The SKA1-LOW receiver: the Italian experience from SKADS to AADC

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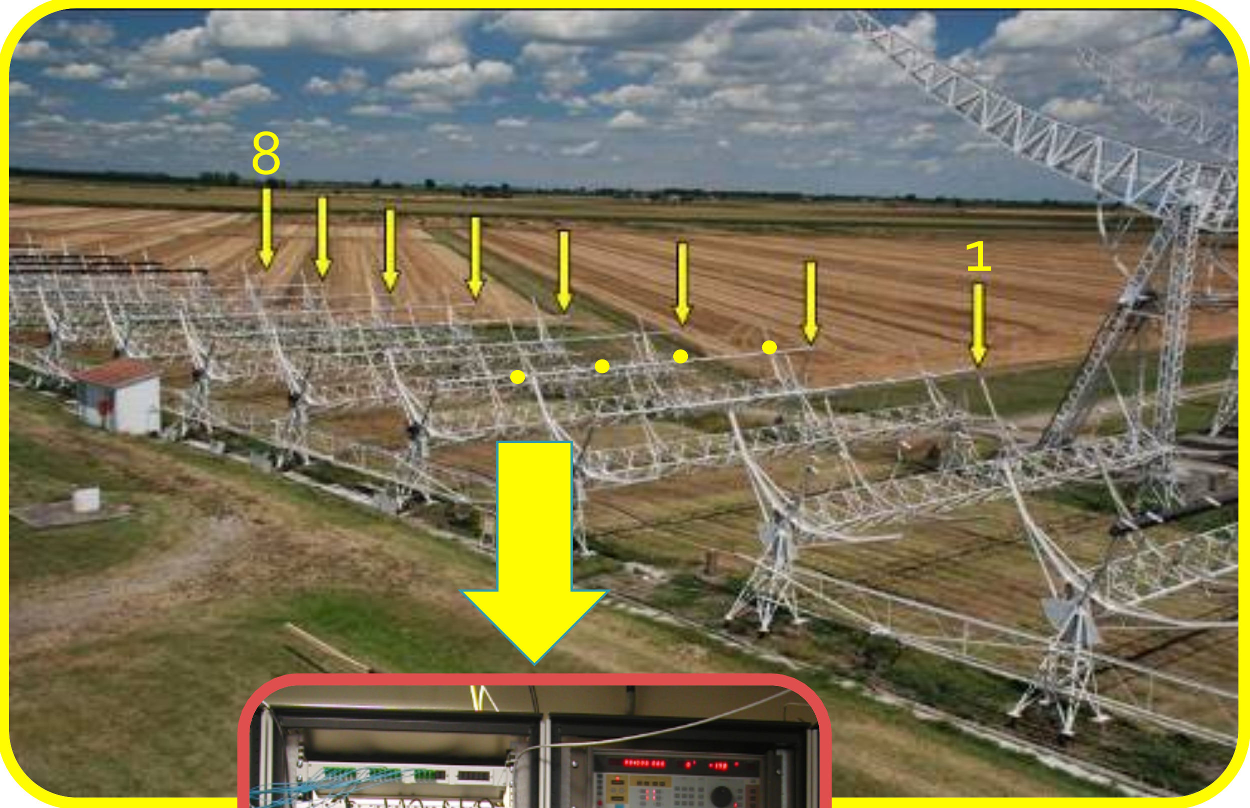
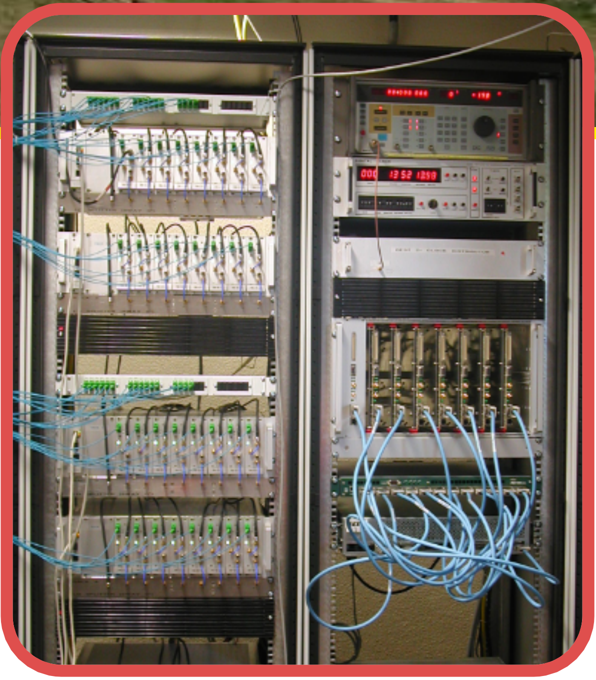
"The II National Workshop of SKA science and technology", Bologna, Dec 3-5 2018

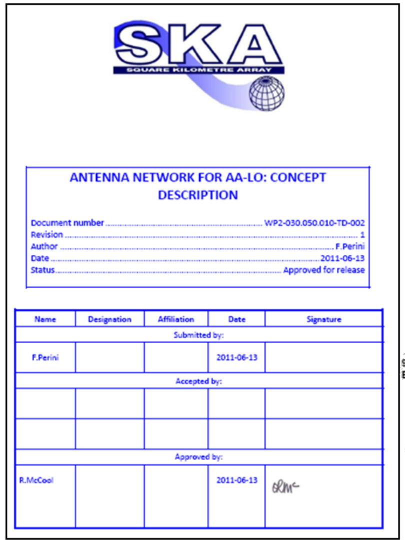
BEST (2004)

First "SKA oriented" European technological demonstrator of an Aperture Array based on RFoF technology





STaN CoDR (2011)



SKA SQUARE KILOMETRE ARRAY

ANTENNA NETWORK FOR AA-LO: CONCEPT DESCRIPTION

Document number WP2-030.050.010-TD-002
Revision 1
Author .... F.Perini
Date 2011-06-13
Status .... Approved for release

