Introduction to Direction of Arrival

Direction of Arrival (DOA) technology enables devices to determine where sound is coming from in physical space. Similar to how humans use two ears to locate sound sources, DOA systems use multiple microphones to detect and calculate the origin of incoming sound waves.

DOA technology has become essential in many everyday devices.

Smart Speakers: When you say, "Hey Alexa" or "OK Google," smart speakers use DOA to determine your location in the room. This allows them to optimize their listening direction and better separate your voice from background noise or other speakers.

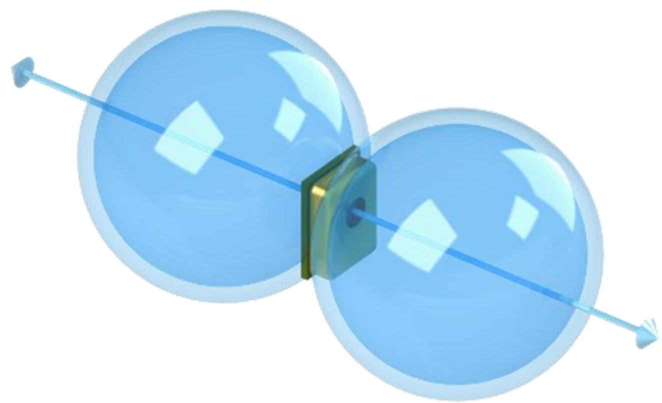
Video Conferencing: Modern conference room systems use DOA to automatically focus on and enhance the audio from whoever is speaking. This information can also be used to turn the camera to focus on the speaker. When someone in a different part of the room starts talking, the system can shift its focus to capture their voice clearly.

Security Systems: Audio surveillance equipment can use DOA to detect and track the location of specific sounds, such as breaking glass or raised voices, helping to identify potential security threats.

Hearing Aids: Advanced devices utilize DOA to help users better understand speech in noisy environments by focusing on sounds coming from specific directions, typically in front of the user where a conversation partner might be.

Leveraging Soundskrit Microphones for DOA

Unlike traditional omnidirectional microphones that capture sound equally from all directions, Soundskrit's directional microphones are inherently sensitive to sound from specific directions while rejecting sounds from other directions. Combining multiple directional microphones enables precise DOA detection. Soundskrit's dipole arrays are well-suited for DOA estimation, offering robustness against environmental noise and improved accuracy.



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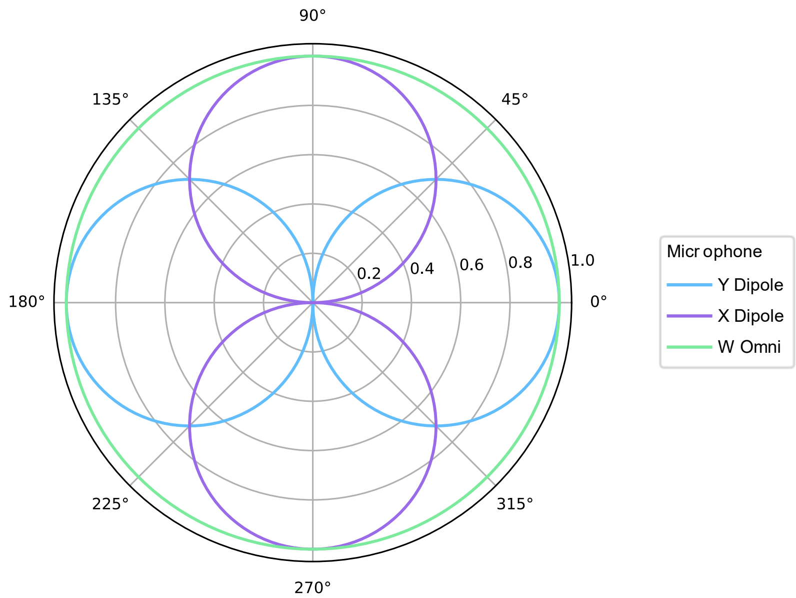
WXY Configuration for 360° DOA

To achieve 360° sound capture and DOA, two Soundskrit directional microphones are oriented orthogonally to one another, forming an "XY" configuration. In addition, we place a single omnidirectional microphone in the center of the XY. These three microphones allow for 360° DOA and sound capture in a convenient co-located array.



