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# THE NEW CONFIGURATION OF MEASURE PCB ELECTRIC PERMITTIVITY USING DE RING RESONATOR

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**Abstract** − In this work it is proposed new configurations for the ring resonator to determine with accuracy the dielectric permittivity of printed circuit boards operating at high frequencies. The procedure is determining the resonance frequency of the ring and its relation with the permittivity of the material. The results obtained are compared to the ones known for the classic configuration of the ring.

**Keywords:** Measurement of electric permittivity, ring resonator, planar circuits coupling.

## 1. INTRODUCTION

As frequency increases, there is a need for greater precision for the characterization of the materials used to make PCB's.

Specifically about the permittivity, the correct determination of this parameter is important for several applications such the design of antennas and microwave circuits using low permittivity substrates[1].

The technique that is usually used requires samples and is based on making filters. To determine with accuracy the resonance frequency, the filter must have a small bandwidth, it means a large Q-factor.

The classic ring resonator (Fig. 1) is the most used configuration to measure the permittivity of PCB's and has shown good results when compared to planar circuit resonators. The ring has the advantage of not having the edge effect.

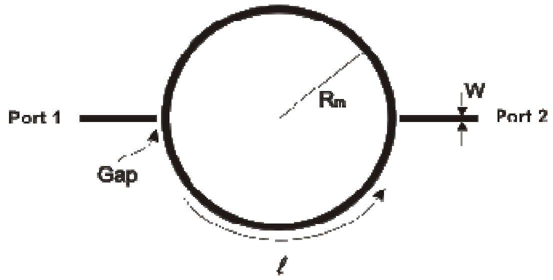


Fig.1. Resonator ring wavelength, with: *W=1.2mm*, *l =119,69mm*, *Gap=1mm*, and *Rm=19,05mm*.

However the coupling between the feed line and the ring must be taken into consideration because its capacitive effect (Fig. 2) may change significantly the resonance frequency.

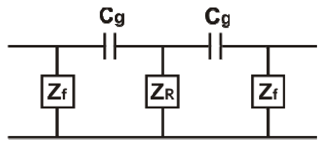


Fig. 2. Equivalent circuit of Fig.1, $C_g$ is the gap capacitance, $Z_f$ is the impedance of the feed lines, and $Z_R$ is the impedance of the ring resonator.

## 2. STUDY OF THE CAPACITANCE

From the configuration end-to-end seen in Fig. 3, it is known that there's a capacitance between the two lines and such capacitance causes a considerable attenuation in the signal transmitted. It also happens between the feed line and the ring seen in Fig. 1. So it is necessary to find new configurations for the ring that can reduce the attenuation of the signal.

Fig. 3. End-to-end configuration.

Now considering the configuration in Fig. 4, we see a half-wavelength resonator. We made two of them with two different lengths, *70 mm* and *90 mm*. However the coupling length is equally *λ/4*. There is an increase in the coupling area. Such increase may cause a change in the resonance frequency of the planar resonator because of its capacitive effect. Since the configuration works as a filter, the real resonance frequency may be filtered, causing the change. However, for this specific configuration, with a *λ/4* coupling length for first case (*L=70mm*), experimental results show that the change in the frequency is small.

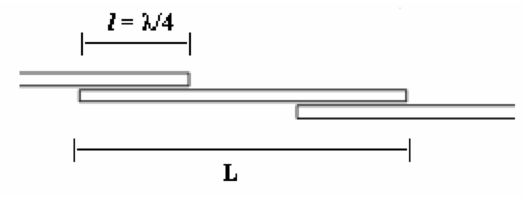


Fig. 4. Half-wavelength resonator. *L=70 mm* or *L=90 mm* and $l = \lambda/4$.

## 3. MICROSTRIP LINE

To better understand how to determine the permittivity, it is necessary to consider the equations for the microstrip lines.

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

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

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

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

Where $\lambda_g$ is the wavelength of the wave that travels in the line, $c$ the speed of light in a vacuum ($3x10^8 m/s$), $\varepsilon_{reff}$ 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 of resonance.

## 4. PROCEDURE

It is important to study configurations like the one seen in Fig. 4 because the coupling between the lines and the resonator may be very useful to determine the permittivity over all directions of the PCB. Using configurations like the classic ring resonator we can only calculate the permittivity over the vertical direction.

Considering this fact, we have introduced a new port in the classic configuration of the ring (Fig. 5). This configuration takes into account the low insertion loss and the low perturbation of the ring's fields and causes the same effect (small change in the resonance frequency) as the configuration seen in Fig. 4.

