
Bowers & Wilkins

Project brief

The 700 Series comprises seven speaker models to cater for a wide variety of 2-channel audio and multi-channel home theatre applications. Occupying the premium ground in the full B&W product range, the 700 Series replaces the CDM NT Series.

In replacing the CDM NT Series, the brief demanded an improvement in both performance and industrial design.

Performance

The primary objective of any new speaker development programme in terms of performance must simply be to give the listener the closest possible experience to a live event. If one considers for a moment just the requirements of listening to music, that in turn may translate further to:

- Accurately portray the timbre, attack and dynamic range of voices and instruments
- Place the performers stably in their correct spatial position
- Recreate the acoustic and ambience of the environment
- Do this for a spread of listener positions

Perfect attainment of these goals, alas, still eludes us, but the brief for the 700 Series was to make a significant step further along the road to perfection compared to the outgoing CDM NT Series. Indeed, part of the reason behind abandoning the CDM classification, while recognising the acclaim those products had enjoyed, was to emphasise that improvement had to be more than subtle.
The Series was to contain an equivalent model to each of the outgoing CDM NT Series, with two exceptions:

1. There should be two subwoofers, to address the requirements of different size rooms.
2. The home theatre surround speaker should offer a choice between dipole and monopole operation.

Industrial Design

If a speaker were no more than a transducer, life would be comparatively easy; but it is also a piece of furniture that has to sit comfortably in the complex environment of the home. More than ever, discerning customers demand good design. However, speakers present a significant problem in this respect. The[a] geometry and materials used have a direct influence on the performance. The designer cannot have a completely free hand and must recognise the needs of the acoustic engineer.

The process of combining the requirements of the industrial designer and acoustic engineer is an iterative one. Proposals from one party are passed to the other for assessment, followed by acceptance or rejection, the latter demanding modification to the concept until agreement is reached. Any residual conflicts in products of the calibre of the 700 Series are settled in favour of the acoustic engineer.

The brief for the industrial designer was to allude to the cabinet shape heritage of the outgoing CDM NT Series, specifically the concept of a free-mounted tweeter above a sloping cabinet top, but incorporate bent wood technology to reduce the angular look and benefit the acoustics.

Components

We shall examine the main component parts in turn:

- Cabinets
- Drive units
- Crossovers (passive)
- Amplifiers (subwoofers)

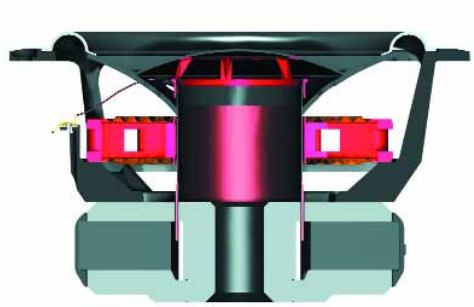
Many of the components and techniques used in this Series derive from the Signature and Nautilus 800 Series products. For a more in-depth treatment of the various topics than is given in this paper, the reader is encouraged to read the earlier B&W publication “Development of the Signature 800”. This may be downloaded in PDF form from the B&W web site www.bwspeakers.com in the technology section.

Cabinets

In the 703, 704, 705 and HTM7, the sloping top and front baffle are formed from a single piece of multiply MDF (*figure 1*). This replaces the 3-part design of the CDM NT Series, losing two glue joints in the process. The result is a stiffer cabinet structure and lower levels of coloration from panel resonance. In addition, the curved edge immediately in front of the tweeter gives reduced diffraction compared to the sharp mitred joint of the CDM NT models, leading to a smoother tweeter response.

The sides of the cabinets taper inwards towards the back. This, together with the sloping top means that only the front and back panels remain parallel. It is often stated that the removal of parallel sides in a cabinet reduces resonances in the internal cavity. This is something of a simplification; the resonances shift to another set of frequencies with a greater proportion of higher-order modes (those involving reflections off more surfaces). The resonances are spread across a wider frequency range, with each individual resonance having lower energy and therefore being less obtrusive aurally.

