PLANAR CIRCUIT ANALYSIS OF MICROSTRIP RADIAL STUB

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Abstract

Microstrip radial line stubs are analyzed using a planar circuit technique and characterized for design purposes. Experiments performed on various structures are in excellent agreement with the theory.

1. Introduction

A number of microstrip circuits, such low-pass filters, bias filter elements, mixers, etc., often require the use of shunt stubs with characteristic impedance as low as 10-20 ohms. At high frequencies, however, a microstripline section with such a low characteristic impedance has a width which is a significant fraction of the wavelength; higher order modes can be easily excited and the structure behaviour differs significantly from that predicted on the basis of a monodimensional line model. Moreover, the large width of the stub renders its location poorly defined. In order to overcome these problems, the use of radial-line stubs has been suggested [1].

In particular, Vinding [1] has proposed a formula for evaluating the input reactance of microstrip radial stubs. Based on Vinding's formula, Atwater [2] has recently developed a design procedure of radial stubs. Like other formulas for microstrip planar circuits wich are based on a mere magnetic wall model, however, Vinding's formula does not yield sufficiently accurate results [3].

A planar circuit analysis of microstrip radial stubs is presented in this paper. The method is based on the EM field expansion in terms of resonant modes of the planar structure [3] and has been succesfully applied to other similar problems [4,5].

2. Electromagnetic model

The EM field expansion in terms of resonant modes in a planar circuit has been already applied to rectangular, circular [3] and annular structures [4].

As shown in [3] accurate results can be obtained through a magnetic wall model, provided that effective dimensions and effective permittivities properly defined for each resonant mode are used. In the case of radial stub (fig.1) we can assume that only TMon (n=0,1,2,..) modes are excited in the structure. On the basis of Wolff and Knoppik formulas [6] and using some geometrical considerations, the following expressions can be adopted for the effective inner and outer radii

$$r_{ie} = \frac{w_e}{2\sin(\alpha/2)} \qquad (1)$$

$$r_{oe} = r_o\left\{1+\frac{2h}{\pi r_o}\left[\ln\left(\frac{\pi r_o}{2h}\right)+1.7726\right]\right\}^{1/2} + \frac{w_e - w}{2}\begin{cases}\frac{1}{\sin(\alpha/2)} & \text{for } \alpha<\pi \\ 1 & \text{for } \pi<\alpha<3\pi/2\end{cases} \qquad (2)$$

where h is the dielectric substrate thickness, w and w_e are the actual and effective widths of the feeding line. The other geometrical parameters are defined in Fig.2, where the actual geometry together with the effective dimensions of the radial stub are shown.

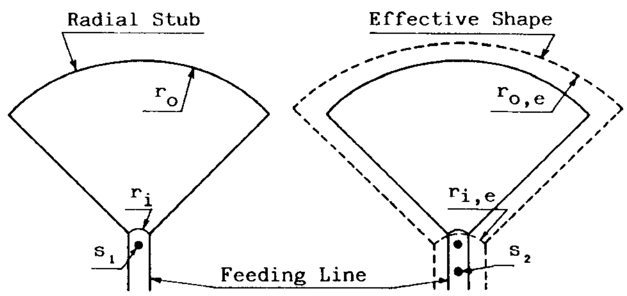

Fig.1 Fig.2

For $\alpha \to 0$ the effective geometry of the radial stub approaches that of a usual straight stub. The above formula makes it possible to overcome the difficulties arising in Vinding's formula when approaches zero. The present model, however, is not supposed to be valid for $\alpha > 3\pi/2$. In such a case the excitation of the EM field may take place along the radii of the sector which are very close to the feeding lines; modes other than

TMon can be excited and a more complicated model should be adopted.

With regard to the dynamic effective permittivity of the TMon mode, the expressions quoted in [5] have been used.

