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Estimation of Cholesterol in the Presence of Urea and Other Constituents in Blood Tissue

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Abstract*: *The determination of cholesterol in pathological laboratories is more painful and may lead to infections if no proper precautions are taken into consideration. The manuscript presented here describes a non-invasive method to estimate blood cholesterol using Radio Frequency (RF) probe signal in the range of 10MHz – 500MHz. The method uses Scalar Network Analyzer and injects RF signal less than -30dbm, which is quite safe for human tissue and the frequency range falls in non-ionizing radiation wavelengths. Due to the absorption of RF signal by various body tissues including cholesterol, the received signal by the spectrum analyzer bears the signatures of percentage of the cholesterol present in the blood. These signatures are then analyzed using multivariate approach to estimate the Cholesterol. The Signal Processing Unit consists of Partial Least Square Regression (PLSR) tool based on the SIMPLS Algorithm. The results show that there is a good agreement between the predicted percentages of Cholesterol as compared to the actual. Though the study here uses only 5 components, the technique can also be used to include other blood components for the estimation of Cholesterol.

Keywords: RF probe signal, PLSR, Signal Processing, Multivariate system.

I. INTRODUCTION

Cholesterol is one of the major constituents of blood which is responsible for CVDs. Cholesterol is a fat like substance in the blood that is built up on the walls of the arteries thereby over the years, the arteries become narrow and the blood flow to the heart is reduced or blocked [1]. High Cholesterol is harmful when the level of HDL Cholesterol is low and LDL Cholesterol is high. CVD is the main killer in the world and last year 17.9 million people died due to the same [2].

Lowering one's Cholesterol is of utmost importance for every human being, whether they have or do not have heart diseases [3].

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Urea is one of the major constituents of blood produced in the liver which affect the prediction of Cholesterol and is the end product of protein metabolism. 0.3g of Urea is produced by 1g of protein [4]. When the level of Urea is too high or too low in the blood, people are prone to the problems associated with liver, urinary tract, kidney, etc. Congestive heart failure, bleeding in the intestines and some medications can also increase the level of Blood Urea [5].

Very often people are not aware that they are suffering from high Cholesterol, since it has no symptoms, people are not aware of their Cholesterol level.

It is very important to have a routine check-up so as to lessen the risk of a heart attack. In order to determine the levels, it is necessary to go to the laboratory and do a blood test.

A blood test can be carried out in 2 procedures: venous blood draw method and finger stick method.

The patient is often very nervous about going for the blood test and neglects the test until it is too late for fear of the blood drawn due to the prick of the needle. It has other disadvantages as given below.

- There is often more than one prick of the needle when the vein is not located
- If the patients is afraid and holds the breath, then the blood flow is restricted and difficult to collect
- The blood may not clot if the patient is on blood thinners
- The patient may feel dizzy and faint.
- There is a possibility of infection
- Blood clots can occur under the skin
- Inflammation of the vein, arterial nicks and Nerve injury could occur

Therefore, it is necessary to design and develop a non-invasive device to know the cholesterol level. There are numerous ways of checking blood cholesterol in human beings: physical tests and chemical tests, as well as non-invasive and invasive.

The significant ones are based on Stimulated Emission Spectroscopy, Photo Acoustic Spectroscopy, Thermal Emission Spectroscopy, Chemical method, Optical Absorption Spectroscopy, Liquid Chromatography method, Enzymatic Colorimetric test, Reference method, Electrophoresis, Ultracentrifugation, Impedance measurement, non-invasive cholesterol test, classification of TC level using Body Mass Index (BMI) and PreVu. The details of the device used in this article are given in the next section.

II. MATERIALS AND METHODS

A cell, made with acrylic sheets, is designed having dimensions, 12.5cms length, 1cm breadth and 2cms height.

