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Blood Diseases Characterization Using Electromagnetic Field Analysis

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Abstract

This paper proposes an effective model for prediction of different blood diseases by measuring the electromagnetic field created by human heart using SQUID meter. Four parameters such as voltage, current, resistivity of blood and accumulation time are measured using the proposed model and hence developed a relationship to find out various types of diseases such as diabetes, polycythemia, and anemia. Resistivity of blood is used as disease determinant that plays a vital role for prediction the disease. A number of experiments have been done to ascertain the accumulation time of blood particles from a patient blood which gives staggering information.

Keywords: *Anemia; Blood cell; Plasma; Polycythemia; SQUID*

1. Introduction

Todays, a considerable number of peoples are affected by blood diseases and a lot of types of blood tests are needed ascertain the diseases. The elementary component of red blood cells is Hemoglobin (H) and a main parameter which its concentration is for determining whether the blood components are healthy or not [1]? Another important parameter to determine the capability of oxygen transportation in blood is the Hb concentration in human blood [2]. Anemia (lower hemoglobin concentration) and polycythemia (higher hemoglobin concentration) can be diagnosed and monitored using this information [1]. It is also possible to observe imminent postoperative bleedings and autologous re-transfusions [2]. Human blood is electrically ionized liquid particle. It contains two part: blood cell (45%) and plasma (55%) [3,8]. The plasma contains dissolved proteins (which has positive or negative charge), glucose, clotting factors, electrolytes (Na^+, Ca^{2+}, Mg^{2+}, HCO_3^-, Cl^-, *etc.*), hormones, and carbon dioxide and some other thing [4]. Blood ionization particles are influenced by external magnetic field as well as those ionized particle create a tiny amount of magnetic field within the liquid blood [5]. With the flowing of blood, the ionized particles also flow. This produces a significant amount of current which in turns make a small amount of magnetic field, which can be determined using Superconducting Quantum Interference Device (SQUID), a SQUID is a very sensitive magnetometer which evaluate extremely subtle magnetic fields, based on superconducting loops containing Josephson junctions [6]. And it capable of measuring the magnetic field creating by human blood.

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In this paper, we develop mathematical model of determining electric field and magnetic field for analyzing blood particle (diseases) measured by DC SQUID by developing relationship between accumulation time and blood characteristics. From electromagnetic field calculations, we calculate four parameters, these are: voltage, current, resistivity and accumulation time. We develop the equation showing the relation between accumulation time and current, accumulation time and resistivity, and accumulation time and voltage. Those three equations give staggering information about all kind of blood diseases. These help to analyze blood particle more accurately with a convenient form. The relationship between hematocrit and voltage are also developed, from which the normality or abnormality of blood can easily be commented. One can perform resistivity test easily by using this method and can measure resistivity. Other desired parameters (*e.g.*, specific gravity, viscosity, hematocrit *etc.*,) can also be measured by using our proposed model. It will be advantageous to the patients as it will minimize their costs for various unnecessary tests. It will be an acted as a friendly method for the doctors in case of blood disease determination. Diagnosis process may be easier and accurate.

2. Model Development

When a biological system as like cell, tissue or the whole organism is exposed to an electric field as well as a magnetic field, the dynamic charges, for instance the electrolytes of blood are forced to move align to the induced electric field lines [7], hence, establishing an electric current measured in amperes (A). The distribution of the current and the distribution of its flow are defined by the current density (J) which is quantified in amperes per square meter (A/m^2). Two dimensional potential of SQUID is given of form [6, 9, 10]:

$$U_{SQUID} = \left[2E_J \left\{ \frac{1}{\pi\beta_L} \left(\frac{\partial_2 - \partial_1}{2} - \pi \frac{\Phi_a}{\Phi_0} \right)^2 - \cos\left(\frac{\partial_2 - \partial_1}{2} \right) * \cos\left(\frac{\partial_2 + \partial_1}{2} \right) - \frac{I}{2I_0} * \frac{\partial_2 - \partial_1}{2} \right\} \right] \quad (1)$$

