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Dielectric Permittivity of Various Organic Solvents Using Concentric Positioned Resonating Chamber

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Abstract- In this paper we explain the use of a concentric positioned resonating chamber for the measurement of dielectric properties of various organic solvents. In this experiment a concentric positioned resonating chamber is filled with organic solvents such as distilled water, dimethyle sulfoxide, ethylene glycol, ethanol, methanol, etc. By using spectrum analyzer, frequency generator, power cable and concentric positioned resonating chamber with solvent as a dielectric material between interior and exterior conductor, an amplitude verses frequency graph is observed. Then by keeping the note of resonance frequency for each chemical from the corresponding graph, dielectric permittivity is determined. From this experiment it is concluded that, an electric property of resonating chamber such as resonance frequency and dielectric permittivity goes on varying with the variation in dielectric properties of organic liquids. Therefore it is very easy to determine the dielectric permittivity of an organic solvent by using the concentric positioned resonating chamber.
Keywords- Concentric, Dielectric, Impedance, Permittivity, Power cable, Resonator, Solvent

I. INTRODUCTION

Recently it is noticed that to understand the dielectric properties of materials, there is a need of development of testing mechanism. Therefore in this paper, the work is focused on the present knowledge of dielectric properties of various organic solvents and their importance in various fields. At microwave frequencies, generally about 1GHz and higher range, concentric positioned resonating chamber as testing mechanism have been generally used. For liquid and semi-liquid organic solvents resonating chamber is used for the measurement of dielectric permittivity.

The purity of water is tested with in-line process in proper time to supply the safe drinking water. Therefore the aim of present research is to develop a concentric positioned resonating chamber as testing mechanism. The basic concept of concentric positioned resonating chamber is that the accommodation of dielectric solvent in the resonator will cause a shift of resonant frequency and detoriation of purity.

Summarizing, the in-line testing mechanism helps in giving the high speed, affordable sample assessment. The interaction of electromagnetic waves with a material is characterized by dielectric properties. The physical parameters like temperature, composition and frequency mainly influences the dielectric properties of organic solvents. Thus the idea given discusses the successful result of in-line dielectric permittivity measurement. In short the concept given here explains the possibility of in-line dielectric parameter measurement in resonating chamber at greater frequency with super quality.

II. RESEARCH OBJECTIVES

A. The objectives of my research work are

1) To construct a new device such as concentric positioned resonating chamber.

2) To measure the dielectric properties of various organic solvents using concentric positioned resonating chamber.

III.EXPERIMENTAL SETUP

The experimental set up shown below consists of attachment of power cable to quarter wavelength concentric positioned resonating chamber. The chamber consists of an interior conductor placed at the middle position of exterior hollow conductor, both made up of copper. In between the interior and exterior conductor an organic solvent is placed as dielectrics. With the help of inlet and outlet of the resonator continuous flow of liquid takes place. The testing mechanism consists of a spectrum analyzer having an internal input resistance 50 Ω with internally connected frequency generator having an internal output resistance of 50 Ω. The resonating chamber joined to spectrum analyzer by a power cable with a characteristic impedance of 50 Ω. Specifications of concentric positioned resonating chamber are given in table I.

Figure I: Spectrum analyzer setup with resonator

Thus the resonance frequency, f_{res} of a quarter wavelengths concentric positioned resonating chamber with length, l is given by the equation,

$$f_{res} = \frac{C(2n-1)}{4l\sqrt{\varepsilon_r \mu_r}} \qquad \text{.......... .... (1)}$$

Where,

f_{res} = resonance frequency (Hz)

C = speed of light in free space (m/s)

n = resonance number

l = length of concentric positioned resonating chamber (m)

