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Selected aspects of traceability and uncertainty of frequency measurements with counters

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***Summary*—Frequency counters are widely used in industry laboratories to facilitate routine frequency measurement and calibration services. Such services require evidence of traceability to internationally recognized standards if an accreditation is sought. And it is the responsibility of the operator to demonstrate his ability and practices to comply with respective requirements from international standards as EN ISO/IEC 17025. In this report we present an example of a full traceability chain for such a service, in detail comprising all links from the measurements with the so-called device under test via the operation of the laboratory standard to the internationally agreed standard, which is Coordinated Universal Time UTC. Some technical aspects of frequency measurements with counters requiring a closer look are addressed and discussed. Finally, a proposal for summarizing and reporting the uncertainty contribution is being made.**

Keywords*—*frequency counter; traceability; GNSS; GPS; uncertainty; disciplined oscillator; DIN EN ISO/IEC 17025

I. INTRODUCTION

The reception of signals from Global Navigation Satellite Systems (GNSS) is widely used to control oscillators almost wherever users need a stable and accurate frequency and time reference. One example is the use of GNSS disciplined oscillators (DO) as frequency refences in industry laboratories offering calibration services in the field of time and frequency.

According to ISO/IEC 17025 [1], operators need to demonstrate traceability by developing an uncertainty budget regarding the contributions from every single link of the traceability chain from their own setup to international agreed standards, for example time scales of national metrology institutes or Coordinated Universal Time (UTC) itself. Substantial work has been done in this field before [2,3]. Based on these papers, already available guidelines [4], and own work [5,6,7] we present in detail the development of an uncertainty budget including all relevant contributions to establish an unbroken traceability chain. A full paper is in preparation [8] and will be submitted to the journal Metrologia.

II. METHODS/RESULTS

We describe the realization and maintenance of the traceability chain for frequency measurements with counters through disciplined oscillators to UTC and its physical realization UTC(PTB) (see Fig. 1). This chain comprises the development of an uncertainty budget for counter measurements with the help of a combined synthesizer counter setup, the operation of a local DO controlled by a GPS receiver, and assessing published observation data as published in the PTB Times Service Bulletin. The latter contains monitoring results of the received signals from GPS, Galileo and DCF77 and results from the BIPM key comparison CCTF-K001.UTC (as published in the monthly Circular T).

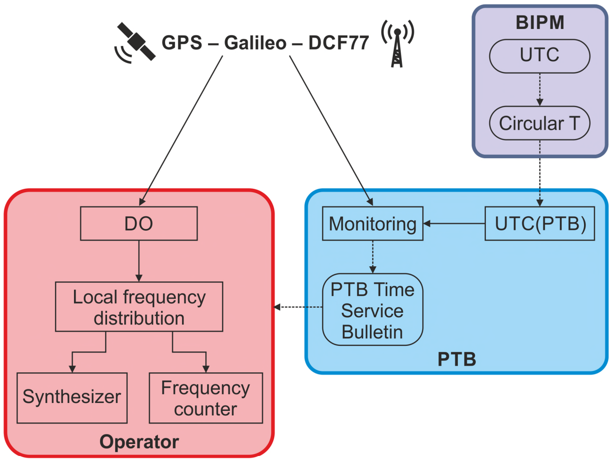

Fig. 1. Scheme for traceable frequency measurements with counters connected to an external frequency reference of a disciplined oscillator which receives broadcast time and frequency signals. In this example traceability is established to UTC via PTB.

We chose a set of standard equipment, consisting of a GPS disciplined Rb atomic clock, a synthesizer, and a reciprocal frequency counter to exemplarily determine the uncertainty contributions. We concentrate here on the use of a Stanford Research Systems SR620 which is a classical reciprocal counter without advanced internal averaging algorithms. It is considered as a representative of a class of instruments, which is widespread and allows us to clearly draw the procedure of uncertainty determination and traceability realization.

All links of the traceability chain are discussed in detail. One focus is on the counter/synthesizer part dominating the overall uncertainty especially at lower frequencies. Characteristic parameters of the devices are theoretically discussed, experimentally determined, and contrasted with manufacturers' specifications. The (relative) uncertainty contributions, developed in this work, are illustrated in Fig. 2 in dependence of the measured frequency.

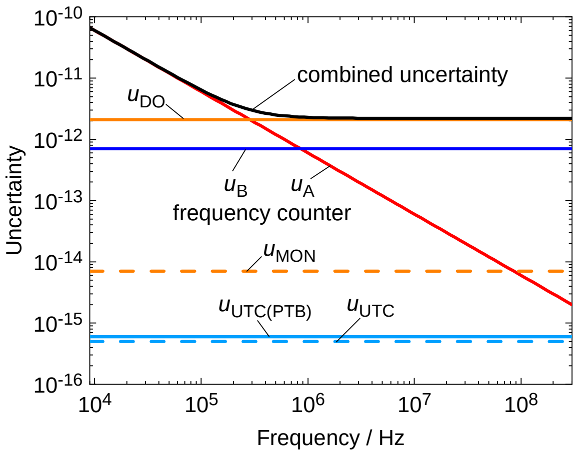

Fig. 2. Illustration of the uncertainty contributions over the chosen setup's frequency range ($f = 9$ kHz … 300 MHz) and frequency counter parameters (i.e. maximum gate time = 500 s and minimum 100 samples) for a calibration laboratory which is equipped with a certain type of GPS disciplined oscillator.

Most contributions are frequency independent. It is obvious, that uncertainties originating from UTC, UTC(PTB), and the GPS monitoring data (MON) recorded at PTB are negligibly small compared with the systematic uncertainty (u_B) of the counter and the uncertainty of the DO. In our case u_{DO} is the dominant frequency independent contribution. But this may depend on the devices chosen for the specific measurement setup. At lower frequencies the statistical uncertainty (u_A) of the frequency counter becomes significantly higher than all other parts and dominates the combined uncertainty.

III. CONCLUSIONS

The uncertainty evaluation to be presented could be used e. g. by calibration laboratories to inspect their own setup and procedures to provide traceable calibrations to their customers.

DISCLAIMER

Commercial Products are identified for the sake of technical clarity. No endorsement by the authors or their institutes are implied. We further caution the readers that none of the described equipment's apparent strengths or weaknesses may be characteristic of items currently marketed.

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