

## **ANALYSIS OF HUMAN BREAST MILK AT MICROWAVE FREQUENCIES**

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**Abstract**—In this communication a comprehensive study of the dielectric properties of human breast milk at microwave frequencies is reported. The samples are collected at weekly intervals following child birth. Measurements are made at the *S*-band of microwave frequency employing the rectangular cavity perturbation technique. The dielectric constants of the breast milk samples are found to increase as weeks elapse, which is attributed to the reduced fat content and increased lactose concentration. The conductivity of the breast milk samples is similarly found to increase due to the increased dilution.

### **1. INTRODUCTION**

Electromagnetic radiation has been used as a therapeutic agent in medicine for many years. Recently several studies of the biological effects of the microwave radiations and the possibilities of their use in medicine have been made. Microwave radiation is a useful thermogenic agent in the practice of physiotherapy if the problems of dosage measurement and method of application to patients could be solved [1]. Concurrently, the search for any specific action of intense microwave fields on microorganisms, virus and other biological molecules has been commenced [2]. From the point of view of microwave propagation, most materials of biological interest can be regarded as lossy dielectrics,

which are frequently macroscopically or microscopically heterogeneous. The processes by which dielectric loss occurs and thereby energy is transferred to the medium depend obviously on the nature of the material and the frequency range of radiations in use. Exhaustive studies of dielectric parameters of various human tissues and body fluids at different RF frequencies have been reported [3–5]. Different measurement techniques have been developed for the measurement of dielectric properties of biological samples at various band of frequencies [6]. Active and passive microwave imaging for disease detection and treatment require proper knowledge of body tissue dielectric properties at the microwave frequencies [7, 8].

A comprehensive study of the dielectric properties of human breast milk at microwave frequencies is reported here. The samples (all donors being Indian women) were collected at weekly intervals following child birth. Measurements are made at the *S*-band of microwave frequency.

## 2. MEASUREMENT TECHNIQUE

The measurement set-up consists of an *S*-band rectangular cavity resonator connected to HP 8714 ET network analyzer. The rectangular cavity resonator is made of rectangular wave guide one or both ends closed and it can be either transmission or reflection type [9]. In this experiment a transmission type cavity resonator is employed. The number of resonant frequencies depends on the length of the resonator. The resonator is excited in the  $TE_{10P}$  mode. The resonant frequency  $f_0$  and the corresponding quality factor  $Q_0$  of each resonant peak of the cavity resonator with the empty sample holder placed at the maximum electric field are noted. The shape of the sample holder is in the form of a capillary tube flared to a disk shaped bulb to facilitate easy movement of the same through the non radiating cavity slot. The sample holder filled with a known amount of the sample is introduced into the cavity resonator. The resonant frequencies of the sample-loaded cavity are 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 corresponding quality factor  $Q_s$  are determined. The same procedure is repeated for other resonant frequencies

## 3. THEORY

When a material is introduced into a resonant cavity, the cavity field distribution and resonant frequency are changed which depend on geometry, electromagnetic properties and its position in the fields of

the cavity. Dielectric material interacts only with electric field in the cavity.

According to the theory of cavity perturbation, the complex frequency shift is related as [9]

$$-\frac{d\Omega}{\Omega} \approx \frac{(\bar{\epsilon}_r - 1) \int_{V_s} E \cdot E_0^* dV}{2 \int_{V_c} |E_0|^2 dV} \quad (1)$$

But

$$\frac{d\Omega}{\Omega} \approx \frac{d\omega}{\omega} + \frac{j}{2} \left[ \frac{1}{Q_s} - \frac{1}{Q_0} \right] \quad (2)$$

Equating (1) and (2) and separating real and imaginary parts we get

$$\epsilon'_r - 1 = \frac{f_0 - f_s}{2f_s} \left( \frac{V_c}{V_s} \right) \quad (3)$$

