Loudspeaker Developments

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Abstract

This paper reviews some of the developments in loudspeaker technology during the lifetime of the Institute of Acoustics.

1. Introduction

Today we celebrate the 25th anniversary of the Institute of Acoustics, so it seems appropriate to review some of the major changes in loudspeaker technology during this period. As the IOA is a British institution, the main focus of attention will be placed upon British innovations. Here we will concentrate on domestic loudspeakers, while recognising that many advances have been made in the professional market, and in many cases the developments cross the boundary between the two areas.

It is often mooted that 'loudspeakers have been cone-shaped for over 70 years, so nothing much has changed'. Whilst it is undeniable that most loudspeaker diaphragms *are* still conical, there are indeed good engineering reasons for the longevity of this geometry. In any event, this 'complaint' should not disguise the fact that many advances in technology *and* fidelity (the two are not irrevocably linked!) have been made in recent years.

These recent developments fall broadly into two categories: *direct* product improvements and *indirect* improvements to the R&D or production process, and we shall take samples from each.

In some cases the developments have been *evolutionary* and, in effect, enabled by the progress of technology. The ideas may not be new, but the original 'inventors' did not have access to the processes and techniques necessary to produce working models. In other cases the ideas are truly *revolutionary*. The reader is left to separate the two groups!

2. Drive Units

Advances in materials technology have led to a number of improvements in loudspeakers diaphragms, among them Kevlar woven-fibre cones (figure 1), injection-moulded cones and metal-dome tweeters. The latter are shown to have significant advantages in mechanical performance over plastic and fabric ancestors (figure 2) and are commonplace even in today's lower priced quality systems.

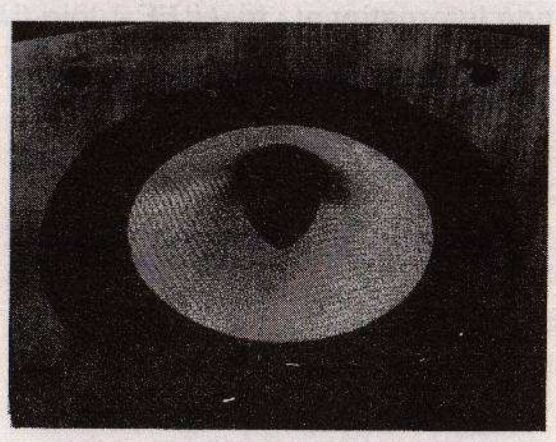

Figure 1. B&W Nautilus 805 (courtesy B&W).

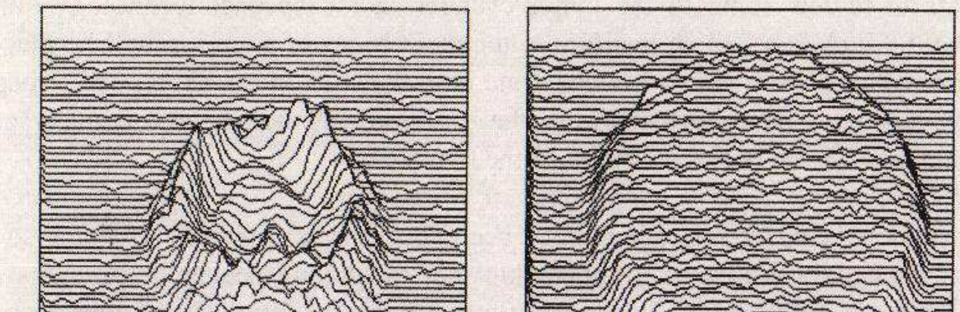

Figure 2. Laser vibrometer images of mechanical behaviour of (a) fabric and (b) metal dome tweeters.

2.1. UniQ Coincident source

Developed by KEF in the late 1980s [1] following the commercial arrival of neodymium iron boron magnets. Extended the concept of *coaxial* drivers to that of *coincident* sources. The reduction in the size of the tweeter magnet structure allows the tweeter to be placed *inside* the voice coil of the bass unit (figure 3). This eliminates any time delay between the two radiators, providing much greater uniformity of off-axis performance, hence improved imaging and greater independence of the listening environment.

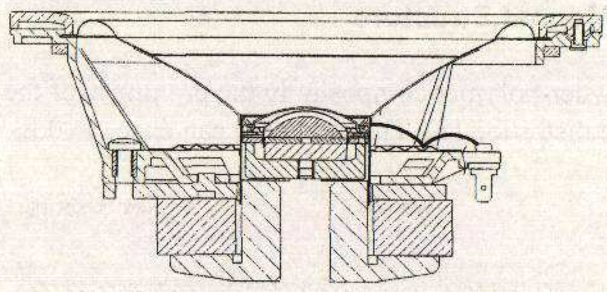

Figure 3. UniQ Coincident Drive Unit.

