Frequency Dependence Dielectric Properties of Caffeine - Chloroform Solution using Time Domain Reflectometry (TDR)

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Abstract: ***Using time domain Reflectometry, dielectric permittivity* (ε') *and dielectric loss* (ε'') *for caffeine - chloroform solution at 25°C over frequency range*10 MHz to 30 GHz *have been measured. Observations are taken for different molar concentration of Caffeine - Chloroform (0M to 0.5M) at* 25°C. *The effect of frequency and molar concentration on dielectric permittivity and dielectric loss has been studied.***

Keywords: Dielectric permittivity, Dielectric Loss, Caffeine, TDR.

1. Introduction

Caffeine $C_8H_{10}N_4O_2$ is natural alkaloid which found in coffee, Tea, Cola etc. In 1819 Friedlieb Ferdinand Rung isolated caffeine from coffee. In 1827 Scientist Oudry discovered caffeine in Tea [1]. Caffeine is extracted with chloroform. It is an organic molecule. It is Purine type Alkaloid [2] caffeine is nitrogenous compound, the molecular structure is as shown fig.1.

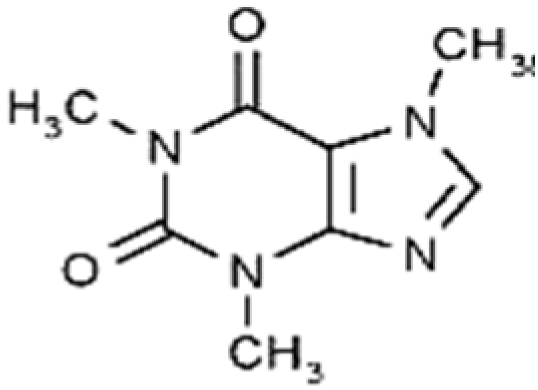

Figure 1: Molecular structure

Caffeine is used for nerve and heart stimulant as a medicine [3]. Its Molecular weight is 194.19 gm/mole. Analytical and some physical properties of caffeine were studied. [4]

The present paper reports the frequency dependent dielectric permittivity (ε') and dielectric loss (ε'') study of Caffeine – chloroform solution for different molar fraction of caffeine at temperature 25° C over frequency range 10 MHz to 30 GHz using time domain Reflectometry (TDR).

2. Experimental

2.1 Material

Caffeine was purchased from OTTO chemie India. Chloroform was and used as a solvent. Considering Molecular mass of Caffeine and its solubility in chloroform, the solutions 0M, 0.1M, 0.2M, 0.3M, 0.4M & 0.5M were p prepared. To avoid moisture from air, solutions were kept in tightly packed flask.

2.2 Experimental Setup and Procedure

H. Fellner-Feldega [5] developed TDR for measurement of Dielectric Permittivity (ε') and Dielectric loss (ε''). The Basic TDR consists of sampling oscilloscope and TDR module. TDR Module 80E08 with step generator and Tektromics Oscilloscope DSA8200 was used [6,7]. The setup is as shown in Fig 2

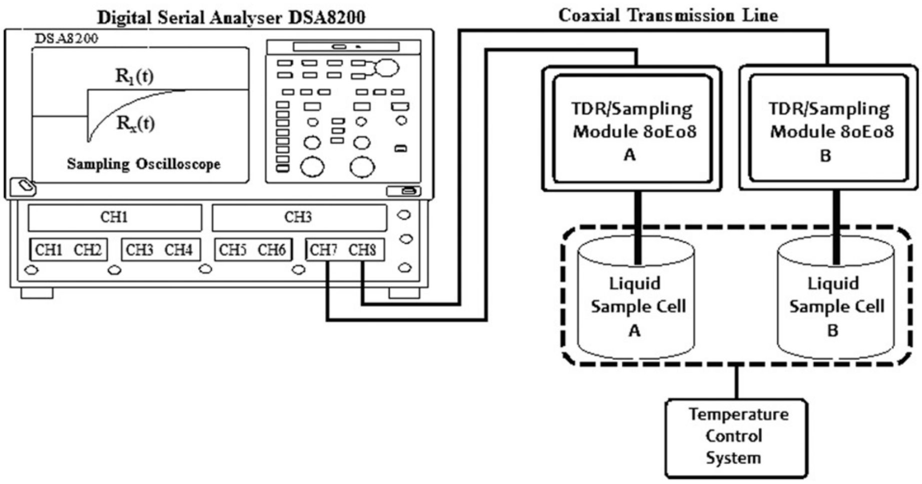

Figure 2: Experimental setup of TDR

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For different molar solutions, Reflected pulse without sample $R_1(t)$ and with sample $R_x(t)$ were recorded in time window of 5ns and digitized in 2000 points, over frequency range of 10 MHz to 30 GHz at 25° C. temperature is as shown in fig.3

