APPLICATION OF RECENT AUSTRALIAN LOUDSPEAKER RESEARCH TO PRODUCIBLE LOUDSPEAKER SYSTEMS


Summary

The old cut and try methods of direct radiator loudspeaker system development have been mini-
mized 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 de-
signer. 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
t wo; power output) to a usable system with a minimum
of empirical investigation. Applications of this
t heory 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's work and the articles of
Small2-6 and Benson7-9) a large number of re-
searchers 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 Vilhur10 and his asso-
ciates 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 Locanthi11,
whose investigations eventually resulted in several
rationally designed systems offered by James B.
Lansing, and to the work of Klipsch12, 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.

Our selves

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, inter-
relationships 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 com-
plementary 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 effi-
ciencies. 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
g oals 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 com-
pliance, 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,
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 re-published 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

References


