STATE STANDARDS

SPECIAL STATE STANDARD FOR THE UNIT OF ELECTRIC FIELD INTENSITY IN THE FREQUENCY RANGE 0-20 kHz

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A description is given of a special State Standard for the unit of electric field intensity in the frequency range 0-20 kHz. It was developed at the VNIIFTRI and was approved in 1996 by the State Committee of the Russian Federation for standardization, metrology, and certification.

Following the results of work carried out in 1992 at the VNIIFTRI (All-Union Scientific-Research Institute of Physicotechnical and Radio Engineering Measurements), a special State Standard for the unit of electric field intensity in the frequency range 0-20 kHz (GÊP 158-96) and a State verification scheme for instruments for measuring the electric field intensity in the frequency range 0-20 kHz were approved by the State Committee of the Russian Federation for standardization, metrology, and certification with the Decree No. 10 of June 19, 1996 and put into force from January 1, 1997 [1].

The State Standard is designed to reproduce, preserve, and transfer the unit of electric field intensity in the frequency range 0-20 kHz and also provides for verifying and calibrating instruments for measuring the electric field intensity in this frequency range.

It consists of a GÊP-0-20 electric field generator and a KÊP-0-20 electric field comparator. The generator includes a KPÊI screened plane-parallel capacitor, a V1-28 universal voltmeter-calibrator, a V1-9 instrument for checking ac voltmeters, a Ya1V-22 voltage amplifier unit, and a Ch3-63 electronic frequency counter. The comparator consists of an ADA4 active dipole antenna with an AMM-01 mechanical modulator, an FPP-01 switchable band filter, an FP35 band filter, a V3-60 ac voltmeter, a V2-38 dc digital nanovoltmeter, and two B5-44A constant current power supplies.

Reproducibility of the unit of electric field intensity (volts per meter) in the frequency range 0-20 kHz is provided by a GÊP-0-20 electric field generator. In a constant electric field the reproducible physical quantity is the modulus of the intensity of a uniform electric field in the working volume of the GÊP-0-20. In an ac electric field (harmonically varying with time) the reproducible physical quantity is the rms value of the modulus of the intensity of a uniform linearly polarized alternating electric field in the working volume.

It should be mentioned that the uniform linearly polarized electric field is excited between the plates of a plane-parallel capacitor to which a dc or ac voltage is applied from the generator. The space between the plates of the capacitor, bounded by a sphere whose center coincides with that of the capacitor, forms the working volume in which the electric field is uniform with a specified accuracy. The diameter of this sphere corresponds to the size of the working volume which is equal to 0.1 m. Supplementary cylindrical electrodes are present in addition to the plane-parallel plates in order to increase the uniformity of the electric field in the KPÊI capacitor.

The electric field vector in the working volume is parallel to the axis of the capacitor and its modulus is defined in accordance with the formula $E = KU$, where $K$ is a conversion coefficient measured in reciprocal meters and $U$ is the voltage applied to the capacitor in volts.

The unit of electric field intensity is reproduced in the following way. A dc or ac voltage from the generator is applied to the input of the KPÊI capacitor in whose working volume a dc or ac electric field having known parameters (polarization, frequency, intensity) is excited. A V1-28 universal voltmeter-calibrator is used as the generator when reproducing a dc electric field, while in the frequency band from 20 Hz to 20 kHz a V1-9 instrument for verifying the ac voltmeters is used with a
Yal V-22 voltage amplifier. The frequency of the voltage applied to the input of the KPE1 capacitor from the V1-9 is measured with a Ch3-63 electronic frequency counter.

It is well known that instruments for measuring dc and ac electric fields can be divided into electric field meters containing measuring antennas and electric field generators. Electric field meters and measuring antennas are verified and calibrated by directly measuring the intensity of an electric field reproduced in a standard. This is done for electric field generators by comparing the intensities of the electric fields of the standard and the electric field generators. In the latter case one uses a carrier antenna which forms part of the electric field generator or a KEP-0-20 electric field comparator from the set of instruments of the standard.

