Progress of cables and connectors

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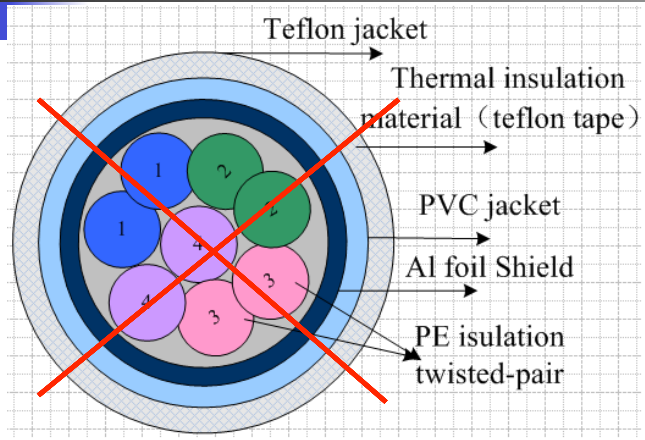
Outline

- Progress
  - Underwater cables status
    - Demands of JUNO cables
    - Different structures
    - Capable cable structures to choose
  - Cables test in deep well
  - Connectors
- Plan

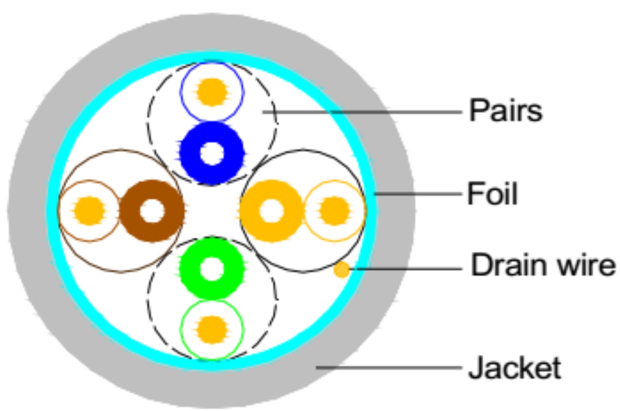
Demands of JUNO cables

- In the actual use conditions, the network transmission requirements,
- In the actual use conditions, the clock and pulse signal transmission to meet the requirements,
- In the actual use conditions, power and ground impedance to meet the requirements
- The failure rate of the outer skin in pure water to achieve reliability requirements;
- To ensure that the appearance of the skin during the installation does not affect the electrical performance damage;
- The material will not pollution the water
- The fluorescence effect will not affect the physical experiments
- Connector and cable connection to achieve reliability requirements;
- After the outer skin damage, resulting in decreased transmission performance will not cause leakage;
- The watertightness of the waterproof connector meets the requirements
- The reliability of waterproof connectors
- The radioactivity of the cable as a whole
- Maximum bending radius, bending times
- Tensile strength of the outer jacket
- Cable anti-interference
- Anti-high-pressure performance
- Aging scheme
- Screening scheme

Different structures



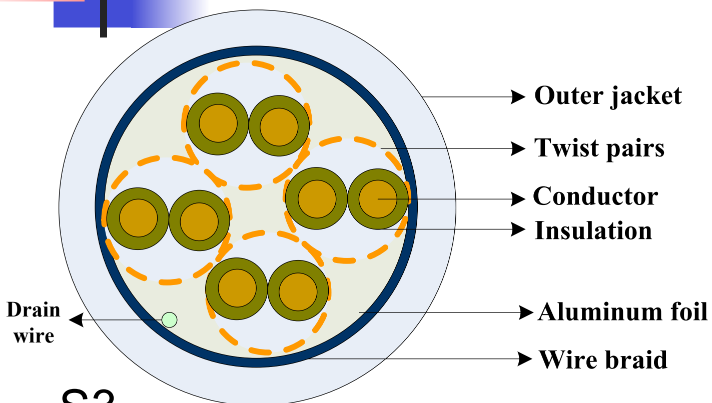
S1



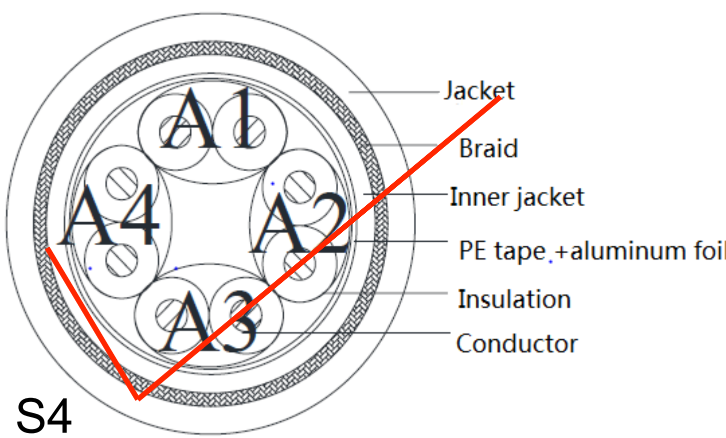
S2

- S1：Commercial cable + Teflon jacket
  - The most expensive structure
- S2：standard structure
  - jackets materials could be Teflon and PE
  - the foil is aluminum

