CAD of RF and microwave filters for wireless communications.

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Abstract: - Tis paper presents the CAD of RF and microwave filters such as lumped element, combline and waveguide bandpass filters for wireless communication systems. A new high-Q periodic resonator has been used for combline filter applications. Significant higher Q factor than conventional combline resonator in the same volume has been achieved.

Key-Words: - CAD, waveguide filters, combline filters. resonators, lumped element filters.

1. Introduction

When a common approach to the design of filters results in a design passband which differs considerably from that which is specified, optimization is required to tune the filter elements to achieve a design that meets certain requirements. Most RF and microwave filters have not yielded exact optimum synthesis. Taking into account parasitic effects, high frequency operation, frequency dependent elements, a narrow range of element values, and so on, a common approach to design provides, at best, only approximate answers. Not infrequently, a common approach may be used to great advantage in providing the initial points for optimization.

Lumped element, waveguide and combline filters have been widely used in RF and microwave wireless systems [3] The backward of the current combline resonators is high loss, and makes its lower Q factor. A lot of researches were made in order to improve the Q factor of the conventional combline resonator. It is well known that Q factor can be improved by replacing its inner conductor with dielectric material. However, the dielectric loaded resonator has higher cost and poor spurious.

Periodic structure can make much smaller resonator [2] which employ the slow wave property of periodic structure to reduce the size of resonator. In this paper, we have designed combline filter with periodic N-disk mounted onto its inner conductor having clearly advantages for use at RF and microwave frequencies and demonstrated their applications in high-Q performance. Using this kind of combline resonator we can reduce the size of conventional combline resonator, or obtain higher Q than conventional combline resonator within the same volume.

2. Problem Formulation

The double terminated low-pass prototype network shown in Figure 1 satisfies a generalized Chebyshev insertion loss response.

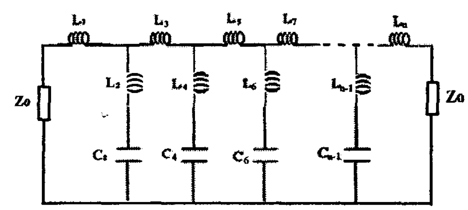

Fig.1. Generalised Chebyshev low pass prototype

This characteristic in terms of insertion loss, L, is given by

$$L = 1+\varepsilon^2 \cosh^2\left\{(n-1)\cosh^{-1}\left[w\left(\frac{w_0^2-1}{w_0^2-w^2}\right)^{\frac{1}{2}}\right]+\cosh^{-1} w\right\} \quad (1)$$

where the transmission zeros are of order (n-1) at $w=\pm w_o$ and one at infinity. n is an odd number equal to the degree of the network, $\varepsilon = \left[10^{\left(R.L/10\right)}-1\right]^{-\frac{1}{2}}$ and R.L. is the minimum return loss level (dB) in the passband.

A typical insertion loss response is illustrated in Figure 1a, where w_m is the frequency of the minimum insertion loss level in the stopband and w_1 is the bandedge frequency of the stopband.

In general, approximate methods based on the synthesis of a generalized Chebyshev prototype to the design a symmetrical filter will not meet the specifications satisfied by (1). Assume that an *n*th degree symmetrical low-pass filter has an insertion loss response L_I of the form shown in Figure 1a. It exhibits *m-1 (m=n-1)* zeros and *m-2* ripples, the maxima of which occur at the frequencies $f_2, f_3, \ldots f_m$.
For a symmetrical low-pass filter all of these *m-2* frequencies lie within the specified passband $f_l \Rightarrow f_u$. The deviation of a ripple maximum from the maximum allowed insertion loss in the passband, L_{Ir}, is a function of the *m=n+1* symmetrical filter parameter values required to specify the low-pass filter. There are *n-1* such functions for the symmetrical case:

$$E_i = L_I(f_i) - L_{Ir}, \quad i = 1,2,3..n-3 \tag{2}$$

E_c and E_m are defined by:

$$E_c = L_I(f_c) - L_{Ir} \tag{3}$$

$$E_m = L_I(f_u) - L_m \tag{4}$$

E_c, E_m are also functions of the *m=n-1* parameter values of the symmetrical filter.