This array allows for features described in the "**Introduction to the XY configuration using MEMS directional microphones"** article and the beamforming ability described in the **"How do microphones combine to create new polar patterns?"** article. In addition to DOA, a WXY array includes stereo audio pickup, 360° beam steering and beamforming features.

The WXY configuration offers several advantages and features:

- Sound Localization: The WXY configuration allows for the accurate determination of the direction of a captured sound. The system can determine the DOA by analyzing the differences between the signals from the WXY-positioned microphones.
- Robustness: The Soundskrit dipoles are inherently sensitive to sound direction, making them robust against environmental noise and improving the accuracy of DOA estimation. The use of directional microphones as the core hardware component leads to superior voice isolation and background noise reduction.
- Compactness: Optimizing an omnidirectional microphone array for DOA needs a large amount of space (e.g., a circular array of omnidirectional microphones) and/or many microphones. The WXY array offers 360° DOA in a compact, co-located, three microphone array.
- 360° Coverage: The two orthogonal dipoles in a WXY configuration enable the directional beam to be steered in any direction, providing 360° coverage around the microphone array. The WXY configuration is convenient for beamforming, as any first-order beam can be created and oriented at any angle by computing a linear combination of the microphone outputs.

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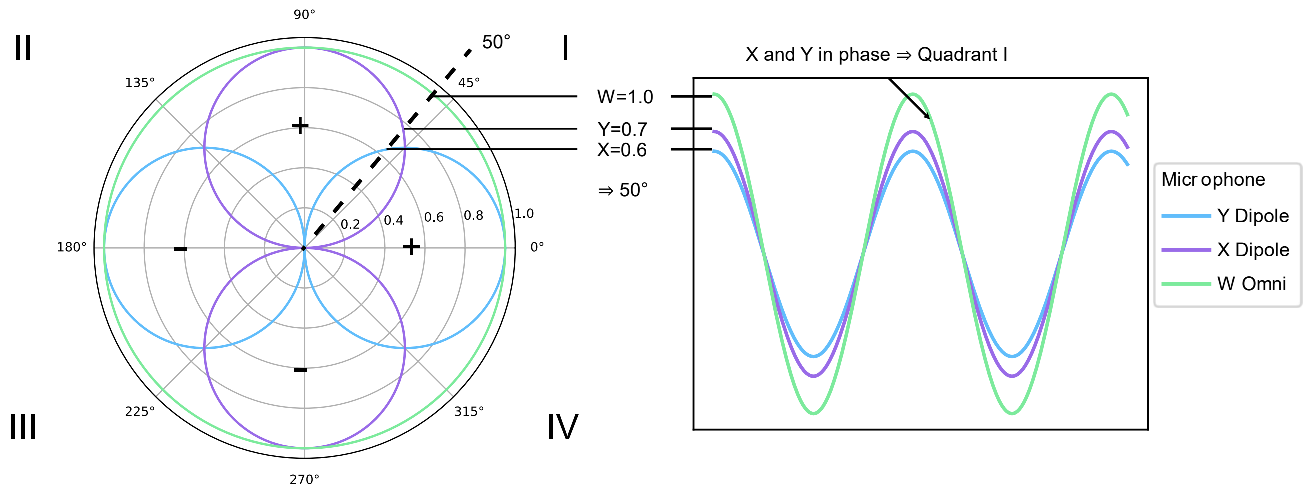
How the WXY works

Consider a smart speaker with multiple microphones arranged in a specific pattern. When you speak, sound waves reach each microphone with different intensities depending on your position relative to the device. The algorithm processes the level and phase differences to calculate your location. DOA estimation with a WXY array relies on analyzing level differences between microphones and the phase relationship of the dipoles relative to the omnidirectional microphone. Because dipole microphones have bidirectional polar patterns with opposite-phase lobes, comparing their phase with the omnidirectional microphone helps determine which quadrant the sound source is in. Once the quadrant is identified, the amplitude ratio between the dipoles allows for precise angle calculation.

