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4-Port Microstrip planar resonator for multiband microwave material characterization applications

Sujith Raman(1) and Anja K. Skrivervik(1)
(1) Microwaves and Antennas Group, Ecole polytechnique Fédérale de Lausanne, 1015 Lausanne, Switzerland, https://www.epfl.ch/labs/mag/

Abstract

Planar microstrip resonators suitable for material characterization application are presented in this paper. The prototype consists of three resonators fed through four ports in a planar dielectric substrate without any additional resonators. The resonators are working in different frequency regions making it suitable for resonant based characterization at different frequencies using a single prototype. In this proposed work, the overall dimension of the prototype is 100mm x 50mm when fabricated in a 1.6mm thick FR4 epoxy substrate of dielectric constant 4.4 and loss tangent 0.02. The three resonators are operating within their fundamental mode at 900MHz, 1.8GHz and 2.4GHz respectively. The analysis in this work is carried out on the fundamental electrical mode for all the three resonators, but is similar for the higher order modes. The prototype is highly compact and low cost compared to the conventional cavity based resonant characterization techniques.

1. Introduction

The use of dielectric materials in electronic industry especially in RF and microwave field is inevitable as well as crucial. The electrical properties of these materials affect the performance of these devices, which are important for specific applications [1]. Understanding the material properties before using them is crucial. Various types of material characterization techniques are available nowadays, either resonant based or non-resonant [2]. Resonant based techniques normally use 3-dimensional bulky cavities or resonating structures for producing the resonances. The latter is perturbed by the material under test(MUT) for its characterization. These non-compact resonant prototypes are difficult for easy usage and are of high manufacturing cost. Planar prototypes with reduced cost are also used for the above purpose with additional resonating structures such as Split ring resonators(SRR) [3] , Complimentary split ring resonators(CSRR)[4] or other type of loops and resonator's. Athira et al [5] proposed a resonant based planar prototype which is compact and suitable for material characterization. However, it works for only one particular frequency/frequency band, which limits its suitability for many practical applications. In this work, we propose a planar resonant based characterization method suitable for three different frequency band, but which can be extendable to multiple frequencies as per requirement. The geometry of the structure results and suitability for material characterization is discussed in the sections below.

2. Geometry of the prototype

The geometry of the material characterization device is shown in figure 1. It is fabricated on a two sided copper clad-FR4 epoxy substrate of dielectric constant 4.4 and loss tangent 0.02 with a thickness of 1.6mm. The bottom layer is fully grounded and the upper surface is having three transmission lines acting as resonators (Resonator 1, Resonator 2 and Resonator 3). The transmission line is converted to resonators by symmetrically inserting the resonant posts (Sp1 and Sp2 for Resonator 1, Sp3 and Sp4 for Resonator 2, Sp5 and Sp6 for Resonator 3 respectively). The resonator 2 and 3 are at a distance D1 and D2 from each other. The three resonators are selected by using the switches S1, S2 and S3, (represented by opens or copper strips in this study). Port 1 and any one of the other port is selected while the remaining two ports can be left open or terminated with a 50-ohm impedance. The dimension of the transmission line is selected for 50-ohm impedance matching. The parameters of the prototypes are given in table 1.

Table 1. Parameters of the resonant prototype

Parameters	Dimension (in mm)	Parameters	Dimension (in mm)
L1	30	D1	13
L2	40	D2	13
L3	86	R1	13
Ws	3	R2	16
Lp1	35	Lp2	35
Lp3	15	Lp4	30
Lp5	38	Lp6	8
X1	16	Y1	23.5
Y2	26.5	Z	1.6

