Introduction to Coaxial Plant Operating Conditions and Requirements

IEEE 802.3 EPOC Study Group

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Purpose

- To provide a BACKGROUND from which the SG and TF can begin to assess the conditions under which a new Coaxial-based PHY will need to operate.
- The operating assumptions given in this deck are only a reference from the DOCSIS 3.0 PHY.
- This deck is NOT intended to be a proposal for the conditions under which EPoC will operate.

Supporters and Contributors

- Matt Schmitt, Cablelabs
- John Bevilacqua, Comcast
- Ed Mallette, Brighthouse Networks
- Volker Leisse, Cable Europe Labs
- John Dickinson, Brighthouse Networks

Source

- The data, characteristics, and parameters given in this contribution are based on
  - Functional Assumptions (Section 5) found in DOCSIS 3.0 PHY (CM-SP-PHY3.0)
  - Additions and Modifications for European Specification (Section B.5) found in DOCSIS 3.0 PHY (CM-SP-PHY3.0)

- The latest version is found at:
  - http://www.cablelabs.com/specifications/CM-SP-PHYv3_0_110-111117.pdf

Other References

- In the United Stated, SCTE 40 is one of the standards by which the FCC measures the cable operators' plant operations
- http://www.scte.org/documents/pdf/Standards/SCTE_40_2011.pdf

Definitions

- Downstream = Transmission from the headend (hub) toward the customer equipment
- Upstream = Transmission from the customer equipment toward the headend (hub)

Coaxial Cable

- Nominal impedance = 75 Ω
- Loss varies with cable type (see March 2012 contribution from Mark Laubach entitled "A First Look at Modeling EPoC on Cable")
- Loss varies with frequency (Tilt or Slope)
  - Active plants apply "un-tilt" measures

CommScope®[1] 59, 6 and 11 Drop Cable

Frequency (MHz)	Maximum Attenuation db/100m 20°C		
	59 Series	6 series	11 series
5	2.82	1.90	1.25
55	6.73	5.25	3.15
83	8.04	6.40	3.87
187	11.81	9.35	5.74
211	12.47	10.00	6.23
250	13.45	10.82	6.72
300	14.60	11.64	7.38
350	15.75	12.63	7.94
400	16.73	13.61	8.53
450	17.72	14.43	9.02
500	18.70	15.29	9.51
550	19.52	16.08	9.97
600	20.34	16.73	10.43
750	22.87	18.54	11.97
865	24.67	20.01	13.05
1000	26.64	21.49	14.27

[1] www.commscope.com Drop Cable Products Product Catalog

Jan 2012 contribution from Mark Laubach entitled
"A First Look at Modeling EPoC on Cable")

CommScope® 59, 6 and 11 Drop Cable

- Approximating beyond 1000MHz
  - Table stops at 1000MHz, approximate loss using formulae based on 1000MHz

6.4 Cable Loss vs. Frequency

If you know the cable loss at a given frequency, you can calculate the loss at a desired frequency using the following formula:

$$L_{F_2} = L_{F_1}\sqrt{\frac{F_2}{F_1}}$$

where:

L_{F_2} = Loss at the desired frequency (dB)

L_{F_1} = Loss at the known frequency (dB)

F_2 = Desired frequency (MHz)

F_1 = Known frequency (MHz)

Frequency (MHz)	Maximum Attenuation db/100m 20°C		
	59 Series	6 series	11 series
850	24.3	19.7	12.7
1000	26.64	21.49	14.27
1150	28.6	23.0	15.3
1300	30.4	24.5	16.3
1400	31.5	25.4	16.9
1600	33.7	27.2	18.1
2400	41.3	33.3	22.1
2800	44.6	36.0	23.9
3000	46.1	37.2	24.7

Jan 2012 contribution from Mark Laubach entitled "A First Look at Modeling EPoC on Cable")

Coaxial Cable

- *The EPOC PHY will need to compensate for varying attenuations and tilt.*
  - *Especially in passive plants*
  - *Perhaps not so much in "active" plants since the service provider compensates for it in the system design*

