Characterization of (High Speed) Transmission Lines

Proposta

Preamble

- Experiments today use detectors with front-end electronics that have to bring out the signal to the back-end R/O sited far from where the signal is generated.
- The signal generated in the front-end must pass through a hierarchy of interconnects from chip to board, to flex circuit, to cables, to connectors, before being passed to optical transmission or arriving at the destination DAQ R/O module.
- The signal from the front-end could be high frequency digital and/or low noise, either analog or digital. You want to optimize the quality of the received signal: low error bit rate and low distortion of the analog shape.
- Today, measurement techniques and CAD simulation allow to check the integrity of the signal. In particular, time domain reflectometry (TDR) is a powerful way to extract the parameters (Scattering matrix) of the interconnect.

Genova: TDR/TDT – WavePulser 40iX Teledyne-LeCroy

		WavePulser 40iX
FREQUENCY	Frequency Range	DC to 40 GHz
	S-parameters	Single-ended, Differential, and Mixed-mode Full S-parameters (S_{11}, S_{12}, S_{21}, S_{22})
	Calibration	Internal automatic & manual OSLT
TIME	Impulse/Step Rise Time	8.5 ps
	Impedance Profile	Differential and Common-mode
	TDR/TDT Solution	TDR/TDT
	Spatial Resolution	< 1 mm
DEEP TOOLBOX	Simulation and De-embedding	Yes
	Time-gating	Yes
	Emulation of Eye Diagrams	Yes
	Jitter Analysis	Yes
PLATFORM	Number of Ports	4
	USB-connected	Yes
	Size/Weight	105mm H x 305mm W x 230mm D, 3.3 kg
	Battery-powered	No

Teledyne LeCroy WavePulser 40iX

Signal Integrity – Examples form Experiment's Cases

- The first example of the use of TDR is to optimize the design of the 1.28 Gb/s line that brings the signal from the **ATLAS-ITk** pixel modules to the opto-boards. The differential electrical signal is transmitted through flex circuits, twinax cables, and several kinds of connectors before being converted to optical. Impedance matching and eye-opening optimization are the reason.

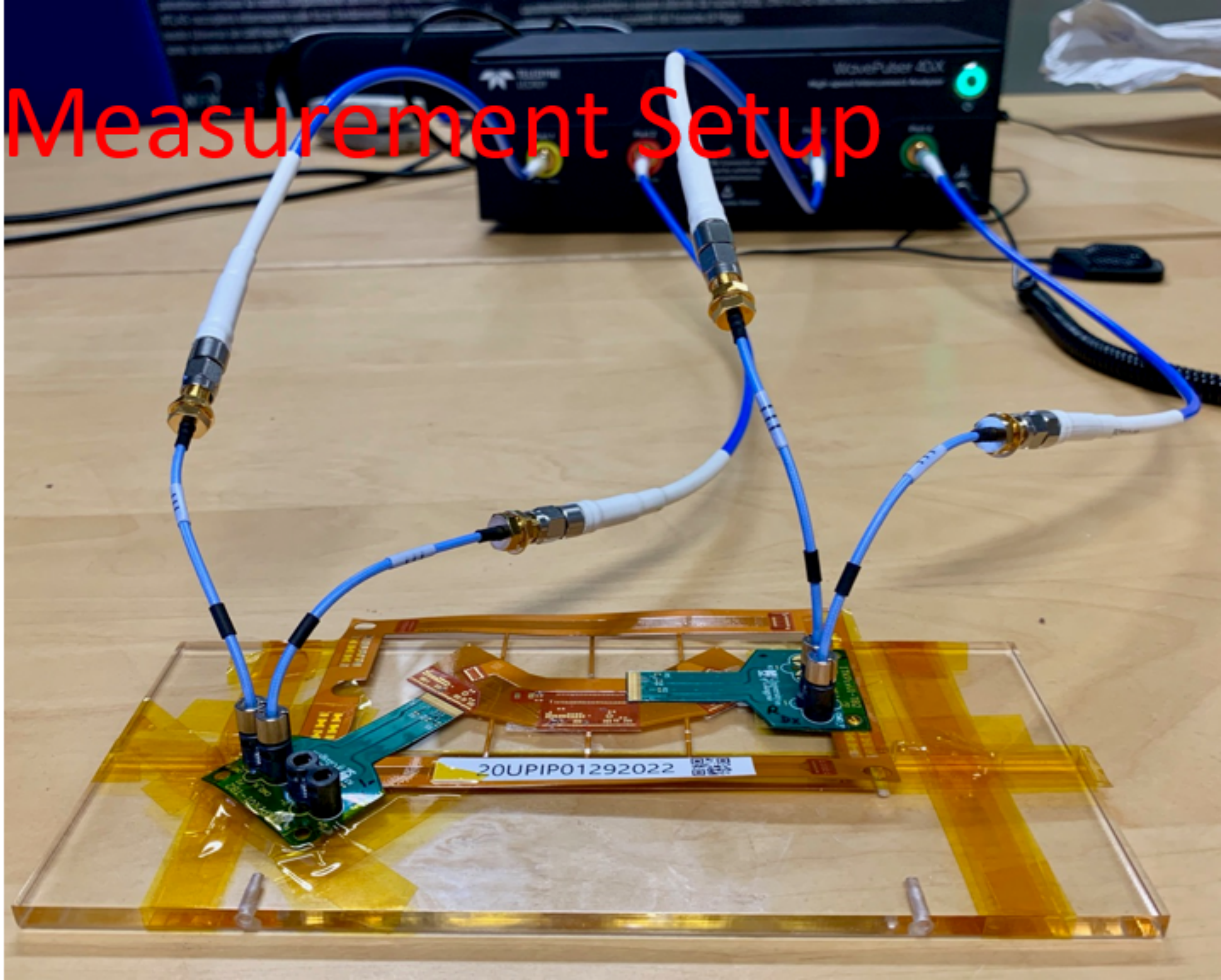
- A second case is the characterization of a bundle of unscreened twisted pairs at cryogenic temperature to be used by **DarkSide-20k** for the readout of SiPM signals.

