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ON THE PERMITTIVITY MEASUREMENTS OF ROCKS

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There are several methods for measuring the dielectric constant ε, of which the most simple method is using aQ-meter. In this case the test material is placed between the plates of a plane capacitor, called measuring [1], and its capacitance is determined at a predetermined frequency. Ε value is then calculated by the formula

$ ε= \frac{C\_{0}d}{ε\_{0}S}$(1)

where: *S* - area of the capacitor plates, $cm^{2}$

*d* - distance between the plates, $cm$

εo-0,085 pF / sm

thus measured capacitance Ce is not true capacity test material, but a certain amount:

*Ce = Ckp + Co + α Co,* (2)

where*Ce* - effective capacitance measured with Q-meter,

*Ckp* - container edge measuring capacitor (capacitance of the edge – fringing fields)

*α* - relative error of measurement capacity, which is a function of many factors considered

difficult

Therefore in the calculation formula (1) can not substitute the value of the measured capacitance Ce.

calculation or experimental determination of the container edge TFR presents no special difficulties [1, 2,

12], so in the future it can not be seen. Then:

*Ce = Co + α Co = (1 + α) Co* (2a)

Decoding error *α* number of papers have revealed the influence of individual factors on the magnitude of this error [1 - 6].

So, S. V.Bogdanov [3] gave a simplified formula that takes into account the effect of inductance *Lpr* connecting wires on the value of *α*

$C\_{0 }= \frac{C\_{э}}{1+ ω^{2 }C\_{э}L\_{pr}}$*(3)*

where:*Lpr* - inductance of wiring

*ω = 2πf* - angular frequency of

*f*  - frequency electromagnetic field, *Hz,*

in turn know that they themselves have the parasitic capacitors (residual) inductance Lo, increases efficiency (measured) capacitance at high frequencies [2, 5, 7]. Research A. L. Grokholsky [5, 7] showed that the reference air dielectric capacitors have inductance of order (6 - 30) 10-9 GN, whose influence is already being felt at frequencies of 10 MHz and above. Measuring capacitors have a greater inductance, which can be neglected only in exceptional cases. Given Lo formula (3) takes the form:

$C\_{0}$ =$\frac{C\_{э}}{1+ ω^{2 }C\_{э}(L\_{0}+L\_{pr})}=\frac{C\_{э}}{1+ω^{2}C\_{э}L}$(4)

Here *L* - total inductance of the measuring capacitor and connecting wires, which can be taken as a first approximation for a constant value. [2]

measuring the capacitance *For* of the system at a low frequency (not more than a few tens of kilohertz) and *Se* at high frequency (for Q-meter type UK-1 70 - 100 MHz) the value of *L* can be calculated as:

$L= \frac{C\_{э}- C\_{0}}{ω^{2}C\_{0}C\_{э}}$(5)

It should be noted that these formulas are valid only when the wire size is less than one quarter of the working wavelength. Comparing the expressions (2a) and (4) it is easy to notice that the term $ω^{2}C\_{e}L$ determines the amount of *α* and is one of the most important sources of error in the measurements. G. M. Strizhkova attempt to cover the most significant factors affecting the error $ΔC = C\_{e }- C\_{0}$ [4].He investigated experimentally function

$∆C=f\_{1}(ω)$, $∆C= f\_{2}\left(C\_{0}\right),∆C= f\_{3}(C\_{k\_{1}})$

$C\_{k\_{1}}$ - capacitance of the measuring capacitor at the first resonance.

But the author of the proposed formulas that take into account only the inductance capacitor measuring circuit kumetra and inductance device insertion, that the maximum measurement error is in the range of small containers (5 - 20 pF). This conclusion is controversial. So, I. Golovnya [11], on the contrary, believes that the measurement of small containers error insignificant.

Analysis of formula (4) shows that the relative error *α* is directly proportional to the magnitude of the measured capacitance $C\_{0}$ and inductance *L.*From these positions are comfortable measuring capacitors with the lowest possible values ​​of inductance and capacitance. In the same meter waves with frequencies up to 150 - 200 MHz such conditions are required.

