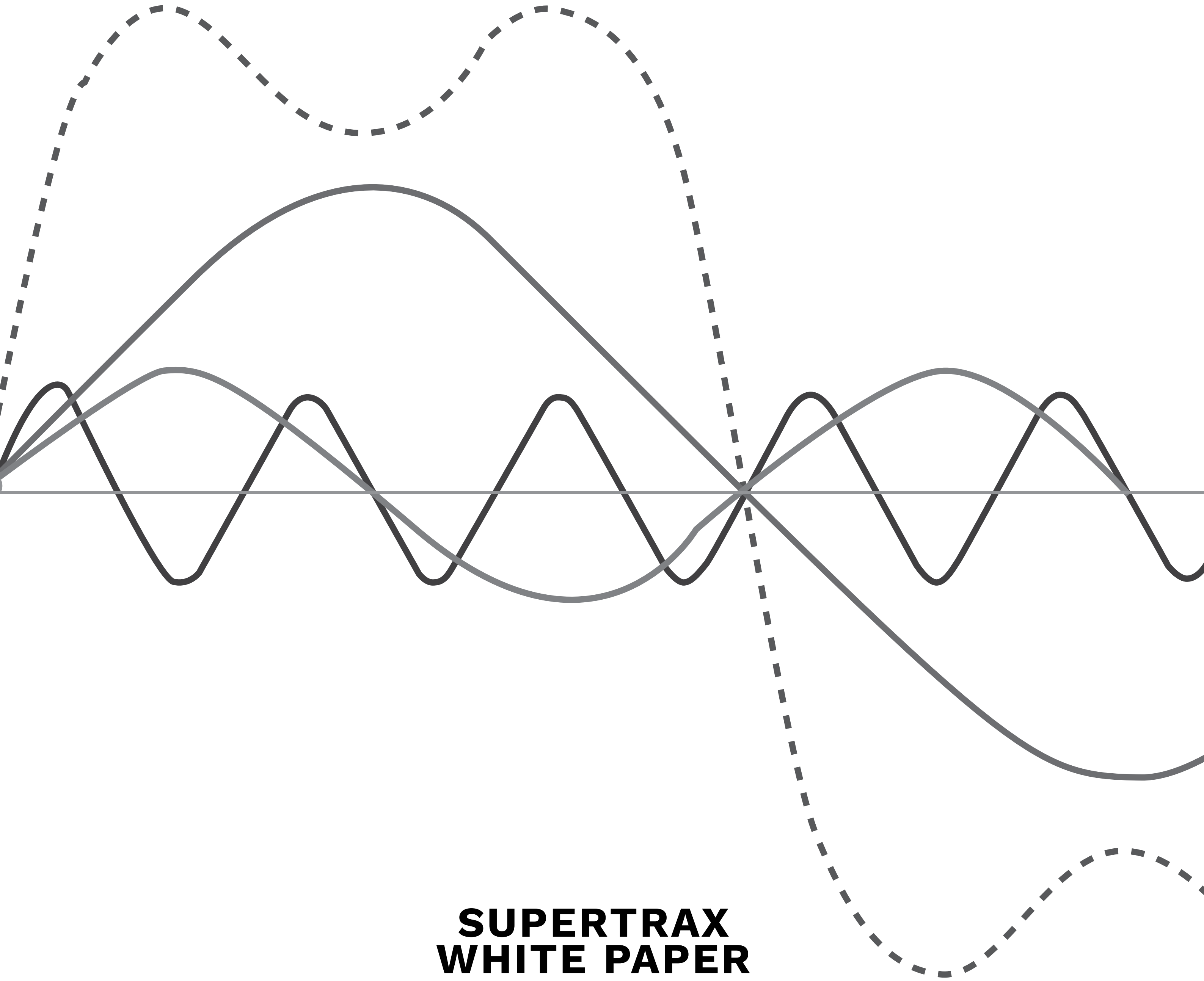
FYNE AUDIO



SUPERTRAX WHITE PAPER

BY DR PAUL MILLS

SUPERTRAX
WHITEPAPER

Dr Paul Mills, Technical Director, Fyne Audio

INTRODUCTION

While we are all familiar with subwoofers, used to extend the low frequency response of a loudspeaker system for added realism, the concept of a super tweeter which extends the high frequency response, is less understood.

Extending the frequency range of the loudspeaker several octaves above the accepted limit of human hearing has several benefits, such as increased tonal accuracy of instruments, improved transient response and greater sense of air, with perceived gains even at low frequencies.

