

HPSP in Harsh Environments on the MeerKAT Telescope

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science and technology

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Science and Technology
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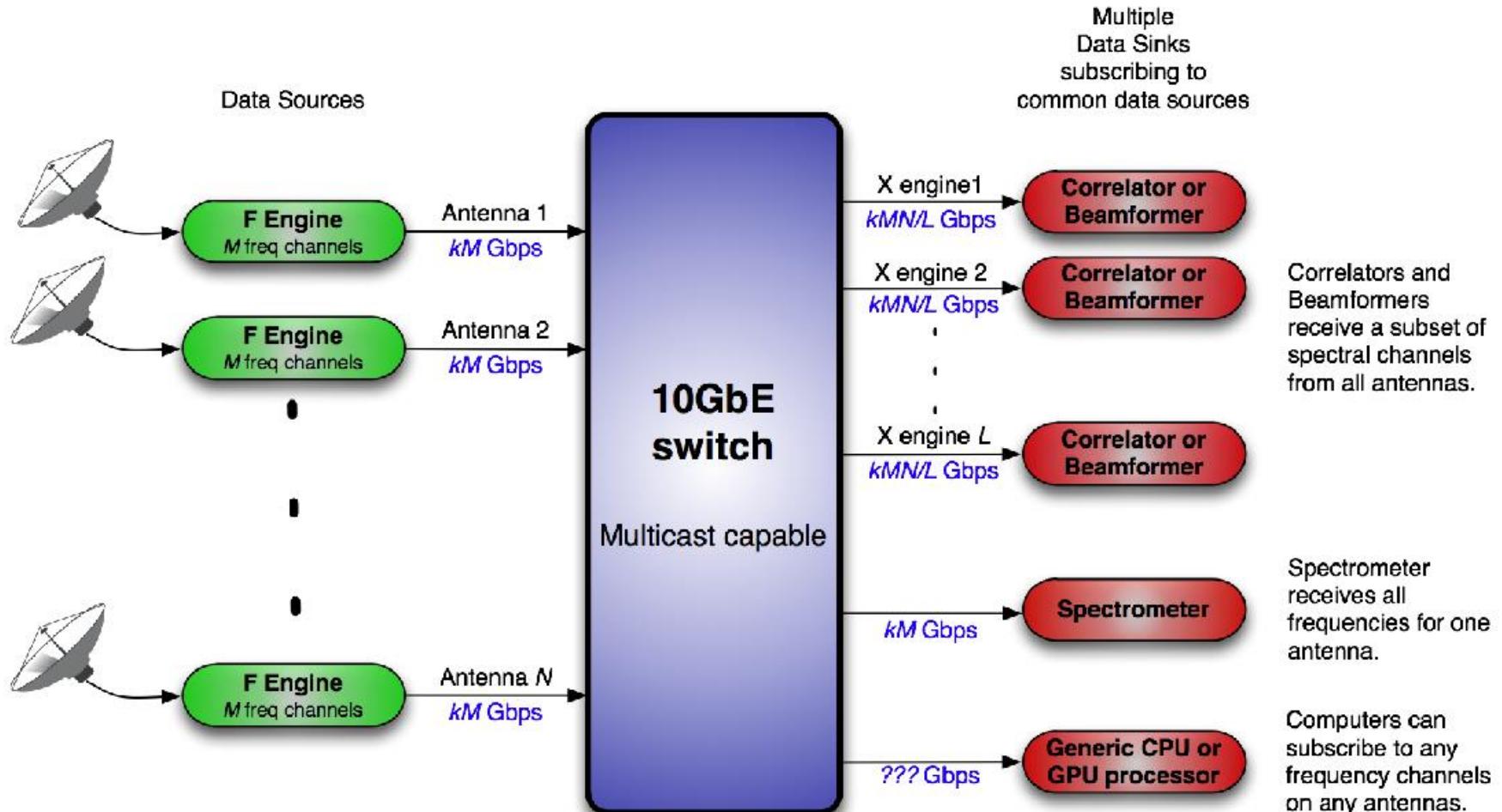
Outline

