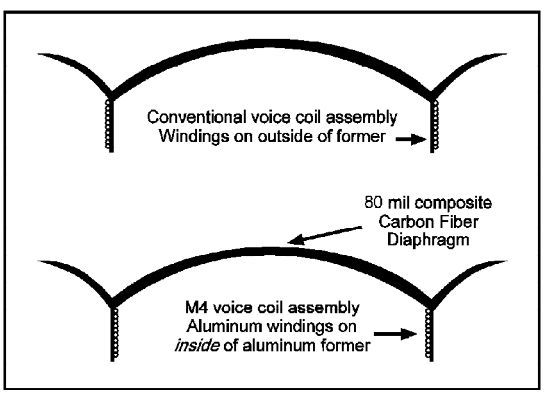
The result was a lightweight, extremely strong and stiff diaphragm that maintains a smooth frequency response to about 2200Hz.

Carbon Fiber

Although the original diaphragm proved very successful and was produced for a number of years, a new diaphragmhas been developed that is now used in all M4s. It takes advantage of newer strutural materials being made of a composite of carbon fiber and rigid foam bound with a resin compound. With the same mass (15 grams) and formed to the same shape as the original, this material considerably increases the diaphragm’s tensile, flexural, and impact strength. The inherently high internal damping of the carbon fiber material helps reduce breakup at higher frequencies. This material has also stretched the mechanical limits of the diaphragm to a point where even extreme physical abuse is unlikely to cause it damage.

Voice Coil

The M4 voice coil is edge-wound aluminum which is copper-flashed to allow proper solder joints on the beryllium copper lead-in wires. It is placed on the *inside* of an aluminum former. This in turn is fastened to the aluminum lower skin of the diaphragm. The consistent use of aluminum throughout the voice coil yields tremendous thermal conductivity, and conducts heat away from the voice coil area. Since voice coil impedance rises with heat (and less amplifier power is drawn), the M4 's impedance remains stable, even at full amplifier power. Power compression is less than 1 decibel at full rated power (200 watts).



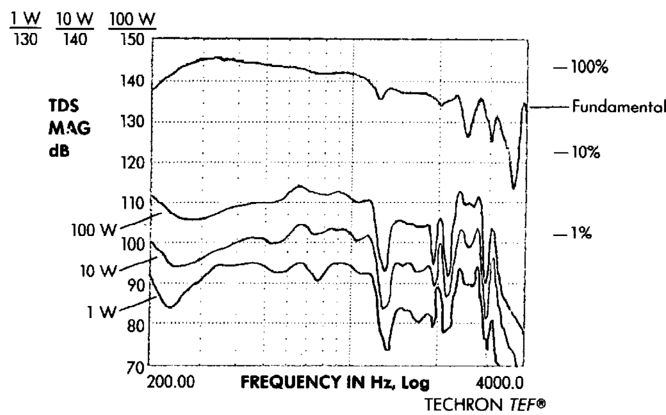
The voice coil design of the M4 uses some innovations that optimize it for its passband. Trying to "stretch" a devices passband to include more than one decade involves compromises that reduce fidelity and reliability.

Throat Distortion

Distortion is a prime consideration for our middle decade device, especially so since the existing array of commonly used devices (12 and 15-inch woofers, 2-inch compression drivers) have inherently high distortion levels due to operation at the fringes of their optimum passband

Throat distortion, for a given horn flare, acoustic power level, and frequency, is inversely proportional to the square root of the throat area. This means that as throat area decreases, distortion increases. The true "throat area" of a compression loudspeaker, however, is not the area at the throat of the horn (the exit of the driver). It is the area at the entrance to the phase plug, that is, the combined area of all the phase plug slits as seen by the diaphragm. This "phase plug throat" area, because it is smaller than the horn throat area, is the area that must be considered for the control of distortion and acoustic power output.

The M4's phase plug throat area is about 8 square inches. The phase plug throat area of a popular 2-inch exit driver (2-inch horn throat, that is) is about 1.25 square inches. Considering just this one factor, phase plug throat area, it would take more than six of this popular 2-inch driver to equal M4's acoustic power output and distortion level.



