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Measurement of material parameters of a microwave substrate

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Abstract: Material parameters of a microwave substrate are determined for microwave circuit design. Reason of this publication is extremely good model accuracy that we have achieved. Material parameters and the connector model can be used for further work.

Keywords: ring resonator, material parameters, duroid, circuit modelling

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I. Introduction

a) Theoretic background

Accurate material parameters of microstrip substrates are very important for microstrip circuit design. Relative permittivity ε_r and tan δ of duroid type 4003 have been determined from measurement. Ring resonator with conductor length of 3/2 lambda and without gaps, has been utilized. S-parameter measurement has been performed at the 1-6 ghz range. Full s matrix was modelled including the model of the connectors.

These parameters can be determined in different ways, here we concentrate on resonator measurements. Resonator measurements are based on the fact, that depending on the length difference between the two arms of the resonator, exotic frequency dependence of the measured |s21| can be observed. This is the dominant effect. From the other effects such as the frequency dependence of the reflections, secondary parameters (tan δ) and the connector models can be determined.

The resonator measurements can be classified if they use gaps [2, 3, 4] or not [3, 5], if there is a difference in length between the two arms and how much [1], or according to the shape of the resonator, circle[2, 3, 4] or other [1]. In this paper we avoid using gaps. Difference between arm lengths is lambda/2. Shape of the resonator is not a circle. In section 2 we describe the resonator measurement principle. In section 3, resonator model parameter identification is detailed.

Devices and parameteres of measurement

The measurements were carried out by an hp8722d network analyzer with the following settings:

- An rf power level of -10dbm
- 1601 measurement points in the 1-6ghz range

The printed circuit board is equipped with sma connectors.

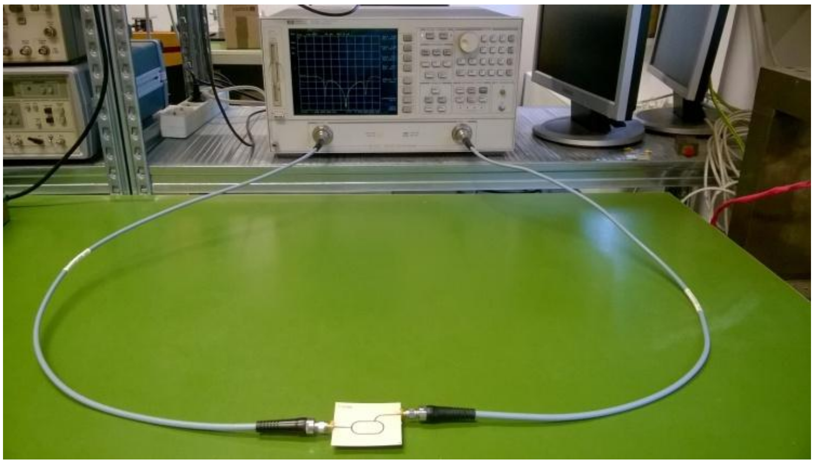

Fig. 0. Photo of the measurement setup. The resonator circuit is connected to the network analyzer via 50Ω, coaxial transmission lines

II. Measured resonator circuit

The measured circuit is a 3/2 lambda resonator without gaps at the input and output lines. Difference in arm lengths is lambda/2. At resonance, signals from two arms cancel each other. Therefore in the frequency dependence of |s21|, deep notches can be observed. These notches make it easy to determine ε_r. Tan δ can be determined from those measurements where |s21| is high. Both material parameters are optimized for perfect match of the simulated s-parameters to the measured ones.