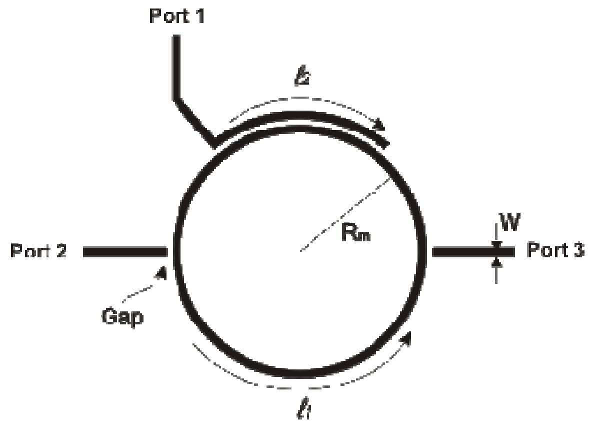


Fig. 5. Resonator with 3 ports. With $W=1.2mm$, $l_1= 119.69mm$, $l_2=(l_1/4)$, $Gap=1mm$, and $R_m=19.05mm$.

Another configuration that satisfies the two conditions mentioned (low insertion loss and low perturbation) is shown in Fig. 6. The ring remains with two ports, like the classic configuration, but there is a larger coupling area. The goal is determine the permittivity over all directions.

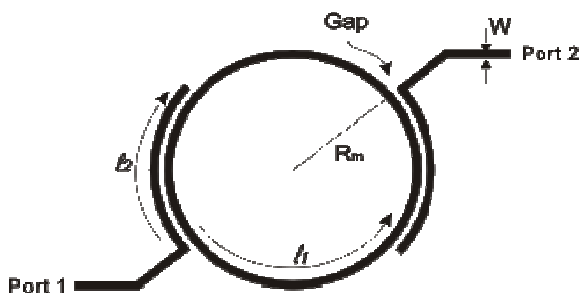


Fig. 6. Resonator with 2 ports modified. With $W=1.2mm$, $l_1= 119.69mm$, $l_2=(l_1/4)$, Gap=1mm, and $R_m$=19.05mm.

## 5. RESULTS

We used two kinds of boards. The first one is made of fiber glass from unknown manufacture with $h$=1.65 mm. The second one is Roger manufactured with $h$=0.508mm and $\varepsilon_r$=3.55. We also used the Network Analyzer HP-8714C.

The rings have the same dimensions for all boards used. In Fig 7, Fig. 8 Fig. 9 and Fig. 10 it is seen the Transmission Power for the configurations seen in Fig. 5 and Fig. 6 for the Roger laminated and for the unknown manufacture.

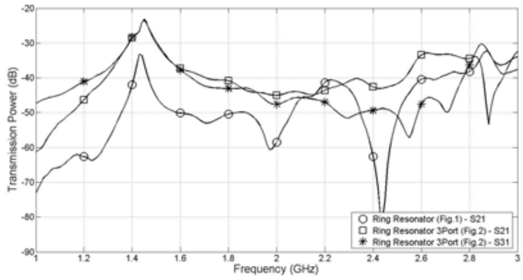


Fig. 7. Transmission Power for the configuration seen in Fig.5 using unknown manufacture laminated.

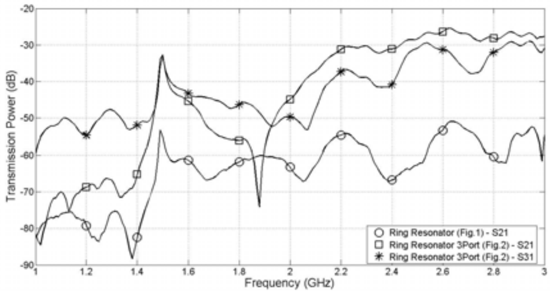


Fig. 8. Transmission Power for the configuration seen in Fig. 5 using laminated Rogers.

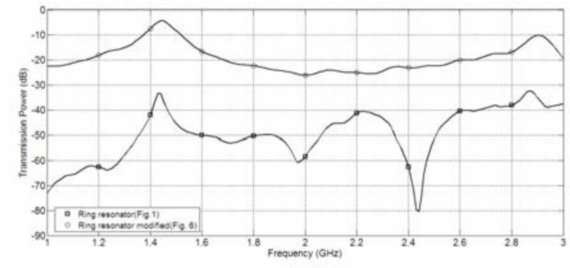


Fig. 9. Transmission Power for the configuration seen in Fig. 6 using unknown manufacture laminated.

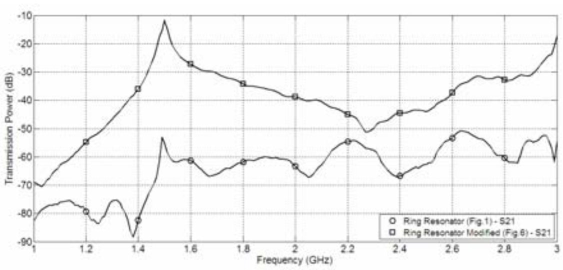


Fig. 10. Transmission Power for the configuration seen in Fig. 6 using Roger laminated.