NOTES: B&K 2209 mic, all measurements made at mouth of horn. This is a composite graph. Resolution is 100 Hz.

3rd Harmonic Distortion is lower than 2nd at all power increments.

Phase Plug

In a compression driver, the sound radiating area of the diaphragm is much larger than the throat area of the horn. The sound from the diaphragm area must be collected and "compressed" down to the size of the horn throat while maintaining the complex phase relationships of the program material. The phase plug performs this function, and its design is critical to the fidelity of the transducer.

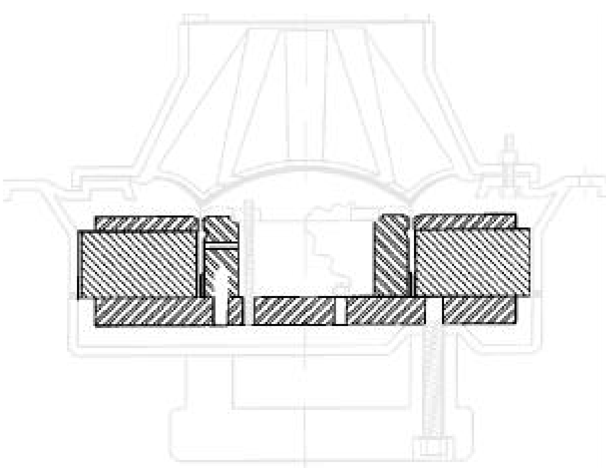
By careful design, the resonant cavity formed by this phase plug can be used to actually boost the driver's response over some narrow band of frequencies. The price paid is that the high-frequency response falls off much faster above the frequency of resonance, and that radical phase shift occurs over a very narrow band. The M4 does not resonate this cavity, and as a result exhibits a more natural response in the critical articulation region surrounding 2kHz.

Magnetic Assembly

A unique feature of M4's magnetic assembly is its position relative to the diaphragm and phase plug. On a conventional mid/high-frequency compression driver, the magnetic assembly is in front of the diaphragm and phase plug. Forcing the sound through the narrow opening in the pole piece contributes to throat distortion. In addition, this opening actually behaves like a short horn section whose flare is only randomly matched to the primary horn. On the M4, the magnet is behind the diaphragm and phase plug.

This placement avoids both the distortion and horn mismatch problems and allows the M4's throat size and other parameters to be selected without regard to the size of the opening in the pole piece.

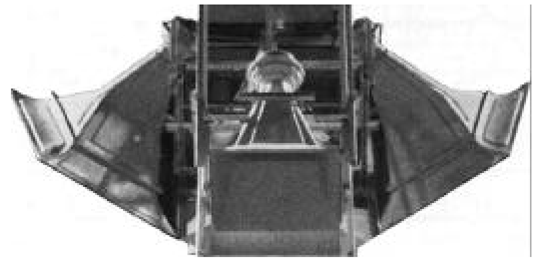
A survey of commercially available ferrite magnets shows that a 9.6 in O.D. (24.3 cm), 1.2 in (1.27 cm) thick ferrite magnet (approximately 5.2 kg) could be used to supply a 4.5 in (11.4 cm) diameter, 0.24 in (6.1 mm) high and 0.055 in (1.4 mm) wide airgap with 17.2 kilogauss. This approaches the highest flux density possible from a commercially available magnet, using good magnetic engineering practice. The final magnet design (patented) is shown below. The thick top and bottom plates reduce fringing and make this extremely powerful magnet structure a manageable weight of approximately 30 pounds.



Cross-section of the patented M4 magnet structure

Impedance

The impedance of a transducer is the complex load that it presents to the amplifier. Since all voice coils are made up of lengths of coiled wire, their impedance will have a reactive component that is frequency-dependent. The lowest impedance that a transducer can have at any frequency is the DC resistance of the voice coil. The M4 rated impedance is 8 ohms.