The KEP-0-20 consists of an electric field meter containing a measuring antenna (AMM1 or ADA4) and an ac voltmeter (a V3-60 ac voltmeter with a V2-38 digital dc nanovoltmeter connected to its output) determining the value of the ac voltage at the antenna output which is proportional to the electric field intensity. A symmetrical voltage is applied from a B5-44A constant current source in order to power the amplifier of the measuring antenna.

An AMM-01 antenna with a mechanical modulator is used as the measuring antenna in order to determine the intensity of a dc electric field. The electric field intensity is calculated from the measured voltage using the formula \( E = K_1 V \), where \( K_1 \) is the calibration coefficient of the AMM-01 antenna in reciprocal meters and \( V \) is the voltage at the output of the AMM-01 (FP35) in volts.

An ADA4 active dipole antenna is used as the measuring antenna in the frequency band from 20 Hz to 20 kHz. Together with the B5-44A constant current source and the ac voltmeter (a V3-60 combined with a V2-38) this forms a device for measuring the rms value of the modulus of the projection of the electric field intensity vector on the axis of the dipole. If the dipole axis is parallel to the electric field intensity vector then the voltage at the output of the ADA4 antenna will be proportional to the rms value of the modulus of the electric field intensity \( E = K_2 V \), where \( K_2 \) is the calibration coefficient of the ADA4 in reciprocal meters and \( V \) is the voltage at the output of the ADA4 (FP-01) in volts.

For a confidence level \( P = 0.99 \) the residual systematic error \( \delta E \) in reproducing the electric field intensity in the standard is determined from the formula

\[
\delta E = 1.4\left(\delta E_1^2 + \delta E_2^2 + \delta E_3^2 + \delta E_4^2 + \delta E_5^2 + \delta E_6^2 + \delta E_7^2\right)^{1/2},
\]

where \( \delta E_1 \) is the error component associated with the nonuniformity of the electric field in the working zone of the KPE1 capacitor (0.8% and 1.2% respectively in the frequency bands from 0 to 10 kHz and 10 to 20 kHz), \( \delta E_2 \) is that due to the inaccuracy in the geometry of the capacitor (0.1%), \( \delta E_3 \) is that resulting from the error in determining the generator output voltage (0.25%), \( \delta E_4 \) is associated with the error in the formula used to calculate the electric field intensity at the center of the capacitor (0.08%), \( \delta E_5 \) is that which depends on the influence of the supply cable and the structural capacitances (0.02%), and \( \delta E_6 \) is that resulting from the frequency dependence of the conversion coefficient (0.5% and 1.4% respectively in the frequency bands from 0 to 10 kHz and from 10 to 20 kHz).

Calculations using Eq. (1) make it possible to determine values of the residual systematic error of \( \delta E = 1.4\% \) in the frequency band from 0 to 10 kHz and \( \delta E = 2.6\% \) in the frequency band from 10 to 20 kHz.

The error of the standard is taken to be the rms deviation of its measured electric field intensity using the measuring antenna included in the standard. It should be noted that the rms deviation is 0.3% for five independent observations.

The principal source of instability of the standard is the change in distance between the capacitor plates due to ageing and deformation of the materials from which it is constructed. The instability \( \nu \) over five years is determined by periodic certification of the standard in accordance with the formula (in percentage terms)

\[
\nu = \frac{\Delta d}{d} \times 100,
\]

where \( \Delta d \) is the change in the distance in millimeters between the KPE1 capacitor plates over five years and \( d \) is the nominal distance between the plates (\( d = 500 \) mm).

According to the verification scheme, the size of the unit is transferred by the direct measurement method or by using the comparator. The error in transferring the size of the unit to working standards and measuring instruments is characterized by an rms deviation \( S_{S_{\nu}} \) of the measured results which is defined by the formula

\[
S_{S_{\nu}} = \left( S_{S_{\nu}^2} + S_{S_{\nu}^2}^2 \right)^{1/2}.
\]