A COMBINED EXPERIMENTAL AND THEORETICAL CHARACTERISATION OF DISCONTINUITIES IN UNILATERAL FINLINES

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Abstract

An optimization procedure for characterizing finline discontinuities has been developed using the generalized scattering matrix formulation for steps in finline technique. The general waveguide representation of a two-taper finline section with a step is investigated first. The scattering matrix representation of the step is deduced from a combined measurement-numerical optimization procedure. Experimental results will verify the feasibility of the method.

Introduction

Many techniques are available to calculate the effects of a discontinuity in an unilateral finline /3,4,5,11/. Among these, the scattering matrix solution is perhaps the most commonly used. One of the scattering matrix methods, for analysing discontinuities, involves the determination of equivalent circuits of the discontinuities using the transmission properties of the considered finlines.

Up to now some authors have performed calculations on equivalent circuits of discontinuities in finlines such as: steps, small capacitive strips and inductive notches /3,6,7/, but their theoretical results have been derived for an idealized cross sectional model of the finlines /8/, i.e. the second order effects such as e.g. the effects of the finite metallization thickness of the fins and the effects of the slits in the finline mounts have been neglected; also the losses caused by the no-ideal dielectric substrate and the finite conductibility of the metallization have not been taken into account.

Theoretical Background

In this paper, a concept for an efficient calculation method of the scattering matrix of finline discontinuities will be presented, taking into account the above-mentioned second order effects.

A simple step between two finitely long, uniform finlines (1) and (2) which are terminated by smooth tapers (T1) and (T2) on the left- and on the right-hand sight is considered (Fig. 1).

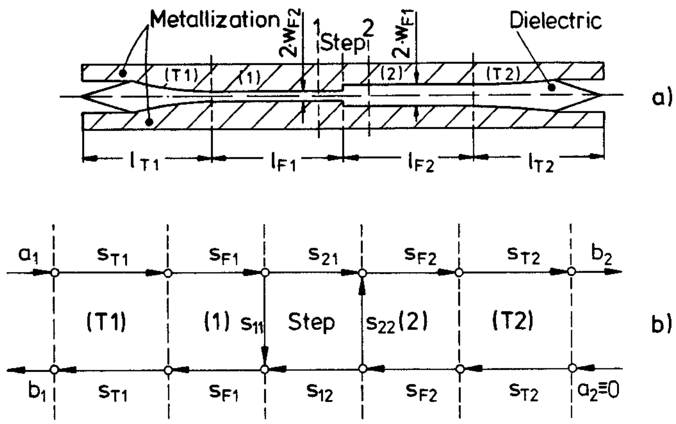

Fig. 1: Longitudinal section of a finline structure with a step.
a) The considered finline structure.
b) The appertaining signal flow diagram.

For the step shown in Fig. 1 the reciprocity theorem is valid:

$$|s_{12}| = |s_{21}| \quad , (1)$$

$$\varphi_{12} = \varphi_{21} \quad . (2)$$

From the symmetry it follows that:

$$|s_{11}| = |s_{22}| \quad . (3)$$

For the finlines yield:

$$s_{F1} = \exp(-\,a_{F1}l_{F1})\exp(-\,j\beta_{F1}l_{F1}) \quad , (4)$$

$$s_{F2} = \exp(-\,a_{F2}l_{F2})\exp(-\,j\beta_{F2}l_{F2}) \quad . (5)$$

From the signal flow diagram shown in Fig. 1b) the transmission loss of the complete finline structure shown in Fig. 1a) follows as:

$$a_1 = s_{T1}s_{F1}s_{12}s_{F2}s_{T2} \quad (6)$$

and for the reflection loss:

$$r_1 = s_{T1}^2 s_{F1}^2 s_{11} \quad (7)$$

with the transmission losses S_{T1} and S_{T2} of the two tapers (T1) and (T2).

