Overview of Pilot Tone Front End industrialization for Elettra 2.0

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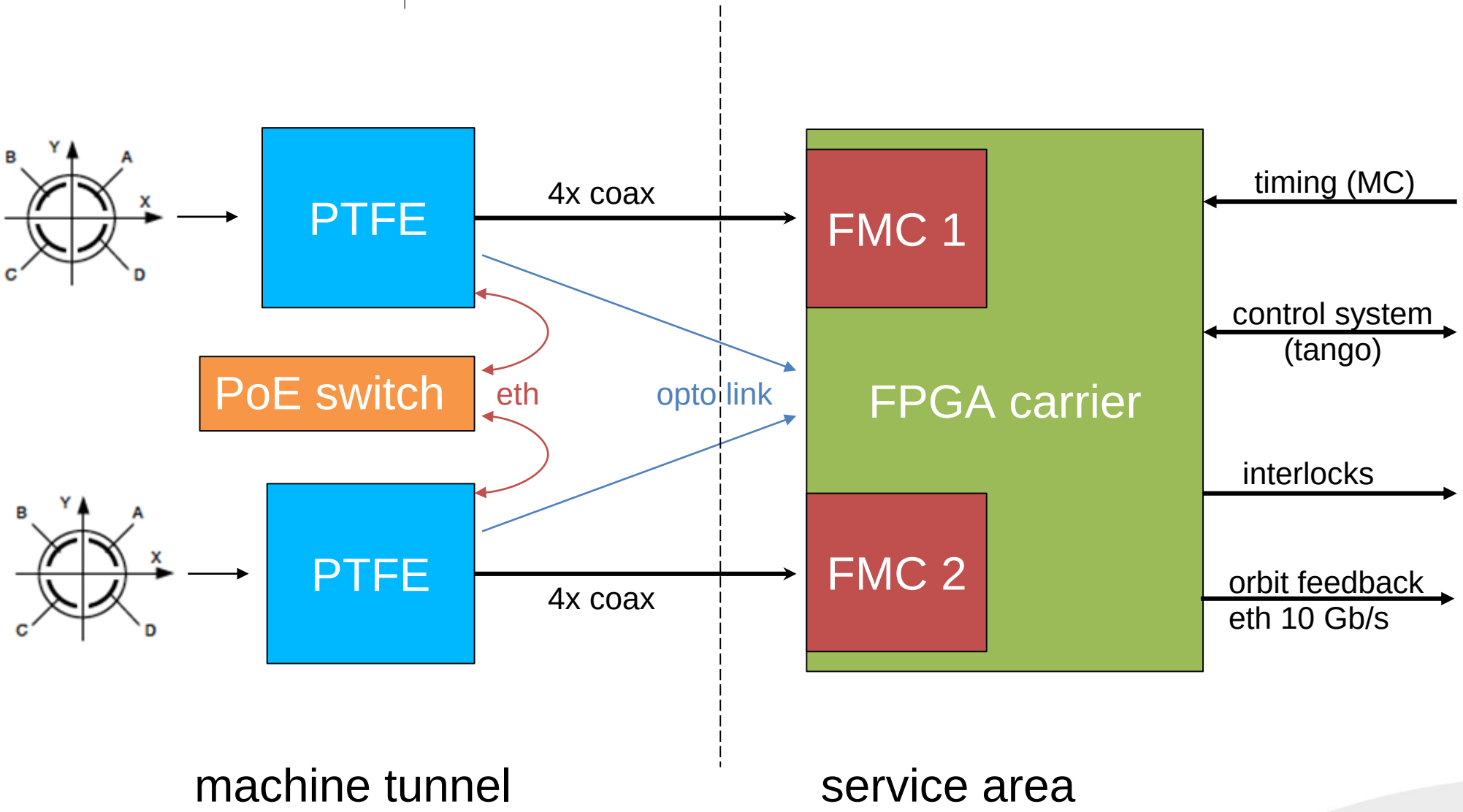
Whole project overview

- Partnership with Instrumentation Technologies for the production of 200 units of BPMs planned for Elettra 2.0, based on **pilot tone compensation**

- Specifications:
  - Sub-micron resolution @ 10 kHz
  - Long-term stability better than 2 µm in 24 hours
  - Compensation of thermal drifts, channel variations, cables response
- Modular approach:
  - analog front end in the machine tunnel
  - digitizer in service area