The inner side of the cell is fitted with a gold foil and forms

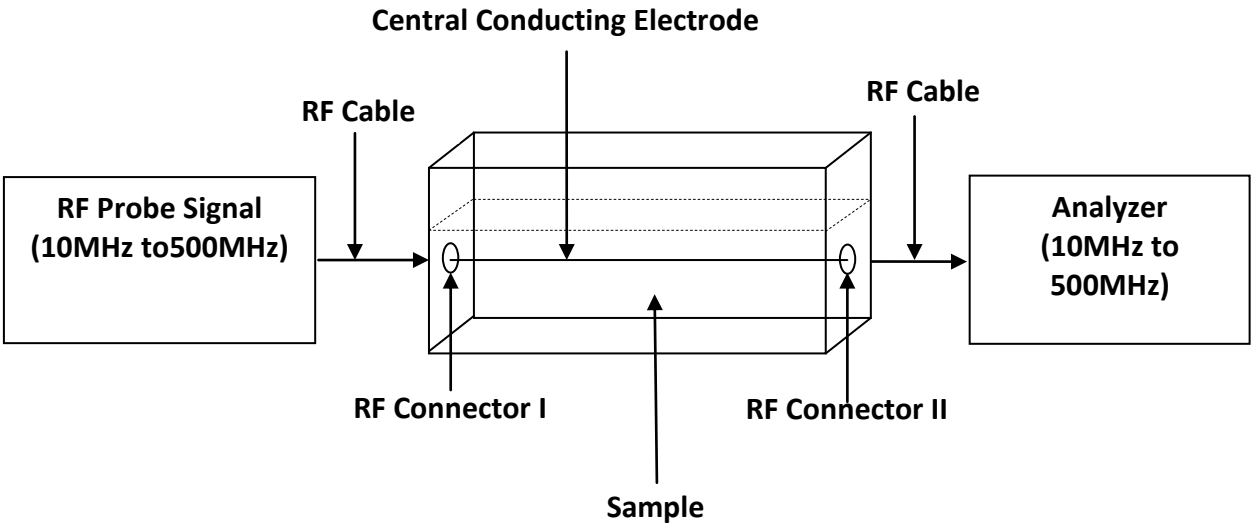

Fig. 1: Experimental Setup Block Diagram

ground electrode, while outer side of the cell is fitted with a copper foil for noise elimination. Two gold plated SMA female RF connectors are fixed on both the sides of the cell. There is a central conducting electrode running across the length of the cell and is attached to the above two RF connectors as shown in Fig. 1.

The cell is placed into an iron container, fabricated using thick walled plates and the same is grounded to reduce RFI. The RF probe signal from tracking generator is applied to connector 1 through a small RF cable and the attenuated signal is received at the other end connector, which is connected to the spectrum analyzer via second RF cable. Thus maximum care is taken to prevent effect of external radiations. The tracking generator and a matched spectrum analyzer with proper triggering feedback arrangement make the entire system a scalar network analyzer.

The instruments used for scalar network analyzer are 'Signal Hound Tracking Generator' and the 'Signal Hound Spectrum Analyzer'. It is also possible to use vector network analyzer for the above study. Since our emphasis is on portable and low cost instrument, signal hound equipment is used. These instruments have dynamic range between 10Hz and 4.4GHz with USB power, and hence do not require a separate power supply. The range used in the experiment is 10MHz to 500MHz. The received signal data from spectrum analyzer is then given to PLSR signal processing block. The signal processing block mainly constitutes ParLes software which is based on SIMPLS algorithm [6]. The ParLes algorithm in the past has been effectively used to estimate body glucose content by way of statistical analysis [7].

Cholesterol in a healthy human being is less than 250 mg/dL, Urea ranges from 10-20mg/dL, Glucose ranges from 70 to 110 mg/dL and Alanine varies from 10-20mg/dL. The average concentration of the above constituents is used in our experiment. The cell can contain only 15mL of liquid. Hence, the values are scaled down from mg/dL to mg/15mL. Urea in the experiment has values of '0.5', '1' and '2' that correspond to 1.13mg/15mL, 2.25mg/15mL and 4.5mg/15mL respectively. Glucose on the other hand is maintained at the avg. conc. of '1' i.e. 13.5mg/15mL, Alanine is also maintained at avg. conc. of '1' i.e. 2.25mg/15mL and Salt is taken as '1' i.e. 135mg/15mL. The details of various concentrations used for Cholesterol are given in Table-I.