where E_J is Josephson coupling energy, equals to $\frac{\phi_0 I_0}{2\pi}$, is a constant parameter, I_0 is the average critical current can be defined as $\frac{i_{01} + i_{02}}{2}$, $\beta_L = \frac{2LI_0}{\phi_0}$ is Stewart-mc-Cumber parameter and $\varphi_a = n\phi_0; \frac{n+1}{2}\phi_0$ is normalized applied magnetics flux. In this paper, we develop the mathematical model of electric and magnetic field using SQUID respectively is given in (2) and (3). This electric and magnetic field model are achieved using equipmental arrangement shown in Figure 1.

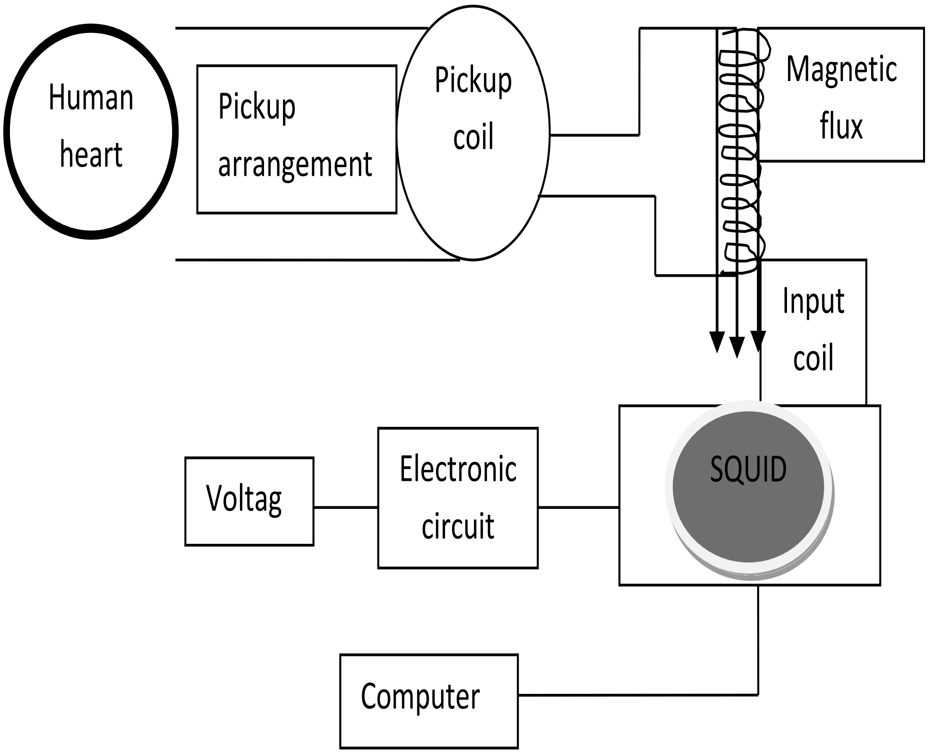
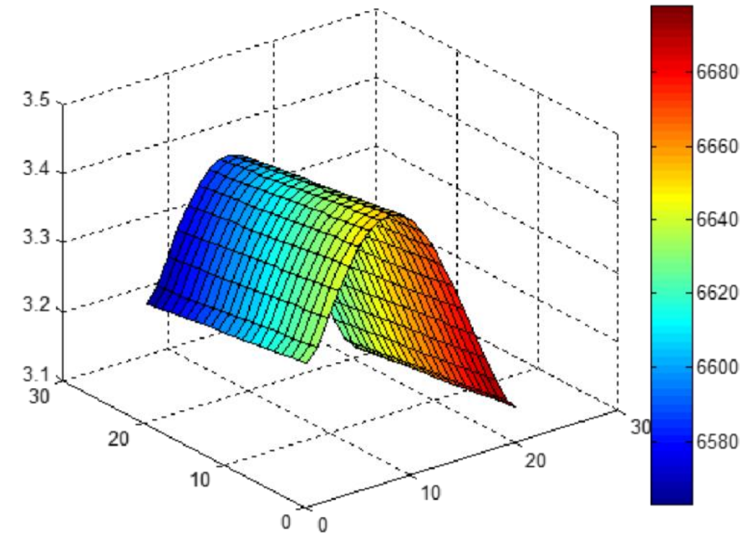