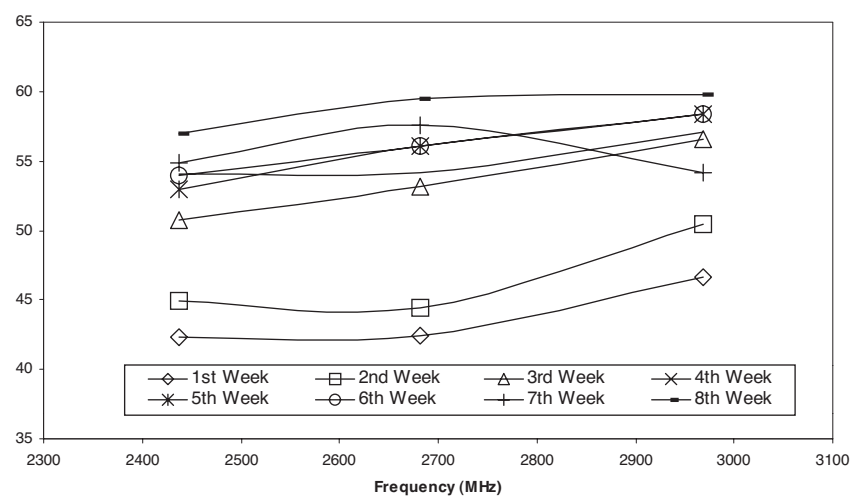
$$\epsilon''_r = \frac{V_c}{4V_s} \left( \frac{Q_0 - Q_s}{Q_0 Q_s} \right) \quad (4)$$

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

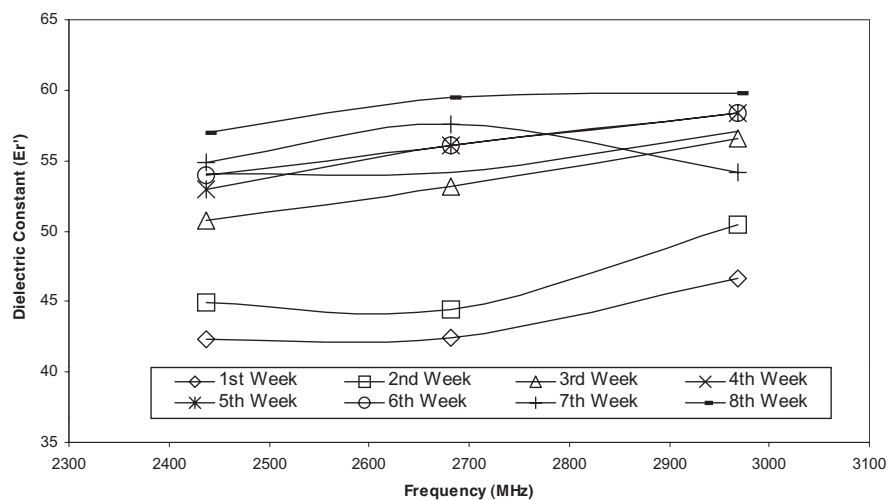
$$\sigma_e = \omega \epsilon'' = 2\pi f \epsilon_0 \epsilon''_r \quad (5)$$

#### 4. RESULTS AND DISCUSSION

The microwave studies of the breast milk samples are done using the cavity perturbation technique and the results are shown in Figs. 1–4. The samples were collected from the donors at weekly intervals from the first to the eighth week following child birth. From Figs. 1 & 2 it is found that the dielectric constant of the breast milk samples increases as weeks elapse. This increase indicates that the fat content in the breast milk decreases and there is a rise in the concentration of lactose as time elapses (Table 1). The results suggest that this method is an indirect way to compare the fat content rather than going for traditional chemical examination, which is time consuming. From Figs. 3 & 4 it is seen that the conductivity of the breast milk also increases with time. This is attributed to the increased dilution of the breast milk with time.