Compatibility with Other Services

- CM and CMTS MUST be interoperable in its assigned spectrum while the balance of the spectrum is occupied by any combination of other digital or analog signals
- CM and CMTS MUST NOT cause harmful interference to other services that operate on the cable network in spectrum assigned outside the spectrum assigned for operation.
- *These statements could just as easily refer to EPoC OLT and the EPoC Terminal Equipment (CNU)*

Compatibility with Other Services

- Three levels of "No Harmful Interference":
  - HIGHEST = No measureable degradation, (best)
  - MEDIUM = No degradation below the perceptible level of impairments for all services
  - MINIMUM = No degradation below the minimal standards accepted by the industry (FCC regulations, for example) or other service provider

- *<u>EPoC should be aiming for "MEDIUM" or higher compatibility</u>*

Terminal Devices

- The CM MUST meet and preferably exceed all applicable regulations for Cable System Termination Devices and Cable Ready Consumer Equipment as defined in
  - FCC Part 15 [FCC15] and Part 76 [FCC76] (for the United States)
  - **[EN 300 429]**
- When these regulatory requirements are less rigorous than those required by the industry, the industry requirements MUST be met.
- *<u>EPoC will have to comply with these same regulations</u>*

RF Channel Assumptions

Transmission Downstream

Assumed DS Channel Characteristics

Parameter	Value (N. America)	Value (Europe)
Frequency Range	Normal: 50-1002MHz; >108MHz for DS in today's network TBD for the future coax network	Normal: 50-1006MHz; >108MHz for DS in today's network TBD for the future coax network
RF Channel Spacing	6MHz in today's network TBD for the future coax network	8MHz for data channels in today's network TBD for the future coax network

Frequency Plans

- *The currently published specifications and standards for spectrum planning do not adequately address what is required for EPoC (or any other technology) to meet the industry's long term needs*

- Please refer to the contribution from Ed Mallette and John Dickinson titled "MSO Use Case Topologies for EPOC"

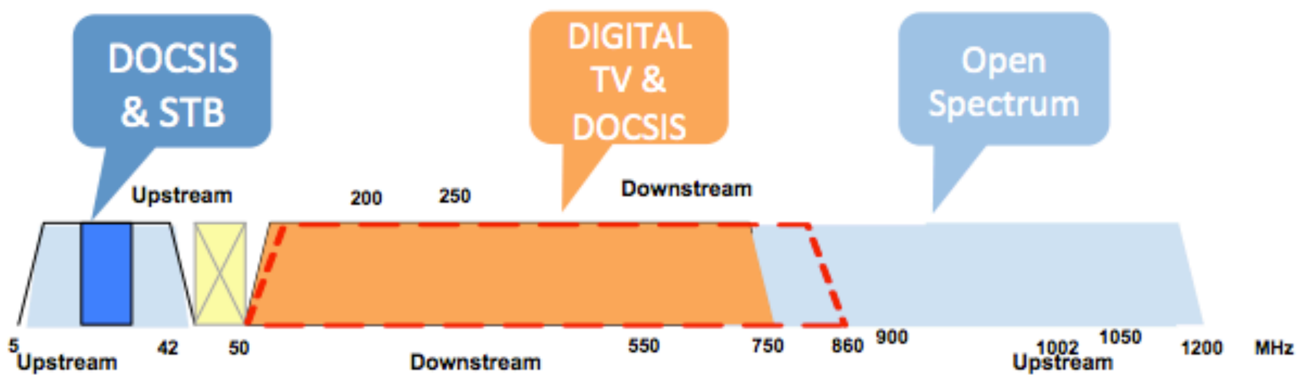
Existing Services Spectrum Utilization

Operator HFC Networks have differing Capacities based on how upgrades performed over the years.

