Verification of Computational Model of Transmission Coefficients of Waveguide Filters

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Abstract— Owing to the recent research a method of estimating transmission coefficients for a waveguide of rectangular cross-section loaded with multi-layered parallel-plane dielectrics is found. Consequently, the analysis of the transmitted and reflected fields in terms of the scattering matrix formalism can be performed explicitly. This article is mainly based on comparisons between real measured and computed transmission coefficients of a waveguide filter. the computation employs analysis of closed-form solutions and numerical multi-parameter optimization. the presented waveguide filter is formed by multi-sectional diaphragms placed in a waveguide of rectangular cross-section. Comparison of the computed and measured transmission coefficients demonstrates that the difference is very low, rather marginal and thus the output of the work is considerably promising.

1. INTRODUCTION

In this work we verify a computation model aimed at direct estimation of transmission coefficients of filters created on the basis of multi-layered parallel-plane dielectric diaphragms in waveguides of rectangular cross section. Waveguide filters and their analysis, synthesis and optimization is interesting as far as alternative possibility of designing specific frequency selective filters is concerned. These filters can for example suppress a specific desired band of frequencies.

This article is mainly based on the previous research presented in [1], it enhances the theory and contains comparisons between real measured and computed transmission coefficients of a waveguide filter using a technique based on the method set forth in [2, 3]. The computation employs analysis of closed-form solutions and numerical multi-parameter optimization [4, 5]. The presented waveguide filter is formed by multi-sectional diaphragms placed in a waveguide of rectangular cross-section. the filter consists of a specific combination of diaphragms of FR4, plexi and RO4003 with defined permittivities and thicknesses.

A specific behaviour of the transmission coefficient characteristic for these structures is governed by frequency, parameters of layers, and geometry of a given filter [11].

The techniques [6, 7, 10, 13] that make use of complicated inclusions in waveguides to design FSSs and filters employ approximate numerical schemes for calculating the transmission characteristics that produce non-controllable errors in the filter design.

An approach presented in this article is virtually free from this drawback because it is based on explicit formulas for the transmission coefficient obtained and applied in [6–9] and careful investigation of its properties as a function of several complex variables (see [4]) and therefore provides more robust determination of the filter characteristics and goals. The method allows simultaneous analysis of not only narrow band-pass but also wider band-pass and band-stop filters — rectangular waveguides loaded with layered dielectric diaphragms.

2. PROBLEM STATEMENT

Assume that a single-mode waveguide [12] of rectangular cross section with a perfectly conducting boundary surface contains a body which has the form of a diaphragm, an insert separated into several sections adjacent to the waveguide walls. the waveguide is filled with an isotropic and homogeneous layered medium of constant permittivity. The sections of the diaphragm are filled each with a medium of a constant permittivity.

Solving the forward problem for Maxwell's equations we obtain explicit expressions for the field inside every section of the diaphragm and outside the diaphragm. An explicit expression for the transmission coefficient of a multi-sectional diaphragm can be obtained [1] from a system of equations related to transmission conditions on the boundary surfaces on the diaphragm sections [6–9]:

$$F = 2\prod_{j=0}^{n}\gamma_j \frac{Ae^{i\gamma_0 l_n}}{\gamma_n p_{n+1} + \gamma_0 q_{n+1}} \tag{1}$$

In Formula (1) the F represents the transmission coefficient, A is the amplitude of the incident wave, n is the number of sections in the diaphragm, and other quantities and symbols like γ, p, q, l are further explained in [6, 7].

If the presumptions above are correct the results of this theoretical approach and a real measurement using a calibrated measuring devices should correspond.

3. EXPERIMENTAL SETUP

The following few points describe the experiment:

- Waveguide: R100 (22.86 mm × 10.16 mm).
- Frequency range: 8 GHz–12 GHz.
- Vector network analyzer: Rohde-Schawrz ZVB20.
- S-parameters are normed with respect to impedance (variable by frequency) TE_{10}.
- Filter consisted of the following specific combination of sections (strictly in this order, in the direction of propagation of the incident wave): RO4003, plexi glass, FR4, plexi glass, FR4, plexi glass, FR4, RO4003 (information about selected materials in more detail can be found in Table 1 below).

Table 1: Details about used materials.

Material	*Relative Permittivity*	*Thickness [mm]*
RO4003	3.55	1.52
Plexi glass	2.50	3.66
FR4	4.20	1.57

All important points of the experimental setup has been mentioned. Results ot the measurement are presented in the next section.

