📘 Concept Document: *Cymarion*

From Cyma (wave) + Arion (a mythic talking horse/savior) Wave + intelligent transmission

"Cymarion — Where Liquids Talk"

In-Fluid Acoustic Binary Signaling for Liquid-Filled Pipelines

www.Cymarion.com

CYMARION

CYMARION

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1. Overview

Project Name: Cymarion
Purpose: Enable low-cost, low-bandwidth binary communication over continuously packed pipelines using **acoustic signals transmitted through the fluid itself**.
Applications: Remote control, diagnostics, event signaling in fuel, oil, or water pipelines.

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2. Problem Statement

Current pipeline communication methods (wired or wireless) are:

- Expensive to retrofit
- Susceptible to interference or physical degradation
- Unavailable inside long, enclosed pipelines (especially for inline tools)

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3. Core Solution

Use **in-fluid acoustic pulses** (sound/pressure waves) to encode and transmit binary signals. This method uses the pipeline's fluid as a **communication medium** and avoids wiring or radio-based limitations.

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4. System Design

4.1 Transmitter

- **Microcontroller** (e.g., ESP32) generates a 40 kHz PWM tone.
- Tone is amplified and sent to a **piezoelectric transducer**.
- Transducer is clamped to the pipeline and couples sound into the fluid.

4.2 Receiver

- **Piezo sensor** mounted downstream detects pulses.
- Signal is amplified (INA128) and digitized via ESP32 ADC.
- Software detects binary values based on presence/absence of tone.

4.3 Communication Protocol

- Each bit is 100 ms long.
- `1` = 40 kHz tone present, `0` = silence.
- Frame = Start Pulse → 8 Bits → (optional checksum)

4.4 Assumptions and Validations

Cymarion is designed based on the following key assumptions, each reviewed for field viability:

- **Pipelines are typically fluid-filled**: This holds for most fuel and water systems, though exceptions exist during batch flow or maintenance. Cymarion includes a mechanism to detect loss of fluid signal and can fall back to standby mode in such cases.
- **Sound propagates well in liquids**: Light hydrocarbons (diesel, gasoline, jet fuel) and water allow stable acoustic transmission. For viscous fluids like crude oil, Cymarion supports frequency/gain adjustment to optimize signal quality.
- **Piezo elements can couple effectively**: Clamp-on piezo modules use acoustic gel and mechanical pressure to ensure stable signal transfer. Cymarion provides mounting specs to avoid loss due to pipe coatings, corrosion, or looseness.
- **Acoustic signaling will not interfere with pipeline flow**: Cymarion uses low-energy pulses with no pressure buildup. It remains fully external, ensuring zero contamination or process interference.
- **Non-invasive mounting is viable**: The system is designed for external attachment with rugged clamps and environmental protection, requiring no pipe penetration or welding.

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5. Prototype Bill of Materials (BOM)

Qty	Component	Description
2	ESP32 DevKit	Signal generation & detection
2	40 kHz Piezoelectric Transducers	Transmit/receive through fluid
1	LM386 Amplifier Module	Amplifies TX tone
1	INA128 Instrumentation Amplifier	Boosts RX signal

1	Optional 12-bit ADC Module (MCP3208)	Higher-resolution input
1	Pipe section (metal/PVC, 0.5–1m)	Filled with water or test liquid
2	Pipe clamps	Secure transducers to pipe
1	Ultrasound gel or glycerin	Acoustic couplant
N/A	Jumper wires, breadboards	Standard prototyping supplies

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6. Example Arduino TX Code (ESP32)

cpp
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```cpp
#define PULSE_PIN 25  // DAC or PWM-capable pin

void setup() {
  ledcSetup(0, 40000, 8);         // Channel 0, 40kHz, 8-bit
resolution
  ledcAttachPin(PULSE_PIN, 0);   // Attach PWM to pin
}

void loop() {
  byte data = 0b10110011;
  for (int i = 7; i >= 0; i--) {
    if (data & (1 << i)) {
      ledcWriteTone(0, 40000); // Send tone
    } else {
      ledcWriteTone(0, 0);     // Silence
    }
    delay(100); // 100ms per bit
  }
  delay(2000); // Delay before repeating
}
```

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7. Key Advantages

Feature	Benefit

Non-invasive	No pipe cutting or fluid injection
Low cost	<$100 for full prototype
Field-deployable	Ruggedizable, clamped externally
Works with fuel	No contamination, sealed system
Flexible	Works with water, oil, fuels

8: Challenges

Challenge	Mitigation Strategy
Signal attenuation in heavy fluids	Lower frequency (e.g., 5–20 kHz), increased gain
Fluid not always present	Include fluid presence detection and auto-idle fallback
Pipe surface irregularities	Require clean surface, strong clamp pressure, couplant
Pumps/valves causing noise	Software filtering, time-domain windowing
Regulatory restrictions	Use certified, spark-safe external hardware only
Multipath or reflected signals	Use consistent framing and optional checksums
Varying speed of sound per fluid	Include calibration mode at deployment

9. Next Steps

Phase	Goal	Deliverable
P1	Benchtop test in water	Working TX→RX signal decoding
P2	Range test with light fuel	Max distance, SNR measurement
P3	Crude oil simulation	Test with thicker fluid or emulsion
P4	Signal error handling	Framing, checksum, retry logic
P5	Hardware packaging	Rugged piezo clamps, enclosures