The Measurement Setup

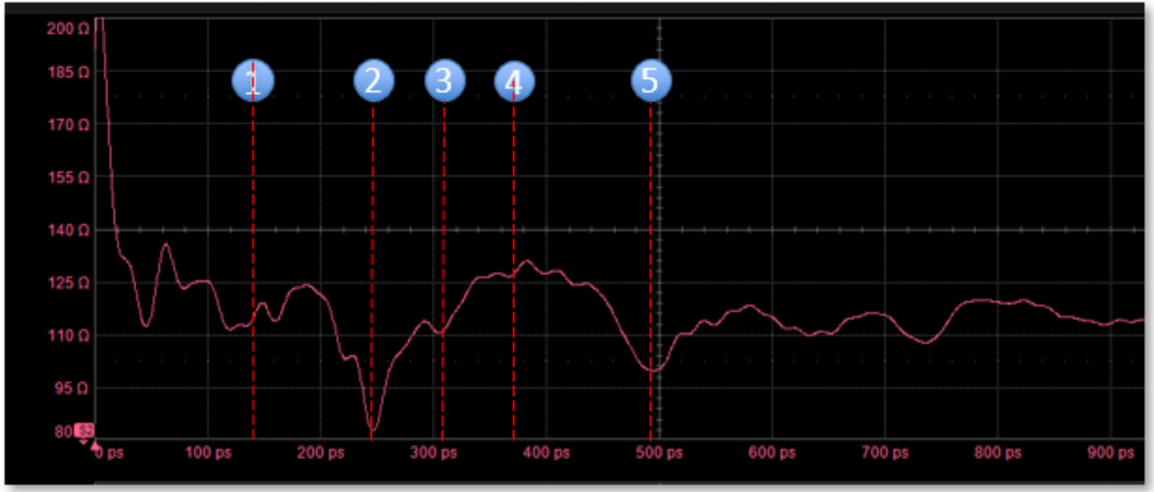
Test setup with 4-ports TDR connected to the DUT via 10 cm *BullsEye* cables and *ItkPixV1 TB2*(*) *fixture*

Fixture in de-embedded using a 2X-thru measurement of two equal fixtures connected head-to-head by wire-bonds

<u>Note</u> (*): Parts designed and given to us by Sneha Naik.

