KEF KEFTOPICS

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KEF are introducing three new loudspeaker systems, which have resulted from significant research particularly into dividing networks, cabinet construction, and power handling capacity.

Introduction

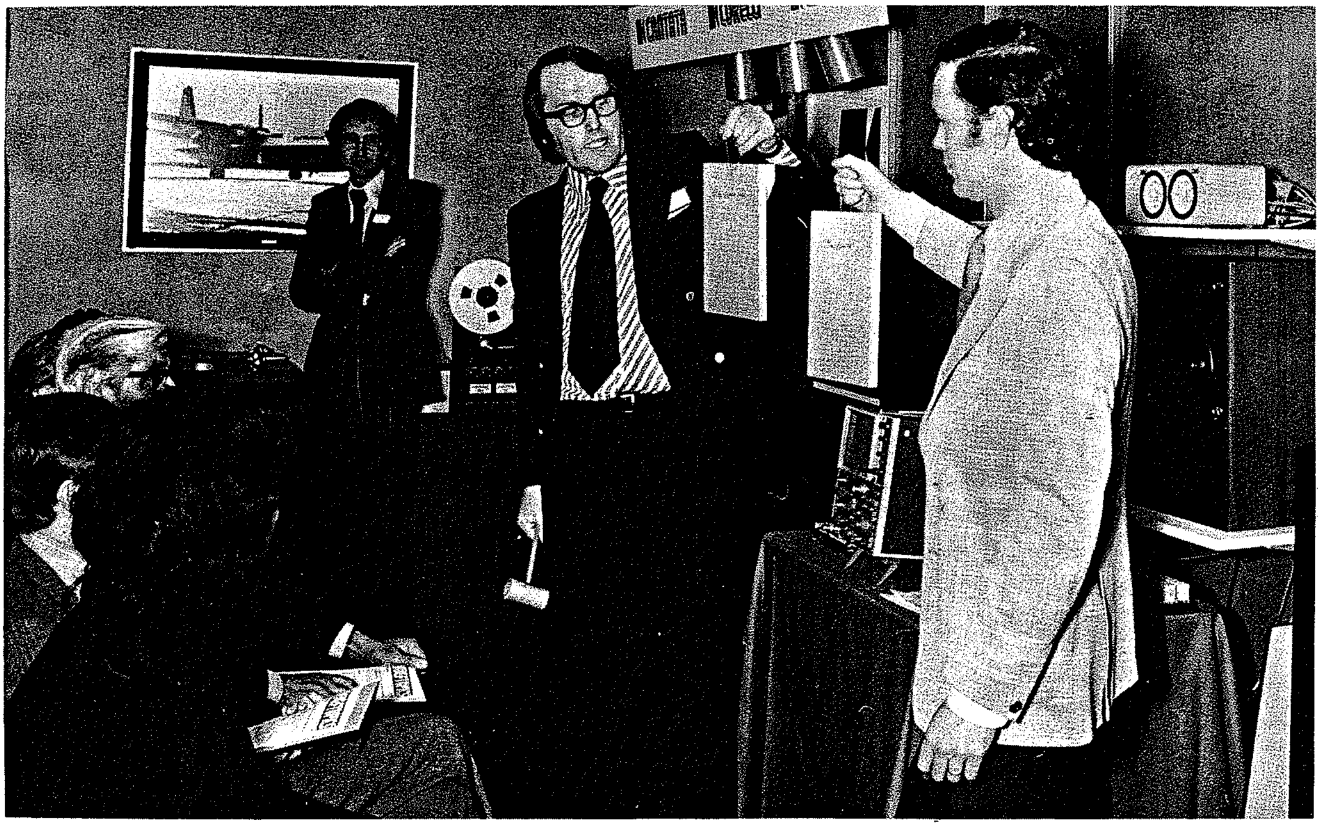
Many parts go into making a loudspeaker. The Model 104 for instance has more than 158 separate items in its make-up. But despite this apparent complexity the essential parts fall into three distinct categories — drive units (tweeter, bass/mid range and passive radiators), filter networks (the most vital and little understood collection of Rs, Cs and Ls) and the enclosure (with its anti-vibration linings, acoustic absorbents and stiffening members).

