ISSN (Online) : 2278-1021
ISSN (Print) : 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 3, Issue 1, January 2014

STUDY OF CHARACTERISTICS FOR DIELECTRIC PROPERTIES OF VARIOUS BIOLOGICAL TISSUES

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Abstract: In this paper, the intensive investigations are carried out of various biological tissues from human and animals bodies. In the literature survey some of the researchers are attempted to evaluate the dielectric properties of various biological tissues using electromagnetic energy. In the above facts the author carried out the behavior of biological tissues using different frequencies for evaluating dielectric properties like conductivity, relative permeability, and relative permittivity at different temperature. These results are observed at the frequency range 10Hz to 100GHz, for various tissues of human and animals.

Index Terms: Dielectric properties, Frequency, Biological Tissues

1. INTRODUCTION

The electrical properties of biological tissues provide the ability to interact with electromagnetic energy. The interaction is affected by electric and magnetic forces created by electromagnetic fields. Basically biological tissue is a non-magnetic material (1). If an electromagnetic field is applied, it acts on different tissues on the body, which is characterized by the presence electric charge. As a result it exhibits electric dipole moment (2-5). This moment in tissues is created by polar molecules. The biological tissues are many in number, for example muscle, fat and bone marrow etc. The properties of these tissues depend on many factors (6). It is understood from dielectric dispersions, variation of parameters as a function of frequency tissues type, the behavior of tissue electrical properties are useful to find different physiological conditions.

In a particular biological tissue under the influence of waves created by Electromagnetic field, a heat wave is released instantaneously. Under these conditions the methods of conduction, radiation, convection, and absorption are also responsible to create temperature equilibrium (7). In most of the cases the tissue is polarized and depolarization takes place with inter molecular system for friction and hysteresis.

2. DIELECTRIC PROPERTIES OF BIOLOGICAL TISSUES

Assuming molecule as a point at the center of a cavity with its volume as $1/N$ and radius as $(3/4\pi N)^{1/3}$, the dipole moment is given by

$$P = \text{volume} \times p \qquad (1)$$

$$= 4\pi r^3 p/3$$

$$= 4\pi r^3 \varepsilon_0 (\varepsilon_r - 1) E/3$$

$$E = 3p/(4\pi r^3 \varepsilon_0 (\varepsilon_r - 1)) \qquad (2)$$

If the applied field is small compared to that of internal agitation energy, the polarization is given by

$$p = fNp^2 E/3k \qquad (3)$$

Here k is Boltzmann constant

f is frequency of applied field

The dielectric properties of biological tissues are basically complex when polarized with dielectric field. This is a result of conduction and displacement currents, as it is well known that the conduction current represents the current flow, that e is in phase with applied voltage and displacement currents are in phase quadrature. The complex permittivity is given by

$$\varepsilon_c = \varepsilon_r' - j\varepsilon_i'' \qquad (4)$$

ε_r' is real part

ε_i'' is imaginary part of the complex permittivity

The real and imaginary parts represent the process of energy storage and distribution respectively. The generated heat depends on frequency and dielectric loss factor. These are related to the conductivity is given by

$$\sigma = \omega \varepsilon_0 \varepsilon_i \tag{5}$$

And the loss tangent,

$$\tan \delta = \frac{\varepsilon_i}{\varepsilon_r} \tag{6}$$

When the tissue absorb the applied energy, it absorption coefficient is expressed as

$$a_c = \frac{\pi\varepsilon_r''f}{V_0\sqrt{\varepsilon_r 2+\varepsilon_i 2)}} \tag{7}$$

Here a_c is the absorption coefficient

If τ is dielectric relavations time which is related to ε_c by the following expression

$$\varepsilon_c = \varepsilon_{ro} + \frac{\varepsilon_{rs}-\varepsilon_{ro}}{1+j\omega\tau} \tag{8}$$

ε_{rs} is static relative permittivity. This is measured at dc

ε_{ro} is optical relative permittivity. This is measured at optical frequency.

$$\varepsilon_r = \varepsilon_{ro} + \frac{\varepsilon_{rs}-\varepsilon_{ro}}{(1+\omega\tau)^2} \tag{9}$$

$$\varepsilon_i = \varepsilon_{ro} + \frac{(\varepsilon_{rs}-\varepsilon_{ro})\omega\tau}{(1+\omega\tau)^2} \tag{10}$$

