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ATLANTA, GA
OCTOBER 11-14
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2021 Fall Technical Forum
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Wireline Access Network

The Scheduler and the Tap: The Odd Infrastructure Couple– A 100 Gbps Coaxial Future Story

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CableLabs

2021 Fall Technical Forum
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VIRTUAL EXPERIENCE
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Broadband Environment

Cable serves a wide diversity of users running numerous services including:

- Residential
- Enterprise
- Mobile Xhaul

In many areas fiber is penetrating very deep in others it is not economically feasible to do so.

Cable needs to leverage all the tools available to cost effectively address current and future demand of users.

A new kind of “Hybrid” Fiber Coax may help address these future challenges.

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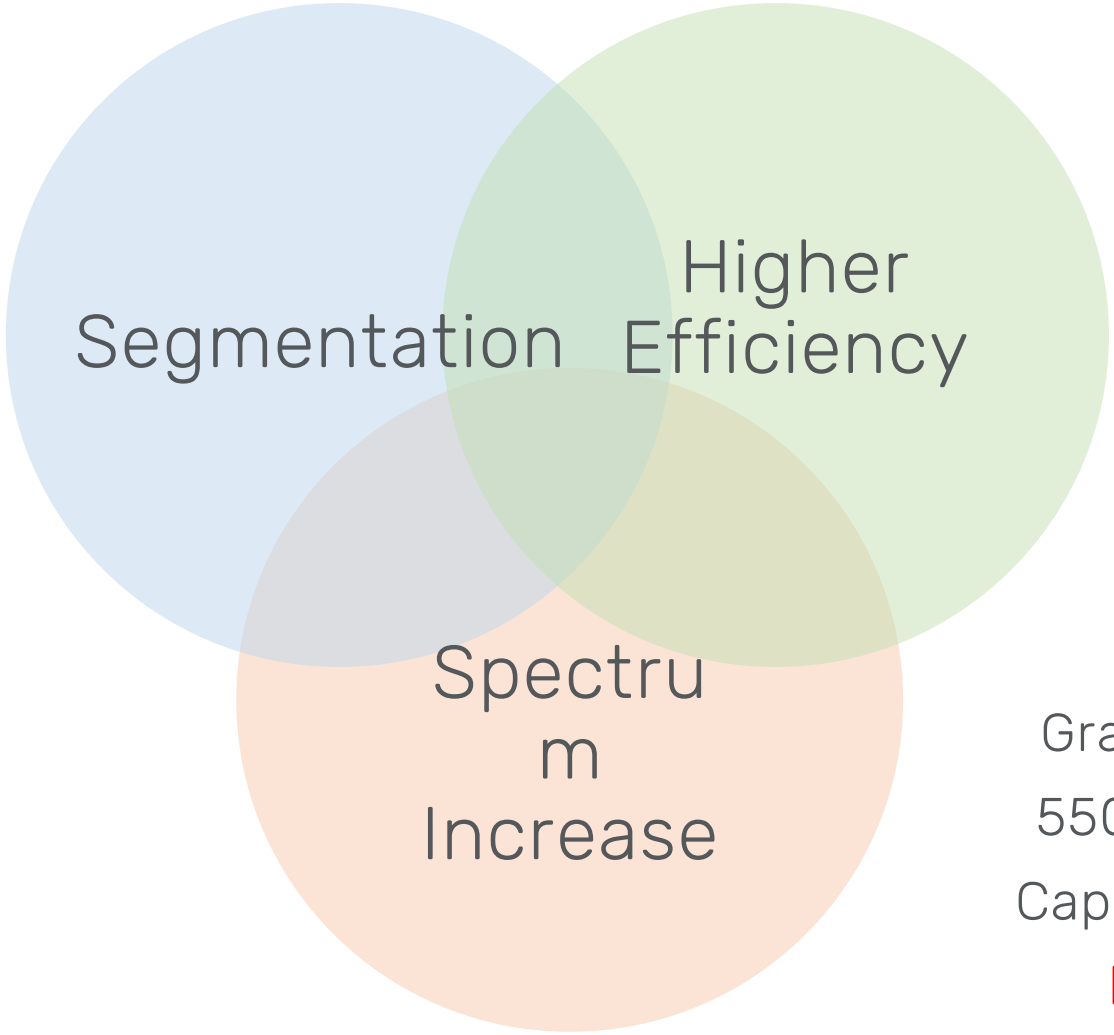
Capacity Enhancement Techniques

Lower HHP/Node

Higher Aggregate Capacity

Surgical/As Needed

Leverages Wavelengths



Higher Modulation Order

Higher bps/Hz

Better compression, Multicast

Gradual increase thus far

550-750-1200-1800 MHz

Capability for all end points

Not fully exploited

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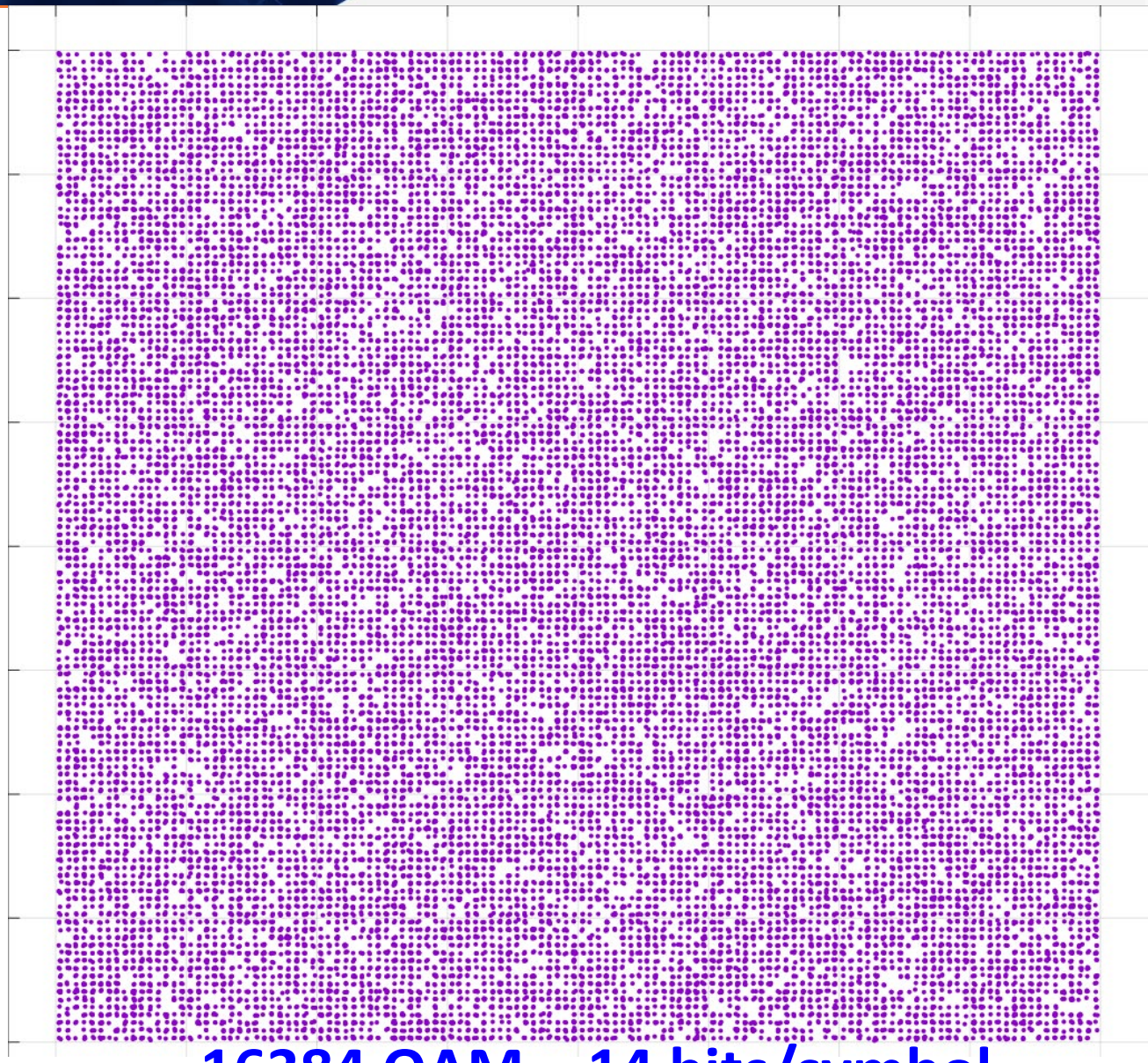
Modulation Order

Downstream

- 16, 64, 128, 256, 512, 1024, 2048, & 4096 QAM
- Optional : 8192 (8k) & 16,384 (16k) QAM