To Illustrate how this works at the fundamental level, let's look at the signal output of each microphone when we have a sine wave playing from 50°. From the fact that both dipoles are in phase with the omnidirectional microphone we know that our signal source must be in quadrant I. Then we can calculate the exact angle from the amplitudes using the arctangent: arctan(0.7/0.6) ≈ 50°



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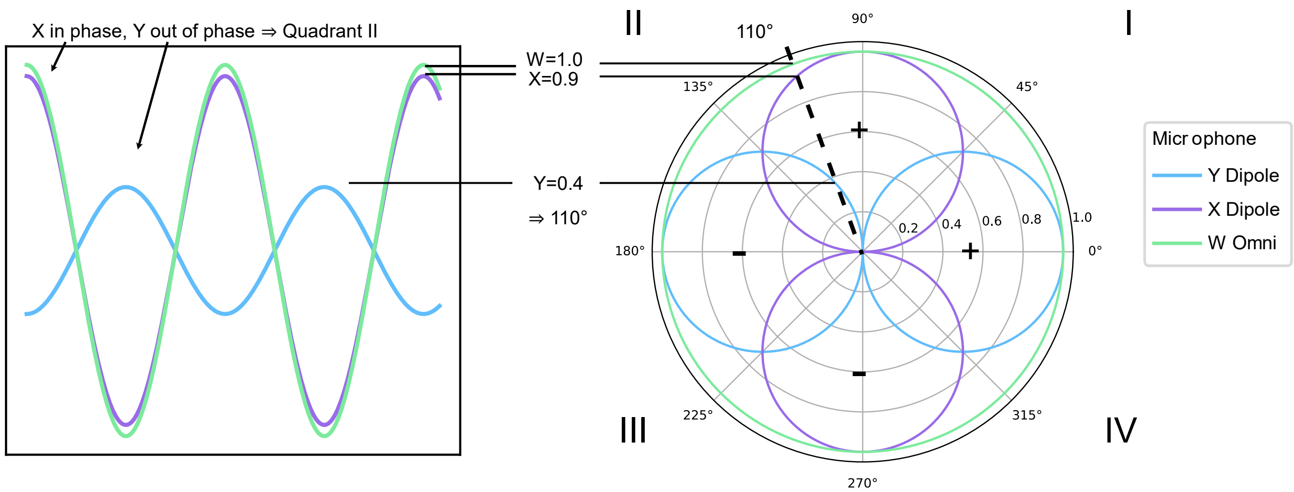
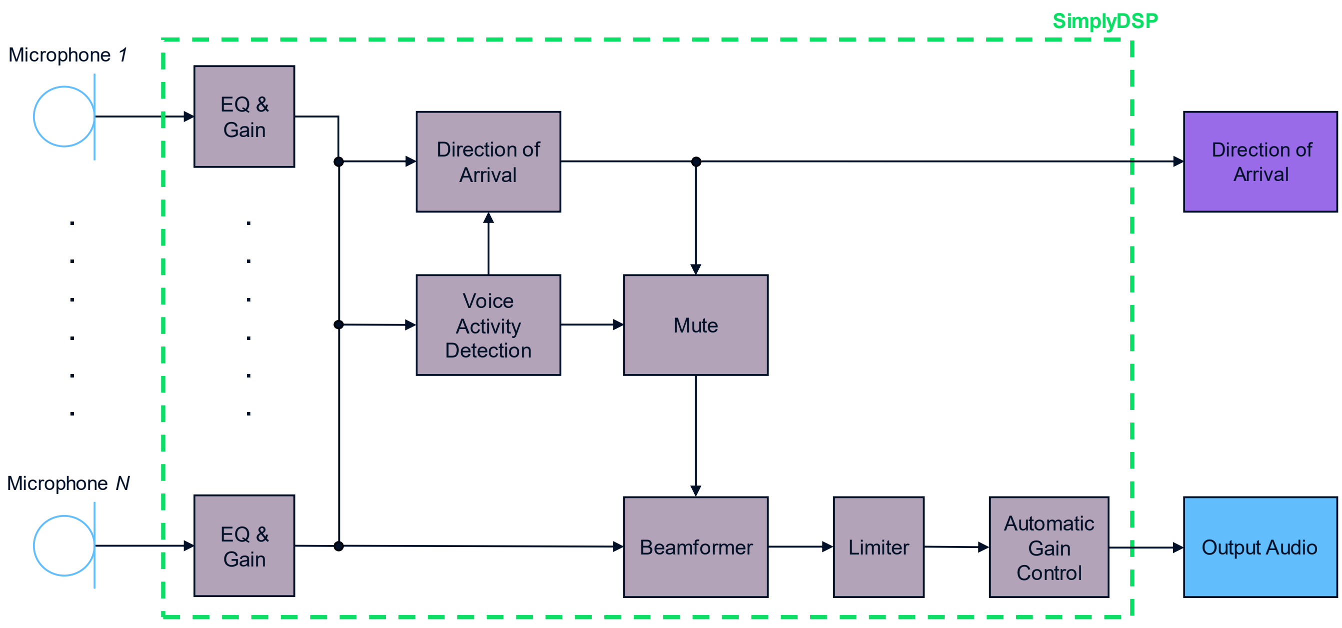
Now let's consider a sine wave at 110°. Since the Y dipole is now out of phase with the omnidirectional microphone, we know the signal source must be in quadrant II. The angle within that quadrant is then arctan(0.4/0.9) ≈ 20° [1]. By adding 90° for quadrant II we get 110°.