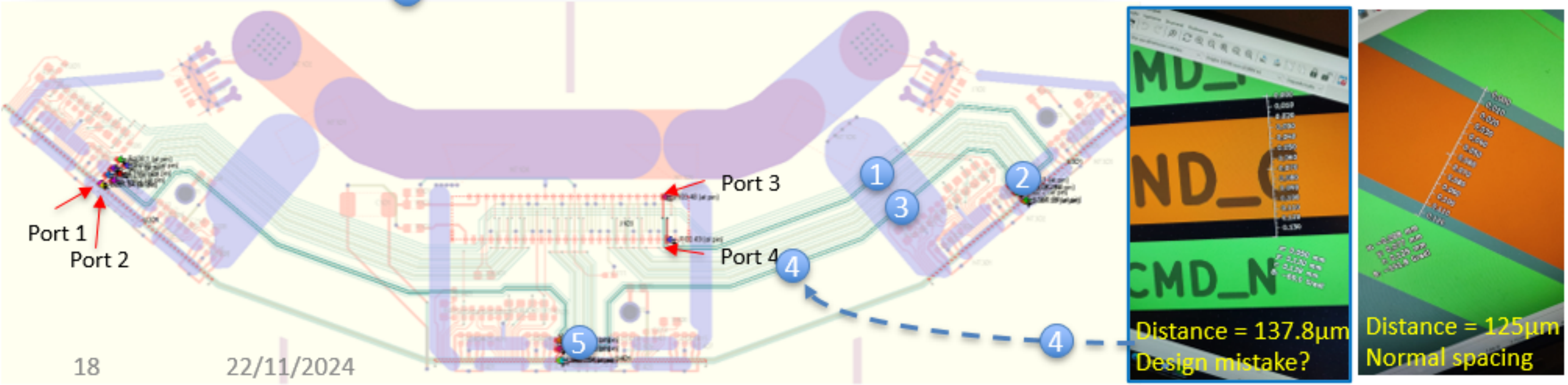


Impedance along the CMD line measured from Port 3 and 4

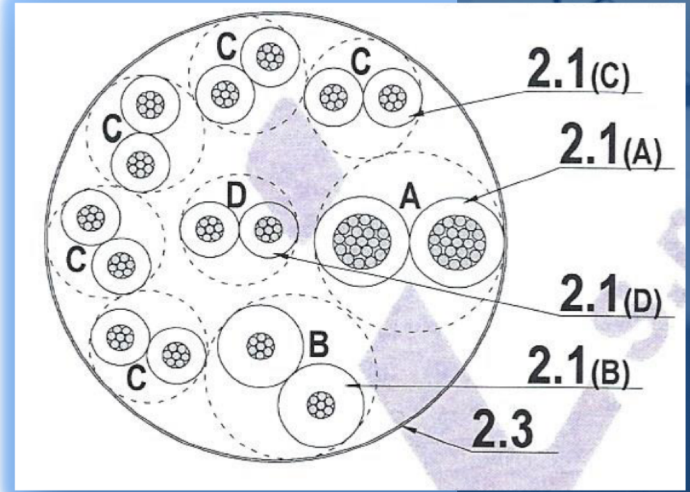


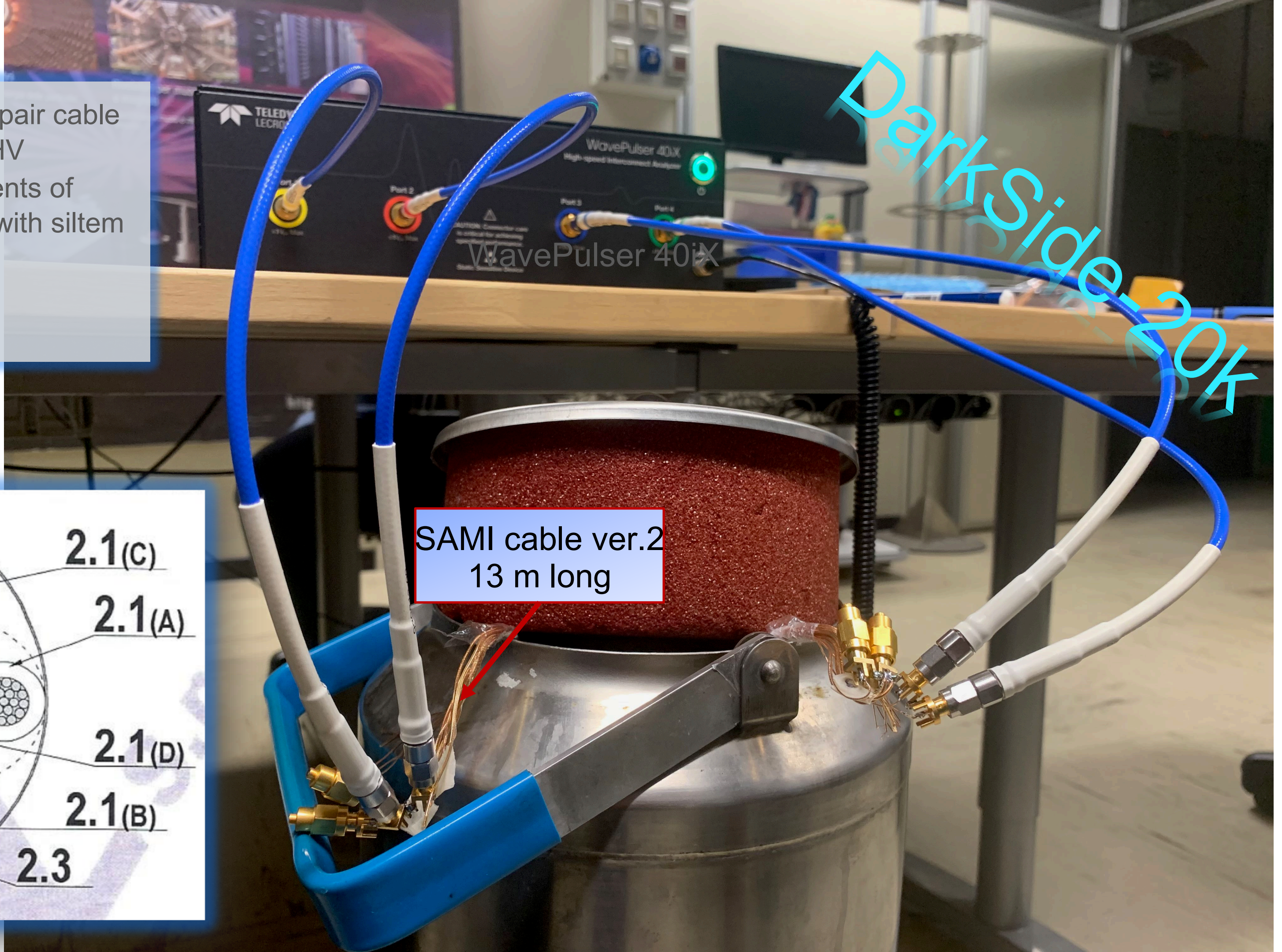
Comment:

- Impedance is well adjusted when differential line runs above power/ground by reducing GND_C line width from 100µm to 75 µm (1) (3)
- Impedance is too high due to increase of spacing between CMD_P and CMD_N in some points (example (4))



- SAMI (prot.3) twisted pair cable
- 8 pairs: signal, LV & HV
- TDR/TDT measurements of signal pairs (AWG30 with siltem jacket)
    - T = 300K
    - T=77K





File
WavePulser Setup
SI Studio
Display
Cursors
Measure
Math
Analysis
Utilities
Help
Setup
Go
Continuous
Abort
Recalculate
Gesture
Undo
102±2 Ω
107±2 Ω
Differential impedence – SD1D1.Z - SD2D2.Z
-1.01 dB @ 20MHz
Insertion loss – SD2D1.dB
Measurements at T=77K
DarkSide-20k
0 ns
7 ns
14 ns
21 ns
28 ns
35 ns
42 ns
49 ns
56 ns
63 ns
70 ns
120 Ω
115 Ω
110 Ω
105 Ω
100 Ω
95 Ω
90 Ω
85 Ω
80
0
-1.25 dB
-2.5 dB
-3.75 dB
-5 dB
-6.25 dB
-7.5 dB
-8.75 dB
-10 dB
0 MHz
40 MHz
80 MHz
120 MHz
160 MHz
200 MHz
S1 SD1D1.Z 5.00 Ω/div 7.0 ns/div
S2 SD2D1.dB 1.25 dB/div 20.0 MHz -1.0133 dB -4.0519 dB
S3 SD2D1.dB 1.25 dB/div 20.0 MHz -1.0133 dB -4.0519 dB
S4 SD2D2.Z 5.00 Ω/div 7.0 ns/div
SDAX:NRZ
10 Mbit/s
X1= 19.6 MHz ΔX= 130.4 MHz
X2= 150.0 MHz 1/ΔX= 7.67 ns
Setup
Calibration
Result Display
TDR/TDT
Result Actions
Instrument Setup
SParam Import
SParam Export
Smith Chart
Gating
Delta-L
More...
CLOSE
S1 SD1D1 Z Config...
S2 SD2D1 dB
S3 SD2D1 dB
S4 SD2D2 Z Config...
S5 SD1D1 dB
S6 SC1D1 dB
S7 SC1C1 dB
S8 SC1C1 Z Config...
S9 SD1D1 dB
S10 SD1C1 dB
S11 SC1D1 dB
S12 SC1C1 dB
S13 SD1D1 dB
S14 SD1C1 dB
S15 SC1D1 dB
S16 SC1C1 dB
Horizontal
Reset Zoom
Vertical
Start 0 MHz
Center 100 MHz
Stop 200 MHz
Scale/div 20.0 MHz
Top 0 mdB
Bottom -10.000 dB
Center -5.000 dB
Scale/div 1.2500 dB
Store
Next
Label
TELEDYNE LECROY
30/09/2024 15:39:36

Laboratory

- The lab will provide hands-on exercises to characterize a transmission line with TDR
    - S-parameters – insertion loss – return loss – impedance – crosstalk
    - Simulate the effect of the line on a high-speed transmission (1.28 GHz) – eye diagram analysis
    - Simulate the correction applied to the signal to improve the eye diagram: pre-emphasis, de-emphasis, equalization
    - …

Proponents

- Nanni Darbo – (ex)-Direttore di Ricerca
- Claudia Gemme – Primo Ricercatore
- Paolo Morettini – Direttore di Ricerca
- Enrico Robutti - Primo Ricercatore
- Ettore Ruscino – Cter Elettronico