FABRICATION AND PERFORMANCE STUDY OF UNIFORM THIN FILM INTEGRATED FILTERS

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ABSTRACT:

The transmission line model of a uniform rectangular thin film R-C-KR structure consisting of a dielectric layer of constant per unit shunt capacitance C sandwiched between two resistive thin films of constant per unit length resistances R and KR has been analysed using the concept of matrix parameter functions. The above filter structure has been fabricated with the help of vacuum evaporation technique and performance of the device has been studied. The effect of loading the device has also been considered. The theoretical performance of the device, evaluated with the help of a digital computer has been compared with the experimental counterpart and it has been observed that the two are in considerable agreement to each other.

INTRODUCTION

In recent past, Thin Film Integrated Devices have been increasingly popular on account of their miniaturized size, appreciably high reliability and low cost of production. The devices are fabricated in form of patterned assemblies of thin films of electronic materials on a suitable substrate, which supplies structural and even electrical properties for the thin film assemblies. The thin film filters, under consideration may be analysed using the mathematical concept of distributed parameter. Networks. The thin film filter consists of alternate thin films of resistive and dielectric materials supported by a suitable (say ceramic) substrate. It is possible to obtain different type of electrical characteristics from a multi-terminal thin film structure by imposing various set of constraints. This paper deals with the techniques adopted for the fabrication of the filter structure and theoretical analysis of the same using a general transmission line model. Further experimental study of the fabricated structure has been done and it has been observed that theoretical and experimental results are in good agreement.

2. ANALYSIS OF THE THIN FILM FILTERS:

A unidirectional transmission line may be regarded as a mathematical model of the filter structure under the assumption that the width and thickness of the thin film filter structure are very small in comparison to the length. The four terminal two port transmission line model indicating the equivalent circuit of an elemental section of an incremental length Δx at a distance of x from the sending end is shown in Fig 1

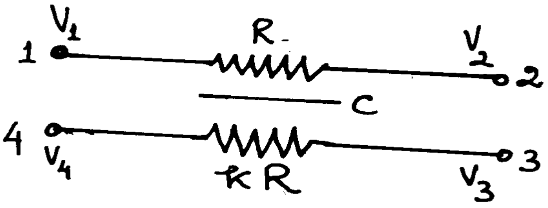

Fig. 1: Symbolic representation for a transmission line

model R-C-structure.

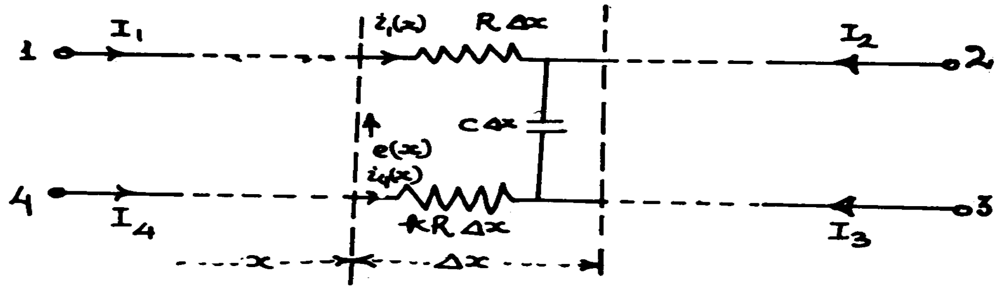

Fig. 2: A general TL model representing a uniform three layer R-C-KR filter structure as a four terminal network.

Let e = e(x) denote the voltage at any distance x(from sending end) of the top resistive layer with respect to the bottom resistive layer.

Also, let $i_1 = i_1(x)$ and $i_4 = i_4(x)$ represent the currents at d1stance x from sending end in the top and bottom layers respectively. Applying KVL and KCL to the elemental section shown in Fig. 2, the following expressions are obtained in complex frequency domain:

$$\frac{de}{d\times} = (i_1\_k\,i_4)R \;\ldots\ldots\ldots\ldots(1)$$

$$\frac{di_1}{d\times} = -SCe \;\ldots\ldots\ldots\ldots(2)$$

$$and\,\frac{di_4}{d\times} = SCe \;\ldots\ldots\ldots..(3)$$

where S indicates complex frequency variable. From the above expressions, the voltage equation may be written

$$\text{as}\,\frac{d^2{}_e}{d\times^2} - (1-k)SCRe = 0 \;\ldots\ldots\ldots\ldots\ldots(4)$$

