## TRANSLATING TECHNOLOGY AND FEATURES INTO BENEFITS

**Feature:** Heavy, totally inert, non-resonant enclosure.
**Benefit:** Exceptionally clean and articulate bass and mid-bass response. Voice and music emerge with superior clarity and far less tonal coloration.

**Feature:** Time-aligned drivers in a stepped-array configuration.
**Benefit:** Low and high frequencies arrive at the listener's position at the same time. The result is better musical balance from the deepest bass to the highest treble.

**Feature:** Four pole crossover network with excellent phase linearity and sharp cutoff slopes.
**Benefit:** Driver distortion is reduced resulting in open, clean, and musical sound with proper stereo imaging.

**Feature:** Iso tips on the bottom of the speaker enclosure.
**Benefit:** Acoustic isolation of the speaker from the room and floor reduces vibrations which mask sound and create sonic disturbances in music and voice.

**Feature:** Amplified, servo-controlled subwoofer system.
**Benefit:** Adds a dimension of low frequency performance found only in extremely expensive and larger systems.

Infinity®



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# modulus™

**TECHNICAL WHITE PAPER**

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# modulus™ TECHNICAL WHITE PAPER

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*Leon Kuby*
*November, 1989*


## INTRODUCTION

In the design of the Infinity Modulus loudspeaker system, a significant amount of attention was paid to even minute details, all of which affect the ultimate performance of the system. It is the purpose of this technical paper to explain in simple, understandable terms the design theory behind Modulus and why Infinity feels these concepts result in a speaker which offers very special performance characteristics.

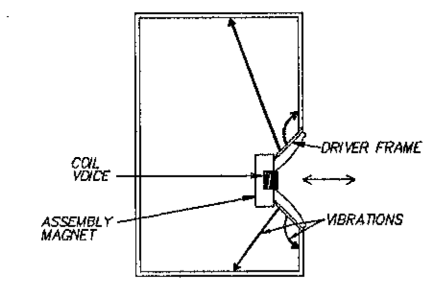
## THE ENCLOSURE

In terms of the importance of a loudspeaker system's components, the enclosure assumes as significant a role as the drivers or any other part of the system. The enclosure must be designed for maximum rigidity and damping. This reduces spurious resonances, which create serious sonic anomalies which detract from the total musical experience. Laboratory tests have shown that improperly designed enclosures radiate considerable parasitic sound pressure waves which are developed by the resonating walls of the enclosure. These unwanted resonances combine with and excite the musical wave forms generated by the drivers, and the result is less articulate sound throughout the entire musical range.

There are two main sources of enclosure vibration:

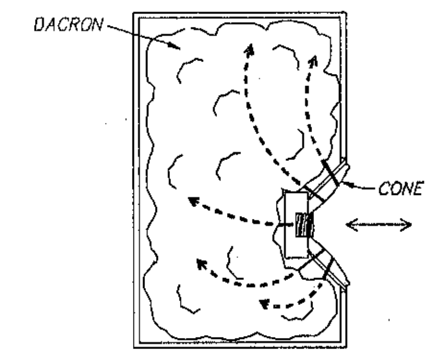
1) The reacting force created by the movement of the driver's voice coil in response to the input signal. This is transferred directly to the enclosure through the driver's frame as a solid borne wave. (Refer to Diagram 1.)

**Diagram 1:**




2) Sound pressure generated within the enclosure by the vibration of the driver's diaphragm in response to the input signal. This type of interference can generally be reduced substantially by the use of an adequate sound absorbing material (such as dacron) suitably distributed inside the enclosure. Choice of the appropriate type of absorptive material and weight is critical to proper absorption. (Refer to Diagram 2.)

**Diagram 2:**



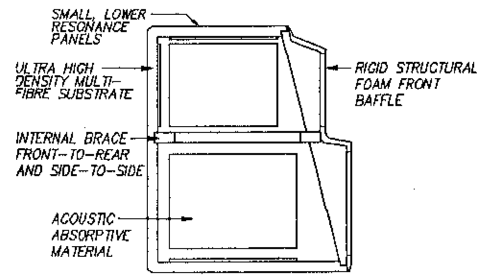

It is essential that the enclosure be constructed solidly and be made as inert as possible. By the use of internal bracing and special materials (which provide absolute rigidity), parasitic resonances and vibrations created by the enclosure can be minimized substantially so they will not interfere with the sound emanating from the speaker.

Modulus was created with close adherence to all of the basic concepts of proper enclosure design. Nothing was overlooked or treated lightly in view of Modulus' exceptionally stiff, damp, and virtually non-resonant enclosure.

Smaller speaker enclosures tend to generate less spurious resonances due to vibration than larger ones. Because there is less surface area to vibrate when the speaker is reproducing low frequencies. When the small enclosure is properly braced, it becomes even more rigid and unwanted vibrations are further damped. Due to the stiffness and damping of the Modulus enclosure, the resonances that are generated move up in frequency which makes them less intense and more directional, and their interference with musical integrity is minimal. Higher frequency resonances produce less acoustic energy which in turn creates less acoustic involvement with the enclosure, drivers, and room. High frequency resonances are easily damped by the use of special absorptive panels adhered to the inside of the enclosure. These spurious high frequency vibrations are absorbed by the panels, converted to heat, and dissipated so they do not interfere with the sonics produced by the speaker system.