Figure 1. Equipmental Arrangement of Proposed Model in which a Pickup Coil is used to Take Field Excitation from Blood Circulation. SQUID is used to Provide Electric Potential Field Components in Term of Voltage and Current

$$\overline{E} = -a_{\delta_1}\left[2E_f\left\{\frac{1}{\pi\beta_L}\left(\frac{\partial_2-\partial_1}{2}-\pi\frac{\Phi_a}{\Phi_0}\right)+\frac{1}{4}\sin\frac{\delta_1}{2}-\frac{I}{4I_0}\right\}\right]$$

$$-a_{\delta 2}\left[2E_f\left\{\frac{1}{\pi\beta_L}\left(\frac{\partial_2-\partial_1}{2}-\pi\frac{\Phi_a}{\Phi_0}\right)+\frac{1}{4}\sin\frac{\delta_2}{2}-\frac{I}{4I_0}\right\}\right] \quad (2)$$

Figure 2 shows the wave nature of electric field, when plot is obtained with respect to (a) considering only δ_1 axis, (b) considering only δ_2 axis and (c) considering both axis component of electric field at a time of (2).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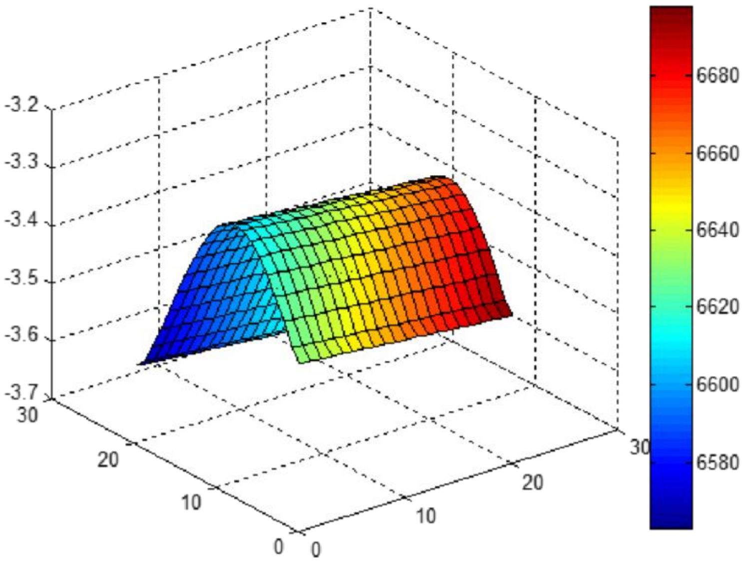
(a)


-3.2
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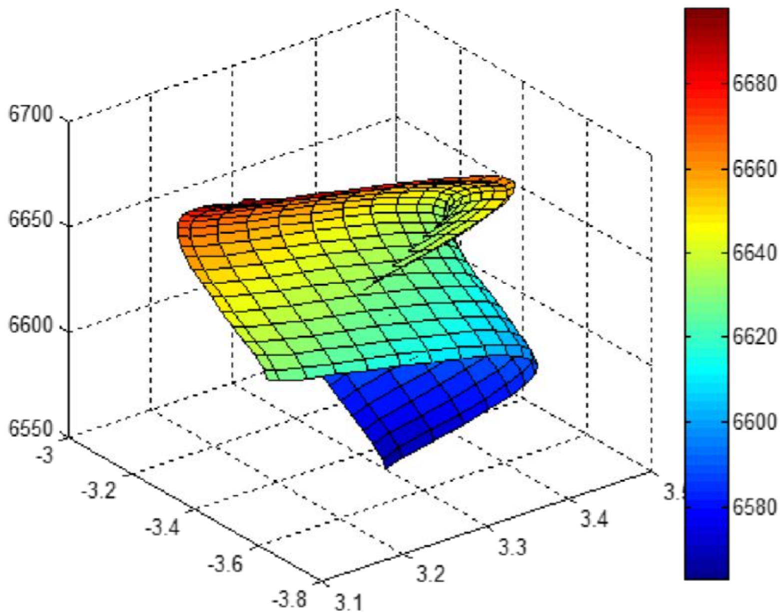
(b)



