

IBEAM[®]

Vibro-Tactile Transducer

An new product from:

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An important trend in the audio industry is a new class of devices that produce “tactile sound”. The term “tactile sound” appears to be a contradiction of terms, in that our concept of sound relates to information that comes solely through our ears. Audiologists would be quick to point out that our perception of sound includes three major stimuli: tympanic (ears), skeletal harmonics (bones) and galvanic response (skin). Tactile sound products provide sound information to the brain primarily through the bone and skin hearing responses, while traditional speakers deliver sound information via a tympanic mechanism.

Perhaps a more proper term for “tactile sound” is vibro-acoustic or vibro-tactile stimulation. Vibro-tactile stimulating devices operate using Newton’s 3rd law. Simply stated, “To every action there is always imposed an equal reaction”. In the case of vibro-acoustic devices a force is produced inside the device because the moving mass of the device is accelerated. As a consequence of the 3rd law, the action is the acceleration of the mass where the device is mounted and the reaction is the resulting stimulation of the listener.

Although relatively new to the audio entertainment industry, there is substantial technical literature and much active research in the field. Recent studies at the Helsinki University of Technology (1999) demonstrated that vibro-tactile stimulation of deaf subjects generates brain activity in the auditory cortex. Historically vibro-tactile devices have been used to enhance the experience of low frequency effects in movies (30Hz and below). The added emphasis of the vibrations in the lower “bass” range of frequencies provides additional percussive information from the special effects.

The first vibro-tactile devices offered for sale were basically “shakers” limited to movie enhancement devices that performed poorly with music content. The products suffered from being too large and/or very inefficient. The devices did find use in some audio and audio/visual applications as sub woofers or sub woofer augmenters. The narrow frequency output bandwidth (30Hz to 80Hz) they produced emphasized the low bass physical sensations associated with subwoofers rather well without the unpleasant “side effects” of rattling room furnishings or automotive side panels. In addition, these early “shakers” eliminated the omni directional radiation into the environment. The low bass sound material was now “personal” rather than being indiscriminately radiated to the outside environment.

The initial application of these vibro-tactile transducers as sub woofer replacements or augmentation devices was an excellent first step. The next step in the evolution of vibro-tactile devices began when researchers experimented with transducers that deliver broader frequency ranges beyond the traditional 30-80Hz. The high frequency sound output from these devices actually enhanced the bass perception of the listener. The extension of vibrations above 80Hz provides additional percussive information as well as details contained in stringed instruments and keyboards. A vibro-tactile device that can make up to 300Hz produces useful sound information and dramatically improves the music listening experience.

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 are the key parameters in vibro-tactile device and amplifier selection.

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 critical 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 conventional “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 and 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, its should be stated that this 800Hz high frequency limit is for classic vibro-tactile stimulation. For applications involving vibro-tactile devices for entertainment, this limit is probably much lower than 800Hz. Never the less, information in the 100Hz to 300Hz range is clearly perceived when the devices produce sound at these frequencies.

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.

The importance of bandwidth can be seen in Figure 1 (all data taken for figure 1 and all subsequent figures was at 4 Vrms. All devices were driven with the same input and all 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 on 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 only, 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.