The Modulus enclosure is constructed for optimum rigidity which results in extremely low vibration. The enclosure composition consists of 60 lb., ultra-high density multi-fiber substrate which resists flexing and vibration. Internal bracing adds further rigidity to the enclosure, and several sheets of absorptive material have been laminated to the enclosure walls to reduce any remaining vibrations to a minimum. (Refer to Diagram 3.)

**Diagram 3:**




The design of the Modulus enclosure - a tightly-sealed acoustic suspension type - was chosen because of its inherent low distortion and faster transient characteristics[1].

## TIME ALIGNMENT

In conventional speakers, high frequencies arrive at the listening position before low frequencies due to the effect of the acoustic centers (voice coils) of the drivers. (Refer to Diagrams 4a and 4b.)

**Diagram 4a:**

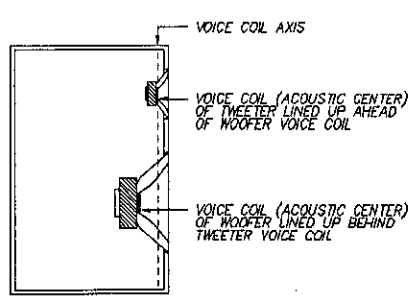
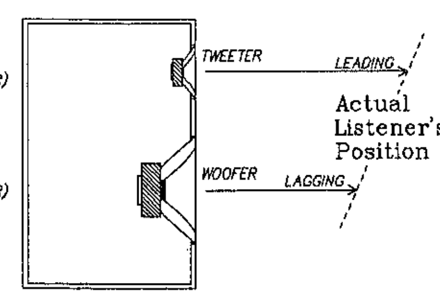
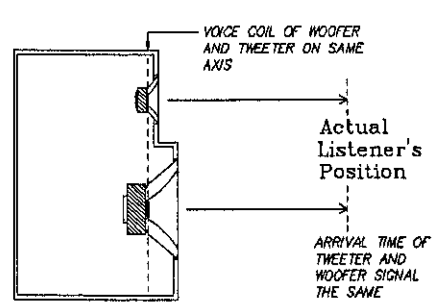



**Diagram 4b:**




A time-aligned system has both voice coils on the same axis enabling the low and high frequencies to reach the listening position at the same time. (Refer to Diagram 5.)

**Diagram 5:**




Essentially, a non-time-aligned driver array creates the optimum listening position for the system at floor level rather than at ear level of a seated listener. (Refer to Diagram 6 on the following page.)

[1]A.N. Theile: "Loudspeakers in Vented Boxes," Journal Audio Engineering Society, VOL. 19, May 1971



This causes time smear (certain harmonics that are not perfectly clear, lack of spaciousness among instruments, loss of front-to-rear detail) because it is possible that certain harmonics can reach the listener before the fundamental. There have been attempts to align the acoustic centers of a speaker system by angling the front baffle upwards which will essentially delay higher frequencies so they reach the listener at the same time as the lower frequencies. Although this method enables the higher frequencies to delay their approach to the listener permitting the lower frequencies to catch up, the maximum output of the system is not directed at the listener but rather above him. This results in a loss of high frequency response due to directionality. (Refer to Diagram 7.)

**Diagram 6:**

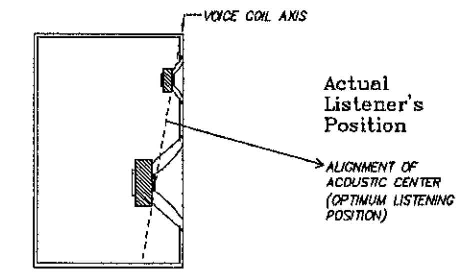
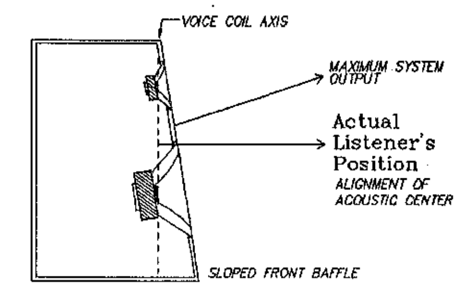
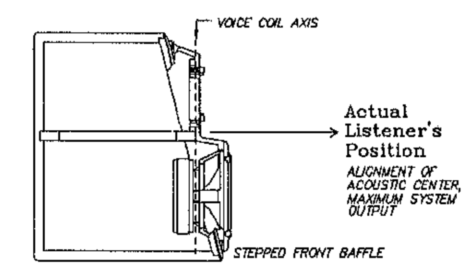



**Diagram 7:**



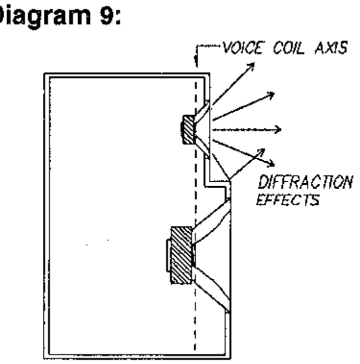

Modulus utilizes a stepped front baffle design which aligns the acoustic centers (voice coils) of the drivers so that the overall pressure response is coincident. The direct sound of the fundamental and its harmonics arrive uniformly at precisely the same time at the listener's position. (Refer to Diagram 8.)