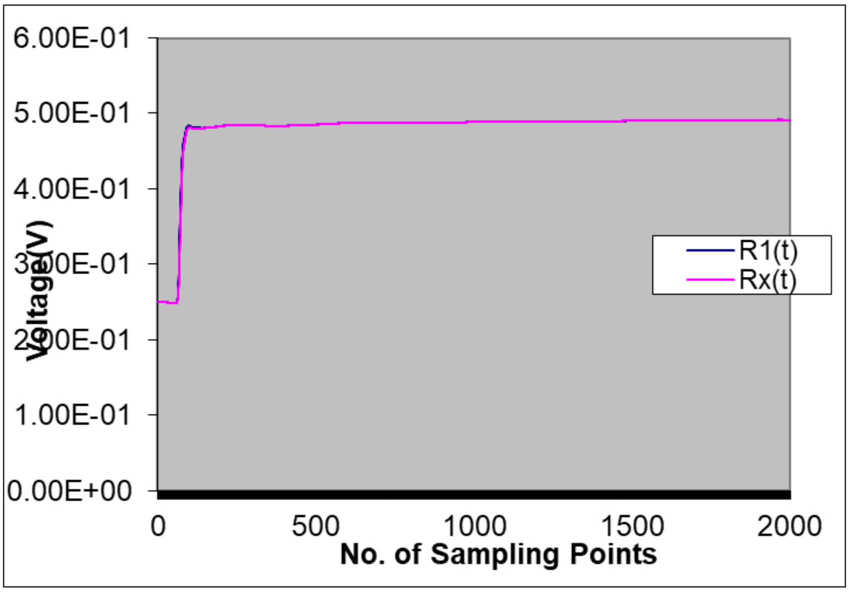

Figure 3: Reflected pulses without R1(t) and with sample Rx(t) for 0.5M Caffeine - Chloroform Solution at 25° C

3. Result and Discussion

$$p(t) = [R1(t)-Rx(t)] \quad (1)$$

Using Computer Software the reflected pulse without sample $R_1(t)$ and with sample $R_x(t)$ were subtracted as The Fourier transform of $p(t)$ and q(t) was obtained by a summation method and Samulon method [8,9]

Sample pulse of [R1(t)-Rx(t)] for Caffeine chloroform solution (0.5M) at 25° C as shown in fig.4

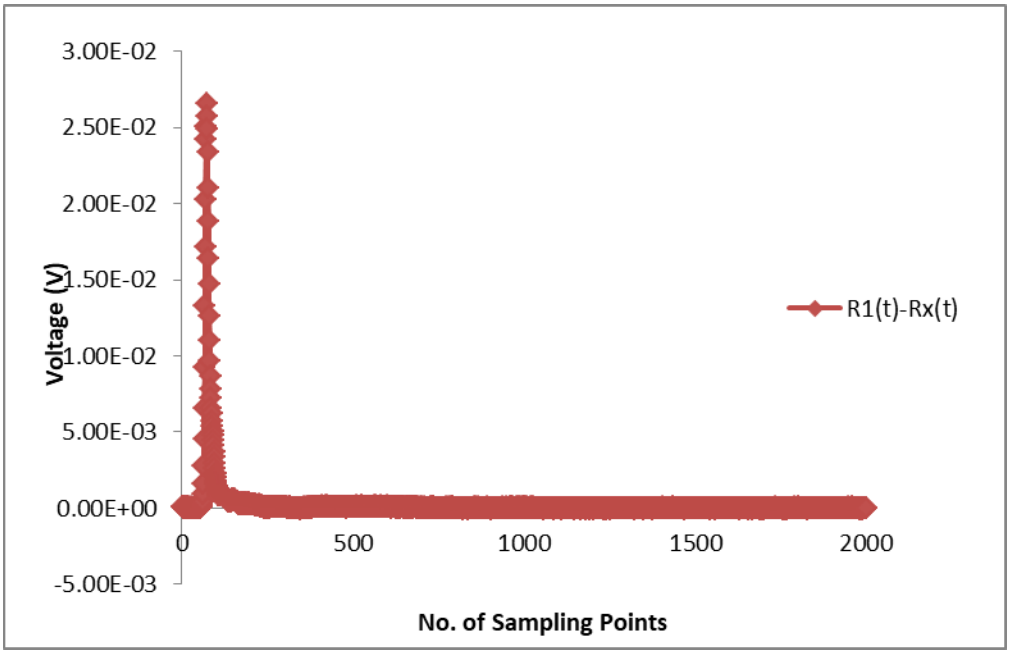

Figure 4: Sample pulse of R1(t) - Rx(t) for Caffeine - Chloroform 0.5M solution at 25° C.

