INFORMATION

HSS®
HYPERSONIC™ SOUND

Frequently Asked Questions And Answers

Revision E

Other ATC Documents for review:

"HSS Technology Introduction"

"HSS Product Brochure"

"HSS Product Owner's Manual"

American Technology™ CORPORATION

Contents

PARAMETRIC SOUND GENERATORS

What is HSS?

HyperSonic™ Sound (HSS™) is a proprietary, ultrasonic-to-audio, parametric sound generator, developed and refined in the labs of American Technology Corporation, offering a unique approach to reproducing sound that provides multiple performance advantages unachievable with conventional loudspeaker systems.

What is a parametric sound generator?

A parametric sound generator uses the nonlinear properties of air to create audio sound waves within the air itself by converting an ultrasonic set of frequencies into sound that we can hear. HSS is an advanced type of parametric sound generator.

Are there any other commercial parametric sound generators on the market?

HSS is the only commercially available, production manufactured, parametric sound generator available anywhere in the world at this time. (Underwater communications devices have also been derived from parametric sound generators, however, they do not operate in air.)

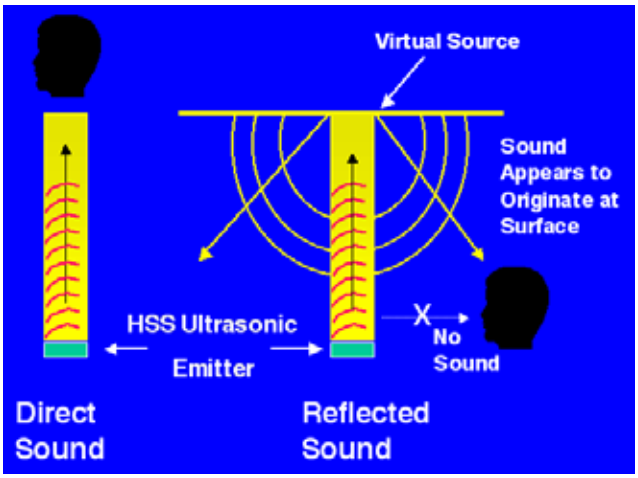
What are the advantages of HSS sound reproduction systems over conventional loudspeakers?

HSS creates a very directional beam of sound, similar to the light from a flashlight, which can be controlled and directed as desired. This directional focus can be used to:

- Isolate sound to a specific region or person
- Communicate over long distances
- Move sound around a room in real time
- Deliver sound to areas which are either physically impossible to access or too costly to install conventional loudspeakers (create virtual sound sources)

What is a virtual sound source?

It is the creation of the illusion of sound coming from a surface or direction where no physical loudspeaker is present. The area where the listener perceives the sound to be coming from is called a virtual loudspeaker or virtual sound source.



How does HSS operate differently from conventional loudspeakers?

HSS technology is quite different from conventional loudspeaker technology. A loudspeaker simply converts an electrical signal containing audio information to audible sound by vibrating the loudspeaker diaphragm. The sound produced by a loudspeaker can generally be heard anywhere in the vicinity of the loudspeaker. HSS, on the other hand, emits sound in a highly controlled, narrow beam, so that HSS sound can be heard only if you are “in the beam” or in a position to hear the reflected sound from a virtual source created by the beam on a reflective surface.

HSS sends out an ultrasonic beam that contains an embedded audio signal. Audio becomes much more directional at higher frequencies and is therefore highly directional at ultrasonic frequencies where HSS operates. The ultrasonic beam emitted by HSS does not spread out like the sound from a conventional loudspeaker. The resultant HSS audible sound is created by the ultrasonic

interaction with the air which causes the audio information to be demodulated from the ultrasonic beam into audible sound.

For more detail, please refer to the *HSS Technology Introduction* document, part # 98-10006-3000 and the HSS Technical White Paper: *Theory, History, and the Advancement of Parametric Loudspeakers*, part # 98-10006-1100.

(Documents are available for download on our website: www.atcsd.com)

What are some typical applications for HSS technology?

The unique ability to control and direct sound obviously creates new opportunities for designers, architects, and engineers to implement and use sound as never before. HSS is applicable in any situation where it is desirable to limit the ability to hear sound to a well-defined space and to eliminate the ability to hear sound where it is not wanted or needed. HSS can also be used to create virtual loudspeakers, so that the sound appears to be coming from an area where it would be impractical or impossible to place a loudspeaker.