ε_r = dielectric permittivity

μ_r = relative magnetic permeability

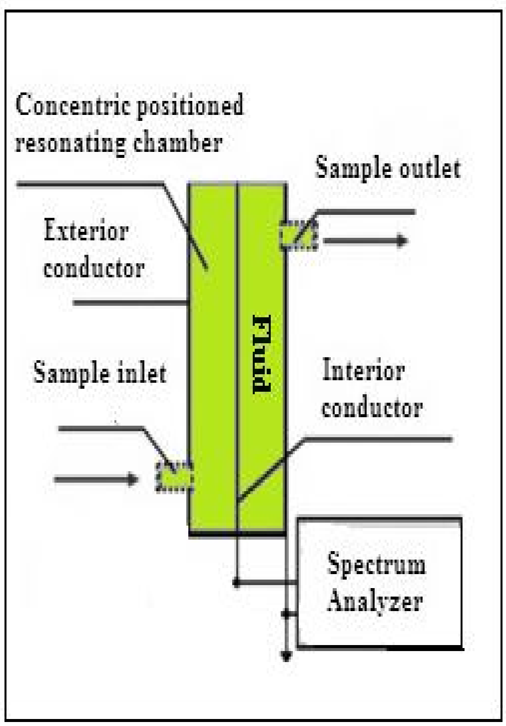


Figure II: System Construction

The well labeled diagram given above represents the concentric positioned resonating chamber with its attachment to the power cable to the spectrum analyzer with internally connected frequency generator. The instrument used for research work is an Agilent N9320B RF Spectrum analyzer having frequency range of 9 KHz to 3.0 GHz with internally connected frequency generator.
Practically it is observed that the dielectric samples between the interior and exterior conductor of the resonator affects the velocity generated by electromagnetic waves.

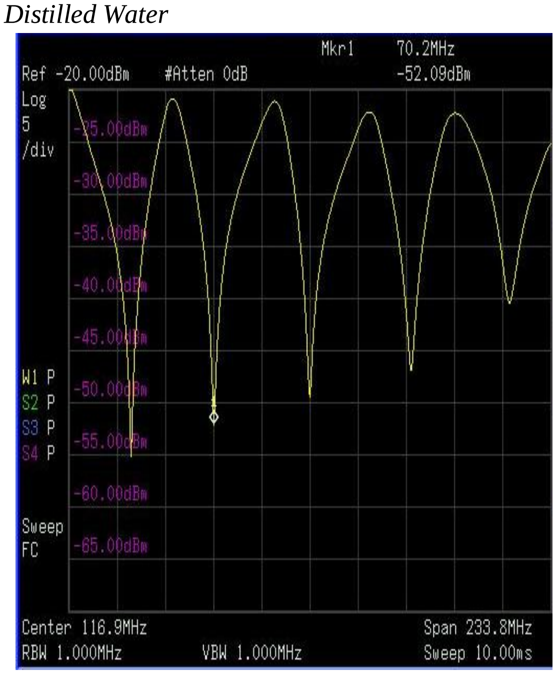
TABLE 1
SPECIFICATIONS of CONCENTRIC POSITIONED RESONATING CHAMBER

Specifications	Resonator
Length of the chamber, l	36.0 cm
Inner diameter of the exterior conductor, D	1.5 cm
Diameter of the sample inlet and outlet	0.7 cm
Interior conductor diameter, d	0.4 cm
Thickness of the exterior conductor	0.1cm

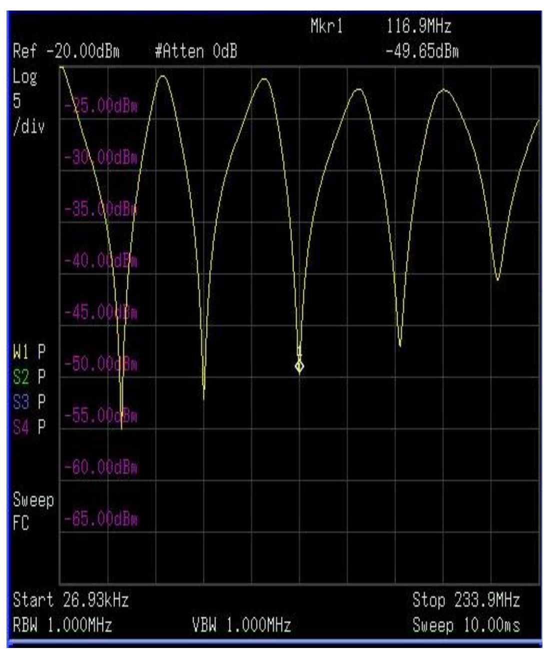
IV. OBSERVATIONS

Amplitude verses frequency graph observed on the spectrum analyzer for continuous flow of different organic solvents in copper resonator are as follows