Overall block diagram



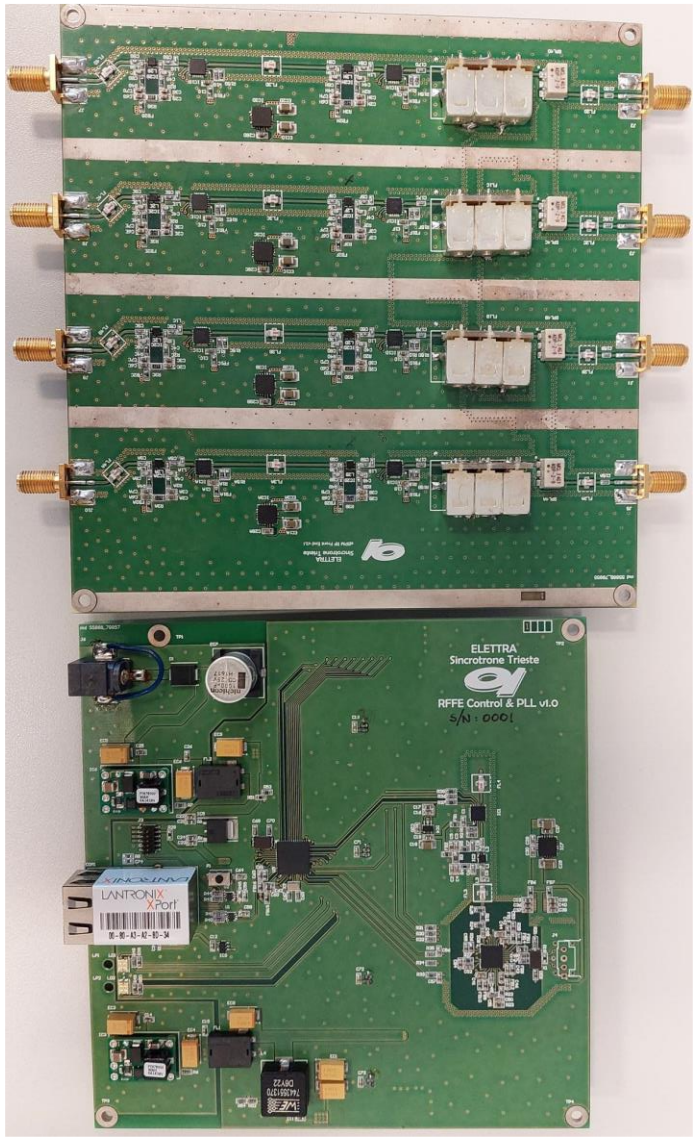
Pilot Tone Front End industrialization

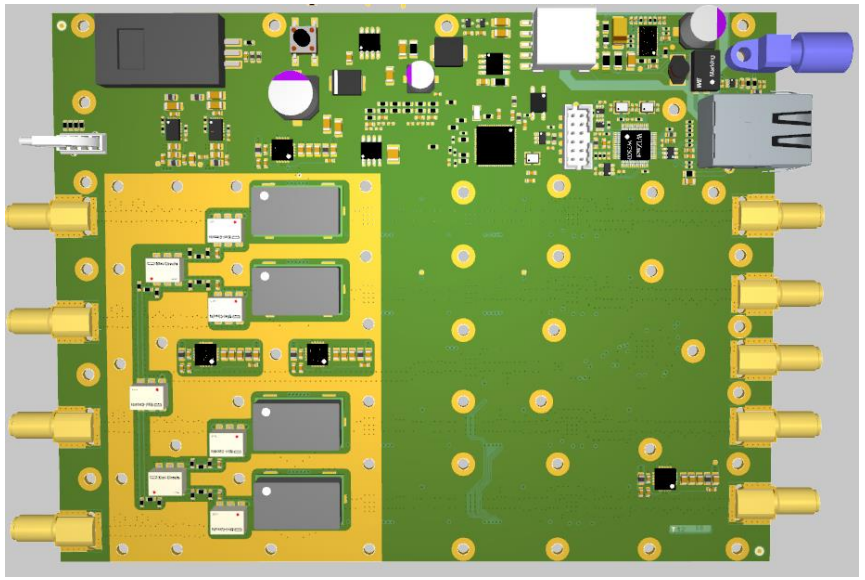
- Although we are working on the whole system, this presentation will focus only on the front end (it is a mature product)

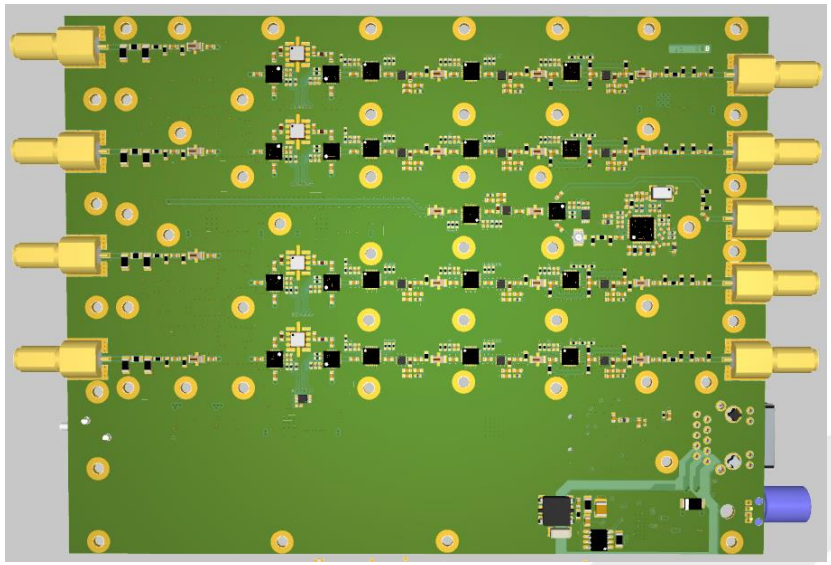
- Constructive dialogue with I-Tech: continuous revisions thanks to their expertise in product engineering and industrialization

- Modifications proposed in last year presentation at LWS
  - Control module + RF module becomes single board
  - Miniaturization, less connections - higher reliability
  - Passive cooling - maintenance free
  - PoE - no external components required + remote power cycle possibility
  - Remote FW upgrade