Refer to the *HSS Technology Introduction* document, part # 98-10006-3000 for more application ideas.

(Documents are available for download on our website: www.atcsd.com)

AMERICAN TECHNOLOGY CORPORATION's PROPRIETARY HSS TECHNOLOGY

What aspects of HSS Technology are being patented by ATC?

- Distortion Cancellation Signal Processing
- Ultrasonic Emitter (Transducer) Devices and Configurations
- Ultrasonic Power Conversion / Amplification
- Pre-Recorded and Real Time HSS Systems
- Multiple Commercial, Industrial, Military, and Consumer Product Applications

What are the advantages of ATC's proprietary HSS technology over other attempts at building parametric sound generators?

Other attempts at parametric sound generators historically have been plagued by either very high distortion or distortion correction approaches that required very wide bandwidth systems causing (1) the need for emitters which are impractical and too costly to build and (2) generate secondary distortion components in the audible range. ATC has developed a sophisticated distortion correction system that virtually eliminates distortion while requiring a zero increase in system bandwidth. It actually requires only one-half the bandwidth of the non-distortion-corrected signal allowing effective use of real world, cost effective, transducers (emitters) and eliminating audible artifacts.

Other attempts at parametric devices have also utilized arrays of individual, small, ultrasonic transducers originally intended for use as single devices and not for parametric applications. When used in multiples, these devices tend to have mismatched phase and amplitude responses and

reliability problems (among other things) that limit their effectiveness for use in parametric sound generators. Also, arrays of the size needed for parametric systems using individual devices are extremely cost prohibitive.

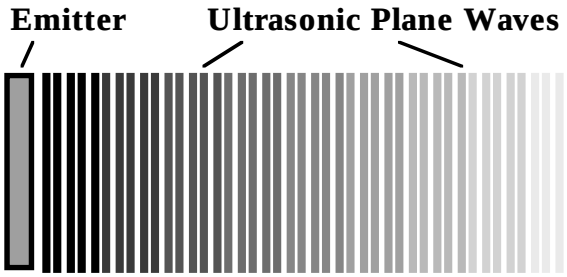
ATC has developed monolithic, thin film, ultrasonic emitters that utilize a single, unified film structure which is highly phase and amplitude coherent across the entire device and are the only 'purpose built' emitters for parametric use. They have the added advantage of significantly lower cost than previous 'non-purpose-built' devices.

ATC has also designed the first ultrasonic power amplification system specifically optimized for parametric power conversion. ATC's ModAmp™ (Modulation Amplifier) Technology uses sophisticated digital switching techniques to achieve both very low distortion and very high efficiencies. Further, the ModAmp can inherently incorporate both the parametric modulation process and the power conversion process in one stage of electronics, replacing costly and bulky, multi-stage (individual components), and inefficient systems of the past. The very high levels of efficiency in this design allow for the elimination of the additional heat sinks normally required while providing virtually any required power level in a package that can be as small as a deck of playing cards.

Remaining ATC intellectual property includes methods for prerecording audio onto digital storage mediums such CF (Compact Flash) memory cards. It can also provide for updating of the signal audio files through the internet or other convenient transmission mediums.

What is the diameter and the directivity of the ultrasonic beam and what affects it?

The ultrasonic beam is comparable in diameter to the active surface area of the HSS emitter array. Due to the wavelengths of the ultrasonic frequencies being on the order of less than 1/20th the diameter of the smallest emitter, the ultrasonic wave will be emitted as a pure plane wave with virtually no expansion in the column diameter with distance. The ability to maintain this high level of directivity is sustained by having a large emitter diameter compared to the wavelength of the primary ultrasonic frequency.



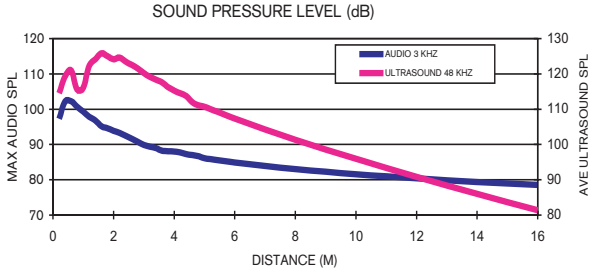
How long is the ultrasonic column and what determines its length?