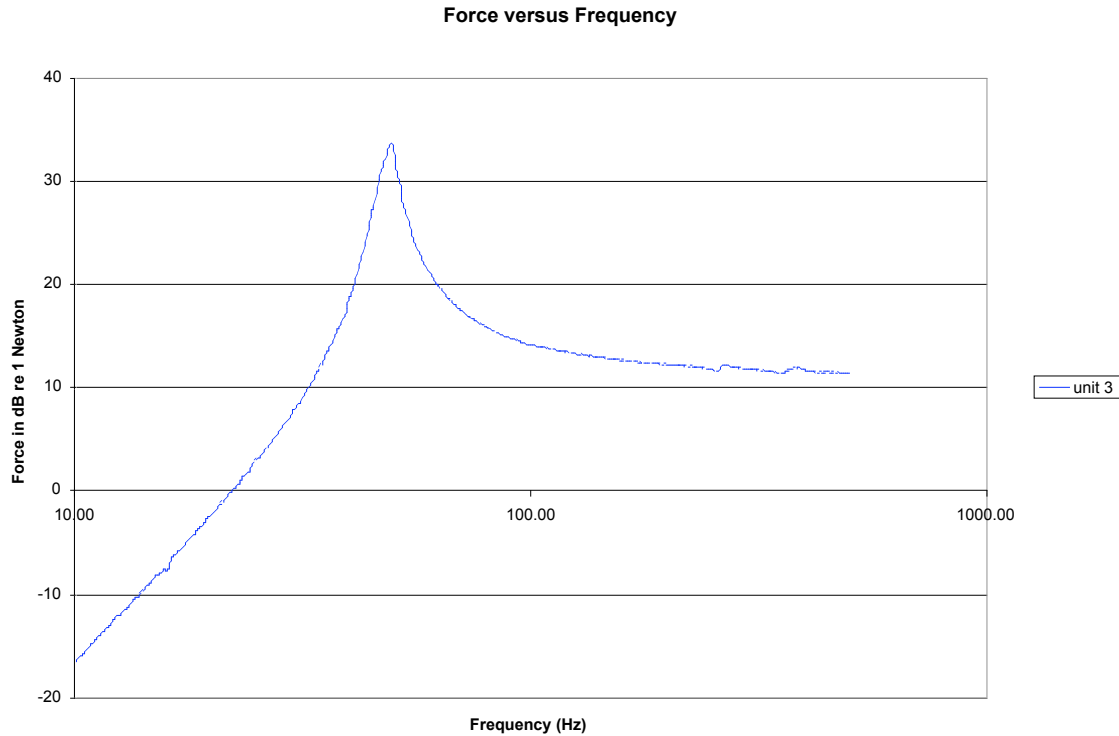


Figure 1.

It should be noted that the nearly flat frequency response associated with loudspeakers is very difficult to achieve in these vibro-mechanical systems. In addition to the response of the excitation devices themselves, the structures that the exciters are mounted to will also substantially effect the linearity of 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 “maximize” the sonic bandwidth so that the best possible response is achieved when using musical sources.

There are currently a few vibro-tactile bass “shaker” devices on the market. These devices all display varying degrees of bandwidth. Figure 2 compares the frequency response of the Sonic Immersion Technologies IBEAM[®] versus several currently available vibro-tactile bass “shakers”. The Sonic Immersion Technologies IBEAM[®] is shown in red. The importance of figure 2 is the representation of the extended energy both above and below the fundamental resonance frequency as compared to the other devices shown in figure 2. The IBEAM[®] displays superior excellent bandwidth and excellent efficiency. The devices included in figure 2 will be compared separately to the Sonic Immersion Technologies IBEAM[®] in subsequent plots.

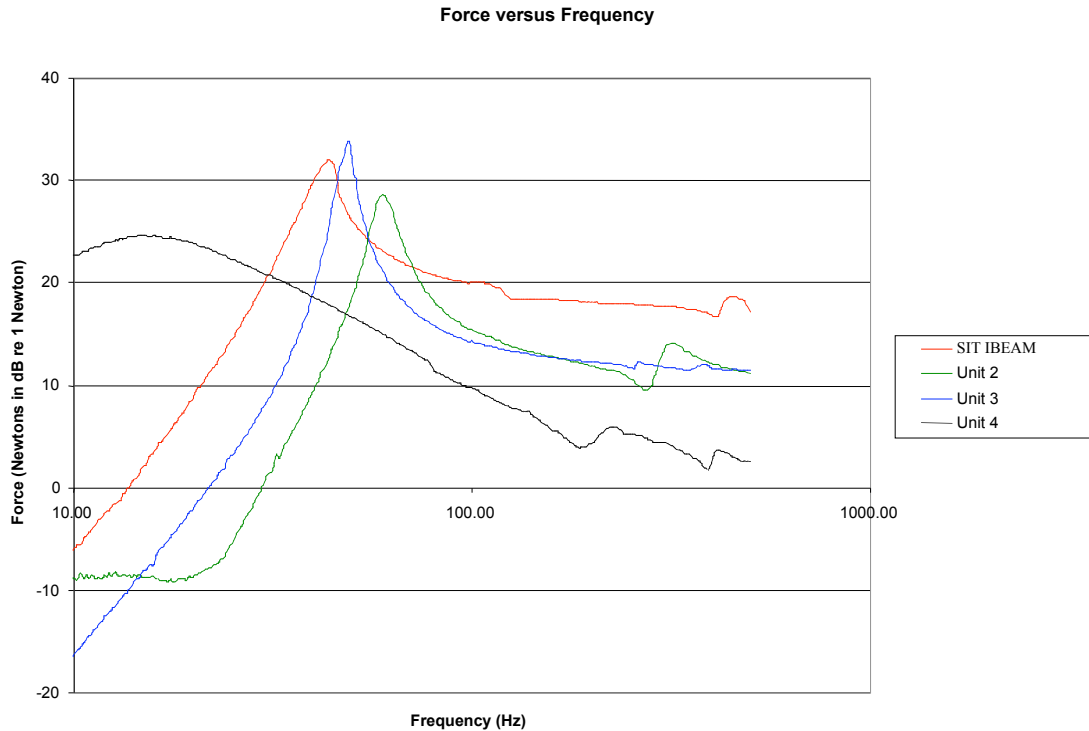


Figure 2.

