

DOCSIS® 4.0 – Bringing DOCSIS To Your Home

Exploring Layer 1

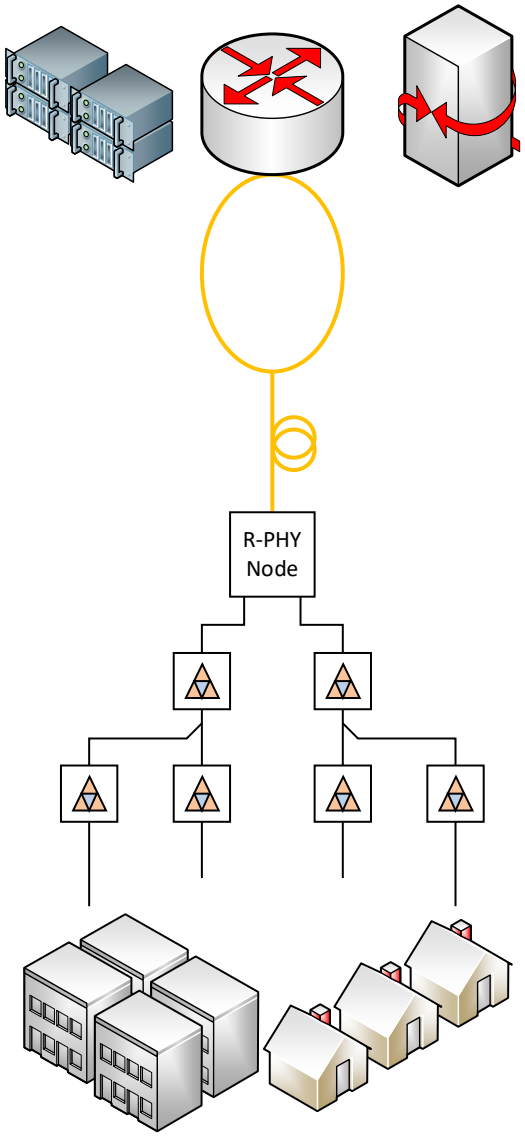
Jukka Saarenlaita – Teleste Networks



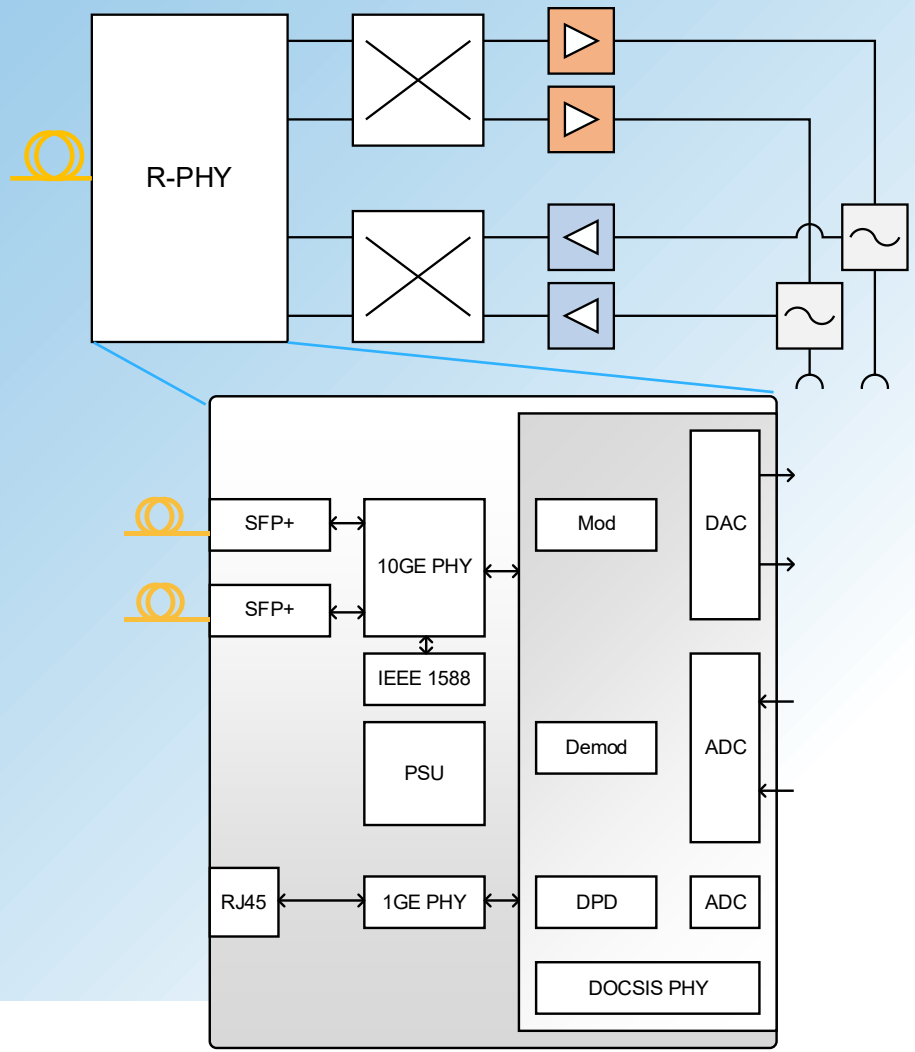
Head-end to node

Network overview

- vCCAP cores handle DOCSIS signals and DVB-C channels
- Various OSS and BSS applications are connected through the CIN
- Access Network management is of particular interest today
- Allows for PNM and faster response to faults in the network
- Depending on multiple factors, can give you a very detailed view of the network and signals
- Management over different standards
  - DOCSIS: Today especially in relation to modems (vCCAP)
  - HMS: The HFC element management standard (vHMTS)
  - LoRA: Special application within the CATV world (Controller)



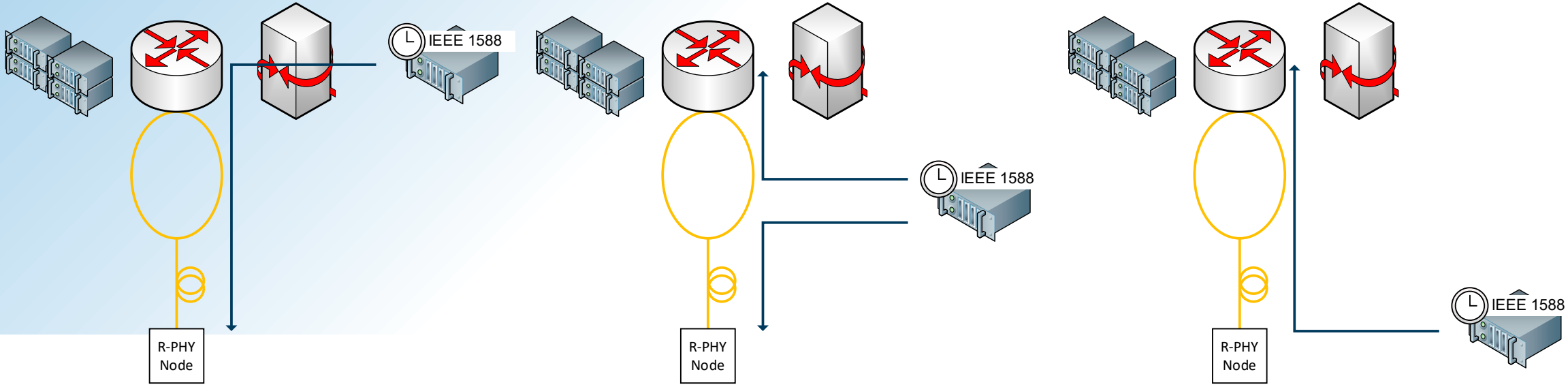
Distributed architecture node (MHAv2)



- Remote PHY devices (RPD) are where the RF signals are finally generated
- Implementation approaches range from FPGAs to dedicated ASICs
  - They mainly rely on high-performance AD/DA converters
  - In addition to DOCSIS PHY there is typically also support for R-OOB and potentially HMS
- The node itself contains a ”launch amplifier” portion, which is used to bring the signal level as high as possible to ensure the best SNR/MER
- In DOCSIS 4.0 world, the expectation is that the signal band extends up to 1794 MHz
- This can mean some concessions in signal levels and therefore quality
- There is also a distinction between FDD and FDX RPDs, especially the node part
- DPD can be used to improve RF performance but with cost in power – it is especially utilized for the FDX echo cancellation

A word on synchronization

- DOCSIS services and some interconnected features require precise timing
- Without synchronization, significant timing differences will accrue over time due to clock drift
- The R-DTI specification tackles this by introducing a PTP clock in the network
- This clock can be located differently depending on network architecture
- In case 10G EPON is used in the CIN, gPTP will be used instead. This still relies on the PTP clock as its basis but allows asymmetrical operation.