The length of the ultrasonic beam is dependent upon several factors. Tightly focused beams travel farther than widely dispersive (non-focused) beams before completely dissipating in air. The length of the column is determined by the overall size of the emitter device, the primary ultrasonic frequency, and the absorption rate of the primary frequency by the air. The ultrasonic beam sound pressure level is highest at the surface of the emitter and it rapidly drops to zero over distance as it is absorbed by the air.

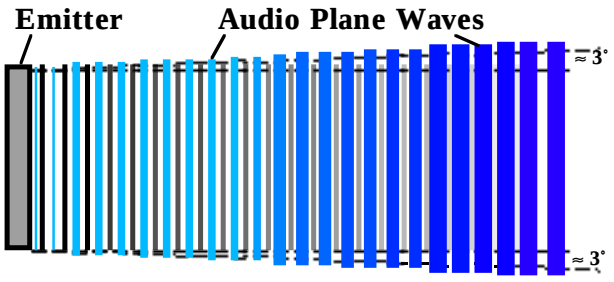
At an HSS operating frequency of approximately 48 kHz, the length of the ultrasonic beam is on the order of 20' (6.1m) for a typical HSS application. The ultrasonic column can be shortened by raising the system operating frequency (carrier).

What is the relationship of the ultrasonic beam to the audible sound beam?

At the surface of the emitter, the beam is 100% ultrasonic. As you observe the output at greater distances from the emitter, the air begins to demodulate the audio, and this process continues throughout the usable length of the ultrasonic beam. This is what causes HSS to actually sound louder at greater distances from the emitter. At some distance, usually greater than 20 feet, the ultrasonic beam will dissipate to a lower level than the audio, no longer contributing significantly to the production of audible sound.



The directivity of the column of audible sound and the lowest frequency to which the system maintains directivity is determined by the effective length of the ultrasonic column. To even approach the directivity control of HSS, a conventional loudspeaker would have to have a cone at least 10' (3m) in diameter, as apposed to an HSS emitter array which can be less than 1' (30cm) in diameter. At frequencies above 100 Hz, the directivity of the audible sound is generally comparable to the directivity of the ultrasonic column, since the audio is produced in plane waves, just like the ultrasonic column. In general, this is less than 6° dispersion overall (3° off each side of the emitter).



How far does the audible sound travel?

The audio sound profile of HSS is completely different than a conventional loudspeaker, which produces the loudest sound at the speaker, but falls off rapidly (following the 'inverse square law') as the distance from the loudspeaker increases. HSS, in contrast, sounds louder as the distance between the transducer and listener increases, up to a point, then diminishes at a rate substantially less than conventional loudspeakers as the distance continues to increase. HSS maintains intelligibility to much greater distances than a conventional speaker. The reason that the loudness of conventional loudspeakers falls off with distance is because the audio is being produced in a substantially spherical pattern (radiating in all directions). With HSS, the audio is contained within a tightly controlled beam.

Early tests indicate that HSS can be a very effective communication device at distances of hundreds of feet with very little attenuation to the audible sound.

What affects how far the audio will project over distance?

How far the audio will project over distance is effected primarily by the frequency of the ultrasonic column and secondarily by the diameter of the emitter array, which ultimately determines the length of the ultrasonic virtual sound generator.

HSS sound generators operate on a similar basis to what is known as an 'end fired array'. An 'end fired array' is realized by using 100 or more conventional transducers lined up directly in front of each other in the shape of a long column. This is one way highly directional sound could be produced using conventional loudspeakers, however, this has never been a practical approach due to size, cost, and complexity.

HSS operates as if it has an infinite number of transducers all along its ultrasonic column, each contributing to the output level and directivity of the audible sound. This highly directional, projected sound can now be achieved through HSS with an emitter only inches in diameter and 0.4" (10mm) thick.

HSS COMMERCIALIZATION

How loud is HSS?

At the current stage of development, HSS can produce >99 dB of audible sound at 20' (6.1m) with a 10.88" x 10.88" x 0.4" thick (27.6cm x 27.6cm x 10mm) emitter array and can also maintain a similar level over much greater distances.

How many different product models are available?

ATC licenses HSS technology to companies for use within their own commercial products. However, in the early phase of HSS introduction, ATC will produce a number of end user products which can be purchased from ATC or one of our licensees.

The first ATC production models are a dual and quad emitter, prerecorded digital playback with real time analog audio input version which is fully self-contained in a compact enclosure.

