# Study of some Electrical Parameters of Food Preservative Acetic Acid Using Time Domain Reflectometry (TDR) Technique

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***ABSTRACT*--Food additives are used for various purposes in processed food. Food preservatives are substances that are added to food items in order to keep the food safe, without spoiling, for longer. Natural as well as many chemical preservatives are used in foodstuffs. Excess use of these preservatives is hazardous to our body so it becomes essential to study the characteristics of the preservatives. The present work deals with the study of Dielectric Constant and Reflection Coefficient of Acetic Acid with the help of Time Domain Reflectometry (TDR) technique. For the study we have developed a low frequency Time Domain Reflectometry (TDR). Eleven different concentrations of Acetic Acid are prepared with freshly collected distilled water. These solutions are kept at four (25$^o$C, 35$^o$C, 45$^o$C and 55$^o$C) different temperatures. Remarkable changes were observed in the Dielectric Constant and in Reflection Coefficient of the preservative Acetic Acid with the concentration as well as temperature. Details are discussed in the text.**

***KEY WORDS--Acetic Acid, Dielectric Constant, Reflection Coefficient, Temperature, Time Domain Reflectometry*.**

## I. INTRODUCTION

Food safety is a major focus of food microbiology. The behavior of microbial populations in foods (growth, survival, or death) spoils the food. Food preservatives are substances that are added to food items in order to keep the food safe, without spoiling, for longer.

Vinegar is frequently used as a natural preservative in processed meat and poultry items. Buffered vinegar may solve taste issues, and antimicrobial blends are featuring vinegar (1). Vinegar is the dilute Acetic acid. Vinegar contents less than 4% acetic acid by volume, making acetic acid the main component of vinegar apart from water.

Acetic acid is a colorless liquid organic compound with the chemical formula $CH_3COOH$ (also written as $CH_3CO_2H$ or $C_2H_4O_2$). Acetic acid has a distinctive sour taste and pungent smell. In addition to household vinegar, concentrated acetic acid is corrosive and can attack the skin and eyes.

The Time Domain Reflectometry TDR technique is widely used technique in impedance spectroscopy to study the various electrical parameters like electrical impedance or conductivity, permittivity of medium and relaxation time of the molecular dipoles in the form of relaxation frequency. The TDR technique is used for variety of systems i.e. conducting, non-conducting, liquids, solids, powder, various biological systems, agricultural products and soils for measurement of various electrical properties.

Electrical Impedance Spectroscopy is a leading technique in various industries (2, 3), Electrical/Electrochemical Impedance Spectroscopy is used for rapid detection of food borne pathogenic bacteria. (4). Researchers used electrode less impedance technique to study the food strategy (5). In Food industries Impedance Spectroscopy is used to detect various Pathogens as well as to check the quality of food material (6, 7). It is a fast and effective tool for microbial detection (8, 9). Impedance technique is also used to study the strategy of food preservative (10.). A novel impedance biosensor for bacterial cell detection was constructed (11).The Impedance Spectroscopy used to detect spoilage and quality of bulk food (12, 13, 14, 15). The Electrical Impedance Spectroscopy used in diary industry to monitor quality of dairy products (16, 17, 18).

## II. EXPERIMENTAL DETAILS

A low frequency TDR unit of the range 200MHz and 5ns rise time was developed in the laboratory. The experimental setup was consist of a oscilloscope DS1000 (19), TDR module, a transmission line and sample cell. The co-axial line transmission line with characteristics impedance of 50 ohm was used for the study. Different types of probes were designed and tested for the accurate measurement. The TDR response of these electrodes is tested with distilled water and standard KCL solution. A stripe type probe of 5.5 cm was used for study of electrical parameters of the sample. The TDR unit is used for measurement after warming up for at least 30 minutes.

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Eleven different volume percent concentrations (0% - 100%) of preservative Acetic Acid are prepared with freshly collected distilled water. These solutions are kept in water bath at four different temperatures which was controlled and monitored by computer. The probe connected with the co-axial transmission wire was immersed in the solution. A fast rising pulse was gets reflected back the solution. The nature of the pulse depends on the properties of the solution. This pulse is observed and stored in the Digital Storage Oscilloscope i.e. DSO. This data was then collected in an external storage and further calculations were done. Each time the probe was thoroughly cleaned with acetone and dried.

