The addition of the zeros will decrease the 3-db bandwidth of the filter, however, as seen in Fig. 3. Therefore, a compromise must be reached between reduction in bandwidth and reduction in overshoot.

An effective way to overcome this difficulty is to scale up the bandwidth by a factor of say 1.8. Then the zeros are placed at $\omega = \pm 1.8$ which will reduce the 3-db bandwidth to approximately its original figure, $\omega = 1.0$ as shown in Fig. 3. The overshoot, however, will be reduced as though the zeros were at the band edge.

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Comments on Some Japanese Contributions*

In the June, 1960 issue of these TRANSACTIONS, recognition was given to several Japanese contributions to Circuit Theory.[1] Here we wish to call attention to some other contributions, which we feel might be of general interest.

Recently Prof. M. Kawakami of the Tokyo Institute of Technology has been visiting this country. During his stay at Stanford we learned of several books which he has authored or coauthored. The ones we would like to call attention to, are

1) M. Kawakami, "Network Synthesis," 1956 (154 pp.).
2) M. Kawakami and H. Shibayama, "Approximation and Synthesis," 1960 (133 pp.).
3) M. Kawakami and K. Yanagisawa, "Fundamentals and Applications of Active Circuits," 1959 (100 pp.).

These are all published by Kyoritsu Publishing Company, Tokyo, and are written in Japanese. These are of the nature of first year graduate textbooks, but contain important material which is (as far as I know) unavailable in English. For instance, the first two books contain a theory of "degenerated" Chebyshev polynomials which allows one to obtain the maximum possible (transducer) gain for even order, double but equally terminated equal-ripple type filters.[2] The low-pass case without finite zeros of transmission is treated in the first book. The case of equal ripple characteristics outside the pass band is covered in the second book mentioned above. Another feature of interest is the convenient charts for the design of maximally flat and equal-ripple responses. These two books also contain a transfer function synthesis, due to Miyata, which yields results equivalent to those obtained by Darlington's method.

The third book mentioned above covers modern methods of active network synthesis using various types of transducers, such as the NIC. The various types of ideal active transducers are conveniently tabulated, as well as are realizations in terms of transistors and vacuum tubes. An interesting feature is the simple treatment of active immittance it contains. The book should be extremely valuable to anyone interested in modern theory. Even though the book is written in Japanese, much of the material of interest is easily accessible to the English speaking reader, being in tabular form.

In the same series, Japanese authors have written books on topics not covered in even the most recent English books, such as, for example, *Synthesis of Distributed Constant Networks* by K. Kuroda and *Variable Constant Networks* by Z. Kiyasa and I. Toda.

Finally we would like to thank Prof. Kawakami for bringing the above works to our attention, and for his illuminating discussions with those of us working in his areas of interest.

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[1] W. R. Bennett, "A recognition of Japanese contributions to circuit theory," IRE TRANS. ON CIRCUIT THEORY, vol. CT-7, pp. 86–87; June, 1960.

[2] The impossibility of achieving this with the normal Chebyshev filter is covered in L. Weinberg, "Network Analysis and Synthesis," McGraw-Hill Book Co., Inc., New York, N. Y., p. 589; 1962.

Group Delay and Dissipation Loss In Transmission-Line Filters*

The letter by T. R. O'Meara [1] was of special interest to me, as I am just completing a report [2] on group delay and dissipation loss. While I hope to publish this eventually as a full length paper, it may be of interest to summarize the principal results in this letter.

The report [2] considers mainly transmission-line stepped-impedance filters [3], [4], such as quarter-wave transformers or half-wave filters. It is shown [2], [4], that the transmission-line filters reduce to lumped-constant filters in the limit as the parameter R (the output-to-input impedance ratio in the case of a quarter-wave transformer) tends to infinity.

Consider a stepped-impedance filter (Fig. 1). At first, suppose the filter to be free of dissipation loss. Let $|a_1|^2$ be the power carried by the forward wave in the first cavity, and $|b_1|^2$ the power carried by the reflected wave. Similarly for other cavities up to the n-th cavity. Let [5]

$$\left.\begin{aligned} U_i &= \frac{|a_i|^2 + |b_i|^2}{|a_i|^2 - |b_i|^2} \\ &= \frac{\text{Gross Power Flow in the } i\text{-th Cavity}}{\text{Net Power Flow in the } i\text{-th Cavity}} \end{aligned}\right\}. \qquad (1)$$

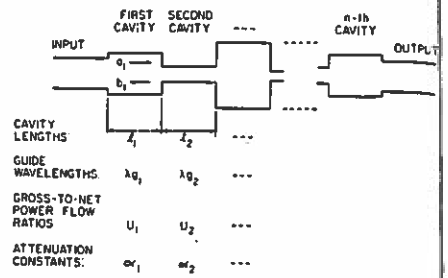

Fig. 1—Stepped-impedance filter.

Then it can be shown [2] that the group delay $(t_d)_0$ at center frequency f_0 and with the notation of Fig. 1 is given by

$$f_0(t_d)_0 = \sum_{i=1}^{n} \left(\frac{\lambda_{gi}}{\lambda}\right)_0^2 \left(\frac{l_i}{\lambda_{gi}}\right)_0 U_i \qquad (2)$$

where λ is the free-space wavelength. The ratio $(l_i/\lambda_{gi})_0$ is therefore the length of the i-th cavity measured in guide wavelengths at center frequency (assumed to be an integral multiple of 1/4), and $(\lambda_{gi}/\lambda)_0^2$ is the dispersion factor [6], [7] at center frequency (equal to unity for nondispersive filters).

It has been shown [5] that the dissipation loss $(\Delta L_A)_0$ of the filter at center frequency, when small, is given by

$$(\Delta L_A)_0 = (1 - |\rho_0|^2) \sum_{i=1}^{n} \alpha_i l_i U_i \quad (3)$$

where ρ_0 is the input reflection coefficient. This can be shown [5] to reduce to Cohn's formula [8] for lumped constant filters when R tends to infinity [except that Cohn omitted the factor $(1 - |\rho_0|^2)$].

When the filter is matched at center frequency ($|\rho_0| = 0$), and when the filter is homogeneous (all the λ_{gi} the same), and when all the attenuation constants α_i are equal, then it follows from (2) and (3) that

$$(\Delta L_A)_0 = \alpha\lambda_g(\lambda/\lambda_g)^2 f_0(t_d)_0 \qquad (4)$$

which can also be written [6]

$$(\Delta L_A)_0 = \frac{\pi}{Q_u} f_0(t_d)_0 \qquad (5)$$

where Q_u is the unloaded Q of each cavity.

A series of "universal" curves was plotted [2] for the attenuation and group delay of maximally flat, Chebyshev, maximally flat time delay, and periodic filters for 1, 2, 3, 4, and 8 and 12 resonators. Although these curves were computed for quarter-wave transformers, they were plotted in normalized form so as to be applicable to lumped-constant filters as well.

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[1] T. R. O'Meara, "Band-center group-delay and incidental dissipation," IRE TRANS. ON CIRCUIT THEORY, vol. CT-9, p. 192; June, 1962.
[2] L. Young, "Suppression of Spurious Frequencies," Stanford Res. Inst., Menlo Park, Calif., Quarterly Memo. No. 1, RADC Contract AF 30(602)-2734; July, 1962. (Section III: "Group-Delay and