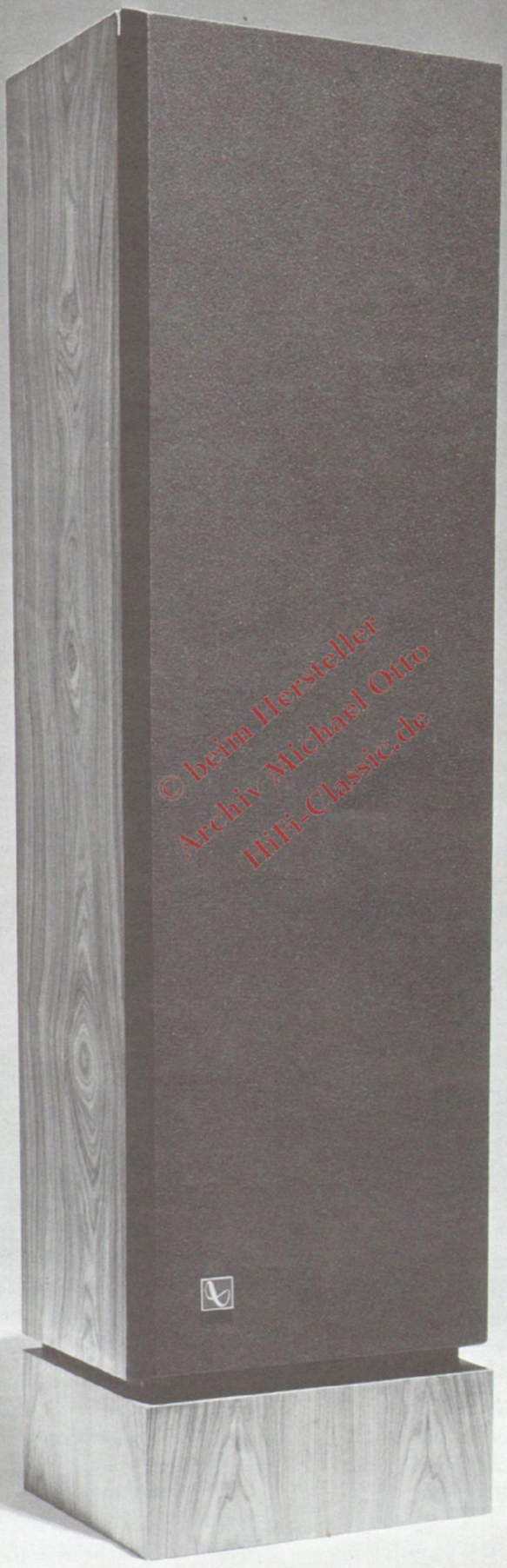
Infinity Quantum Line Source



The Infinity QUANTUM LINE SOURCE

Technical aspects of extracting essentially flat frequency from an enclosure (free of characteristic resonance peak in the bass) from 18 to 32,000 Hz, with the polar dispersion effectivity of a point source.

The goal.

The theoretically perfect way of reproducing sound in a room is to have a massless point source that radiates. In effect, such a source could ideally reverse the process by which the microphone initially gathered in the sound at a point, and subsequently could reissue it from a point. In fact, a microphone playing backwards out into the air would do virtually what is desired.

Unfortunately, no speaker the size of a microphone can, with present technology, reproduce the entire music spectrum. For this, radiators larger than a microphone are required for all but the highest frequencies, and, to obtain equal intensity and quality of sound all along the sound spectrum, several radiators are required, each handling a portion of the frequency band.

At the low end of the sound spectrum, the radiators are quite large — woofers over a foot in diameter are commonplace. Thus, a speaker that contains several radiators takes up a large frontal area, perhaps 5 to 10 square feet, contrasted with the 1 square inch or so that the microphone's sensing face occupied when it gathered in the sound waves at the recording session. Sound gathered at a point, and then reproduced from several points over a frontal plane, differs from the original, lessening the illusion of reality that speakers aim to produce.

Another factor — the fact that several discrete frequency bands of the music are reproduced by individual radiators — leads to phase differences between the bands because of the individual response times and mass/acceleration characteristics of the radiators. Thus, portions of the output music signal are staggered in their arrival at the listener's ears, whereas they should all arrive at exactly the same point in time. The result is blurred transients and imprecise staging of the total frequency spectrum.