Unlike a conventional direct radiating super tweeter, the Fyne Audio patent pending SuperTrax products, which radiates energy through 360 degrees brings further important benefits in performance, while using a new type of thin ply carbon diaphragm (TPCD). So, in this white paper we want to consider the following topics:

- Is there musical information above 20kHz, generally considered to be the upper limit to human hearing?
- If so, can we perceive this information?
- How can adding a super tweeter improve reproduction of the whole audio band, even low frequencies?
- Does it benefit all source material?
- Why is an omnidirectional super tweeter much better?
- Importance of time alignment with the main loudspeaker.
- Benefits of TPCD diaphragms over established materials.

THE NATURE OF MUSICAL INSTRUMENTS

To start with, let's look at the frequency range of musical instruments. Fig. 1 shows the accepted frequency range of musical instruments. In addition to the pitch or fundamental frequency, a wider bandwidth is required to reproduce the overtones or harmonics. It is these harmonics that give instruments their character. Without them, all instruments would sound like a sine wave test signal. There is also a family of pitchless instruments, such as the cymbal or triangle. In all cases, energy is seen to extend to 15kHz. This has been the accepted wisdom since the 1930's, and is still being reproduced in most modern text books

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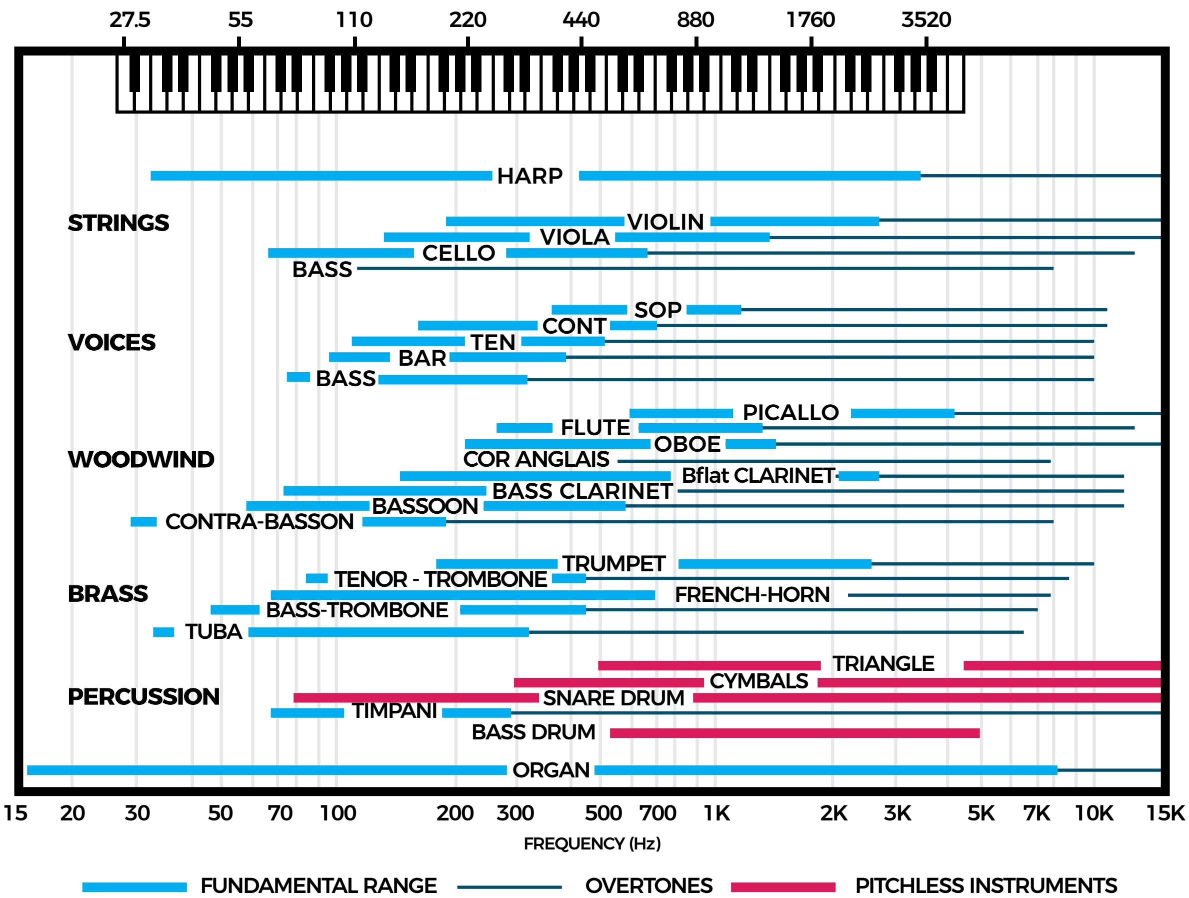


Fig. 1 The Frequency Range of Musical Instruments

Few researchers have considered the true bandwidth of musical instruments or have investigated the in-depth mechanism of human hearing at high frequencies.