The specifications

$$L_I(f) \leq L_{Ir} \quad , 0 \leq f \leq f_c \tag{5}$$

$$L_I(f) \geq L_m \quad , f_o \leq f \leq f_m$$

are satisfied when

$$E_i = 0, \quad i = 1,2,3....m \tag{6}$$

This is a system of *m=n-1* nonlinear equations in *m=n-1* variables for the symmetrical case. Solving (6) gives the parameter values of a filter satisfying (5). The E_i *(i = 1,...,m)* can be regarded as the components of an *m* dimensional error vector. Optimization is carried out by equating each of these components to zero (a vector process) rather than minimizing the magnitude of the vector (a scalar process). Thus equal ripple optimization can be regarded as a vector procedure whereas general purpose optimization routines are scalar procedures. Usually the convergence criterion applied in general purpose optimization routines is that the gradient, with respect to the filter elements, of the magnitude of the error vector is zero. However a zero gradient may correspond to a local minimum and the error may not be truly minimized. The convergence criterion applied in equal ripple optimization is that each component of the error vector is zero. Thus on convergence the error is reduced to zero. The problem of local minima does not arise..

To apply an iterative nonlinear equation solver it is necessary for a given set of filter parameter values to know the insertion loss only at the bandedge frequency, f_m (minimum) and at the ripple maxima. However, the frequencies at which the ripple maxima occur are unknown and are functions of the filter parameter values.

3. Numerical Results

In order to illustrate our approach, a fifth order lumped element generalized Chebyshev band-pass filters have been designed as first example. The band-pass filter can be described by 6 parameters: inductors (L1=L5, L2=L4, L3) and capacitors (C1=C5, C2=C4, C3) as marked in Figure 2. We used equal ripple optimization with L1, L2, L3 and C1, C2, C3 as variables for filter shown in Figure 2. Figure 3 shows the calculated return loss (solid line) and insertion loss (dashed line) of filter before optimization. The return loss (solid line) and insertion loss (dashed line) calculated using the filter elements obtained on convergence are shown in Figure 4. A five resonator X-band ridged waveguide Chebyshev bandpass filter, in which the widths of the ridges are arbitrarily chosen (see Figure 5), with passband specification $L_I(f) \leq 0.05$ dB, 9.30 GHz $\leq f \leq$ 9.80 GHz as second example has been design. Figure 6 shows the calculated passband insertion loss of the ridged waveguide filters (rwg. gap (s_1) = 10.00 mm, rwg. gap (s_2) = 9.00 mm, rwg. gap (s_1) = 8.00 mm and rwg. gap (s_2) = 7.00 mm and rwg. gap (s_2) = 6.00 mm respectively) using the approximate method described in [3]. This approximate design was used as a starting point for equal ripple optimization. The passband insertion loss calculated using the insert dimensions obtained on convergence are shown in the Figure 7.

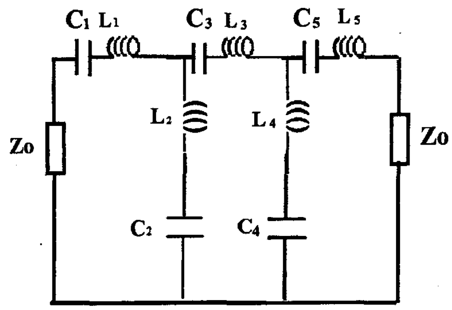

Fig. 2. Generalized Chebyshev band-pass filter

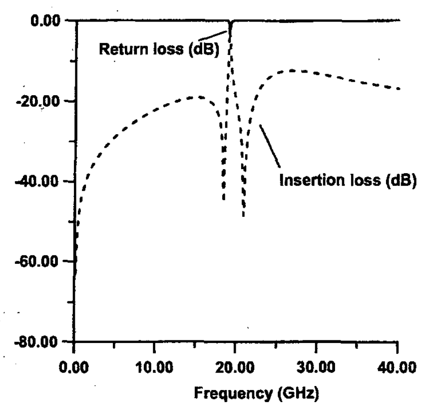

Fig. 3. Simulated Insertion and Return loss of generalized Chebyshev band-pass filter before optimization

