Passive Amplifiers Add Directional Sensitivity to MEMS Microphones

Dean R. G. Anderson,
Daniel J. Anderson,
Dean G. Anderson, M.D.

ABSTRACT- Directional sensitivities are reported for a passive amplifier added to a MEMS microphone.

A microphone's directionality indicates how sensitive the microphone is to sounds arriving from different angles compared to sounds arriving on its principal axis. Directional microphones are most often used for speaker discrimination by reducing background noise to increase the signal-to-noise ratio (SNR).

Historically, directionality has been obtained through off-axis phase cancellation where the incoming sound signal is mixed with time-delayed sound signals. Multiple microphone arrays use phase-shifting and superposition to achieve directionality.

Directional microphone testing results are typically reported for only certain pure tone frequencies and harmonics which result in destructive cancelations (“nulls”) in anechoic settings.

Here we explore the directional sensitivity of a passive amplifier added to a MEMS microphone in a real-world, reverberant setting for all 1/3 octave speech bands.

Pixation has made advancements in understanding how design, shape, volume, and materials of construction influence passive amplifier performance. The unique passive amplifier designs from Pixation use air momentum to compress longitudinal sound waves as they move from the passive amplifier mouth to the interior apex. The port opening of the MEMS microphone is located at the interior apex.

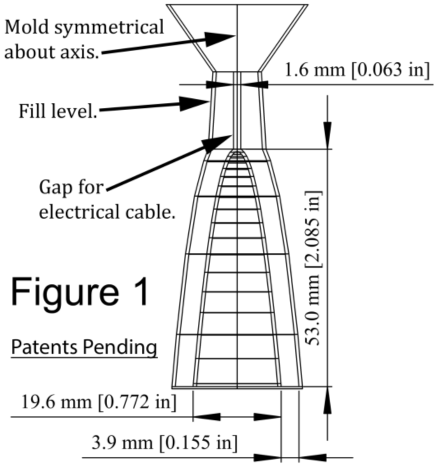

Figure 1

Patents Pending

Methods

Passive amplifiers were constructed with soft platinum-catalyzed silicone (8 hardness Shore-A ASTM D-2240) using the 3D printed mold as illustrated in Figure 1.

Two demolded 53 mm passive amplifiers are shown in Figure 2 in different positions to provide the reader with perspective.

White noise was used for directional sensitivity measurements for the MEMS microphone with and without a passive amplifier. The white noise had balanced power spectral density. The white noise was attenuated at 48 dB per octave at 1/3 octave speech band limits. The MEMS microphones used had the industry standard 24-bit digital I²S interface to report audio signals sampled during every 32 microsecond period (a 31,250 Hz sampling rate). The samples were combined together to determine an audio output measurement with 0.1 dB SPL precision during a 40.96 millisecond period. The average audio output level was determined during a 41.94304 second period with 1,024 sequential measurements.

Both speaker (JBL Control 1 Pro) and microphone were pole mounted (16 mm diameter poles) 1.1 meters above a carpeted floor. The microphone pole was attached to a rotary table. The microphone and speaker were separated by 28 cm and positioned asymmetrically in an otherwise reverberant residential room.

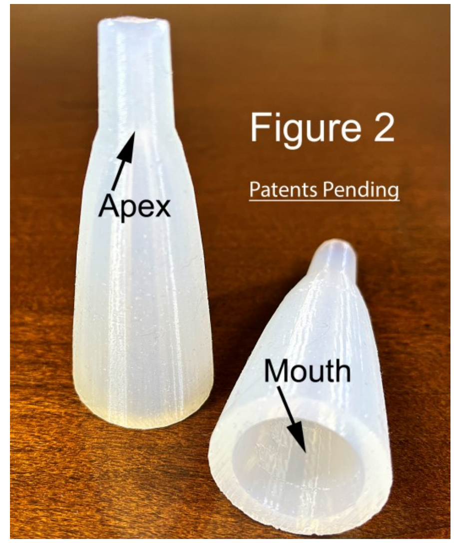

Figure 2

Patents Pending

Directional sensitivity for a passive amplifier added to a MEMS microphone was computed by subtracting audio output levels determined for the MEMS microphone without a passive amplifier from the audio output levels determined using the same MEMS microphone with a passive amplifier. The audio output levels determined for the MEMS microphone without a passive amplifier were measured with the MEMS microphone port opening facing the speaker. The audio output levels determined for the MEMS microphone with a passive amplifier were determined with the same MEMS microphone with its port opening positioned at the interior apex of a passive amplifier and with the passive amplifier in various azimuthal orientations relative to a speaker.

Results

The curves in Figure 3 depict the directional sensitivity measurements for a passive amplifier added to a MEMS microphone using the method just described.

Discussion

For the 53 mm passive amplifier added to a MEMS microphone in Figure 3, the average speech band directional sensitivity variation is 5.34 dB. These directional sensitivity variations range from 3.9 dB for the 160 Hz band to 10.9 dB for the 8,000 Hz band.

Traditional directional microphone testing is performed at specific frequencies and harmonics in an anechoic (non-reverberant) setting. These measurements are artificially constrained and are not representative of real-world recording conditions.

The passive amplifier measurements reported here were made in a standard, residential type reverberant room for the full range of speech frequencies.

We expect that head, neck, torso, arm, wrist, hand, dashboard, fender and/or tabletop shadowing will increase directional sensitivity for a passive amplifier added to a MEMS microphone. Such increased directional sensitivity will result from increased airborne sound isolation and attenuating mass.

As demonstrated in earlier papers[1,2], the additional gain shown in Figure 3 contributes significantly to improved speech intelligibility.

Conclusions

Passive amplifiers add directional sensitivity to MEMS microphones.

Passive amplifiers enhance the performance of existing MEMS microphone solutions and thus serve as an additive technology.

Similar to binaural summation, a passive amplifier added to a MEMS microphone enables critical band summation for directional hearing and speaker discrimination.

Contact pixation@pixation.com for additional information.

[1] Anderson D. Understanding Microphone Equivalent Noise. www.pixation.com, 2022.
[2] Anderson D. Expanding the Reach of Microphones: Improving Intelligibility. www.pixation.com, 2021.