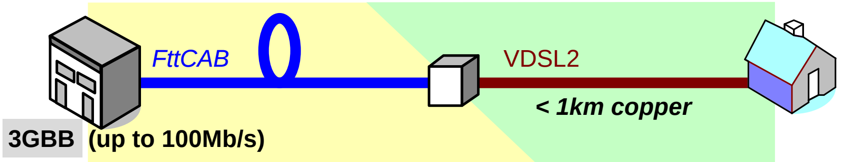
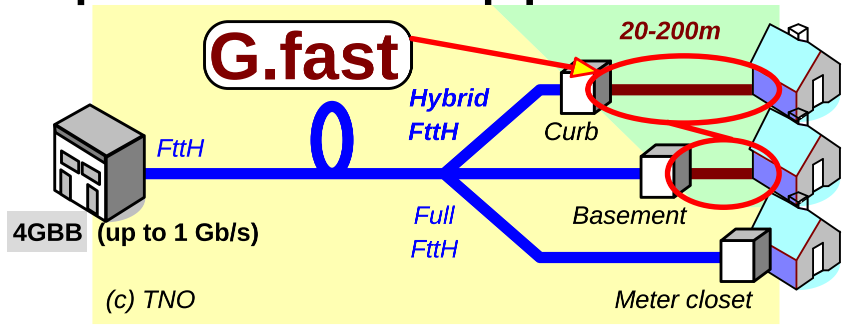
Deploying G.fast from existing streetcabinets in dense city areas

Where to use G.fast and where VDSL/35b

Rob F.M. van den Brink – TNO

Higher bitrates? à different options for copper





Compatible with the legacy	Start with something new
Extent existing VDSL, and accept all restrictions from VDSL	New product standard, and design according to state of the art
Same management system, same procedures à easy to introduce	New concept à Less easy to introduce
Offers limited improvements	Offers significant improvements
Compatible with VDSL + vectoring	Incompatible with VDSL
à **VDSL/35b** (up to 35 MHz) *branded as Vplus, Super Vectoring,*	à **G.Fast** (up to 106MHz)
Typically up to ~1000m	Typically up to ~200m range
Aims at 300 Mb/s (>200Mb/s)	Aims at 1 Gb/s (>500Mb/s)

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

(*made available via 4GBB consortium*)

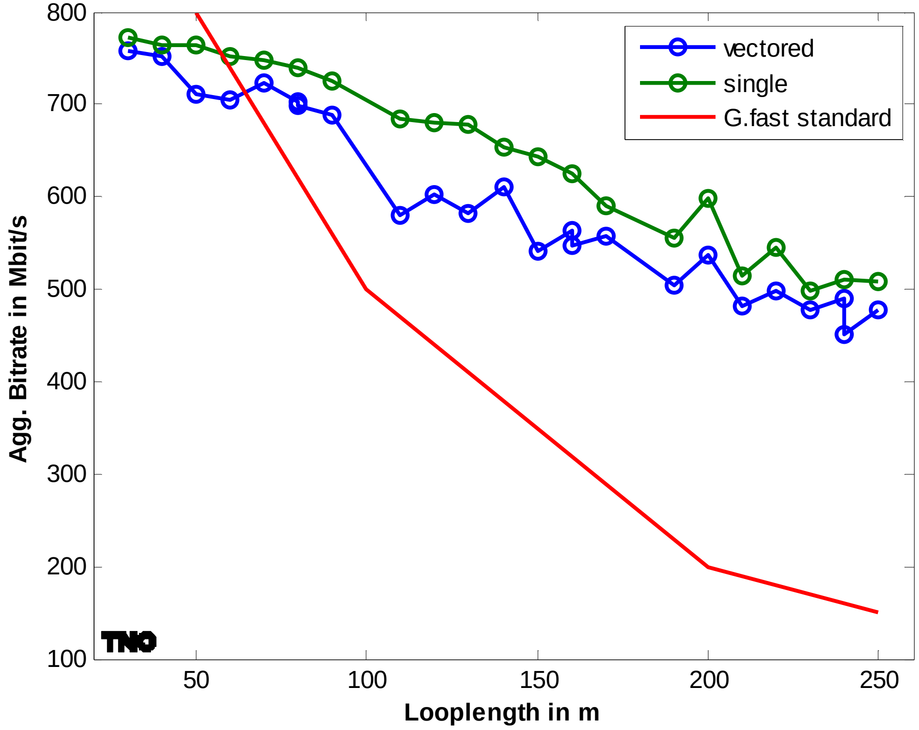
Sckipio at TNO

4GBB
HFCC/G.fast

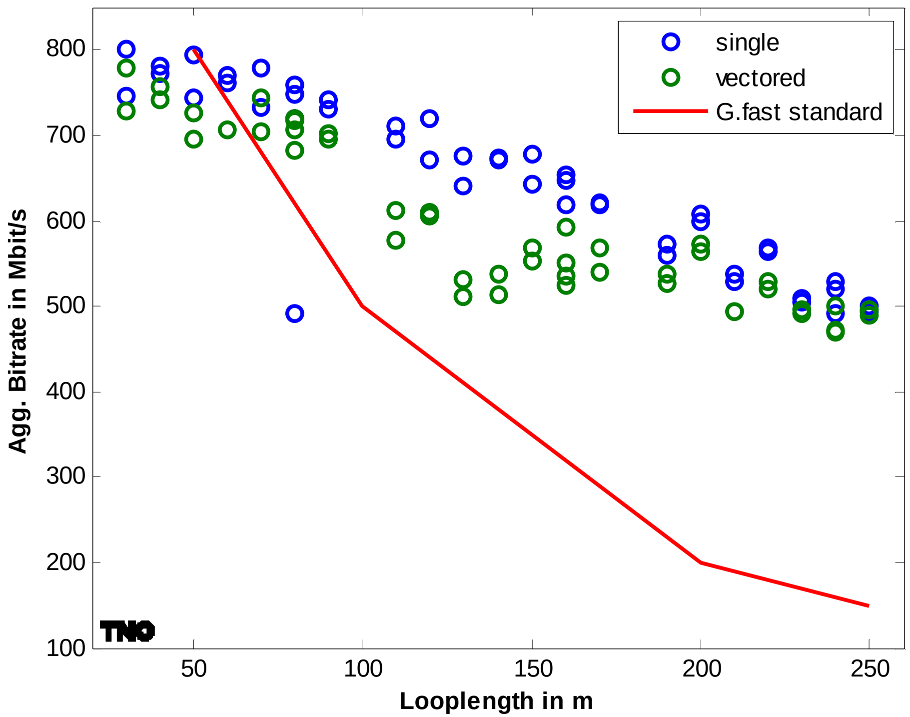
Comparing technologies: G.fast

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

Vendor 1



Vendor 2



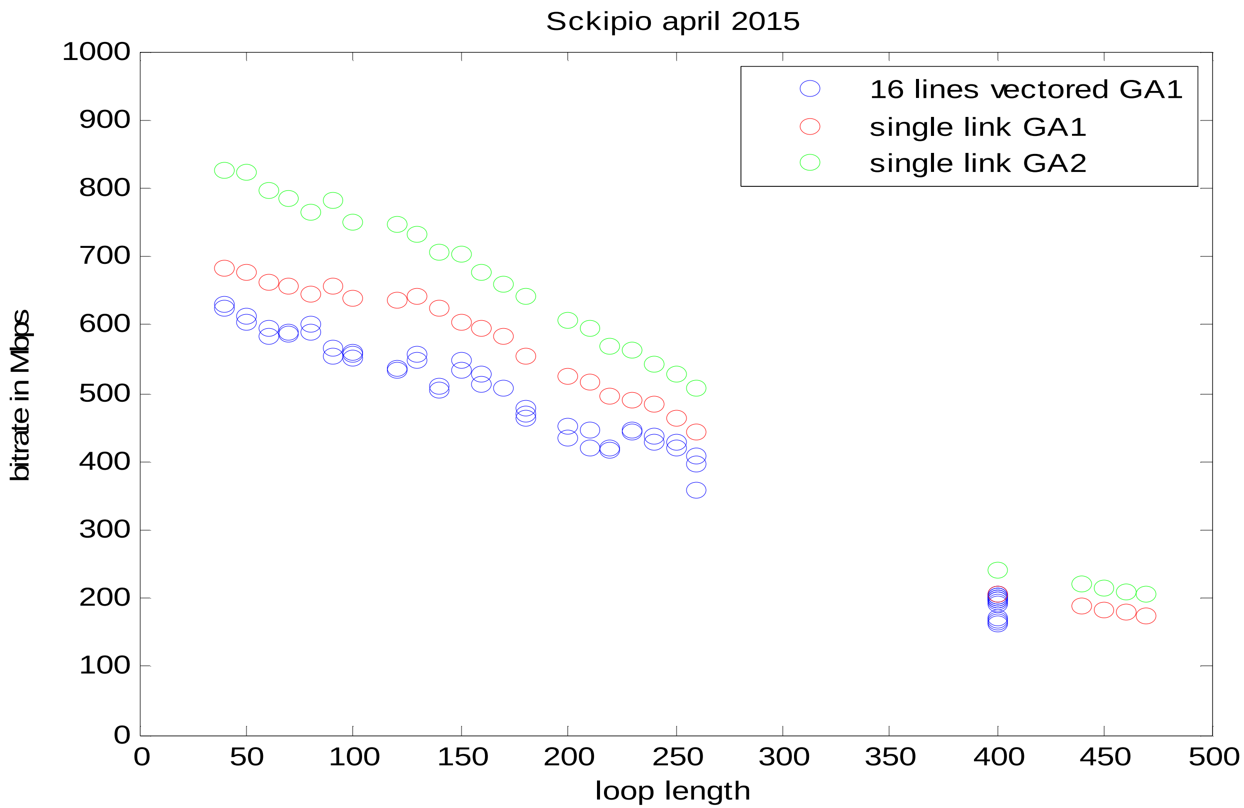
Observations so far (4 vectored lines):