In addition, a continuing problem of speaker design has been the inherent characteristic resonance of a speaker enclosure, which introduces an impedance peak, resulting in back-EMF (electro-motive force), and drastically alters the character of bass frequency response. This characteristic resonance and subsequent loss of efficiency is subject to the immutable laws of Physics and has vexed acoustic designers for decades.

The net result of these factors is that even the best speakers, until now, have fallen short of presenting truly accurate music reproduction because of three predominant limitations: (1) they cannot produce a flat frequency response over the entire sound spectrum because of enclosure resonance in the bass region, (2) they introduce phase discrepancies between various frequency bands of the music signal, and (3) they are unable to radiate the sound spectrum from the ideal point source.

In one speaker enclosure, three solutions.

Infinity Systems, Inc., has addressed itself to all of these problems in designing the Quantum Line Source, and is presenting in this speaker practical solutions for all three dilemmas.

The first problem — that of obtaining a truly flat frequency response, free of an enclosure resonance peak — has been solved by the invention of a woofer driven with two voice coils of different sizes, each having its own impedance and each responsive at differing frequencies.

The second problem — phase discrepancies — has been solved by developing extremely fast drive units, by phase-correcting the crossover, and by positioning these drivers properly in relation to the enclosure and to the other drivers.

The third problem, that of devising a point source radiator, was approached by rephrasing the question: "If it is not possible to produce a true point source,

then how, using a frontal plane containing several radiators of considerable area, can we generate sound, *within the fan-shaped slice of space occupied by listeners in a room*, that is identical in polar dispersion and physical character to that which would be produced by the theoretically perfect point source?"

This rephrasing of the problem excludes any consideration of the amount and quality of the sound that would be heard at ceiling and floor level and behind the speaker, since the practicality is that listeners will not be in these areas. The importance of this rephrasing, however, lies in the fact that, though the original problem was *not* practicably soluble with present technology, the rephrased version *is*, by utilizing the special acoustic properties of a unique geometric configuration of radiators known as a *line source*. It should be emphasized that within the prescribed listening space, a line source is every bit as desirable as a point source.

Solving the three problems, and then combining the three solutions in one speaker enclosure, has produced the Infinity Quantum Line Source. Within the most advanced limits of present technology, this reproducer comes as close as is possible to recreating the original recorded auditory material within the angular limits of the sound focus (180° horizontal polar dispersion from the frontal plane of the speaker).

The respect in which the Quantum Line Source fails to recreate the original sound is in the acoustics of the room in which the Line Sources are placed. All echoic qualities contributed by the listener's room are, in addition to those impressed on the recording; therefore, with this extremely accurate reproduction of the acoustic situation prevailing during the recording session, room-acoustic contributions create error.

All these factors are discussed in detail in the following paragraphs.

Efficiency vs bass response: a solution to the dilemma.

Newton's third law, familiar to all beginning physics students, states that "F=MA," or, "Force equals Mass times Acceleration." In speaker terms, this can be elaborated as follows: high frequencies require very rapid vibrations of the air, in which the air molecules move extremely short distances. Low frequencies require slow vibrations of the air, in which the molecules move long distances.

Thus, the high-pitched whine of a mosquito requires infinitesimal power usage to vibrate the insect's filmy wings at high speed for tiny distances. However, the bass "thrum" of a great steamship's propellors requires several hundred horsepower to move the giant blades. Similarly, in the ancient, hand-pumped cathedral organs, the rippling runs of high notes through the narrow, short pipes of the upper keyboard required only an occasional swing of the choirboy's arm to replenish the chest of air. But the ponderous swells of Bach's pedal C's through 32-foot-tall pipes of huge diameter called for several of the boys to pump with holy zeal.

Similarly, in an acoustic suspension speaker, increased bass response (requiring more power to drive the woofer) has always been a corollary of decreased efficiency.

Traditionally in speaker design, if more efficiency is desired in a system of given cabinet volume, bass response must be sacrificed. Conversely, to obtain more bass, it has always been necessary to sacrifice efficiency.

