# 17.4GHz Ultra-wideband Digital Correlator in NTU-Array

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# Outline

- NTU-Array Correlator Architecture
  - NTU-Array
  - Front-end ADC
  - Tbps real-time DSP system
- Testing method and Results
  - Digital system test
  - Correlator full-system verification

# NTU-Array

Science target:

- CMB primary and secondary anisotropies cross-over

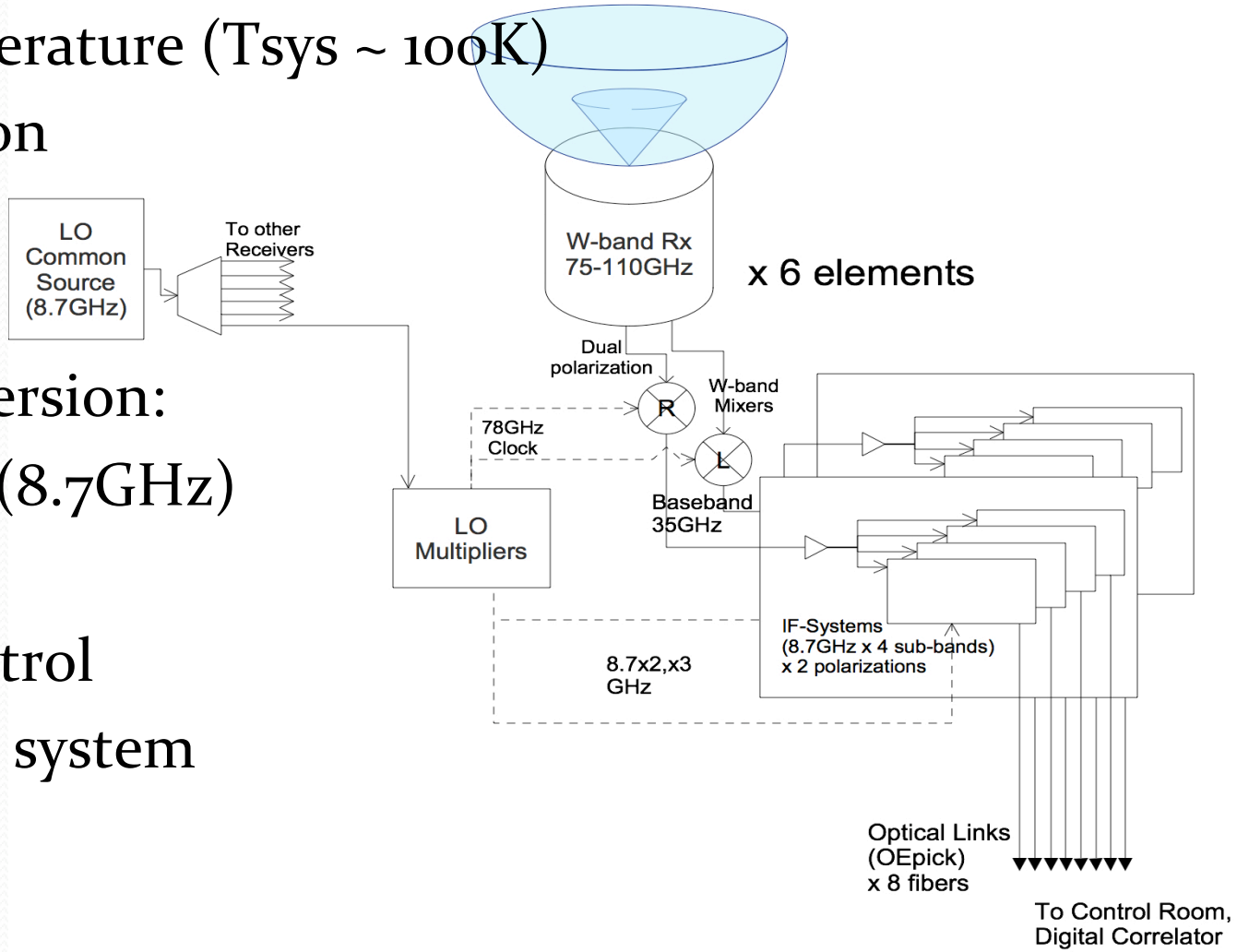
# NTU-Array: Receiver and RF system

- 6 receivers
  - 35GHz BW(78-113GHz)
  - low noise temperature (Tsys ~ 100K)
  - dual-polarization
- LO-IF down-conversion:

  RF -> 4 IF-bands (8.7GHz)
- Optical link:

  telescope -> control

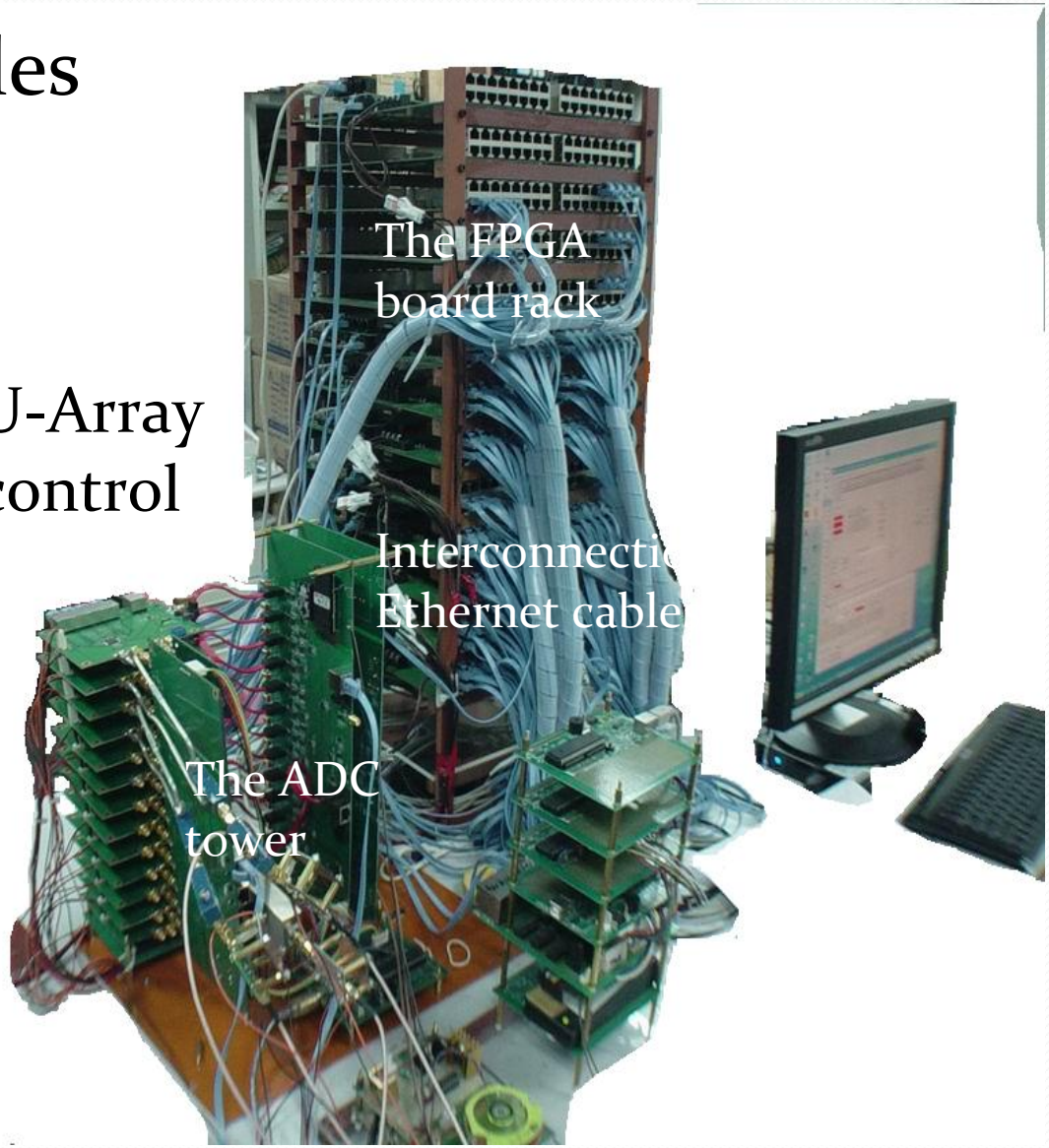
  room/correlator system



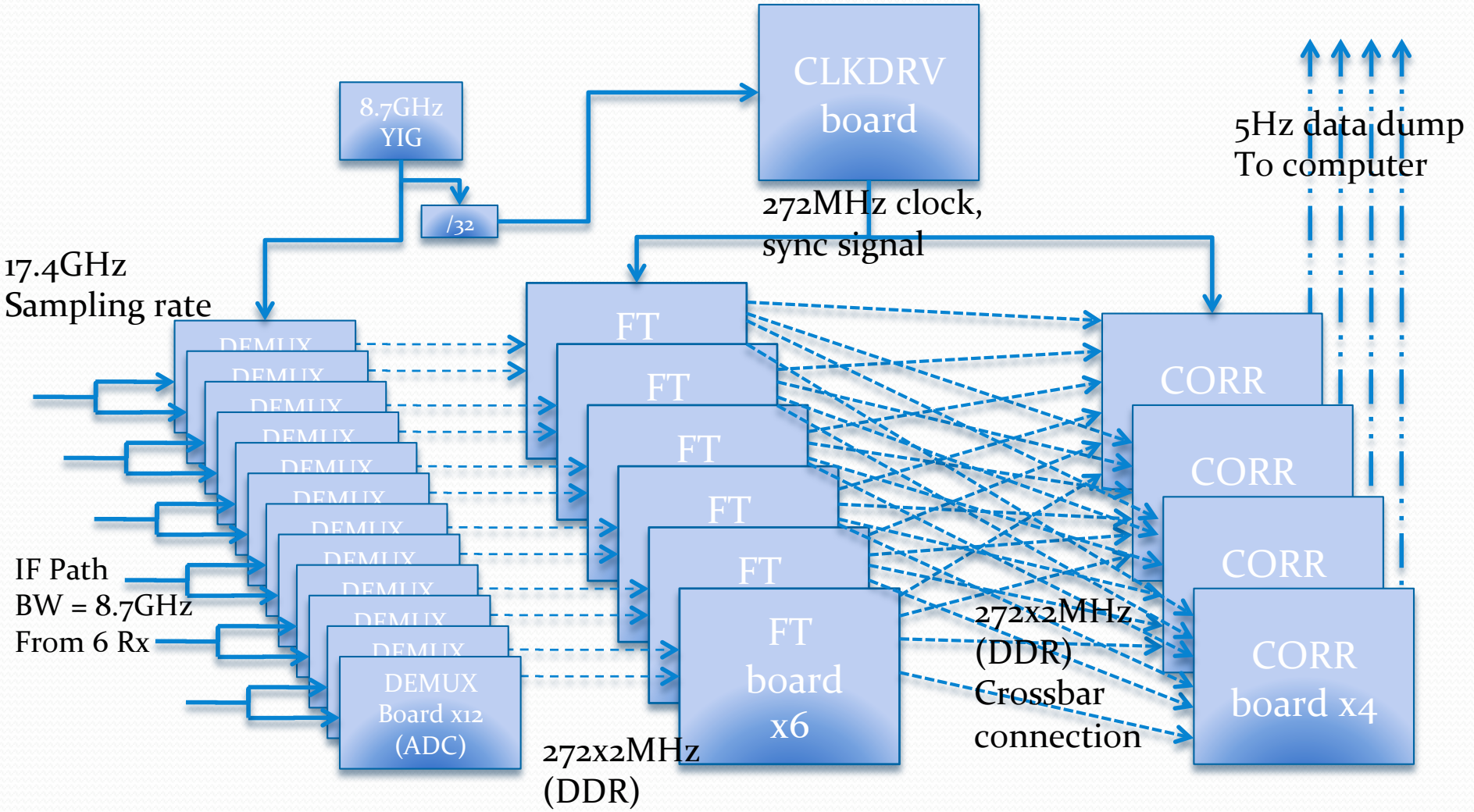
# NTU-Array Correlator System

- 8 identical modules for 2 polarization

One module of NTU-Array correlator with the control terminal

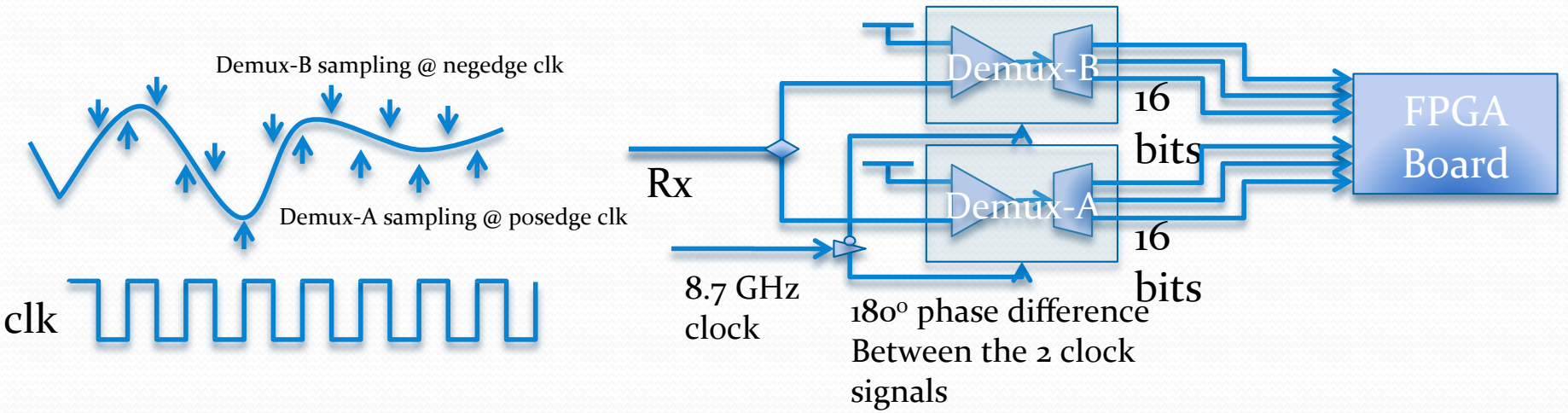


