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Novel Method of Detecting Pregnancy Using Microwaves

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ABSTRACT

This paper reports a study of the dielectric properties of pregnant women's blood samples as well non-pregnant women's blood samples at microwave frequencies. The cavity perturbation technique in the frequency range between 2 and 3 GHz was used in this study. It is observed that the dielectric constant of pregnant women's blood samples is higher than that of non-pregnant women's blood samples, and the conductivity of pregnant women's blood samples is higher than that of non-pregnant women's blood samples. This is a novel *in-vitro* method of determining pregnancy. The same samples were also subjected to investigations in the clinical laboratory for quantitative pregnancy blood tests. Determination of pregnancy will help the woman to make preparations for proper prenatal care or family planning.

Keywords: Pregnancy; Blood; Prenatal Care; Family Planning

1. Introduction

Pregnancy is the fertilization and development of one or more offspring, known as a fetus or embryo, in a woman's uterus. The beginning of pregnancy may be detected by a pregnant woman in a number of different ways, with or without medical tests, or by using medical tests with or without the assistance of a medical professional. Pregnancy symptoms differ from woman to woman and pregnancy to pregnancy. The most common pregnancy signs and symptoms are delayed or missed menstrual cycle, implantation bleeding, tender breasts, tiredness, morning sickness, backaches, headaches, frequent urination, darkening of areolas, food cravings or food aversions [1,2]. Pregnancy detection can be accomplished using one or more of various pregnancy tests, which detect hormones generated by the newly formed placenta. Clinical blood or urine tests can detect pregnancy 12 days after implantation. Blood pregnancy tests are more accurate than urine tests. Pregnancy tests with urine samples cannot detect pregnancy until at least 12 to 15 days after fertilization. A quantitative blood test can determine approximately the date the embryo was conceived [3-5]. Presence of Human Chorionic Gonadotropin (hCG) in blood or urine will determine pregnancy in a woman. hCG is a glycoprotein hormone secreted by the developing placenta shortly after a fertilized egg has implanted in the uterine lining. The presence of hCG soon after conception and its subsequent rise in concentration during early gestational growth, make it an excellent marker for the early detection of pregnancy [6]. It is important that a woman be tested as soon as she suspects pregnancy, so that she can make preparations for proper prenatal care or family planning.

The biological effects of microwave and the application of microwaves in medicine are developing areas of research. The increasing use of microwave technology is prevalent in various applications in diagnostic and therapeutic medicine [7]. The nonionizing microwave radiation interacts with tissues and obtains a large dielectric contrast according to their water content. Thus, there is a need to study the interaction of microwave with tissues especially its effect on biological materials. The key element in the microwave study is the determination of the absorbed energy. The amount of energy absorbed is a function of the complex permittivity of a material [8]. Hence, it is crucial to know the dielectric properties of biological materials and the various constituents thereof. Exhaustive studies of dielectric parameters of various human tissues and body fluids at different RF frequencies have been reported [9-11]. Different measurement techniques can be adopted to measure the complex permittivity of a material, and the chosen technique depends on various factors, such as the nature of the sample and the frequency range used [12-15]. When only very small volumes of the sample are available, the cavity perturbation technique is an attractive option as it requires only minute volumes for the measurement [16]. This makes it suitable for the dielectric study of blood as only very small volumes can be extracted by the procedure. However, no data is available for the complex permittivity of blood during pregnancy in the literature.

This paper reports dielectric properties of pregnant women's blood samples as well as non-pregnant women's blood samples using the rectangular cavity perturbation technique in the frequency range 2 to 3 GHz. It is noticed that a remarkable change in the dielectric properties of pregnant women's blood samples as well as those of non-pregnant women, and these measurements were in close agreement with clinical analysis. This microwave measurement procedure is simple and extraction of blood from women is the least painful method and nonsurgical in nature. These results provide an *in-vitro* method of detecting pregnancy based on the measurement of the dielectric properties of blood samples using microwaves

2. Sample Preparation

The blood samples were drawn from a vein on the forearm of pregnant women and non-pregnant women donors, by using a fine needle. Then each sample was treated with heparin, sealed in a sample holder at 5°C in order to prevent coagulation and to maintain its viability. Measurements were carried out on samples that were less than one day old.

3. Experimental Set-Up

The experimental set-up consists of a transmission type S-band rectangular cavity resonator, and an HP 8714 ET network analyser. The cavity resonator is a transmission line with one or both ends closed. The numbers of resonant frequencies are determined by the length of the resonator. The resonator in this set-up is excited in the $TE_{10\rho}$ mode. The sample holder, which is made of glass in the form of a capillary tube flared to a disk-shaped bulb at the bottom, is placed into the cavity through the non radiating cavity slot at the broader side of the cavity to facilitate the easy movement of the holder. The resonant frequency f_o and the corresponding quality factor Q_o of the cavity at each resonant peak with the empty sample holder placed at the maximum electric field, are noted. The same holder filled with a known amount of the sample under study is again introduced into the cavity resonator through the non-radiating slot. The resonant frequency of the sample-loaded cavity is selected and the position of the sample is adjusted for maximum perturbation (*i.e.* maximum shift of resonant frequency with minimum amplitude for the peak). The new resonant frequency f_s and the quality factor Q_s are noted. The same procedure is repeated for other resonant frequencies.

4. Theory

When a material is introduced into a resonant cavity, the cavity field distribution and resonant frequency, which depend on shape, electromagnetic properties and its position in the fields of the cavity, are changed. Dielectric material interacts only with the electric field in the cavity.

