ALMA 64-antenna Correlator

Status and VLBI Compatibility

Alain Baudry

Univ. Bordeaux, OASU/LAB & European ALMA Project Office, ESO

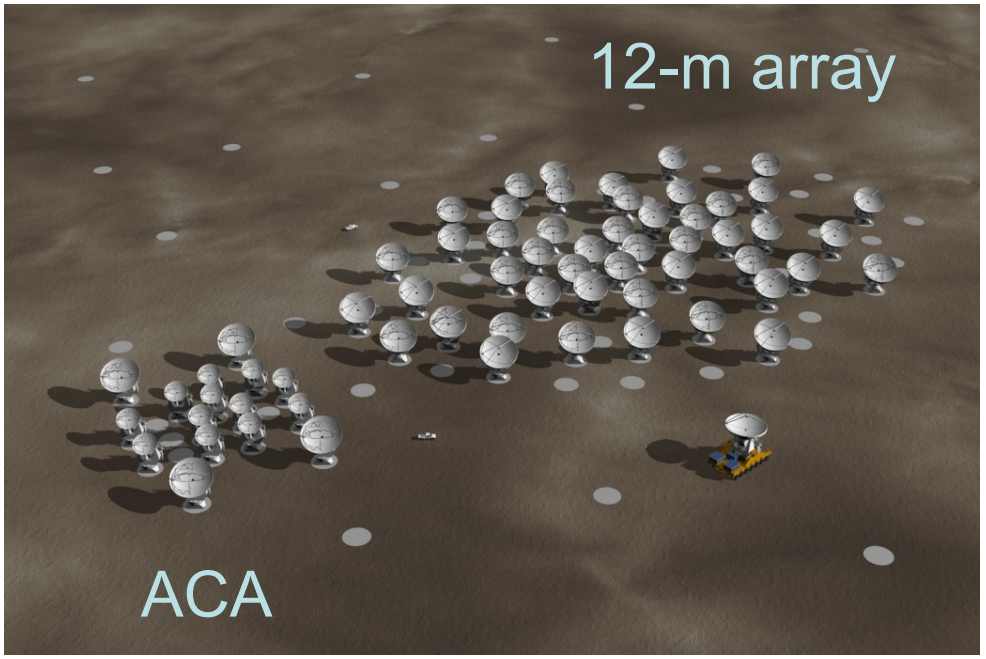
'mm-VLBI with ALMA and Other Telescopes, Scientific Workshop'

June 27-28, 2012, ESO

Contents

ALMA 64-antenna correlator

- Vey brief history
- Main Specifications
- Status
- VLBI compatibility



64-antenna Correlator / History

- Development began at NRAO with pure XF architecture
- Evolved into a digital hybrid XF system to include the core of the 2GC study in Europe
  - FXF architecture
  - Digital filter cards with 32 frequency mobile sub-bands
  - Filter outputs sent to 32 correlator planes

Deliverables

- 4 independent Quadrants of hardware
  - Each Qt. processes a 2GHz pair for up to 64 antennas
  - Modularity for commissioning
- Working internal hardware and firmware
- Additional important hardware
  - Custom Test Fixtures (Filter and Correlator cards) for maintenance/repair in addition to embedded testing
  - Two 2-antenna correlators at OSF
- Documentation

Main Specifications

64-antenna correlator

- ***Antennas*** 64 (2016 pairings + 64 auto-correl.)
- ***Input / Output sample format*** 3-bit ADC / 2- or 4-bit correlation
- ***Baseband per antenna*** 4 x 2 GHz x 2 polars. (8 BBs)
- ***Polarization products*** 1, 2 or 4
- ***Max baseline delay range*** 30 km (up to 300km)
- ***Processing rate*** 125 MHz
- ***Hardware correlators / baseline*** 32 klags & 32 kleads
- ***Max spectral resol. & Channels*** 3.8 kHz, 8192 channels