# Block Diagram for 1 correlator module

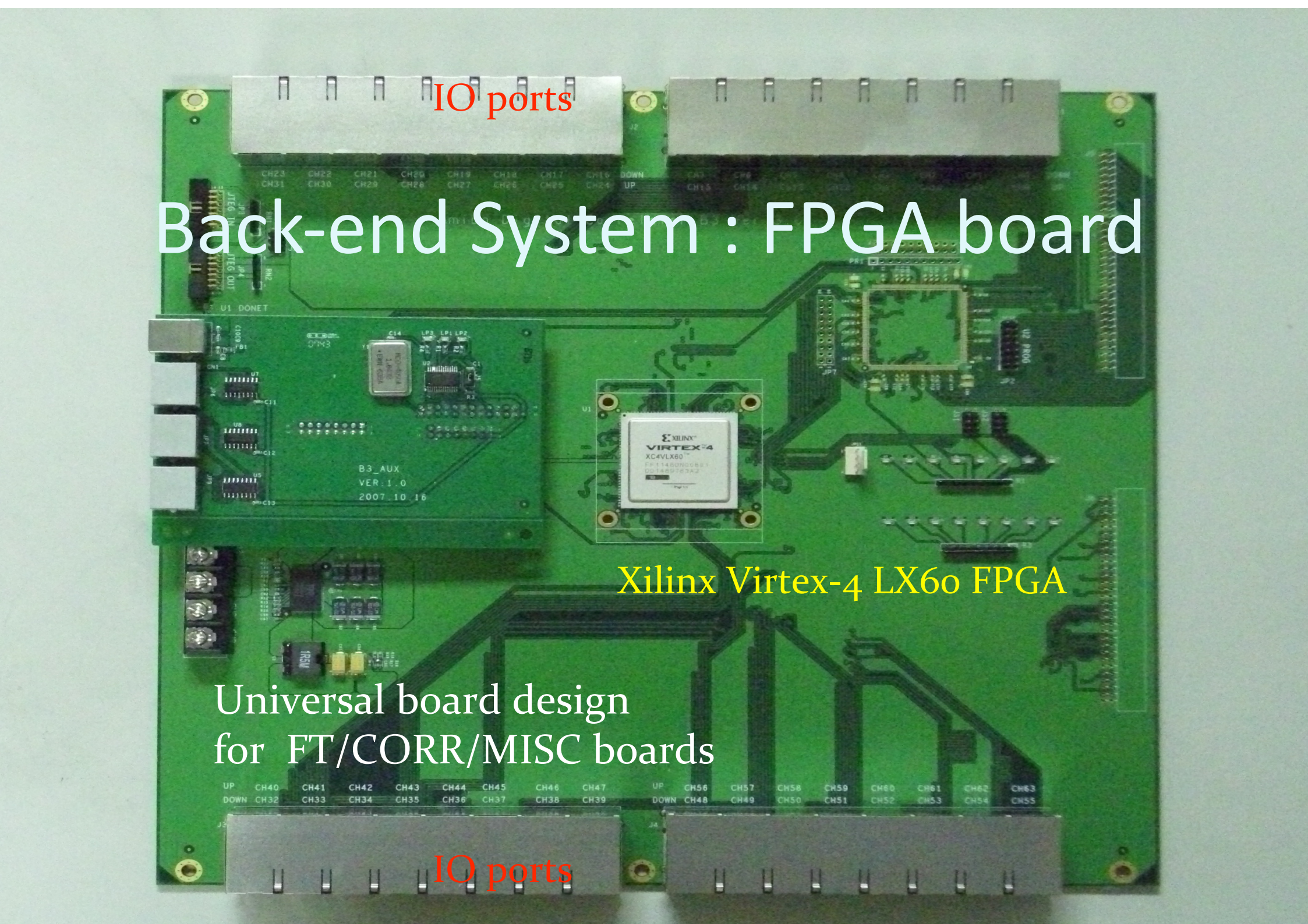


# Front-end System: 1-bit ADC (Maxim 3950)

- 2-way interleave sampling
- 1-bit digitization
  - by Demux CML input comparator & latch
- Parallelize => 32-bit data-buses @ 544MHz




- 3-bit 20GHz ADC under develop


IO ports
Back-end System : FPGA board