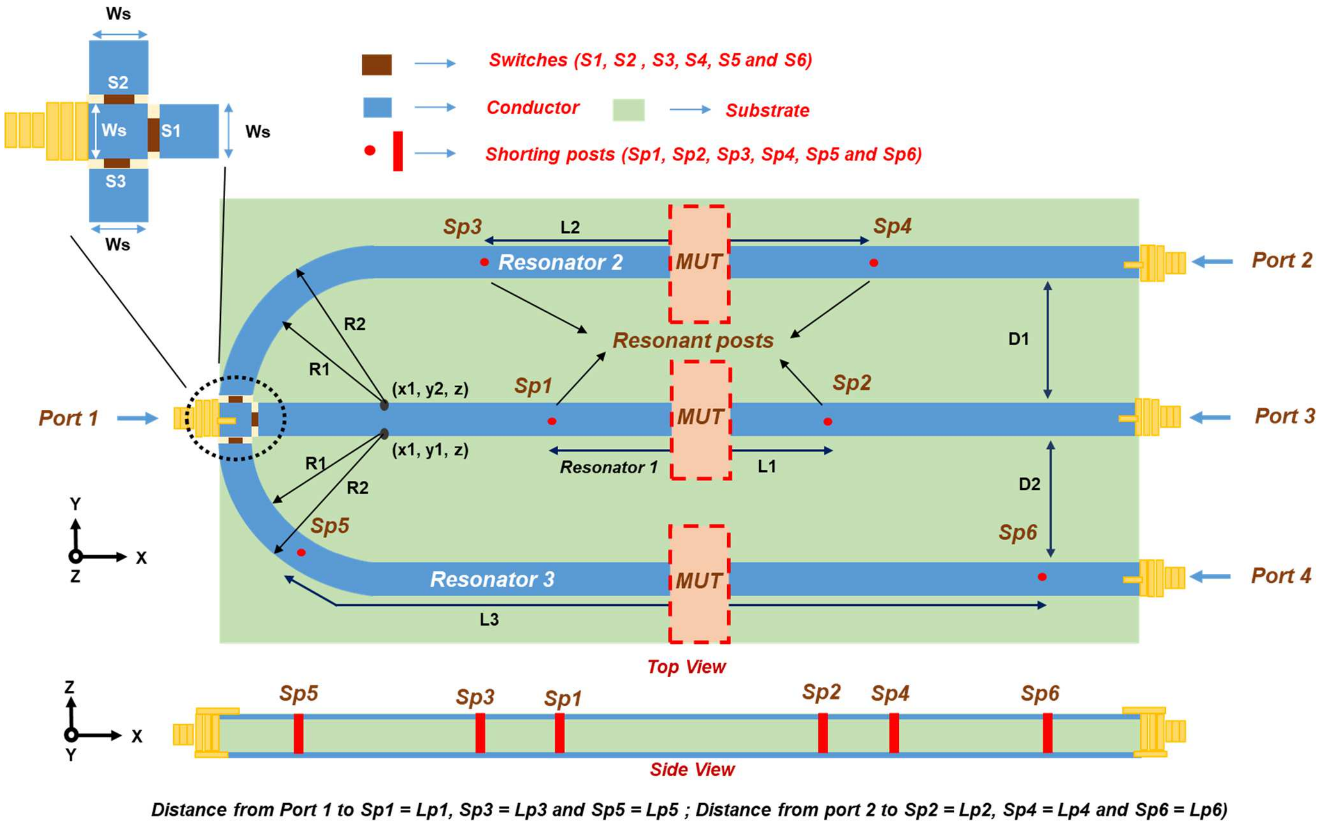


Figure 1. Schematic diagram of the microstrip transmission line resonator

3. Results and Discussions

The transmission parameters of the prototype with and without shorting post are shown in figure 2. Without shorting and by properly connecting the transmission line with switches it is seen that the prototype act as a transmission lines with very little insertion loss throughout the frequency region of interest. With the shorting post, when the switch S1 is ON, Sp1 and Sp2 will act as resonant post and a resonance peak can be seen at 2.4GHz. When the switch S2 is On and other Switches are in OFF condition, a resonance peak at 1.8GHz will be generated corresponding to the resonator 2 length L2. Similarly, when Resonator 3 is excited by switching On S3 only, the resonance peak is on 900MHz frequency as shown in the figure.

Resonator 1, 2 and 3 are resonating around 900MHz, 1800MHz and 2400MHz with their corresponding –3dB band width of 20MHz, 55MHz and 80MHz having a transmission coefficient of -21.75dB, -11.6dB and -9.12dB respectively. The transmission coefficient at resonance becomes higher with the increase in frequency and the resonance bandwidth is smaller in lower frequencies. Apart from the fundamental resonance, it is also resonating at higher modes, which are corresponding to alternate electric and magnetic modes. However, in this work we are concentrating on the first modes, which is electric and is influenced by the permittivity of external materials. Thus the fundamental mode of the three resonators can be a good option for characterizing the dielectric permittivity and loss tangent of materials under test (MUT). The magnetic modes can be used to find out the relative permeability of materials.