Different structures



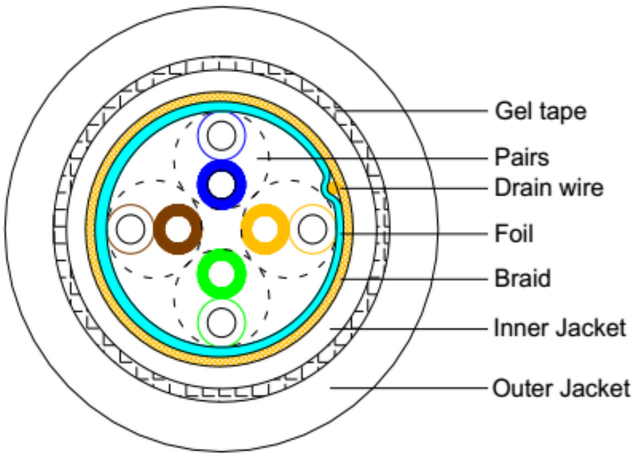
S3



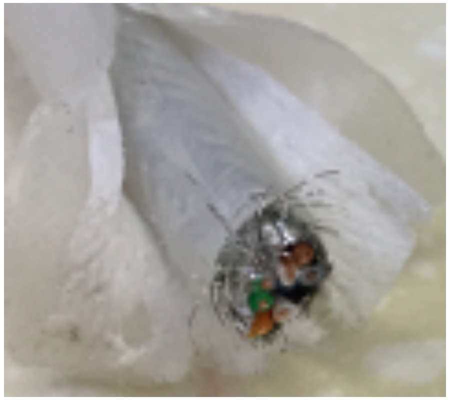
S4

- S3：wire braid is added to S2
  - Braid makes the cable strength
- S4：quite like S3
  - PE tape is added
  - PE tape can keep the twisted wires in the right direction
- Weight(S3/S4): about 6kg/100m
- Price(S3/S4): almost same
- S4 is a better choice

New design：Double outer jackets



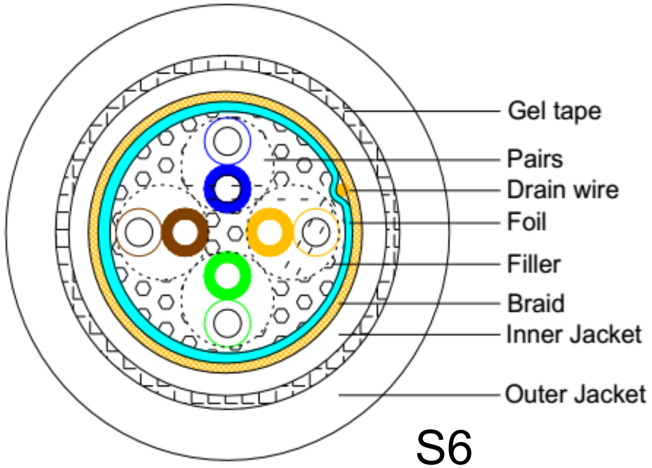
S5



cable

- S5: Double HDPE jackets
  - offer additional resistance to water pressure
- Gel tape between the two jackets: block the water

New design：Double outer jackets

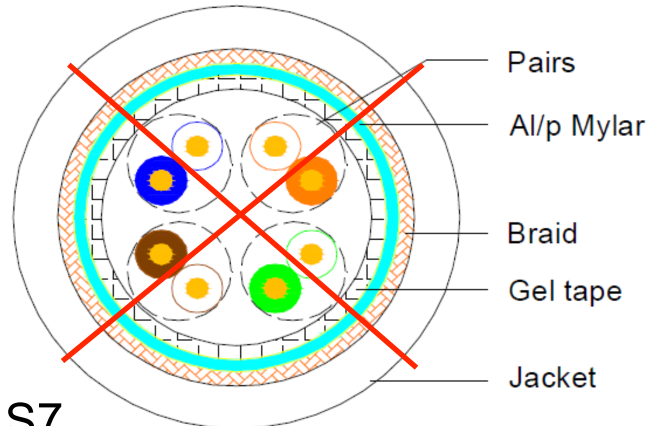


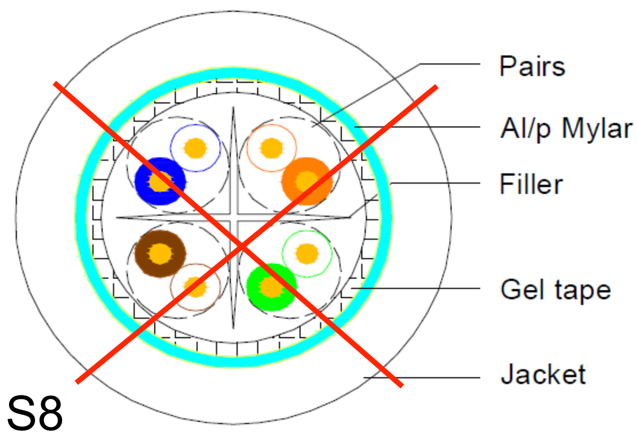
S6

cable

- S6: one difference compare with S5
- Filled with expanded PE inside
  - Keep the twisted pairs in the right direction
  - offer additional resistance to water pressure
- Difficult to separate the conductor and expanded PE
- S5/S6 Weight: about 8kg/100m

New design：4ΩDC Resistance for one conductor





- conductor：20AWG(0.8mm)
- outer diameter(OD)：10mm
- Weight：about10kg/100m
- No standard plug to fit
- Theoretical minimum bend radius：10×OD
- Very hard to bend