Xilinx Virtex-4 LX60 FPGA
Universal board design
for FT/CORR/MISC boards
IO ports

# Back-end : real-time DSP

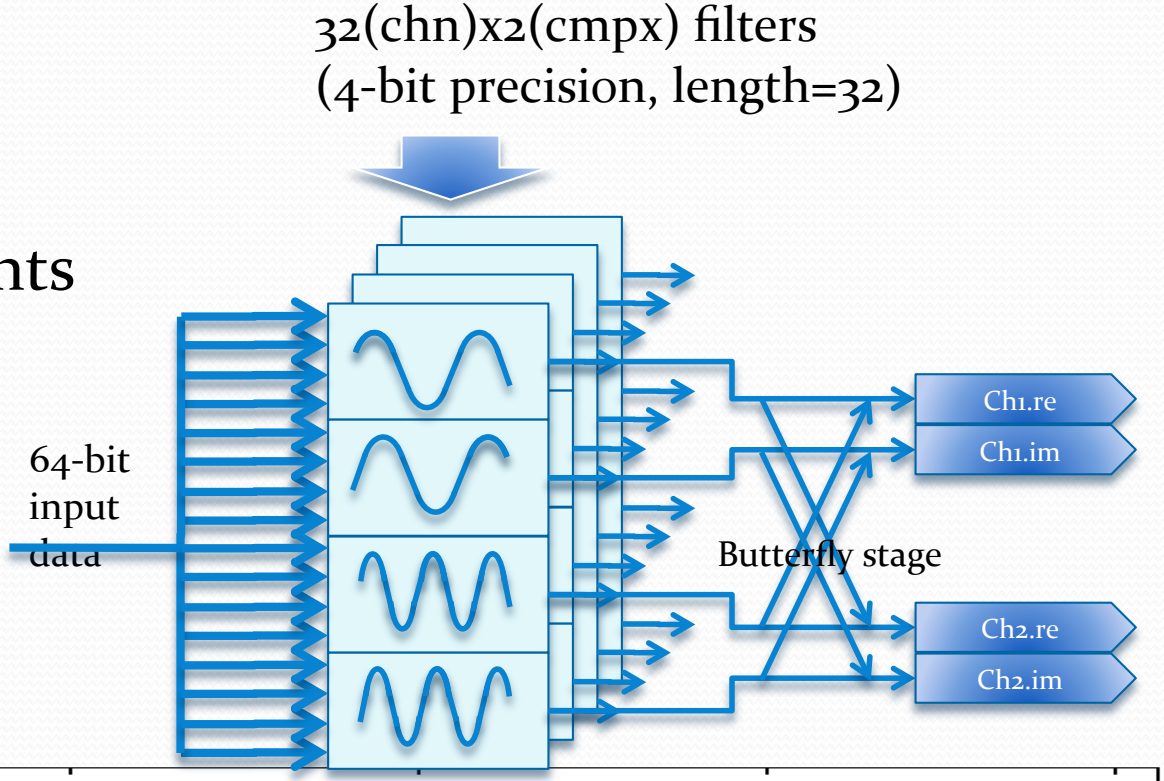
- 88 FPGA boards
- optimized for short word-length arithmetic & logic operation
- 40T fixed-point arithmetic op/sec
- Aggregate Comm. BW = 4 Tbit/s
- Power consumption: < 1200W