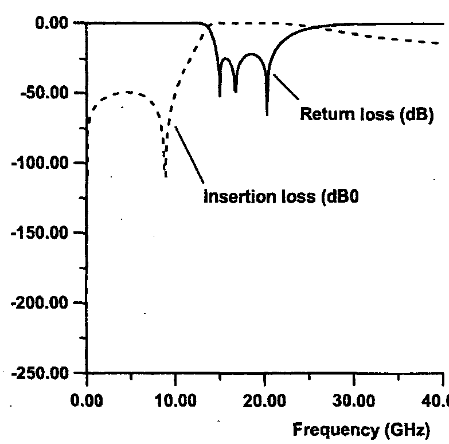

Fig. 4. Simulated Insertion and Return loss of generalized Chebyshev band pass filter after optimization

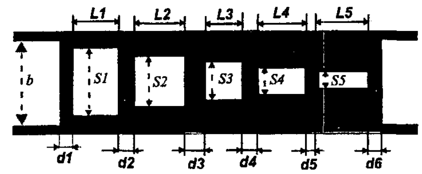

Fig. 5. Configuration of a five resonator ridged waveguide bandpass filter

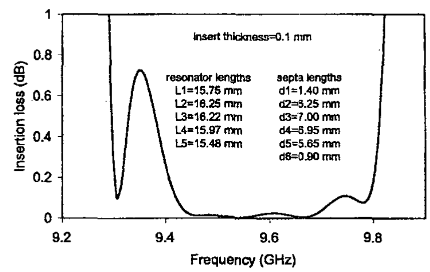

Figure 6.

Fig. 6. Calculated insertion loss of Chebyshev band-pass before optimisation.

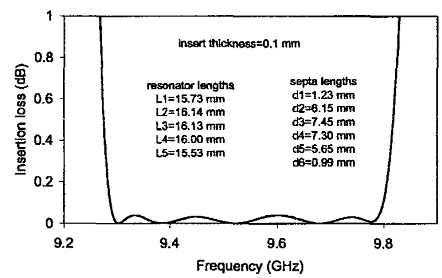

Fig. 7. Calculated insertion loss of Chebyshev band-pass filter after optimisation.

The schematic of two poles combline filter (see Figure 8) was designed. It employs electric coupling by a gap between two resonators. We can adjust the height of the wall H, that is, the distance of the gap between the wall and enclosure to obtain the tuneable bandwidth. Figure 9 shows the simulated insertion loss response and return loss. The filter has 53 MHz bandwidth and insertion loss of 0.15dB at the centre frequency of 3.10 GHz.

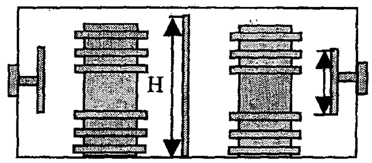

Fig. 8 Configuration of a two resonator combline filter.

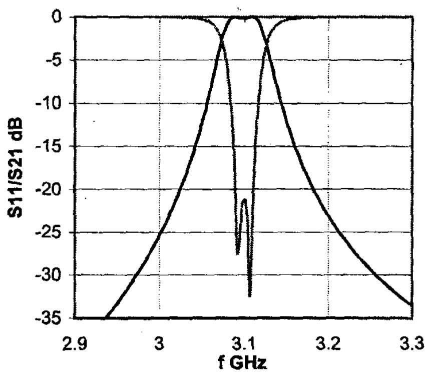

Fig. 9 Simulated insertion loss and return loss of the periodic 6-disk loaded combline bandpass filter

Conclusion

CAD of RF and microwave combline, and waveguide Chebyshev band pass filters has been presented. A new periodic structure combline resonator has been used for combline filter applications. Significant higher Q factor than conventional combline resonator in the same volume has been achieved.

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