1 Detail of cabinet top and baffle



2 Section through subwoofer drive unit, showing Mushroom Construction

3 Bass drive unit from 704

Bass drive units

Drivers that are used only for bass frequencies, as opposed to bass/midrange drivers, benefit from having stiff diaphragms. The term ‘slam’ is often used to describe the ability to reproduce impulsive bass. This refers to instruments such as bass drum, plucked bass guitar and the like. Such signals actually contain higher frequencies in order to create the correct waveform. Nevertheless, the acceleration forces on the bass driver diaphragm are considerably greater than for sustained bass notes and it is important that the diaphragm be restrained from deforming under the influence of high forces from both the voice coil and pressure changes within the cabinet.

All bass-only drivers, whether used in the two subwoofer models, ASW700 and ASW750, or the 703 and 704 use cones fabricated from a mixture of paper and Kevlar fibres, stiffened with resins. This already stiff structure is further stiffened by our ‘mushroom’ construction (*figure*). Here the voice coil bobbin (the mushroom stalk) is extended to join the centre of the large dust cap (the mushroom cap) to form a ring shaped girder section.

The use of Kevlar fibres in the cone provides resistance to buckling under high forces from the voice coil. This technique was first used in the electric instrument speaker market. It was found that normal paper cones, even those with a high resin content, tended to buckle close to the neck when driven hard. Kevlar has high tensile strength and the fibres are extremely difficult to break in tension. Any bending stress on the cone causes a stretching force on the fibres, which then resist the bending. Effectively, energy is rapidly dissipated through the cone instead of being concentrated in one area. It is this very property that makes Kevlar so effective in bulletproof vests.

All the bass and bass/midrange drivers in the 700 Series use techniques to reduce distortion in the motor system, but these differ between the subwoofer drivers and the full range system drivers.

Simple magnet systems (*figure 4*) give an asymmetrical distribution of fringing flux either side of the magnet gap and this increases the level of even harmonic distortion. Below the gap there is the metal of the centre pole, but above there is not. Two traditional techniques to overcome this are to extend the centre pole forwards (*figure 5*) or to have a T-shape pole, where the pole diameter is reduced below the level of the top plate (*figure 6*). Of the two techniques, the T-shape pole is preferred. Extending the centre pole increases the total level of fringing flux at the expense of the flux density in the main gap, and this reduces driver sensitivity.

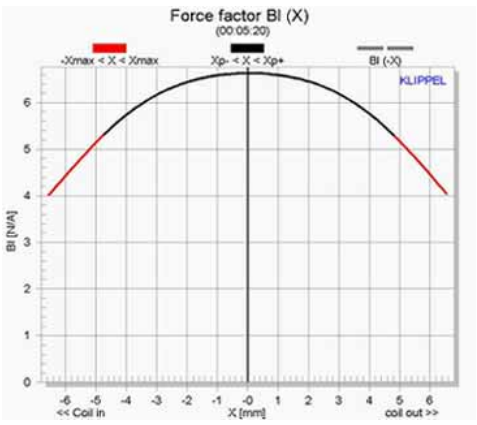
A T-shape pole is used in the subwoofer drivers. Both have large diameter centre poles (76mm diameter in the case of the ASW700 and 100mm diameter in the case of the ASW750) and the method works very well. However, if this method is applied to the smaller 32mm diameter pole of the bass drivers in the 703 and 704, magnetic saturation occurs in the pole with a commensurate reduction of flux in the gap and a lowering of driver sensitivity. For these drivers, a different solution was used, based on the simple recognition that it is not the flux distribution itself that matters, so much as the force factor (Bl). Simply offsetting the rest position of the coil significantly improves force symmetry (*figure 7*).

The T-shape pole in the subwoofer drivers also allows the use of an aluminium tube to be added below the pole overhang. This reduces distortion caused by flux modulation from the motion of the coil in the gap.

