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Waveform Technique For Detection of Dielectric Constant of Human Blood Using Indigenous TDR

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***Abstract*—The presented paper describes a waveform technique that can be used to detect the dielectric constant of human blood using developed TDR. This TDR has a pulse generator with rise time of 5.8ns and a Digital Oscilloscope of sampling rate 60MHz. Several blood samples have been collected from the pathology lab and the digital data are stored using the developed TDR by putting single drop of blood at sample holder for each sample. Dielectric constant is determined with the help of a computer program. The plotted graph of dielectric constant vs first peak voltage has shown the linear relationship.**

Keywords—dielectic constant, pulse generator, sample holder, TDR

I. INTRODUCTION

The blood is a circulating tissue which consists of plasma and cells. It is a non-Newtonian type of fluid as it shows a non linear relationship between stress and strain rate. This rate is known as viscosity which is observed in blood. The measurement of blood impedance using an alternating current helps to determine the blood disorders [1]. This measurement can help to determine the dielectric constant, sugar content, blood group, etc. of human blood. This measurement is based on the correlation between it electrical and mechanical properties as well as its microstructure. In this paper, an Indigenous developed TDR is used to determine the dielectric constant of the human blood. This determination of dielectric constant of blood plays an important role for various medical applications such as hyperthermia and ablation [2-5].

II. PRINCIPLE OF TDR

Figure 1 shows the working principle of TDR. Time Domain Reflectometer (TDR) is also known as the closed circuit radar [6]. It consists of a fast rise time pulse generator, a Digital Storage Oscilloscope and Transmission line as the main components [7-9].

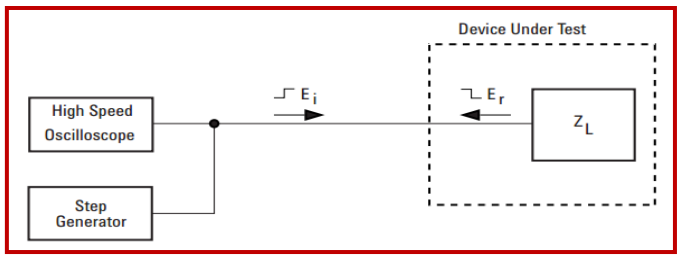

Fig. 1. **Working Principle of TDR**

It transmits a low intensity electromagnetic pulse using the pulse generator along a flexible conductor (transmission line) at the speed of light. One end of this conductor is connected to the Digital Oscilloscope and the other end is connected to the sample holder. When this transmitted pulse reaches to the end of the pulse, this pulse is reflected back with intensity depending on the dielectric constant of the sample in sample holder [10-12].

III. DEVELOPED TDR AND SAMPLE HOLDER

A TDR is developed with all the basic requirements. Several sample holders have been designed and tested with this TDR and finally the highly sensitive one is selected for the experimental part. Figure 2 shows the developed sample holders.

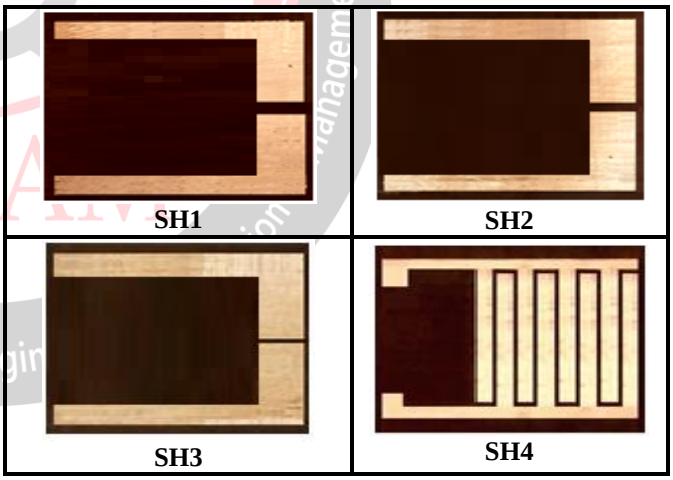

Fig. 2. **Developed Sample Holders**

The small space between each conductor was used to put a drop of blood sample. The sample holder SH1 has not shown the satisfactory sensitivity. The sample holder SH2, SH3 and SH4 have shown the approximately same sensitivity but SH2 is selected as the others were having the cleaning problem.

This sample holder SH2 is used with the developed TDR which has the rise time of 5.8ns and digital data storing points of 600 using the DSO of sampling rate 60MHZ. This TDR used the transmission line of 75Ω characteristic impedance. The MX BNC connecters are used to connect the pulse generator and sample holder with the DSO to make this

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system to work as TDR. Figure 3 shows the image of developed TDR.