Equation 4 is a second order homogeneous ordinary differential equation in general form whose solution is given by:

$$e = \mathcal{L}m(\times) + \beta N(\times) \ldots\ldots\ldots\ldots..(5)$$

$$\text{where: } m(\times) = \exp(m\times) \text{and} N(\times) = \exp(-mx)\; m = [(1+k)SCR]\frac{1}{2}$$

$\mathcal{L},\beta$ are boundary constants. The expressions for i_1 and i_4 may be written as [1]

$$i_1 = \frac{1}{(1+K)R}[\,\mathcal{L}M^1(\times) + \beta N^1(\times)] + KK_1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(6)$$

and

$$i_4 = \frac{1}{(1+k)R}[\mathcal{L}m^1(\times) + \beta N^1(\times)] + kk_1 \ldots\ldots\ldots\ldots\ldots(7)$$

$$where M^1(\times) = \frac{dm(\times)}{d\times} = m\{\exp m\times\}$$

$$N^1(\times) = \frac{dN(\times)}{d\times} = -m\{\exp - (m\times)\}.$$

K_1 is a constant having the dimentions of current. If the input and output ends of the structure R-C-kR is assumed to be at x = d and x = q from the sending end, the length of the elemental section of transmission line will be given by

$1 = (q - d)$

From Fig. 1, the IAM. (Indefinite Admittance Matrix) may be written as

$$\begin{Bmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \end{Bmatrix} = \begin{bmatrix} Y_{11} & Y_{12} & Y_{13} & Y_{14} \\ Y_{21} & Y_{22} & Y_{23} & Y_{24} \\ Y_{31} & Y_{32} & Y_{33} & Y_{34} \\ Y_{41} & Y_{42} & Y_{43} & Y_{44} \end{bmatrix} \begin{Bmatrix} V_1 \\ V_2 \\ V_3 \\ V_4 \end{Bmatrix} \ldots(8)$$

Using the general expressions or

various elements of the admittance matrix [Y) in terms of MPF (Matrix Parameter Functions) the elements of Admittance Matrix of the uniform R-C-kR structure have been evaluated in terms of circuit parameters as given below.

$$Y_{11} = Y_{22} = \frac{1}{yo}\left[\frac{m1}{\tanh(m1)} + k\right]$$

$$Y_{12} = Y_{21} = \frac{1}{yo}\left[\frac{m1}{\sinh(ml)} + k\right]$$

$$Y_{13} = Y_{31} = Y_{24} = Y_{42} = \frac{1}{yo}\left[\frac{m1}{\sinh(m]} - 1\right]$$

$$Y_{14} = Y_{41} = Y_{23} = Y_{32} = \frac{1}{yo}\left[1^{-}\frac{m1}{\tanh)m1)}\right]$$

$$Y_{33} = Y_{44} = \frac{1}{yo}\left[\frac{m1}{\tanh(m1)} + \frac{1}{k}\right]$$

and

$$Y_{34} = Y_{43} = -\frac{1}{yo}\left[\frac{1}{k} + \frac{ml}{\sinh(m1)}\right]$$

where

$$Y_O = (1 + K)1R$$

These results are in confirmation to those obtained earlier. It may be possible to develop various subnetworks from the four terminal R-C-kR structure by introducing various limitations on its terminals. In the present case, we have considered a three terminal two port network for the study of the filter characteristics.

3. TWO PORT THREE TERMINAL SUBNETWORK:

The two port three terminal configuration shown in Fig. 3 is the representation of the sub network obtained from the structure shown in Fig. 1.

On the basis of IAM of eq. 8: the **short** circuited admittance matrix is evaluated and resulting matrix is as follows:

$$\begin{bmatrix} I_i \\ I_0 \end{bmatrix} = \begin{bmatrix} Y_{ii} & Y_{io} \\ Y_{oi} & Y_{oo} \end{bmatrix} \begin{bmatrix} V_i \\ V_o \end{bmatrix} \qquad (9)$$

Where

$$Y_{ii} = \frac{1}{Y1}\left[\frac{MK}{1+K}\left\{2\tanh\left(\frac{m1}{2}\right) - m1\right\} + \frac{m1(1+k)}{\tanh(m1)}\right]$$

$$Y_{oi} = Y_{io} = -\frac{m}{y1}\left[\frac{k}{\tanh(m1)} + \frac{1}{\sinh(m1)}\right]$$

$$Y_{oo} = \frac{(1+k)m}{y1^{\tanh(m1)}}; Y_1 = R\left[\frac{K\,m1}{\tanh(m1)} + 1\right]$$