4 Simple magnet design

5 Extended centre pole

6 T-shape pole



7 Variation of force factor with coil position

Balanced Drive

Asymmetry in the magnet geometry also creates another distortion mechanism. The inductance of the voice coil is influenced by the presence of the metalwork around it, especially the centre pole, and tends to vary as the coil moves back and forth in the gap. This is not a serious problem for subwoofer drivers, because they only operate below the range where inductance becomes a significant proportion of the total driver impedance. Nor is it a problem for low excursion drivers such as dedicated midrange units and tweeters. But for the bass drivers in full range systems, and even more so for bass/midrange drivers, this mechanism can be a significant cause of amplitude modulation distortion.

It is a rather bizarre situation that a speaker is a current transducer (Force = Bli, where B is the flux density in the gap, l is the length of conductor in the gap and i is current), yet we drive it with a voltage-controlled source – a low source impedance amplifier.

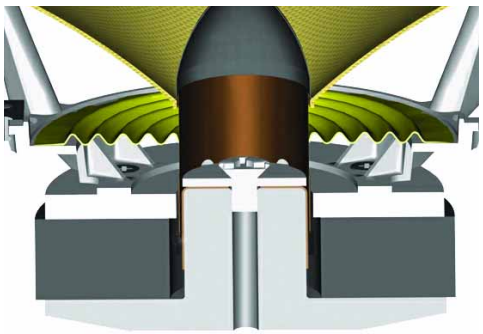
Any variation in the load impedance creates a change in the current through the speaker and thus a change in the shape of the frequency response of the driver throughout each cycle. Inductance increases with increasing frequency, so the variation causes the response of the driver to tilt up and down as the coil moves back and forth.

The first method of attack is to reduce the absolute value of the inductance by the use of a copper cap on the centre pole (*figure 8*). The upper graph (*figure 9*) shows the effect on the inductance. Not only is the overall value reduced, but the variation in value from one extreme of coil travel to the other also reduces from ±40% to ±13%. Interestingly, instead of decreasing as the coil moves forward, the inductance now decreases.

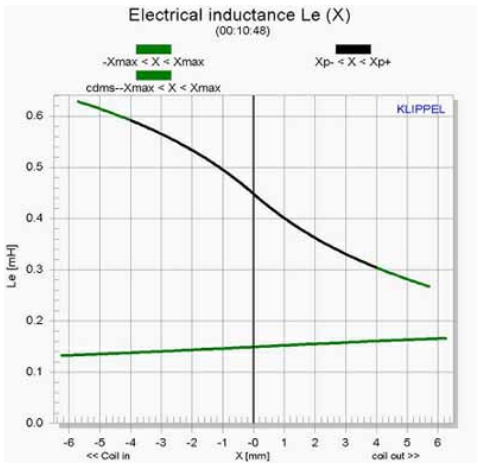
The copper cap is has been widely used to good effect in previous drive units, but the advent of modern speaker distortion analysis equipment, that can separate out the different distortion mechanisms, has enabled us to go a stage further.

The second stage came out of work to investigate how and why the sound of drivers was affected by the material used for fixed centre phase plugs. It consists of adding a disc of aluminium to the pole tip and the induced eddy currents further affect changes in coil inductance. The graph (*figure 10*) shows the line gradient reduced virtually to flat and it is one of the rare cases that one can actually claim that a type of distortion has been truly eliminated, rather than simply reduced.

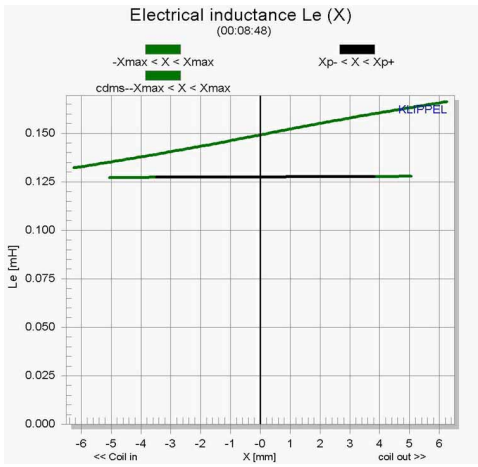
It is the combination of copper cap and aluminium disc that constitutes Balanced Drive and it is new to the 700 Series. The reduction in intermodulation distortion is a major factor in the improvement in detail retrieval and realism shown by the drive units compared to equivalent older designs.



