

Evaluation of Dielectric Properties of Some Polar Liquids Through Microstrip Terminated In Liquid Systems Using TDR Technique

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Abstract- Time Domain Reflectometry is extensively used to study dielectric relaxation properties over a broad frequency range in 0.01-20 GHz region. In this paper we have attempted a different approach to evaluate the dielectric relaxation parameters for some polar liquids. The static permittivity (ϵ_0), and relaxation time (τ) for chlorobenzene, dichloroethane, dichloromethane, Ethanol, Methanol, Propanol, de-ionized Water and Formamide can be evaluated through time domain reflectometry (TDR) technique at room ambience. In this method a microstrip of 50 ohms characteristic impedance fabricated on FR-4 glass epoxy type material is suitably terminated in the experimental liquid and its reflected response is observed on the sampling oscilloscope, in the TDR unit. The air and liquid responses are used to compute the complex reflection coefficient (ρ^*), for various embedded lengths (d) in the range 0-10 mm. The static permittivity (ϵ_0), and relaxation time (τ) for sample liquid can be estimated from the raw spectra (ρ^*) without applying any corrections. It is observed that there are periodic and systematic variations in raw spectra (ρ^*) in the frequency domain. The periodicity in (ρ^*) is of the order of ~ 1 GHz, which may be attributed to the resonant properties of the microstripline. The connector and co-axial cable reflections are superimposed on true liquid responses. The relaxation parameters like static permittivity (ϵ_0), and relaxation time (τ) are estimated under low frequency approximations, which match fairly well with the literature values.

Keywords- Polar liquids, Microstrip, TDR, Permittivity, Relaxation Time.

I. INTRODUCTION

The pico-second time domain reflectometry (TDR), is extensively used to study the dielectric relaxation properties like dielectric static permittivity (ϵ_0) and relaxation time (τ) of polar liquids typically in the frequency range from 0.01-20 GHz¹. A.E. Jadhav and S. C. Mehrotra² reported the work on Simulation of dielectric spectra under quarter-wave resonance conditions and applied corrections using Newton-Raphson

method. In the conventional TDR system, the sample under investigation is put in the SMA cell which is connected to 50 ohms characteristic impedance air-line transmission system. For the given SMA cell, the length of a central conductor is fixed in the liquid sample and it is difficult to change without disturbing the whole transmission line system. To change the length of the central conductor in a given liquid without disconnecting the transmission line, a microstrip as a complete electrical cell of 50 ohms characteristic impedance can be terminated in the desired liquid, where the length of microstrip can be easily manipulated by the travelling microscope³. In the present paper, the attempt is made to estimate the dielectric relaxation parameters using microstrip-liquid embedded system by performing routine data analysis.

II. MATERIALS

The liquids under study considered are Chlorobenzene (CBZ), dichloroethane (DCE), dichloromethane (DCM), Ethanol, Methanol, Propanol, de-ionized Water and Formamide of AR grade, E. Merck, India without further purification for the wide range of electrical permittivity and relaxation time. The microstrip of 50 ohms characteristic impedance is fabricated on 1.56 mm thick FR-4 glass-epoxy material of length 74 mm by usual photo-chemical etching method.

III. EXPERIMENTAL

The experimental set-up for the variation of physical terminal-length for microstrip and sample liquid system without disconnecting the transmission cable is shown in Fig.1.

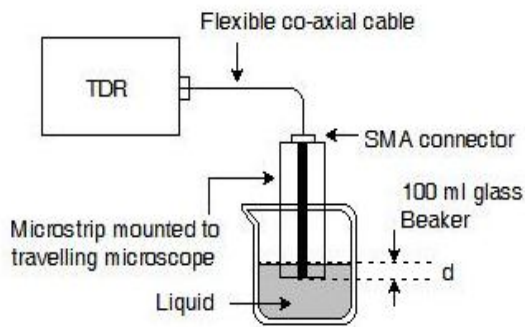


Fig.1: Schematic arrangement for microstrip-liquid embedded system

The Hewlett Packard HP 54750A sampling oscilloscope with HP 54754A TDR plug-in-module has been used. A fast rising step voltage pulse of height 200 mV generated by tunnel diode about ~40 ps rise time is propagated through a semi-rigid co-axial transmission line of 50 ohms characteristic impedance is connected to the matching microstrip, keeping reflections from the connector minimum. The rise time of the reflected pulse from microstrip and co-axial cable system is about ~100 ps in air i.e. under open load conditions. The change in reflected pulse waveform in air and microstrip-liquid system contains all the necessary electrical information about the sample liquid. The reflected pulses in microstrip-air $R_1(t)$ and microstrip-liquid sample $R_x(t)$ for successive terminal-lengths (0-10 mm) are observed in the time window of 5ns and digitized into 1024 points with 64 average-count in the memory of sampling oscilloscope then transferred to PC through 1.44 MB floppy diskette drive. All the observations are carried out at ambient temperature 25°C.

