A Single-Chip RF-CMOS Receiver for SKA Pathfinders

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To achieve simultaneously the current mid-band SKA field-of-view (FoV) and collecting area specifications, millions of individual receivers are needed. Low-density, high wafer cost, GaAs and InP processes commonly used in today’s radio-telescopes may not offer the cost and integration levels necessary to achieve an RF-system goal of under $5 per receiver. RF-CMOS and SiGe processes, with their lower wafer costs and high integration levels, could be enabling technologies for SKA.

As part of a continuing research effort into receiver technologies for next-generation radio-telescopes, a single-chip RF-CMOS receiver has been developed to cover the 300 – 1700 MHz RF band. This receiver integrates a noise-cancelling LNA, RF filters and amplifiers, quadrature direct-conversion mixers, IF anti-aliasing filters, and six-bit ADCs into a commercially-available 0.18 µm RF-CMOS process. The receiver is a complete “RF to bits” solution in a single package. When coupled with a simple external LNA optimised for dense phased arrays or other complex feeds, the chip is a functional replacement for discrete RF systems in mid-band SKA pathfinders. Future designs, fabricated in faster CMOS processes may allow a complete, optimised, one-chip solution.

Low Noise Amplifier:
The Low Noise Amplifier (LNA) is a wideband noise-cancelling design, utilising a shunt-feedback matching amplifier and a cascode common source voltage amplifier. The circuit has inherently broadband performance, with $T_{th}$ being 80 K mid-band, degrading to 110 K at the band edges. Gain is better than 20 dB to 2 GHz. It occupies 0.04 mm² and consumes 70 mW.

Quadrature LO Generator:
An accurate quadrature LO is generated from a four-times reference tone, using high-speed differential Current Mode Logic (CML) comparators and dividers.

IF Filter:
For the NTD application, the IF filter is a four-pole Chebyshev multiple-feedback design, using high-speed two-stage opamps.

ADC:
The ADC is a six-bit flash design, utilising two stages of averaging termination and interpolation, with distributed sample and hold. Rather than using comparators, the ADC uses fixed-gain error amplifiers. The output of each error amplifier is averaged with those of neighbouring amplifiers to reduce systematic offsets caused by process variations. The thermometer-to-binary encoder uses a fat-tree topology, with two stages of averaging termination and interpolation, with distributed sample and hold. Rather than using comparators, the ADC uses fixed-gain error amplifiers. The output of each error amplifier is averaged with those of neighbouring amplifiers to reduce systematic offsets caused by process variations. The thermometer-to-binary encoder uses a fat-tree topology, with two stages of averaging termination and interpolation, with distributed sample and hold. Rather than using comparators, the ADC uses fixed-gain error amplifiers. The output of each error amplifier is averaged with those of neighbouring amplifiers to reduce systematic offsets caused by process variations.

Mixer:
A pair of Gilbert-cell mixers perform direct conversion to complex baseband. The mixers use a fully-differential topology to minimise second-order distortion. Each mixer occupies 0.08 mm² and consumes 90 mW. Its accompanying active balun occupies 0.01 mm² and consumes 40 mW.