With the concept and realization of the Infinity/Watkins Dual-Drive Woofer, it becomes possible for the first time to obtain high sound-pressure levels of essentially flat frequency response *along with* high efficiency from the same speaker. Further, the device effectively eliminates the reproduction of the undesirable enclosure resonant peak with its distorting effect upon bass response.

Low bass response and "Hoffman's Iron Law."

For about twenty years, such advances as acoustic suspension woofers, transmission lines, bass reflex designs, and a variety of new materials and processes have steadily improved power-handling capabilities and midbass smoothness. Low bass frequency response, impulse response, and distortion have not significantly improved.

Infinity created the servo-controlled woofer for the state-of-the-art Servo-Statik IA. It has almost incredible bass performance, responding well under the 100 Hz level, but requires a servo amplifier to operate. This system is extraordinarily expensive, and is, therefore, not the most desirable solution to the problem of powering low bass.

Altering the geometry of the enclosure in a conventional, closed-box system is not a workable solution, either. "Hoffman's Iron Law" states that above 150 Hz the efficiency of a bass system, E, is equal to the system's resonant frequency, f_r, cubed and multiplied by the enclosure volume. Thus, $E = (f_r)^3 \times$ enclosure volume.

The relationship implies that to raise efficiency (lessen power demand) and still maintain flat frequency response, it is necessary either to *raise the resonant frequency* or to *increase the volume of the enclosure*. Obviously, there are severe practical limits as to the size of enclosure that most persons are willing

to tolerate, and so this route is not acceptable in home uses.

The other approach, increasing the flux density of the magnetic field to brute-force response, does not work, either, as shown in Figure 1:

Figure 1

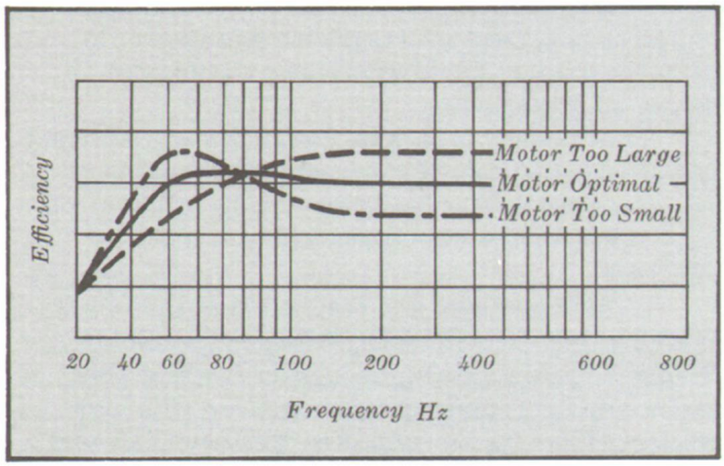


Figure 1 shows what is commonly referred to as The "See-Saw Effect." If the motor is too small for a given speaker enclosure volume, efficiency is low and there is a bump in the bass; conversely, if the motor is too large, efficiency is gained but bass response is reduced. (This also points up the fallacy of assuming that a larger magnet will necessarily improve bass response in a speaker.) As can be seen, desired efficiency and bass response are achieved only with a motor which properly balances the two opposing see-saw characteristics.

Figure 1 shows that the *efficiency* and *bass frequency response* are clearly predetermined for a given size box and the motor efficiency dictated by this parameter. In other words, if more efficiency is desired, bass response must be sacrificed. Conversely, to obtain more bass, it is necessary to sacrifice efficiency. This fact is well known and all high-efficiency systems (other than horns) have very limited bass response, while those speaker systems with extended bass response are of very low efficiency. This is one of those immutable laws of physics.

It will be seen by examining Figure 1 that for optimal bass response with *none* of the limitations imposed by "Hoffman's Iron Law," one needs a *varying* motor strength. For good efficiency above resonance a large motor is needed, and for good bass efficiency a smaller motor is necessary. Must we repeal the laws of physics to accomplish this?