3. FIELD COMPONENTS OF TEM MODE

The field components of TEM mode are given by

$$E^o{}_{ps} = \frac{A}{\rho}e^{j\beta z} + \frac{B}{\rho}e^{j\beta z} \tag{11}$$

$$H_{\varphi s}{}^0 = \frac{A}{\eta\rho}e^{j\beta z} + \frac{B}{\eta\rho}e^{j\beta z} \tag{12}$$

Here η is intrinsic impedance of free space

A and B are constants

Applying boundary conditions at z=0 and L,

We get $A = -B$

$$E_{ps}{}^o = \frac{A}{\rho}\sin\beta z = E_{0,max}\sin\beta z \tag{13}$$

$$H_{\varphi s}{}^0 = \frac{A}{\eta\rho}\cos\beta z = H_{o,max}\cos\beta z \tag{14}$$

The stored energy in the cavity is

$$W_e = \frac{\varepsilon_0}{2}\int E_{ps}^{0\ 2}dv \tag{15}$$

$$W_e = \frac{\varepsilon_0}{2}\int_0^{2\pi}\int_b^a\int_0^l E_{0,max}{}^2\sin^2\beta z\rho d\varphi dz \tag{16}$$

Here a is inner radius of the coaxial resonator

b is outer radius of the coaxial resonator

If a sample is kept in the cavity, the relative frequency shift becomes

$$-\frac{dF}{F} = (\varepsilon_r - 1)G\int_v E.E^*_{0,max}dv + \frac{(\mu_r - 1)\mu_0\int_v H.H^*_{0,max}dv}{\int_v (D_0E^*_{0,max} + B_0H^*_{0,max})dv} \tag{17}$$

The numerator is energy stored in sample and the denominator is total energy stored in the cavity $4W_e$. Maximum electric field

$$-\frac{dF}{F} = \frac{(\varepsilon_r - 1)\varepsilon_0 \int_v E^0_{ps} E^*_{0,max} dv}{4W_e} \tag{18}$$

$$= \frac{(\varepsilon_r - 1)v_s}{4\pi\pi(^2 - a^2)\frac{L}{2}}$$

$$= \frac{(\varepsilon_r - 1)v_s}{\pi l(b^2 - a^2)}$$

Here

$$\varepsilon_{\rho s}{}^0 = \varepsilon^*{}_0 \tag{19}$$

$$v = \pi r^2 (b - a) \tag{20}$$

r is the radius of the sample

also $\varepsilon_c = \varepsilon_r - j\varepsilon_i$

$$-\frac{dF}{F} = \frac{(\varepsilon_r - 1)r^2}{L(b+a)} + j\frac{\varepsilon_i r^2}{L(b+a)} \tag{21}$$

$$= \frac{f_s - f_0}{f_s} + \frac{j}{2}\left(\frac{1}{Q_s} - \frac{1}{Q_0}\right) \tag{22}$$

$$(\varepsilon_r - 1) = \frac{L(b+a)}{r^2}\frac{(f_0 - f_s)}{f_s} \tag{23}$$

if $\sigma \neq 0$ for a dielectric material

$$\tan\sigma = \frac{\sigma + \omega\varepsilon}{\omega\varepsilon} \tag{24}$$

The effective conductivity σ_e is

$$\sigma_e = \sigma + \omega\varepsilon \tag{25}$$

For small σ

$$\sigma_e = \omega\varepsilon = 2\pi f\varepsilon_0 \tag{26}$$

And $\tan\delta = \frac{\varepsilon_s'}{\varepsilon_r}$

It is also possible to produce different resonant frequencies with a transmission type rectangular cavity. The number of resonant frequencies is determined from the length of the resonator it is excited in the TE_{10p} mode. An expression for the resonant frequency shift is obtained as,

$$\frac{\omega - \omega_0}{\omega} = \frac{\int(\Delta\Delta\varepsilon E.{}^*{}_0 + \Delta\mu H.H^*{}_0)dr}{\int(\varepsilon\varepsilon E.{}_0{}^* + \mu H.H^*{}_0)dr} \tag{27}$$

4. RESULTS

The variation in relative permittivity and conductivity the following different tissues as a function of frequency are presented in figs (1-10).