Upstream

- QPSK, 8, 16, 32, 64, 128, 256, 512, 1024, 2048, & 4096 QAM



16384 QAM = 14 bits/symbol

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Fiber Deeper

N+2

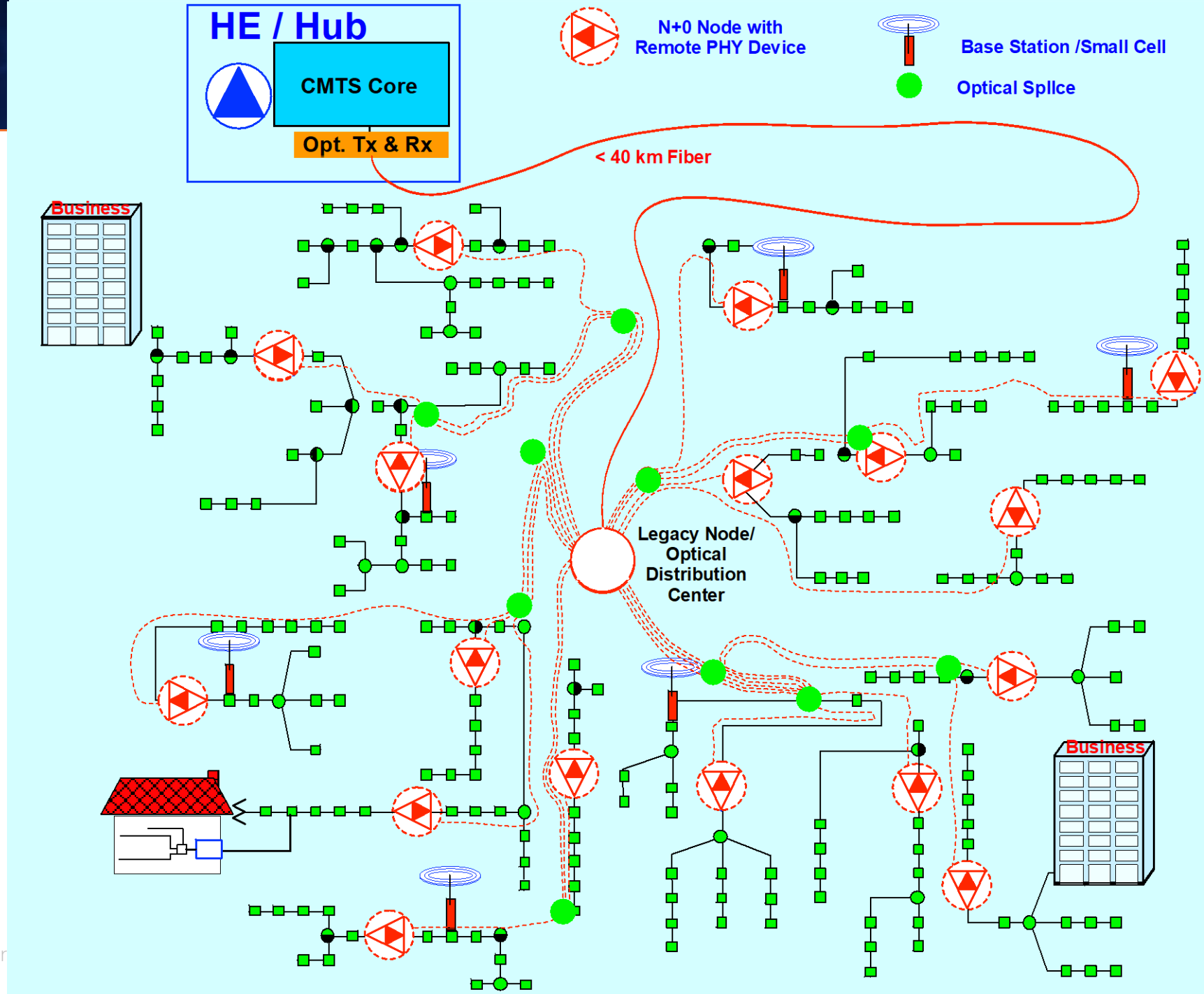
4-8

Child Nodes

N+0

10-18

Child Nodes



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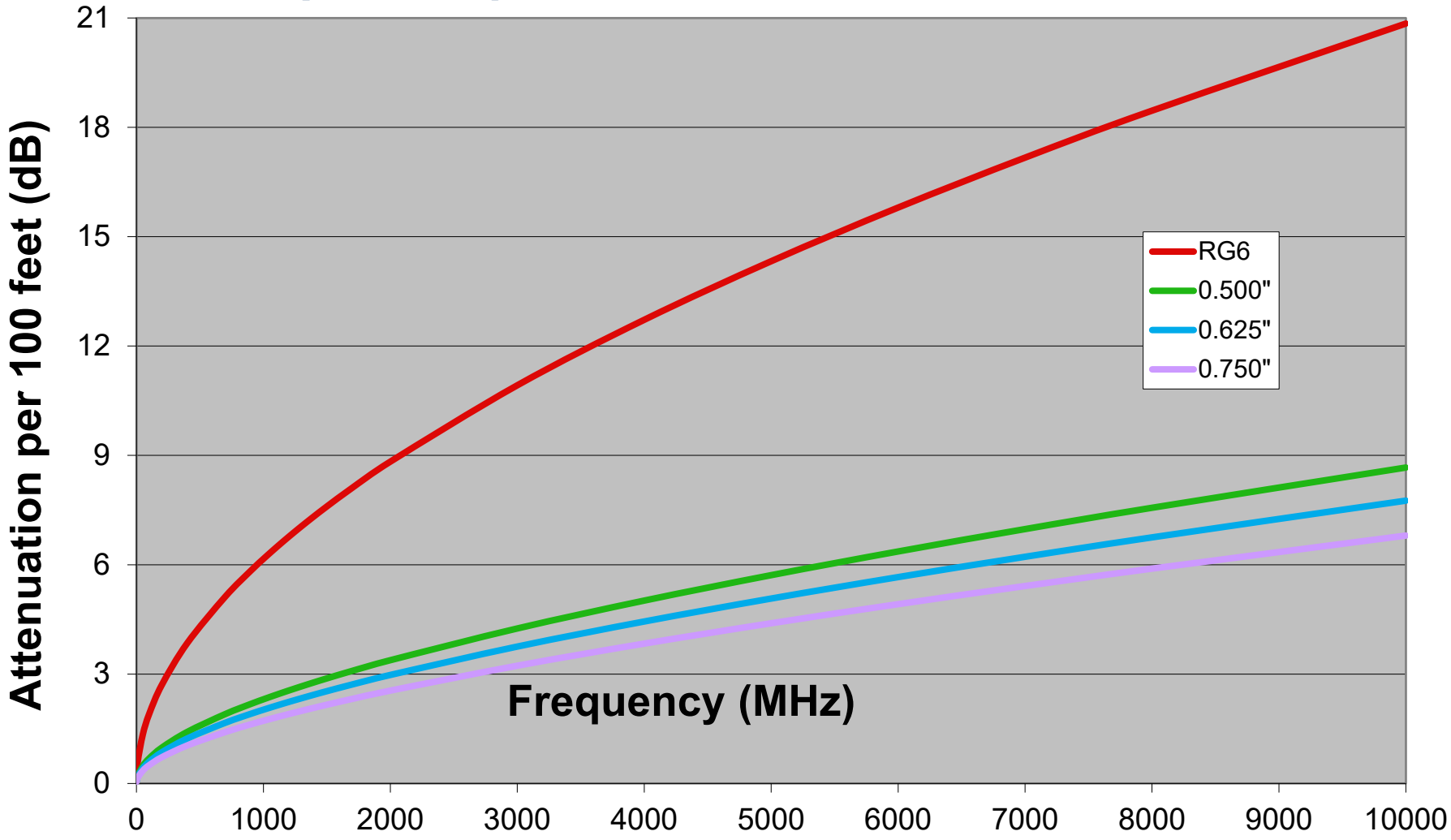
Coax Attenuation vs. Frequency

Not only hardline cable but also drop cable and passives frequency response are critical for spectrum increase strategy



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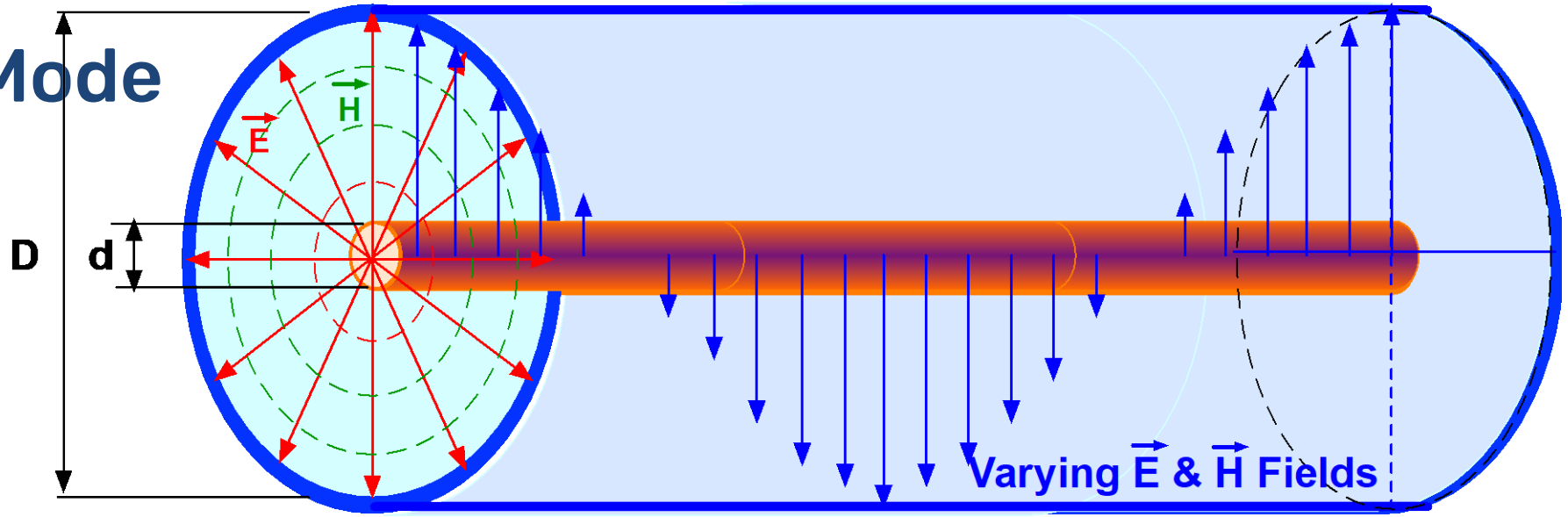
Dominant TEM Mode



Interfering TE_{11} Mode

Cut-Off Frequency f_c

Cable Type	Cut-Off Freq
RG6	29.1 GHz
RG11	18.6 GHz
0.5"	11.5 GHz
0.625"	9.3 GHz
0.75"	7.7 GHz
0.875"	6.6 GHz

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Legacy of Analog Video

Analog video channel had to be received within specific power level range

Challenges	Varying attenuation versus frequency
	Diverse distribution and home network environment
	Wide and increasing frequency range
Solution	Design plant to limit receive power level range
	Decreasing tap values along coaxial segment
	Signal uptilt with frequency
	Additional in-line equalization in longer coaxial segments
	Increase launch power and/or limit coaxial segment length & number of taps

Basic Premise: Everyone is equal

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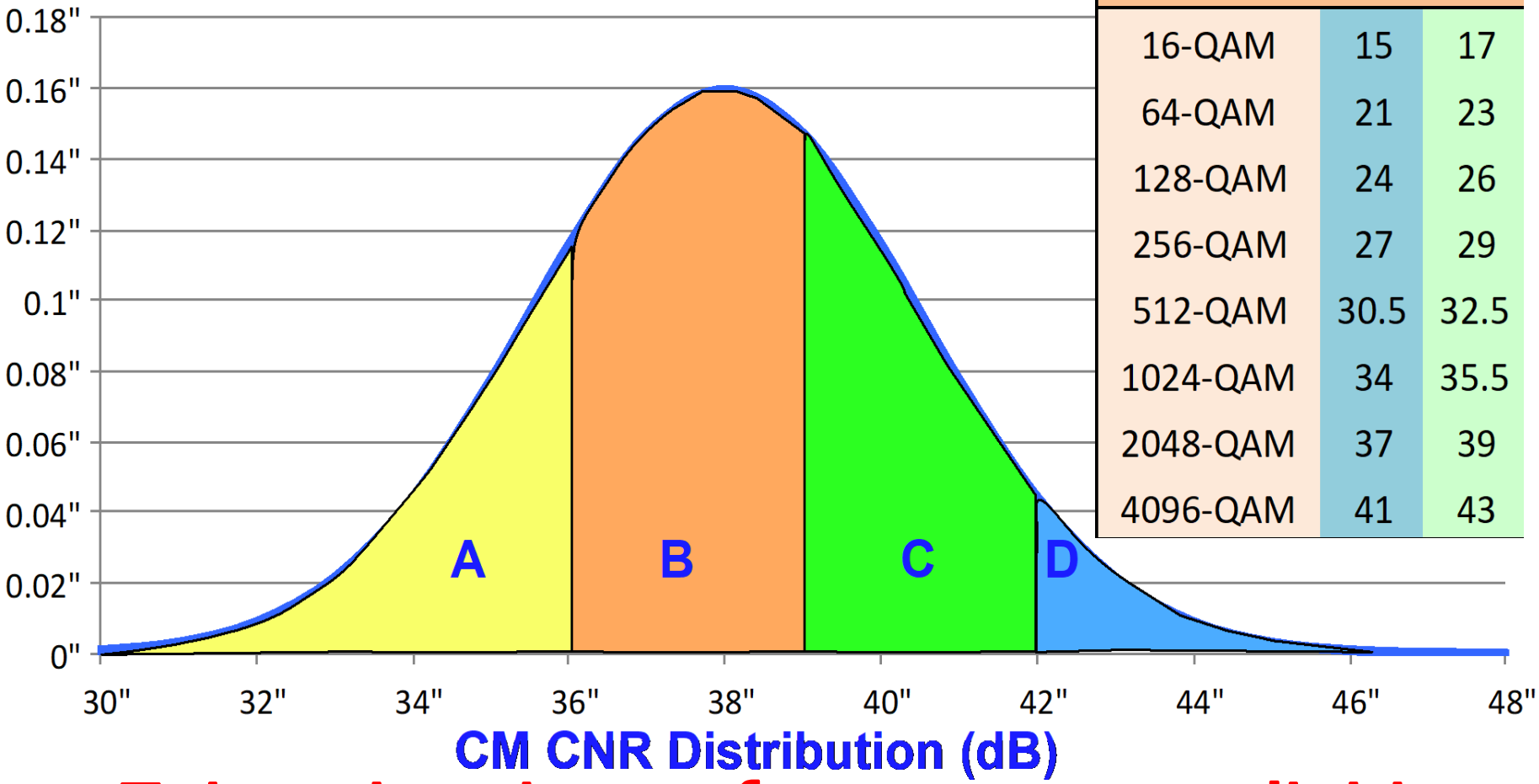
DOCSIS 3.1 Profiles & CNR

