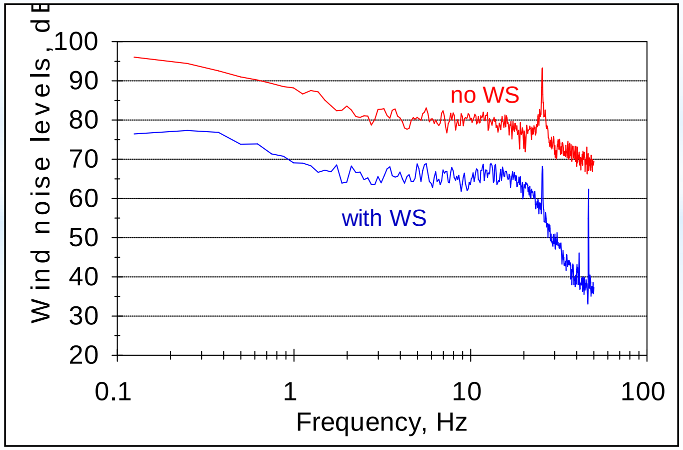
Wind speed 3 m/s



Wind speed 5 m/s

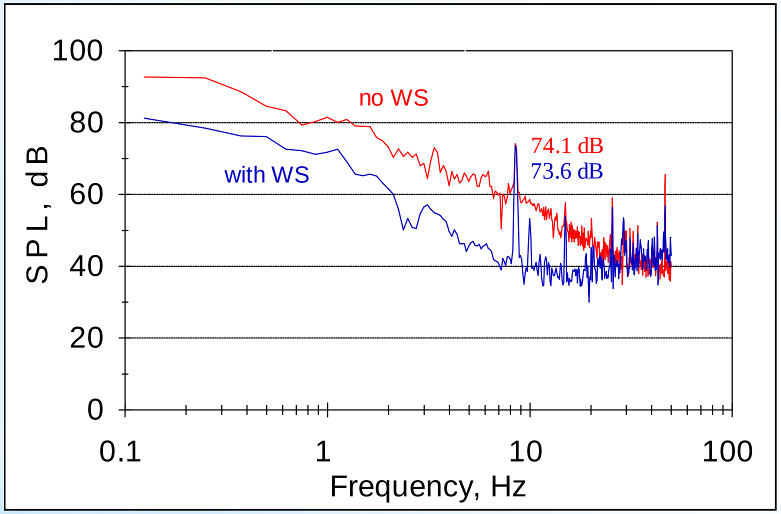


Wind speed 7 m/s



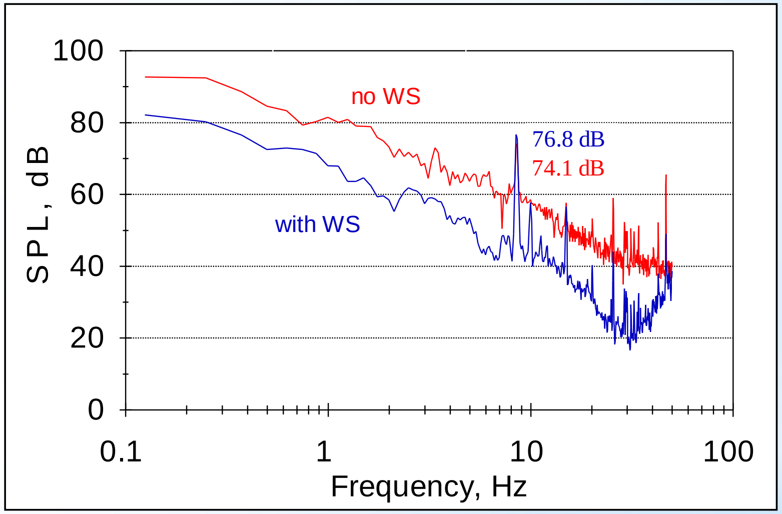
Signal Transmission

4 lb foam



Net gain -0.5 dB

15 lb foam



Net gain 2.7 dB

Field Testing

- Simulated Point Source Output

  104 ± 0.2 dB @ 8.75 Hz

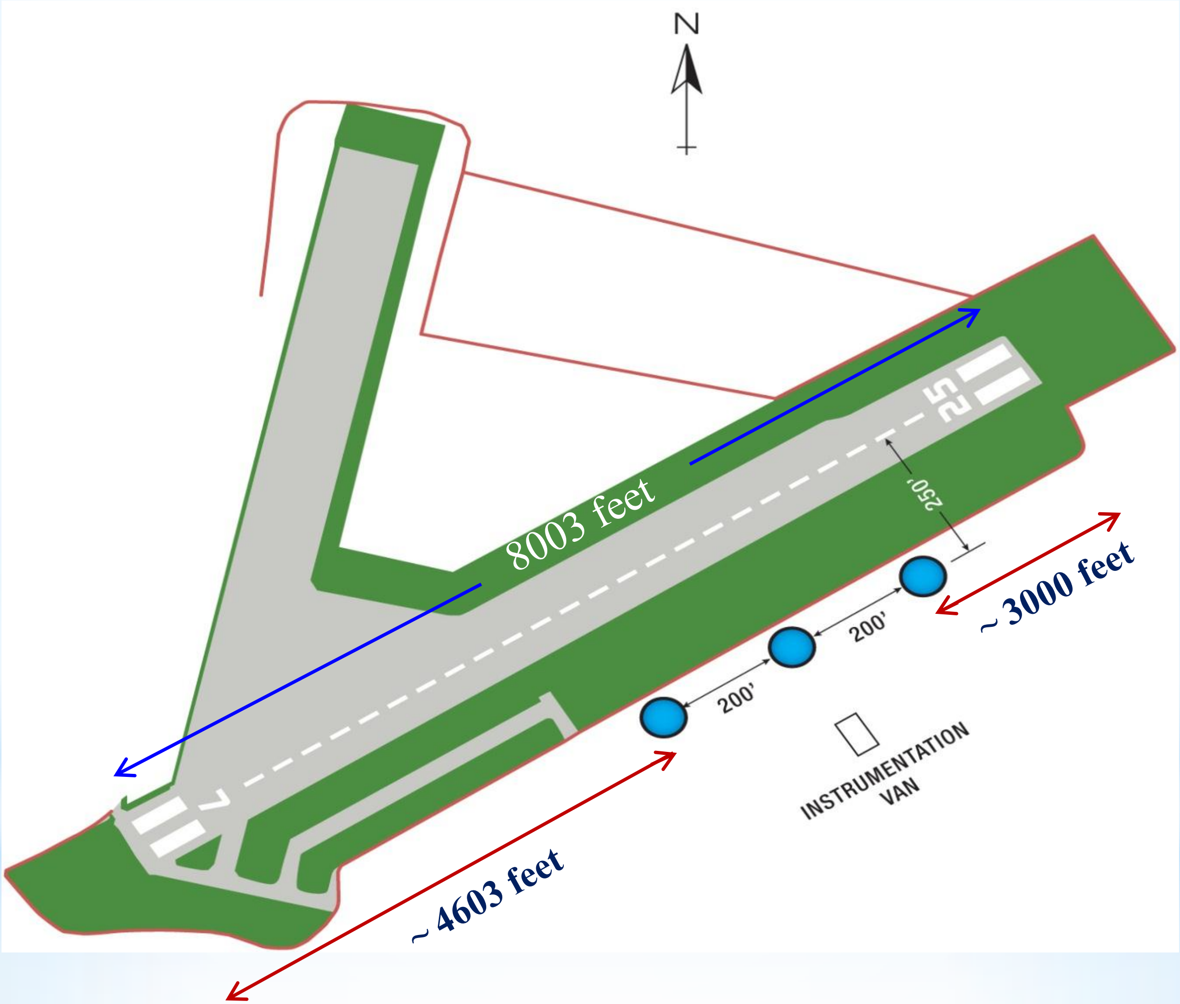
- The acoustical response of each microphone can be recorded, and compared for 6 dB per doubling of distance.

- For a distance of 145 feet, # of doubling will be 5.466 and ΔdB = 32.796 hence the signal received at the system should be 71.204 dB

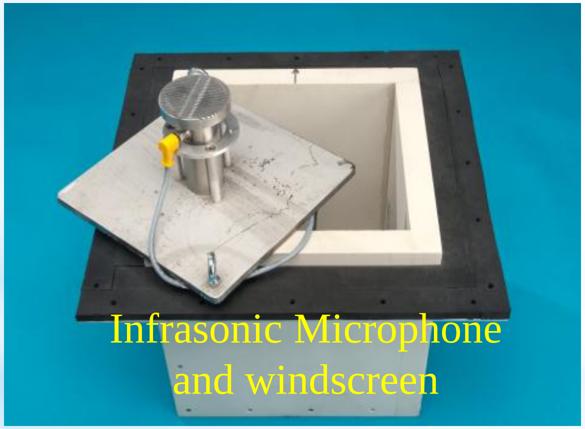
Sensor Performance as a Field Array

Performance Criteria	Infrasonic Microphone
Power (mW)	35 mW
Self-Noise (dB at 1 Hz)	-105
Self-Noise (rms 0.1 – 10 Hz)	20 µPa
Dynamic Range	Approximate 120 dB
Location Limitations	None
Custom Modification	Easily Tailored
Field Calibration	Yes

Microphone Array Installation at the PHF Airport



Microphone Array Installation at the PHF Airport



Microphone Array Installation at the PHF Airport

- The spacing between microphone systems exceed the outer scale of turbulence of the inertial subrange ~ 30 feet

- The convected (non-propagating) pressure fluctuations are prevented from reaching the microphone by windscreens.