- For varied tissues, relative permittivity Vs frequency fig (1).
- For varied tissues, conductivity Vs frequency fig (2).
- For varied tissues, relative permittivity Vs frequency fig (3).
- For varied tissues, conductivity Vs frequency fig (4).
- For varied tissues, relative permittivity Vs frequency fig (5).
- For varied tissues, conductivity Vs frequency fig (6).
- For varied tissues, relative permittivity Vs frequency fig (7).
- For varied tissues, conductivity Vs frequency fig (8).
- For varied tissues, relative permittivity Vs frequency fig (9).
- For varied tissues, conductivity Vs frequency fig (10).

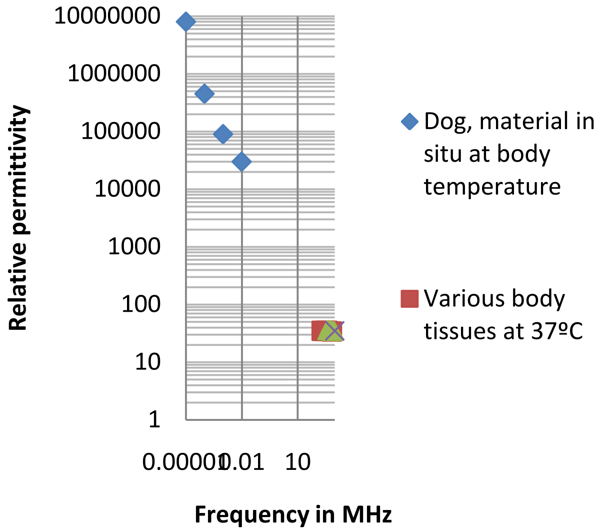

Fig. 1. Dielectric properties of *various lung tissues* Relative Permittivity

