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A New Optimized Radio Telescope Receiver Architecture

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ABSTRACT
Popular receiver architectures use the superheterodyne technique to trap source frequencies using associated discrete analog signal processing devices. Nurturing and processing faint intercepted signals through several analog stages to a digital backend via coaxial feed has hitherto resulted in expensive, bogus, non – reproducible receiver systems that are susceptible to drifts. Hence, the complexities that characterize radio astronomy receiver design. This paper highlights the inherent problems associated with conventional superheterodyne radio astronomy receiver architecture and presents a new optimized architecture that solved most of the inherent problems and offers better reliability and reproducibility without compromising performance.
Keywords: *ADC, Analog, Digital, LNA, Mixer, Superheterodyne.*

INTRODUCTION
The receiver system is the heart of a radio telescope [1]. The need to achieve greater sensitivity and observing efficiency in receiver systems calls for efforts to have tighter control of systematic errors in astronomy instruments and effectively correct them [2]. Employing modern digital signal processing systems has been sluggish in radio astronomy due to hardware configuration that can handle the characteristic large bandwidth requirements in astronomy. To advance astronomy and discover more of the unending deep space phenomena, a complete redesign of architecture upon which receiver systems are based is essential. This would involve migrating critical functions from analog domain to digital domain in order to leverage on the much needed characteristics on digital signal processing systems. It would equally be essential to redesign subsystems rather than manage those subsystems that are prone to drifts and that are known to introduce spurious signals into signal paths in receiver systems.
These inherent problems have made us to seem to have reached saturation in receiver cryogenics and hence sensitivity. The instrumentation and technologies now tilts towards VLBI systems more than deepening instrumentation to achieve greater sensitivity in receiver systems

Problems with Conventional Receiver Architecture

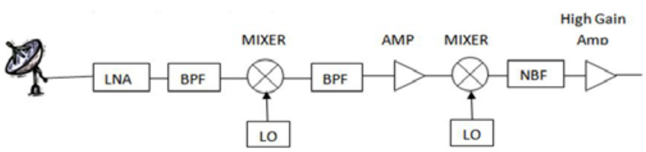
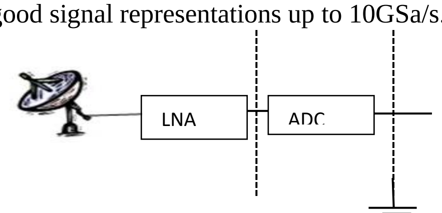


Fig 1: Conventional superheterodyne astronomical receiver architecture [1]

First, processing of astronomical signals in the analog domain generally results in expensive, non – reproducible receiver systems that are susceptible to drifts, taking into account the number of analog stages and devices along the processing line. Again, conventional architecture deploys complex multiple mixing for selectivity. Multiple independent Local Oscillators (LOs) introduce instabilities and spurious noise into signal path and could distort the signal characteristics. Sometimes this situation results in drifting of receiver systems. In addition, with the cryogenic limit reaching saturation at around 25 Kelvin, it becomes extremely difficult to improve sensitivity of receiver systems on conventional architecture if the cryogenic limits are not brought much lower. Moreover, taking into account the discrete device instabilities, processing delicate signals using these devices contributes to the deterioration of signal to noise ratio and system instability. Furthermore, relaying IF usually from the front – end to the back – end via coaxial feeds generally makes the system prone to environmental disturbances. Coaxial feeds have the tendency to pick stray signals into the IF path. If such happens at this stage, there is little or nothing that can be done to rid the line of such interference. It would get to the backend systems. This situation vitiates the signal and deteriorates the signal / Noise ratio. For us to discover entirely new deep space phenomenon, current limits has to be broken by dipping down cryogenic limits so as to achieve better signal to Noise ratio and sensitivity.
Nurturing and processing of weak astronomical signal through all these analog processes from RF to baseband is herculean and generally results in expensive, non – reproducible systems that are subject to drift, which is of great concern in conventional architecture.

The proposed Architecture for Astronomy Receiver Design
The new architecture leverages on the capabilities of Digital Signal Processing (DSP) and proposes migration from RF to Baseband, from Analog to Digital and from Copper to Fibre.
It is essential to digitize RF close to the antenna as possible with good signal representations up to 10GSa/s.



This would result in a sharp drop of required total Gain in a receiver system from about 120dB to about 80dB. There would be shorter signal signal path between the antenna and digitizer which would in turn result in cleaner signal and simplified receiver system.
Furthermore, there is the need to modulate the digitized RF for Optic Fibre transmission. This will eliminate copper linkages, transmission line losses and eliminate environmental effects.

