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Research Article

Time Domain Reflectometry (TDR) based Technique for Detection of Blood Group

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Abstract: Time Domain Reflectometer (TDR) based techniques are known to be very useful for studying dielectric properties of liquids over a wide range of frequencies. Dielectric properties of liquids cover a vast area of interest for scientists from a variety of disciplines of science and technology including medical physics and bio sciences. Human Blood consist of complex biological molecule and exhibit different characteristics based on the constituents and their relative proportion. We present TDR technique for determination of human blood group. This method of determination of blood relies on dielectric properties of blood and makes use of the lag time introduced by blood sample in the reflected waveform. The approach works well and can be further refinements by designing different sample cells with impedance matching and improved waveform analysis techniques using sophisticated instrumentation for higher time resolution. The blood group of the sample is found from the reflected waveform from the TDR setup by measuring the lag time introduced. The system is tested for its reproducibility and accuracy by conducting series of experiments. The resulting waveforms are analyzed manually and using computer program, from graphs using the TDR data file. There is excellent agreement between blood group determination using this technique and the conventional pathological laboratory methods. The relation between the lag time and the blood group of the sample is presented and details discussed.

KEYWORDS: TDR, Microwave, dielectric properties, dielectric constant, Low Frequency TDR.

INTRODUCTION

The study on dielectric relaxation of liquids gives important information about molecular structure, molecular interaction between components of solution, dynamics and kinetics of the solution. Since, the molecular response is in microwave region, most of the measurements are carried out in microwave region to know the liquid properties. The dynamic-kinetic and kinetic properties of liquid are generally carried out in dilute solutions with non polar solvent using frequency domain technique. To study the dielectric properties of the solution of polar liquid in polar solvent the most reliable technique is Time Domain technique.

Measurement of dielectric properties of blood is known to reveal valuable information of interest to medical physicists and is used for diagnosis of diseases. The dielectric properties of diseased blood cells are different from those of healthy blood cells. Depending on the presence of sugar or glucose in the blood, the dielectric properties of blood changes[1.] This could be used to identify blood containing excess glucose from normal blood. Microwave techniques can be used to estimate blood sugar level[2]. Similarly it is observed that the blood samples from different blood group samples introduce different amount of lag time when a low frequency TDR pulse undergoes reflection from the blood sample. We have developed a Time Domain Reflectometer identical to that developed by Cole et.al. for the estimation of dielectric properties of blood samples. A Low Frequency TDR[3-6] is designed and is used for determination of the dielectric constant of whole blood and related parameters.

Different sample cells are designed and tested for the purpose of the dielectric properties of blood and it was observed that the cell with better impedance matching gives better results. The TDR signal are recorded stored for further processing. For converting time domain signals into frequency domain, the reflected pulse without sample [$R_1(t)$] and with sample [$R_x(t)$], are used and their sum and difference is calculated. Subtraction gives [$p(t)=R_1(t) - R_X(t)$] and addition gives [$q(t)=R_1(t) + R_x(t)$]. These time dependent p(t) and q(t) waveforms are converted in frequency domain using Fourier transforms. The frequency dependent data of p (ω) and q (ω) are used to compute reflection coefficient of the blood under study over the frequency range 10 MHz to 10 GHz using equation[7]

$$\rho^*(\omega)=[C\, j\, \omega\, d][p(\omega)/q(\omega)] \qquad (1)$$

Where C is velocity of light, ω is angular frequency, d is effective pin length and $j=\sqrt{-1}$.

This reflection coefficient $\rho^*(\omega)$ gives the frequency dependent complex permittivity spectra $\varepsilon^*(\omega)$ over the corresponding frequency range.

The Havriliak Negama equation [8] relates the static dielectric constant, average relaxation time, permittivity at infinite frequency, Cole-Cole and Davidson-Cole distribution parameters with complex permittivity spectra as

$$\varepsilon^*(\omega) =\varepsilon_\infty + (\varepsilon_o -\varepsilon_\infty)/[1+ (j\, \omega\, \tau)\, (1-\alpha)]\beta \qquad (2)$$

Where $\varepsilon^*(\omega)$ is complex permittivity, ε_o is static permittivity, ε_∞ is permittivity at infinite frequency, τ is relaxation time, α is Cole-Cole distribution parameter and β is Davidson-Cole distribution parameter.