Refer to the HSS Product Brochure, Part # 89-10061-0002 and HSS Product Owner's Manual, Part # 99-10054-2500 for more detailed product information.

Multiple models are planned over the next several months, and those models will have different emitter sizes, power outputs, real-time processing systems, and packaging configurations, depending upon customer application requirements. Information regarding each available model, as it becomes available, will be posted on the ATC website: www.atcsd.com.

How durable is the HSS Emitter device?

In terms of durability, HSS is at least equal to, and in some ways superior to, conventional loudspeakers. The transducer is quite durable, however, it is usually mounted in a protective enclosure to protect it in the same manner as other equipment would be protected.

How does HSS mount to a wall or other location?

The first ATC model has standard mounting bracket options available; however, many users will likely provide their own mounting bracketry designed specifically for their unique application.

Are there any mounting restrictions?

No. HSS can be mounted just about anywhere. HSS should be mounted securely so that it can't be moved. One should be sure that it remains "focused" in the correct direction. Because HSS has no rear sound wave, it can be mounted directly on a wall or other hard surface and can also be embedded inside other equipment.

Can the emitter be mounted in a separate location from the electronics?

Yes, however, several considerations are necessary for UL and FCC compliance. One is that a shielded cable be used between the amplifier and emitter and the other is that the emitter be mounted in an acceptable enclosure. ATC will provide appropriate cable and connection specifications to fulfill each specific application requirement.

Are there any environmental limits?

The emitter requires protection from direct rain and snow. High humidity does not pose a problem. If water collects on the emitter surface, the output level may be slightly affected. However, as soon as the surface drys, performance will return to normal. High humidity can actually increase the efficiency of the parametric conversion process in air, causing greater sound pressure levels at greater distances.

Specialized emitters and hardware can be appropriately adapted for extreme applications. The HSS process itself is not generally affected by inclement weather.

Does the amplifier design have any effect on the performance of HSS?

Yes. The amplifier must operate with low distortion at ultrasonic frequencies and the power output must be adequate to produce the required ultrasonic sound pressure level. Due to the requirements for a combination of several processed and phased audio signals and a control signal modulated onto an ultrasonic carrier frequency, this processing can be integrated directly into the HSS ModAmp. The ModAmp has significant advantages over any other alternative amplification system.

What is the usable frequency bandwidth of the audio?

Audio bandwidth is dependent primarily on the maximum audio SPL required and secondarily on the size of the emitter array. The first system designed for 'Point of Purchase' applications maintains a useful frequency range of 400 Hz - 16 kHz.

Refer to the HSS Product Brochure, Part # 89-10061-0002 and HSS Product Owner's Manual, Part # 99-10054-2500 for more detailed product information.

What is the warranty period?

HSS systems from ATC are provided with a one year limited warranty.

Refer to the Limited Hardware Warranty statement packaged with each HSS unit for detailed warranty information.

How do I get HSS service if required?

All HSS warranty service is performed by simply exchanging the unit. During the warranty period, a replacement unit will be shipped at no charge as long as the defective unit is returned to the factory within 1 year. After the warranty period has expired, customers have the option of either sending their unit to the factory for repair or purchasing a new unit and receiving an exchange allowance for their defective unit.

TECHNICAL ENGINEERING QUESTIONS

What is the recent history of parametric loudspeaker development?

• 1975 - Dr. Blackstock proves a parametric loudspeaker can work with air as the transfer medium.

• 1983 - Dr. Yoneyama develops Double Sideband (DSB) with low modulation index. Could have more than 50% distortion unless you use a very low modulation index which significantly reduces conversion efficiency (lower SPL output).

• 1984 - Japanese group implements square rooting to minimize parametric distortion but discovers infinite bandwidth and demanding emitter requirements for ideal correction.

• 1996 - Elwood Norris at ATC discovers parametric effect while not knowing of previous work.

• 1997/98 - ATC begins to discover history of parametric development by Dr. Blackstock and Japanese groups after pursuing parallel development path and discovering substantially the same problems to be solved:

- The need for effective distortion reduction without loss of efficiency.
- The need for effective distortion reduction without requirement for nearly infinite transducer bandwidth.
- The need for a new, high efficiency, low thermal dissipation transducer is required for parametric use.
- The need for high efficiency power conversion for parametric modulation compatibility and optimized for capacitive emitter transducers. (Piezoelectric or electrostatic).
- The need for a dynamically modulated ultrasonic carrier.
- The need for a new, lower distortion, narrower bandwidth modulation system.
- The need for monolithic, purpose built ultrasonic emitter, with constant phase and resonant frequency across the entire surface.