A. Solvent 1: Distilled Water



Figure(a): Resonant frequency for the second resonance is 70.2 MHz



Figure(b):Resonant frequency for the third resonance is 116.9 MHz

Volume 5 Issue VI, June 2017
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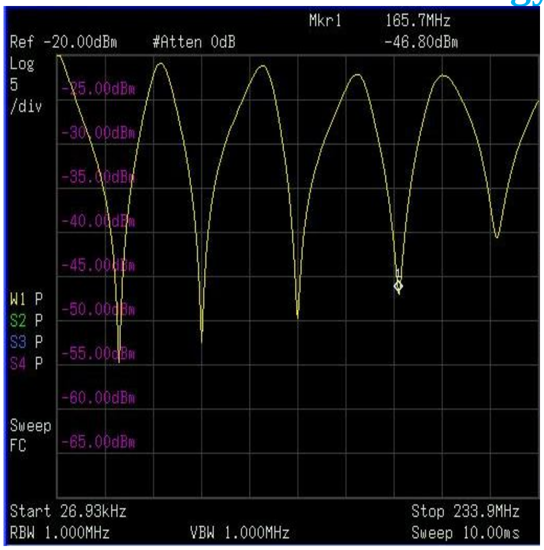
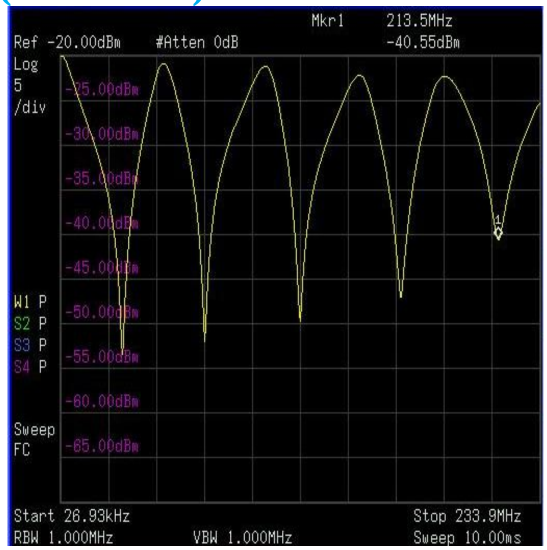


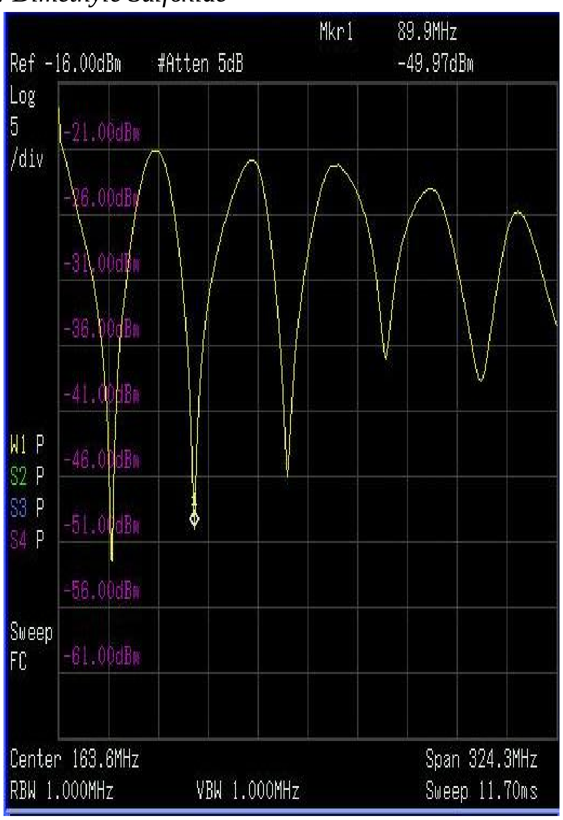
Figure(c):Resonant frequency for the fourth resonance is 165.7 MHz