The most thorough investigation into musical instrument bandwidth we know is by James Boyk, was pianist in residence CALTECH, Sheffield Labs engineer and founder of Reference Recordings. Fig. 2 shows the spectral content of a trumpet. There is considerable energy above 20kHz, as can be seen, the level of which does not drop into the noise floor until 100kHz. A similar result is found with instruments from other musical families, with the violin and oboe showing energy above 40kHz. Even sibilants in speech were found to have energy above 40kHz

The cymbal crash gave 40% of its energy above 20kHz, while the triangle was found to have a healthy output at 100kHz

It is the pitchless instruments, such as members of the percussion family that generate the greatest amount of ultrasound. The cymbal crash (Fig. 3) gave 40% of its energy above 20kHz, while the triangle was found to have a healthy output at 100kHz (Fig. 4).

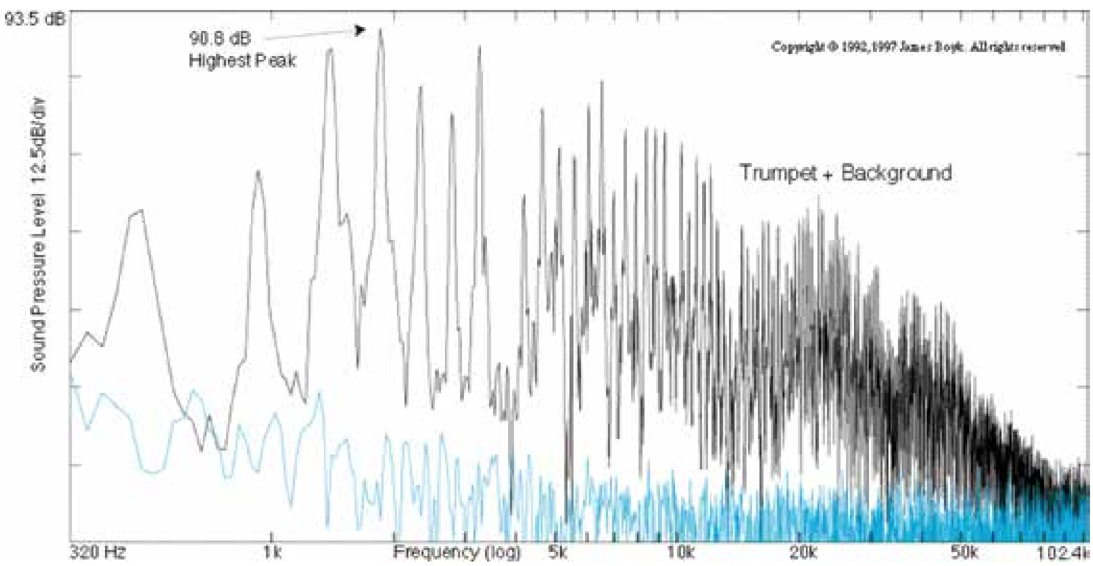


Fig. 2 Spectral Energy from Trumpet

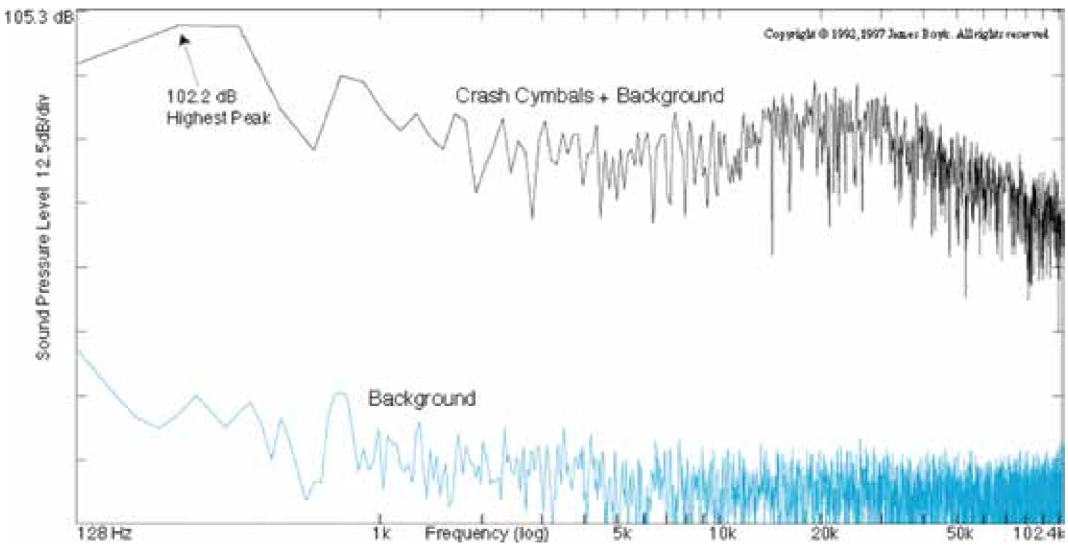


Fig. 3 Spectral Energy from Cymbals