Providing Pattern Control

Once a high level of efficiency and acoustic power have been achieved from a transducer, the next design problem becomes delivering that acoustic power to the audience. This is accomplished by confining the acoustic energy to a defined unit of area, via a pattern control device, such as a horn.

Our attention now shifts back to the wavelength problem that we discussed earlier. Sound waves have a physical size, which is inversely proportion to frequency. Since our midrange device is reproducing a lower frequency than a conventional 1" or 2" driver, the associated horn must be much larger to allow pattern control.

The PC1500 series horns are designed to channel the immense acoustic output of M4 to a defined area, the audience. This provides increased direct sound level for listeners, and reduces energy delivered to the reverberant sound field. Directivity control, or "Q", is one of the most valuable tools available to the system designer, often allowing for sound system solutions to room problems. Maintaining dispersion control down to 250Hz may tame an otherwise hostile acoustic environment. The clever system designer will utilize the absorption of an audience along with well defined coverage patterns to reduce excitation of a very reverberant space, making both intelligible speech and natural music reproduction possible.

M4/Horn Specifications (200 Hz - 2k Hz Pink Noise)

Pattern-Control Horn	Sens. (1W/1M)	Q	Directivity Index
PC1594M	110.5	16	12
PC1594M-EXT	110.3	17	12
PC1564M	112.2	25	14
PC1564M-EXT	112.0	24	14
PC1542M	113.8	44	16
PC1542M-EXT	113.4	42	16
SH1894M	108.9	10	10 above 800Hz

The Rebirth of the Coaxial Horn

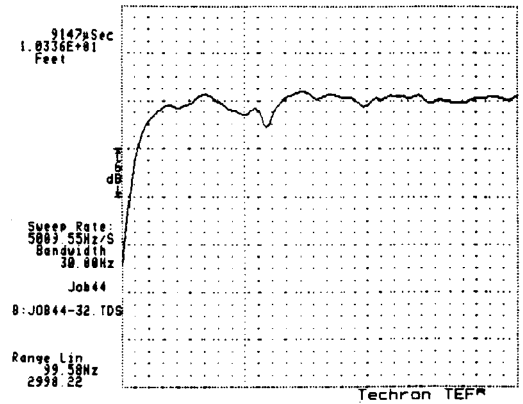
Obviously part of the definition of a coaxial is that two loudspeakers share the same axis. But, if they do share the same axis, do they have the same acoustic origin? And what about the acoustic centers? For a coaxial device to work properly, all of these questions must be resolved.

The concept of placing one horn inside another has been attempted in past decades, most notably by Blattner in the 1930's, Community (FRC, For Real Coaxial) in 1972, and Frazier in 1975.

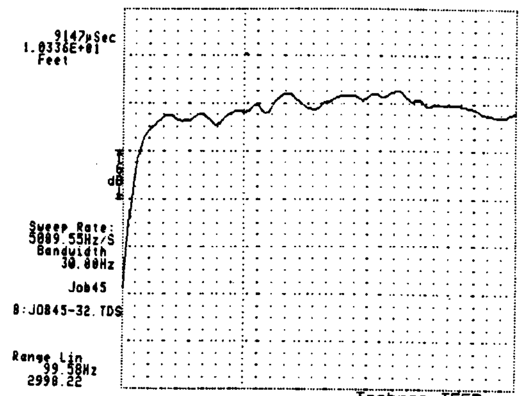
Unfortunately, since both horns are radiating from a unique point in space, the resulting pressure wave was severely distorted in the region of crossover due to phase cancellation. The horn within a horn was doomed until crossover and delay technology advanced to the point where the needed corrections in time and bandpass could be realized and implemented.

In 1987, consultant Jim Young of Ruston, Louisiana approached Dr. Eugene Patronis, a physics professor at the Georgia Institute of Technology. He needed assistance in reducing the size of an array he was designing for a church. Dr. Patronis suggested the concept of a horn within a horn, utilizing the components Mr. Young had hoped to use in the array.