A Fourier transform can decompose more complex signals into their sine wave components, allowing them to be processed similarly.

The device uses DOA information to implement various features like beamforming, which focuses the microphone array's sensitivity on specific directions while reducing sensitivity to sounds from other directions. Here is a simplified block diagram of how DOA would be integrated alongside different features in a product.



[1] X and Y are flipped here because we are imagining the polar plot rotated -90°, so that we can handle quadrant II as if it was quadrant I. Most programming languages offer the atan2 function to handle the different quadrants.

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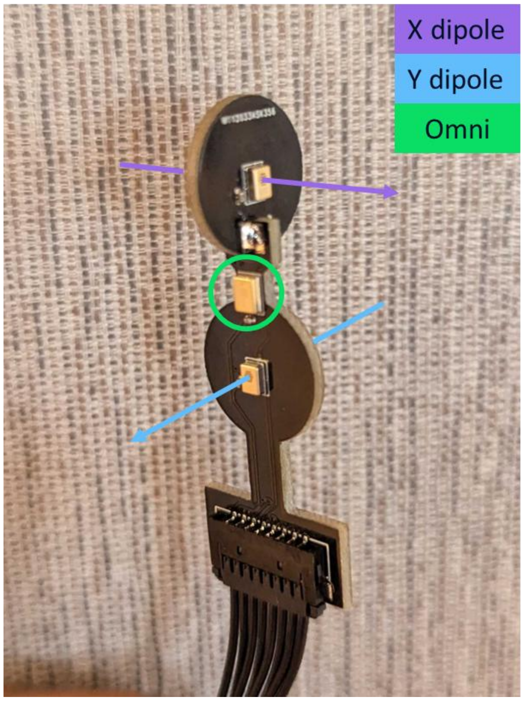
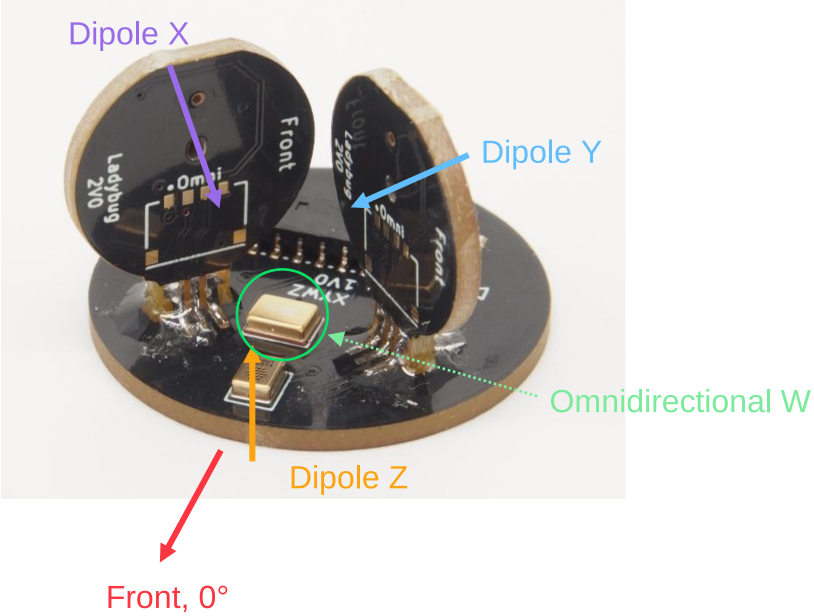
Making a WXY

Totem:
The "Totem" configuration is a stacked tower of three PCBS to create the WXY array. This configuration ensures all microphones are co-located in the horizontal plane, enabling consistent beamforming along the entire plane.



