APPLICATION OF RECENT AUSTRALIAN LOUDSPEAKER RESEARCH TO PRODUCIBLE LOUDSPEAKER SYSTEMS

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Summary

The old cut and try methods of direct radiator loudspeaker system development have been minimized by the recent work of Australians Thiele, Small, and Benson. The operation of systems in the so-called low-frequency piston range where the wavelength is larger than the radiator is now quite predictable and predetermined. The Australians have contributed substantially to the storehouse of information that can aid and direct a systems designer. Well developed theory has been made available, permitting a designer to proceed from the specification of important end goals (such as efficiency, system size, low frequency limit, and power output) to a usable system with a minimum of empirical investigation. Applications of this theory to the design of several loudspeaker systems will be discussed.

Early History of Direct Radiator Loudspeaker Systems

Contributions of Others

In the period of roughly 1930 to 1970 (before U.S. republication of Thiele[1] and the articles of Small [2-6] and Benson [7-9]) a large number of researchers and loudspeaker system constructors contributed to the pool of accumulating knowledge for closed and vented-box systems. Some of these workers "flew it by the seat of their pants" while others pursued more analytic approaches to solving their problems. Dr. Richard Small describes the work of many earlier workers in the introduction to his excellent articles on closed and vented-box systems [4, Part I; 5, Part I].

Some of the early endeavors resulted in the creation of high quality commercially available systems. In particular Villchur[10] and his associates became allied with the early commercial success of the small closed-box system format in the early 1950's. In the area of early vented-box designs mention might be given to Locanthi[11], whose investigations eventually resulted in several rationally designed systems offered by James B. Lansing, and to the work of Klipsch [12], whose Cornwall system of the late 1950's was carefully and laboriously worked out before the republication of Thiele's elegant article. These people, together with unnamed others, have contributed their efforts empirically and analytically toward the creation of usable acoustical products before the wealth of information poured forth from the Australians.

Ourselves

In the period of the late 60's and early 70's we were attempting to cope with the intricacies of closed-box systems at our company. To a great extent this involved duplicating formats developed by Acoustic Research and KLH. We were up to our necks in two-way eights and tens and three-way twelves. Unfortunately, interrelationships between such matters as efficiency, box size, low frequency cutoff, and system type (which would later be revealed) were understood only in a crude empirical way. In an effort to strike out along a new and hopefully better path, it was proposed to create a (then) mildly radical form of closed system using an integral and complementary circuit or equalizer. The equalizer was intended to restore 6 dB worth of intentionally tapered off low frequency response. In this fashion relatively deep bass appeared to be available in modest box sizes with reasonable mid-band efficiencies. 45 and 32 Hz response was planned for in respective eight and twelve inch systems.

Vented boxes?--they were strange devices which were tuned to the loudspeaker's free air resonance frequency. Often as not they had exaggerated "boomy" bass, although sometimes, mysteriously, they had surprisingly thin bass when large motor woofers were employed--they were an odd and suspicious system format.

Unknown to us, matters were soon to be changed.

What They Told Us We Could Do

The research by Thiele, Small, and Benson has considerably simplified the design of the low frequency portion of direct radiator loudspeaker systems.

The normal design procedure consists of two parts: (1) selection of end goals and (2) driver/enclosure synthesis. Some of the important end goals for the system which the designer must specify are items such as efficiency, maximum acoustic output versus frequency, physical size, low frequency limit, and frequency response shape (maximally flat, gradual rolloff, humped, etc.). Once these goals are established, the physical details of the driver and its enclosure must be determined. The type and style of enclosure (whether closed or vented box) has to be selected. The driver's physical characteristics, such as diaphragm area, moving mass, suspension compliance, excursion capabilities, and motor strength have to be pinned down.

The design equations and mathematical models presented in the papers by Thiele, Small, and Benson allow the designer to proceed directly from the first part of the design procedure to the second part with a minimum of empirical investigation. Unfortunately, the major part of a design effort, once the low frequency performance is pinned down,

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is often centered on optimizing the response of a particular driver in the upper end of its frequency range. Here the unpredictable effects of cone breakup, nonlinearities, narrowing polar response, etc., complicate the designer's job and make recourse to the old empirical design methods almost mandatory.

What We Did

After months spent digesting Thiele's republished article, it was evident that a unique systematic approach had been made available to a system designer interested in vented boxes. Thiele's table of twenty-eight "alignments," or methods of coordinating the parts of a system to achieve a specific output characteristic, provided a wealth of design information (once understood)--almost so much of a wealth it was difficult to know where to begin. A certain excitement and panic seized us as we envisioned wheezing, vibrating tubes throbbing away in the loudspeaker laboratories of the U. S. in a pell-mell rush to convert theory into product. At about this time the work of another Australian, Richard Small, further reinforced the impression that the newly revealed vented-box systems were well worth the effort necessary to comprehend how to properly create them.

Fortunately, these startling revelations (and they were startling then) could not have happened at a better time for us. Our closed-box equalized system which was to use an eight inch woofer and have 45 Hz low frequency capabilities could now descend an additional half octave to 32 Hz but still keep the same box size and conversion efficiency as before. [13, 14] This was especially gratifying, as in our pre-Thiele, Small, and Benson days it was felt necessary to create a substantially larger twelve inch closed system to accomplish this. The Australians provided us with a most satisfying and useful path to travel in those days.

What Others Have Done

The excellent design data presented by the Australian researchers has contributed to the implementation and design of several recent loudspeaker systems by manufacturers other than Electro-Voice. Some of these manufacturers are CBS Labs, A&I Sound, Magnavox (Australia), and Ohm Acoustics to name a few. These systems are vented designs which in many cases are based on the fourth-order Butterworth high-pass frequency response alignment number 5 [1, Part I, p. 388] or an adjacent alignment. Low frequency cutoffs (-3 dB) in the range of 30 to 50 Hz are common in these systems. These manufacturers have used the recently available data to produce systems of high value to the user. Furthermore, it has been possible to approach these new systems with greater surety of end results than would have been possible a few years ago.

What Can Be Done

The earlier mentioned apparition of wheezing tubes materializing in the back rooms of acoustical laboratories throughout the nation has not occurred to the degree once imagined. It is strongly suspected that most systems are still being designed empirically, and it might be observed that the vented box format is still much in the minority. It would therefore seem that much remains to be accomplished in the optimization of the low to mid-frequency portion of the acoustic spectrum that the Australians have been addressing themselves to. In addition, the storehouse of detailed information to be tapped is continually growing through the continued efforts of Small [3-6] and Benson [7-9]. Besides the further optimization of the low-frequency section of systems, it may be that the area of very high-conversion efficiency held by horn type transducers in the low and mid-band acoustic areas may receive more serious competition from direct radiators as their characteristics and possibilities are better understood.

The same careful analytic approach which has been applied to the low frequency end of direct radiator speaker systems needs to be applied now to the high frequency operating range. Topics such as high frequency polar response, power output, and nonlinear second order effects need to be tied analytically to such physical parameters of the driver as cone geometry/material, surround type, voice coil type and geometry, etc. Some work has been done in this direction with complex, sophisticated computer modeling techniques by Phillips Research Labs. [15]

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