For each measuring capacitor is useful to determine the cutoff frequency at which the error in measuring the capacitance will not exceed a predetermined value *α:*

$f\_{c}= \frac{1}{2π}\sqrt{\frac{α}{C\_{0}L 100}}$ (6)

where:*α*– error, %

$C\_{0}$ - capacity, *F*

*L* - inductance, *H*

Of great interest is the work of A. F. Kugaevsky [9], in which the dielectric constant is measured using a sample holder, representing a miniature coaxial line, up to 2%. With this method there is no need of adjustment in the calculations. But to use this method requires ring samples which manufacture of rocks difficult. Therefore, the method A. F.Kugaevskycan not exclude conventional measurement using a Q-meter.

These works show that the measurement errors are not random capacity and systematic. Therefore, methods are necessary theoretical or practical accounting resolve these errors, given the impact of all factors.

When studying the equivalent circuit of the total circuit of Q-meter convenient to represent it in the form of two coupled circuits: internal, which includes the measuring circuit and Q-meterresidualinductance $L\_{k,}and $external (measured capacitor with the test substance and connecting wires). Value of the inductance and capacitive coupling can be neglected when dealing with capacitors having the parasitic inductance of not more than (5 - 15) $10^{-8}Mr.$Then if the external contour parameters are determined fairly simple equation (4), which is not the function that describes the inner loop [4]. In this paper [4] the dependence of measurement error *αω* from $C\_{k\_{1}}$ for a particular operating frequency *ω* (Fig. 1).



Fig. 1

$C\_{k\_{1}}$ - capacitance of the measuring capacitor kumetraat the first resonance

Anderror*αω* can be both positive and negative. Frequency error *α = f (ω, Sο, L)* always only positive.

 Therefore, measurement at a certain frequency *ω*can choose a capacitance measurement at the first resonance capacitor $C\_{k-1,\_{}}$in which the outer contour positive error *α = f (ω, Co, L)* will be compensated for the negative inner loop error $α = f(C\_{k\_{1).}}$)

quite clear that one shift inductor *Lk* can operate without error only on one frequency *ω.*On adjacent frequencies at intervals of $\pm Δf$ MHzvalues  *Se* ​​change. Increase at high frequencies and decrease at low frequencies. The experiment showed that when working with capacitors having parameters *Co*<20 pF and *L*<20 mH, margin of error does not exceed 4 - 7% at $Δf = \pm $ 5 - 10 MHz.

Thus, several interchangeable spools with a short interval work frequency allow to perform measurements with sufficiently high accuracy in a wide range of frequencies. For example, picking up 8 replacement coils are available in the frequency range 30 - 175 MHz of the Q-meterUK-1 eight "reference" points to an accuracy of about 1% and at least 16 points with an accuracy of 4 - 5%. Generally the number of replacement coils depends on the task.

Based on the above can be offered to the next method of measuring the capacitance on Q-meter. The total measurement error *α* is considered as the sum of the "internal" inaccuracy of Q-meter inner contour, and "external", determines the magnitude of the measured capacitance of the capacitor *Co* and its inductance *L.*The "internal" error is compensated for each operating frequency selection capacitance $C\_{k\_{1}}$Q-meter measuring circuit at the first resonance. "External" error is calculated by the formula (4) and subtracted from the measured results. Selection capacitance $C\_{k\_{1}}$ isdone using a reference capacitor that is connected to both the measured capacitance by adjusting the inductance of the coilreplacement*Lk* until when the reference capacitor $Δ$*C= Se - Co* becomes zero or decreases to a value of 0,02 pF.The main requirement for the reference capacitor - the immutability of its effective capacitance at all frequencies. Such a condition is satisfied ceramic capacitor type KDU, stray inductance is negligible, and therefore in the range of 200 MHz to his *Se = Co* [10]. Verify that you can compensate for the "internal" error was made ​​by adjusting capacitance $C\_{k\_{1}}$ reference to a *With* = 8 pF. The values ​​of $C\_{k\_{1}}$ this capacitor at various frequencies are shown in Table 1.

