Measurement of the Electrical Properties of Spelled Grains – T. Dicoccum

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Abstract

The aim of this work is to present the measurements of electrical properties on sample of spelled grains with glumes, of which had not been sufficiently measured. Electrical properties were measured with LCR meter. Resistance R, capacity C, relative permittivity ε_r of sample of spelled in different frequency intervals were measured. The results are presented graphically and analytically. Obtained results were analyzed. The measured values and results obtained allow to conclude that resistance, capacity and relative permittivity of spelled functionally dependent on the frequency, as obtained by other authors. The study was developed in response to the global trend to increase and control the quality of plant production and increased interest in the production and consumption of healthy and organic food (De Vita et al, 2006). Increased productivity of traditional crops requires hard work and guidance in improving product quality. This explains the increasing interest towards spelled - T. Dicoccum, which is a valuable source of vitamins, essential amino acids and minerals. Research on electrical properties of biological materials and the results can be used when constructing the apparatus for measuring moisture content based on electrical and dielectric properties of materials. Knowing the dependencies would allow to find the most optimal and accurate method for measuring moisture content in agricultural production.

Keywords: spelled seeds, resistance, capacity, relative permittivity, frequency

1. Introduction

Interest in electrical properties of biological materials resulted in engineering research in the field of agriculture last years. The knowledge of physical properties of agricultural products is useful, if not essential, in the design of any agricultural machine. The investigation and determination of physical properties of agricultural materials has also resulted in the development of many instruments. The study of electrical properties is important for predicting the behaviour of materials in electric field or for knowing how the presence of material can influence the field or an associated electrical circuit. Electrical measurements on these materials are of fundamental importance in relation to the analysis of quantity of absorbed water and dielectric heating characteristics. Dielectric properties of materials represent an important part of electrical properties. The research of electrical properties is finding utilisation in many technical applications.

Results of measurements are used for determining the moisture content, the surface level of liquid and grainy materials, for controlling the presence of pests in grain storage, for the quantitative determination of mechanical damage, and in many other cases [1]. Electrical properties of many biological materials have already been investigated. It was discovered that electric properties of these materials are very affected by the moisture content of material. Small quantities of adsorbed water can cause large changes in electrical properties of hygroscopic materials. An extensive review of the literature on dielectric properties of agricultural materials was published [6] and includes a number of potential applications in which dielectric properties of such products are of interest. The most important parameters, which affect the electrical properties of grains and seeds, are the moisture content and frequency of electric field. Dielectric properties of grains and seeds have been explored in certain frequency ranges, where these properties were important for dielectric heating applications or of interest for moisture measurement or detection for process control [9]. Dielectric properties of most biological materials vary with frequency and temperature. They are also highly dependent upon moisture content in hygroscopic materials. Some aspects of the nature of frequency dependence of dielectric properties have been included in the published review [6].

A study of the frequency dependence of dielectric properties of insects and grain has also been reported for the range from 250 Hz to 12 GHz [6]. In that study, the range from 10 MHz to 100 MHz was identified as the most promising frequency range for selectively heating rice weevils in wheat through differential energy absorption from alternating electric field. For a more complete picture, however, similar data are needed for the temperature dependence of dielectric properties. With recent advances in the practical application of microwave heating, there has developed a need for information on dielectric properties of materials to which such energy is applied. While some information is available on dielectric properties of grains and seeds at lower frequencies [4,6,9], there is a lack of information on these properties at microwave frequencies. Therefore, dielectric properties of several kinds of grains and seeds have been measured at a few different microwave frequencies, and dependence on moisture content has been considered.

Nelson (1991) gave a comprehensive summary of dielectric methods for measuring moisture present in materials. Nelson (1999) discussed some methods of measuring the moisture content of soil. One of these methods is a dielectric method. Nelson (1999) also noted a resultant accuracy and temperature effects. Interest in the dielectric behaviour of biological materials increased with the advent of radio frequency heating techniques. Lawrence et al. (1992) discussed in detail the application of radio frequency heating to good electrical conductors as well as poor electrical conductors. You and Nelson (1988) conducted a study of the dielectric constant of rice grains. They measured the dielectric constant and loss factor at frequencies from 435 Hz to 1740 Hz and found that the dielectric constant of rice grains depended on density, moisture content, temperature and frequency. An overview of the literature review and research publications found no similar studies of spelled.

The object of the study is to find the dependency of electric characteristics of spelled from the frequency of the electromagnetic field. To verify that they match with found by other authors that make similar studies of granular materials.

