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Phase Synchronization for the Mid-Frequency Square Kilometre Array Telescope

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The Square Kilometre Array (SKA) project [1] is an international effort to build the world's most sensitive radio telescope operating in the 50 MHz to 14 GHz frequency range. Construction of the SKA has been divided into phases, with the first phase (SKA1) accounting for the first 10% of the telescope's receiving capacity. During SKA1, an array of 197 mid-frequency parabolic-dish antennas, incorporating the 64 dishes of MeerKAT, will be constructed in South Africa (SKA1-mid).

Radio telescope arrays, such as the SKA, require phase-coherent reference signals to be transmitted to each antenna site in the array. In the case of the SKA1-mid, these reference signals will be generated at a central site and transmitted to the antenna sites via overhead fiber-optic cables up to 175 km in length [2]. Environmental perturbations add phase noise to the reference signals received at the antennas, thereby reducing the fidelity and dynamic range of the astronomical signals [3]. Given the combination of long fiber distances and relatively high frequencies of the reference signals, the SKA will need to employ actively-stabilized, photonic technology to suppress the fiber-optic link noise in order to maintain phase-synchronization across the array [2].

The SKA1-mid phase-synchronization system is the first photonic technology to employ acousto-optic modulators (AOMs) as the servo-loop actuators for ultra-stable microwave-frequency transfer [4]. The AOM's ability to compensate phase fluctuations through actuation of frequency results in servo-loops with infinite feedback range, ensuring that the synchronization system can operate robustly across the overhead fiber links without ever requiring an integrator reset. The AOMs also mitigate against unwanted reflections, which are inevitably present on real-world links. In addition, the SKA1-mid phase-synchronization system is immune to distance-dependent signal fading; uses only a single laser thereby limiting chromatic dispersion related issues; incorporates Faraday mirrors eliminating the need for any polarization specific components or specialty fiber; and is also robust against environmental perturbations at the transmitter and receiver sites.

This photonic technology has been extensively tested using standard metrology techniques over metropolitan fiber networks [4]; on 154 km of overhead fiber at the South African SKA site [5]; and verified using astronomical methods with the Australian Telescope Compact Array (ATCA) telescope [6]. Furthermore, we are developing the capability to mass-manufacture this photonic technology in readiness for SKA Construction.

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