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Design of the Analogue System for the HERA Radio Telescope

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The Hydrogen Epoch of Reionization Array (HERA) is a radio telescope dedicated to observing large scale structure during and prior to the epoch of reionization. It is an instrument developed internationally and currently being deployed in the Karoo, South Africa [1]. It will provide an order of magnitude more sensitivity than first generation instruments and will be capable of statistical characterization and imaging of large scale HI structure.

The instrument relies on a number of important RF components such as the front-end module (FEM) which is the front-end receiver attached to the feed antenna. These receivers have been carefully designed to minimize reflections caused by mismatch with the antenna using optimal matching networks with little or no impact on receiver temperature in order to achieve the best sensitivity and match tradeoff.

The FEM features an in-situ calibration system which relies on internal 'Dicke' switching to enable field measurements of a calibrated internal noise source and an internal 50Ω ambient load. With additional laboratory measurements, it is possible to use the Bayesian noise waves calibration pipeline [2] to determine the antenna temperature at sub-Kelvin levels.

The front-end and back-end design use a bespoke I2C over CAN-bus control network to command a number of sensors used to determine parameters such as feed rotation, temperature and output power as well as to control analogue signal attenuation, phase switching and calibration. The analogue system relies on RF-over-fibre signaling over long cable lengths to ensure any signal reflections produced are outside of the spectral delay window of interest [1], thus having minimal impact on the observational data.

1. D. R. DeBoer et al., "Hydrogen Epoch of Reionization Array (HERA)," *PASP*, vol. 129, no. 974, p. 45001, Apr. 2017, doi: 10.1088/1538-3873/129/974/045001.

2. I. L. V. Roque, W. J. Handley, and N. Razavi-Ghods, "Bayesian noise wave calibration for 21-cm global experiments," *MNRAS*, vol. 505, no. 2, pp. 2638–2646, Aug. 2021, doi: 10.1093/mnras/stab1453.