

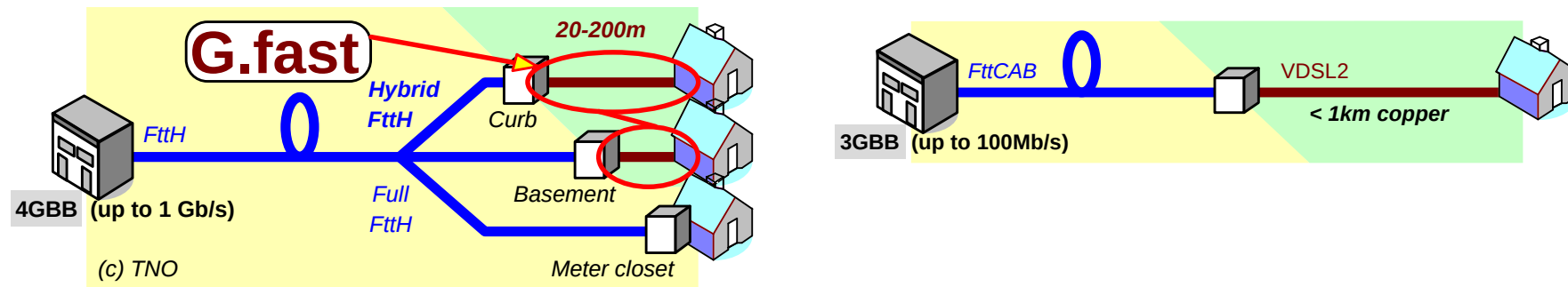
Broadband deployments in dense city areas

Comparing G.fast and VDSL/35b from street cabinets

Rob F.M. van den Brink – TNO

TNO innovation
for life

Different broadband migration strategies:



Disruptive copper approach	Gradual copper approach
From new nodes, near/at the home	From existing nodes, e.g. street cabinets
Aims at 1 Gb/s (>500Mb/s)	50 à 100 à 200 à 400 à 800Mb/s VDSL à VDSL/vec à VDSL/vec/bond
Typically within 20-200 range	Typically within 300-1000m range
Reverse powered	Locally (or remotely) powered
New developments: à G.Fast (up to 106MHz)	New developments: à VDSL/35b (up to 35 MHz, 8192 carriers) branded as Vplus, Super Vectoring, ...

When to use G.fast and/or when VDSL/35b? à **measurements**

Comparing technologies: G.fast

Results with first G.fast prototypes (Q4/2014) from different vendors



Adtran at TNO

First prototypes Q4/2014:

- 2 vendors, different implementations
- Up to 4 vectored lines
- Retransmission fully supported
- Improvements are ongoing

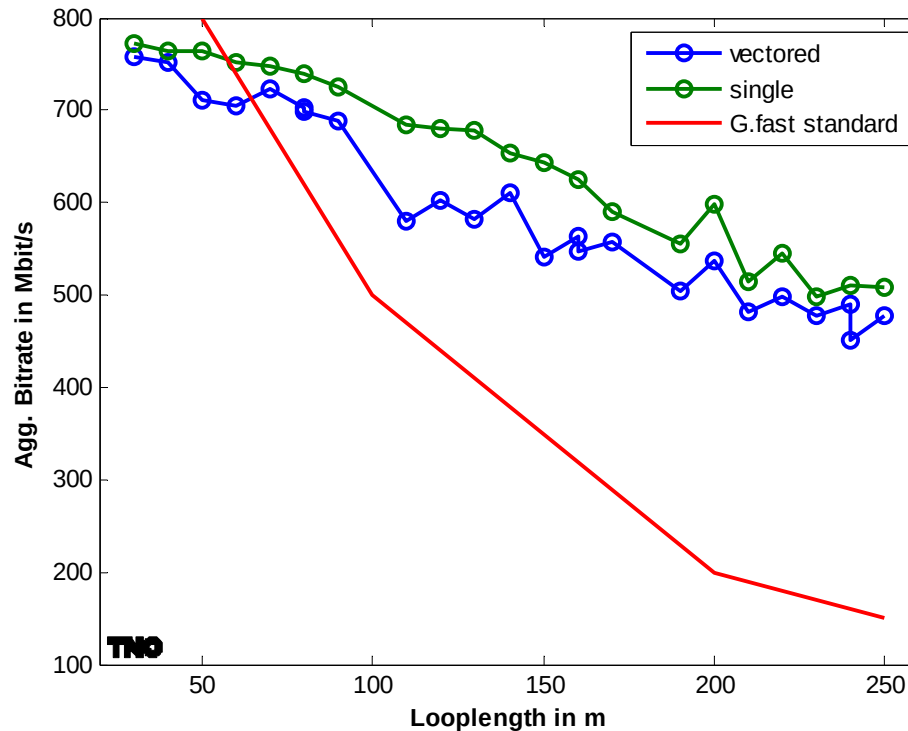


Sckipio at TNO

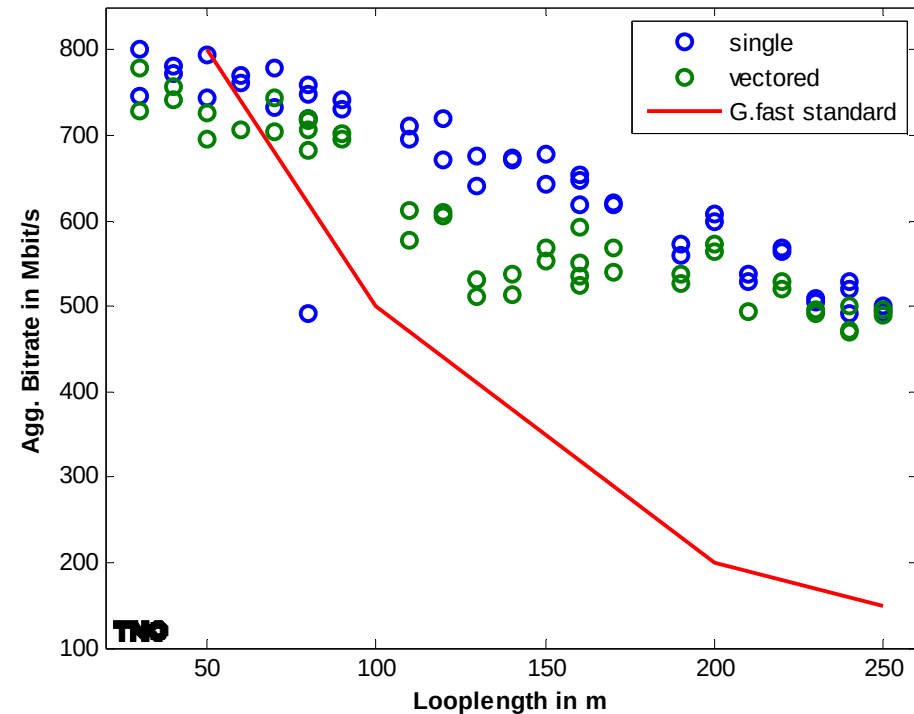
Comparing technologies: G.fast

TNO measurements on first G.fast prototypes (Q4/2014)

Vendor 1



Vendor 2

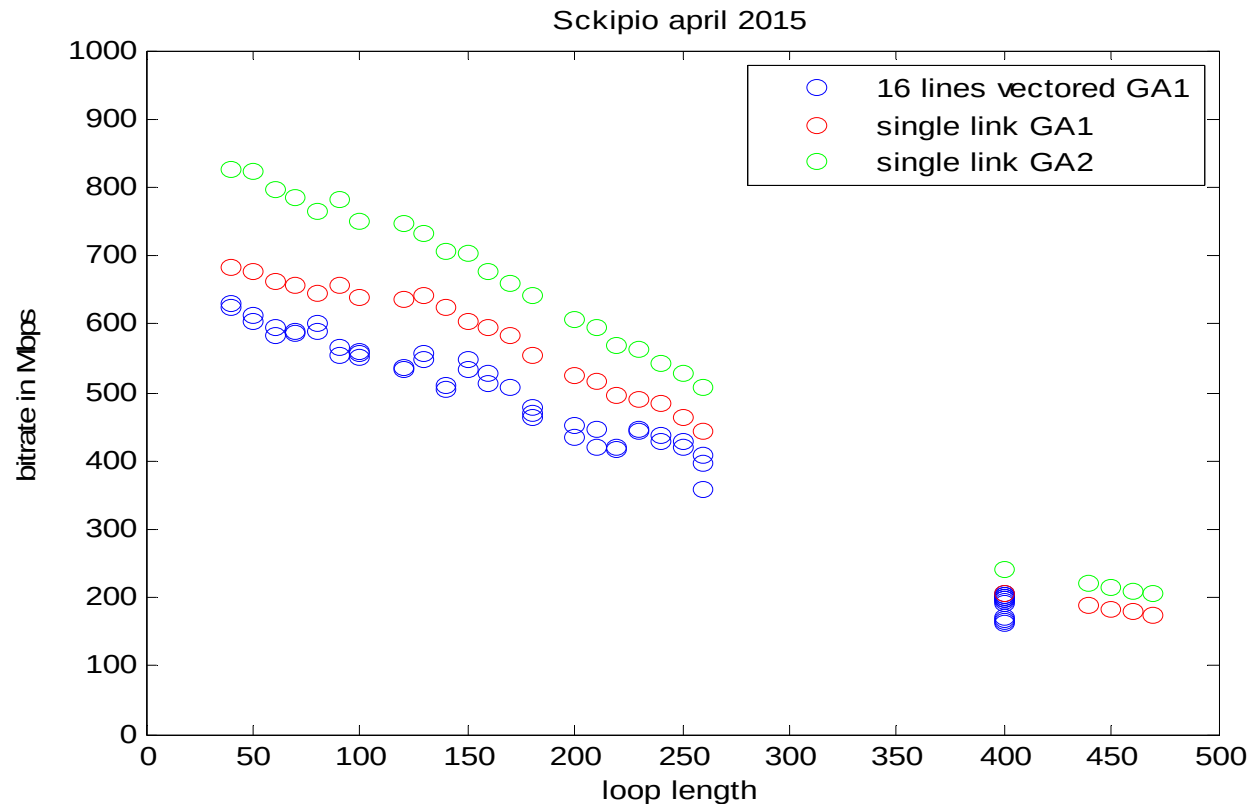


Observations so far (4 vectored lines):