- 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

4GBB HFCC/G.fast

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

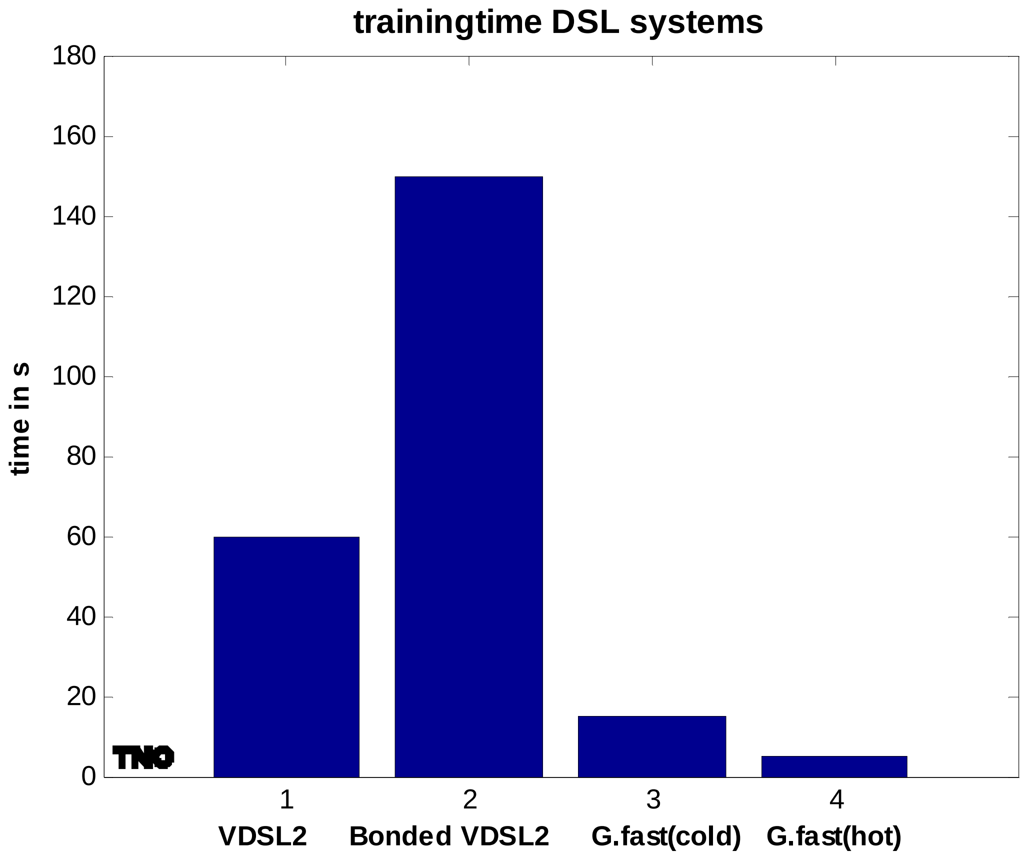
TNO measurements on G.fast prototype (Q2/2015)

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 interuptions)

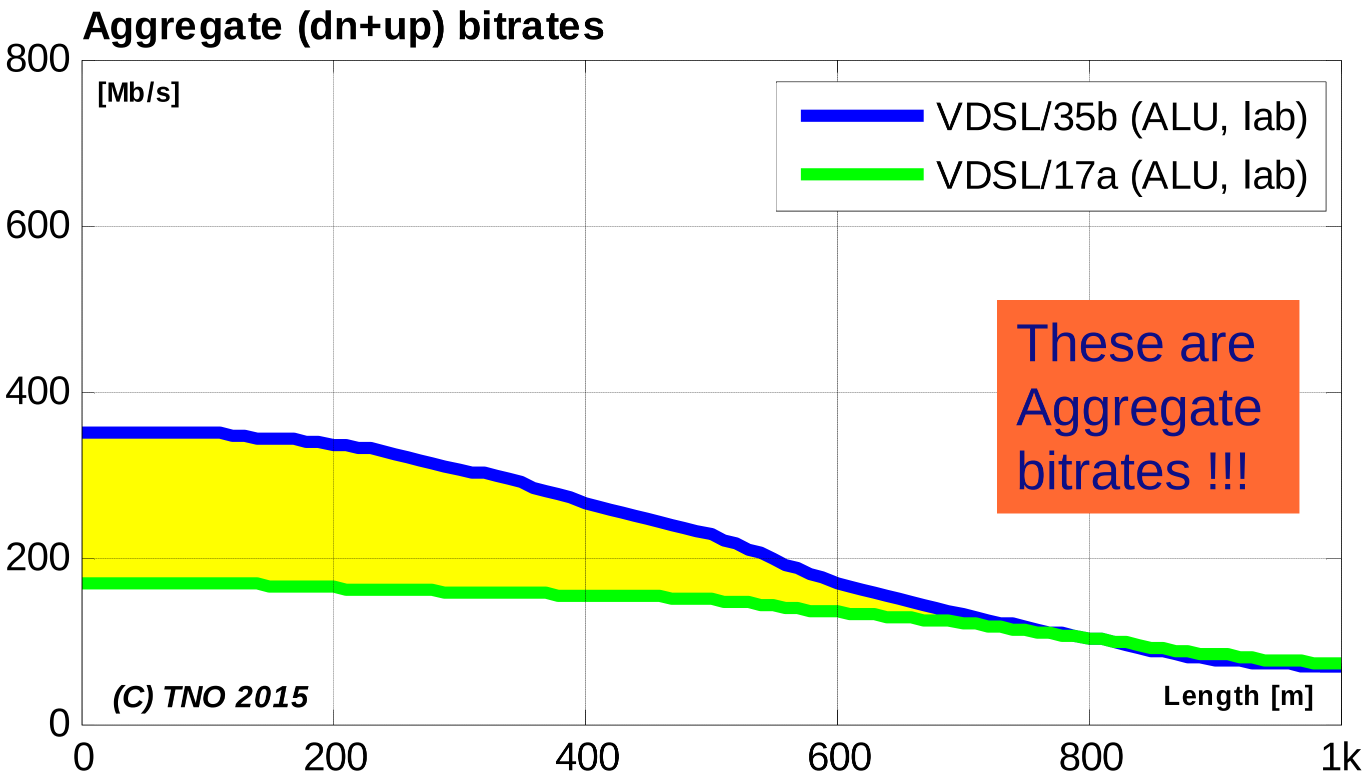
- G.fast starts-up in seconds!
- Much faster then we have seen for VDSL/17a
- This is related to the higher sync symbol rate of G.fast (fundamental difference with VDSL)

Comparing technologies: G.fast and VDSL/35b

VDSL/35b equipment not available yet for testing @ TNO

Measurement not yet public either

Comparing technologies: G.fast and VDSL/35b

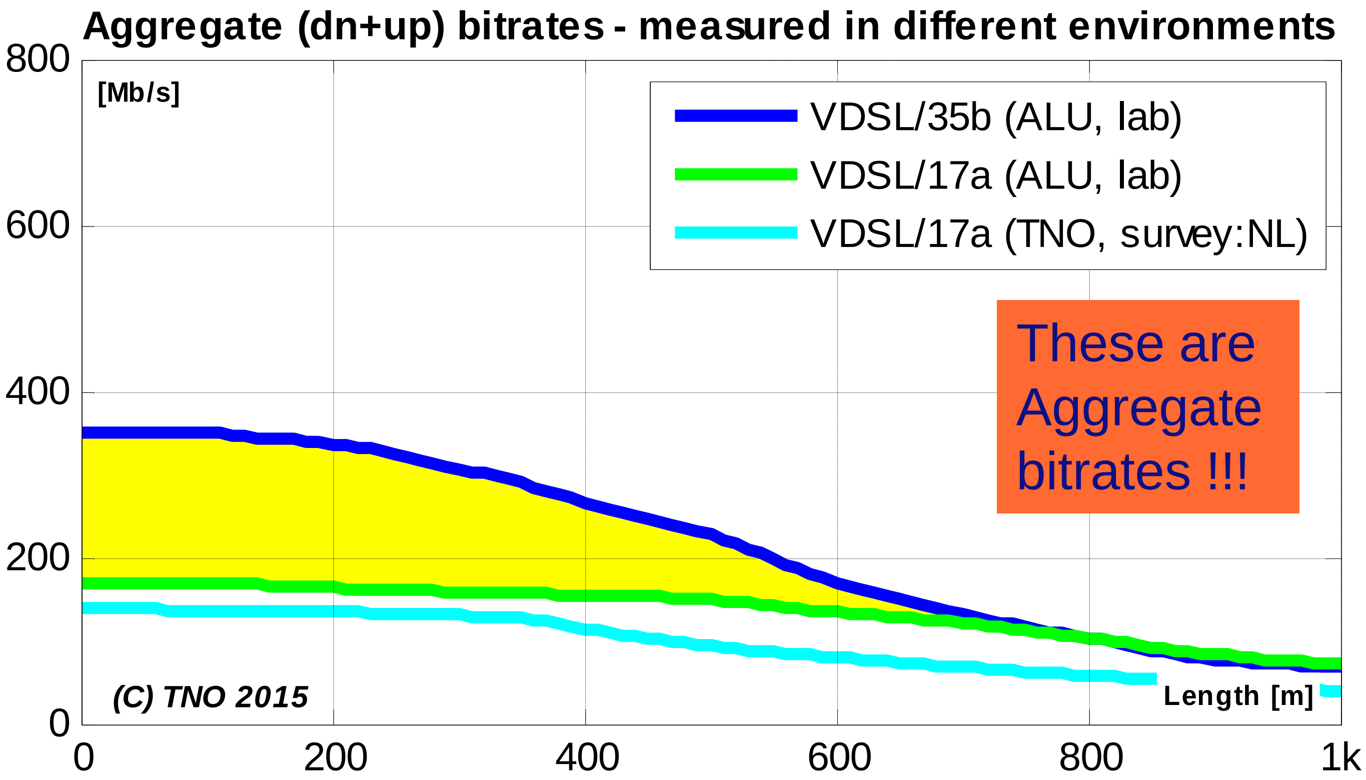


Measured lab bitrates for VDSL/35b

- VDSL/35b lab rates measured by ALU
- VDSL/17a lab rates measured by ALU (*made available via 4GBB consortium*)