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Accepted by:				
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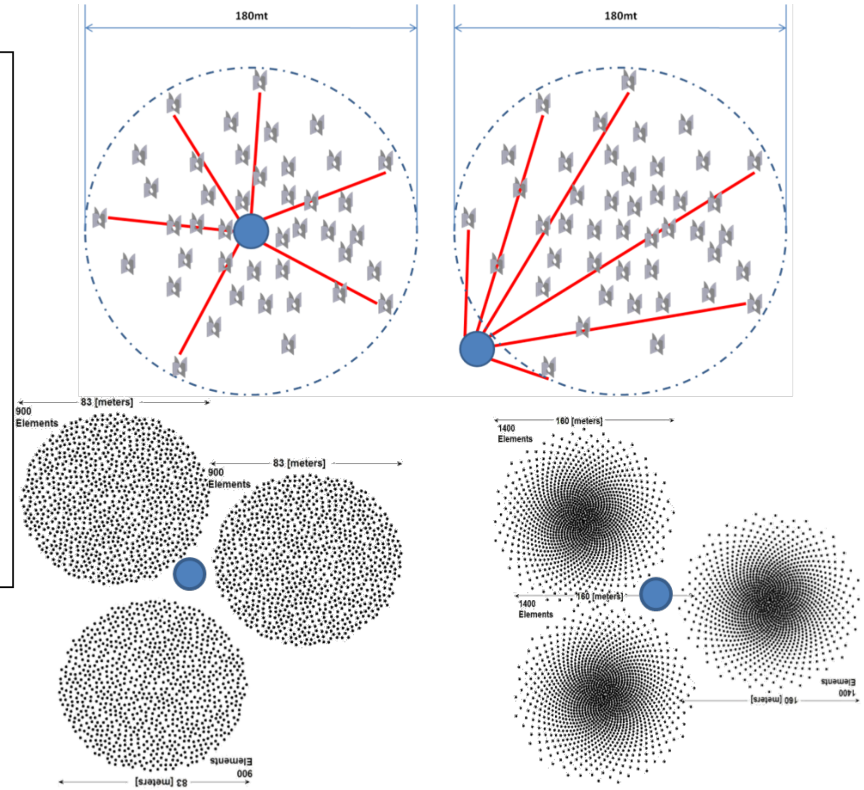
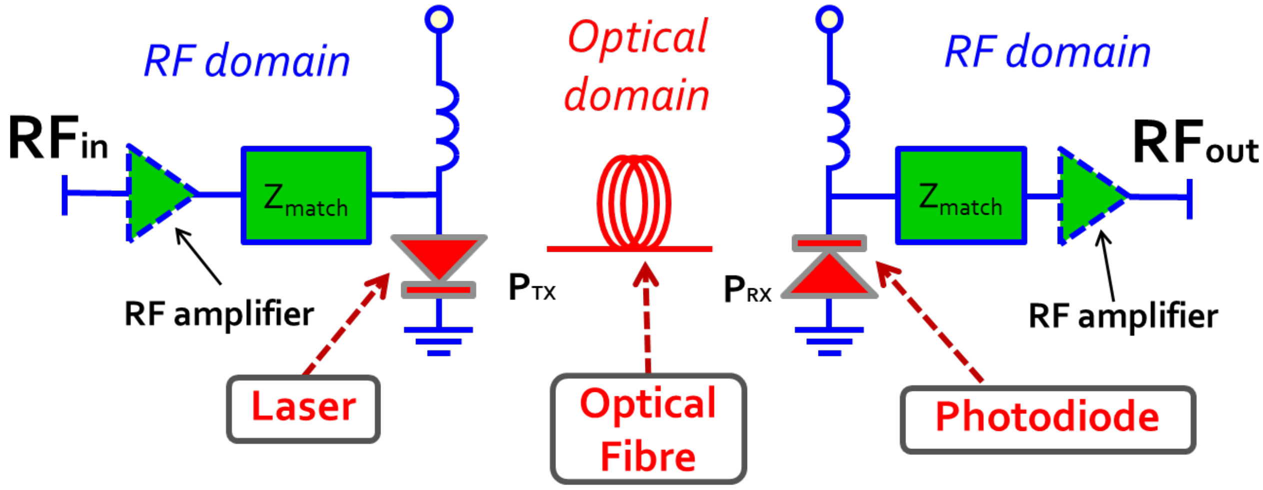
R.McCool			2011-06-13	[signature]



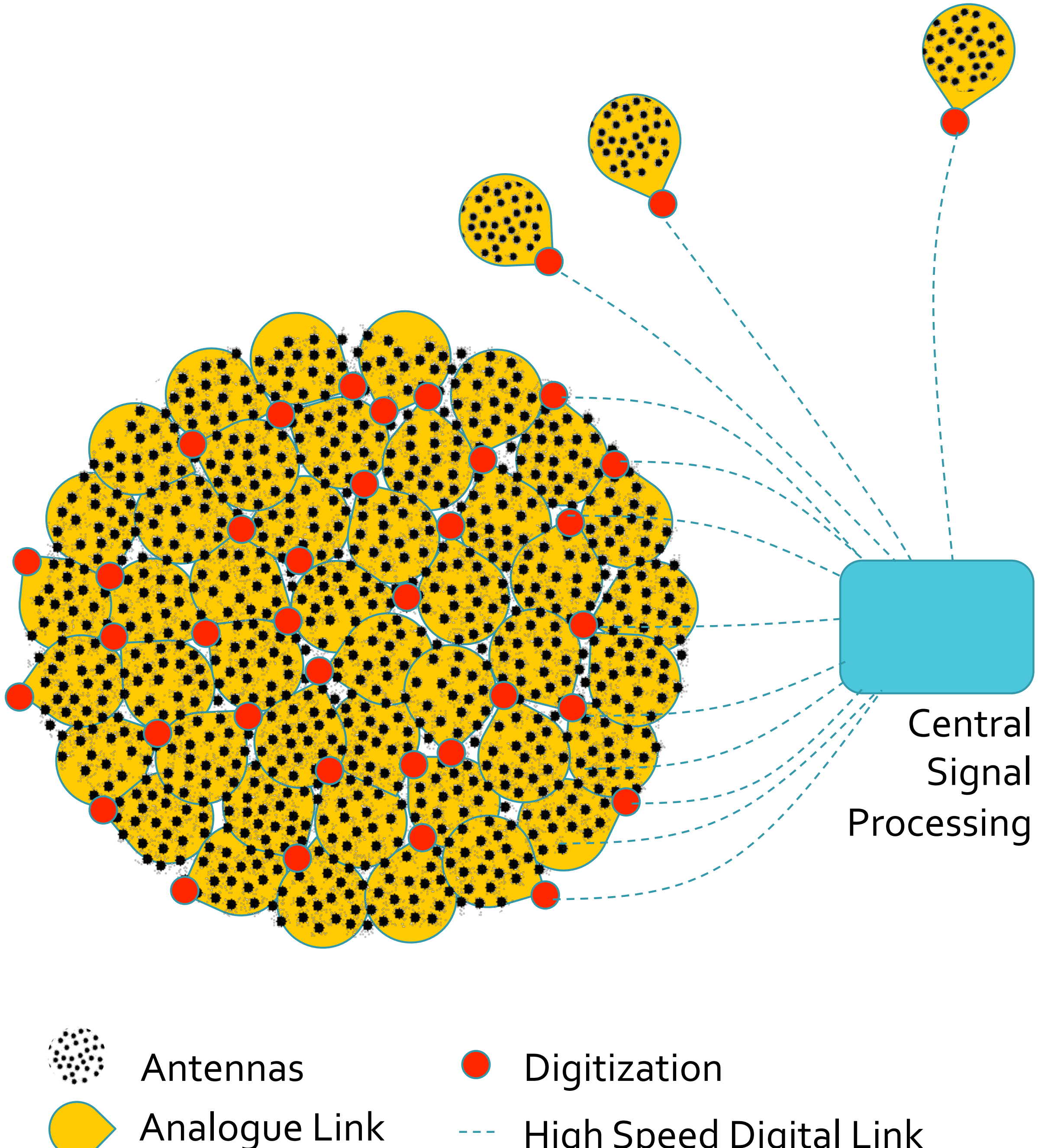
RFoF?



Cheaper, lighter, smaller than copper cables

Freq	Att.	LOFAR Coax Cable (75Ohm TV)				Att.	G.652D Equivalent RF attenuation			
[MHz]	[dB/m]	50m	100m	200m	500m	[dBo/Km]	1Km	2Km	5Km	10Km
50	0.041	2.05	4.1	8.2	20.5	0.4	0.8	1.6	4	8
100	0.056	2.8	5.6	11.2	28	0.4	0.8	1.6	4	8
200	0.082	4.1	8.2	16.4	41	0.4	0.8	1.6	4	8
400	0.118	5.9	11.8	23.6	59	0.4	0.8	1.6	4	8