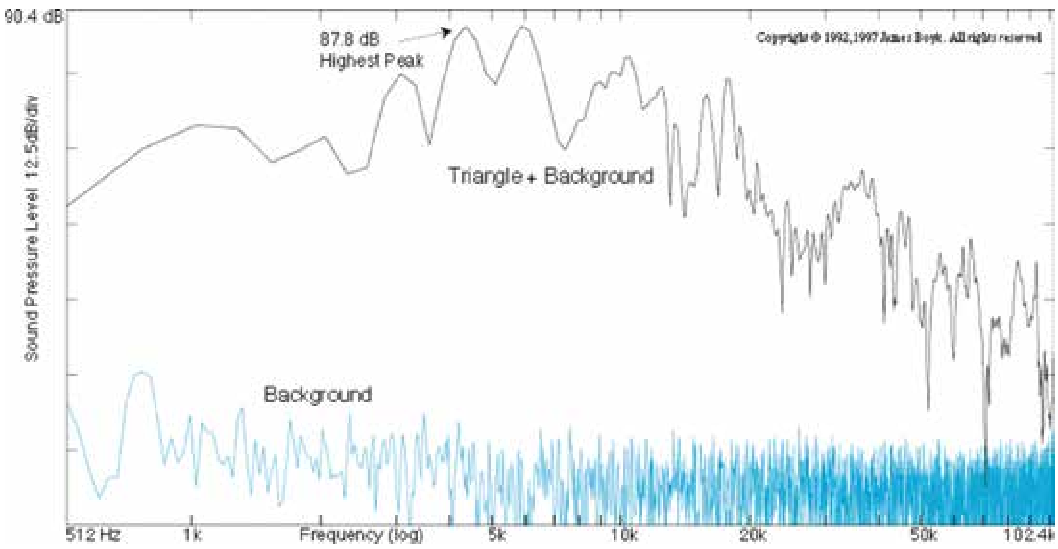


Fig. 4 Spectral Energy from Triangle

HUMAN PERCEPTION OF ULTRASOUND

We know that musical instruments have energy up to and beyond 100kHz, but can we perceive it?

Japanese researcher Oohashi conducted experiments with wide bandwidth material to 60kHz, whereby a super tweeter could be either switched in or out. By monitoring the subjects' brainwave activity and subjective scores under blind conditions, they concluded that the listeners were indeed responding to the ultrasonic components in the music.

Profoundly deaf subjects relied on ultrasonic detection in their discrimination of speech and tones. They concluded the mechanism was through bone conduction

A further paper by Lenhardt concluded that profoundly deaf subjects relied on ultrasonic detection in their discrimination of speech and tones. They concluded the mechanism was through bone conduction, probably to a small organ in the inner ear called the saccule, that perceives acceleration and gravity, which is effectively linked to the cochlea, the organ responsible for hearing as we know it.