8 Section of bass/midrange drive unit



9 Variation of inductance with coil position
Upper trace – without copper cap
Lower trace – with copper cap



10 Variation of inductance with coil position
Upper trace – with copper cap only
Lower trace – with copper cap and aluminium

Bass/midrange drivers are used in all the 2-way systems – 705, HTM7 and DS7 – and the requirements are somewhat different to bass-only drivers. With a much wider bandwidth, the high-Q resonances that always plague the higher frequency responses of drivers with stiff diaphragms are unacceptable and for this application the familiar woven Kevlar cone is a superior solution.

Woven Kevlar cones not only take advantage of the tensile strength of Kevlar, but also the woven nature of the material. A typical homogeneous cone suffers from concentric ring break-up modes (*figure*). These modes hang on and radiate delayed sound to the listener. The effect is sometimes called time smearing and impairs the clarity of the signal and the ability to discern fine detail. The break-up patterns in a woven Kevlar cone are much more random (*figure*). It is a result of the speed of bending waves being different in different directions, depending on whether they travel in line with the fibres or at some angle be different directions, depending on whether they travel in line with the fibres or at some angle between them. In these patterns superimposed on the desired cone motion, the areas moving back are closely balanced by those moving forward, so a high degree of cancellation occurs at the surface of the cone. Far less delayed energy is transmitted to the listener than with a homogeneous cone and the original signal is far better preserved.

All the bass/midrange drivers also incorporate Balanced Drive, where it is an even more effective technique than it is for bass-only drivers, because of the greater influence of the inductance in the midrange. It improves the speaker's ability to resolve fine detail in the signal and, moreover, maintains this ability as the signal becomes more complex. For the listener, each instrument or voice becomes more easily distinguishable and its character remains more consistent with changes of level and signal complexity.

Midrange driver

The 703 is the only full 3-way system in the Series and features an FST (Fixed Suspension Transducer) midrange in its own isolated cavity within the main cabinet. This driver was originally developed for the 3-way systems of the Nautilus 800 Series and improves on the standard Kevlar cone driver. Because the excursion demands of a midrange driver are much lower than a bass/midrange driver, it is possible to do away with the normal roll surround. Roll surrounds are difficult to match mechanically to the cone and can exhibit their own resonances. In the FST, the outer edge of the cone is supported by a ring of foam polymer operating in compression (*figure 11*) and which has a mechanical impedance matched to that of the rim of the cone. Bending waves generated in the cone are better absorbed by the surround, with the result that less energy is reflected back into the cone to cause delayed resonances. It is analogous to terminating a coaxial antenna cable with a resistor having the same value as the characteristic impedance of the cable.

Because of the lower excursion in a midrange driver, distortion created in the motor system is inherently lower than in bass or bass/midrange drivers. Nevertheless, the centre pole has a layer of copper and the aluminium centre bullet also helps control variations in voice coil inductance. The result is a driver with unparalleled levels of detail retrieval.

11 FST midrange

12 Tweeter on top

Tweeter

The most obvious feature of the tweeter is that it is mounted in its own housing on top of the main cabinet (*figure 12*). Tweeter-on-top has been a familiar B&W feature ever since the introduction of the DM7 in 1977. The design benefits are:

- The tweeter can readily be positioned physically back from the baffle to time align it with the bass/midrange driver. This makes crossover design easier and the integration of the two units better.
- The response of the unit it smoother. There is less diffraction of energy from the sides of the cabinet to interfere with the direct sound from the diaphragm.
- The dispersion is improved.