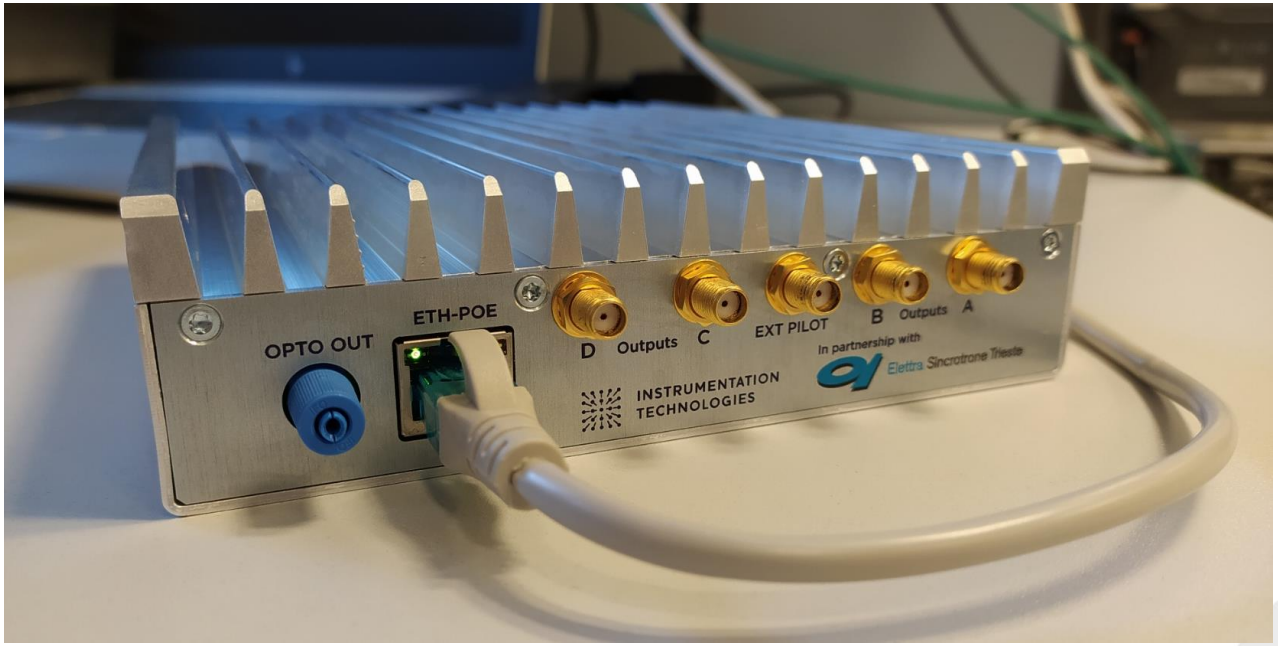
Pilot Tone Front End industrialization







Pilot Tone Front End industrialization



Pilot Tone Front End industrialization

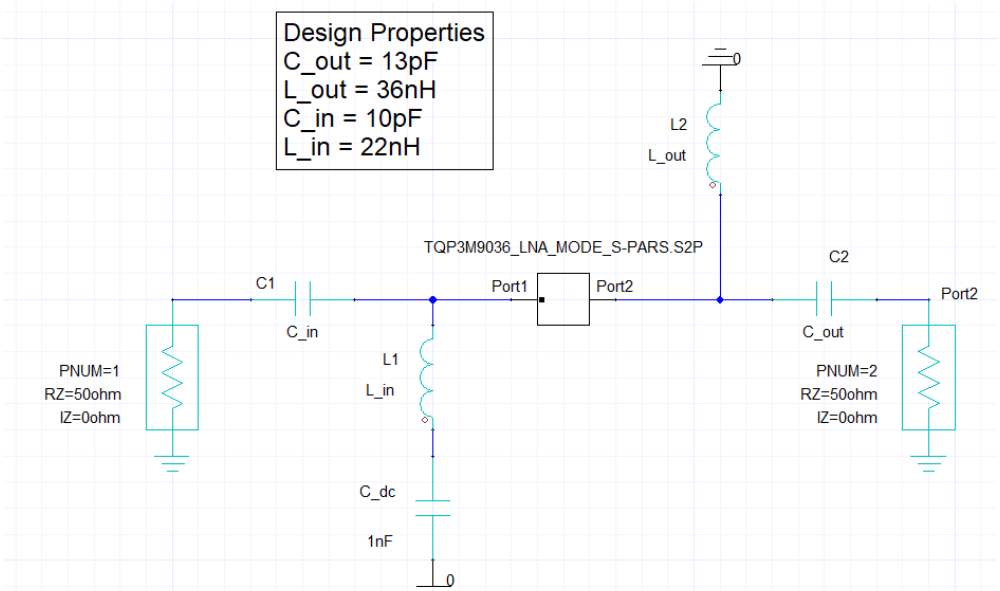
Results obtained working together:

1. Technical improvements:
   - Improvement on input/output matching
   - Improvement on pilot tone phase noise
   - Better shielding – better temperature stability
   - Improvement on compensation (pilot tracks changes better)

2. "Ease of use" improvements:
   - "rugged" and reliable instrument (use "on field")
   - Full documentation (user's manual)
   - Performance checked extensively with reports