4GBB GOLD/G.fast

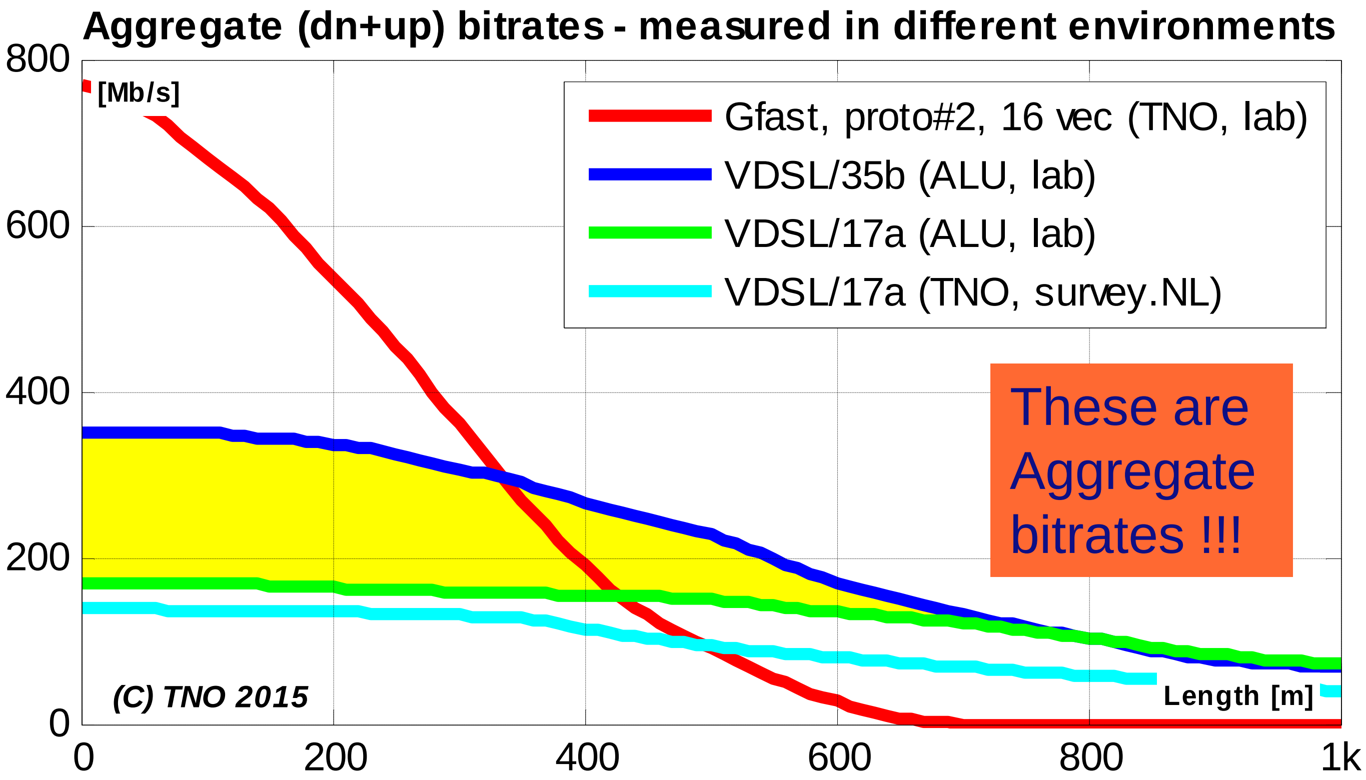
Comparing technologies: G.fast and VDSL/35b



Measured lab bitrates for VDSL/35b, compared with measured field rates

- VDSL/35b lab rates measured by ALU
- VDSL/17a lab rates measured by ALU
- VDSL/17a field rates based on 180k operational lines, variety of Dutch cables
- VDSL/17a field rates indicate how lab results may ***scale*** to field performance
- Lab rates above ~350m may be too optimistic compared to field rates

Comparing technologies: G.fast and VDSL/35b

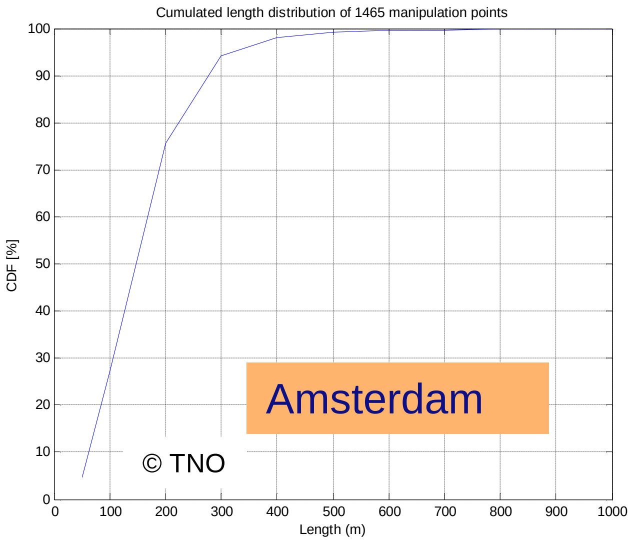


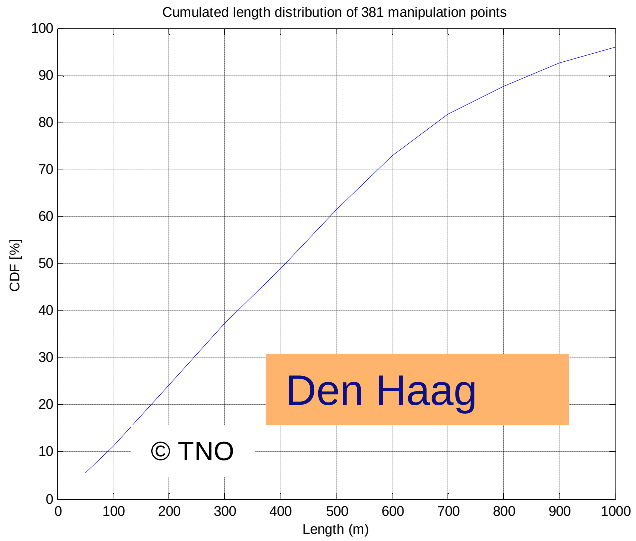
Measured bitrates for G.fast and VDSL/35b

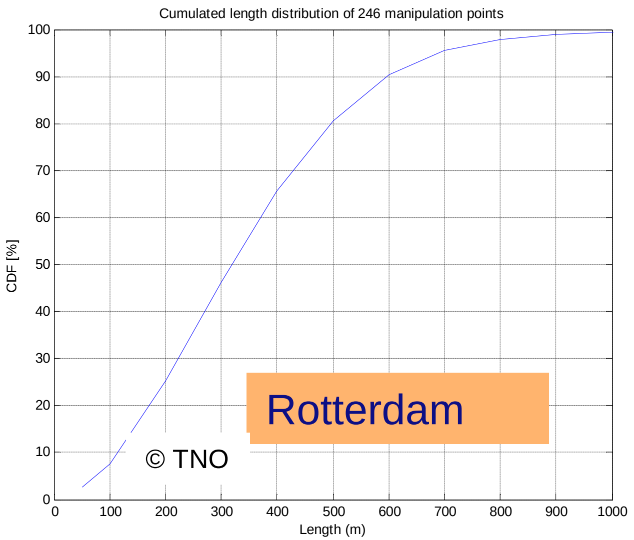
- G.fast lab rates easily outperform VDSL/35b lab rates on loops up to ~350m
- VDSL/17a field rates indicate how lab results may scale to field results
- Lab rates above 350m may be too optimistic compared to field rates (G.fast & VDSL)

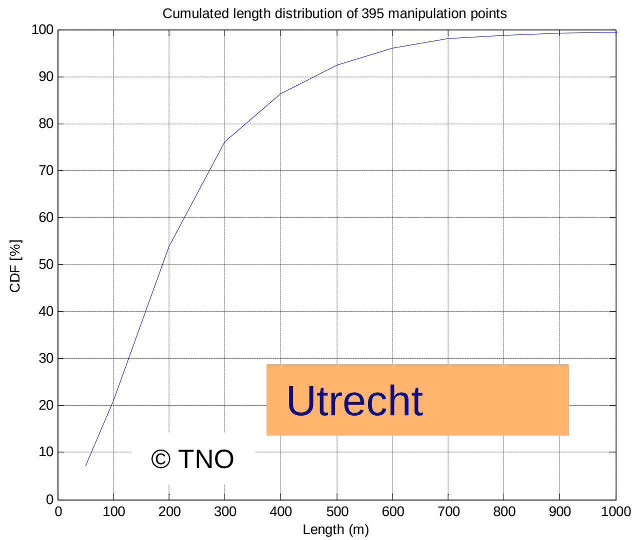
Q: How often do short loops occur in practice?