# Interconnection

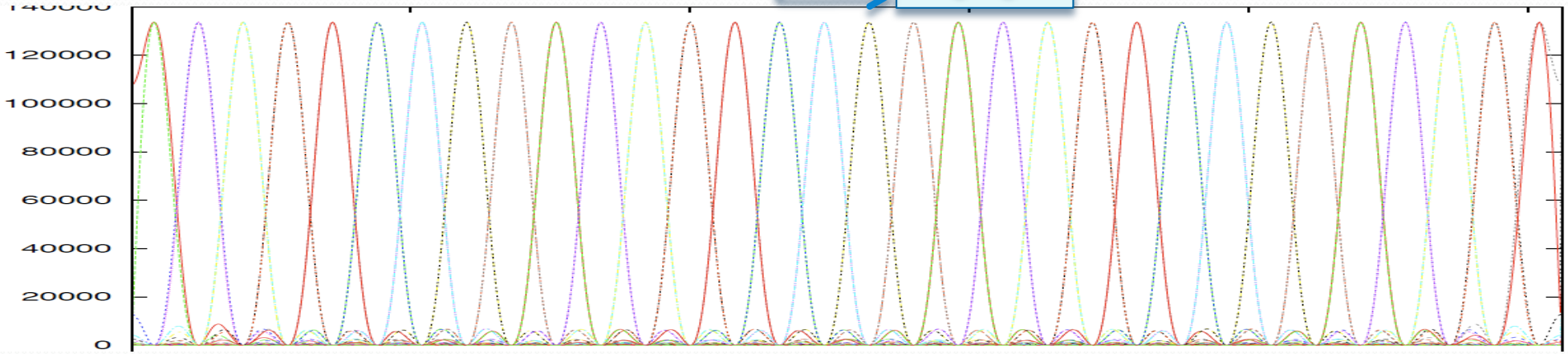
- SI issue & phase variance
- Auto-alignment scheme:
  - programmable tap delay lines & shifter registers
- PRBS check result : BER < $10^{-7}$ at 544MHz

# Frequency Filter Boards

- No FIR filter ahead
- precision
  - 4-bit filter coefficients
  - 4-bit decimation
    for freq components

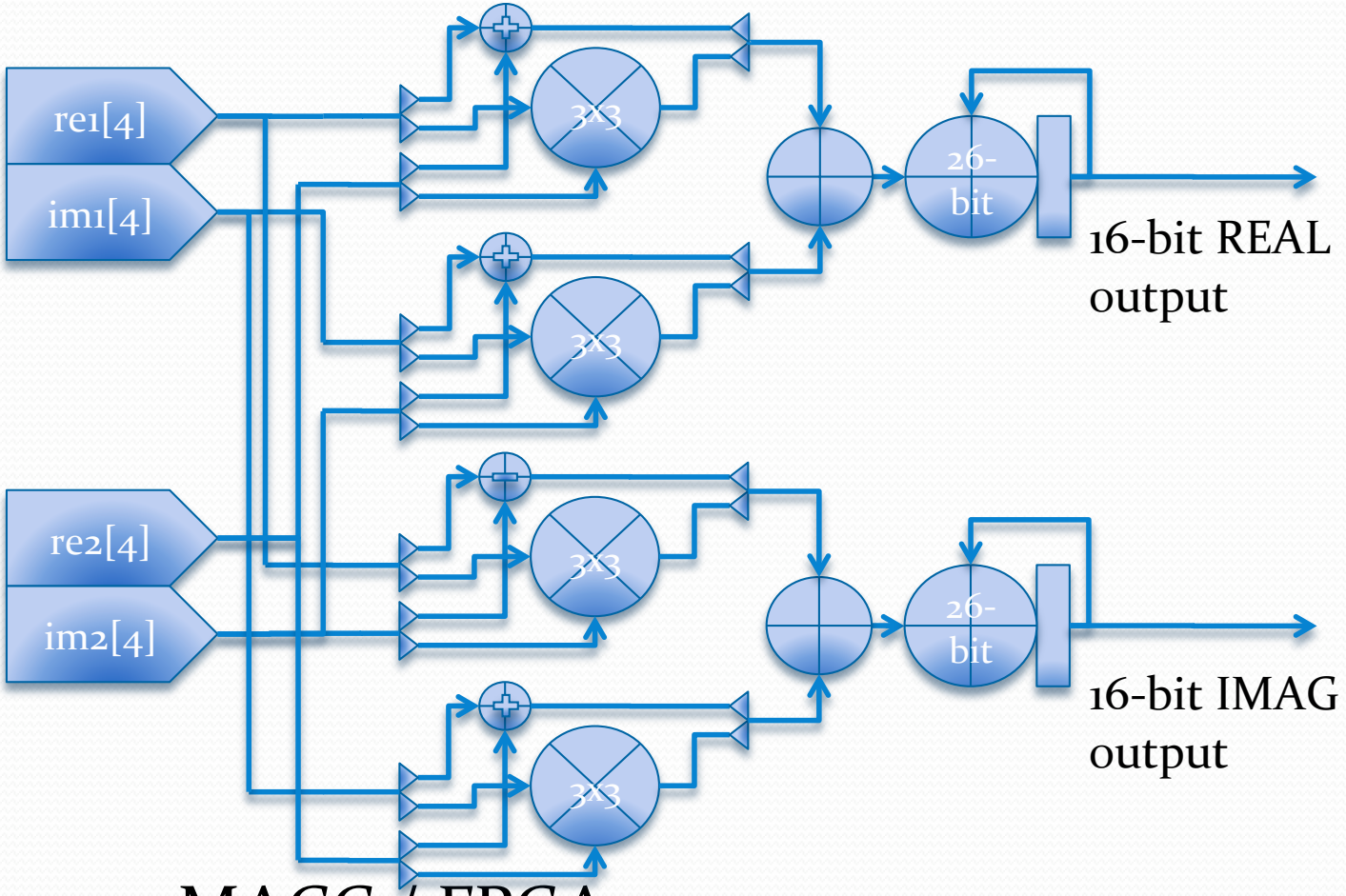



- band-pass filters:



# Cross Correlation Boards

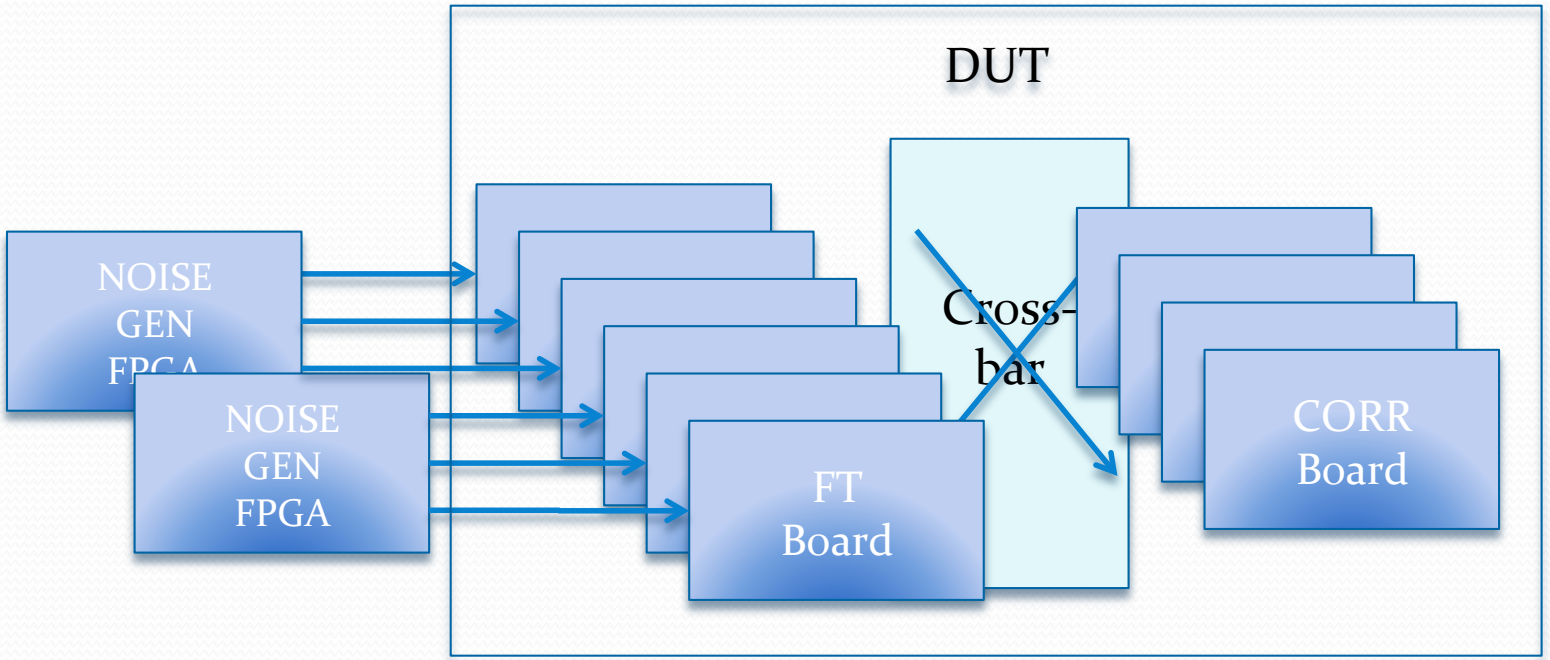
- Basic module: 4x4-bit complex MUL/26-bit ACC




- 120 cmpx MACC / FPGA
- data reduction: dump rate = 5Hz

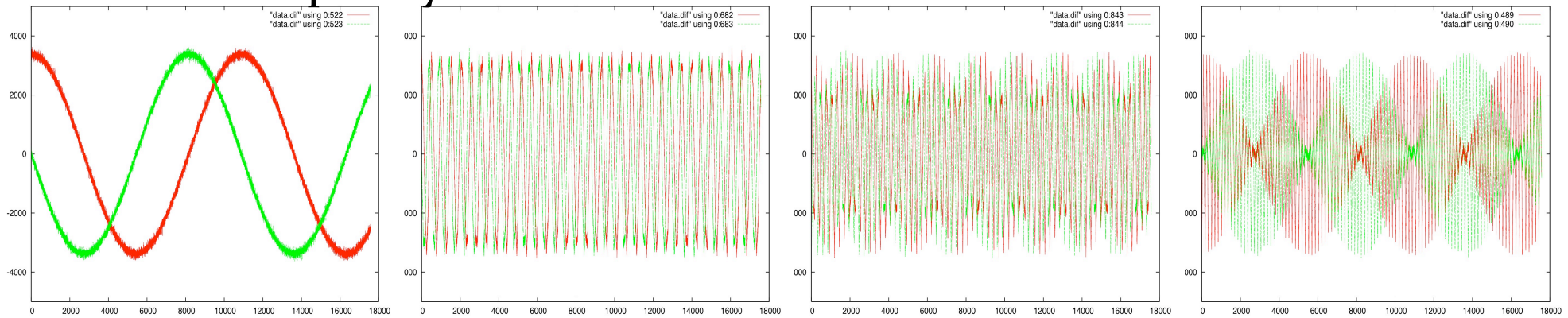
# Digital system Testing

- 121- to 126-bit PRBS generators
  - Digitized AWGN (period > $10^{25}$ sec)
- small correlated signals inserted : SNR = 1/256
  - dynamic delay shifting => artificial fringes