CMs have different CNR depending on location within topology

Efficiency dictated by CNR

DOCSIS 3.1 profiles optimizes transport depending on channel conditions



Minimum CNR (dB)		
Constellation	DS	US
16-QAM	15	17
64-QAM	21	23
128-QAM	24	26
256-QAM	27	29
512-QAM	30.5	32.5
1024-QAM	34	35.5
2048-QAM	37	39
4096-QAM	41	43

Basic Premise: Take advantage of resources available

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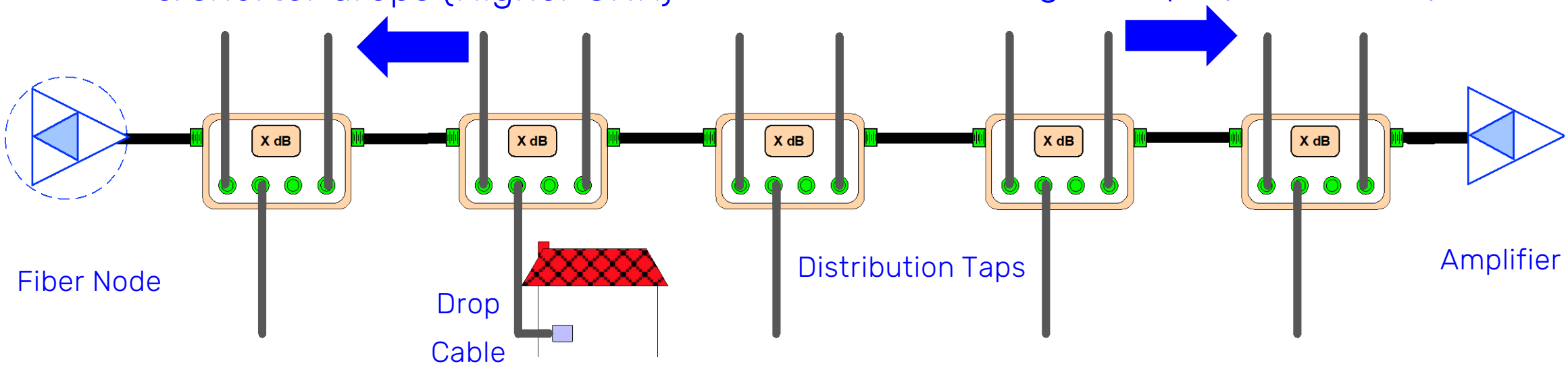
Frequency Dependent Coaxial Segment

@ Higher Frequencies

Lower loss closer to Node/Amplifier & shorter drops (Higher CNR)

Higher loss farther from Node/Amplifier & longer drops (Lower CNR)



Cable Attenuation vs. Frequency

Taps' Frequency Response

Noise/Impairments vs. Frequency

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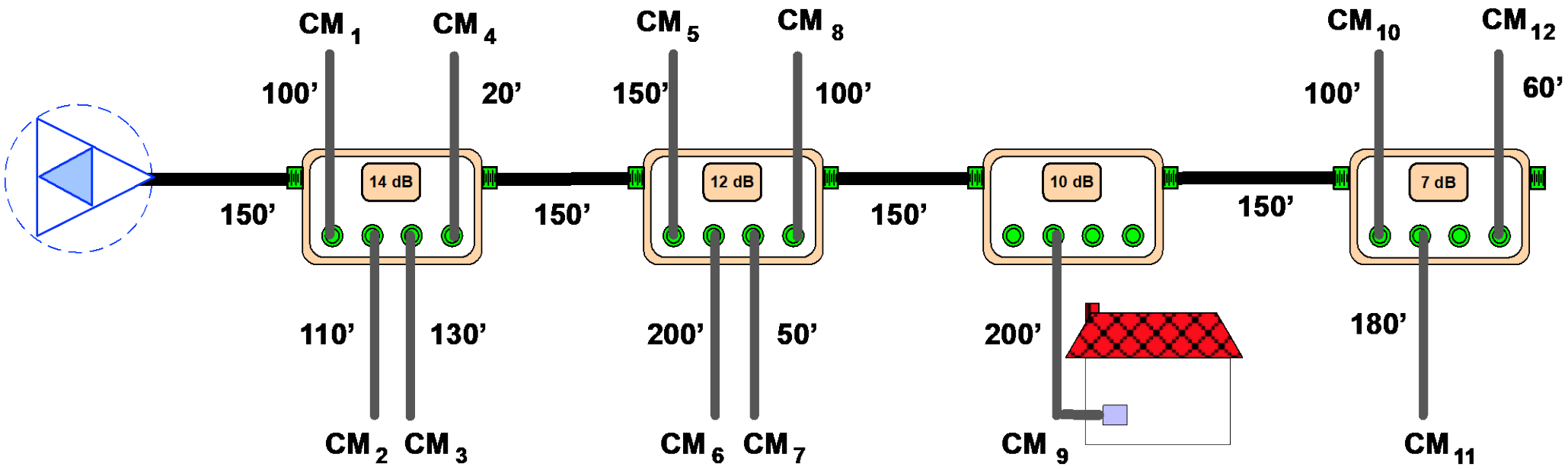
Coaxial Segment Simulation -1



Modem	Full Bw. Gbps
CM_1	134.3592
CM_2	129.5459
CM_3	118.1095
CM_4	146.1113
CM_5	105.6579
CM_6	75.2112
CM_7	145.609
CM_8	134.6757
CM_9	74.7192
CM_{10}	134.053
CM_{11}	85.2012
CM_{12}	144.8434

Avg. capacity /user = 9.345 Gbps => 112.14 Gbps Aggr.

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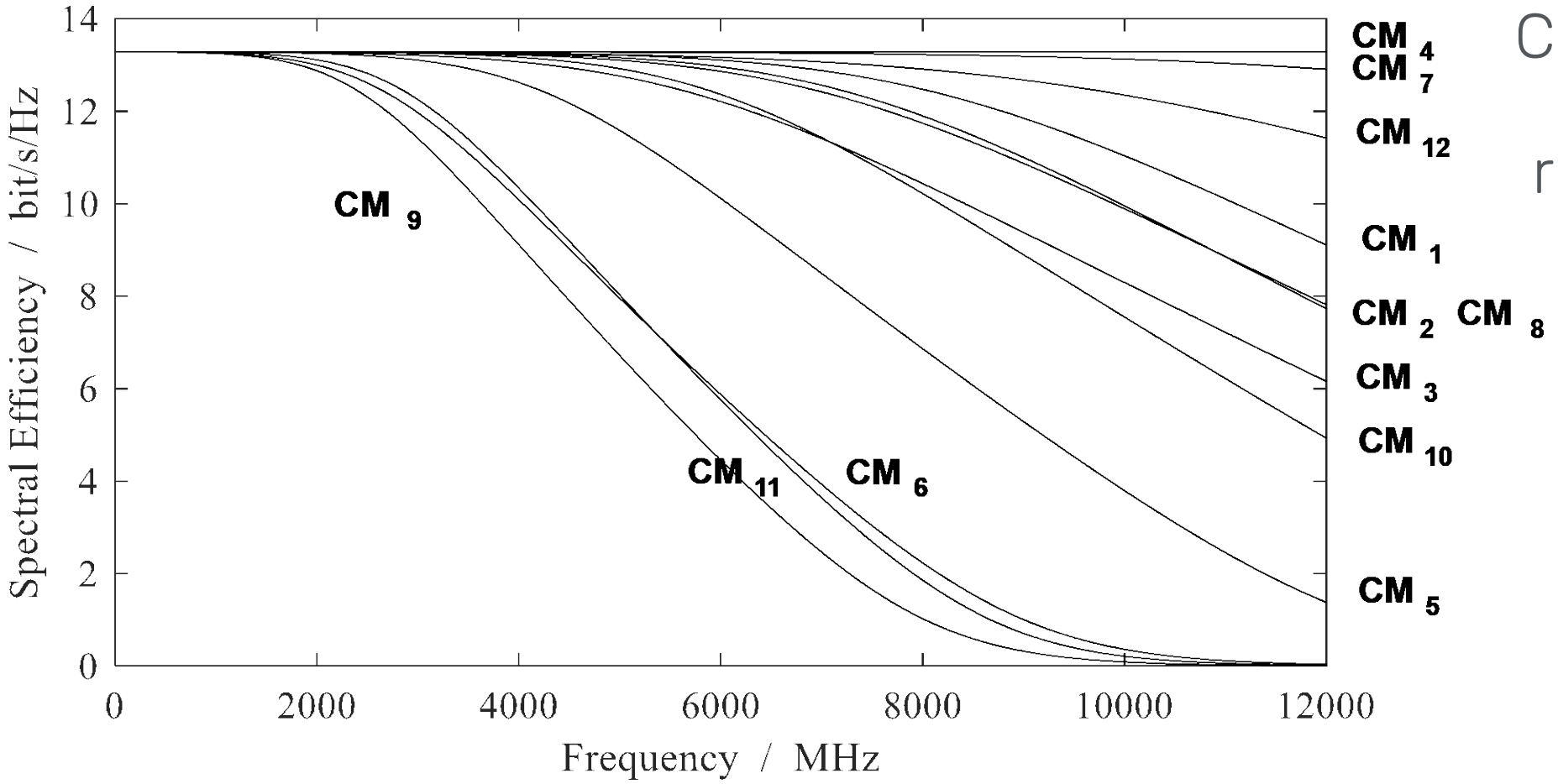
Response over 11 GHz