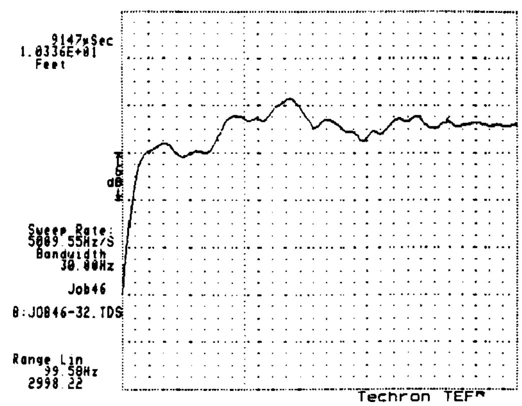
The M4 with pattern control horn was the midrange device of choice. It's high acoustic output and low distortion made it ideal for the installation. Dr. Patronis added an EV HP640 horn with an EV DH1A driver inside the Community horn to convert it to a coaxial unit. Next, a 24dB/octave crossover was added, and the optimum corner frequency was determined to be 1250 Hz. This solved the bandpass problems, but the offset acoustic origins remained. A Klark-Teknik 20-microsecond/step delay reconciled the origins, and provided a true mid/hi range device with excellent pattern control and smooth response. The rebirth of the horn within a horn was complete, and many companies rushed to develop similar products.



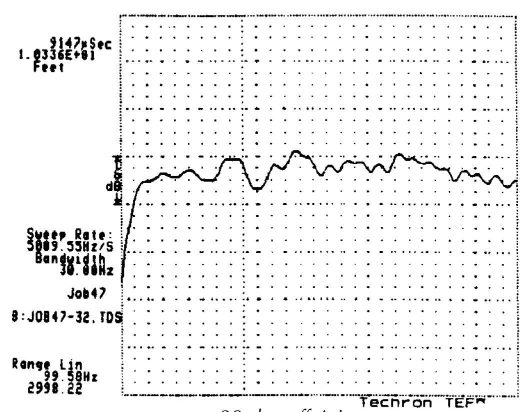
On-Axis



10 deg off-Axis



20 deg off-Axis



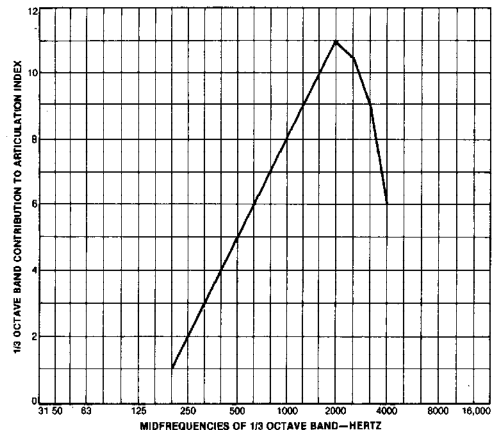
30 deg off-Axis

Voice-only System Design Using the M4

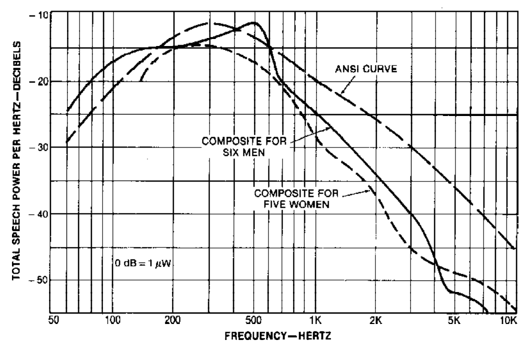
Voice-only applications, such as paging and warning systems, are often required to operate in difficult environments or over very long distances. The characteristics of the M4 make it ideal for these applications. Let us consider the design parameters for such a system.

A human voice has the highest power output in the 500Hz octave band. Consonants of speech (essential for articulation) are centered in the 2kHz octave band. A good voice device should provide high acoustic output and pattern control over a passband that extends to either side of these two critical octave bands.