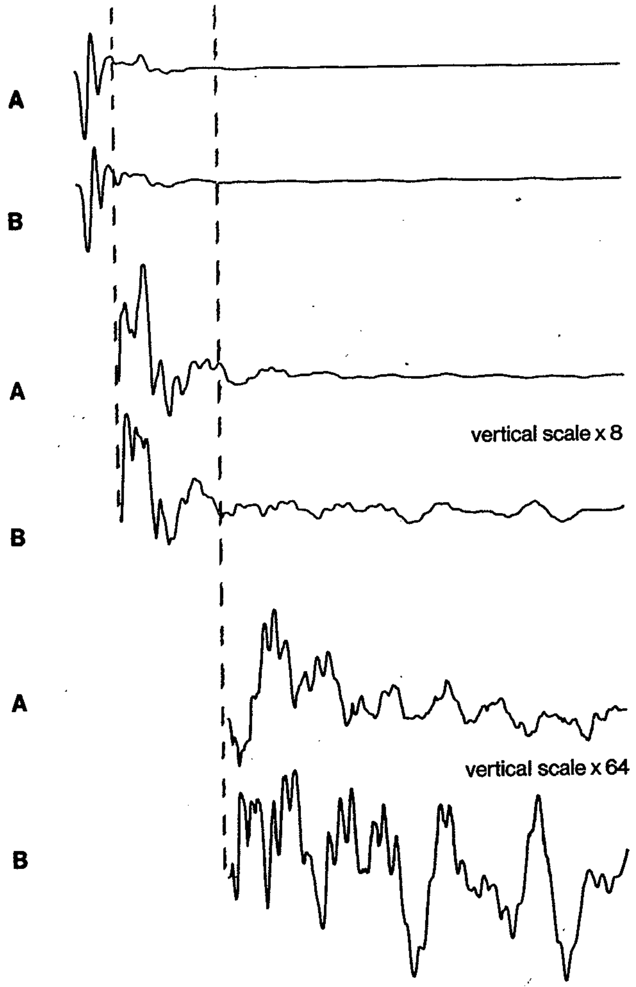
Each component contributes significantly to the overall performance although individual influences may differ with respect to time or frequency or both.

Recent research using digital computer techniques has shown that drive units generally influence early time domain behaviour, whereas enclosures effect later time domain performance. Both drive units and cabinets influence frequency domain characteristics as also do filter networks.

Spatial radiation characteristics are affected by all three components.

Laurie Fincham (Technical Director) and Bob Cox (Sales Director) discussing panel resonance during a presentation





110mm moving coil units in 7 litre closed box
A control unit (box 12mm chipboard with 12mm panel damping material)
B as control unit but box 6mm hardboard without panel damping

Fig. 1. Impulse response of damped and undamped enclosure.

Drive Units

Important developments in drive unit design using damped plastics materials have resulted in some modern products which are notable for smooth frequency response and low colouration. The main limitations on the acoustic quality are now found to be in enclosures and frequency dividing networks rather than the drive units.

Enclosures

The traditional method of determining the relative inertness of cabinet walls is the “knock test”. This is useful qualitatively but it cannot determine the optimum amount of damping nor the most efficacious use of it. Analysis using impulse response techniques are valuable in optimising cost effective design.

The impulse response shown in Fig. 1 illustrates the overhang due to energy reradiated by the cabinet walls. This condition can be remedied by increasing the mechanical loss factor of the enclosure walls using layers of damping material.

Dividing Networks

The first dividing networks came into domestic use only about thirty years ago. Prior to that high fidelity speakers were generally single unit devices. Early models were crudely designed using circuitry adapted from classical filter theory and constructed with air cored inductors and paper capacitors. Component values were small because of the relatively high crossover frequencies, around 1kH and nominal speaker impedances of 15 ohms.

Not surprisingly results were far from ideal. Nevertheless the overall effect was such a startling improvement over most single unit radiators that it took a decade for the possibilities of better network design to become appreciated.

BBC engineers were among the first to use complex networks designed specifically for a particular system and incorporating additional elements to correct response curve variations and diffraction effects. The elaborate networks which were developed for use in high quality monitoring loudspeakers such as LS5/1A and LS/3 were largely responsible for the success of these designs. The drive units were no more than good, fairly consistent, commercially available products.

The BBC's design work culminated in the LS5/5 (circa 1967) which employed 16 component elements in addition to a large auto-transformer for adjustment of sensitivity. Radio metal cored inductors were used to achieve reasonable size, also 7 circuit capacitors were made up of 53 individual polyester capacitors to achieve close tolerances.