According to the theory of cavity perturbation, the complex frequency shift is related as [16]

$$-\frac{d\Omega}{\Omega} \approx \frac{(\bar{\varepsilon}_r - 1)\int\limits_{V_s} E \cdot E_0^* dV}{2\int\limits_{V_c} |E_0|^2 dV} \qquad (1)$$

$$\frac{d\Omega}{\Omega} \approx \frac{d\omega}{\omega} + \frac{j}{2}\left[\frac{1}{Q_s} - \frac{1}{Q_o}\right] \qquad (2)$$

Equating (1) and (2) and separating real and imaginary parts results

$$\varepsilon_r' - 1 = \frac{f_o - f_s}{2f_s}\left(\frac{V_c}{V_s}\right) \qquad (3)$$

$$\varepsilon_r'' = \frac{V_c}{4V_s}\left(\frac{Q_o - Q_s}{Q_o Q_s}\right) \qquad (4)$$

Here, $\bar{\varepsilon}_r = \varepsilon_r'\varepsilon_r'z - j\varepsilon_r''$, $\bar{\varepsilon}$ is the relative complex permittivity of the sample, ε_r' is the real part of the relative complex permittivity, which is known as dielectric constant. ε_r'' is the imaginary part of the relative complex permittivity associated with the dielectric loss of the material. V_s and V_c are corresponding volumes of the sample and the cavity resonator. The conductivity can be related to the imaginary part of the complex dielectric constant as

$$\sigma_e = \omega\varepsilon'' = 2\pi f \varepsilon_0 \varepsilon'' \qquad (5)$$

## 5. Results and Discussions

Quantitative analysis of various blood samples is made in the clinical laboratory and is shown in **Table 1**. The microwave studies of the same samples done using cavity perturbation technique are shown in **Figures 1** and **2**. From **Figure 1** it is observed that the dielectric constant of the pregnant women's blood samples is higher than that of non-pregnant women. This increase in the dielectric constant is attributed to the increased presence of the hormone hCG. As gestational growth develops, the hCG content in the blood increases, which will increase the dielectric constant. From **Figure 2** it is observed that the conductivity of the pregnant women's blood samples is higher than that of non-pregnant women. This increase in conductivity is due to presence of hCG in pregnant women's blood samples.

6. Conclusion

The cavity perturbation technique is quick and will not have any reaction time like test strips and midstream tests. The procedure is simple and accurate for measuring and can detect the presence of hCG. The dielectric constant

Table 1. Quantitative analysis of blood in the clinical laboratory.

Pregnant				
	P-1	P-2	P-3	P-4
Hemoglobin (g/dl)	15	16	15	14
Red cell count (10^{12}/l)	4.85	5.23	4.78	5.02
Hematocrit (%)	42.5	47.8	46.3	45.7
White cell count (10^9/l)	5.53	6.49	4.61	4.32
Neutrophils (%)	63.1	60.3	64.4	61.7
Platelet count (10^9/l)	278	306	332	260
ESR (mm/hr)	13	21	19	17
Sodium (mmol/l)	137	140	139	138
Potassium (mmol/l)	4.2	3.6	4.1	4.7
hCG (mIU/mL)	22	31	29	17
Non-pregnant				
	NP-1	NP-2	NP-3	NP-4
Hemoglobin (g/dl)	14	15	13	17
Red cell count (10^{12}/l)	4.92	4.87	5.12	4.72
Hematocrit (%)	41.3	44.7	45.1	48.3
White cell count (10^9/l)	4.41	7.73	6.32	5.98
Neutrophils (%)	62.8	65.5	66.1	60.8
Platelet count (10^9/l)	356	398	291	272
ESR (mm/hr)	25	23	16	12
Sodium (mmol/l)	139	142	141	140
Potassium (mmol/l)	3.8	4.9	4.2	4.3
hCG (mIU/mL)	2	1	1	2
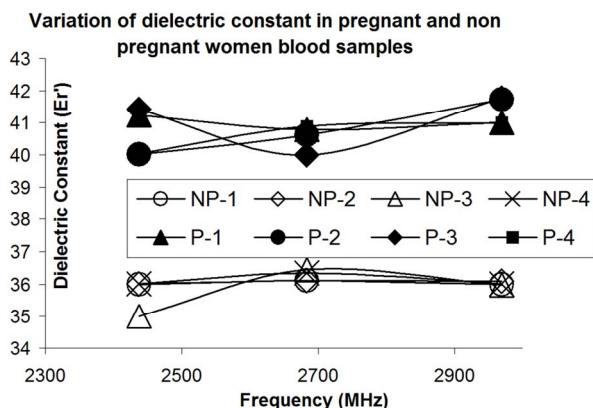
Figure 1. Variation of dielectric constant in pregnant women's blood samples and non-pregnant women's blood samples.
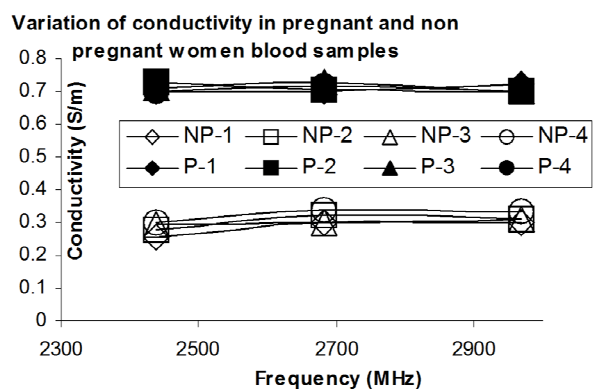
Figure 2. Variation of conductivities in pregnant women's and non-pregnant women's blood samples.

of pregnant women's blood samples is higher than that of non-pregnant women's blood samples and the conductivity of pregnant women's blood samples is higher than that of non-pregnant women's blood samples, from which pregnancy can be determined. This is an *in-vitro* method of determining pregnancy, which will help the woman to make preparations for proper prenatal care or family planning.

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