Comparing technologies: G.fast and VDSL/35b





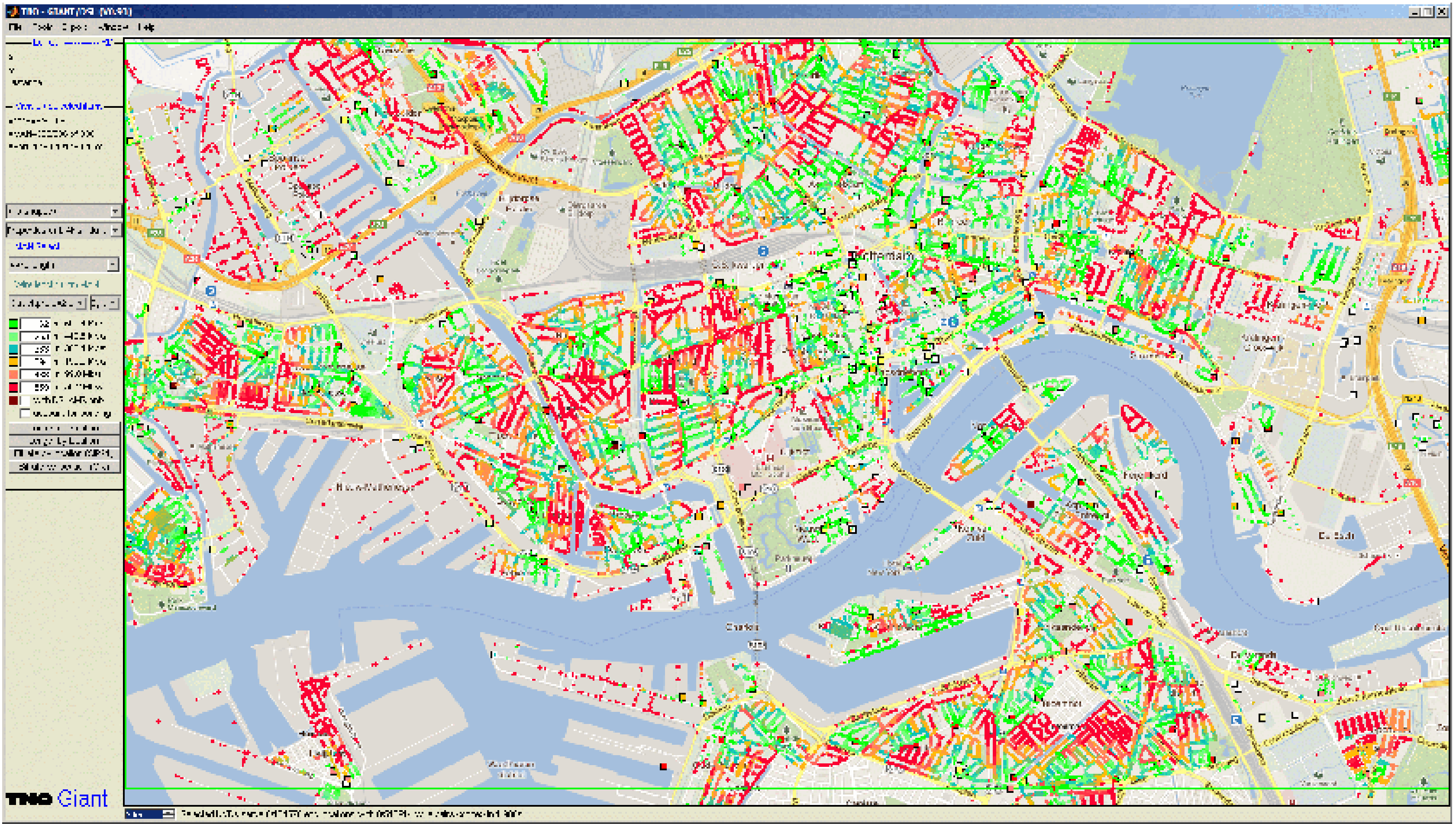




Length distribution beyond cabinets in city centers

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

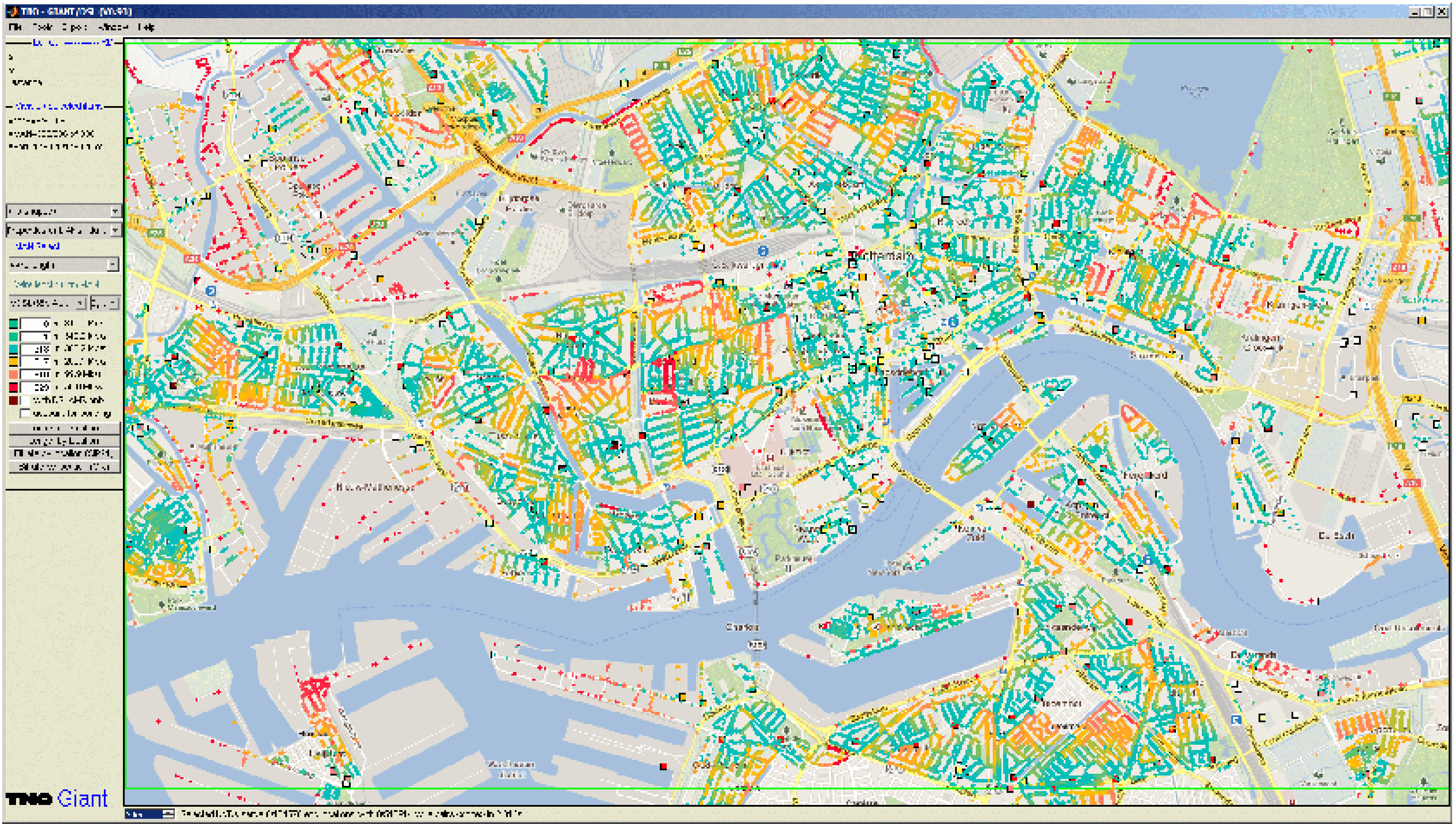
Comparing technologies: G.fast and VDSL/35b



Extreme example #1: (aggregate bitrates)

- Bitrate coverage when deploying only G.fast from cabinets
- Large vector groups required if delivered to ***all*** homes

Comparing technologies: G.fast and VDSL/35b



Extreme example #2: (aggregate bitrates)

- Bitrate coverage when deploying only VDSL/35b from cabinets
- Large vector groups required if delivered to *all* homes

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 Consent in ITU expected in feb 2016
à 2014: prototypes (different vendors)	à Extension on mature technology
à Potential for many improvements on both short and long reach	à No Further outlook beyond annex Q in G.993.2
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)

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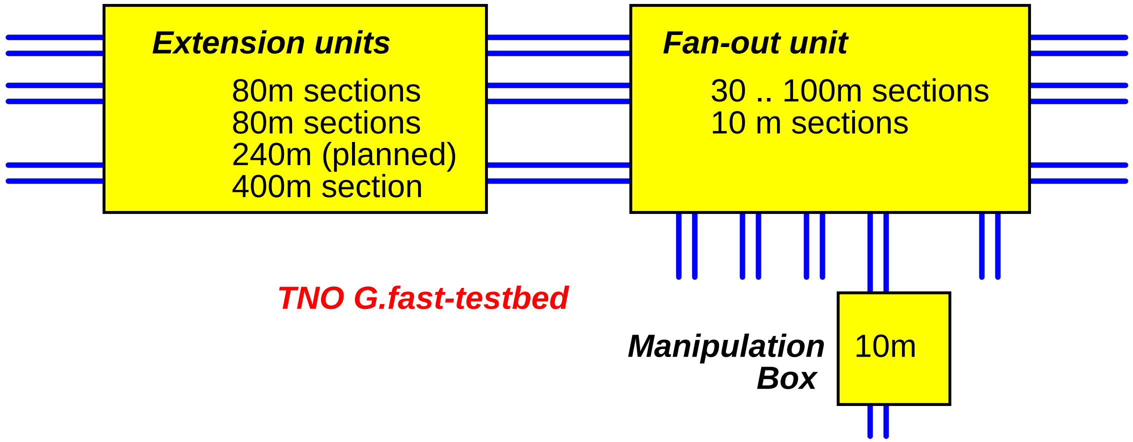
Benchmark the differences via lab measurements