- Vectored bitrate (4 lines) close to single-line performance
- Transmission feels already as pretty robust (for a prototype)
- Starts up rapidly (within seconds)
- G.fast performs much better as expected at loops above 250m

Comparing technologies: G.fast

TNO measurements on improved G.fast prototype (Q2/2015)



Observations so far (16 vectored lines):

- Again: vectored bitrate close to single-line performance
- Again: Very fast startup times
- G.fast outperforms VDSL/17a up to 450m
- Product upgrade during test à significant improvement

Comparing technologies: G.fast

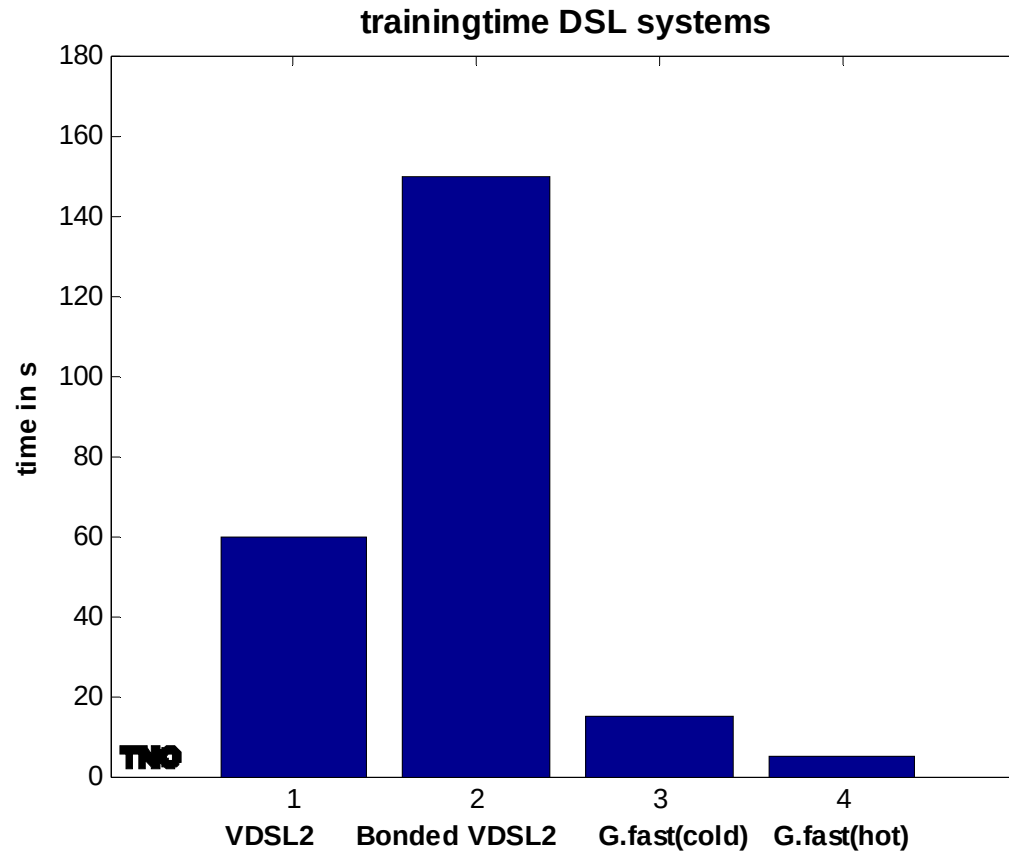
TNO measurements on G.fast prototype (Q2/2015)

First conclusion:

**G.Fast has significant
potential in Cabinet
deployments as well**

Comparing technologies: G.fast and VDSL/17a

TNO measurements on G.fast prototype, compared with VDSL/17a



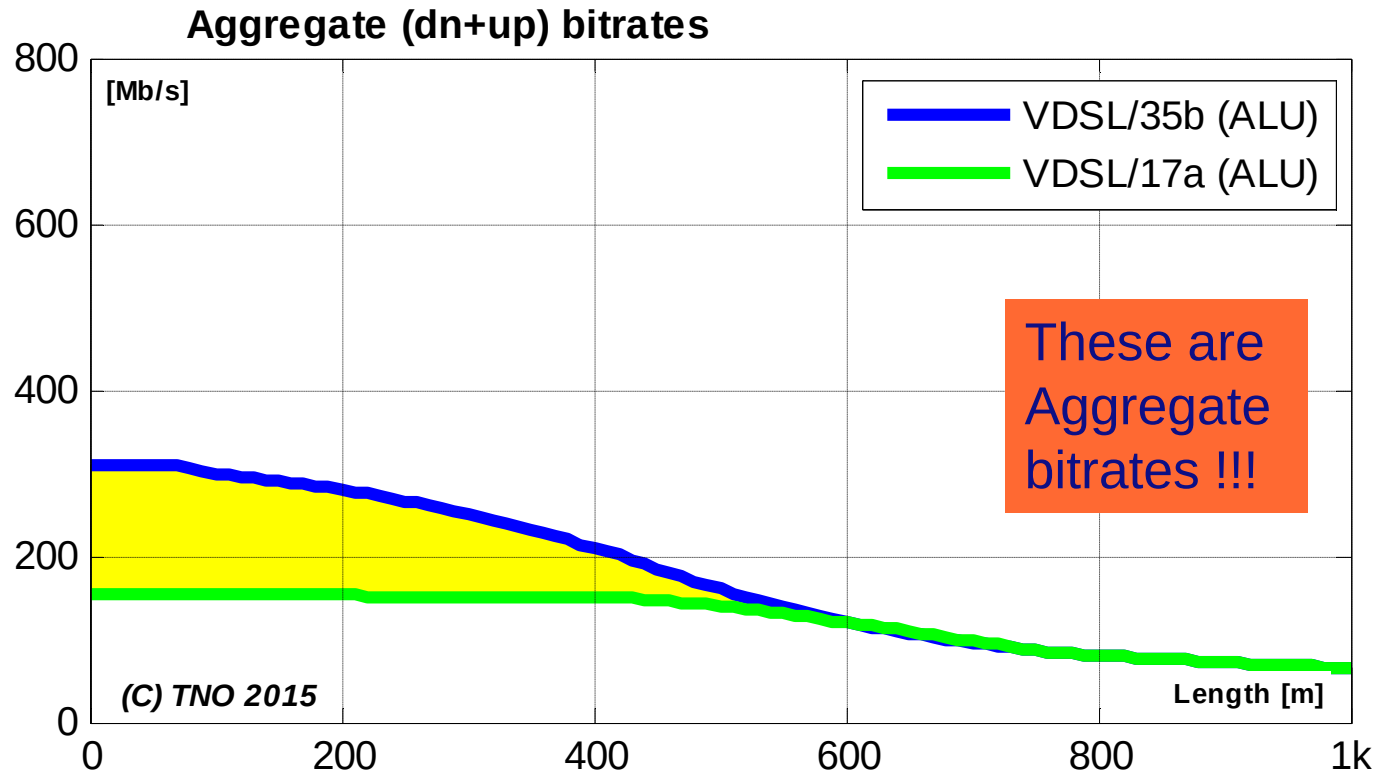
Start-up times (cold starts or after severe interruptions)

- G.fast starts-up in seconds!
- Much faster then we have seen for VDSL/17a
- Seems to be a fundamental difference between G.fast and VDSL