- Context
- Harsh Environment
- Mechanical
- Mitigation
- Processing
- Reuse

Context: KAT-7



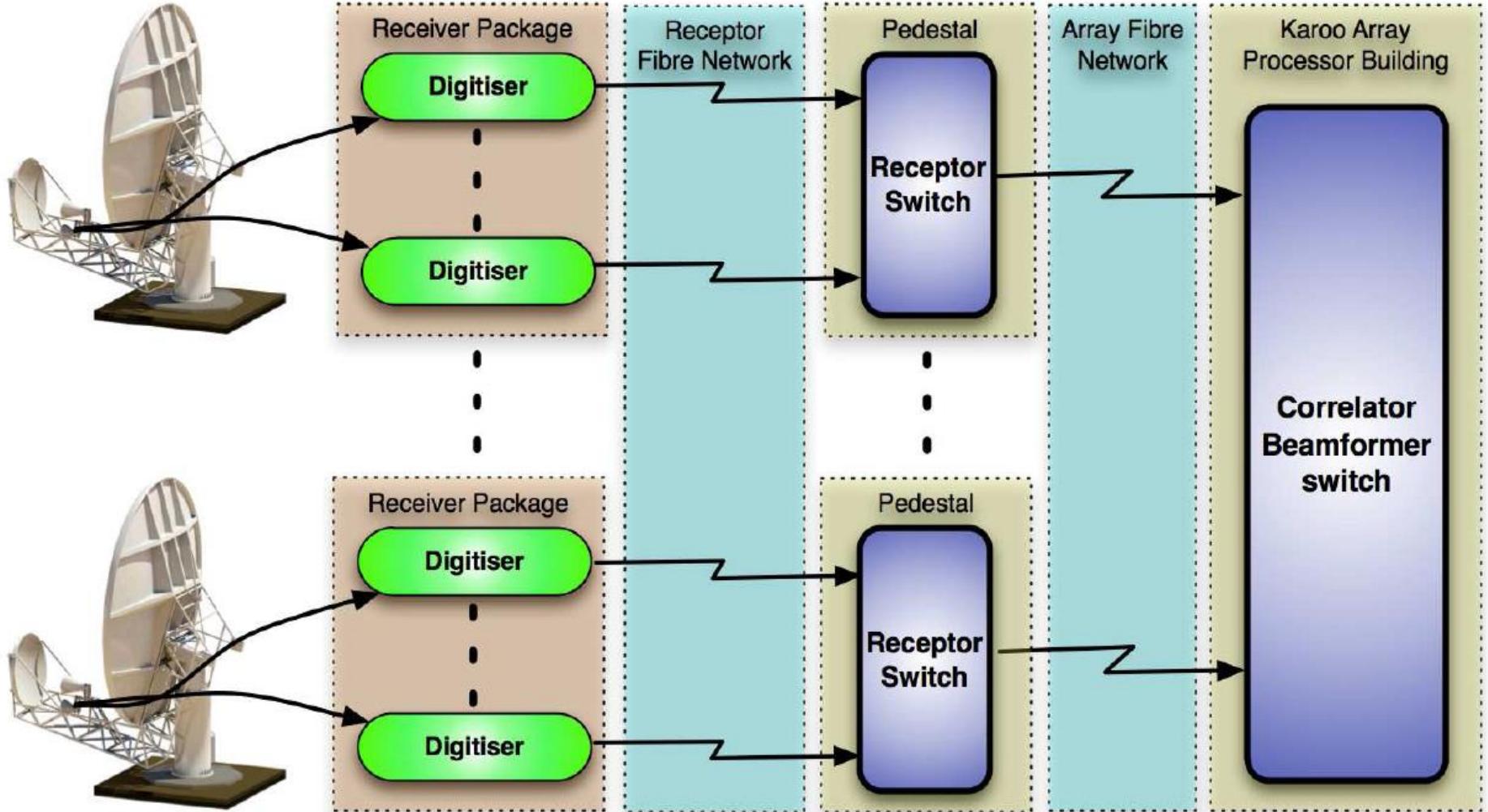
Context: KAT-7 Block Diagram



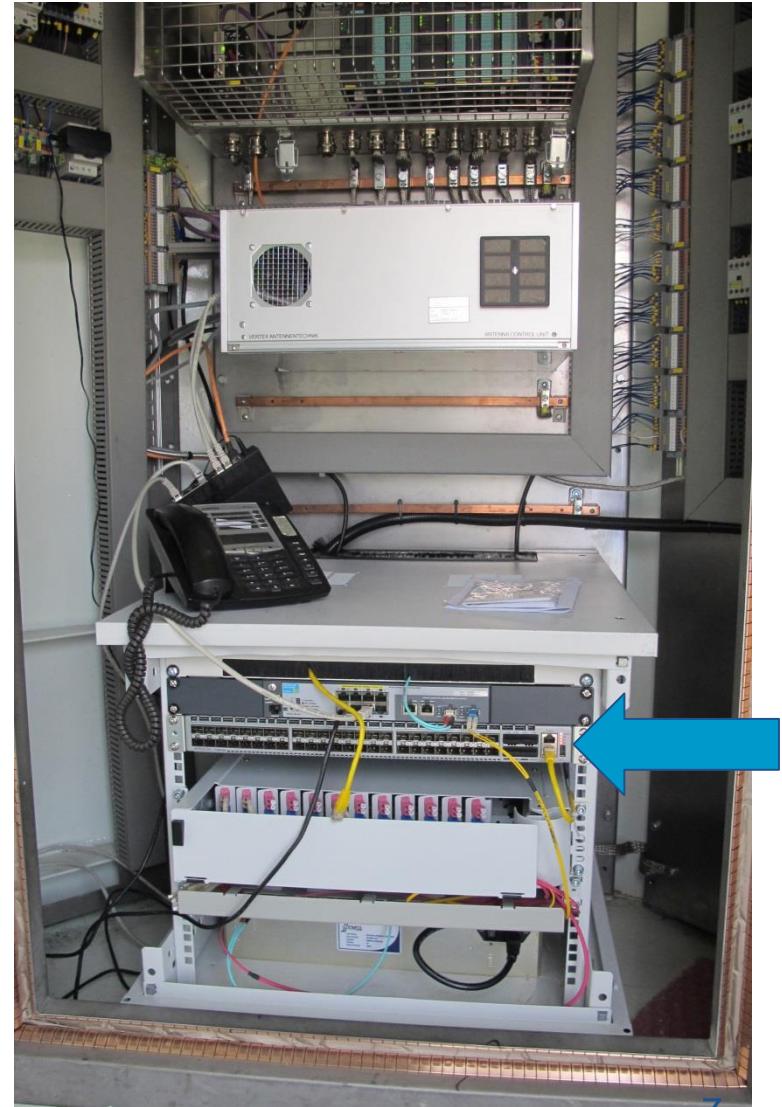
Context: MeerKAT



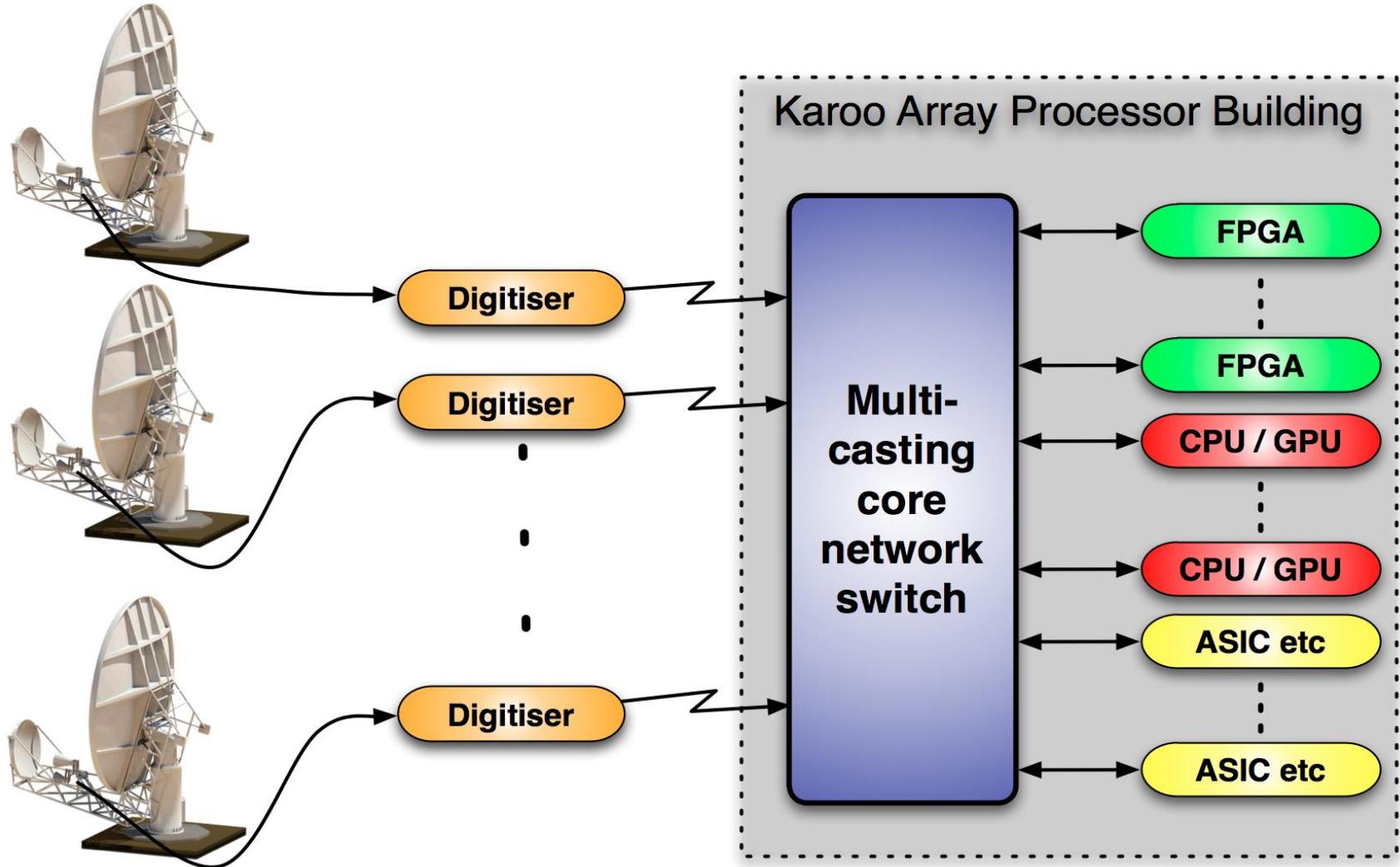
MeerKAT Processing Diagram



Receptor Data Switch



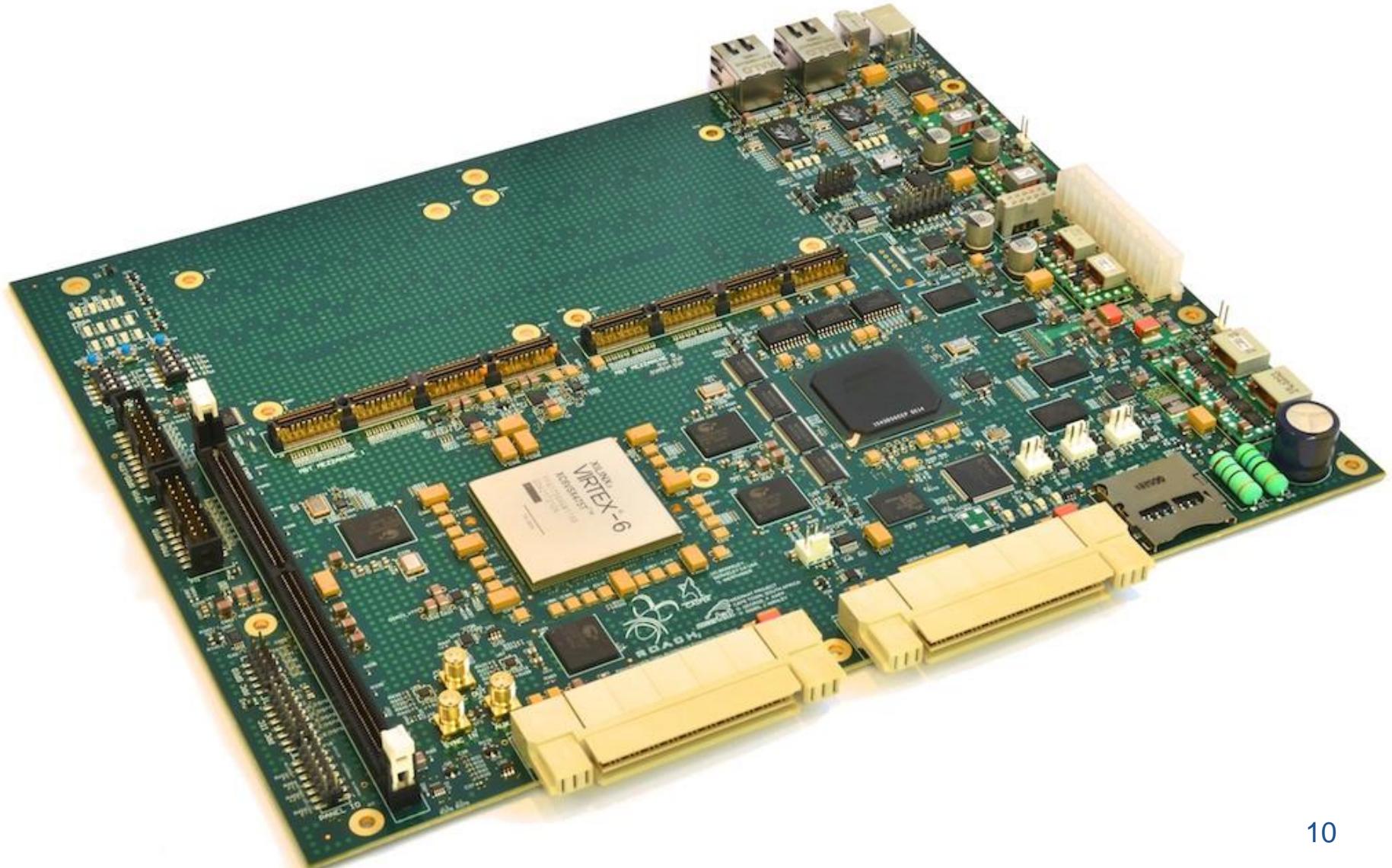
Processing Diagram



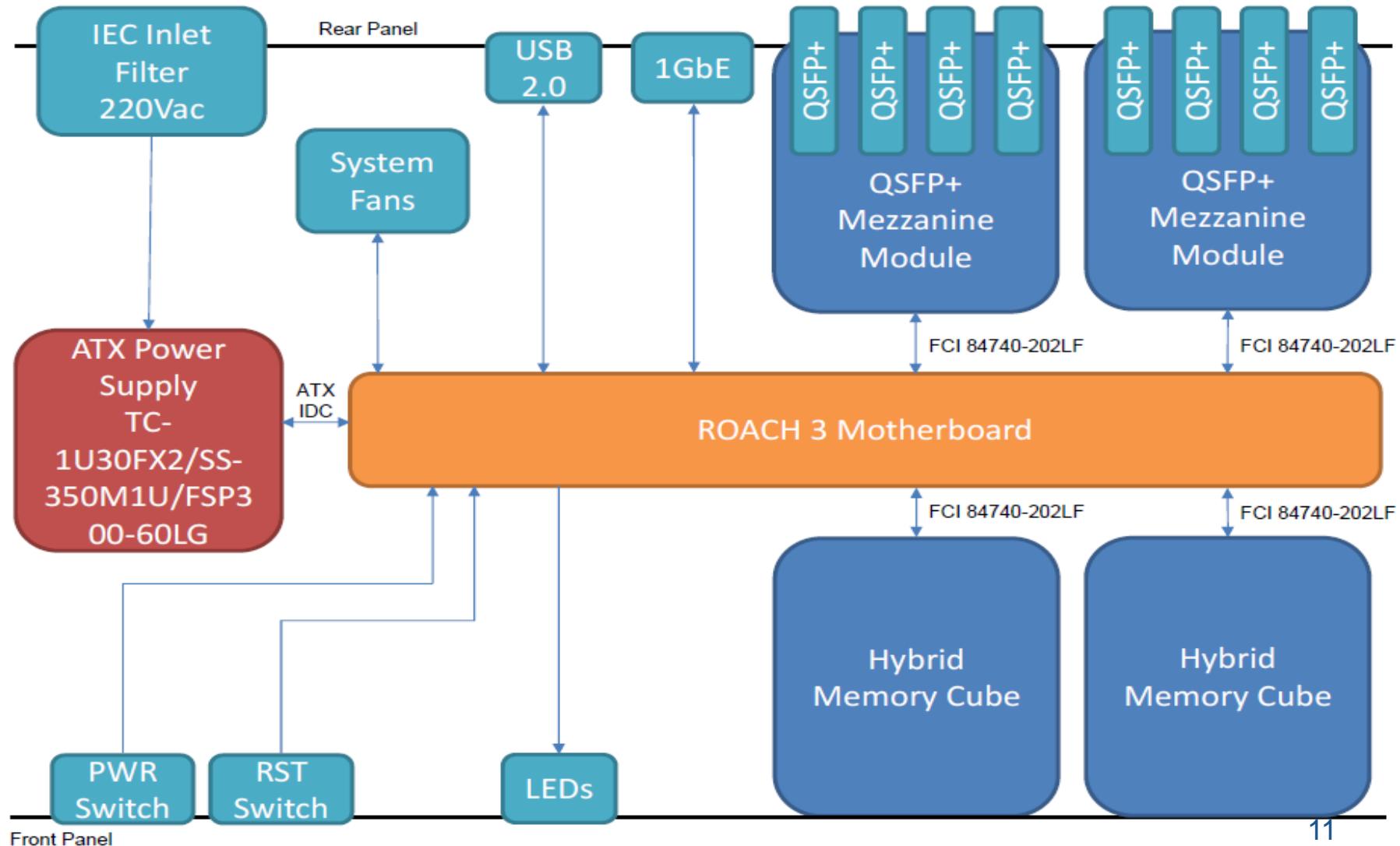
Karoo Array Processor Building



ROACH II



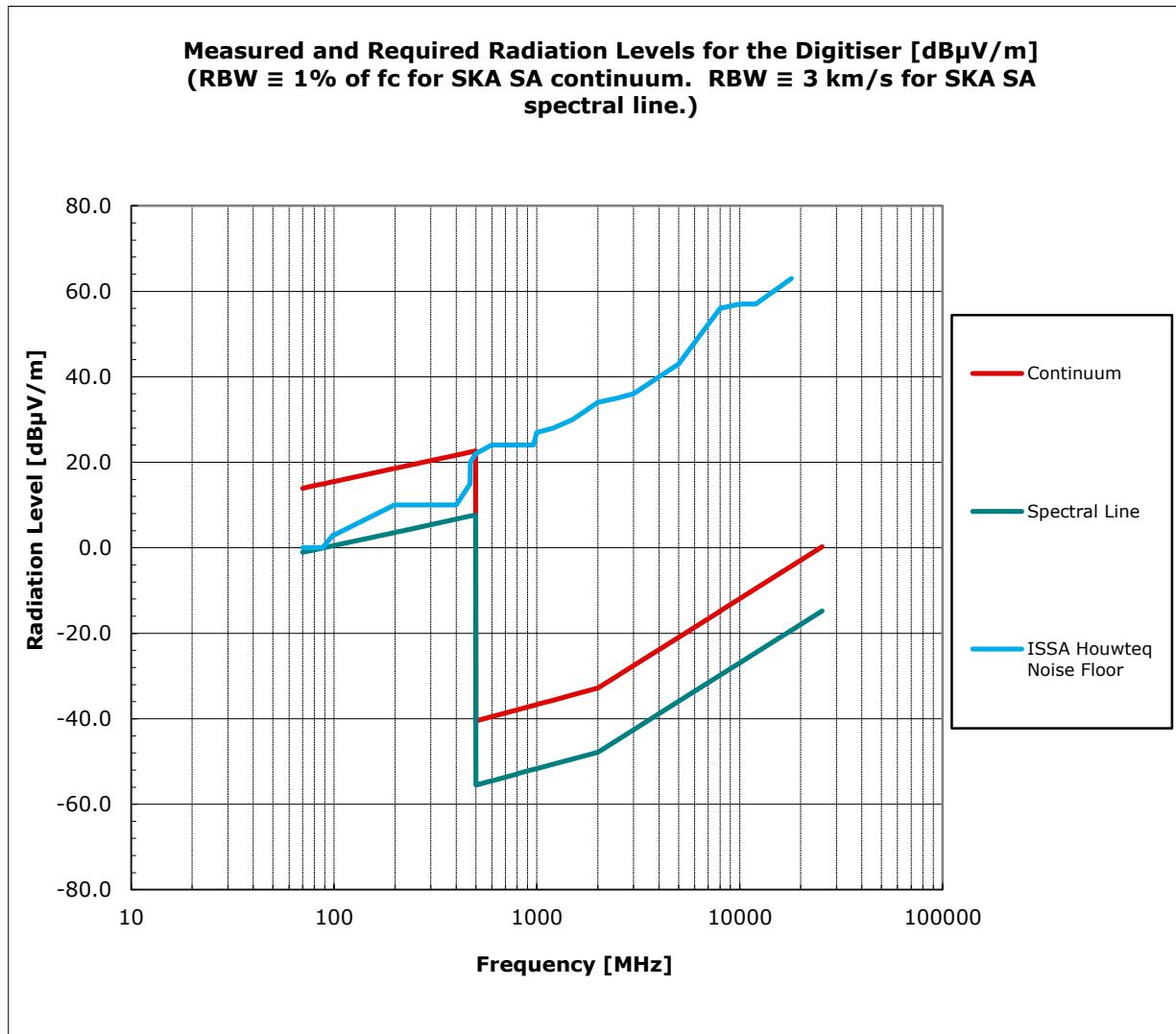
SKARAB



SKARAB



Harsh Environment: RFI



Harsh Environment



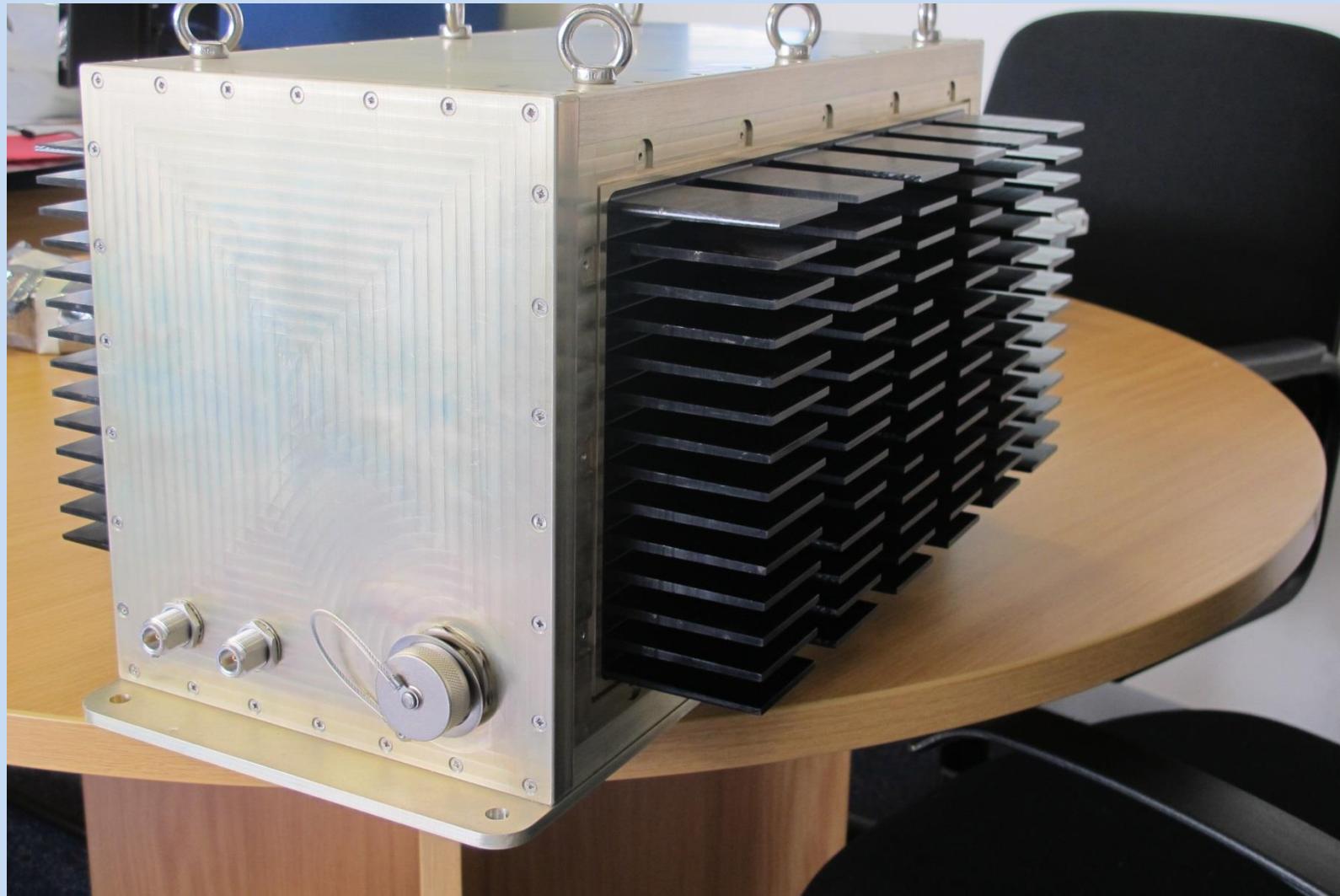
Environmental parameter	Description
Air temperature	<u>Digitiser ambient conditions</u> <ul style="list-style-type: none">• Temperature change (R.D.E.5): -5 to +40°C• Rate of change (R.D.E.6): 3°C in 20min and 2°C in 10min• Survival (R.D.E.1): -20 to +55 °C
Humidity	<ul style="list-style-type: none">• Relative: 93% at 40 °C• Condensation: 90-100% at 30 °C
Precipitation	<ul style="list-style-type: none">• Submersed in 0.4m head of water for 30min
Solar radiation	<ul style="list-style-type: none">• 1120W/m²
Mechanically active substances	<ul style="list-style-type: none">• Dust• Sand
Vibration and shock	ETSI EN 300019-2-4 V2.2.2 (2003-04)