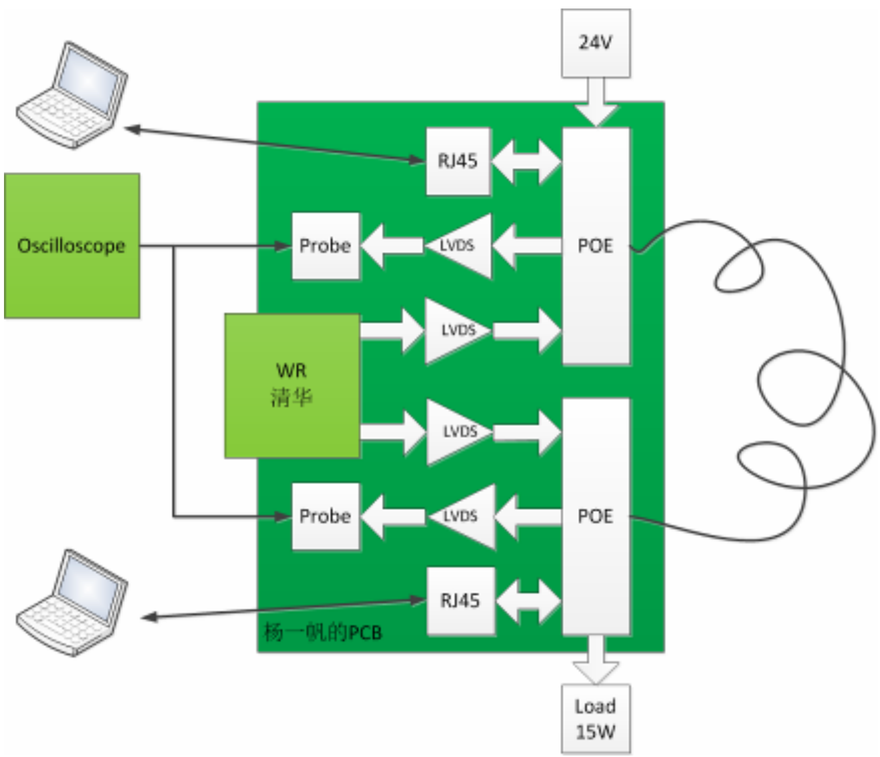
Capable cable structures to choose

- Capable cable structure:S2/S4/S5/S6
  - S2: simple structure and good price
    - Problem: the water pressure
  - S4/S5/S6: more stable structure and acceptable price
- Sample cables to produce
  - HDPE jacket
- Ground
  - Use the wire braid as a separate ground
  - Low impedance

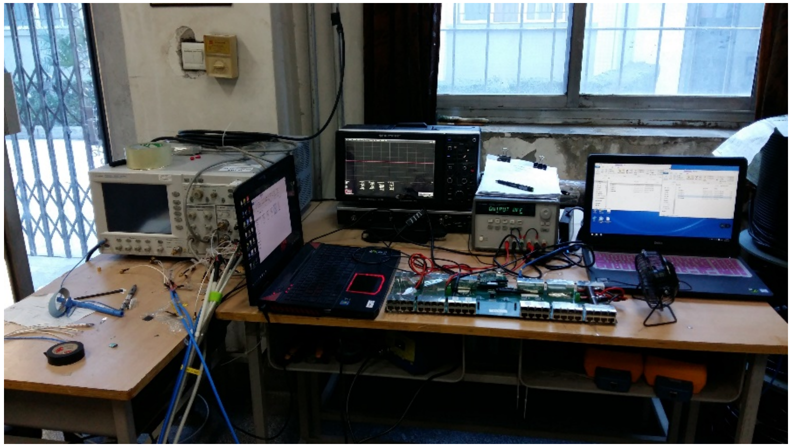
Purpose of the experiment in the well

- If cables impedance and electrical performance change with different depth water.
- If different structures have different changes.
- Which structure is the good for JUNO
  - More Stable
  - Electrical performance
  - Mechanical performance

Electrical test with BEC board



Cables test block diagram



WR board to generate a 125MHz clock

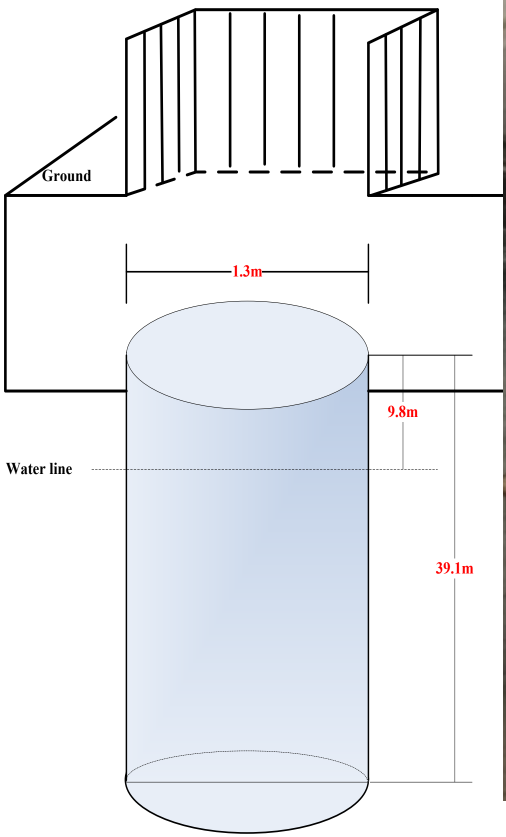
Run POE with 15W resistor load

Test the LVDS clock jitter@100M Ethernet

Test with BEC board

- Clock jitter
  - original jitter of BEC board: j_0
  - jitter with the cable transmission: j_1
  - Cables jitter J= $\sqrt{j_1^2 - j_0^2}$
- Use two computers to test network bandwidth.