Therefore MSO Networks will have Differing Capacity / Spectrum availability

Existing Service Spectrum Allocations

Note: these vary by MSO Operator



March 2012 Contribution from
Ed Mallette and John Dickinson entitled
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FDD Profile 1
EPOC US Low band & DS High band

FDD Upstream in the 5-42MHz Range

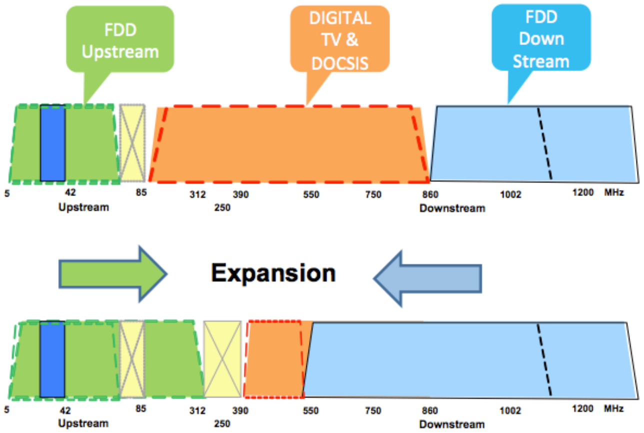
FDD Upstream grows into 65, 85 or 100 MHz

FDD Downstream 750MHz to ~1100MHz

FDD Upstream expands 5-200MHz

FDD Downstream 550MHz to1100MHz

FDD Downstream 400MHz to1100MHz



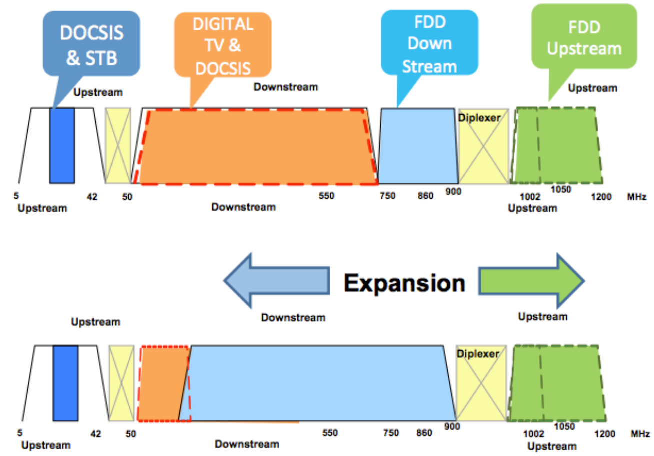
FDD Profile 2
EPOC DS High Band and US High Band

FDD Upstream in the > 1000MHz

FDD Downstream in 750 - 900MHz

FDD Upstream in the 1000 – 1200MHz

FDD Downstream in 300 – 900MHz



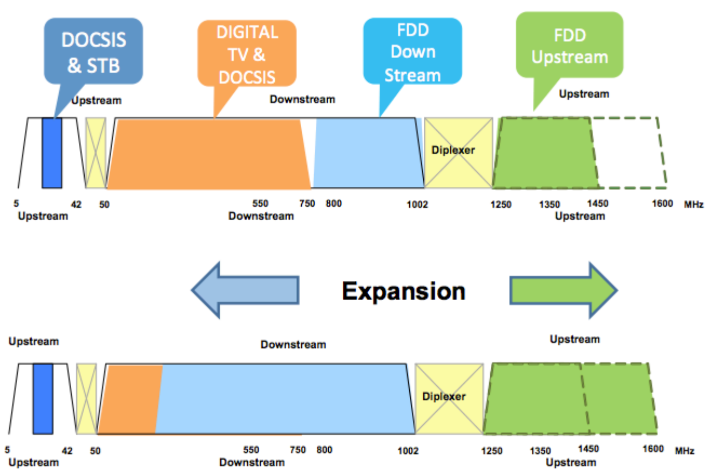
FDD Profile 3
DS High Band and US Ultra High Band