Mitigation



- Holistic design approach
- Component level
- PCB
- Enclosure (shielding)
- Connectors
- Filtering
- Fibre
- Clocking
- Processing

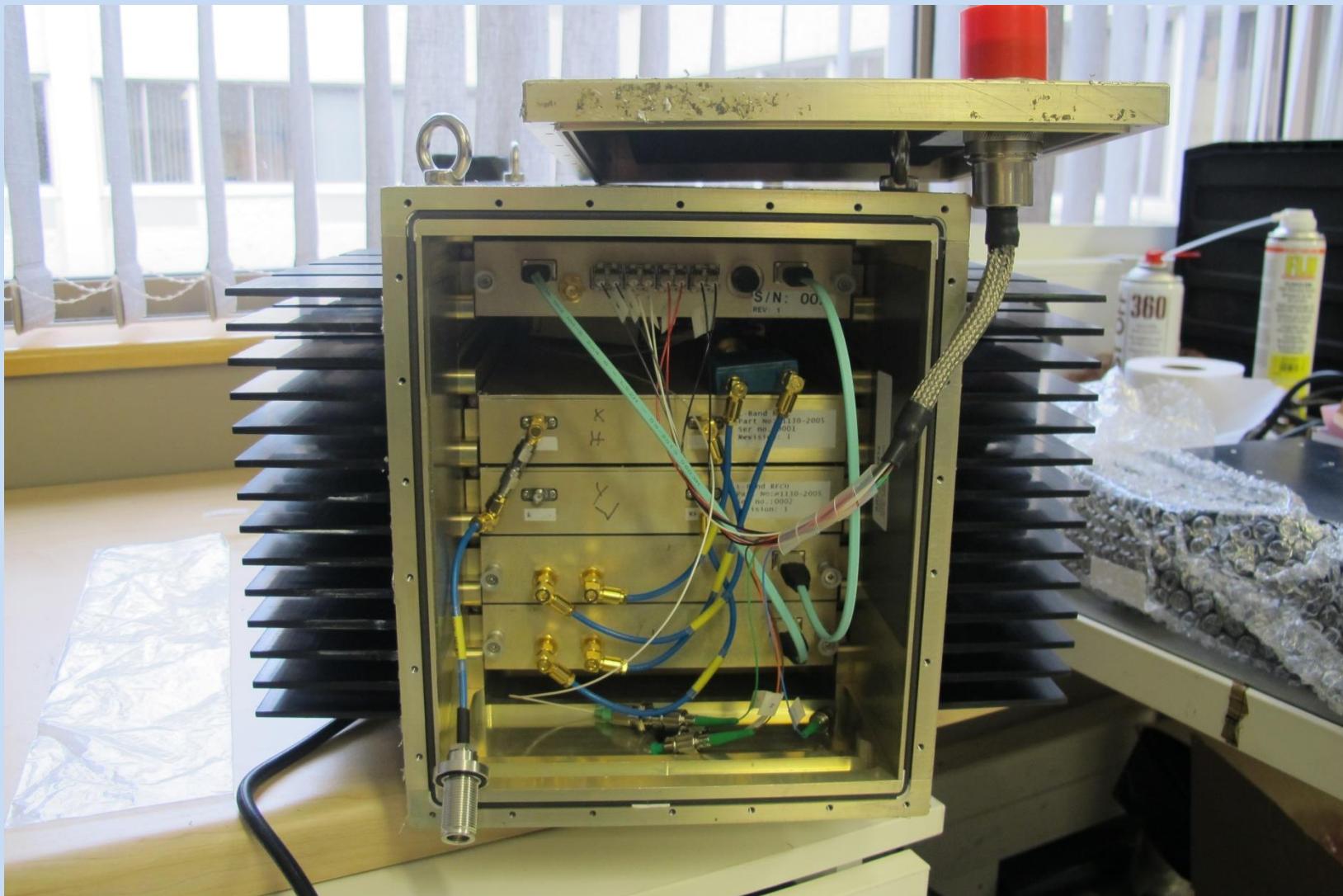
Mechanical Concept



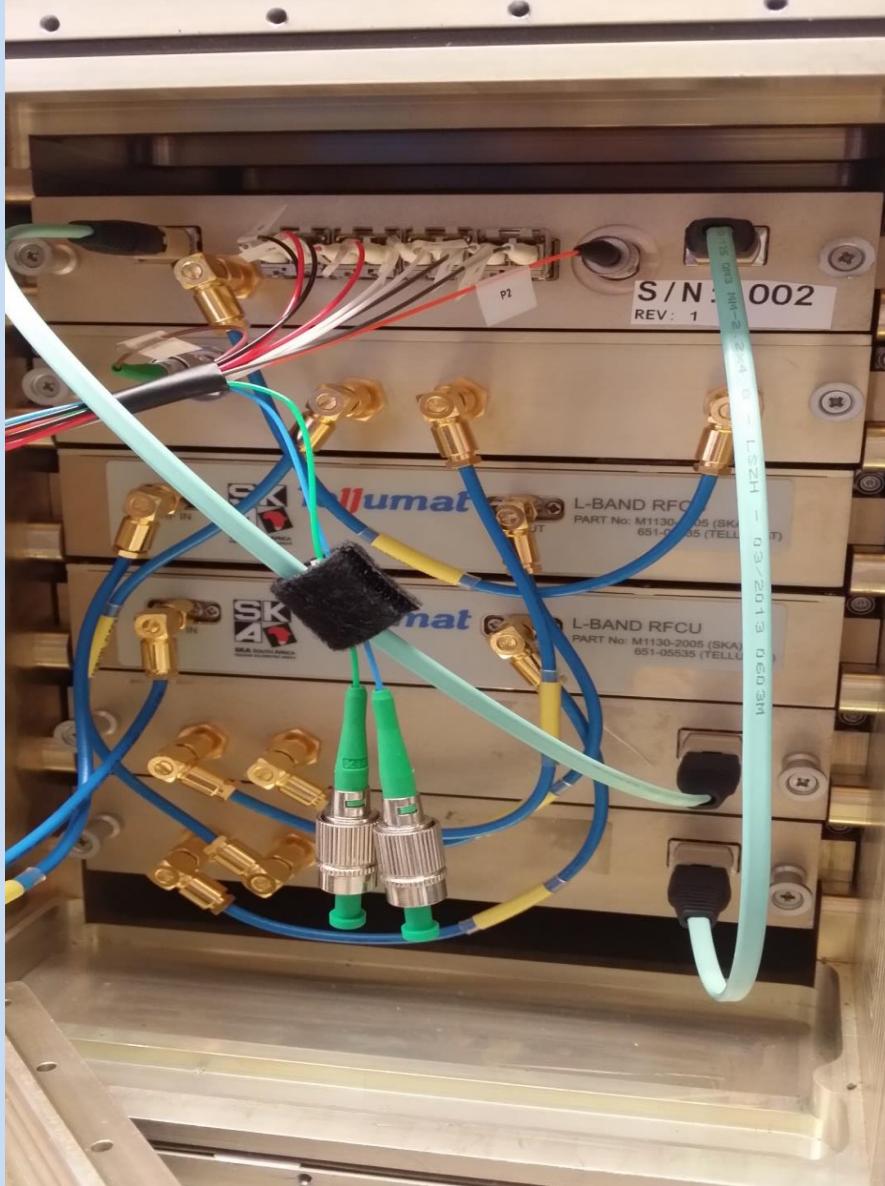
Mechanical Concept



Mechanical Concept



Mechanical Concept



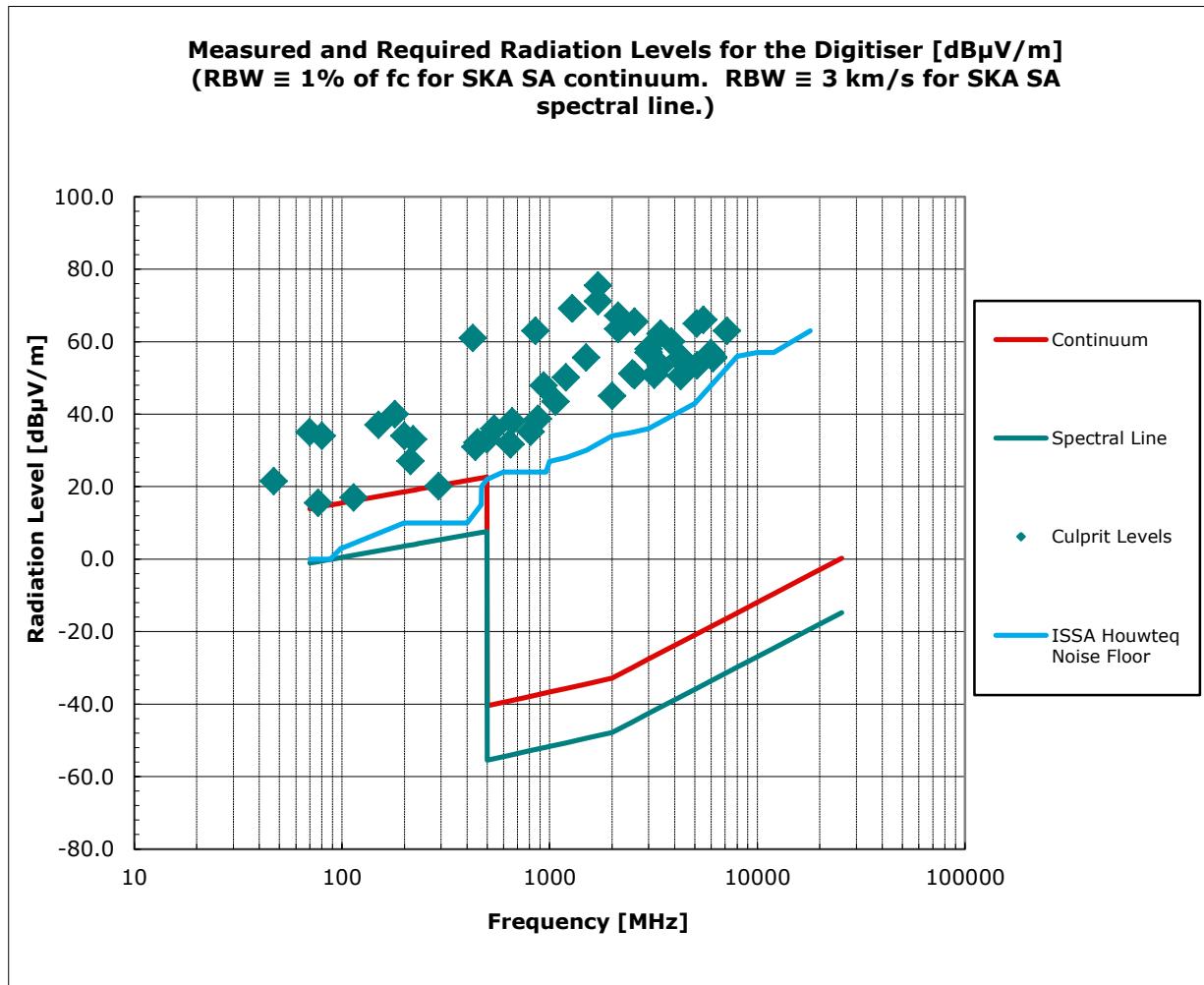
Digitiser fibre connectors



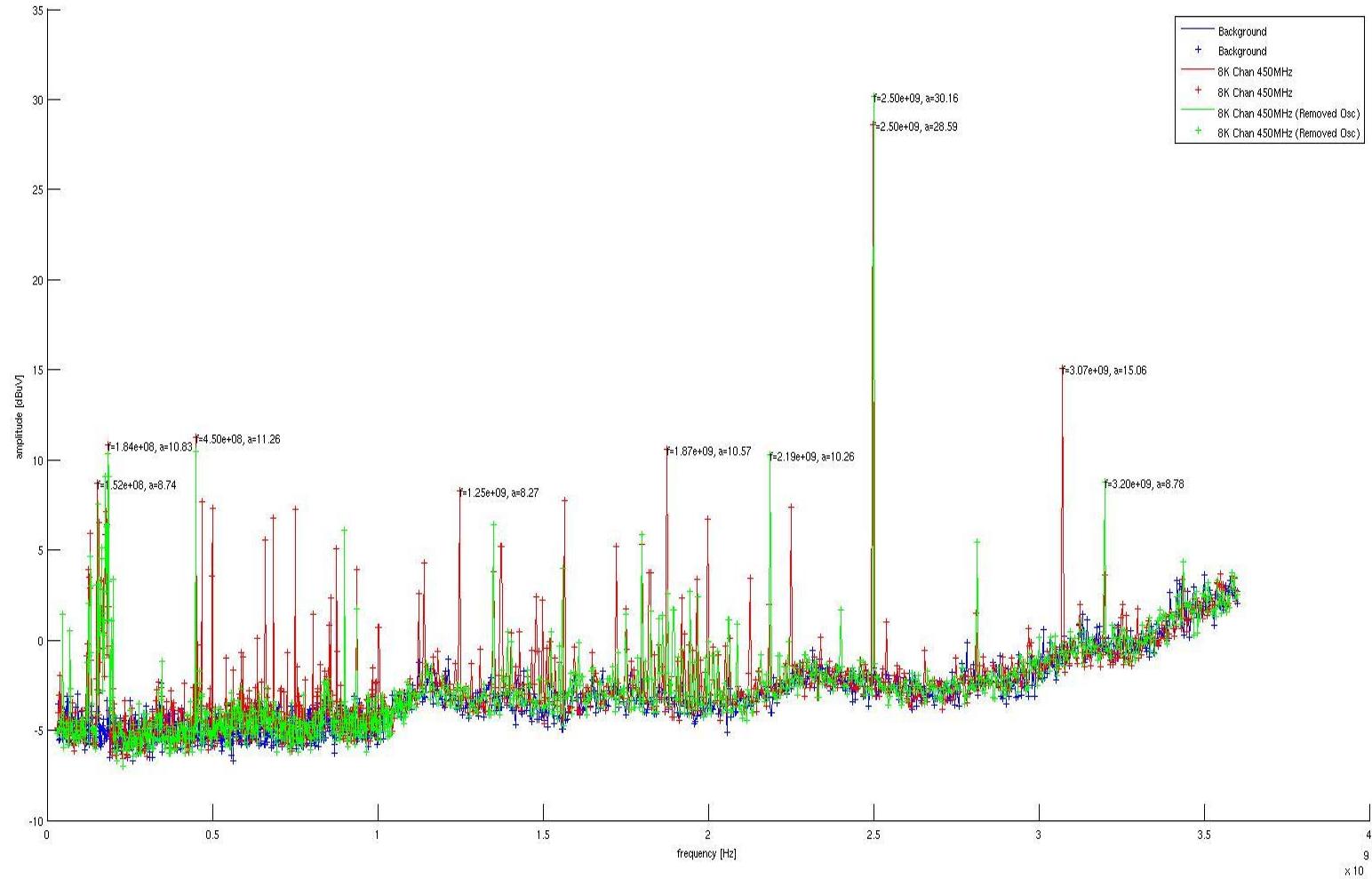
MXL38999
Circular Optical Connectors
106386