Considering fig. 4 where

Z_g = source impedance

Z_1 = load impedance

Voltage transfer function T_V is given by the expression

$$T_V = \frac{V_O}{e_g}$$

$$= \frac{z_1 Y_{oi}}{1 + z_1 Y_{oo} + z_g y_{ii} + z_1 z_g\, y} \dots\dots\dots\dots\dots\dots\dots\dots (10)$$

Where e_g = generated source voltage

v_o = output voltage and $\Delta y = y_{ii}\, y_{oo} - y_{io}\, y_{oi}$

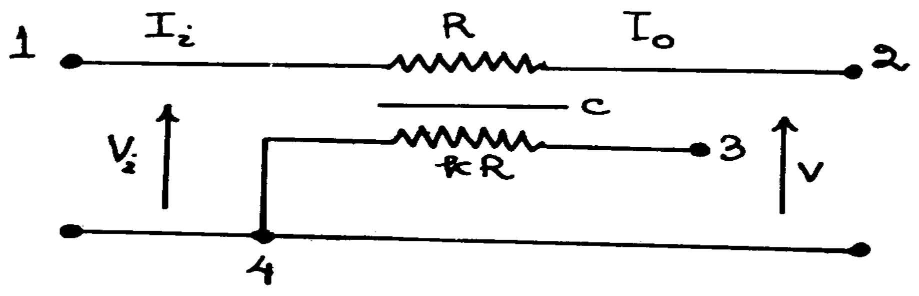

Fig. 3. A three terminal two port sub network of uniform R-C-KR structure.

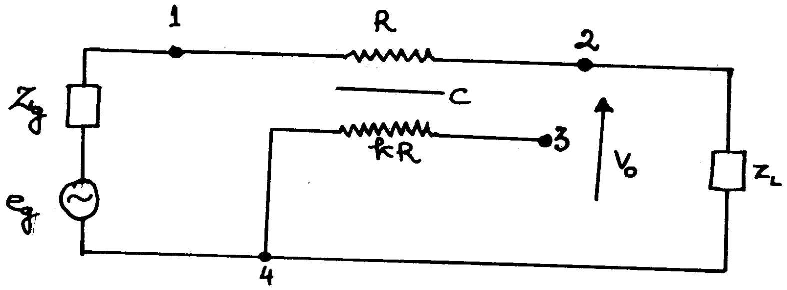

Fig 4: Two port three terminal Sub network of R-C-kR Structure for Voltage transfer function.

T_V has been evaluated using a Digital Computer IBM 1620 and the results are presented in Fig. 5.

