Five-hundred-meter Aperture Spherical radio Telescope (FAST) Analogue Receiver Design Challenges and Progress

Kanapathippillai Jeganathan, Yoon S. Chung, Alex Dunning,
Paul Doherty, Simon Mackay, Les Reilly, Peter Roush, Robert D. Shaw.
CSIRO Astronomy and Space Science, Cnr of Pembroke and Vimiera Roads, Marsfield, NSW, AUSTRALIA

Extended Abstract:

The FAST telescope in China is expected to be the world's largest single telescope. CSIRO is building a 19-beam, dual polarized, cryostat receiver system which will be the largest receiver system in the FAST telescope. This poster discusses the design challenges and progress made towards realizing the system, particularly the analogue part of the receiver system. The system requires 2 x 19 independent receiver chains. Each receiver chain consists of a Low Noise Amplifier (LNA), pre-optical RF chain (pre-RF chain), 3 km optical-link, post-optical RF chain (post-RF chain) and a digital back-end. The critical specifications [1, 2] include pass band of 1050 MHz – 1450 MHz, maximum system noise temperature (NT) of 25K, RF gain of 78 dB, gain adjustment of ±7 dB and feed input noise temperature of less than 10K. The LNA specification includes 30 dB of gain, 3K typical noise and input 1dB compression point greater than -30 dBm. The challenges of the project include the filtering Radio Frequency Interference (RFI), cryogenic LNA design for volume production, use of a commercial optical-link, lengthy coax cable assemblies in critical locations, and the massive mechanical structure.

RFI at 960 MHz poses a significant challenge at the FAST site, and requires sharp filtering. **Anti-alias filtering:** A sharp roll-off filter is required to suppress the closest anti-alias bands at 550MHz-950MHz and 1550MHz-1950MHz with 1GHz sampling frequency. **LNA**: Meeting tight requirements while minimizing the variation for volume production is challenging with commercial components. **Optical-link:** A bare optical-link is lossy and noisy, requiring additional amplifiers for compensation. This lowers the system's dynamic range and stability. Integration of the commercial optical-link, which is designed for a wider market, is even more challenging. **Coax cable assembly:** The feed-OMT-LNA assemblies, spreading over 1.6m in diameter in cryostat cooled sections, require lengthy coax cables to connect up with the pre-RF chains located at room temperature. In addition, the loss in the cables degrade the system noise. The simplified analogue chain line-up is shown in Figure 1.

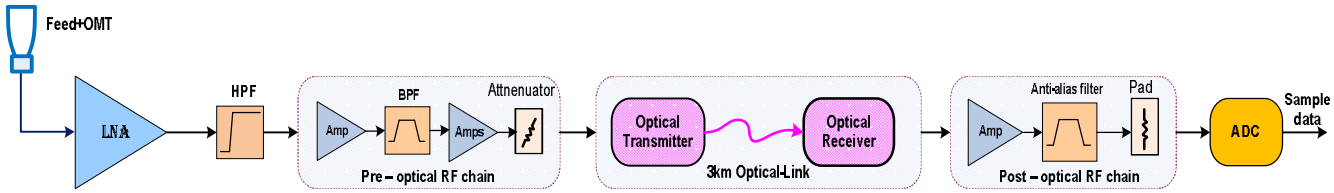

Figure 1: Simplified analogue chain from feed to the sampler

The receiver system is designed to provide <10K of feed input noise, 9.8K noise addition from Feed+OMT, 3.4K from LNA and 0.5K each from the analogue receiver chain and the digital back-end – totaling under 25K of system noise. The RF gain of 78dB is distributed along the chain at the LNA (32dB), pre-RF chain (28dB), optical-link (8dB) and the post-RF chain (10dB) to maintain optimal performance of the receiver chain. The LNA has been designed and fabricated using low noise GaAs HEMT. The bare die unpackaged transistors were used in a two-stage LNA design together with lumped element tuned circuits for optimum performance and excellent input return loss. The filtering is done with 3 sharp roll-off filters on the chain, which includes a suspended microstrip filter with a tuning option. A noise coupler is integrated at the feed, allowing complex gain to be measured and monitored. The system has been designed to provide remote control over electrical, electronic and mechanical parts. The system blocks are currently undergoing verification; final integration of the complete system is expected soon. We will present the optimal solution implemented with a high level of PCB integration, which reduces the impact from optical-link and other accessories and satisfies the requirements.

4. References:

1. B. Peng, C. Jin, Q. Wang, L. Zhu, W. Zhu, H. Zhang, R. Nan, "Preparatory study for constructing fast, the world's largest single dish", Proceeding of the IEEE, vol.97, no.8, pp.1391-1402, Aug 2009.

2. R. Nan, D. Li, C. Jin, Q. Wang, L. Zhu, W. Zhu, H. Zhang, Y. Yue, L. Qian, "Five-hundred-meter Aperture Spherical radio Telescope (FAST) project", International Journal of Modern Physics D, Vol,20, No.06, pp989-1024. (2011).