Reply to "Comments on 'A Weighted Least-Squares Method for the Design of Stable 1-D and 2-D IIR Digital Filters'"

W.-S. Lu, S.-C. Pei, and C.-C. Tseng

***Index Terms*—IIR filter, weighted least-squares method.**

When the work reported in [1] was performed, the authors were unaware of the 1963 paper by Sanathanan and Kerner and the 1965 paper by Steiglitz and McBride on system identification and their subsequent development. Nevertheless, we believe that the comments made in [2] are insightful and encourage further studies of the Steiglitz–McBride iteration in the context of digital filter design.

Following the analysis given in [2, Sec. III], a reasonable estimate of n such that σ_{n+1} is sufficiently small could be obtained as follows. For a given $F_d(\omega)$, use an established method to find a high-order FIR filter that well approximates $F_d(\omega)$. We then examine this FIR transfer function in a state-space and computes its Hankel singular values. The pattern of these singular values usually would exhibit a sudden drop at a certain n, which suggests the order of the IIR filter to be designed. Furthermore, a balanced-realization based model-reduction procedure can be applied to the FIR filter to generate an nth-order stable IIR filter as an initial point for the Steiglitz-McBride iteration. This initial point should be considered good as the difference between the FIR filter and the initial IIR filter in the Hankel norm is known to be less than $2\sigma_{n+1}$ [3].

Concerning the stability of the Steiglitz–McBride iteration, it was recognized in [1] that the constraints in (20) or (21) imposed *sufficient* constraints on the filter. An interesting and relevant recent development is the use of Rouché's theorem for the design of stable IIR filters [4]. Let $D^{k-1}(z)$ be the stable denominator polynomial obtained in the $(k-1)$th iteration, and let the denominator polynomial in the next iteration be given by

$$D^{(k)}(z) = D^{(k-1)}(z) + \alpha\delta^{(k)}(z)$$

where $\delta^{(k)}(z)$ is an nth-order polynomial, and $0 < \alpha < 1$. Rouché's theorem states that $D^{(k)}(z)$ remains stable if

$$|\delta^{(k)}(z)| \le |D^{(k-1)}(z)| \quad \text{on } |z| = \rho \tag{1}$$

where $0 < \rho < 1$ can be used to control the stability margin of the filter to be designed. Note that the constraints in (1) are *linear* with respect to the coefficients in $\delta^{(k)}(z)$. The design examples described in [4] indicate that constraints in (1) can be less conservative than those imposed in [1].

Manuscript received February 14, 1999; revised February 25, 1999. The associate editor coordinating the review of this paper and approving it for publication was Dr. Ali H. Sayed.

W.-S. Lu is with the Department of Electrical and Computer Engineering, University of Victoria, Victoria, B.C., Canada V8W 3P6.

S.-C. Pei is with the Department of Electrical Engineering, National Taiwan, University, Taipei, Taiwan, R.O.C.

C.-C. Tseng is with the Department of Computer and Communication Engineering, National Kaohsiung First University of Technology and Science, Kaohsiung, Taiwan, R.O.C.

Publisher Item Identifier S 1053-587X(99)04664-4.

References

[1] W.-S. Lu, S.-C. Pei, and C.-C. Tseng, "A weighted least-squares method for the design of stable 1-D and 2-D IIR digital filters," *IEEE Trans. Signal Processing*, vol. 46, pp. 1–10, Jan. 1998.

[2] P. A. Regalia, "Comments on 'A weighted least-squares method for the design of stable 1-D and 2-D IIR digital filters,'" *IEEE Trans. Signal Processing*, this issue, pp. 2068–2070.

[3] K. Glover, "All optimal Hankel-norm approximations of linear multivariable systems and the L_∞-error bounds," *Int. J. Contr.*, vol. 39, pp. 1115–1193, 1984.

[4] M. C. Lang, "Weighted least-squares IIR filter design with arbitrary magnitude and phase responses and specified stability margin," in *Proc. IEEE Symp. Adv. Digital Filtering Signal Process.*, Victoria, B.C., Canada, June 1998, pp. 82–86.

Comments on "A Variational Approach to the Extraction of In-Phase and Quadrature Components"

David Vakman

***Abstract*— With a variational method, Gordon defined the quadratures and carrier frequency different from the analytic signal (AS). This approach ignores, however, that quadratures must be bandlimited. Restriction of bandlimiting results in another solution and leads to the AS model.**

***Index Terms*—Analytic signal, Doppler radars, quadrature components.**

I. Gordon's Method

Let us consider a narrowband real signal $s(t)$ given by

$$s(t) = p(t)\cos\omega_0 t - q(t)\sin\omega_0 t. \tag{1}$$

Here, $p(t)$ and $q(t)$ are slow functions (quadratures), and ω_0 is the carrier frequency. Note that the quadratures and the carrier frequency are ambiguous since, for a given $s(t)$, (1) is an equation with three unknowns: p, q, and ω_0. Therefore, it is unclear variation of what frequency ω_0 should be measured in Doppler radars.

For a fixed ω_0, the p and q can be obtained as

$$\begin{aligned} p(t) &= s(t)\cos\omega_0 t + r(t)\sin\omega_0 t\\ q(t) &= -s(t)\sin\omega_0 t + r(t)\cos\omega_0 t \end{aligned} \tag{2}$$

where the *auxiliary signal* $r(t)$ is a real function associated with the pair $p(t)$ and $q(t)$ as

$$r(t) = p(t)\sin\omega_0 t + q(t)\cos\omega_0 t. \tag{3}$$

Manuscript received June 30, 1998; revised December 18, 1998. The associate editor coordinating the review of this paper and approving it for publication was Dr. Xiang-Gen Xia.

The author is at 213 Bennett Avenue, Apt. 2D, New York, NY 10040 (e-mail: DVakman@aol.com).

Publisher Item Identifier S 1053-587X(99)04680-2.