Figure 2 illustrates two basic classes of available vibro-tactile devices. Class 1 includes the IBEAM[®] and units 2, 3. These devices have a resonant frequency in the 30 Hz to 70 Hz range (as mounted). They show attenuation below tuning, as all resonant devices will, and frequency extension above resonance that is relatively flat versus frequency. The IBEAM[®] has the broadest frequency profile of the Class 1 units. Unit 4 represents the Class 2 device. It is tuned very low (below 15 Hz) and is optimized for the lowest bass frequencies found in cinema soundtracks.

The “Class 1” devices are shown in Figure 3. The Sonic Immersion Technologies IBEAM[®] exhibits an average of 6 dB higher output above its tuning frequency. The relative output levels at the tuning frequency of each device are relatively similar. This illustrates the bandwidth improvement above tuning. (All of these devices have response up to 500 Hz, the limit of the data taken, but the ratio of peak output to average output is superior for the IBEAM[®] device. The superior ratio of peak to high frequency response will produce a more balanced vibro-tactile stimulus.

Below the fundamental tuning frequency the bandwidth extension can be easily seen. At 30Hz the IBEAM[®] 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

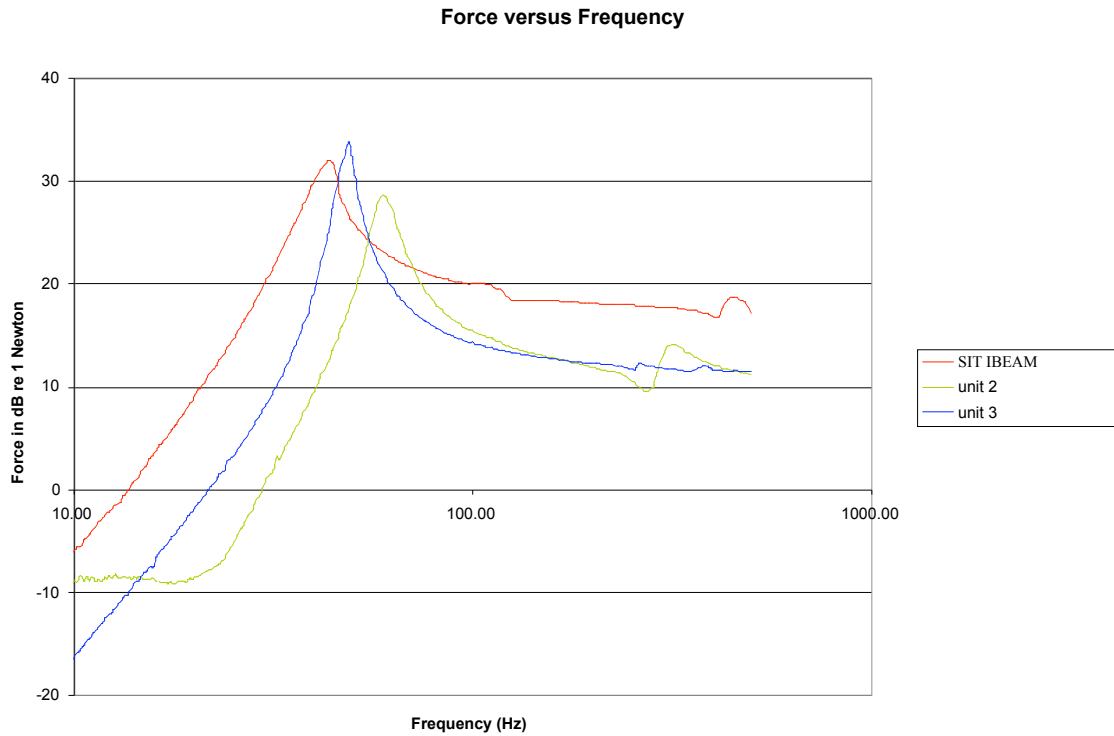


Figure 3.

response for the program material. The IBEAM[®] design is intended to provide a maximized efficiency bandwidth product. Comparison of the three devices in figure 3 clearly shows both low frequency and high frequency extension for the Sonic Immersion Technologies IBEAM[®].