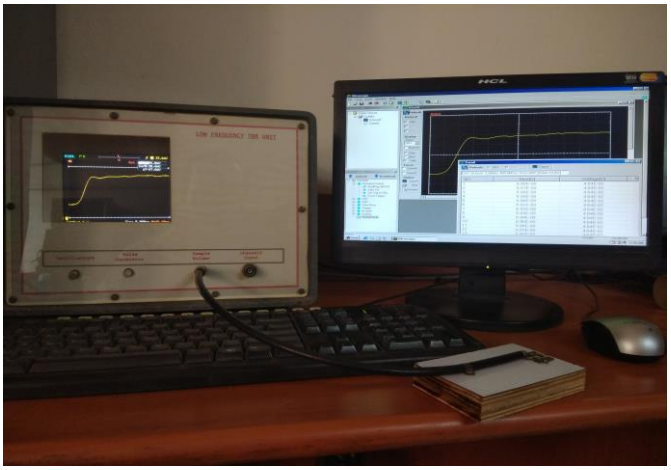

Fig. 3. **Image of developed TDR**

IV. DATA ACQUISITION OF BLOOD SAMPLE

Approximately 800 blood samples have been collected from a pathology lab on an average rate of 10 to 20 samples per day depending on the availability. Each collected blood samples were with mixture of anticoagulant and the digital data for each is stored by putting a drop of blood sample at sample holder. This TDR unit is interfaced with a computer and a GUI base developed computer program is used to reduce the time of storing the data for each sample.

The digital data for each sample were stored twice, one when the sample holder was empty and the other with sample using the time window of 5ns. The file for reflected pulse without sample was named as r1(t) and the reflected pulse with sample was named as rx(t).

V. DIELECTRIC MEASUREMENT

Primarily, both the reflected pulses were added and subtracted. The addition of reflected pulse without sample r1(t) and with sample rx(t) was represented by p(t) and the their subtraction was represented by q(t).

$$p(t) = [r1(t) + rx(t)] \quad \textbf{(1)}$$

$$q(t) = [r1(t) - rx(t)] \quad \textbf{(2)}$$

This obtained data was time domain and so it was converted to frequency domain using Fourier transformation. The Samulon method is used to find p(ω) and q(ω) of p(t) and q(t) respectively. The frequency dependent complex reflection coefficient is calculated using equation (3).

$$\rho^*(\omega) = \frac{c}{j\omega d}\frac{p(\omega)}{q(\omega)} \quad \textbf{(3)}$$

where c is the velocity light, ω is the angular frequency, d is the effective pin length and $j = \sqrt{-1}$

The frequency dependent complex permittivity $\boldsymbol{\varepsilon}^*(\omega)$ data was fitted using the Havriliak-Nigami equation for evaluation of dielectric parameters as shown in equation (4).

$$\varepsilon*(\omega) = \varepsilon_\infty + \frac{\varepsilon_0 - \varepsilon_\infty}{[1+(i\omega\tau)^{1-\alpha}]^\beta} \quad \textbf{(4)}$$

where , $\boldsymbol{\varepsilon}_0$ is the static permittivity, $\boldsymbol{\varepsilon}_\infty$ is the permittivity at infinite frequency, ω is the angular frequency and τ is the average relaxation time, α is symmetrical distribution parameter and β is Davidson Cole distribution parameter.

VI. RESULT AND DISCUSSION

The dielectric constant of these samples were calculated using the equation and the graph of all the recorded reading for each sample is plotted using Origin Pro software as shown in figure 4.

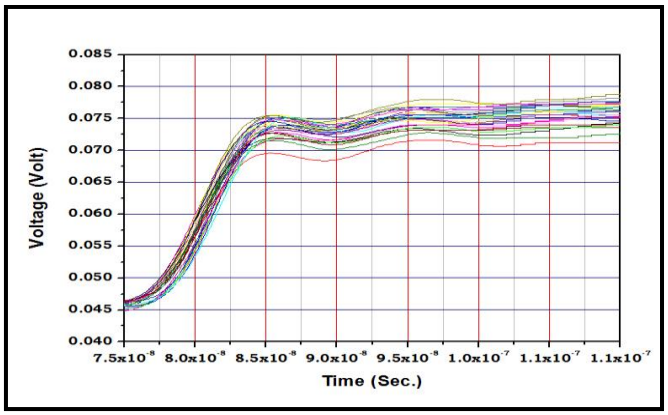

Fig. 4. **Graph of all recorded samples**

The first peak point as shown in figure 5 is recorded for all the plotted graphs and tabulated in table 1 along with their dielectric constant values.

