

LETTERS TO THE EDITOR

COMMENTS ON "A PSYCHOACOUSTICALLY OPTIMIZED LOUDSPEAKER"^{*}

We have read with interest the above engineering report.¹ In principle, we agree with several of the points raised in the area of sound localization due to early delays of the primary radiated signal, specifically within a time aperture of 250 μ s to 2 ms. Such delays are comparable with inter-ear time difference, which is a critical parameter related to image localization in two-loudspeaker two-channel stereophonic reproduction. It is clear that many loudspeaker designers have failed to take account of early delays, and as a result, such loudspeaker systems cannot reproduce optimum stereophony.

The principal mechanism responsible for early delays is a result of finite baffle geometry, specifically where the baffle edge is abrupt and forms an impedance discontinuity in the propagation medium across the baffle surface. However, in the report it is stated that the delayed signal is a result of reflection and refraction from loudspeaker cabinet elements. This, in general, is incorrect. Reflection and refraction have specific meanings: the former refers to a wave-boundary encounter where the angles of incidence and reflection are equal, while the latter refers to the interface of two differing media where the direction of propagation is changed due to differing material properties. In general, these are not the appropriate mechanisms for a finite baffle geometry.

The process that describes the generation of the delayed signal due to a baffle edge or irregularity is that of diffraction, and was described in our recent paper [1]. The term "reflection" has had a long history of misuse. For example, Nichols's paper [2] of 1946 talks of partial reflection at the edge of a baffle (though it is also clear in the paper that the mechanism of diffraction is properly understood). More recently, Kates uses incorrect terminology and refers to reflection [3, fig. 1]. In fact, Eq. (1) of Kates's paper is actually a mathematical expression of the geometric theory of diffraction (GTD), where a is equivalent to M_k and τ is equivalent to τ_k in our paper [1].

The use of acoustic foam to control directivity and also to attenuate the acoustic field prior to a baffle edge encounter is a useful technique which was cited in a

recent article [4] with respect to edge diffraction. We also believe that AR have used foam to control directivity in loudspeaker systems. However, care must be exercised in the selection of absorbent material specifically with respect to rigidity, since motion of the foam in sympathy with the acoustic field can lead to audible coloration due to local kinetic energy.

Fig. 1 shows an active loudspeaker which incorporates an acoustic loss filter both to attenuate side radiation and to reduce the effect of edge diffraction, specifically within the critical midband. This system was developed around 1983–1984. The substantial filter was arranged so that the side radiation from the drive units propagated through the lossy medium (open-cell acoustic foam), thus undergoing attenuation. Subjectively, the system gained in stereophonic focus, yielding greater image precision together with less dependence on room coloration, particularly from sidewall reflections.

We are in close agreement on the points raised with respect to loudspeaker directionality and early error signal delays, but we are more apprehensive about ambient sound field generation. Ideal and faithful listening conditions are anechoic where there is zero room col-



Fig. 1. Example of acoustic foam loss filter (c. 1983) to reduce baffle edge diffraction and side radiation.

^{*} Manuscript received 1987 February 12.

¹ K. L. Kantor and A. P. de Koster, *J. Audio Eng. Soc. (Engineering Reports)*, vol. 34, pp. 990–996 (1986 Dec.).

oration. From a purist viewpoint it is only the primary source information that should be auditioned. All secondary signals from room reflection and diffraction or artificial enhancement are strictly undesirable and not a function of the source material. It is there that directional loudspeakers, which maintain a well-defined polar response over their operational bandwidth, are advantageous as they minimize room interaction, leading to a better interface to the listening environment. However, the close approximation to a windowed point source of sound, where early delays due to diffraction are minimized, is clearly desirable; we believe that the importance of this aspect of loudspeaker performance on sound localization, until recently, has been generally ignored.

We also believe it to be important that the distance between a drive unit and a discrete baffle edge is not comparable with the distance between the pinnae, which inevitably leads to early delays close to the critical 500- μ s time period. This unfortunately is typical of many loudspeaker systems where diffraction is not correctly controlled.

In sound reproduction it is the acoustic of the recording that should be auditioned and not the ambience of the listening room/reproduction system. True ambience can only be approached using the ambisonic surround sound system in conjunction with theoretically optimum recording practice, as recently highlighted in Lipshitz's discussion paper [5].

MALCOLM J. HAWKSFORD
RICHARD BEWS
Audio Research Group
Department of Electronic Systems Engineering
University of Essex
Colchester, Essex, UK

REFERENCES

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- [4] M. J. Hawksford, "The Essex Echo: Reflexions," *Hi-Fi News Rec. Rev.*, vol. 30, pp. 35-40 (1985 Dec.).
- [5] S. P. Lipshitz, "Stereo Microphone Techniques . . . Are the Purists Wrong?" *J. Audio Eng. Soc. (Features)*, vol. 34, pp. 716-744 (1986 Sept.).

Author's Reply

I would like to thank Dr. Hawksford and Mr. Bews for taking the time to comment on the above engineering report.¹ There is little to disagree with in their letter,

but I wish to briefly address two of the points raised. The first concerns the use of the words "reflection" and "refraction." I regret the use of "refraction" rather than "diffraction." This error was noticed quite some time ago. Unfortunately circumstances prevented by re-viewing the text prior to its recent publication. I stand by the assertion that reflection can be an important mechanism contributing to early delays. Reflections often result from internal driver structures (such as pole pieces), from improperly designed grille frames, and from front baffles with large recesses, for example.

Second, I consider the presentation of delayed ambient energy to be very justifiable, especially if it is properly controlled and fully removable. Even if one subscribes to the view that proper ambience reproduction can only be achieved by means specific recording and encoding procedures, it is still possible to allow that correctly adjusted supplemental radiation might produce a more accurate subjective experience with many existing recordings.

KENNETH L. KANTOR
Product Design and Evaluation Services, Inc.
San Francisco, CA 94107, USA

CORRECTION

FURTHER CORRECTIONS ON "DESIGN OF OPTIMIZED LOUDSPEAKER CROSSOVER NETWORKS USING A PERSONAL COMPUTER"*

I am grateful to Mr. Witold Waldman of Melbourne, Australia, for the following corrections to the above paper¹ and suggestions to modify the program given in Appendix 2.

Due to an error on my part, the derivation in Appendix 1 and the program code given in Appendix 2 require revision. This error when corrected as indicated below will increase the speed of the optimization program by approximately a factor of 10 and will make the program much more robust and less sensitive to the initial component values. The changes are as follows.

- 1) In Appendix 1, Eq. (32) should have read

$$\frac{\partial V_n}{\partial a_k} = -V_l^q V_m + V_l^q V_l + V_m^a V_m - V_m^a V_l \quad (32)$$

- 2) In Appendix 1, Eq. (33) should have read

$$V_0^q = V_1^q = 0 \quad (33)$$

- 3) In Appendix 2, the program code requires the following modifications: delete lines 2780, 2790, and

* Received 1987 January.

¹ P. L. Schuck, *J. Audio Eng. Soc.*, vol. 34, pp. 124-142 (1986 Mar.).