Cables test in the well

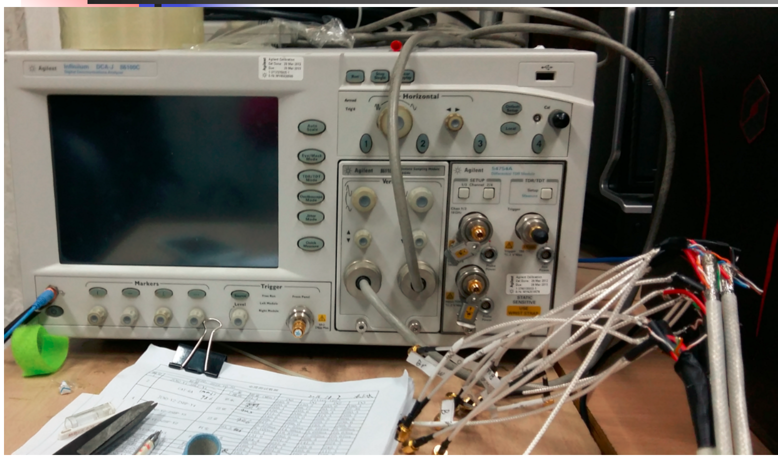


the well

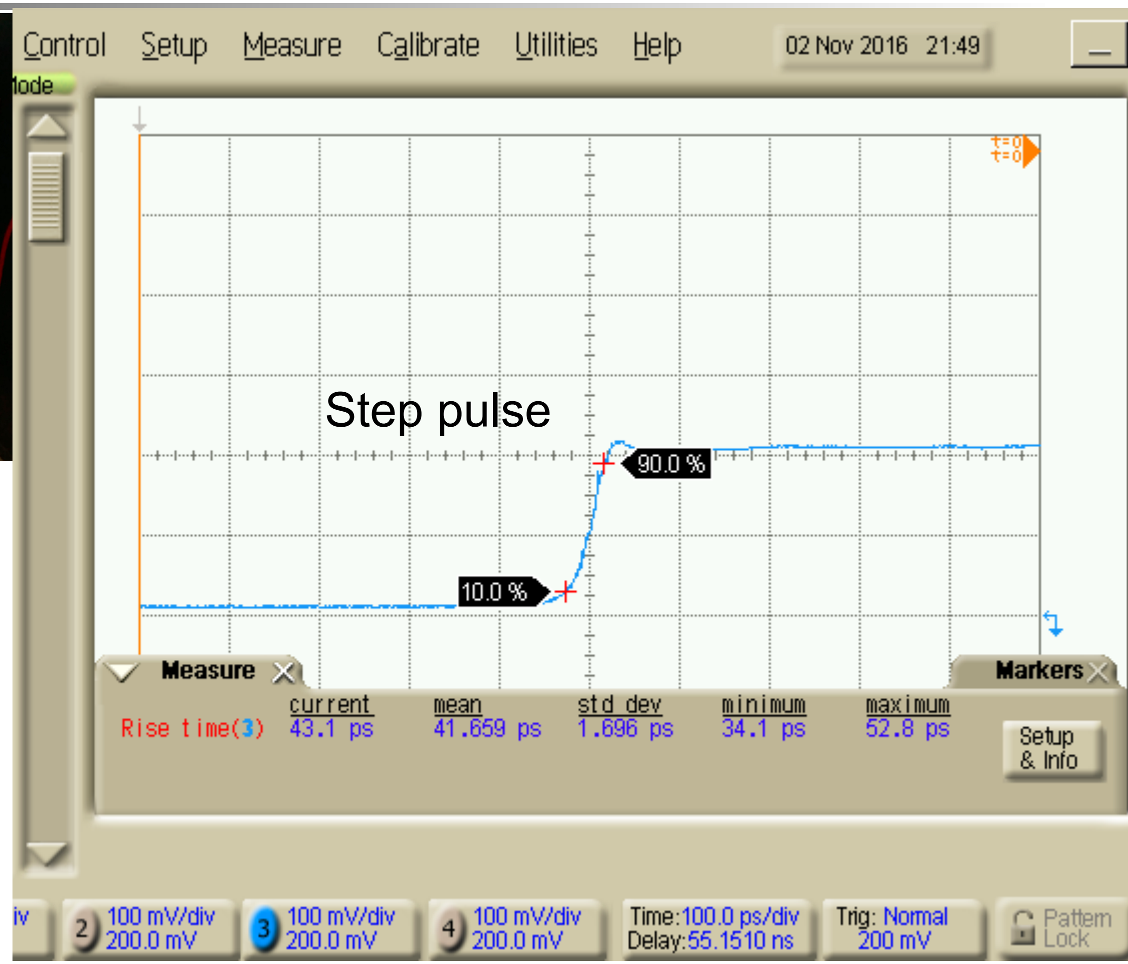
highest water level

cables on the ground

TDR Test