Comparing technologies: G.fast and VDSL/35b

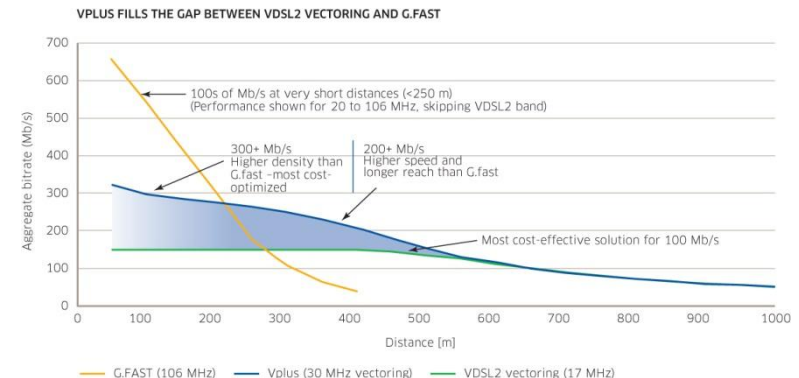
VDSL/35b equipment
not available yet

Comparing technologies: G.fast and VDSL/35b

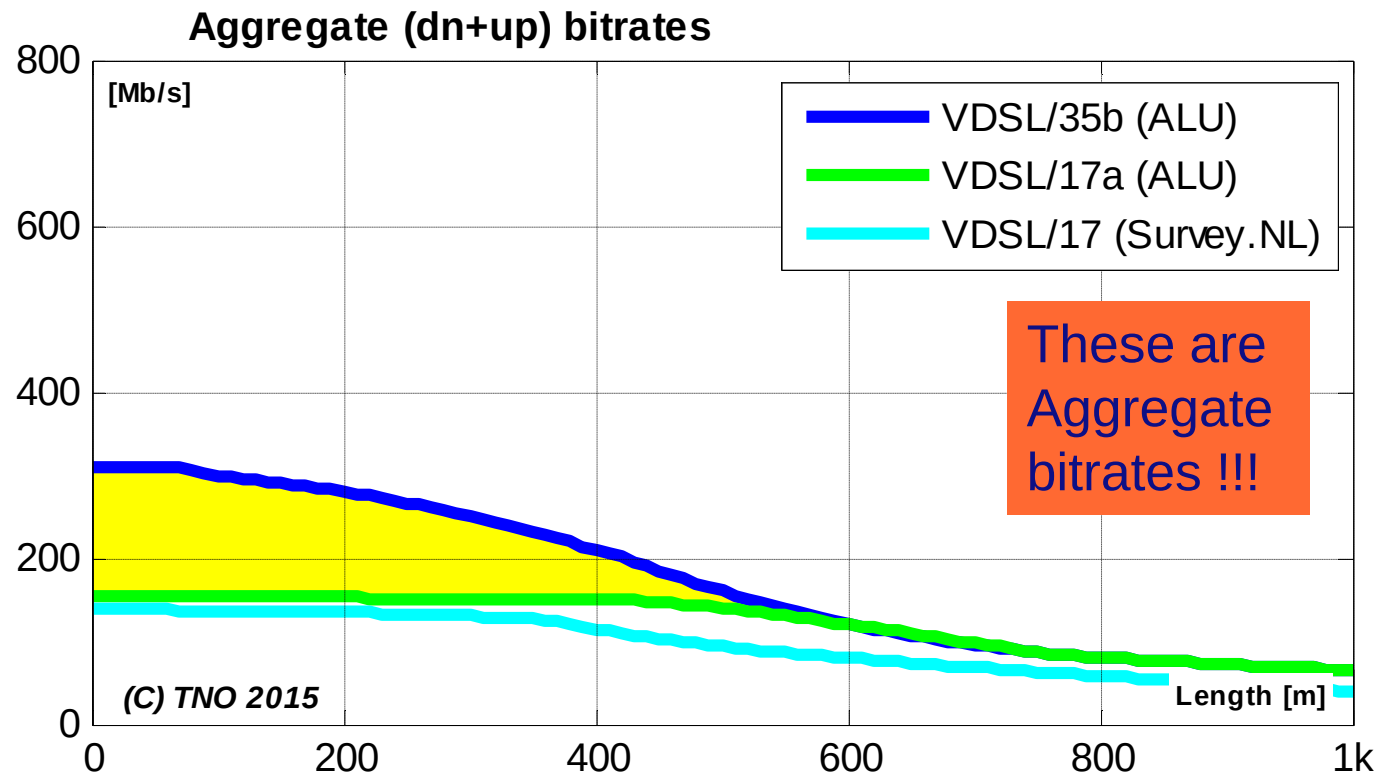


Aimed bitrates for VDSL/35b

- Bitrates found on ALU website (Russell, Spruyt, VanHastel; Oct 2014)
- Not yet tested by TNO



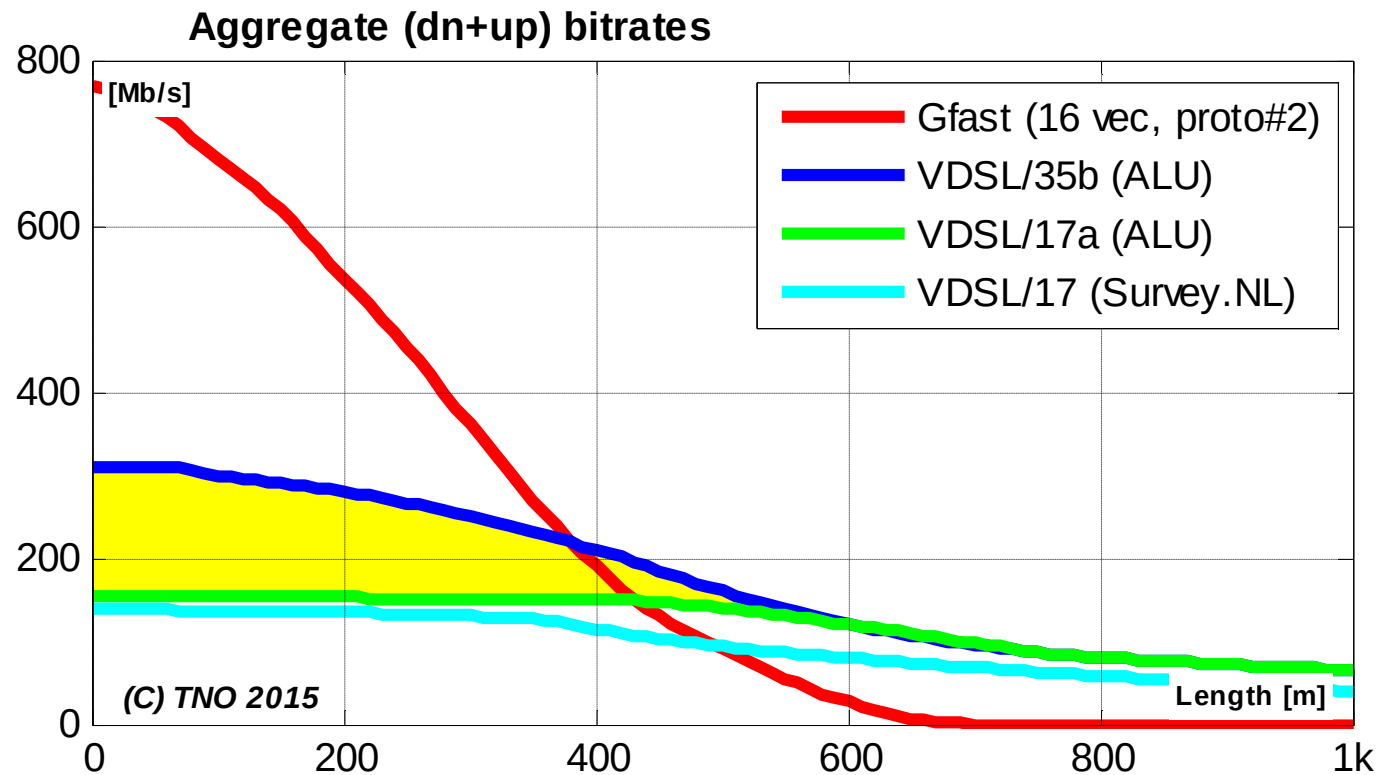
Comparing technologies: G.fast and VDSL/35b



Comparison with deployed VDSL/17a

- Survey of many operational VDSL/17a lines (vectored) in the Netherlands, as reference
- Aimed VDSL/35b rates plausible below 300m
- Aimed VDSL/35b rates optimistic above 350m

Comparing technologies: G.fast and VDSL/35b

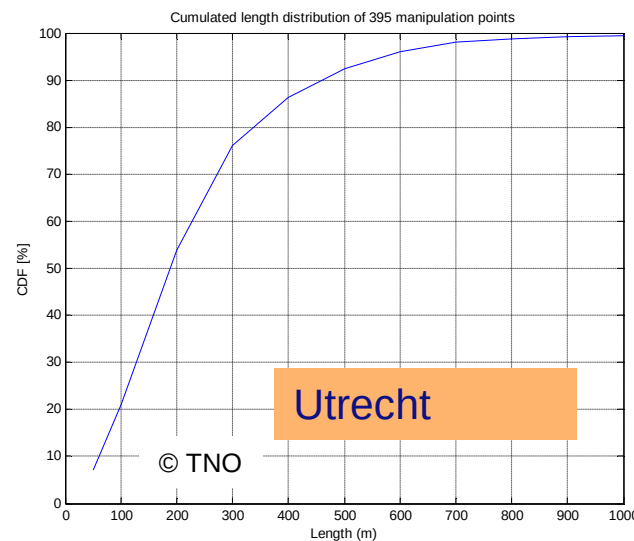
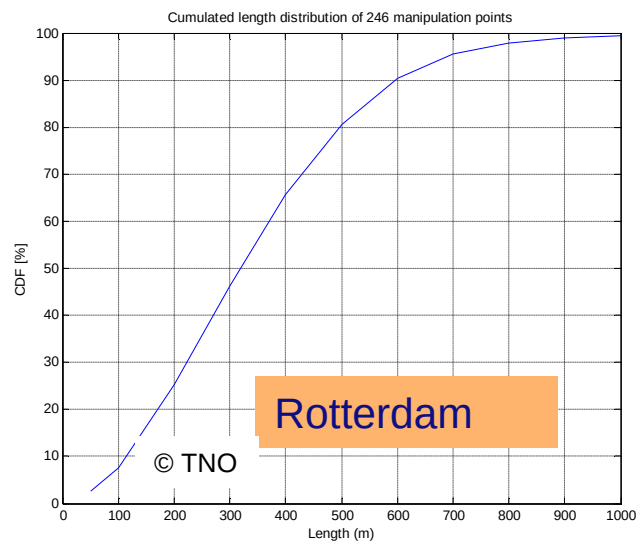
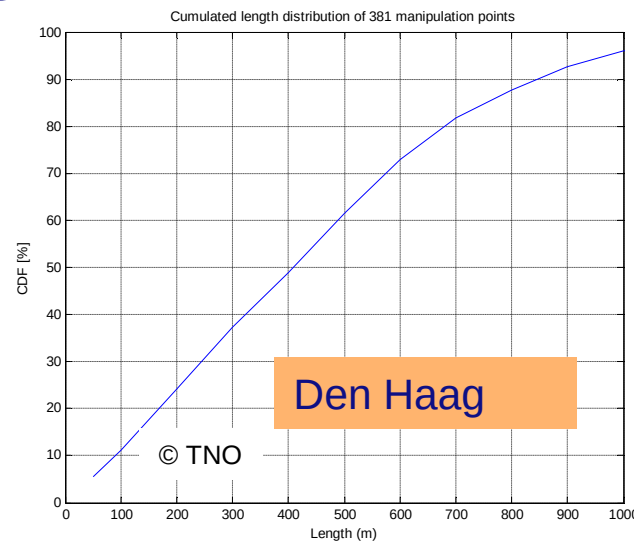
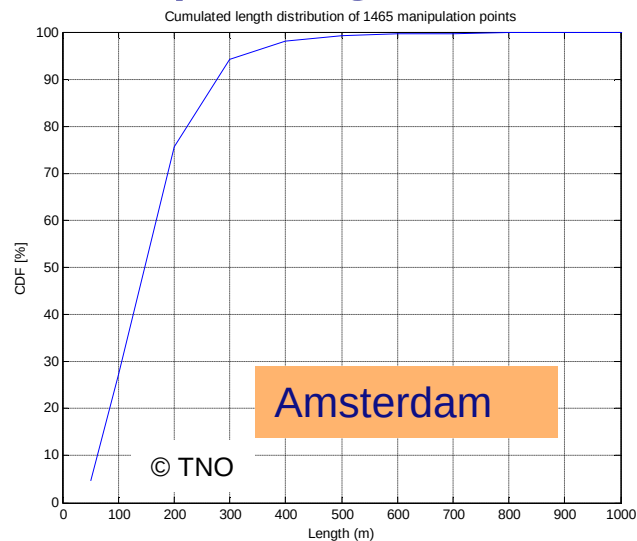


