Proposal new configuration of Ring Resonator to Measure PCB Electric Permittivity

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Abstract: In this work it is proposed a ring resonator to characterize with accuracy the electrical properties of dielectric substrates commonly used in the design of printed circuit board and devices, particularly operating at high frequency. This characterization is important for building prototypes. The tests are made on samples supplied by manufacturers and retailers acquired in the trade. The procedure to be applied is based on determining the resonance frequency and its relation with the permittivity of the material. Some results are presented and compared with known ones.

Keywords: PCB measurement, electric permittivity, ring resonator, planar circuits coupling, S parameter.

1. INTRODUCTION

Today, with increasing frequency in the circuit, there is a need for greater precision in characterization of dielectric materials used in circuit prototypes (PCB).

When you have a wrong effective permittivity, it can result in differences in the phase jitter or BER (Bit Error Rate) transmission. This kind of PCB is frequently used to design planar antennas, which have its parameters (impedance, resonant frequency, efficiency) strongly influenced by the permittivity value.

Other parameters can readily be measured, as Q-factor, coupling coefficient or dispersion characteristics, to help us determine those quantities.

The classic technique commonly used to measure permittivity is classified as destructive method, since it requires a sample, and it is based on the conception of microwave filters. Although there are others forms of transmission lines (coplanar waveguides, slot line) that can be employed as microwave filters, the microstrip line is the most used.

From these techniques we can find in the literature [1-6] that the classic ring resonator (Fig. 1) most commonly used has shown to be satisfactory when its results are compared to the others' ones. One of the reasons is that the ring resonator presents the advantage of not having the edge effect. It causes a $\Delta\ell$ increase (electric length) in the physical length of the transmission line, i. e., the edge line introduces a capacitive effect because it is opened.

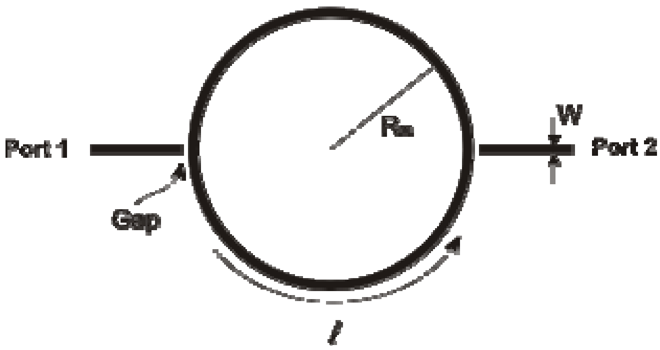

Fig.1. Resonator ring wavelength, with: *W=1.2mm*, *l =119,69mm*, *Gap=1mm*, and R_m*=19,05mm*.

2. REVIEW OF MICROSTRIP LINE

To better understand the technique of the ring resonator, it is necessary a few words about the equations that govern the microstrip circuits.

$$r_m = \frac{l}{2\pi} \tag{1}$$

$$l = \frac{n\lambda_g}{2} \tag{2}$$

$$\varepsilon_{reff} = \left(\frac{c}{f\,\lambda_g}\right)^2 \tag{3}$$

$$\varepsilon_r = \frac{2\varepsilon_{reff} - 1 + \left(\frac{1}{\sqrt{1+12(h/w)}}\right)}{\left(1 + \frac{1}{\sqrt{1+12(h/w)}}\right)} \tag{4}$$

Where λ_g is the wavelength of the wave that travels in the line, c the speed of light in a vacuum ($3x10^8 m/s$), ε_{reff} the effective dielectric permittivity (supplied by the manufacturer or the type of material), w is the thickness of the microstrip line, h is the height of the dielectric substrate, ℓ is the circumference of the ring, r_m the average radius of the circle, f is the frequency peak of resonance.

3. PROCEDURE

There are several ways to analyze the coupling between the feed line and the resonator for some possible configurations, shown in [6]. It is interesting to note that the capacitive effect of feeding allows us to calculate the effective permittivity not only over z, but also in x or y.

It was initially performed the study of the influence of the capacitive effect on the feed line in the ring. A new feeding port was introduced, shown in Fig.2. This new port is important to observe the effect caused by the increase of the capacitance C_g shown in Fig.3. This increase brings a better determination of the effective permittivity of laminated.

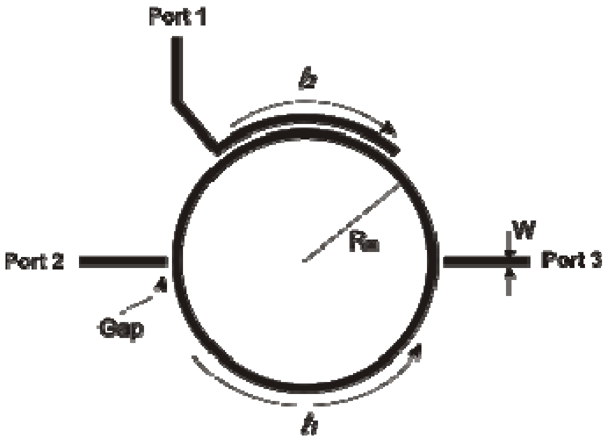

Fig. 2. Resonator with 3 ports. With $W=1.2mm$, $l_1= 119.69mm$, $l_2=(l_1/4)$, $Gap=1mm$, and $R_m=19.05mm$.