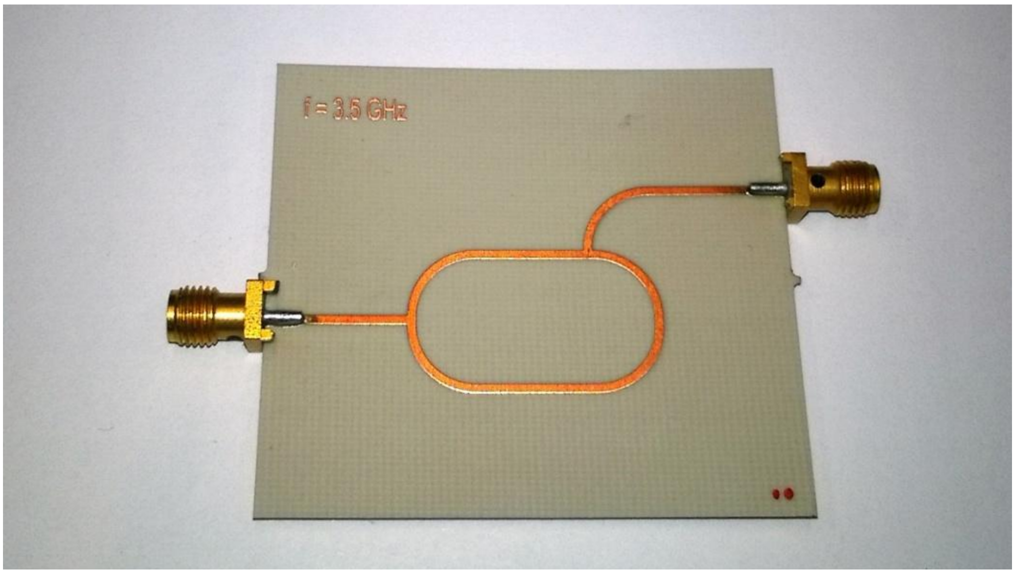

Fig. 1. Photo of the realized ring. Dimensions are designed for notch frequency around the middle of the frequency band of circuit design

III. Resonator circuit modelling

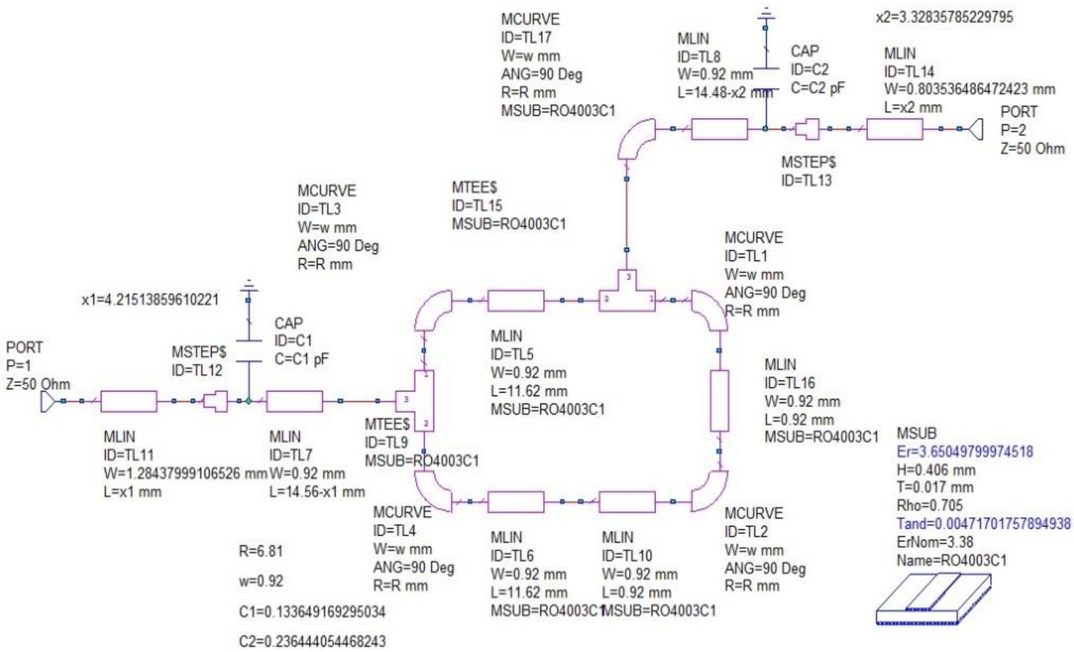

Fig. 2. Model of the measured circuit in awr. Connectors are modelled by an ideal line, a step and a capacitor to the ground. Lengths of the t-s are compensated at the opposite arms by additional lines tl16 and tl10

S matrix of the circuit model is fit to the measured one using the analysis program awr. We minimized the sums of amplitude and phase differences at each frequency point. Results of optimization are shown in the next tables and figures.

