White Paper

HYPERSOUND CLEAR™ TECHNOLOGY

HyperSound Clear is an innovative, highly-directional audio solution that delivers sound using a fundamentally different method compared to traditional audio speakers. This paper provides a brief overview of directed audio technology and outlines the specific uses and advantages of its application within hearing healthcare.

HyperSound vs. Traditional Audio Speakers

When you think about traditional audio in its common form, you might think of a speaker vibrating and generating sound. Traditional speakers often vibrate at a relatively high rate, depending on frequency, and push sound throughout a space. Sound bounces off objects in its path before ever reaching a human ear. Regular, everyday sound is delivered through conventional speakers at anywhere between 1-10khz, and the sound wave spreads out rather wide from the source (i.e. speaker).

Audio from the HyperSound Clear™ solution is fundamentally different. A traditional loudspeaker can be thought of as a bare light bulb and HyperSound technology as a flashlight beam. As with the light bulb, traditional loudspeakers radiate sound in all directions; it does not matter where the listener is positioned within the room, sound will be heard. Often, the listener can point directly to that speaker from anywhere in a room and say "that is where the sound is coming from".

HyperSound speakers, on the other hand, emit sound in a highly controlled, narrow beam, so that audio can be heard only if you are "in the beam" or in a position to hear the reflected sound from a virtual source. This is because, rather than creating sound directly using a vibrating speaker cone, HyperSound technology uses ultrasound, creating audio in the air itself.

This ultrasonic carrier frequency is generated from the emitter at approximately 100 kHz, or 100,000 Hz. The audio is generated in the air itself and is carried to the listener through a narrow sound beam.

The audio is highly directional because it is created at an infinite number of points all along an ultrasonic energy column. This provides the unique flexibility to place sound exactly where you want it, while substantially masking sound from other areas.

By beaming sound with similar precision to a flashlight, sound is directed towards the intended listener. Because audio can be directed to a specific area it provides individuals in that area the benefit of audio without disturbing others. Additionally, because sound is created in the air rather than at the source, the experience is highly immersive, similar to wearing headphones. HyperSound speakers deliver sound precisely, and consequently less volume is necessary to deliver sound where it is needed.

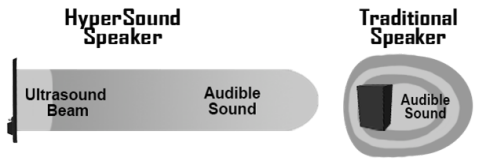

Figure 1: HyperSound vs. Traditional Speakers

HyperSound travels in a focused direction along the beam, unlike typical point source loudspeakers that emit sound waves in all directions.

History of the Technology

Approximately 150 years ago, a German Physicist named Hermann von Helmholtz discovered that air is nonlinear. The output of a nonlinear system is not directly proportional to the input. He played two organ notes very loudly on his pipe organ and was able to hear what he thought to be a higher frequency and a lower frequency. Through careful measurement, he proved that these new frequencies did exist as new tones and were measured to be the sum and the difference of the original notes.[1]

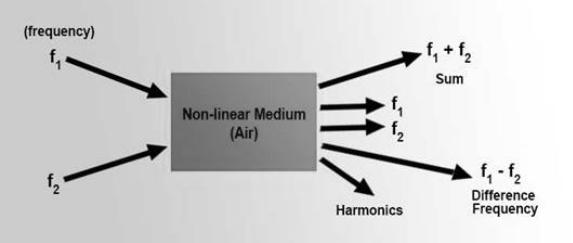

Figure 2: Air is a Non-Linear Medium

The Helmholtz experiments were further explained by Westervelt (Brown University) and Blackstock (University of Texas at Austin). They proved that the new tones were the result of propagation distortion caused by the air itself.[2,3]

It is understood in the world of electronics, that sending two frequencies into a non-linear device produces an output that contains both of the original signals, plus the sum of the two, the difference of the two, and a set of harmonics. This process is called demodulation.