This last point deserves further explanation. The dispersion of the speaker is a vital ingredient in forming the sound stage or image. It has a bearing on how much sound reaches the back wall to help give the impression of depth and it affects how well the image is presented for those listeners seated away from the centre line between the left and right speakers. If the dispersion is too wide, the image becomes less well defined and more susceptible to the vagaries of the listening room.

If it is too narrow, off-centre listeners will hear a vastly different presentation from those in the 'hot seat' and the sound can become fatiguing after extended listening. The best approach is to have the housing for each driver only a little wider than the radiating surface. The two drivers are then in a similar situation and the off-axis response is more consistent with the on-axis.

The benefits to the listeners are:

- The performance off centre better maintains the correct sonic character of the music and the position of the performers.
- The effect of instruments moving as the pitch changes is virtually removed.
- The listener becomes less aware of the position of the speakers and more aware of the virtual image between them.

Looking inside the housing, the tube loading can be seen at the back of the driver (*figure 13*). Normally the unused radiation from the back of a cone drive unit is dissipated inside the speaker cabinet. In the case of tweeters, it is often left to reflect off the pole back through the dome, the delayed energy time smearing the original. Here, the energy is dissipated in the tube, filled with absorbent fibre, which is long enough to absorb the energy before it can reflect back.

Like the bass/midrange driver, there is a copper cover on the magnet centre pole. Here the purpose is mainly to reduce the inductance of the coil to get more current flowing at ultra high frequencies and raise the output level. All designers are aware of the need to extend the response of tweeters and this is one design detail to help do it. The high sampling rate recording formats SACD and DVD-A are obvious beneficiaries, but even normal CD recordings benefit.

Other techniques used to extend the high frequency response include:

- Use of single layer ribbon cable to further lower coil inductance
- Use of copper coated aluminium wire (CCAW) to reduce moving mass
- Improvement of the coil to dome joint to raise the first break-up frequency

At B&W, we believe that adding a separate supertweeter is not the best way to achieve an extended high frequency response. The benefits of the new high sampling frequency formats are not restricted to extending the amplitude response, and include the ability to raise the cut-off frequency of anti-aliassing filters so that the associated phase and group delay distortion is moved further above the limits of human hearing. It seems to defeat the object if an extra crossover is introduced, which brings its own phase distortion.

13 Section through tweeter

Every improvement made to the design in one area often shows up deficiencies in another. Certainly the use of good drive units makes it easier to judge the differences between crossover components. The audible differences between different components are not well indicated in published specifications, and so the speaker designer must spend a good deal of time auditioning different samples to find the best component for the job. Our crossovers tend to be as simple as possible. All things being equal, the fewer components used, the less the signal is likely to suffer. However, one should have proper equalisation and the drivers should be in phase with one another through crossover – something that very simple crossovers have difficulty in achieving.

The majority of inductors used in the circuits are air core for minimum distortion. Only the large value inductors used in the low-pass sections for the bass drivers of the 703, 704 and DS7 in dipole mode have cores and these are high-quality sintered iron P-cores, which offer high saturation levels.

Crossovers in all passive systems except DS7 allow bi-wiring and the gold plated terminals accept all common forms of connection. Previously, we have provided for heavy gauge bare wire ends to be used in the side holes of our terminals at the expense of being able to use 1⁄4 in (6mm) spades. In this design, a 6mm diameter side hole is provided, but below this the body diameter of the post narrows to 6mm. A sliding collar enables both types of termination to be securely clamped (*figure 14*).

Subwoofer amplifiers

There is strong commercial pressure to reduce the physical size of subwoofers for domestic applications. With passive speakers, this process is limited by the physical relationship between box size, bass extension and efficiency. However, once the concept of active equalisation is established, there are a number of different routes to any given final alignment coupled with a defined output level capability, as the system response is a combination of the raw drive unit in its cabinet and the response of the amplifier.