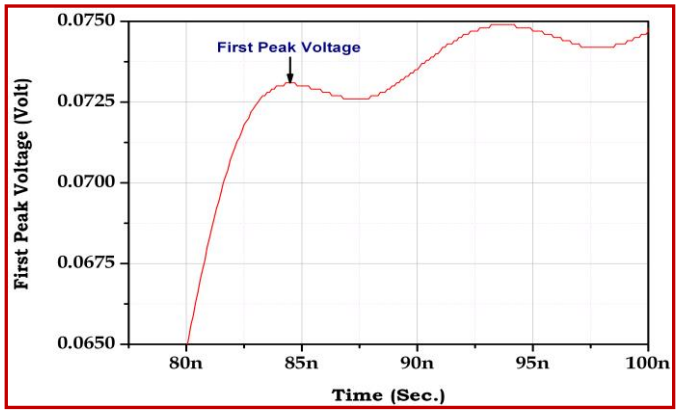

Fig. 5. **First Peak Voltage of a sample**

This first peak voltage was found from the stored digital data of sample using a computer program. The same is shown in figure 5 for a single blood sample.

A graph of Dielectric constant vs first peak voltage is plotted and a linear nature was observed as shown in figure 6. The obtained linear equation can be used to find the dielectric constant of any human blood sample. Now there is no requirement of any mathematical calculation as the detection is based on the first peak voltage of the sample.

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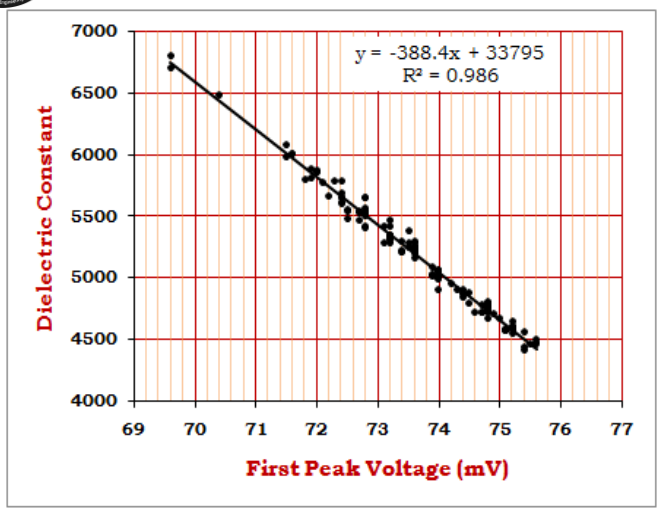

Fig. 6. **Dielectric Constant vs First Peak Voltage**

TABLE I. **DIELECTRIC CONSTANT AND FIRST PEAK VOLTAGE FOR SOME BLOOD SAMPLES**

Sample Name	First Peak Volt. (mV)	Dielectric Constant
BL2131X	69.6	6812
BL2152X	74.8	4801
BL2171X	70.4	6490
BL2201X	74	5063
BL2441X	72.8	5650
BL2442X	72.8	5573
BL2491X	73.9	5029
BL2511X	75.6	4498
BL2611X	72.7	5470
BL2651X	72.5	5560
BL2721X	73.2	5352
BL2741X	75.2	4645
BL2891X	73.6	5240
BL2921X	74.8	4757
BL2961X	73.2	5349
BL3031X	72.8	5413
BL3092X	73.6	5240
BL3162X	71.5	5990
BL3191X	75.4	4414
BL3201X	75.2	4580
BL3311X	74.8	4782
BL3401X	73.9	5031
BL3421X	71.8	5799
BL3461X	73.1	5421
BL3521X	75.5	4470
BL3801X	73.2	5355
BL3821X	72.8	5521
BL3881X	73.2	5421
BL3941X	74.8	4803
BL4092X	71.9	5890
BL4111X	74.8	4786
BL4311X	74.8	4771
BL4321X	75.2	4599
BL4341X	73.4	5216
BL4431X	74	4996
BL4521X	74.2	4951
BL5081X	74	5021
BL5082X	74	5002
BL5111X	72.5	5480
BL5121X	75.6	4473
BL5462X	74	5052
BL5721X	73.6	5219
BL5771X	75.2	4607
BL5811X	73.9	5089
BL5862X	74.4	4887
BL6042X	74.6	4728
BL6192X	75.1	4583
BL6221X	74.4	4847
BL6241X	72	5865
BL6511X	73.6	5230
BL6561X	73.5	5348
BL6671X	74.4	4832

VII. CONCLUSION

This developed TDR is tested for approximately 800 human blood samples for detection of their dielectric constant. The plotted graph of dielectric constant vs first peak voltage has shown the linear nature and so the waveform technique for detection of dielectric constant can be used as a new method of detection. This method can be tried to detect the sugar content and blood group also.

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