Further, let measurements of the reflection- as well as of the transmission-coefficients have been made for the step feeded at port (1) and port (2) /1/. Then the customary definition of the scattering parameters which describe the step, leads to the equation for the absolute magnitudes of these quantities; e.g. for S_{11} yields:

$$|S_{11}| = \frac{|r_1|_M}{|S_{T1}|^2 |S_{F1}|^2} \qquad (8)$$

with r_{1M} the measured value of the magnitude of the reflection loss r_1 from (7). Provided that the transmission properties of the applied impedance transformers S_{T1}, S_{T2} between the rectangular waveguide and the homogeneous finline sections and the transmission properties S_{F1}, S_{F2} of the homogeneous finline sections are known, the magnitudes of the other elements of the scattering matrix of the step can similarily be calculated from the measurements.

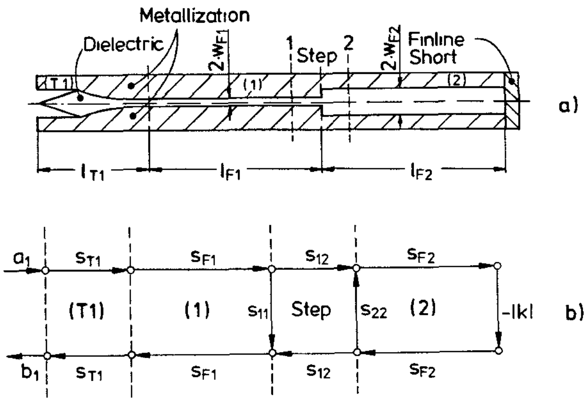

Fig. 2: Longitudinal section of a finline structure with a step and a short circuit.
a) The considered finline structure.
b) The appertaining signal flow diagram.

Now, the finline structure shown in Fig. 2a) will be inspected. The reflection loss of the arrangement follows from the appertaining signal flow diagram (Fig. 2b)):

$$r_2' = S_{T1}^2 S_{F1}^2 \left(S_{11} - \frac{|k_2| S_{12}^2 S_{F2}^2}{1 + |k_2| S_{22} S_{F2}^2}\right) \qquad (9)$$

whereby $|k_2| \leqq 1$ describes the properties of the finline short.

The phase angles φ_{11}, φ_{12} and φ_{22} of the considered step scattering parameters will be calculated from the measurements of $|r_2|$ by the aid of an optimization criterion. Hereby the following equations are valid:

$$E_1 = |r_2'|_C^2 - |r_2'|_M^2 \quad , (10)$$

$$E_2 = |r_2''|_C^2 \quad |r_2''|_M^2 \qquad (11)$$

with E_1 and E_2 two error functions which must fulfill the condition:

$$E = E_1^2 + E_2^2 = \text{min. value} \quad , (12)$$

whereby $|r_2'|$ is defined by eq. (9) and $|r_2''|$ is the reflection loss of the structure shown in Fig. 2 inspected by the right-hand side. The indeces C and M stand for the calculated and the measured values of $|r_2|$, respectively.

Numerical and Experimental Results

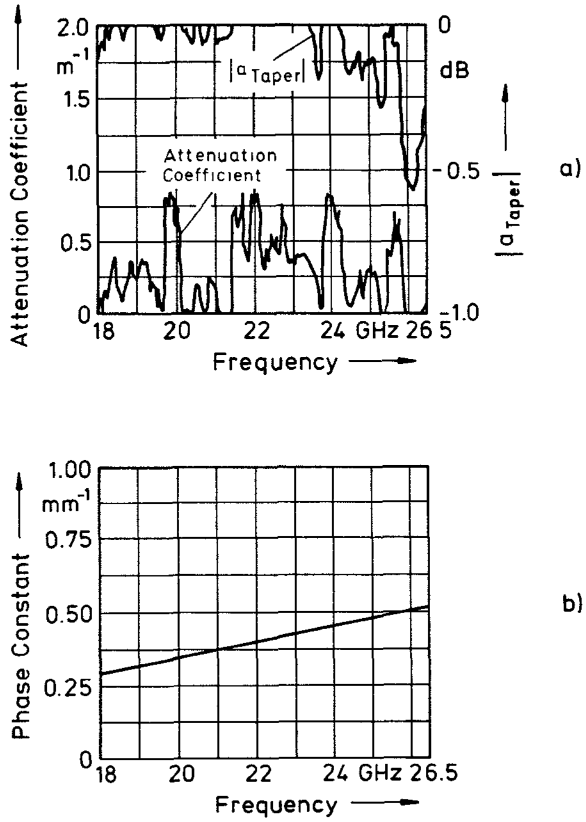

Fig. 3: Transmission properties of a homogeneous finline section with the length l_{F1}=240mm and the slotwidth $2W_F$=100µm and a single taper section.
a) The attenuation coefficient of the homogeneous finline section and the damping of a single taper.
b) The phase constant of the homogeneous finline section.

