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Letters to the Editor

Comments on "The effects of plant and disturbance uncertainties in active control systems on the placement of transducers"

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In Ref. [1], Baek and Elliott investigated the effects of plant uncertainties in active control systems on the placement of loudspeakers by deriving the minimum residual error with unstructured uncertainty in plant response. The minimum residual error of Eq. (44) in Ref. [1] was derived using the optimal input vector as follows:

$$\mathbf{u}_{opt} = -[(\mathbf{G}_0 + \mathbf{\Delta G})^{\mathrm{H}}(\mathbf{G}_0 + \mathbf{\Delta G})]^{-1}(\mathbf{G}_0 + \mathbf{\Delta G})^{\mathrm{H}}\mathbf{d}_0. \tag{1}$$

This means that the uncertainty $\mathbf{\Delta G}$ is assumed to be known and can be used when obtaining the optimal input vector. The assumption is not correct since the optimal input vector should be calculated from the nominal values only. The cost function J can be written as

$$J = (\mathbf{d}_0 + \mathbf{Gu})^{\mathrm{H}}(\mathbf{d}_0 + \mathbf{Gu}). \tag{2}$$

Hence, the correct derivation for the minimum residual error J_{min} should take the form of

$$J_{min} = \mathbf{d}_0^{\mathrm{H}}\mathbf{d}_0 + \mathbf{d}_{\mathrm{o}}^{\mathrm{H}}(\mathbf{G}_0 + \mathbf{\Delta G})\mathbf{u}_{opt} + \mathbf{u}_{opt}^{\mathrm{H}}(\mathbf{G}_0 + \mathbf{\Delta G})^{\mathrm{H}}\mathbf{d}_0 + \mathbf{u}_{opt}^{\mathrm{H}}(\mathbf{G}_0 + \mathbf{\Delta G})^{\mathrm{H}}(\mathbf{G}_0 + \mathbf{\Delta G})\mathbf{u}_{opt}, \tag{3}$$

where the optimal input vector is

$$\mathbf{u}_{opt} = -[\mathbf{G}_0^{\mathrm{H}}\mathbf{G}_0]^{-1}\mathbf{G}_0^{\mathrm{H}}\mathbf{d}_0. \tag{4}$$

If Eqs. (39)–(42) of Ref. [1] are used, the mean value of J_{min} is simplified as follows:

$$E[J_{min}] = J_0 + E[\Delta J], \tag{5}$$

where the nominal minimum cost function J_0 related only to the nominal value is

$$J_0 = \mathbf{d}_0^{\mathrm{H}}[\mathbf{I} - \mathbf{G}_0(\mathbf{G}_0^{\mathrm{H}}\mathbf{G}_0)^{-1}\mathbf{G}_0^{\mathrm{H}}]\mathbf{d}_0 \tag{6}$$

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and the value ΔJ related to the uncertainties is

$$\Delta J = \mathbf{u}_{opt}^{\mathrm{H}} \mathbf{\Delta G}^{\mathrm{H}} \mathbf{\Delta G} \mathbf{u}_{opt}. \tag{7}$$

Consequently, the $E[J_{min}]$ can be derived as follows:

$$E[J_{min}] = J_0 + \beta \mathbf{u}_{opt}^{\mathrm{H}} \mathbf{u}_{opt}, \tag{8}$$

where $\mathbf{u}_{opt}^{\mathrm{H}} \mathbf{u}_{opt}$ is a control effort and β represents the amount of uncertainty defined in Ref. [1]. This equation appears to have a simple analytic form whereas the analysis presented in Ref. [1] does not. The result definitely implies that among many variations of loudspeaker arrangement with the same nominal minimum cost function J_0 which give good attenuation, a particular loudspeaker arrangement with low control effort $\mathbf{u}_{opt}^{\mathrm{H}} \mathbf{u}_{opt}$ has robust performance to the random variations in the plant response. Therefore, the above derivation leads to the same conclusion as in Ref. [1].

References

[1] K.H. Baek, S.J. Elliott, The effects of plant and disturbance uncertainties in active control systems on the placement of transducers, *Journal of Sound and Vibration* 230 (2) (2000) 261–289.