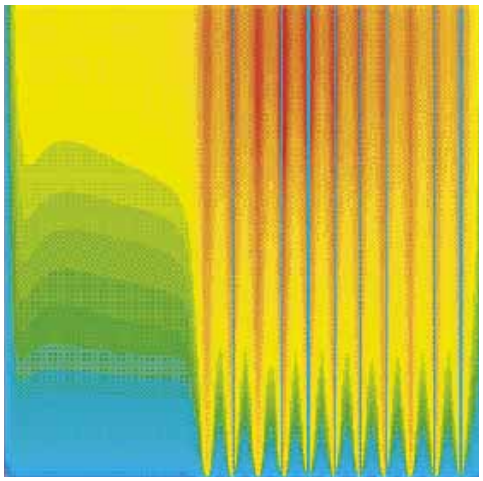
One could, by a combination of increasing the moving mass and lowering the magnet strength, make the driver's passive response the same shape as the final target. The passband sensitivity would be low, of course, so the amplifier would need to have a high output, and the driver be capable of handling that power, simply to reach the required levels. Large voltage signals would need to be provided right across the full bandwidth.

Using a lighter cone driver with a large magnet gives higher sensitivity at the top end of the range, but the bass response is relatively curtailed in extension and grossly overdamped. High voltage capability is still required from the amplifier, to boost this overdamped response at lower frequencies. However, the reduced need for high voltages at upper frequencies, coupled with the fact that there is less energy in most programme at the low boost frequencies, reduces the overall likelihood of clipping in the amplifier. Moreover, the drive unit has to handle less total power and runs cooler.

So although the linear model of both approaches may indicate similar performance, the real-world situation is quite different and the large magnet driver with equalisation, because it runs cooler, is more reliable and gives a superior dynamic performance because there is less compression from voice coil heating.

The power outputs for the 700 Series subwoofer amplifiers are 500W for the ASW700 and 1000W for the ASW750. The most practical and efficient way of producing such high power outputs is to use Class-D operation. Because they only produce significant heat when working hard, Class-D amplifiers require far less heat sinking than traditional Class-A, Class-B or Class-AB designs. Indeed, many Class-D designs eschew the use of fins in the heatsink altogether. Not so here. If the amplifier is called upon to produce sustained high power, and this can often happen with subwoofers, inadequate cooling can cause the output level to sag. The 700 Series designs were thoroughly modelled for heat dissipation (*figure 15*) and do have fins on the heatsink.

14 Input terminals



15 Thermal modelling of amplifier heatsink

Unlike many Class-D subwoofer amplifiers, which are of limited bandwidth, those used in the ASW700 and ASW750 are a high-quality full-range design, which improves the overall sound. Two equalisation settings are provided to help tune the subwoofer to the room acoustics and enable bass extension to be traded for higher output level.

Subwoofers are often called upon to operate near their limits and, should the driver bottom out or the amplifier momentarily go into clipping, unpleasant noises are created that detract from the listening experience. To counteract this the amplifier is designed with a bass overload suppression system. Here, the output of the amplifier soft limits with a characteristic that is matched to the excursion capability of the drive unit.

To further increase amplifier efficiency, switch mode power supplies are used. They are more compact than traditional designs, having no need for a large transformer.

The power supplies operate without adjustment from nominal mains voltages in the range 100V – 230V, with a 10% tolerance, making the effective range 90V – 253V.

Power factor correction ensures negligible interference with other electronics in the system through the mains supply.

Model range

The full 700 Series comprises:

705	2-way stand-mount vented-box speaker
704	21/2-way floor-standing vented-box speaker
703	3-way floor-standing vented-box speaker
HTM7	2-way magnetically shielded vented-box centre speaker
DS7	2-way switchable dipole/monopole closed-box wall-mount surround speaker
ASW700	10-in/500W closed-box powered subwoofer
ASW750	12-in/1000W closed-box powered subwoofer

705

Apart from the HTM7, which is acoustically similar, the 705 is the only stand-mount system in the range. A compact 2-way vented-box design, it delivers remarkable bass for its size.