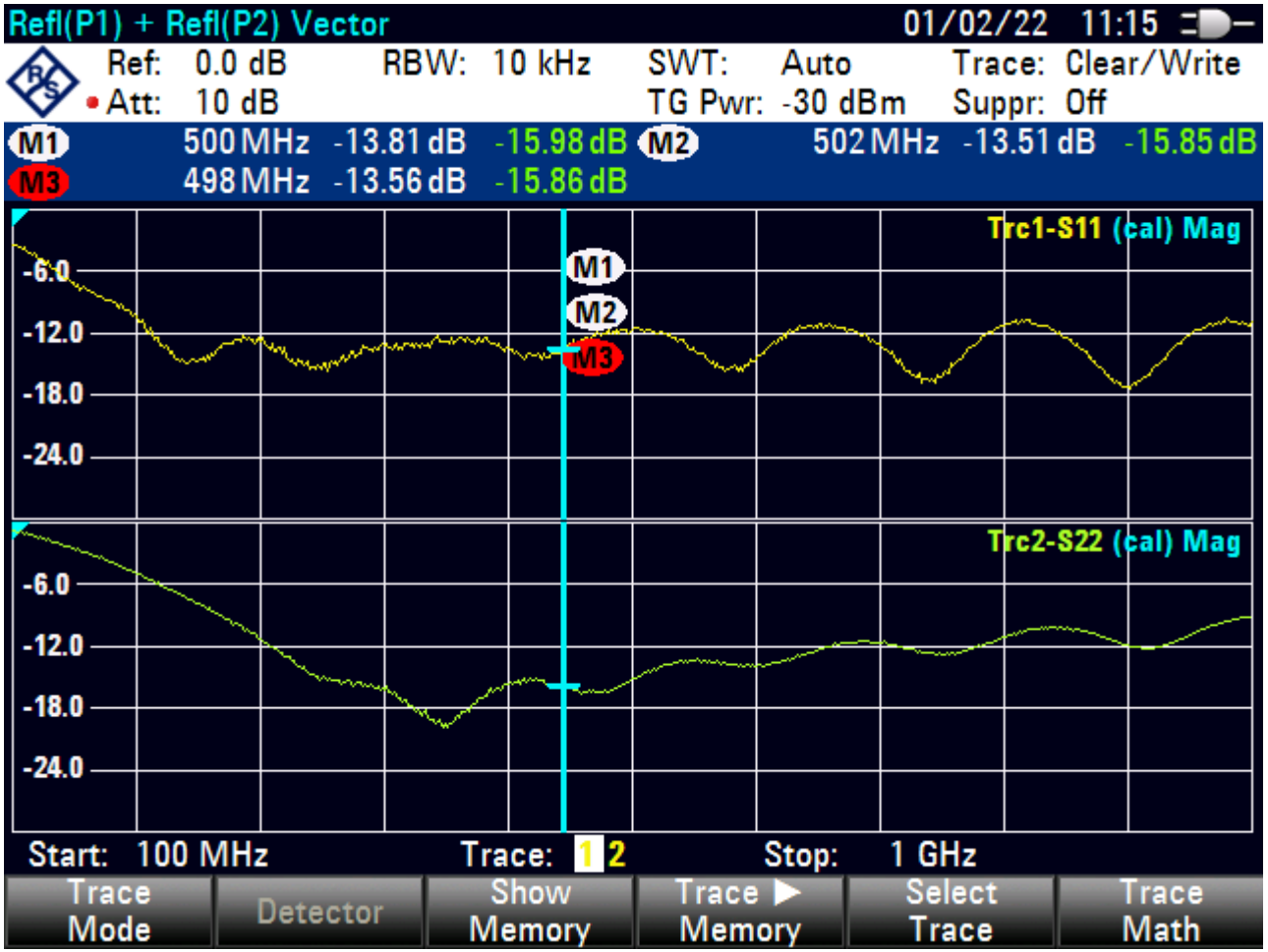
Amplifiers matching improvement

- Reduce signal reflections and standing waves
- Trade-off between components number and values of matching circuit, performance and repeatability of the design



meas @ 500 MHz	Prototype	Ind. version
S11 (input return loss)	-14 dB	-31 dB
S22 (output return loss)	-16 dB	-26 dB