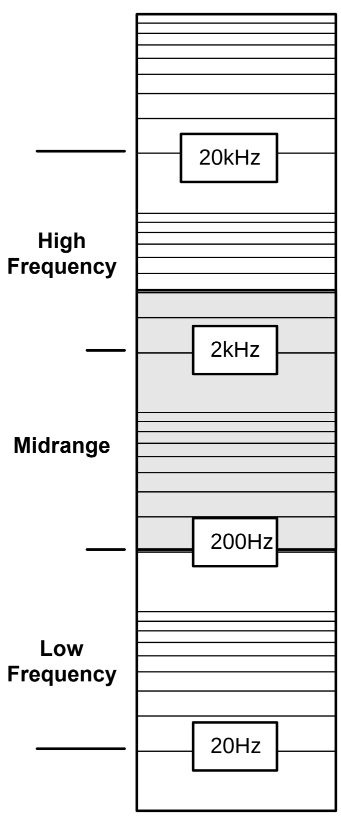
The unequalized response of the M4 is from 200Hz to 2000Hz. Given the M4's robust construction, this can be equalized within 3dB of flat response out to 4kHz, extending its response through the articulation range for human voice. Used with the proper horn, M4 completely satisfies the requirements for a high-level, voice-only system. The chart shows the levels that can be delivered by a single M4 at various distances with two typical horns. As always, these are conservative estimates based on the M4's capabilities at the lower limit of its passband. With proper equalization, M4 can typically exceed these levels by 3dB.

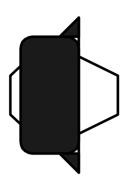


Contribution to articulation at one-third octave centers



Power spectrum of the human voice





M4 as a Voice-Only Device

	With 90x40 Horn (Q=10) DI=10dB	With 60x40 Horn (Q=16) DI=12dB
@ 4 '	138dBSPL	140dBSPL
@ 30'	120dBSPL	122dBSPL
@ 100'	109.5dBSPL	111.5dBSPL

3-Way System Design Using the M4

Let us now turn our attention to designing a full-range reproduction system using the M4. A full-range system should be capable of delivering the same acoustic power at each octave throughout its bandpass. If we use this criteria to design our system, we can begin by noting that the acoustic output of a single M4 can be up to 150 acoustic watts in the middle of its bandpass. To be conservative, we will base our estimates on the M4's output at 200Hz, the lower frequency limit of its pass band. At 200Hz, the acoustic output power of a single M4 is:

$$W_{out} = 200(.5) = 100 \text{ acoustic watts}$$

at 50% efficiency and full input power

How many low-frequency devices will be necessary to deliver the same 100 acoustic watts into the environment? Assuming a 200 watt power rating and 5% efficiency (both very typical specifications), our required number of bass speakers will be:

$$W_{out} = 200(.05) = 10 \text{ acoustic watts each}$$

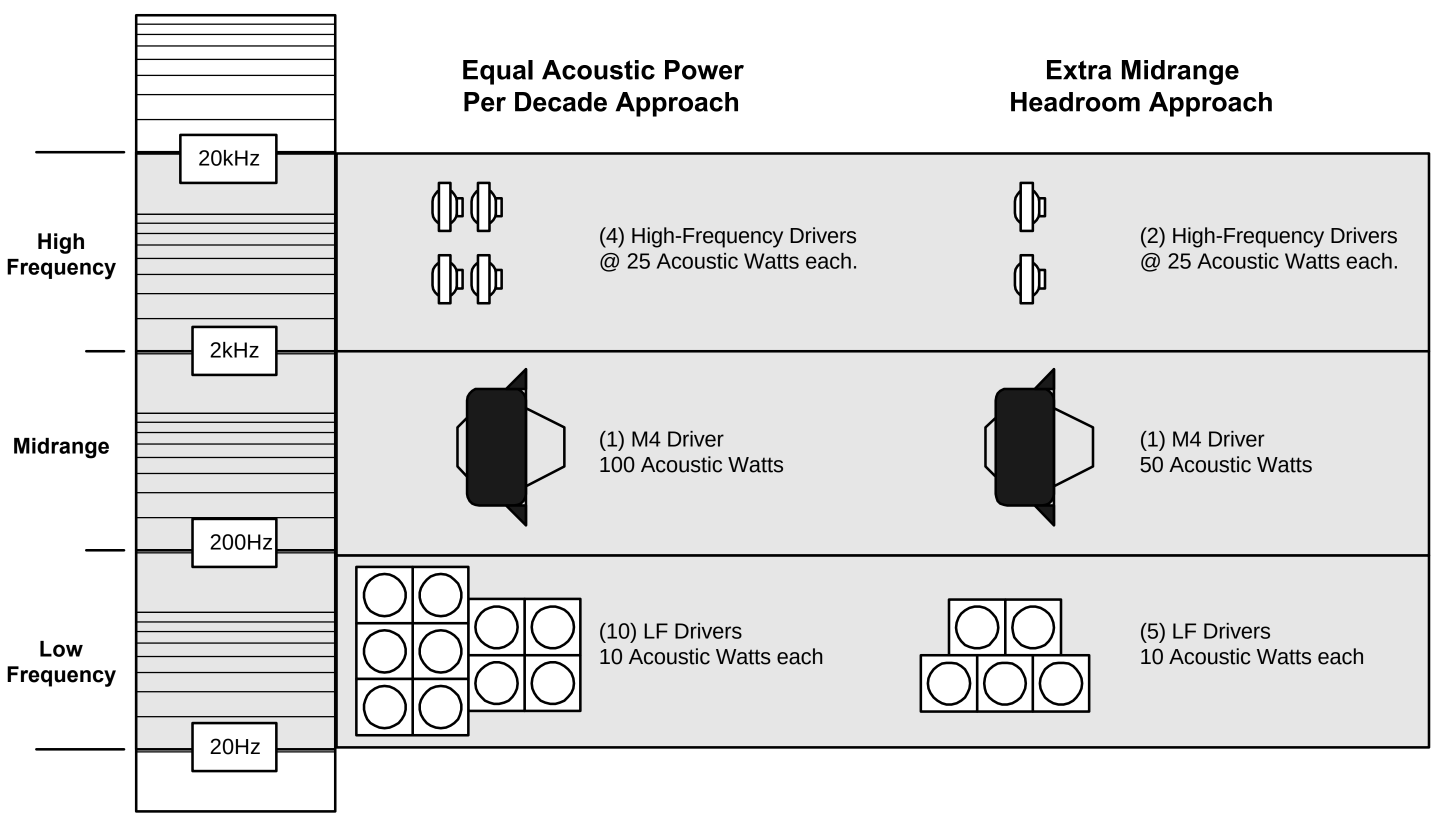
$$\# \text{devices} = \frac{100}{10} = 10 \text{ bass speakers}$$

How many high-frequency devices will be necessary to deliver the same 100 acoustic watts into the environment? Let us assume that our high-frequency driver can handle 100 watts from 2000Hz up, and that it is 25% efficient in this passband. Our required number of drivers will be:

$$W_{out} = 100(.25) = 25 \text{ acoustic watts each}$$

$$\# \text{devices} = \frac{100}{25} = (4) \text{ high - frequency drivers}$$

At this point it becomes apparent that the massive output capability of a single M4 can dwarf the output capabilities of the other devices needed to complete the passband. One solution is to relax the acoustic output of the system to a practical working level, which will mean that the M4 will be operating with a large amount of headroom, not a bad idea for the critical midrange. It should also be pointed out that a few assumptions have been made in our design problem. The same directivity factor has been assumed for each device. This means that bass horns or special arraying techniques must be used to provide directivity that extends into the bass region. Remember that wavelengths get larger as frequency goes lower, so the required pattern control devices can become quite large. Also, it should be emphasized that this is a very conservative and worst case estimate for the M4, whose typical acoustic output is closer to 150 acoustic watts through most of its passband. But, it never hurts to be conservative, and this approach results in an extremely reliable system.