The production cost of such a dividing network is now about £150 which is of course quite impractical for domestic products. It is necessary to devise networks of comparable quality at far lower cost. Cheaper alternatives are in fact possible, they work well and are reliable.

KEF's involvement in the production of BBC monitoring loudspeakers since 1962 provided valuable experience in network design and manufacture. The Company has for some years concentrated on the refinement of network designs and their economical production. Dividing networks for high quality domestic loudspeakers are now getting very complex and may contain 10-15 circuit elements so attention must be given to the production of effective networks at reasonable prices. Clearly this cannot be done using air cored inductors and paper capacitors so we have had to investigate cost effective production methods very carefully.

Electrolytic Capacitors

The most economical type of large value capacitor for operation in the medium voltage range is the reversible electrolytic. Unfortunately these have acquired a bad reputation over the years for wide tolerance variations, high loss factor and lack of stability.

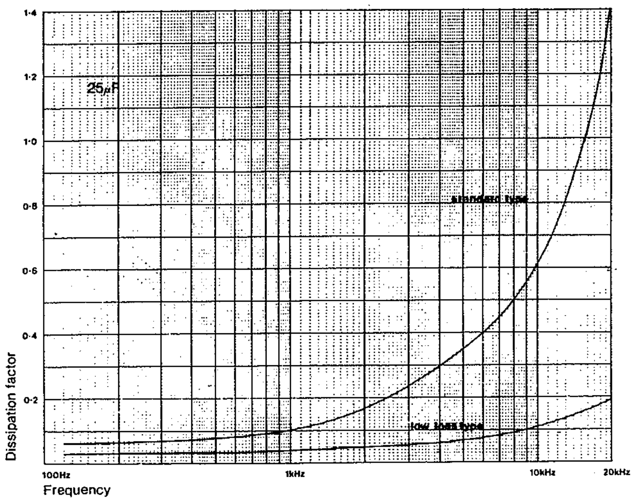


Fig. 2

The wide spread of tolerance can be overcome by measurement and selection.

For many years KEF have purchased capacitors to a tolerance of ±20% and subsequently graded them into batches of 2½% tolerance using semi-automatic equipment. Such a test also verified Q and leakage current so it is useful as a means of quality control. Considerable numbers of capacitors, totalling millions, have been inspected and we have built up a great deal of useful experience in this way. It is in fact far cheaper to purchase capacitors to normal tolerances and then to grade them in this way, than to attempt to buy close tolerance varieties.

The capacitors which we use in critical locations are all special low loss types, made to KEF requirements.

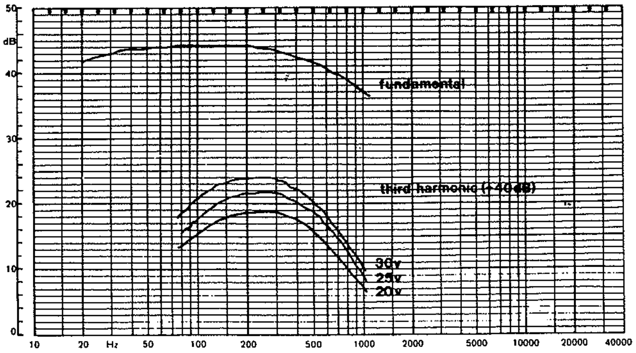
The secret is to have a sufficiently large foil area. Fig. 2 shows a comparison of a normal reversible electrolytic with a low loss type. The improvement obtained in going to a polyester capacitor becomes purely academic about 0.2dB at 20kHz — definitely not worth the vastly increased price, not to mention its bulk.

Stability is no problem with the high quality types now available. KEF have been monitoring samples for ten years and can report that values do not vary by more than 3% at most.

Ferrite Inductors

The great fear with cored inductors of any kind is from non-linear distortion caused by magnetic saturation. Provided that cores have adequate cross sectional area, distortion from this cause will remain negligible, Fig. 3.

It would certainly be almost impossible to construct networks using air cored inductors where values in excess of 5mH are called for. The bulk, weight and cost



Distortion due to Ferrite Cored Inductors LF section Model 104

Fig. 3

would be enormous if high Q's are required. Mutual coupling between filter sections also becomes a problem with high Q air cored inductors.

Circuit Design

Dividing networks are actually made up of individual filter sections, one for each drive unit, to control its terminal voltage as a function of frequency. Circuits were originally derived from classical filter theory but they were designed for resistive loads of fixed value and took no account of the reactive and highly variable loads imposed by loudspeakers. As a result the acoustic output bore little resemblance to the intended characteristic.

