Enabling Time-Frequency synchronization over long distances for Radio Astronomy

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Radio interferometers work by measuring the coherence of the electromagnetic radiation received at the antennas. It is therefore essential that these antennas are synchronized, which can be achieved through distribution of a common reference frequency. In addition, some of the most exciting future radio astronomy science goals require very precise timing of the arrival of signals from phenomena such as pulsars. This paper will review these synchronization and timing requirements, and then examine in depth how they will be addressed by the Synchronisation and Timing (SAT) network for the Square Kilometre Array (SKA).

The SKA will be the world's largest and most sensitive radio telescope. It will address fundamental unanswered questions about our Universe including how the first stars and galaxies formed after the big bang, how dark energy is accelerating the expansion of the Universe, the role of magnetism in the cosmos, the nature of gravity, and the search for life beyond Earth. For imaging work, the SKA will work as an interferometer and so it is essential that phase coherence is maintained across the whole telescope. This implies that a pico-second accuracy frequency and clock signal must be distributed from a central clock ensemble to all the receptors. In addition, pulsar timing for gravity wave detection and tests of General Relativity, have stringent long term timing specifications. These equate to a level of 10ns accuracy over a period of 10 years. We outline the preliminary design for the sub-systems that address these requirements which comprise:

- The SKA Clock Ensemble, which consists of three Active hydrogen masers. A master and back-up timescale are formed from the frequency references of two of these masers. The third allows for a "three cornered hat" approach to be adopted where the short and medium term stability of each maser to be determined.
- The System for the Time and Frequency Reference signals (STFR). This is an active frequency compensation scheme that differences a single pass 2GHz signal, locked to the SKA Clock ensemble, with a double pass 1 GHz signal locked to a "flywheel" crystal oscillator at the antenna. This produces a 1 GHz reference signal at each antenna that has had the phase changes introduced by distortions in the optical fibre removed.