CMs with better frequency response have greater spectrum allocation flexibility

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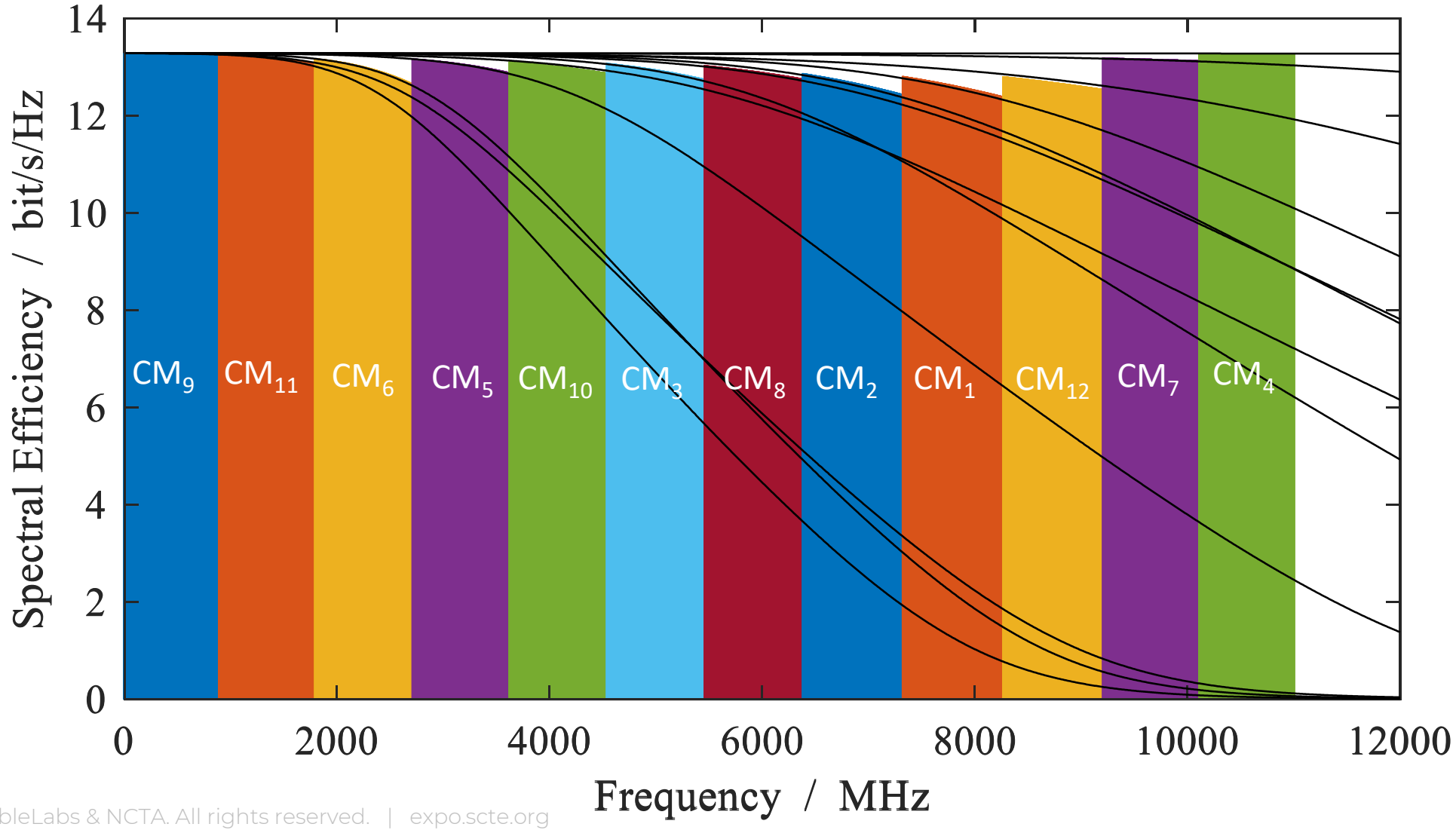
Higher-Frequency-Off First

Avg. capacity /user = 11.901 Gbps => 142.81 Gbps Aggregate 27% Improvement



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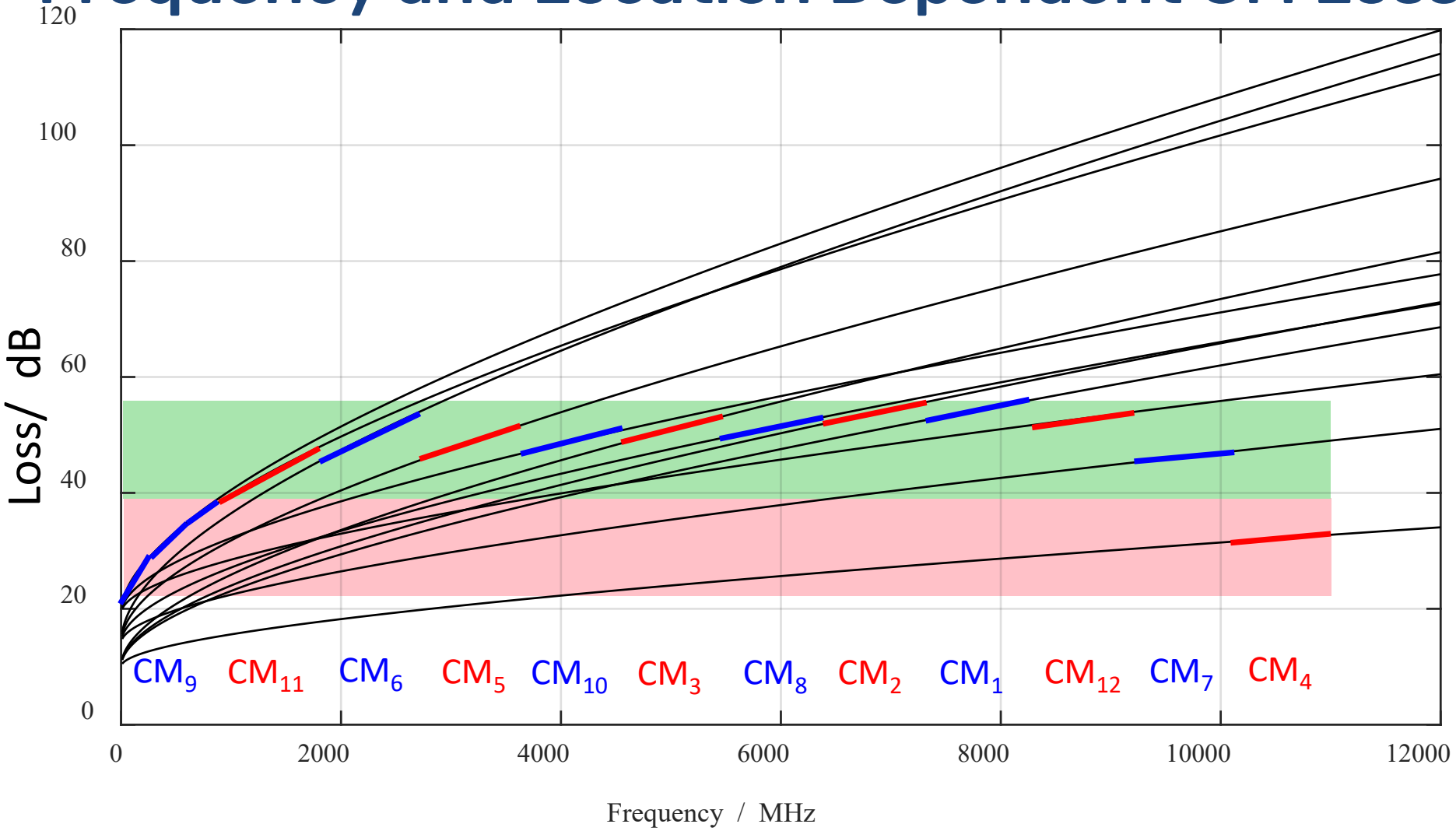
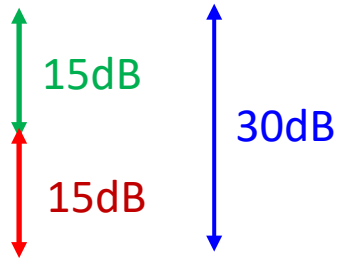
Frequency and Location Dependent CM Loss



Depending on location and path traversed, CMs have different loss vs. frequency characteristics



100 Gbps within Reach

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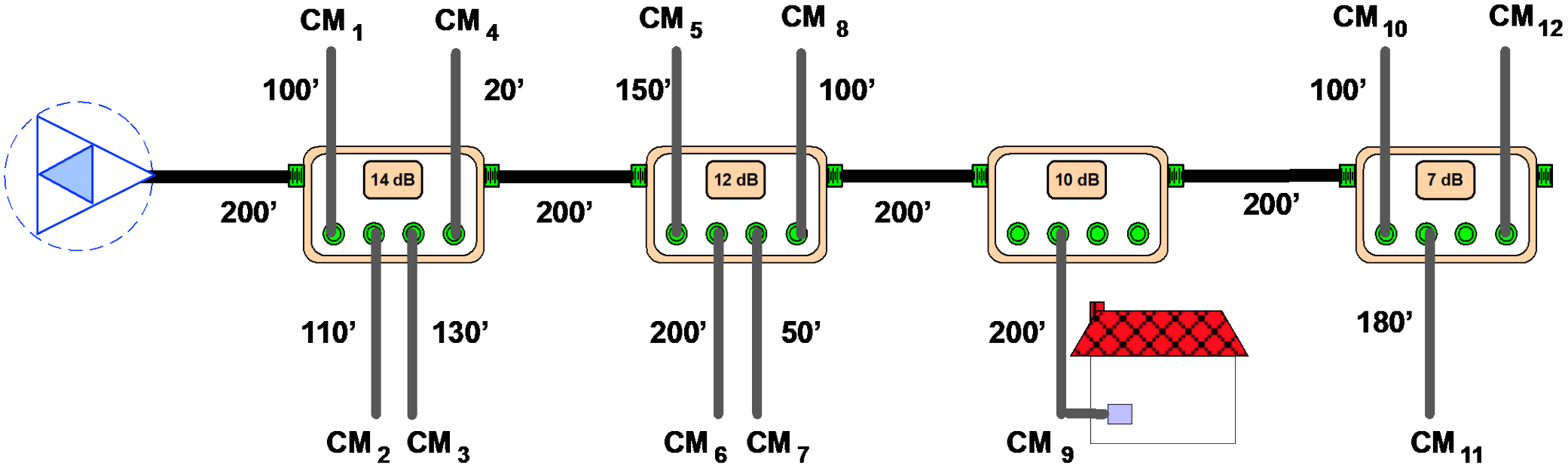
800’ Coaxial Segment Simulation



Modem0 22	Full Bw. Gbps
CM_1	128.3892
CM_2	122.7905
CM_3	110.2571
CM_4	146.0233
CM_5	97.4335
CM_6	69.3176
CM_7	144.7654
CM_8	128.7774
CM_9	68.8586
CM_{10}	128.0151
CM_{11}	78.1782
CM_{12}	143.1207

Traditional - Avg. capacity /user = 8.824 Gbps => 105.888 Gbps Aggr.