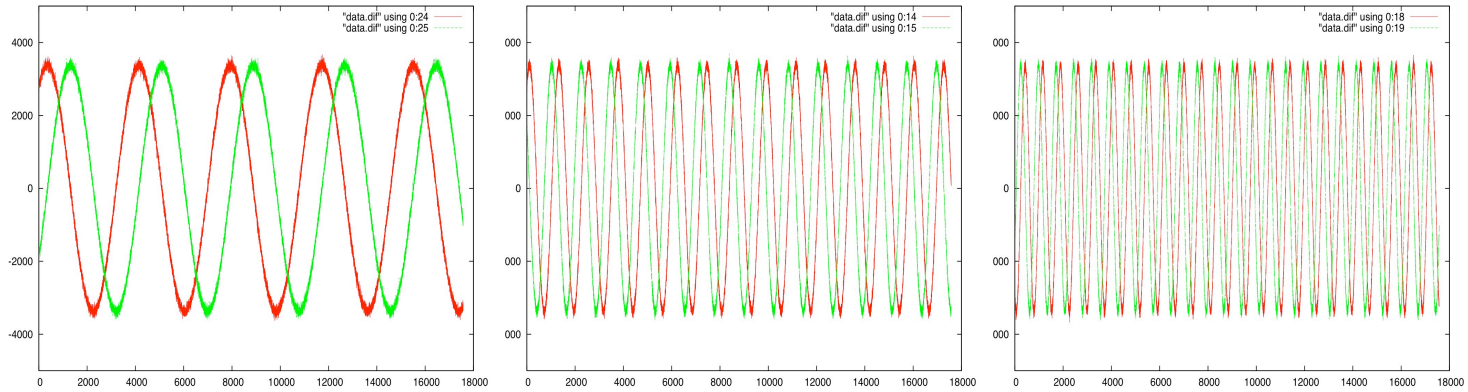
# Testing results: comparison between channels

Different frequency channels:




Ch. 0, fo=136MHz  Ch. 10, fo=2.85GHz  Ch. 20, fo=5.57GHz  Ch. 31, fo=8.56GHz

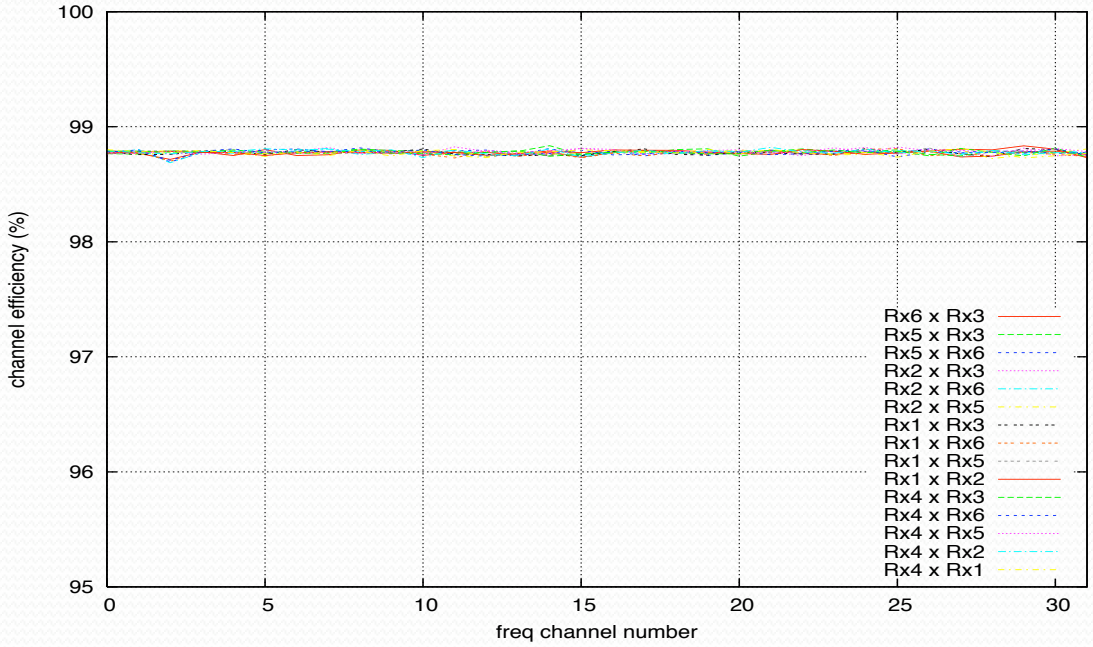
Different pairs with various fringe periods:



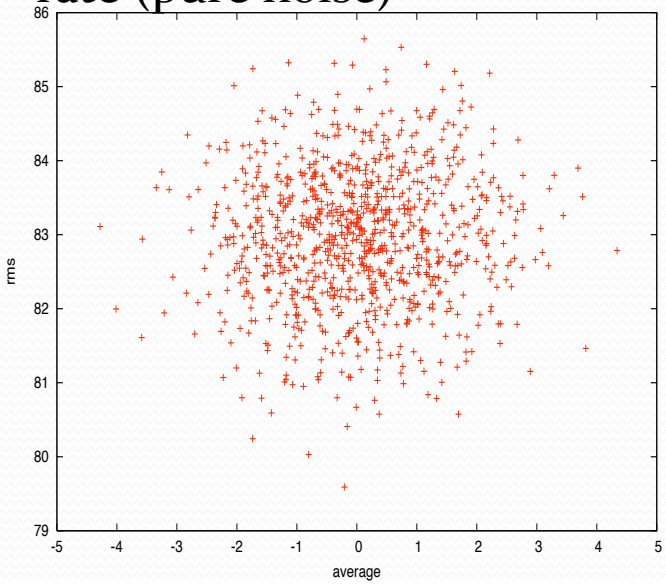

Rx4 x Rx3 Ch.1  Rx2 x Rx5 Ch.1  Rx1 x Rx6 Ch.1

# Testing results : SNR

- The SNR of all the 480 channels in one module is calculated from amplitude fitting of the artificial fringes
- All the channels give ~98.8% consistent efficiency (due to 4-bit decimation)

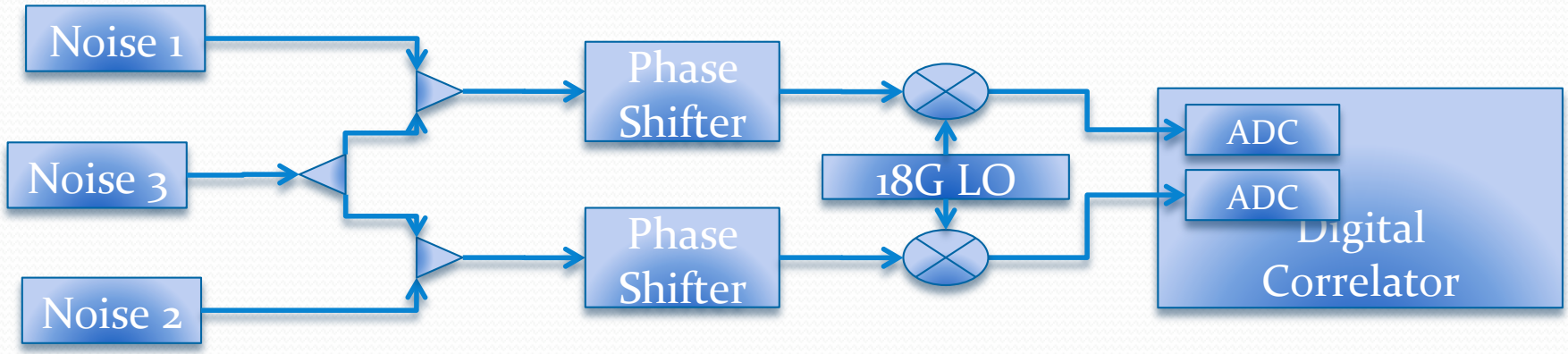



rms and average distribution of correlation data at 5Hz dump rate (pure noise)



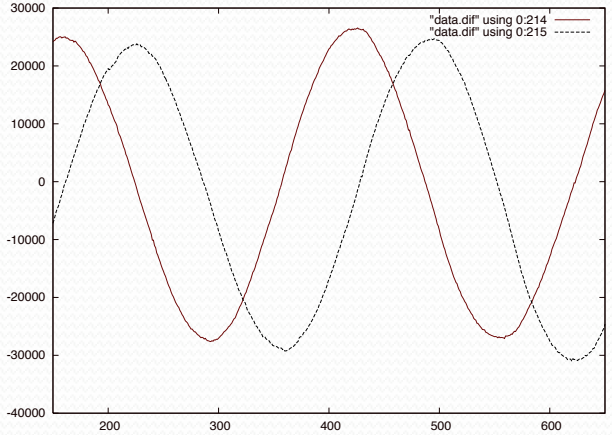
# Performance verification: full-system

- Broad-band noise & signal input (9-18GHz)

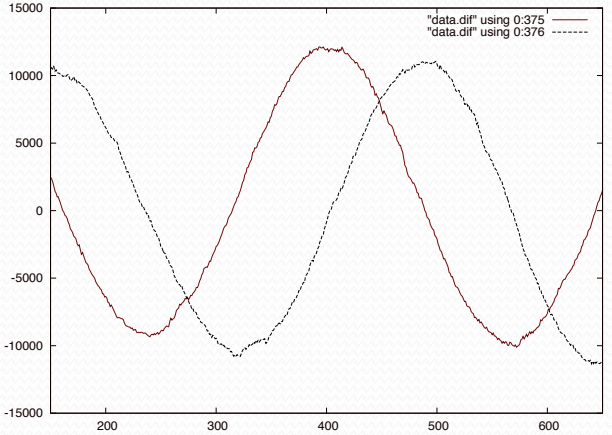



Results:

3.67GHz




6.39GHz



# Expansibility

- Switchable operation modes
  - X1*X2 + Y1*Y2 : I parameter
  - R1*L2 , L1*R2 : Q,U parameter
  - R1*L1 : gain calibration
- Scalable to 16 receiver arrays
- Finer spectrum resolution
  - Additional FFT stage : 4k channels
  - FIR filters

# Thank You!