Benchmarking DSL: TNO G.fast Test bed

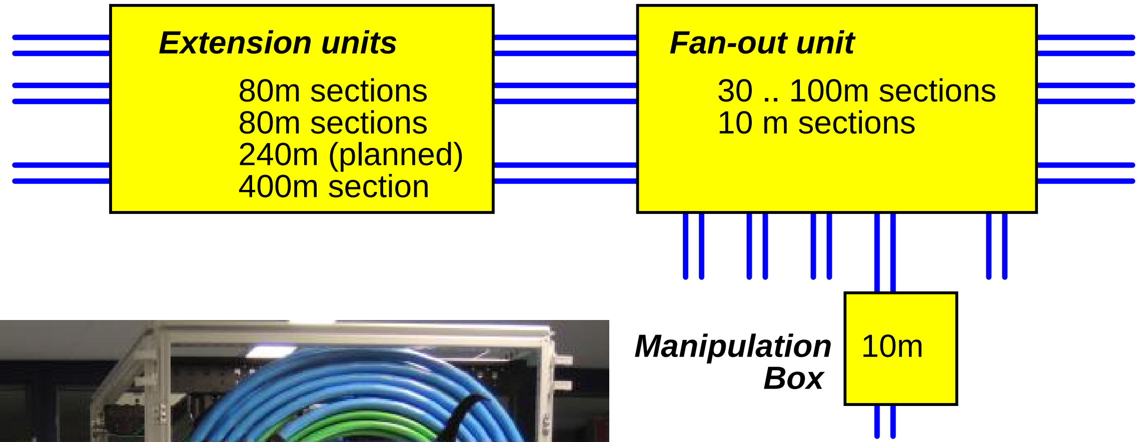


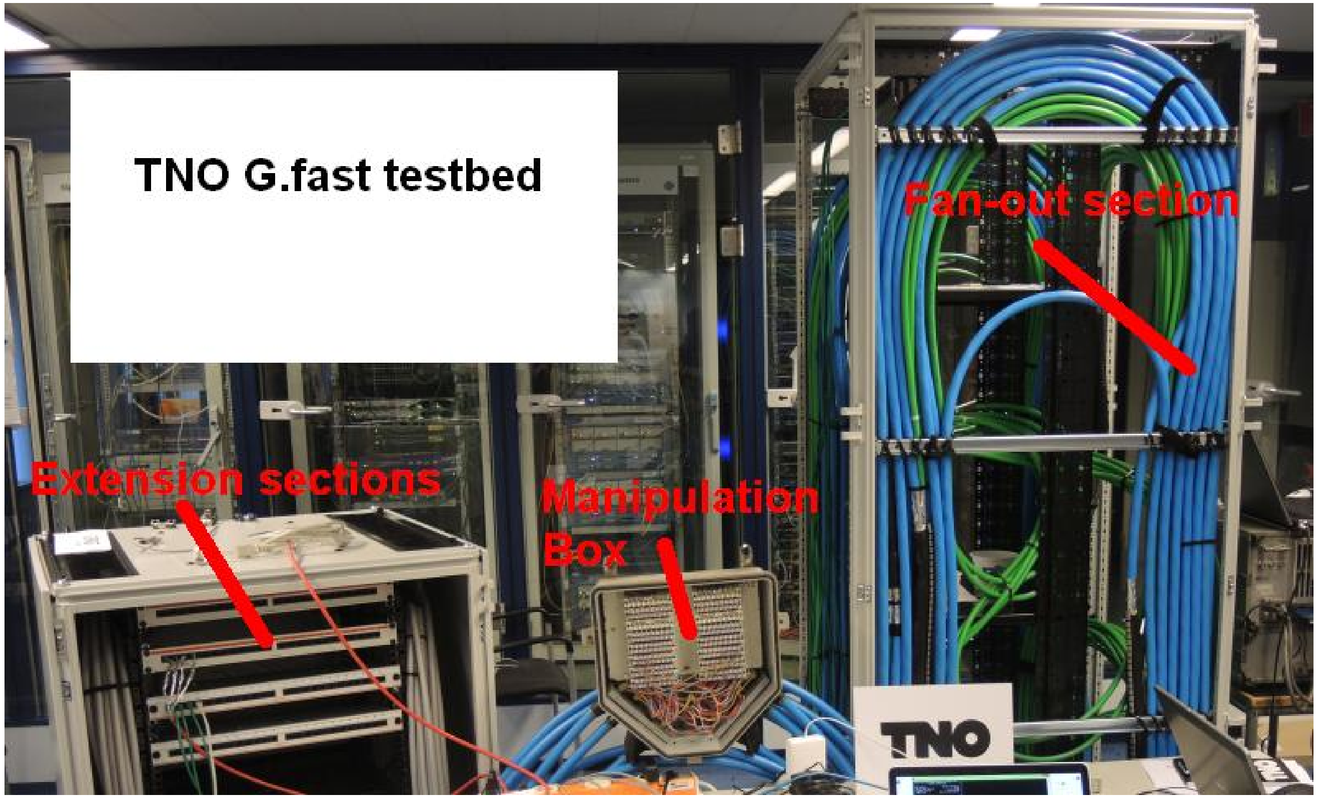
High level overview

- **Based on real cables**
  - Currently: 30-500m range, in discrete steps
  - 12 quads per cabel = 24 wirepairs
  - All cables are shielded

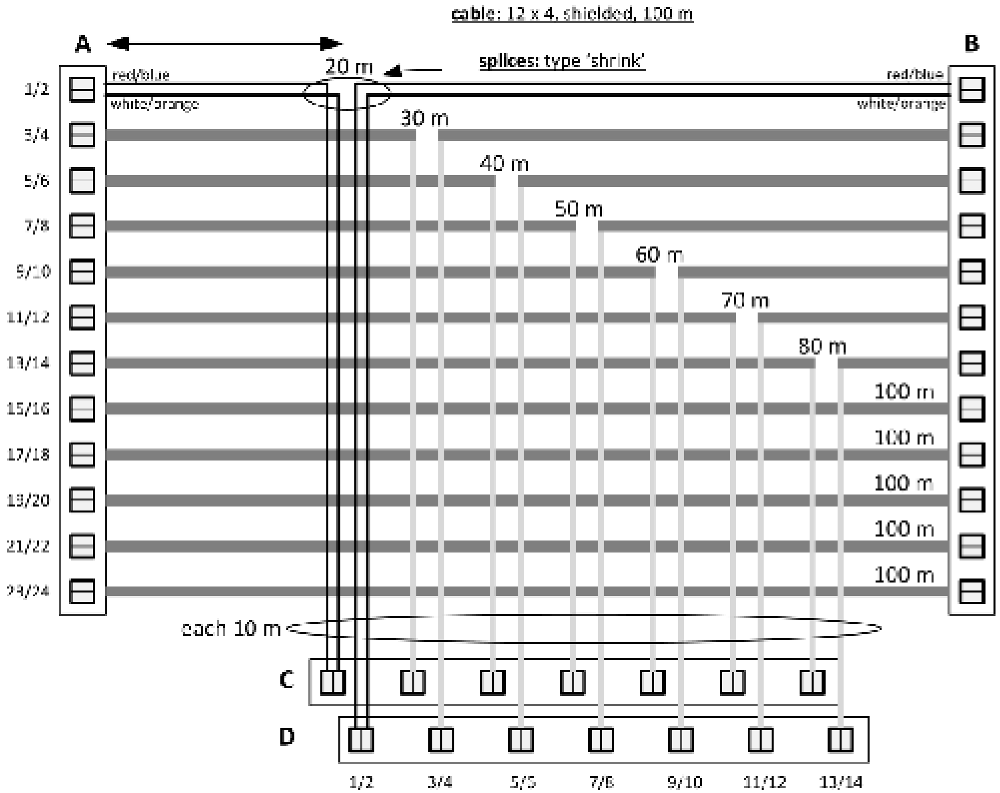
- **Mimics reality in several ways**:
  - Crosstalk from customers at *different* locations
  - Reflections from *splices* can be added
  - Reflections from *waterstops* included (typically 2-4m)
  - Reflection from *manipulation* boxes can be added
  - Others (like bridgetaps) may be added in future