HFOF – Avg. capacity / users = 11.666 Gbps => 139.992 Gbps Aggr. (+32%)

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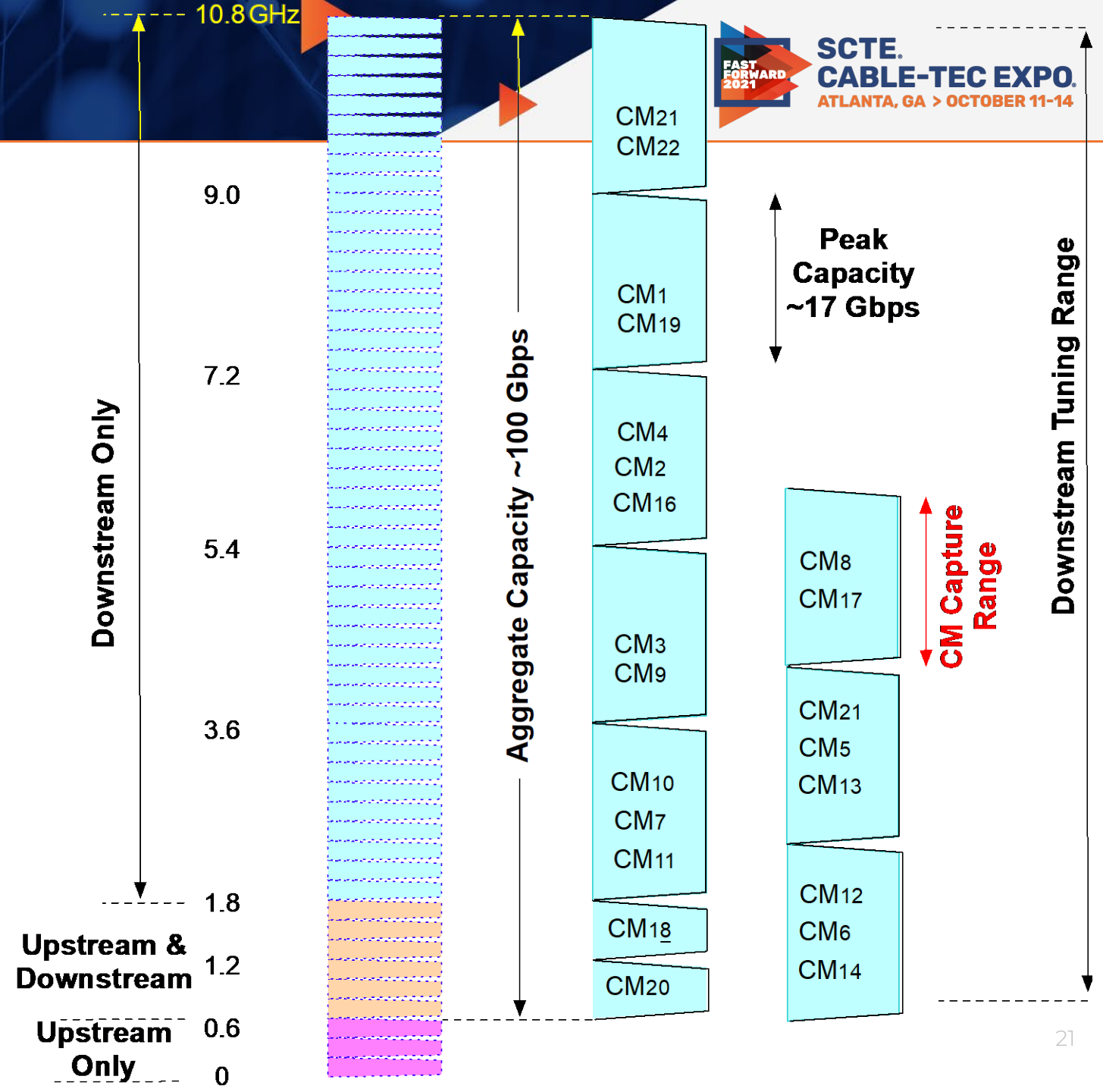
Peak & Aggregate Rates

Limiting Peak Capacity bounds CM processing requirements and complexity

Tunability enables aggregate capacity ~ 100 Gbps



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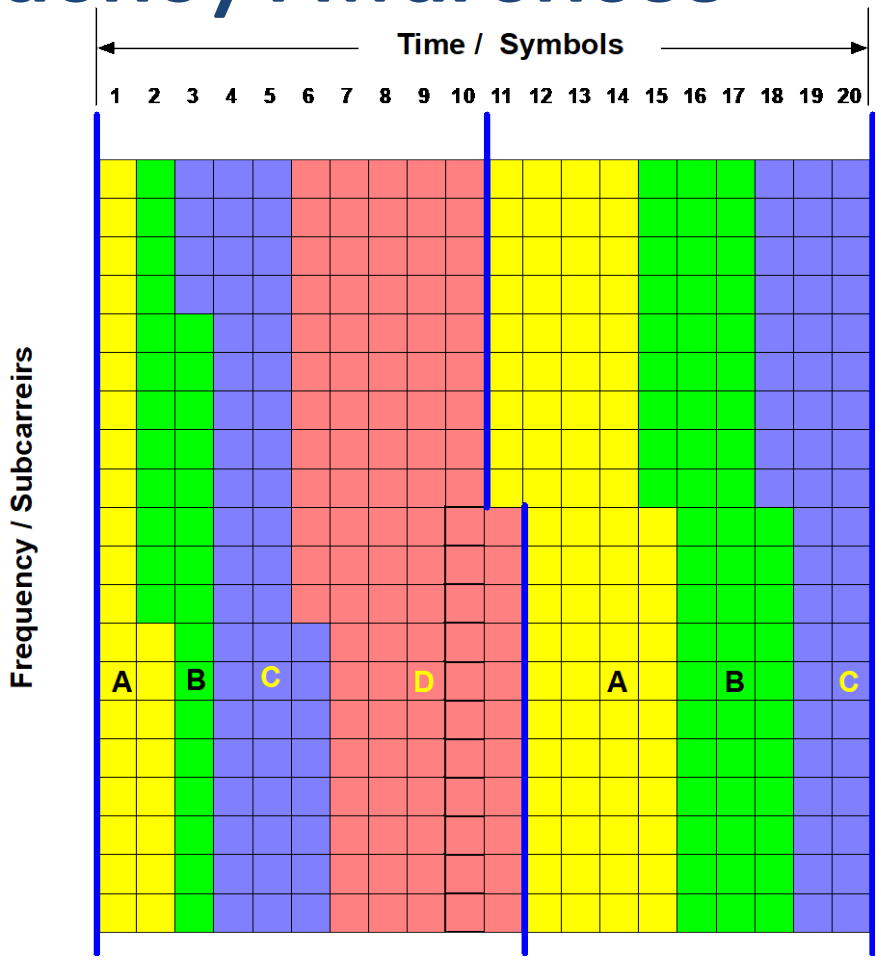
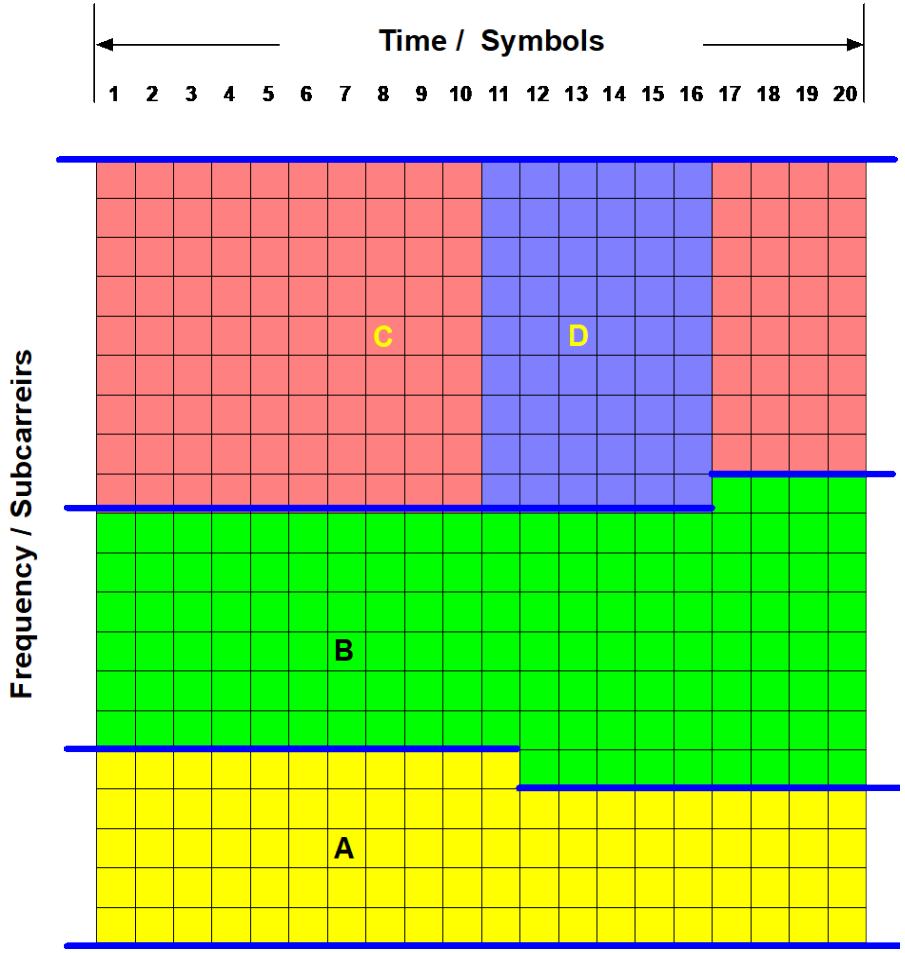
Frequency Awareness



Traditional



Proposed

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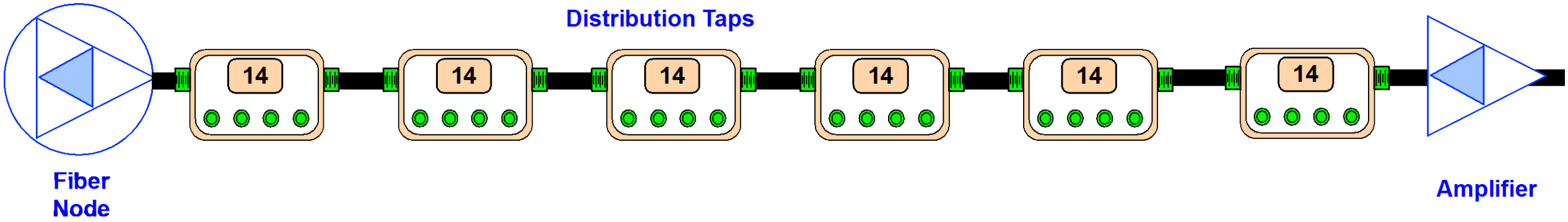
Single Value Tap



Traditional

2-port	29	26	23	20	17	14	11	8	4
4-port	29	26	23	20	17	14	11	8	
8-port	29	26	23	20	17	14	11		