2.2. Inductive Coupling Technology (ICT)

Conceived by Boaz Elieli and realised in volume production by Goodmans [2]. Utilises the high-frequency eddy current energy in and around the pole to drive a passive tweeter diaphragm (figure 4).

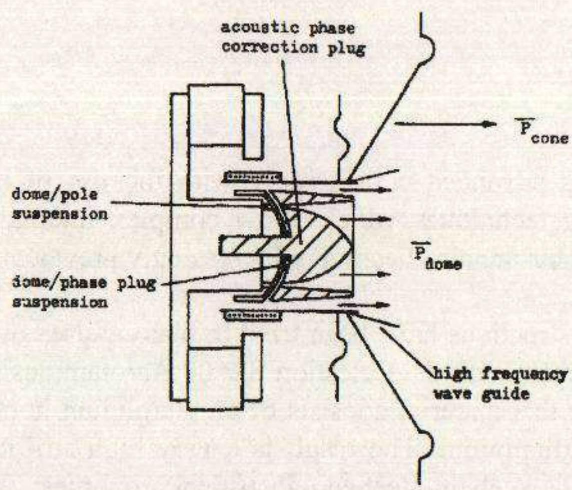

Figure 4. Inductively-coupled loudspeaker (courtesy Goodmans).

2.3. Distributed Mode Loudspeaker (DML)

Under development by NXT from work started at DERA [3,4]. Uses moving-coil actuators to excite bending waves in flat or shallow panels (figure 5). Potential benefits include elimination of cabinets, less intrusion into living spaces, and wider dispersion than conventional systems.

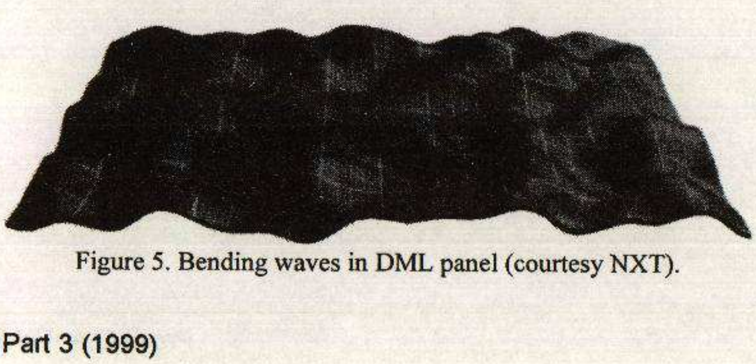

Figure 5. Bending waves in DML panel (courtesy NXT).

2.4. ATC 'Tipped' Magnet Structure

Uses rings of iron powder-polymer composite in the proximity of the magnetic gap to reduce third harmonic distortion [5]. The reduction can exceed 10dB in the mid-band.

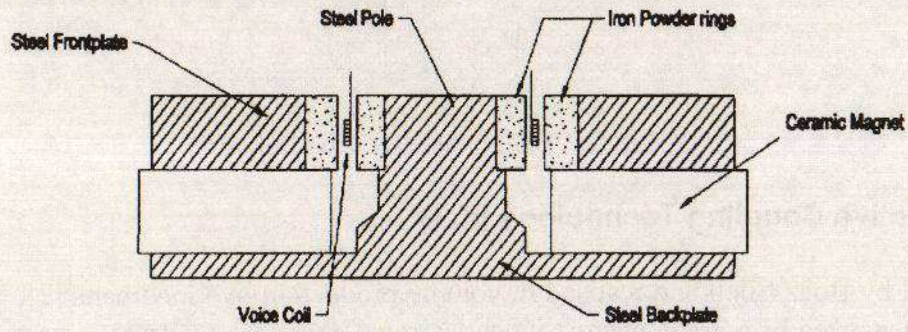

Figure 6. Magnet structure 'tipped' with iron powder-polymer composite (courtesy ATC).

3. Systems

3.1. Cabinets

Cabinet technology has advanced considerably with the use of exotic materials and/or advanced woodworking techniques which allow complex internal bracing or curvature. Injection-moulded cabinets are also becoming increasingly prevalent.

