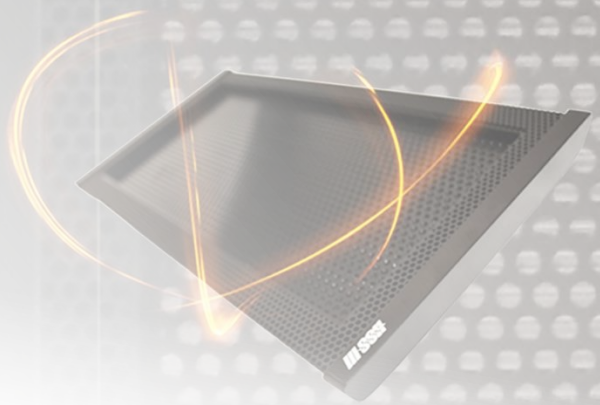
WHITE PAPER | *sound innovation*



HYPERSOUND:
TECHNOLOGY INTRODUCTION

HyperSound® is a disruptive audio innovation that is highly-directional and can drive immersive audio experiences within commercial applications.

Directional sound speakers are a breakthrough technology that offers retailers, systems integrators, and other organizations the ability to create isolated sound zones without bleed. This white paper provides a brief introduction to the technology and discusses its potential within a wide range of commercial applications.

WHITE PAPER – July 2014

HYPERSOUND™

CONTENTS

TECHNOLOGY INTRODUCTION

INTRODUCTION

DIGITAL SIGNAGE AND AUDIO

As digital signage continues to grow, visual content has become an increasingly important tool for marketers. But what about audio?

When it comes to today's digitally-driven out-of-home world, marketers are finding that consumers are much more engaged and influenced within immersive, multi-sensory environments.[1] We also know that auditory perception can be a major factor in engagement, memory, and message assimilation.[2] So why is this often overlooked?

For audio engineers and integrators, the challenge to add audio to retail, museum, trade show, and other acoustically complex commercial spaces has been daunting, often resulting in the elimination of audio within the application. This is because most commercial loudspeakers create audio that bleeds into other spaces, or adds distracting, unwanted reflections.[3]

For example, in retail environments using digital advertising, LCD monitors are typically silent because conventional loudspeakers produce audio at uncomfortable levels – and allow sound to spread in all directions.

While the playback of audio messages is an option, the predominant media used in digital signage networks are visual, as sound may be perceived as noise by consumers and staff present in the vicinity of the audio sources.[4]

40% recall hearing retail audio during their most recent grocery store visit

57% think ad-supported retail audio is an acceptable form of advertising

18% recall hearing retail audio commercials and promotional announcements in a grocery store

25% think that retail audio advertising would influence their buying decisions

The Arbitron Retail Media Study[5]

Unfortunately, most audio experiences have lacked sound directivity – which is an important factor when designing spaces requiring isolated audio zones and/or needing to minimize the negative effects of audio bleed.

The purpose of this publication is to discuss the technology behind HyperSound speakers, provide a brief background of its history, and to outline the business potential of directed audio systems within commercial applications.

1. Cisco. (2012). *Digital Signage for Retail: Attract and Keep Your Customers.* Retrieved from http://www.cisco.com/web/strategy/retail/downloads/dms_brochure_0709.pdf
2. Wolvin, Andrew D. (2012). *Listening, Understanding, and Misunderstanding.* 21st Century Communication: A Reference Handbook. Retrieved from http://www.sagepub.com/edwards/study/materials/reference/77593_5.1ref.pdf
3. Miranda, J. (2013). *Directional Sound: An Underused but Highly Valued Audio Tool.* Commercial Integrator Solution Series. Pg. 2. Retrieved from http://www.commercialintegrator.com/whitepaper/directional_sound_an_underused_but_highly_valued_audio_tool
4. ITU-T Technology Watch. (2011). Digital signage: the right information in all the right places. Pg. 3. Retrieved from http://www.itu.int/dms_pub/itu-t/oth/23/01/T23010000150002PDFE.pdf
5. Williams, D. (2005). *The Arbitron Retail Media Study: Vol I.* Retrieved from http://www.bestbusinessmusic.com/ArbitronRetailMediaStudy.pdf