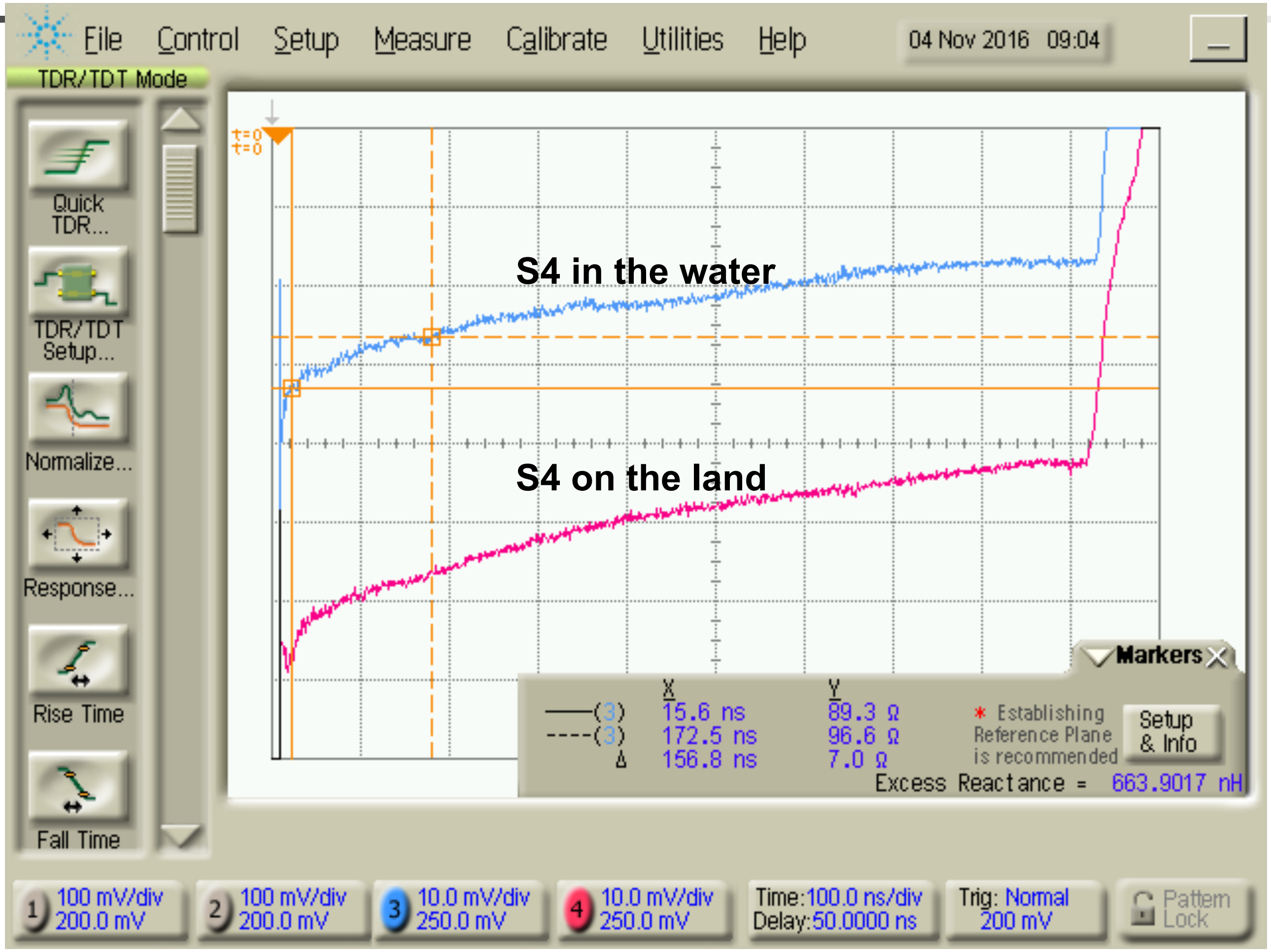


Agilent 861000C



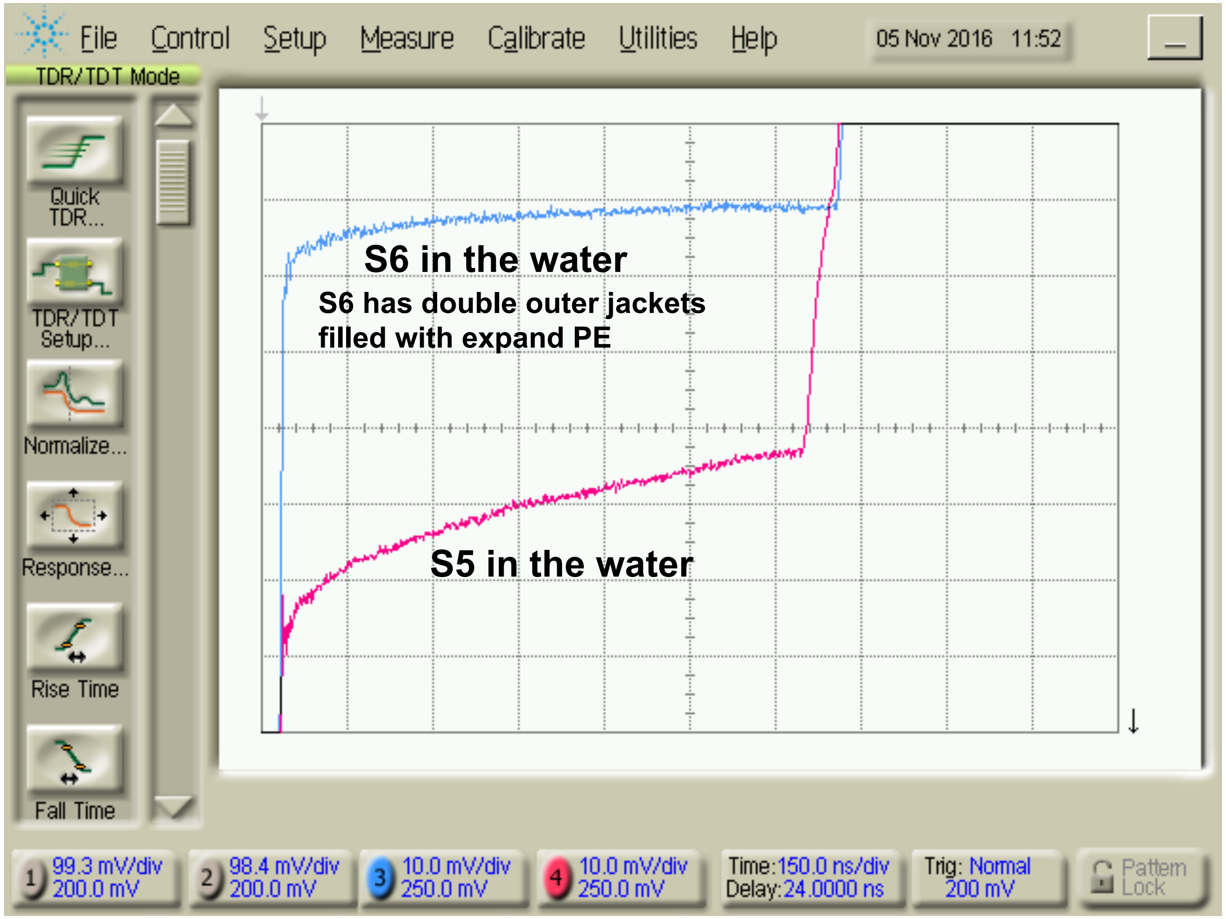
We used a 20cm long coaxial cable to connect the Agilent and JUNO_Cables .

