Comparison of Position Estimation Methods for the Rotating Equatorial Microphone

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1 – Introduction

- State-of-the-art microphone arrays use many microphones and are often costly
  → **A fast rotating microphone may provide an alternative to microphone arrays**
- We developed a proof-of-concept prototype of a rotating microphone and compared estimation methods for its instantaneous position
- **> 100 rotations per second (RPS) were achieved**

3 – Microphone Position Estimation Methods

The instantaneous microphone position can be derived from the RPS and the initial position of the microphone. We compared four RPS estimation methods:

- **Electronic Speed Controller (ESC) Readout**: the motor control signal generated by the ESC correlates with RPS
- **FM Demodulation**: the microphone rotation causes a frequency modulation of the recorded audio (see 4); the distance between the resulting spectral lines correlates with RPS
- **BrushLess DC (BLDC) Motor Self-Noise**: vibrations create an audible tone during rotation, the frequency of which correlates with RPS
- **Zero-Phase**: a photodiode placed at the equator of the sphere records time stamps of light peaks as it passes an external LED, from which RPS can be derived
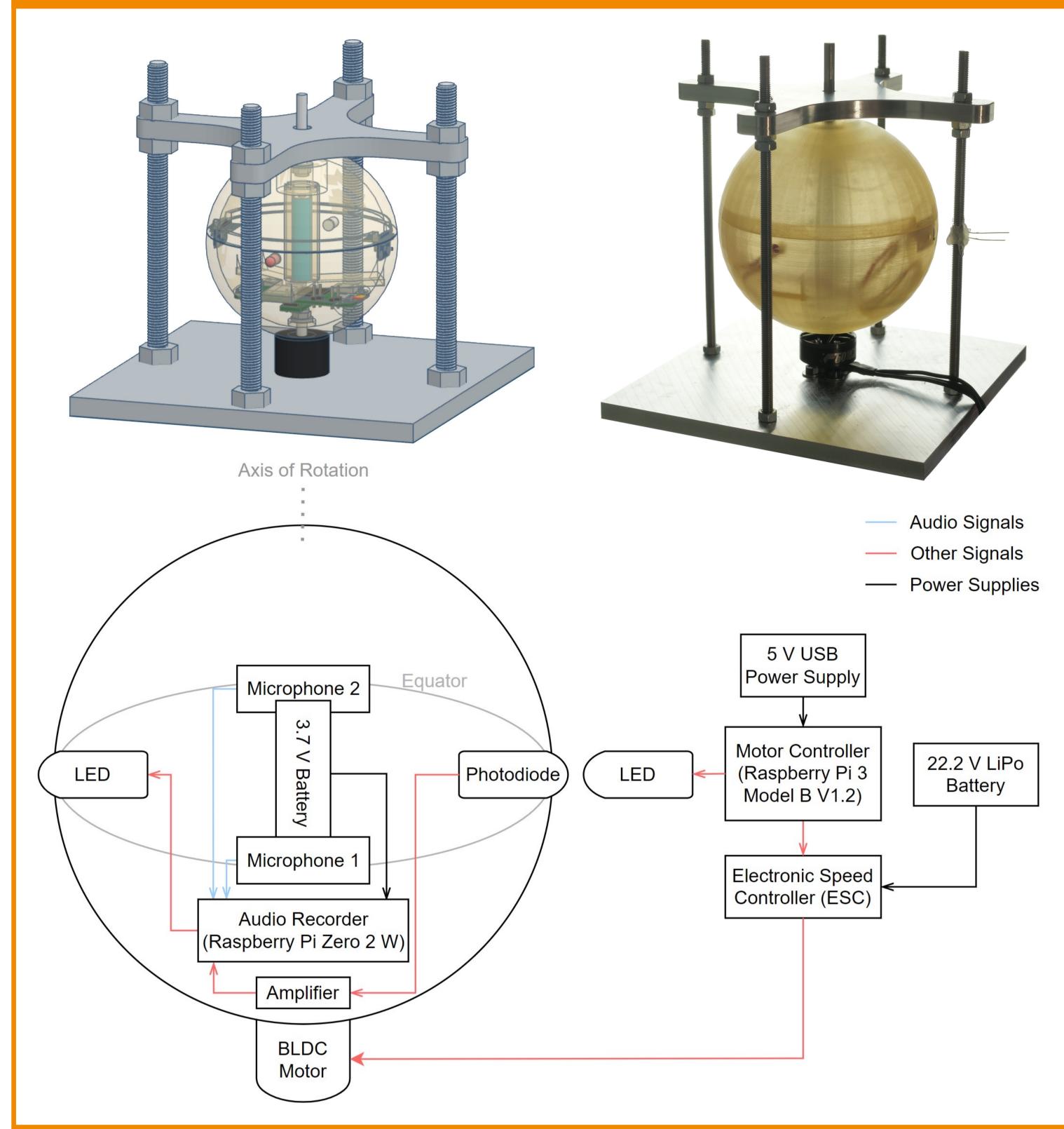
6 – Conclusion