To calculate the elements of the scattering matrix the properties of the homogeneous finline and of the tapers are needed. Fig. 3a) shows the measured attenuation coefficient for a homogeneous finline with the length l_{F1}=240mm and a slot width of $2W_F$=100µm which is determined in dependence on the frequency. In Fig. 3b) the calculated values of the phase constant are shown for the same finline. The calculations took into account the finite metallization thickness and the influence of the slits in the finline mounts /2/. Fig. 3a) shows the calculated attenuation for a taper with a length of l_T=30mm which is used between the rectangular waveguide and the above described finline structure. Using the results in Fig. 3 and the corresponding results of another finline slot width of $2W_F$=200µm and the parameters of the used tapers the magnitudes of the scattering parameters of the finline step can be calculated as a function of the frequency. In Fig. 4 these parameters are shown in dependence on the frequency.

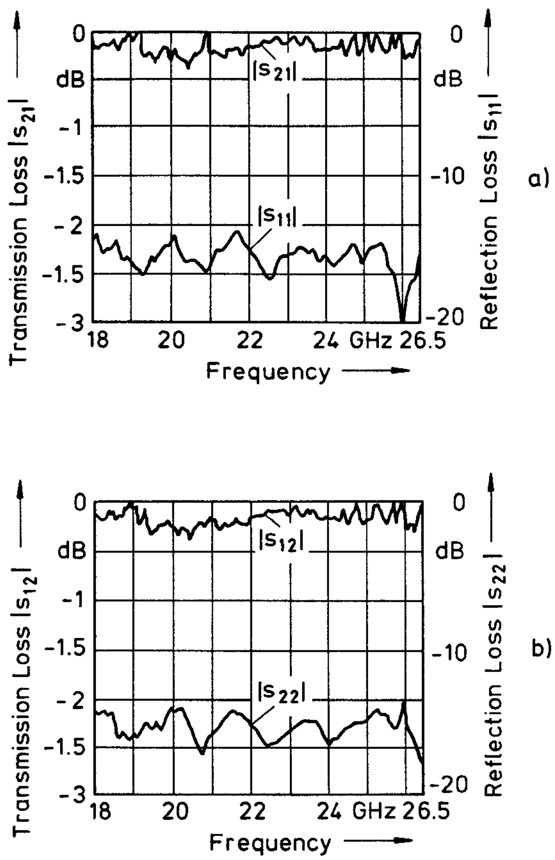

Fig. 4a)-b): The magnitudes of the scattering parameters of a finline step with the slot widths $2W_{F1}$=100µm and $2W_{F2}$=200µm.

Fig. 5 shows the measured properties of the used finline short, which are used for the optimization process to determine the phase angles. It can be realized that the finline short has a strong frequency dependence.

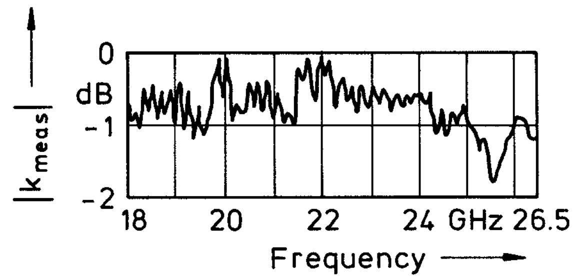

Fig. 5: The reflection loss of the used finline short (see Fig. 2).

The optimized values of the phase angles of the finline step due to the quantities in Fig. 4 are shown in Fig. 6.

In a similar way discontinuities such as capacitive strips or inductive notches can be investigated and filter structures can be developed. In the continuation of these activities it is scheduled to present and discuss some discontinuities and filter structures.