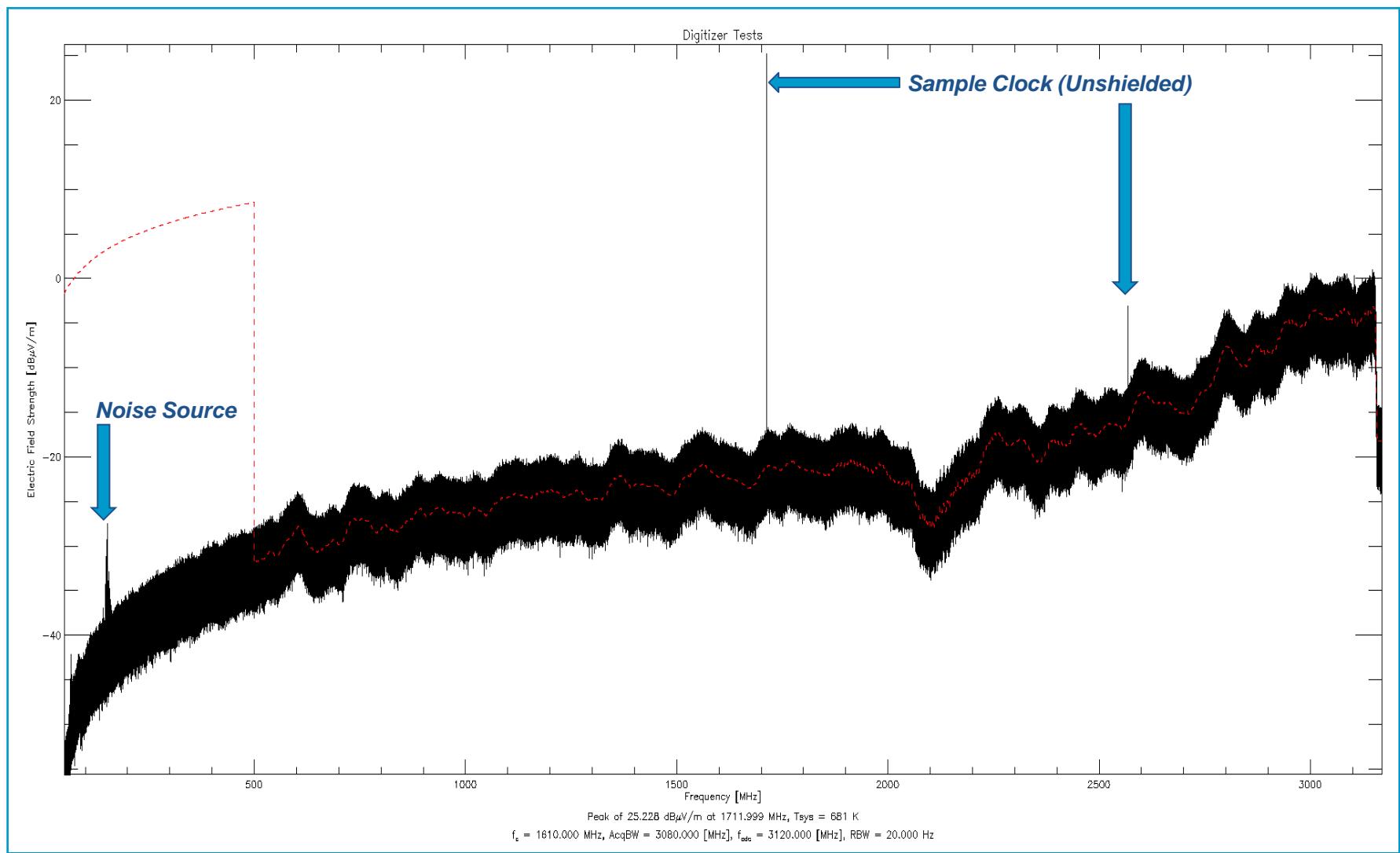
Harsh Environment: RFI



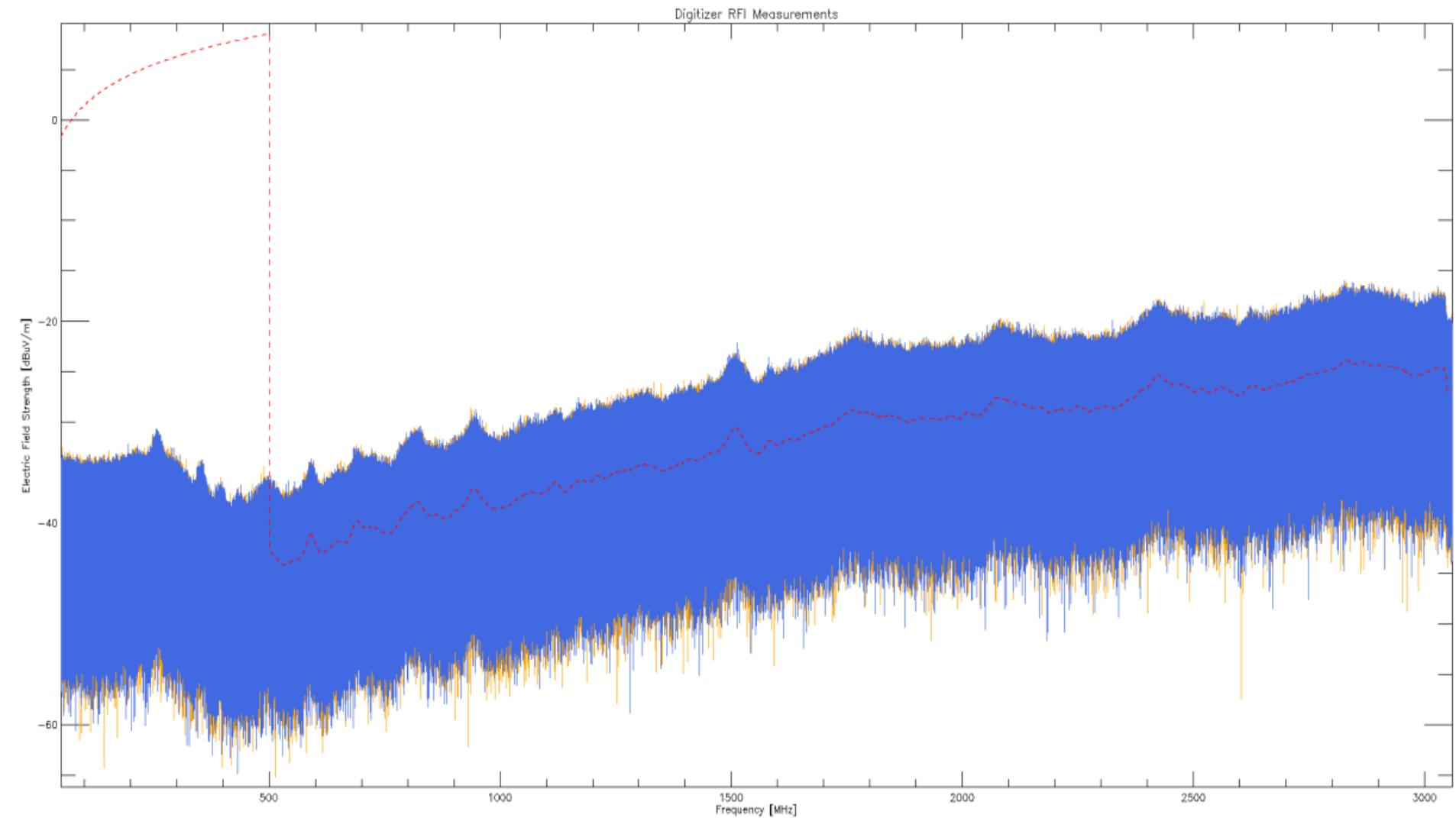
Where we started: Radiated RFI KC705 Prototype



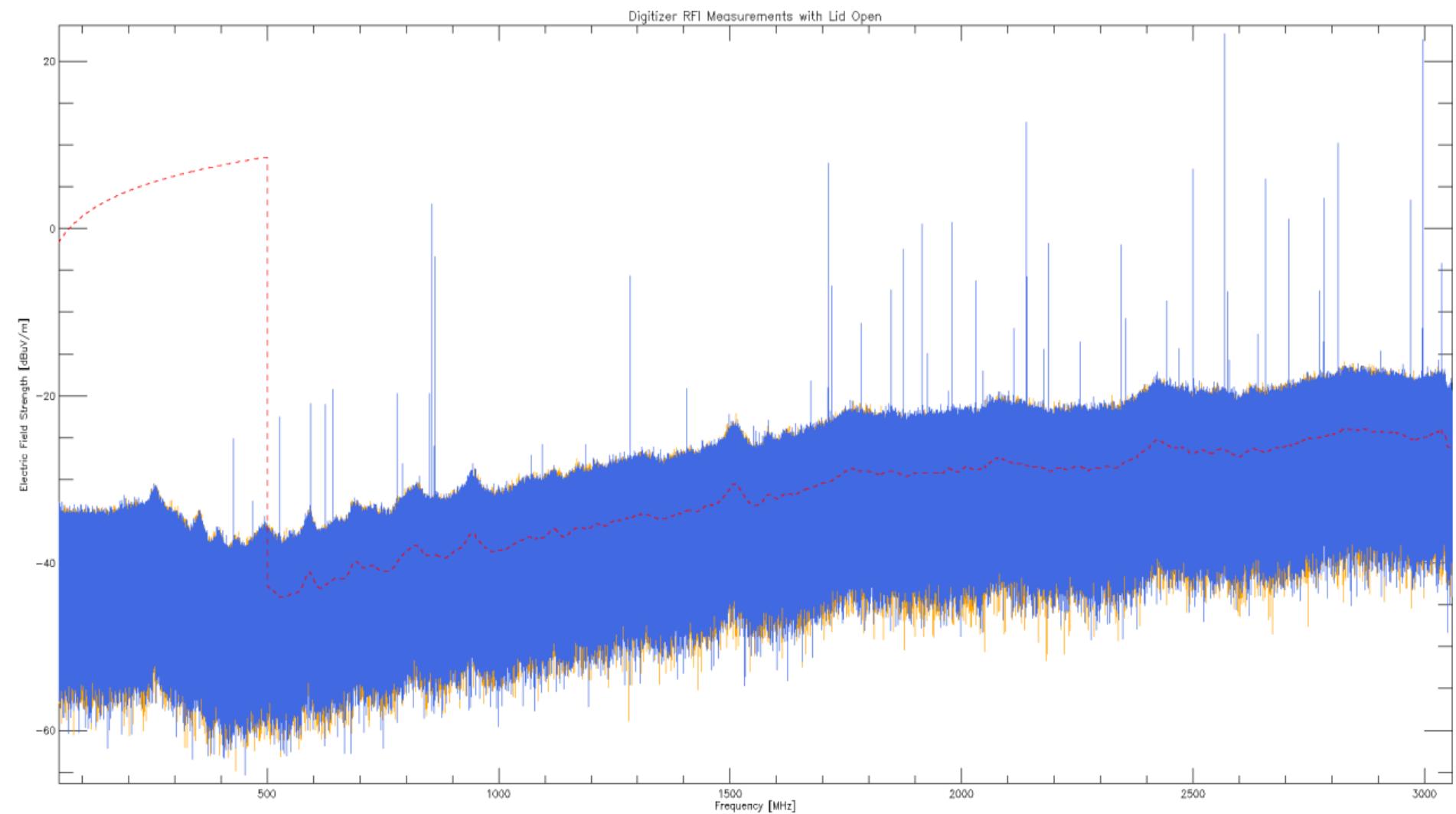
Measured Results: Radiated RFI Performance



