SUB-MICROSECOND TIME TRANSPORT WITH A RUBIDIUM PORTABLE CLOCK

Helmut Hellwig and A. E. Wainwright

Frequency & Time Standards Section
National Bureau of Standards
Boulder, Colorado 80302

Abstract

Based on a commercially available rubidium standard, the National Bureau of Standards (NBS) developed a portable rubidium clock.Technical modifications which improve the temperature and magnetic environment characteristics allow stabilities in the 10^{-12} range under typical clock transport conditions. The physical size is such that the clock can be carried as hand-baggage on commercial airlines allowing up to 18-hours continuous battery operation.

Introduction

For time comparisons with precisions of better than a few microseconds between distant locations, cesium clocks are used exclusively at present. The use of these devices is not without constraints and problems due to their size as well as their relatively high power demands. For example, with reasonable and portable battery power supplies, available cesium clocks must be powered from outlets on the airplane on any trans- or intercontinental trip. Their size requires the purchase of a separate seat, and their weight necessitates usually two persons to handle the clock. As a result, cesium clocks not only pose logistics problems but these problems also affect the reliability of time comparisons.

Commercial cesium clocks are under development which promise significant reduction of the above problems. Nevertheless, it appeared prudent to explore the possibilities of small, commercially available rudibium standards, which offer the potential of very small clock packages. Even mailable clocks appear feasible.

Technical Data

The general stability requirement for time comparisons with errors of less than 1μs can be stated as*

$$\sigma_y(\tau) < 10^{-6} \tau^{-1}$$

where τ is the interval in seconds between the time comparisons at two remote locations. From this it is obvious that only environmental effects are of concern. For long clock trips (a few hours to one-half day) environmentally induced frequency changes should be individually in the 10^{-12} range or calculable.

On a trip, the clock encounters three major environmental changes: a) in position, b) in temperature, c) in barometric pressure. The performance of the particular unit which NBS acquired was tested against these requirements. For atomic frequency standards, frequency changes due to re-positioning are principally magnetic field effects. The performance of the unit under test was:

(a) position (magnetic field) → up to 10^{-10}, strongly dependent on the particular position, i.e., of the orientation in the earth's magnetic field.

(b) temperature → approximately 4×10^{-12}/C

(c) barometric pressure → parts in 10^9 from atmospheric pressure to vacuum.

It was suspected that the barometric effect was related to temperature, in particular, temperature gradient effects and that the barometric sensitivity would be much less around atmospheric pressure. We therefore decided to reduce the magnetic field and temperature sensitivity and hope for a corresponding reduction in the barometric sensitivity.

The existing outer magnetic shield of the unit is partially reworked to eliminate by adequate overlaps any gaps in the shield, and to provide at least 7 mm distance everywhere to the inner shield. A third magnetic shield is added and the space inside of this shield was filled with foam. This latter measure highly reduces convective cooling of the unit and forces the mounting (base) plate to act as the only significant heat-sink. This reduces the possibility of temperature gradients within the unit which would depend on the state of air circulation around the unit.

The commercial rubidium standard features temperature compensation via current feedback into the internal magnetic field, i.e., the atomic frequency is changed magnetically to compensate for temperature induced frequency shifts. In a series of temperature tests from 26 C to 40 C at the baseplate an optimum adjustment for this feedback was experimentally found. In order to "harden" the rubidium standard against shock and vibration, critical electronic components are glued down and the adjustable magnetic field potentiometer is replaced by a fixed resistor. The unit is mounted with its baseplate inside a carrying case, thus securing adequate cooling. A battery power pack is inside the case including charging circuits from 110 V or 220 V (switchable) powerline voltage. The charging circuits are self-protecting; thus, no precaution is necessary in connecting or disconnecting from powerline service. The batteries are of the sealed lead-acid type.

A divider circuit provides one pulse per second; adequate buffering and 50 Ω load capability for this and the 10 MHz output is provided.

The characteristics of the portable clock are given in Table 1. Figure 1 shows a photo of the complete unit. Table 1 clearly shows, that, as expected, the barometric problem has become tolerable.

Conclusions

The clock has proved itself in a trip to the U. S. Naval Observatory in Washington, DC.**It demonstrated its long battery powered operation, its portability as carry-on luggage, and, most importantly, its capability to transport time with a precision of 0.1μs. The measured time difference was Δt = UTC(NBS)-UTC(USNO) = 7.63μs. The Loran-C values suggested Δt = 7μs. An independent cesium clock trip carried out by a commercial company (J. Marshall, private communication) two weeks later yielded Δt = 7.56 μs. It appears possible that by use of modern, lightweight batteries (e.g. silver-zinc) the weight could be reduced to less than 10 Kg. This would allow unattended clock transport via air cargo. Also, sealing the unit airtight would highly reduce the remaining barometric sensitivity. Although the present value is not limiting because the aircraft cabin pressure is reliably at 600 torr ± 5%, it would offer added convenience and would make unattended trips easier.