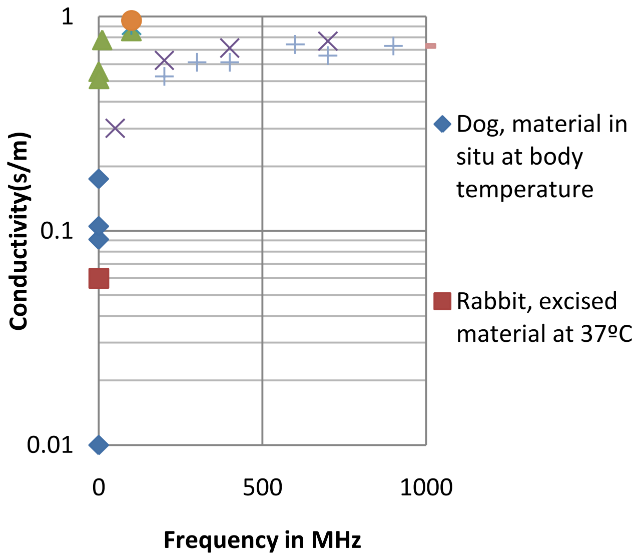

Fig. 2. Dielectric properties of *various lung tissues Conductivity(s/m)*

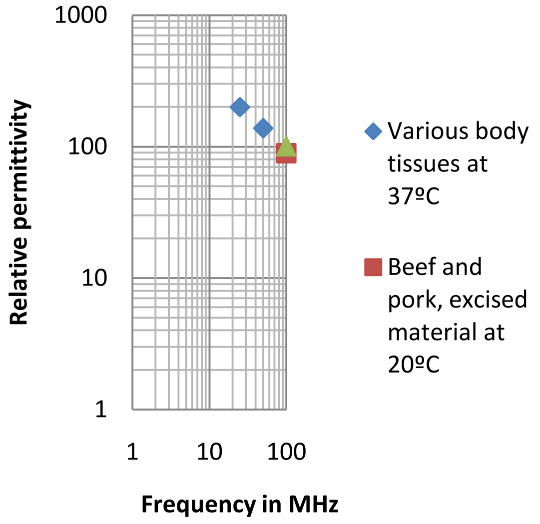

Fig. 3. Dielectric properties of *various spleen tissues* Relative Permittivity

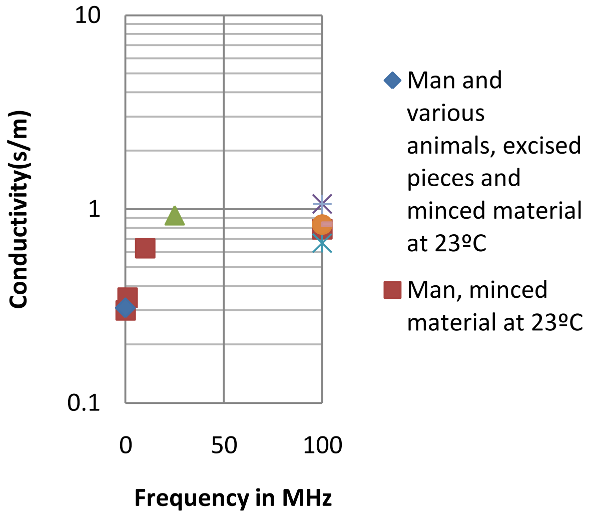

Fig. 4. Dielectric properties of *various spleen tissues Conductivity(s/m)*

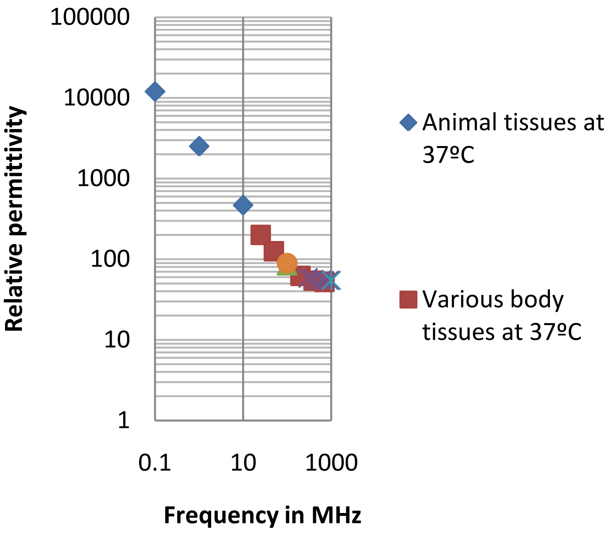

Fig. 5. Dielectric properties of *various kidney tissues* Relative Permittivity

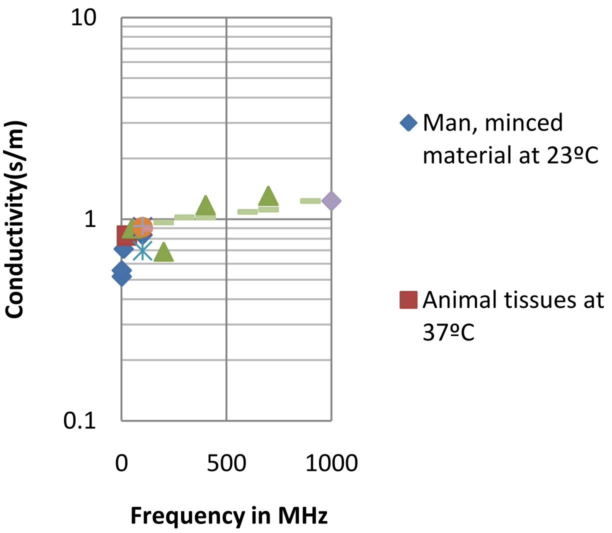

Fig. 6. Dielectric properties of *various kidney tissues Conductivity(s/m)*

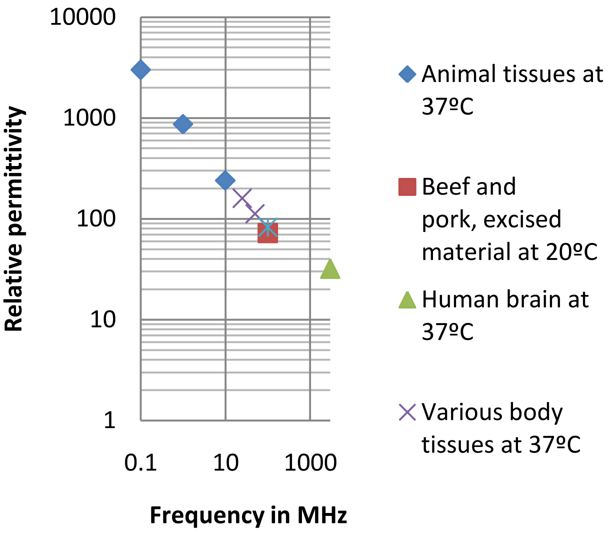

Fig. 7. Dielectric properties of *various brain tissues* Relative Permittivity

