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Study on Microwave Propagation Properties of Skeletal Muscle

Dr.M.Sarada,
Assistant Professor of Physics,
KVR Government College for Women (A), Kurnool, Andhra Pradesh, India

Abstract

A Biological body is represented as heterogeneous and lossy dielectric, whose macroscopic electrical properties are described by complex permittivity. The electrical properties of biological tissues control the propagation, reflection, attenuation and other behavior of electromagnetic fields. These properties are to a great extent, responsible for the interaction of electromagnetic fields with molecules and biological super molecular structures. The present paper deals with the measurement of dielectric properties such as dielectric constant, dielectric loss, loss factor, conductivity, attenuation constant, percentage of power absorbed and percentage of power reflected of a skeletal of animal ox at X band (8.96GHz) microwave frequency. 2K25 reflex Klystron, rectangular wave guide, drum type frequency meter are the parts of microwave instrumentation. Short circuited two point method is employed for the measurement. The fresh excised soft tissues are taken for the study where the length of the sample is less than one fourth of the guide wavelength. The observed parameters are guide wavelength, position of first voltage minimum with air in the wave guide, with sample in the wave guide and voltage standing wave ratio. The requisite parameters of the tissue are propagation constant, phase difference and reflection coefficient. A complex transcendental equation is solved from vonhipple chart. Dielectric properties are calculated from the mean value of admittance for a pair of length of the sample. The study shows that the tissue dielectric properties are characterized at microwave frequency range.

Key words: Skeletal Muscle, Dielectric properties, Microwave frequency

1. Introduction

A living body is made up of a complex structure of biological tissue (lossy dielectric) with very dissimilar electric properties (dielectric permittivity and conductivity). These properties are, to a great extent, responsible for the interaction of electromagnetic fields with molecules and biological super molecular structures.

The proper knowledge of the dielectric properties of the biological systems is essential either to determine safe levels for the personnel exposure to electromagnetic radiation or to effectively employ electromagnetic radiation in beneficial biomedical application [1]. Thus the measurement of dielectric properties of biological tissues would play a significant role in any well founded effort containing tissue interaction with electromagnetic energy. It is well recognized that radiofrequency and microwave energy can be effectively used in the treatment of many diseases. It must be considered that the dielectric properties of the tissues will determine the absorption and propagation of electromagnetic energy through the tissues. So from the knowledge of dielectric constant, tissue properties can be characterized in the microwave frequency range. Dielectric constant is one of the important parameter to predict the nature of biological tissue at microwave frequency range [2].

In view of the above, an attempt is made to study the dielectric properties of biological tissues at microwave frequencies.

2. Materials and methods

2.1 Sample collection and preparation

The biological soft tissues of animal ox (Skeletal Muscle) are collected from local market. The sample is collected within 6hrs of slaughtering. The fresh excised tissues of different individuals are taken for experimentation.

The fresh excised tissues that are under study of different individuals are cut into a rectangular wave guide dimensions (2.2cm x 0.95cm) of different lengths. The cross sectional area of all samples is equal. In microwave dielectric measurement of tissues, where transcendental equations are applied, the sample thickness should be about one quarter of a wave length of the radiation ($\lambda_g/4$) contained in the sample [3]. In order to ensure no loss of water content, the samples were kept in Petri dishes and closed [4]. The thickness of the sample should match the wave guide dimensions. Every care is taken to see that there is no air gap in the sample. The sample of the tissue is so flexible, that it takes the shape of the wave guide.

Fig. 2.1 Specimen of skeletal Muscle

2.2 Experimental setup

Fig. 2.2 shows a block diagram of experimental set-up for measuring dielectric parameters of a biological soft tissue at microwave frequency. Microwave bench and wave guide is shown in Fig.2.3

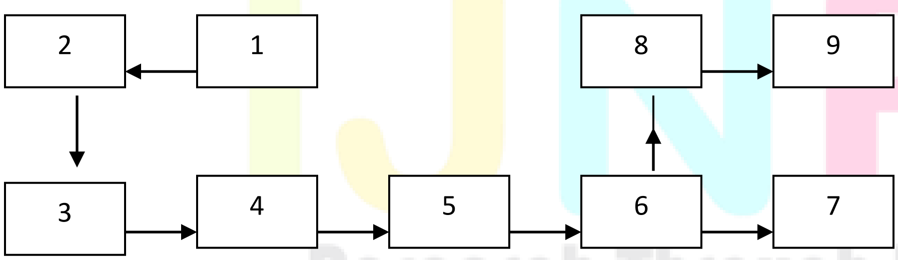

Fig. 2.2 Block diagram of X -band Microwave Bench

1. Klystron power supply
2. Reflex Klystron.
3. Isolator
4. Attenuator
5. Frequency meter.
6. Slotted Section
7. Short circuited wave guide
8. Tunable detector.
9. VSWR meter

Wage guide

Fig. 2.3 Microwave setup

2.3 Experimental procedure

Two point method is employed for the measurement of dielectric parameters of biological soft tissues at microwave frequency (X – band). A rectangular wave guide is used. Reflex Klystron is the source of microwave power. Klystron is set into operation by applying beam voltage, repeller voltage and beam current through Klystron power supply. To avoid damaging of the Klystron, repeller voltage is applied before beam voltage. The frequency of operation is measured by means of drum type frequency meter. It is measured by rotating frequency meter and observing resonance dip in cathode ray oscilloscope. The frequency of operation varies with respect to repeller voltage.

