DESIGN AND SIMULATION OF MICROWAVE FILTER

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ABSTRACT

A microwave filter has been designed. The designed filter has been simulated by using an efficient general purpose analysis program based on state space approach. The practical design has been built by using microstrip technology. The results of practical measurements and the simulated results are with good agreement.

1- Introduction

Microwave filters have many applications in radars, guidance, satellite communication and electronic warfare. The microstrip filters are very suitable for these applications because the microstrip has the advantage of small size,light weight, low cost and easy fabrication. Various kinds of filters can be realized by using microstrip type structures[1].

The objective of this paper is to introduce the analytical and practical design of microwave filter. A program based on state_space approach has been applied for the analysis of the designed circuits in both time and frequency domains. Practical design and simulation results are compared.

2- Analytical Design

The design of microwave low pass filter with cutoff frequency of 2Ghz has been developed. Microstrip filters may be designed with maximally flat response or Chebyshev response in the pass band. The design is based upon the normalized g-values. These values must be converted into inductances and capacitances.The elements values $g_1, g_2, \ldots, g_n$ and g_{n+1} of the low pass prototype filters for both maximally flat (Butter worth) and Chebyshev are given in [2]. In printed form, these types of filters will be realized as a series of high impedance and low impedance sections as shown in Fig.1. The length of the high impedance inductive sections may be calculated by[2].

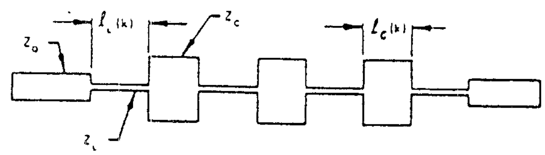

Fig.1 Microstrip L.P.F

$$\ell_l(k) = \frac{\vartheta}{w_0} \sin^{-1}(g(k).Z_0/Z_L) \quad (1)$$

where ϑ..is the velocity of propagation in microstrip

$$\vartheta = \frac{C}{\sqrt{\epsilon_{eff}}} \quad (2)$$

C = 3E+8 m/sec

ϵ_{eff}...effective dielectric constant

Z_L is the characteristic impedance of the inductive section.

z_0.... is the characteristic of the terminating resistance.

The length of the capacitive section is given by [2]

$$\ell_c(k) = X_{cc}(k) \frac{\vartheta}{W_0} , \quad (3)$$

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$$X_{cc}=\frac{g(k)}{Zo}-\left[X_{c\pi}(k-1)+X_{c\pi}(k+1)\right], \tag{4}$$

and

$$X_{c\pi}=\frac{wo\ \ell_1(k)}{2\omega\ Z_c(k)} \tag{5}$$

X_{cc}.....corrected value of capacitance susceptance.

3- Simulation program

A general computer program for the analysis of microwave circuits has been applied. The program is based upon the formulation of the state and output equations using an efficient topological method with no restriction on the topology. The state and output equations for any network can be represented as the following.

(3a) The state and output equations :-

It has been shown [9] that the state variables of a distributed network are the reflected parameters at all the transmission line terminals or ports. The state variables of a lumped/ distributed network are the voltages on all the independent capacitors, the currents in all the independent inductors and the reflected parameters (or the reflected voltages)at all the transmission -line ports.

The state equation is the differential-difference equation of the form:

$$\begin{bmatrix} \dot{X}_1(t) \\ \hline X_2(t+T) \end{bmatrix} = \left[\begin{array}{c|c} A_{11} & A_{12} \\ \hline A_{21} & A_{22} \end{array}\right] \begin{bmatrix} X_1(t) \\ \hline X_2(t) \end{bmatrix} + \begin{bmatrix} B_1 \\ \hline B_2 \end{bmatrix} u(t), \tag{6}$$

where $X_1(t)$ and $X_2(t)$ are the state vectors of the lumped and distributed elements respectively and u(t) is the input vector. The output equation is given by :-

$$y(t)=\left[\begin{array}{c|c} C1 & C2 \end{array}\right] \begin{bmatrix} X_1(t) \\ \hline X_2(t) \end{bmatrix} +E\ u(t) \tag{7}$$

Equations (6) and (7) are derived using topological methods with no restriction on the network topology. Where A, B, C and E are the matrices of the state and output equation of the systems.

When the Laplace transform is applied to equations (6) and (7) we obtain the frequency-domain equations.

$$\begin{bmatrix} X_1(s) \\ \hline X_2(s) \end{bmatrix} = \left[\begin{array}{c|c} sI_m-A_{11} & A_{12} \\ \hline A_{22} & zI_{2n}-A_{22} \end{array}\right]^{-1} \begin{bmatrix} B_1 \\ \hline B_2 \end{bmatrix} U(s) \tag{8}$$

$$Y(s,z)=\left\{ \left[\begin{array}{c|c} C_1 & C_2 \end{array}\right] \left[\begin{array}{c|c} sI_m-A_{11} & A_{12} \\ \hline A_{21} & zI_{2n}-A_{22} \end{array}\right]^{-1} \begin{bmatrix} B_1 \\ \hline B_2 \end{bmatrix} +E \right\} U(s) \tag{9}$$

where z = exp sT , I is the identity matrix, m,n are the number of lumped-state elements and transmission lines, respectively.

