Time & Frequency Dissemination in the UK

John Laverty
Time and Frequency Section, Centre for Electromagnetic & Time Metrology,
National Physical Laboratory, Queens Road, Teddington, Middlesex, TW11 0LW,
United Kingdom

Abstract

This paper provides a qualitative review of those standard-frequency and time signals available in the UK which can be used to trace time and frequency measurements to national standards. Particular emphasis is given to use of the Global Positioning System, as well as the more traditional terrestrial radio broadcasts from Rugby on 60 kHz and Droitwich on 198 kHz. A brief mention is given to telephone and inter-net time services, where similar traceability principles apply but where they are likely to be in demand from a new and wider community because of the growth in electronic commerce.

1. Comparing Time and Frequency Measurement Standards

The base unit of time, the second, is the most accessible of all the SI units. A signal generated by a time and/or frequency standard can be directly broadcast over a wide geographical area, making that standard directly available to users with the appropriate receiving equipment. The fact that the same standard-frequency and/or time signal can be received by many users allows for the indirect comparison of remote standards, a mechanism used at the international level for comparing the time held by national laboratories and at the national level for establishing a traceable measurement chain to one of those national standards. In contrast, measurement standards for other physical quantities have to be disseminated through the transfer of artefacts - either by transfer standards or by the direct calibration or inter-comparison of measurement instruments - a much slower and more cumbersome process.

2. Co-ordinated Universal Time (UTC)

Co-ordinated Universal Time (UTC) is the foundation of the international time system, and is both a measurement system and a time scale. The fact that UTC is generated by national time laboratories, and that the seconds of UTC are based on the SI definition of the second, means that UTC is the mechanism for establishing quantitative agreement on the performance of the various national time standards around the world. As a time scale, it provides the internationally agreed *time of day* and *date* for science, technology, commerce as well as for everyday communications. Thus the time used for the most mundane and for the most technologically demanding tasks are locked to the same reference. The value in this approach is that time and frequency measurements are transparent across national boundaries and across different science and technology sectors.

The UTC time scale is determined using some 260 atomic clocks in some forty national time laboratories around the world, including the National Physical Laboratory (NPL) in the UK. The time difference between the laboratories is compared using the Global Positioning System (GPS) satellites as transfer standards, via the "classical GPS common-view" method. The Bureau International des Poids et Mesures (BIPM) in Paris collates time data from each laboratory, along with time transfer data, and computes UTC. The medium term stability of UTC (up to 40 days or so) is set by the stability of the contributing clocks, and the statistics associated with the algorithm used to compute the time scale. The accuracy and long term stability of UTC is established with measurements from a small number of primary frequency standards. Over the last year, measurements have been made using six primary frequency standards at the PTB in Germany, NIST in the United States and NRLM and CRL in Japan. While the primary standards ensure that UTC keeps time in a highly accurate and regular manner, additional procedures are needed to keep UTC in approximate agreement with the time based on the rotation of the Earth (i.e. UT1, the more scientifically precise version of Greenwich Mean Time). The agreement is maintained by inserting leap seconds into UTC, effectively setting the UTC "clock" either backwards or forwards by one second when required, typically every 18 months.

One key point to note is that UTC is a post-processed time scale, with the latest results published each month by the BIPM in their Circular T. If access to UTC is required in real-time, one must establish a link to a national time laboratory either directly or indirectly through a broadcast system referenced back to a national time laboratory (e.g. the MSF 60 kHz transmission which is under the control of NPL, or GPS which obtains UTC from the US Naval Observatory). The uncertainty in the comparison will be dependent on the quality of the link, and the ability of the national time laboratory to predict its own departure from the UTC ahead of the publication of next BIPM Circular T.

3. Standard-Frequency and Time Signals for Traceability in the UK

Three standard-frequency and/or time signals are listed below which can be used to establish a traceable measurement link to NPL in the UK. The two terrestrial VLF radio broadcasts (i.e. MSF 60 kHz broadcast transmitted from Rugby and the BBC Radio 4 long wave transmission from Droitwich on 198 kHz) have been the mainstay of time and frequency calibrations in the UK in recent years. While GPS has dominated the time and frequency market in recent years, particularly for telecommunications applications, it has only just been accepted as a method for achieving NAMAS accreditation for time and frequency measurements. The GPS common-view method is a differential time transfer method rather than a broadcast service: it is not currently used for disseminating national standards at present, but new services are planned in the very near future.

SFTS	Geographical Coverage	Nominal Time dissemination accuracy	Nominal Frequency dissemination accuracy
Droitwich on 198 kHz	Southern England	n/a	10^{-11}
MSF on 60 kHz	UK	2 ms	10^{-12}
GPS (one-way)	Global	340 ns	10^{-12}
GPS (common-view)	Global to NMI's (UK only to NPL)	10 ns	10^{-13}

3.1 MSF and Droitwich

In the case of the MSF 60 kHz transmission from Rugby, the time signal is broadcast by the BT but under contract from NPL. Hence NPL has direct control of the signal. In the case of the Droitwich transmissions, the signals is not under active control from a