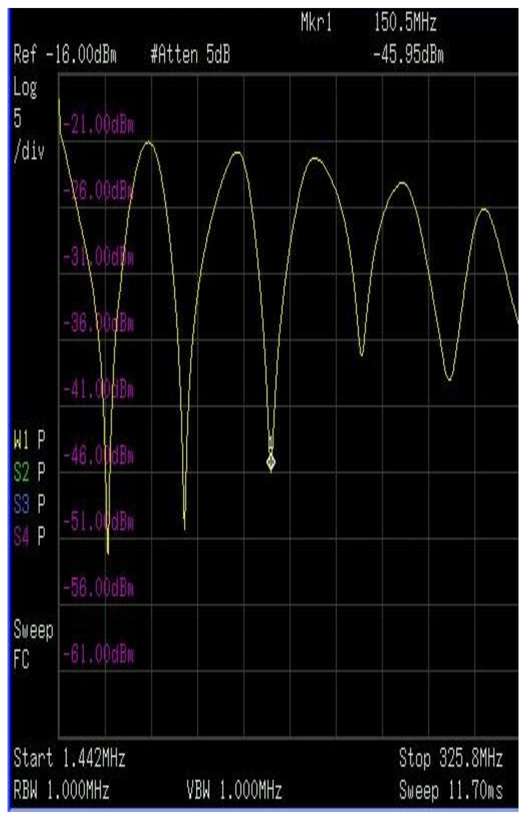
Figure(d):Resonant frequency for the fifth resonance is 213.5 MHz

Figure. III: Amplitude verses frequency graph for distilled water

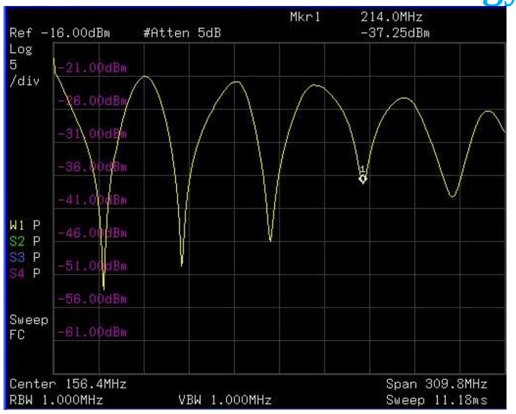
B.: Solvent II: Dimethyle Sulfoxide



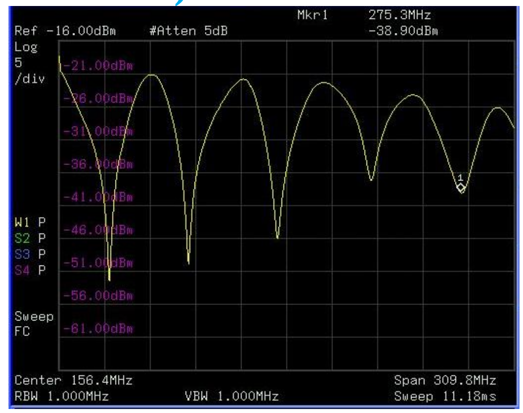
Figure(a):Resonant frequency for the second resonance is 89.9 MHz



Figure(b):Resonant frequency for the third resonance is 150.5 MHz



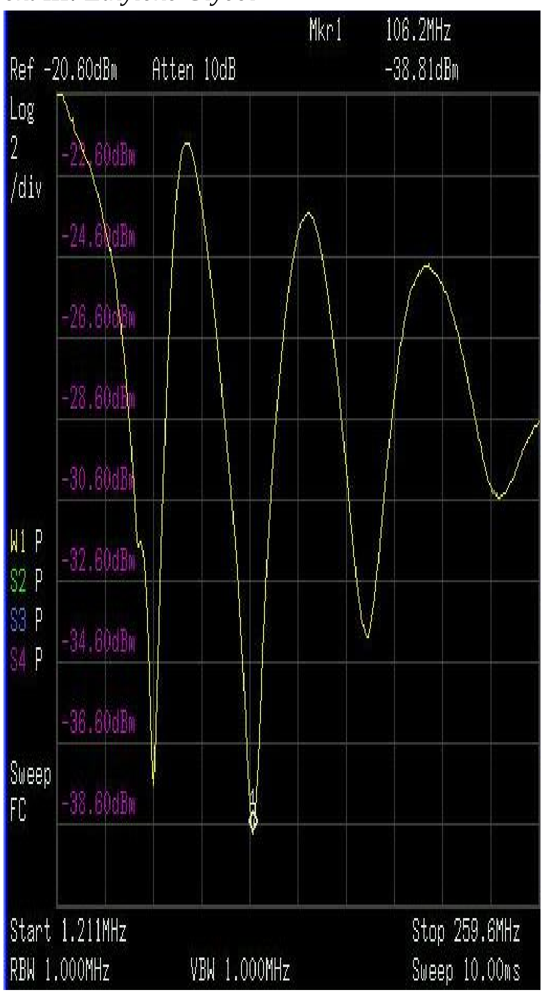
Figure(c):Resonant frequency for the fourth resonance is 214.0 MHz