FDD Upstream in the 1250 – 1450MHz

FDD Downstream in 750 – 1000MHz

FDD Upstream in the 1250 – 1800MHz

FDD Downstream in 300 – 1000MHz



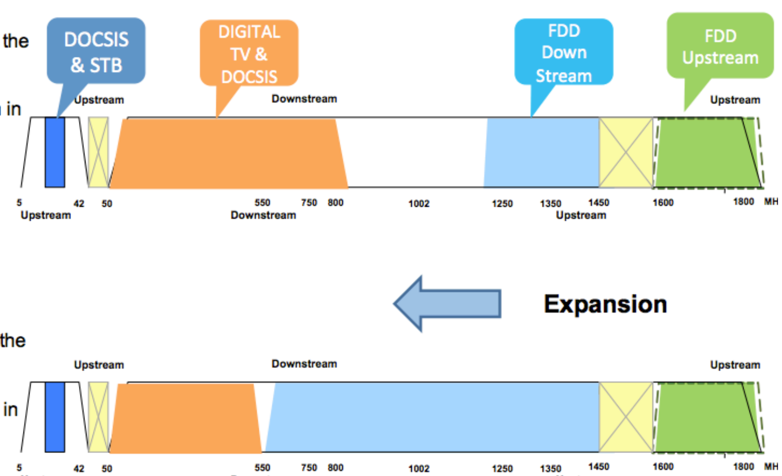
FDD Profile 4
DS Ultra High Band and US Ultra High Band

FDD Upstream in the 1600 – 1850MHz

FDD Downstream in 1250 – 1450MHz

FDD Upstream in the 1600 – 1850MHz

FDD Downstream in 300 – 1450MHz



March 2012 Contribution from Ed Mallette and John Dickinson entitled "MSO Use Case Topologies for EPOC"

Frequency Plans

- *Because the future spectrum architecture is uncertain, EPoC will need to be flexible to operate the downstream anywhere in the 5MHz to at least 1002MHz range*

Assumed DS Channel Characteristics

Parameter	Value
Transit Delay from Head-end to Most Distant Customer	≤ 0.800ms

- 0.800ms transit equates to 1.6ms RTT
- Compare to "best practice" 200 μ sec RTT in EPON
- Equivalent distance is approximately 160km (@ V_p=0.66*c)
- *Distance is going to be a KEY discussion point*

Assumed DS Channel Characteristics

Parameter	**Value (N. America)**	**Value (Europe)**
CNR in 6MHz band	≥ 35dB	N/A
Carrier to Composite Triple Beat	≥ 41dB	N/A
Carrier to Composite Second Order	≥ 41dB	N/A
Carrier to Cross Modulation	≥ 41dB	N/A
Carrier to any other Discrete Interference (ingress)	≥ 41dB	N/A
Carrier Hum Modulation	≤ -26dBc	≤ -46dBc
Burst Noise	≤ 25 μ sec @ 10Hz avg. rate	≤ 25 μ sec @ 10Hz avg. rate

Assumed DS Channel Characteristics

Parameter	Value (N. America)	Value (Europe)
CNR in 8MHz band	N/A	≥ 44dB
Composite triple beat distortion	N/A	≤ -57dBc
Composite Second Order Distortion	N/A	≤ -57dBc
Cross Modulation	N/A	Undefined
Carrier to Interference (broadband+discrete ingress)	N/A	≥ 52dB

Assumed DS Channel Characteristics

Parameter	Value (N. America)	Value (Europe)
Amplitude Ripple	3dB within the design BW	2.5dB in 8MHz
Group Delay Ripple	75ns within the design BW	100ns over 0.5-4.43MHz
Maximum Analog Video Carrier at Input to Customer Equipment	17dBmV	17dBmV
Seasonal and diurnal signal level variation	unspecified	8dB
Signal level slope	unspecified	≤ +/-12dB, 85 – 862 MHz

Assumed DS Channel Characteristics

Parameter	Value (N. America)	Value (Europe)
Micro-reflections bound for dominant echo	-10 dBc @ ≤ 0.5 μsec -15 dBc @ ≤ 1.0 μsec -20 dBc @ ≤ 1.5 μsec -30 dBc @ > 1.5 μsec	-10 dBc @ ≤ 0.5 μs -15 dBc @ ≤ 1.0 μs -20 dBc @ ≤ 1.5 μs -31.5 dBc @ > 1.5 μs

- Micro-reflections are reflections with a time delay equal to or less than the symbol period
- Micro-reflections are caused by impedance mismatches along the coax cable transmission path. These can occur at bends, connectors, inside active and passive system components, etc.

