PIPELINE MONITORING TECHNIQUES

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Introduction

Pipelines are the lifelines of modern infrastructure, but leaks, corrosion, and hidden faults often go undetected, leading to costly failures and environmental damage.

- **Pipelines transport critical resources: water, oil, gas.**

Problem Statement

Current inspection methods (ultrasonic, radiography, GPR) are:

- **Expensive**
- **Intrusive / time-consuming**
- **Not suitable for continuous monitoring**

Need:

A low-cost, portable, real-time monitoring system to detect leaks, corrosion, and buried anomalies.

Why Our Approach is Better than Traditional Methods

Area	Traditional Method	Our Method	Why Better
Leak Detection	• Listening rods/ground microphones (manual) • Tracer gas (expensive) • Pressure drop tests (Indirect)	**Acoustic Holography Flex-Array** 16-mic ring with beamforming, real time LED hotspot visualization.	• Automated • Real-time • portable| • gives leak direction instead of just presence • less operator-dependent.
Corrosion Monitoring	• Ultrasonic Thickness Gauging (contact, slow, couplant needed) • radiography (accurate but costly, radiation risk) • magnetic flux leakage (complex).	**Whisper Test** Acoustic sweep (1–20 kHz), resonance analysis, non-contact.	• Non-contact • Faster (<30s per section) • Safer • Portable • Low cost • Covers more area quickly.

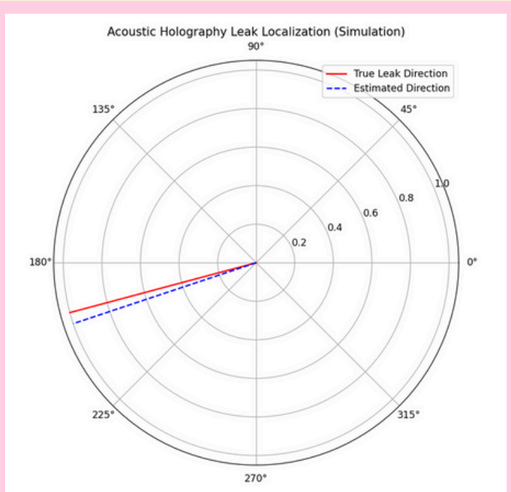
Acoustic Holography Flex-Array

Invisible to the eyes, But Hissing sound heard

Physical Prototype:

- Mic (INMP441 MEMS digital microphones)
- I²S bus (ESP32) — But limited to 2 or 4 channels
- Audio codec (ADAU1701, PCM1808)

Real-time siumlink purpose : MATLAB/Octave



Generate broadband hiss

⇩

Add envionmental Noise

⇩

TDOA + GCC-PHAT validation

⇩

Polar -Output

Leak produces hiss 2–20 kHz

16 microphone circular array wrapped around a pipe

Signal Processing Unit

- GCC-PHAT TDOA estimation
- atan2(y,x) for asmith AoA (0–360°)

Output

- Polar plot
- Alarm/alert system
- LED ring shows angle

TDoA by GCC

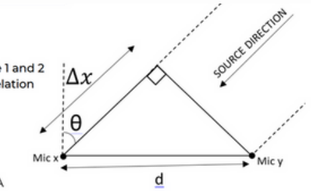
The Time DIffference of Arrival between microphone 1 and 2 can be found by locating the peak in the cross correlation

$$R_{xy}(\tau) = \int_{-\infty}^{\infty} X(f)Y^*(f)e^{i2\pi f\tau}\,df$$

$$\Delta T_{xy} = argmax\, R_{xy}(\tau)$$

Then Using geometry we can find out the AoA

$$\Delta x = v * \Delta T \quad \longrightarrow \quad \theta = \sin^{-1}\frac{v * \Delta T}{d}$$



Pipe Corrosion “Whisper Test”