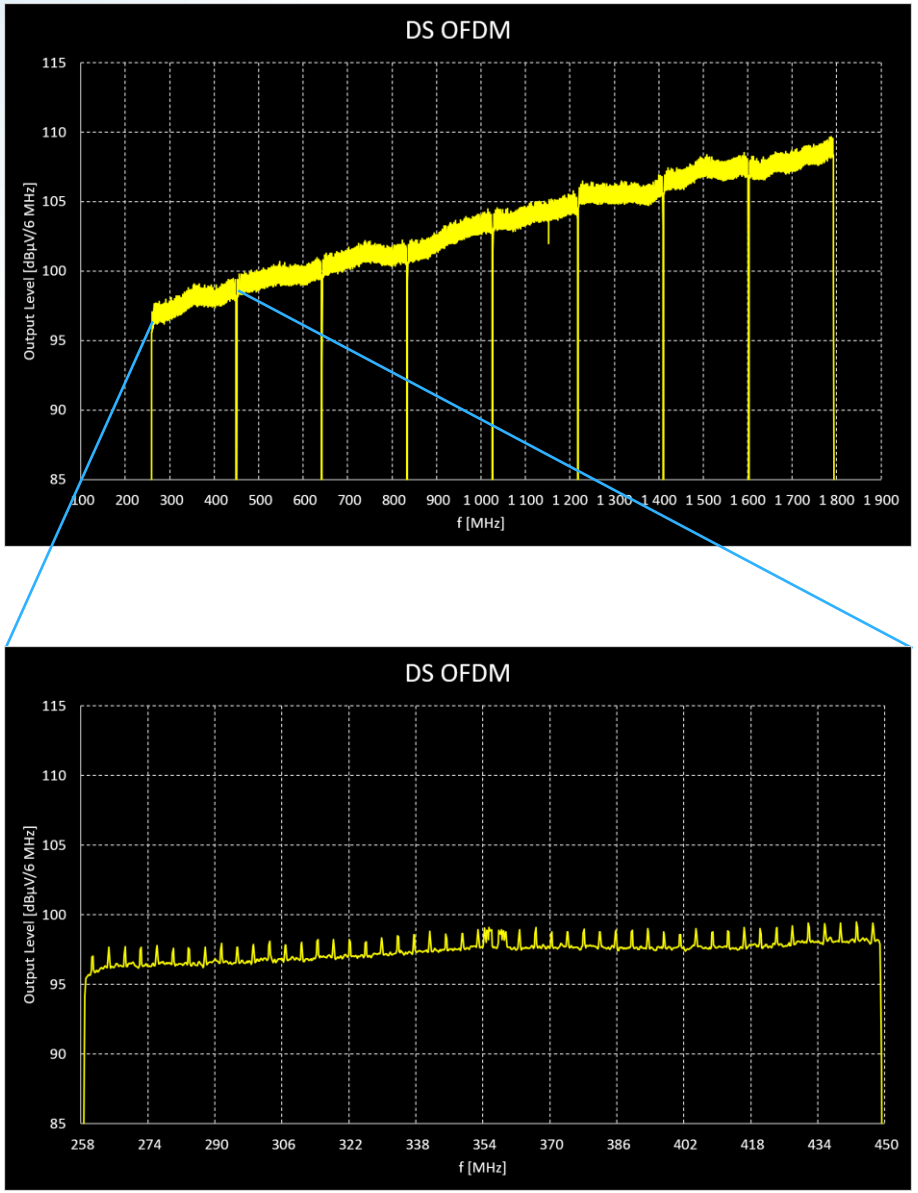
Entering the coax

The signal types

- Signals are determined by the DVB-C and DOCSIS standards
- DOCSIS OFDM allows different profiles for different blocks and automatic scaling of modulation scheme depending on the signal quality
- Element Management signals are utilizing FSK
- DOCSIS 4.0 signals are

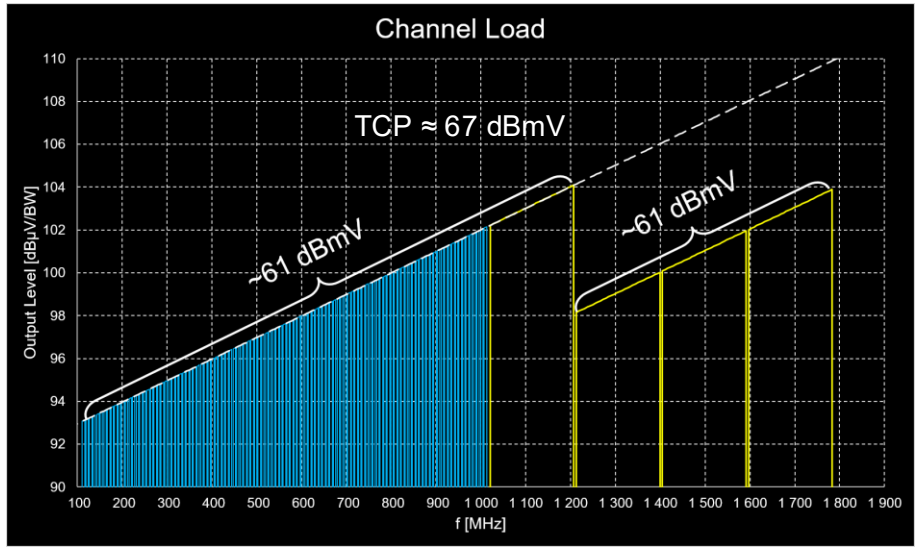
OFDM in forward path and OFDMA in return path

- The modulation scheme is a complex of QAM sub-carriers with pilots
- Signal blocks come in multiples of 6.4 MHz or 24 MHz, typical sizes are 48 MHz, 96 MHz and 192 MHz
- Return path signals are additionally TD multiplexed