RFoF and SKA architecture



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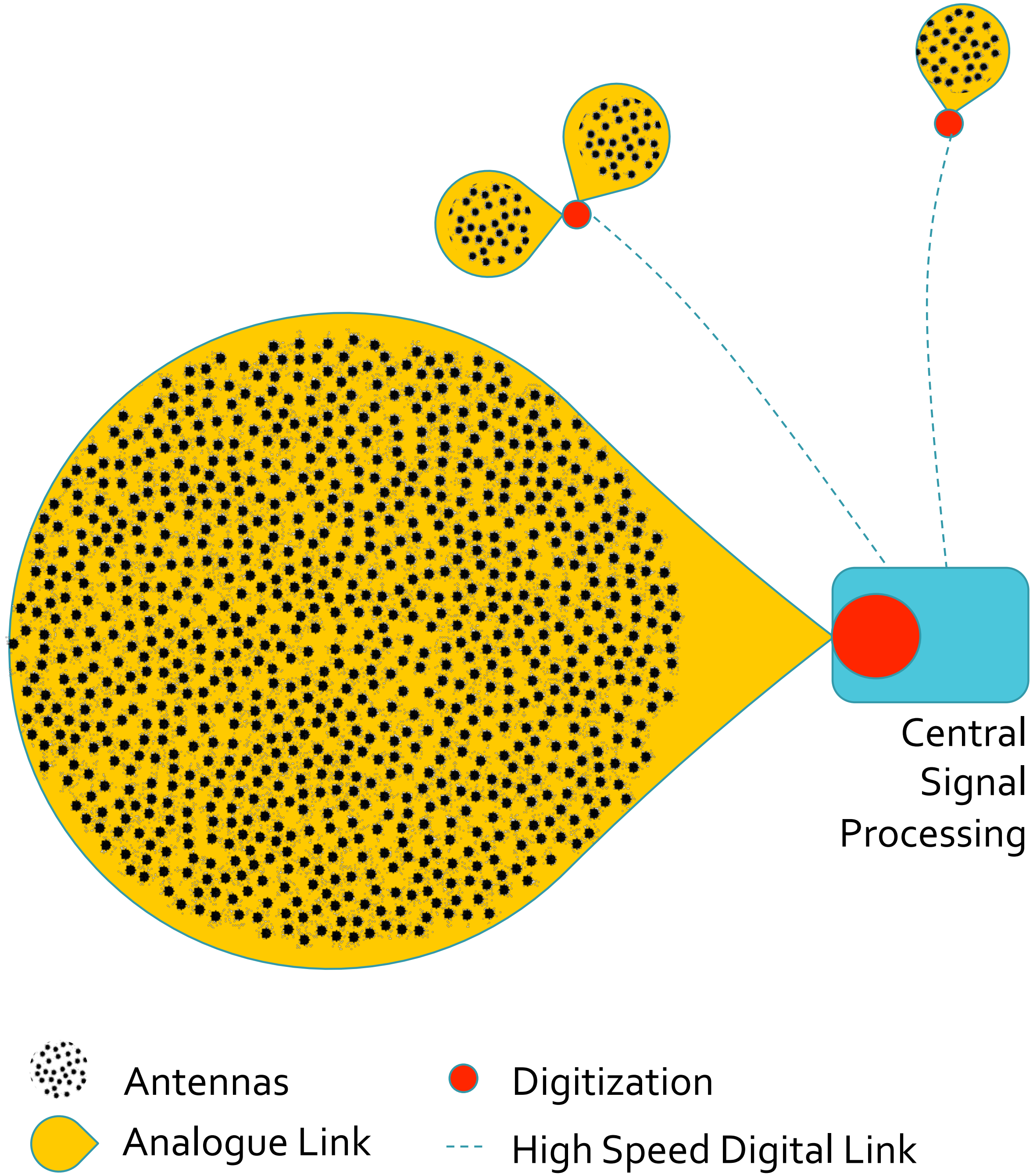
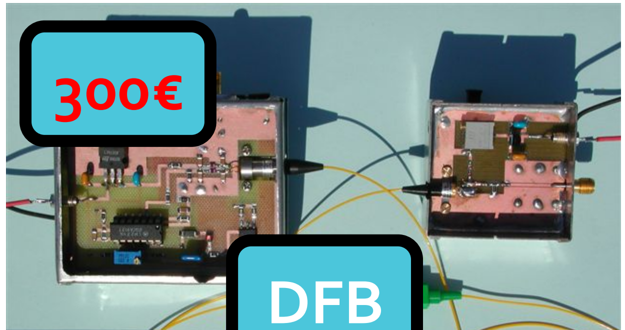
RFoF and SKA architecture



RFoF components

Technology or market evolution?

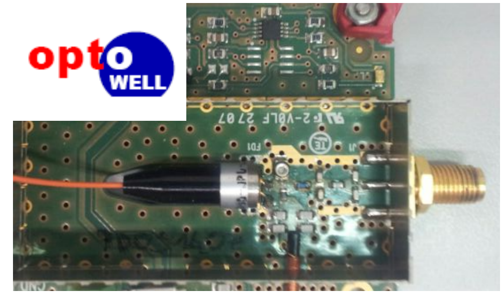
300€



DFB

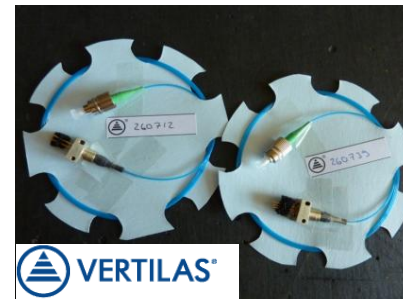
2003

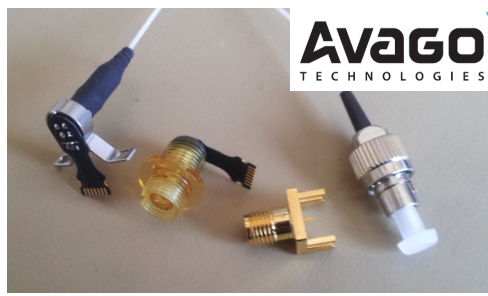
VCSEL



FP

U·L·M PHOTONICS





DFB

2013

30€

RX specs?

RF-Performance	
Frequency Range	50 - 650MHz
Low Band & High Band	50-375MHz 375-650MHz
Outband suppression	LB >50dB @35-425MHz HB >50dB@325-750MHz
Noise Figure	<22dB
Input P1dB Compression Point	-34dBm
Gain	Min >35dB
Input IP2	-74dBm [illegible]
Input IP3	[illegible]
Input return loss	<-10dB
Output return loss	<-10dB
Gain ripple	±1dB
Gain disequalization	<3dB
Maximum gain drift	±3dB
Relative gain variation between two chains (within 600 seconds)	< 0.42, 0.17, 0.17 and 0.42 dB at 50, 100, 160 and 220 MHz
Relative phase variation between two chains to the same station (within 600 seconds)	< 2.9, 1.2, 1.2 and 2.9 degrees at 50, 100, 160 and 220 MHz
Maximum crosstalk level between chains	-30dB

Fibre length: 10Km
Power consumption: 1W
Operative temperature: -10°C ÷ +50°C

At PDR time and with PDR assumptions
(i.e: T_{sky} and T_{LNA} from BD, GT_{ANT}=40dB, P_{ADC}=-10dBm,…)

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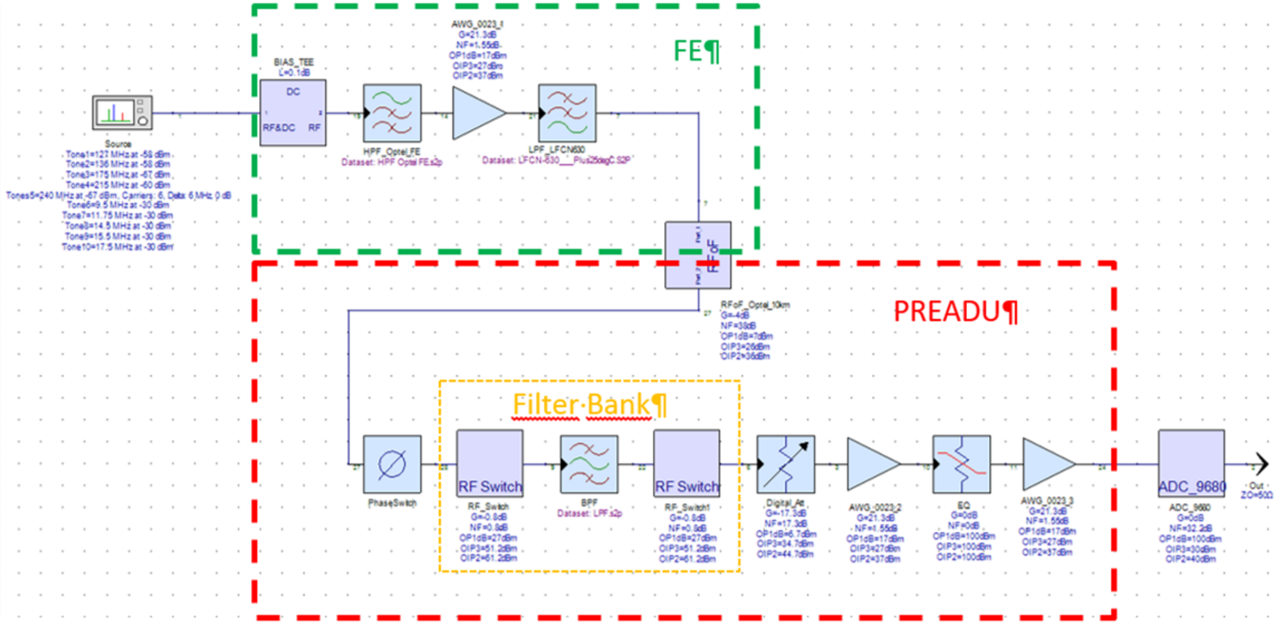
RX first generation (2014)