Comparison with G.fast measurements @ TNO

- G.fast easily outperforms VDSL/35b up to 350-400m

Q: How often do short loops occur in practice?

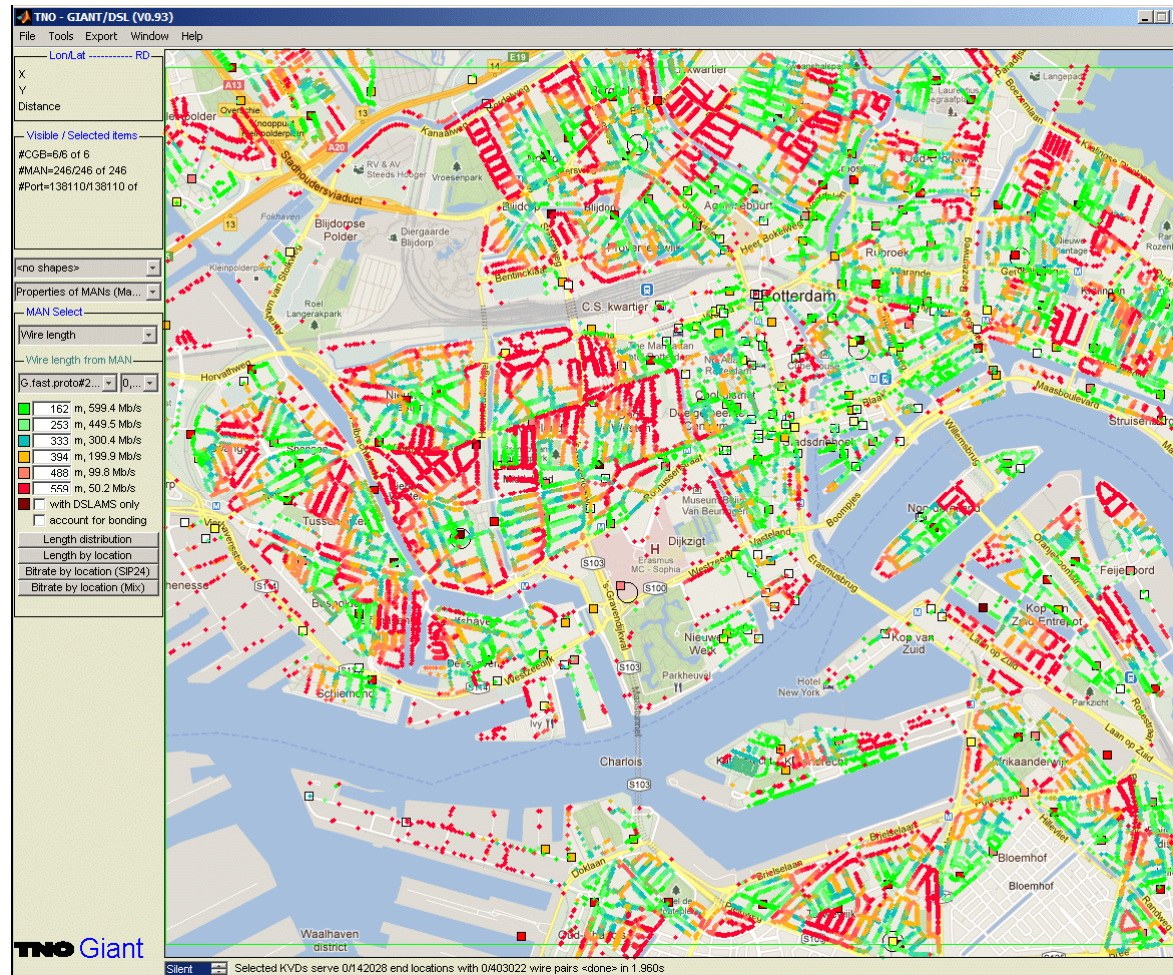
Comparing technologies: G.fast and VDSL/35b



Length distribution
beyond cabinets in
city centers

- Significant differences among cities
- Ranges from 95% to 37% within 300m for major cities in the Netherlands
- Technology optimum even different per street cabinet

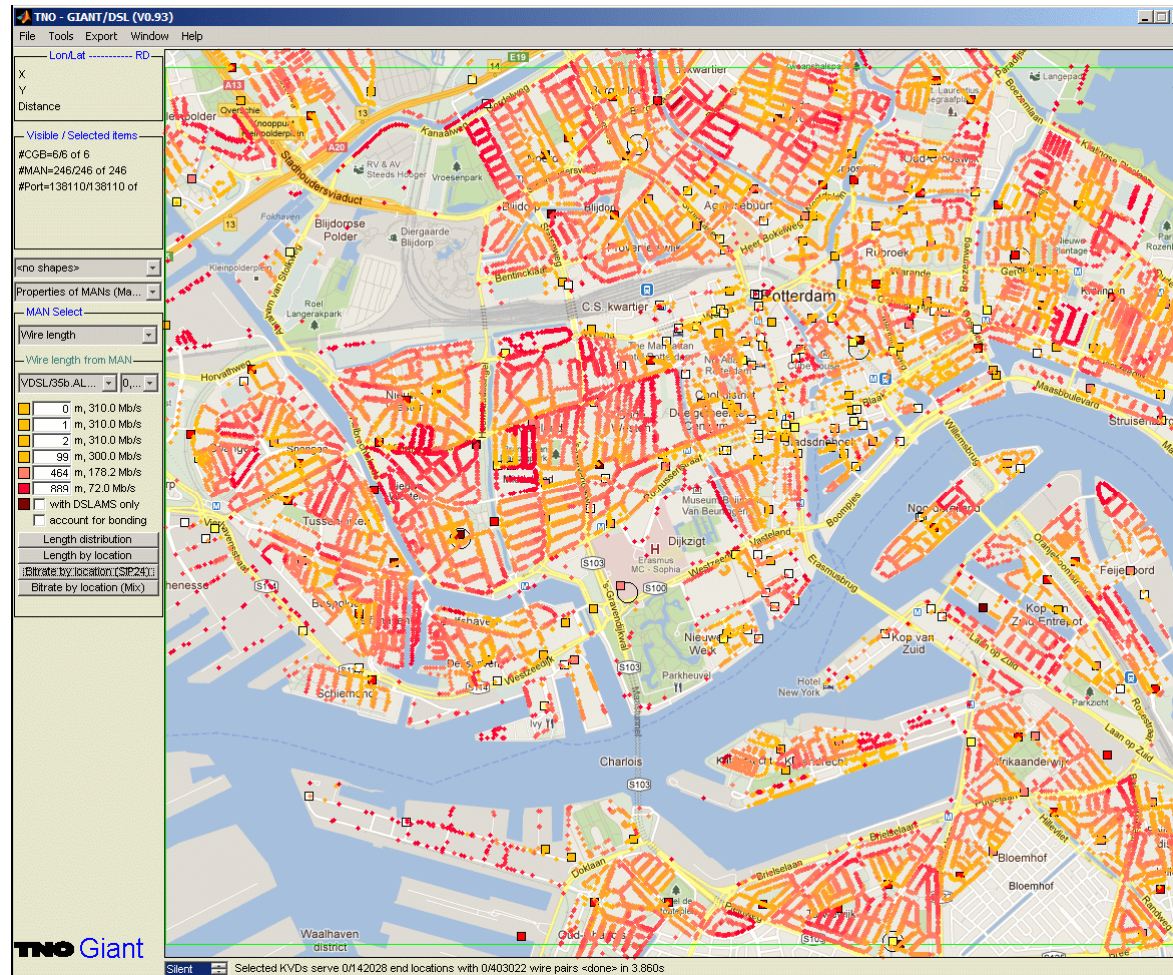
Comparing technologies: G.fast and VDSL/35b



Bitrate coverage
when deploying
G.fast from
cabinets

Large vector
groups required if
delivered to all
homes

Comparing technologies: G.fast and VDSL/35b



Bitrate coverage
when deploying
VDSL/35b from
cabinets

Large vector
groups required if
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Comparing technologies: G.fast and VDSL/35b

Optimum technology is location and ambition dependent and relies on how each of these technologies perform