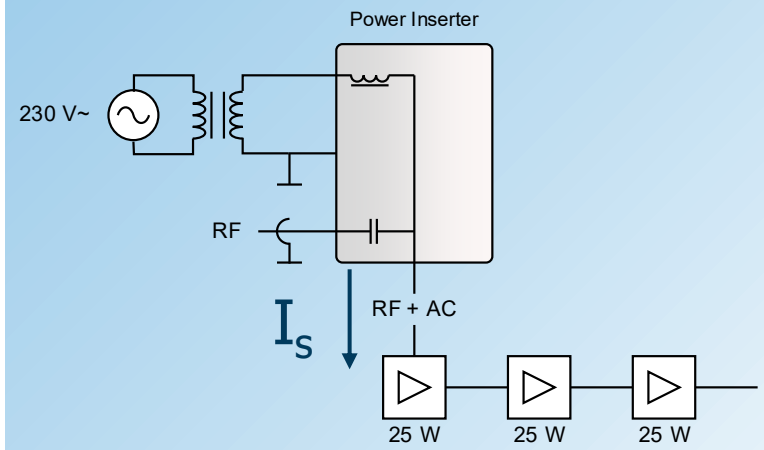


To step down or not?

- The RF performance of an amplifier is principally characterized by the forward path output stage
- Semiconductor technologies set the expectation on what can be achieved (GaAs and GaN today)
- There is still a limit to performance in comparison to DC power (e.g. 72+ dBmV/12 W)
- There is always a tradeoff between bandwidth and output level
- Stepping down the signal level at specific ranges can be considered – SNR at those channels will be lower
- Without step down, SNR will be more uniform over the whole band but lower than the maximum with step down



Powering considerations



- With 50 V~: I_S = 1.5 A
- With 65 V~: I_S = 1.2 A
- With 90 V~: I_S = 0.8 A
- Passive losses = $I^2 \times R_{DC}$

- Moderate power increase for DOCSIS 4.0 compared to DOCSIS 3.1 at around ~10-15 % for amps
- Active elements behave as constant power sinks – voltage decrease causes current increase, which causes voltage decrease in passives…
- Current draw can be managed by increasing voltage level – this is determined by safety regulations (EU LVD → EN 60728-11)
- Today's equipment can benefit from Power Save features to minimize power usage depending on RF loading and performance

- The bootup time of the RPD makes the node a critical location
  - PSUs can be equipped with "super capacitors" to keep enough charge for some hundreds of ms
  - More robust UPSs can be utilized with enough capacity to keep the immediate network powered
  - PSU redundancy in case primary supply fails
- Especially in long power chains, having PFC helps in reducing apparent power losses and instantaneous voltage and current draw

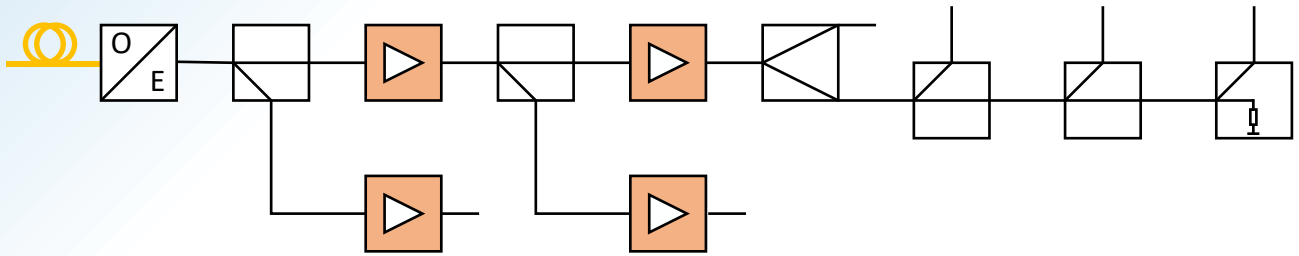
Branching the signal

- When the signal leaves the node, its level decreases in direct and square root relation to the frequency in the coaxial cable

$$A_{coax} = \ell \times (A_1 \sqrt{f} + A_2 f) \quad [dB]$$

- Signal frequencies of up to 1.8 GHz can easily ~50 dB attenuation in the span of a few hundred meters – due to both cabling and linear losses in passive equipment

- Outdoor tap equipment RF losses are affected by frequency dependence but also by increased power passing and surge protection requirements
- Every connection also introduces some losses – connector quality is important