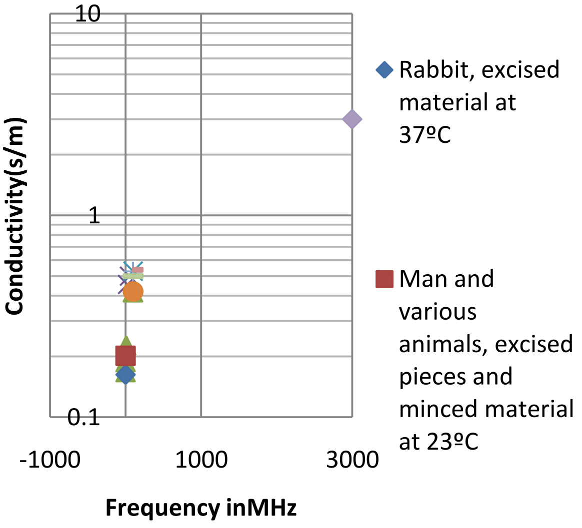

Fig. 8. Dielectric properties of *various brain tissues Conductivity(s/m)*

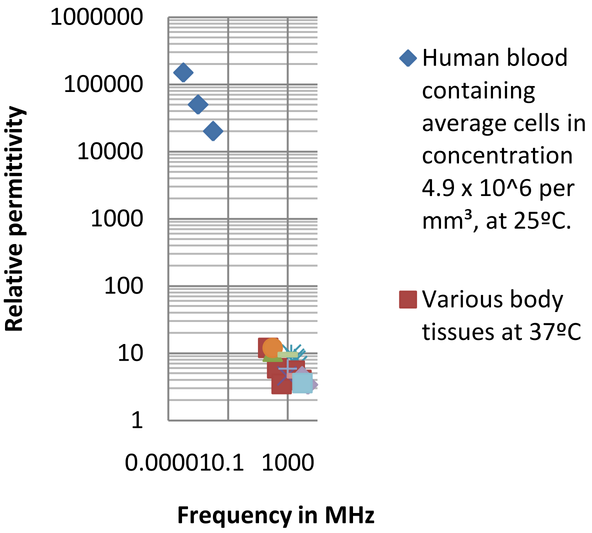

Fig. 9. Dielectric properties of *various fatty tissues* Relative Permittivity

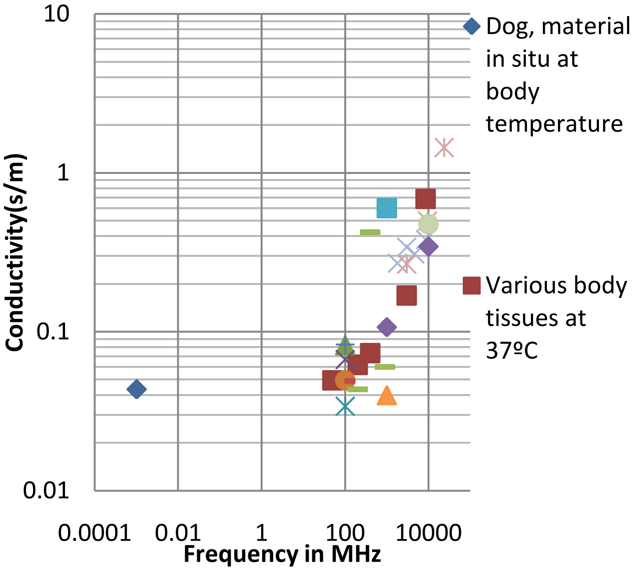

Fig. 10. Dielectric properties of *various fatty tissues* *Conductivity(s/m)*

5. CONCLUSIONS

From the results fig. (1-10), the properties of dielectric materials varying the frequency are observed. These results are very much useful to detect the cancerous tissue in the human and animal bodies.

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BIOGRAPHIES

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