Cryogenic PAF Receiver Design for the Parkes Telescope

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Phase array feed (PAF) technology is being explored in great detail as the next generation radio telescope. This is expected to provide outstanding improvements in receiver sensitivity and survey speed. Unlike conventional radio telescopes, PAFs require a large number of receiver elements/receiver chains to be co-located within close proximity. The designer faces a number of challenges in designing such a complex system without degrading performance. Receiver challenges include compactness, susceptibility to external RFI, providing sufficient channel to channel isolation, controlling RF signal leakage, thermal management, weight and cost considerations. Co-locating the digitizer with the RF chain makes the system very compact and eliminates the need for long coaxial cable or fibre link connection, but some potential issues to be addressed to implement this option.

This paper discusses the design challenges and progress, with emphasis on the warm RF chain, made towards realizing a 98-element/196-channel cryogenic PAF system covering from 600 MHz to 1950 MHz for the Parkes 64m radio telescope in Australia. The receiver will incorporate rocket-shaped feed elements with 80 mm spacing and will be optimized to match to the LNA and for beamformed efficiency. As the telescope site is heavily impacted by external RFI on the lower end of the observing band, the RF signal from the cryostat will be processed in the RF chain as two bands, namely full band or RFI free band which lies on the high side of the spectrum. The full band option is likely to accommodate a step filter with gently roll-off characteristic to suppress external RFI and avoid receiver saturation while keeping sufficient astronomical signal at the expense of slightly increased system noise temperature.

The system provides the flexibility to sample one or the other band with adjustable signal level to the digitizer. The signal will be sampled by the Xilinx Zync Ultrascale+ RFSoC, which has 8 integrated 4GS/s ADCs. The able below provides the system specifications, and the electro-mechanical structure is shown in the following figure.

Observing band	600 – 1950 MHz
Processing bands	600 – 1950 MHz (full band) 1100 – 1950 MHz (RFI free band)
Number of elements/channels	98/196
Sampling frequency	4096 MSPS, 12bit ADC
System temperature	≤ 30K (600 – 1950 MHz); ≤ 20K (1100 – 1950 MHz)
Weight	≤ 500 KG

Table 1: Cryo-PAF system specifications

Electronics will be grouped into 8-channel cards to reduce the number of connectors, cables and also to match the RFSoC which comes with 8 samplers per chip. The RF, digitizer with QSFP devices for data transportation, LNA bias cards and other supporting electronics, will be housed in an RFI tight mechanical structure suitable for blind-mate connection with the cryostat section. 26 such modules will be produced to make up 196 active receiver chains. An efficient integrated cooling mechanism is being designed to manage the high power density in the warm electronics. There will be a full remote control and monitoring (C&M) facility over electrical, electronic and mechanical parts.

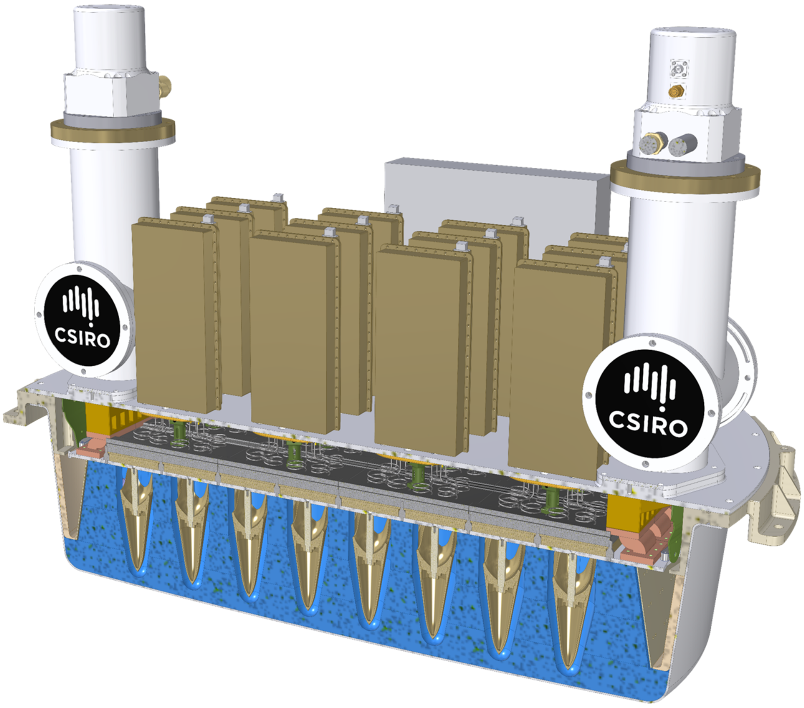

Figure 1: Electro-mechanical structure of the Cryo-PAF

The typical noise contribution from the warm electronics is expected to be below 0.5 K for the RFI free band and below 1.5 K for the full band due to RFI impact. With the 64m Parkes telescope, the system noise temperature is expected to be 25K and 30k for the respective bands.