William Watkins faced this enigma in a brilliantly ingenious fashion. He realized that the motor strength was equal to the product of the magnetic field strength of the magnet and the *length* of coil contained within the magnetic field; that is:

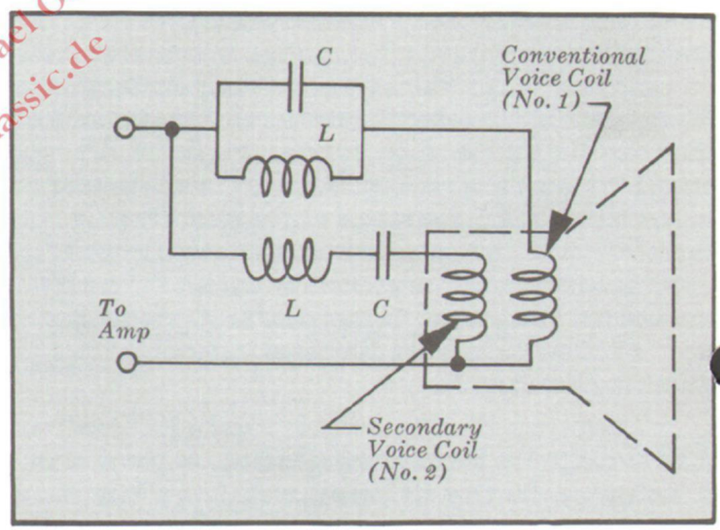
Motor strength = Bl, where
B = magnetic field strength
l = length of coil in the magnetic field.

He then began to look at the Bl product in a different way. He reasoned, suppose l could be, in effect, *varied with frequency* in such a manner that a lower value of Bl in one frequency range would not effect a higher value of Bl in another range and vice-versa. Watkins, at this point, began to see clearly how to solve this enduring problem, and also how to embody it in a loudspeaker system.

The Infinity/Watkins Dual-Drive Woofer

Figure 2 shows the mechanization of the principle. A second voice coil is wound over the conventional voice coil, and is driven by a series LRC (inductance-resistance-capacitance) resonant circuit adjusted to resonate at the fundamental resonant frequency of the woofer in the enclosure. In addition, it can be shown that if the main voice coil can be disconnected at resonance, a further increase in acoustic output occurs. This can be accomplished with a parallel LRC resonant circuit in series with the main voice coil.

Figure 2



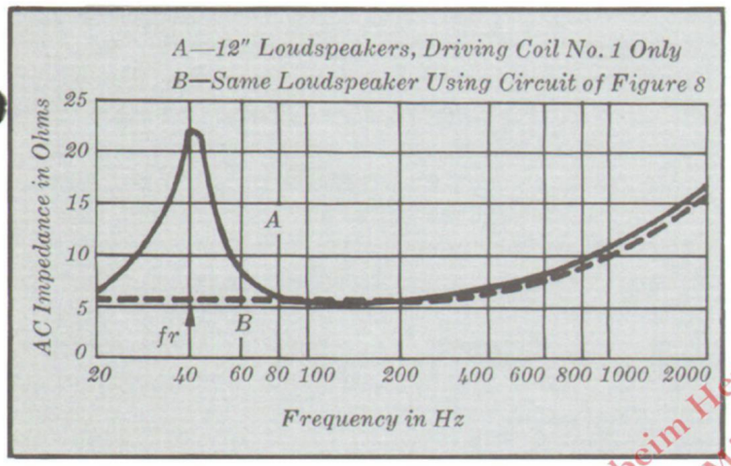
The conclusion, then, is simple. With proper design of inductor L and capacitor C, the LRC circuit presents almost zero impedance one octave either side of resonance, to effectively remove the secondary voice coil from the current. Furthermore, the parallel LRC circuit in series with the conventional voice coil effectively removes it from the circuit at resonance. Therefore, instead of the usual large increase in impedance at resonance, the impedance will remain virtually constant throughout the *entire* bass range.

**Manufactured by Infinity Systems, Inc. under license by Watkins Engineering, Inc.*

At this point, it should be noted that Mr. Watkins did not violate the laws of physics. A second motor is merely added, which, because it is of different size, generates less back-EMF and presents lower impedance to the driving amplifier, allowing more *wattage intake* to the speaker in the area of resonance (essentially, the resonance is eliminated), thereby providing more bass response.