• 1997 - ATC implements DSB with square rooting and develops first purpose built parametric emitter devices.

• 1997/98 - ATC develops and implements single sideband (SSB) system with theoretically zero distortion using single audio tones and increasing distortion with increased program complexity. SSB technique utilizes program complexity to mask a significant portion of the resulting distortion.

• 2001 - ATC optimizes new manufacturing processes for piezoelectric film emitters. ATC adds proprietary Lole Sideband MODAMP processing/power amplifier to HSS system.

• 2001 - High power, slotted ultrasonic emitters developed by ATC.

• 2002/03 - ATC optimizes processes for lareg scale monolithic, seamlessly poled PVDF film emitter structures providing phase and frequency precision across the entire film surface allowing optimum calibration with recursive distortion correction. Distortion correction moved from stationary PC into portable electronics for use with new film emitters.

- ATC found Double Sideband (DSB) with low modulation index to be too inefficient.
- ATC found that Square rooting was effective as a theoretical ideal but required very wide bandwidth transducers, with symmetrical and matched slope response

above and below resonance (not inherent in transducers). Also bandwidth requirements caused greater demands on power conversion and also could cause distortion correction frequencies to fall into the audible range on the lower sideband side.

- As a result, ATC develops Single Sideband Modulation system.
- ATC also developed recursive inband, distortion correction systems to eliminate the need for wide bandwidth emitters.

How is the audio output level of HSS related to the ultrasonic SPL?

Increasing the ultrasonic SPL by 3 dB (by turning up the amplifier gain by 3 dB, for example) will result in a 6 dB increase in the audio output level of the HSS system, up to the point of air saturation.

What is the ratio of ultrasonic SPL to audio SPL within the effective ultrasonic beam?

In general terms, 100-110 dB of ultrasonic SPL on average will produce ~90 dB of audible sound. The actual conversion efficiency in air is dependent on frequency, distance, and the setting of the modulation & processing parameters.

Is there a lower limit to the audio dynamic range which HSS can produce?

There is no lower limit. The system will continue to produce audio all the way down into the noise floor.

How much AC power is needed?

The typical HSS dual emitter, self-contained system draws approximately 70 watts depending on the audio program material. Systems with larger emitter arrays and amplifier systems will require higher power.

Does HSS require any special cabling between the amplifier and the emitter?

Current systems use coaxial cable to eliminate any possibility of signal interference. While twisted pair with adequate insulation will also work, in order to comply with FCC Part 15 regulations we do not recommend it. The production design will or can have the transducer and electronics in the same enclosure, which will eliminate the need for any lengthy interconnect cabling.

Does feedback occur using a live microphone with an HSS system?

The directivity of an HSS system allows you to direct the produced audio away from any live microphone, significantly reducing the tendency to feedback. Early testing also suggests that the actual conversion process from ultrasonic frequencies to audible frequencies lessens the tendency of an HSS system to feedback even when directed toward a live microphone.

Will you have more than one emitter type?

Yes. We are developing a number of emitter types and expect to have multiple devices available, each with a matching set of electronics. Choice of appropriate emitter device will be based on the specific application requirements.

Does the distortion of the audio change with distance?

While distortion does change slightly with distance, using ATC's proprietary distortion cancellation system, the distortion at any distance will be maintained at low levels at all effective distances from the emitter array.

What governmental or safety agency approvals are required for HSS?

HSS systems manufactured by ATC will meet or exceed the following government and safety requirements and regulations.

- **UL**  UL Standard 6500

- **CE** 

- **OSHA** (USA) OSHA Technical Manual, Section III, Chapter 5, Section V, Table III:5-4 "*TLV's For Ultrasound*"

- **FDA** (USA) American Technology Corporation (ATC) has submitted the applicable reports to the FDA pursuant to Title 21, CFR, subchapter J as it pertains to ultrasonic devices for other than medical device applications. The abbreviated report is pursuant to Section 1002.12 of the regulations. According to this report, the FDA has assigned the following Accession numbers to HSS™ products: 0181485 and 0191486.

- **FCC** (USA) This device complies with Part 15 of the FCC Rules. This Class A digital apparatus complies with Canadian ICES-003.

American Technology™ CORPORATION

Shaping the future of sound ™

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