The Measurement Set-Up

For the design of high-quality millimetre-wave filters in finline technique the exact knowledge of the equivalent circuit elements at the operating frequency is needed /9,10/. Therefore, a measurement technique was developed for determining the transmission properties of the considered discontinuities. The measurement set-up is an automatic system which is steered by a small desk-top computer. The computer controls the measuring frequency, the input power and it stores the measured values. Additionally, the complete optimizing procedure for the evaluation of the measuring results is programmed on the same computer. It should be mentioned that the considered finline discontinuities are lossy two ports. Consequently, all the phase angles of the scattering parameters of the investigated discontinuity must be optimized separately.

Conclusions

A design method is described which allows a more realistic description of finline discontinuities. In contrast to other methods for equivalent circuits of the finline discontinuities, the present technique takes into account the influence on the transmission properties of both the finite thickness of the fins and the finite longitudinal slit in the waveguide mount as well as the losses of the finline discontinuities.

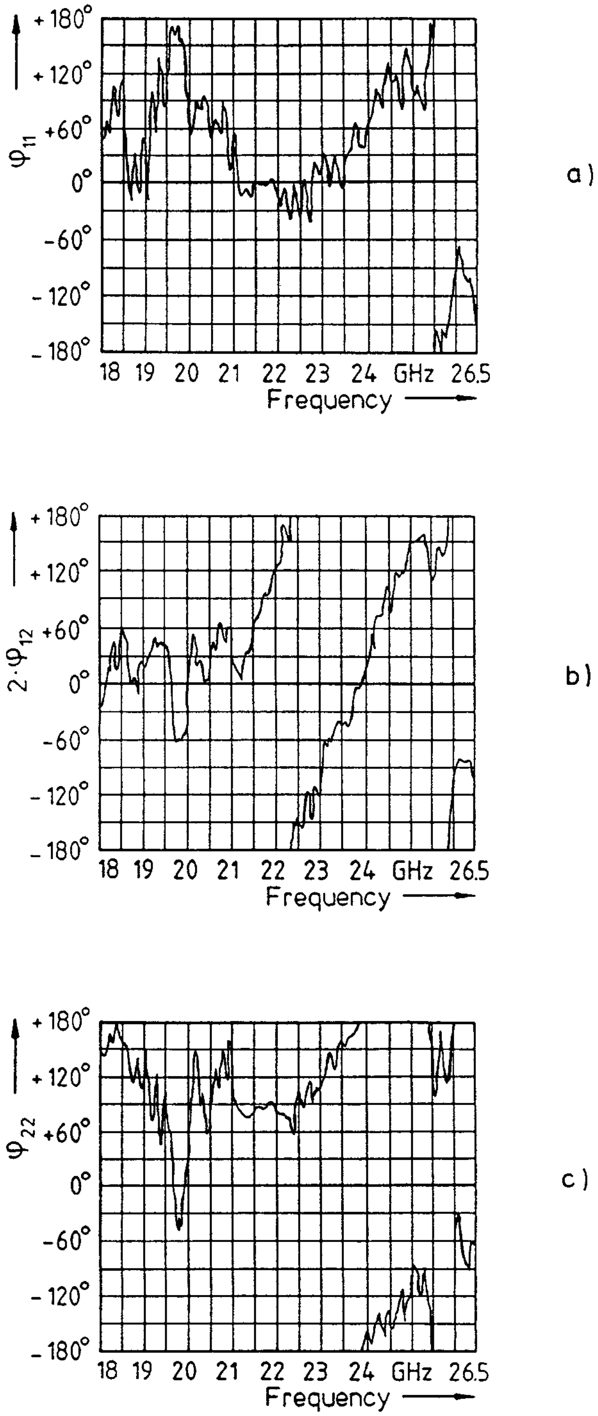

Fig. 6: The phase angles of a finline step with the slot widths of $2W_{F1}=100\mu m$ and $2W_{F2}=200\mu m$.
a) The phase angle φ_{11}.
b) The phase angle $2\varphi_{12}$.
c) The phase angle φ_{22}.

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