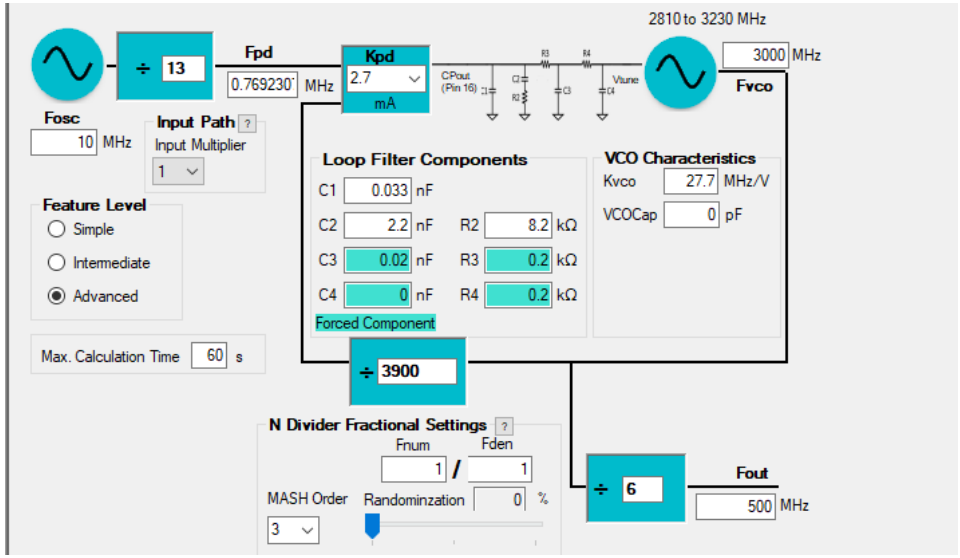
Amplifiers matching improvement -before



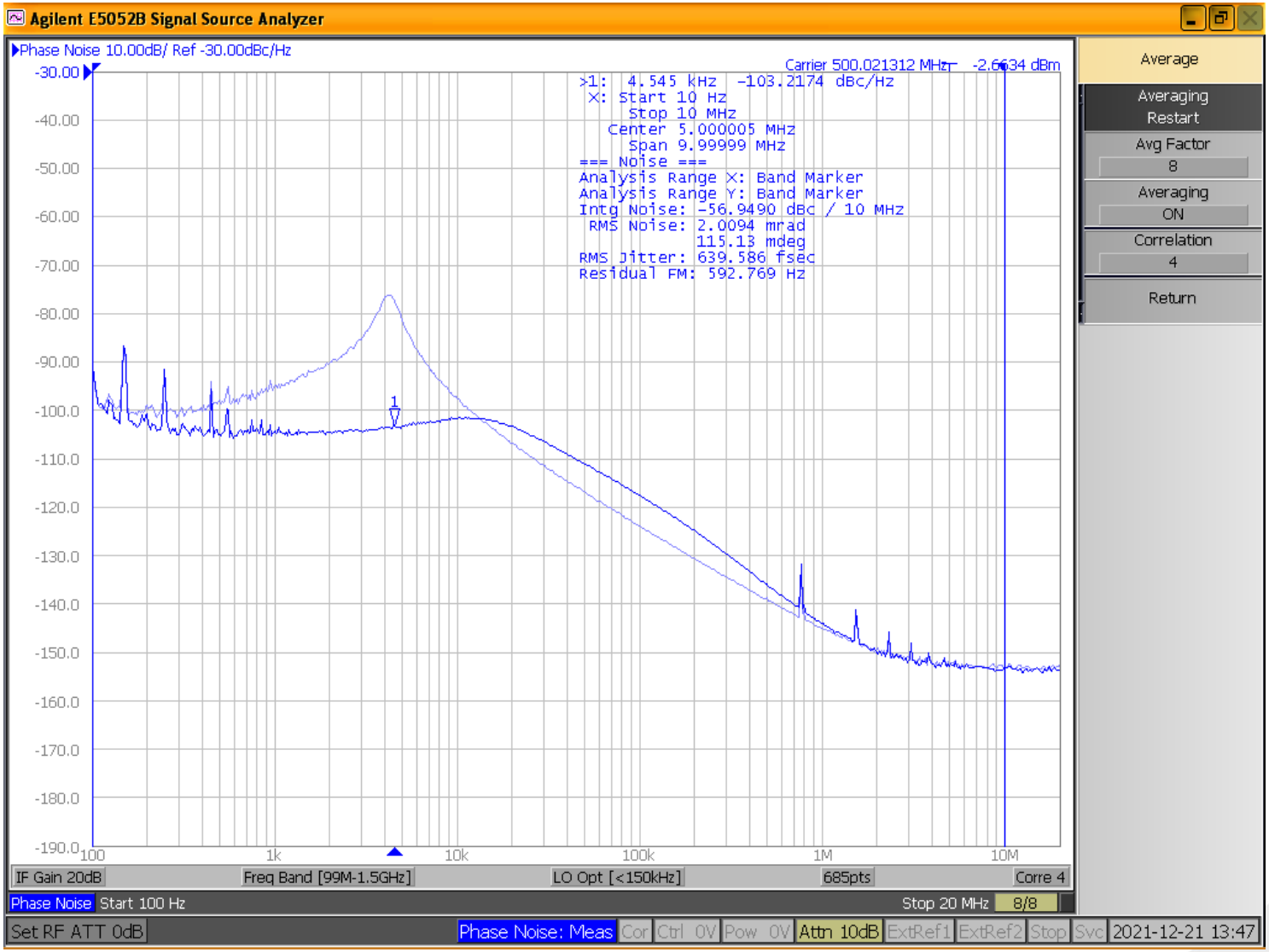
Amplifiers matching improvement - after

Pilot phase noise improvement

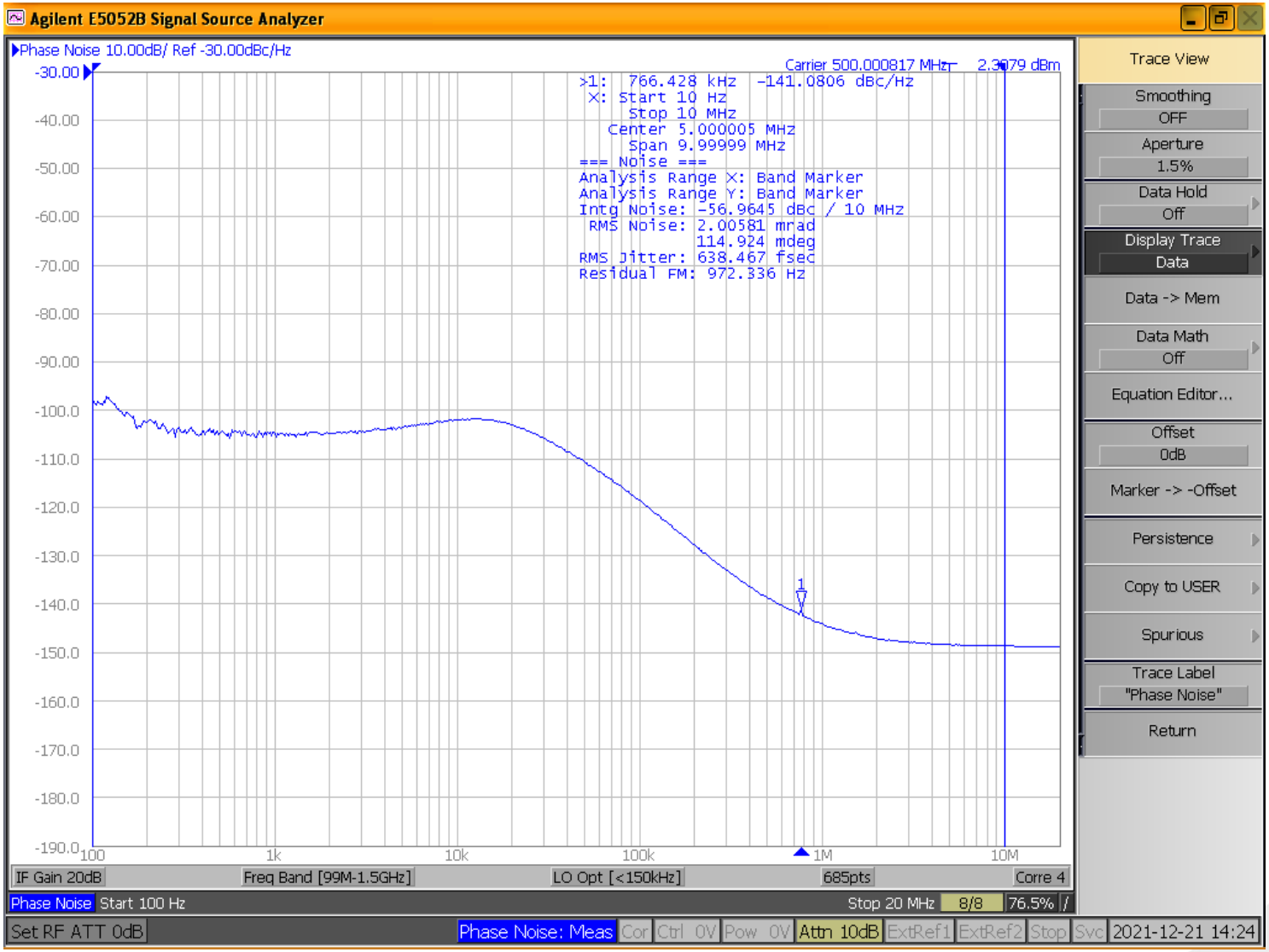
- The source of pilot tone can be internal or external (SMA)
  - In the former case is generated by a low phase noise PLL
- Frequency and amplitude are programmable
- Reference frequency from a 10 MHz crystal
