Modeling Reverse HFC Plant for Advanced Services

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Goals For Today

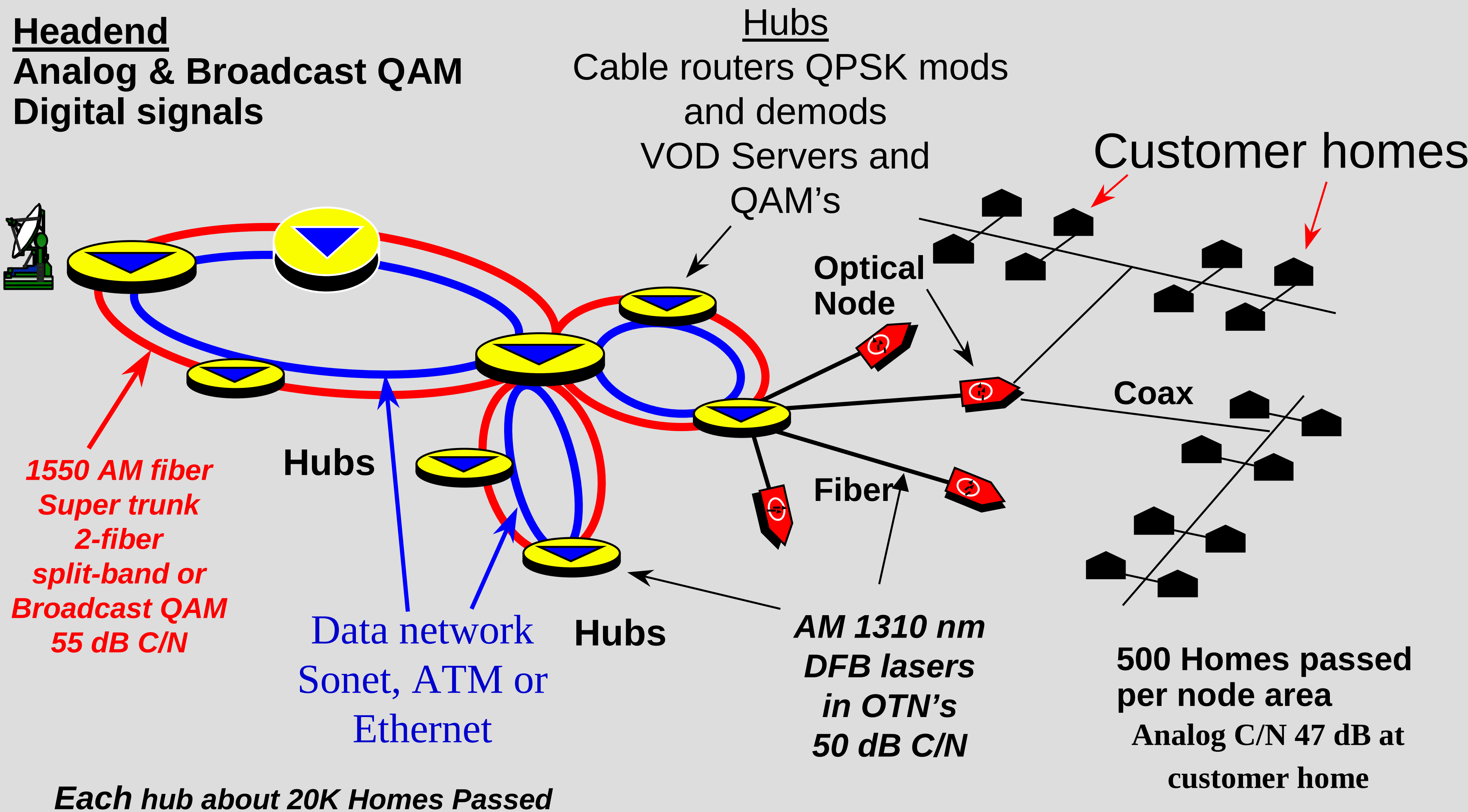
- Link HFC reverse plant performance to the hardware and services used to provide advanced services.
- Indicate areas that have been problems in the deployment of advanced services.
- Provide "Situational Awareness" as it relates to HFC plant, headend, hub sites, and network architectures.

What is the CATV Network?

- Broadband delivery of Multiple Services to the Residential Home or Business.

- A Bi-directional Network capable of delivering both analog and digital services in a switched or subscription format.

AM and Digital Transmission System For HFC Plant



The reverse HFC plant is divided into four main areas

- The drop plant feeding customer premise equipment. Modems, Digital set tops, Etc.

  (The Home or Business site where the customer is located)

- Reverse coaxial plant

- Reverse optical link

- Headend or hub   (Inside plant)

Decisions for reverse path parameters include

- Intelligent choices of reverse frequencies.
- Intelligent choices of modulation formats.
- Reverse laser Characterization and RF power loading for maximizing Carrier-to-Noise while avoiding clipping.
- HFC reverse RF plant design for reverse RF levels.
- Establish minimum reverse plant Carrier-to-Noise goals by service
- Establish reverse combining standards by node to to achieve proper Carrier-to-Noise

The Home or Business location

The Home or Business location

- To overcome reverse path loss at a customers location a device should not need any more than 55 dBmV of RF output to properly range.

  (DOCSIS 16-QAM will be 3 dB lower)

- It's not just modems any more. We should start planning for the day when all outlets are two-way capable to support VOD and other "On demand" video and data services.

