A NEW STATE TIME AND FREQUENCY STANDARD OF THE USSR

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ABSTRACT

In 1976 a new state primary time and frequency standard of the USSR was certified and confirmed with an error of reproducibility less than 1×10^{-13} and with an unavoidable systematic error less than $3\text{-}4 \times 10^{-13}$. This standard includes a laboratory primary cesium beam frequency standard providing an independent definition of units in the SI system, primary hydrogen frequency standards preserving the units of frequency and time intervals, and hydrogen and cesium clocks providing the TA(SU) and UTC(SU) time scales.

Measurements within the standard are made automatically by computer. Comparisons within the Soviet Union and with standards of other countries are made by television, portable atomic clocks, and meteor trails. Errors in comparisons are less than 0.1 - 0.5 μs. Loran-C is used as a reserve means of comparison.

1. INTRODUCTION

The USSR state primary time and frequency standard is the basic means for the measurement of time and frequency in the Soviet Union. This standard includes systems which produce the units of frequency and time interval, provide continuous USSR astronomical and coordinated time scales, and provide a means of comparison with external and internal standards. Secondary systems guarantee an uninterrupted power supply and provide for measurements of environmental and system parameters. The basic elements of the state standard are the systems for the reproducibility of frequency and time interval as well as the TA(SU) and UTC(SU) time scales.

2. CESIUM BEAM FREQUENCY STANDARD

The cesium beam frequency standard developed in 1975 provides frequency reproducibility of the unperturbed transition of the cesium 133 atom to the order of $3\text{-}4 \times 10^{-13}$. Comparisons of this standard are made with

D. D. McCarthy and J. D. Pilkington (eds.), Time and the Earth's Rotation, 19–21.

the hydrogen frequency standards included in the state standard.

3. HYDROGEN FREQUENCY STANDARDS

The high stability and reproducibility of the hydrogen frequency standards permit almost a half order-of-magnitude decrease in the uncertainty in the length of the second in the state standard. The hydrogen standards were first incorporated in the state standard in 1967. In 1976 hydrogen standards of a new design, characterized by an error in reproducibility of the order of $0.6 - 1.2 \times 10^{-13}$, were introduced in the state standard. Three sets of hydrogen standards, whose frequencies are periodically defined by comparison to the cesium frequency standard, are incorporated in the state standard.

4. TIME SCALE

The clock time scale is produced by three hydrogen and six cesium clocks. The gradual transition from cesium to hydrogen clocks is expected because of the smaller variation in the frequency of the hydrogen clocks. This will occur as the operational reliability of the hydrogen clocks improves. The TA(SU) and UTC(SU) time scales are calculated analytically through the intercomparison of standards by an electronic computer. A working time scale $UTC(SU)_w$ is maintained to within $\pm$ 0.2 μs from UTC(SU).

5. INTERNAL COMPARISONS

All of the time and frequency measurements are made automatically and recorded on magnetic tape, which is then processed by electronic computer. The error of a time comparison is $\pm$ 1 ns while the error of a frequency comparison is of the order of $\pm 1 \times 10^{-14}/1000$ s.

6. EXTERNAL COMPARISONS

Comparison with external standards is accomplished by various techniques. Time and frequency comparisons are made using VLF and LF radio signals. The uncertainty is less than 0.5 - 3.0 μs. Television signals are also used for comparison. For a distance of 500 km the uncertainty of a measurement is less than 0.5 μs. Meteor trail reflections may also be used with an uncertainty of 0.2 - 0.3 μs. The most accurate method is the use of portable atomic clocks with an uncertainty of 0.5 - 0.10 μs. Comparisons of UTC(SU) with UTC(BIH) have been carried out using portable clocks and Loran-C.

7. CONCLUSION

The state primary standard has the following metrological characteristics: a systematic error less than $\pm 4 \times 10^{-13}$, an error of reproducibility of frequency and time intervals less than 1×10^{-13}. Work is currently in progress to decrease the error of frequency reproducibility of the cesium beam frequency standard to 1×10^{-13} and that of the

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hydrogen standards to 2 - 3 x 10^{-13}. Efforts are also being made to improve the automization of comparisons and to develop new types of clocks. Work on the use of lasers is now in progress. The He - Ne laser (λ = 3.39 μm) is characterized by an error in frequency reproducibility of the order of 6 x 10^{-13}. Direct comparisons of the laser frequency to the primary state standard frequency and to a D_2O laser (λ = 84 μm) frequency are made with a comparison uncertainty of 1 x 10^{-13}. Investigation of ways of improving the accuracy of lasers is continuing.

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