Fourier analysis has proven that any signal can be decomposed into a sum of many sine waves

Figure 2: Air is a Non-Linear Medium

with varying amplitude and phase. Because the phenomenon works for tones, we can therefore conclude that it must work for complex waveforms. HyperSound technology takes advantage of this through a patented and patent pending set of electronics, digital signal processing, and algorithms that create complex waveforms such that the nonlinearly-created difference tones in the air reconstruct into the desired audio signal. That waveform is projected from a single emitter (parametric loudspeaker) using ultrasonic frequencies to prevent diffraction. This generates a highly directional sound beam.

How HyperSound Technology Works

The first step for creating sound through HyperSound technology is to form an ultrasonic beam. Acoustic beaming is an effect which comes about by traditional acoustics through the ratio of speaker size to emitted wavelength. When this ratio is large, sound spreads out from the speaker and fills the nearby area. When this ratio is small, a beam is formed.

Traditional audio wavelengths are large. Middle-C on a piano has a fundamental wavelength of over 4 ft. In contrast, even an extremely large speaker (the part that vibrates) is rarely more than 1 ft. in diameter. As a result, this causes the sound waves to spread out. The situation is analogous to ocean waves in a marina. Despite no direct-line access to the open ocean, surface waves manage to bend around corners and make it to every last corner. This spreading of long wavelengths is called diffraction and is an everyday phenomenon that we experience with regular sound.

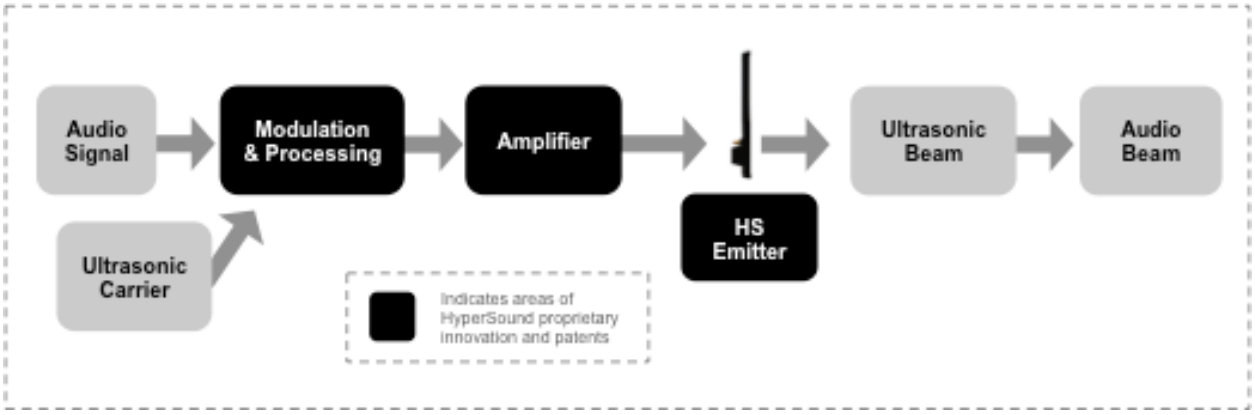

Figure 3: Diagram of HyperSound Process: Figure 3 displays a functional diagram of HyperSound's audio beam system. First, the emitted ultrasonic wave is inaudible, but as it impresses audio signals onto the carrier in the air, the audio signal is demodulated by the parametric array effect and becomes audible. This demodulated audio wave retains the directivity of the ultrasonic wave, thus producing an audio beam.

HyperSound, in contrast, uses the extremely small wavelengths of ultrasound to create an audio beam. At 100khz, the wavelength of sound is 0.13 inches. With an emitter size of several inches, we fall into the opposite limit. Much like how shining a flashlight through a quarter-size hole produces a quarter-size beam of light, our HyperSound emitter produces a emitter-size beam of ultrasound.