Table-I: Actual Values of Cholesterol

Conc. Of Samples	Cholesterol mg/15mL
0.75	25.5
1	34
1.25	42.5
1.5	51
2	68
2.5	85

In Table-I, values from '1.25' to '2.5' are above the normal concentration, whereas 0.75 to 1.25 is within the normal range. Solution samples are prepared using 14mL double distilled water and 1mL alcohol as shown in Table-II.

Table-II: Combination of Solution Samples Used in the Experiment

Sr. No.	Cholesterol	Urea	Salt	Glucose	Alanine
1	0.75	0.5	1	1	1
2	1.5	0.5	1	1	1
3	2	0.5	1	1	1
4	2.5	0.5	1	1	1
5	0.75	1	1	1	1
6	1	1	1	1	1
7	1.5	1	1	1	1
8	0.75	2	1	1	1
9	1	2	1	1	1
10	1.25	2	1	1	1
11	1.5	2	1	1	1
12	2	2	1	1	1
13	2.5	2	1	1	1

Experiments were carried out in two modes: slow sweep and fast sweep to cross check the repeatability.

III. RESULTS

The response of the cholesterol is shown in Fig. 2 – Fig. 5. Though the response was recorded from 10MHz to 500 MHz, the sections shown here are having the best responses.

The rest of the spectrum has a lot of overlaps and is difficult for deciphering.

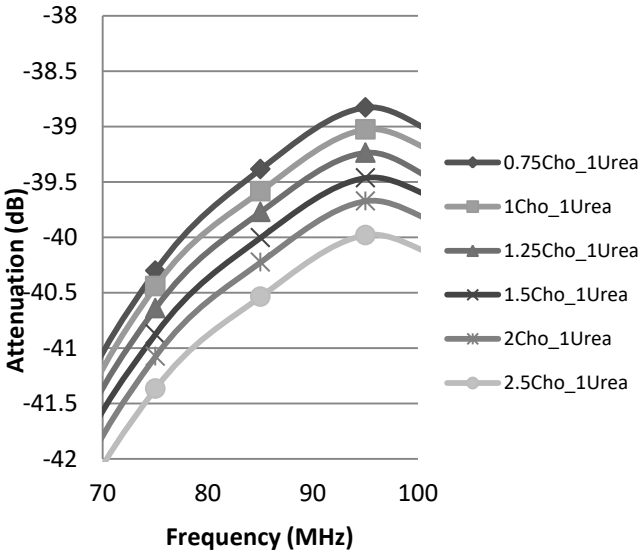

Fig. 2: Graph of Urea (Normal Concentration) in the range 70-100MHz

Fig. 2 shows the change in the attenuation of the signal for different concentrations of Cholesterol from below average value to above normal. Urea is kept at the average of the normal range i.e. '1' and the other components are also retained at average of the normal range. Here, the attenuation increases as the conc. of Cholesterol increases.

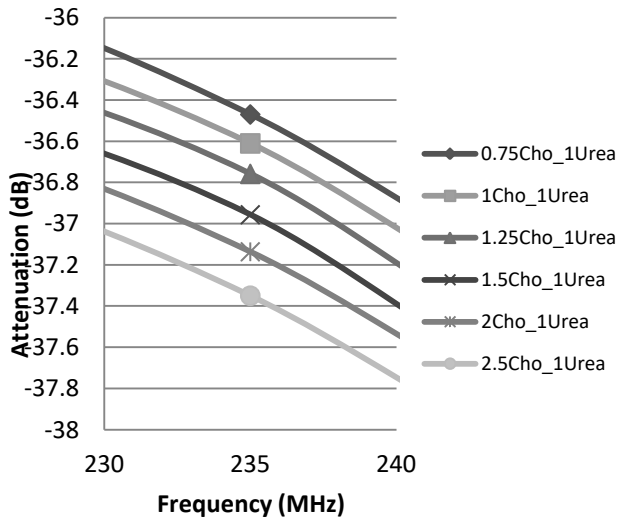

Fig. 3: Graph of Urea (Normal Concentration) in the range 230-240MHz

Fig. 3 depicts the change in the attenuation of the signal for different concentrations of Cholesterol ('0.75' - '2.5') in frequency range (230MHz - 240MHz). Urea is kept at the average of the normal range i.e. '1' and the other components are also retained at average of the normal range. Here, the attenuation increases as conc. of Cholesterol increases.