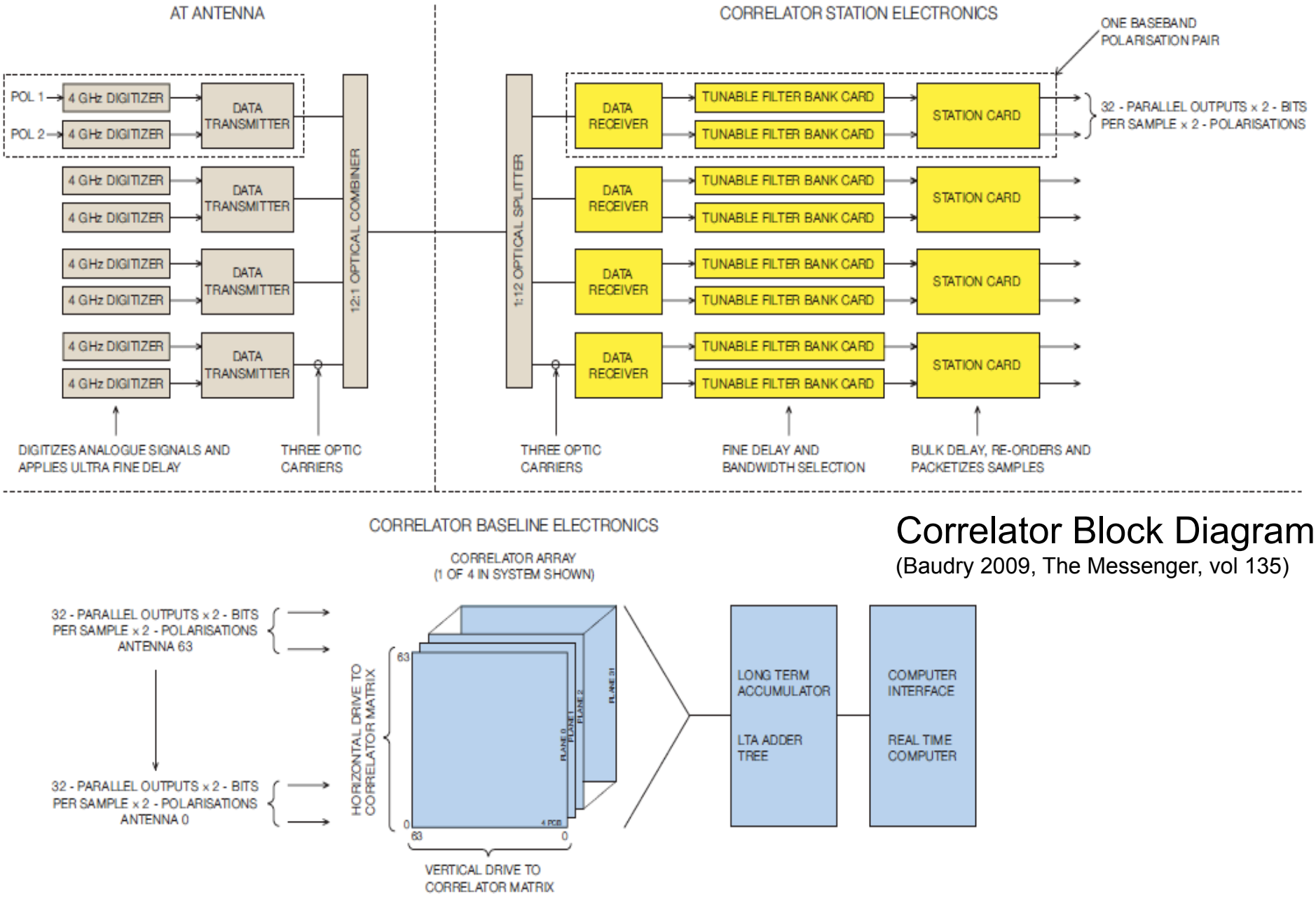
* ***Min. accumulation time*** 16 ms cross-correl. & 1 ms auto-correl.