Initial investigation using low frequency TDR techniques on blood samples give encouranging results and the estimation of blood sugar level using this technique was found to be excellent. It is observed that there is relationship between some properties of the reflected waveform and the important properties of blood samples including the blood group the sample belongs to.

Time domain dielectric spectroscopy has been used by others for various pathological tests[1, 9, 10.] Jean et.al[11]. and Gaur et.al[12].has reported the relationship between the blood sugar content and its dielectric properties.

This Time Domain Reflectometry (TDR) technique has been used in the present work to study few dielectric relaxation properties of blood which is a complex mixture of bimolecules. The analysis of reflected pulses is carried out from the point of view of lag time introduced and relationship between the lag time and the blood group presented.

EXPERIMENTAL

The experimental setup makes use of TDR based setup designed for study of blood samples using DS1000 oscilloscope with its standard plugins for TDR. The step pulse waveform used for the study was taken from the pulse generator and had a rise time of 5 ns and the amplitude of the pulse was 100 mV. The reflected waveform was monitored using a time window of 60 ns, recording 600 points corresponding to a resolution of 0.1 ns (100ps). The signal was connected to the sample cell (shown in Fig. 1.) with the help of a coaxial transmission line with characteristic impedance of 56 Ω and the coaxial cable had SMA connectors at the ends for matching of impedance on either sides. The design of sample cell is critical in the sense that impedance matching of the sample holder poses difficulties of estimating characteristic impedance[13]. The reflected pulse without sample [$R_1(t)$] and with sample [$R_x(t)$] are digitized with 1024 points per waveform and stored in oscilloscope memory after averaging over 64 times. These reflected pulses (data) are transferred to PC and saved in a file with appropriate name for further processing. Computer programs are developed for analyzing the data from reflected pulse.

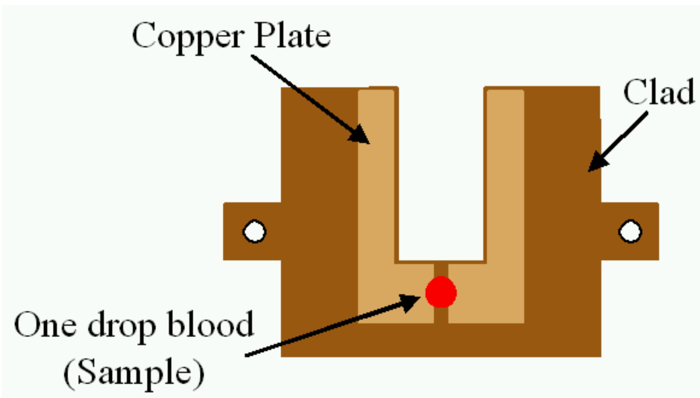

Fig. 1: Showing Sample Cell made from fibreglass epoxy copper clad sheet with the blood sample loaded.

The arrival time of the reflected pulse is found to be affected by the change in the dielectric properties of the blood sample which in turn depend on the blood group of the sample. Blood contains Plasma, RBC, WBC etc and water as major constituents and thus the dielectric properties are governed by the composition of these components.

We studied large number of blood samples from different blood groups with different values of blood sugar levels. The reflected waveforms were analyzed for peak values of voltage of the reflected pulse and the lag time introduced in the reflected pulse. It was observed that the blood group affects the lag time introduced and the value of peak voltage value is related to the blood sugar level. The blood groups estimated from TDR waveform are in close agreement with the actual values obtained in pathological laboratory using standard conventional methods.

The TDR waveform data from the experiments can be analyzed by plotting a graph to determine the blood group from the lag time of the first pulse. The blood group can be found from a single set of data of reflected waveform. Computer programmers are developed to read in the text files containing the TDR waveform data of the reflected pulse. This program then finds out the lag time at certain level and from this the blood group is found. Fig. 2. shows a screen shot of the computer program used for analyzing the TDR waveform. The software was developed in Visual Basic, this reads in the given file and finds the blood group along with the blood sugar level and displays the results and the plot of the waveform.