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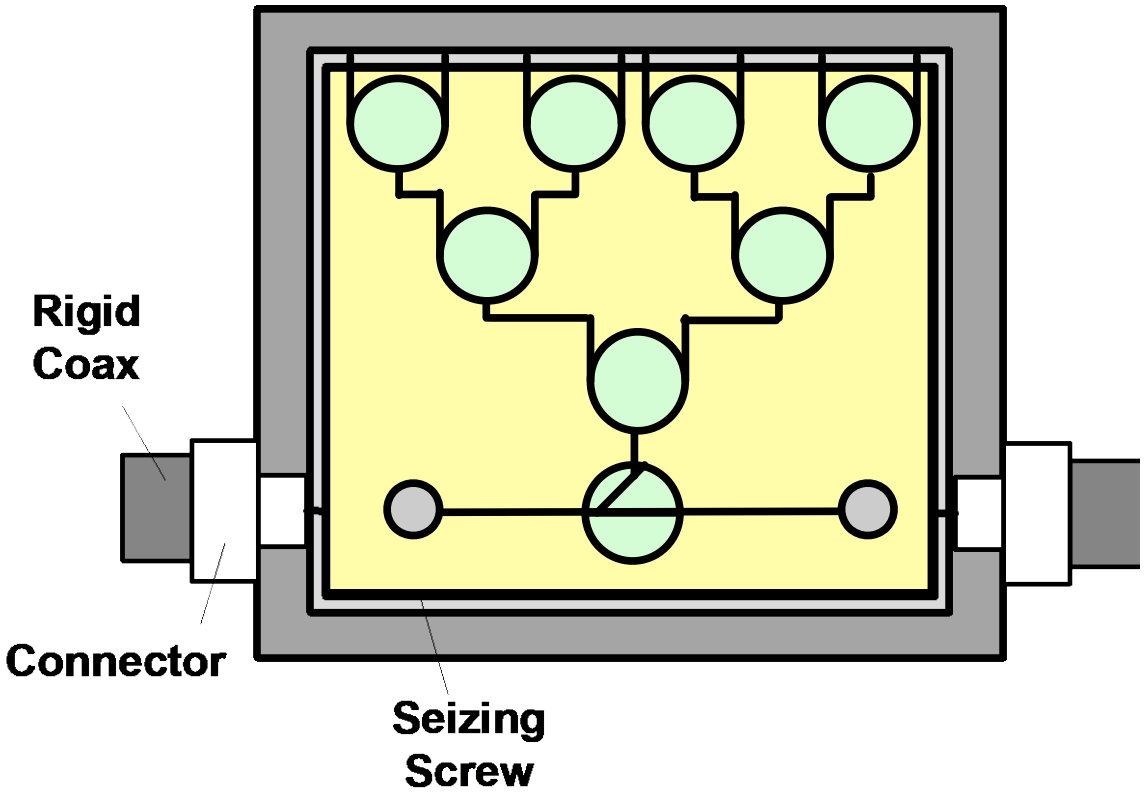
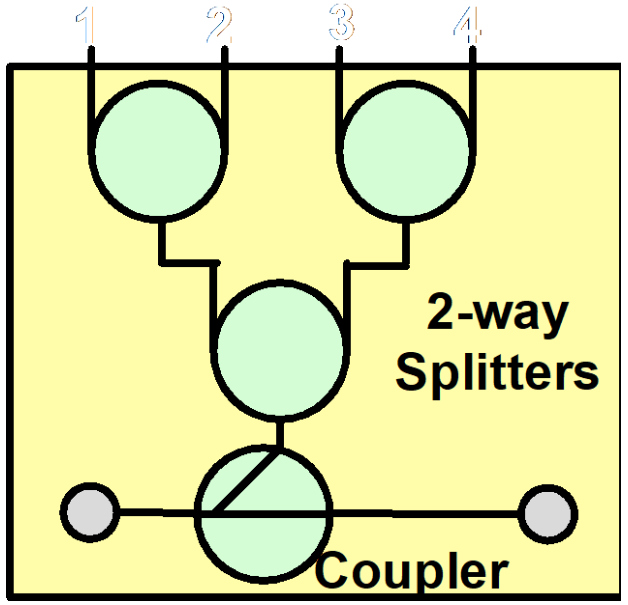
Legacy – Removable Faceplate Concept





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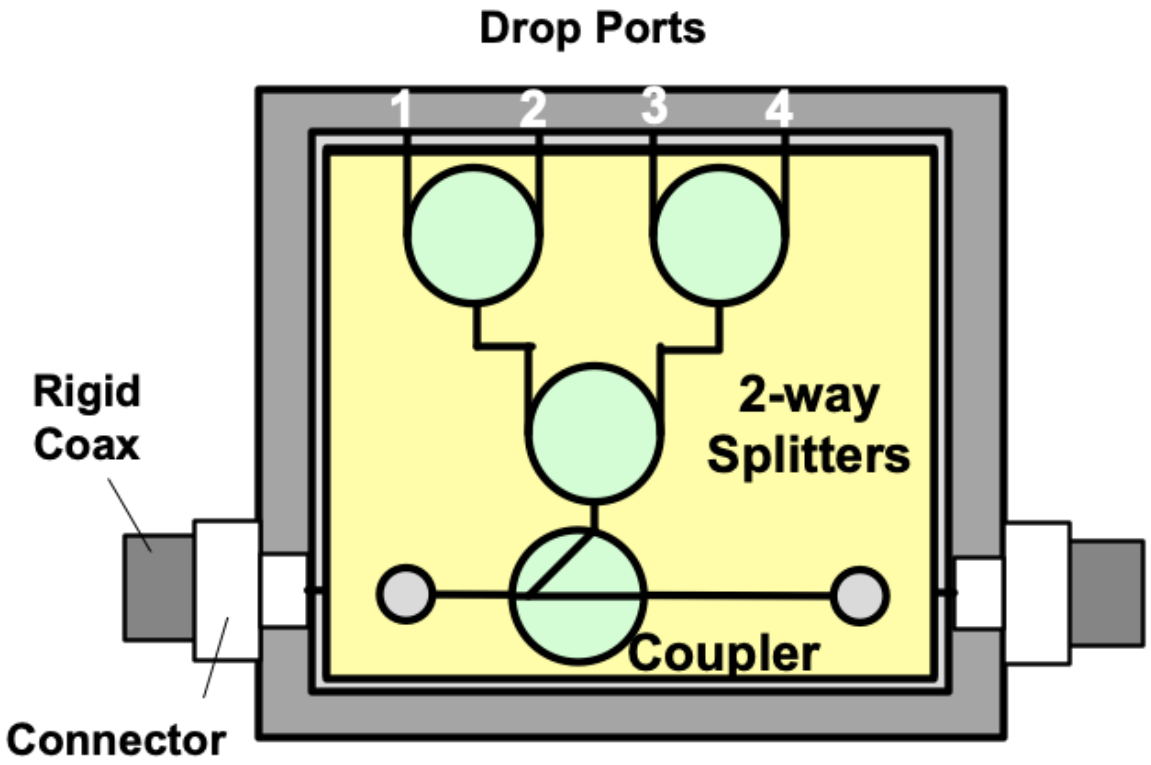
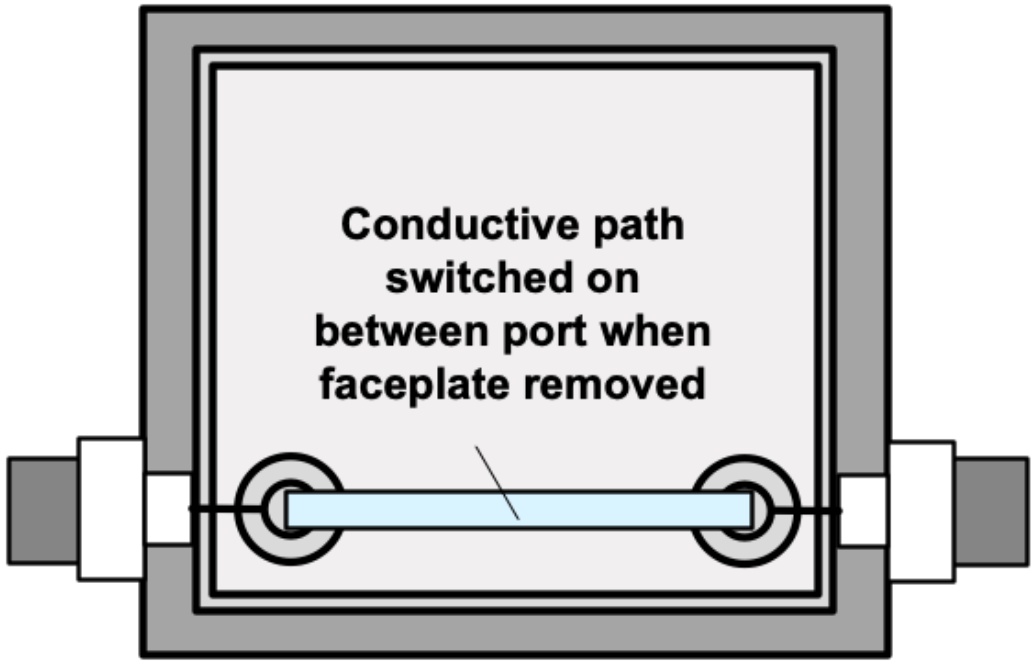
Operation while faceplate is off





Conductive path with faceplate remove gives false sense availability as performance is degraded.