1.1 Data for sample of study – spelled (T. Dicoccum)

Triticum turgidum ssp. dicoccum Schrank ex Schübler (synonym T. dicoccum), known as dvuzarnest spelled a tetraploid species with weeding grain of the genus Triticum (2n = 28, AABB). It is assumed that this is the oldest cultivated wheat cultivation, which occurred about 10,000 years BC acquired in the so-called "Fertile Crescent" (a historical region in the Middle East). In Europe, the spread of spelled first is related to the territories of Greece and Bulgaria

At present, the species occupies about 1% of the mailbox of wheat in the world, is grown mainly in Ethiopia, Iran, eastern Turkey, Transkavkaziya, basin of the Volga River, the former Yugoslavia, Central Europe, Italy, Spain and India. Spelled is still an important crop for countries like India, Ethiopia and Yemen, where the grain is used for the preparation of traditional foods. According to information, it is grown in Bulgaria in limited sizes in foothill and mountain areas, mainly in the spring crop. In spelled grain is found to be higher in lysine than bread wheat. Nutritional value of spelled, confirmed by medical records, mainly due to the high content of fiber and antioxidants, high digestibility of protein and high resistant starch content. The low glycemic index of grain types makes it suitable for diabetes. Most of these properties have been associated with higher total dietary fiber content.

In that regard, it is interesting to use spelled for treating high blood cholesterol, colitis, allergies, due to the information contained in the grain starch, fibers and antioxidant compounds. No chance to present in India grain type is used to prepare meals for diabetics and pasta to increase endurance athletes. A healthy nature of the food in which the main ingredient is the grain of T. dicoccum, is complemented by their importance as a preventive agent against colon cancer and heart disease. Spelled can be used for people suffering from celiac disease (gluten intolerance).

Selection value is ecological plasticity of the species, expressed in adaptation to grow in poor soils and climatic conditions recommended keeping the species in areas where moisture is a limiting factor. Samples spelled demonstrate high dry and heat resistance as well as high resistance to waterlogging of common wheat.

Analyzing the qualitative characteristics (qualitative traits, nutrition and health, resistance to disease, pests, abiotic stress) of T. turgidum ssp. dicoccon gives reason to conclude that the species is of particular interest as a source of many important genes in the selection of the ordinary winter wheat.

Of considerable interest, are the opportunities for growing the type of fertile soil in terms of organic farming, where sowing of modern conventional sort durum and bread wheat is not suitable because they cannot reveal their productive potential. Furthermore, should not be underestimated the fact that the cultivation of spelled involves both lower production costs, making it economically viable.

1.2 Brief theory

It is known that electrical properties of living cells are passive and active. From the microscopic point of view inside the cell has ion conductivity. Cell membrane is not conductive and has a highs resistance values10^8-10^9 Ω.

For various tissues and biological materials, electrical properties are different. In applying an alternating current biological material, have not only resistance R, but also capacity C, inductance L and total resistance - impedance Z that is greater than R.

$$Z = \sqrt{R^2 + \left(X_L - X_C\right)^2} = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$$

Where $\omega = 2\pi f$. f is frequency of the electromagnetic field. There are studies, which found what is dependence of R, C and Z on frequency of the alternating current [1]. Dependency is a monotonically decreasing function of the type

$$R = R_0\left(\frac{f}{f_0}\right)^{-n} \qquad Z = Z_0\left(\frac{f}{f_0}\right)^{-n} \qquad C = C_0\left(\frac{f}{f_0}\right)^{-n} \qquad (1)$$

In these formulas R_0, Z_0, C_0 are constants, and n is coefficient.

From the macroscopic point of view in cell membrane there are channels through which can pass physiological ions and anions, and particle charge carriers.

The density of electric current is:

$$i_d = \sigma.E + \frac{d(\varepsilon.E)}{dt}$$

In last formula E is the electric field intensity and ε is the dielectric permittivity of the material (insulator).

$$\varepsilon = \varepsilon_r.\varepsilon_0,$$

where ε_r is the relative permittivity of the substance, ε_0 = 8.85. 10^{-12} $F.m^{-1}$ is the dielectric constant.

There are studies [1,7], showing that $\varepsilon_r = \varepsilon_r\left(f, t^0\right)$. Last dependence is determined by the method of connecting the water with the material, of variability in it and by chemical bonds. For bulk materials, the dependence is affected by the mass in bulk, the frequency of the electric field and temperature.

