3rd URSI AT-AP-RASC, Gran Canaria, 29 May – 3 June 2022

Fiber Optic Delivery of Time and Frequency References for the Next Generation Very Large Array

Bill Shillue* (1), Hitoshi Kiuchi (2)
(1) National Radio Astronomy Observatory, Charlottesville, VA, USA, e-mail: bshillue@nrao.edu
(2) National Astronomical Observatory of Japan; Mitaka, Tokyo, Japan, e-mail: hitoshi.kiuchi@nao.ac.jp

The ngVLA is envisaged as a next generation interferometric array with ten times greater sensitivity and spatial resolution than the current VLA and ALMA, operating in the frequency range of 1.2 - 116 GHz. The array will consist of nominally 263-element synthesis array of very wide extent, with 244 antenna stations of 18-m diameter and 19 6-m antennas. Currently the project is in a conceptual design phase, during which the architecture for the overall system as well as the antenna, receivers, digitizers, software, science, and other subsystems is being defined. This work addresses the conceptual design of the time and frequency distribution subsystem, which is driven by the need to provide stable and accurate reference signals to each antenna station for the purpose of timekeeping, digitization clocks, and local oscillators. In addition to the stringent time and frequency requirements, the design is constrained by the wide-spanning geographic area of the array (up to 800 km spiral arms and continent spanning long baseline stations), and the limited existing base of commercially installed fiber.

The array is centered on the plains of San Augustin in New Mexico, extending into Texas, Arizona, and Northern Mexico, as well as including long baseline stations across the North American continent. Of the 263 antenna stations, there are three different mediums envisaged for the communications link layer. A majority of stations (187) are located within 30 km of the array center and will be connected by a new, buried, dark fiber installation. Thirty additional stations are in the "long baseline array" which spans continental USA and beyond (Hawaii and Virgin Islands), for which standalone time and frequency (e.g. hydrogen maser and GPS) is currently envisaged. The remaining 46 stations form a set of five spiral arms with center-to-station distances increasing from 30 km to about 800km. This latter group of antenna stations presents unique design challenges, beginning with the limited existing infrastructure, the likely need for cooperative agreement with commercial fiber network operators for use of dark channels, and the as yet unknown condition of the fiber (e.g. fiber type, dispersion profile, age of fiber, burial vs. pole-mounted, etc.)

Despite these design challenges, there has been much recent time and frequency work in the fields of telecommunications, clock development, particle accelerators and radio astronomy, which includes several possible approaches for the implementation of a system that will compensate for the fiber optic time-dependent delays - even in the case of very long links and aerial fibers.

Recently a frequency transfer technique has been developed at NAOJ and now extended: a dual-wavelength frequency transfer [1] with a post-processing phase stabilizer up to a distance of 250 km. Additionally, experiments have been conducted to verify that the technique works well in the presence of a large chromatic dispersion equivalent to at last 1000 km. Finally, a straightforward time transfer technique has been developed and will be presented. We will present the chosen design implementation for the time and frequency including required laser sources, transmitters, receivers, and, in particular for the five spiral arms - a design including regeneration and repeaters.

1. Kiuchi, Hitoshi. "Postprocessing phase stabilizer for wide frequency range photonic-microwave signal distribution." *IEEE Transactions on Terahertz Science and Technology* ,7, no. 2 (2017): 177-183, doi: 10.1109/TTHZ.2017.2662584