4. RESULTS & COMPARISON

In this section we present and briefly analyse results of computations and output of actual measurements.

Figure 1 shows a waveguide containing a special profile loaded with sections of different material connected to a vector network analyser.

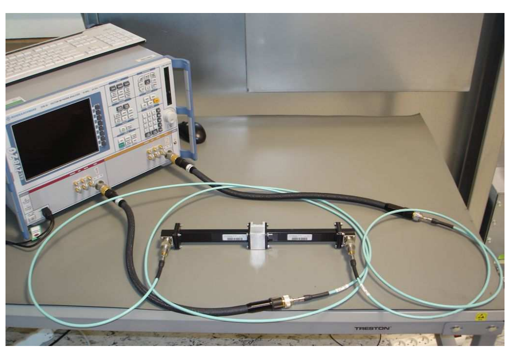

Figure 1: Photography of the experimental setup (a vector network analyser connected to the waveguide containing a profile with a multilayered diaphragm).

The output of the real measurement is presented in Figure 2 and the comparison is depicted in Figure 3.

We see that the measured and calculated data agree very well. It can be shown in addition that the observed deviation does not exceed the accuracy frames of the experimental setup and the tolerance of theoretical determination of permittivity of dielectrics.

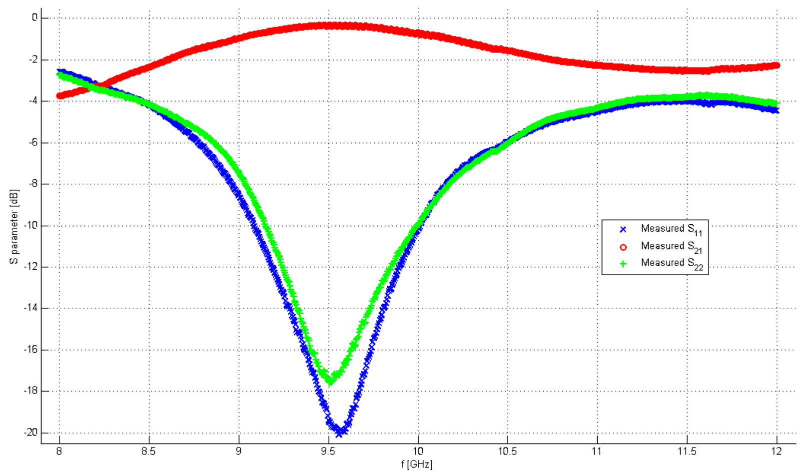

Figure 2: Results of real measurement (S_{21}, the red line, represents the transmission coefficients).

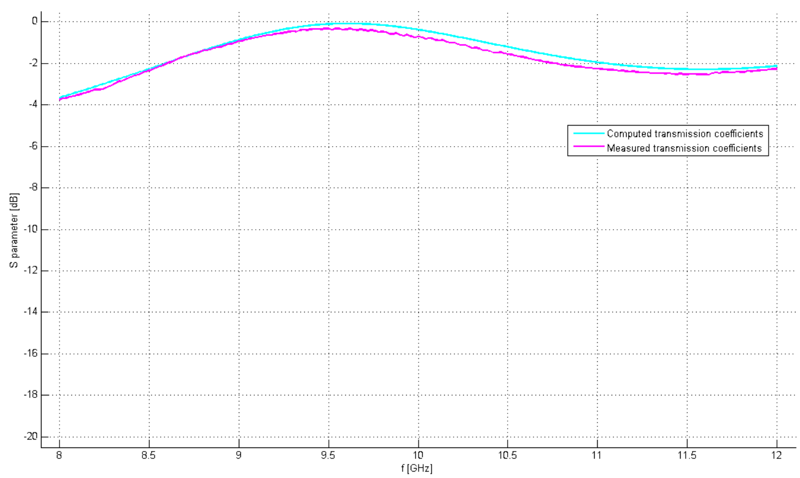

Figure 3: Transmission coefficients computed (azure colour) and measured (magenta colour).

5. CONCLUSION

Comparison of the computed and measured transmission coefficients demonstrates that the difference is very low, rather marginal and thus the output of the work is considerably promising. In this particular case the results prove the ideas, approach and the final implementation of the mathematical background used for computation of the transmission coefficients of a waveguide filter.

In further work we could aim at analysis of another more complicated filter and then estimate the relative deviation from a set of experiments.

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