

**A new product from Sonic Immersion Technologies, LLC.
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One of the most important trends in the audio industry is that of "tactile sound". Tactile sound appears to be a contradiction in terms because our concept of sound relates to information traveling thru the air and sensed by our ears. Audiologists would be quick to point out that our perception of sound also includes mechanical and even electrical stimuli.

A more proper term for "tactile sound" is vibro-acoustic or vibro-tactile stimulation. Substantial technical literature exists in this very active field of research. Despite this attention vibro-tactile sound products are relatively new to the audio entertainment industry. Clinical studies demonstrate that vibro-tactile stimulation of deaf subjects generates brain activity in the auditory cortex.

All vibro-tactile devices operate using Newton's 3rd law. Simply stated, "To every action there is always imposed an equal reaction: or, the mutual actions of two bodies upon each other are always equal and directed to contrary parts." This is the classic phrase, "for every action there is an equal but opposite reaction." In the case of vibro-tactile devices a force is produced because

the moving mass of the device is accelerated. As a consequence of Newton's 3rd law, the reaction is the acceleration of the mass where the device is mounted, which transfers the sound energy to the listener.

It is clear that the addition of vibratory stimulus to music can enhance the listening experience. The extension of vibrations above the classic "bass" range of frequencies (30Hz to 80Hz) can provide additional percussive information, such as the lower frequency details contained in stringed instruments and keyboards. The use of transducers up to 300Hz produces useful information that generally improves the listening experience. The original use of "tactile sound" products in audio and audio/visual applications was as a subwoofer or subwoofer augmentation device.

High sound pressure level (SPL) bass material at "live concerts" is capable of producing a physical sensation as well as the traditional acoustic stimulus of loud perceived volume. A classic example is the kick drum "thump in the chest" felt during concerts. These high SPL levels create structural vibrations in the floors and walls that can add dimensions to an overall listening experience. Typical

consumer subwoofers are not capable of producing the sound pressure levels of a concert system and therefore lack the impact of the "live" experience. Additionally, when a typical consumer subwoofer is turned up the noise associated with the surrounding room vibrations overwhelm the desired vibrational effect of the music.

The first vibro-tactile devices had narrow useful output frequencies and were termed "bass shakers". They were used in many environments in an attempt to produce the physical sensations of a live concert without the acoustic side effects of subwoofers: rattling rooms, furnishings, automotive interior panels, etc.. These "shakers" eliminated omnidirectional radiation of low frequency noise pollution into the environment. For the first time intense bass material playback became "personal" rather than being radiated to everyone nearby. The initial application of these devices as subwoofer replacements or subwoofer augmentation devices was an excellent first step.

The next step in the evolution of vibro-tactile products for entertainment applications began when users began experimenting with vibro-tactile transducers in more full range frequency applications. The addition of higher frequency material began to demonstrate the potential of wider bandwidth devices and the associated additional dimensions that vibro-tactile products bring to the overall experience. It is very tempting to call vibro-tactile stimulation a "listening" experience, but it is clearly more than that. The impression of these devices are broader than the information provided solely by the ears.

There are many parameters that need to be evaluated when selecting a vibro-tactile device for inclusion in an entertainment system. Bandwidth, efficiency, and power handling need to be understood. These parameters play a big role in which vibro-



tactile device and amplifier is selected. It is well understood in the loudspeaker industry that sufficient bandwidth (i.e. flat frequency response with sufficient low frequency and high frequency limits) is a critical element for high fidelity reproduction. Vibro-tactile devices, like loudspeakers, are resonant devices and must be properly designed to provide the required bandwidth for accurate response.

From a "sound in air" standpoint, the human ear has a nominal response of 20 Hz to

20,000 Hz. Although these limits vary from person to person this nominal bandwidth has become the conventionally quoted requirement for high fidelity loudspeaker systems. In reality, most recorded material rarely has content below 30 Hz. The required enclosure volumes or losses in efficiency required to achieve response below 30 Hz practically limit actual -3dB limits to 30Hz or above. The typically quoted bandwidth of vibro-tactile stimuli is from very low

frequencies to roughly 800 Hz. Again, it should be stated that this 800Hz high frequency limit is for classic vibro-tactile stimulation. For applications involving entertainment shakers, this limit is probably much lower than 800Hz. Never the less, information in the 100Hz to 300Hz range is clearly perceived when the devices are used in this frequency range.

As is the case with sound in air, the actual low frequency and high frequency limits depend on a wide variety of parameters and the actual response to these "tactile" stimuli vary greatly from person to person.