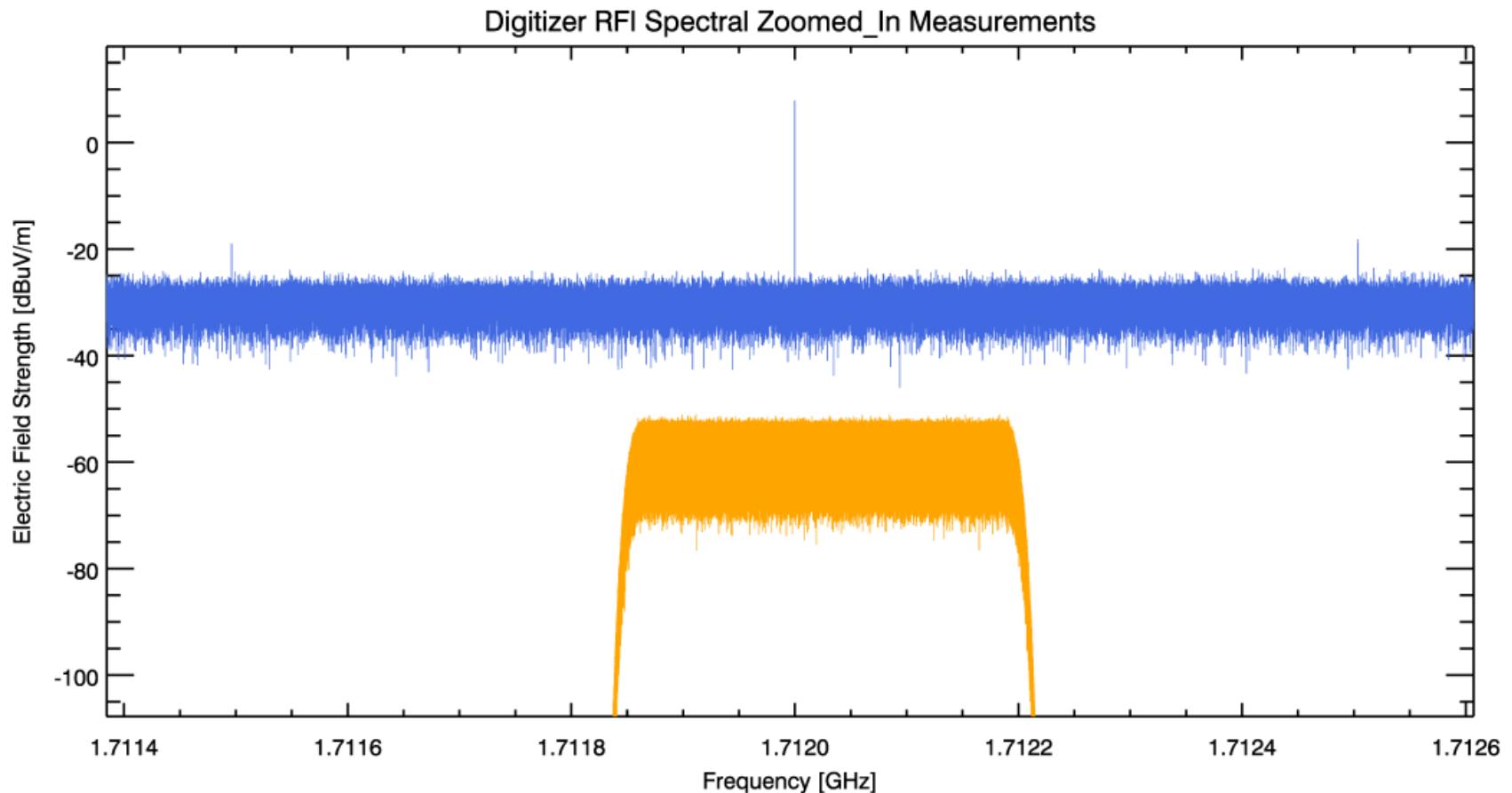
Measured Results: Radiated RFI Performance



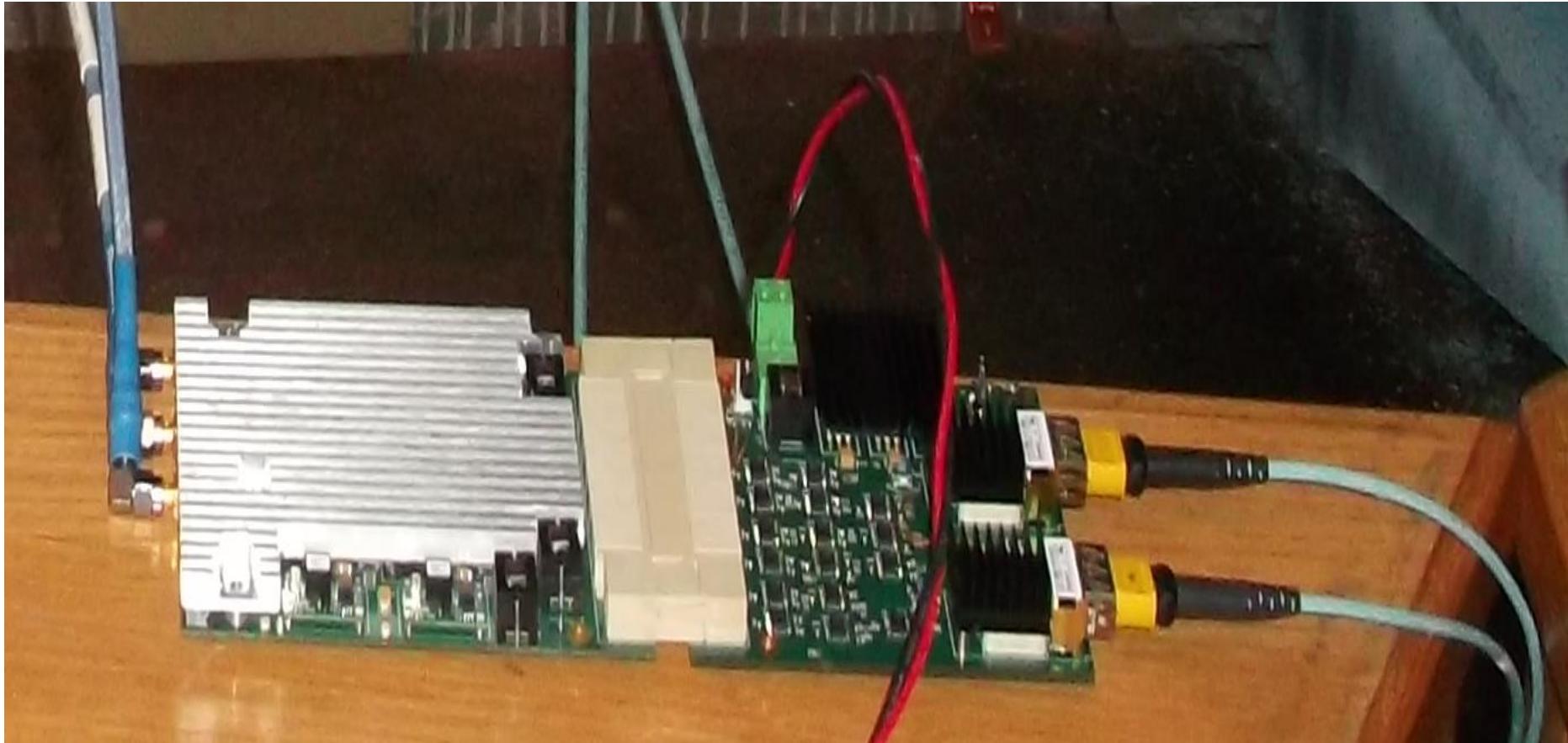
Measured Results: Radiated RFI Performance



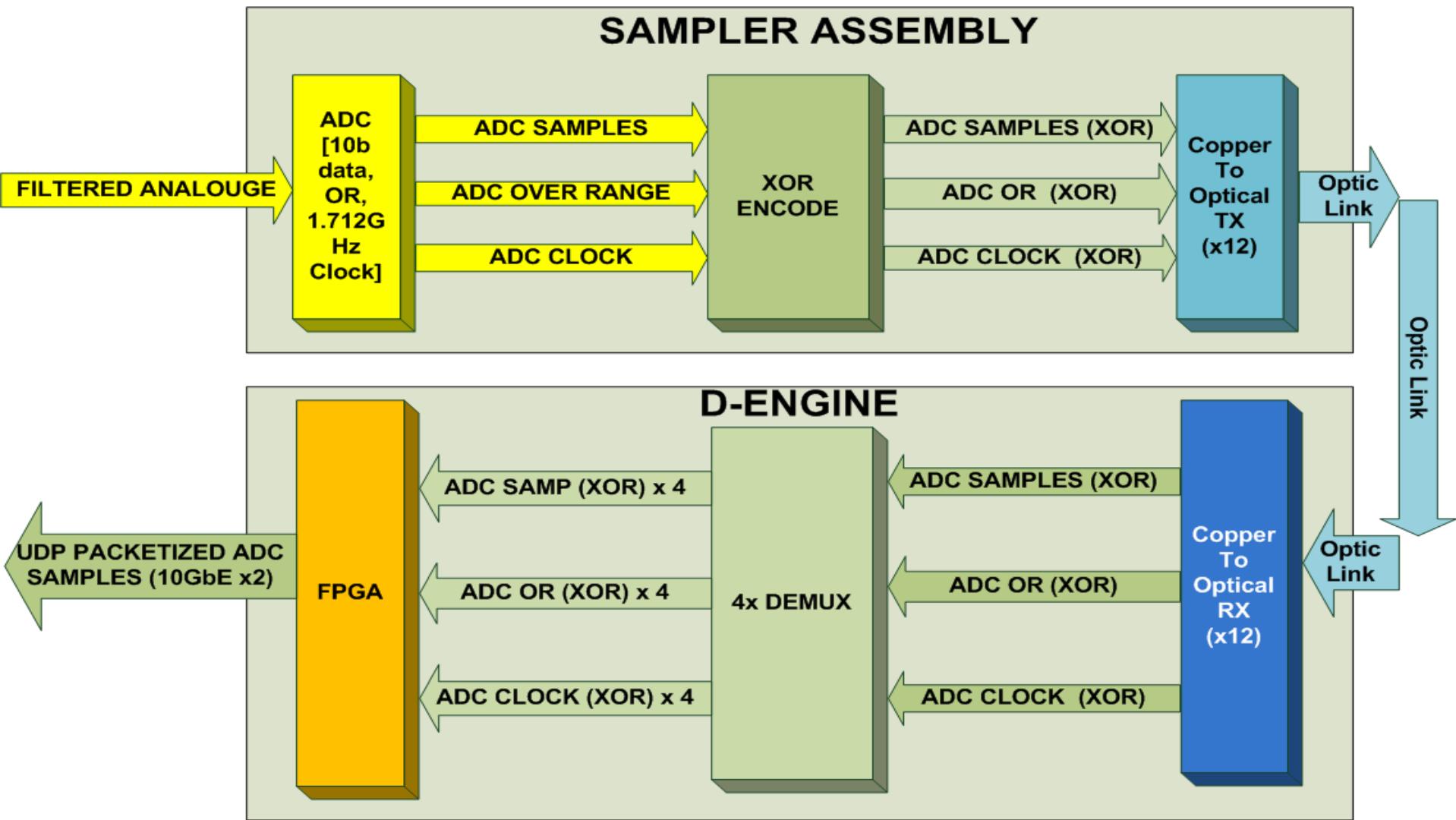
Measured Results: Radiated RFI Culprits



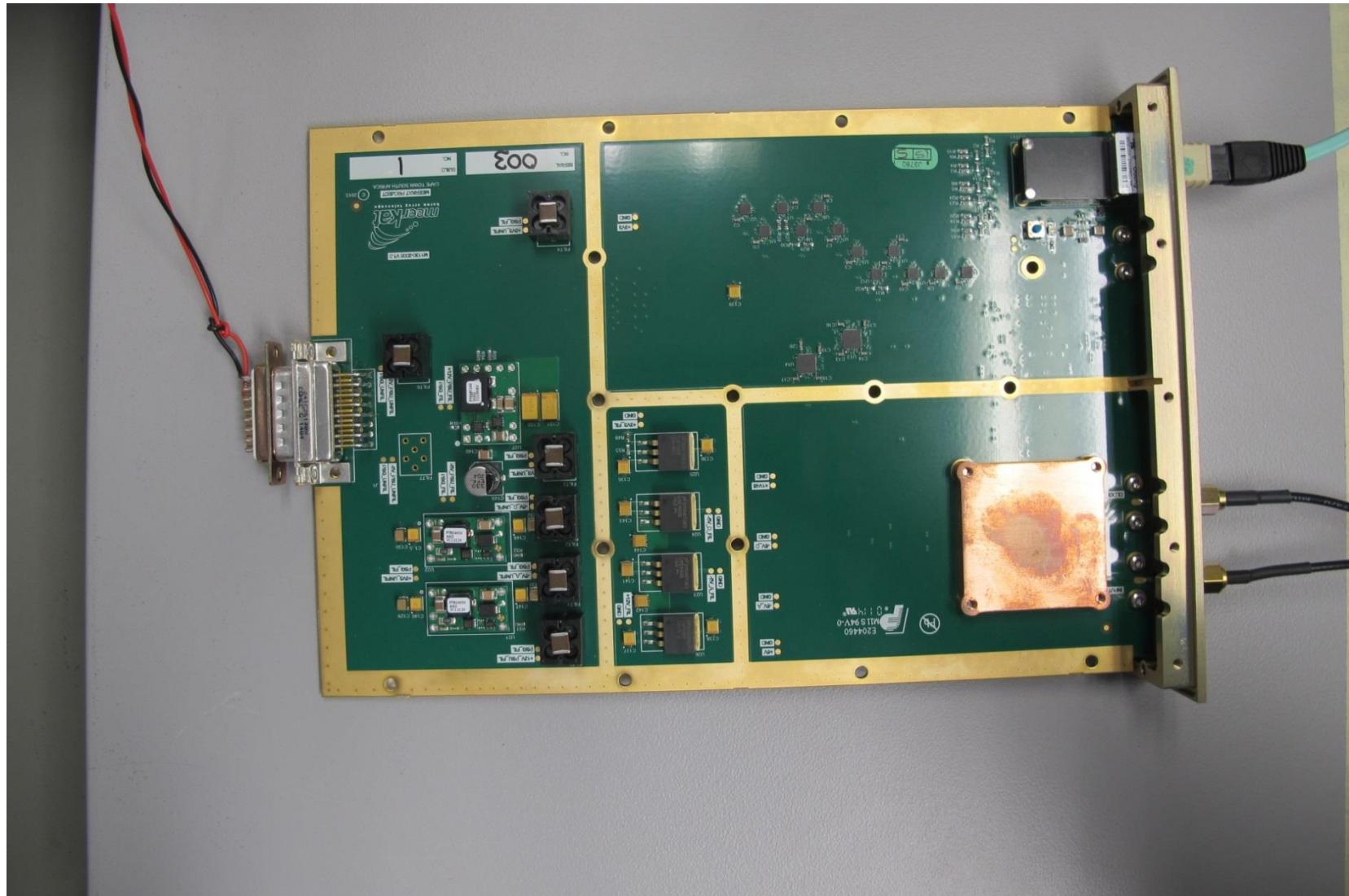
ADC Optic Transmission (RFI)