These pulses are added as

$$q(t) = [R1(t)+Rx(t)] \quad (2)$$

Sample pulse is as shown in fig.5

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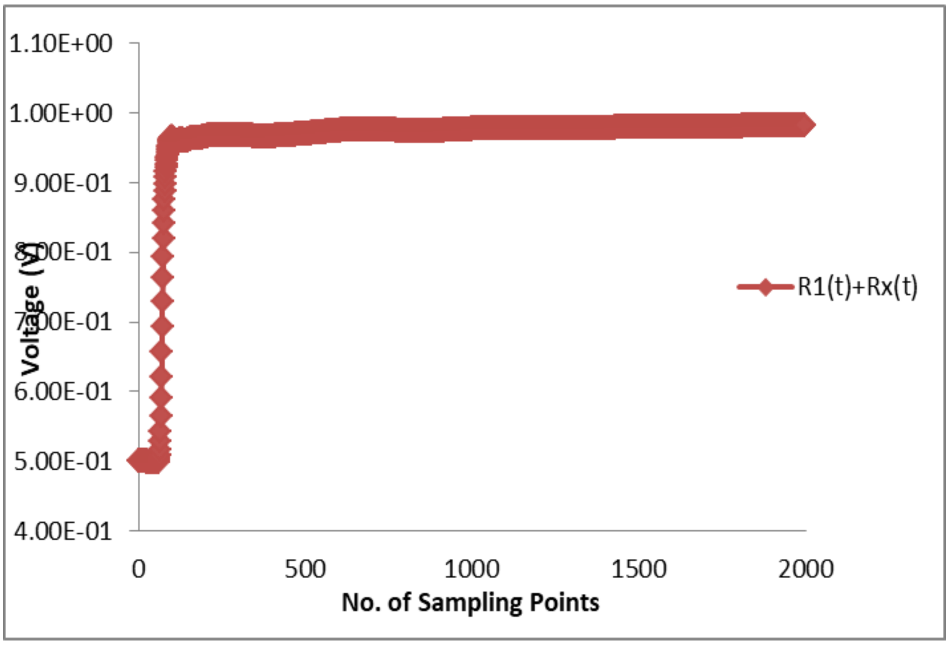

Figure 5: Sample pulse of R1(t) + Rx(t) for 0.5M Caffeine - Chloroform solution at 25° C

Using Fourier Transformation Considering summation and Samulon method frequency domain data is obtained.

$$p(\omega) = T \sum_{n=0}^{N} \exp(-i\omega nT) p(nT) \quad (3)$$

$$q(\omega) = \frac{T}{1-\exp(-j\omega T)} \left[\sum_{n=0}^{n} (q(nT) - q(n-1)T) \exp(-j\omega nT)\right] \quad (4)$$

p(ω) and q(ω) are Fourier Transform of $p(t)$ and q(t) respectively. The frequency dependent complex permittivity ε*(ω) are determined as [10] and the reflection coefficient spectra ρ*(ω) were determined as

$$\rho * (\omega) = \frac{c}{j\omega d} \frac{p(\omega)}{q(\omega)} \quad (5)$$

The dielectric permittivity (ε') and dielectric loss (ε'') over frequency range 10MHz to 30GHz is as given in table-1

Table 1: Dielectric permittivity (ε') and dielectric loss (ε'') for Caffeine Chloroform solution with frequency

Concentration in Molar → Frequency in GHz ↓	0 M		0.5M	
	ε'	ε''	ε'	ε''
0.01	4.816346645	1.11E-03	5.766239166	8.82E-03
0.1	4.816271305	1.40E-02	5.759236813	0.110216618
1	4.811950684	0.112161718	5.432582378	0.714697421
2	4.799263477	0.227851674	4.968847275	0.915933847
3	4.778364658	0.349063963	4.730070114	0.971521914
4	4.749578953	0.474929243	4.54545784	1.021184325
5	4.713326454	0.602045953	4.424681664	1.045689344
6	4.670177937	0.725521326	4.337397575	1.08714366
7	4.620974064	0.84054482	4.260970116	1.133666873
8	4.566953182	0.94393146	4.187973976	1.17810607
9	4.509798527	1.035194874	4.118746758	1.23285377
10	4.451335907	1.116777062	4.015388966	1.274348378
11	4.392718315	1.193102479	3.94721055	1.276473522
12	4.333521843	1.268375278	3.900380611	1.327337146
13	4.271864891	1.343938351	3.822178841	1.377495766
14	4.206078529	1.417197824	3.750059366	1.422768593
15	4.136388302	1.483412623	3.676542282	1.452103496
16	4.0648489	1.538911462	3.627732038	1.480618954
17	3.993919611	1.583141565	3.570902348	1.513334155
18	3.92539525	1.618728757	3.514962196	1.534760356
19	3.860269547	1.650260687	3.454401493	1.544552088
20	3.798980474	1.682603836	3.41451478	1.552726507
21	3.741509914	1.719214439	3.356761456	1.588901758
22	3.687333822	1.760818362	3.279343843	1.598113537
23	3.635571718	1.804967999	3.237717867	1.592756271
24	3.585348845	1.846929789	3.220028877	1.634607315
25	3.535883665	1.881708741	3.116971254	1.675318837
26	3.486034632	1.906181216	3.066079855	1.585195661
27	3.433917761	1.92011559	3.103346109	1.58926177