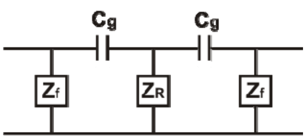

Fig. 3. Equivalent circuit of Fig.1, C_g is the gap capacitance, Z_f is the impedance of the feed lines, and Z_R is the impedance of the ring resonator.

With the goal to get high and accurate Q-factor and well defined resonant frequency, a new configuration taking into account these two mentioned characteristics (low insertion loss and field perturbation) is studied.

4. RESULTS

This work will use two kinds of laminates. The first laminated fiber glass of unknown manufacture and the second is one laminated Rogers. It was used the network analyzer (HP-8714C) and the same dimensions for both rings.

In Fig. 4 and Fig. 5 it is shown the transmission power for each kind of laminate and for $h = 1.65mm$.

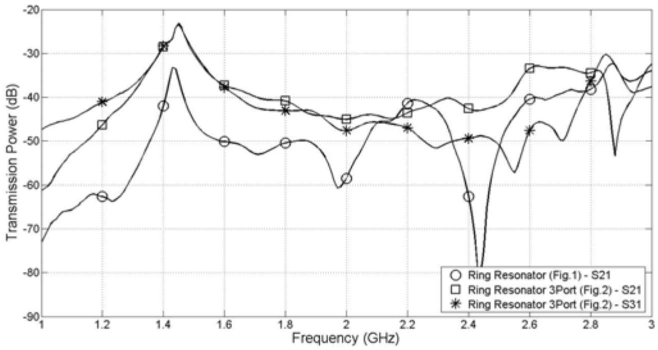

Fig. 4. Transmission Power for the ring resonators using unknown manufacture laminated.

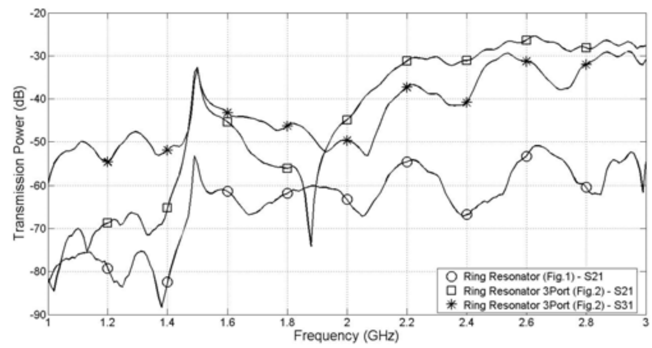

Fig. 5. Transmission Power for the ring resonators using laminated Rogers.

The prototypes were designed for the frequency of 1.5 GHz and it can be seen a good correlation between the frequency calculated and the frequency measured.

It confirms that the technique is quite precise. From Fig.5, increasing the capacitance we get a good transfer of power between the input and output signal and a more prominent frequency peak. It has the influence of C_g.

The configuration for measured permittivity using the ring resonator with feeding by a common line(Fig. 1) only allows greater prominence in the second or third modes of resonance of the ring, and then to perform the study it is necessary to make a prototype for a lower frequency, increasing the size of the laminate to be used and the loss of laminate.

The modified circuit ring resonator (Fig. 2) shows the best result among the other configurations.

Table 1. Resonant frequency and permittivity for results in Fig.4

	f_{res}	ε_r
S_{21} (Fig.1)	**1.43 GHz**	**4.33**
S_{21} (Fig.2)	**1.45 GHz**	**4.2**
S_{31} (Fig.2)	**1.45 GHz**	**4.2**

Table 2. Resonant frequency and permittivity for results in Fig.5

	f_{res}	ε_r
S_{21} (Fig.1)	**1.490 GHz**	**3.6035**
S_{21} (Fig.2)	**1.501 GHz**	**3.55**
S_{31} (Fig.2)	**1.501 GHz**	**3.55**

Using the equations (3) and (4) presented for the microstrip theory, we obtain the tables above for each resonant frequency from Fig. 4 and Fig.5.

The new configuration allows us to observe the effect of the shift of resonant frequencies. This occurs due to increased capacitance between the feed line and the ring resonator (C_g).

The new configuration for measured permittivity can be used to achieve excellent results for measuring the permittivity because it allows a better coupling between the ring and feed line.

5. CONCLUSION

In this paper the ring resonator technique was applied and optimized to measure the PCB permittivity. It was presented a structure to increase capacitance without causing disturbance in the ring resonator and improve its response.

It is well know that the increase in capacitance changes the resonant frequency, as verified in Fig. 4 and Fig. 5. It was achieved when a new port in the circuit is inserted. This effect occurs because of the presence of the capacitance C_g that can be furnished with two different configurations.

This optimized configuration of the ring resonator technique in measuring permittivity is really accurate. It also allows the permittivity measurement of laminated without spend a lot.

The permittivity determination through the capacitance C_g allows a better approach in the coupling calculation between two close lines.

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