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Low-Noise Technologies Completes Noise Theory for Next-Generation Radio Telescope Design

DERBY, Kans., February 28, 2014 – Success of next-generation radio telescopes such as the international Square Kilometer Array (SKA) depends not only on their physical size, but on the microwave receivers that must detect very weak signals collected by the antennas. A recently published network noise theory from Low-Noise Technologies shows how to optimize the design of these low-noise receiving systems for best weak-signal performance.

The paper, entitled "Unified Theory of Linear Noisy Two-Ports," appears in the past November issue of *IEEE Transactions on Microwave Theory and Techniques* and addresses the general behavior of low-noise amplifiers, a critical component of radio astronomy systems. "Current two-port noise theory dates from the 1950s and is like a giant jigsaw picture puzzle with half the pieces missing," said James Dietrich, principal investigator at Low-Noise Technologies. "Our unified noise theory completes this puzzle for a clear picture of amplifier operation, and corrects misconceptions that have persisted for decades."

The landmark paper presents for the first time mathematical relations between all known amplifier parameters and provides new insights into the physical operation of low-noise amplifiers from a network perspective. With respect to radio astronomy, one aspect of the noise theory has a particular significance to system optimization. A noise parameter describing the rate of amplifier noise increase with impedance mismatch between antenna and amplifier was, until now, thought to lie in a 2-to-1 range of values. It was also believed that this rate of noise increase could be lowered by semiconductor device (e.g., transistor) design. The completed theory shows, however, that the rate parameter is fixed in value at the upper end of the range for any low-noise amplifier, and cannot be changed by amplifier or semiconductor device design.

"Receiver noise characterization in the design and optimization of the SKA has not been done correctly, and the present system design is much too noisy," Dietrich stated. "This will severely limit the ability of the instrument to perform intended science," he added.

The explanation rests in the relative amounts of two components comprising system noise: antenna noise and receiver noise. A unique feature of the SKA's mid-band aperture array is that the antenna elements are shielded from microwave noise radiated by the warm Earth at 300 K temperature. Consequently, the antenna elements "see" only cold sky at the 3 K temperature of Cosmic Microwave Background (CMB) radiation. However, system noise of the present design is at least an order of magnitude greater than the CMB noise floor, and is dominated by receiver noise and the effects of impedance mismatch.

Low-Noise Technologies believes that with proper design, the ideal noise conditions of a space-based system—very low noise cooled receivers and CMB antenna noise floor—can be combined with the unprecedented collecting area and survey capabilities of the Earth-based SKA mid-band aperture array. "For some time, we have proposed a proprietary amplifier device technology and array architecture that would lower SKA system noise dramatically," Dietrich said. "Our uncooled amplifiers operate at the CMB level of 3 K noise temperature, thereby removing the dominance of receiver noise and, at the same time, reducing the effects of impedance mismatch. We strongly encourage the scientific community to review our noise theory paper and consider these design concepts, as they are essential to performance and success of SKA in its scientific mission over the coming decades."

Low-Noise Technologies is a research and development laboratory providing world's most advanced noise technology.

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