MARL

NYU Music and Audio Research Laboratory

ABSTRACT

While public interest for technologies that produce and deliver immersive VR content has been growing, the price point for these tools has remained relatively high.

We present a low-cost, high-quality first-order ambisonics (FOA) microphone based on low-noise MEMS systems..

To facilitate high resolution directivity response measurements, a low-cost, automatic rotating microphone mount using an Arduino was also designed.

The automatic control of this platform was integrated into an in-house acoustic measurement library built in MATLAB, allowing the user to generate polar plots at resolutions down to 1.8°.

BACKGROUND

Ambisonic technology was first explored in the 1970’s by Michael Gerzon and Peter Fellgett [1] .

By using four highly coincident capsules in a tetrahedral configuration, A-format signals can be encoded to a B-format matrix, which consists of three figure-eight pressure gradients and an omnidirectional pressure gradient, all coincidentally located.

.

The FOA recording approach can also be considered an extension of the Mid-Side (M/S) technique created by the pioneer of stereophonic sound, Alan Blumlein, in the 30s [3] .

The concept of decoding audio signals via a set of sums and differences is augmented in the FOA model which converts the four signals into a zero-order information monophonic sound pressure component (W) and three first-order pressure gradients as loosely depicted in Figure 1.

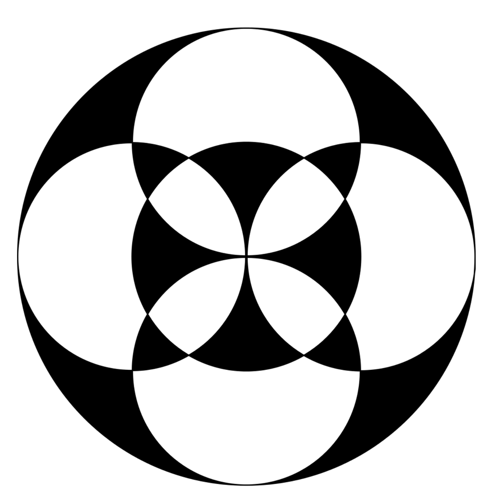

Figure 1. 2-Dimensional Representation of Pressure Gradients

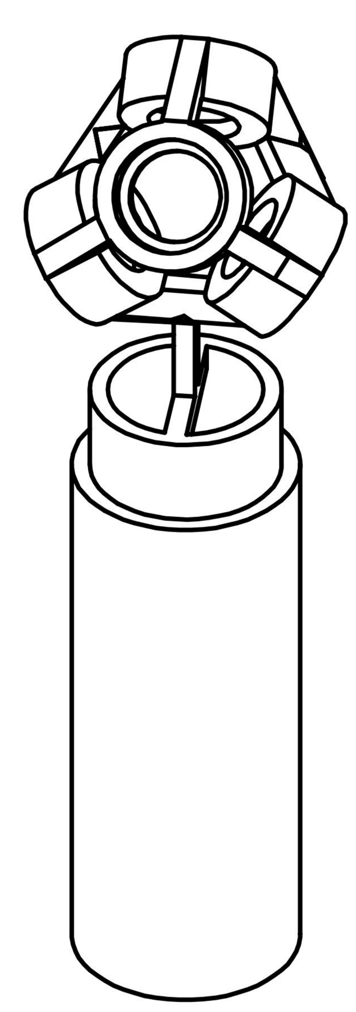

Figure 2 - Assembly Schematic MEMS Microphone

CAPTURE & REPRODUCTION

The most basic soundfield microphone, a FOA mic, consists of four cardioid capsules mounted in a tetrahedral shape which captures a soundfield from a single point in space over four channels resulting in A-format signals, in their raw, unprocessed state.

During reproduction, B-format vectors are projected onto either real or virtual speakers.

In the case of virtual speakers, a set of Head Related Transfer Functions (HRTFs) are convolved with these signals to create the sensation that sound are reproduced by a speaker behind, above or below.

MicroElectrical Mechanical Systems (MEMS)

In recent years, interest in MEMS microphones has expanded due to their versatile design, greater immunity to radio frequency interference (RFI) and electromagnetic interference (EMI), as well as low cost and environmental resiliency [4,5] .

Current MEMS models are generally 10 times smaller than their more traditional electret counterparts; this miniaturization allows for additional circuitry, such as a preamp stage and an analog to digital converter (ADC), to be included within the MEMS enclosure.

“MEMS microphones consist of a flexibly suspended diaphragm that is free to move above a fixed backplate, all fabricated on a silicon wafer. An incoming sound pressure wave passing through holes in the back plate causes the diaphragm to move in proportion to the amplitude of the compression and rarefaction waves” (analog.com).

