MICROWAVE FILTERS WITH ARBITRARY PRESCRIBED PHASE CHARACTERISTICS

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Abstract

With the advent of practical non-minimum phase microwave networks, greater flexibility is now achievable in the design of frequency selective microwave filters. Design techniques are presented for the construction of generalized TEM mode interdigital filters and waveguide generalized direct coupled cavity filters which exhibit selective amplitude characteristics simulataneously approximating arbitrary prescribed phase characteristics.

Introduction

For high density communication systems which employ either analogue or digital frequency modulation techniques, several specifications upon both the phase and amplitude response of the individual channel filters have to be met. In the microwave region, the generalized interdigital (1,2) and generalized direct coupled cavity (3) filters, have provided practical structures of the non-minimum phase type which are potentially capable of achieving the desired amplitude and phase responses simultaneously.

Initial design procedures concentrated upon the ideal amplitude and exact linear phase response either approximating in a maximally flat sense (4) or a periodic approximation over the entire passband (5,6). For the maximally flat and periodic phase delay, realization in the form of generalized interdigital filters was demonstrated.

Unfortunately, in an attempt to maintain a linear phase response over 100% of the passband, for a given degree of filter selectivity is lost in the transition region into the stopband adjacent to the edge of the passband. For most frequency or phase modulation techniques, the linear phase response is not absolutely necessary towards the edge of the passband if the error follows a prescribed characteristic.

Thus, to improve band edge selectivity, a design technique has been devised whereby arbitrary prescribed phase responses may be approximated together with an approximation to ideal amplitude characteristics in a near optimum manner. This technique is analytical in nature and enables any amplitude and phase specification to be met with a minimum number of elements (7). This is achieved through the solution to the following problem for the low-pass prototype filter:

Determine the scattering transfer coefficient $S_{12}(j\omega)$ of a resistively terminated lossless reciprocal two-port of degree $2n$ which satisfies the following constraints:-

a) $|S_{12}(j\omega)| \leqslant 1$

b) $|S_{12}(\pm j\omega_i)| = 1$

c) $\text{Arg}\, S_{12}(\pm j\omega_i) = \pm\psi(\omega_i)$

$$\left.\begin{array}{l} b) \\ c) \end{array}\right\} \quad i = 1 \rightarrow n$$

where the ω_i arbitrary and $\psi(\omega)$ is any odd phase function. The solution is in terms of the arbitrary phase polynomials of the first and second kinds which are capable of being generated through simple recurrence formulas.

Two types of phase error distributions have been considered. The first is where the error deviation from linearity is of a maximally flat form. This is suitable for multipurpose channels which may contain either analogue frequency modulated signals or digitally phase modulated signals. An experimental filter of 10th degree, bandwidth 36 MHz at a centre frequency of 1 G Hz has been constructed. This generalized interdigital filter exhibited a loss of 1.5 db with a ripple of ±0.02 db over the central 80% of the passband rising to 1.9 db at band edge and exhibiting a selectivity equivalent to an 8th degree Chebychev filter at the 25db point in the stopband. Detailed response characteristics are shown in Fig. 1.

The second case is concerned with wideband frequency modulated signals. The phase error from linearity in this case is of a Gaussian form for minimum overall signal distortion. An example on an 8th degree filter of this type will be given.

In conclusion, a design technique is now available to allow strigent specifications on both amplitude and phase response of microwave filters to be met by practical structures which may be constructed to meet individual requirements at costs comparable to conventional minimum phase filters.

1) J.D. Rhodes, "The Theory of Generalized Interdigital Networks", I.E.E.E. Trans on Circuit Theory Vol. CT-16, pp. 280-288. August, 1969.

2) J.D. Rhodes, "The Generalized Interdigital Linear Phase Filter", I.E.E.E. Trans on Microwave Theory and Techniques, Vol. MTT-18, pp. 301-307, June, 1970.

3) J.D. Rhodes, "The Generalized Direct-Coupled Cavity Linear Phase Filter", ibid. pp. 308-313

4) J.D. Rhodes, "Generalized Interdigital Linear Phase Networks with Optimum Maximally Flat Amplitude Characteristics", I.E.E.E., Trans on Circuit Theory Vol. CT-17 pp. 399-408, August, 1970.

5) J.D. Rhodes, "A Low-Pass Prototype Network for Microwave Linear Phase Filters", I.E.E.E. Trans on Microwave Theory and Techniques, Vol. MTT-18 pp. 290-301, June, 1970.

6) J.D. Rhodes, "Filter with Periodic Phase Delay and Insertion Ripple", Proc. I.E.E., Vol. 119, pp. 28-32, January 1972.

7) J.D. Rhodes, "Filters Approximating Ideal Amplitude and Arbitrary Phase Characteristics", To be published in I.E.E.E. Trans. on Circuit Theory.

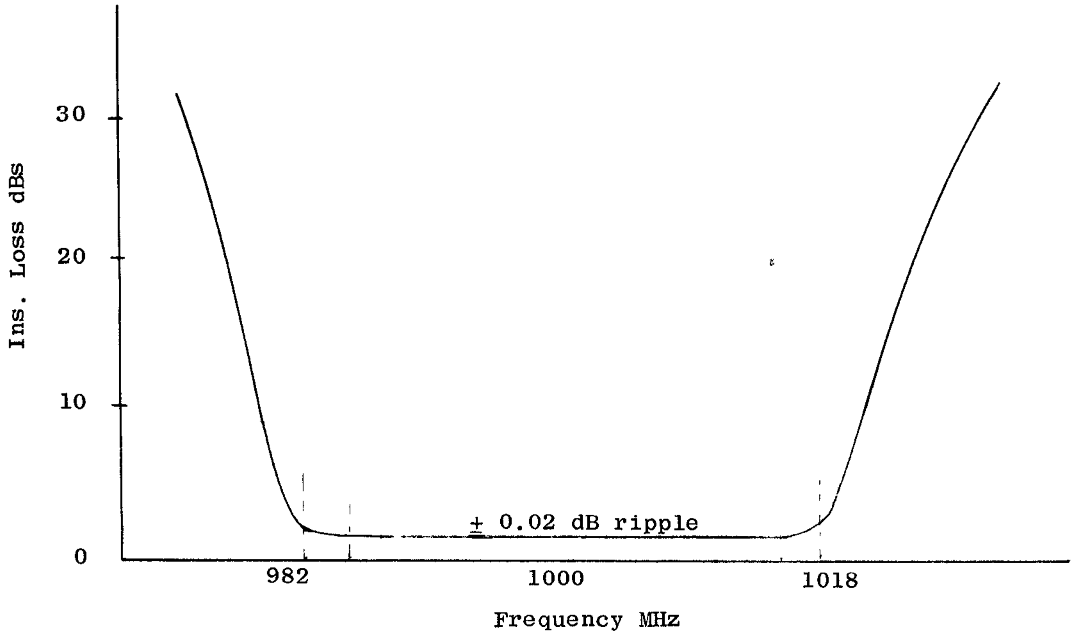

FIG. I