In the present case, the normalized input impedance evaluated at the inner radius r_i in terms of TMon resonant modes is given by:

$$Z_{in}=-j\frac{k_g P_{oo}^2}{k^2}+jK_g\sum_{n=1}^{\infty}\frac{P_{on}^2}{k_{on}^2-k^2} \quad (3)$$

where k_g is the wavenumber of the feeding line,

$$k = \omega\sqrt{\mu_0\varepsilon_0\varepsilon_d}$$

is the wavenumber of the radial stub, k_{on} is the eigenvalue of the TMon mode [3,4] ; Pon is the coupling coefficient between the quasi-TEM mode traveling of the feeding line and the TMon mode excited in the stub:

$$P_{on}=\sqrt{\frac{W_e}{\pi}}\left[A_{on}J_o(k_{on}r_{ie})+B_{on}N_o(k_{on}r_{ie})\right]$$

$$A_{on}=\frac{2}{\alpha\pi}\left\{r_{oe}^2\left[J_o(k_{on}r_{oe})+K_nN_o(k_{on}r_{oe})\right]^2-r_{ie}^2\left[J_o(k_{on}r_{ie})+K_nN_o(k_{on}r_{ie})\right]^2\right\}^{-1}$$

$$B_{on}=K_nA_{on}\ ;\ K_n=-J_1(k_{on}r_{oe})/N_1(k_{on}r_{oe})$$

3. Results

The present theory has been tested on the experiments by Atwater [3], performed on two radial stubs fabricated on a 25-mil alumina substrate, both having an outer radius r_o=5.49 mm [7]. Fig. 3a,b shows the comparison between the experiments by Atwater (dots) and the reactances calculated according to the present theory (solid line) and to Vinding's formula (broken line). Only the first 4 modes have been used in the expansion [6]. In spite of the low number of modes, the present theory fits the experiments much better that Vinding's formula.

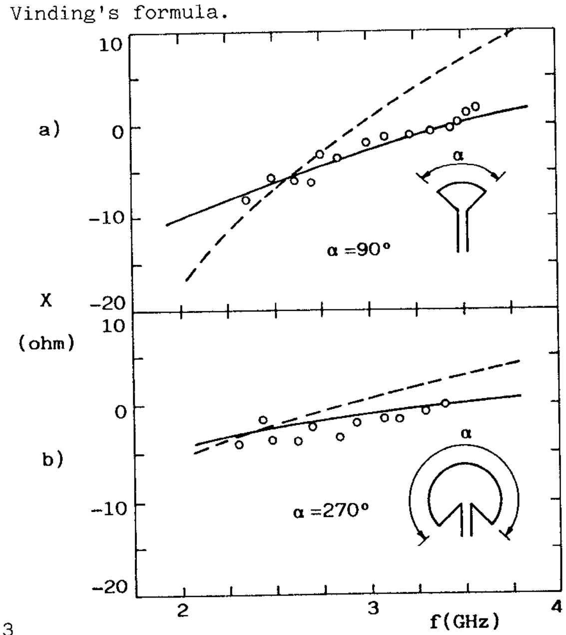

Fig.3

For design purposes the radial stubs can be characterized in terms of its zero input reactance f_o and its equivalent characteristic impedance $Z_o=(2f_o/\pi)dX/df$. The latter quantity is defined as a conventional stub having the same slope parameter at $f=f_o$. Fig.4a,b shows the computed behaviours of f_o and Z_o vs α for microstrip radial stubs with r_o-r_i=4.7 mm. Experiments performed are in excellent agreement with the theory. Moreover this figure demonstrates the suitability of radial line stubs as an alternative to conventional stubs when very low characteristic impedances are required as predicted by Vinding.

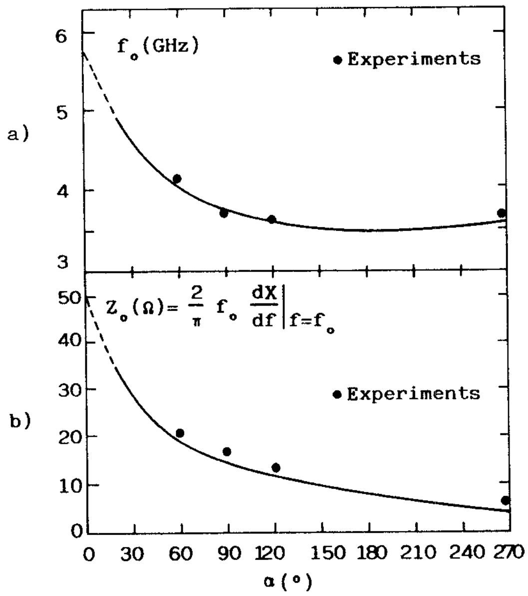

Fig.4

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