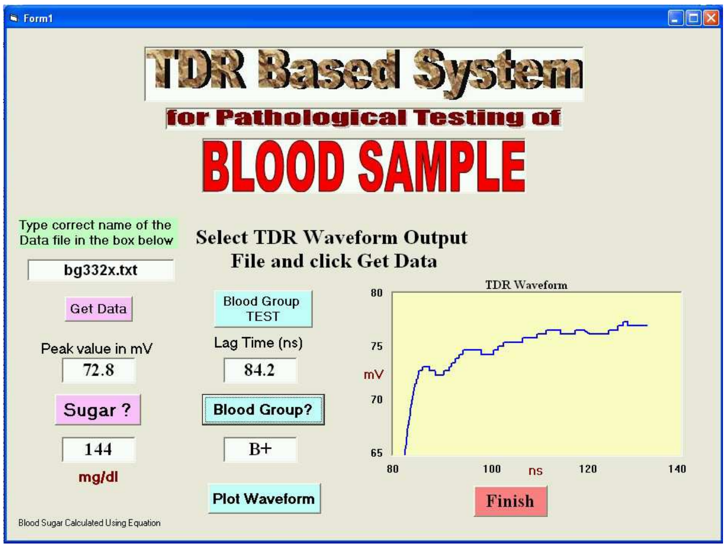

Fig. 2: Screenshot of the software developed and used for estimation of blood sample parameters like blood group and sugar level.

For the present study blood samples were collected from time to time as it was required that fresh samples are used. Therefore, the collected samples were used within six hours of collecting the sample. The samples collected were mixed with anticoagulant for storage till the experiment.

One drop of blood from the sample was used and placed in the sample cell after cleaning the sample cell using distilled water and tissue paper. The cell was then dried using hot air blower to remove any traces of water after washing and cleaning. The sample cell was connected to the experimental setup for recording the waveforms from TDR. Before every observation a waveform was recorded without blood in the sample cell as empty reading and the data was stored for further processing. With the help of a fresh syringe a drop of blood was carefully placed on the sample cell. With the sample in the sample cell, the waveform of TDR was recorded and the data was saved for further processing under appropriate file name to keep record of the observation for different samples. The same sample was re-analyzed by cleaning the cell and loading a fresh drop of blood from the sample using a fresh syringe. The purpose of taking two readings for each sample was to ensure the reproducibility in the readings and reduce experimental error.

RESULT AND DISCUSSION

Initial testing used normal blood samples with known blood groups. The experimental setup sends a fast voltage pulse of 100 mV with a rise time of 5 ns using a coaxial transmission line to the sample cell and the reflected waveform is saved in the form of a text file in the computer attached to the experimental setup. These TDR waveforms so recorded are used to plot the waveforms for further investigations or use in computer programs for finding out the parameters like peak voltage values and lag time.

During the process of calibration and standardization it was observed that several blood samples with same blood group but different values of blood sugar level show identical delay or lag time. This suggests that the parameter delay or lag time can serve as an indicative of blood group. However it was found that inspite of reasonable time resolution of 100 ps, a faster measuring setup will improve the predictability of the blood group from lag time.

Fig. 3. below shows a set of selected plots of TDR waveforms obtained from different blood samples having different blood sugar levels but the same blood group i.e. B–. The values of blood sugar levels for different curves are also shown in legends on the plots. It is seen that different peak voltages represent corresponding blood sugar levels but the samples are from the same blood group and thus have the same lag time of 83.6 ns.