DIRECTED SOUND

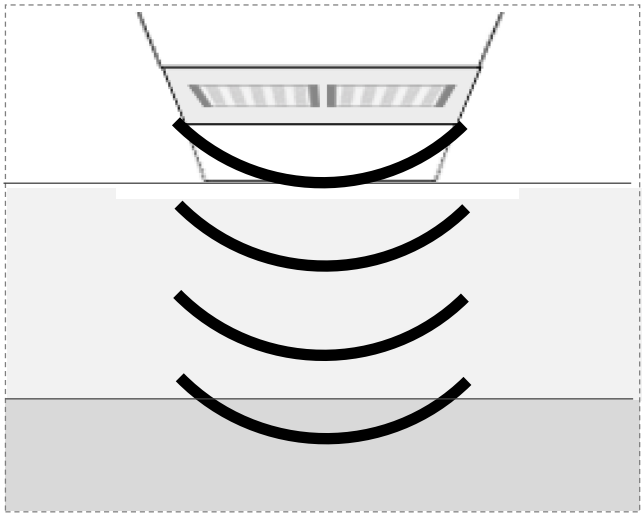
DIRECTED SOUND AS AN EMERGING TECHNOLOGY

Directional audio is an emerging technology that has great potential within a wide range of commercial environments.

The levels of audio "directivity" varies greatly amongst today's loudspeakers. When we discuss directivity, we are referring to the characteristic of how a loudspeaker sends sounds in different directions. When sound is "directional", it travels along a specific axis with minimal dispersion.

Currently, there are several ways to generate directional sound:

- **Loudspeaker Arrays:** Spatially steers audible sound beam in a horizontal plane. This approach of creating focused sound incurs a high cost and cannot be generated by a small loudspeaker. Directionality is low.
- **Sound Domes:** Focuses sound waves to listeners below the dome. Directivity is limited, depending on the size of the dome, and can only be deployed in overhead applications.
- **Parametric (or Ultrasonic) Loudspeakers:** Modulates audible sound signals onto an ultrasonic carrier and projects the signals through ultrasonic emitters, generating audible sound in a tight column. This type of speaker provides the greatest audio directionality, and can be developed in a wide range of emitter sizes and shapes.



The parametric loudspeaker provides an effective means of projecting sound in a highly directional manner, without using large loudspeaker arrays, to form sharp directional beams.[6]

6. Gan, W., Tan E., Kuo S. (2011). *Audio Projection: Directional sound and its application in immersive communication*. IEEE Signal Processing Magazine [57] . Retrieved from http://eeeweba.ntu.edu.sg/DSPLab/audiobeam/docs/sp.pdf

THE TECHNOLOGY

DIRECTED AUDIO SPEAKERS VS TRADITIONAL LOUDSPEAKERS

HyperSound is an innovative, highly-directional parametric speaker.

A traditional loudspeaker can be thought of as a bare light bulb and HyperSound technology as a flashlight beam.

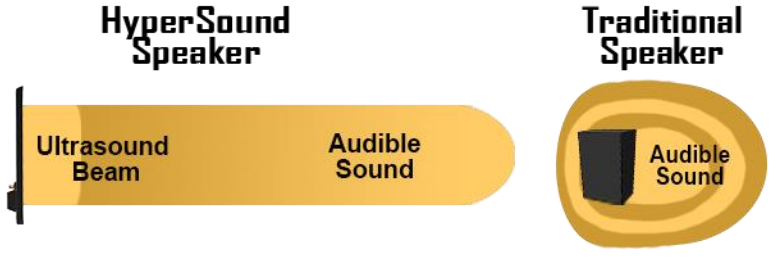
As with the light bulb, traditional loudspeakers radiate sound in all directions; it does not matter where the listener is positioned within the room, sound will be heard. Often, the listener can point directly to that speaker from anywhere in a room and say “that is where the sound is coming from”.