Figure(d):Resonant frequency for the fifth resonance is 275.3 MHz

Figure IV: Amplitude verses frequency graph for dimethyle sulfoxide

*C. Solvent III**:** Ethylene Glycol*



Figure(a):Resonant frequency for the second resonance is 106.2 MHz

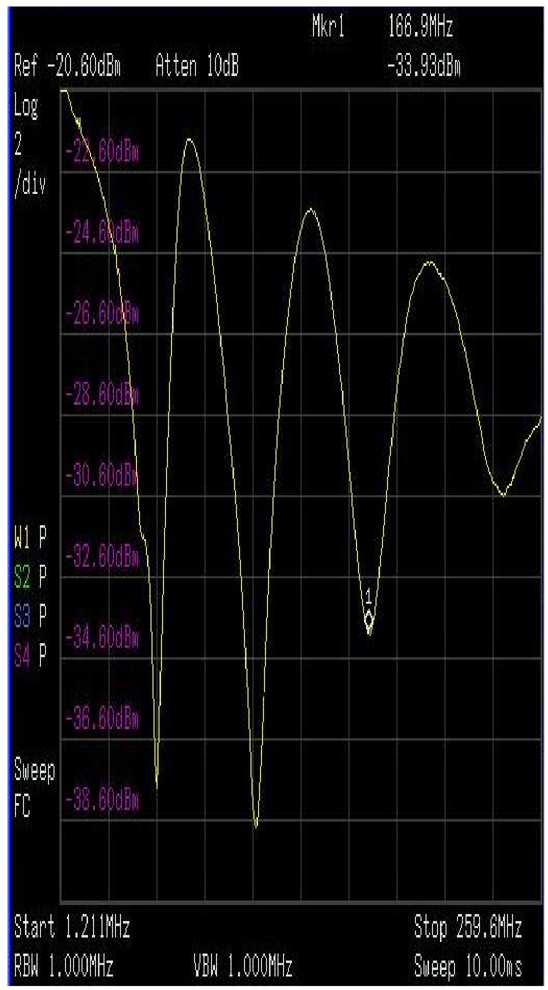


Figure (b): Resonant frequency for the third resonance is 166.9MHz.

Volume 5 Issue VI, June 2017
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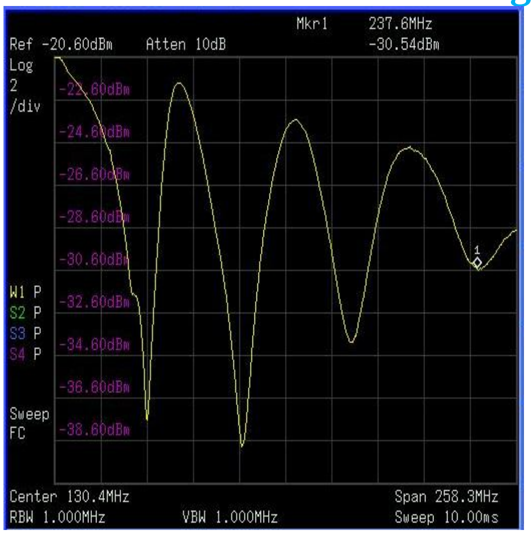


Figure(c): Resonant frequency for the fourth resonance is 237.6MHz.

Figure V: Amplitude verses frequency graph for ethylene glycol.