Modern networks attempt to equalise not only the electrical and acoustical characteristics of the drive units but also to compensate for other phenomena such as defraction. Present day networks are therefore complex and the performance of a complete loudspeaker depends to a very large extent upon how closely the dividing network achieves its objectives.

Colouration due to Drive Unit/Dividing Network Interaction

In a multi-way loudspeaker system, the passive dividing network usually consists of multiple parallel connected filter sections each of which feeds a separate drive unit. These filters sub-divide the audio spectrum so that low frequencies pass to the LF units, middle frequencies to the MF units and so on.

The theory and design of electrical filters is well established but there are problems in applying it in a simple loudspeaker system dividing network. Most filter design charts or formulae assume that filter load is a simple resistor whereas a loudspeaker presents a much more complicated load whose impedance varies considerably with frequency. Consequently when a drive unit is connected to a theoretically designed network it does not give the desired frequency response and so, in practice, the filter must be modified on a "cut and try" basis until a satisfactory approximation of the required response is obtained.

Often this design approach is not successful particularly for high pass filters for HF units whose fundamental resonance frequencies are right in the frequency band where the ear is most sensitive i.e. 1-4kHz. A distinct colouration can often be heard

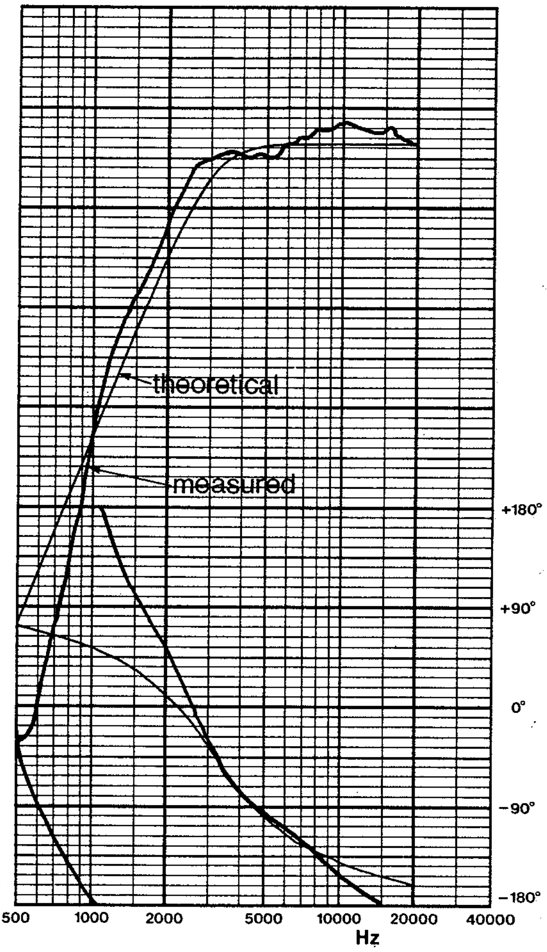


Fig. 4

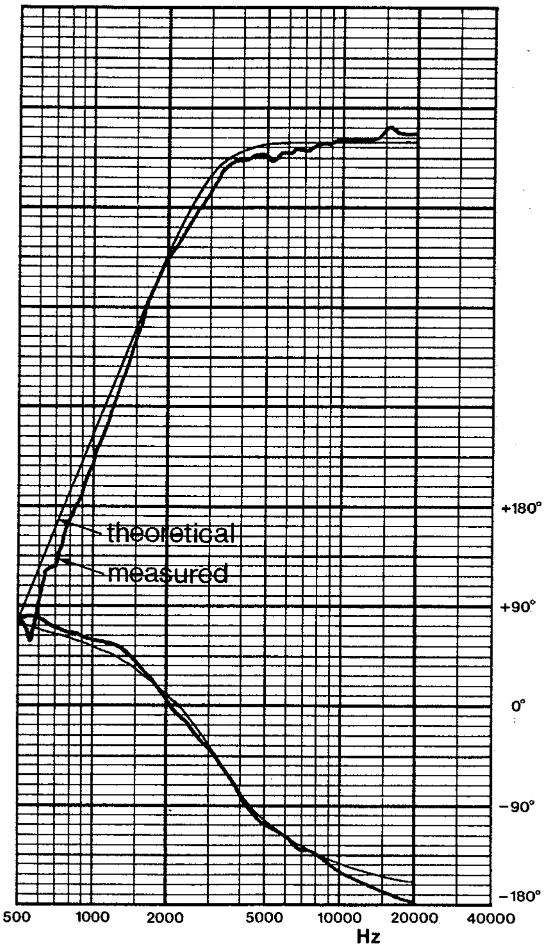


Fig. 5

even though the response of the unit itself has been substantially attenuated in the region of its resonance frequency by the high pass filter. This colouration may be difficult to detect in a full range system, without extended critical listening, due to the masking effect of the low frequency unit. It can be readily revealed, however, by listening to the high frequency unit alone when fed with pink noise via its network.

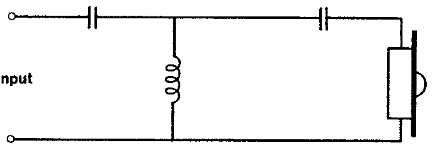
A novel KEF designed third order high pass filter which compensates for the frequency dependant impedance of the drive unit and gives a frequency response which corresponds closely with that of a theoretical third order Butterworth high pass filter.

The marked reduction in colouration using the KEF network is clearly audible.

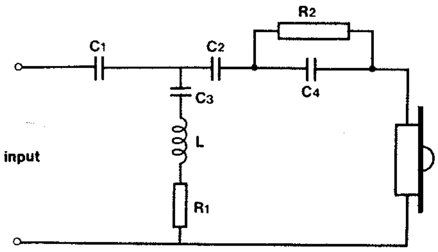