Measurement of moisture content in biological objects (grains, seeds, etc.) is the most important in storage and processing of agricultural produce. The accuracy of these measurements depends on several groups of factors. Physical properties of agricultural products affect the accuracy of measurement of moisture.

Depending on the measuring method used for the physical properties can be separated: measuring the dependence of electrical resistance in hygrometers and specific resistance, conductivity, impedance, permittivity of moisture content [2].

Many methods have been used to measure moisture content especially high-frequency intervals.
One method for measuring the moisture content is the dielectric method that is based in dielectric hygrometers. On that with electrical methods, follow the behavior of the dielectric (organic material) over time for a change of the electric field.

Under the influence of electric field, dielectric is polarized and its dielectric permittivity can be measured by measuring the capacity at different frequencies of alternating current. The test substance is placed between the plates of a capacitor. One way to measure, the capacity of the condenser is bridge method by resonance and after is calculated ε of the substance. Novak [7] makes such measurings at frequencies from $1\,MHz$ to $16\,MHz$. He found that in this frequency range there is a linear relationship between ε and $\omega\%$.

If the condenser is plane, then by $C = \varepsilon_r.\varepsilon_0 \dfrac{S}{d}$ for a capacitor with a dielectric (organic matter) and $C_0 = \varepsilon_0 \dfrac{S}{d}$ for air condenser, then relative permittivity can calculate from formula $\varepsilon_r = \dfrac{C}{C_0}$ (2).

The last formula allows measurement of both the capacity to find the relative permittivity of the material - the biological material.

Our studies [10] on the electrical properties of rapeseed seeds show that the dependence of the relative permittivity of the frequency is in the form of the functions (1), i.e.

$$\varepsilon_r = \varepsilon_{r0} \left(\frac{f}{f_0} \right)^{-n} \qquad (3).$$

2. Experimental Work

2.1 Materials and method of measurement

There was test - studied spelled seeds with shuck harvest in 2012 in Bulgaria with approximately equal-sized seeds. Two measurements were made on sample.

First (F) - Measurement were made in physics laboratory in SUA in Nitra, Slovak Republic, conditions at 20^0C and humidity $\omega = 58\%$.

Second (S) - Measurement were made in physics laboratory in TU – Varna, Bulgaria, conditions at 29^0C and humidity $\omega = 53\%$

2.2 Data of sample for testing for two measurements

F: Moisture content - $\omega = 11{,}4\%$, mass of sample - $m = 34{,}11g$,

Volume of sensor - $V = 55{,}13.10^{-6} m^3$, bulk density - $\rho = 618{,}83 \dfrac{kg}{m^3}$

S: Moisture content - $\omega = 11{,}0\%$, mass of sample - $m = 19{,}00g$,

Volume of sensor - $V = 34{,}19.10^{-6} m^3$, bulk density - $\rho = 555{,}72 \dfrac{kg}{m^3}$

Mass is measured with an electronic balance accurate to 0,0001g.

2.3 Sensors

F. For sensor is used plane capacitor with copper plates, which are circular with a diameter of 37,78 mm and the distance between them is 49,2 mm. The surrounding area is Plexiglas with high resistance values. On top of the sensor, there is a spring so that the sample is under constantly mechanical pressure. This provides a minimal presence of air between seeds of the sample.

S. For sensor is used plane capacitor with copper plates, which are circular with a diameter of 55,00 mm and the distance between them is 14,40 mm. The surrounding area is Plexiglas with high resistance values. On top of the sensor, there is a spring so that the sample is under constantly mechanical pressure. This provides a minimal presence of air between seeds of the sample.

To determine the dielectric permittivity we use the formula $\varepsilon_r = \frac{C_X - C_P}{C_0 - C_P}$, where C_X is the capacity of the condenser that is filled with seeds, C_0 is the capacity of the empty capacitor - no seeds, C_P is the capacity of the air spaces between the seeds. Assuming that all samples were under constant mechanical pressure, this may allow disregarding C_P.

2.4 Method of measurements

F. Measurement of electrical properties R, C_X and C_0 for sample becomes with a LCR meter Good Will8211. Measurements were made in the frequency range – **from 20 kHz to 200 kHz.**

S. Measurement of electrical properties R, C_X and C_0 for sample becomes with a LCR meter Good Will819. Measurements were made in the frequency range – **from 0,2 kHz to 1,2kHz.**

With the program Graffer are built graphs $R = f(f)$ and $C = f(f)$ with average values of three measurements. The relative permittivity is calculated from formula (2) by the average values of the capacity of each sample at various frequencies. Dependence $\varepsilon_r = \varepsilon_r(f)$ is plotted. The program allows determining the type of function, the relevant coefficients and the coefficient of determination.