1. **Rotating microphones feasible in practice**
2. Zero-Phase estimation most consistent RPS estimation method, allowing for position estimation with < 0.5 deg accuracy in theory (no ground truth available!)
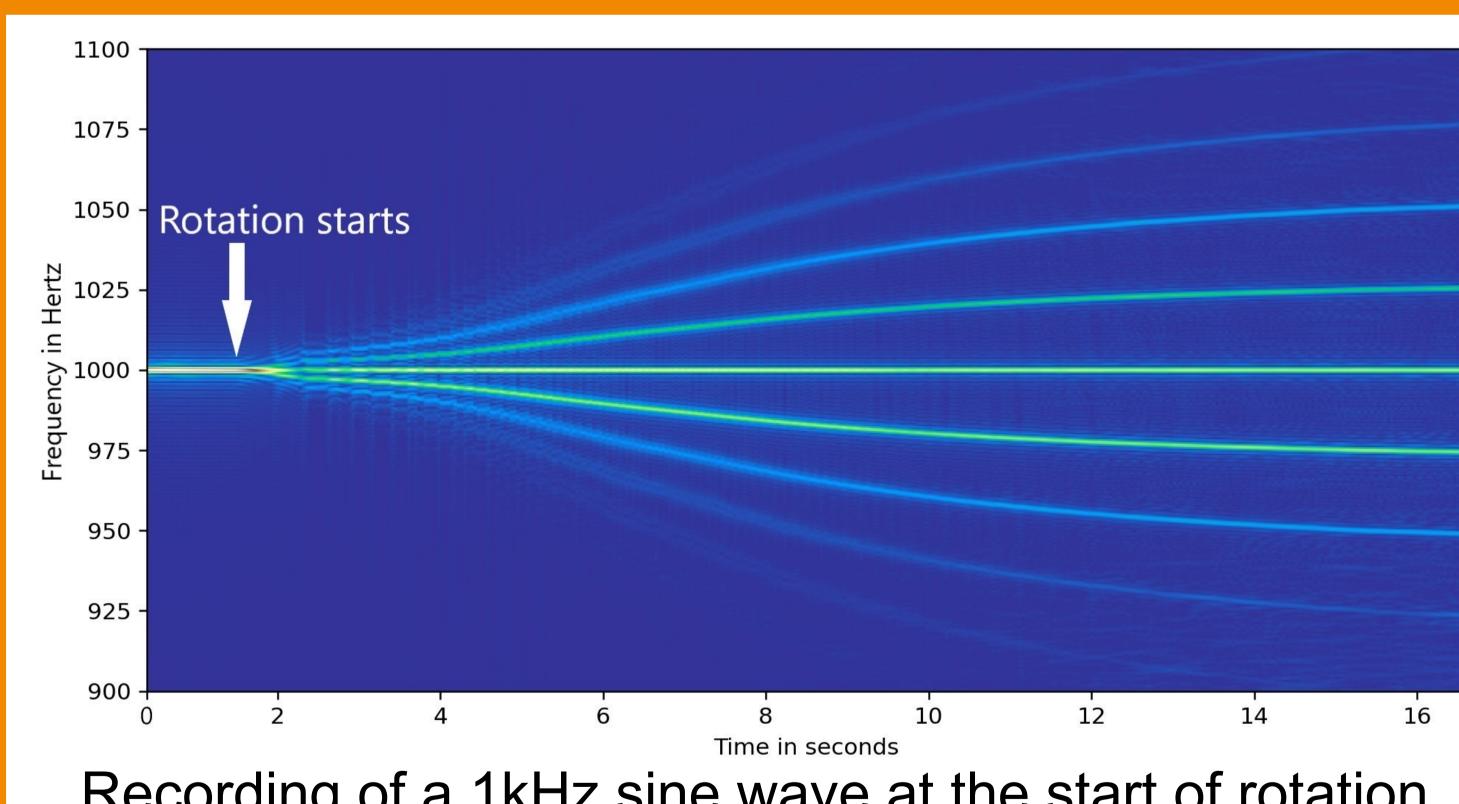3. External audio processing possible, since raw microphone signal can be streamed via Wi-Fi

7 – Future Work

- Reduce structure-borne noise and wind noise with hardware improvements and software filters
- **Develop algorithms for sound field analysis**
- Test higher rotational speeds
- Experiment with different housing geometries and materials

2 – Rotating Equatorial Microphone Design

4 – Frequency Modulation due to Rotation

Recording of a 1kHz sine wave at the start of rotation

5 – Comparison of Position Estimation Methods

ESC Throttle Setting	ESC Readout	FM Demodulation	BLDC Self-Noise	Zero-Phase
8%	19.49, (0.08)	19.18, (0.48)	27.57, (0.85)	19.49, (< 0.01)
9%	41.70, (0.28)	42.31, (1.06)	41.74, (0.04)	41.70, (0.01)
11%	76.48, (0.42)	74.74, (6.93)	76.48, (0.36)	76.48, (0.02)
13%	101.90, (0.98)	-	102.78, (0.03)	101.90, (0.04)

Detected RPS at different ESC Throttle Values: Mean RPS, (standard deviation of the first derivative of the RPS)

8 – References

[1] J. Lawrence, J. Ahrens, and N. Peters, "**Comparison of position estimation methods for the rotating equatorial microphone**," (IWAENC 2022).
[2] J. Ahrens, H. Helmholz, D. L. Alon and S. V. A. Garí, „**Spherical harmonic decomposition of a sound field based on observations along the equator of a rigid spherical scatterer**,"The Journal of the Acoustical Society of America, vol. 150, no. 2, pp. 805–815, 2021.