Beetle:
The "Beetle" configuration uses three PCBS but adds in a Z axis dipole. This results in a four microphone array (three dipoles and one omnidirectional) which works similarly to the totem. The Z-axis dipole enables vertical DOA and beamforming.



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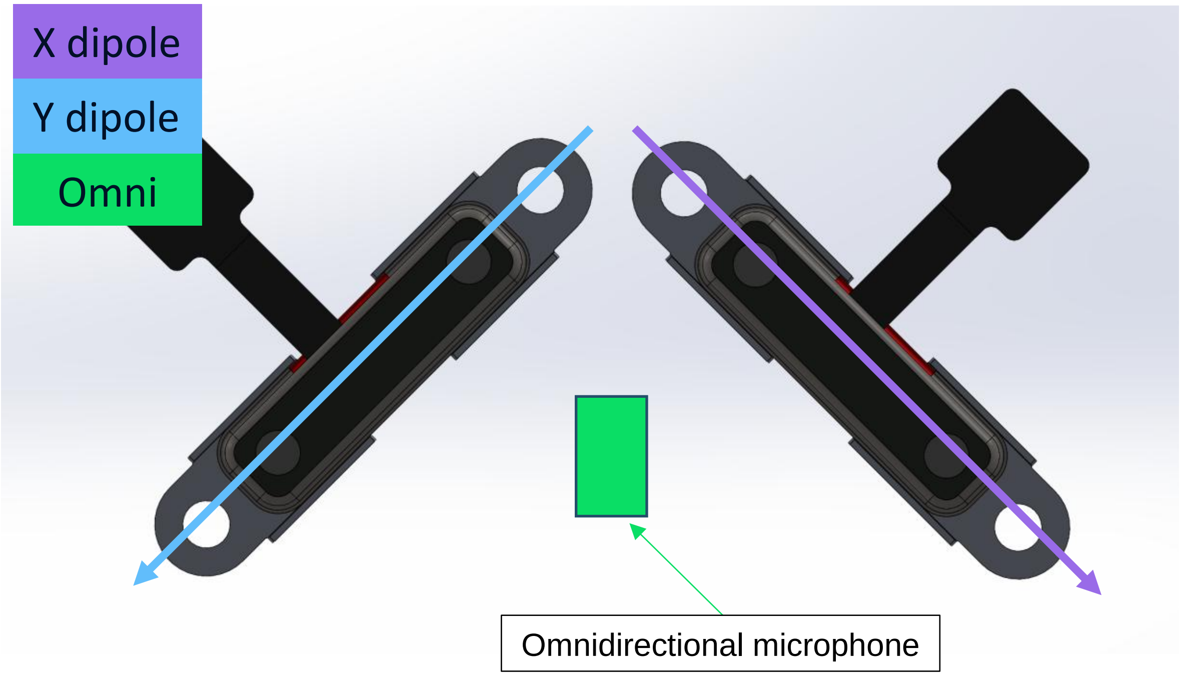
Modular Approach:
A WXY array can be made and integrated easily using Soundskrit's modules. This can be done using a combination of two SKM2600s and one omnidirectional microphone. The modules are oriented 45° off the center axis. The omnidirectional microphone would be placed in the center. It is best to orient the microphones as close as possible and all microphones should be contained within a 20 mm diameter circle.



Design and Applications Support

For additional design and applications support, please reach out to applications@soundskrit.ca.