- Filter of PLL need to be optimized for 500 MHz operation
- Jitter improvement: from 2.8 ps to 650 fs in a 100 Hz-10 MHz bandwidth



Pilot phase noise improvement - before

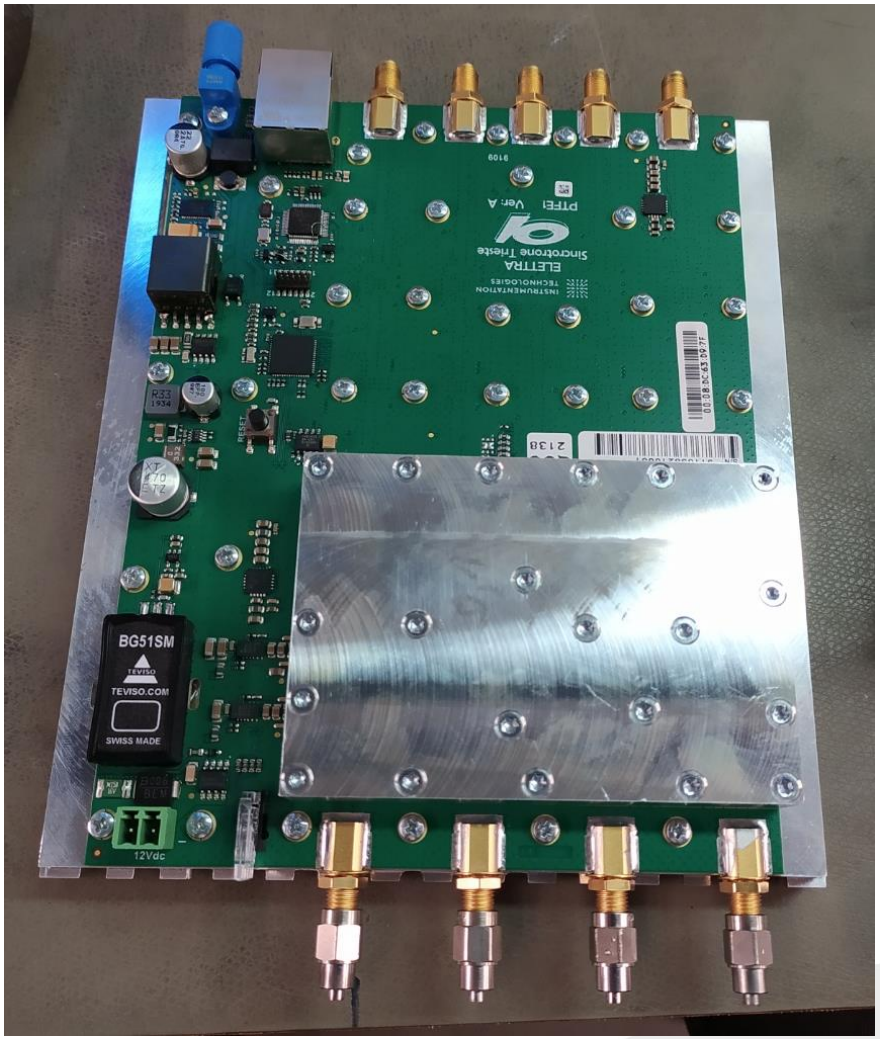


Pilot phase noise improvement - after



Benefits from shielding

- Large heatsink – homogeneous heat dissipation
- RF chain fully shielded
- Pilot tone tracks better channel variations (due to temperature, gain changes, etc)