'Sandwich' cabinet constructions have been tried in many guises over several decades, but arguably reached a pinnacle with the Celestion SL600 Aerolam design. Designed for use in construction of aircraft, this material consists of an aluminium honeycomb core (figure 7) between two skins of aluminium. The result is a very high stiffness-to-mass ratio and a loudspeaker cabinet with excellent mechano-acoustical properties.

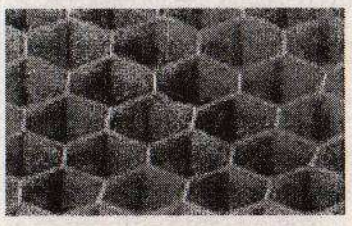

Figure 7. Aerolam core.

Cabinet bracing reached a peak with B&W's Matrix construction (figure 8).

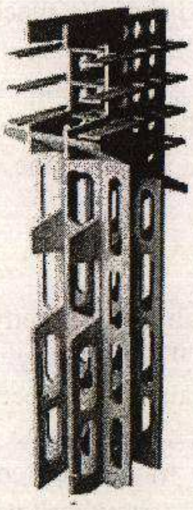

Figure 8. Matrix cabinet bracing system (courtesy B&W).

Figures 9a and 9d show a direct comparison between the vibration velocities of similar wood and Aerolam cabinets.

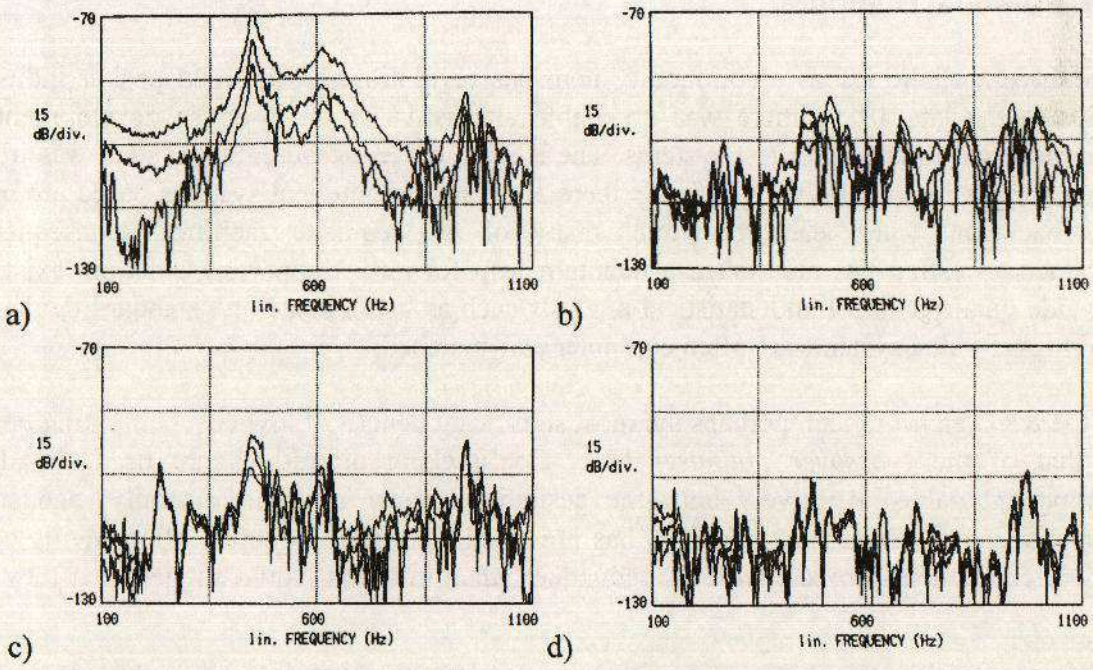

Figure 9. Comparison between different braces and effect of material on cabinet vibration. Side panel of cabinet, approx. 375 x 240mm. a) wood, unbraced (b) wood, single brace (c) wood, dual brace (d) Aerolam, unbraced.

Within the last 25 years we have also seen the rise to prominence of the *subwoofer* as a separate component, and this device is partly responsible for the parallel increase in popularity of bandpass and coupled-cavity low frequency systems [6].

3.2. Stands

During the 1980s it became accepted that the mechanical stability of loudspeaker stands played an important role in fidelity. Cliff Stone's Foundation Stands were arguably the first commercial loudspeaker stands *designed* to improve fidelity by their stability, usually achieved by making them inert by filling the columns with sand or lead shot. In figure 9d above the most significant vibration at 970Hz is the *stand* resonating!