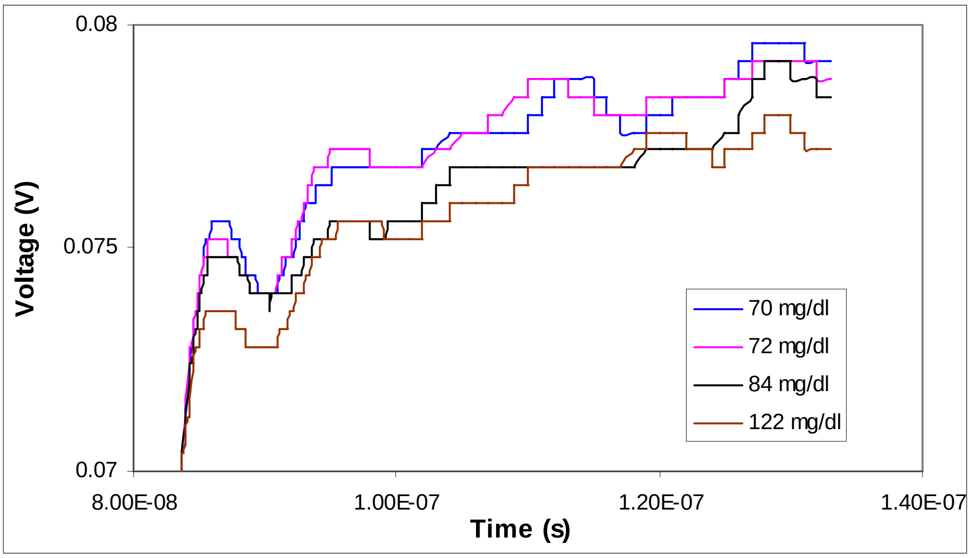

Fig. 3: TDR waveform for four blood samples with same blood group B– but with different sugar levels.

Different values of the lag time are associated with different blood group, once the time value is found this can be used for the prediction of the blood group. The test is repeated several time and values were almost same for the same group of blood. Number of samples was studied for different ranges, the data was recorded and analyzed, and we used computer programs for finding out the blood group from the given data. The results are encouraging and are found to predict correct blood group for different samples of blood with different blood groups. The values of lag times found from TDR studies of large number of samples with known blood groups in humans is shown in Table – 1 below. Fig. 4 shows TDR waveforms for different blood groups selecting one from each blood group.

Table – 1: Table showing relation between blood group and lag time.

Blood Group	Lag time (ns)
B+	84.2 - 84.3
O+	84.0 - 84.1
A+	83.9
AB+	83.8
AB-	83.7
B-	83.6
O-	83.5
A-	83.2 – 83.4

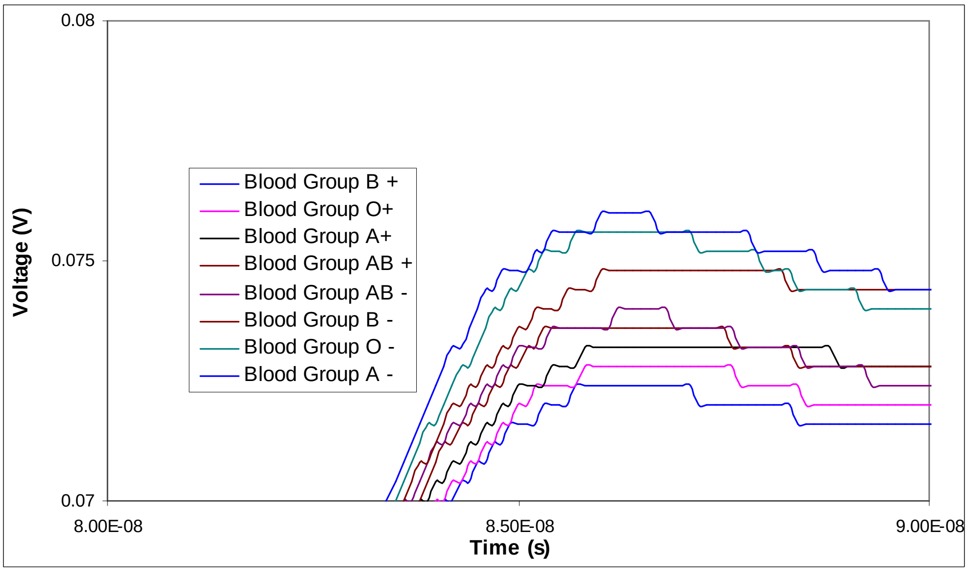

Fig. 4: TDR waveform for blood samples for different blood groups showing different lag times for different blood groups.

All the waveforms clearly indicate that the lag time for different blood groups is different and every blood group shows it own characteristic lag time.

CONCLUSION

The TDR setup presented proves to be a good tool in determining parameters like blood group and blood sugar concentration. The predictability of the experimental setup is very good and the measurements show good reproducibility. The advantage of this technique is that only one drop of blood is needed and results are obtained in minutes. The blood groups obtained from lag time of the first peak of the TDR wave form are found to be in good agreement with the actual blood groups (measurement from pathological laboratory). The rise time of the TDR pulse was limited to 5 ns and the resolution on the time scale was 0.1 ns (100 ps). Use of faster rising voltage step pulse and better time resolution is expected to further improve the performance of the blood group determination.

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