Service category 2.1.1

Calibration of local frequency standard by dual mixer time difference method

Basic information

- Quantity — frequency
- Instrument or artifact — local frequency standard
- Instrument type or method — dual mixer time difference measurement
- Measurement level or range — 1 MHz to 20 MHz
- Measurement condition — 0.9 V_{pp} to 4.5 V_{pp} with 50 Ω

Instrument used

- Dual mixer time difference system

Measurement setup

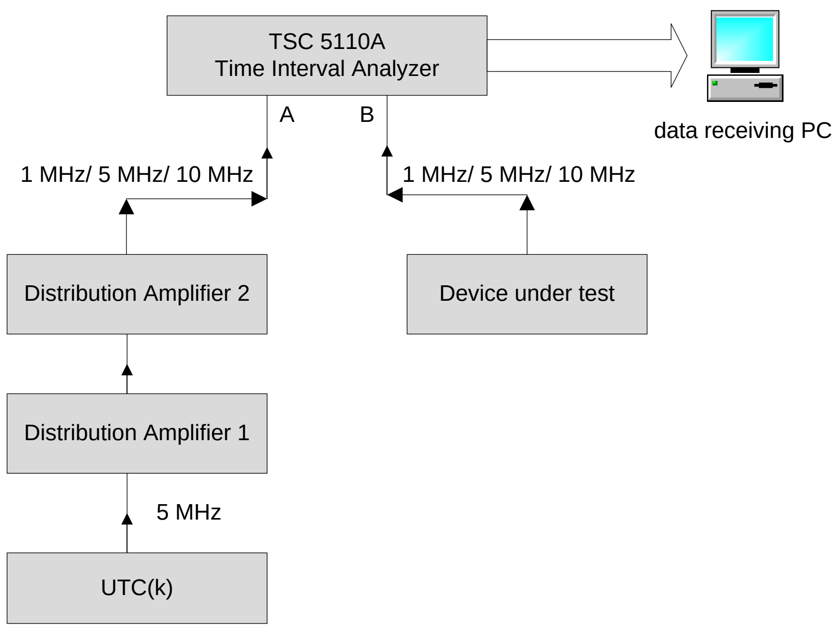

Figure 1. Measurement setup.

List of uncertainty

1. UTC uncertainty
2. UTC – UTC(k) link uncertainty
3. UTC(k) prediction uncertainty
4. UTC(k) source uncertainty
5. Cable uncertainty
6. Measurement system noise uncertainty

Detail of uncertainty calculation

1. UTC uncertainty includes two parts: fractional deviation *d* and standard uncertainty *u* as described below

   $$U_{UTC} = \sqrt{d^2 + u^2} = \sqrt{(5.2\times10^{-15})^2 + (0.3\times10^{-15})^2} = 5.2\times10^{-15}$$

   - *d,* fractional deviation, 5.2E-15 (the worst value in previous year, as published on Circular T)
   - *u,* standard uncertainty, 0.3E-15 (the worst value in previous year, as published on Circular T)

2. UTC-UTC(k) uncertainty

   $$U_{link} = \frac{u_A}{86400 * 5} * \sqrt{2} = 1.3\times10^{-15}$$

   - Uncertainty u_A =0.4 ns (the worst value in previous year, as published on Circular T)

3. UTC(k) prediction uncertainty is comprised of two factors:
   - Average difference of UTC-UTC(k) from previous year data
   - Standard deviation of UTC-UTC(k) from previous year data

   $$U_{UTC(k)} = \sqrt{average\ difference^2 + standard\ deviation^2}$$

   $$= \sqrt{(1.4\times10^{-16}\times\sqrt{5})^2 + (8.6\times10^{-15})^2} = 8.6\times10^{-15}$$

4. UTC(k) source uncertainty
   - Stability of the master clock at one day time interval, $U_{UTC(k)\_source} = 3.0\times10^{-15}$

5. Cable uncertainty

   $$U_{cable} = \frac{0.001ns/^0C/m \times temperature\,\mathrm{var}\,aition \times cablelength}{43200s} = 2.8\times10^{-15}$$

   - The temperature coefficient $\Delta f/f$ = 0.001 ns/^{0}C/m, as measured in the lab using a temperature chamber
   - The lab ambient condition is (23±2) ºC
   - The cable length is taken as 30 m

6. Measurement system noise uncertainty
   - The measurement system noise can be measured by the setup shown in Appendix A
   - The uncertainty U_{noise} is the stability of the measurement result at one day time interval