Table 1. Materialparameters

	E_r	Tan δ
1st measurement	3.66	0.0069
2nd measurement	3.65	0.0089
Average	**3.655**	**0.0079**

Table 2. Connector model (mm, pf))

	X1	W1	C1	X2	W2	C2
1st meas	4.05	1.007	0.176	3.01	0.804	0.189
2nd meas	3.90	1.090	0.164	3.35	0.804	0.181
Average	**3.975**	**1.0415**	**0.171**	3.18	0.804	0.185

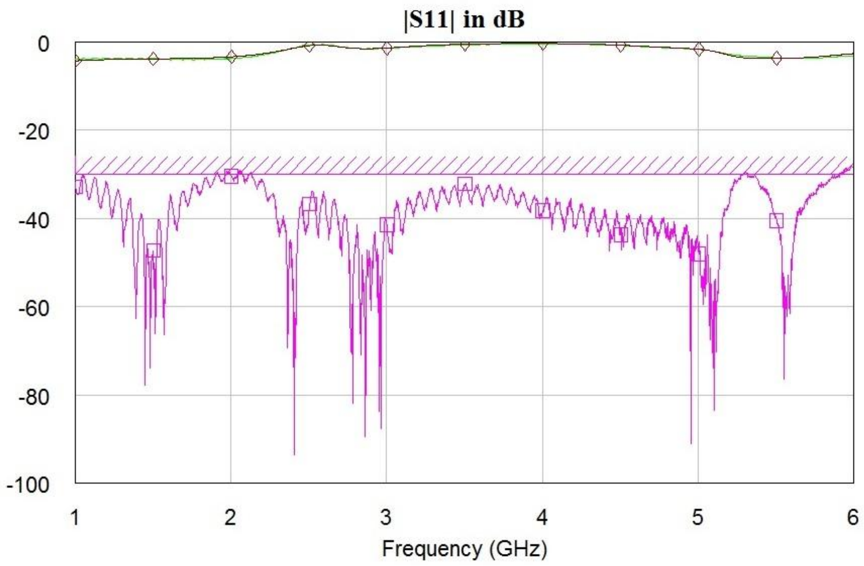

Fig. 3 diamonds: circuit model, without marks: measurement, squares: difference between model and measurement

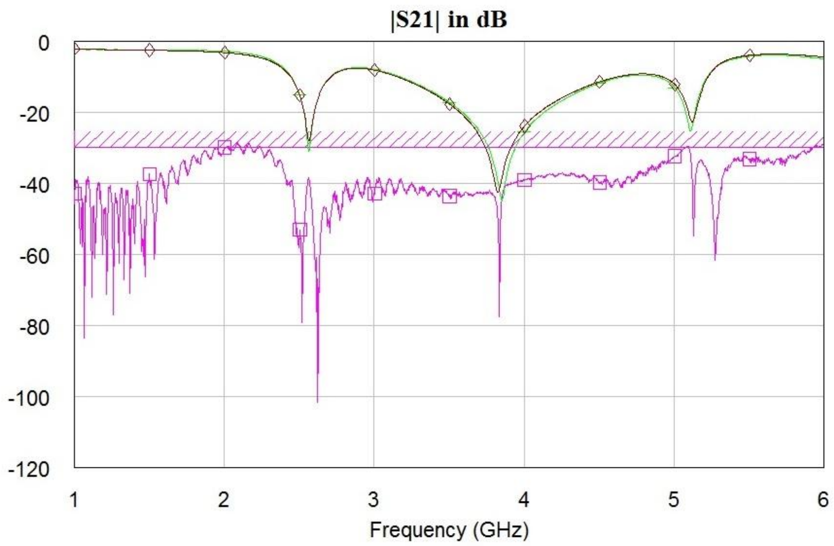

Fig.4 diamonds: circuit model, without marks: measurement, squares or triangles: difference between model and measurement