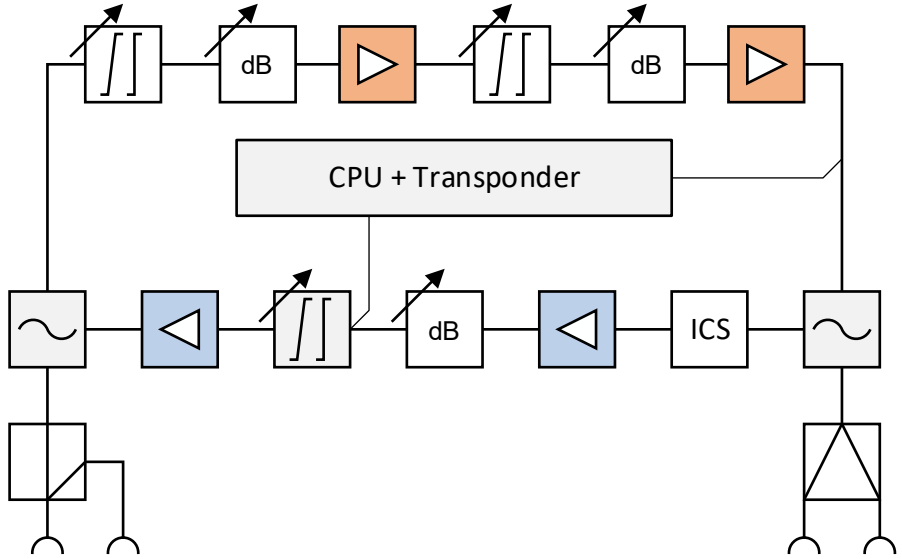




Active network elements

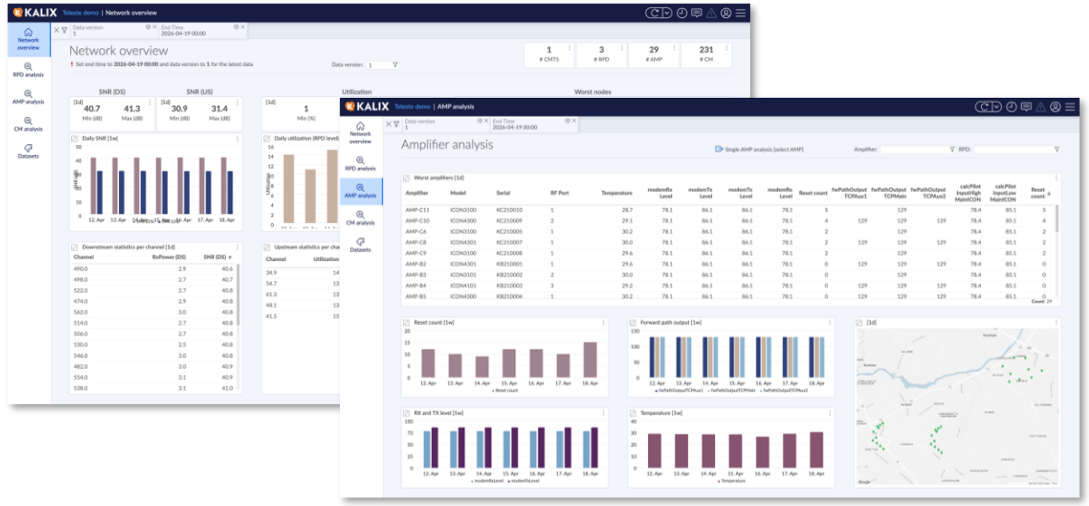
The amplifier plant

- A lot of the performance is characterized by the amplifier
- One key topic is the RF output TCP, just like in the node
- For DOCSIS 4.0 plants, there are also other considerations
  - Backwards compatibility: frequency splits, a dedicated 1.2 GHz mode…
  - Higher return path capacity and RF performance requirements
  - Do you need automatic level control?
- Transponders enable remote connectivity
- Higher frequencies require higher gains to be supported
- In cases with extremely long cable sections repeater / booster amplifiers can be needed



What can remote management do for you?

- The remote control of the amplifiers can allow you to track and manage many things:
  - Forward path signal levels, automatic level controls
  - Temperature, tamper switches, voltage levels, power saving
  - Return path spectrum, ingress suppression, automatic alignment
- This information could be made available to the NMS for making decisions and inferences about passive elements as well
- Other relevant sources are the CMs that are source for subscriber data
- Data aggregation and analysis is a rising field of application

