SPECIAL STATE STANDARD FOR THE POWER UNIT OF ELECTROMAGNETIC OSCILLATIONS IN WAVEGUIDE CHANNELS AT 2.59-37.5 GHz

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STATE STANDARDS

The experts of the All-Union Scientific-Research Institute of Physicotechnical and Radiotechnical Measurements (VNIIFTRI) have developed and tested out in 1965-72 a set of devices for measuring power in waveguide channels in the centimeter range with the maximum possible precision. This equipment was approved in July 1972 by the USSR State Committee of Standards (Gosstandart) as the special state standard for the power unit of waveguide channels.

Its basic characteristics include: frequency range of 2.59-37.5 GHz; rectangular waveguide cross sections of 72 x 34, 48 x 24, 35 x 16, 28.5 x 13.6, 23 x 10, 17 x 8, 11 x 5.5, and 7.2 x 3.4 mm; dynamic range of 1-10 mW; power measurement error of ±(0.3-0.5)%, depending on the waveguide cross section; error of 1% in calibrating 1st grade reference instruments; frequencies at which work is carried out are determined by the All-Union State Standard (GOST) 15129-69.

The development of the special state standard, the test scheme, and other normalizing documents are required for ensuring uniform and accurate measurements of power in waveguides by transmitting the dimension of the unit from this standard to reference and working instruments on the national scale.

The waveguide power unit standard is based on a flow-type differential microcalorimeter for measuring the conversion factor of receiving transducers [1, 2]. In this case the microcalorimeter is used for comparing the measured uhf power with a known dc power by converting them into heat in the receiving transducer.

The development of techniques for measuring uhf power has shown the advantages of calorimetric wattmeters, which possess the highest precision [3-6]. The proposals [4, 6] for combining the advantages of the calorimetric and bolometric methods for measuring power played a decisive part in raising the precision of uhf power measurements. The NBS (USA) and the All-Union Scientific-Research Institute of Metrology (VNIIM) (USSR) have developed equipment incorporating the calorimetric method for measuring with an error of 0.2-0.3% the conversion factor of bolometric receiving transducers. The essence of this method consists of substituting dc power for the uhf power dissipated in the thermistor and measuring the difference between the dc and uhf powers with a microcalorimeter. The “dry” calorimeter method for determining the conversion factor is at present basic for national uhf power unit standards of several countries.

A flow-type microcalorimeter and wide-band thermistor heads are used in waveguide channels of the special power-unit state standard as receiving transducers. Although the flow-type microcalorimeter is less sensitive than a “dry” one, it provides high operating speeds (observation time of 2-10 min for receiving transducers with cross sections up to 72 x 34 mm) and the possibility of adjusting the coolant’s flow for determining and eliminating systematic errors [7].

The wide-band thermistor head has a stepped connector from the rectangular to the II-type waveguide, a thermistor slug, and a short-circuited plug. The connector and plug have channels for the coolant. The head has a VSWR ≤ 1.15 in the waveguide frequency range [8]. The differential flow-type microcalorimeter whose schematic is shown in Fig. 1 has a sensitivity of 1°K/W and a drift of 2 μW/min for a flow of ~0.25 cm²/sec. The certified receiving transducer is denoted in Fig. 1 as 1, the reference receiving transducer as 2, the thermistor bridge as 3, the temperature difference stabilizer as 4, the monostat as 5, the pump as 6, the signal generator as 7, the frequency meter as 8, the voltage amplifier as 9, the printer as 10, and the coolant channels as 11.

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Analysis of errors has shown that the unexcluded systematic error in measuring the conversion factor of receiving transducers amounts to 0.1-0.3%, depending on the waveguide size, and that the root-mean-square deviation of a single observation does not exceed 0.2%. In order to reduce the random error, each conversion factor measurement consists of 5-10 observations which are averaged out. The resulting error in measuring the conversion factor does not exceed ±(0.2-0.5%).

The special state standard for the power unit of electromagnetic oscillations in waveguide channels includes a set of standard cells, reference resistors, and a dc potentiometer, which jointly provide a reference measure of dc power; a flow-type differential microcalorimeter with an indicator; three sets of receiving transducers for each waveguide size; a set of power calibrators consisting of differential directional couplers with thermistor heads in the lateral arm; and automatic thermistor bridges.

The conversion factor of a receiving transducer is measured by means of the microcalorimeter. The power calibrator is calibrated by means of three similar-type receiving transducers whose measurements are averaged out. This composition of the state standard serves to calibrate and test 1st grade reference instruments by means of the direct comparison method with an error not exceeding 1%.

In order to maintain continuity the special state standard was compared to a wide-band calorimetric uhf power meter [10] and to isothermal “dry” calorimeters [11] which serve as the initial means for measuring power in waveguides. The results of these comparisons have shown that the adoption of the new special state standard has not changed the dimension of the unit, but the error in its determination has been reduced by a factor of approximately three.

International comparisons of the special state standard to national standards of a number of countries (Hungary, Italy, France, Japan, USA, etc.) have confirmed the validity of the metrological analysis and the expected precision. The results of these comparisons indicate that the dimensions of the participating countries’ waveguide power units do not differ by more than 0.5%.

Normalizing documents for determining the methods and means of transmitting the unit dimension from the standard to reference and working instruments have also been drafted. These documents are based on the test scheme which is used for measuring power at high and ultrahigh frequencies and, to a considerable extent, reflects the practice adopted in the USSR for testing uhf wattmeters.

The preferred method for testing according to the scheme [9] consists of direct comparison. The dynamic range is extended towards large and ultrasmall powers at the level of the reference 2nd grade instruments by means of power dividers (for instance, a directional coupler, or a polarized attenuator) and reference means for measuring attenuation.

Metrological characteristics of the special state standard meet the requirements of providing uniform and accurate uhf power measurements for the next 5-7 yr.

It is to be expected that the application of this standard will raise the precision of working instruments, whose error is determined to a great extent by the error of calibration. Therefore, the task of improving further and raising the precision of the standard and reference instruments is a topical one. The precision in measuring power in waveguides at the level of standards and reference instruments is limited by the error of bridges, the matching parameters and long-term instability of receiving transducers, and by the parameters of measuring generators (level instability and the presence of harmonics). Analysis of errors shows that, on the basis of the implemented technical measures, the error of the standard can be halved and that of 1st grade reference instruments reduced to ±0.5%.

Further progress in measuring uhf power in waveguides can be attained by:

1) developing wide-band and highly-stable receiving transducers (comparison standards) which have a VSWR < 1.1 in the working frequency range and a stability not worse than 0.1-0.2% per annum, and reference equipment for measuring attenuation with an error not exceeding 0.02 dB in the range of 0-50 dB;

2) starting mass production of thermistor and bolometric automatic bridges with a power substitution measurement error not exceeding ±(0.1-0.15)% and reference means for measuring pulsed power in waveguide channels on the basis of the special state standard in a condition of continuous oscillations;