Power hungry subsystems are also automatically shifted to the backend. Impedance is resultantly lowered, space is conserved, weight is reduced and bandwidth can be handled using the Laser transmitter and diode receiver.

Digital Sideband Separating Mixer (DSSM) could handle the mixing digitally. It would reduce spurious signal from LOs & mixers, help to miniaturize and reduce the analog signal paths. The use of a multiple LOs is eliminated. A LO on the DSSM yields high level of system stability and minimizes drifts. Polarization conversions can equally be handled digitally thereby reducing overall weight of the system.

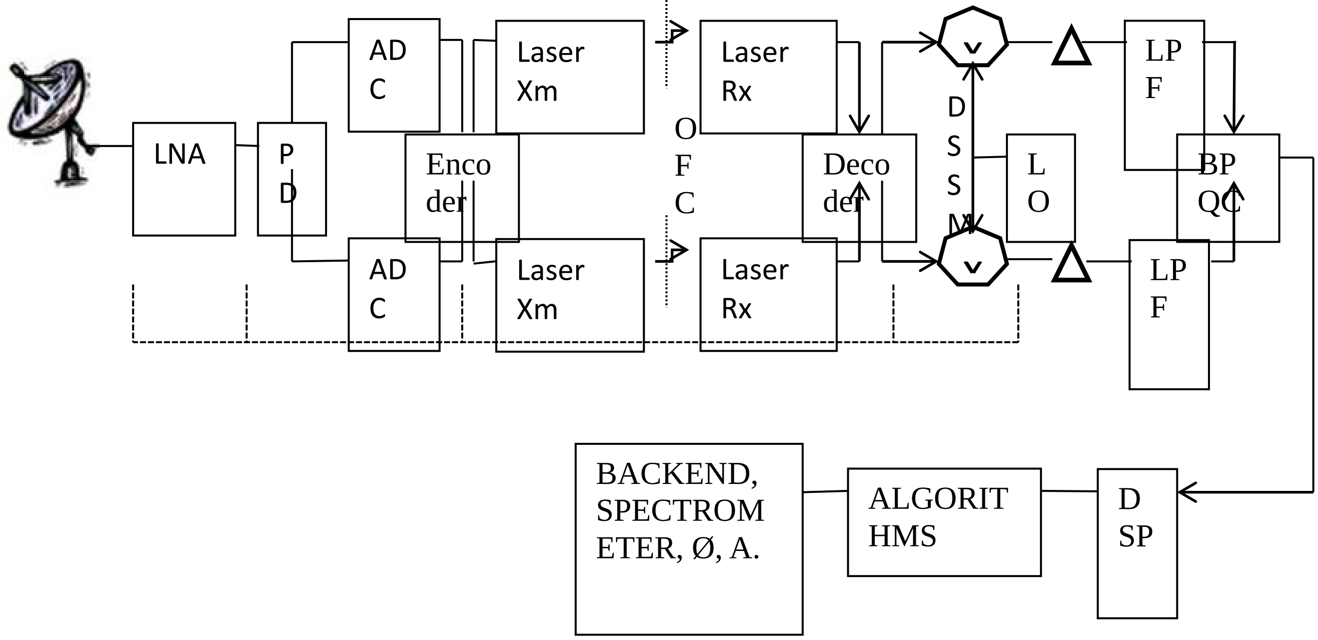


Fig 3: The New Optimized Astronomical Receiver Architecture

Interference Protection cavities which usually increases the size and weight are equally eliminated. Systems that needed to be shielded from spurious signal emission or interception are simply shielded in earthed shielding sheets. This architecture would no doubt yield a receiver system with better cost and that is more compact, more reliable, better weight, reproducible, more stable having shorter design period without compromising performance.

CONCLUSION

Several celestial objects still emit radio waves (much weaker) at known bandwidths and yet undetected. Until we break away from the current cryogenic limits and redesign our instruments to leverage on the capabilities of digital signal processing systems that the astronomy community can unveil sciences hitherto unknown. Improved sensitivity is key to achieving this. Common problems such as interferences are significantly reduced and consequently, a better signal to noise ratio would be achieved in the new architecture. Comparatively, this new architecture would enhance stability in receiver systems. It will offer better weight and more convenient signal processing technique that would yield better receiver system reproducibility.

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