G.Fast from current street cabinets	VDSL/35b from current street cabinets
à up to 106MHz, TDD	à up to 35MHz, FDD
à Coexistence issues with VDSL	à Aims to be compatible with VDSL/17
à Rapid start-up times (5..10 sec)	à Slower start-up times (VDSL>1min), bonded VDSL even >2.5 min observed
à First standard in dec 2014	à First standard still in progress
à 2014: prototypes (different vendors)	à Extension on mature technology
à Potential for many improvements	à Close to its final performance
à Can extend the value of copper for many years	à Quick solution for the short term, but restricts further frequency usage
à Technology for large vector groups still to be developed (>96 should be feasible)	à Technology for large vector groups available (>200 should be feasible)

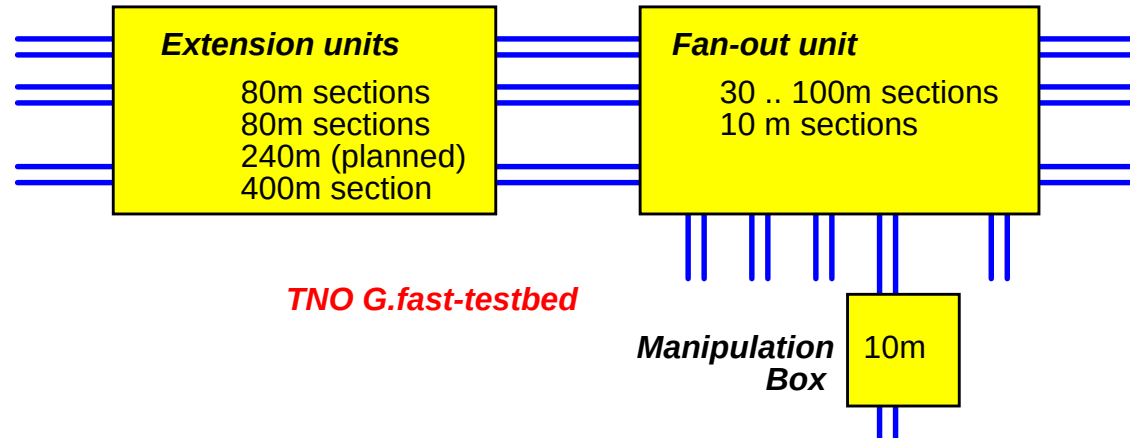
Comparing technologies: G.fast and VDSL/35b

Optimum technology is location and ambition dependent and relies on how each of these technologies perform

G.Fast from current street cabinets	VDSL/35b from current street cabinets
à up to 106MHz, TDD	à up to 35MHz, FDD
à Coexistence issues with VDSL	à Not compatible with VDSL/17
à Rapid start-up times (5..10 sec)	à Long start-up times (VDSL>1min), observed VDSL even >2.5 min observed
à First standard in deployment	à First standard still in progress
à 2014: prototype (100m/s)	à Extension on mature technology
à Potential for improvements	à Close to its final performance
à Can extend value of copper for many years	à Quick solution for the short term, but restricts further frequency usage
à Technology for large vector groups still to be developed (>96 should be feasible)	à Technology for large vector groups available (>200 should be feasible)

Benchmark the differences
via lab measurements

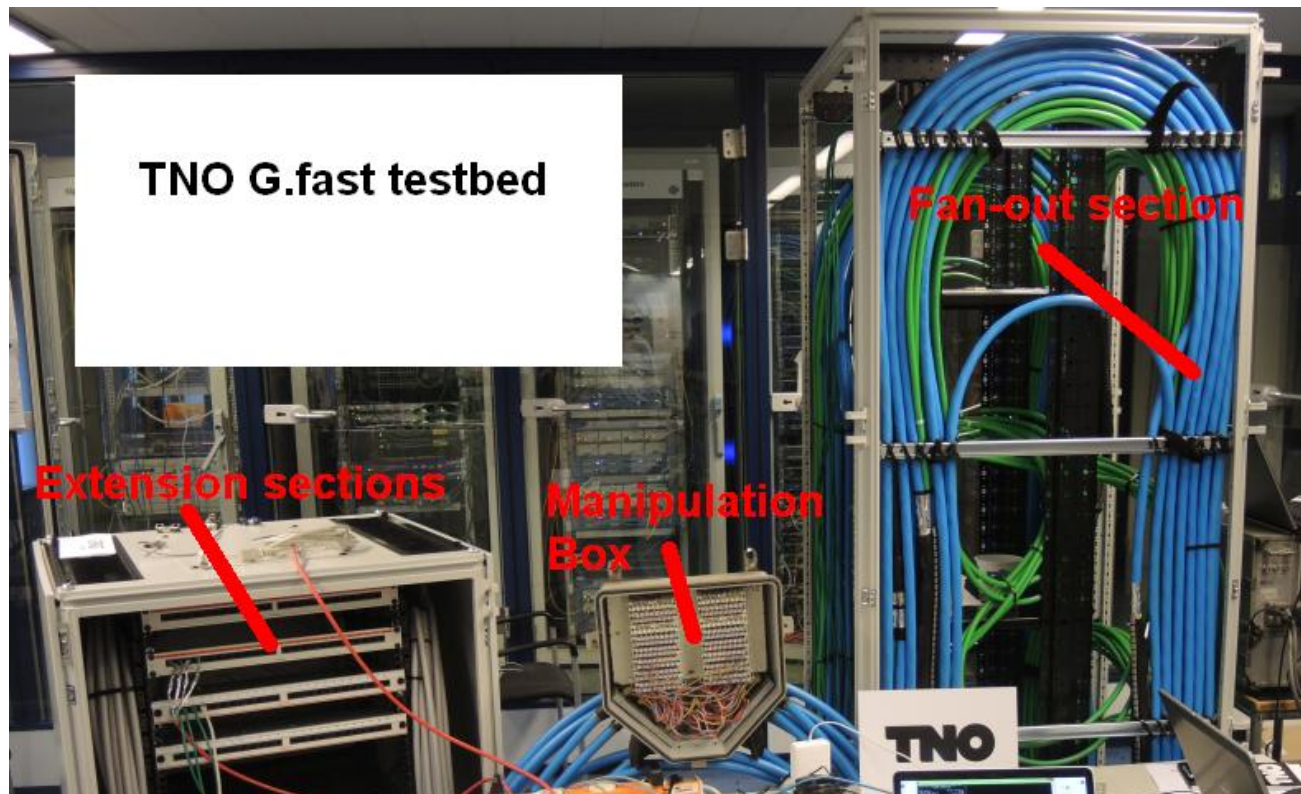
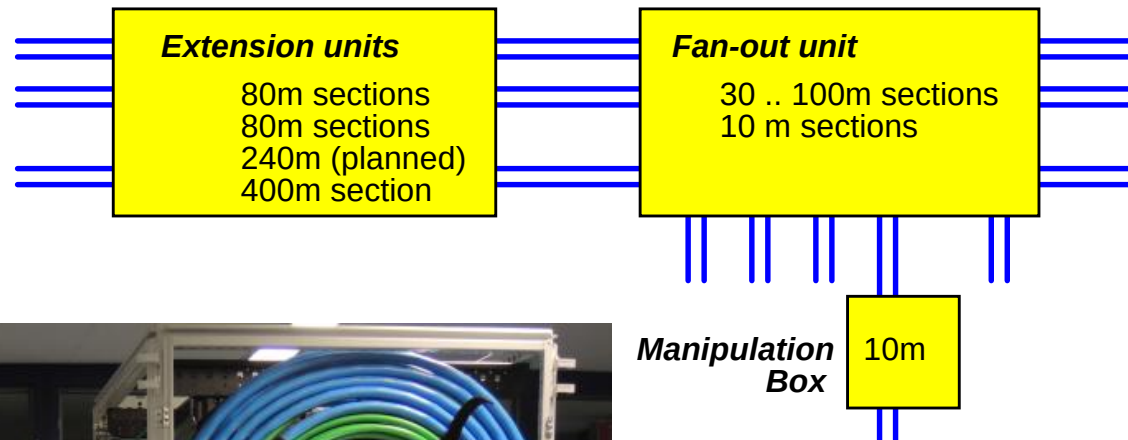
Benchmarking DSL: TNO G.fast Test bed