**Diagram 8:**



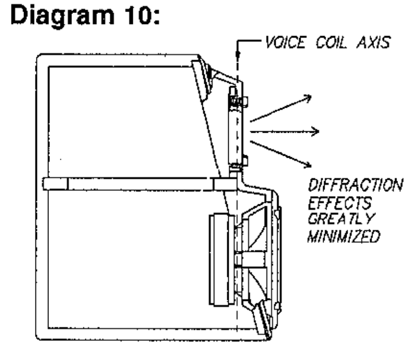

Virtually all speakers which are configured with stepped time alignment utilize dome tweeters which have a broad radiation pattern in the horizontal and vertical plane. A broad vertical pattern, when used with a stepped front enclosure, creates serious diffraction effects resulting in smeared imaging and harmonic anomalies. (Refer to Diagram 9.)

**Diagram 9:**




Modulus employs Infinity's EMIT™ tweeter which offers limited dispersion in the vertical plane due to its special geometry. Diffraction effects created by the stepped front baffle are, therefore, greatly minimized. (Refer to Diagram 10.)

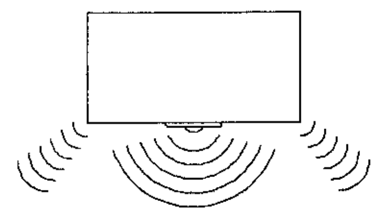
**Diagram 10:**




Diffraction, or boundary reflection, occurs when sound waves from the drivers bounce off the front of the cabinet. These unwanted reflections mix with the direct sound waves of the speaker system creating smearing and a loss of spaciousness. (Refer to Diagram 11 on the following page.)

The front baffle of the Modulus loudspeaker is composed of an extremely lossy but rigid structural foam material which dampens mechanical vibrations that may be transmitted from the front surface of the enclosure. The front baffle is also sculptured for optimum dispersion of higher frequencies thereby reducing diffraction. This results in sound that is more spacious with greater inner detail and exceptionally stable stereo imaging.

**Diagram 11:**



Diffraction, or boundary distortion, is caused by sound waves reflected off the front of the enclosure

## THE DRIVERS

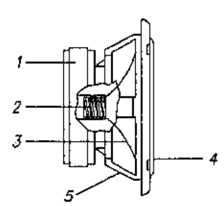
Drivers, as they presently exist, are reasonable and acceptable compromises in many operating areas. This is not to say, however, that virtually any of these areas cannot be improved by the use of innovative engineering techniques. What was considered satisfactory a year or two ago may no longer be acceptable if the search continues for major improvements in sonic quality. Infinity has always developed its own technological advances to solve inherent problems in drivers, and it was necessary to do so again in the design of Modulus. Our engineers examined existing driver technology with the goal of finding a way to improve upon the accuracy of music and voice reproduction. During the months of development, a number of significant problems were resolved as we worked on a new woofer with special electrical and acoustic characteristics as well as a refinement of our EMIT tweeter which now had the requirement to operate in the mid-high frequencies as well as in the extreme highs.

## THE LOW FREQUENCY TRANSDUCER

The Modulus woofer is comprised of the following main elements: (Refer to Diagram 12.)

1. Magnet and magnet assembly
2. Voice coil assembly
3. Diaphragm (cone)
4. Flexible suspension system
5. Frame

**Diagram 12:**




Of all these elements, only the voice coil assembly is electrical in nature. The others are mechanical or magnetic.

The magnet is essentially the heart of the entire magnetic structure and produces magnetic energy measured in gauss of flux. It is encased within a magnetic return housing (commonly referred to as a pot) which forms the structural support for the entire magnetic assembly. This structure must be extremely rigid in order to maintain the critical tolerance of the entire assembly.

The magnetic assembly employed in the Modulus woofer is carefully constructed with a concentric voice coil gap which assures the same intensity of magnetic energy throughout



the entire circle. If magnetic intensity is unequal, the voice coil, and subsequently the cone, will not move with precise linearity, thus creating audible distortion.

The voice coil is the only electrical element found in a dynamic driver. It is connected directly to the output of the power amplifier, usually through a crossover network, and is responsible for the movement of the cone. It is the voice coil which accepts the high current produced by the power amplifier, and it is for this reason that it must be constructed of special material in order not to char or burn under highly dynamic conditions. The voice coil wire is wrapped on a specially constructed high temperature polyamadol former which uses a material similar to that used in flameproof coveralls worn by fire fighters and race car drivers. This method is superior to the use of an aluminum former in the same application because an aluminum former can degrade from the transient performance of the driver if it extends beyond the top plate and pole piece where there is no flux.