M4 Applications

Outdoor Stadiums

Inherent to stadium sound reinforcement systems are very long throw distances, often hundreds of feet. Projecting sound over these distances requires that the source generate a very large amount of acoustic power, since the spherically expanding wavefront will drop in level 6dB each time the distance from the source doubles (inverse-square law). In addition, the noise levels in stadiums can often exceed 90 dBA, driven by large crowds and noise from the event itself. This requires the sound reinforcement system to routinely provide levels of 100 dBA to all seats for speech communication. The M4 is ideally suited for such an application, since it can generate more acoustic power per watt than any device on the market. This fact, along with the M4's inherent high power handling, provides the designer with a tool to reach the masses. Used in conjunction with the proper waveguide, the M4 can not only provide adequate level, but has the high reliability necessary for such applications.

Arenas

When a sound system is used indoors, it must compete with high levels of noise from crowds, HVAC equipment, machinery, etc. The problem is compounded by energy storage from the room itself. The reverberation times of typical arenas are often 4-5 seconds in the 2 kHz octave-band, and even longer at lower frequencies. Throw distances often approach 150 feet, rivaling stadium systems. To overcome such environments, the best tools available to the system designer are pattern control and high efficiency. Pattern control allows the energy from the sound system to be confined to audience areas, reducing excessive excitation of the room itself. High efficiency means that the available amplifier power produces the maximum possible amount of acoustic power with the least amount of heat. The M4 driver, used with the proper pattern-control horn, provides the system designer with the best available specifications in both pattern control and efficiency. Control of these vital parameters can be more effective than room treatment in providing intelligible speech in such spaces.

Houses of Worship

Sound systems for worship spaces are faced with a different set of requirements than the previous examples. Typical spaces have very low ambient noise levels, making even moderate degrees of distortion audible. Since both speech and music are reproduced, the system must provide intelligibility while retaining the ability to sound musical, two often conflicting parameters. The system must be able to reproduce the subtleties of a violin or guitar, and yet have the available headroom and linearity to reproduce a clap of thunder for a musical production, or a mic inside a kickdrum. Pattern control extending into the mid-bass region is necessary for sufficient gain-before-feedback. The lack of it can mean excessive notch filtering and its audible by-products. No device on the market today addresses all of these needs like the M4. For this reason, the M4 has become a very popular device for church sound systems.

Touring Systems

Touring companies utilize the M4 for many reasons, one of which is that it provides the highest level of acoustic power per watt available today. When you consider that a 3dB increase in efficiency can mean halving the number of midrange amplifiers needed for a touring group, it becomes apparent that a device that can provide both fidelity and efficiency is what this market demands.

Voice Warning

Research has shown that the most effective emergency warning systems should be capable of reproducing both voice messages and warning signals. This means that robust midrange reproduction is what is required. Massive areas must be covered with sound, and reliability can mean life or death to those involved. The M4 has found widespread use in such applications, due to its efficiency and reliability.

Studio Monitors

From the earliest days of recording and playback technology, engineers have realized that the midrange is the key band for accurate music reproduction. It is in this region that the human ear/brain system is most sensitive to abrupt shifts in the phase of the acoustic signal. Critical monitoring applications require a device that can reproduce an entire decade, beginning at about 250Hz and extending to about 2200Hz, without the nonlinearities produced by crossovers and multiple devices. The M4 provides the accuracy that engineers demand, and has found a home in some of the top control rooms in the world.

Cinema Systems

The audio reproduction requirements of modern motion pictures are some of the most demanding in the sound reinforcement world today. Movies require exemplary voice reproduction in order to convey the dialog (and the plot) to the audience. In addition to level and bandpass, the phase response of the loudspeaker is critical to providing accurate localization of on-screen dialog and effects. The M4 does not require crossovers in the voice range (and their inherent phase nonlinearities) making it an excellent choice for cinemas. It also has the power handling and transient response needed for accurate reproduction of special effects.