A Novel Optical Timing System for Space Telescopes

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Timing History

About 25 years ago, we installed the first Timing Systems in banks and insurance companies – equipped with either high quality oscillators or Rubidium units.

These companies had to synchronize their large number of computer systems to about 10 to 100 µs, and later insisted in accuracies better than 1 µs. These installations have been modernized, and now 100ns or better is the usual request from bank houses.

On the other hand, there are scientific systems in local timing labs, research institutes, telecom companies or satellite ground stations. The latter are often very demanding, and I would like to tell you about one of our projects in this area.

Precise Timing Required

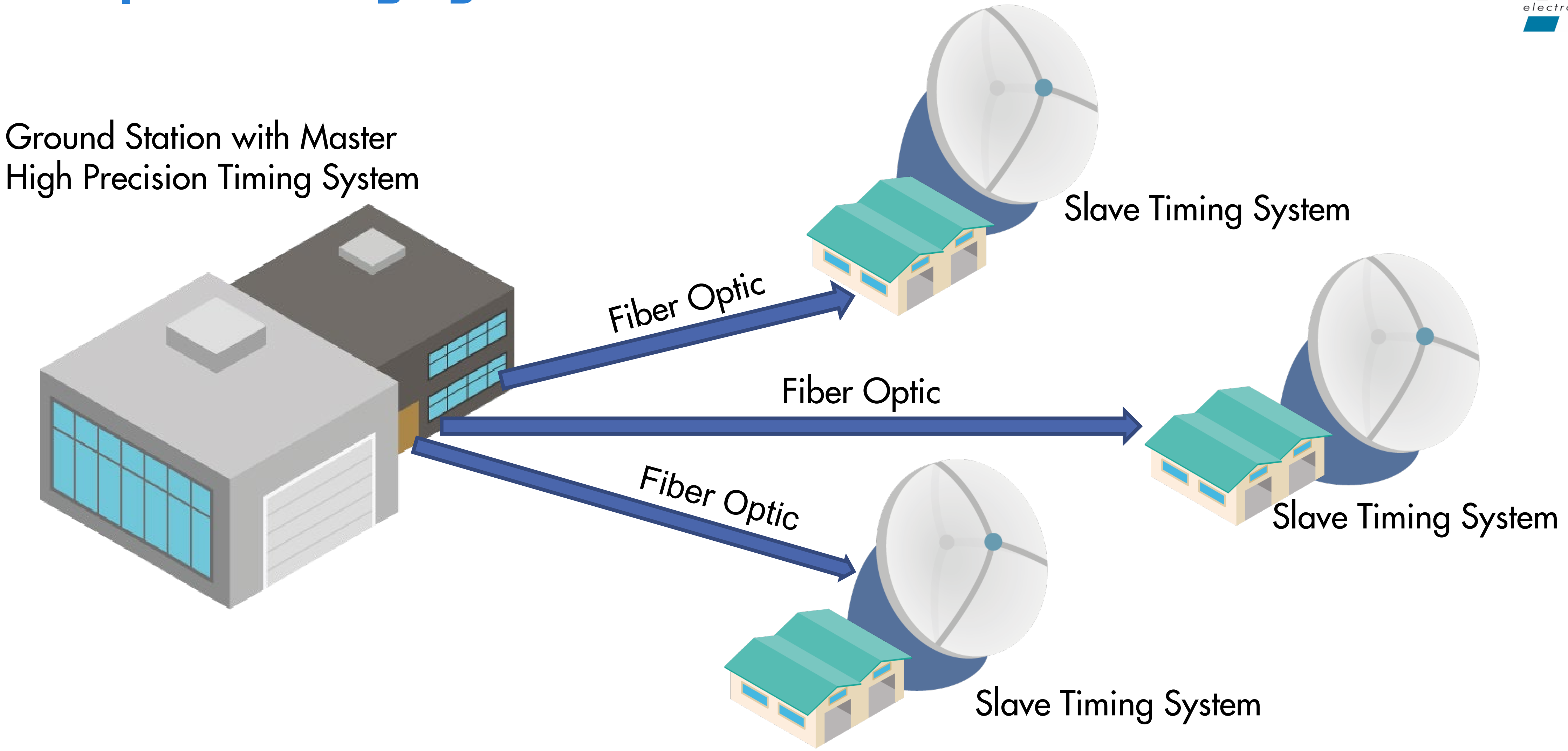
To control one or more Deep Space Antennas from a Ground Station and combine the data with further Ground Stations, a very precise time base and stable frequency is needed.