The Modulus woofer uses a 13mm voice coil with a diameter of 25mm. This carefully constructed part is designed to remain perfectly concentric, and it will operate in a linear manner even under heavy excursions.

The woofer cone converts mechanical energy into acoustic energy, and the conversion must be as efficient as possible to provide the greatest amount of acoustic power output for any given electrical power input. In a speaker, the quality of the output signal is far more important than its quantity (power). In this regard, the cone has the greatest effect on how a driver will ultimately sound. It is largely in this area that Infinity has achieved both sonic quality and high power handling by careful design of the cone which employs the proper materials to obtain the optimum ratio of strength-to-weight and rigidity.

During operation, the cone acts as a moving piston, which is prone to excessive forces acting on it. If by bending or wrinkling it cannot precisely follow the signals fed to it, the final acoustic output will be distorted from the original source. The cone can be constructed from a number of different materials. Choice of the material, as well as the mass, stiffness, size, and shape, depends largely upon the application of the driver and, more specifically, on what the designer wishes to accomplish.

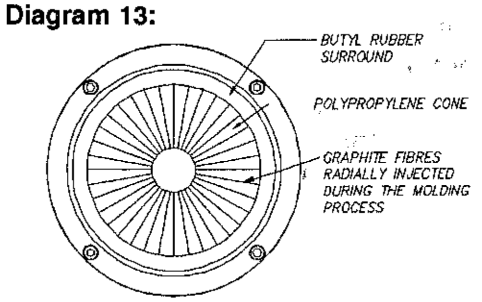
Driver cones are generally well-balanced at moderate excursions for approximately three octaves above their own free-air resonant frequencies. Their operating region (often referred to as the piston region) can be made more linear by substituting polypropylene for paper or coated paper as was achieved by Infinity in a pioneering series of drivers developed in the late seventies. However, in spite of the remarkable improvements in performance brought about by the use of polypropylene, the overall performance parameters of certain drivers, especially woofers, still required a great deal of improvement.

The Modulus woofer is a totally new design from its frame to its injection molded cone. It was the opinion of Infinity's engineers that design changes in every important parameter were required in order to achieve a major improvement in sonic quality.

To begin with, the woofer frame is an aluminum die-casting rather than stamped steel and will, therefore, hold its precise structural integrity indefinitely. Furthermore, a well-constructed die-casting is more inert than steel which results in less ringing, a phenomenon that is created by vibrations and which interferes with sonic integrity.

The cone material of the Modulus woofer is a composite construction consisting of a blend of polypropylene and graphite fibers. Fabrication is made under extremely high heat and pressure to injection mold the cone to very tight tolerances. The graphite fibers are molded into the cone in a precise pattern which flows from the center to the outer circumference. The result is excellent rigidity preventing cone breakup throughout the frequency range of the woofer. (Refer to Diagram 13.)

**Diagram 13:**




Superb rigidity of the cone material and a specially tailored curvilinear shape which provides added strength enable the designer to extend the woofer to higher frequencies than what is considered normal. This makes it possible to join the woofer and tweeter in a tight seam which yields smoother frequency response across the critical area of the crossover. In addition, the combination of polypropylene and graphite fibers produces superb damping of cone resonances (accomplished by the polypropylene) and rigidity (accomplished by the graphite fibers). The combined cone structure has less mass than previous polypropylene-only cones, permitting it to react more quickly to transients.

To sum up, the new Modulus woofer has the following salient features:

*Die-cast aluminum frame offers greater rigidity, less ringing, and a more elegant appearance. It will maintain its precise structure indefinitely.

*A composite cone of polypropylene and graphite fiber resulting in greater stiffness and exceptional damping of spurious cone resonances. This yields lower bass coloration combined with faster transient response.

*A curvilinear cone which adds strength for a more precise piston action while permitting the woofer to extend higher in frequency response.

*Heavy duty, rigid magnet structure is used to maintain perfect alignment of the voice coil. The voice coil is long which keeps it in the magnetic gap even under heavy excursions. This results in higher power handling and lower distortion.

*The flexible suspension system which supports the woofer cone at two points ensures high mechanical stability and accurate axial movement; the spider compliance connects to the outer periphery of the cone and the spider to the apex. The outer surround is butyl rubber which dampens standing waves of the cone. The resistance of this material is carefully chosen because it influences frequency response, sensitivity, transient capability, as well as the suppression of self-resonance.

*The inner suspension (spider) is molded in an accordion shape from a fabric impregnated with special resin which makes the suspension very stable and produces inordinately high



mechanical linearity even at extreme power levels. The spider is also acoustically transparent topreventexcessive stiffness due to the build up of trapped air beneath it. A secondary function of the spider is to prevent dust from reaching the magnetic gap.