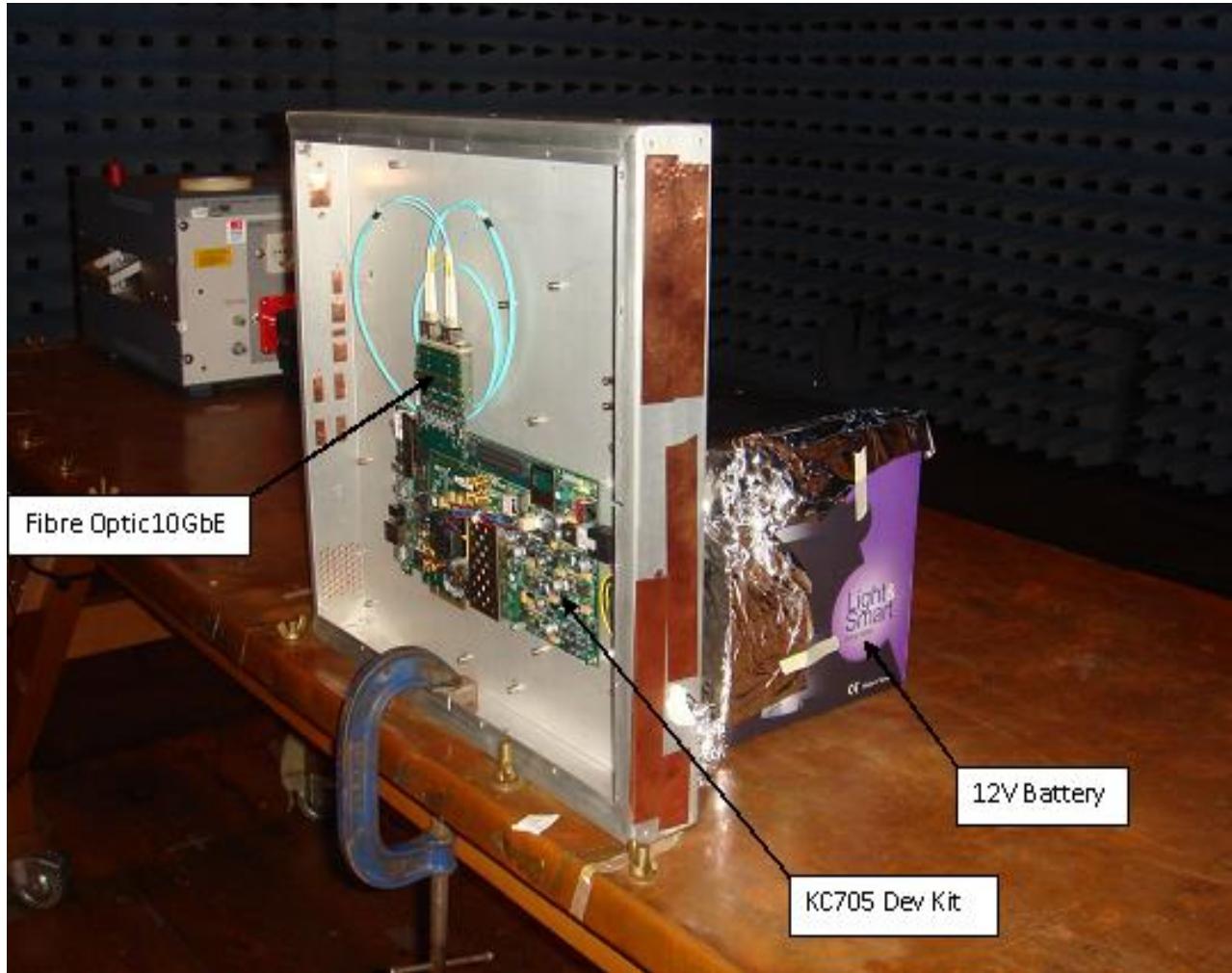
ADC Optic Separation



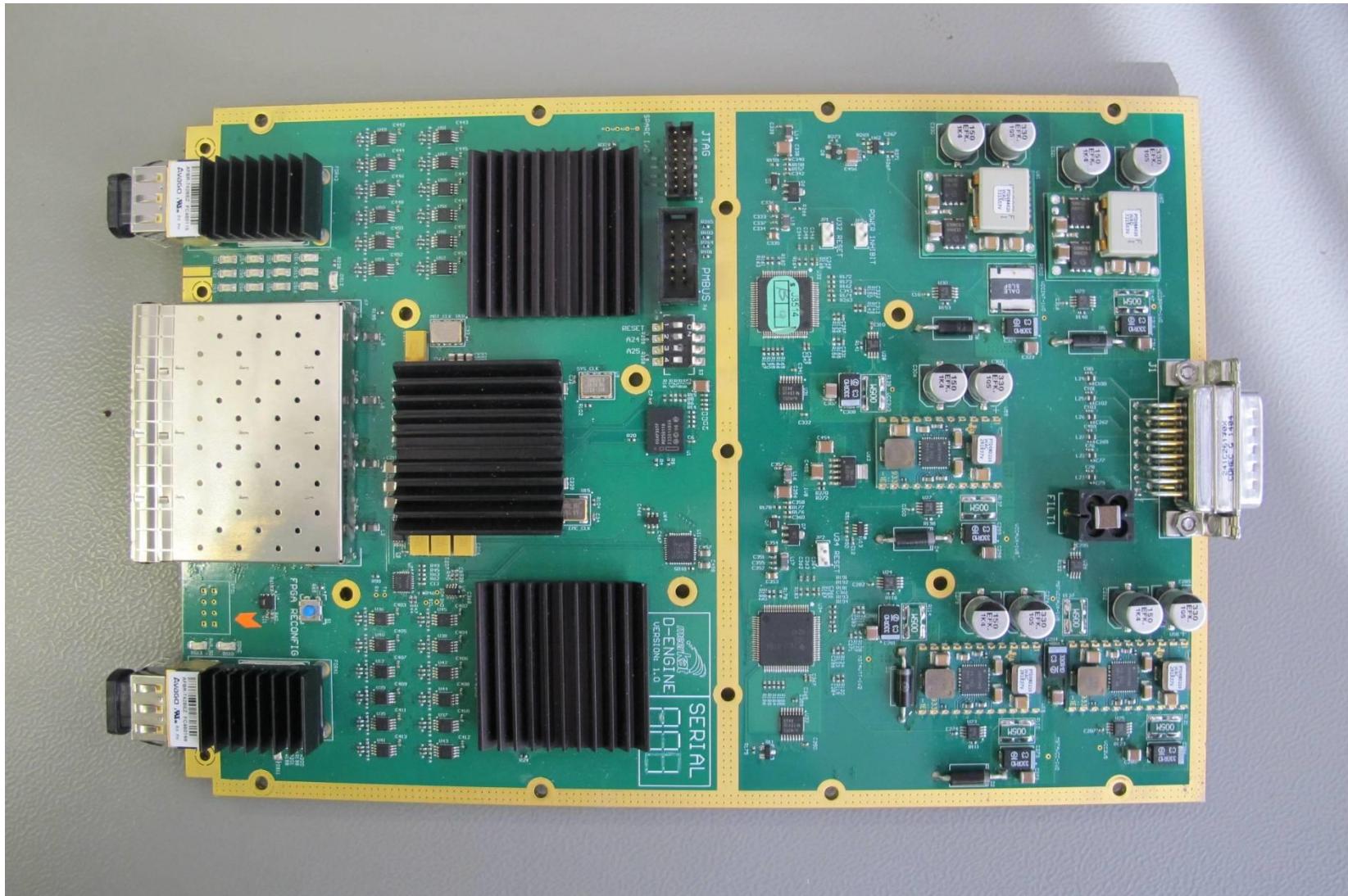
Sampler PCB



D-Engine: RFI



D-Engine FPGA Processing



D-Engine Layer Stack

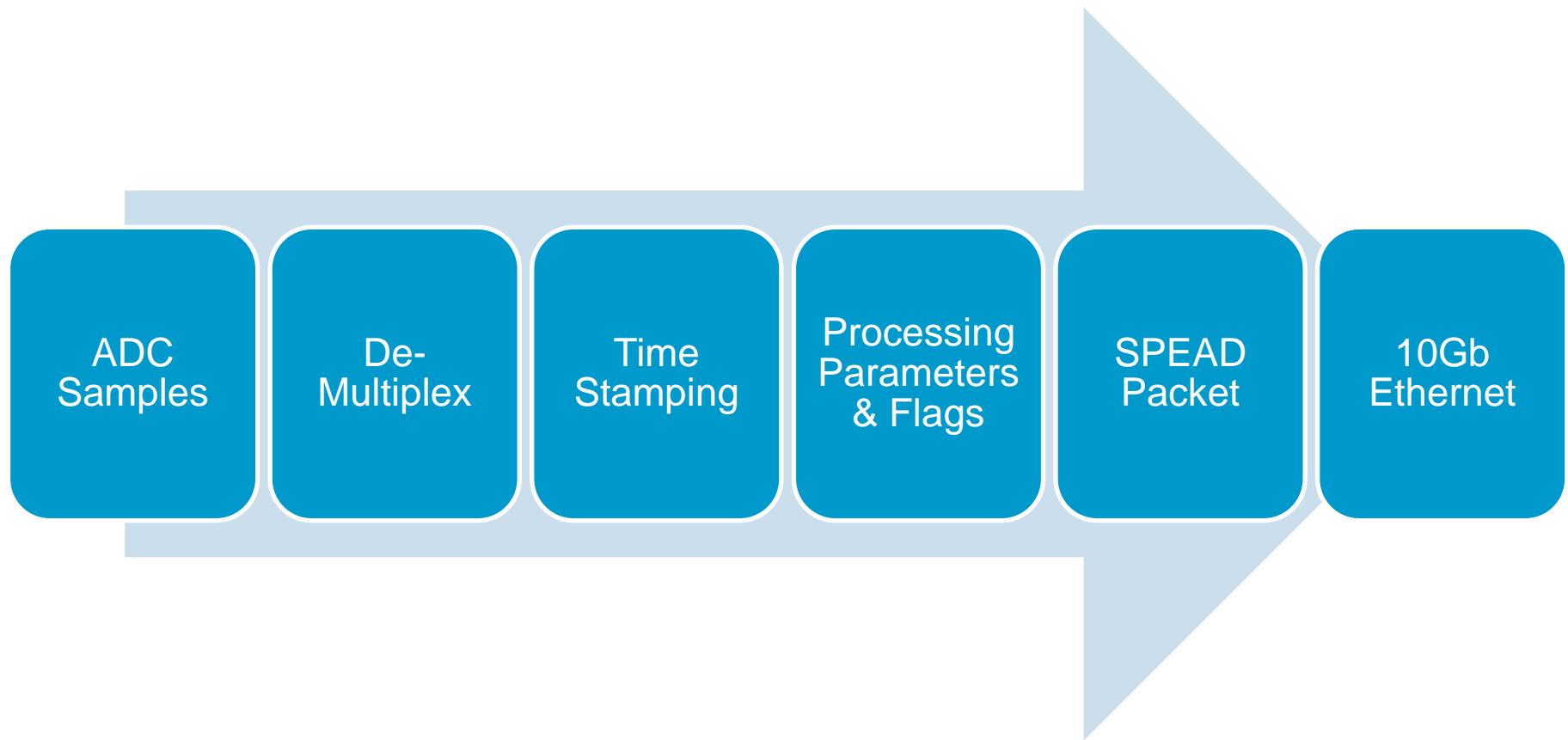


Operational Temperature Range

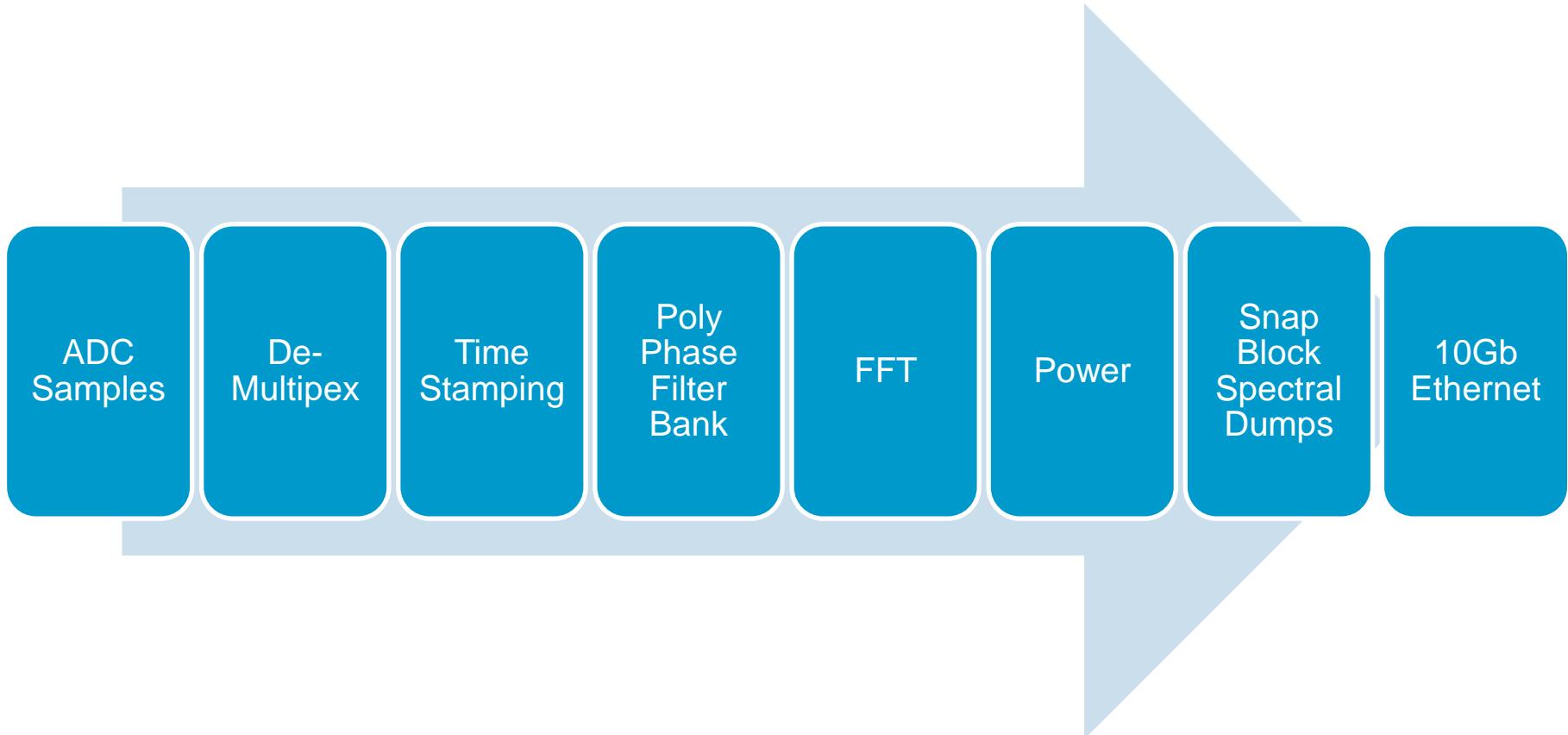


- Operational Temperature: -5C to 42C
- Hottest components:
 - ADC (4.5W) Max Operational Temp 90C
 - FPGA (8W) Max Operational Temp 100C
- Environmental chamber test: 50C
 - ADC Die Temp 72C
 - FPGA Die Temp 68C
- At Antenna (33C):
 - ADC Die Temp 56C
 - FPGA Die Temp 51C

