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Receiver system design for low frequency radio astronomy applications

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1 Extended Abstract

Over the past two decades we have seen an emergence of low frequency (sub 500MHz) radio interferometers which fit the description of Large N arrays including the proposed Square Kilometre Array (SKA) [1] and the Hydrogen Epoch of Reionization Array (HERA) [2] telescopes. Whilst the fundamental science goals and thus requirements for these instruments are different, they do have similar challenges which include the RF receiver design.

One of the most important requirements for these instruments is sensitivity which relies on the antenna gain and it's losses as well as the matching to the noise impedance of a suitable low noise transistor to ensure the RF system is dominated by sky noise for the entire band. This is especially important at higher frequencies where the sky brightness temperature is comparable to the noise temperature of existing non cryogenically cooled MMIC low noise amplifiers. Furthermore, the matching to the antenna impedance which is a necessary part of the process to insure the lowest possible receiver noise and thus maximal instrumental sensitivity typically comes at the price of reduced power match which for instruments such as HERA can be detrimental since they effect the data processing, which in this case is the delay spectrum analysis [1]. Clearly there is a balance to achieve here and this will be discussed in detail along with the types of measurement techniques which can be deployed to evaluate these effects.

Other considerations which are fundamental to such arrays include signal transport such as RF-over-Fibre (RFoF) technology which aims to transport the RF signal over single-mode fibre by directly modulating the laser current. Whilst for CCTV and telecommunication applications, RFoF has been used effectively, it is also now being considered for many of these large arrays as it can allow the signal to travel many tens of km without much signal degradation into a central processing facility where the signal can be digitised and further processed. There are some critical design parameters for such links which must be taken into account for radio astronomy applications including dynamic range, field reliability and stability over temperature as well as WDM signalling, for example to permit two polarisations on a single fibre connection thus decreasing field deployment cost.

In addition to this, concepts such as in-situ calibration can be considered for such instruments to enable calibration of the antenna spectrum in the field and on the fly similar to experiments such as EDGES [3]. Furthermore, with the emergence of low-power, low-cost, low-EMI MEMS sensors, a great deal of information can be captured from the receiver system in the field to aid with faultfinding and system characterisation. Such sensors rely on fault-proof monitor and control systems which can work reliably over long distances. These considerations will also be discussed in the context of the HERA telescope.

References

[1] Square Kilometre Array Telescope [Online]. Available: http://www.skatelescope.org/

[2] D. R. DeBoer, A. R. Parsons, J. E. Aguirre, *et. al.* Hydrogen Epoch of Reionization Array (HERA). arXiv:1606.07473v2 [astro-ph.IM], 2016.

[3] A. E. E. Rogers and J. D. Bowman. Absolute calibration of a wideband antenna and spectrometer for accurate sky noise temperature measurements. *Radio Science*, 47:RS0K06, August 2012.