CHAPTER – 1
INTRODUCTION

This chapter introduces the reader with the work done on some of the investigations held over years regarding the measurement of blood parameters by exposing Electromagnetic radiation and also describes the role of MW dielectric diagnostic methods in the field of biomedical instrumentation. The details of the contents of blood and relevance of MW diagnostic techniques are also discussed.

Section A: Basic Introduction:

ROLE OF MICROWAVES IN BIOMEDICAL FIELD

Electromagnetic (EM) radiation and propagation characteristics in a fluid depends upon the complex constants of the media, and so the propagation constant $\gamma$, viz., expressed in terms of attenuation constant $\alpha$, and phase shift constant $\beta$ (in the media). As such, they depend upon the nature of the media and its constants. One can estimate the media constants by measuring these parameters in the fluid by propagating the electromagnetic radiation. Measurements of microwave region parameters like, complex dielectric constant $\varepsilon$, attenuation constant $\alpha$, Phase shift constant $\beta$, electron (ion) density $n_e$ and collision frequency $\nu$ provide the necessary information to estimate the characteristics and constituents of the fluid under test. With the help of these measurements, diagnostics of the fluid can be performed. In the present research work, it is proposed to perform diagnosis by propagating EM radiation in blood plasma.
Recent Investigations revealed that effect of non-ionising EM radiation on human body may not be restricted to thermal effects only, but it may help to explain some of the unsolved important biological activity. Keeping in view of this fact, an attempt is made to determine the blood parameters using Microwave EM radiation. The present work is based on the fact that the changes in electrical properties are caused by the prevalence of disease at varied severity.

From a technical point of view microwave detection has the potential to detect blood diseases. It is also expected to be less expensive than methods such as MRI and nuclear medicine. This is because microwave equipment costs a fraction of the equipment needed for MRI and nuclear medicine installations.

A Microwave system will become a useful and painless low risk diagnostic aid. It is not expected that such a system will replace X-ray / MRI / nuclear methods as a screening tool. But these systems used together can improve the estimating methods of severity of disease and cater a limitation for the falsified positive findings.
Section B: Introduction to Blood Parameters

BLOOD PARAMETERS

In this section, a brief description of the various components of blood is presented.

Blood: - The liquid part of the blood is called blood plasma. While the elements like the blood cells are analyzed during its chemical examination. The blood plasma accounts for about 60% of its volume, and the blood cells occupy the other 40%. The study of blood flowing through human organs and the related diseases is known as hematology.

Blood Plasma: - The plasma is obtained by centrifuging a blood sample that has been prevented from coagulating by adding an anticoagulant. During centrifugation, the heavy blood cells become packed at the bottom of the centrifuge tube and the plasma can be removed. The plasma is viscous, light yellow colored liquid that is almost clear in the fasting rate.

The plasma is the river in which the blood cells travel. It carries not only the blood cells but also the nutrients (sugars, amino acids, fats, salts, minerals etc) antibodies clotting proteins (called clotting factors), chemical messengers such as hormones and proteins that help maintain the body's fluid balance[1-2].
Composition of blood plasma:

<table>
<thead>
<tr>
<th>Component</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>92</td>
</tr>
<tr>
<td>Proteins</td>
<td>6-8</td>
</tr>
<tr>
<td>Salts</td>
<td>0.8</td>
</tr>
<tr>
<td>Lipids</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Blood Serum: - The blood serum is obtained by centrifuging a blood sample that has been allowed to clot. During coagulation a dissolved macromolecular substance, fibrinogen, is converted to insoluble fibrin. Fibrin consists of invisible fibers that hold the clot together. Blood serum is thus the liquid part of clotted blood.

Electrolytes in Blood: The most abundant positive ions in the body are sodium, potassium and calcium. The most abundant negative ions are phosphate, chloride and bicarbonate. The correct concentration of ions is necessary for the normal and harmonious functioning of the cells and the body. The ion concentrations vary over wide limits at different places in the body; for e.g., most of potassium is located intracellular and most of sodium is located extra-cellular.