3. Results and Analysis

Table1. Results from measurement F.

ν, kHz	$\overline{R}, k\Omega$	$\overline{C_x}, pF$	ε_r
20	82715	1,475	1,12
25	61110	1,466	1,17
30(28,6)	57674	1,458	1,18
33,3	52920	1,446	1,18
40	47661	1,429	1,17
50	39529	1,396	1,15
66,6	32357	1,378	1,14
100	19957	1,383	1,15
200	10398	1,409	1,13

Table2. Results from measurement S.

ν, kHz	$\overline{R}, k\Omega$	$\overline{C_x}, pF$	ε_r
0,2	17677	11,59	2,63
0,3	10731	10,83	2,50
0,4	7385	10,42	2,40
0,5	5246	10,09	2,34
0,6	3780	9,89	2,32
0,7	2806	9,71	2,27
0,8	2011	9,56	2,23
0,9	1438	9,45	2,22
1,0	937	9,36	2,21
1,1	585	9,28	2,19
1,2	213	9,20	2,19

Graphs (Fig.1, 2 and 3) from measurement F**.**

Fig 1: Dependence of resistance on frequency

Fit 1: Power : Alternate Y = pow(X,-0.8716776236) * 1128508.301
Coef of determination, R-squared = 0.98893
Residual mean square, sigma-hat-sq'd = 0.005194

$$R = R_0\left(\frac{f}{f_0}\right)^{-n},\ R_0 = 1128508.301 k\Omega,\ n = 0.871677,\ R^2 = 0.98893$$

Fig 2: Dependence of capacity on frequency

Fit 1: Power: Alternate Y = pow(X,-0.04408420175) * 1.680609101
Coef of determination, R-squared = 0.924081
Residual mean square, sigma-hat-sq'd = 9.75021E-005

$$C = C_0\left(\frac{f}{f_0}\right)^{-n},\ C_0 = 1.6806091 pF,\ n = 0.044084,\ R^2 = 0.924081$$

Fig 3: Dependence of relative permittivity on frequency

Fit 1: Power: Alternate Y = pow(X,-0.0397493177) * 1.341908148
Coef of determination, R-squared = 0.866069
Residual mean square, sigma-hat-sq'd = 0.00014921

$$\varepsilon_r = \varepsilon_{r0}\left(\frac{f}{f_0}\right)^{-n},\ \varepsilon_{r0} = 1.3419,\ n = 0.039749,\ R^2 = 0.866069$$

Fit 2: Polynomial
Equation Y = 1.192163472 - 0.0007066155775 * X + 4.831997418E-007 * pow(X,2)
Degree = 2
Coefficients:Degree 0 = 1.192163472; Degree 1 = -0.0007066155775
Degree 2 = 4.831997418E-007
Degree: 0; Residual sum of squares = 0.00988889; Coef of determination, R-squared = 0
Degree: 1; Residual sum of squares = 0.00044760;Coef of determination, R-squared = 0.954736
Degree: 2; Residual sum of squares = 0.000432972; Coef of determination, R-squared = 0.956216

Graphs (Fig.4, 5 and 6) from measurement S.

Fig 4: Dependence of resistance on frequency

Fit 1: Power: Alternate Y = pow(X,-2.177350616) * 876.3646363
Coef of determination, R-squared = 0.89042
Residual mean square, sigma-hat-sq'd = 0.211188

$$R = R_0\left(\frac{f}{f_0}\right)^{-n},\ R_0 = 876.3646 k\Omega,\ n = 2.1773,\ R^2 = 0.89042$$

Fit 2: Exponential: Alternate Y = exp(-3.922167633 * X) * 39282.96106
Coef of determination, R-squared = 0.975586
Residual mean square, sigma-hat-sq'd = 0.0470515

Fig 5: Dependence of capacity on frequency

Fit 1: Power: Alternate Y = pow(X,-0.1260806295) * 9.330439429
Coef of determination, R-squared = 0.990003
Residual mean square, sigma-hat-sq'd = 5.81054E-005

$$C = C_0\left(\frac{f}{f_0}\right)^{-n},\ C_0 = 9.3304 pF,\ n = 0.12608,\ R^2 = 0.990003$$

Fig 6: Dependence of relative permittivity on frequency

Fit 1: Power: Alternate Y = pow(X,-0.1033100535) * 2.201142857
Coef of determination, R-squared = 0.980462
Residual mean square, sigma-hat-sq'd = 7.69875E-005

$$\varepsilon_r = \varepsilon_{r0}\left(\frac{f}{f_0}\right)^{-n}, \ \varepsilon_{r0} = 2.201142, \ n = 0.103310, \ R^2 = 0.980462$$

For two frequency intervals 0,2 kHz – 1,2 kHz and 20kHz – 200kHz with increasing frequency R ,C and ε_r decreased function of the type (1).