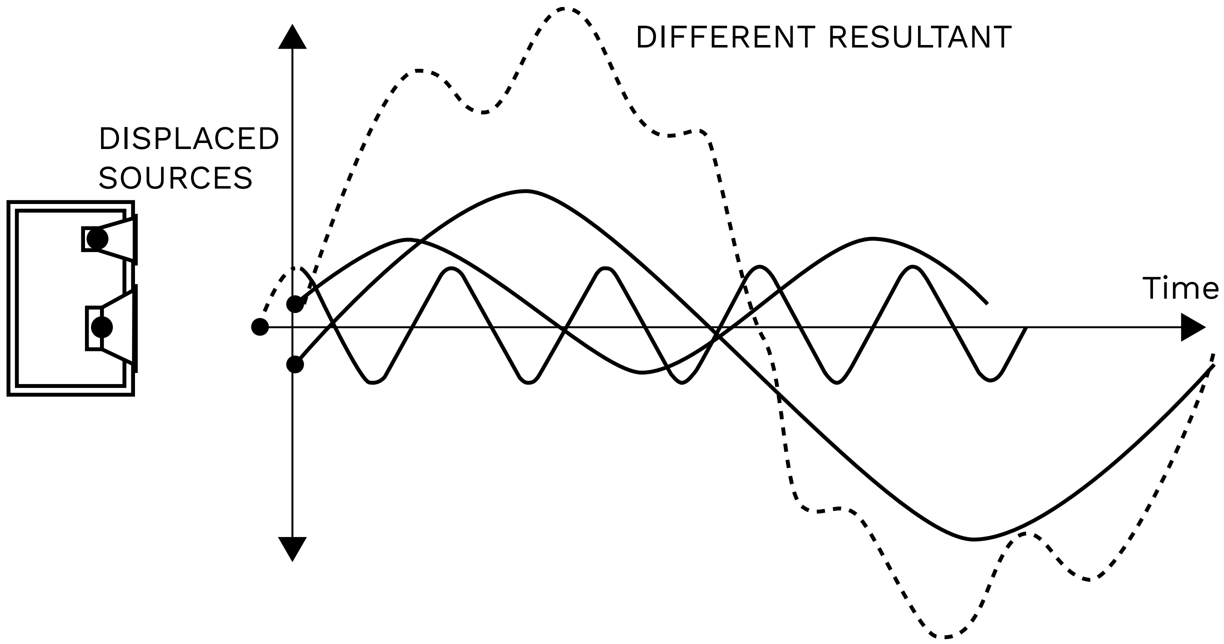
HARMONICS, PHASE & THE IsoFlare POINT SOURCE

Fyne Audio's IsoFlare driver is a point source system whereby the bass / midrange driver shares a common time aligned centre with the high frequency unit. Providing outstanding stereo imaging, even off axis, energy is radiated isotropically with constant directivity, following the flare of the driver cone. Sound is produced as if emanating from a single point in space.

Over the frequency range that the IsoFlare operates, it does a far better job of preserving the harmonic content of instruments compared with a conventional discrete drive unit arrangement. This is because the low and high frequency sounds are generated from the same point in space (point source), and there are no time and phase differences between harmonics below and above the crossover point, as with discrete speakers.

Also, the relationship in amplitude of fundamental and harmonics is accurately preserved both on axis and at points off axis. In a normal room, the majority of sounds perceived by the human ear are reflections generated by the off axis response of the speaker. The even off axis response of the IsoFlare means that the reflected energy has the same harmonic structure as the direct on axis energy. This is illustrated in Fig. 5.