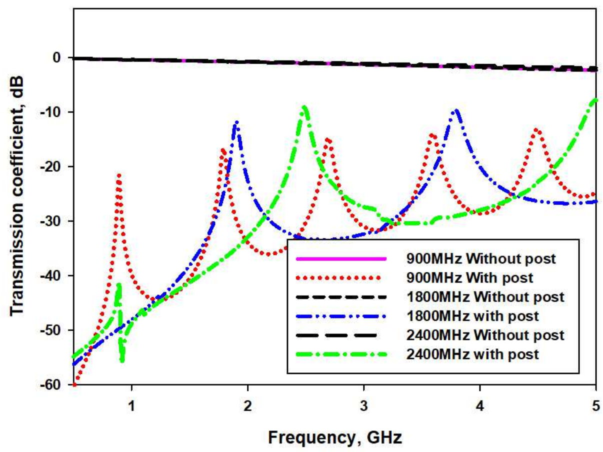
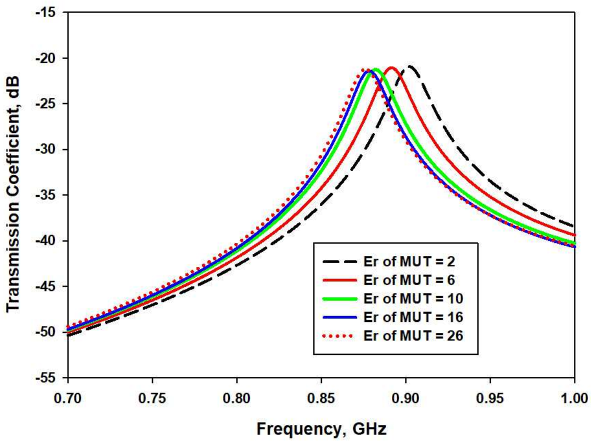
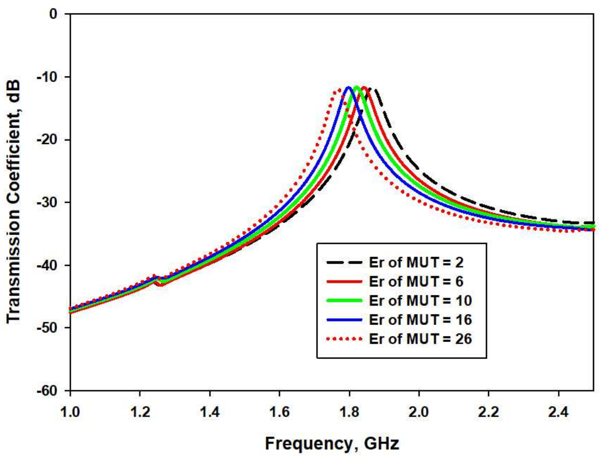


Figure 2. Transmission properties of device with and without shorting post

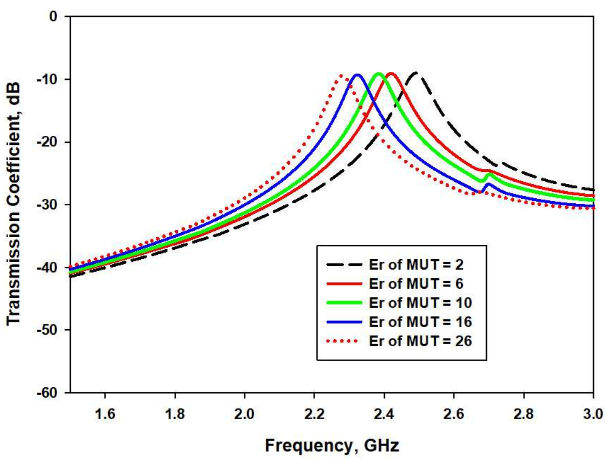
The material under test is placed at the center of the resonator and by properly exiting the device (Placing at the maximum field location), it is found that the transmission coefficient is influenced by the property of the material. The size of the MUT is taken as 3mm x 10mm with a thickness of 1.6mm. The variation of resonant frequency with respect to material dielectric constant is shown in figure 3. When we place the MUT on the 900MHz resonator with a dielectric constant changing from 2 to 26, a corresponding shift in the resonance is observed as shown in figure 3(a). It is interesting to note that the relative shift reduces with respect to increasing permittivity. This indicates that this method is suitable for low dielectric materials, preferably less than 15 at 900MHz.



(a)



(b)



(c)

Figure 3. Transmission properties of device with Material Under Test(MUT) by changing dielectric constant a) 900MHz resonator b).1800MHz resonator c) 2400MHz Resonator

The variation in transmission coefficient with respect to dielectric constant for second and third resonator working at 1800MHz and 2400MHz is shown in figure 3 (b) and (c) respectively. There is a clear indication of frequency shift with respect to the change in dielectric parameter. The equations used in [5] can be used to identify the dielectric parameters from the corresponding frequency shift. Thus this method and technique is highly useful for the material characterization at various microwave frequency bands. The prototype can be extended to the frequency of interest by simply changing the resonator length. Further analysis will be done and presented in future communications.

6. Acknowledgements

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