The second type of vibro-tactile exciter is shown in figure 4. The device, as compared to the IBEAM[®] clearly shows its design intent in terms of very high output capability at the very lowest of frequencies. At frequencies below 30 Hz unit 4 shows an output advantage over the IBEAM[®]. Used as a “special effects” device for movie soundtracks unit 4 offers capabilities.

The IBEAM[®] again demonstrates the 30 Hz and above advantage of over 10 dB of additional output per a given input and a flatter frequency response. The tradeoff is a conscious choice in the design of the product. The increased response above 30 Hz produces a device capable of responding to a far greater range of musical inputs. Figure 4 clearly shows the applicability of each device to a particular application. The IBEAM[®] was designed for full range vibro-tactile reproduction while the device labeled unit 4, although capable of responding to full range signals, was optimized for special effects applications.

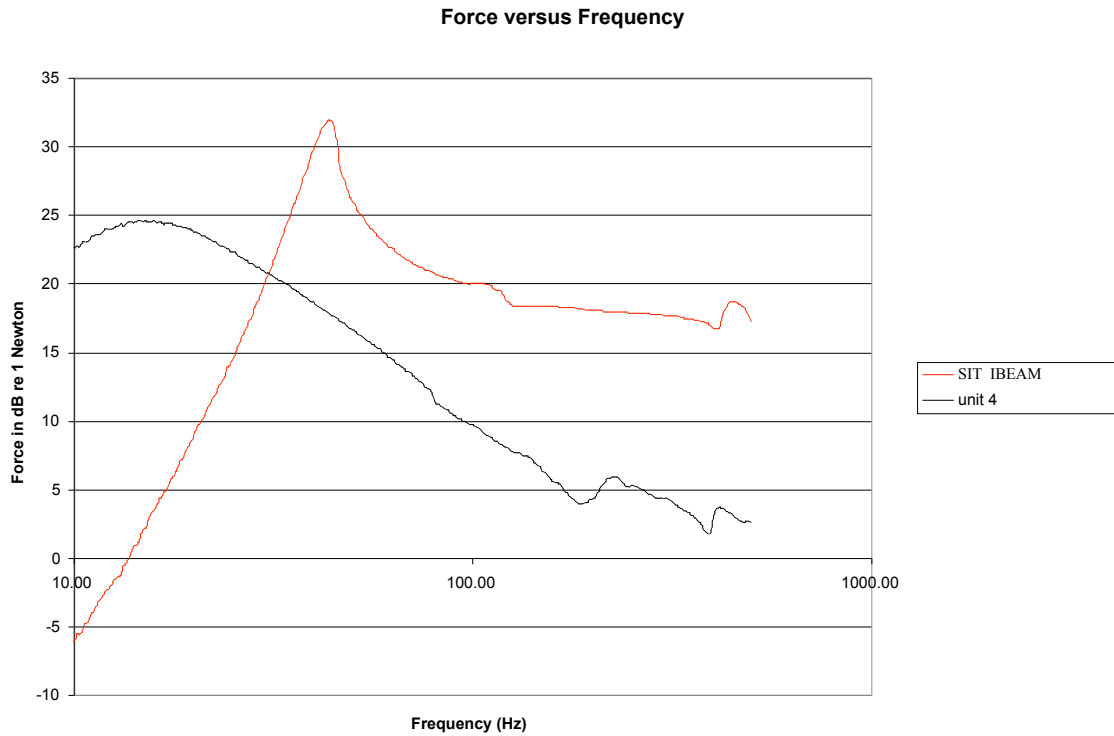


Figure 4.

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. Great care should be taken when reviewing power-handling specifications of devices. Many devices 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 IBEAM[®] enjoys a 12 dB output advantage over unit 4. To produce the same force, if the IBEAM[®] were driven with 1 watt, unit 4 would require almost 16 watts to produce the same force. Again, it should be remembered that unit 4 represents a tradeoff and was designed for certain special effects response.

Figure 3 could also be used for this comparison and, because the devices are all designed for a more full range application, the comparison is even more important. To produce the same force that the IBEAM[®] produces at 40 Hz at 1 watt, unit 2 will require 125 watts. Unit 3 will require 14.5 watts.

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 the IBEAM[®] device represents a dramatic advancement in the vibro-tactile products available to the consumer. The IBEAM[®] efficiently provides extended low frequency response without the environmental side effects noise of rattling walls, furniture, car panels etc. It adds to the overall listening experience by providing the additional sensory musical information that the mind associates with high sound pressure levels (SPL) of “live” performances. The IBEAM[®] reinforces the lower frequencies and delivers the physical acoustic stimulus right through your seat.