Recent work at KEF, using digital analysis techniques, has shown that high frequency units in particular are substantially minimum phase shift devices. This means, in simple terms, that the transient behaviour of the unit depends only upon the shape of its amplitude frequency response. So, for example, when fed via its filter network, the unit has a frequency response corresponding to that of a theoretical third order high pass filter it will have the same amplitude and phase response (and therefore the same transient behaviour) as that of the theoretical filter.

Fig. 4 shows the measured frequency response of a high frequency unit fed via a theoretically designed third order Butterworth (constant resistance) high pass filter compared with the response a theoretical third order filter. At high frequencies the measured response is down due to the inductance of the voice coil. Around 5kHz response is up slightly due to the voice coil inductance resonating with the second capacitor in the filter network and at 3kHz the role off slope is incorrect and ultimately falls at nearly 30dB/8ve below the fundamental resonance frequency of the drive unit compared with the theoretical attenuation rate for a 3rd order network of 18dB/8ve.

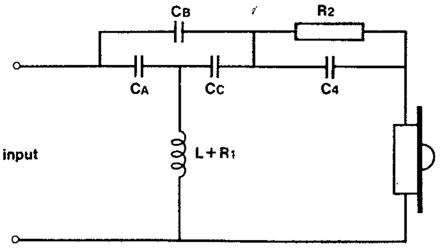
Fig. 5 shows the frequency response of the same unit but this time fed via the new KEF designed high pass filter section. Here the correspondence between the theoretical and measured responses is much closer, being within ±1dB over most of the frequency range from 500-20,000Hz.



Conventional 3rd order high pass network



Acoustic Butterworth Circuit



$$C_A = \frac{C_1\ C_2}{C_1 + C_2 + C_3}$$

$$C_B = \frac{C_1\ C_3}{C_1 + C_2 + C_3}$$

$$C_C = \frac{C_2\ C_3}{C_1 + C_2 + C_3}$$

Practical realisation of Acoustic Butterworth Circuit

Fig. 6

Fig. 6 illustrates the circuit configuration for a theoretical 3rd order Butterworth high pass filter and the stages in the design of the KEF so called Acoustic Butterworth filter network.

The Acoustic Butterworth section has three functions

1 to compensate for the high frequency roll off due to the voice coil inductance.
2 to exactly compensate for the 'Q' and impedance of the drive unit as its fundamental resonance frequency.
3 to provide terminal volts at the drive units for constant volts IN, which vary with frequency in such a way that the ACOUSTICAL frequency response of the drive unit corresponds to that of a third order Butterworth high pass filter.

All new KEF 'C' Series models employ this new computer designed filter section.

System Design

It is well known that there is a fixed relationship between box size V_B, efficiency E, and lower cut off frequency f_3 for dynamic loudspeaker systems given by

$$E = K V_B f_3^3$$

where K is a constant depending on system parameters.