## III. RESULTS AND DISCUSSION

Collected data from the TDR unit was in the form of voltage with respect to time. This time domain data was converted in the form of frequency domain data using Fourier transform. Dielectric Constant was calculated with the help of Fourier transmission.

### A. *Dielectric Constant:*

Table: 1 shows the values Dielectric Constant of Acetic Acid solution of different volume percentage at four different temperatures. According to the collected information and calculated values of dielectric constant the graph is plotted (fig.1). Graph shows the changes in nature of the studied preservative Acetic Acid according to the concentration and temperature.

| Vol % | Dielectric Constant | | | |
|---|---|---|---|---|
| | 25 °C | 35 °C | 45 °C | 55 °C |
| 0 | 79.46 | 68.06 | 66.51 | 53.32 |
| 10 | 80.46 | 86.36 | 91.73 | 88.13 |
| 20 | 76.11 | 89.92 | 76.11 | 81.16 |
| 30 | 71.23 | 66.51 | 71.23 | 77.77 |
| 40 | 69.64 | 64.97 | 66.51 | 72.84 |
| 50 | 59.00 | 60.46 | 60.46 | 64.97 |
| 60 | 54.71 | 46.62 | 49.24 | 53.32 |
| 70 | 40.37 | 39.17 | 39.17 | 37.99 |
| 80 | 17.41 | 22.48 | 21.59 | 24.32 |
| 90 | 12.90 | 11.65 | 8.64 | 7.05 |
| 100 | 6.80 | 6.08 | 3.97 | 2.60 |

**Table 1: Dielectric Constant of aqueous solution of Acetic Acid**

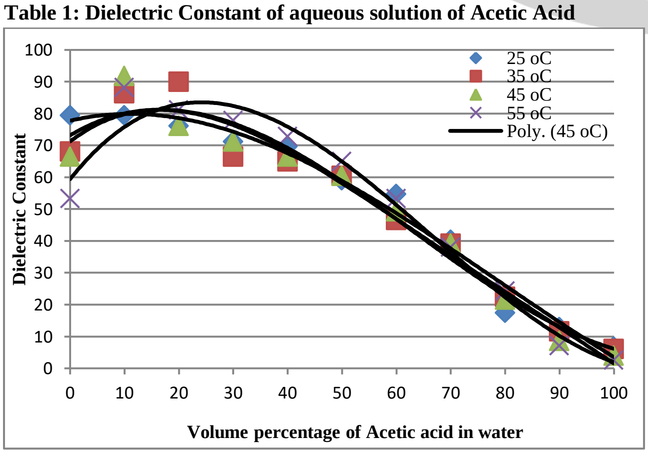


**Fig. 1: Variation of dielectric constant in aqueous solution of Acetic acid**

Initially Graph shows an increase in the Dielectric Constant in aqueous solution of Acetic Acid till the 20% volume was mixed with 80% freshly collected distilled water at all four temperature. The nature of the graph changes after further increase in the volume of Acetic Acid in water. There is decrease in the Dielectric Constant with increase in the concentration of Acetic Acid in water. For pure water and pure Acetic Acid the Dielectric Constant decreases as temperature of the solution increases. The change is observed in the nature for the binary mixture of the two liquids according to the temperature. Highest and lowest Dielectric Constant is calculated for the 10% Acetic Acid at 45 oC and pure i.e. 100% Acetic Acid at 55oC respectively.

### B. *Reflection Coefficient:*

The values of Real and imaginary part of Complex Reflection Coefficient of aqueous solution of Acetic Acid was plotted n the following graphs (fig.2–fig.9). Real part is denoted by ρ' and Imaginary part is denoted by ρ". Separate graphs are plotted to observe the variations in the solution according to the concentration and temperature.