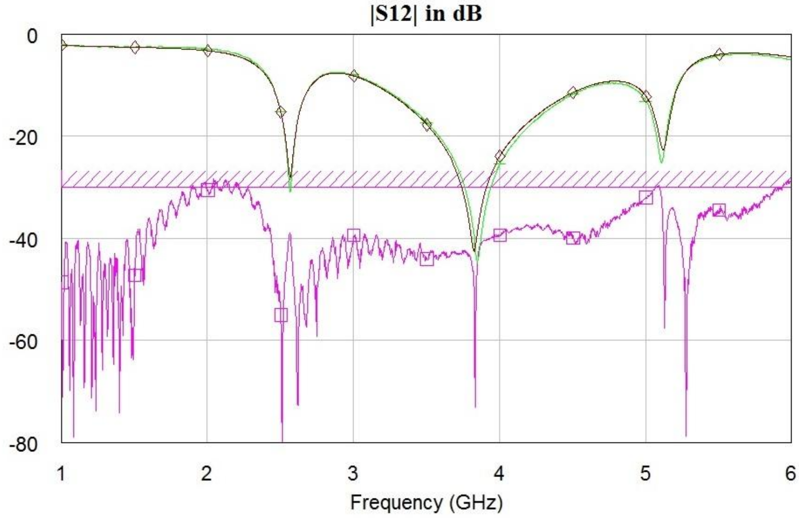

Fig. 5 diamonds: circuit model, without marks: measurement, squares or triangles: difference between model and measurement

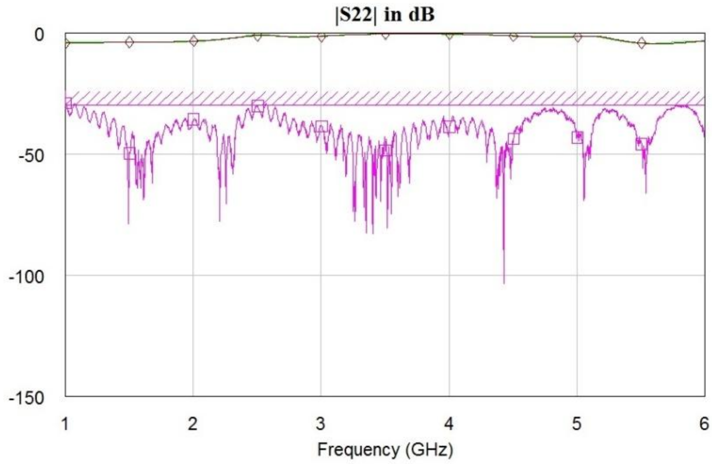

Fig. 6 diamonds: circuit model, without marks: measurement, squares or triangles: difference between model and measurement

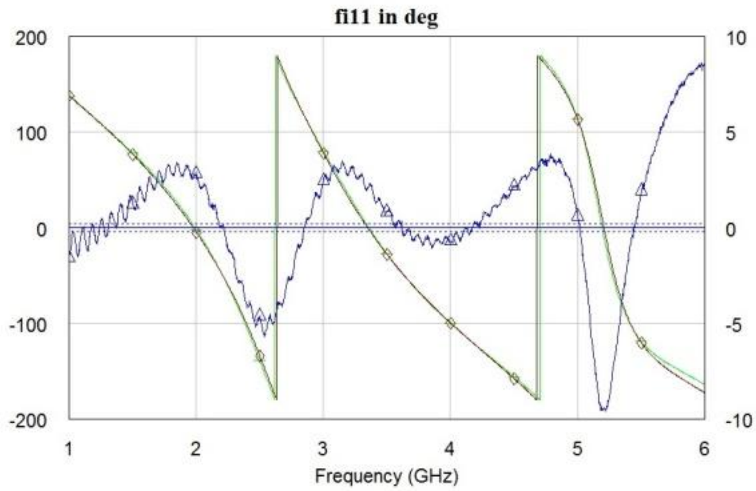

Fig. 7 diamonds: circuit model, without marks: measurement, triangles: difference between model and measurement, right axis