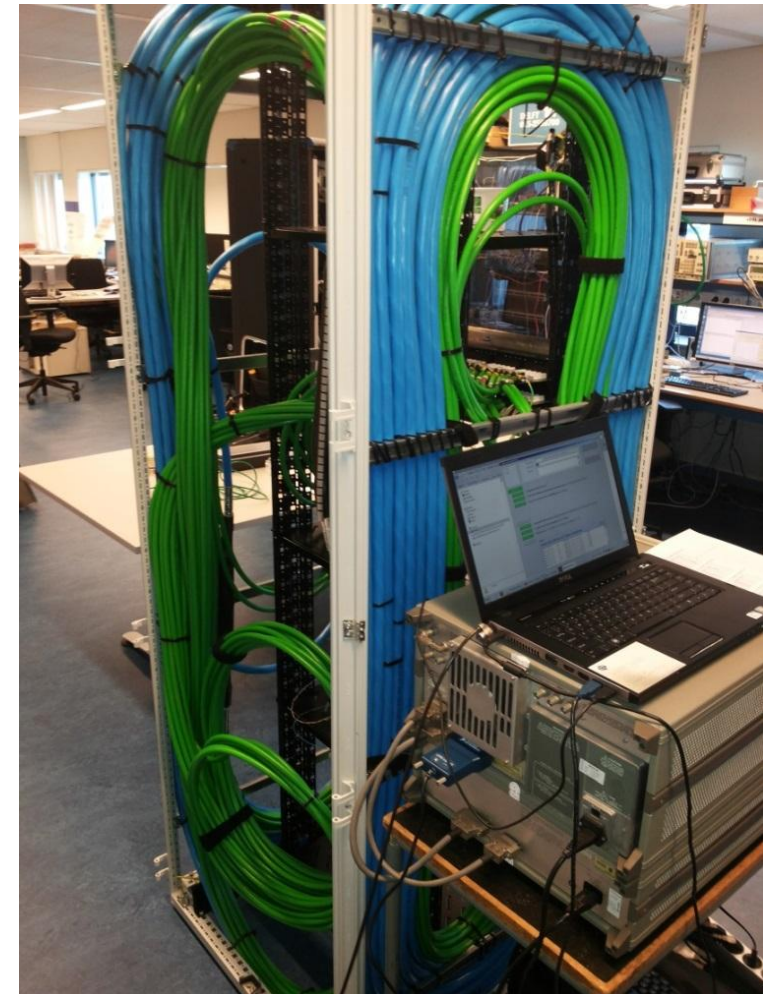
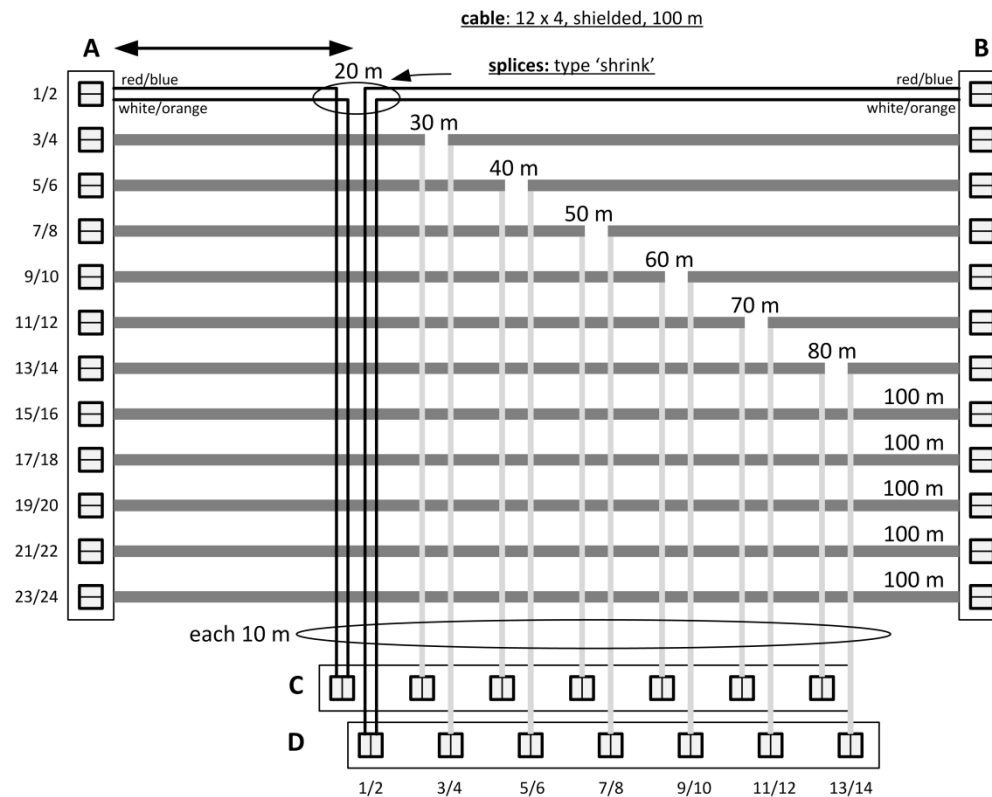
High level overview

- **Based on real cables**
 - Currently: 30-500m range, in discrete steps
 - 12 quads per cable = 24 wirepairs
 - All cables are shielded
- **Mimics reality in several ways:**
 - Crosstalk from customers at different locations
 - Reflections from splices can be added
 - Reflections from waterstops included (typically 2-4m)
 - Reflection from manipulation boxes can be added
 - Others (like bridgetaps) may be added in future

Benchmarking DSL: TNO G.fast Test bed



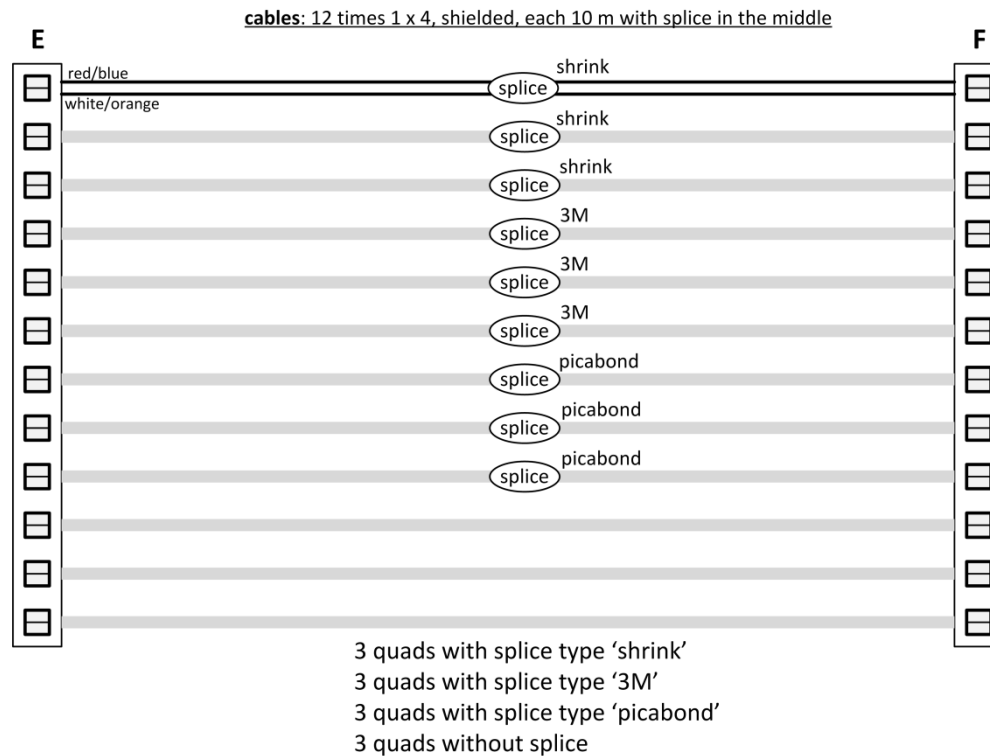
Benchmarking DSL: TNO G.fast Test bed



Fan-out unit

- 30-100m in 10m steps
- Crosstalk from customers at different locations

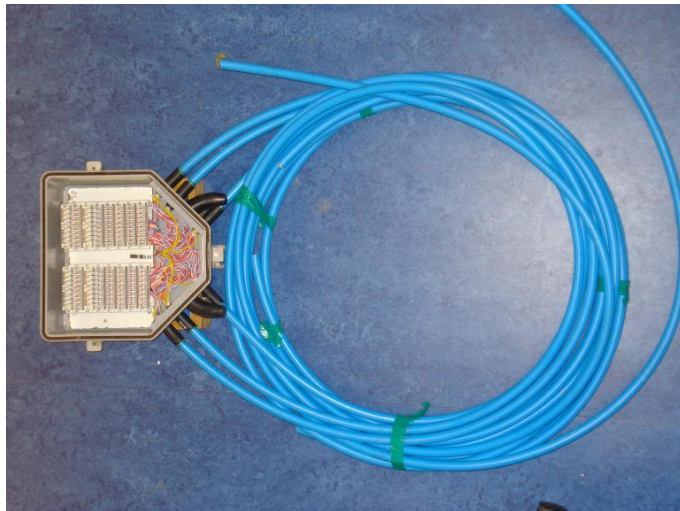
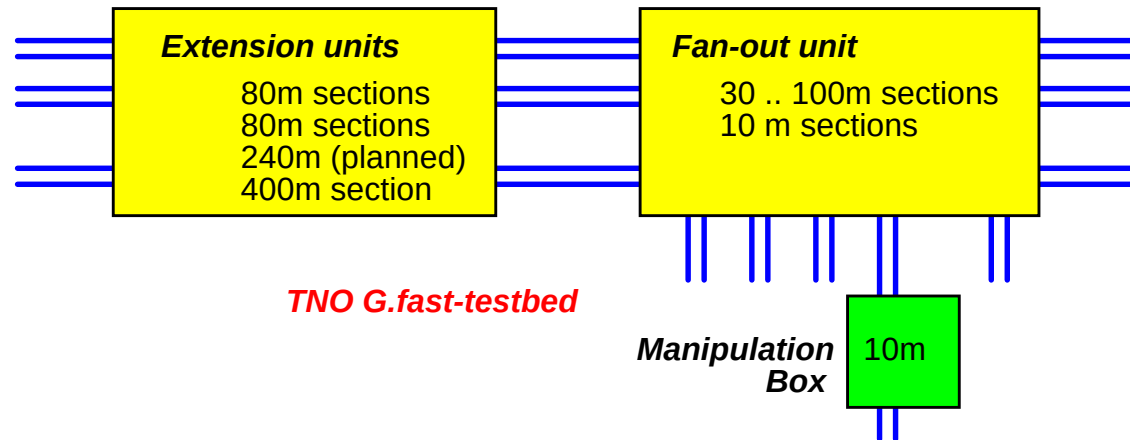
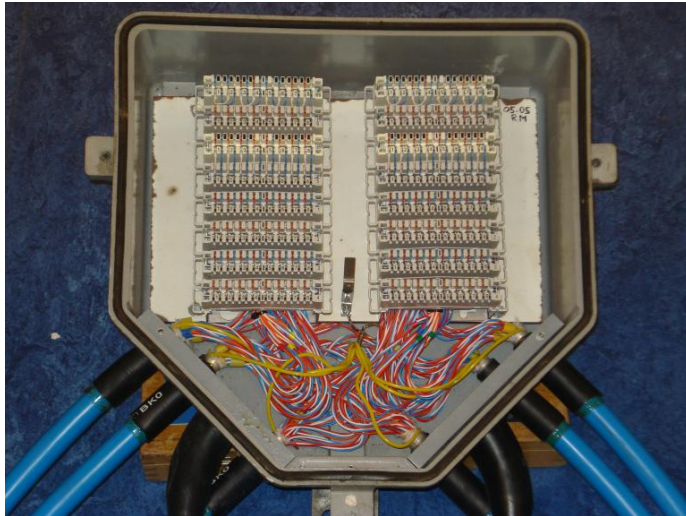
Benchmarking DSL: TNO G.fast Test bed