(c)

Figure 2. Plot of (a) δ_1 Axis Component of Electric Field, (b) δ_2 Axis Component of Electric Field and (c) both Axis Component of Electric Field at a Time of Equation (2)

$$\overline{H} = \frac{\Phi}{\pi U_{SQUID} A}\left[\cos^{-1}\left(\frac{I}{2lc\sin^{-1}\left(\frac{\partial_1 + \partial_2}{2}\right)}\right)\right] \quad (3)$$

The resistivity of blood and cumulative time can easily be measured by calculating field components in (2) and (3).

2.1. Development Relation between Voltage and Hematocrit

A mathematical equation presenting the relationship between voltage and hematocrit is shown in the following form [11]:

$$V= \frac{LI(1+\frac{H}{100-H}C)}{\sigma_p A} \quad (4)$$

Here, V= blood voltage, H=hematocrit, I= plasma current, A= area, C= specific constant and σ_p= conductivity of plasma, can be defined as [11]:

$$\sigma_p = \sigma_b[1 + \frac{H}{100-H}C] \quad (5)$$

where σ_b is the conductivity of blood can be determined by reversing the blood resistivity which is developed in the next section.

2.2. Development Relation between Accumulation Time and Current at Voltage Constant

An equation showing the relationship between accumulation time and current when the measured voltage is constant is developed illustrating in the following form:

$$I=I_1 - \frac{T}{1000}\text{; or, } I=I_1 - kT \quad (6)$$

Here, K= accumulation constant equals to 0.001, I=current, I_1= initial current at accumulation time when zero (~current flows through the plasma), T = accumulation time. Using this equation accumulation time can be calculated for any blood sample and measuring this accumulation time.

2.3. Development Relation between Accumulation Time and Resistivity at Voltage Constant

Another equation showing the relationship between accumulation time and resistivity is developed in the following manner:

$$\rho = \rho_1 + KT \quad (7)$$

Here, ρ= resistivity of blood, ρ_1 =standard resistivity/ initial resistivity of blood, K= constant equals to 0.02619. This equation gives accumulation time alternatively resistivity of human blood.

2.4. Development Relation between Voltage and Accumulation Time

We firstly convert electric field which extracted from the proposed model explained in Figure1 to the voltage and then develop a relationship between voltage and accumulation time:

$$T = k * \frac{1}{v} \quad (8)$$

Accumulation time exponentially decays with the increase of converted voltage that is given in (8).

3. Results and Discussion

We performed results in order to achieve informative information such as the variation of accumulation time for sample blood. The experimental results that we observed and measured are given below:

Table 1. Resistance and Accumulation Time of Blood

Time (sec)	E-field (V/m)	H-field (I/m)	Resistance (ohm)
0	10	0.05	200
14	20	0.10	200
25	30	0.17	176.47
32	40	0.20	200
45	50	0.00	infinite
55	60	0.00	infinite

The average blood resistance is calculated before getting its value to infinity and its value is 194.11 Ω. The resistivity (ρ=RA/L) of these sample blood is then calculated by placing pick-up coil of radial distance 1.5 cm and cross sectional area ($A=\pi r^2$) 1.76 cm^2. The resistivity for the above sampled blood is 2.287 Ω-m. Blood is clotted with the being of electrical current is zero, and then it works as an insulator. As a result, high hematocrit is produced which is a danger sign of an increased risk of dengue shock syndrome. Chronic obstructive pulmonary disease (COPD) and other pulmonary conditions associated with hypoxia may elicit an increased production of red blood cells. This increase is mediated by the increased levels of erythropoietin by the kidneys in response to hypoxia. A plot is done which shown the variation of H-field with respect to accumulation time in Figure 3. When the voltage is kept constant, there adding of the current with respect to time is taken, it tends to increase the value of resistance.