* ***Subarraying*** up to 6

* ***Phased array outputs*** VLBI

* ***Output rate 2GByte/s per Qt.*** ALMA system supports 60 MByte/sec peak

Routine operation, ~25% peak rate or ~50GByte/hour



Correlator Block Diagram

(Baudry 2009, The Messenger, vol 135)

Status (1)

- *Hardware and Firmware complete and verified for all elements in correlator*

- *Operational software first used in system testing at integration center prior to shipping to AOS*
  - Close cooperation with ALMA Computing

Status (2)

32 racks in 4 Quadrants

First Quadrant installed at AOS in October 2008

Second & third Quadrants installed in 2009 & 2010

2-quadrant operation in routine use for CSV & Early Science

all BB pairs for up to 32 antennas

Fourth Quadrant

at AOS, testing on-going, final acceptance-on-site meeting by mid-July

Migration to 4-Quadrant configuration and testing finished by the end of Sept … can process up to 64 antennas

4-Quadrant operation ready for ES well before Cycle 1 starts

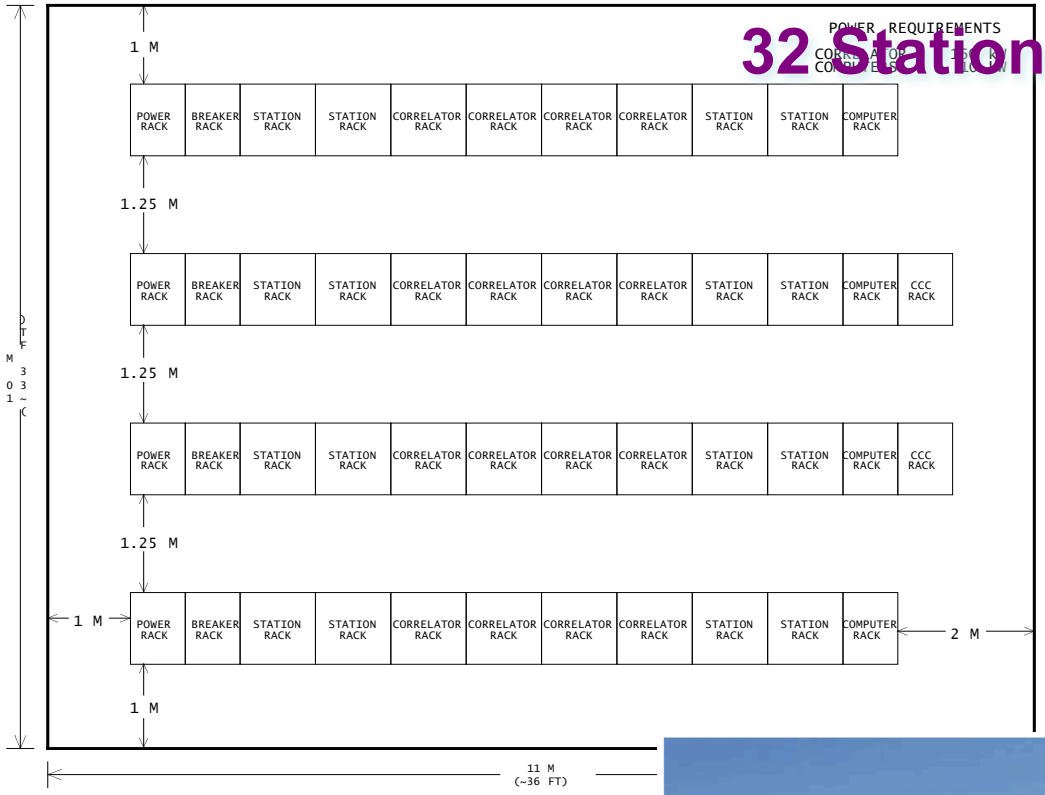
One Quadrant

Complete Correlator System, 32 racks in 4 Quadrants

- ~2600 printed circuit boards total in system
- ~20 million solder joints
- 8192 Altera Stratix II FPGAs (90 nm technology) in TFB cards
- 32768 custom correlator chips
- 64-antenna Correlator is a highly specialized computing system

  1.7×10^{16} operations/sec (multiply-and-add calculations)

Correlator room at AOS, 5000m



32 Station & Correlator racks in 4 Qts.

- ***Power <150 kW*** including control & computing racks
- Heat dissipation was a challenge (board and system level)