HARMONIC RELATIONSHIPS USING MULTIPLE SOURCES



HARMONIC RELATIONSHIPS PRESERVED USING A SINGLE POINT SOURCE

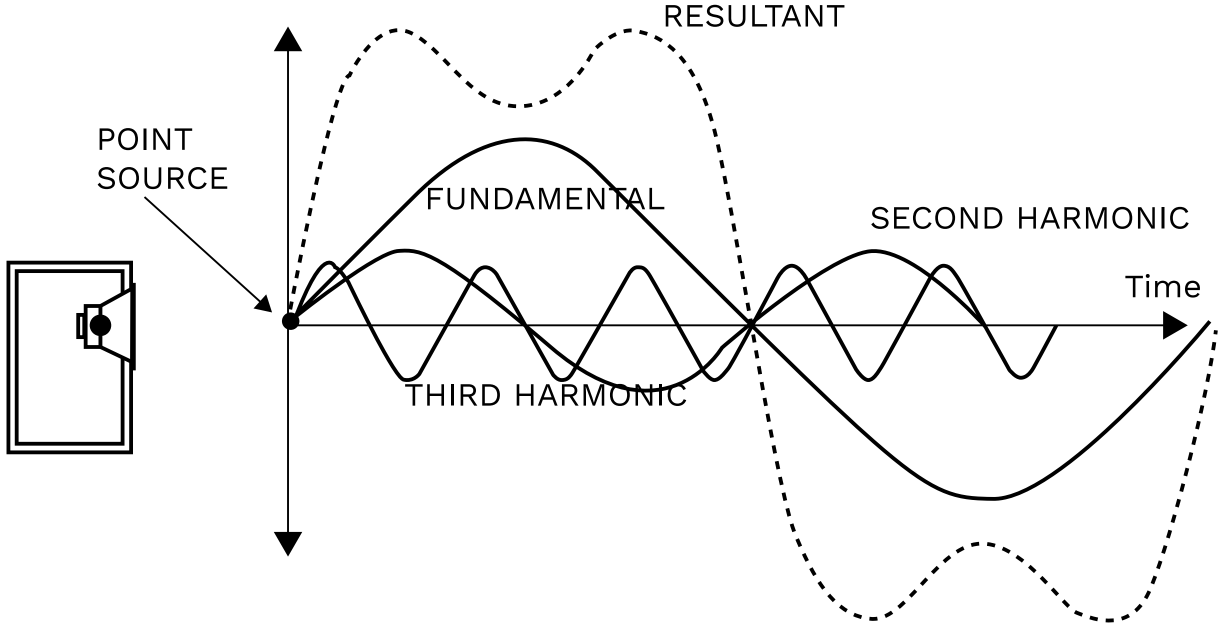


Fig. 5 How the IsoFlare Driver Preserves Harmonic Relationships

The other element of the IsoFlare that is a function of its point source nature, is it provides linear phase response. Every loudspeaker or audio device exhibits a low pass filter function and consequently acts as a frequency independent time delay in the pass band, otherwise known as a linear phase response. However, with discrete drive units that are not time aligned, severe phase errors occur in the pass band, while the IsoFlare offers an almost ideal linear phase response (Fig. 6). This better preserves the harmonic relationship of instruments and improves the transient performance. Note though that the phase response does deviate from the ideal at very high and very low frequencies. This is a natural result of the high and low frequency roll off points of the system. To reduce the low frequency phase error, we would add a subwoofer, which does more than just add bass. It is this reduction of phase error that is one of the main benefits of a well integrated subwoofer. Music with no apparent bass content will sound more natural when this error is removed.

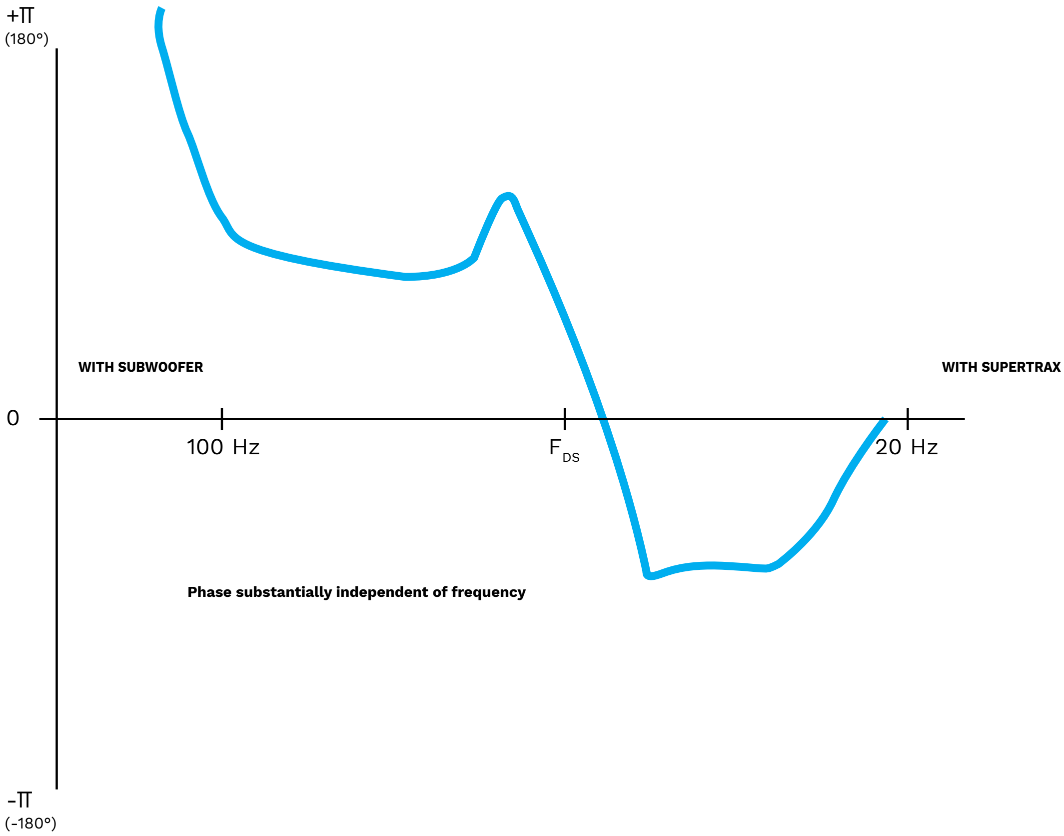
Likewise, the addition of a super tweeter, time aligned to the acoustic centre of the IsoFlare, will reduce the high frequency phase error by moving the low pass roll off point much higher. So even if we ignore for now the perception of sound above 20kHz, the addition of a super tweeter will better preserve the harmonic relationship between instruments and is apparent down to low frequencies. This is a very important fact which is not intuitive.