3.3. Electrical Components

Moving into an area which remains almost as controversial today as when the issues were first widely discussed in the mid-1970s, it is generally agreed that careful choice of crossover components and cabling can often affect the quality of sound reproduction. In particular, polypropylene capacitors have become 'desirable' and cored inductors often benefit from iron dust instead of the traditional ferrite, significantly increasing saturation headroom. And then we have oxygen-free and/or linear-crystal cables...

4. Tools

4.1. Personal Computer

The advent of the PC as a commodity item has revolutionised the loudspeaker industry. Prior to the late 1980s there was no viable alternative to an in-house development of computerised loudspeaker test systems. The KEF impulse measurement system was in the vanguard in the mid 1970s [7]. Today there are many commercial systems based around a PC backplane card, each providing many of the requisite facilities. Consequently production testing has also taken a quantum leap forward. Supporting software exists to provide quality control and statistical analysis such as batch mean and standard deviation, and higher-value systems are often computer pair-matched.

In the R&D environment, perhaps the most significant benefit of low-cost computing power is that of the *crossover optimiser* [8]. Goal-seeking algorithms are used to adjust component values iteratively until the desired electrical or (more usefully) acoustical response is achieved. This technique has produced significant benefits, often saving costs where components are shown to be redundant when intuition would suggest that they are not.

4.2. Lasers

The loudspeaker industry discovered the attractions of laser metrology in the mid 1970s [9,10] and the technique was turned into a fine art by Bank and Hathaway around 1980 [11]. In its most useful form, a laser beam is reflected by a moving loudspeaker component and the carrier is frequency-modulated (Doppler shifted) in proportion to the velocity of the surface. The laser beam scans the surface and a computer animation of the motion is thus built up. The resulting metrology is best described as a 'dynamic microscope' (figure 2).

4.3. Finite Element Analysis (FEA)

There are two ways to model loudspeaker behaviour: with *lumped parameters* or with *distributed parameters*. Lumped-parameter modelling has been in use for several decades and provides a quick, simple analysis which is usually fairly accurate at low frequencies. However, as frequency increases the reliability of this method decreases. At frequencies where the loudspeaker cannot be treated as a lumped-parameter system, the distributed-parameter approach must be used. One popular version is Finite Element Analysis (FEA).

Whilst FEA has been in use for many years for structural analysis (particularly for major civil engineering projects such as dams and bridges, and in the aerospace and automotive industries), it is only comparatively recently that attention has turned to acoustics [12,13]. This is somewhat surprising given the immense analytical complexity of problems in acoustics. There are still only a few commercial programs which provide a truly integrated mechano-acoustical analysis.

The ability to allow the fluid (air) to load the structure is ultimately vital to precision modelling of loudspeakers. Figure 10 shows a coupled mechano-acoustical model of a cone driver in a wooden cabinet. This model includes air inside and outside the cabinet (although it is interesting to note that we could readily construct a model with *no* air inside the cabinet!) and vibrating cabinet panels.

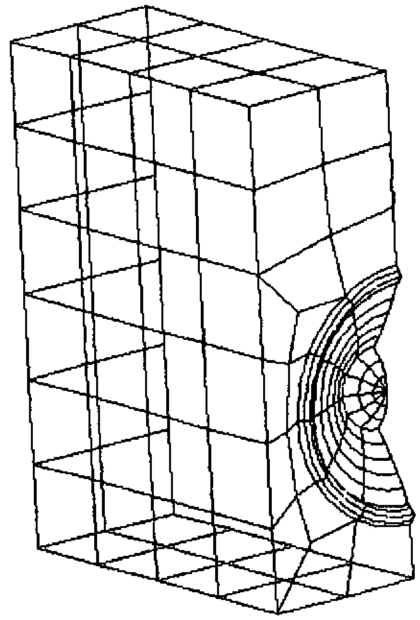

Figure 10. Fully-coupled model of drive unit in cabinet.

5. The Future?

It is in the nature of innovation that predictions will (hopefully) never be entirely accurate. However, the short-term road-map seems well defined. There is little doubt that even greater emphasis will be placed on computer-aided design, with FEA at the forefront. This in turn may lead to the development of unusual geometries, and specialised materials, composites or polymers.

The field of Auralisation is likely to make a major contribution to loudspeaker design, eventually providing the designer with the ability to experience his prototype in many different environments.

The development of 'immersive audio' (including surround/home theatre) is likely to drive a greater adoption of on-board electronics, leading to a increased use of active loudspeaker systems.

We look forward to the next 25 years with the same enthusiasm and awe as our counterparts did in 1974 !

6. Trademarks/Patents

Many of the items or concepts discussed here are subject to trademark or patent protection.

7. References

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