HyperSound, on the other hand, emits 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 uses ultrasound to generate audio in the air itself.

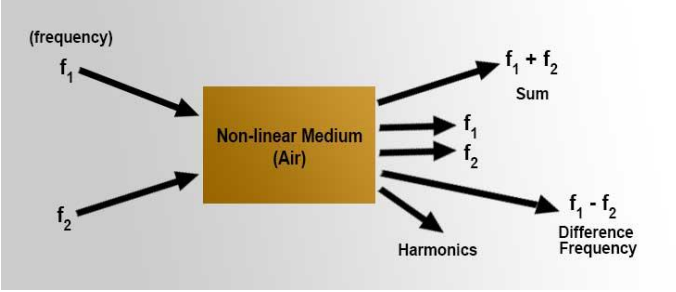
The audio is highly directional because it is created at an infinite number of points all along an ultrasonic energy column.

This provides the unique flexibility to place sound exactly where you want it, while substantially masking sound from other areas.



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

THE HISTORY
MOVING FUNDAMENTAL TONES BEYOND RANGE OF HEARING



Approximately 150 years ago, a German Physicist named Hermann von Helmholtz discovered that air is non-linear. 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.[7]

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.

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.[8,9]

According to Westervelt, Berktay, Blackstock, et al.,[9] non-linear acoustics theory postulates that when two ultrasonic primary tones are combined, they may produce harmonics of each primary as well as sum and difference tones.

Since we do not often listen to sine waves (which the prior studies examined), Elwood Norris and co-founders behind HyperSound decided to find a method to produce complex wave sounds in the air such as voice or music. In terms of the HyperSound application, it is the generation of these difference tones that are within the range of human hearing that are important.

The result is a set of electronics, digital signal processing, and a patented set of algorithms that creates complex waveforms containing all the required components to make difference tones in the air, and then project that waveform from a single, ultrasonic emitter (parametric loudspeaker). Because this emitter operates on the principle of nonlinearities in air, it generates a highly directional sound beam.

KEY HYPERSOUND MILESTONES	
1996	Technology was incepted by founder Elwood Norris[10]
1997	Named one of the Best of What's New Issue of Popular Science[11]
2002	Named Best Invention of 2002 by Popular Science[12]
2004	TED Talk by Norris on hypersonic sound and other inventions[13]
2005	Norris received the Lemelson-MIT Prize for inventing "hypersonic sound"[14]

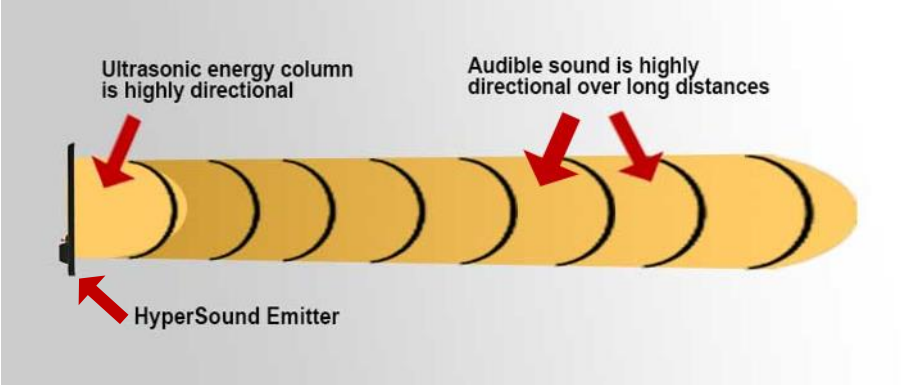
7. L.J. Black. (1940). A Physical Analysis of Distortion Produced by the Non-Linearity of the Medium. J. Acoust. Soc. Am. 12:266.
8. Westervelt, P. (1963). *Parametric Acoustic Array.* J. Acoust. Soc. Am. 35 (4):535-537.
9. Beth, M., Blackstock, D. (1975). Parametric Array in Air, J. Acoust. Soc. Am. 57 (3): 562-568.
10. Eastwood, Gary (7 September 1996). "Perfect sound from thin air". New Scientist: 22.
11. "Best of What's New: Sound Projectors". Popular Science (Bonnier Corporation) 251 (6): p. 78. December 1997. ISSN 0161-7370.
12. "Sound technology turns the way you hear on its ear". USA Today. Retrieved from http://usatoday30.usatoday.com/tech/news/techinnovations/2003-05-19-hss_x.htm
13. "Hypersonic sound and other inventions." TED. Retrieved from http://www.ted.com/talks/woody_norris_invents_amazing_things.
14. "Inventor Wins $500,000 Lemelson-MIT Prize for Revolutionizing Acoustics" (Press release). Massachusetts Institute of Technology. 2004-04-18. Retrieved 2007-11-14.