A super tweeter will affect the overall sound across the frequency domain, not just at high frequencies.

So, for a super tweeter to work correctly in the time domain, it has to be positioned backwards on the cabinet, to match the acoustic source of the main driver. Positioning the super tweeter at the front of the cabinet, as is often seen, is not ideal, although it could be argued that with a discrete non-point source loudspeaker this is of even less consequence.

We can now appreciate how adding a super tweeter improves system performance, not just with wide band material such as hi-res digital files, vinyl and tape, but with limited bandwidth material such as 22kHz CD Red Book standard.

PHASE RESPONSE OF TYPICAL DISCRETE NON-ALIGNED SYSTEM



PHASE RESPONSE OF TYPICAL ISOFLARE POINT SOURCE

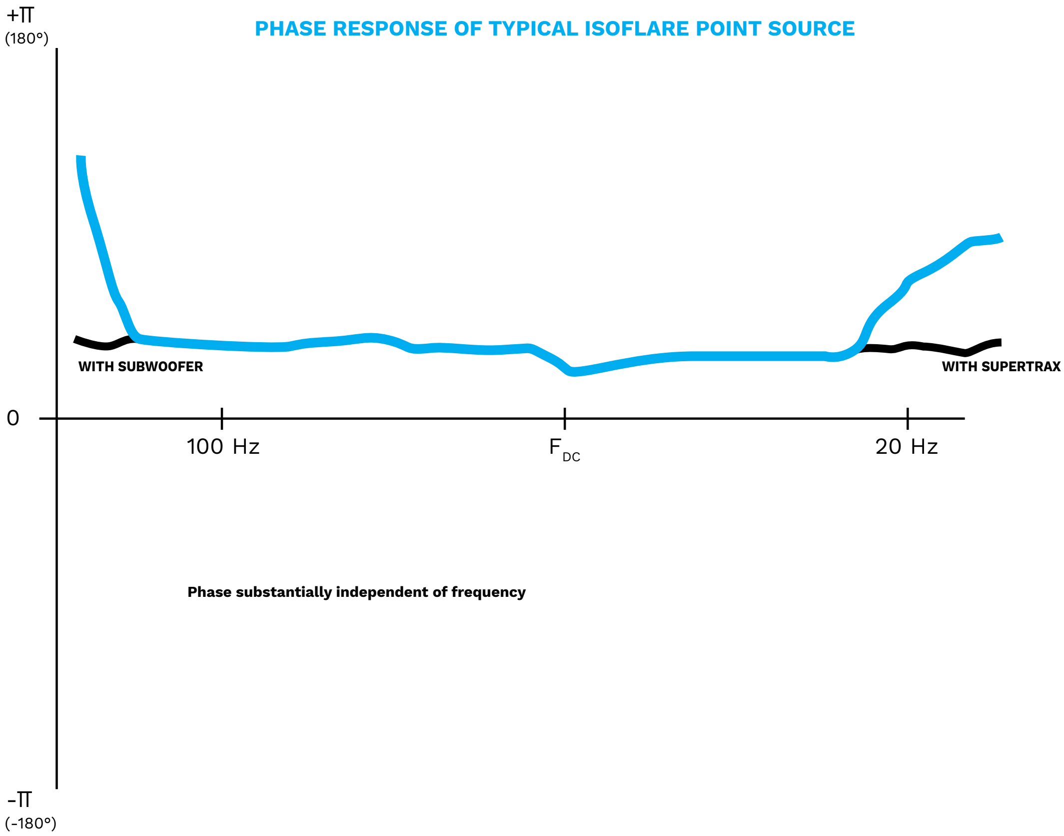


Fig. 6 IsoFlare Phase Error Compared to a Discrete System

WHY AN OMNIDIRECTIONAL SUPERTWEETER?

As we stated initially, the concept of a super tweeter is by no means new and over recent years, commercial examples have come to market by manufacturers such as Townsend Audio, Aperion Audio and Tannoy. These are designed to sit on top of the main loudspeaker cabinet and radiate energy directly at the listener, either from a directly radiating dome, a ribbon transducer or similar device. Such devices will have a very narrow dispersion at these ultrasonic frequencies, which means they will beam like a torch.

We noted earlier that the relationship in amplitude of fundamental frequency and harmonics needs to be accurately preserved both on axis and at points off axis. In a normal (typical) room, a high proportion of sounds perceived by the human ear are reflections generated by the off axis response of the speaker. The even off axis response of a point source IsoFlare driver, means that the reflected energy has the same harmonic structure as the direct on axis energy.