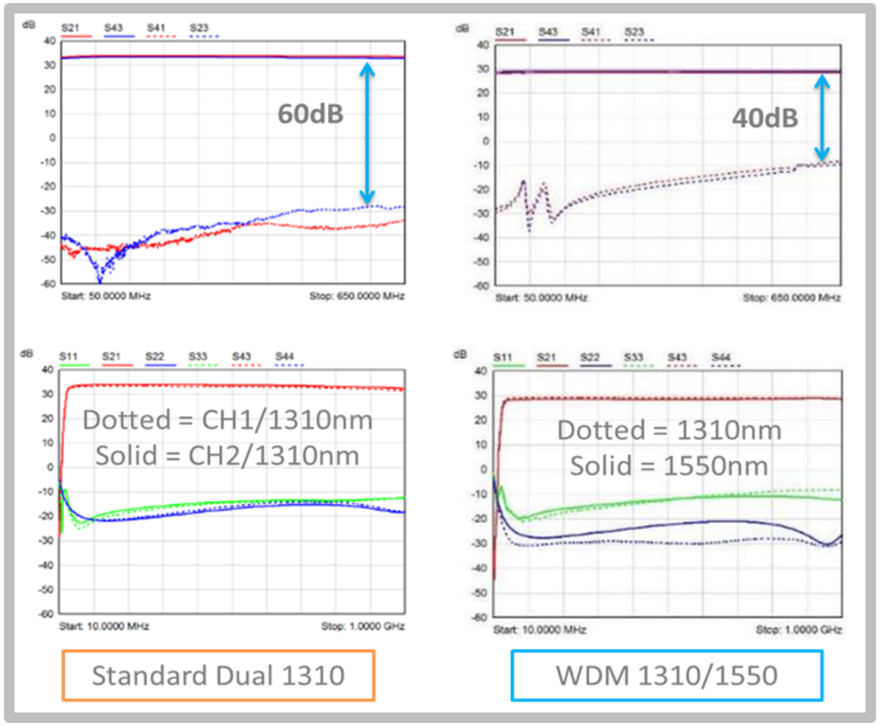
Small and Large Signals RF Model

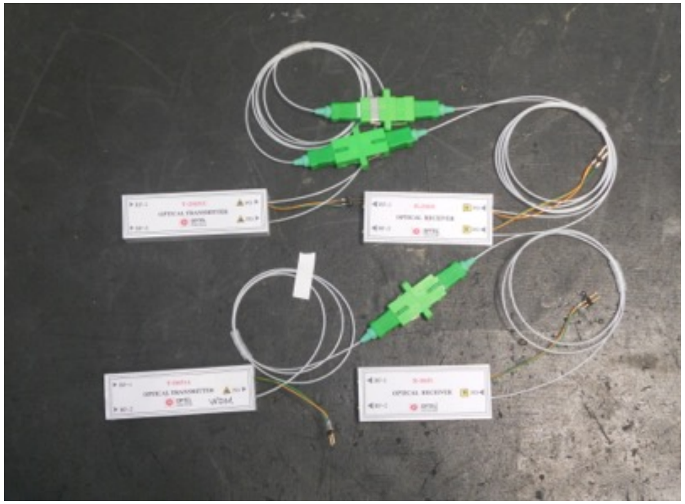


	Gain (dB)	NF (dB)	IIP3 (dBm)	IIP2 (dBm)	P1dBin (dBm)
RX Simulation	34.9	18.1	-9.8	-4.5	-17.7
RX L3 specs	35	<21.4	>-32.7	>-7.4	>-34

RX first generation (2014)

RFoF Link





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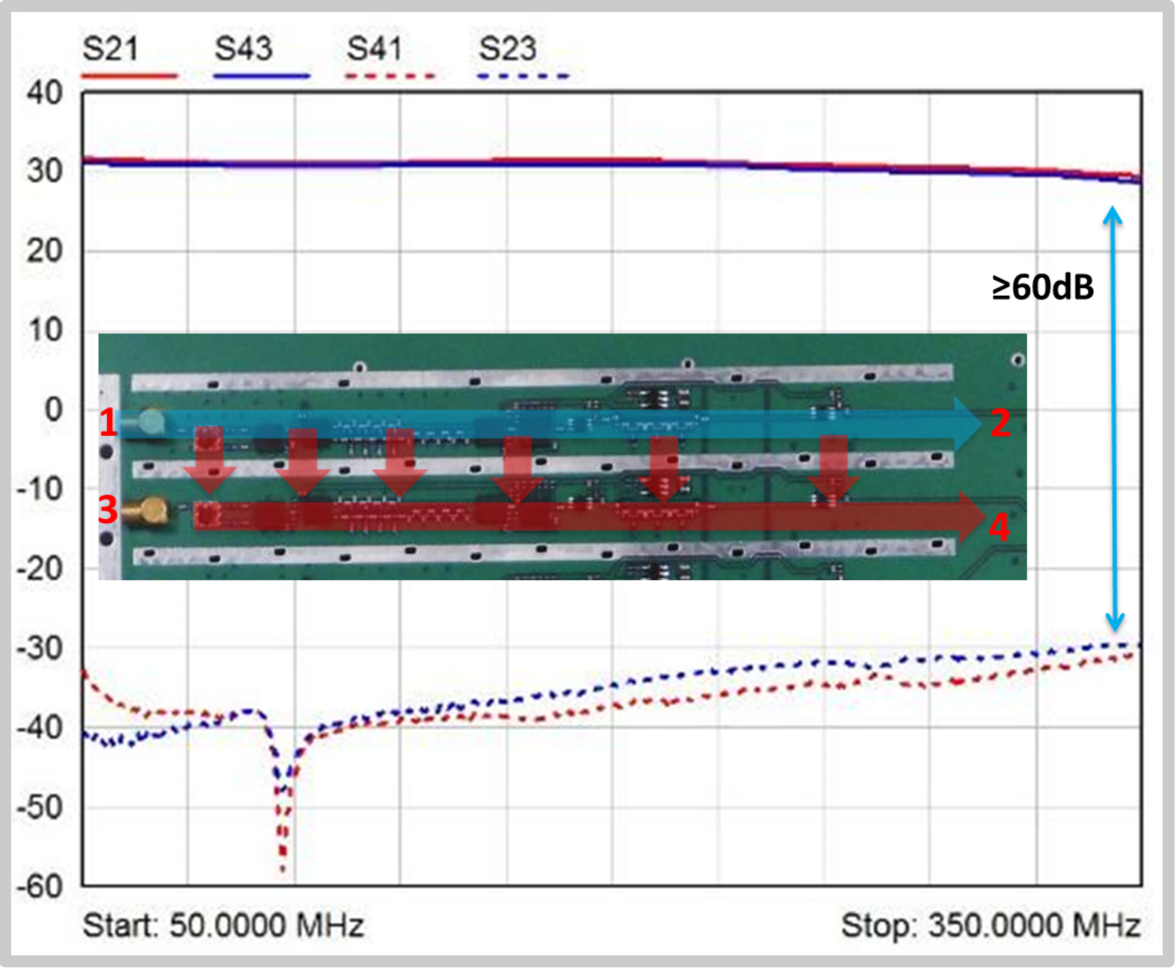
RX first generation (2014)

preADU1.0



- Demonstration of integration of 16RF chains (RF isolation)
- O_{RX} detachable and interchangeable
- RF_{RX} receivers mounted on the carrier PCB
- SPI or Dip Switches RX control
- Designed to meet RF PDR specifications