Overview of Spectral Capabilities

- Two categories of Observing Modes

Frequency Division Mode (FDM)

2 GHz BB divided into 32 sub-bands (digital hybrid architecture)

- Adequate for spectroscopy (high resolution)

Time Division Mode (TDM)

correlator behaves as an XF machine

- Adequate for continuum sources or broad spectral emission

- 67 modes validated by Correl IPT

Small subset of modes offered for Early Science

Phasing up the Array

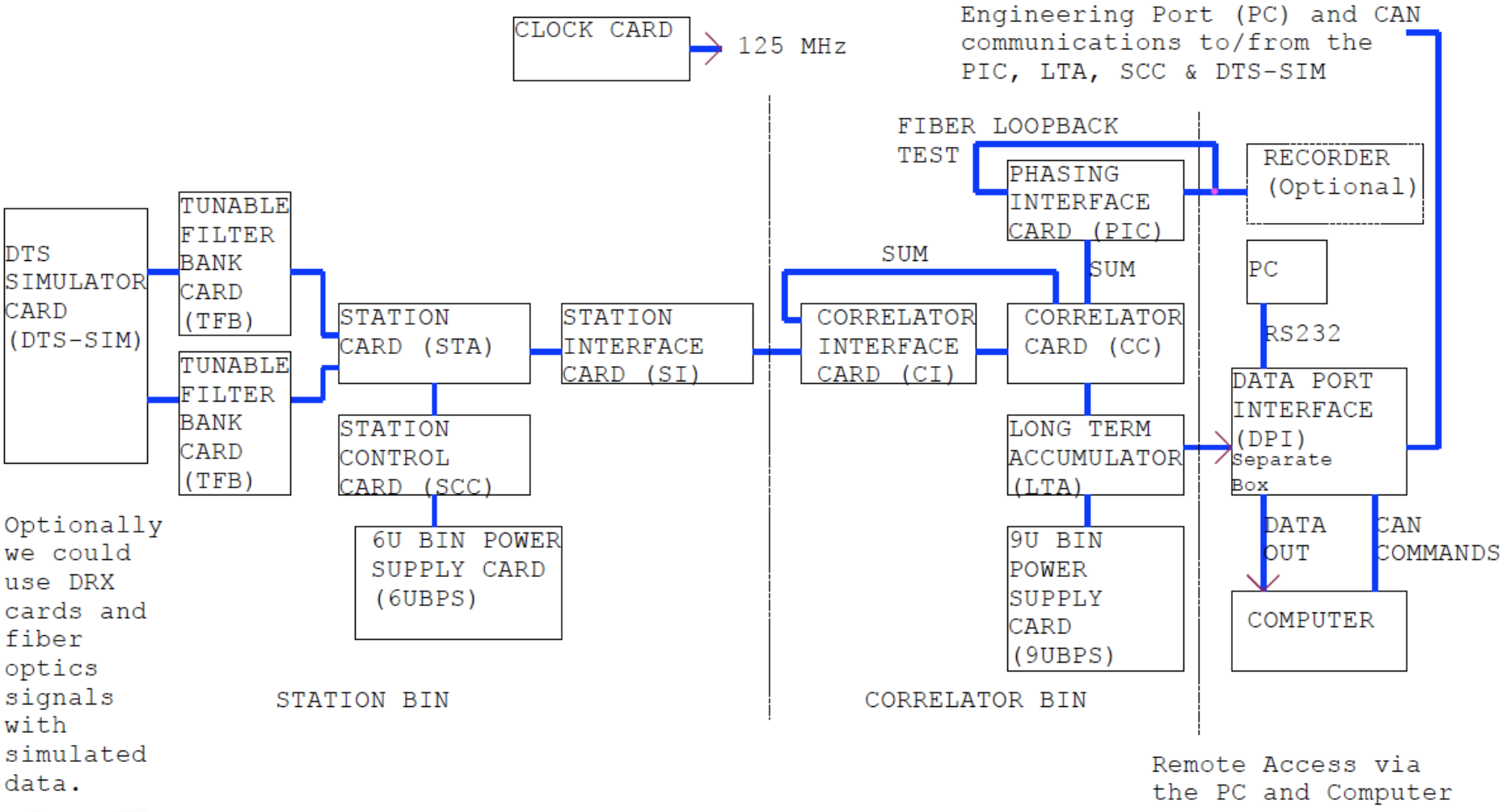
All basic requirements to phase up the array are in place in 64-antenna Correlator