TDR test



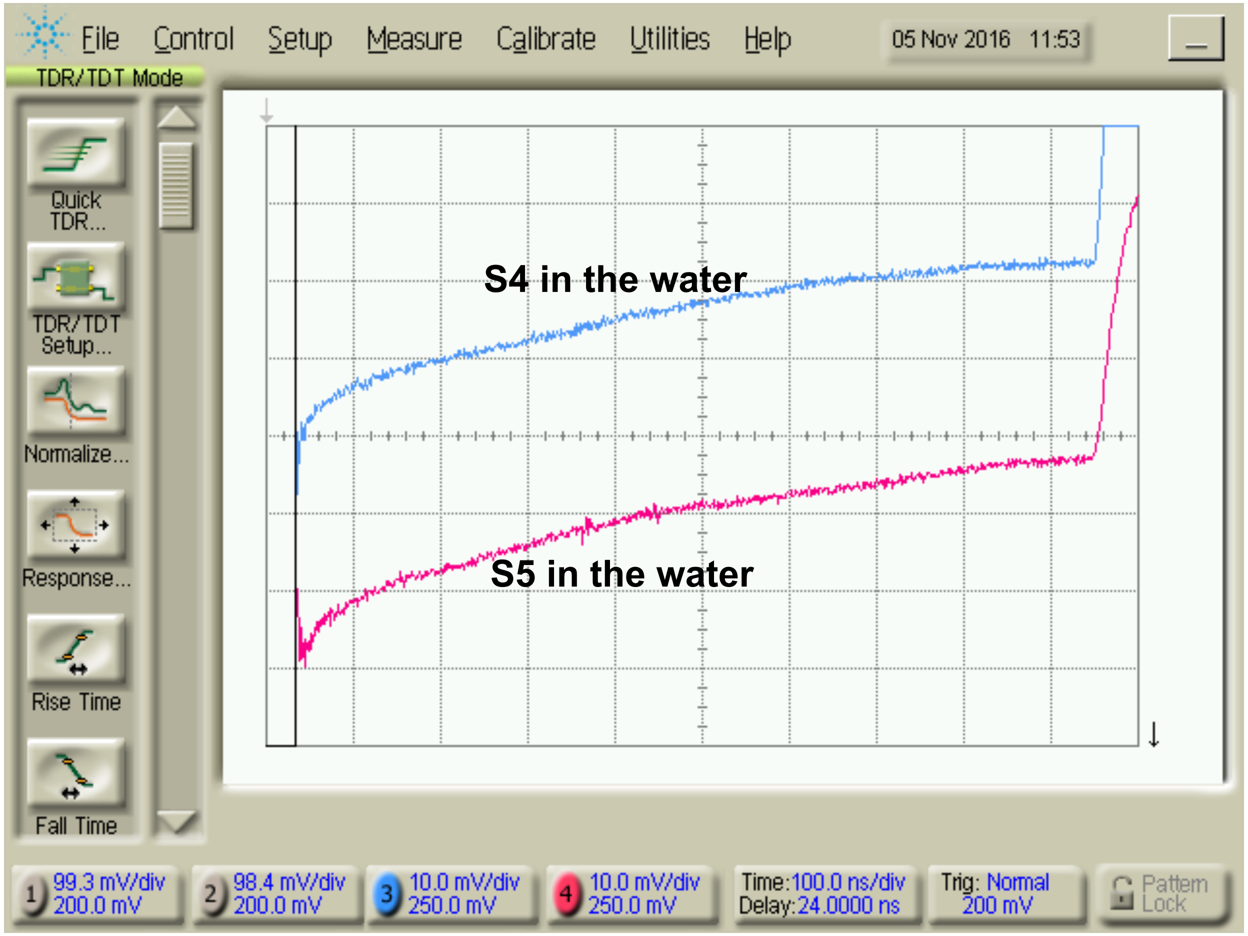
File Control Setup Measure Calibrate Utilities Help
04 Nov 2016 09:04
TDR/TDT Mode
Quick TDR...
TDR/TDT Setup...
Normalize...
Response...
Rise Time
Fall Time
S4 in the water
S4 on the land
Markers
X Y
(3) 15.6 ns 89.3 Ω
(3) 172.5 ns 96.6 Ω
Δ 156.8 ns 7.0 Ω
Establishing Reference Plane is recommended
Setup & Info
Excess Reactance = 663.9017 nH
1 100 mV/div 200.0 mV
2 100 mV/div 200.0 mV
3 10.0 mV/div 250.0 mV
4 10.0 mV/div 250.0 mV
Time:100.0 ns/div Delay:50.0000 ns
Trig: Normal 200 mV
Pattern Lock