Values of resistance in the range of the lower frequencies are less than when the values of the capacity and the relative permittivity are higher.

4. Conclusions

The measured values and results obtained allow to conclude that resistance and capacity of spelled seeds depend on the frequency depending on function on type (1) obtained by other authors. The relative permittivity of spelled seeds depend on the frequency depending on function on type (3) obtained by us in [10]. Research results show that both frequency ranges are suitable for the study of the electrical characteristics of spelled.

Research on electrical properties of biological materials and the results can be used when constructing the apparatus for measuring moisture content based on electrical and dielectric properties of materials. Knowing the dependencies would allow to find the most optimal and accurate method for measuring moisture content in agricultural production.

We can conclude that the resistance, capacity and relative permittivity of spelled seeds decrease with the frequency of electric field. Other authors presented similar results for other biological materials. The relationship of the dielectric constant of spelled seeds samples provides a basis for the design of many commercial moisture-testing instruments. The results would allow programmed electrical hygrometers for the study of moisture content in agricultural production and the type of spelled seeds. In the future, more measurements on a wider frequency range would be desirable.

5. Acknowledgments

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References

Hlavacova,Z. 1999. Some electrical properties of amaranthus seeds. Zemedelska technika, 45,1999(3), p. 99-104.

Hlavacova,Z. 1994. Physical properties of plant material in view point of accuracy of moisture measuring. Zemedelska technika, 40,1994(2), p. 81-86.

Hlavacova,Z. 2003. Low frequency electrical properties utilization in agricultural and food treatment.RES.AGR.ENG.,49,2003(4). p.125-136.ISSN 1212-9151

Lawrence, K.C. – Nelson, S. O. – Kraszewski,A. 1992. Temperature dependence of dielectric properties of pecans.Trans.ASAE, vol.35,1992,no.1,p. 251-255.

Nelson,S.O. 1999. Dielectric properties measurement techniques and applications. Trans.ASAE, vol.42,1992,no.2,p. 523-529.

Nelson, S. and all. Dielectric properties of Watermelons and Correlation with Soluble Solids Content. In: ASABE Annual International Meeting, 2007.

Novak,J. Electrical properties of colza seeds. Acta technologica agriculturae, (1) 2011, SUA in Nitra, p.11-14.

Priatkova,L.- Hlavacova, Z. Uncertainties of the biological materials electrical properties measurement using the LCR bridge. International student scientific conference, RAAGMEWP, 2009, p.251-256.

You, T.S.- Nelson, S.O. 1988. Microwave dielectric properties of rice kernels. J. Microwave Power and Electromagnetic Energy, vol.23, 1988, no.3, p. 150-159.

Kardjilova, K. - Hlavacova, Z. - Ketzer, A. Measurement of electrical characteristics of rapeseed seeds with LCR meter Good Will8211, International Journal of Applied Science and Technology, Vol.2 No.8, ISSN 2162-139X (Print), ISSN 2162-142X (Online)’2012, p.35-44.