Satellite Ground Stations

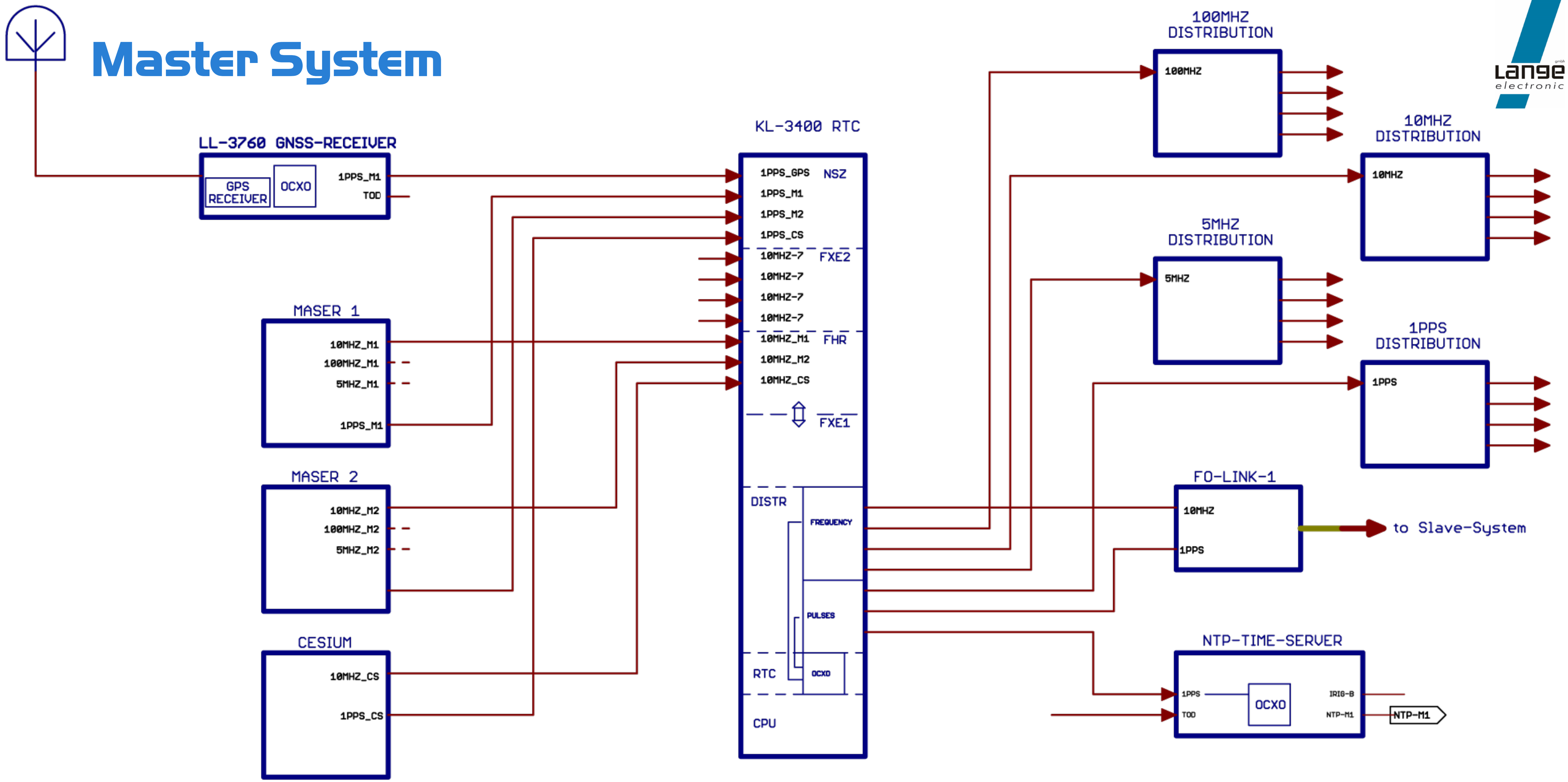
Looking into a satellite ground station and asking for the timing system you will find a few masers – often 2 , sometimes 3 units whose frequency outputs and – if available 1pps - are fed into the usual dual redundant timing system.