The importance of bandwidth can be seen in Figure 1 (all data taken for all Figures is 4 Vrms. All devices were driven with identical input and are rated at 4 ohms). This response data shows the RMS force versus frequency for a typical "tactile sound" transducer. The peak centered at 49 Hz is indicative of a poorly damped mechanical resonator. Musical information centered around the 49 Hz peak will be very energetically reproduced. Unfortunately, music never consists of a single note or single packet of frequencies that are narrowly spaced. As an example, if a musical passage consisted of a kick drum, the device shown in Figure 1 would do a very good job of providing vibro-tactile stimulation that was "faithful" to the original signal. A far more common situation could consist of a kick drum, floor tom toms, a bass guitar, and a keyboard signal all being played in time. The result, experienced by using the device in Figure 1 would be a loss of balance and information both below the peak frequency and above the peak frequency. This unbalanced delivery of information is noticeable to the listener.

It should be noted that totally flat frequency response is very difficult to achieve in these mechanical systems. In addition to the response of the excitation devices themselves, the structures that the exciters are mounted to can substantially effect the response. Floors, walls, seats, chairs etc. will all act to modify the response, just as a room will modify the acoustical response of a loudspeaker system. The key is to at least "maximize" the bandwidth so that the best possible response is achieved.

Figure 1 – Typical tactile bass "shaker"

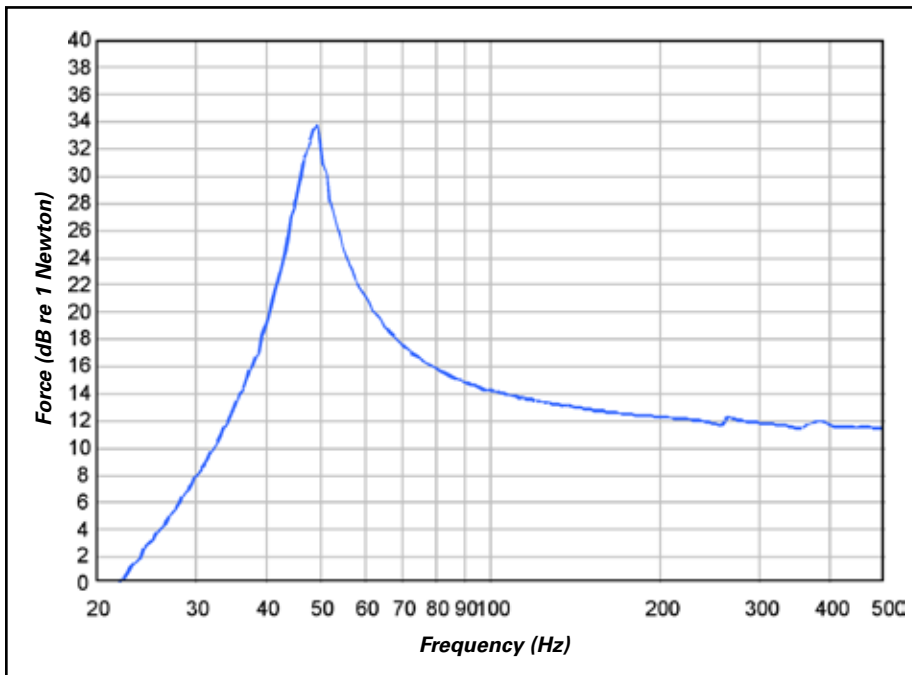
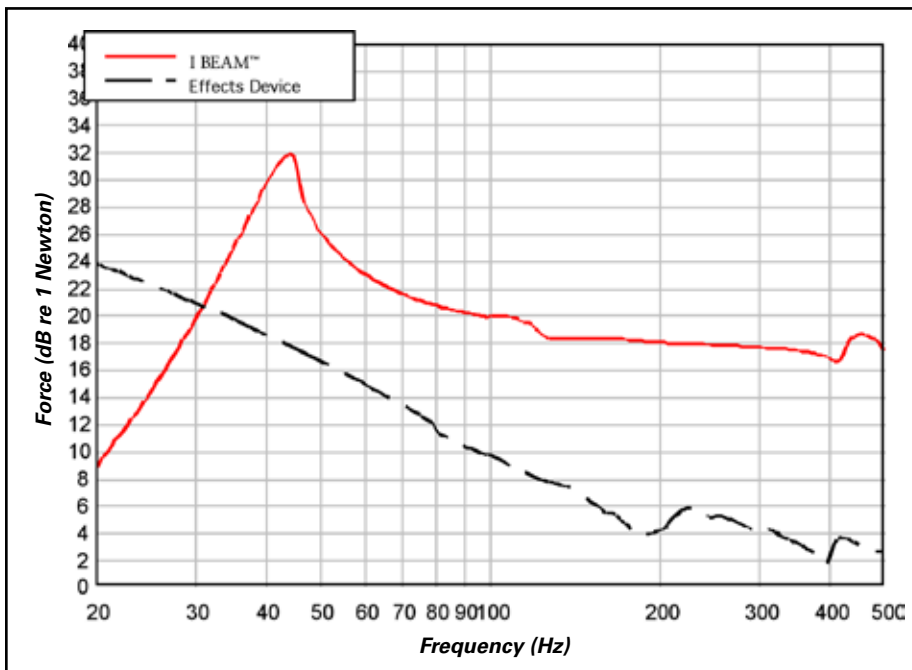