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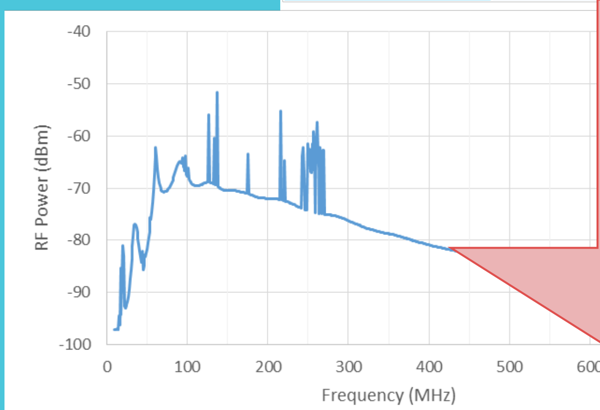
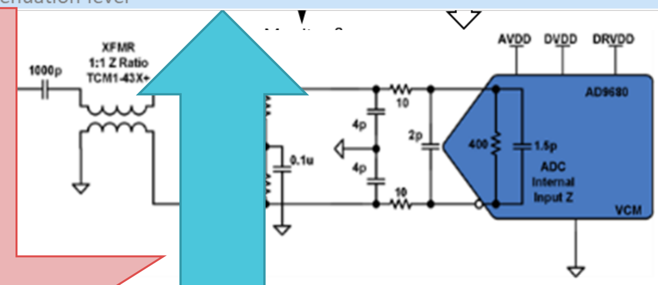
RX specs updating

Parameter	Value	Notes
RF band	50-650MHz	Overall frequency band
Low Band (LB)	50-375MHz	3dB cut frequency
High Band (HB)	375-650MHz	3dB cut frequency
Flatness	+/-1.5dB	Measured in the two separate sub-bands LB and HB
HP filter rejection	≥45dB	Freq≤20MHz, HP filter integrated in the FE PCA
LB filter rejection	≥45dB	Freq≥450MHz, LB filter integrated in the PREADU PCA
HB filter rejection	≥45dB	Freq≤325MHz & Freq≥750MHz, HB filter integrated in the PREADU PCA
Gain	Min 54dB Typ 60dB Max 66dB	Freq=100MHz FE and ORX connected directly DSA set at minimum attenuation level
IRL	>12dB	Measured at both FE inputs on the overall RF band 50-650MHz.
ORL	>12dB	Measured at both ORX+RF outputs on the two sub-bands LB and HB.
NF	<16dB	Measured in the two sub-bands LB e HB FE and ORX connected directly DSA set at minimum attenuation level
RF channels isolation	>30dB	Defined as the difference of the gains measured at the two PREADU PCA outputs with the same FE PCA input on both LB and HB bands. DSA set at minimum attenuation level
OP1dB	>+17dBm	Freq=100MHz FE and ORX connected directly DSA set at minimum attenuation level
OIP3	>+18dBm	Freq=100MHz FE and ORX connected directly DSA set at minimum attenuation level
OIP2	>+38dBm	Freq=100MHz FE and ORX connected directly DSA set at minimum attenuation level

Fibre length: 10Km
Power consumption: 1W
Operative temperature:
-10°C ÷ **+80°C**

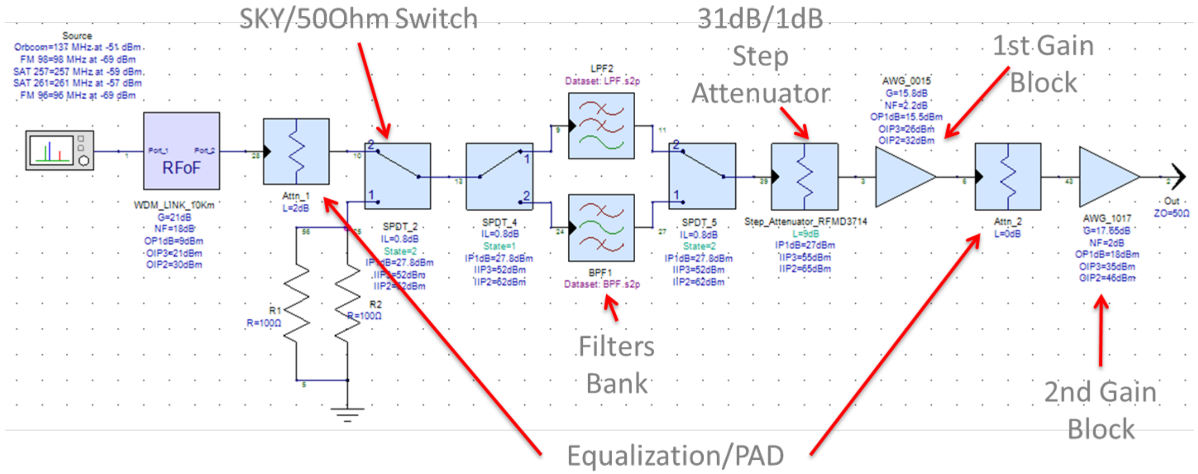




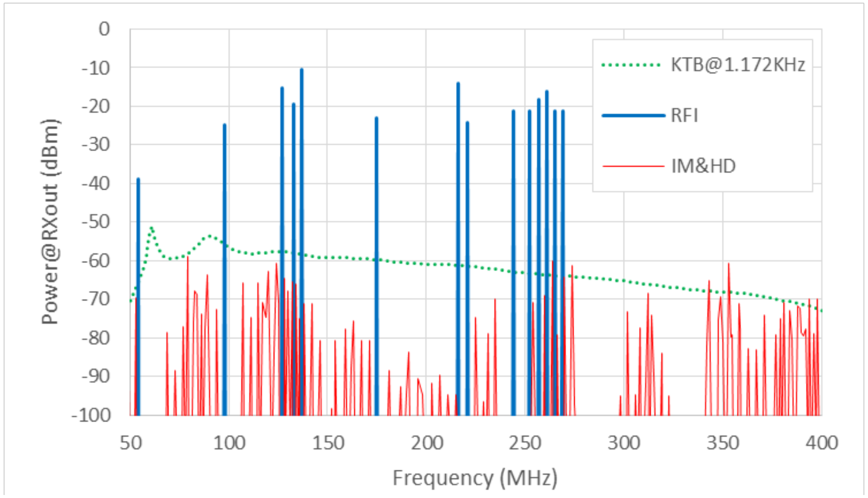
...est driv... ...vel → 17.5 ADU RMS
...ss of the AD... ...ut matching network

Updated Specifications
(L3 and L4)

RX second generation (2016)



	Gain (dB)	NF (dB)	IIP3 (dBm)	IIP2 (dBm)	P1dBin (dBm)
RX 2.0 Simulation	40.7	18	-7.1	-2.1	-22.1
Revised RX L3 specs	41	<22	>-23.6	>-3.1	>-22.6