Off course – precise time is such an important part of these kind of systems that redundancy is simply mandatory. The masers are the most important first stage of such a system.

Novel Optical Timing System



Master System



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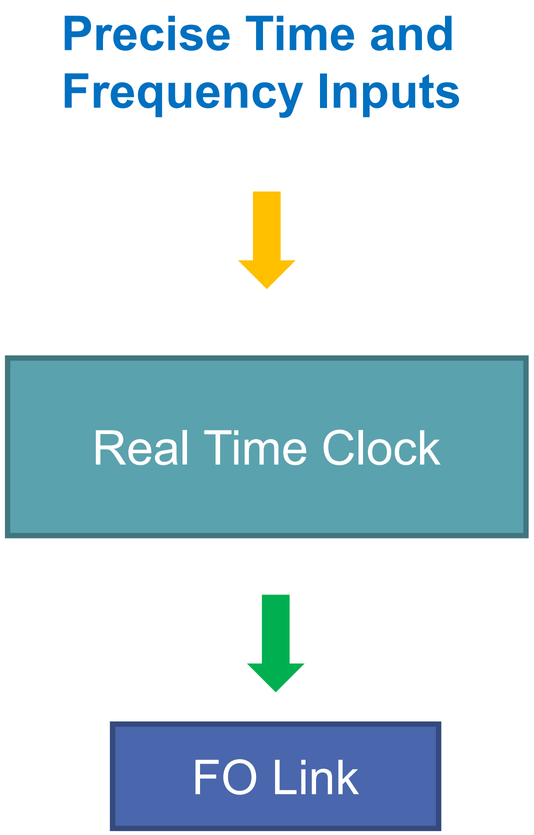
Master System

The time base of the system contains the outputs of one or two GNSS Timing Receivers, two Masers and a Cesium. All time and frequency signals are fed into the „Real Time Clock“, which is capable to form outputs as a combination of this clock ensemble, which are more stable and precise than each of the inputs.

The frequency outputs from both Masers and the Cesium are measured constantly parallel by the RTC with a resolution of 5 x10E^{-14} @1s, calculating a clock ensemble that will be represented by RTC’s 100MHz, 10MHz, 5MHz and 1PPS output signals. The long term drift of the clock ensemble is corrected by measuring also the GNSS-Receiver(s) and tie the “system time” to UTC time scale.

10MHz and 1PPS are distributed as reference for PTP/NTP, IRIG and other timing signal generation.

Also the Fiber optic link will compensate the time delay of the link, each of the slave links will have a dedicated 1PPS signal compensating other delays like cable length.



Fiber Optic Link

Fiber Optic Link using OSTT-3 – fiber optic time and frequency distribution system.
Part of the System providing the time and frequency signals to external users with the <u>currently lowest possible degradation</u>.
Active compensation of a propagation delay fluctuations, observed in optical fibers due to temperature variations, mechanical stresses and vibrations is the OSTT-3 unique feature.

- Basic parameters and performance:
- Frequency signal: 10 MHz (100MHz option available),
- Time signal: 1 PPS, 100 PPS (phase synchronous with the frequency signal),
- Delay correction range: 2000 ns,
- Output 1 PPS position adjustment: 10 ns resolution, negative delay also possible (upcoming OSTT-4 improves the resolution to 4 ps!),
- Frequency transfer stability: ADEV < 3×10-13 for 1 s averaging, < 3×10-17 for 105 s averaging,
- Time transfer stability: TDEV < 3 ps for 10 s averaging, < 1 ps for 105 s averaging,
- Time calibration uncertainty: 15 ps (assuming 5 ps uncertainty of time interval measurements and 5 ps/nm uncertainty of fiber dispersion measurement.