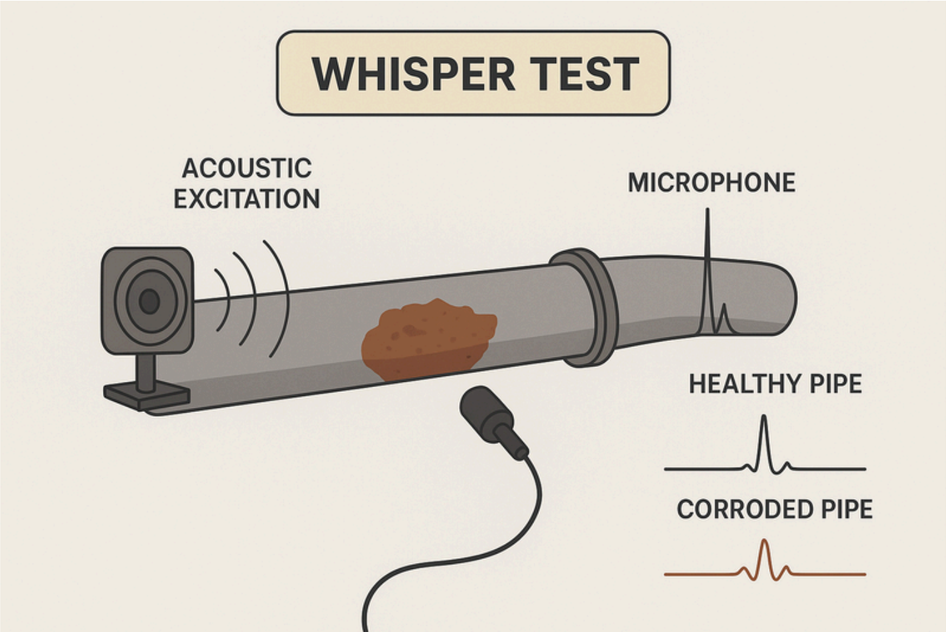
- Pipe acts like a resonator
- Acoustic sweep (1–20 kHz) excites pipe → resonance response reveals wall condition.

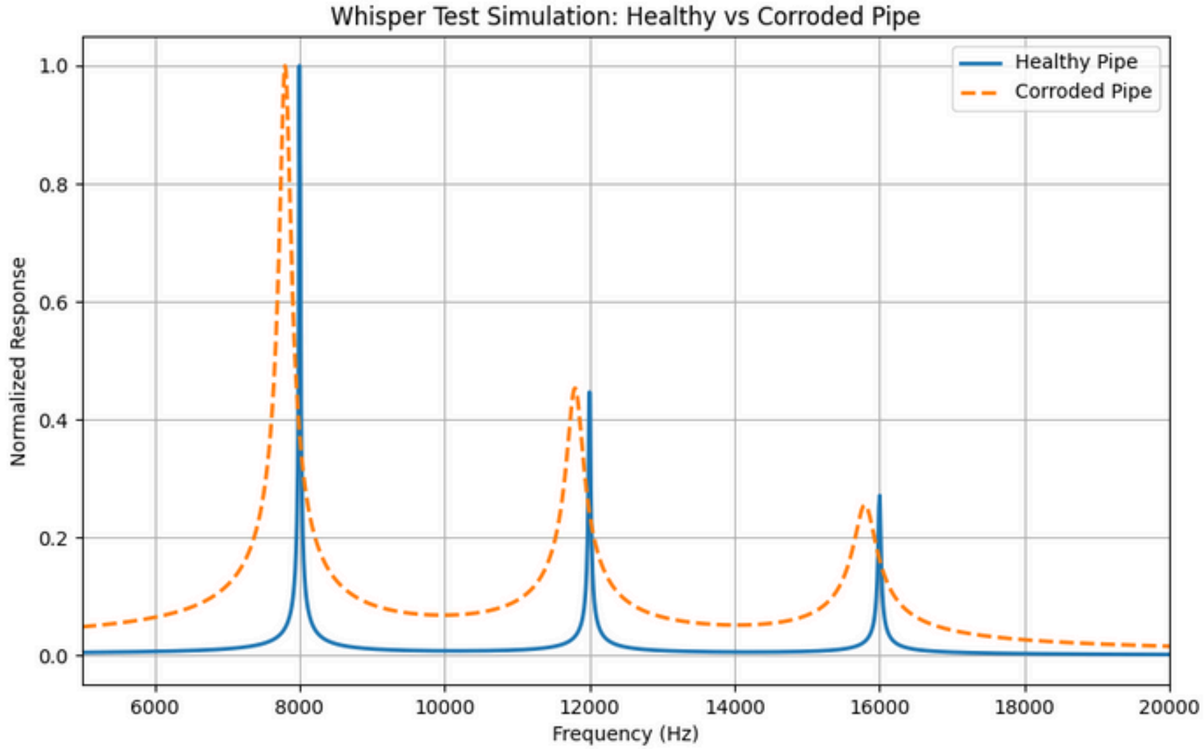
How It Works:

- Healthy pipe → Sharp, predictable resonance peaks.
- Corroded pipe → Peaks shift lower + weaker due to thinning & damping.

Components:

- Speaker / Piezo actuator (excitation)
- Microphone / sensor (response capture)
- FFT analysis (compare spectrum vs baseline)





Q & A
THANK YOU!