Fig 1: Dependence of resistance on frequency

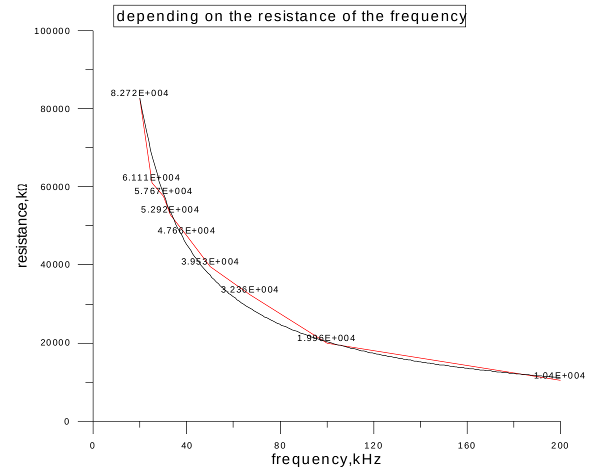

Fig 2: Dependence of capacity on frequency

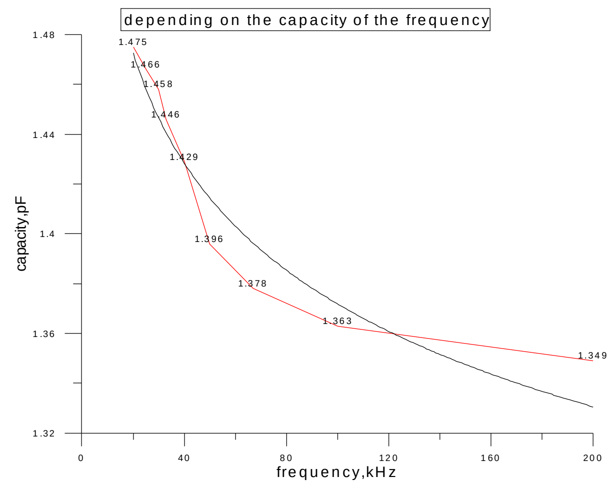

Fig 3: Dependence of relative permittivity on frequency

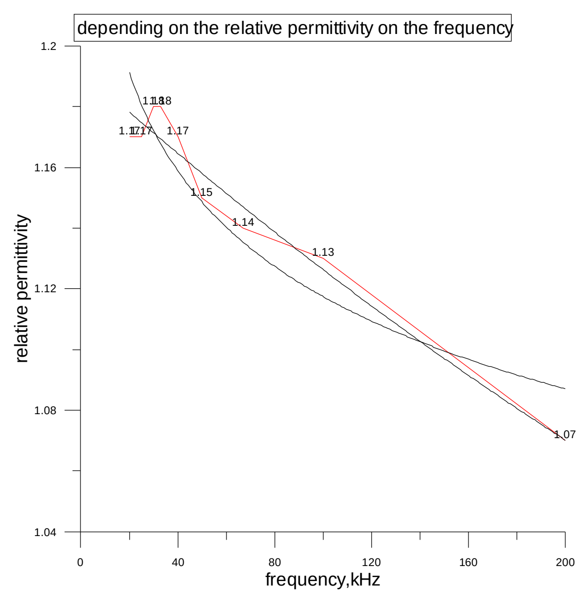

Fig 4: Dependence of resistance on frequency

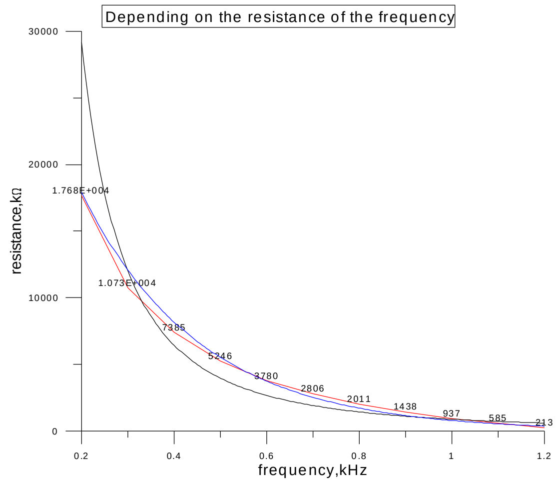

Fig 5: Dependence of capacity on frequency

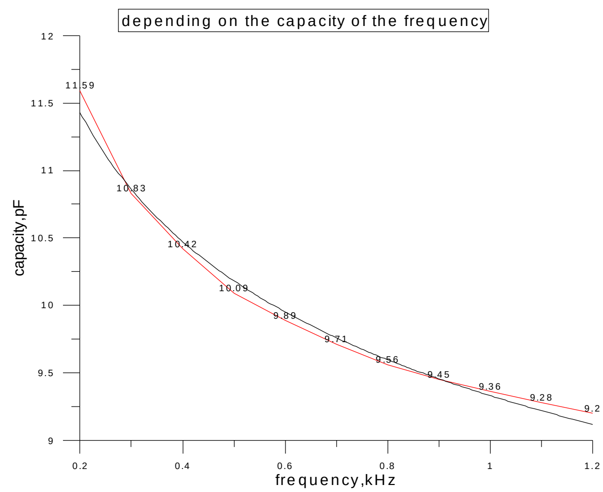

Fig 6: Dependence of relative permittivity on frequency