Fan-out unit, addition of splices

- 10m sections, with/without splices
- Different splice types

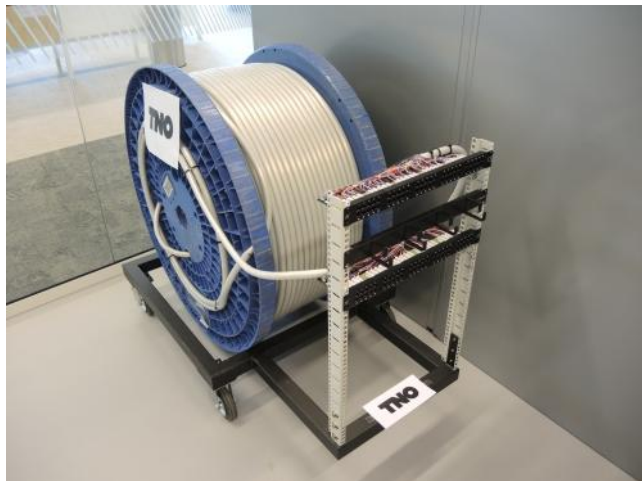
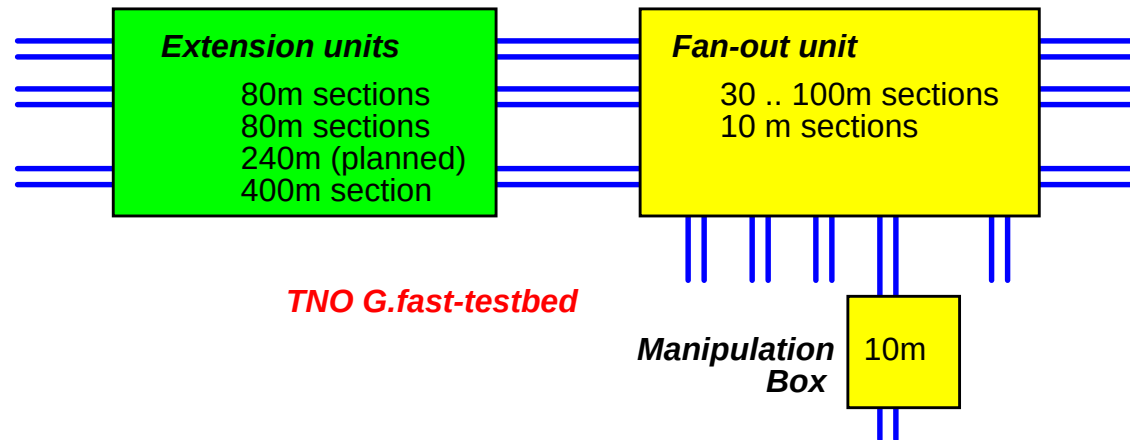
Benchmarking DSL: TNO G.fast Test bed



Manipulation box

- Cross connects near customers

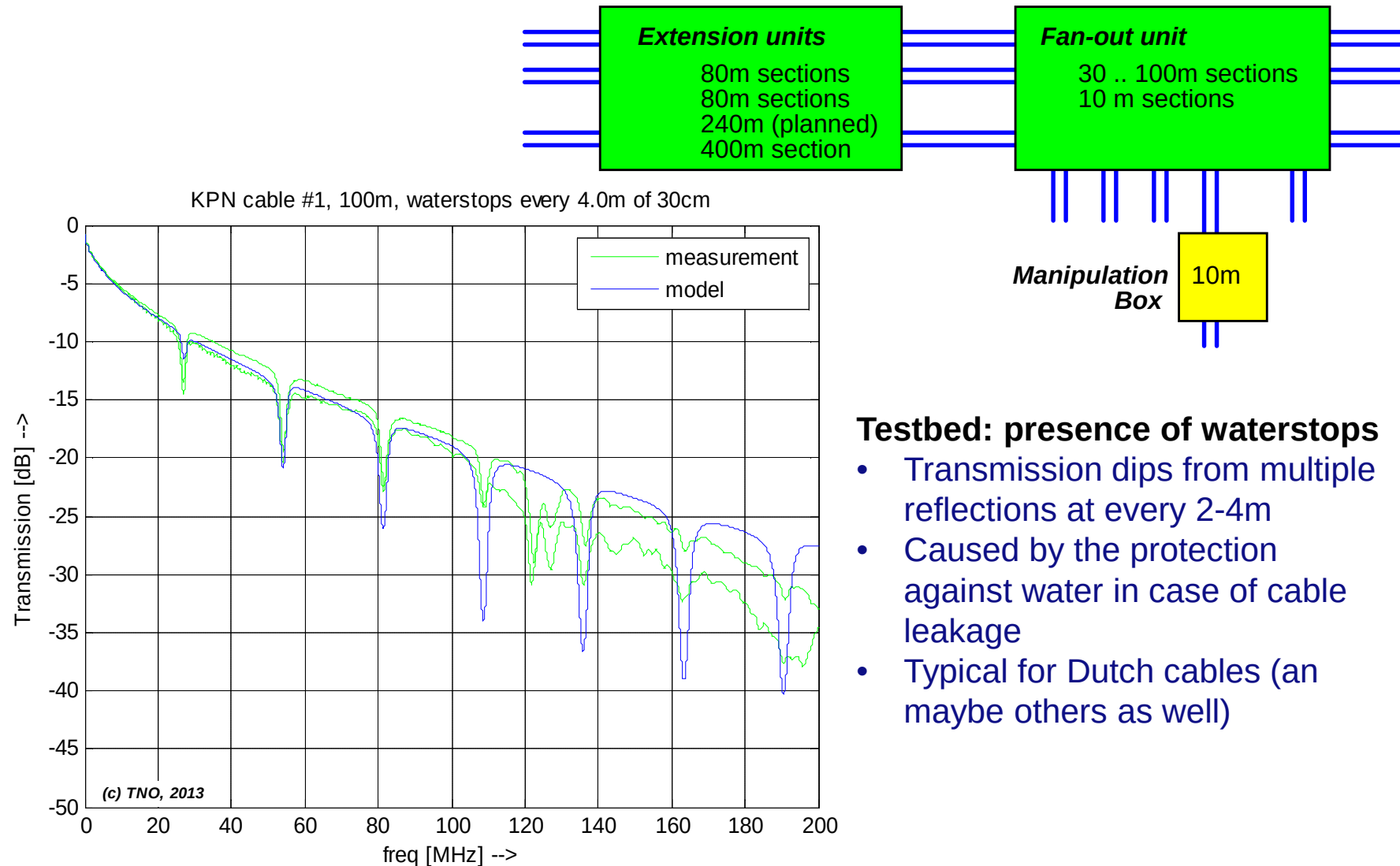
Benchmarking DSL: TNO G.fast Test bed



Extension unit

- Multiple cascable sections
- 12 quads, crosstalk from 11 or 23 customers
- Reflections from waterstops

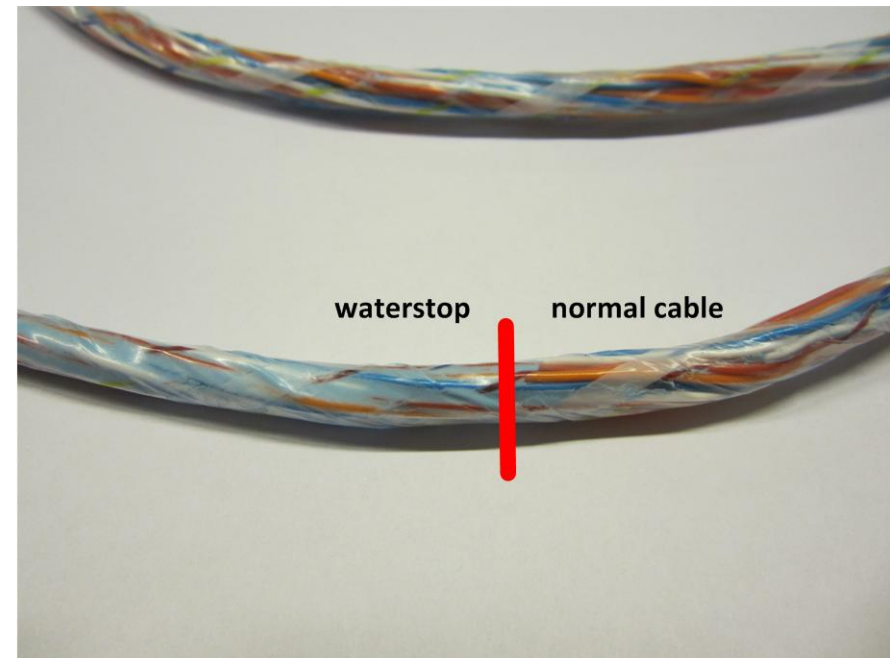
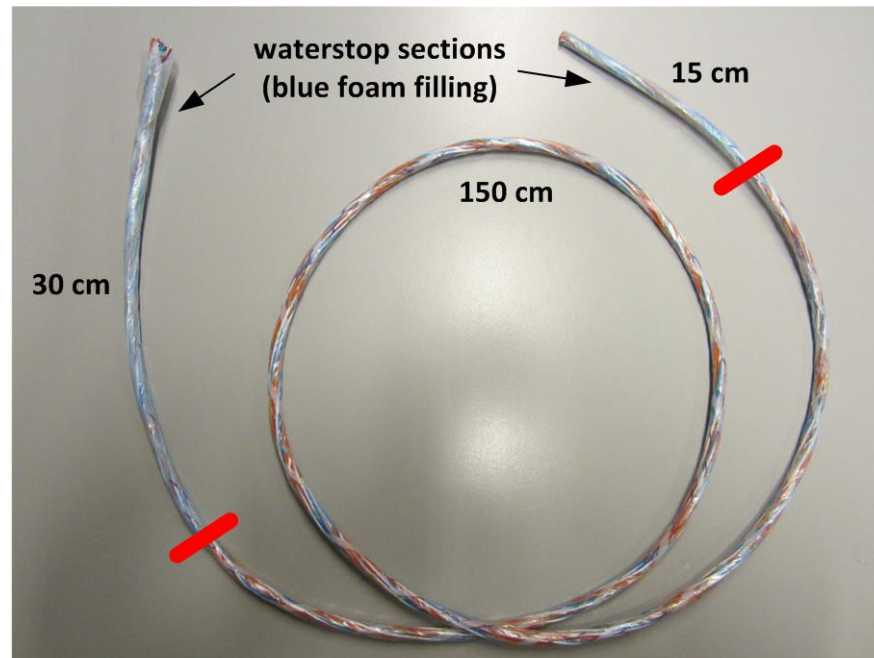
Benchmarking DSL: TNO G.fast Test bed