Figure 2 – Class 1 device versus Class 2 device



The currently available vibro-tactile devices on the market display varying degrees of bandwidth. Figure 2 shows the force versus frequency response for the two classes of currently available products. Class 1 devices are designed for broadband response and excel in reproducing music and cinema soundtracks. Class 2 devices are designed to reproduce the lowest frequencies used in "special effects". In Figure 2, the red curve represents the Class 1 full range device and the black curve represents the Class 2 special effects device. It is important to note that the ultra low frequencies of special effects are rarely, if ever, present in music and cinema soundtracks have little information below 20Hz. The importance of Figure 2 is the representation of the distribution of the sound energy between Class 1 and Class 2 devices.

Figure 3 illustrates the general response of Class 1 devices. The I BEAM™ transducer is compared to other commercially available Class 1 products (Unit 2 and Unit 3). All the devices are tuned in the 30 Hz to 70 Hz range as mounted. They show attenuation below tuning and frequency extension above resonance that is relatively flat versus frequency. These designs are optimized for broad range music applications and recognize that musical or special effect content below

30 Hz is essentially limited in the typical recording processes of audio and audio/video applications. The relative output levels at the tuning frequency of each device are similar. The Sonic Immersion Technologies I BEAM™ exhibits an average of 6 dB higher output above its tuning frequency when compared to the existing technologies. This difference between the fundamental tuning peak and the broadband level illustrates significant bandwidth improvement above tuning. While all of the devices exhibit response up to 500 Hz, the ratio of peak output to average output is superior for the I BEAM™ device. This superior ratio of peak to high frequency response will provide a more balanced vibro-tactile stimulus to the listener.

At this point it is appropriate to introduce a relative measure of broad bandwidth and efficiency. The "Total Force" under the curve can be measured and compared on a device-to-device basis. The force in each frequency step is calculated and the entire series of force/frequency steps are added to generate an overall measure of the effect that can be easily seen in Figure 3. The data was taken between 20 Hz and 500 Hz. Notice that in general the I BEAM™ device (the red curve in Figure 3) is higher, overall, than either the blue curve or the green curve.

When each device is summed, the I BEAM™ device exhibits a 52% increase over the device represented by the green curve. The I BEAM™ also exhibits a 41% increase in total energy over the device represented by the blue curve.

The data is shown below and easily illustrates the advantage of the I BEAM™ transducer.

DEVICE	Force/Watt/Hz
I BEAM™	0.39 lbf/Watt/Hz 1.75 N/Watt/Hz
Unit #2	0.19 lbf/Watt/Hz 0.85 N/Watt/Hz
Unit #3	0.22 lbf/Watt/Hz 1.0 N/Watt/Hz
Unit #4*	0.18 lbf/Watt/Hz 0.79 N/Watt/Hz

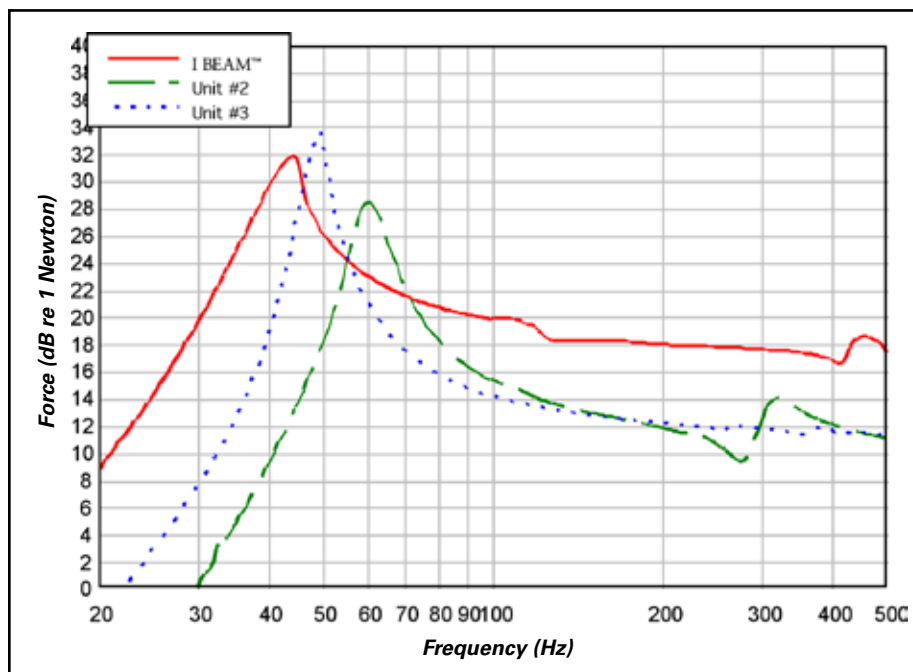
*Unit #4 is shown in Figure 4. It is included in the data above to illustrate the concept of energy under the curve.