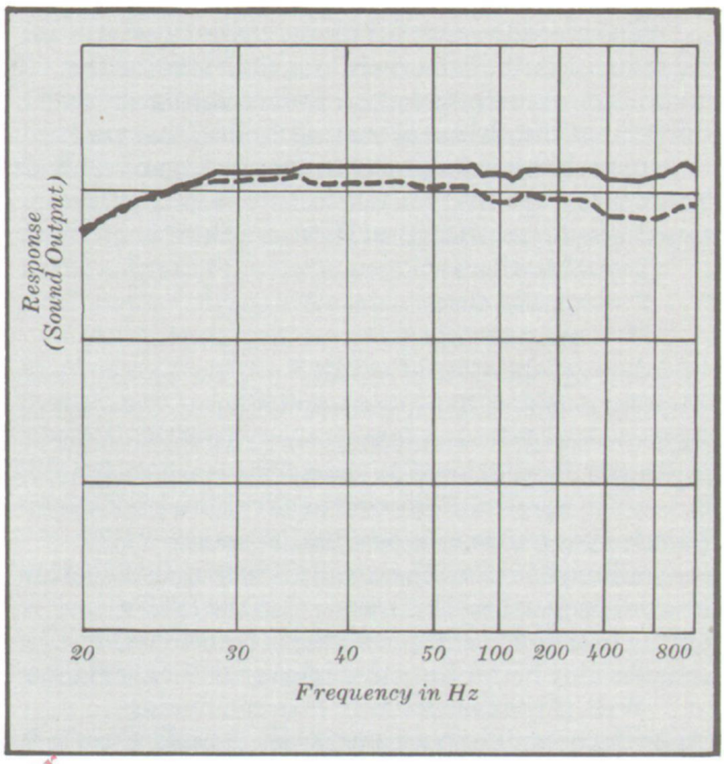
Watkins is simply using the wattage that was there all the time in a given power amplifier, but was never being used in the bass range because the impedance barrier at resonance (see Figure 3) prevented it from being accepted.

Figure 3



What has been embodied in the Infinity-Watkins Woofer is a revolutionary, yet simple, solution to the problem of extracting bass frequencies from a box. The extraordinarily wide and linear frequency response (see Figure 4), the almost perfect impulse response, and the relatively high efficiency are truly a panacea. The listening experience takes on a new dimensional quality, a relaxed ease of almost overpowering low-frequency energy, *like live music itself.*

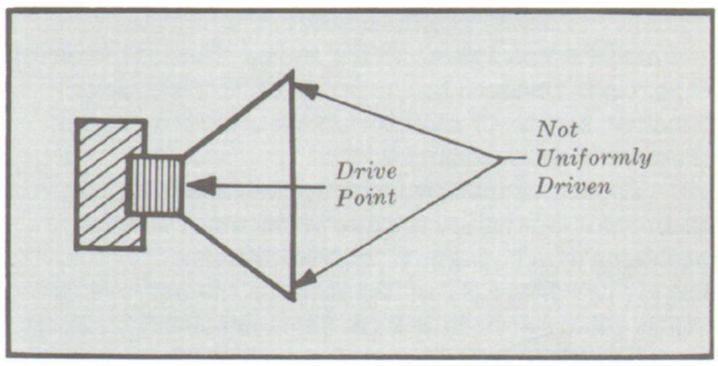
Figure 4



EMIT: The Infinity Electromagnetic Induction Tweeter

For the most realistic reproduction of high-frequency sound energy, electrostatic tweeter (EST) devices still reign supreme. There are two basic reasons for this phenomenon. The push-pull electrostatic tweeter is uniformly driven over its entire surface area, as opposed to a conventional tweeters being driven only at a central point. The portions of a cone which are not uniformly driven must coast along with more or less the same motion as the driven part (See Figure 5).

Figure 5



It is obvious that various kinds of distortion result from the fact that the non-uniformly driven portion of the tweeter cannot accurately follow an input audio signal. It then becomes easy to understand that the EST can readily follow the input signal, since all of the

radiating area is *equally driven* with the very powerful electrostatic forces.

The second reason for electrostatic tweeter superiority is that the mass per unit area of the diaphragms is extremely low. In fact, it is lower than the mass of the airload operating on the speakers to extremely high frequencies, usually beyond 25 KHz. This concept is called the inertial propensity of the tweeter and is expressed as Newton's third law,

F = MA, where:
F = applied force
M = mass of object
A = acceleration of object.