Sodium- Sodium is the most abundant extra cellular positive ion. It plays a central role in the body’s electrolyte and fluid balance. An increase in the sodium concentration in the blood serum results in dehydration, certain types of renal damage causing edema (accumulation of fluid interstitially) and adrenal cortical hyper function. A reduction in sodium ion concentration in the blood serum results in diarrhea (in which the body loses sodium), in types of renal damage (that
increases excretion of sodium) and adrenal-cortical hypo function (inadequate output of hormone), as in addition's disease.

The correct potassium ion distribution is of vital importance for cell functioning. Serum must have a correct potassium concentration for normal nerve cell conduction for signal transduction and for normal muscle cell contraction.

**Calcium** – Calcium has several functions in the body. Besides being a component of skeleton, it occurs extracellularly in ionic form. The optimum calcium ion concentration is considered to be important for harmonious functioning of nerve and muscle cells. Calcium is also of importance for the permeability of cell membranes and for clotting of blood.

**Phosphate** – phosphorous metabolism is linked with calcium metabolism. This is due to the fact that the substance that endows skeleton with its hardness is hydroxyapatite (calcium phosphate). The body tends to maintain the product of calcium and phosphate ions in the plasma to be constant.

**Bicarbonate** ions are essential for maintaining the stipulated hydrogen ion concentration in the body.

**Chloride** ion is the most abundant negative ion in the extra cellular fluid. Less is known about the mechanisms of chloride ion balance, but it provides useful information regarding the presence of other positive ions in blood; i.e., chloride is displaced by the positive ions or organic acids that are not routinely measured. The presence of low chloride and low bicarbonate ion concentration is an indirect evidence of the presence of organic acid based negative ions.
Low-Molecular Weight Organic substances in Blood Serum:

The low-molecular organic substances in the blood serum consist of nutrients, which are taken up by the intestine, or which are mobilized from the body’s store, and of waste products, which are formed during the metabolism in the cells. Examples of some low molecular weight substances in blood serum with their normal values of concentration [3-5] and the diseases caused due a deviation from the normal are tabulated below.

<table>
<thead>
<tr>
<th>Substance</th>
<th>Normal value (mg/dl)</th>
<th>Disease due to elevated value</th>
<th>Disease due to lowered value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glucose</td>
<td>60-110</td>
<td>Diabetes</td>
<td>Hyperinsulinism, starvation</td>
</tr>
<tr>
<td>Triglycerides</td>
<td>20-150</td>
<td>Diabetes, hyperliproteinemia</td>
<td></td>
</tr>
<tr>
<td>Cholesterol</td>
<td>80-300</td>
<td>Diabetes, arteriosclerosis</td>
<td>Disturbed intestinal absorption, liver damage</td>
</tr>
<tr>
<td>Ketene bodies</td>
<td>1-5</td>
<td>Diabetes, starvation, dehydration</td>
<td></td>
</tr>
<tr>
<td>Creatinine</td>
<td>0.8-1.3</td>
<td>Renal failure, dehydration</td>
<td>Reduced muscle mass</td>
</tr>
<tr>
<td>Urea</td>
<td>20-45</td>
<td>Biliary stasis, liver damage</td>
<td></td>
</tr>
<tr>
<td>Bilerubin</td>
<td>&lt;0.8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
CONSTITUENTS OF BLOOD PLASMA