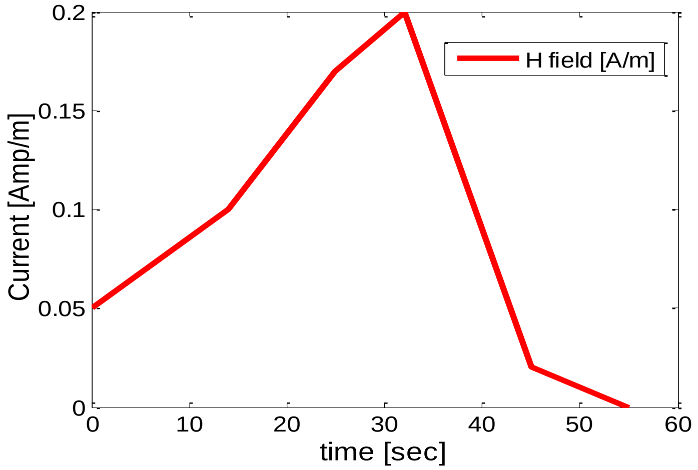


Figure 3. Variation of H-field with Respect Accumulation Time

After a certain time, the value of current is zero. And the resistance become infinite. Because the clotted blood cell act as an insulator. The clotting of blood mainly occur for hematocrit. Which also known as packed cell volume (PCV). Its normal amount is 45% for men and 40% for women. The relationship between resistance and accumulation time is shown in Figure 4.

Table 2. Resistance and Accumulation Time of Blood

Time (min:sec)	E-field (V/m)	H-field (A/m)	Resistance (ohm)
0:0	20	0.08	250
0:42	20	0.09	222.22
1:0	20	0.12	200
1:20	20	0.125	200
2:0	20	0.16	190.47
3:0	20	0.14	200
3:10	20	0. 12	222.22
3:25	20	0. 09	333.33
3:40	20	0.08	400
3:50	20	0.10	500
4:30	20	0.05	1000
5:0	20	0.01	infinity
7:30	20	0.00	infinity

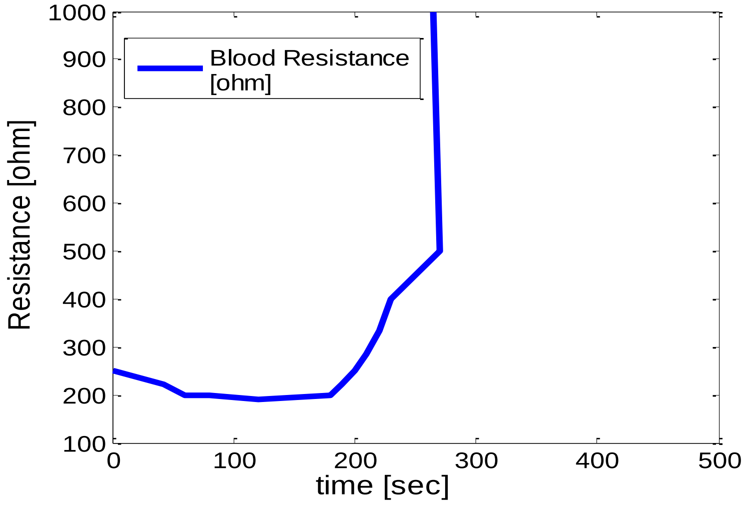


Figure 4. Variation of Resistance with Respect Accumulation Time

When a comparatively high voltage is applied, the time to decay the currents to zero becomes faster as well as the resistance of the blood increases rapidly.

