URSI GASS 2021, Rome, Italy, 28 August - 4 September 2021

SARAS-3 Radiometer: Design and Performance of the Receiver

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The spin-flip transition of neutral Hydrogen, with a rest-frame wavelength of about 21 cm and redshifted to 40–200 MHz due to cosmological expansion, is considered to be an excellent probe of the dark ages and epoch of re-ionisation (CD/EoR) to constrain the astrophysics of the first stars and galaxies. The sky averaged or global component of this signal has the potential to be detected with relatively simple, well calibrated radiometers with feasible integration times to gain sufficient signal to noise ratio (SNR) [1]. However, due to the bright Galactic and extragalactic low frequency radio foregrounds that are several orders of magnitude greater in brightness temperature, design of a radiometer to measure this faint signal is a challenging task.

In order to have an unambiguous detection, it is essential that there are no additive or multiplicative confusing spectral structures in the measured sky spectrum originating from instrumental systematics. As the 21 cm signal has spectral structure with multiple turning points while the foregrounds are expected to be spectrally smooth, a radiometer that presents smooth spectral characteristics is conducive to such an experiment. Specifically, a radiometer whose response can be modelled with maximally smooth polynomials [2] has the potential to ease the tasks of calibration and foreground subtraction.

The system design of the SARAS 3 version of the receiver will be presented here. The radiometer receiver incorporates design elements to ensure spectral smoothness when presented with antennas of suitable impedance. Dicke switching, double differencing and optical isolation are used for accurate calibration and rejection of additive and multiplicative systematics. We also present the results from various laboratory tests conducted on the receiver with the antenna replaced with various terminations including an antenna simulator circuit that closely matches the measured antenna impedance characteristics. A measurement equation for the SARAS 3 receiver is presented and laboratory data fitted with it. Maximally smooth fits to the laboratory data demonstrate that the residual structures in the data are less than a $\sim$ mK in two separate octave bandwidths, thus qualifying the radiometer for global 21 cm cosmology.

References

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