RF Channel Assumptions

Transmission Upstream

Assumed Upstream Channel Characteristics

Parameter	Value (N. America)	Value (Europe)
Frequency Range	5-42MHz or 5-85MHz for upstream in today's network TBD for the future coax network	5-65MHz for upstream in today's network TBD for the future coax network
RF Channel Spacing	N/A	N/A

- Because the future spectrum architecture is uncertain, EPoC will need to be flexible to operate the upstream anywhere in the 5MHz to at least 1002MHz range

Assumed Upstream Channel Characteristics

Parameter	Value
Transit Delay from Head-end to Most Distant Customer	≤ 0.800ms

- 0.800ms transit equates to 1.6ms RTT
- Compare to "best practice" 200 μ sec RTT in EPON
- Equivalent distance is approximately 120km (@ V_p=0.8*c)
- *Distance is going to be a KEY discussion point*

Assumed Upstream Channel Characteristics

Parameter	Value (N. America)	Value (Europe)
Carrier to Noise Ratio	N/A	≥ 22dB
Carrier to (Interference + Ingress) Ratio	≥ 25dB	N/A
Carrier to Ingress	N/A	≥ 22dB
Carrier to Interference	N/A	≥ 22dB

- Ingress = (the sum of discrete and broadband ingress signals)
- Interference = The sum of noise, distortion, common-path distortion and cross modulation

Assumed Upstream Channel Characteristics

Parameter	Value (N. America)	Value (Europe)
Carrier Hum Modulation	≤ -23dBc	≤ -23dBc
Burst Noise	≤ 10 μ sec @ 1kHz avg. rate	≤ 10 μ sec @ 1kHz avg. rate

- Burst Noise is capable of partially or fully masking the data carrier

Assumed Upstream Channel Characteristics

Parameter	Value (N. America)	Value (Europe)
Amplitude Ripple	0.5dB across the upstream frequency range	2.5dB in 2MHz
Group Delay Ripple	200ns/MHz across the upstream frequency range	300ns in 2MHz
Seasonal/Diurnal loss variation	≤ 14dB min to max	≤ 12dB min to max

Assumed Upstream Channel Characteristics

Parameter	Value (N. America)	Value (Europe)
Micro-reflections single-echo	-10 dBc @ $\leq$ 0.5 μsec -20 dBc @ $\leq$ 1.0 μsec -30 dBc @ > 1.0 μsec	-10 dBc @ $\leq$ 0.5 μsec -20 dBc @ $\leq$ 1.0 μsec -31.5 dBc @ > 1.0 μsec

- Micro-reflections are reflections with a time delay equal to or less than the symbol period
- Micro-reflections are caused by impedance mismatches along the coax cable transmission path. These can occur at bends, connectors, inside active and passive system components, etc.

Summary of Operation in the Upstream

- Current plant architecture has the upstream operating in the "unimproved" spectrum
  - Ingress is more frequent and more intense in the lower frequencies
  - The lower band is more susceptible to
    - broadband noise (electrical equipment, motors, etc.), and
    - High intensity narrowband noise (Citizen's Band Radio, for example)
- The upstream is a noise funnel – noise enters in many places and is summed across all branches and sent to a single receiver at the top of the topology

Closing Remarks

- These characteristics are based on data collected and documented early in the life of DOCSIS
- Many cable networks that run DOCSIS will operate in better conditions due to higher standards of maintenance
- Q&A

Thank You!