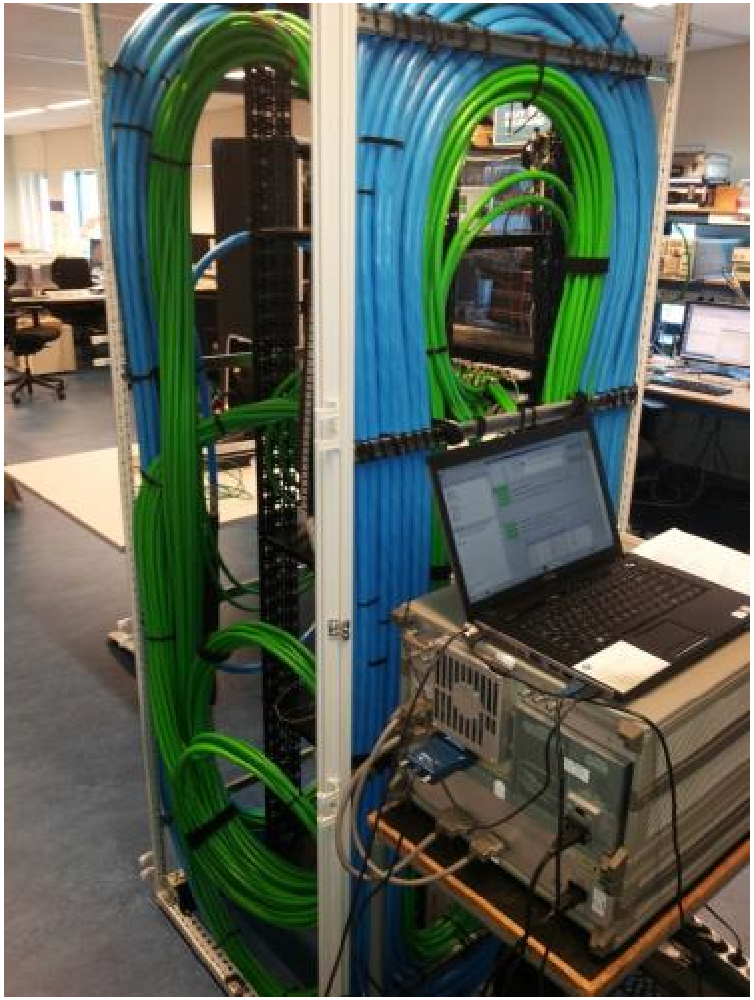
Benchmarking DSL: TNO G.fast Test bed





Benchmarking DSL: TNO G.fast Test bed

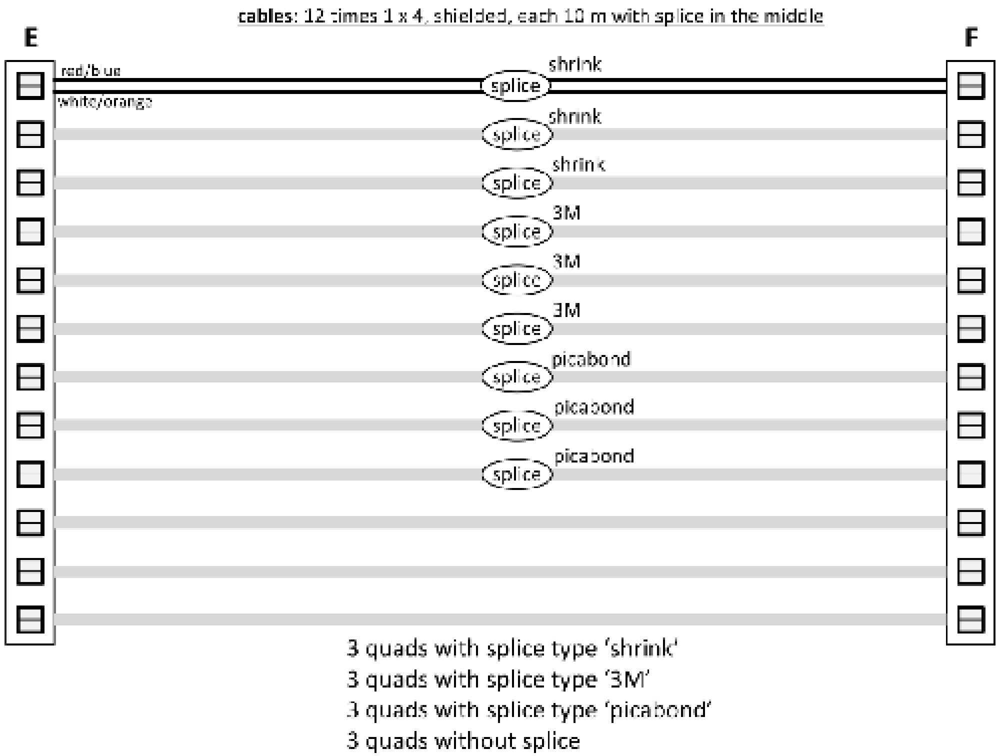


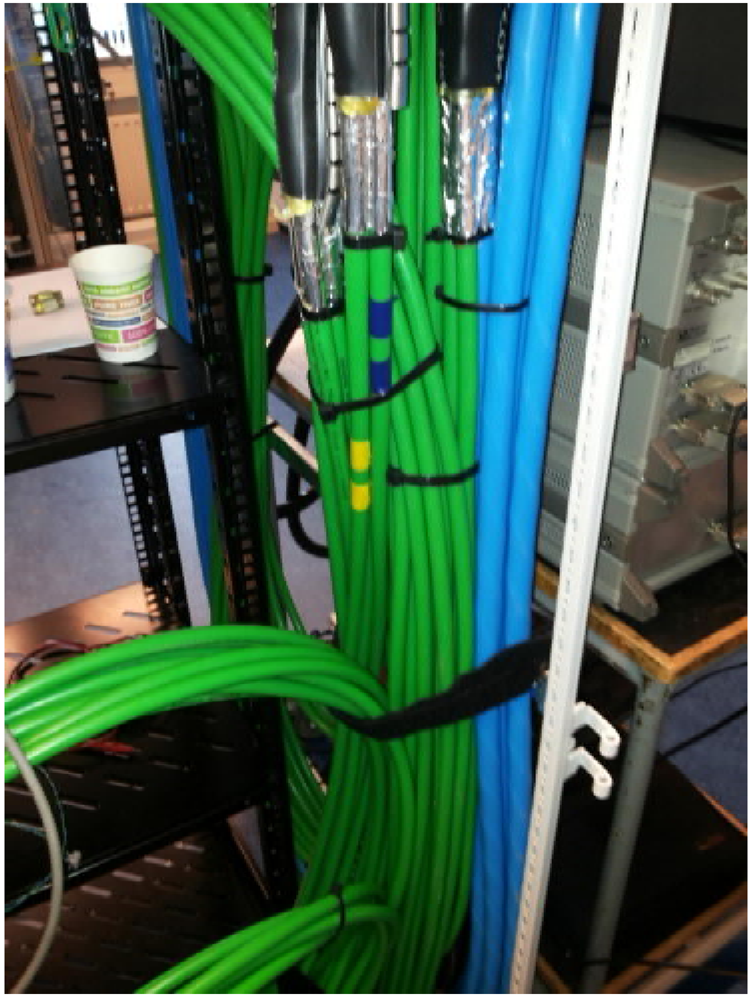


Fan-out unit

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

Benchmarking DSL: TNO G.fast Test bed

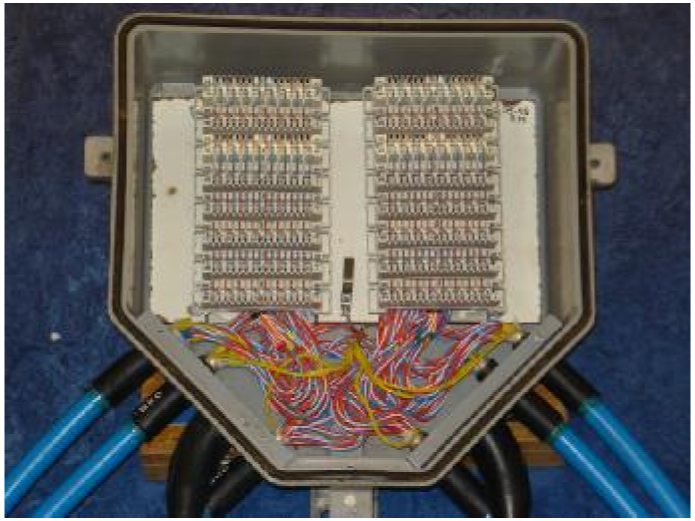


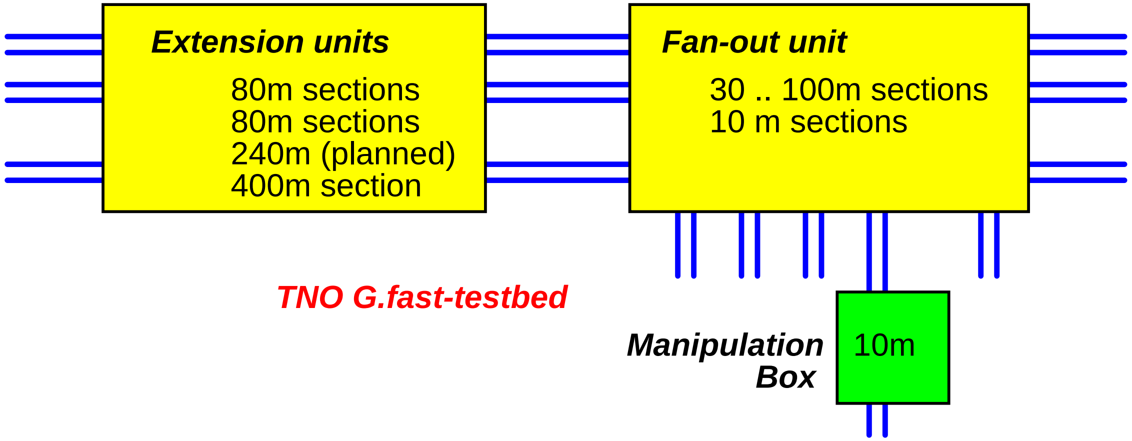


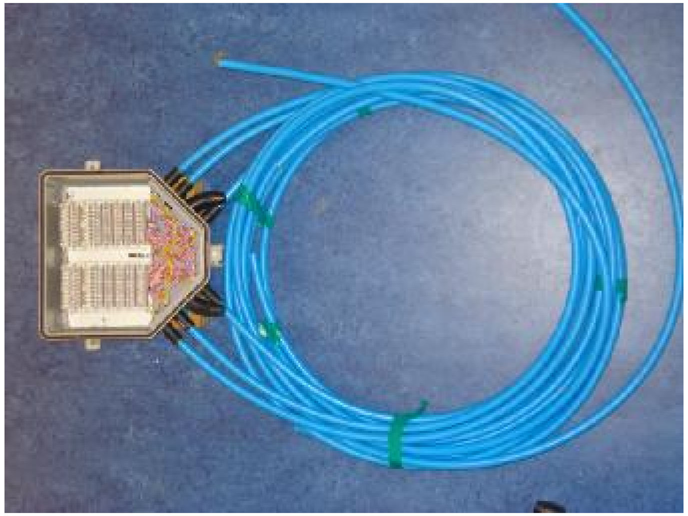
Fan-out unit, addition of splices

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

Benchmarking DSL: TNO G.fast Test bed



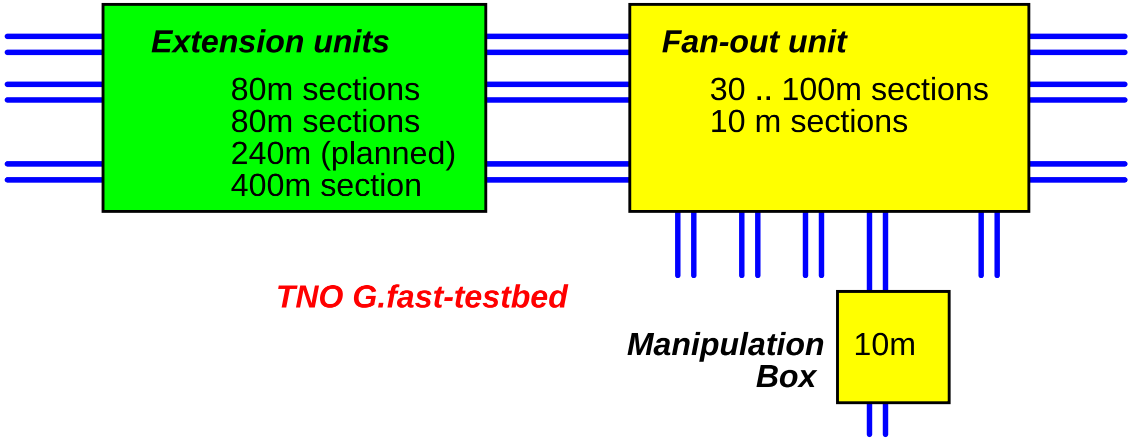