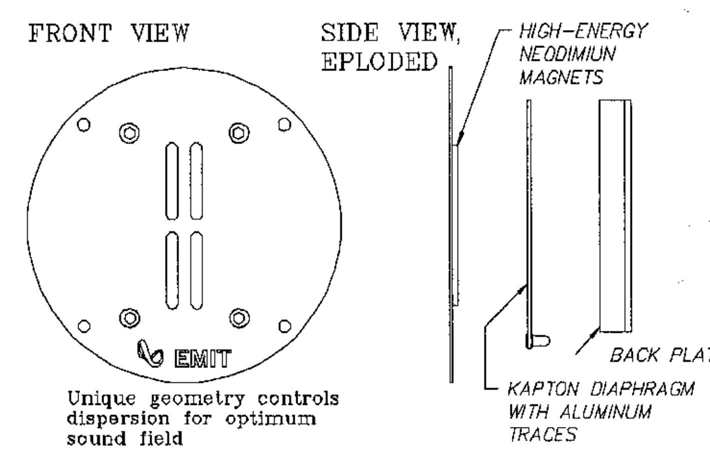
## THE HIGH FREQUENCY DRIVER

The Modulus Loudspeaker employs the newest generation of Infinity's famous EMIT$^{tm}$ (Electro-Magnetic Induction Tweeter) high frequency driver which was originally designed for the Infinity Reference Standard system. The EMIT$^{tm}$ combines an extremely light diaphragm made of kapton, which is about ten times lighter than conventional domes, and rare earth neodymium magnets aligned in a push-pull configuration for maximum efficiency and minimum distortion. The lightness of the moving diaphragm and the superior strength of the neodymium magnets enable the EMIT$^{tm}$ to extend in response to 45kHz, an astonishingly broad range. Extending frequency response beyond the range of normal hearing provides greater linearity within the musical range resulting in greater depth, clarity, and harmonic integrity.

The EMIT$^{tm}$ employs carefully designed apertures which provide extremely broad horizontal dispersion while limiting vertical dispersion to prevent reflections from the floor and interaction with the other drivers.

When the original EMIT$^{tm}$ was in its early design stages, Infinity engineers had the choice of employing kapton, or a super-light metal for the diaphragm. After countless hours of measurements and listening, it was decided to use kapton because of its inherent light weight and excellent damping qualities. Metal diaphragms have a tendency to ring; and even if they are kept extremely light and the ringing occurs at frequencies well above the range of hearing, this annoying phenomenon reflects back into the musical range manifesting itself as an edginess that masks the true harmonic content of voice and musical instruments. (Refer to Diagram 14.)

**Diagram 14:**




Due to its unique design and high quality component parts, the EMIT$^{tm}$ guarantees effortless transient response and low distortion in the upper ranges of human audibility, a range that lesser tweeters must strain to reach.

## THE DIVIDING NETWORK

The crossover network is one of the most important elements in speaker system design. It controls the response characteristics of the drivers within their optimum operating frequency range while creating a seamless transition from driver to driver. The network must be designed for minimum distortion and optimum phase characteristics. It is for this reason Modulus employs a fourth order Linkwitz-Riley dividing network (24dB/octave.)[2] The advantages of this type of crossover are numerous and as follows:

*More symmetrical vertical polar response.

*Woofer and tweeter are wired in phase thereby preserving the harmonic structure of music and voice.

*More rapid attenuation in each driver's stop bands yields minimized audibility of the cone's breakup and other distortions.

*Each driver is attenuated 6dB at the crossover point, as opposed to 3dB down for other slopes, producing a flat overall amplitude response. This reduces the power requirement to the tweeter at crossover.

All crossover network components have heavy duty ratings and are capable of fail-safe operation even under the most taxing conditions. Capacitors were chosen for their sonic quality as well as their reliability over long periods of operation. Highest quality polypropylene capacitors are used in the signal path of the EMIT™. Inductors are precision adjusted to value on a bridge for adherence to specifications, and the high frequency potentiometer is a heavy-duty wire-wound device for high power capacity. An internal protection circuit guards the EMIT™ from damage due to overload conditions such as an overdriven amplifier.

The design of the Modulus crossover network was researched by actual measurement of the total system rather than by merely following a textbook formula. By designing the network in real time, the effects of phase, amplitude, and the reactive effects of the individual components were considered as they influenced performance and most especially sonic quality. Each time a component was changed, the system was put through a subjective listening test to insure cohesiveness and no deterioration in musicality. Non-linear time delay or excessive dynamic distortion can smear the sound, or shift the depth of the stereo image.

The input terminals are gold-plated for long-term resistance to corrosion and for the best possible contact with the speaker wire. Two sets of terminals permit the user to connect a separate power amplifier for the bass and treble for optimum power and clarity.

## DISPERSION AND TOTAL RADIATED POWER

Often overlooked as an element in judging speaker performance, dispersion and its associated total radiated power characteristics must be regarded as a significantly important performance parameter. Excellent dispersion, or the lack of it, can make the difference between superb and rather mundane reproduction of music and voice.

This important performance characteristic is especially difficult to achieve in two-way systems because of the manner in which the drivers generally operate. Poor dispersion of frequencies in the musical band blemishes the harmonic structure of a two-way system producing overall sonic characteristics that are hollow and lacking in proper balance and musicality. These sonic anomalies have been avoided in the design of Modulus by carefully blending the response of the low and high frequency drivers with an ultra-sophisticated crossover network and by using a newly formed woofer cone which extends the high frequency response of the woofer beyond 4000 hertz. This arrangement blends the upper and lower frequencies into a homogeneous sound presentation without audible seams, dips, and peaks. The sound stage is broad and well-defined with superb clarity and depth. Furthermore, special attention has been paid to the design of the enclosure which has an acoustically sculptured front panel to reduce diffraction distortion and to obtain uniform dispersion at all frequencies.