Revision History

Revision Label	Revision Date	Sections Revised
-	February 2025	Official release

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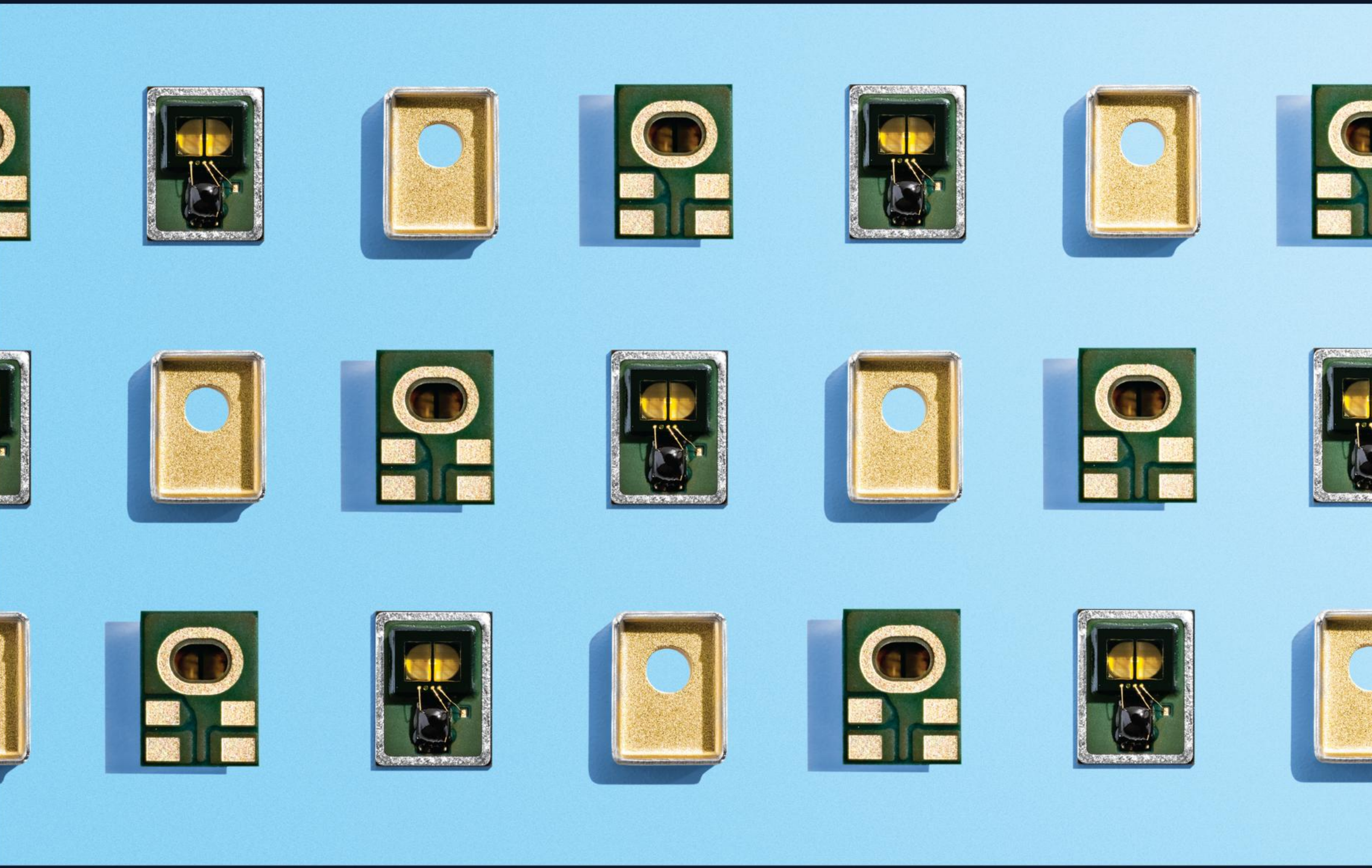
Soundskrit developed the first high-performance directional MEMS microphone on the market, leveraging years of research in bio-inspired MEMS based on how spiders and other insects in nature hear. In combination with Soundskrit's in-house audio processing algorithms, directional microphones can be used to capture and isolate any sound in an environment with a fraction of the size, power, and computation of traditional omnidirectional-based microphone arrays.

Soundskrit was founded in 2019 and is headquartered in Montreal, Quebec with an R&D facility in Ann Arbor, Michigan.



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