OSTT-3 – fiber optic time and frequency distribution system – technology and equipment provided by PIK TIME SYSTEMS®

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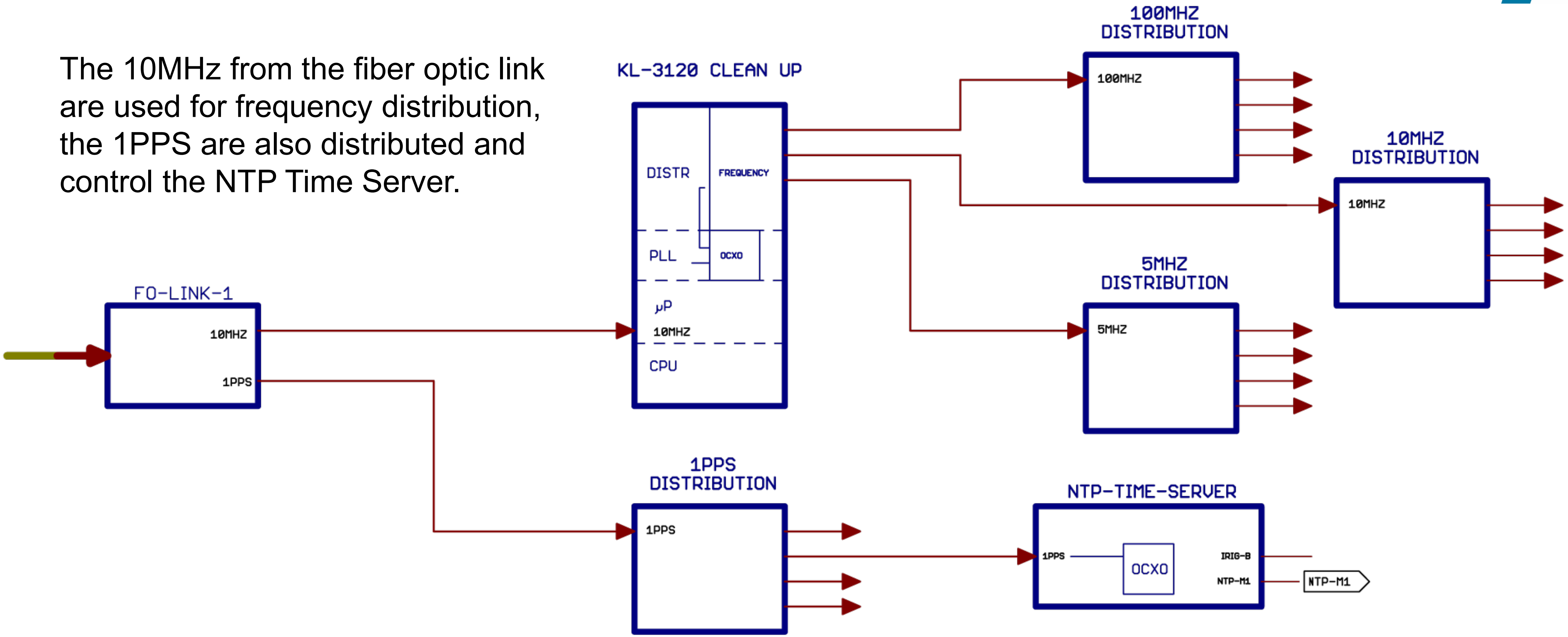
Slave System

The 10MHz from the fiber optic link are used for frequency distribution, the 1PPS are also distributed and control the NTP Time Server.