## 6. RESULTS

Using the equations (3) and (4) presented for the microstrip line, we obtained tables 1, 2, 3 and 4.

Table 1. Resonance frequency and permittivity for Fig. 7.

| | $f_{res}$ | $\varepsilon_r$ |
|---|---|---|
| **$S_{21}$ (Fig.1)** | **1.43 GHz** | **4.33** |
| **$S_{21}$ (Fig. 5)** | **1.45 GHz** | **4.2** |
| **$S_{31}$ (Fig. 5)** | **1.45 GHz** | **4.2** |

Table 2. Resonance frequency and permittivity for fig. 8.

| | $f_{res}$ | $\varepsilon_r$ |
|---|---|---|
| **$S_{21}$ (Fig.1)** | **1.490 GHz** | **3.6035** |
| **$S_{21}$ (Fig. 5)** | **1.501 GHz** | **3.55** |
| **$S_{31}$ (Fig. 5)** | **1.501 GHz** | **3.55** |

Table 3. Resonance frequency and permittivity for Fig 9.

| | $f_{res}$ | $\varepsilon_r$ |
|---|---|---|
| **$S_{21}$ (Fig.1)** | **1.43 GHz** | **4.33** |
| **$S_{21}$ (Fig. 6)** | **1.45 GHz** | **4.2** |

Table 4. Resonance frequency and permittivity for Fig. 10.

| | $f_{res}$ | $\varepsilon_r$ |
|---|---|---|
| **$S_{21}$ (Fig.1)** | **1.49 GHz** | **3.6035** |
| **$S_{21}$ (Fig. 6)** | **1.501 GHz** | **3.55** |

The resonators were designed for a resonance frequency of 1.5 GHz. As we can see, the new technique has improved the value of the resonance frequency of the ring.

From Fig. 8 – 10, we must realize that an increase in the coupling area causes a lower attenuation of the signal. We also obtain a more prominent peak of the transmission power in the resonance.

## 7. CONCLUSION

In this paper, the new configurations for the ring resonator have improved the measurement of the permittivity of the PCB's.

The coupling between the ring and the feed lines were made considering a low attenuation of the signal and a low perturbation of the ring. Because of it, we have obtained a more precise value for the resonance frequency and, consequently, for the permittivity.

## REFERENCES

[1] D. Thompson, M. Falah, X. Fang and D. Linton. “Dielectric Characterization Using the Microstrip Resonator Method”

[2] J. I. Takemoto, C. M. Jackson, R. Hu, J. F. Burch, K. P. Daly, And R. W. Simon, “Microstrip Resonators And Filters Using High-Tc Superconducting Thin Films On

Laalo3", IEEE Transactions on Magnetics, Vol. 27, No. 2, March 1991

[3] I. Waldron, S. N. Makarov, "Measurement of dielectric permittivity and loss tangent for bulk foam samples with suspended ring resonator method", Antennas and Propagation Society International Symposium 2006, IEEE 9-14 July 2006 Page(s):3175 – 3178

[4] J. Carroll, M. Li, and K. Chang ," New Technique To Measure Transmission Line Attenuation", IEEE Transactions On Microwave Theory And Techniques, Vol. 33, No. 1, January 1995

[5] S. A. IvanoV, and V. N. Peshlov, "Ring-Resonator Method—Effective Procedure for Investigation of Microstrip Line", IEEE Microwave And Wireless Components Letters, Vol. 13, No. 6, June 2003

[6] K. Chang,"Microwave Ring Circuits and Antennas", Willey, 1996

[7] W.J.R. Hoefer, **"**Measurement of the Equivalent Circuit Parameters of Discontinuities in a Resonant Microstrip Ring", Microwave Symposium Digest, MTT-S International Volume 75, Issue 1, May 1975 Page(s):103 – 105

[8] K. Chang, "Microwave Ring Circuits and Antennas", Wiley,1996

[9] R. E. Collin, "Foundations For Microwave Engeneering", IEEE Press, 2000

[10] D. M. Pozar, "Microwave Engineering", Addison Wesley,1993

[11] C. Y. Chang and T. Itoh, "Microwave Active Filters Based on Coupled Negative Resistance Method", IEEE MTT, Vol. 38, December 1990

[12] P. Troughtom, P. J. B. Clarricoats, and C. D. Hannaford, "Measurement Techniques in Microstrip", Electronic Leters, Vol. 5, January 1969

[13] K. Chang, S. Martin, F. Wang, and J. L. Klein, "On the Study of Microstrip Ring and Varactor-Tuned Ring Circuits", IEEE MTT, Vol. 35, December 1987

[14] T. S. Martin, F. Wang, and K. Chang, "Theoretical and Experimental Investigation of Novel Varactor-Tuned Switchable Microstrip Ring Resonator Circuits", IEEE MTT, Vol. 36, December 1988.