*D: Solvent IV**:** Methanol*

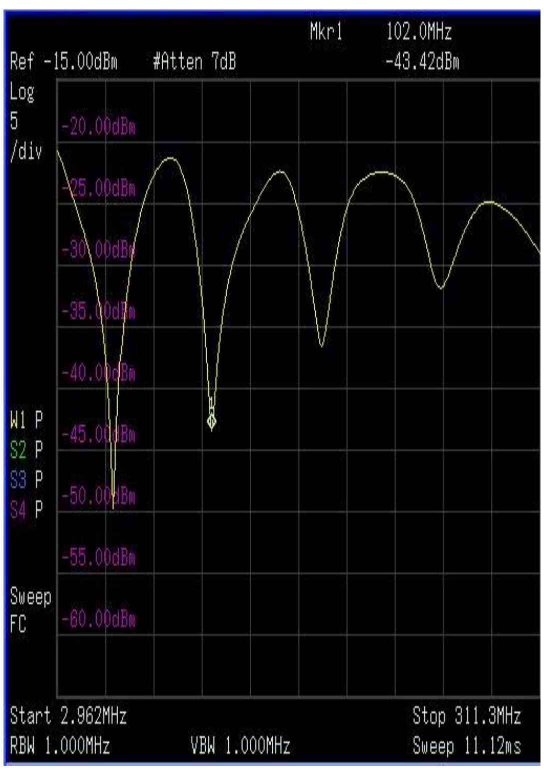


Figure (a): Resonant frequency for the second resonance is 102.0MHz.

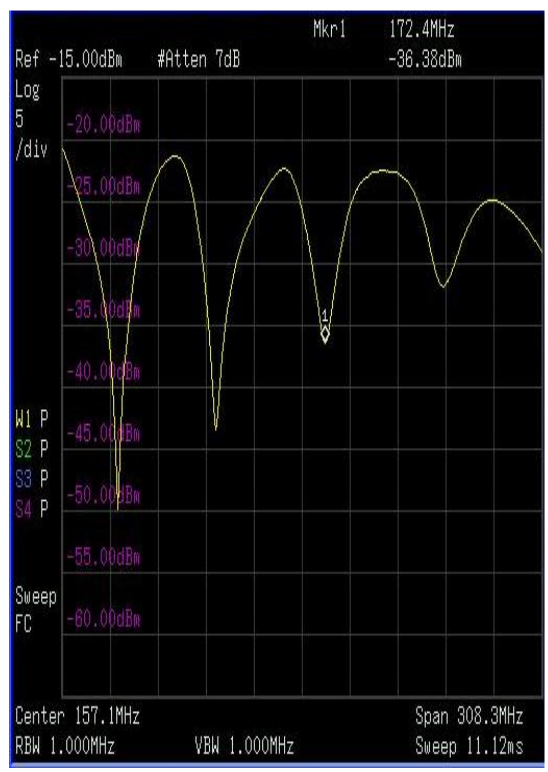
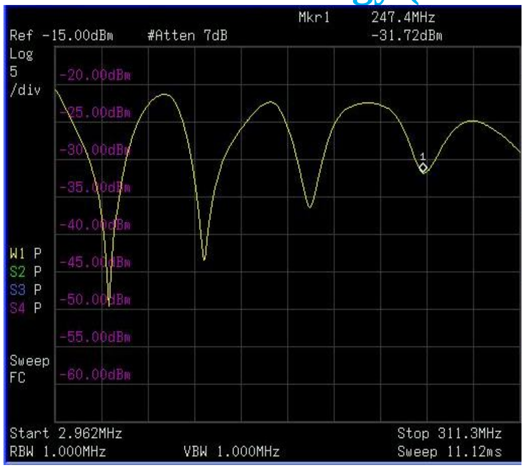


Figure (b): Resonant frequency for the third resonance is 172.4MHz.

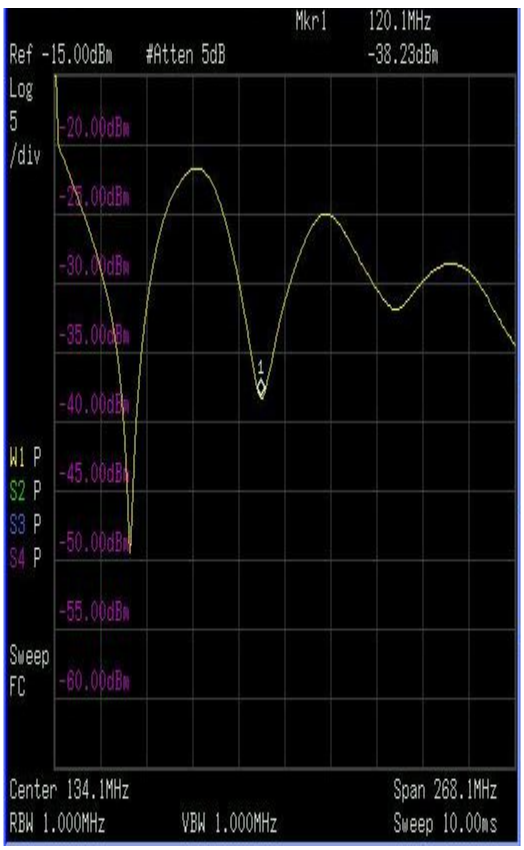
Volume 5 Issue VI, June 2017
ISSN: 2321-9653