These "Total Force" measurements directly relate technically derived values of the devices with the real world experience by a "listener". It is frequently difficult to look at a list of specifications and relate those numbers to the actual listening experience.

When the Class 1 devices are demonstrated an unbiased "listener" will perceive more energy associated with the I BEAM™ device. This effect can be thought of, as one listener described it, as "more bass per watt". Class 2 devices are not technically "competitive" in a broad frequency comparison.

Below the fundamental tuning frequency the bandwidth extension of the I BEAM™ device can also be easily seen. At 30Hz the I BEAM™ enjoys a 10 dB advantage over Unit 3 and a full 19 dB advantage over Unit 2. Again, this extension in bandwidth is significant in terms of providing a balanced response for the program material. The I BEAM™ design is intended to provide a maximized efficiency bandwidth experience. Comparison of the three devices in Figure 3 clearly shows both low frequency and high frequency extension for the Sonic Immersion Technologies I BEAM™.

Figure 3 — I BEAM™ versus competitive products



The Class 2 type of vibro-tactile product compared to the I BEAM™ device is shown in Figure 4. The device clearly shows a design intent of very high output capability at very low frequencies. Below 30 Hz Unit 4 clearly shows an output advantage over the I BEAM™. This type of device is designed for maximum output at extremely low frequencies. Used as a “special effects” device Unit 4 offers extremely high output capabilities.

However, the I BEAM™ device again demonstrates its advantages above 30 Hz. The advantages of over 10 dB of additional output at any given input and a flatter frequency response are apparent. The increased response above 30 Hz produces a device capable of responding to a far greater range of musical and cinematic inputs. Figure 4 clearly shows the applicability of each device to a particular application. The I BEAM™ was designed for full range vibro-tactile reproduction while the Unit 4 was optimized for only the lowest frequencies of movie special effects.

Efficiency is also a very important factor in overall device performance. In the application of vibro-tactile devices the force resulting from a given electrical input is of great importance.

Several manufacturers quote a specific force per watt output from simple calculations to provide the user an idea of what force levels to expect at maximum power. Unfortunately, this type of calculation is extrapolated from measurements made at very low power levels and can be extremely misleading. This maximum output rating given by other manufacturers assumes that the device responds in a linear fashion. The assumption means that if the rating of 2 pounds of force per watt is given then at 100 watts the device will produce 200 pounds of force. All mechanical shakers are a combination of a spring and a mass. The spring is never capable of perfect linear travel, so the maximum force is never equal to the product of the force per watt rating and the device power handling at significant power levels. All springs are nonlinear. Each spring responds differently to applied power. A major factor differentiating the performance of vibro-tactile products is the design of the suspension system, which is a sophisticated spring mechanism.

Just like the maximum force specification, great care should be taken when reviewing the power handling specifications of vibro-tactile devices. Some require extremely large electrical power inputs to produce a given force. As an example Figure 4 may be used to compare the required power input to produce

a specific force at a specific frequency. At 40 Hz, the I BEAM™ device enjoys a 12 dB output advantage over Unit 4. Unit 4 would require almost 16 watts to produce the same force as the I BEAM™ driven with 1 watt. In fairness, it should be remembered that Unit 4 was designed for ultra low frequency special effects response and not musical efficiency.

Figure 3 could also be used for this efficiency comparison. Because the devices are designed for a more full range frequency application the comparison becomes even more important. At 40 Hz Unit 2 will require 125 watts and Unit 3 will require 14.5 watts to equal the force produced by the I BEAM™ device at 1 watt.

These power differences are directly related to power handling in the sense that any user “turns the unit up” not to a specific power but to a required force. Less efficient devices require more power for a given force so power handling must always be considered along with device efficiency. The key here is that vibro-tactile device efficiency is a very important parameter and power handling specifications are only of value if they are related to efficiency. The critical parameter is the force supplied to the structure to be vibrated.

It is clear that these vibro-tactile devices represent advancements in the personal listening environment. They provide extended low frequency response without the environmental noise pollution of rattling walls, furniture, car panels etc. They add impact to the overall listening experience by providing musical information found at live performances.

Figure 4 – I BEAM™ versus “effects device”