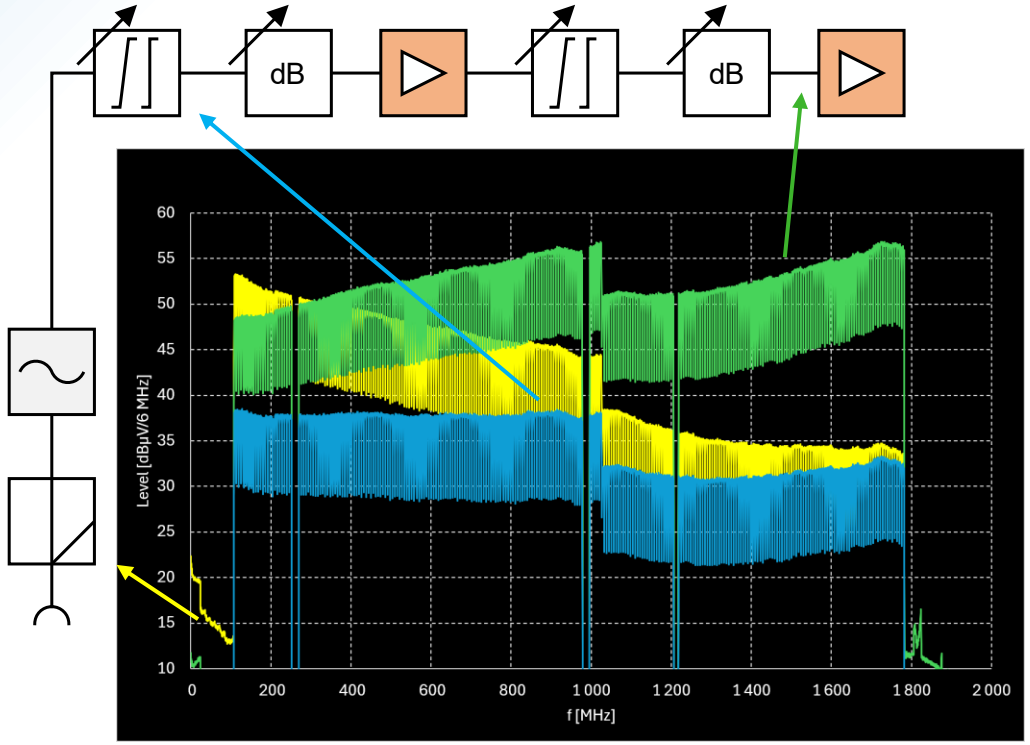


FDX, FDD and frequency splits

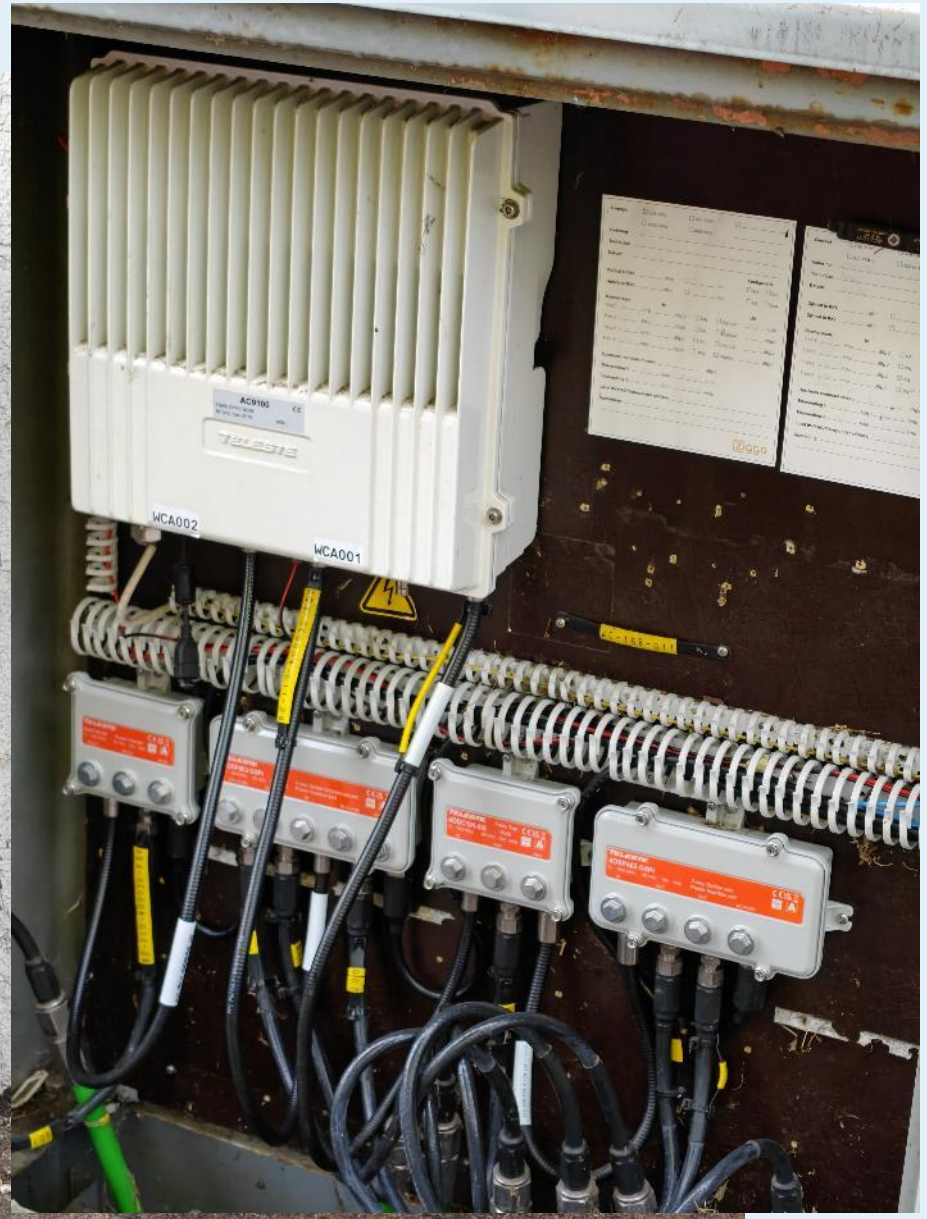
- The DOCSIS 4.0 standard also brought about the concept of Full-Duplex active elements
- It allows for DS and US channels to coexist in the 108…684 MHz
- Traditional fixed Frequency Division Duplex mode divides the band strictly to US or DS
- The highest supported US frequency for both modes is 684 MHz – notably making the link almost symmetric (DS band begins above 800 MHz)
- Implementing a network in FDX requires rethinking the amplifier, basically requiring similar capabilities from it as the RPD has
- FDX promises more efficient use of the spectrum with fixed smaller cross-over bands and easier scaling of both US and DS capacity
- On the other side of the coin are higher power consumption and some limitations on what network topologies can be used (typical N+1)
- The *new* splits in DOCSIS 4.0 extend the upstream to 300/396/492/588/684 MHz