Uncertainty budget table

S/N	Uncertainty Source	Uncertainty Value	Type	Distribution	Conversion factor K	Standard uncertainty (Hz/Hz)
1	U_{UTC}	5.2×10^{-15}	A	normal	1	5.2×10^{-15}
2	U_{link}	1.3×10^{-15}	A	normal	1	1.3×10^{-15}
3	$U_{UTC(k)}$	8.6×10^{-15}	A	normal	1	8.6×10^{-15}
4	$U_{UTC(k)\_source}$	3.0×10^{-15}	A	normal	1	3.0×10^{-15}
5	U_{cable}	2.8×10^{-15}	B	rectangular	√3	1.6×10^{-15}
6	U_{noise}	2.0×10^{-16}	A	normal	1	2.0×10^{-16}
Combined Uncertainty = $\sqrt{U_{UTC}^2 + U_{link}^2 + U_{UTC(k)}^2 + U_{UTC(k)\_source}^2 + U_{cable}^2 + U_{noise}^2} = 1.1\times10^{-14}$						
Expanded Uncertainty = 2 × $\sqrt{U_{UTC}^2 + U_{link}^2 + U_{UTC(k)}^2 + U_{UTC(k)\_source}^2 + U_{cable}^2 + U_{noise}^2} = 2.2\times10^{-14}$						

APPENDIX A: Measurement of System Noise

The measurement system noise was measured with setup in Figure A1. The result is illustrated in Figure A2.

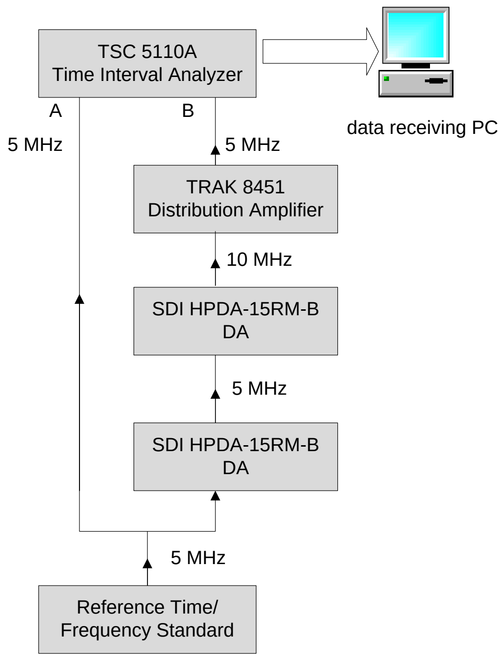

Figure A1. Measurement setup of system noise.

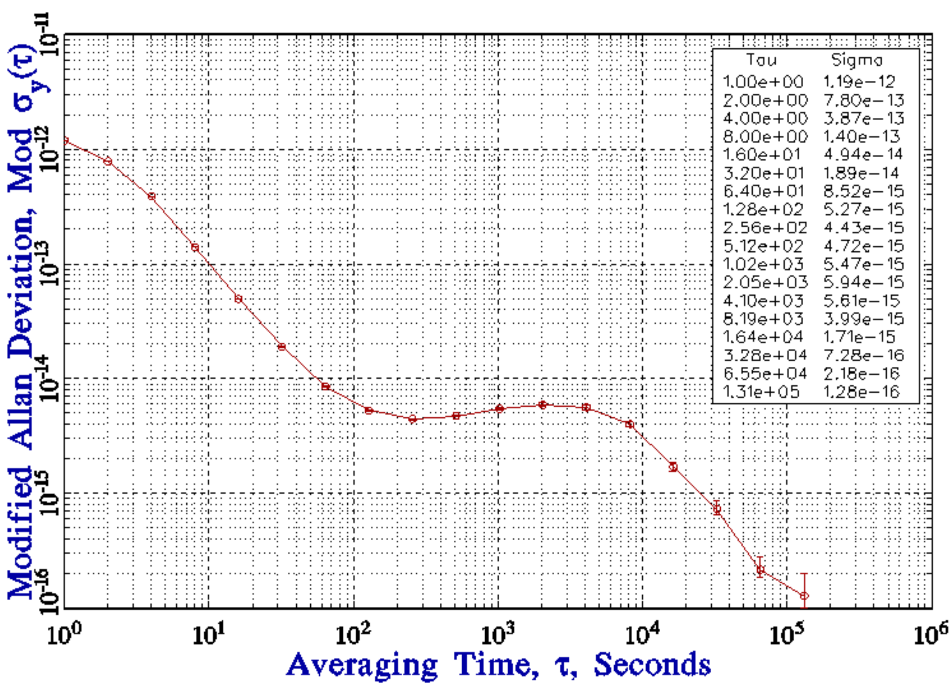

Figure A2. Frequency stability of system noise measurement.