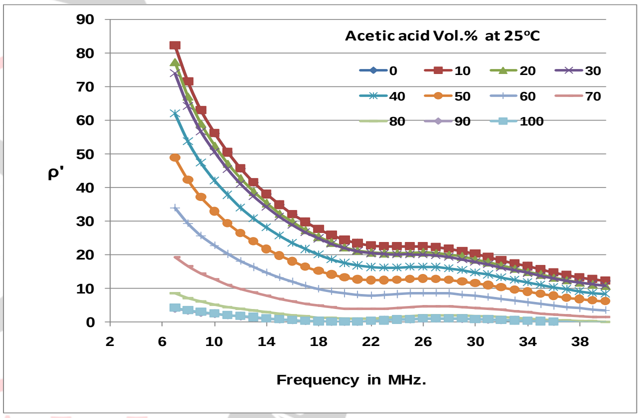


Fig 2 Variation of ρ'of Acetic Acid with Frequency at 25°C

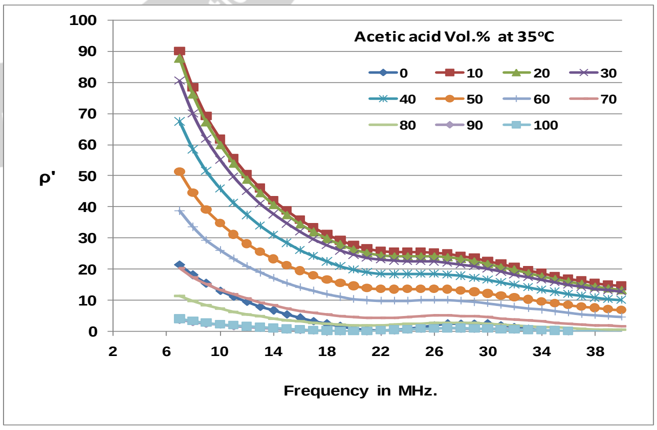


Fig 3 Variation of ρ'of Acetic Acid with Frequency at 35°C


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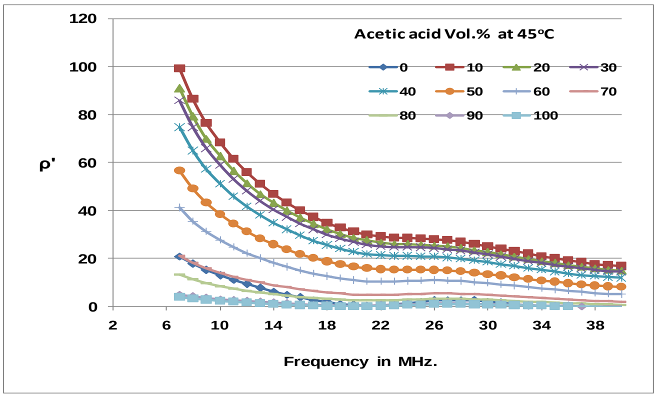


