Advanced Multimode Cavity Filter Design Using Source/Load-Resonance Circuit Cross Couplings

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Abstract— **Several degenerate resonances of one cavity are simultaneously coupled to the same interface (waveguide) port that represents source or load of the network. This new method extends significantly the design possibilities for multimode cavity filters— odd-order true elliptic function designs are now possible and other conspicuous design variants by novel coupling structures. Experimental verification is provided for this approach by a 3-order elliptic function filter realized with one triple-mode cavity.**

I. Introduction

The growth of communications systems has implied increasing demands on the filtering. To keep pace with this development the filter design has been steadily enhanced and extended by many new design ideas.

The introduction of multimode cavities in the filter design—starting with dual-mode cavities in the early seventies and continuing with triple and quadruple mode cavities in the eighties [1]–[3] has led to mass and size reduction of filter equipment of more than 50% compared with the former single-mode cavity designs. This fact is a considerable aspect especially for satellite equipment. Moreover, the application of couplings of nonadjacent resonance circuits (cross couplings) has been established for these filters to provide additionally the design of favorable filter responses such as elliptic or linear phase ones, (see e.g., [4], [5]) leading to additional improvements and mass savings.

Despite the coupling structures known for this class of filters there are often inherent limitations for the design of desired responses. They result for example from different modes within adjacent cavities which cannot be coupled owing to a different polarization or an unwanted interaction with other modes. Furthermore, in general, cross couplings have only been performed between resonance circuits of the filter itself. This fact restricted additionally the filter design, especially the maximum number of symmetric attenuation pole pairs n_p of odd order filters $n_p = (n_z - 3)/2$ (n_z number of transmission zeros) i.e., realizations of odd-order elliptic function responses have been impossible. Although the principle of additional source/load resonance cross couplings was indicated in [1, Fig. 1], up to now, there was only a realization with coaxial probe interfaces in [6].

The source/load-resonance cross (bypass) couplings for multimode cavity filters with waveguide interface ports is introduced in this letter. This new design is shown to be easily implemented and to provide new design possibilities for realizing favorable filter functions. In particular, the maximum number of symmetric attenuation pole pairs of odd-order filters is increased by one, i.e., odd-order true elliptic function filter designs can now be created. A primary approach for realizing such filters of any odd order is established for a dual/triple-mode cavity application. Experimental results are presented for a three-pole elliptic function filter realized by only one triple-mode cavity. The variety of additional new design variants is demonstrated by a six-pole elliptic function filter design with two triple-mode cavities using a conspicuous coupling approach.

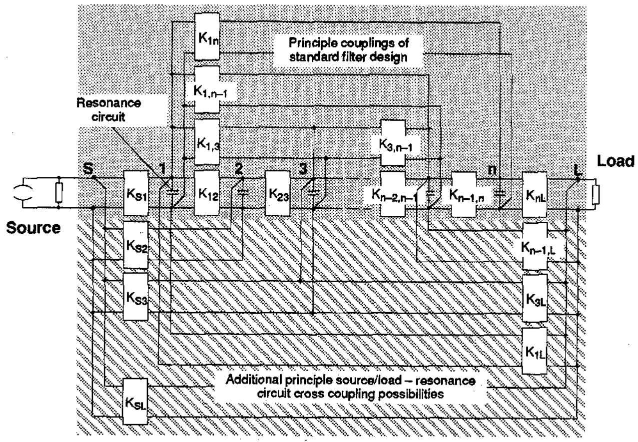

Fig. 1. Principle low-pass equivalent circuit diagram with the source/load cross couplings.

II. Design Considerations

The source/load-resonance circuit cross coupling simplifies that the interface ports (i.e., input and output) of the filter (which are representative for the source and load, respectively) are coupled to several resonance circuits-not only with the first and the last one, respectively. Thus, a portion of the signal energy bypasses the electrical sequential filter circuits at the respective interface port in a similar manner as known from the internal filter cross couplings.

A principle equivalent circuit diagram of this approach is depicted in Fig. 1. A filter synthesis method for this approach was presented by Bell in [7].

In the following, this principle is introduced for the comprehensive class of cavity filters using waveguide interfaces.

The input and output couplings, respectively, of these filters are generally realized by means of an aperture that is inter-

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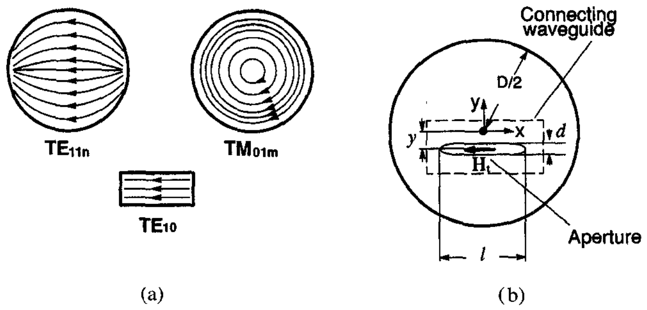

Fig. 2. (a) Principle magnetic fields of the TE_{10} waveguide mode and the TE_{11n} and TM_{01m} cavity resonance modes at a front side interface location. (b) Interface aperture design with additional source/load cross coupling.