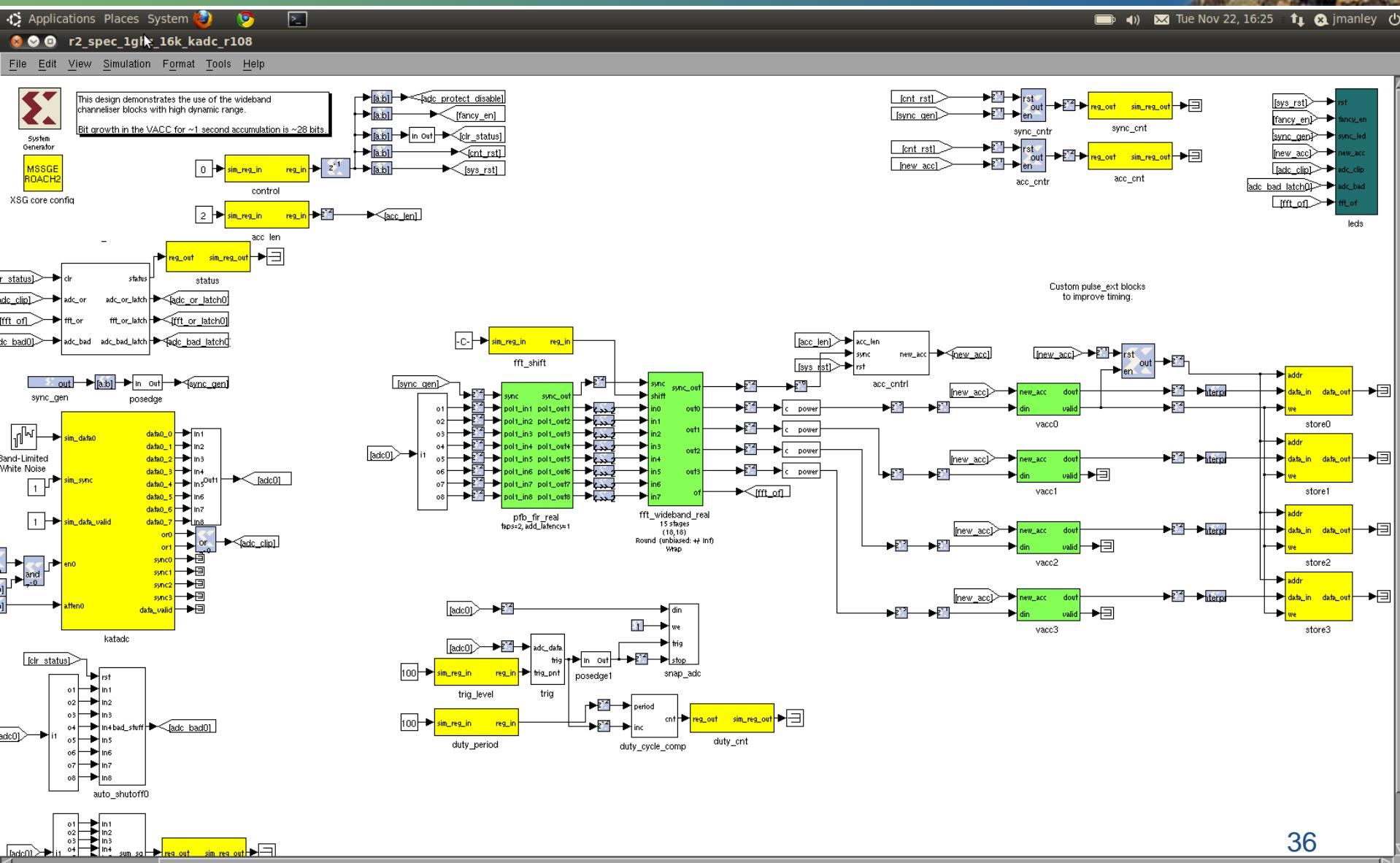
Processing Flow: Raw ADC



Processing Flow: Spectrum



CASPER Tool Flow:Simulink View



ADC Data (Polarization)



- 2 Polarizations – H & V
- 1.712 Gsps
- 10 bit
- 2nd Nyquist Sampling

De-Multiplexing

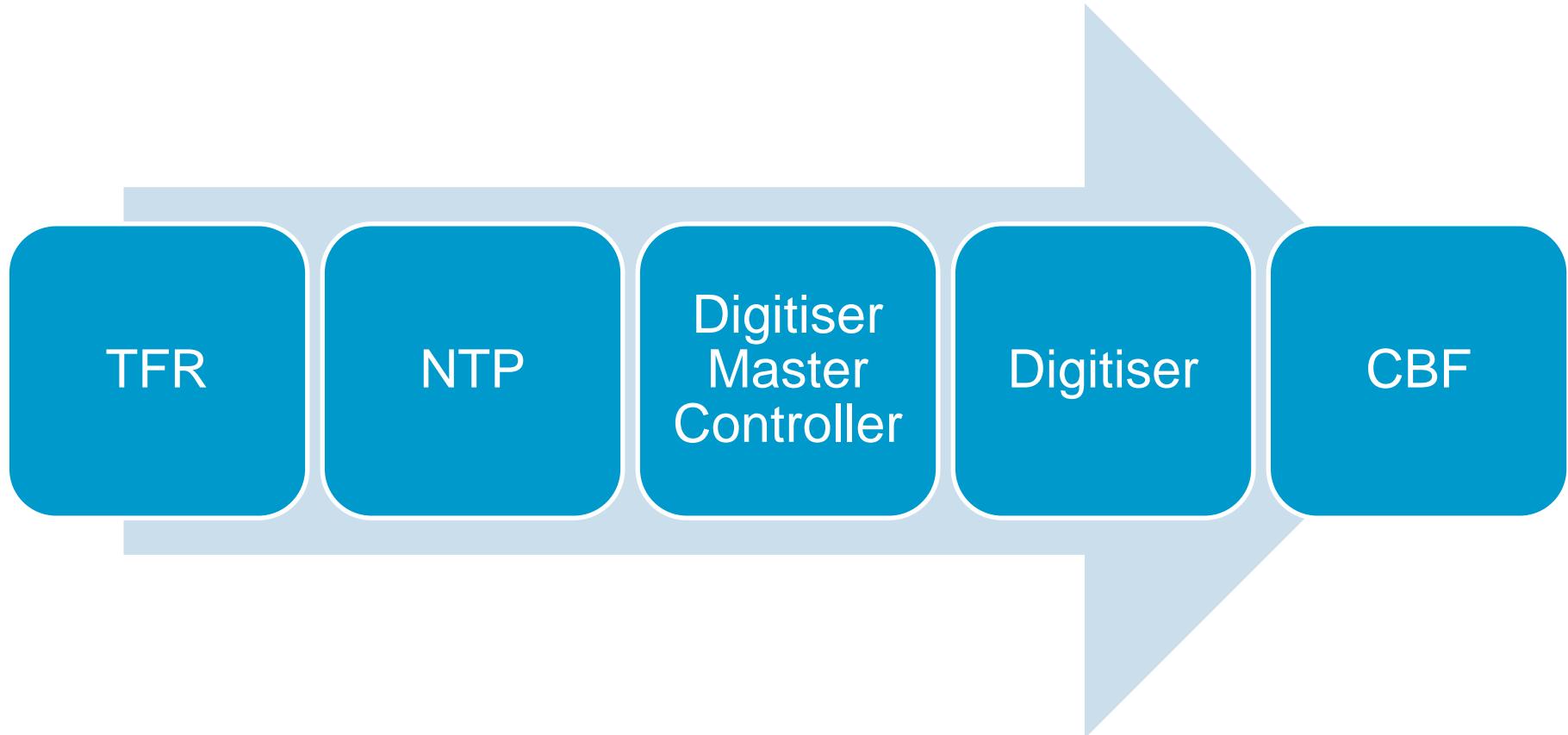


- 2 Polarizations – H & V
- Hardware Demux 1:4
- Data rate 428 Msps x 4
- FPGA Demux 1:2
- FPGA processing rate 214Msps x 8 x 10bits x 2 polarizations

Flags

- ADC Clip
- Noise Diode Status
- Frequency Band
- Sample Time Stamp
- Polarization
- Receptor ID

