The design of a primary standard developed at the Scientific Production Association of the D. N. Mendeleev All-Union Scientific Research Institute of Metrology, its operating algorithm, functional capabilities, and metrological characteristics are described.

The working primary voltage standard RÉN-3 can transfer the magnitude of the volt unit in the 30-2000 MHz frequency range to reference measuring instruments (RMIs) of the 1st order [1] and to measuring instruments (MIs) with 20 x 3, 12 x 1, and 8 x 1 mm high-impedance probes, and MIs with type III GOST 13317-89 [2] and type N MIL-C-71 coaxial input connectors used with coaxial transmission lines.

Below 30 MHz the volt unit is provided by RÉN-2 and RÉN-2M working primary voltage standards. The upper operating frequency of RÉN-3 is limited to 2000 MHz only by the fact that the now available 1st order RMIs have an upper operating frequency of 1500 MHz and that MIs with an upper operating frequency of 2000 MHz are presently being developed. However, the thermistor converter included in the RÉN-3 thermistor comparator has an upper cutoff frequency of 3000 MHz.

The RÉN-3 block diagram [3] shown in Fig. 1 has two ac voltage sources 1 and 2, a control unit 3, thermistor comparator 4, a dc RMI 7, and a personal computer (PC) 8. The thermistor comparator consists of a type PTV-6 feed-through thermistor converter (TC) 5 and a type MTR-4 automatically balanced dc bridge that includes a controlled high-frequency (HF) switch and an interface board. The RMI to be calibrated is connected to the TC output; GPB is a general-purpose bus.

Interactive operation of the RÉN-3 with the PC proceeds as follows. The desired frequency and voltage are set either in source 1 (up to 1000 MHz) or in source 2 (up to 2000 MHz). This voltage is applied to the input of the controlled high-frequency switch of the thermistor bridge through a manually operated HF switch in the control unit. When the PC delivers a control signal (Signal ON mode), the output of the controlled HF switch of the bridge is connected to the TC input and the voltage level of source 1 or 2 is adjusted to the required nominal voltage across the RMI 9. In the Signal OFF operating mode no HF voltage from source 1 or 2 is applied to the TC input.

The dc RMI is a V1-18 calibrator that measures both voltages \( U \) and voltage increments \( \Delta U \). The RÉN-3 operating algorithm implements the measurement equations.

For voltages less than 0.5 V, the measurement equation has the form

\[
U_\infty = \frac{K_f}{4} V \Delta U (2U_1 + \Delta U),
\]

and for voltage high that 0.5 V the equation becomes

\[
U_\infty = \frac{K_f}{4} \sqrt{U_2^2 - U_1^2},
\]

where \( K_f \) is a coefficient that allows for the systematic frequency error of the TC and is established during metrological certification of the RÉN-3, \( U_2 \) and \( U_1 \) are voltages measured by the dc RMI in the \( U \) mode before and after the HF signal and \( \Delta U \) is the voltage increment measured by the dc RMI in the \( \Delta U \) mode.

The ac voltages reproduced by the RÉN-3 are normalized in the transverse plane \( aa \) that passes through the contact plane of the TC output connector to which the thermistors are connected. The mismatch error \( \Delta_m \) may be neglected in practice if the calibrated MI can be connected directly to the \( aa \) plane of the TC. This is possible in certification of 1st order RMIs or in calibration of MIs with a high-impedance input operating with unmatched transmission lines [4]. This also is possible in calibration.
TABLE 1

<table>
<thead>
<tr>
<th>Frequency, MHz</th>
<th>$10^{-4}$ SD at 0.1 V</th>
<th>$10^{-3}$ $\Sigma S$ at 1.0 V</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>5</td>
<td>2.5</td>
</tr>
<tr>
<td>100</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>600</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>1000</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>2000</td>
<td>10</td>
<td>12</td>
</tr>
</tbody>
</table>

Note. Errors at frequencies and voltages inside the indicated ranges are calculated by linear interpolation.

![Fig. 1](image)

Fig. 1

of MIs with unipolar coaxial input connectors. Otherwise, it is necessary to connect to the TC output (in the $aa$ plane) a section of an ordinary transmission line ($\varepsilon_r = 1.0, Z_0 = 50 \Omega$) of length $l$ provided with the TC. The input of the calibrated MI is now connected to the output of this transmission line, and the reproduced ac voltages are normalized in the $bb$ plane passing through the contact plane of the coaxial output connector of the section. The error $\Delta_m$ is calculated in percent from [4]:

$$\Delta_m = \left( \sqrt{\frac{1 - 2 \Gamma_1 \cos \varphi_2 + \Gamma_2^2}{1 + 2 \Gamma_2 \cos (2 \beta - \varphi_2) + \Gamma_2^2}} - 1 \right) 100,$$

(1)

where $\Gamma_2$ is the complex input reflection coefficient of the calibrated MI, $\Gamma_2 = |\Gamma_2|$, $\varphi_2$ is the $\Gamma_2$ phase angle, $\beta$ is the phase constant, and $l = 9.5 \pm 0.025$ mm for a type PTV-6 TC.

If $\varphi_2$ is unknown, the boundaries of $\Delta_m$ are calculated for the worst-case phase relations from

$$\Delta_m = \left( \frac{1 + |\Gamma_2|}{1 - |\Gamma_2|} - 1 \right) 100.$$

(2)

Metrological certification of the RÈN-3 is carried out by comparison with the State special primary standard GÈT27-82 with the aid of a comparator, and the method of calculating the RÈN-3 error complies with GOST 8.381-80 [5].

The estimated standard deviation (SD) of the results of measurement and the total error $t_{S_2} S$ in relative units, as a function of voltage and frequency, do not exceed the figures listed in Table 1 for a confidence probability $p = 0.99$ and $n = 10$ observations.

In the transfer of the volt unit to MIs operating with coaxial transmission lines, the error $\Delta_m$ is calculated from (1) and is used to correct the result of measurement. Otherwise, the boundaries of $\Delta_m$ are calculated from (2) and included in the total RÈN-3 error.