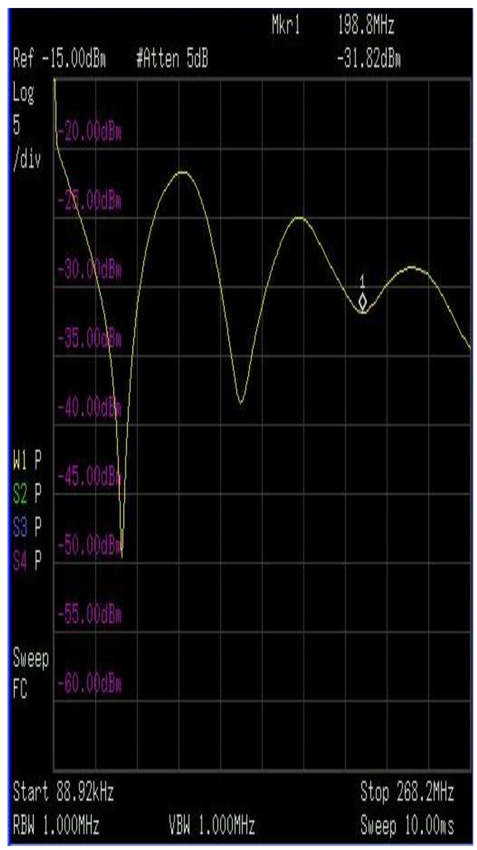
Figure(c): Resonant frequency for the fourth resonance is 247.4MHz.

Figure VI: Amplitude verses frequency graph for methanol.

*E. Solvent V**:** Ethanol*



Figure(a): Resonant frequency for the second resonance is 120.1MHz



Figure(b): Resonant frequency for the third resonance is 198.8MHz

Figure VII: Amplitude verses frequency graph for ethanol

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TABLE II

Experimental value of dielectric permittivity for various organic solvents

Organic Solvent	Standard Value of ε_r	Experimental value of ε_r for different resonances with deviation(Δ) from standard value							
		n=2	Δ%	n=3	Δ%	n=4	Δ %	n=5	Δ%
Distilled Water	78.54	79.33	1.00	79.34	1.01	77.42	1.42	77.11	1.82
Dimethyle Sulfoxide	47	48.33	2.82	47.90	1.91	46.43	1.21	46.38	1.31
Ethylene Glycol	37.7	34.61	8.19	38.96	3.34	37.67	0.26	---	---
Methanol	32.6	38.04	16.68	36.87	13.09	34.93	5.30	---	---
Ethanol	24.3	26.97	10.69	27.45	12.75	---	---	---	---

V. RESULT

Thus the experimental values of dielectric permittivity for water, ε_{water} = 79.33, for dimethyle sulfoxide, $\varepsilon_{dimethyle\ sulfoxide}$ = 46.43, for ethylene glycol, $\varepsilon_{ethylene\ glycol}$=37.67, for methanol, $\varepsilon_{methanol}$ =34.93 and for ethanol, $\varepsilon_{ethanol}$ =26.97 are obtained by studying the amplitude verses frequency graph of each sample and by substituting the observed values of resonant frequencies [70.2MHz (n=2) of water, 214.0MHz (n=4) of dimethyle sulfoxide, 237.6MHz (n=4) of ethylene glycol, 247.4MHz (n=4) of methanol and 120.1MHz (n=2) of ethanol] into equation (1).Thus it is observed that the experimentally calculated values of dielectric permittivity of mentioned organic solvents are nearly equivalent to their standard values given in table II.

VI. CONCLUSION

Concentric positioned resonating chamber works well with fluid samples such as distilled water, dimethyle sulfoxide, ethylene glycol, methanol and ethanol as dielectrics. To detect the purity of the fluid samples, the simplest method is the measurement of dielectric parameters of the fluids. In water purification plant due to the requirement of high purity water, such an in-line testing mechanism is beneficial.