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28	3.377412558	1.925768495	3.026044607	1.595970869
29	3.315633297	1.926692247	2.958724022	1.573367119
30	3.254791498	1.926572561	2.793495893	1.487125397

The complex permittivity spectra with respective frequency of caffeine chloroform solution at 25° C is as shown in fig.6

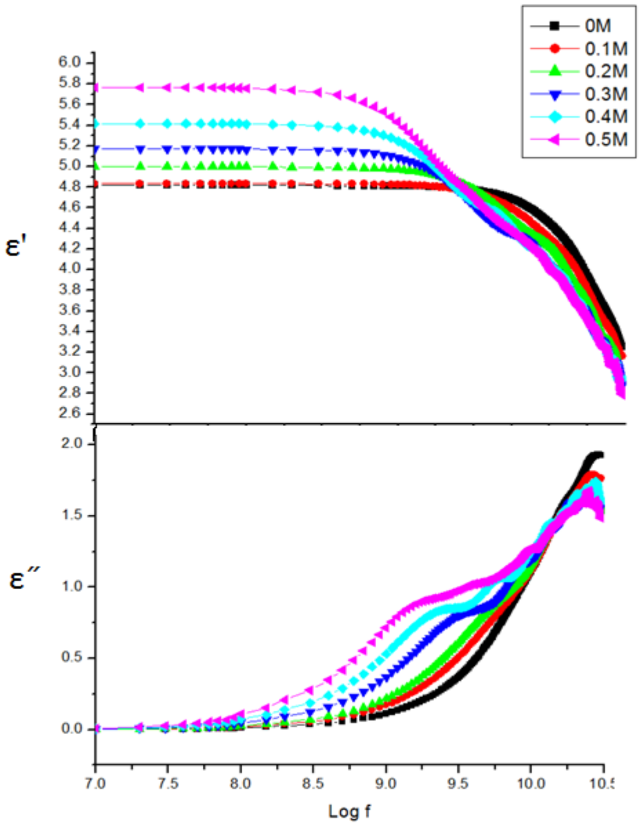

Figure 6: Complex permittivity spectra for Caffeine - Chloroform solution for various concentrations at 25^{0}C

4. Conclusion

With increase in concentration dielectric permittivity (ε') increase where as it decreases with frequency. Dielectric loss (ε'') increases with frequency and concentration.

5. Acknowledgement

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References

[1] Bennett A. Weinberg , Bonnie K. Bealer, ' The world of Caffeine' Rotledge Pub. , Newyork & London.
[2] K.W. Bentley, The chemistry of natural products: The alkaloids Vol. 1. P-162 Interscience Publishers a division of John wiley sons, Inc, Newyork, London, Sydney.
[3] O. P. Agrawal , 'Organic Chemistry Natural Products Vol. I' Krishna Prakashan Meerut
[4] Franscis Agyemang – Yeboah, Sulvester raw oppong, reasearch sign post – 2013 27-37 ISBN 978-81-308-0521-4
[5] H. Fellmer – Feldegg, J. Phys. Chem. 73, 616 (1969).
[6] B. Gestblom and B. Jonsson, J. Phys. E: Sci. Instrum. 13, 1067(1980).
[7] B. Gestblom, J. Phys. E: Sci. Instrum. 15, 87 (1982).
[8] H. A. Samulon, "Spectrum Analysis of transient response curves" Proc. IRE. 39, 175 (1951).
[9] C. E. Shannon, "Communication in the Presence of Noise", Proc. IRE. 37, 10 (1949).
[10] R.H. Cole, J.G. Berberian, S. Mashimo, G. Chryssikos, A. Burns and E. Tombari, J. Appl. Phys. 66(2), 793, (1989).

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