Obviously, with a given applied force, the acceleration of the diaphragm of any tweeter device is directly proportional to *mass*. This is where the EST has enormous advantage over conventional devices. Its mass per unit area is 5 to 10 times smaller than conventional devices, thereby having greatly superior inertial properties. This means that the EST's ability to follow fast input signals (transients) is considerably better than that of conventional devices.

Well, if the case for EST is so convincing, then why doesn't everyone use them in one for or another? The answer is that these devices also have some very serious disadvantages, several of them virtually impossible to overcome in any practical way. The three major disadvantages are that EST's:

a) Are subject to voltage breakdown when overdriven.
b) Must be tranformer-coupled.
c) Have bad dispersion problems.

Voltage breakdown problems are probably the greatest factor in preventing their general usage. Since these are high-impedance devices and the output of audio amplifiers is low impedance, a matching transformer is necessary between them. This introduces both distortion and phase shift, which practically offsets the good quality of the EST. Finally, in their optimized configuration they have a tendency to *beam* high-frequency sounds at the listener —which destroys some of the stereo effect. This effect is partially resolved by the fact that EST's usually function as dipole radiators. However, this makes them very room-sensitive.

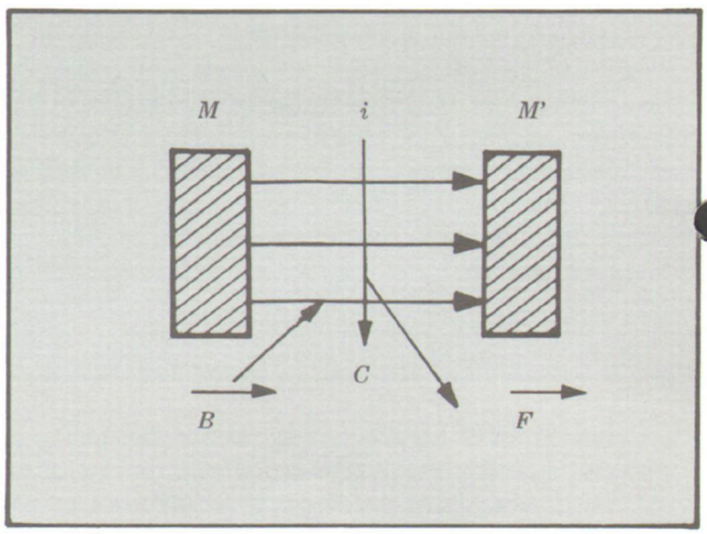
To recapitulate, we have spoken about EST being audio state-of-the-art in spite of the many serious problems which plague it. Indeed, Infinity has always used EST in its "state-of-the-art" Servo-Statik I and Servo-Statik IA. The scientists at Infinity have been thinking about these problems for many years. Specifically, if a *magnetic analogue* to the EST utilizing EMI could be made, essentially all the EST problems could be eliminated. The problem is, however, that the electrostatic forces involved are enormous; thus, accurately controlling the moving diaphragm and rendering the device reasonably efficient would be complicated to the extreme. And even the best alnico magnets could not create the necessary diaphragm control and requisite efficiency to construct a viable magnetic tweeter.

The dilemma persisted until a number of years ago, when Infinity scientists heard about experimentation with a new *rare earth* magnetic material, Samarian Cobalt. Our technical staff immediately realized that this material could be the key to the magnetic analogue of the EST. Samarian Cobalt, having energy products four to seven times greater than alnico, could create the powerful forces *magnetically* that the EST create electrostatically.

It was this discovery of new *rare earth* magnetic technology, coupled with the theoretical panacea of line source radiation (to be discussed shortly), that allowed Infinity to construct an almost ideal method of reproducing high-frequency sound radiation.

The Infinity Samarian Cobalt tweeter is constructed in the following fashion: a diaphragm material was selected of exotic plastic material that permits high dissipation of heat. Onto this diaphragm a tiny microcircuit of conducting material is etched in a specific configuration which allows huge currents to pass through the intense magnetic field in a specific manner, creating a uniform motion of the diaphragm.