Water is the largest single constituent of human body. The average adult male contains about 600ml water per kg of body weight, amounting to 40 to 45 liters water. The proportion of water varies with sex, age and built. The human body consists of three main components viz., lean tissue mass, water and fat. Of these, the first two components are constant in relation, to the height (of the individual) and to each other. However, the fat is happens to be an independent variable. The water content of the body is highest in infancy, falling to adult levels in late childhood, and then tending to fall slightly (but progressively) with age. Water is present both inside and outside cells. There is a constant exchange of water between the intracellular and extra-cellular compartments, and isotopic ally labeled water is evenly distributed throughout the body fluids within half an hour of administration. Of these, the intracellular is the larger (constituting some 55 to 60% of the total body water), while the extracellular fluid constitutes only about 40% of the total body water. This extracellular fluid is further split into two main portions – the extravascular or interstitial fluid, which lies [6-8] outside the blood vessels in the interstices between the cells and the intravascular fluid or Plasma water.

The plasma volume is smaller than the total blood volume, which consists of the plasma and the volume of the erythrocytes, leucocytes and platelets. Under normal circumstances, the blood volume is constant, any alteration in red cell volume being compensated by changes in the plasma volume. Like the total volume of water in the body, the blood volume is related to height, and its proportion (in
relation to weight varies) according to the obesity of the subject. Despite this, the blood volume is usually expressed in relation to weight. In a person of average built, it is usually about 70 ml/kg of body weight and the plasma volume of about 40 ml/kg of body weight, to predict the absolute figures for blood and plasma volume of 51 and 31 respectively.

The body fluids differ greatly in their composition. Extracellular fluid occupies 45% of the fluids, while plasma water constitutes about 7.5%. Intracellular fluid is an integral part of protoplasm, and as such, contains protein. Its main cations (positive ions) are potassium and magnesium, and its main inorganic anions (negative ions) are monohydrogen phosphate, and sulphates. By contrast, extracellular fluid contains little potassium as its main cation is sodium, and anions are chloride and bicarbonates. Within the intracellular space, the composition of interstitial and intravascular fluids is almost identical except in respect of their protein content. The interstitial fluid contains only trace levels. The intravascular (plasma) fluid contains the protein at a concentration of 6 to 8 g/100ml. (Albumin 5g. and globulin 3g/100ml.). These plasma proteins play an important part in the distributions of fluid within the extracellular space.
Section C  MW Diagnostic Technique

Some of the blood plasma diagnostics are listed as below:

Coincident potassium deficit efficiently lowers the urinary and plasma potassium concentration below the normal levels. Magnesium deficiency, which causes hypercalcemia and nephrocalcuous and removal of functioning of parathyroid tumor, is recognized by plasma magnesium concentration. Water intoxication due to excessive administration and retention of water may result in the decease of kidneys. The excess retained water in the body is distributed throughout the intra and extra cellular spacing causing effluence of body fluids. The plasma of many patients with adult-type diabetes shows an increased concentration of insulin. However, the insulin activity is reduced because of binding by an antagonist. Potassium deficit causes mixed body fluid depletion.

This proposed research work mainly aims at the study of constituents of blood plasma for their concentrations, properties and electrical constants estimation of normal as well as diseased cases.

Under normal circumstances, the blood volume is considered to be constant. As such, any alteration in red cell volume is compensated by changes in the plasma volume. These changes in the plasma through underlying changes in protein content causes a variation in electrical properties of the blood, as well as causes the severity of the disease. The blood of a normal person and diseased person give distinct indications when exposed to clinical tests. In turn these indications are imperative of change in constituents and components of blood due to the disease severity. The
corresponding changes in the electrical properties viz. the dielectric constant, velocity and impedance of the blood of a normal and abnormal person is estimated by exposing the blood sample to EM radiation using the proposed method. The results of the two measurements are compared in order to obtain a possible relation.

Exhaustive measurements were carried out for estimation of various EM parameters of blood samples, collected from various hospitals and clinical laboratories using the microwave bench setup designed specially for this purpose for the following case studies.

1. Typhoid disease
2. Blood Sugar
3. Renal failure
4. Blood cancer

The dielectric measurements at microwave region can be considered as a strategic accurate diagnostic tool for the measurement severity of blood diseases.