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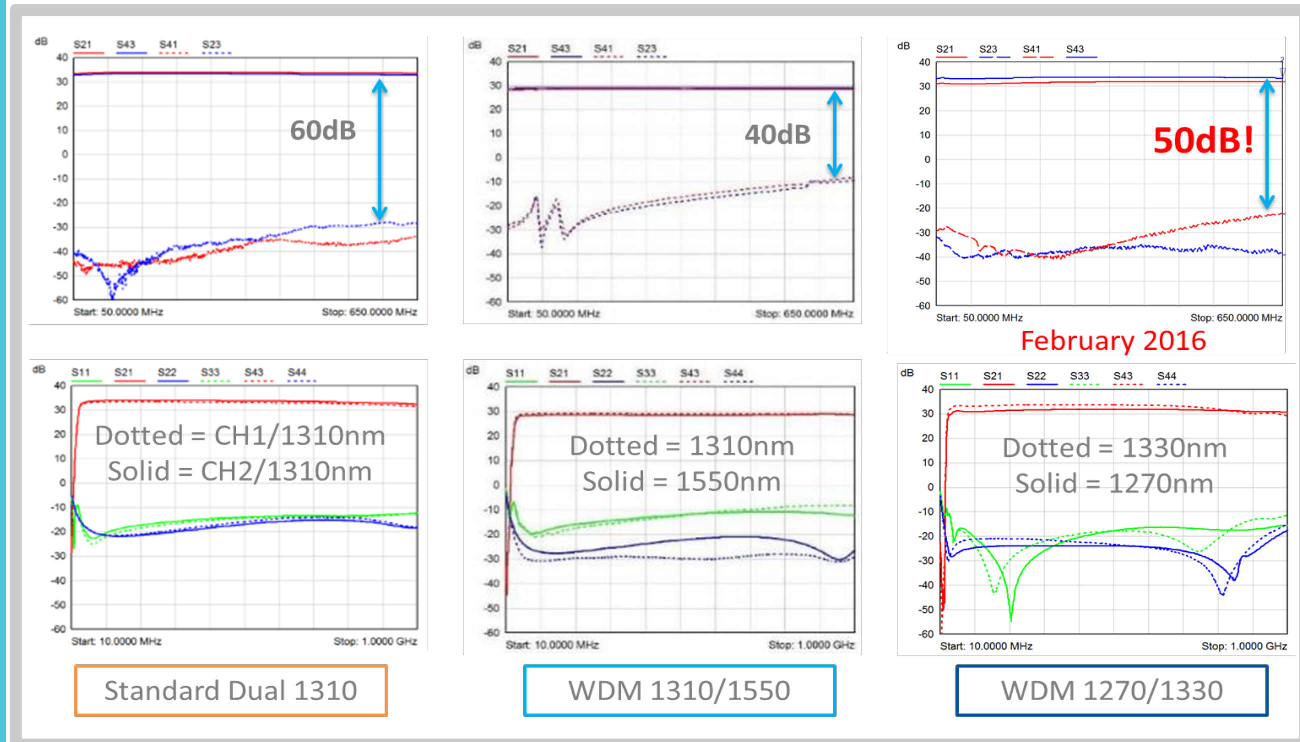
RX second generation (2016)

RFoF Link



G652D fibre: minimum dispersion @ 1300-1324nm. Reduction of phase variations (phase difference between polarization) by 4-5 times.

RX second generation (2016)

preADU2.0

- Same size of 1.0
- Both O_{RX} and RF_{RX} modules are detachable
- Easier replacement
- SPI and Dip Switches RX control
- Improved RF specifications to meet DDR specifications

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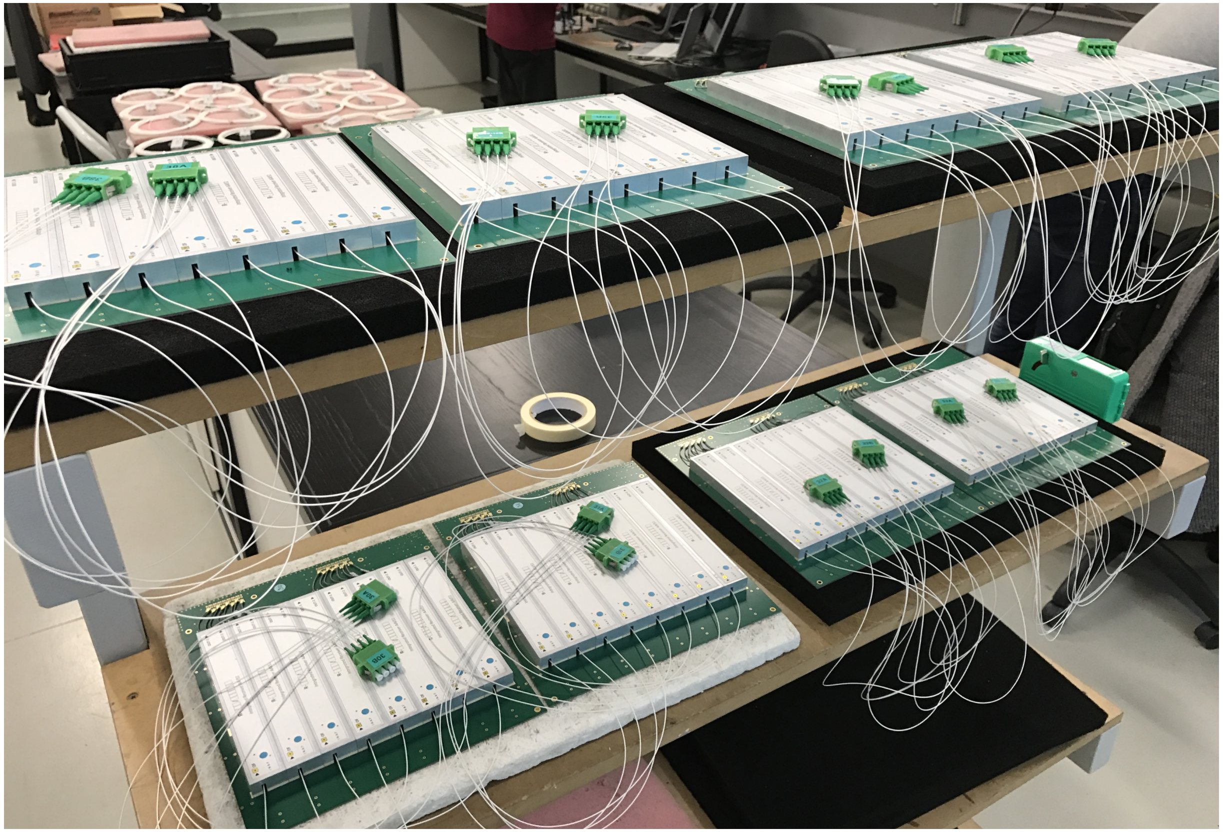
RX second generation (2016)

preADU2.1 = AAVS1



- One single PCB and shielding enclosure for both O_{RX} and RF_{RX}
- No more coax connectors between O_{RX} and RF_{RX} receiver
- Same size, controls and performance 2.0
- AAVS1 version

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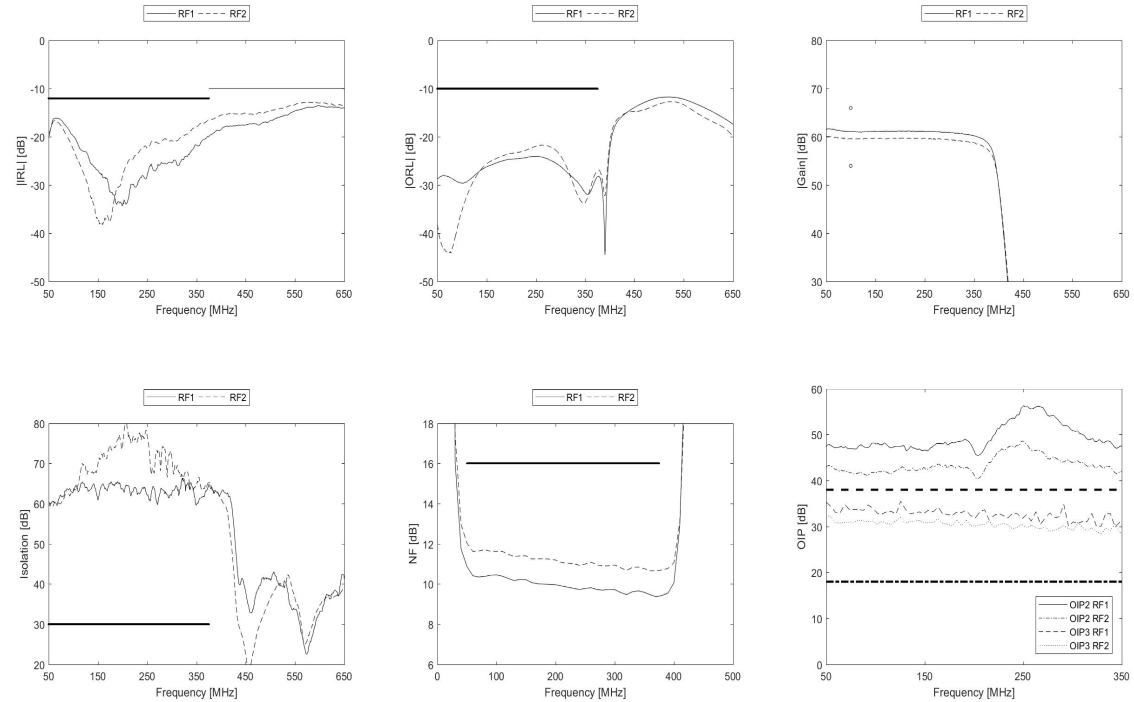
RX second generation (2016)

preADU2.1 = AAVS1



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Report date	30/11/2016
Measure date	30/11/2016
SN	F-100/201611