Therefore any enhancements by means of a super tweeter are best served by an omnidirectional device with even response at any angle, placed at the acoustic centre of the main driver, rather than a forward facing one, that beams energy directly at the listener.

The SuperTrax makes use of an upwards firing super tweeter, designed to be placed on the main loudspeaker cabinet, above which is mounted a contoured acoustic diffuser. The acoustic diffuser makes use of a Tractrix profile. The Tractrix profile is known to maintain a 90 degree angle at each intersection of the expanding wavefront. The plane acoustic wavefront generated by the dome is translated into a spherical wavefront into the room, where it meets the diffuser. Fyne Audio made use of the Tractrix profile in their patented BassTrax loading system, where the principles are similar.

THIN PLY CARBON DIAPHRAGMS

To give an extended high frequency response, it is usual to use a metal dome radiator. All these materials suffer from a break-up mode, where the dome stops acting as a piston, and becomes uncontrolled resulting in a peak in the response of some 10dB or more. Aluminium, titanium and magnesium range in order from around 20kHz to 32kHz and whereas considered out of the audio band, this can be perceived as harshness as well as limiting the maximum frequency the tweeter can operate. Berylium is better at typically 60kHz and diamond around 65kHz, but these two solutions are extremely expensive. The solution we have adopted is to use a new and unique Thin Ply Carbon Diaphragm (TPCD), the result of the material science and technology used to engineer TeXtreme thin ply carbon fabrics. Where a conventional carbon fabric is woven from thick round yarns, a TeXtreme carbon fabric is woven from ultrathin carbon tapes.

This results in higher stiffness, lower weight and tailored properties. By optimising the thickness and stiffness in all areas, the Composite Sound Metamodal diaphragm can be engineered for a tailored modal behaviour, frequency response linearity, improved pistonic motion and moving mass optimization, as required. The modal behaviour can be tailored by optimising thickness and stiffness in different parts of the cone or diaphragm.

The concept of distributed break up ensures a controlled break up behaviour with low distortion. By varying the properties of the TPCD in different areas and directions, the symmetric break up modes are eliminated and replaced with smaller and local distributed break up modes, enabling a more linear and extended frequency response, without any high level resonances. This makes use of COMSOL composite and acoustic simulations to optimize thickness, stiffness and damping at every given point of the diaphragm to achieve this. Thus, the frequency response of our SuperTrax super tweeter is seen to extend to over 60kHz.

CONCLUSIONS

In this White Paper we have shown that musical instruments produce energy well above the generally considered limit of human hearing. Research has shown that we are capable of responding to this energy, justifying the addition of a super tweeter where wide bandwidth sources are used.

Even with restricted bandwidth sources the addition of the super tweeter reduces phase error and improves transient performance significantly below 20kHz. This leads to increased tonal accuracy at all frequencies, as the harmonics of instruments are not distorted in time.

By using this newly developed patent pending time aligned omnidirectional super tweeter, the reflected energy in the room has the same harmonic structure as the direct on axis energy, thus giving advantages in perceived air and space compared to a more conventional forward firing super tweeter.

The IsoFlare driver, with its superior time alignment in the first place, benefits particularly from the addition of the SuperTrax super tweeter, while still acting effectively as a coincident point source, as it is still responsible for generating the vast majority of musical information.

DR PAUL MILLS

TECHNICAL DIRECTOR

FURTHER READING

[1] W. B. Snow, Jour. Acous. Soc. Amer., Vol. 3, No. 1, Part 1 (1931).

[2] J. Boyk, There's Life Above 20kHz- A Survey of Musical Instrument Spectra to 102.4kHz:
https://www.tnt-audio.com/casse/life_above_20khz.pdf

[3] D. Jensen, High Frequency Phase Specifications- Useful or Misleading? JAES, Vol. 36, No. 12 (Dec. 1988).

[4] W. Marshall Leach JR, The Differential Time Delay Distortion and Differential Phase-Shift Distortion as Measures of Phase Linearity, JAES, Vol. 37, No. 9 (Sept. 1989).

[5] T. Oohashi et al, High-Frequency Sound Above the Audible Range Affects Brain Electric Activity, AES Preprint No. 3207 (91st Convention, New York).

[6] M. Lenhardt et al, Ultrasonic Speech Perception, Science, Vol. 253 (July 1991).

[7] TPCD Diaphragms: https://device.report/m/9b4b496c9f7fab65c6b0326742dfe83dc750a69c0f1bde83fcf158a0b9f56559.pdf

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