Figure 6



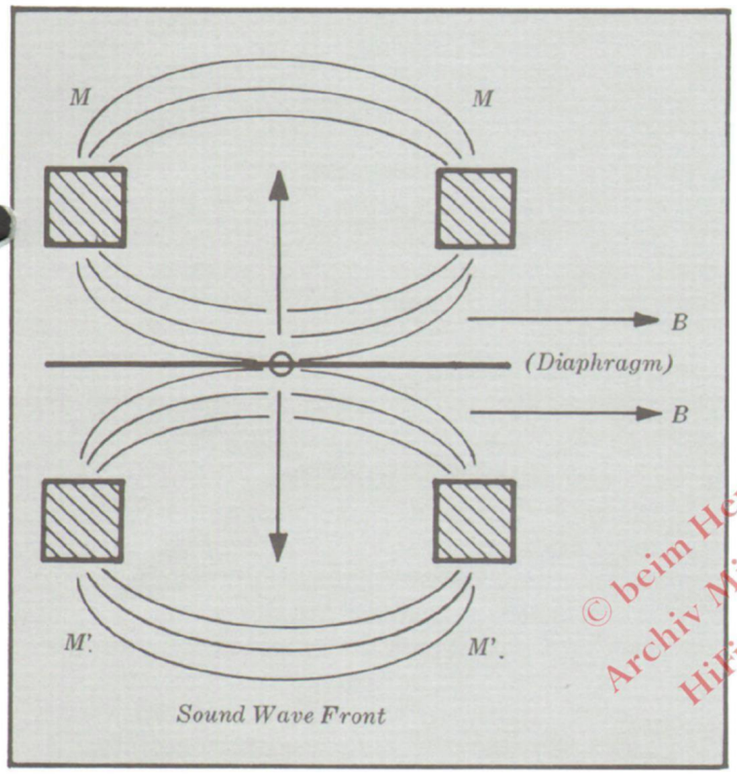
The Samarian Cobalt magnet.

As can be seen in Figure 6, Samarian Cobalt magnets M and M' create a magnetic field, B (left to right across the page.) A current, i, is then passed through a microcircuit conductor, C (from top to bottom of the page), and exactly perpendicular to the magnetic field B. Then, since F (the force on the conductor) is equal to B x i x l (where l is the

length of the conductor in the magnetic field), a force is produced on the conductor in a given direction (out of the page, towards the reader).

If, then, the conductor is attached to a lightweight diaphragm, the current flow in the intense magnetic field will cause the diaphragm to move in and out, depending upon the direction of the current flow, i. It is this motion of the diaphragm that causes high-frequency sound radiation.

Figure 7



Specifically, the device is mechanized in a push-pull fashion: the diaphragm, D, suspended between magnets M and M', is pushed and pulled according to the instantaneous direction of the applied current. The current is represented by the small circle on the diaphragm and the sound wavefront emanates as shown by the arrows and sound waves.

How successfully, then, has Infinity overcome the problems of the electrostatic tweeters?

Since the EMIT is a current device as we have seen, voltage breakdown is totally absent. In fact, the only input limit is the amount of power the diaphragm can accept without melting. Conventional cone tweeters are good for about 5 watts RMS before failing. The individual EMIT can easily dissipate 30 watts RMS with no failure and, used in multiples (which is always done), it can sustain even the most powerful amplifiers on the market today. EMIT, being a current device, obviously does not need a matching transformer for operation with an audio amplifier. This means that the EMIT is *directly coupled* to the output of the audio amplifier without being *predistorted* through the use of a transformer.

Another natural benefit that arises as a by-product from the EMIT is that the load presented to the audio amplifier is essentially resistive to beyond 50 KHz. (EST's present large capacitive loads to the amplifier which cause some of them to be extremely unstable, creating distortion and damage.)

The final benefit, and one of the most important, of the EMIT is that its horizontal polar dispersion is nearly perfect. This makes it ideal for application in a line source sound generator, a concept to be explained in later paragraphs.

Assembling a diverse variety of radiators in a phase-concurrent manner.

The actual sound generators in the Quantum Line Source consist of the new 12" Infinity/Watkins Dual-Drive Woofer, a midbass coupler handling 200 to 600 Hz, a line source of special 1½" midrange dome drivers, and a 48-inch vertical strip of EMIT high-frequency drivers. Though each of the 4 elements has its own mass/acceleration characteristics, all work meticulously in phase.

