GENERAL EXTRACTED POLE SYNTHESIS TECHNIQUE WITH APPLICATIONS TO LOW-LOSS TE_{011} MODE FILTERS

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ABSTRACT

A new synthesis technique is developed for filters which exhibit arbitrary transfer characteristics. The real frequency transmission zeros are extracted using simple resonators separated by phase shifters. The remaining transmission zeros are realised by a cross-coupled double array with the entire filter possessing complex conjugate symmetry. Since all of the coupling elements are positive, TE_{011} mode filters may be directly realized and an example of a 6th degree filter at 19.6 GHz with both real and imaginary transmission zeros is cited.

Introduction

A novel synthesis technique is developed for two-port networks which possess finite real frequency transmission zeros. The lowpass prototype is synthesised in the form of a network with complex conjugate symmetry where the real frequency transmission zeros are extracted from both ends and realized by simple resonators separated by phase shifters. The remaining transmission zeros are realized by the central part of the filter in the form of a cross-coupled double array.

This prototype is particularly suitable for designing waveguide bandpass filters and each real frequency transmission zero is independently tunable. Furthermore, in the case of the most complex transfer function with all possible types of transmission zeros, the realization requires only one type of coupling which is necessary in the important case of TE_{011} cylindrical mode cavity resonators.

The general synthesis technique is given and the process will be illustrated by a non-trivial example. Additionally, from the results of a computer program based upon the synthesis technique, the important differences between the possible prototype forms for the same transfer function resulting from extracting the transmission zeros in different orders may be obtained.

The technique is applied to the design of a sixth degree TE_{011} mode filter which possesses a pair of transmission zeros at infinity and pairs of finite transmission zeros on both the real and imaginary axes. Results on an experimental device operating at 19.6 GHz shows excellent agreement with theory having low loss and a high power handling capability.

Description of Synthesis Procedure

Lowpass transfer functions for two-port resistivity terminated networks may be synthesised in many ways. The classical cascade synthesis techniques enable the transmission zeros to be independently realized by separate interacting two-port sections and are therefore attractive from a practical viewpoint. However, when the transmission zeros are complex or on the real axis of the complex plane, as is the case with selective linear phase filters with monotonic stopbands, then a more useful prototype is the cross-coupled double array (1). A main application is in microwave bandpass filters.

In both cases, when j-axis transmission zeros (real frequency transmission zeros) occur in the complex frequency variable, then each zero at either side of the passband is not independently tunable by a single component in the network. Since the location of this type of transmission zero is very sensitive, from a practical viewpoint it would be desirable to extract them from either above or below the passband in an independent manner.

This was appreciated in the development of the 'natural prototype' for the elliptic function filter. In that case explicit formulas for the element values resulted from the synthesis procedure (2). In this paper, this technique is extended for arbitrary transfer functions where the resonant circuits for each j-axis transmission zero are separated by unity impedance phase shifters.

Since most transfer functions resulting from approximation theory for lowpass filters (2) may be realized by a symmetrical structure, this will enable the network to be synthesised with complex conjugate symmetry. Such a restriction is implied in this paper.

Initially, the different extraction cycles required in the synthesis procedure are developed in a general manner. The first is the extraction of unity impedance phase shifters from either end of the network with complex conjugate symmetry. This is followed by the extraction of single shunt resonators at either end to extract a complementary pair of j-axis transmission zeros from each side of the passband. This process is repeated until all the finite j-axis zeros have been extracted and the remaining network is realized by a double cross-coupled array which also has complex conjugate symmetry.

In the full paper, (3) the entire synthesis procedure is illustrated by a non-trivial example which possesses pairs of transmission zeros at infinity on the j-axis and on the real axis. Additionally, using a computer program based on the synthesis procedure, an example of a sixth degree elliptic function prototype with four j-axis transmission zeros is investigated with the four possible forms

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resulting from extracting the transmission zeros in a different order.

For any transfer function the synthesis technique results in all coupling coefficients being positive. Thus it is ideal for low-loss TE_{011} mode cavity filters with purely inductive iris coupling. The prototype synthesis has been extended to cover this waveguide filter and a sixth degree filter has been designed and built at 19.6 GHz.

This filter possesses a pair of j-axis transmission zeros and a pair of real axis transmission zeros with the latter providing group delay equalization over the central 50% of the passband. The synthesised prototype filter is shown in Fig. 1. The six TE_{011} mode cavities were formed together with the rectangular guide coupling the j-axis transmission zero cavities by milling two solid blocks of aluminium each forming half of a cavity.

The final device required little tuning and the experimental results are given in Fig. 2-5. These results agree very closely with theory and even though the cavities were unplated and not polished, the loss was < 0.7 dB with an estimated power handling capability of several kilowatts.