(3b) Network Analysis Using the State Equat

The previous results are used to analyze lumped/ distributed networks in either the frequency or time domain .

(1)**Frequency domain analysis** : is Based on the expansion of the equation (9) to obtain the transfer function of the form.

$$F(s,z)=\frac{\sum_{i=0}^{2n}\sum_{j=0}^{m} A_{ij}\ S^j\ Z^i}{\sum_{i=0}^{2n}\sum_{j=0}^{m} B_{ij}\ S^j Z^i} \tag{10}$$

This expansion is achieved by using a modified faddeeva algorithm[7] for the inversion of the two variable matrix in equation (8).

(2)**Time domain analysis :** The output in the time domain is calculate d from equation (7) when the state vector $[X_1(t) \vdots X_2(t)]^T$ is known. The state vector is first determined from the solution o f (6). Equation(6) represents two simultaneous differential and difference equation :

$$X_1(t)=A_{11}X_1(t)+A_{12}X_2(t)+B_1u(t) \tag{11}$$

and

$$X_2(t)=A_{21}X_1(t-T)+A_{22}X_2(t-T)+B_2u(t-T) \tag{12}$$

The state vector $[X1(t) \vdots X2(T)]^T$ is assumed to be zero at t<0. The vector X2(t) is calculated by substituting the values of X1 (t-T), X2 (t-T) and u(t-T) in equation(12). The vector X1(t)is then calculated by solving the differential equation (11)numerically in each time period kt < t < (k+1)T, where k = 0,1,2..............

The state and output vectors have discontinues at t= KT and the initial values of the state vector at the start of each time period are obtained from the condition that the integral of the state vector is continuous.

The insertion loss predicated by simulation program is shown in Fig.1

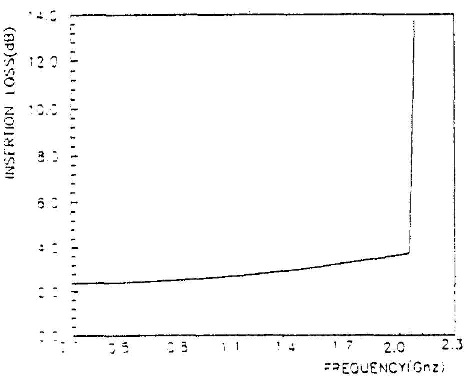

Fig.1 Insertion loss versus frequency(Ghz) of an L.P.F

4- Practical Design

The practical design of the microwave filter with cutoff frequency of 2Ghz has been developed in a stepped impedance form by using microstrip technology according to the following considerations.

1-The choice of the substrate material depends on the frequency of operation, cost, and applications. High dielectric constant substrates result in small size circuits. RT-Duriod 5880 (Teflon) of ε_r = 2.33 and h = .787 mm is chosen. The substrate with copper clad with is widely used in microwave integrated circuits.

2-A conventional microstrip synthesis technique described in [3]is carried out to calculate the dimension of microstrip circuits. The layout of the circuit is carefully prepared keeping in mind the microstrip discontinuity at step in width the mask layout is shown in Fig.2.

3- Fabrication process of thin film microwave integrated circuits using photolithographic technique is applied.

4-The circuits is measured by using direct measurement technique. An input signal ranging from 0.8 to 2.4 Ghz with varying amplitude is applied to the input port of the filter. The power of the output signal and spectrum of the fundamental and other harmonics are measured at the output port.

The insertion loss is given by:

$$IL(dB) = P_{out}(dBm) - P_{in}(dBm)$$

The insertion loss versus the frequency(Ghz) is shown in Fig.3.

Fig.2. The layout of the L.P.F

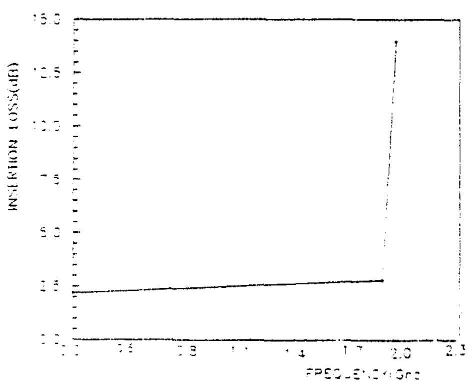

Fig.3. The insertion loss versus the frequency(Ghz)

5-Conclusion

The design procedure of microstrip low-pass filter is presented. The computer aided analysis adopted in this paper is with good stability and suitable computation time. The results show good agreements between simulation and measurements.The deviation between the measured and predicted simulated values was due to imperfection associated with the connectors used and the fabrication tolerances.

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