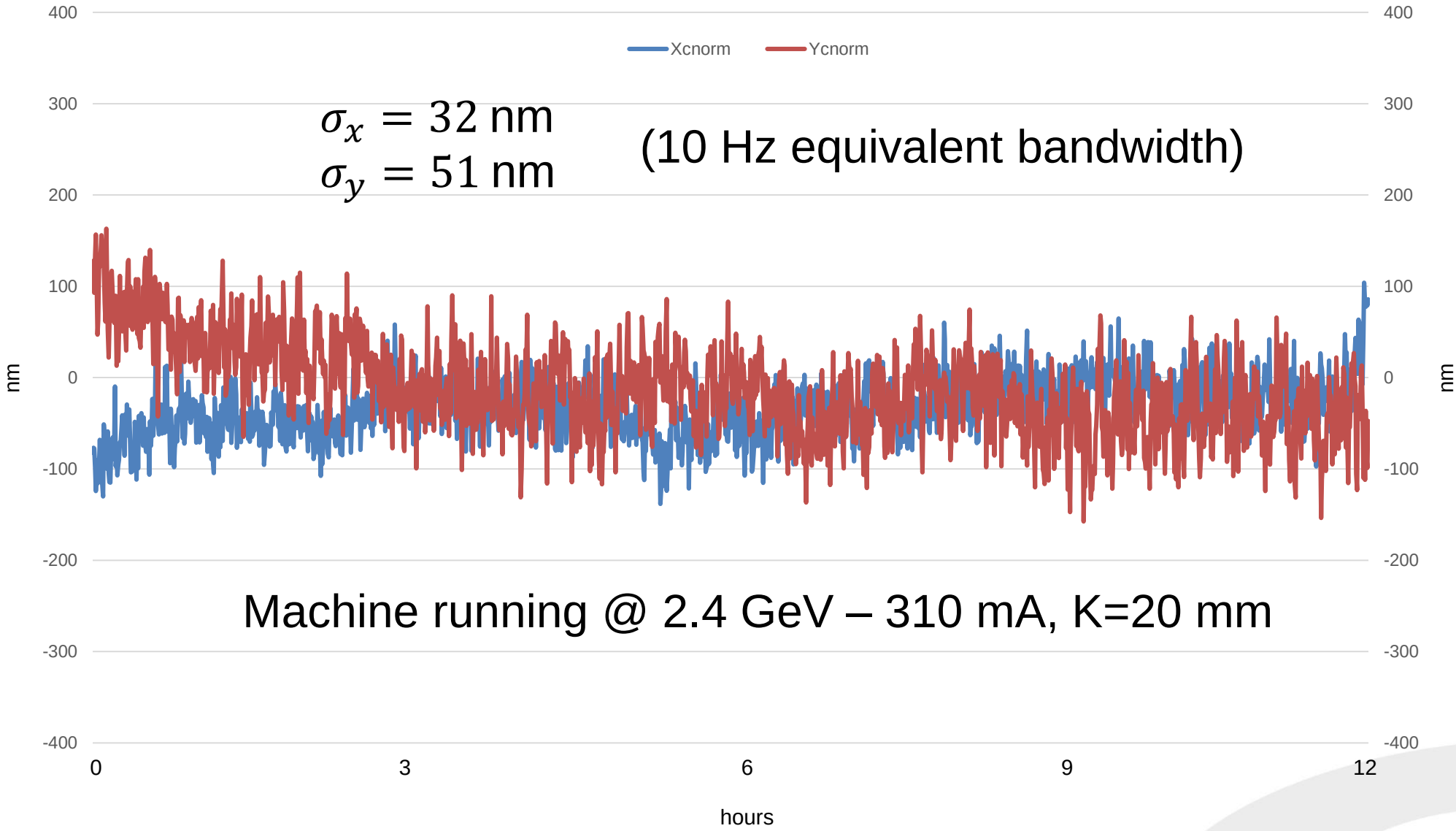
Benefits from shielding

- Measurements of temperature dependence with a 22-metre coaxial cable (LMR-195)
- 3 times better with respect to the prototype (measurements in climatic chamber – courtesy of A. Vigali, I-Tech)

compensated position

T variation (°C)	X/T proto (µm/K)	X_C/T proto (µm/K)	X/T ind (µm/K)	X_C/T ind (µm/K)
25°-15° step	-8.2	-3.7	-6.5	0.9
15°-35° ramp	-7.8	-3.65	-6.3	1.0
35°-25° step	-7.9	-3.6	-6.2	1.0

Long term measurement in Elettra



$\sigma_x = 32$ nm
$\sigma_y = 51$ nm

(10 Hz equivalent bandwidth)

Machine running @ 2.4 GeV – 310 mA, K=20 mm

Project next steps

- First series of 10 BPMs – will equip a cell in Elettra 1
- Second series of 200 BPMs

- Electronic components shortage remains critical…

- Assure same level of performance on all units - challenge on repeatability

- FAT procedure on every unit (A. Vigali, P. Leban – I-Tech)
  - Checks for basic functionality
  - Short term measurements (SNR, crosstalk)
  - Long term measurements (stability)