- The drainage rock around the protective case remove rain water from the immediate vicinity of the windscreen assembly.

- The system is a truly all-weather system.

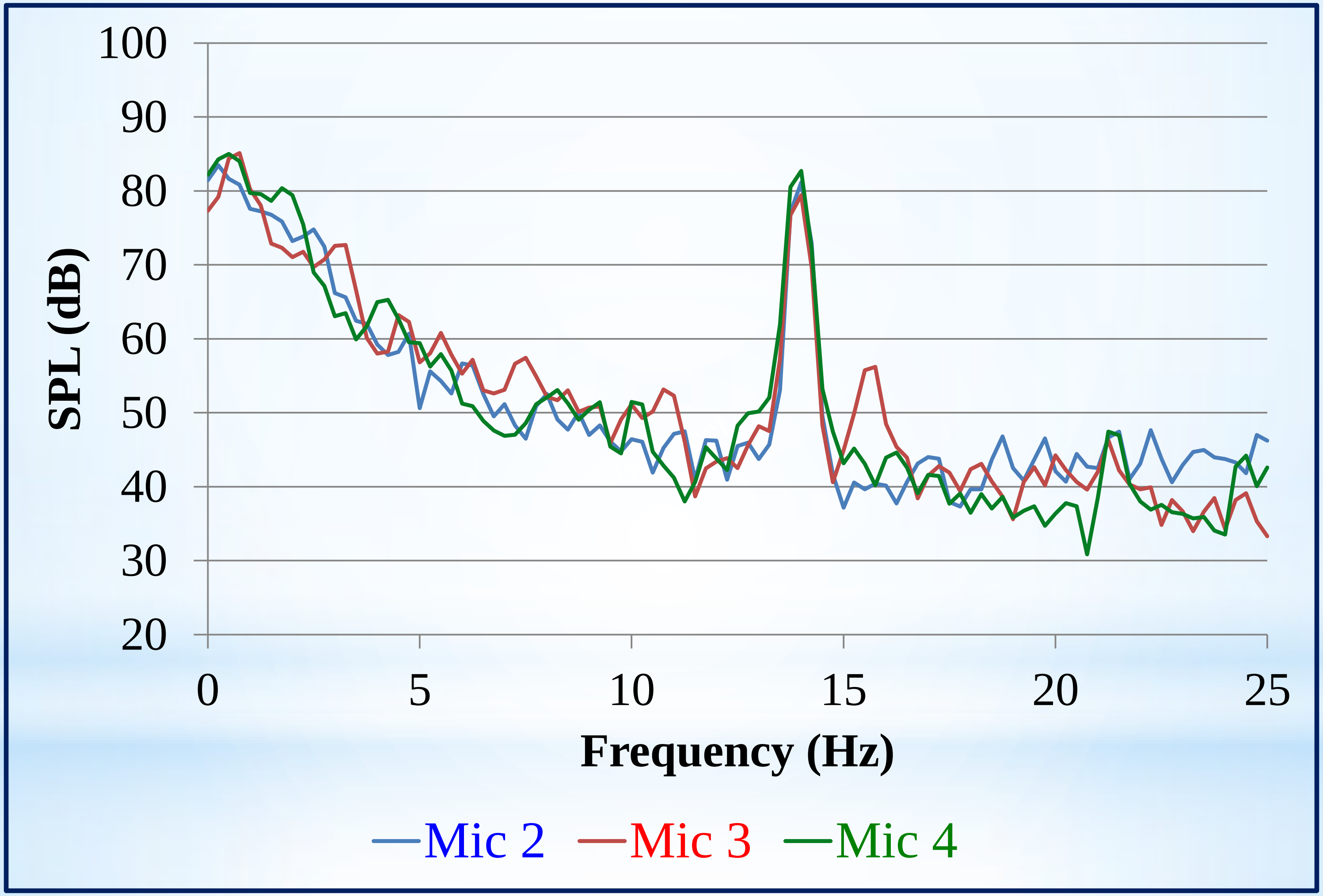
Field Calibration

- Long-term service requires continual monitoring of the health of the system.
  - Calibration
  - Characterization

- The removable lid permits access to the microphone for calibration by a recognized method, e.g. a pistonphone.

- The calibration of pistonphone is referenceable to a standard.

Field Calibration



Conclusions

- The system conforms to airport safety constraints *(no obstacles near the runway or flight path)*
- Have all-weather service capability.
- Have field calibration capability.
- Have site proximity to avoid intervening effects.
- Have fail-safe operation.
- Provide service for take-off, approach, and landing.