In the equivalent CDM NT models, the internal volume above the top of the front baffle (where the slope starts) was lost to the bass drivers (midrange driver in the CDM 9NT). This was because the tweeter protruded into the cavity and had to be sealed off. 700 Series tweeters remain totally outside the cabinet, so this volume has been effectively regained. With the floor standing models, the proportion is relatively small, but with the 705, the internal volume has increased from 11 litres to 16 litres, with little change to the total outside volume. This is significant and means that the 705 has a more extended bass response than the CDM 1NT, with the -6dB frequency moving from 48Hz to 43Hz.

704

As a 21/2-way system, both cone drivers operate in parallel at low frequencies, which allows greater output levels than the smaller 705. Gradual attenuation of the lower drive unit above 150Hz ensures that the system vertical dispersion does not suffer in the midrange.

703

The 703 is the only full 3-way system of the Series. The FST midrange delivers uncanny realism and detail, partly because of the properties of Kevlar and the unique way in which the cone is terminated and partly because the midrange rendition is not affected by the need to produce bass from the same driver.

HTM7

Specifically designed for centre channel applications, the drivers are essentially the same as the 705, but with added magnetic shielding to avoid television picture distortion. The lower profile sits better on a television, while the vertical disposition of the drive units maintains the same dispersion characteristics as the left and right speakers.

DS7

The DS7 is designed as an on-wall surround speaker for multi-channel audio and home theatre installations.

Surround speakers generally fall into two main types – those that one might describe as 'normal' speakers – so-called monopoles, where the sound comes from a set of drive units mounted on the front of the enclosure – and those that give a more diffuse sound field, such as dipoles. Each type has its advantages.

Most multi-channel music is monitored using monopole surround speakers, whatever the multi-channel recording format. This enables better location of side and rear images, although the formation of such images is never quite as precise as it is between the front speakers.

Conversely, most films are originally balanced for cinemas, where a large number of speakers spread around the auditorium are used to create a surround sound field that gives an all-enveloping effect. Dipoles are better at recreating this type of sound field in the home, but using fewer speakers to do it, and they make the installation easier to balance for a larger listening area.

The DS7 offers a choice of both monopole and dipole operation, either via a switch located on the front baffle, or remotely, using a 12V trigger.

In monopole mode, the two front facing drive units deliver a similar performance to the 705. However, the cabinet size is shallower and smaller in order to give minimum visual intrusion in its on-wall application, but commensurate with achieving a reasonable bass extension. Because of this, the tweeter is baffle mounted and a closed-box alignment is used, with the bass balanced to take account of the proximity of the rear wall.

In dipole mode, the front tweeter is disconnected and the system uses a pair of 100mm (4 in) side-firing drivers with woven fibreglass cones. These operate above 250Hz and are connected in opposite polarity to create the characteristic dipole figure of eight polar pattern. A wedge-shaped null zone is created at right angles to the wall. If the listeners sit within this zone, they become less aware of the location of the speakers and hear more reflected sound; hence the diffuse nature of the sound field.

In order to preserve symmetry in the sound field at left and right of the room, the positive dipole lobe may be directed either to the left or right of the speaker by a second switch on the front panel. A third switch alters the tweeter level ±1.5dB from nominal flat. This is simply in recognition of the practicalities of using surround speakers in a domestic situation. Treble cut may be required either to overcome a lively room acoustic or reduce aural awareness of the speakers' position. Boost may be required if the speaker has to be mounted further off axis than is optimal, or if the room acoustic is dull.

ASW700

The smaller of the two subwoofers specified, The ASW700 combines a 250mm (10 in) driver with a 500W amplifier. Extensive bracing is used in the substantial cabinet, as it has to provide a stable bedrock for the heavy drive unit.

ASW750

The ASW750 follows the same design parameters as the smaller ASW700, but uses a larger driver and higher amplifier power to deliver more extended bass and greater output levels commensurate with the needs of larger listening rooms.