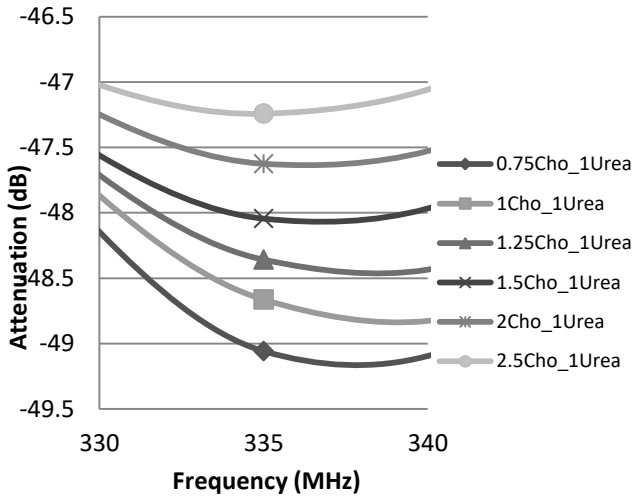

Fig. 4: Graph of Urea (Normal Concentration) in the range 330-340MHz

Fig. 4 shows the change in the signal attenuation in frequency range (330MHz - 340MHz) for varying concentration of Cholesterol ('0.75' - '2.5'). Urea is kept at the average of the normal range i.e. '1' and the other constituents are also retained at average of the normal range. Here the attenuation decreases as the conc. of Cholesterol increases.

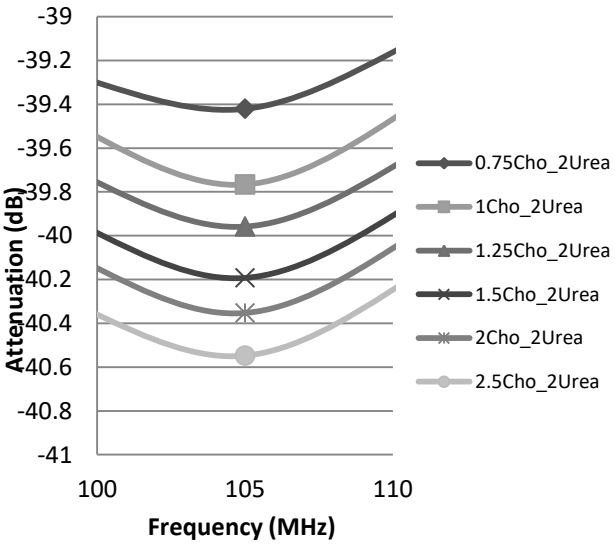

Fig. 5: Graph of Urea Concentration (double the normal) in the range 100-110MHz

Fig. 5 depicts the change in the attenuation of the signal in the frequency range (100MHz - 110MHz) for varying concentration of Cholesterol from below average to above normal. Urea is kept at twice the average of the normal range i.e. '2' and the other components are retained at the average of the normal range i.e. '1'. Here the attenuation increases as conc. of Cholesterol increases.

Cholesterol estimation: The data from the above graphs are used to estimate the Cholesterol present in the unknown sample using least square regression technique. The samples with unknown concentrations are fed to the ParLes software which is propriety multivariate software based on SIMPLS, an advanced least square regression technique.

The software pretreats, preprocesses and transforms the spectra. It also cross validates data, implements PLSR and PCA. Finally the unknown value is displayed on the GUI [8].