Real Time Clock

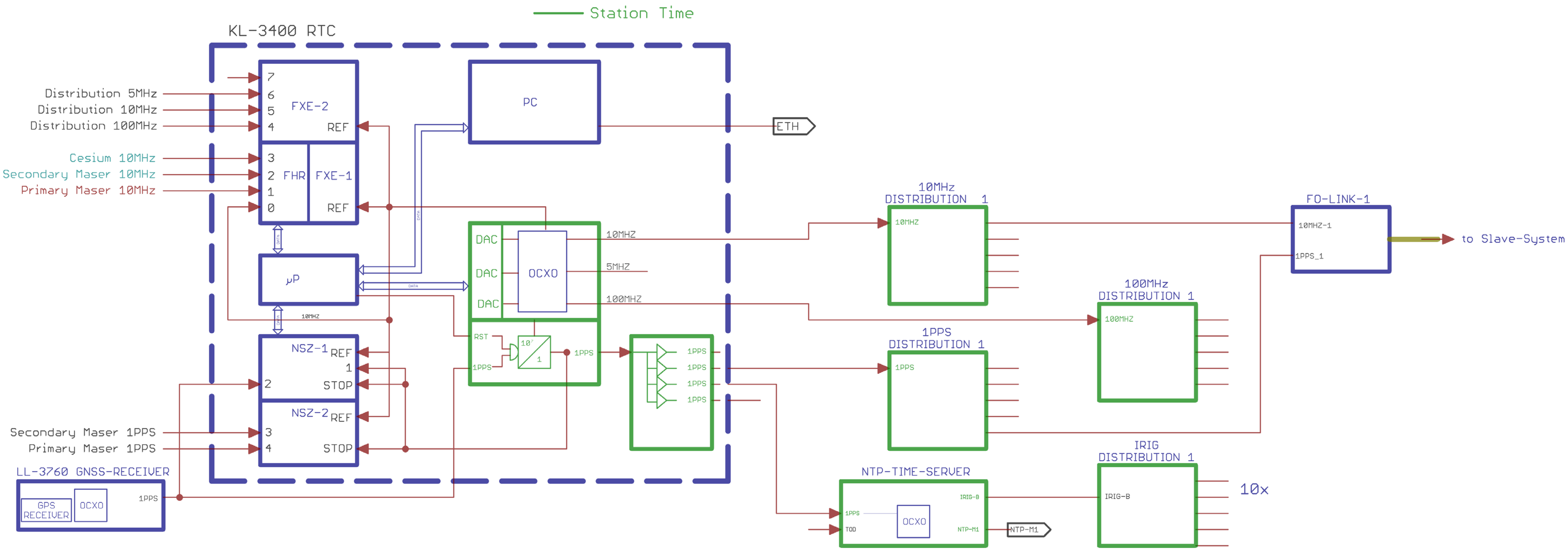
The Real Time Clock creates an output, from an Ensamble of up to 11 high precision inputs, that is more precise and stable than each of the inputs.

Real Time Clock

FHR is a multichannel 'Dual Mixer'-type of front end for the FXE phase meter used to enhance the phase resolution by a factor of 20, resulting in a noise level of 4E-14 @ 1s.
Like FXE, each card provides 4 channels, each of them locking the 500kHz subharmonic of a 10MHz oscillator to the beat frequency between the nominally 10MHz RF input signal and a 9.5MHZ local oscillator which is common to all channels.
This common LO signal is generated by a DDS board from the 10MHz FXE reference clock. By changing the local oscillator frequency to maintain the IF frequency of 500kHz, FHR can easily be adapted to other RF input frequencies, e.g. 100MHz.
A standard FXE phase meter is then used to count the 10MHz oscillator frequencies, where one period (100ns) corresponds to only 5ns of the FHR input signal. Accordingly, the 12.2ps resolution of the standard FXE translates to 0.6ps resolution of the FXE combined with the FHR front end

In FXE phase difference mode between channels, the fluctuations of the common LO cancel out, thus allowing for very high quality phase comparison between highly stable clocks like H-Masers, even with only moderate requirements for the stability of the common local oscillator.
FHR accepts input signals with appr. 2...7dBm power level and no more than 1E-8 relative frequency offset from the nominal 10MHz.