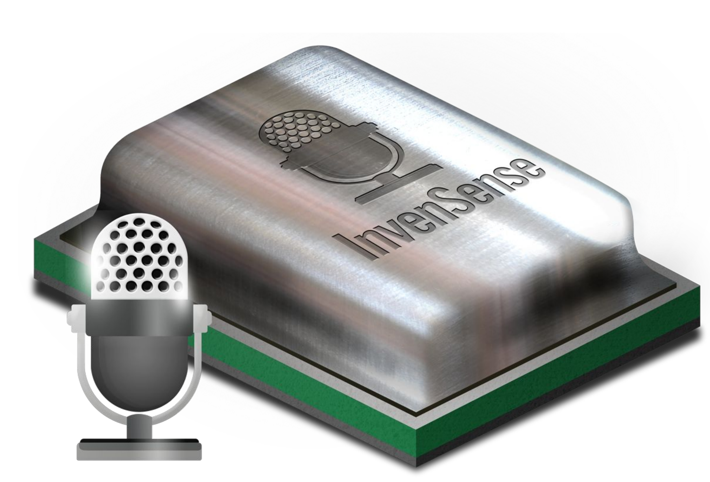

Figure 3 - MEMS Capsule

A Low-Cost, High Quality MEMS Ambisonic Microphone

Gabriel Zalles, Charlie Mydlarz, Spencer Cappiello, et al.

HARDWARE DESIGN

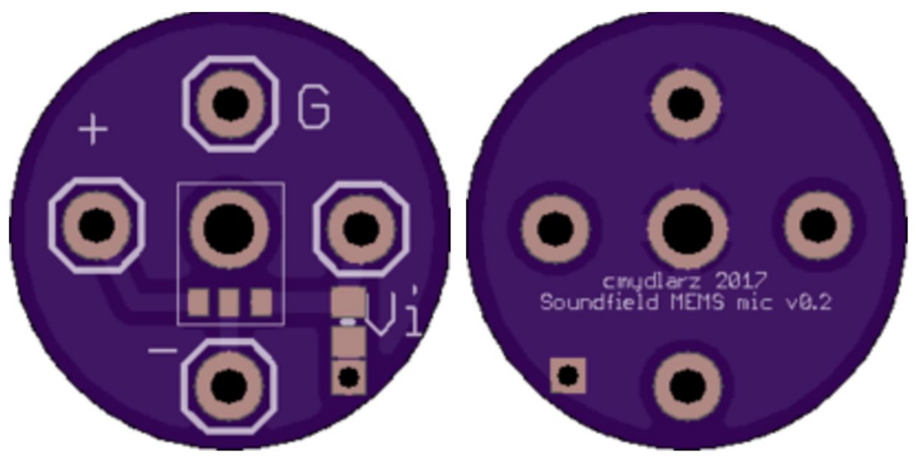

Figure 4 - Custom Printed Circuit Board

The microphone chosen was of the MEMS type, specifically the TDK InvenSense ICS-407201.

This specific capsule boasts a signal-to-noise ratio (SNR) of 70 dBA, acoustic overload point of 124 dB SPL, an unfiltered frequency response of 50Hz to 16kHz, and a low-noise differential output for reduced noise pickup over long cable run.

These microphones exhibit omni-directionality when operated without any coupled hardware such as a Printed Circuit Board (PCB) or housing. The 12.5mm diameter PCB board is shown in Figure 3.

Our team is currently working on further reducing the size of these PCBs, to increase the coincidence of the four transducers required for FOA recording.