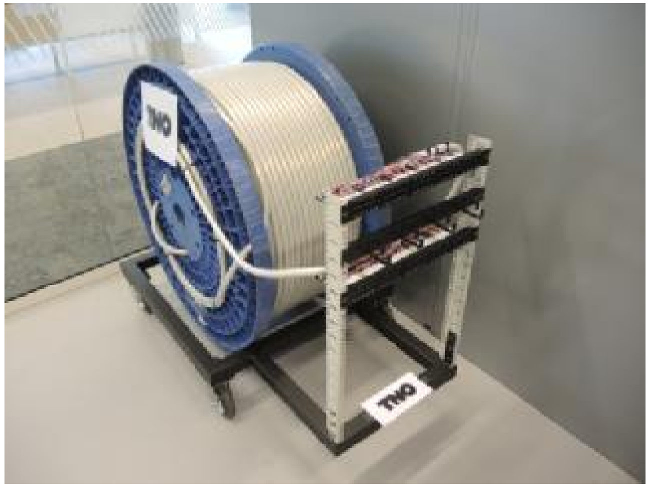


Manipulation box

- Cross connects near customers

Benchmarking DSL: TNO G.fast Test bed

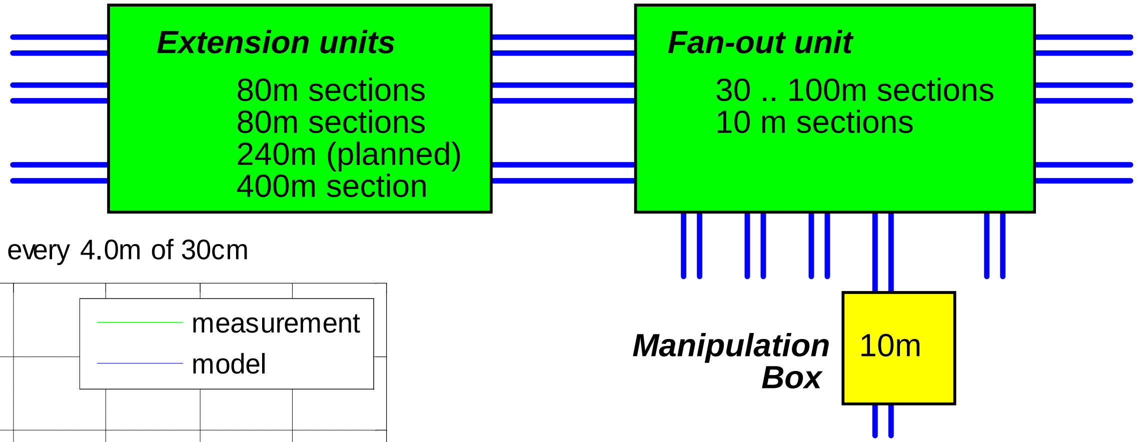


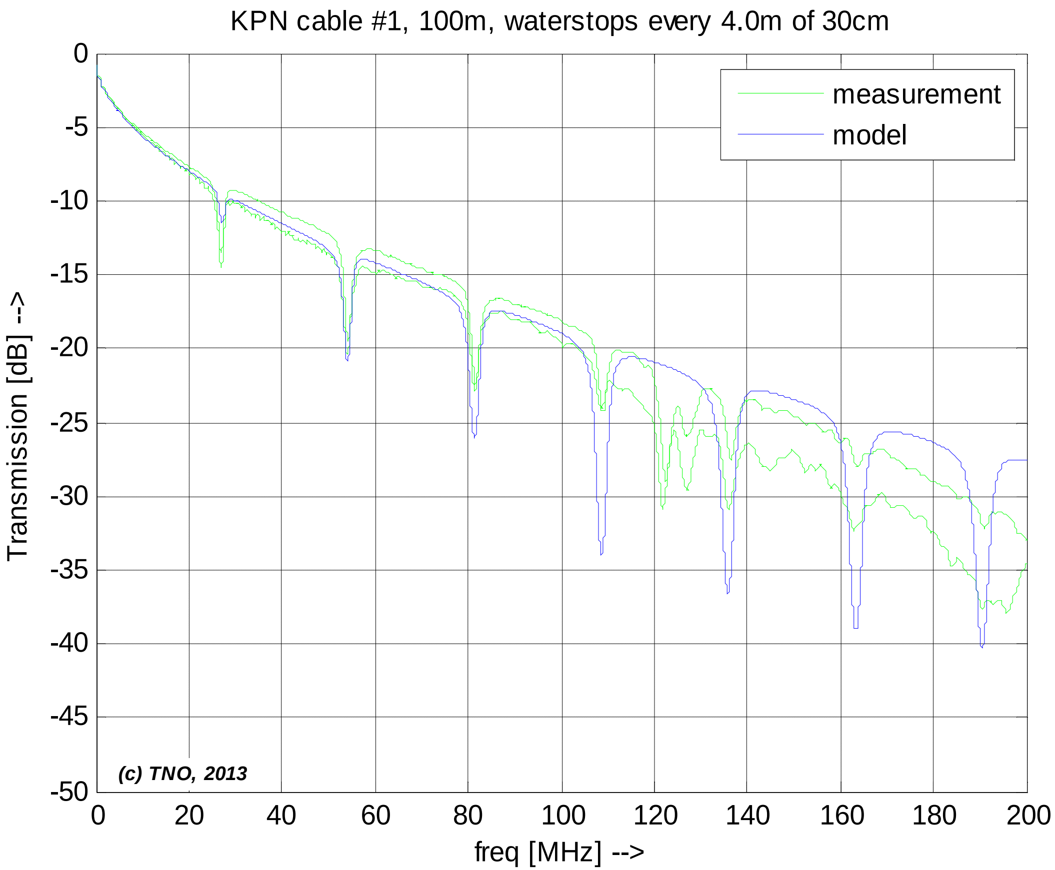


Extension unit

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

Benchmarking DSL: TNO G.fast Test bed

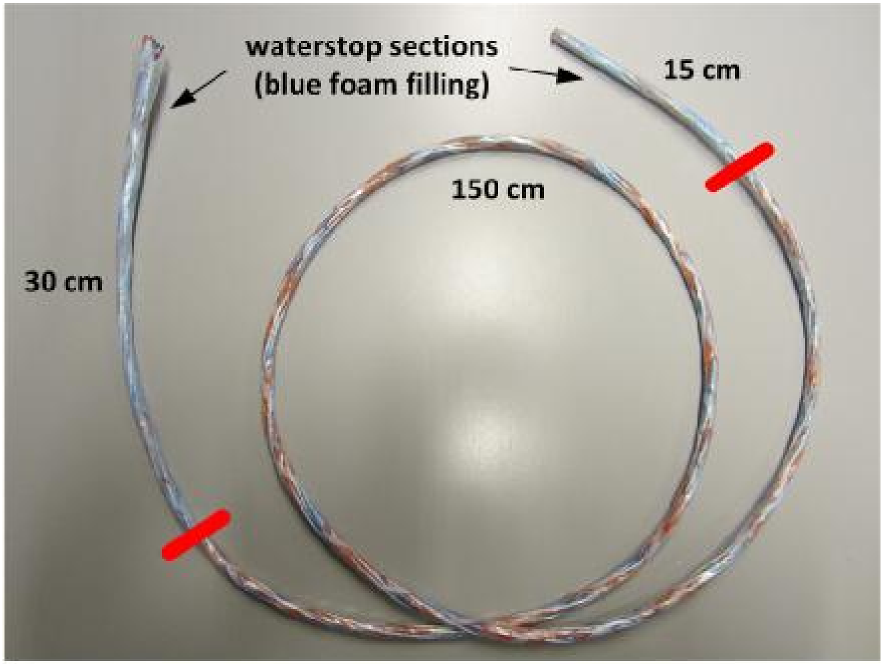


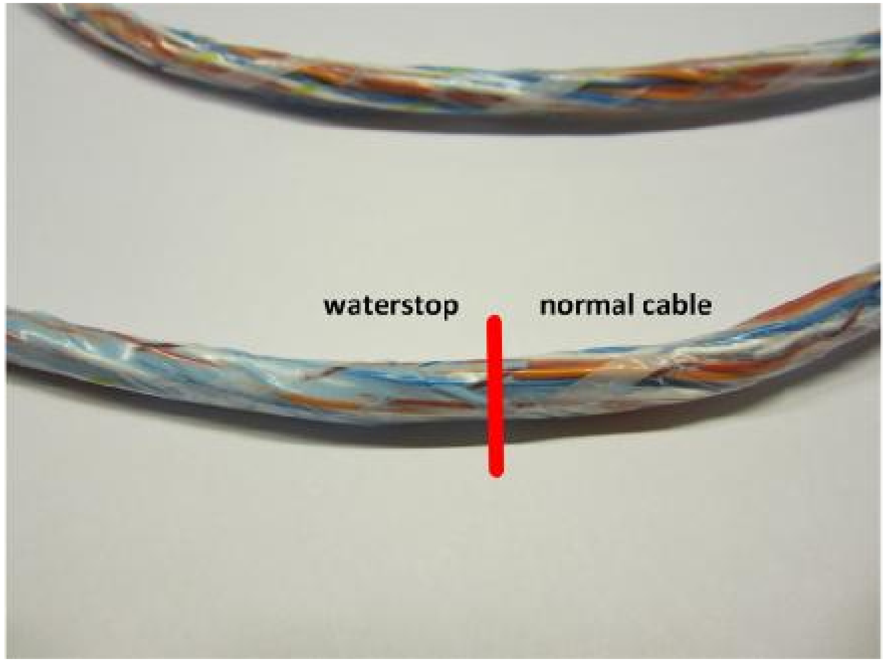


Testbed: presence of waterstops

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

Benchmarking DSL: TNO G.fast Test bed



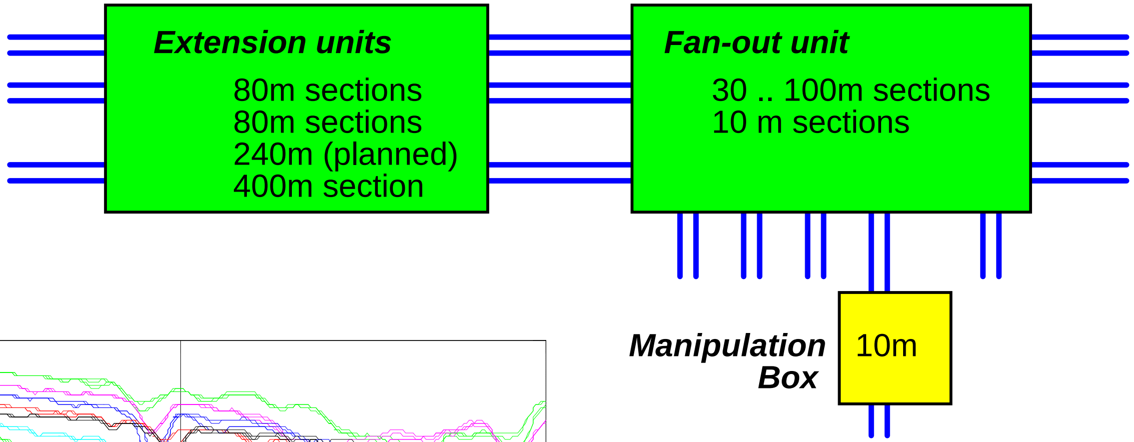


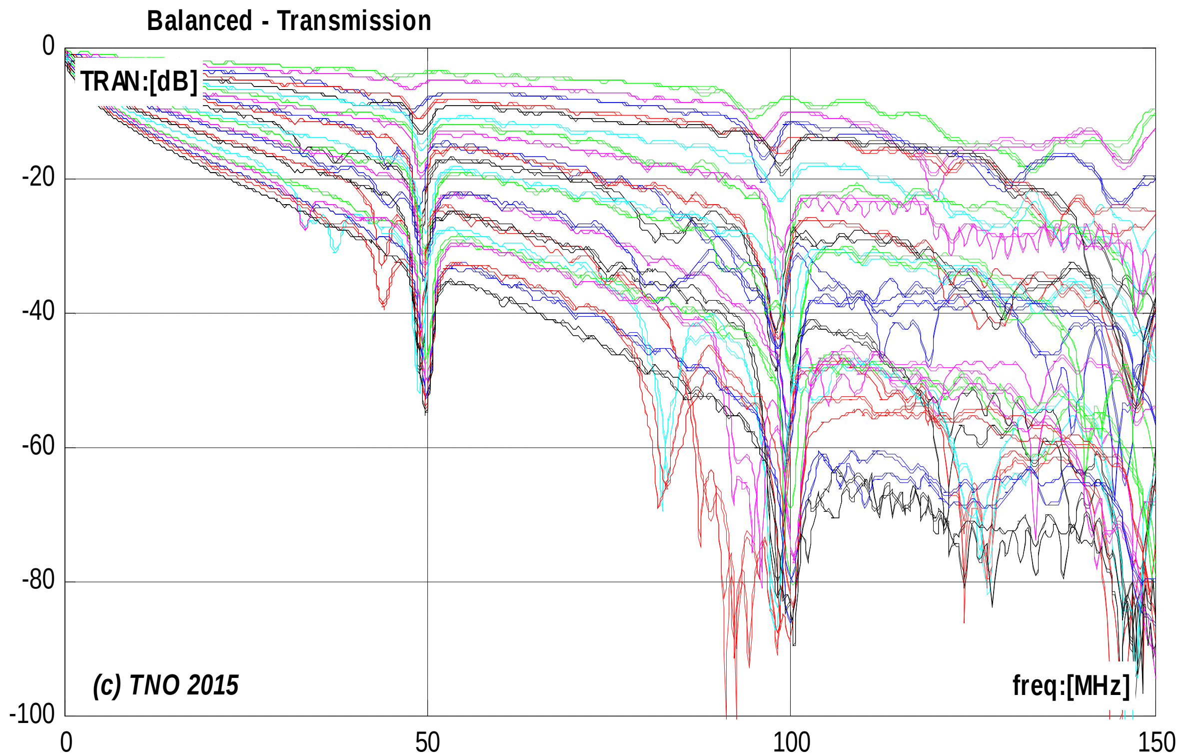