TDR test

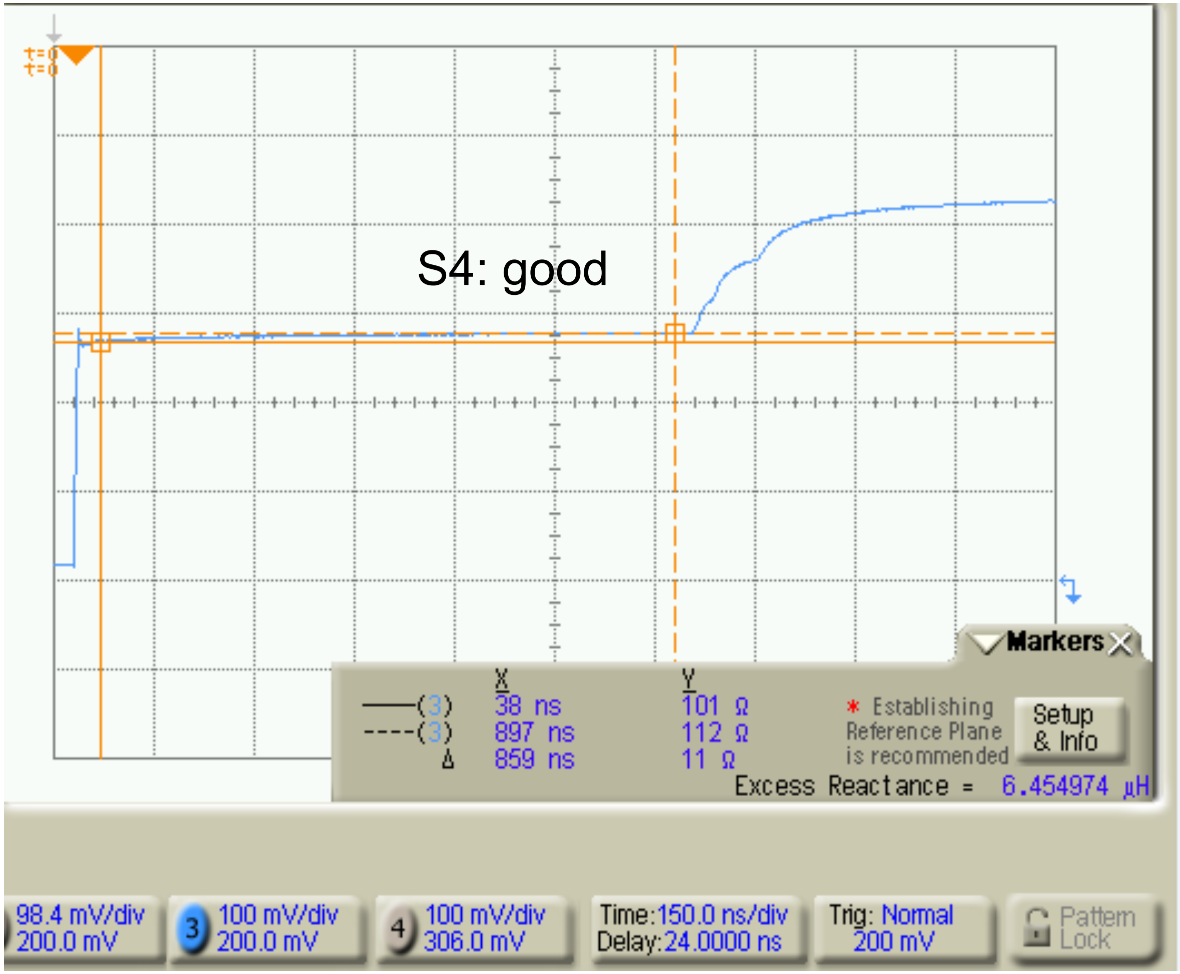


File
Control
Setup
Measure
Calibrate
Utilities
Help
05 Nov 2016 11:52
TDR/TDT Mode
Quick TDR...
TDR/TDT Setup...
Normalize...
Response...
Rise Time
Fall Time
S6 in the water
S6 has double outer jackets
filled with expand PE
S5 in the water
1 99.3 mV/div 200.0 mV
2 98.4 mV/div 200.0 mV
3 10.0 mV/div 250.0 mV
4 10.0 mV/div 250.0 mV
Time:150.0 ns/div
Delay:24.0000 ns
Trig: Normal 200 mV
Pattern Lock