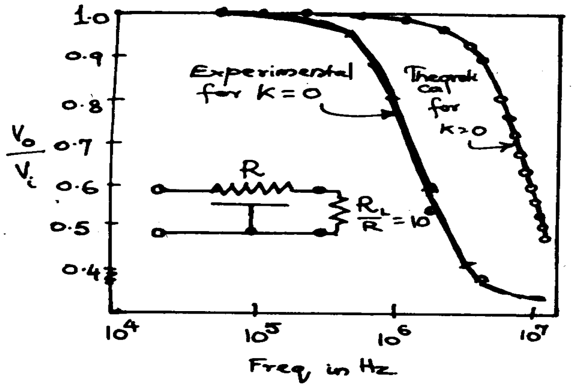

Fig.5 (i) voltage transfer characteristics for k = o $R_i/R_o = 10^6$

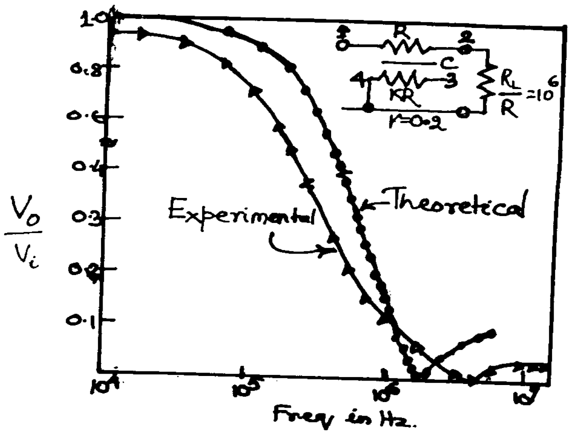

Fig.5(ii) voltage transfer characteristics for $k = 0.2 \frac{R_i}{R} = 10^6$

4. FABRICATION TECHNIQUE:

The Uniform Thin Film Integrated Filter under study were of the form of uniform layer resistor (R) capacitor (C) resistor (kR) structure. A few specimen of the structure (R-C-kR) were fabricated using thin film deposition technique. The resistive (Nichrome) layers of various thicknesses were deposited on Pyrex glass substrates. Nichrome in the form of wire of size 24 *SWG* was heated up in a conical basket for bare tongsten wire of 0.5 mm diameter, at a pressure of 10^{-5} torr inside the bell jar chamber of the vacuum coating unit. A current of 2.5 ampere was passed through the filament basket for about 10 minutes until nichrome started melting at 1450^{0}C approximately. As soon as the M.P of nichrome reached the filament current was raised from 2.5 Amp to 10 ampere which was maintained at that value for a short duration of a few seconds. The evaporated nichrome got deposited on the substrate in a rectangular shape defined by a prefabricated metal mask having perforation of desired shape and dimensions. Following nichrome deposition, conducting thin film of aluminium were deposited at the two narrow ends of each rectangular nichrome film in order to provide electrical contact with external connecting wires. Copper wires were connected to the aluminium film with the help of cold soldering technique using Poxy Silver paint. A very thin mica sheet of rectangular shape and of 20 micron thickness was sandwiched between the two resistive films of nichrome of different thickness. This arrangement constituted the uniform thin film R-C-kR configuration of the integrated filter.

5. EXPERIMENTAL RESULTS:

The total resistance (R_t) of the rectangular film across its two narrow ends and the total capacitance (C_t) of the entire structure were determined at a frequency of 1KHz with the help of Marconi Universal bridge. If Rt_1 and Rt2 are the total resistances of the first and the second film respectively of the R-C-kR structure, then

$$k = \frac{Rt_2}{Rt_1}$$

where $Rt_1 = 1R$

$Rt_2 = kIR$

$I =$ length of the conductor

k was evaluated for the various fabricated structures [2]. In present study, value of k was found to be 0.2 the experimental arrangement for the performance study of the fabricated device is shown in Fig. 6.

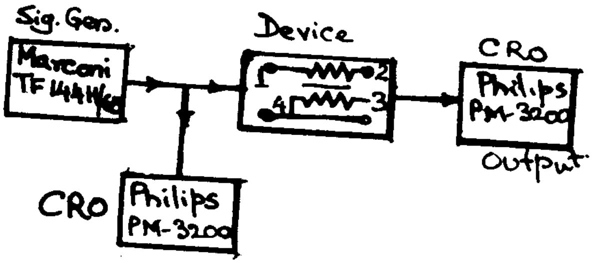

Fig. 6: Schematic diagram of experimental set up.

The configuration of the device is shown in Fig 4. and the observations are plotted in Fig 5 along with the theoretical results. Also the performances of the device under different load conditions have been experimentally studied and are ploted in Fig. 7

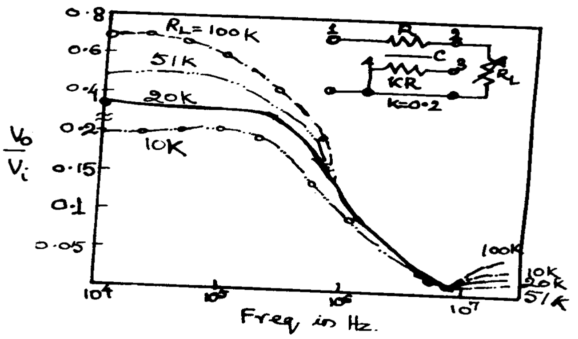

Fig. 7: Voltage Transfer Characteristics with different resistive loads for k = 0.2.

6. CONCLUDING REMARKS:

The indefinite admittance matrix of the R-C-kR structure is obtained by using the concept of Matrix Parameter Functions (MPF). The results thus achieved have conformed to those reported earlier [3]. Some deviations have been observed between theoretical and practical results but these are well within reasonable bounds of experimental discrepancies. The low pass characteristics of the device are almost consistent with those obtained earlier [4], Fig. 5 shows a SHIFT in null frequency in comparison to theoretical one. The reason for the shift stems from the variations per unit length parameters at higher frequencies caused by skin effect and lead inductance. Integrated devices are normally realised either in semiconductor or thin film forms. The thin film devices, governed by the concept of the distributed parameter structures, have definite ideal characteristics which are not achieved from lumped component circuits. The classical circuit design concept involving discrete elements is not found to be popular for the design of ICs. The terminal behaviour of the (integrated) devices and thus their performance study are of much significance to Functional Device approach. This paper may provide some useful information's for the formulation of the approach.

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