So, for example, for a given lower cut off frequency, the efficiency of the system can only be doubled by doubling the size of the box. Similarly, for a bass extension of one octave i.e. down to $\frac{1}{2} f_3$ either the box must be 8 times the volume or the efficiency must be reduced to $\frac{1}{8}$ with no change in box volume.

Modern recording determines the bandwidth requirements for realistic reproduction and there are clearly limitations in the size of a domestically acceptable loudspeaker system. Compact, wide range, systems are therefore inevitably comparatively less efficient, which fortunately is not so serious today with amplifiers of 50W or more readily available, providing, of course, that the loudspeaker can handle the power.

Loudspeaker power handling capacity is a much abused and little understood term. It is often bandied about as if it were somehow a figure of merit i.e. the bigger the better, which is obviously nonsense. Its main purpose is to guide the customer when choosing a power amplifier. Too low an amplifier power may lead to distortion due to the amplifier clipping before the required listening level is achieved and too much amplifier power may lead to three main effects.

1 Onset of audible distortion due to
  a) Non-linearities in the dividing network.
  b) Non-linearities in the drive units.
2 Mechanical damage or noise from the drive unit due to excessive diaphragm excursions.
3 Burnt out voice coils.

Items 1 and 2 can be readily dealt with because their effects are clearly audible and may be cured by lowering the listening level sufficiently. Burnt out voice coils are more difficult to deal with because, particularly in the case of high frequency units there is no audible warning that thermal overload is being approached.

Ideally, therefore, it seems that the customer should use the largest practical amplifier which will not, under normal conditions of use, damage the loudspeakers.

It is common practice to quote a loudspeaker's power handling capacity in terms of its ability to withstand a continuous sine wave of given level and frequency, or many hundreds of hours of a given power, using a random noise signal, whose frequency spectrum has been shaped to correspond to that of average programme material.

Neither of these rating methods, although both useful in their ways, is suitable for determining the thermal limitations of a loudspeaker system, as they do not approximate sufficiently well to the heating effects of real programme material.

Voice Coil Temperatures With Music and Test Signals

An experiment was conducted to continuously monitor the temperature of drive unit voice coils while a two-way loudspeaker system, rated as being able to handle 80 watts (programme), was fed by an amplifier delivering 100 watts into 8 ohms.

With each music or test signal the maximum temperature reached by each of the two drive units in the system was recorded when the amplifier was being driven into clipping. The RMS level was shown on a true RMS voltmeter and the wave form was monitored on a C.R.O.

The maximum service temperature for which the drive unit voice coils had been designed are bass 260°C and tweeter 120°C.

The results of the tests were:—

Input	Note	Max. Temp. °C	
		LF Bass Unit	HF Unit
1 Music			
a Piano	Loud solo (Amp. clipping)	100	25
b Orchestra	Fortissimo passage (Amp. clipping)	150	40
c Pop	Heavy rock with synthesiser	100	50
d Pop	Heavy rock with 6dB boost at 100Hz and 10kHz	120	75
2 Test			
a Continuous Sine	50-20,000Hz Sweep at 12v RMS (18)	100	75
b Gated Sinewave	50-20,000Hz Sweep on/off 1:10 Amp. clipping (80V Pk to Pk)	100	50
c Pink Noise	Amp. clipping	65	65
d Shaped Noise (Din. Weighting)	Amp. clipping	110	30

From these results the following observations may be drawn.

Continuous sinewave at only 12V RMS (18W) gave temperatures in the LF unit corresponding to piano, 1a, and heavy rock, 1c, and in the HF unit corresponding only to heavy rock with 6dB treble boost, 1d.

It may be seen that different programme items put different thermal demands upon the two drive units but none of the test signals gave heating effects which corresponded well with the worst case achieved by using actual programme material.

It seems that the best guide to a loudspeaker's power handling capacity should still be that given by the manufacturer based on personal experience and knowledge of the product and not on the loudspeaker's ability to withstand some arbitrary test signal. Normally such a guide is known as the systems programme rating and is usually taken to mean that size of amplifier with which the system may be safely used on normal programme.

Conclusion

It is hoped that you can now appreciate that when we say these three new products, Corelli, Calinda and Cantata, offer improved power handling capabilities and improved acoustic performance because of new techniques particularly in cabinet construction and crossover design it is not just a glib sales argument — it is the result of serious research and engineering.