Maintaining signal integrity in coax

- The amplifier will equalize the signal based on coax loss
- Equalization is done with electronically controlled elements
- The equalization largely determines the loading of the output stage and therefore the performance
- For long cascades, signal stability requires ALSC and installations will benefit from automatic alignment
- Smart amplifiers can also keep track of the output level so that the maximum performance is not exceeded
- Cumulative response issues can be compensated in amplifiers by pre-defined or custom correctors




TELESTE
CX4-OG-H
Ziggo Services BV
TELESTE
CX4-O-H


AC9100
WCA002
WCA001



Towards the customer premises

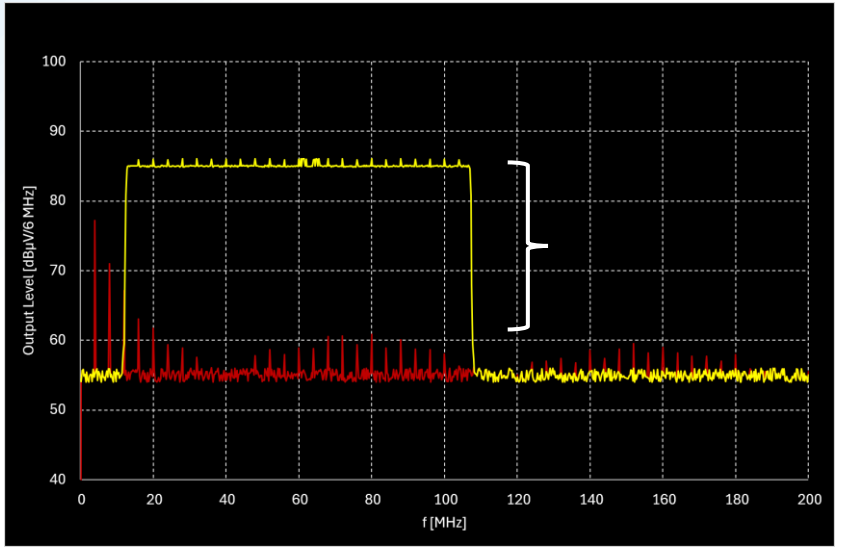
The end of the line

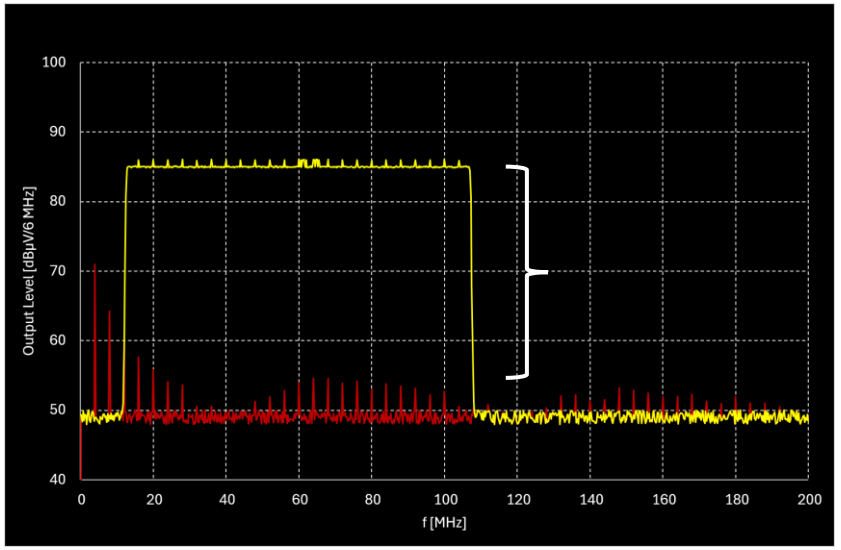


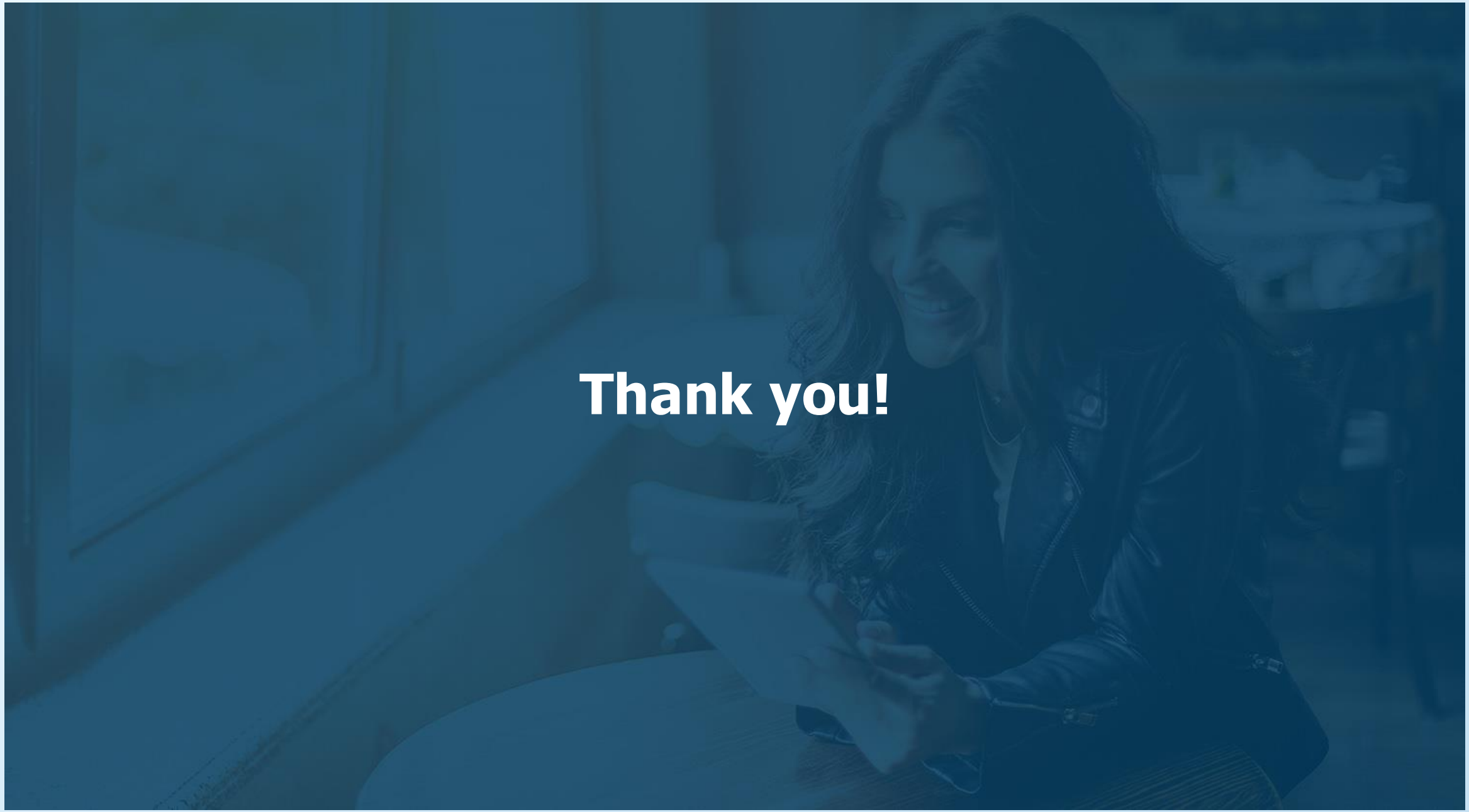
- Drop taps can have compensation for the drop cables, which is especially important with increasing frequencies
- The drop taps also help isolate the network as no power is passed down to customer premises
- Sometimes multitaps are used – these can have over a dozen outputs
- Premises have their own wiring and outlets that can also be compensated for
- In DOCSIS 4.0 contexts there is typically no need for a home amplifier

Ingress and disturbances

- Ingress can come from external sources and leak into the network such as through unterminated connections (e.g. homes)
- Bad connector interfaces are another potential cause
- Amplifiers and / or nodes can measure ingress and utilize return path attenuators (or filters) to help block it out
- RPDs offer another place where measurement can be done
- NMS can detect and mitigate the fault until the source is found and issue is eliminated
- The measurement functionality can also be applied to other disturbances






Thank you!