EFFECT OF FEEDBACK ON THE FREQUENCY RESPONSES OF SYSTEMS CONTAINING NONRECURSIVE DIGITAL FILTERS

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Nonrecursive digital filters (NDF) constitute a widely used element in systems for digital signal processing. They are implemented by means of integrated circuits, solid-state devices based on surface acoustic waves (SAW), and devices with charge coupling (see [1]). In a number of cases the necessity arises of controlling the amplitude-frequency response (AFR) of systems, which is usually carried out by changing the coefficients of the NDF; this is difficult from the engineering standpoint, especially for solid-state implementations. Therefore, methods which allow the AFR of a system to be varied without altering the internal structure of the NDF are of interest. Such a result may be achieved by commutation of filters having known AFR (see [2]), but under these conditions hardware expenditures increase. The control of the system passband by means of quadrature processing of the input signal may be effectively accomplished only for NDF which are close to ideal differentiators or Hilbert converters and requires the presence of two such filters (see [3]). In radioelectronics, extensive use is made of feedback (FB) in order to control AFR. The use of FB converts an NDF into a recursive filter, but the AFR of such a structure has not been considered in the theory of recursive filters.

The complex AFR of low-pass NDF having a linear phase in the presence of FB (H_{FB}) can be written in the form

$$H_{FB}(f) = H(f)\exp(-j2\pi fT)/\{1 - \exp[-j2\pi f(T+t)]\,H(f)\,k_1\},$$

where H, T are the modulus of the AFR and the delay of the original NDF; k_1, t are the transmission factor of the signal and the delay in the FB circuit ($k_1 = k/H(0)$, where k is the normalized FB factor). The value of $|k| < 1$ guarantees the stability of the filter and is of greatest interest. The normalizing factor for H_{FB} is $H_{FB}(0)$, it being true that

$$H_{FB}(0) = H(0)/(1-k); \qquad q_{FB} \leqslant q(1-k); \qquad \Delta f_{FB} = \Delta f y(1-k);$$
$$\tau_{FB}(0) = (T + kt)/(1-k),$$

here q, q_{FB} are the normalized level of the side lobes of the original NDF and of the NDF with FB; Δf, Δf_{FB} are the widths of the passbands of the NDF and the NDF with FB, respectively; y(x) is a certain function (y(1) = 1) that is monotonically increasing on the interval [0; 2]; τ_{FB} is the group time delay of the system. In the case $k > 0$, an increase in k leads to a decrease in the level of the side lobes and in the width of the system passband compared with the original NDF (i.e., it leads to a sharpening of the frequency response; see [2]). For $k < 0$ a reduction in k leads to a broadening of the passband (the level of the side lobes increases by no more than a factor of 2). If k is made to be complex, the possibility is provided of altering the center frequency of the filter within certain limits (the center frequency is the one at which the phase-balance condition is satisfied).

An NDF with FB is a recursive device and has a nonlinear phase-frequency response (PFR). However, for $f_n(T + t) \leq 1$, where f_n is the frequency of the first null of the AFR of the NDF, the AFR does not have additional extremums in the passband, and the PFR is fairly smooth. This conditions is satisfied for NDF whose coefficients are equal to the quantized values of the nonparameter Dirichlet, Hamming, and Fejer window functions or to the values of a number of parametric window functions for small values of the parameter. The conditions may be satisfied for NDF having broader bands when the group time delay error is uniform and the signal delay in the filters is chosen to be shorter than it is in NDF having a linear phase (see [4]). For $f_n(T + t) > 1$, the AFR of the

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