How HyperSound Works

The processes that create sound "in the air"

Ultrasonics and Audio

HyperSound creates audible sound through a series of processes (see figure 1 below). An audio signal is sent to a proprietary electronic preprocessor circuit, distortion control circuit, and then through a multiplier circuit where a composite ultrasonic/sonic waveform is produced.



HyperSound generates an ultrasonic energy beam that is highly directional, and converts to audible sound in the air. The length of the column determines the directionality at audio frequencies. This sound is directional over longer distances than traditional loudspeakers.

This signal is then amplified and sent directly to the HyperSound ultrasonic emitter. A column of ultrasonic energy is produced in front of the speaker, which contains all required properties needed for the air molecules to produce audible sound. The sound we can hear is demodulated all along this column, created in the air molecules by a down-conversion process, resulting in regular audio within the audible frequency range.

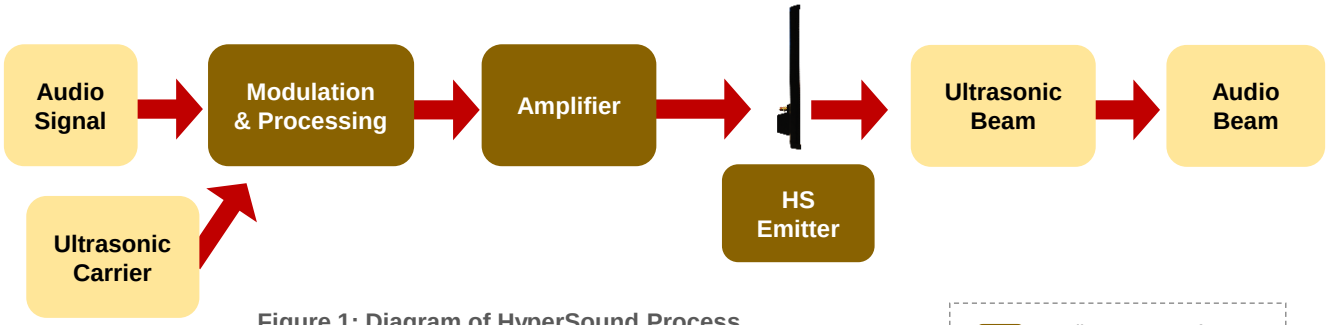


Figure 1: Diagram of HyperSound Process

Figure 1 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.[15]

Indicates areas of HyperSound proprietary innovation and patents

15. 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

HyperSound Innovations

Key developments in HyperSound Technology

Pushing the envelope for commercial audio technology innovation.

Since HyperSound's inception in the late 1990s, countless innovations have been made to the original system design and functionality. Currently, there are 27 patents surrounding HyperSound's proprietary technology, and 25 more pending for both commercial and consumer innovations.[16]

This has created a "picket fence" that protects its 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.[17] 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.[18] 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 released that make the system more stable and its technology more refined. For example, its circuits underwent technological enhancements and an advanced matching device was introduced, leading to increased system efficiency.[19] Electronics advancements have also enabled the use of low voltage cables and lower overall power consumption

Turtle Beach Corporation now holds

27 patents

for its HyperSound technology, and has 25 more pending for both commercial and consumer audio innovations.