Table 1 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Operating frequency, f MHz \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

 30 50 75 100 125 150

$C\_{k,\_{1}}$pF53,1049,77 44,27 30,6626,33 20,38

*Se,*the standard DCD, pF 8,00 7,997,98 7,98 8,007,99

$C\_{1e}$cap*L* = 1,2.10-8 H, pF7,96 7,99 8,07 8,19 8,30 8,57

$C\_{2e}$ capacitor *L* = 1,5.10-8 H,pF 7,988,04 8,10 8,23 8,358,65

Effective capacity standard in the range 30 - 150 MHz is true capacity , which means the complete exclusion of "internal" erroacitorrs. For the other two capacitors with different inductances increasing the effective capacitance *Ce* is described by formula (4). This table shows the two capacitors of the capacitor Cwhich1 is a measuring sample of polystyrene, and the capacitor C2 similar design but without the test sample, that is between the capacitor plates is air. Figure 2a shows the dependence of the frequency error of $α\_{C\_{0}}$KDU capacitor, the capacitor with polystyrene $α\_{C\_{1}}$andfor air condenser $α\_{C\_{2.}}$



Fig.2 Frequency error of capacitance with different inductance L.

Comparing all three errors can say that for the standard can not accept KDU-type capacitor with very low inductance and air capacitor, since the difference of their errors $α\_{C\_{2}}$- $α\_{C\_{1}}$ = $Δα\_{C\_{1}}$ is much smaller than the difference $α\_{C\_{0}}$ - $α\_{C\_{1}}$ = $Δα\_{C\_{2.}}$Deciphering $Δα\_{C,}$we get:

$Δα\_{C\_{1}}$= $ω^{2 }C\_{0}L\_{2}-ω^{2}C\_{0}L\_{1 }= ω^{2}C\_{0}(L\_{2 }- L\_{1)}$ (7)

$Δα\_{C\_{2}}$ = $ω^{2}C\_{0}L\_{0}- ω^{2}C\_{0}L\_{1}≅ -ω^{2}C\_{0}L\_{1}$ This implies that the frequency error can be small and can be neglected if the inductance and capacitance of the measuring capacitor and the reference will be the same. In general, the equation should be satisfied

*C1 L1 = C2 L2*

where the indices 1 and 2 are denoted by the reference parameters and measuring capacitor. In this case, the curves $α\_{C\_{1}}$and $α\_{C\_{2}}$ merge.Very comfortable with using the same compensation capacity of the first resonance kumetra $C\_{k\_{1}}$ "straighten» $α\_{C\_{2}}$That frees from calculating frequency error $α\_{C\_{1}}$. In the transformed coordinate system so that all errors will have the form shown in Figure 2b. Reference capacitor can be air cooled condenser, since the permittivity of air is almost equal to one and does not change with the frequency of the electromagnetic field. In practice, there is always the possibility of measuring very low inductance capacitors. But, if the geometric dimensions of the air reference and measuring capacitor does not exceed the dimensions 30h30h5 mm, the difference in their inductance is usually no higher than 10-100 nH. In this case, the frequency error for α capacitance *Co* <10 pF will be 1-4% at a frequency of 150 MHz and can be neglected.



Fig. 3 Frequency dependence of permittivity

1 - polystyrene with air bubbles. 2. - Polystyrene (A. F. Kugaevsky [9]). 3 - polystyrene (A.Tilvikas [6]). 4 - apatite ore.

Dependence of the permittivity of polystyrene and apatite ore *(ρ* = 3050 kg / m3, moisture 0.02%) obtained using the proposed method, excluding the frequency of errors are shown in Figure 3. Ore samples used were cylindrical (r = 15 mm, h = 5 mm). The wiring length should not exceed 2 mm. Deviation with a frequency of 200 MHz was 3-4%. Given the estimated frequency error error does not exceed 1 - 2%.

Should be noted that the frequency error is not always given adequate attention. For example, in a recently published paper byA. T. Bondarenko [8] the frequency dependence of the dielectric constant and loss tangent of granites are lifting at the end of the frequency range of the Q-meter KV-1 (Fig. 4a).



Fig. 4

The reason for this is likely to include the frequency error, rather than changes in rock properties, as the author explains. For comparison, Figure 4b shows the frequency dependence of the permittivity of apatite ore $ε\_{1}- $ in an array and$ε\_{2}- $ loosened ore, receive, excluding the frequency error. In fact, the frequency dispersion of the dielectric permittivity ore absent in this wavelength range.

CONCLUSIONS

1. In order to determine the permittivity of rocks in a VHF should be constructed measuring capacitors with the lowest possible values ​​C and L.
2. Under this condition the proposed method makes it possible to obtain sufficiently accurate measurements of the dielectric permeability of the rocks (the error of 1 - 2%) with a simple, common device –Q-meter.

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