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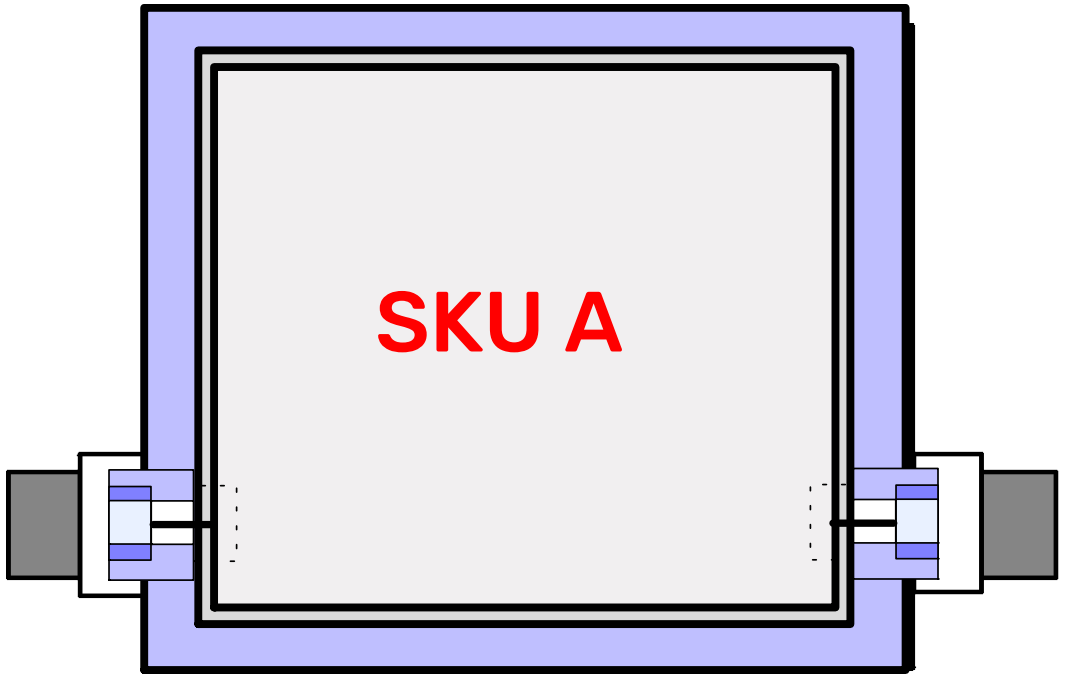
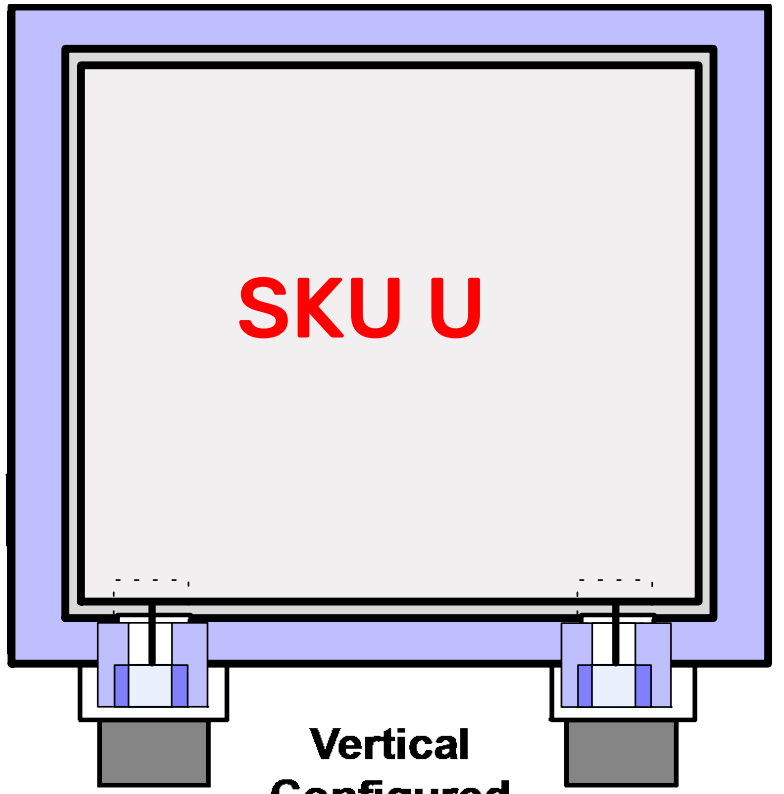
Current: One tap housing adapts to aerial or underground

Proposed: Separate/fixed aerial/underground housings



Horizontal Configured Connector (Aerial)



Vertical Configured Connector (Underground)

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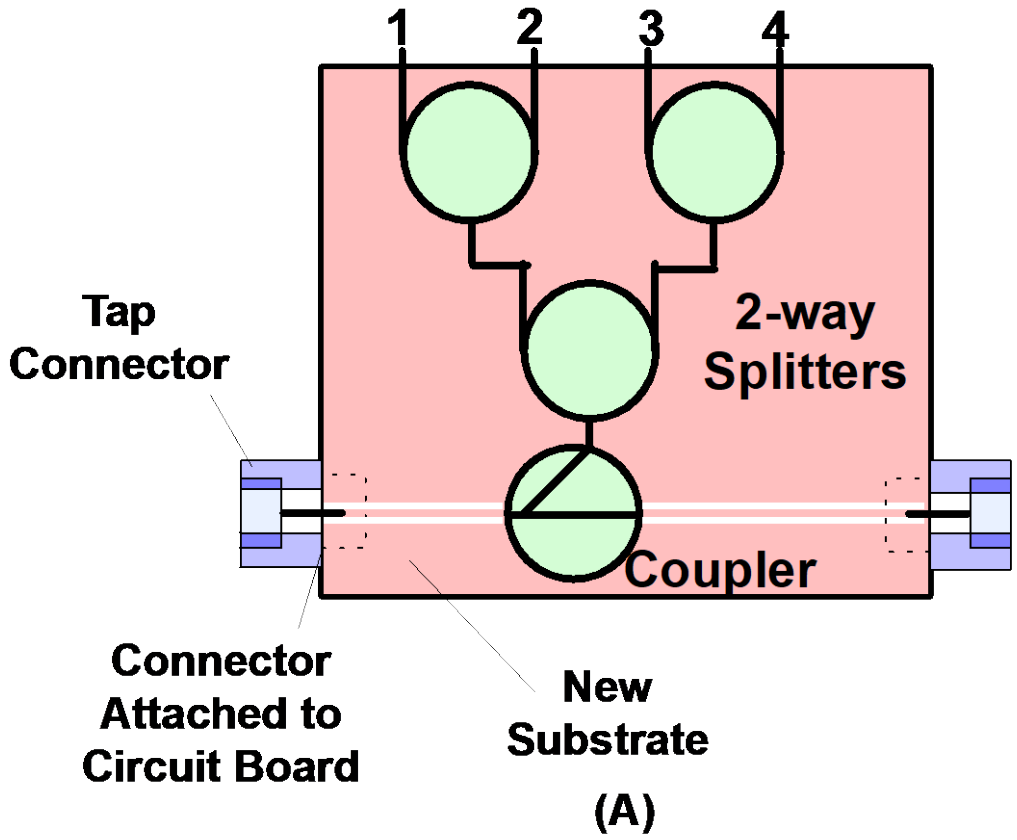
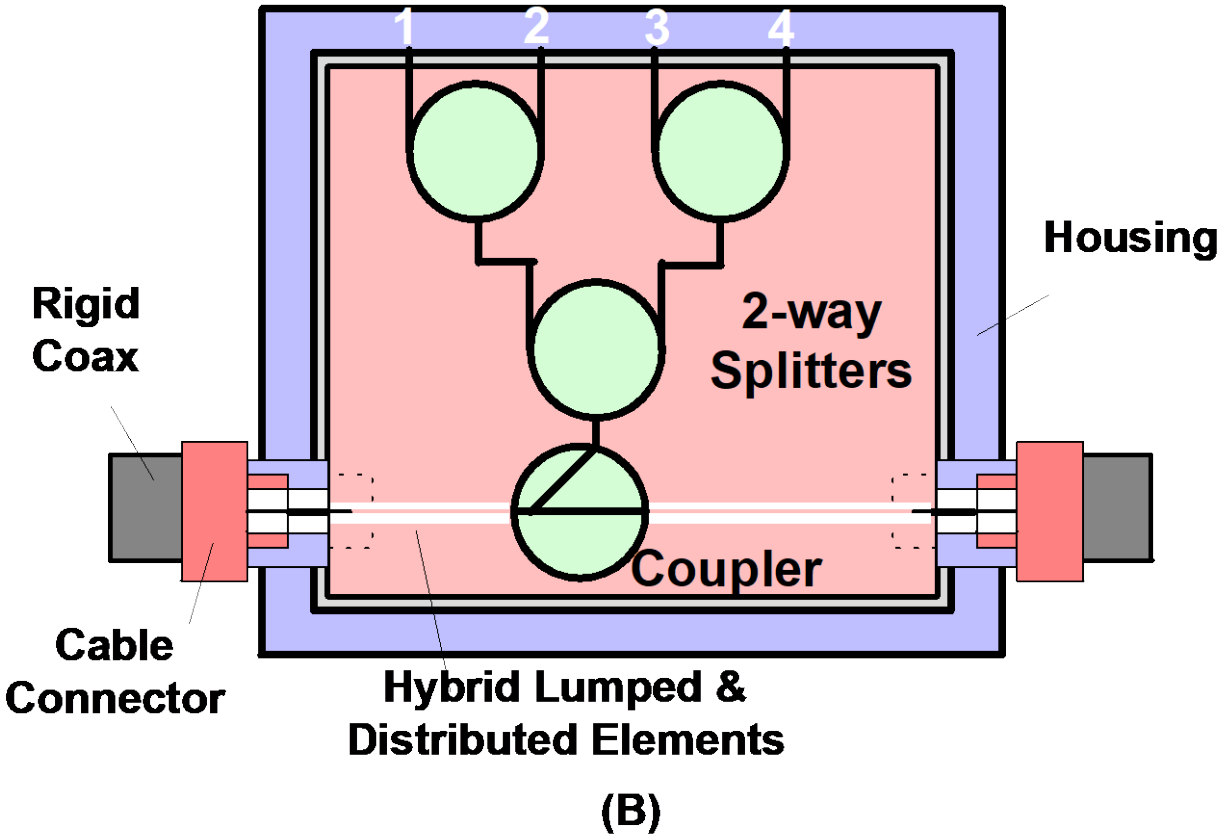
Evolved Tap





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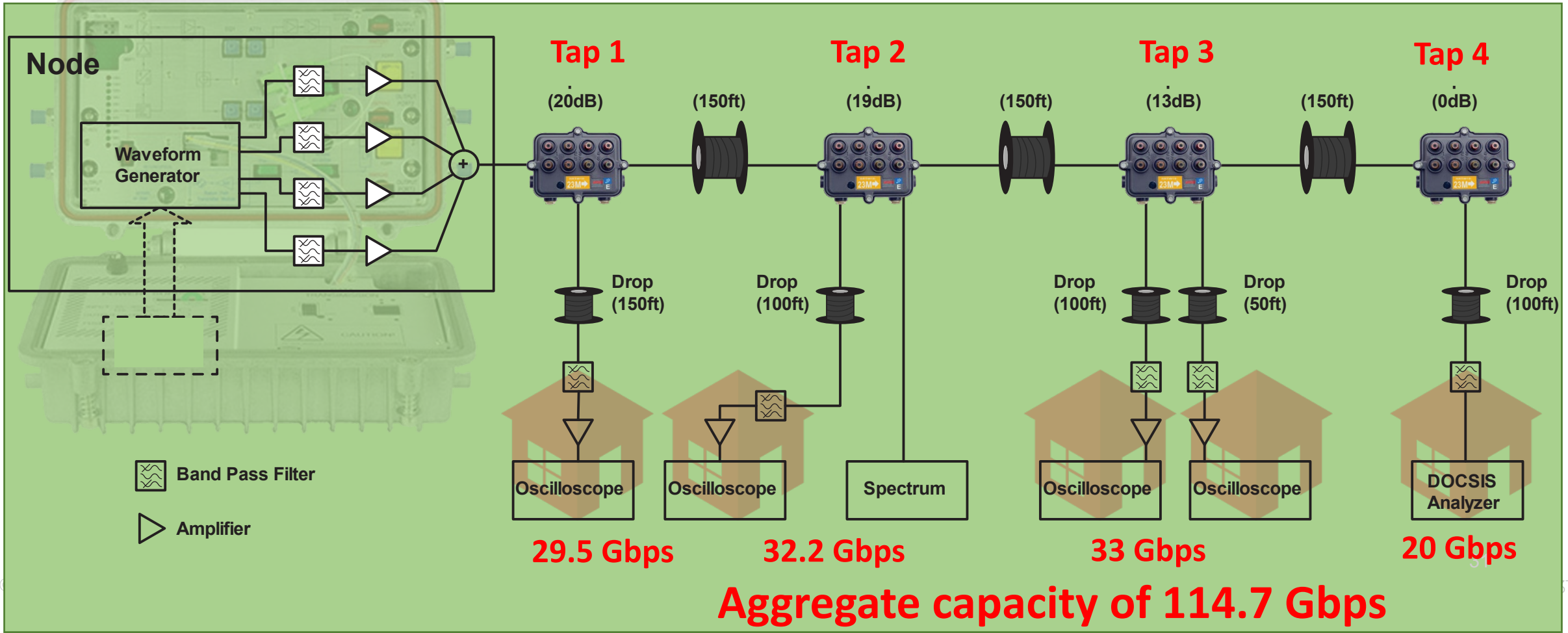
Extreme Cable Experimental Setup