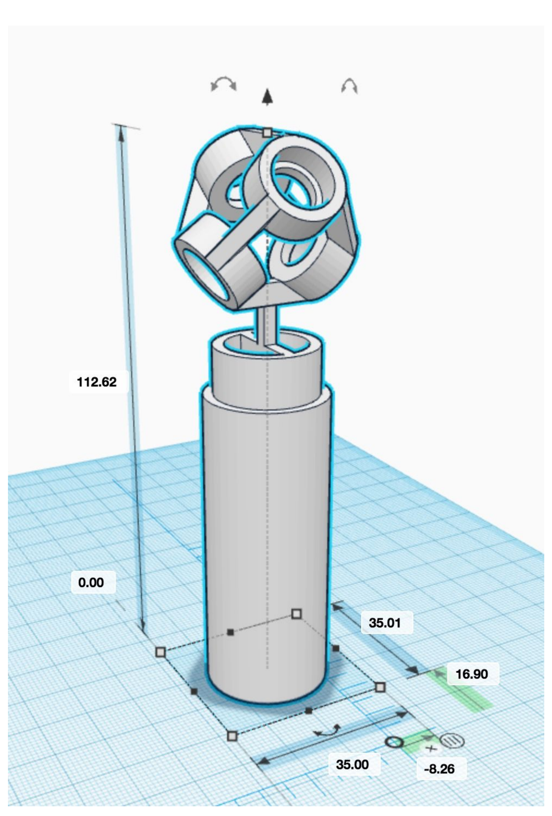

Figure 5 - Mic Enclosure in CAD Software

Figure 6 - Automatic Rotating Microphone Mount

The housing for the MEMS-based FOA mic prototype was 3D printed with Acrylonitrile Butadiene Styrene based filaments (ABS) using a high-end Stratasys Mojo 3D Printer at the NYU La Guardia Studio's in Manhattan.

An automatic rotating microphone mount was designed in order to obtain the necessary polar response plots for the microphone.

Manually measuring microphone directivity consumes considerable amount of time due to the inherent need to rotate the microphone some number of degrees repeatedly until at least 180° is reached for a single plot. Due to this necessity, automated rotating mounts are used to accurately and efficiently acquire the required data.

OBJECTIVE EXPERIMENT DESIGN

The frequency response of the MEMS ambisonic in red was compared to the professional grade Sennheiser Ambeo VR mic. The MEMS solution showed a distinct and audible high frequency component above 10kHz.

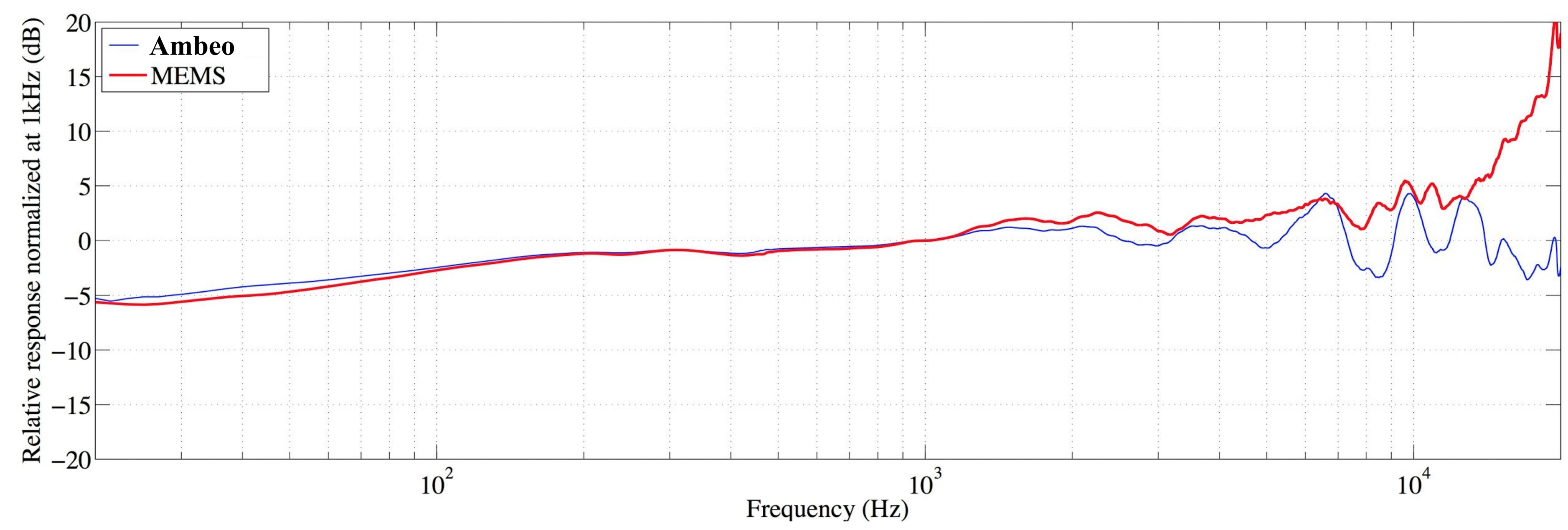

Figure 7 - Frequency Response

SUBJECTIVE EXPERIMENT DESIGN

A preliminary subjective assessment was carried out using an online survey in order to determine the relative preference between the two recording solutions.

Thirty-two participants were recruited from various university's music technology programs, audio-related mailing lists and small groups of non-audio experienced subjects.