Fig 4 Variation of ρ'of Acetic Acid with Frequency at 45°C

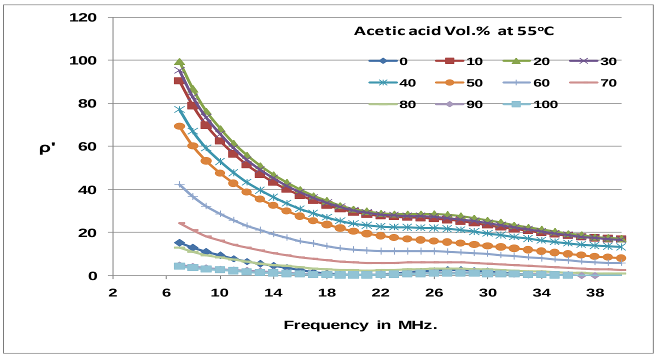


Fig 5 Variation of ρ'of Acetic Acid with Frequency at 55°C

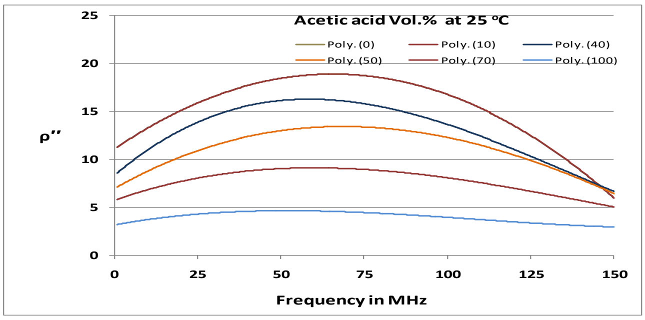


Fig 6 Variation of ρ''of Acetic Acid with Frequency at 25°C

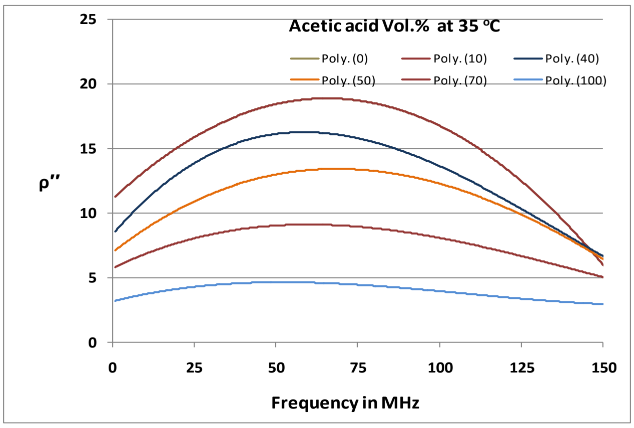


Fig 7 Variation of ρ''of Acetic Acid with Frequency at 35°C

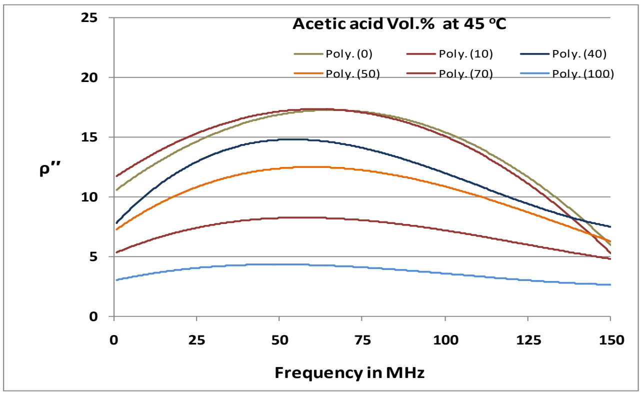


Fig 8 Variation of ρ''of Acetic Acid with Frequency at 45°C

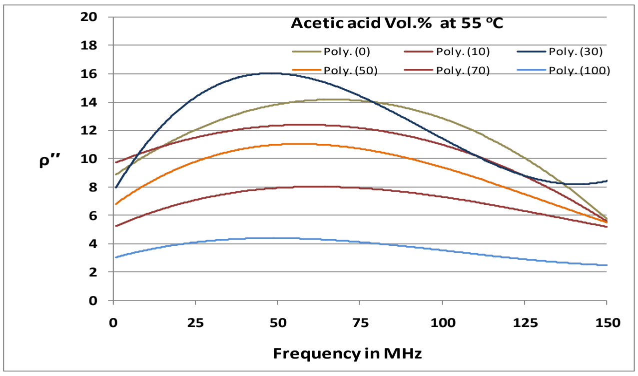


Fig 9 Variation of ρ''of Acetic Acid with Frequency at 55°C

at higher frequencies the real part of impedance of aqueous solution decreases. The variation of ρ' with frequency is different in aqueous solutions of different frequencies. The frequency response of the solutions is observed at lower frequencies in the range of 50 MHz.

The Imaginary part of the Complex Impedance gives the losses and absorption of energy in the medium. The response of aqueous solution of preservative is observed in lower frequency range of 150 MHz.

## IV. CONCLUSION

The developed TDR unit works successfully for the measurement of Dielectric Constant and Reflection Coefficient of aqueous solution of preservative Acetic Acid. Changes are observed with the change in volume percentage of Acetic Acid in Distilled Water as well as the change in temperature of the solution. Initially Dielectric Constant increases with increase in volume percentage of Acetic Acid then it goes deceasing. Real and Imaginary part of Reflection Coefficient of Acetic Acid shows the response at lower frequency.

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