A dispersion diagram showing the radiating patterns of a driver is actually a loudness curve where the distance from the center of the circle indicates variations in two perpendicular planes.

A published specification might read, "dispersion: 120 degrees." This means if the listener moves 60 degrees to the left or right of the of the speaker's center axis, the relative loudness level will remain the same as it is along the center axis. This specification would be more meaningful and accurate if it also gave the frequency range over which dispersion remains 120 degrees.

Dispersion in a speaker is related directly to the size of the moving piston (cone) and the frequency being reproduced. High frequencies have short wavelengths while lower frequencies have progressively longer wavelengths. When the driver's cone is large compared to the wavelength of the frequency being reproduced, sound energy becomes focused, or beamed. Diagram 15 depicts this graphically. This loss of dispersion places a limit on the cone size and its ability to reproduce specific frequencies within a broad panorama.

**Diagram 15:**

Directivity patterns of loudspeaker in an "infinite baffle" as a function of $ka=\frac{2\pi a}{\lambda}$ where a=radius of cone

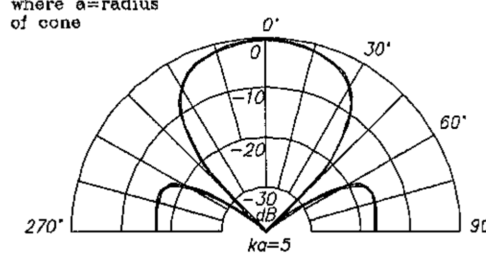



Diagram 15A is a 8" diameter loudspeaker at 5.7 kHz.

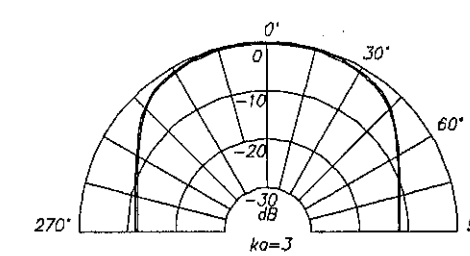



Diagram 15B is a 5" diameter loudspeaker, such as Modulus woofer, at 2.7 kHz. (Note improved dispersion.)

Infinity has taken several important and significant steps in the design of Modulus to create optimum dispersion and power response. The drivers, for example, are appropriately spaced from one another and are mounted in a straight line which maintains a constant distance

[2]S.H. Linkwitz, "Active Crossover Network for Non-Coincident Drivers," Journal Audio Engineering Society, Jan/Feb 1976.

between each driver and the listener regardless of the listener's horizontal position. This results in a constant arrival time of all frequencies which enables the brain to comprehend the sounds created by the individual drivers as a well-defined, cohesive sound source.

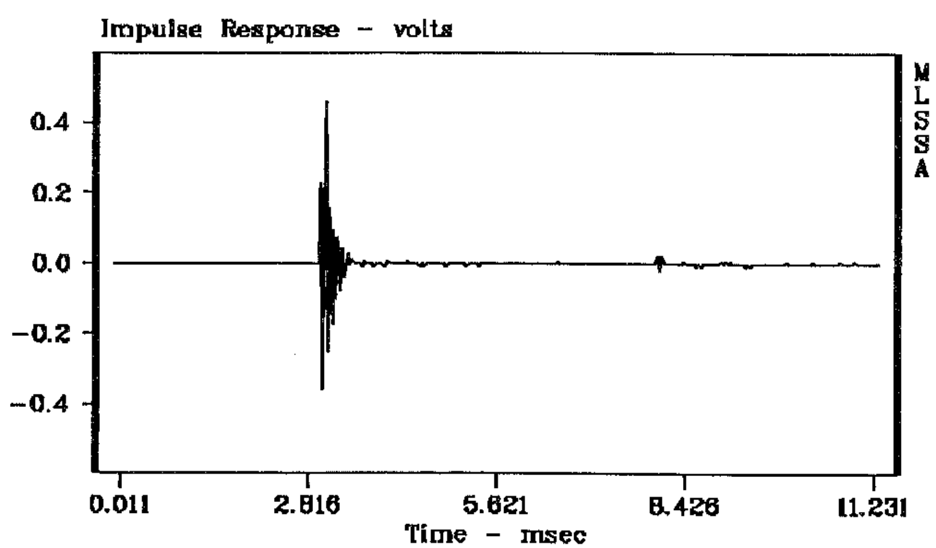
A polar response diagram reveals the horizontal dispersion characteristics that can be expected from a speaker especially when listening to the system off axis. At the extreme sides (70-90 degrees) most speakers fall off considerably in polar response as the frequencies involved become higher; however, speakers which offer broader dispersion produce more energy at the sides which results in a more accurate harmonic structure and musical integrity. Furthermore, wide dispersion enables the listener to sit off-axis and still obtain maximum power response. In other words, the listener does not have to be planted directly in front of the speaker, afraid to move to the left or right.