The attenuator should be kept at minimum attenuation position for microwave transmission. With the air inside, the wave guide is short-circuited. A stationery wave is formed inside the wave guide. The voltage of the maxima and minima of a stationery wave is detected by a diode and measured by VSWR meter. With air inside the waveguide, the plunger is moved along the slotted section and the position of first voltage minimum (D_R) is noted on the scale by observing in VSWR meter. The least count of the Vernier Scale of the slotted section is 0.01 cm.

The positions of first, second and third minima are noted on the scale with air in the wave guide. The difference of the positions of first and second minima or second and third minima gives the half of the wave length of stationery wave.

After noting down the value of D_R and λg, the sample of definite length is introduced into the wave guide and short-circuited. The position of the first voltage minimum (D) is noted by observing VSWR meter. By moving a plunger on the slotted section, voltage standing wave ratio(S) of the sample is measured by VSWR meter. The experiment is repeated for different lengths of the sample of different individuals.

The electromagnetic field at any point of a transmission line is considered as the sum of two traveling waves. The wave from the generator incident on the load is reflected towards the generator due to mismatch. The reflected wave will combine with the forward waves to give a standing wave pattern. The maximum field strength is found when two waves add in phase and the minimum occurs when the two add in opposite phase. The ratio of the amplitude of the maximum to the minimum field strength of the wave is called voltage standing wave ratio.

$$VSWR = \frac{E_{max}}{E_{\min}}$$

The ratio of E_{max} and E_{min} are calibrated in VSWR meter. VSWR lies between

1 and ∞

Measurement of high VSWR(S>10) is done by double the minimum method using the formula, $VSWR = \frac{\lambda_g}{\pi(X_1 - X_2)}$ where X_1 and X2 are the positions of the probe for full scale deflection.

2.4 Calculation of dielectric parameters of tissue

A pair of different lengths of the tissue of an individual is taken as a single entity. A pair of different lengths of the tissue of different individuals is considered to calculate mean value of dielectric parameters

A sample whose length is less than $\lambda_g/4$ is inserted into the wave guide and is short circuited. The position of the first voltage minimum with the sample in the wave guide is noted. Voltage standing wave ratio is measured by VSWR meter. The value of l_ε , D, D_R and S are the observed parameters of the tissue.

A complex transcendental equation is computed using Mathlab Software programme. The value of C,ψ are known from computation. The complex transcendental equation is solved by knowing the values of X and θ corresponding to $C \angle -\psi$ and $\frac{1}{c}\angle -\psi$ from Von- hipple charts for a pair of lengths of the sample. The admittance corresponding to X and θ of $C\angle -\psi$ and $\frac{1}{c}\angle -\psi$ of a pair of lengths is computed. For a given pair of lengths of the sample, the admittance corresponding to either $C\angle -\psi$ or $\frac{1}{c}\angle -\psi$ will coincide approximately. The mean value of admittance for a pair of lengths of the sample is calculated. The dielectric properties such as dielectric constant, dielectric loss, conductivity, loss tangent, attenuation coefficient, percentage of power reflected and percentage of power absorbed are calculated from equations mentioned elsewhere [5].

3. Results

The Results of the experiment are tabulated in table-1 to table 2.

Table 1 - Data on observed parameters of biological tissue - skeletal muscle.

S.No.	*Tissue*	*Sample code*	*l_ϵ(cm)*	*D_R (cm)*	*D (cm)*	*VSWR (S)*
1	SKELETAL MUSCLE	SM1	0.4	8.06	8.52	13
		SM2	0.6	8.06	8.71	13
2		SM1	0.4	8.06	8.41	12
		SM2	0.6	8.06	8.73	13
3		SM1	0.4	8.06	8.52	13
		SM2	0.6	8.06	8.71	12
4		SM1	0.4	8.06	8.52	12

	SM2	0.6	8.06	8.79	13
5	SM1	0.4	8.06	8.59	11
	SM2	0.6	8.06	8.69	12

l_ϵ: Length of the sample

D_R: Position of the first minimum with air in the wave guide

D: Position of the first minimum with sample in the wave guide

S: Voltage standing wave ratio (VSWR)

Table 2 - Data on Microwave propagation properties of Biological Tissues-skeletal muscle.

S. No	*Sample code*	ε'	ε''	*Tan δ*	*σ (mho/cm)*	α (cm^{-1})	*% PR*	*%PA*
1	SM I	46.96	6.37	0.135	318.50	0.87	73.40	26.50
2	SM II	47.80	7.70	0.161	385.0	1.04	72.40	27.50
3	SM III	46.96	6.37	0.135	318.50	0.87	72.40	27.50
4	SM IV	31.06	4.83	0.156	241.50	0.81	72.40	27.50
5	SM V	48.12	5.42	0.112	271.00	0.73	71.06	28.93
	Mean +SD	44.18 ±6.57	6.13 ±0.97	0.14 ±0.017	306.9 ±48.85	0.864 ±0.102	72.33 ±0.74	27.58 ±0.77

ε' : Dielectric constant.

ε'' : Dielectric loss.

Tan δ : Loss Tangent.

σ : Conductivity.

α : Attenuation coefficient.

% PR : Percentage of power reflected.

%PA : Percentage of power absorbed.

4. Conclusion

The results of the study show that the dielectric parameters are high for a skeletal muscle which is a contractile tissue due to long and thick fibrous nature of the tissue. The results show that the dielectric loss, conductivity and attenuation constant are directly related to each other. The tissues interact, absorbs and propagate electromagnetic radiation through it which is a characteristic property that is determined by its anatomical features.

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