The decoding of the B-format signals for reproduction was accomplished via the popular JavaScript Library, ForgeJS. This library makes use of the binaural FOA decoder Omnitone written by Google using the Web Audio Application Programming Interface (API).

By simulating the rotation and tilt of a listener's head, controlled via the subject's mouse or keyboard, subjects can rotate in virtual space.

Below is a figure of the self reported level of experience in music technology.

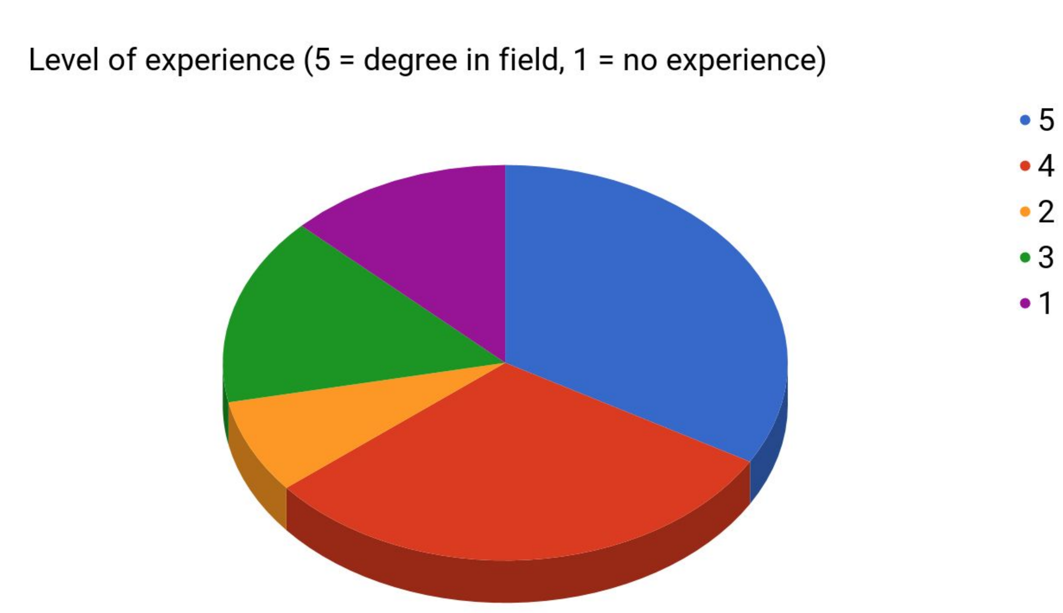

Figure 8 - Experience Plot

NYU STEINHARDT

RESULTS

Preliminary findings showed that subjects perceived a significant low-frequency reduction within the MEMS microphone recording, even though the measured low-frequency response showed little difference between the MEMS capsules and the Ambeo VR electret capsules.

Subjects also noted that the MEMS recording contained overall more high frequency content than the Ambeo recording. While some noted a preference for this, others described it as overly bright.

DISCUSSION

Overall, a preference towards the Ambeo mic can be seen as per the mean values shown in Table 2 for the three subjective criteria and the overall preference question.

