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# A new technique to measure noise parameters for global 21-cm experiments

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## 1 Expanded Abstract

Numerous ongoing experiments (e.g. [1–4]) are seeking to detect the global 21-cm signal from the Cosmic Dawn, using radiometer systems operating across 30–250 MHz. Such a detection requires an exquisitely calibrated radiometer and a well characterized antenna. Any spectral features introduced by the radiometer may obfuscate, or be mistaken for, the expected $\sim$100 mK amplitude absorption feature.

The EDGES experiment reported the presence of an apparent $\sim$500 mK absorption feature in their calibrated data [1]; however, there are concerns that this is partly or fully due to unmodelled systematics that have introduced a spectral feature [5, 6]. In tension with the EDGES result, the SARAS-3 experiment has recently reported a significant non-detection of the absorption feature in their calibrated spectra [7]. Gaining a better understanding and characterization of systematics within global 21-cm experiments will be critical for breaking this tension.

One potential source of unwanted spectral features deserving more attention is the self-noise introduced by amplifiers within the radiometer. As the noise performance of a radiometer depends upon the impedance of the antenna it is connected to, a radiometer's noise figure will differ when deployed in the field as compared to laboratory measurements with a 50 Ω noise source. This difference is a source of error that must be accounted for.

To date, most global experiments have used a method involving a long coaxial cable to determine the magnitude of the difference, following the approach employed in EDGES [8, 9]. This method is primarily based upon the "noise wave" formulation by Meys [10]. Here, we introduce a new technique to characterize noise performance for global 21-cm experiments, based on the related "noise parameter" formulation commonly used in the microwave engineering community [11, 12]. A paper with a full description of the technique is currently in preparation (Price et al., in prep). Our technique only requires a standard Vector Network Analyzer (VNA) and calibration kit, a short cable, and a calibrated noise source.

In the long-cable approach, the frequency resolution of noise wave solutions is dependent upon the length of the cable, with longer cables required for higher resolution. As such, rapidly varying spectral structure may be missed. In contrast, our approach is limited only to the frequency resolution of the radiometer. As the apparatus required is physically small, the approach could feasibly be performed in the field, or incorporated as part of the experiment's in-built calibration. We demonstrate our approach on the HYPEREION radiometer, extracting the noise parameters, and discuss the effects for the detection of 21-cm features.

## References

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