12 x 192 MHz D3.1 Channels

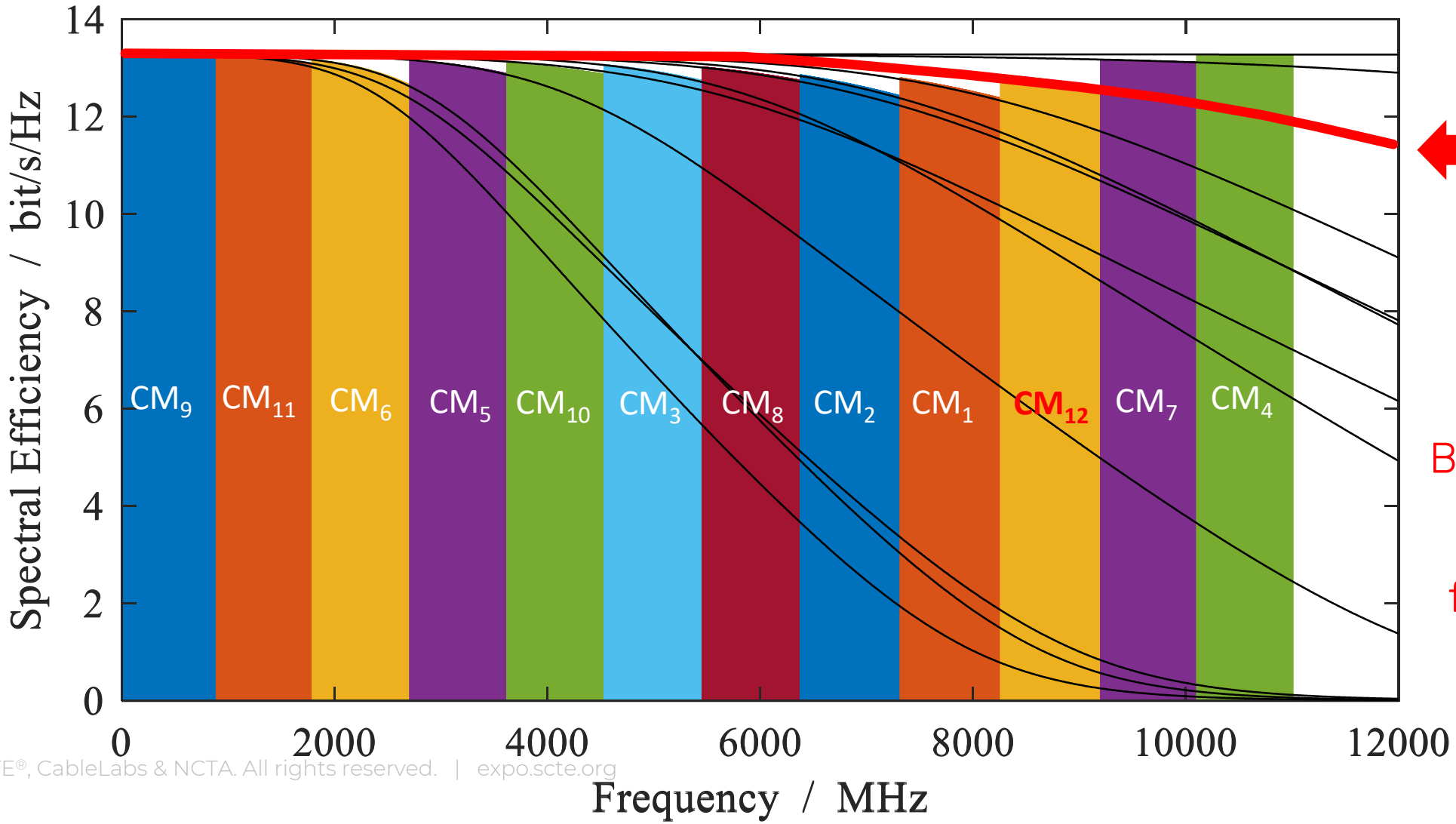
Re-Designed OFDM

500 MHz **3000 MHz** **12 GHz**



Drop cable impacts performance, first amplifier (N+1) "NOT" impacted by drop loss

Significant capacity available after first coaxial segment



Hardline only response estimate

Base-station or AP could be feed directly from Hardline coupler

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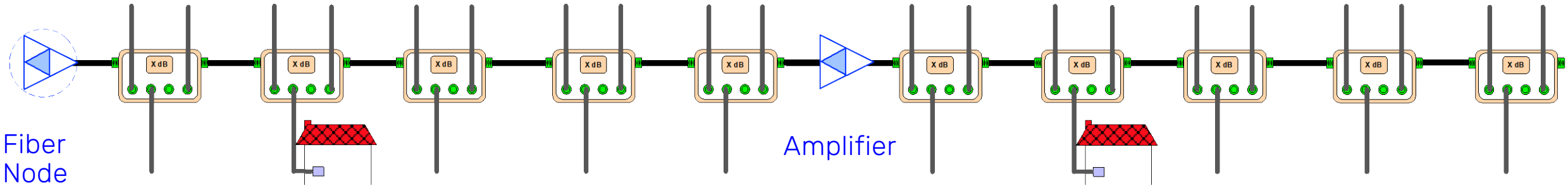
Frequency Allocation



OPTION 1

Fiber Node Bandwidth => 0 – 10 GHz

Last Amplifier Bandwidth => 0 – 6 GHz

OPTION 2

Fiber Node Bandwidth => 0 – 6 GHz

Last Amplifier Bandwidth => 0 – 6 GHz

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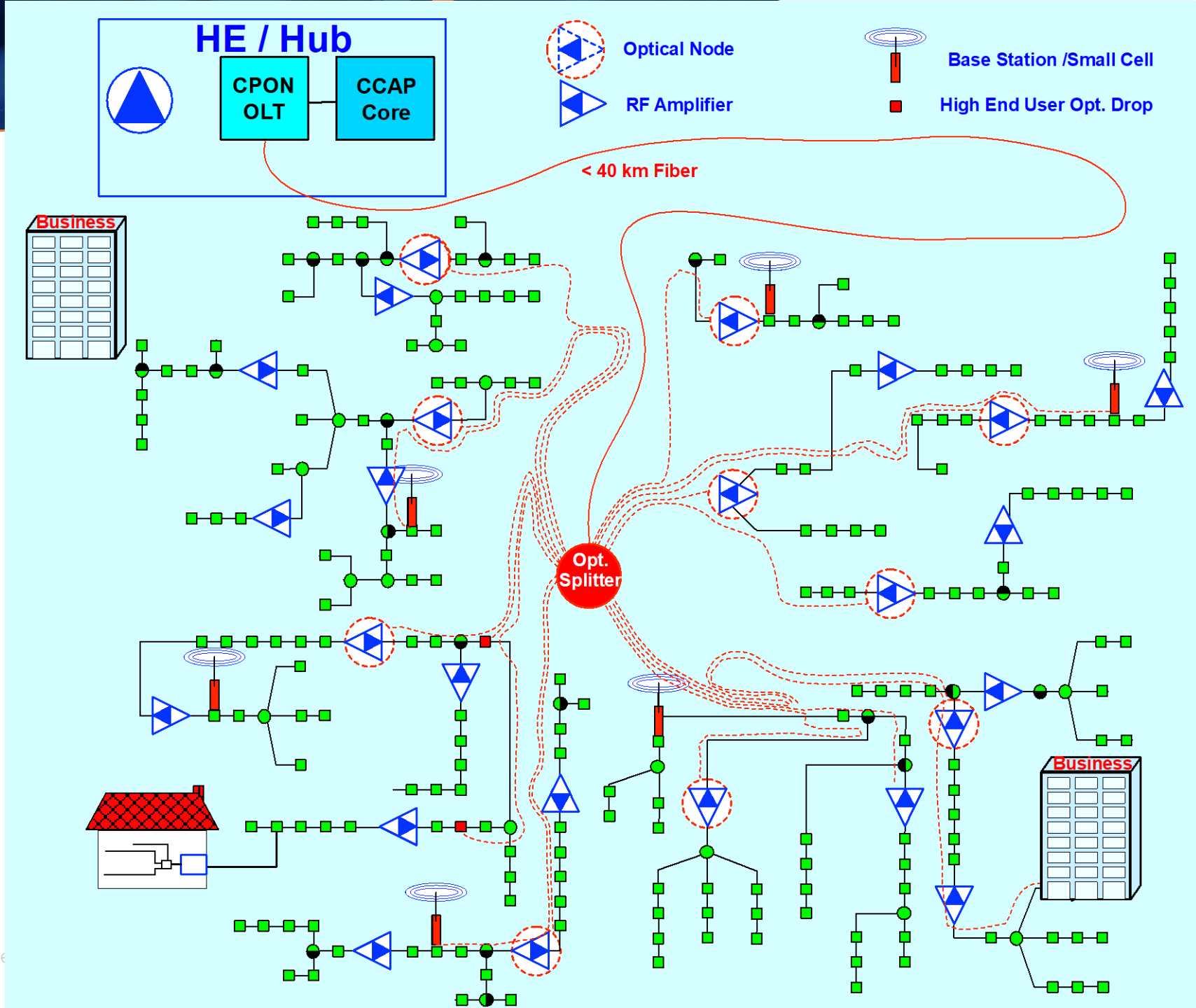
New Kind of "Hybrid" CPON/Extreme

- CPON covering base stations, businesses, fiber nodes (if DAA) and high-end/high-peak-rate users
- Success based CPON deployment
- Extreme spectrum covering lower consumption users up to 25 Gbps (50 Gbps?)



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Conclusion

Different premise: No longer same power at receivers

Leverage ultimate coaxial capacity – Extreme Cable; > 10 GHz, > 100 Gbps

Higher Frequency Off First approach

Frequency aware scheduling

Peak vs aggregate complexity control strategy

Single value tap

Tap & connector redesign

New “Hybrid” Fiber Coax => Coordinated CPON + Extreme Cable

- Success based FTTH
- 25 – 50 Gbps coax peak rates
- CPON to address 100 Gbps long term peak rates

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