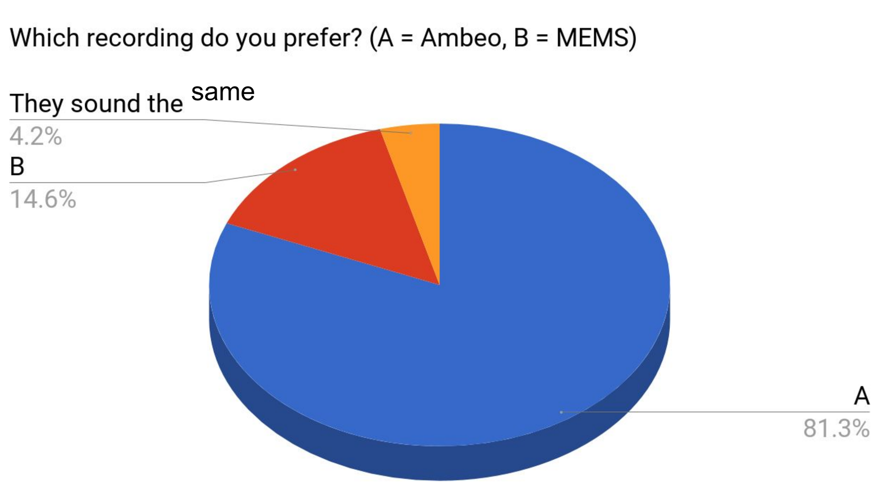

Figure 9 - Preference Plot

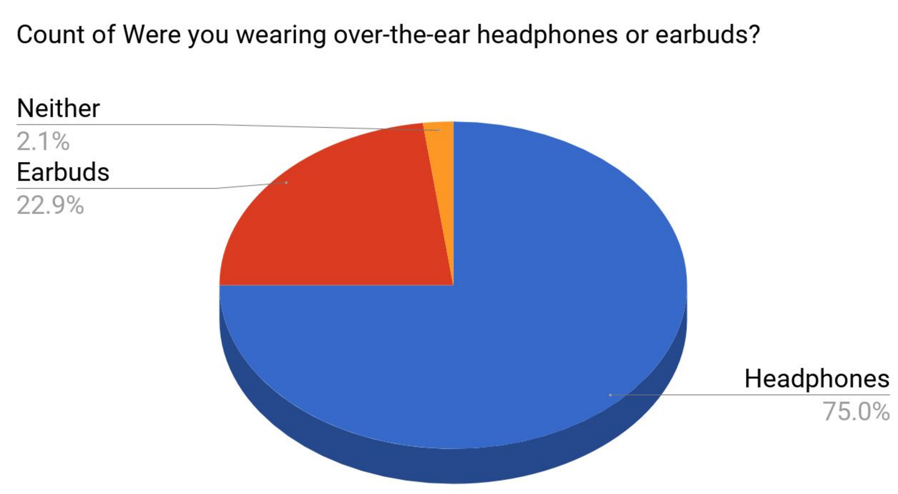

Figure 10 - Reproduction Method Plot

Beside the decreased spatialization, which we attribute to the MEMS's omnidirectional polar response, and the overly present high frequency content, subject also reported a slightly higher noise floor on what they believed was the MEMS mic recording. *(Subject were at no point told which recording pertained to which microphone.)*

The omni polar response of the MEMS microphone, whilst modified slightly by the microphone housing, had an overall negative impact on the subject's ability to perceive any panning compared to the Ambeo mic's recording.

The low degree of directivity featured in each capsule, and its predominantly omnidirectional response across multiple frequency bands, is considered the main factor contributing to the lack of spatialization during MEMS reproduction.

Subjects were also asked to evaluate the audio in terms of a number of subjective descriptors. Table 1 shows the mean and standard deviation of our results. A full definition of the descriptors can be found in the associated AES paper.

	Ambeo		MEMS	
	Mean	*Std*	*Mean*	*Std*
Naturalness	3.38	1.16	2.94	1.16
Clearness	3.81	0.78	3.50	0.84
Accuracy	3.78	0.83	3.00	1.11

Table 4 - Subjective Assessment Table

FUTURE WORK

Our group is in the process of building the second iteration of this MEMS FOA microphone.

We are developing a new microphone with more coincident capsules, the ability to power the capsules using phantom power and some filtering to eliminate the brash high end.

We are also testing several different ways in which we could improve on the directivity response of MEMS capsules via structural design changes or certain DSP processes.

CONCLUSION

The prototype MEMS-based ambisonics microphone shows promise in its ability to capture high quality 3D audio at a fraction of the cost of commercially available devices.

While the MEMS capsules directivity deviated from the desired cardioid response, its frequency and noise floor characteristics were generally well received.

Results showed that subjects tended to perceive the MEMS recording as “thinner” and lacking bottom-end in general; however, most also noted that the MEMS capsules did not exhibit *unfavorable* signal-to-noise ratios, something often associated with micro-capsules

REFERENCES

1. Gerzon MA. The Design of Precisely Coincident Microphone Arrays for Stereo and Surround Sound. Audio Engineering Society Convention 50. Audio Engineering Society; 1975.

2. Malham D. Higher Order Ambisonic Systems for the Spatialisation of Sound. International Computer Music Conference. International Computer Music Association; 1999. pp. 484–487.

3. Malham DG, Myatt A. 3-D Sound Spatialization using Ambisonic Techniques. Computer Music Journal. 1995. pp. 19-58.

4. Van Renterghem T, Thomas P, Dominguez F, Dauwe S, Touhafi A, Dhoedt B, et al. On the ability of consumer electronics microphones for environmental noise monitoring. J Environ Monit. 2011. pp. 544–552.

5. Mydlarz C, Salamon J, Bello JP. The implementation of low-cost urban acoustic monitoring devices. Applied Acoustics. 2017. pp. 207–218.

6. Boren B, Roginska A. Multichannel Impulse Response Measurement in Matlab. Audio Engineering Society Convention 131. Audio Engineering Society. 2011.