- Analog sum FPGAs on correlator cards to compute sums of antenna signals
- TFB cards already have phase adjust capability with digital LO for each of 32 sub-bands
- Power capacity sufficient to add up VLBI mode
- Unused space in correl. racks to include the additional cards for interfacing to fibers & VLBI terminal

Phasing up the Array & VLBI

- Details on how to close the overall « phasing loop » still to be investigated in depth (software mainly)
- Data processing route for VLBI observing once phase corrections are known
  - TFB phase adjusted outputs => passed to Correl cards which output antenna sums (mask selectable set of antennas) => PIC card (Phasing Interface Card) … new interface card connected to Fiber and VLBI Terminal
- Main function of PIC (new card for Correlator)
  - Format the data into packets for 10Gb ethernet
  - Being developed at NRAO with PIC Test Fixture
  - 2 cards per Qt.

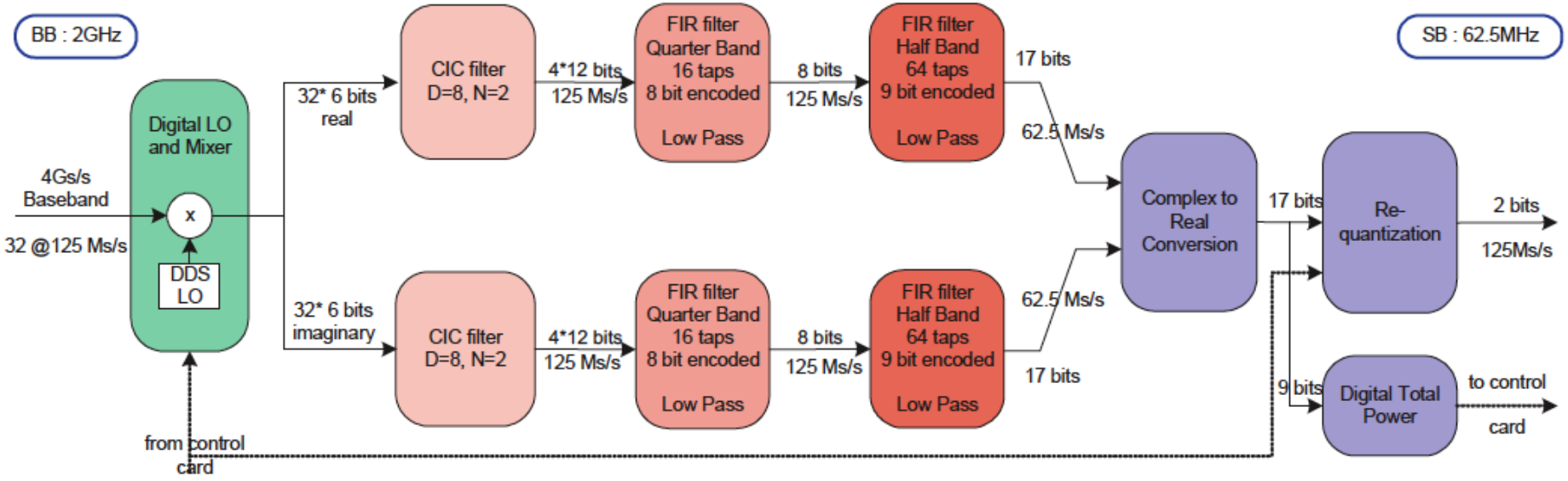
Data processing & PIC Test Fixture



Digital Tunable Filter Bank (TFB)

Phase shift and *Gain* (tot power) controlled from/to SCC

Firmware implemented in TFB



Phasing Interface Card