Time Synchronization



Time Synchronization



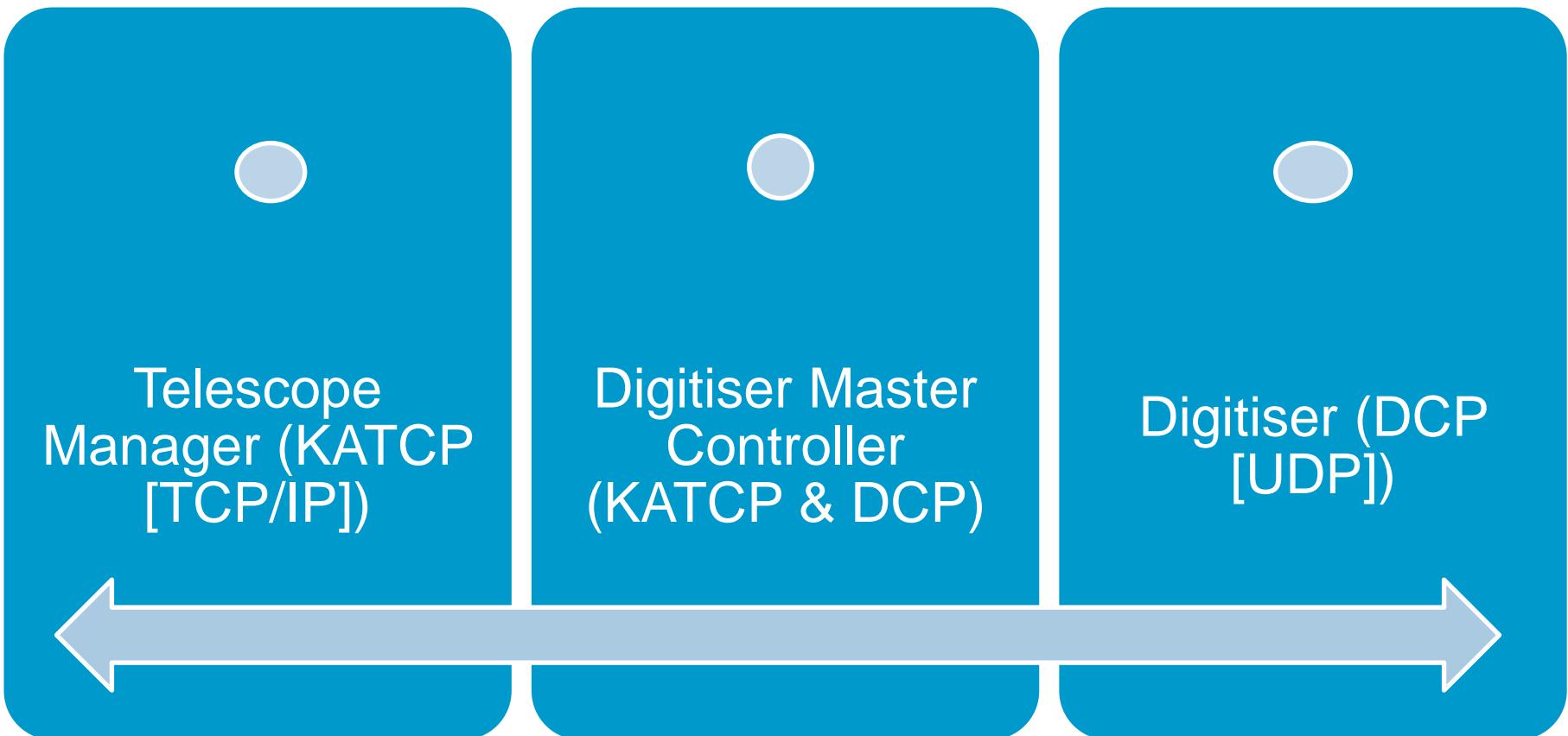
TFR

PPS

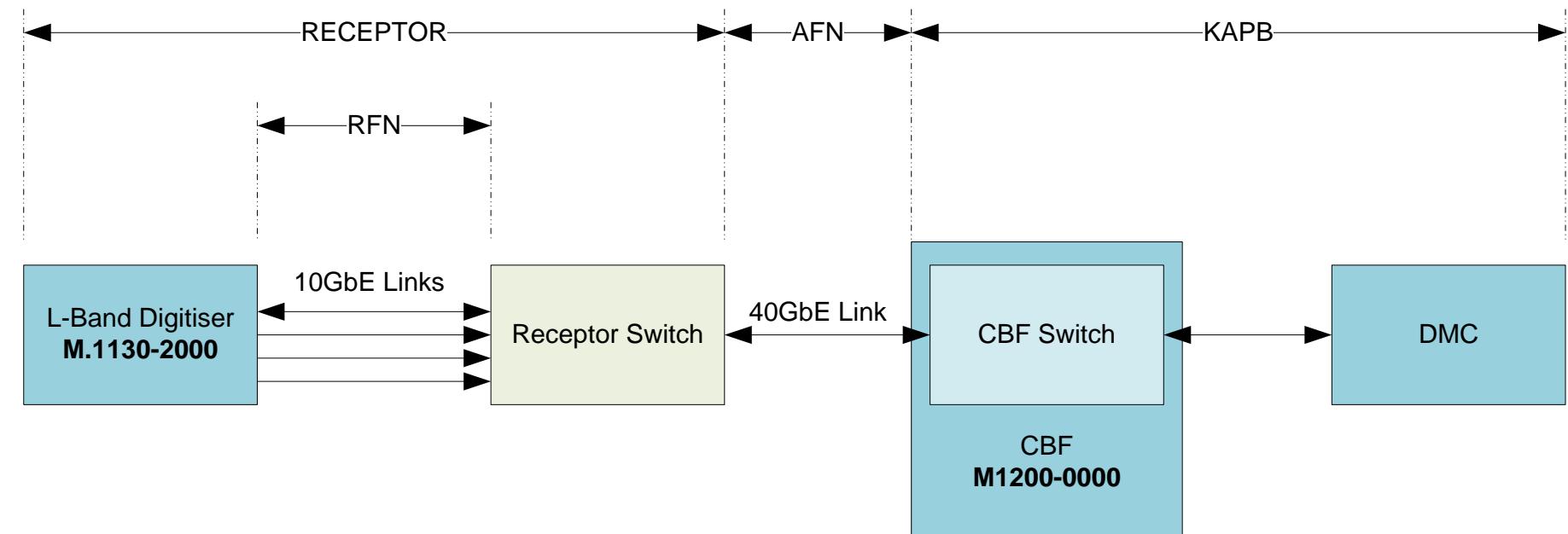
Digitiser

CBF

Control and Monitor



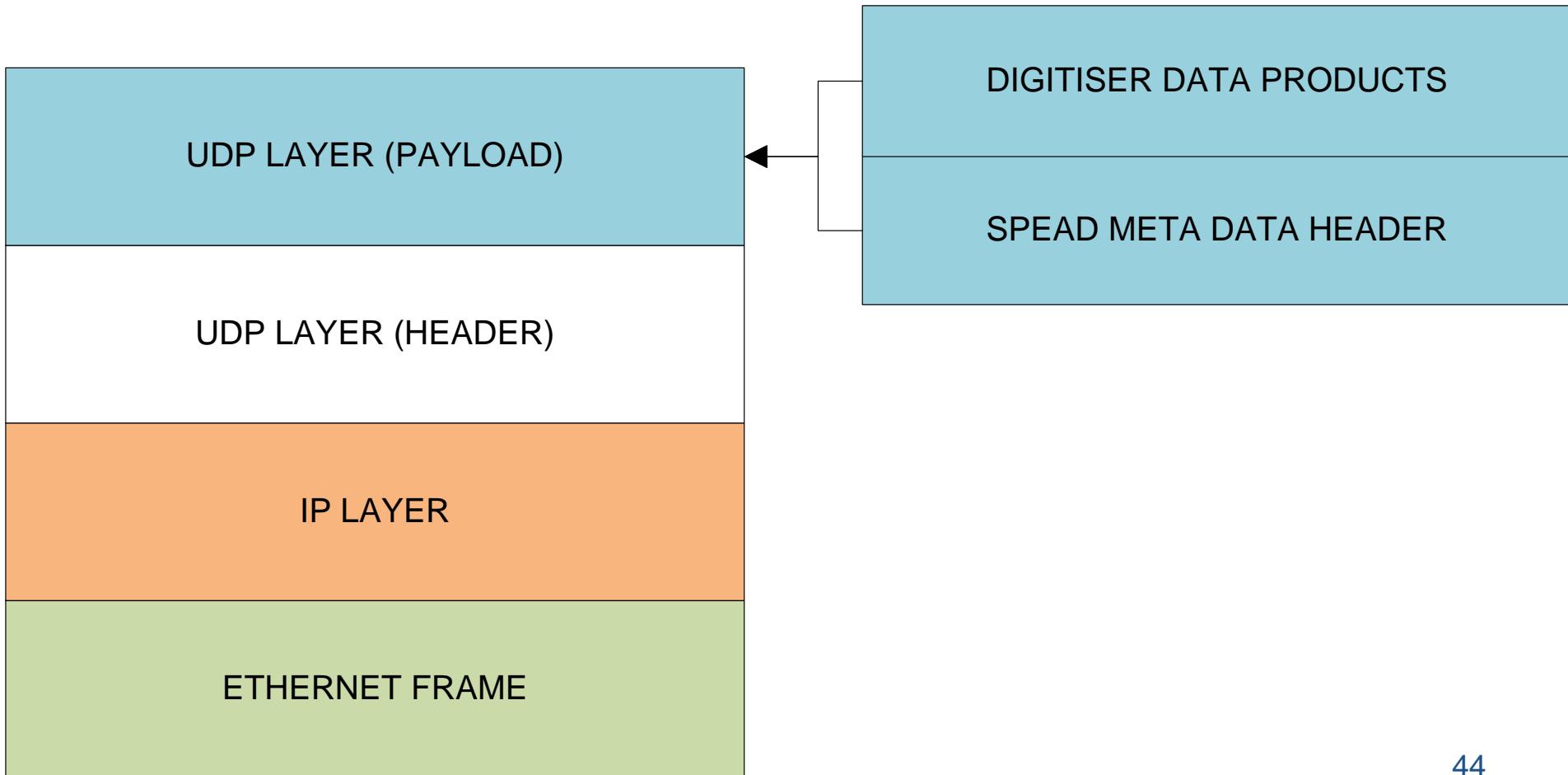
Control and Monitor Digitiser



Digitiser Data: SPEAD Packet



Streaming Protocol for Exchanging Astronomical Data

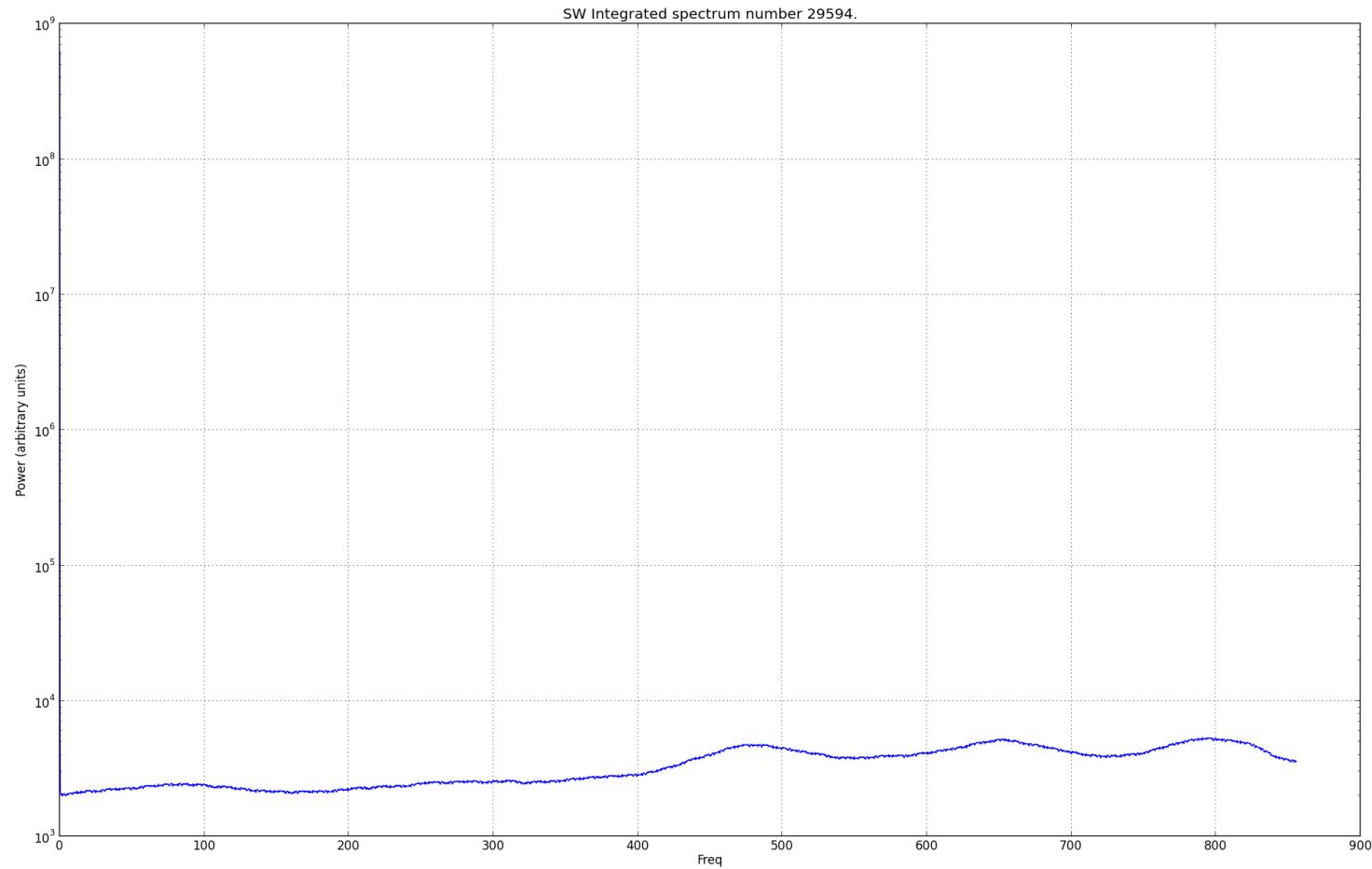


Data Link Budget

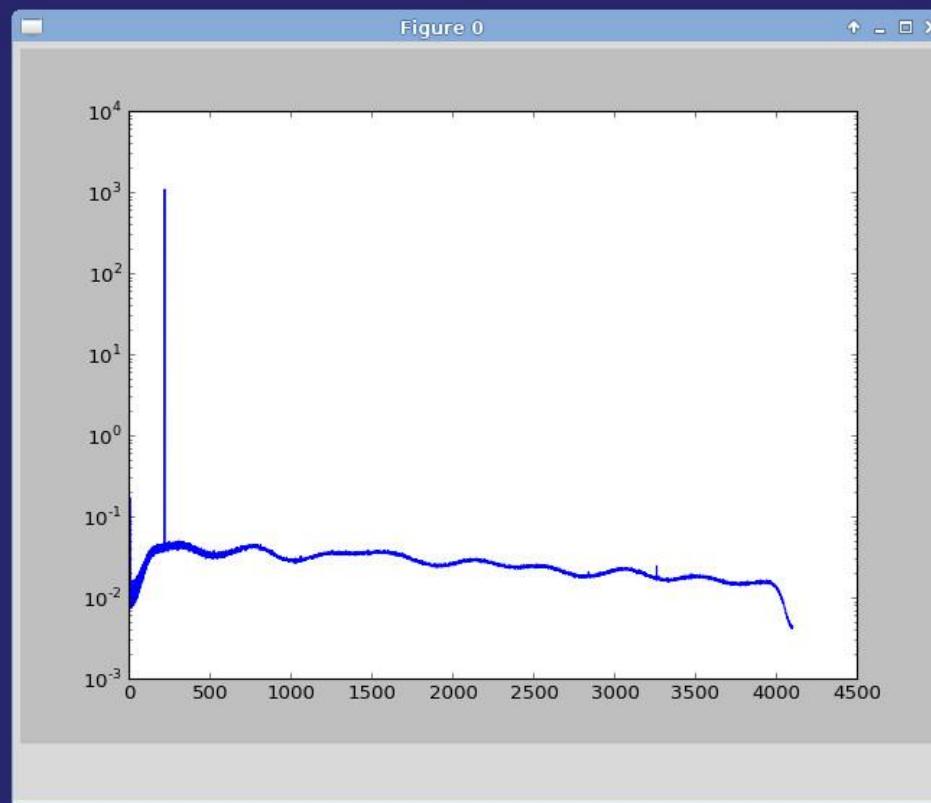
ADC Data Frame	Number of bytes
Preamble	7
Start of Frame	1
MAC	12
Proto	2
IP Header	20
UDP Header	8
SPEAD Header	64
Padding	6
CRC32	4
Dead Time	2
Data Payload Max	5120 (4096 ADC samples * 10bits)
Efficiency	97.60%

Digitiser Data Link Rates	L-band
BW (MHz)	770
Guard Band (%)	11.17%
Sample rate	1712
NOB	10
Polarisations	2
Required payload throughput (Mbps)	34240
Link efficiency	97.60%
Effective data rate (Mbps)	35081.97
ADC Snap Block Dump Rate (Mbps)	0.50
Total (Mbps)	35082.47
10GbE	Utilisation
	Number of links required
40GbE	Utilisation
	Number of links required

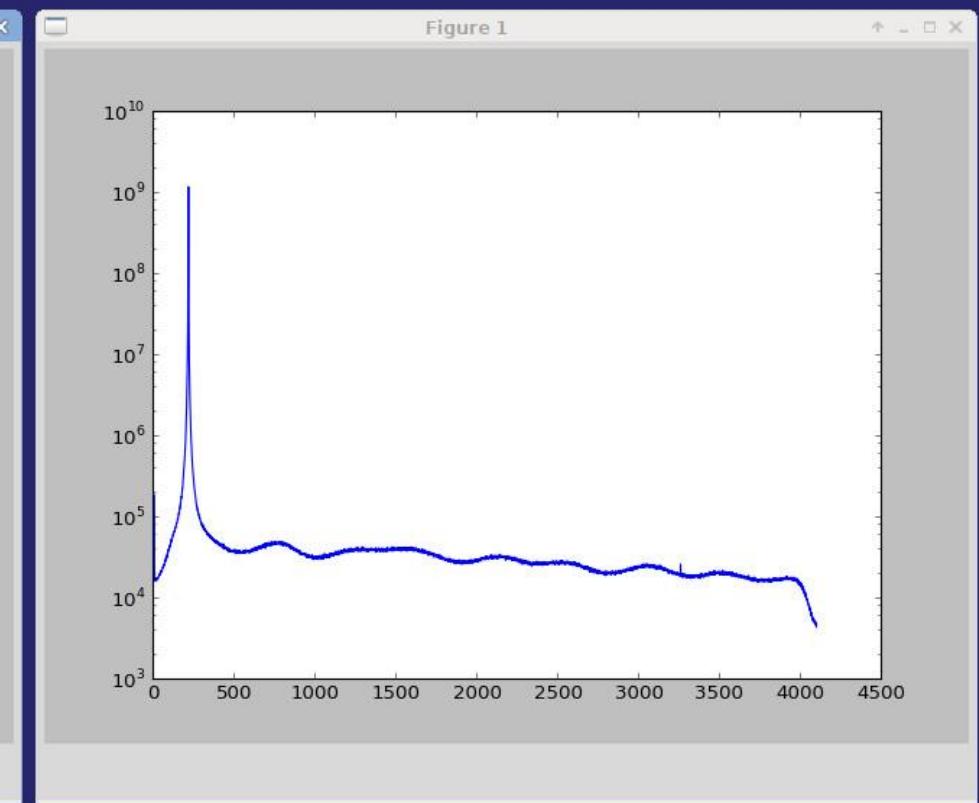
Measured Results: Self Generated RFI Performance - CASPER Spectrometer



Measured Results: Spectrum from F-Engine



CBF F-Engine Spectrum



ADC Raw Software Spectrum

Overview Diagram: UHF Band - Reuse



L-Band Digitiser design reuse per module for UHF-Band

- Enclosure – no change
- Power Supply – no change
- Backplane – no change
- D-Engine (FPGA DSP Board) – no change
- Sampler Module (2.2 GSps ADC) – no change
- Connectors and harnesses – no change
- RF conditioning unit – ***band pass filter***
- Sample clock generator – ***clock filter***

Overview Diagram: S Band - Reuse



L-Band Digitiser design reuse per module for S-Band

- Enclosure – no change
- Power Supply – no change
- Backplane – no change
- D-Engine (FPGA DSP Board) – **40G Ethernet**
- Sampler Module (2.2 GSps ADC) – **ADC**
- Connectors and harnesses – ***internal links***
- RF conditioning unit – ***band pass filter***
- Sample clock generator – ***clock filter***

Overview Diagram: X Band - Reuse



L-Band Digitiser design reuse per module for X-Band

- Enclosure – no change
- Power Supply – no change
- Backplane – no change
- D-Engine (FPGA DSP Board) – **40G Ethernet**
- Sampler Module (2.2 GSps ADC) – **ADC**
- Connectors and harnesses – ***internal links***
- RF conditioning unit – ***band pass filter***
- Sample clock generator – ***clock filter***

Overview Diagram: SKA Band 1 & 2 - Reuse



L-Band Digitiser design reuse per module for SKA Band 1 & 2

- Enclosure – no change
- Power Supply – no change
- Backplane – no change
- D-Engine (FPGA DSP Board) – no change
- Sampler Module (2.2 GSps ADC) – no change
- Connectors and harnesses – no change
- RF conditioning unit – ***band pass filter***
- Sample clock generator – ***clock filter***

Questions?