Parameter	Nominal Value	Note/Conditions	Measured Value	Test
Power FE consumption	<650mW	At room temperature with Vin=3.5V and without the LNA boards connected and biased.	629.5mW	Pass
Power ORX-RF consumption	<1300mW	At room temperature with Vin=3.5V. The value is obtained dividing by 8 the total absorption of a complete PREADU.	1239.5mW	Pass
Flatness	+/-1.5dB	Measured in the two separate sub-bands: LB(50-375MHz) & HB(375-650MHz).	+/-1.3dB RF1 +/-1.2dB RF2@LB +/-1.2dB RF1 +/-1.1dB RF2@HB	Pass
High Pass filter rejection	>=45dB	Freq<=20MHz (+/-5MHz).	24MHz RF1 24MHz RF2	Pass
LB filter rejection	>=45dB	Freq>=450MHz (+/-5MHz).	428MHz RF1 431MHz RF2	Pass
HB filter rejection	>=45dB	Freq<=325MHz & Freq>=750MHz (+/-5MHz).	324MHz RF1 and 322MHz RF2@HP 722MHz RF1 and 730MHz RF2@LP	Pass
Gain	Min 54dB, Max 66dB	Freq=100MHz, FE connected directly to ORX-RF module with DSA at the minimum attenuation level.	61.1dB RF1 59.7dB RF2	Pass
IRL Low	>12dB	Measured at the FE input in LB band.	15.7dB RF1 16.1dB RF2	Pass
IRL High	>10dB	Measured at the FE input in HB band.	13.3dB RF1 12.6dB RF2	Pass
ORL	>12dB	Measured at the ORX-RF output. Measured separately in the two sub-bands LB and HB.	23.9dB RF1 and 21.7dB RF2@LB 13.5dB RF1 and 14.7dB RF2@HB	Pass
NF	<16dB	Measured separately in the two sub-bands, FE connected directly to the ORX-RF module with DSA at 16dB attenuation level.	10.9dB RF1 and 12.0dB RF2@LB 9.7dB RF1 and 10.9dB RF2@HB	Pass
RF channel isolation	>30dB	Defined as the difference between the measured gains at the two outputs of the ORX-RF module with the same input of the FE. Measured on both bands LB e HB with DSA at the minimum attenuation level.	59.4dB RF1 and 59.2dB RF2@LB 54.6dB RF1 and 51.7dB RF2@HB	Pass
OP1dB	>17dB	Freq=100MHz, FE connected directly to the ORX-RF module with DSA at the minimum attenuation level.	18.4dBm RF1 and 17.9dBm RF2	Pass
OIP3	>18dB	Freq=100MHz, FE connected directly to the ORX-RF module with DSA at the minimum attenuation level.	32.9dBm RF1 and 30.4dBm RF2	Pass
OIP2	>38dB	Freq=100MHz, FE connected directly to the ORX-RF module with DSA at the minimum attenuation level.	46.9dBm RF1 and 41.7dBm RF2	Pass

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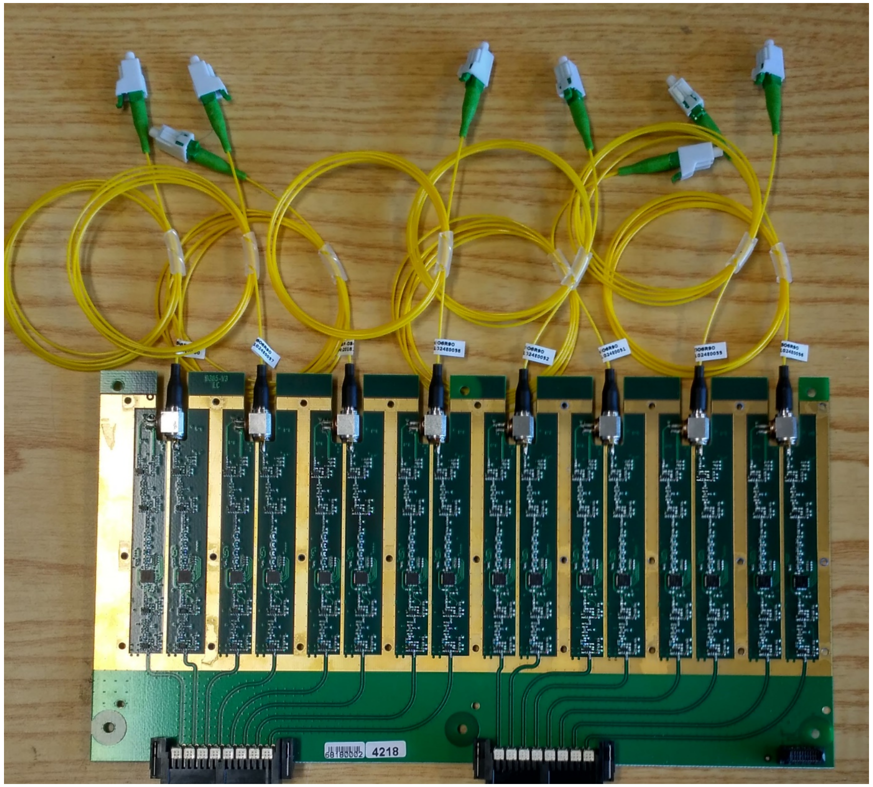
preADU3.0 (2018)



- Reduced dimensions (length)
- Still TPM compatible
- RF circuit simplification and optimization
- Step towards a full integration into ADU board

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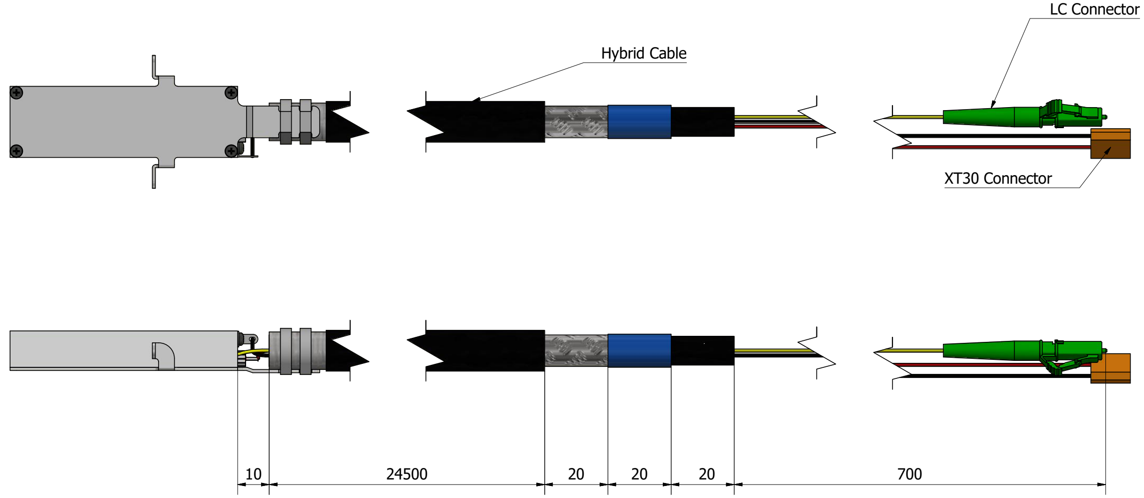
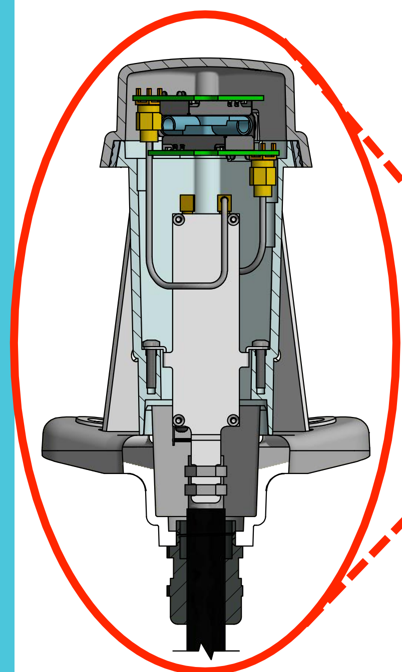
RX interfaces at the antenna