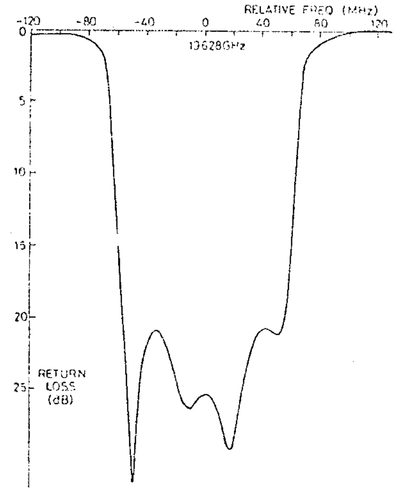

Fig. 4 RETURN LOSS - SYMMETRIC CHARACTERISTIC

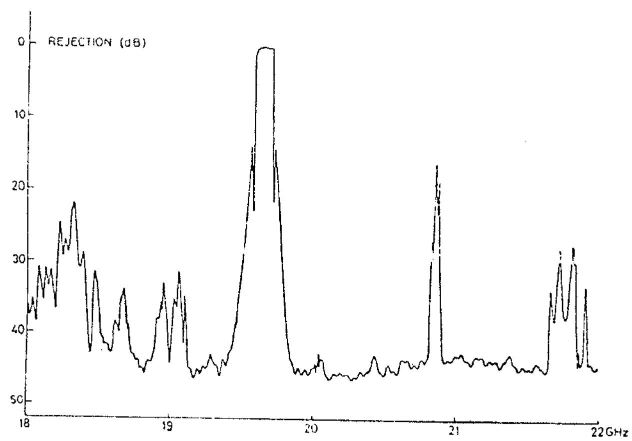

Fig. 5 WIDEBAND SWEEP 18-22GHz

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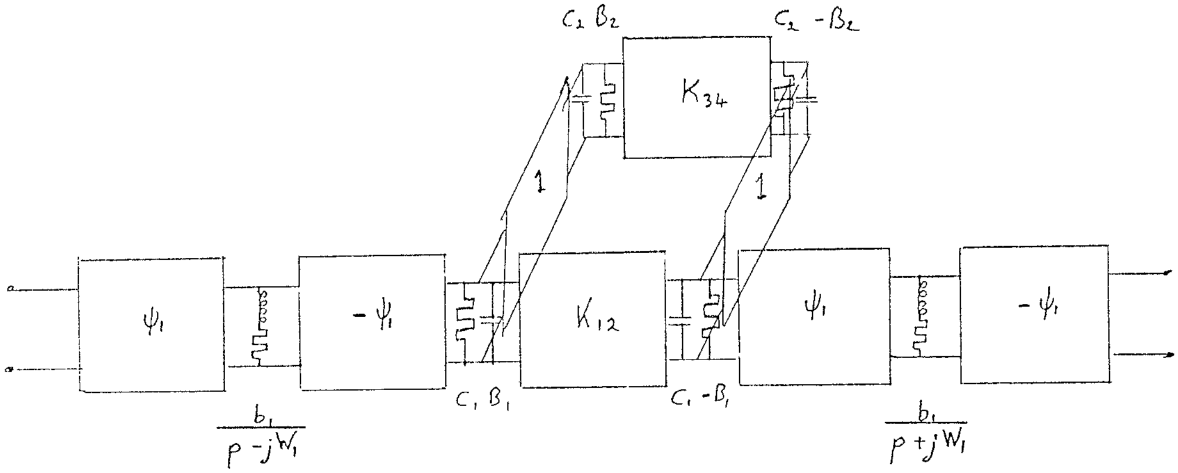

Fig. 1

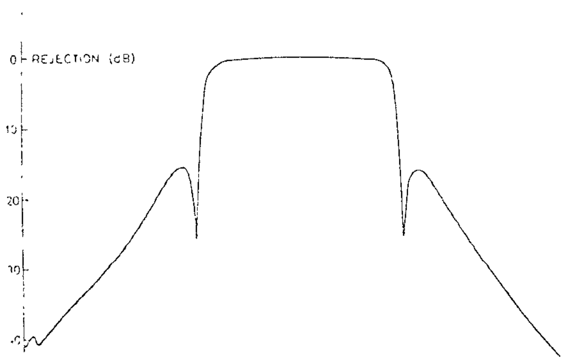

Fig. 2 SYMMETRIC ATTENUATION CHARACTERISTIC

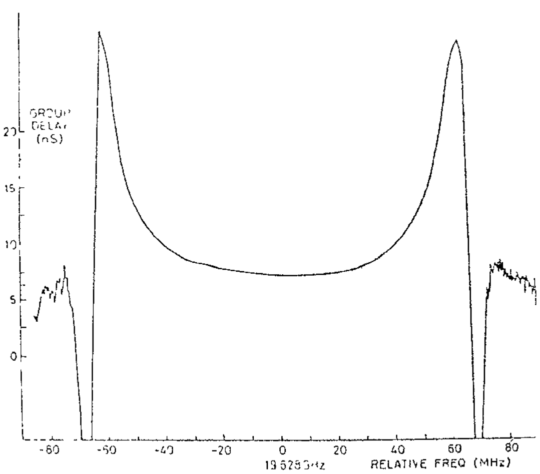

Fig. 3 GROUP DELAY, SYMMETRIC CHARACTERISTIC