## IMPULSE RESPONSE

A speaker's ability to respond to fast transients can be shown by impulse response testing[4]. A pulse of known voltage is fed to the speaker, and a plot can be drawn to indicate how rapidly the speaker responds to the pulse and tapers off to zero. Theoretically, there should not be an overshoot; and if an overshoot in the response is noted, it should be damped very quickly.

Extensive testing of Modulus was done with our MLSSA FFT[5] (Maximum-Length Sequence System Analyzer). When compared to a famous competitive speaker, Modulus clearly shows faster damping with less ringing. (Refer to Diagram 16, which continues on the following page.)

**Diagram 16:**



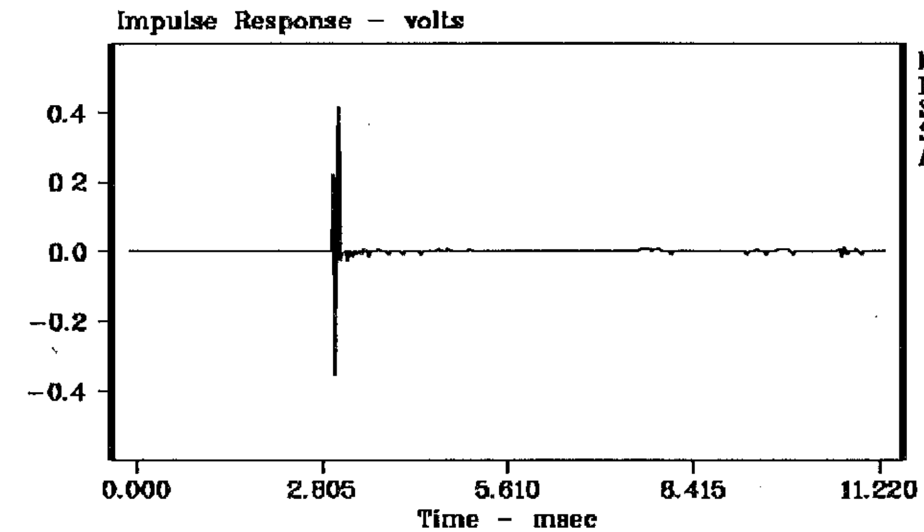

Impulse response of a popular, higher-priced competitive speaker system

[4] J. Berman and L. Fincham, "The Application of Digital Techniques to the Measurement of Loudspeakers," Journal Audio Engineering Society, June 1977.

[5] D. Rife and J. Vanderkooy, "Transfer Function Measurements with Maximum Length Sequences," Journal Audio Engineering Society, June 1989.



**Diagram 16, continued**



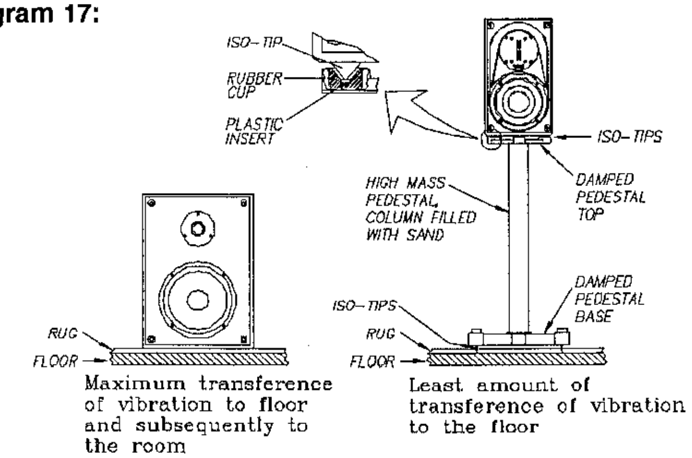

Impulse response of Modulus speaker system (note vastly improved decay)

## THE MODULUS PEDESTAL

Loudspeakers are generally mounted either directly on the floor, on a bookshelf, or on another piece of furniture such as a desk top or end table. This type of installation rarely offers optimum acoustic isolation between the speakers and the room which results in less than satisfactory bass response. Bass frequencies can be heavy and inarticulate. After a series of listening tests and measurements in various home environments, Infinity engineers became convinced that the only satisfactory method to achieve totally dry, articulate low and mid-bass performance was to install the speakers on pedestals specifically designed to decouple the speakers from the room. The pedestals must be heavy, acoustically damped pillars designed specifically to reduce acoustic resonances which can originate in the pedestals or from their direct coupling to the air of the floor. Employing a pedestal of this type adds mass to the speaker system which brings the resonance down in frequency where it can be further reduced by placing the pedestals on iso-tips. This acoustically isolates the system from the floor and results in deep, clean and solid bass even if the floor of the listening room is not firm.

