Response to "Comments on 'Design of active structural acoustic control systems by eigenproperty assignment' " [J. Acoust. Soc. Am. 99, 1785–1788 (1996)]

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The authors wish to thank Professor Cunefare[1] for the interest he has expressed in our paper "Design of active structural acoustic control systems by eigenproperty assignment."[2] However, Professor Cunefare has shown some concern that we have not appropriately recognized previous related work, particularly with regard to his research on multimodal radiation efficiency.[3] It appears that Professor Cunefare's concerns stems from a lack of full understanding of the formulation that we presented in Ref. 2 and we wish to clarify these aspects in this Letter to the Editor.

Firstly, it must be stated that we *did* acknowledge the research contribution of Professor Cunefare in our paper.[2] This citation, for clarity, is repeated verbatim from Ref. 2 below:

> "It should be mentioned that Cunefare[25] developed a similar eigenvalue formulation for obtaining the optimum velocity distribution on a finite beam that minimizes the radiation efficiency of the beam response at a single frequency. It was suggested in this work that the optimum velocity response could be used as the objective function for the design of active control systems. Though similar in concept, the proposed formulation differs markedly from Cunefare's work in a fundamental aspect. Here the formulation searches for controlled eigenfunctions that are weak radiators and which are independent of the frequency."

The key statement in this reference is that while the formulation is related to Cunefare's work, it is different in a fundamental aspect. It is this difference we will now discuss.

To address Professor Cunefare's comments, it is convenient to briefly review the design formulation in Ref. 2. The formulation takes advantage of the fact that a feedforward controlled system has new eigenvalues and eigenfunctions. The design approach is based on finding the control actuator and error sensor such that (i) the eigenvalues of the controlled system lay away from the dominant part of the input spectrum, and (ii) the eigenfunctions are a set of weak radiating modes.

One approach, used by several researchers, is by solving a radiation eigenvalue problem as nicely reviewed by Cunefare.[1] Among them, the first application was by Borgiotti[4] that implemented this method to find a set of weak radiation velocity patterns in a infinite beam system. Cunefare[3] then used this technique to solve for the optimum velocity distribution of a finite beam at a single frequency that yielded minimum radiated power. The same eigenvalue problem (with a different mathematical formulation) was implemented in our work[2] to find the required mode shapes of the controlled system at the design frequency. Though the eigenvalue problem yields a set of eigenfunctions and associated radiation efficiencies at a single frequency, its use and interpretation is completely different from Cunefare's work.[3] In his work, Cunefare[3] only considers the eigenfunction with the lowest radiation efficiency to determine the optimum velocity distribution for the beam while the other eigenfunctions are discarded or left unused. That optimum velocity distribution will then be a function of the frequency. On the other hand, in our work[1] the first $N-1$ (N is the number of modes in the uncontrolled structure) are used while only the one with the highest radiation efficiency is discarded. Furthermore, the actuator and sensor are designed such that the *controlled system mode shapes* are identical to these $N-1$ eigenfunctions. As it is well known, the mode shapes of the controlled system are independent of frequency. It appears that Professor Cunefare has confused the eigenfunctions of his weak radiator expansion formulation with the eigenfunctions of the controlled dynamic system of our work.

Finally, it is clear from Ref. 2 that the radiation eigenformulation discussed above is only a minor part of the eigenfunction assignment control technique that we have developed in Ref. 2. Other approaches to determining the controlled expansion coefficients such as finding a set of modal expansion coefficients which render the first controlled $(N-1)$ modes nonvolumetric[5] or minimize the supersonic wave-number components within the radiation circle[6] could have been used to design the controller. Either of these approaches would give very similar results.

In summary, we do feel that we have adequately referenced and related Professor Cunefare's work to the new formulation that was presented in Ref. 2. We hope this Letter clarifies the matter.

[1] K. A. Cunefare, "Comments on 'Design of active structural acoustic control systems by eigenproperty assignment,' " J. Acoust. Soc. Am. **100**, 1785–1788 (1996).
[2] R. A. Burdisso and C. R. Fuller, "Design of active structural acoustic

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[3] K. A. Cunefare, ''The multimodal radiation efficiency of baffled finite beams,'' J. Acoust. Soc. Am. **90**, 2521–2529 (1991).
[4] G. V. Borgiotti, ''The determination of the acoustic farfield of a vibrating body in an acoustic fluid from boundary measurements,'' J. Acoust. Soc. Am. **88**, 1884–1893 (1990).
[5] R. A. Burdisso and C. R. Fuller, ''Dynamic behavior of structural-acoustic systems in feedforward control of sound radiation,'' J. Acoust. Soc. Am. **92**, 277–286 (1992).
[6] R. L. Clark and C. R. Fuller, ''Active structural acoustic control with adaptive structures including wavenumber considerations,'' J. Intelligent Mater. Syst. Struct. **3**(2), 296–315.