16. The United States Patent and Trademark Office. Retrieved from http://www.uspto.gov/patents/
17. Amplification systems, carrier tracking systems and related methods for use in parametric sound systems. Retrieved from http://www.google.com/patents/us7343017.
18. Improved parametric signal processing and emitter systems and related methods. Retrieved from https://www.google.com/patents/CA2802862A1
19. Parametric transducers related methods. Retrieved from https://www.google.com/patents/WO2013158298A1.

The Benefits

HyperSound's Unique Features and Advantages

HyperSound provides designers with the unique ability to control the footprint of audio. Sound can be focused directly at the listening audience, and nowhere else. Sound is delivered clearly to the target audience even in high ambient noise environments. The technology also helps in reducing the reflections and potentially destructive interferences from the environment, such as the floor, surrounding walls, and ceiling.

Another core feature is that the system is small and lightweight; its thin form factor makes integration into applications easy. Mounting and positioning can be more precise, without detracting from the overall design.

One of HyperSound's most important features, controlled directionality, is fundamentally not available with traditional loudspeakers.

Key Features	Benefits
Small speaker size, lightweight	• Easy integration into commercial applications • Multiple mounting options, easy to mount, very thin and flat
Highly directional	• Creates tight audio zones • Isolates sound to a specific region or person • Diminishes sound bleed and noise pollution • Communicate audio over longer distances while maintaining intelligibility • Effective in high ambient noise environments
Can act as a virtual audio source	• Sound can be made to seem to come from surfaces if the ultrasonic beam is pointed at a hard surface such as a window or wall
Ability to target each ear individually	• Produces 3D audio effect
Patented DSP processing	• Innovative techniques generate low distortion and enhanced frequency response to support a multitude of directed audio applications

DISCUSSION

CURRENT APPLICATIONS WITHIN COMMERCIAL AND EMERGING MARKETS

HyperSound speakers are uniquely designed for directing immersive, targeted messages in museums, art galleries, shopping malls, libraries, casinos, theme parks, and other commercial areas.

Trade shows can also benefit from directed sound, by drawing people into their exhibition booths and also significantly reducing the noise level of the surroundings, thus focusing the message more clearly.

Additionally, HyperSound opens the door to disruptive, novel applications yet to be uncovered, that can potentially push this innovation to an even wider range of markets.

To fully grasp HyperSound's potential, it is important to first have an understanding of how the technology works, how it differs from other loudspeakers, and which markets and applications can most benefit.

Also, although HyperSound speakers have tremendous potential to transform the way we experience audio and video within our daily lives, its impact is still far from being fully realized.

"Every company wants to have that "it" thing that is instantly impressive. They want a piece of tech so useful and intuitive all it takes is a moment's experience to make a believer out of someone who, moments before, didn't even know it existed. Turtle Beach, best known for their top-of-the-line gaming headphones, has "it" with HyperSound."

- iDigital Times[20]

When it comes to the deployment of audio systems, a slew of important factors come into play, such as content, location, and environment.

In final analysis, HyperSound can be used as a powerful vehicle for creating immersive audio experiences. The outlook for its implementation within commercial applications is strong, fueled by the creative imagination of audio designers for use in new and exciting applications.

20. iDigital Times. (2014). *CES 2014: Turtle Beach HyperSound Will Blow Your Mind*. Retrieved from http://www.idigitaltimes.com/articles/21437/20140110/ces-2014-turtle-beach-hypersound-parametrics.htm

About HyperSound
by Turtle Beach Corporation

Turtle Beach Corporation (www.turtlebeachcorp.com) designs audio products for consumer, commercial and healthcare markets. Under the brand Turtle Beach (TurtleBeach.com), the company markets premium headsets for use with personal computers, mobile devices and video game consoles, including officially-licensed headsets for the next-generation Xbox One and PlayStation®4 consoles. Under the brand HyperSound (HyperSound.com), the company markets pioneering directed audio solutions that have applications in digital signage and kiosks, consumer electronics and healthcare. The Company's shares are traded on the NASDAQ Exchange under the symbol HEAR.

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