The Infinity-designed Modulus pedestal represents the highest technology in speaker isolation. It is constructed of a heavy, die-cast aluminum center piece with a hollow center that can be filled with sand or lead shot to make it even more massive and inert and more able to dissipate sonic and kinetic energy. The acoustically isolated, quadrangulated base employs four iso-tips that are fully adjustable for optimum balance even on floors that are not level. All mass of the speaker and stand is transmitted through the exceedingly small tips which prevents transference of vibration energy from reaching the floor. The top mounting plate is similarly constructed of die-cast aluminum with three rubber cups plus hard plastic inserts fitted into the structure for additional damping. Three iso-tips fitted into the base of the speakers fit into the hard plastic inserts on the top plate which directs all of the speaker's mass on three specific small tips for maximum isolation. The rubber prevents the speaker from skidding which can occur when both the tips and receptacles are made from the same hard material. Rubber also acts as an impedance mismatch which further reduces the transferral of unwanted resonances. (Refer to Diagram 17.)

**Diagram 17:**



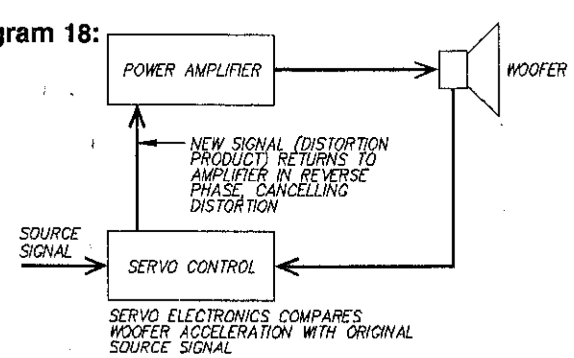

## THE MODULUS SUBWOOFER

Most speaker systems produce reasonable bass response, but very few can reach into the depths of bass with the clarity and power that can be reproduced by a subwoofer. This is true for larger systems as well as smaller satellites which require the assistance of bass enhancement. In other words, every speaker can probably sound better when connected to a quality subwoofer. It might be of interest to learn that Infinity developed its first speaker, the Servo Statik I, around a servo-controlled subwoofer; and we have been using subwoofers in various systems since that time.

It is our belief that unless a subwoofer is servo controlled, it cannot faithfully reproduce the lowest frequencies with total power and clarity. A servo system is actually a form of motional feedback which seeks errors in the bass region and corrects them. The form of distortion in the bass frequency range can be classified as linear and non-linear distortion. Linear distortion is caused primarily by the effects of inertia: the woofer cone, having mass, does not want to move instantaneously with the demands of the signal. Non-linear distortion is caused by the cone's suspension elements constraining movement at the ends of excursion, along with the lack of magnetic linearity over the entire excursion range. Both linear and non-linear distortions give rise to non-musical sounds that are not in the input signal.

To overcome the distortions normally produced by the woofer, Infinity employed an electronic servo-control system to "read" the woofer cone's acceleration. The cone's acceleration output is compared to the input signal by means of a device known as a differential servo amplifier. This amplifier generates a signal representing the difference between the electrical input signal and the woofer's acoustic output, and sends it back to the woofer's power amplifier in reverse phase (like inverse feedback in a power amplifier) to cancel distortion products which were produced by the moving system. (Refer to Diagram 18.)

**Diagram 18:**






This type of mechanical/electronic sampling is done instantly each time the woofer moves, always correcting any distortion which may exist at any given period of time, resulting in bass reproduction which is always deep, clear and distortion-free. While the correction of distortion is the main result of a servo-control system's function, there are additional benefits which, in total, produce the cleanest, deepest bass imaginable. A servo control will also extend bass response by almost an octave below its normal roll-off point. This permits the designer to use a smaller enclosure than he normally would while still obtaining deep bass well below the cutoff of the system if it didn't have a servo-control system.

The Modulus subwoofer is a complete, self-contained bass system which includes a powerful 250 watt RMS amplifier and all of the required controls to give the user complete flexibility.

A properly performing subwoofer will enhance the low frequency response of any music system; however, this excludes many of the add-on subwoofers which merely employ an outside power amplifier to drive the satellites and subwoofer. In our opinion, the subwoofer must be a complete system with its own power amplifier and servo-control system. In this way, the subwoofer is not subject to outside influences which could result in very poor performance. The Modulus delivers superior bass performance with a switchable 22Hz or 35Hz low frequency cutoff point. And this is achieved with exceptionally low distortion and fine control over the movement of the woofer cone. When placed in the proper location in the listening room, bass performance will be deep, dry, and exceptionally clear.

In our evaluation of subwoofer performance, we found that placement of the subwoofer enclosure in relationship to the room is of critical importance. If the subwoofer is too close to a wall or corner of the room, bass response can become heavy and muddy. At times, movement of the subwoofer even a few inches to the left or right, forward or rearward can make an astonishing difference in sonic balance and quality. Although bass is considered to be omni-directional below 80 or 90 hertz, and while this may essentially be true in theory, in practice, due to room reflections and other acoustic phenomenon, bass becomes more directional and harder to manipulate into a cohesive sound stage. With a little effort, however, it is quite possible to reproduce dry, clean bass in virtually any room. All it takes is patience and a little bit of hard work moving the woofer around.