IV. DATA ANALYSIS

The time dependent data for air and liquid responses are processed to obtain a complex reflection coefficient spectra $\rho^*(\omega)$ over the frequency range from 0.01-15 GHz. For closed waveform in time domain $P(t)$, the summation method for Fourier transform is used while for open curve $Q(t)$, the Samulon's^{4,5} method is used to get the corresponding data in the frequency domain. The complex reflection coefficient $\rho^*(\omega)$, may be given as⁶⁻⁹

$$\rho^*(\omega) = \frac{c}{j\omega d} \left[\frac{p(\omega)}{q(\omega)} \right] \tag{1}$$

Where $p(\omega)$ and $q(\omega)$ are the Fourier transforms of $[R_1(t) - R_x(t)]$ and $[R_1(t) + R_x(t)]$ respectively, c is the velocity of light, ω is the radian frequency and d is the effective electrical terminal-length and $j = \sqrt{-1}$. For microstrip, the

velocity of step-pulse is reduced from c to $c/\sqrt{\epsilon_{eff}}$ where $\epsilon_{eff} = 3.6$ at ~1 GHz, is the effective permittivity of microstrip-substrate material. The complex reflection coefficient spectra $\rho^*(\omega)$ obtained over the frequency range from 0.01-15 GHz are known as raw spectra. The typical set of CBZ raw spectra for 2.5, 5, 7, 10 mm physical terminal-lengths are shown in Figures 2 and 3. Further the non-linear least squares fit method is used for the estimation of static values of permittivity (ϵ_0) and relaxation time (τ) under the low frequency approximation limit.

V. RESULTS AND DISCUSSIONS

The typical complex reflection coefficient spectra (Figs.2 and 3) for chlorobenzene shows the periodical variations in $\rho^*(\omega)$ in the frequency range 0.01-15 GHz.

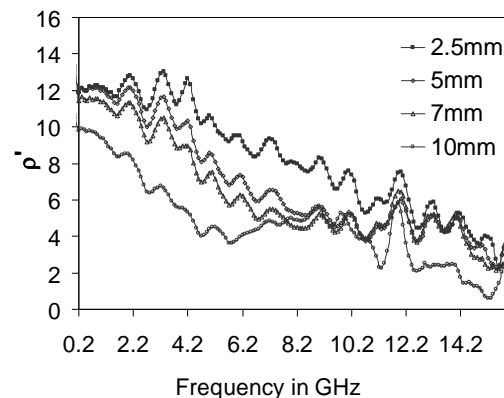


Fig. 2: Typical raw spectra for Chlorobenzene (ρ' -real part).

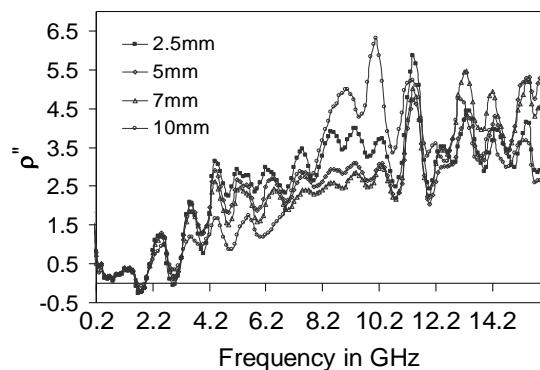


Fig. 3: Typical raw spectra for Chlorobenzene (ρ'' -imaginary part).

The periodicity in (ρ^*) values in the frequency range 0.2-15 GHz is observed to be of the order of ~1 GHz. By considering the microstrip as half wave ($\lambda/2$) resonator¹⁰,

Length of microstrip (L) = $n \lambda/2$ for order of resonance (n) = 1, 2, 3, ...

$$L = \frac{n\lambda_n}{2} = \frac{c}{2\sqrt{\epsilon_{eff}} f_n} \quad (2)$$

for FR-4 material glass epoxy microstrip $\epsilon_{eff} = 3.6$, at ~1 GHz and $L = 74$ mm, $n = 1$, $c = 3 \cdot 10^{11}$ mm-sec⁻¹

$$f_n = \frac{c}{\sqrt{\epsilon_{eff}} 2L} = 1.08 \text{ GHz} \quad (3)$$

this is nearly same in frequency-periodicity as expected.

The noisy appearance observed in the raw spectra (Figs.2 and 3) may be due to the superposing of the reflections generated at discontinuities from cable-connector-microstrip system. From the estimated values of static permittivity (ϵ_0) and relaxation time (τ) from raw spectra (Figs.4 and 5) it is noticed that (ϵ_0) values shows fairly constant values and (τ) values rises slightly with increase in physical terminal-lengths.