The importance in having coherent phasing is that it determines the ability of speakers to preserve stereo imagining when the listener varies his position from side to side in front of the speakers. In a perfect system, the listener should be able to move anywhere in the designed listening area without losing stereo imaging, just as would be the case if he were listening to a performance and moved about in front of the musicians.

In the Quantum Line Source, we designed an unusual group of 1½" dome drivers, paying careful attention to phase and acceleration capability. Then we added a phase-coherent midbass driver to match the acceleration times and acoustic output between the midrange Line Source and the Infinity/Watkins Dual-Drive Woofer. This midbass coupler, expressly handling frequencies from 200 to 600 Hz, is a critically important element in the Quantum Line Source concept—it is within this range that approximately 50% of music fundamentals lie, and we felt it was vital to provide a driver that would speak with absolute accuracy within this range.

Transmission-line loading is used to avoid back pressure on the driver, and thus eliminate constraints on its speed of response; prevent reflection of waves back into the driver; and permit further steps to be taken to achieve linear phasing.

Assembling radiators into a line source, and what this accomplishes.

Infinity has explored the forefront of speaker technology to design the very best sound reproducers in each band of the sound spectrum. And we have gone to a considerable amount of trouble to design, configure, and phase them so that they work together to produce flat frequency response over the entire spectrum, with great power-handling capability. But, as you will recall from the beginning of this paper, our ideal would be to combine them into an infinitesimally small "point source"—an obvious impossibility.

Why would we wish to have that point source? Because it would radiate equally in all directions, both horizontally and vertically. In other words, it would have equal polar dispersion in both horizontal and vertical planes. If this condition existed, a listener could walk all around a pair of speakers, and even listen from the top of a stepladder, without losing exact stereo imaging. This is the same condition that prevails at a live performance, where moving the listener's position may result in amplitude change —hearing the instruments more or less loudly— but no loss of the stereo imaging.

In normal listening, however, the listener does not walk all around the speakers, and he does not perch on top of a stepladder, or listen from under a table. Instead, he occupies a position somewhere between 90° to the left of the speakers and 90° to the right. And his head is usually within a foot or two up or down from the position of a person's head when he sits in a chair or on a couch somewhere in front of the speakers.

It is this volume of space that concern us, from a practical viewpoint, then, and within this volume we can achieve sound propagation that duplicates that which would be generated by a point source. This comes from utilizing the unique properties of *line source radiation.*

If our matched drivers are placed in a 48-inch vertical line, one above the other, and if these drivers are so constructed that they have superb horizontal polar dispersion, then they have more than the necessary vertical polar dispersion in order to cover the six feet or so that sitting and standing listeners' heads may be occupying.

The Line Source is a long vertical line of virtually massless high-frequency radiators radiating beyond 20 KHz over a 180° horizontal arc, from full left to full right, and with nearly perfect phase response and frequency response. To the listener within the fan-shaped slice of space just described, *the music sounds the same as if it came from a point source.* In fact, to return to the beginning, he receives the music in exactly the reverse of the manner in which it went into the microphone from the musicians' throats and instruments. Thus, to him, it sounds as if he is listening to the performance at the same point from which it was recorded.

Summarizing

The Infinity Quantum Line Source consists of a number of radiators with unusual characteristics:

The Infinity/Watkins Dual-Drive Woofer employs two voice coils, with the second (lower impedance) voice coil taking over at resonance and presenting a low impedance path in the region of resonance. Thus the amplifier never sees an impedance peak; only a flat impedance curve. This permits bass response, combined with efficiency of the speaker.

A midbass coupler is assigned frequencies from 200 to 600 Hz; its acceleration capability and phasing are carefully matched to its adjacent radiators, the Dual-Drive Woofer and a midrange Line Source of six 1½" dome drivers.

An Infinity Electromagnetic Induction Tweeter (EMIT) has been developed using the rare-earth material Samarian Cobalt, to provide a configuration that is the magnetic analogue of the electrostatic, and requires no transformer. EMIT, a 48-inch vertical line of virtually massless high-frequency radiators combines 180° horizontal dispersion with Line Source vertical radiation for maximum dispersion of high frequency information.

The perfection of the Quantum Line Source, which brings together several high-technology advances, has effectively removed the speaker system as a source of inaccuracy.

Infinity

We get you back to what it's all about. Music.

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