Table 3. Variation of Resistance and h-field with Respect to Time at Highly e-field Components

Time (min:sec)	E-field (V/m)	H-field (I/m)	Resistance (ohm)
0:0	50	0.25	200
0:30	100	0.05	1000
3:0	150	0.00	Infinite
3:50	200	0.00	Infinite

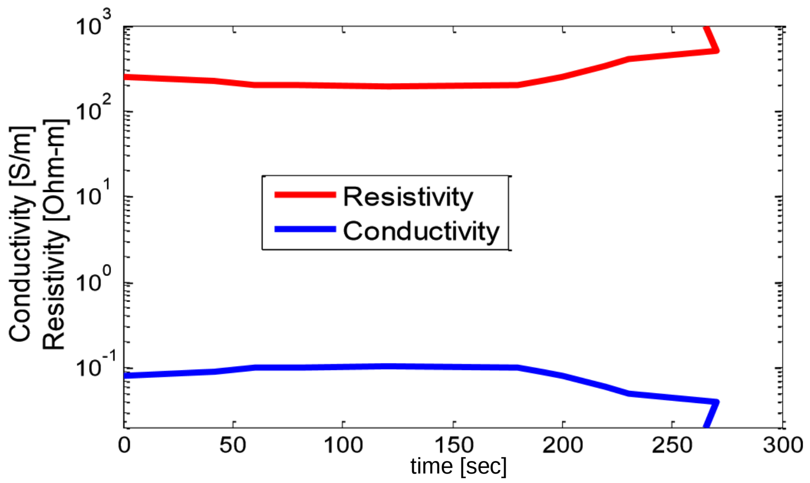


Figure 5. Variation of Conductivity and Resistivity with Respect Accumulation Time

We finally plot blood conductivity and resistivity in a same graph with respect accumulation time with constant voltage which suggested the same result that as obtained before shown in Figure 5.

4. Prediction of Blood Diseases and Abnormality

Blood resistivity can be considered as a disease determinant that has a close relationship between the blood diseases.

4.1. Diabetes Mellitus (DM) Prediction

Diabetes is the combination of metabolic diseases in which there are high blood sugar levels over a prolonged period.

Table 4. Diabetes Mellitus Prediction [12]

Unit	m-mol (mg/dl)	Resistivity (ohm-meter)	Time (sec) at 20 V/m
Normal	<7.8 (<140)	0.637 to 0.787	450
Diabetes	≥11.1 (≥200)	0.90 to 2.357	450

Since the resistivity of sample blood is 2.287 ohm-meter, then it will be concluded that he/she may be suffered by diabetes mellitus diseases. Conductivity of blood (σ_b) is determined using (5). By measuring conductivity of blood, hematocrit can be calculated using this equation. Anemia is a reduction in the number of RBCs, the quantity of hemoglobin, or the volume of RBCs, so anemia causes by reduction of hematocrit. By calculating the hematocrit using (9), a prediction is also done that the patient is suffered by anemia or not.

4.2. Polycythemia Prediction

Polycythemia (also known as polyglobulia) is a disease state in which the proportion of blood volume that is occupied by red blood cells increases [13]. The status of polycythaemia of blood can be conducted by knowing the conductivity as the following table.

Table 5. Polycythemia Vera Prediction [13]

Unit	Conductivity (s-m)
Normal	~1.2706
Polycythemia	<= 1.16

Conductivity of the sampled blood is 0.437 s-m which tells us that the patient has possibly suffered by polycythemia.

5. Contributions and Conclusions

In this paper, a mathematical model based on electromagnetic field created by human heart using SQUID meter is developed for prediction of various type blood diseases. Four parameters such as voltage, current, resistivity of blood and accumulation time are measured using the proposed model and then developed a relationship that helps to find out various types of diseases such as diabetes, polycythemia, and anemia. Resistivity of blood is used as disease determinant that plays a vital role for prediction the disease. A number of experiments have been done to ascertain the accumulation time of blood particles from a patient blood which gives staggering information.

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