Table-III: Combinations used as unknown samples

Sample	Cholesterol	Urea	Salt	Glucose	Alanine
1	1	0.5	1	1	1
2	1.25	0.5	1	1	1
3	1.25	1	1	1	1
4	2	1	1	1	1
5	2.5	1	1	1	1

Table-III gives the combination of unknown samples with varying levels of Cholesterol and Urea while concentration of Salt, Glucose and Alanine are kept at normal.

Table- IV: Prediction of unknown Cholesterol in mg/15ml

Sample	Cholesterol (actual)	Cholesterol (predicted)	Normalized Error %
1	34	34.42	1.23
2	42.5	41.69	1.91
3	42.5	41.73	1.81
4	68	64.26	5.5
5	85	84.01	1.16

Table-IV shows the values of actual and predicted Cholesterol and percentage error. The results obtained are within the limits of the error 8.9 % defined by National Institutes of Health [9].

IV. CONCLUSION

The manuscript describes the use of multivariate signal processing algorithm to estimate Cholesterol non-invasively. In this article, the laboratory samples have been used which are prepared in accordance with the standard procedures followed by a pharmacist. The analysis is done with five major constituents taken into account for Cholesterol estimation. The error in estimation of cholesterol is within 5.5% and is way below the norms of 8.9% set by National Institutes of Health. It may be possible that when other minor constituents of blood are taken into account, the percentage error may slightly increase, because more constituents appear as noise in the signal processing system. However, their effect can be minimized by taking average of many samples. The study in this regard is under progress.

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AUTHORS PROFILE

Dr. Ingrid Anne Nazareth completed her doctorate in the Dept. of Electronics, GU, Goa with the thesis entitled "Estimation of Cholesterol by Impedance Measurement based on DSP Technique". She secured the 1st Rank at the M.Sc. Electronics and was awarded the "IV SERC School in Physics Gold Medal". She secured the post of a project fellow and the project was entitled "Design of Hyperspectral Smart Sensors using soft-core processors and IP cores". She was a visiting faculty and was then appointed as Assistant Professor at the department. She has presented her research work at several National Conferences and Symposiums as well as published in International and National Journals too. Her research interest pertains to Biomedical Electronics.

Dr. Jivan Parab completed his doctorate from the Dept. of Electronics GU with the thesis entitled "Development of Novel Embedded DSP Architecture for Non-Invasive Glucose Analysis". In 2005, he completed his Masters in Electronics having secured the Gold Medal. He co-authored 3 books in embedded system and exploring C for microcontrollers and using FPGA boards published by Springer. He presented his research work at several International and National Conferences and Symposiums as well as published in International and National Journals too. He is an Assistant Professor as well as a member of the Library committee and the faculty board of GU. He was recently awarded "Visvesvaraya Young Faculty" of Rs. 38,00,000 by the Indian Government.

Prof. Rajendra Gad secured his Ph.D. in Electronics and is presently the HOD, Electronics, GU. He has worked on research projects in the field of non-invasive glucometer funded by UGC and ICMR, Delhi. He is closely linked with the Million Book Project, US Carnegie Mellon University. He is associated with digital repository projects from the Indian Navy related to ALTERA University program and ALTERA Inc. US under the MOU. He is administered as well as sponsored by International Biographical Center, England as one of the 2000 Outstanding Intellectuals in 2009/2010 in the 21st century and the Leading Engineer of the World in 2008. He was a winner in Design contest by Mentor Graphics with the project entitled "Design and verification of LC3 processor" in 2010. He was awarded a Fellowship by the Indian National Science Academy in 2012-2013.

Prof. Gourish Naik completed his Ph.D from IISc, Bangalore in 1987. He was a research associate upto 1993 in the field of Communication and Optoelectronics. He is closely related with the Electronics Program GU for the last 25 years. He established Wireless Communication Network and Fiber optic LAN at GU, hence being the founding head of the Dept. of USIC and coordinator of DEITI (Supported by ISR). He presented and published over 75 papers at International and National Conferences and Symposiums and International and National Journals too.He is a Professor (HAG) and the Dean of Faculty of Natural Science at GU, Goa, India.