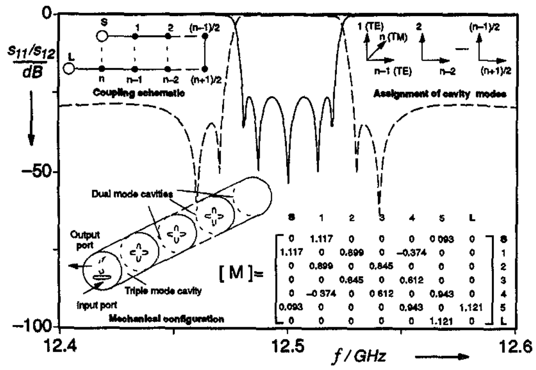

Fig. 3. Odd-order elliptic function filter design with multimode cavities (including an exemplary 5-pole filter design, synthesized coupling matrix and responses).

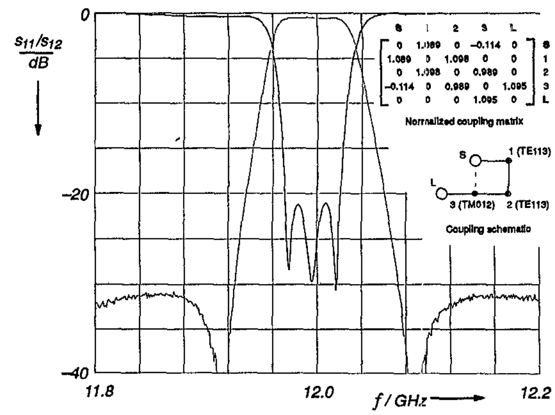

Fig. 4. 3-pole elliptic function filter design based on above approach (coupling matrix and structure, measured selectivity and return loss).

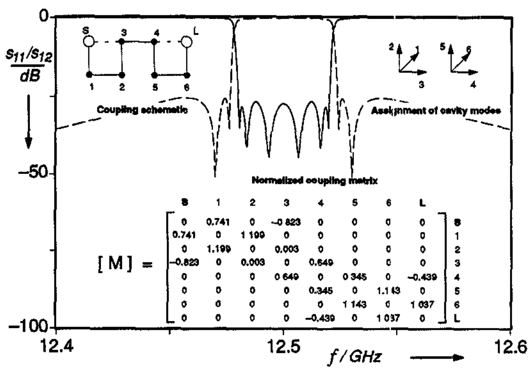

Fig. 5. Novel 6-pole elliptic function filter design with two triple-mode cavities (synthesized coupling matrix and responses, coupling schematic and allocated filter modes) .

connected between the front side of the interface waveguide and the assigned cavity containing the first and last resonance, respectively. Relevant for this kind of coupling are the equal magnetic field components of the TE_{10} waveguide mode and the dedicated resonance mode.

Additional couplings from the interface port to further filter resonance circuits are only suitable if these modes share the cavity that is interconnected with the respective interface. Otherwise, if at all possible, a considerable development expense is necessary to design the couplings with additional waveguides or cables leading to rather sensitive and complex filter arrangements.

Consequently, prerequisite of a primary realization is the careful study of the multimode filter cavities including a proper mode set and an appropriate electrical and mechanical allocation of the resonance modes to allow a convenient design of the required couplings.

The TM_{01m}–TE_{11n} mode intercavity coupling design introduced in [5] as well as the common port interfacing of different filters established for the multiplexing method in [8] can be easily adapted to the design of source/load-cross couplings. Fig. 2 shows, for example, the interface offset aperture design providing simultaneous couplings of the TE_{10} waveguide mode with the TE_{11n} and TM_{01m} degeneracies of a triple-mode cavity. Discrimination of the different coupling factors is obtained by variation of the aperture dimensions (d, l) and its location (y).

The application of this design combined with dual-mode cavities makes evident one advantage of this new method—namely the realization of true elliptic function filters of any odd order. Fig. 3 exhibits the electrical coupling structure and the principle mechanical design. To set an example the synthesized coupling matrix and the computed responses of a 5-pole filter are also illustrated in Fig. 3.

Experimental verification of this principle has been performed by a 3-pole elliptic function filter design realized only by one triple-mode cavity. Coupling matrix, the applied coupling structure and the measured responses of the filter are depicted in Fig. 4. Although the response of this filter agrees closely with theory, the out-of-band isolation of these odd-order elliptic function types is limited since the input and output ports are situated at the same physical cavity.

III. Discussion

Additional benefits of the new source/load resonance circuit cross coupling method result from the considerable extension of design variants for the same filter function. Hence, interfacing aspects as well as reduction of design effort can be accommodated by the determination of the design. To set an example, a novel design of a 6-pole elliptic function filter is depicted in Fig. 5. Only one coupling must be performed between the two triple-mode cavities owing to the application of the above introduced source/load resonance circuit cross coupling using the H_{ϕ} side wall coupling approach of TE_{11n}

modes (introduced in [9]) combined with the TM_{01m} side wall interfacing. Hence, the design effort of the intercavity iris is essentially reduced compared with the design of an iris that provides three independent couplings simultaneously as required in [2], [5].

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