TDR test

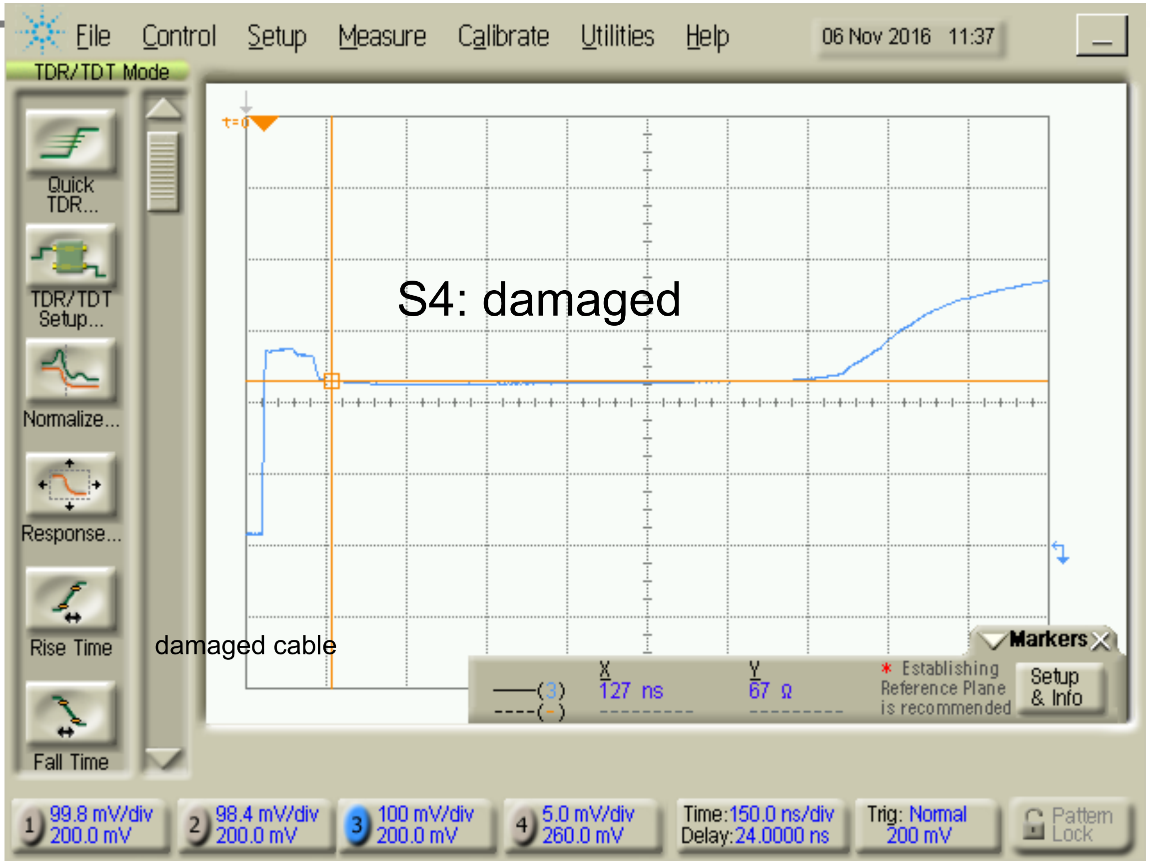

File
Control
Setup
Measure
Calibrate
Utilities
Help
05 Nov 2016 11:53
TDR/TDT Mode
Quick TDR...
TDR/TDT Setup...
Normalize...
Response...
Rise Time
Fall Time
S4 in the water
S5 in the water
1 99.3 mV/div 200.0 mV
2 98.4 mV/div 200.0 mV
3 10.0 mV/div 250.0 mV
4 10.0 mV/div 250.0 mV
Time: 100.0 ns/div Delay: 24.0000 ns
Trig: Normal 200 mV
Pattern Lock

TDR test(when cables broken)



TDR test

Exposed twisted wires to water



✓ When the cable was damaged, the impedance change can be obversed.

Test with BEC board

- Damaged cable
  - performance test of clock jitter.
  - The jitter changed with time , but bandwidth not
  - Not got the stable status when we end the experiment.

2016/11/04						
BECvoltage: 3.42V BECcurrent: 3.71A						
POEvoltage: 23.98V POEcurrent: 0.51A						
No	water (m)	时间	OUT (ps)	IN (ps)	Jitter	bandwidth (MHz)
16	good	09:00	36	76	61.2454	
BEC voltage: 3.42V BEC current: 3.70A						
POE voltage: 23.99V POEcurrent: 0.51A						
No	water (m)	time	OUT (ps)	IN (ps)	Jitter	bandwidth (MHz)
17	34m(damaged)	10:02	37	180	174.284	
18		10:16	33	400	397.461	
		10:22		63	44.0908	94.6
19		10:36	39	236	231.67	94.5
20		11: 02	32	198	192.819	94.6
21	36.8	11:38	45	102	91.5369	94.5
22	38.2	12:13	51	180	174.284	94.4
23	37.2	12:48	44	86	73.2871	94.5
24		15:34	44	123	114.473	94.5
25	water pumping	16:30	42	247	242.866	94.4
26	36.4	17:48	48	150	143.091	94.3
27	37	20:25	41	256	252.014	94.5
28		22:30	46	247	242.866	94.5
2016/11/05						
BEC voltage: 3.42V BEC current: 3.69A						
POE voltage: 23.98V POE current: 0.51A						
No.	water (m)	time	OUT (ps)	IN (ps)	Jitter	bandwidth (MHz)
29	29.9	08:51	40	177	171.184	94.5
30	water pumping	09:57	55	177	171.184	94.5
31	39	11:44	57	177	171.184	94.4
32	38.8	14:53	55	210	205.122	94.3
33	39.4	16:54	38	64	45.5082	94.5
34		21:13	43	113	103.653	94.4
35		22:22	50	89	76.7854	94.6

JUNO cables

- S4/S5/S6 structures are much more stable than S2.
- Commercial cables performance in the well are not good enough as they work on the ground, and worse than the cables we custom-made for JUNO.

Connector

- Considered the high reliability of JUNO, using connectors should be a good idea.
- Make a study of underwater connectors
  - Have got some conception design
  - Attempt to make prototypes and test

Plan

- More performance test in the water
- Prepare cables for the prototype
- Final design of cable
- Cable aging
- connectors test
  - Electronical performance
  - Reliability

Thank you!

Questions and comments are welcome!