**Figure 1.** Dielectric constant variation of Sample 1.



**Figure 2.** Dielectric constant variation of Sample 2.

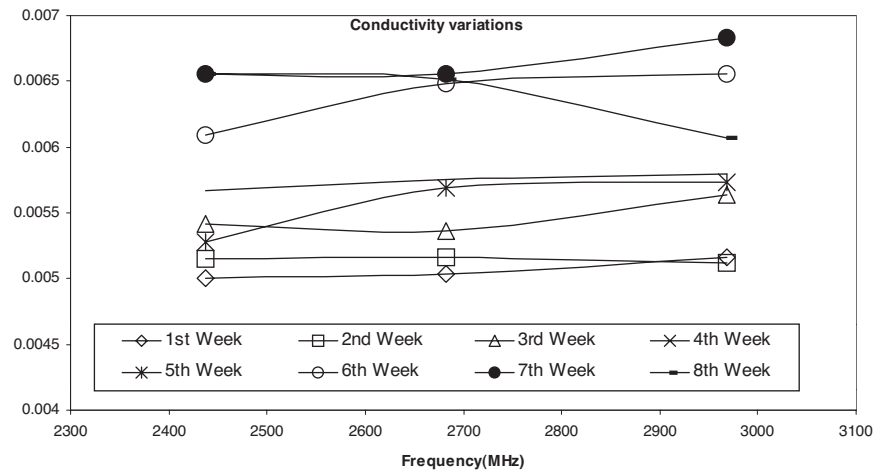


Figure 3. Conductivity variations.

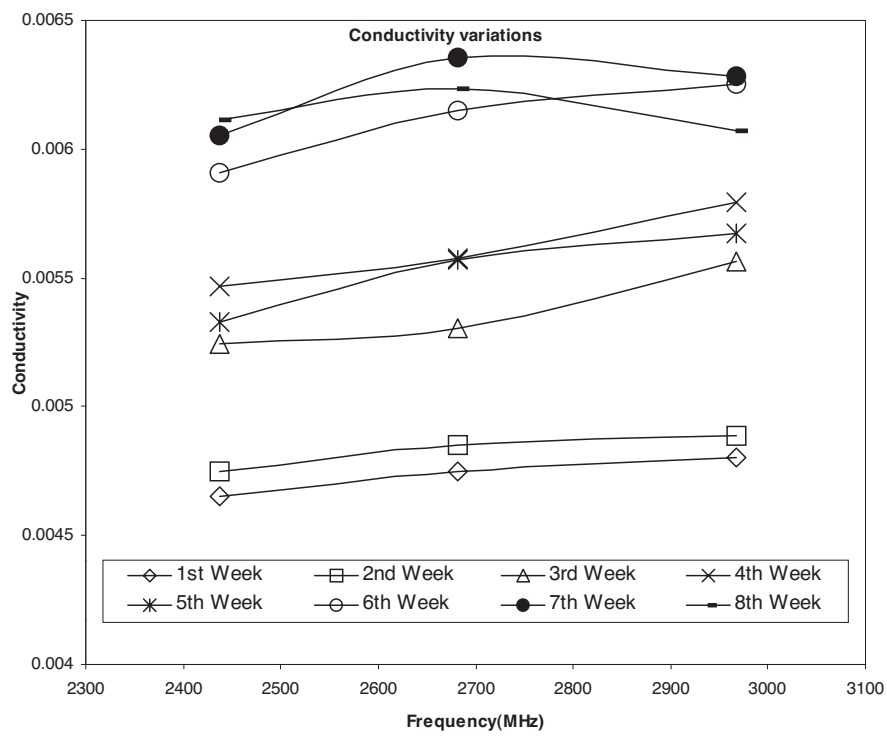


Figure 4. Conductivity variations.

**Table 1.** Quantitative analysis of breast milk.

Constituents	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Milk fat	13.6%	12.4%	11.3%	10.2%	9.8%	9.1%	8.3%	8.2%
Milk solids not fat	8.5%	8.9%	9.3%	9.9%	11.2%	13.4%	13.2%	13.4%
Protein	3.3%	3.6%	3.4%	3.3%	3.6%	3.3%	3.5%	3.1%

## 5. CONCLUSION

This experiment is an alternative in vitro method of analyzing human milk to the conventional techniques of chemical analysis. The technique is quick, simple and accurate and requires less volume of the samples. The permittivity profiles indicate that the dielectric constant increases as time progresses, which indicates the presence of increased water content and lactose concentration and the fall in fat content. Similarly the conductivity of the samples also increases with time, which is attributed to the increased dilution of the breast milk.

## ACKNOWLEDGMENT

Authors Anil Lonappan and G. Bindu thankfully acknowledge Council of Scientific and Industrial Research (CSIR), Government of India for providing Senior Research Fellowship. Author Vinu Thomas thanks the Institute of Human Resource Development, Government of Kerala for providing sponsorship for the research.

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