HyperSound travels in a focused direction along the beam, unlike typical point source loudspeakers that emit sound waves in all directions.

The figures above illustrate this effect. At 1khz and 10khz (regular audio frequencies) an emitter the size of that employed by HyperSound would create a wide-angle dispersion but at 100khz the beam stays tightly collimated.

The next step to create HyperSound audio is to exploit the nonlinearity of air itself. Doing this creates sound from ultrasound and only does so within the tightly collimated beam.

A New Category of Products for Individuals with Hearing Loss

Directed audio solutions have been around for decades. While directed audio holds great potential within a wide range of applications, the technology has been limited and difficult to perfect. HyperSound technology has overcome those limitations.

Over the last several years, significant investment went into perfecting HyperSound technology for use across both commercial and consumer markets, and is now considered the first and only directed audio solution of its kind designed specifically for the hearing healthcare industry. As indicated by clinical[5] and preference[6] research, HyperSound Clear™ improves clarity and speech intelligibility for those with hearing loss. Key innovations such as HyperSound's patented DSP processing and proprietary emitter design have made way for a truly clear, optimized audio experience unlike anything else currently available.

Major Innovations in HyperSound Technology

Since HyperSound's inception in the late 1990s, countless innovations have been made to the original system design and functionality. Currently, there are 36 U.S. patents surrounding HyperSound's proprietary technology, and 25 more pending for both commercial and consumer innovations.[7]

This has created a "picket fence" that protects HyperSound innovations in distortion control,

software algorithms and modulator processing. Key areas of recent innovation include:

- **Emitter Design**: Vast improvements have been made to HyperSound's emitter and amplifier design that optimize its application within commercial environments. Additionally, innovations in emitter panel design have improved the ratio of audio volume to panel size, allowing for the production of much smaller panels.

- **Modulation**: Out of HyperSound's wide range of innovations, perhaps the most important and promising deals directly with modulation; more specifically, improvements to HyperSound's sophisticated and highly complex modulation algorithms. These patented improvements correct harmonic distortion and intermodulation, improving audio quality and frequency response.

- **Electronics**: HyperSound's core electronics components have also received numerous renovations, with new patents issued that make the system more stable and its technology more refined. For example, HyperSound circuits have been technologically enhanced and an advanced matching device was introduced, leading to increased system efficiency. Electronics advancements have also enabled the use of low voltage cables and lowered overall power consumption.

References

1) L.J. Black. (1940). A Physical Analysis of Distortion Produced by the Non-Linearity of the Medium. J. Acoust. Soc. Am. 12:266.

2) Westervelt, P. (1963). *Parametric Acoustic Array.* J. Acoust. Soc. Am. 35 (4):535-537.

3) Beth, M., Blackstock, D. (1975). Parametric Array in Air, J. Acoust. Soc. Am. 57 (3): 562-568.

4) Johannes, R., Gan, W. (2009). 3D Sound Effects with Transaural Audio Beam Projection. Retrieved from http://www.researchgate.net/publication/228751051_3D_Sound_Effects_with_Transaural_Audio_Beam_Projection/file/3deec5170069f736e6.pdf

5) Mehta, RP. Novel ultrasonic sound carrier significantly improves speech discrimination in subjects with hearing loss. Otology/Neurotology Scientific Session presented at the Combined Sections Meeting of the Triological Society. January 22, 2015, San Diego, CA (Ten patients with mild to severe hearing loss in a single-blind, randomized cross-over study demonstrated improvement in sound clarity, measured with standard speech tests, over conventional speakers at 70 dB at 1 meter, including in background noise.)

6) Taylor, B et al. (2015) Patient preferences for a directed audio system. Hearing Review (in press) (Survey of 58 adults exposed to 2 minute demonstration of HyperSound directed audio with 79% indicating the listening experience enhanced the ability to hear and understand speech.)

7) Data as of April 30, 2015 as reported by Turtle Beach Corporation.