waterstop section is **at least** 30 cm, so center distance between waterstops is **at least** 180 cm

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 (an maybe others as well)

Benchmarking DSL: TNO G.fast Test bed





Many combinations:

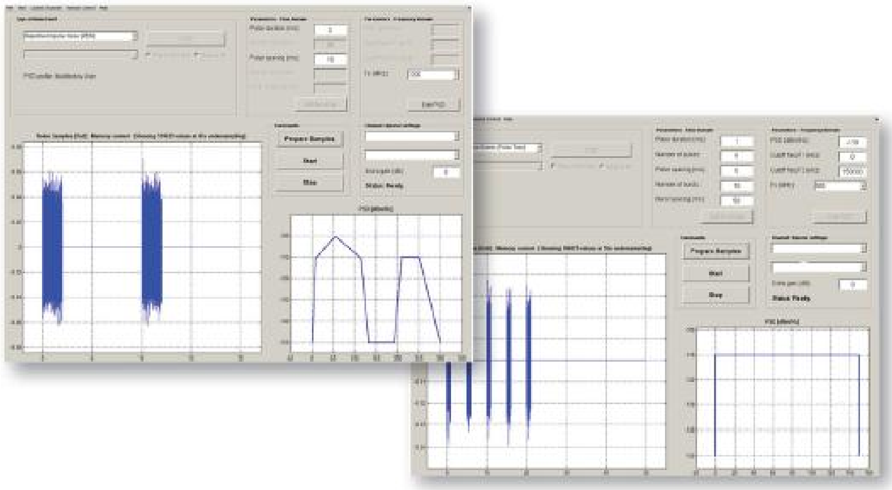
- 30m
- 40m
- 50m
- …
- 260m
- …

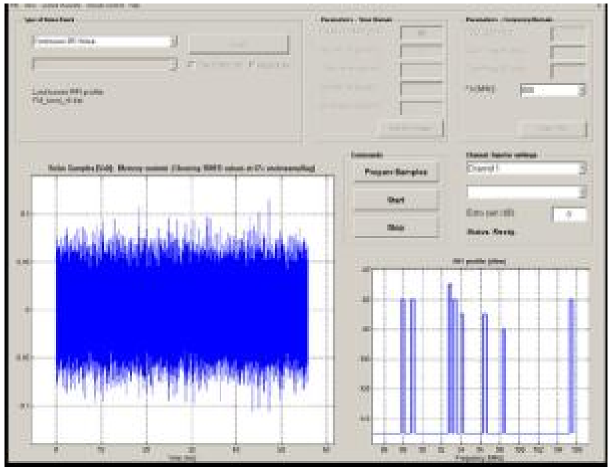
Benchmarking DSL: You also need to inject noise

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 labtrials with first G.fast prototypes:
  - Aggregate bitrates allready 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 tress 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