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

PRATUSH: Probing ReionizATion of the Universe using Signal from Hydrogen

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1 Extended Abstract

The ΛCDM model of cosmology posits that following the end of the epoch of recombination (redshift $z \sim 1100$), baryonic matter in the Universe was almost completely neutral, with residual ionisation fraction $\sim 10^{-3}$. Several observations, including observations of high redshift quasars and high resolution angular power spectrum of cosmic microwave background (CMB), have confirmed that the late Universe is mostly ionized. The cosmological periods over which the first sources of radiation formed and whose radiation subsequently re-ionized the Universe are termed the Cosmic Dawn (CD) and Epoch of Reionization (EoR), respectively ($80 \gtrsim z \gtrsim 6$). The 21-cm signal, arising from the spin-flip transition of neutral hydrogen atom, is one of the most promising observational probes of CD and EoR. It is predicted that the variation of spatially-averaged intensity of this 21-cm signal with frequency – over 30-200 MHz after cosmological redshift – can be observed as a global signature whose spectral shape, strength can be used to directly infer the astrophysics and cosmology of CD and EoR [1].

An inevitable challenge to 21-cm signal detection is foreground emission from the local Universe, which is $4-6$ orders of magnitude brighter. The predicted 21-cm signal strength is of the order of $\sim 10-100$ milli-kelvin in brightness temperature units compared to the foreground emission that can be $10^2 - 10^4$ kelvin depending on frequency and sky-direction. This necessitates a high-precision measurement of the radio sky spectrum for a detection of the signal from CD and EoR. Additional challenges unique to ground-based experiments [2] include (a) strong emission from terrestrial radio sources, including FM and TV stations, (b) parasitic coupling of Earth ground radiation to the instrument, and (c) refraction, emission, and absorption effects from ionosphere.

PRATUSH is a proposed space-based radiometer in a lunar orbit that will observe the sky spectrum over 30-220 MHz on the far side of the moon, thereby alleviating the challenges of observing from Earth. The radiometer will consist of two elemental antennas operating in split-band for sensing the electromagnetic field, followed by a self-calibratable analog receiver and an electromagnetically shielded digital receiver with on-board data-reduction and storage. All the sub-systems are designed such that their frequency response, both multiplicative and additive, can be calibrated or modeled to required accuracy imposed by the 21-cm signal detection criteria. PRATUSH is currently funded for pre-project phase by the Indian Space Research Organization, with the expectation that successful demonstration of the challenges with purpose design and qualification of laboratory models would lead to project mode building of a flight model.

We present a baseline design of PRATUSH. This includes the design-motivation, specifications, and preliminary design of major sub-systems; namely antenna, analog receiver, and digital receiver. We also discuss the proposed system integration strategy aimed to minimize susceptibility to self-generated electromagnetic interference from the payload and satellite package electronics.

References

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