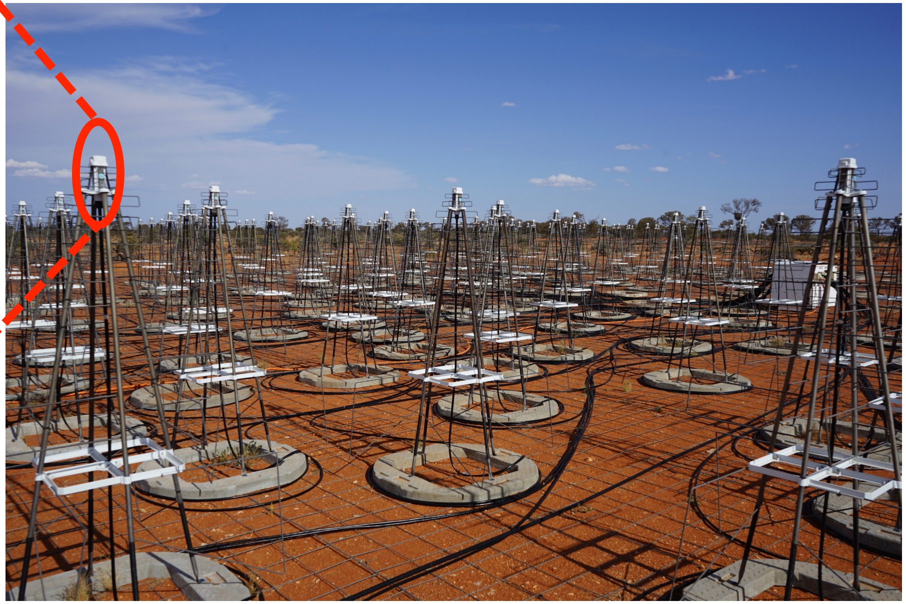
Trumpet with hybrid higtail (AAVS1)

Hybrid connector/cable

SMART BOX







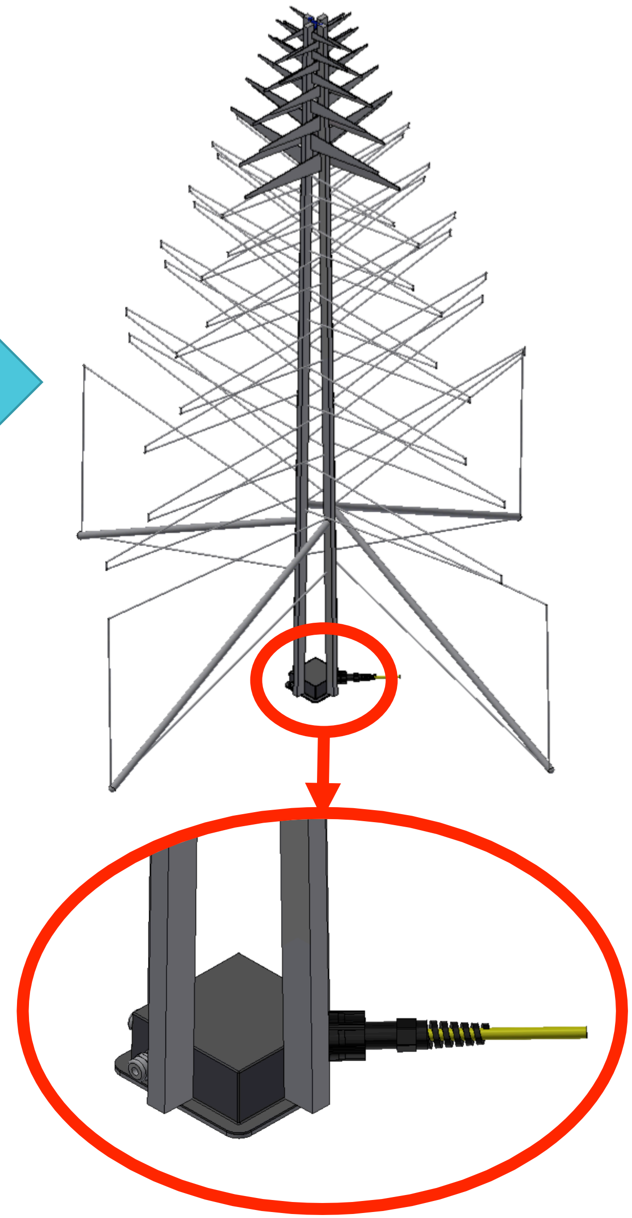
Sardinia Array Demonstrator

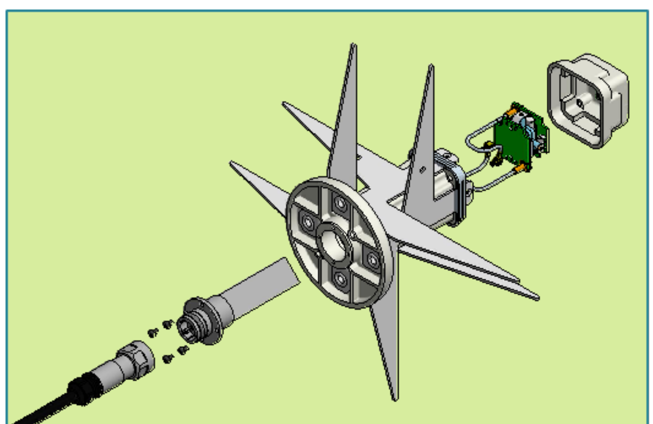
RX interfaces at the antenna

Trumpet with hybrid pigtail (AAVS1)

Hybrid connector/cable

SMART BOX





RX interfaces at the antenna

Trumpet with hybrid pigtail (AAVS1)

Hybrid connector/cable

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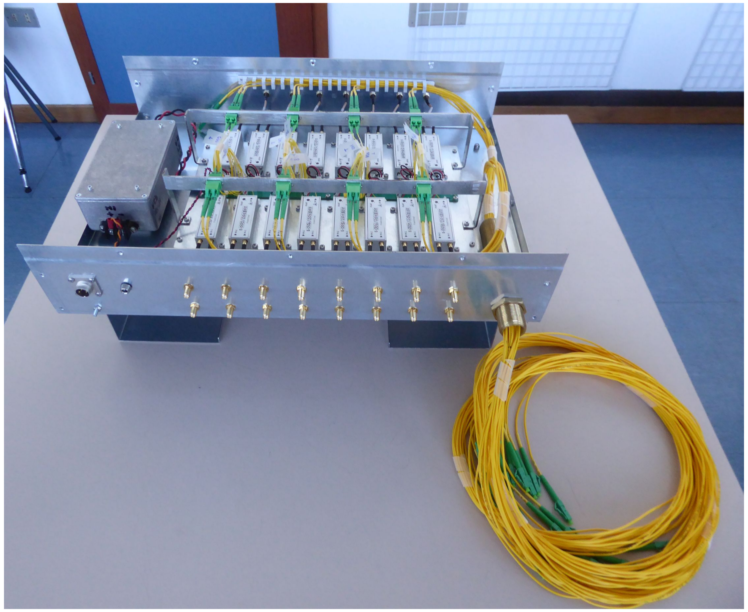

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Conclusion

What's going on?

- RX specs fine tuning (SKALA4, L1/L2,…)
- Interface at antenna level
- Reduction of the cost of the optical components?
- Integration with ADU board in a single PCB?

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Thanks!

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