INSTRUMENTATION TECHNOLOGIES

Elettra PTFE Test Record

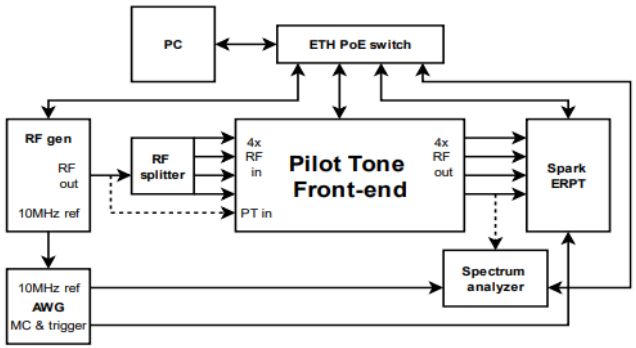


Figure 1: Test setup diagram

Unit serial number:	911038210004
MAC address:	00:26:32:00:0A:55
FW version:	1.0~r2018
Tested by:	Ales Vigali
Date:	25.mar.22

Initial checks

Visual inspection	OK
PoE & LED check	OK
Voltages check	OK
Temperature check	OK
Optic latch check	OK
BP filter check	OK
FRAM check	OK

Radiation sensor

	Measurement	Limit
Uptime [min]	17	> 5
Acc. Dose []	259	> 1
Rate [cpm]	15.2	< 2

Frequency setting

pll:n	Calculated Freq. [MHz]	Measured Freq. [MHz]	Delta [ppm]	Limit [ppm]	Power [dBm]	PLL locked
3890	498,7179	498,7206	5,2	40	-30,7	OK
3895	499,3590	499,3617	5,4	40	-30,7	OK
3900	500,0000	500,0027	5,3	40	-30,7	OK
3905	500,6410	500,6437	5,3	40	-30,8	OK
3910	501,2821	501,2848	5,4	40	-30,8	OK

INSTRUMENTATION TECHNOLOGIES

Signal-to-noise

RF generator signal

Power [dBm]	att_1 [dB]	att_2 [dB]	att_3 [dB]	max adc []	A [
0	10	30	30	2418	8
-5	5	30	30	2483	8
-10	0	30	30	2554	8
-15	0	25	30	2545	8
-20	0	20	30	2552	8
-25	0	15	30	2557	8
-30	0	10	30	2582	8
-35	0	5	30	2649	8
-40	0	0	30	2821	7
-45	0	0	25	2948	7
-50	0	0	20	3214	6
-55	0	0	15	3667	6
-60	0	0	10	4559	5

* calculated on 10k FA samples

Internal Pilot tone generator

pt_att [dB]	att_1 [dB]	att_2 [dB]	att_3 [dB]	max adc []	A [
0	0	20	30	2980	8
5	0	15	30	2995	8
10	0	10	30	3027	8
15	0	5	30	3082	8
20	0	0	30	3270	7
25	0	0	25	3381	7
30	0	0	20	3638	7

* calculated on 10k FA samples

External Pilot tone generator**

pt_att [dB]	att_1 [dB]	att_2 [dB]	att_3 [dB]	max adc []	A [
0	0	20	30	2904	8
5	0	15	30	2920	8
10	0	10	30	2952	8
15	0	5	30	3013	8
20	0	0	30	3181	7
25	0	0	25	3330	7
30	0	0	20	3579	7

* calculated on 10k FA samples

** power on PT input is -14.7dBm

INSTRUMENTATION TECHNOLOGIES

RF generator + Internal Pilot tone generator

						Signal-to-Noise*				
Power [dBm]	pt_att [dB]	att_1 [dB]	att_2 [dB]	att_3 [dB]	max adc []	A [dB]	B [dB]	C [dB]	D [dB]	Limit [dB]
-20	0	0	20	30	5461	84,0	84,1	83,9	84,0	80
-25	5	0	15	30	5464	83,8	84,0	83,9	83,8	80
-30	10	0	10	30	5504	82,3	82,5	82,3	82,4	80
-35	15	0	5	30	5585	79,8	79,9	79,6	79,8	80
-40	20	0	0	30	5834	75,9	76,2	75,8	76,2	70
-45	25	0	0	25	5946	71,5	71,6	71,2	71,6	70
-50	30	0	0	20	6173	66,6	66,7	66,3	66,8	65

* calculated on 10k FA samples

Internal Pilot tone generator

					Channel-to-Channel difference*				
pt_att [dB]	att_1 [dB]	att_2 [dB]	att_3 [dB]	max adc []	delta A [%]	delta B [%]	delta C [%]	delta D [%]	Limit [%]
0	0	20	30	2980	0,2	1,5	0,7	0,9	5
5	0	15	30	2995	0,2	1,3	0,8	0,7	5
10	0	10	30	3027	0,2	0,9	0,7	0,4	5
15	0	5	30	3082	0,2	0,7	0,8	0,2	5
20	0	0	30	3270	0,4	0,4	1,0	0,3	5
25	0	0	25	3381	0,5	0,3	1,0	0,2	5
30	0	0	20	3638	0,6	0,2	0,9	0,0	5

* calculated on 10k FA samples

Crosstalk

		Output channel [dB]			
		Ch A	Ch B	Ch C	Ch D
Input channel	Ch A	0,0	61,9	60,9	61,0
	Ch B	62,8	0,0	62,1	61,7
	Ch C	61,9	61,0	0,0	61,1
	Ch D	61,4	63,2	62,9	0,0

* all PTFE attenuators set to 0dB

** limit set at 50dB

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Thank you!

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