Real Time Clock



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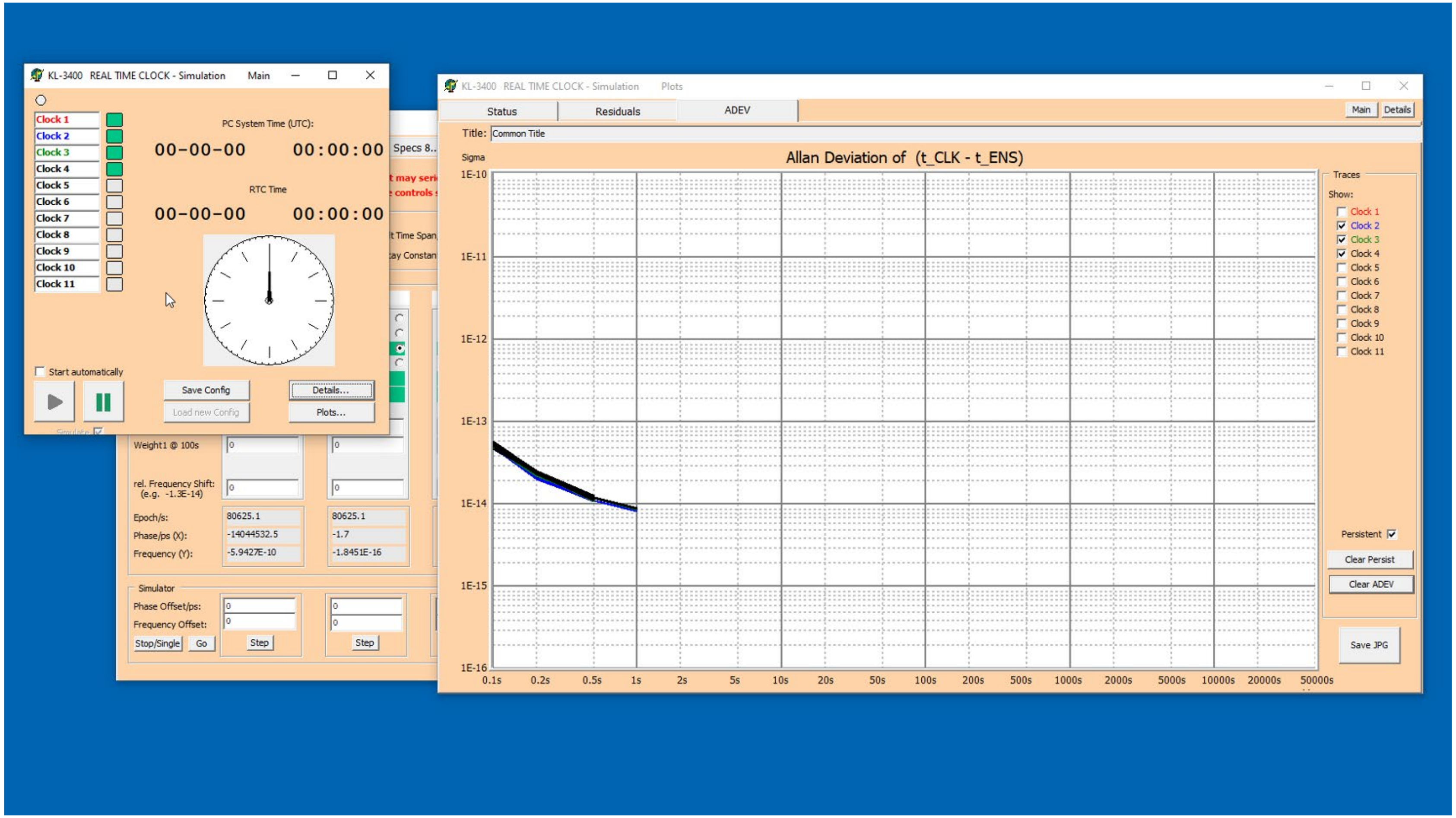
Real Time Clock



Here you can see the control software of the Real Time Clock.

The Allan Deviation of clock 2, 3 and 4 develops over time.

The values of each clock can be set seperately.

All marked clocks are included in the clock ensamble for the high precision output.

Conclusion

The different systems I did show you shall demonstrate that precise time can be „produced“ in different ways….

But that is not surprising – from ESO via Eumetsat, ASTRA and DLR to ESA there are different problems that require different solutions, every solution has to be made with the latest possible technology.

Any questions?
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Fiber Optic Information PIK Time Systems®

KL-3400 Real Time Clock in collaboration with K+K Messtechnik K+K