The cooperation and help of G. M. R. Winkler of the U. S. Naval Observatory in the taking of data is very much appreciated.

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* $\sigma_y(\tau)$ is the squareroot of the 2-sample variance of fractional frequency fluctuations.

** 26 May 1975.

TABLE I PORTABLE NBS Rb-CLOCK

SIZE:	42 x 24 x 19 cm (16.5 x 9.5 x 7.5 inch)
WEIGHT:	21 Kg (46 lb)
BATTERY-POWERED OPERATION:	18 hours
RECHARGING TIME (from fully discharged):	Built-in supply (0.3A) ⟶ 4 days External charger (1.5A) ⟶ 20 hours
OUTPUT:	(A) 10 MHz, 1 V_{rms} into 50 Ω (B) 1 pps, 5 V_{pp} into 50 Ω Positive, 10 ns risetime
STABILITY:	$\sigma_y = 5 \times 10^{-12}\tau^{-1/2}$ Flicker floor $= 1 \times 10^{-13}$ Drift $< 1 \times 10^{-13}$/day
MAGNETIC FIELD:	Change for any orientation in earth's field $\le 1 \times 10^{-12}$
TEMPERATURE:	$< 2 \times 10^{-13}/°\mathrm{C}$ (Total change for 26°C ⟶ 40°C at Baseplate: $- 2 \times 10^{-12}$)
BAROMETRIC SENSITIVITY:	$\lesssim 1 \times 10^{-13}$/torr (Total change from sea level to 600 torr: $+ 1.8 \times 10^{-11}$

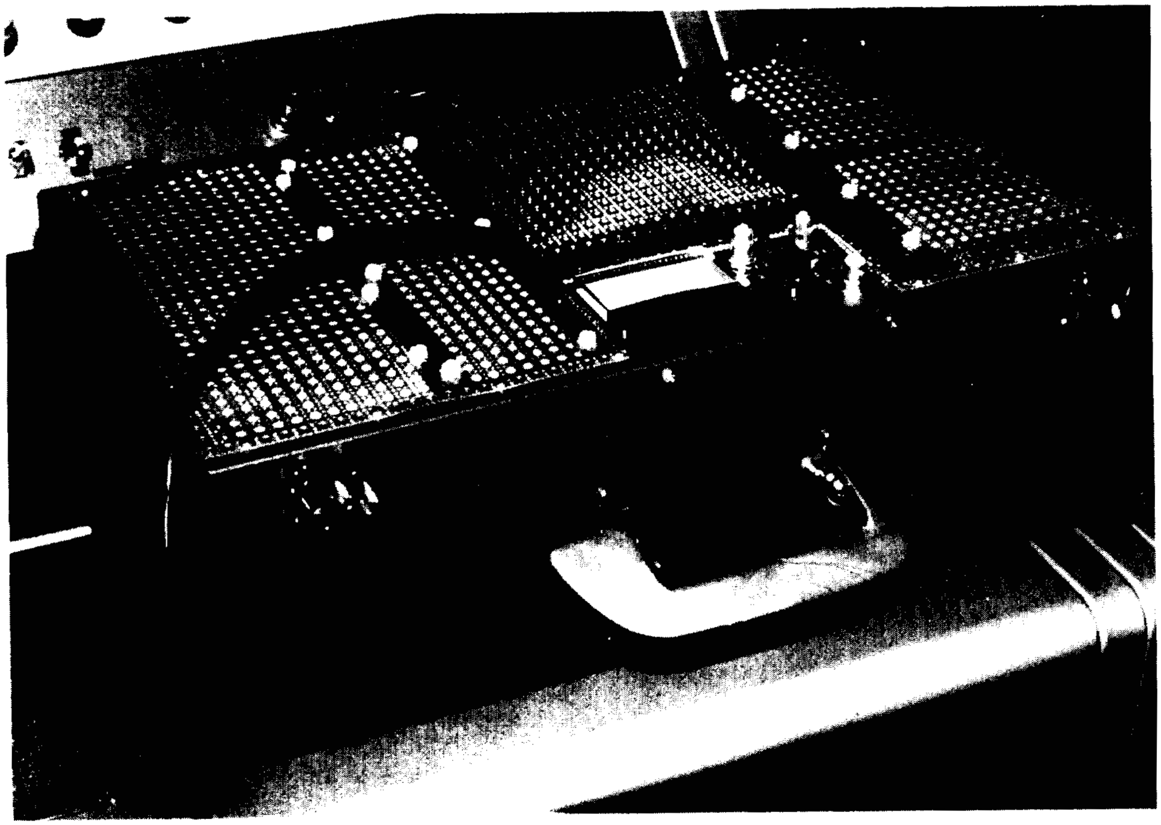

FIGURE 1 PHOTO OF THE NBS RUBIDIUM CLOCK