Testbed: presence of waterstops

- Transmission dips from multiple reflections at every 2-4m
- Caused by the protection against water in case of cable leakage
- Typical for Dutch cables (and maybe others as well)

Benchmarking DSL: TNO G.fast Test bed

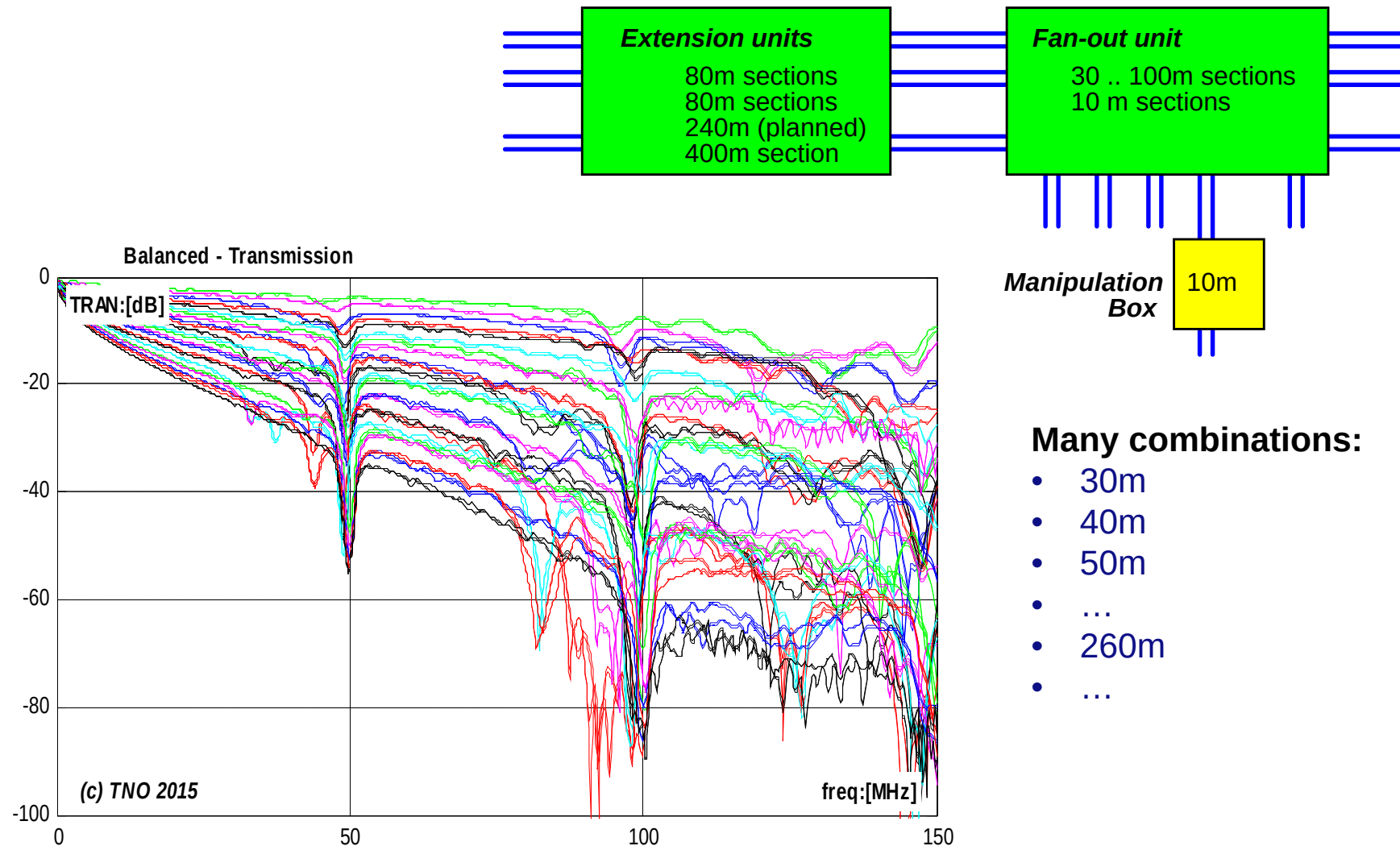


waterstop section is **at least** 30 cm, so center distance between waterstops is **at least** 180 cm

Testbed: inclusion of waterstops

- Transmission dips from multiple reflections at every 2-4m
- Caused by the protection against water in case of cable leakage
- Typical for Dutch cables (and maybe others as well)

Benchmarking DSL: TNO G.fast Test bed



Many combinations:

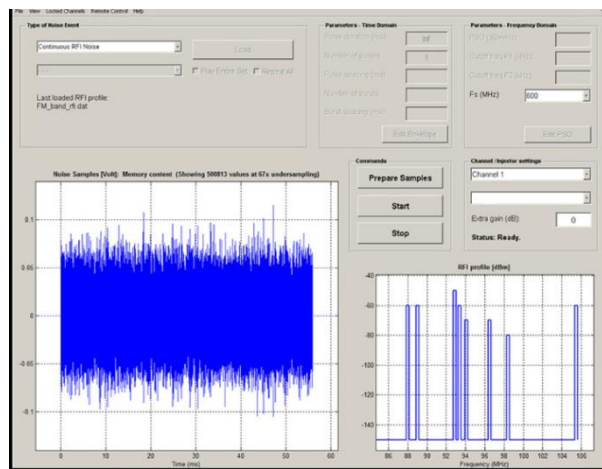
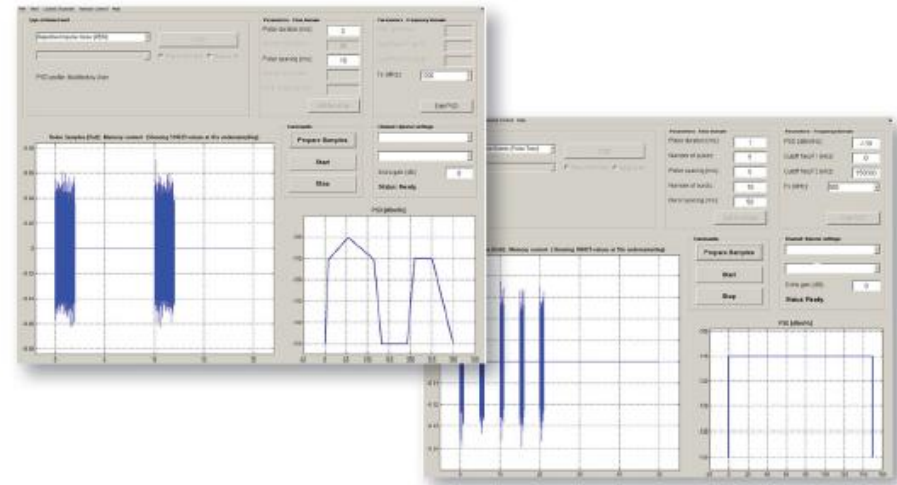
- 30m
- 40m
- 50m
- ...
- 260m
- ...

Benchmarking DSL: You also need to inject noise

Copper loops alone are not enough,

You also need to generate noise
(full *G.fast band*)

- Stationary noise (to mimic Alien disturbance)
- RFI noise (to mimic radio interference)
- Impulse noise (real world measurements)
- Noise injection unit



TNO has developed this all for G.fast frequencies

- We offers benchmarking as a service
- Our G.fast noise generation technology can also be obtained from Spirent (DLS 5900)

Conclusions

Discussed options for broadband deployment in dense city areas

- Results from lab trials with first G.fast prototypes:
 - Aggregate bitrates already above 700-500Mb/s, within 0-200m.
 - Fast start-up times, vectoring already up to 16 lines, progressing well.
 - G.fast performs much better than expected: usable up to even 450m.
 - G.fast bitrate outperforms VDSL/35b bitrate within 350m.
- Loop length from cabinets are often short in dense city areas:
 - Ranges from 95% to 37% within 300m for a few major cities in NL.
 - Both G.fast and VDSL/35b are good candidates within this reach.
 - Preference depends on much more than just bitrate:
max vector size, compatibility with legacy, investments vs ambition, robustness, start-up time, etc
- Benchmarking essential part of choosing what technology:
 - To stress a modem under realistic and different conditions (testbed, noise, ..)
 - To identify the maturity, limitations and true capabilities of a technology.

Using G.fast from existing street cabinets has significant potential



For more information about G.fast,
join us at ultrafastbroadband.nl