VIII. ACKNOWLEDGMENT

Completion of this work is a task which would have not accomplished without cooperation and help from my guide. At the outset, I wish to express my deep sense of gratitude to my guide. I am very much thankful to all my faculty members whose presence always inspires me to do better. At last I also thank my parents. I am also thankful to my friends who have helped me in completion of the report.

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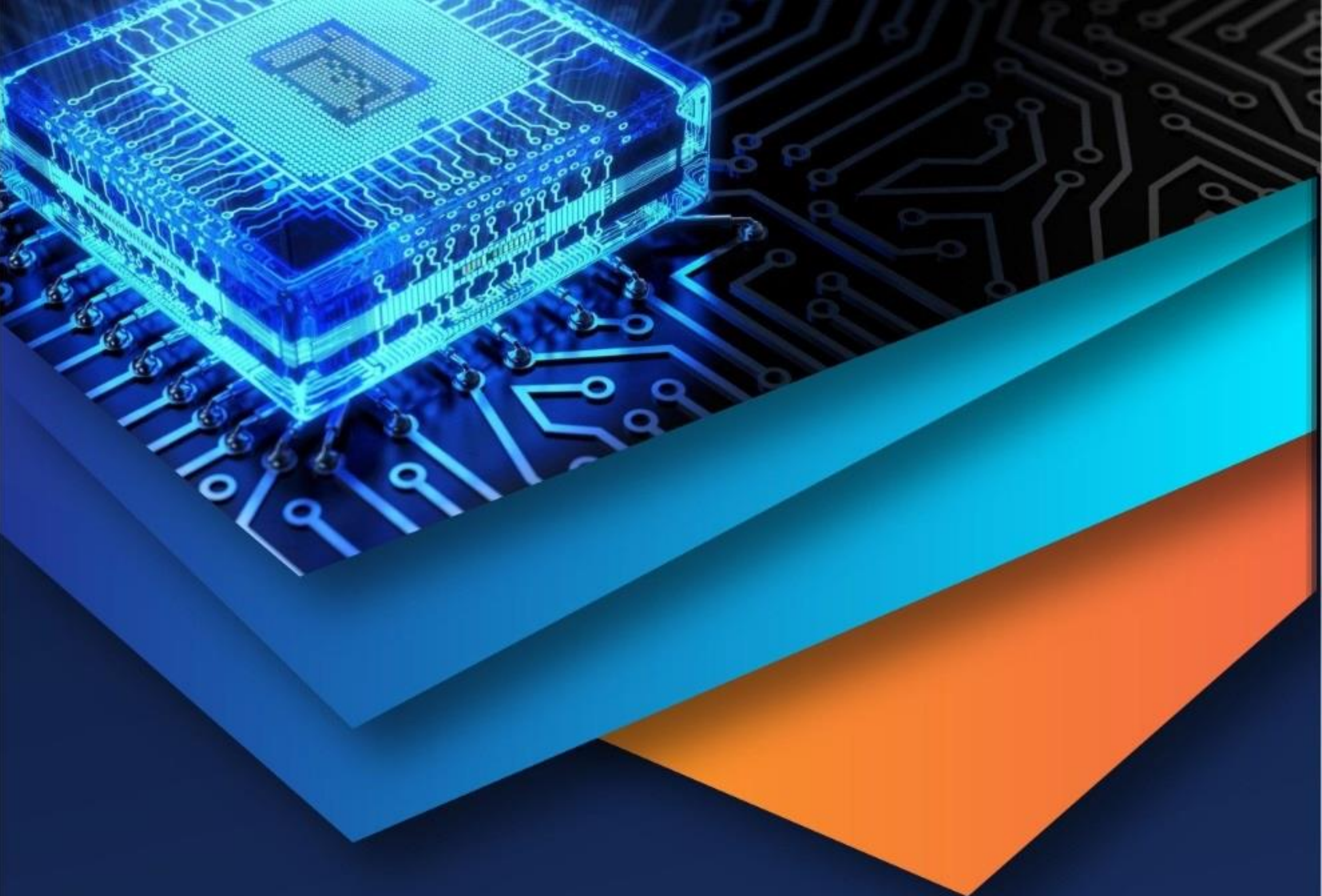

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