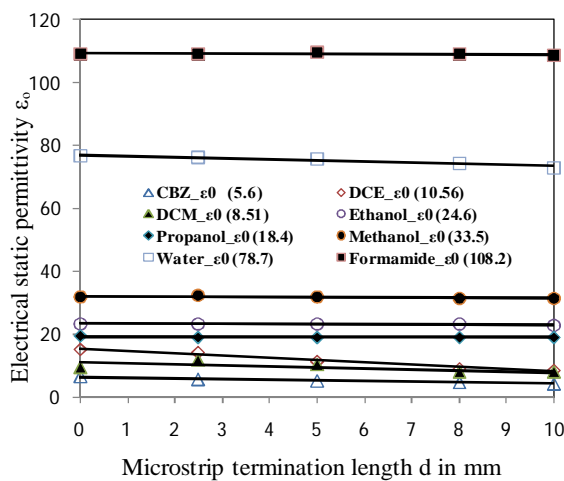


Fig. 4: Estimated permittivity values of various liquids

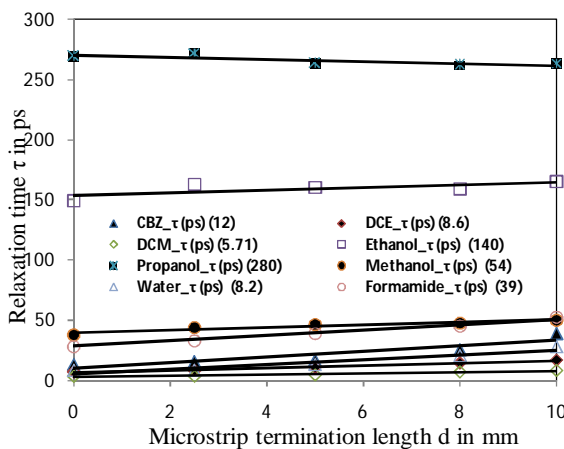


Fig. 5: Estimated relaxation time values of various liquids

This terminal-length dependence in their estimated values is not expected. This may be attributed to the inaccurate values for effective terminal-lengths from earlier work used¹⁰. Further the raw spectra can be corrected by suitable bilinear calibration and Newton-Raphson iterative methods or similar methods using root function.

VI. CONCLUSIONS

From the above discussions, the present method is potentially useful for the estimation of permittivity and relaxation time in the broad range. It is possible to study the dielectric response of polar liquids with the variation in terminal-lengths using a microstrip-liquid embedded system without disconnecting the co-axial cable, which is otherwise difficult to manipulate the central conductor pin length in the SMA cell. The unwanted microstrip resonant signals need corrections.

REFERENCES

- [1] John G. Berberian and Edward King, "An overview of time domain spectroscopy," J. Non-Crystalline solids, 305, 10-18, 2002.
- [2] Ashok E. Jadhav and S.C. Mehrotra, "Simulation of dielectric spectra under quarter wave resonance conditions", J. Mol. Liqs. 108/1-3, 61-67 2003.
- [3] B.R. Sharma and S.C. Mehrotra, "Pico-second time domain reflectometry response of microstripline embedded in various liquids". IEEE proc., 14th Int. Conf. on dielectric liquids (ICDL), Graz (Austria), 329-332, July 2002.
- [4] C. E. Shannon, "Communication in the presence of noise", Proc. IRE, 37, 10, 1949.
- [5] H. A. Samulan, "Spectrum analysis of transient response curves", Proc. Ire, 39,175, 1951.
- [6] V.P. Pawar and S.C. Mehrotra, "Dielectric Relaxation study of Chlorobenzene Dimethylformamide mixtures using time domain reflectometry", J.Mol.Liq.95, 63-74, 2002.
- [7] V. P. Pawar, G. S. Raju and S. C. Mehrotra, "Influence of molecules with chloro group on the associative liquid methanol: A dielectric relaxation approach", Pramana-j. Physics, 59(4), 693-699, 2002.
- [8] V. P. Pawar and S. C. Mehrotra, "Dielectric relaxation study of dimethylenechloride with ethanol using time domain reflectometry", J. mol. Liqs., 108/1-3, 95-105, 2003.
- [9] V.P. Pawar, G. S. Raju S. C. Mehrotra, "Dielectric Relaxation Study of Chloro group of Molecules with Associative Liquid Ethanol", Microwaves and Optoelectronics, Anamaya Publishers, New Delhi, 176-

180, 2004.

- [10] B. R. Sharma and S. C. Mehrotra, “Study of Microstrip-Liquid Embedded Systems through TDR: Application of Bilinear Calibration”, *Frontiers of Microwaves and Optoelectronics*, Proc. ICMO-2007, Anamaya Publishers, New Delhi, 328-333, 2007.