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Systematics characterization for Global Signal Extraction

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Cosmic dawn and epoch of reionization, the period during which the first stars and galaxies form and reionize the universe, can be studied using the 21-cm line transition of the neutral hydrogen atom. The sky averaged global 21-cm signal component corresponding to $6 < z < 34$ is redshifted to metre wavelengths and lies between 40 MHz to 200 MHz. The detection of the signal is challenging owing to exceptionally bright foregrounds[1]. This 21-cm global signal can be detected by subtracting spectrally smooth foreground emissions as shown in Figure 1.

However, instrumental systematics introduced by the antenna can be prohibitive to signal detection. The antenna's primary beam and impedance, which also depends on the properties of the observing environment, play an influential role in distorting the signal. It is to be noted that each of these factors is frequency dependent; hence their effect is specific to the spectral nature of the global signal. Additionally, the non-ideal response of the receiver further adds to the difficulty in modeling instrument systematics.

SARAS radiometer is designed to have characteristics conducive to global 21-cm signal detection[2]. The latest edition of SARAS observes on water bodies to minimize additional systematics arising from stratified ground. Motivated by its design and observations, the talk focuses on the antenna and receiver related non-idealities and their impact on the global 21-cm signal, along with mitigation strategies. We explore perturbations in the primary beam and antenna impedance due to realistic variations in the antenna observing environment. We further assess the impact of the non-ideal receiver performance due to multipath reflections in the signal chain. We characterize systematic errors arising due to these effects and evaluate their impact on the extraction of the global 21-cm signal from SARAS observations.

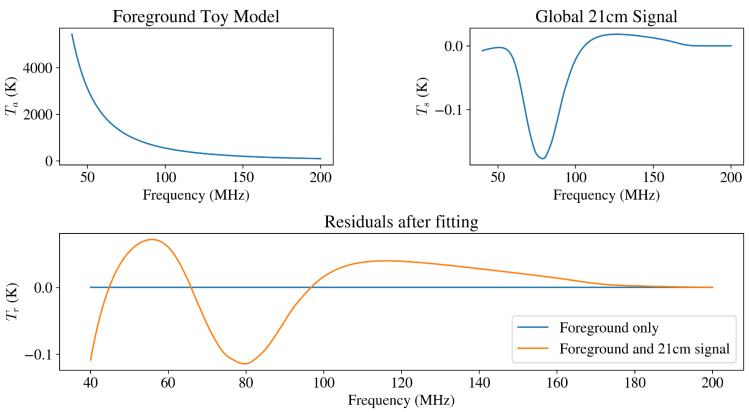

Figure 1. Upper left panel shows Foreground toy model, upper right panel shows standard 21cm signal, and lower panel shows residuals obtained after subtracting smooth component from foreground-only spectrum (blue) and foreground plus 21cm signal spectrum (orange).

1. Shaver, P. A., Windhorst, R. A., Madau, P., et al. 1999, Astronomy and Astrophysics, 345, 380

2. S. Singh, R. Subrahmanyan, N. U. Shankar, M. S. Rao, B. S. Girish, A. Raghunathan, R. Somashekar, and K. S. Srivani, “SARAS 2: a spectral radiometer for probing cosmic dawn and the epoch of reionization through detection of the global 21-cm signal,” Experimental Astronomy, vol. 45, no. 2, pp. 269–314, 2018