HIGH AND ULTRAHIGH-FREQUENCY MEASUREMENTS

THERMISTOR BRIDGE WITH AN AUTOMATIC DIGITAL DISPLAY
AND ZERO CORRECTION
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The precision of reference self-balancing direct-reading thermistor power bridges is limited in its upper measuring ranges by the error of the reading device. Among the Soviet and foreign self-balancing direct-reading, low-power meters maximum precision (1.5% of f.s.d) has been attained in instruments M4-1 (MTO-1) and M4-3 [1,2], which use a pointer wattmeter as the reading device.

The lower measuring limit of a power meter is determined by its zero instability due to its thermistor temperature drift. In the improved thermistor bridge type M4-3, which uses an efficiently adjustable temperature compensation [3], the zero drift can be reduced to 0.3 μW/min, thus producing an additional error of 5pW in the lower measuring range for measurements lasting 30 sec ± 6%

The reduced error in certifying thermistor and bolometric heads (down to 0.5-0.2% [4,5]) requires increased precision of thermistor and bolometric bridges, thus raising the precision of the entire power meter.

In the instrument described in this article, the precision in the upper measuring ranges has been raised by using an automatic digital display, and the threshold of sensitivity (the lowest value of power measured with adequate precision) has been lowered by applying an automatic zero correction.

The automatic digital display of the measured power is provided with a multiplying device whose principle of operation is based on a pulse-time method of multiplying two dc voltages [6] obtained from the bridge circuit. The multiplying device is connected through an analog-to-digital converter of the voltage into a proportional time interval, to an electronic meter with a digital display for measuring this interval.

The automatic zero-correction method is based on a periodic shorting of the channel by the UHF modulator and, when the measured power is disconnected, balancing the measuring circuit by means of an electronic tracking system which stores the value of the thermistor heater-current level. In order to raise precision, the measured power is read off the digital display immediately after zero correction.

The schematic of the instrument (see figure) comprises a galvanometric photocompensated voltage stabilizer 1, double thermistor bridge 2, photogalvanometric amplifier 3 with an autocompensation system, electronic circuit 4 for multiplying two dc voltages V1 and V2 and converting their product into a time interval, and a time interval meter 5 with a digital display.

The automatic zero correction circuit comprises unit 6 for programming the measurement cycle and correction, electromechanical modulator 7, and an electronic relay tracking system. The latter includes dc amplifier 8 of the null detector, null detector 9 (polarized relay), a source of correcting voltage consisting of storage capacitance 10, cathode follower 11, and voltage sources 17 and 18.

A model of the thermistor UHF power meter made according to the above schematic consisted of a UHF modulator with exchangeable bolometric heads, a measuring unit (stabilizer, measuring circuit units, automatic compensation systems, a tracking system for automatic zero compensation, and a circuit for programming measurement and correction cycles) and an electronic multiplier unit.

The electromechanical UHF modulator used for extending the frequency range comprises a Π-type waveguide matched to the exchangeable thermistor heads 12 by means of Chebyshev matching units 13.* The UHF modulator

*The electromechanical modulator model with the Chebyshev matching units was developed by M. A. Cheremnykh
model comprises a II-type waveguide on the base of a 17 x 8-mm waveguide and is suitable for operating with exchangeable thermistor heads in the range of three standard waveguides of 17 x 8 mm, 23 x 10 mm, and 35 x 15 mm. The modulator shuts off the UHF power by means of absorbing plate 14, which is rigidly connected to the plunger of traction relay 15 and inserted into the II-type waveguide. During measurements a voltage is fed to the relay winding and the absorbing plate is withdrawn from the waveguide.

The supply source 1 consists of a highly stable galvanometric voltage stabilizer [3,8]. The autocompensation system 3 includes a photogalvanometric amplifier [2]. Programming unit 6 is made in the form of a semiconductor multivibrator whose operating conditions are set by adjusting its RC network.

In order to reduce the error of the autocompensation circuit due to the low sensitivity of the null detector, the zero autocorrection system is provided with dc amplifier 8, which consists of a chopper for converting the dc output current of the autocompensation system into an alternating current fed through an ac transistor amplifier to a phase-sensitive detector where it is rectified. The rectified current is fed to the excitation winding of polarized relay 9.

The linearity of the UHF power scale is ensured by multiplying two dc voltages, one of which is proportional to $2I_T - \Delta I_T$, and the second to $\Delta I_T r_T$, where $I_T$, $\Delta I_T$, and $r_T$ are, respectively, the heater current, the substitution current, and the thermistor resistance.

One of the multiplied voltages $V_1$ is taken off the measuring circuit as the sum of two voltages. The first voltage consists of the voltage drop across $r_T$ of thermistor 12 and resistor $r_1$ produced by the difference of heater current $I_T$ and substitution current $-\Delta I_T$ of the thermistor. The second voltage consists of the voltage drop across resistor $r_2$ produced by the supply current of the circuit. The second voltage $V_2$ is taken off resistor $r_3$ in the autocompensation circuit.

The instrument scale equation in terms of the measuring circuit parameters is equal to

$$N = V_1 V_2 = r_3 \left(1 + \frac{r_1 + r_{1-II}}{r_{12} + r_{12}}\right) \frac{r_T}{r_1} \left(1 + \frac{r_T}{r}\right)^2 \times r_3 + r_{10} + r_{1-II} \frac{r_{10}}{r_{10}} + r_{1-IV} \frac{r_{10}}{r_{10}} - r_3,$$

where $r_{1-II}$, $r_{1-III}$, and $r_{1-IV}$ are the equivalent resistances of separate parts of the measuring circuit.

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