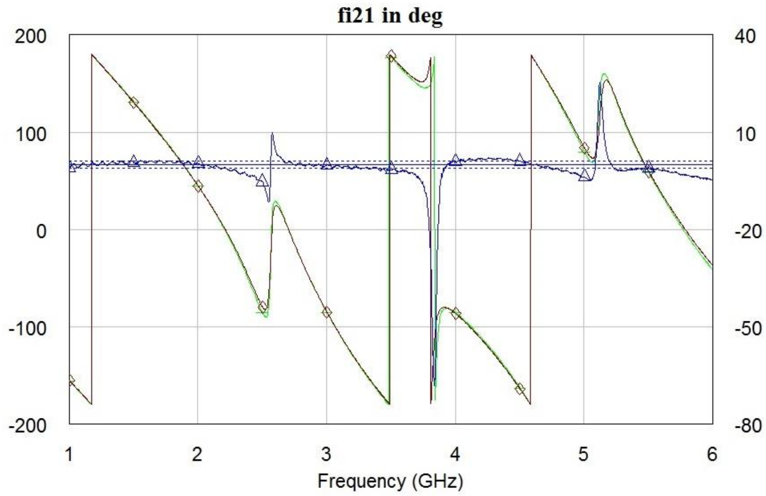

Fig. 8 diamonds: circuit model, without marks: measurement, triangles: difference between model and measurement, right axis

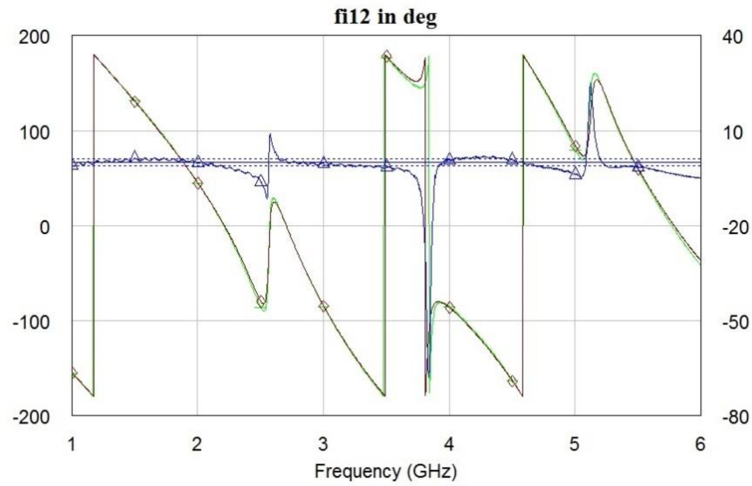

Fig. 9 diamonds: circuit model, without marks: measurement, triangles: difference between model and measurement, right axis

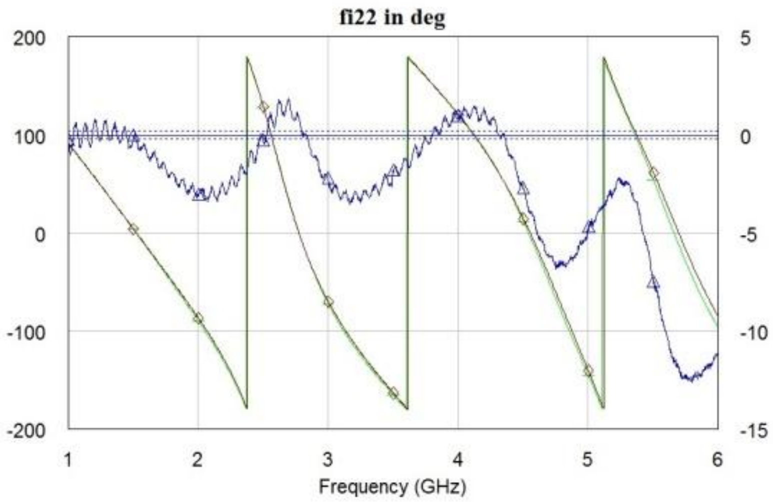

Fig. 10 diamonds: circuit model, without marks: measurement, triangles: difference between model and measurement, right axis

Excellent match between simulated and measured data verifies the circuit model.

IV. Conclusions

Material parameters (relative permittivity ε_r and tan δ) of a microstrip substrate have been determined from s-parameter measurements. Model accuracy is extremely good over a wide frequency range. Determined material parameters are ε_r=3.655 and tan δ=0.0079.
Results in this paper are parts of the bsc thesis of the first author.

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