Customer Equipment Output Level
Two Way Splitter

Using Two Way Splitter For Modem or Digi converter Feed						
Amplifier Input Level (18 Dbmv)	18	18	18	18	18	18
Diplex Filter Loss (In Amp Housing)	1	1	1	1	1	1
Tap Value (All Taps 4 Port)	26	23	20	17	14	11
Tap Insertion Loss (Through Loss of all Taps in line)	0	0.5	1.2	1.9	2.9	4.6
Feeder Cable Loss (500 P3 - 175 Ft Tap to Tap)	0	0.7	1.4	2.1	2.8	3.5
Drop Loss at RR Rev Carrier (RG-6 / 150 Ft Average)	1.77	1.77	1.77	1.77	1.77	1.77
Flat loss from house splitters	4	4	4	4	4	4
RR Modem Reverse Output Dbmv	50.77	48.97	47.37	45.77	44.47	43.87
Average Output level with Two Way	46.87					

Customer Equipment Output Level
Four Way Splitter

Using 4 Way Splitter For Modem or Digi converter Feed						
Amplifier Input Level (18 Dbmv)	18	18	18	18	18	18
Diplex Filter Loss (In Amp Housing)	1	1	1	1	1	1
Tap Value (All Taps 4 Port)	26	23	20	17	14	11
Tap Insertion Loss (Through Loss of all Taps in line)	0	0.5	1.2	1.9	2.9	4.6
Feeder Cable Loss (500 P3 - 175 Ft Tap to Tap)	0	0.7	1.4	2.1	2.8	3.5
Drop Loss at RR Rev Carrier (RG-6 / 150 Ft Average)	1.77	1.77	1.77	1.77	1.77	1.77
Flat loss from house splitters	7	7	7	7	7	7
RR Modem Reverse Output Dbmv	53.77	51.97	50.37	48.77	47.47	46.87
Average Output level with 4 Way Splitter	49.87					

Customer Equipment Output Level
8 Way splitter or a 2 and 4 Way Mix

Using 8 Way Splitter For Modem or Digi converter Feed						
Amplifier Input Level (18 Dbmv)	18	18	18	18	18	18
Diplex Filter Loss (In Amp Housing)	1	1	1	1	1	1
Tap Value (All Taps 4 Port)	26	23	20	17	14	11
Tap Insertion Loss (Through Loss of all Taps in line)	0	0.5	1.2	1.9	2.9	4.6
Feeder Cable Loss (500 P3 - 175 Ft Tap to Tap)	0	0.7	1.4	2.1	2.8	3.5
Drop Loss at RR Rev Carrier (RG-6 / 150 Ft Average)	1.77	1.77	1.77	1.77	1.77	1.77
Flat loss from house splitters	11	11	11	11	11	11
RR Modem Reverse Output Dbmv	57.77	55.97	54.37	52.77	51.47	50.87
Average Output level with 8 Way Splitter	53.87					

You may need a reverse house amplifier at some locations with high tap values. Keep the gain low, 8 to 10 dB

At the customer's home or business be alert for

High Reverse Loss

- Excessive reverse path splitter loss. Occurs mostly on homes fed by higher value taps. 23, 26 or 29 taps.
- If you are using 16-QAM for reverse modulation it has 3 dB less output power than QPSK. This is part of the DOCSIS standard.

Ingress

- Most ingress problems start in the drop plant. Make sure drop cable is good and F fittings are tight and properly installed.
- Use a broadcast FM or low band broadcast TV carrier to check for ingress. Check at the ground block **<u>outbound</u>** from house.
- Use CLI equipment to track faults.

The Reverse Coaxial Plant

Reverse Coaxial Plant

- The input level to every reverse amplifier is the same and flat (equalized). The level is usually in the 15 to 20 dBmV range.
- The output of each reverse amplifier location is padded and equalized for the cable span it is going to feed.

Reverse Coaxial Plant

Test equipment

- Two instrument types are mainly used.
- A cable modem tester. This is a DOCSIS modem with a display that provides data on RF parameters. (reverse levels, packet loss, etc.) It also is a QAM analyzer (MER, and error correction) and a signal level meter. (Hukk, Acterna, others)
- A reverse sweep system using a separate sweep transmitter in the hub or headend. (Hukk, Acterna, others)
- Standard signal level meters don’t help much here but they are good for tracking down ingress.

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Reverse Coaxial Plant

DOCSIS modem test set

- A cable modem tester will let you see what the customers DOCSIS modem is seeing.
- Most allow you to “spoof” the customer modem MAC address to check for routing or configuration problems.
- If the CMTS is down it will not work for reverse trouble shooting.

Reverse Coaxial Plant
Reverse Sweep Systems

- An RF sweep system lets you check forward and reverse plant response at the same time.
- It uses a separate transmitter at the hub or headend so it works even if the CMTS is down.

Reverse Coaxial Plant Testing

- Its good to have a mix of both types of test platforms for troubleshooting.
- If the reverse levels test OK and modem test set will not log on but the reverse sweep system is working the problem is likely in the hub or headend. (cable router or network problem)
- If both the modem test set and reverse sweep are not working it is likely an outside plant issue.
- Having both tells you where to start; hub, node, or plant.

The Reverse Optical Link

The Reverse Optical Link

We use three major optical reverse transmitter technologies. They are:

- Fabry-Perot – FP
- Distributed Feedback – DFB
- Digital Return

Most reverse transmitters today are Fabry-Perot but as costs are reduced and multiple returns from single nodes are used for more data bandwidth digital return is becoming more popular.

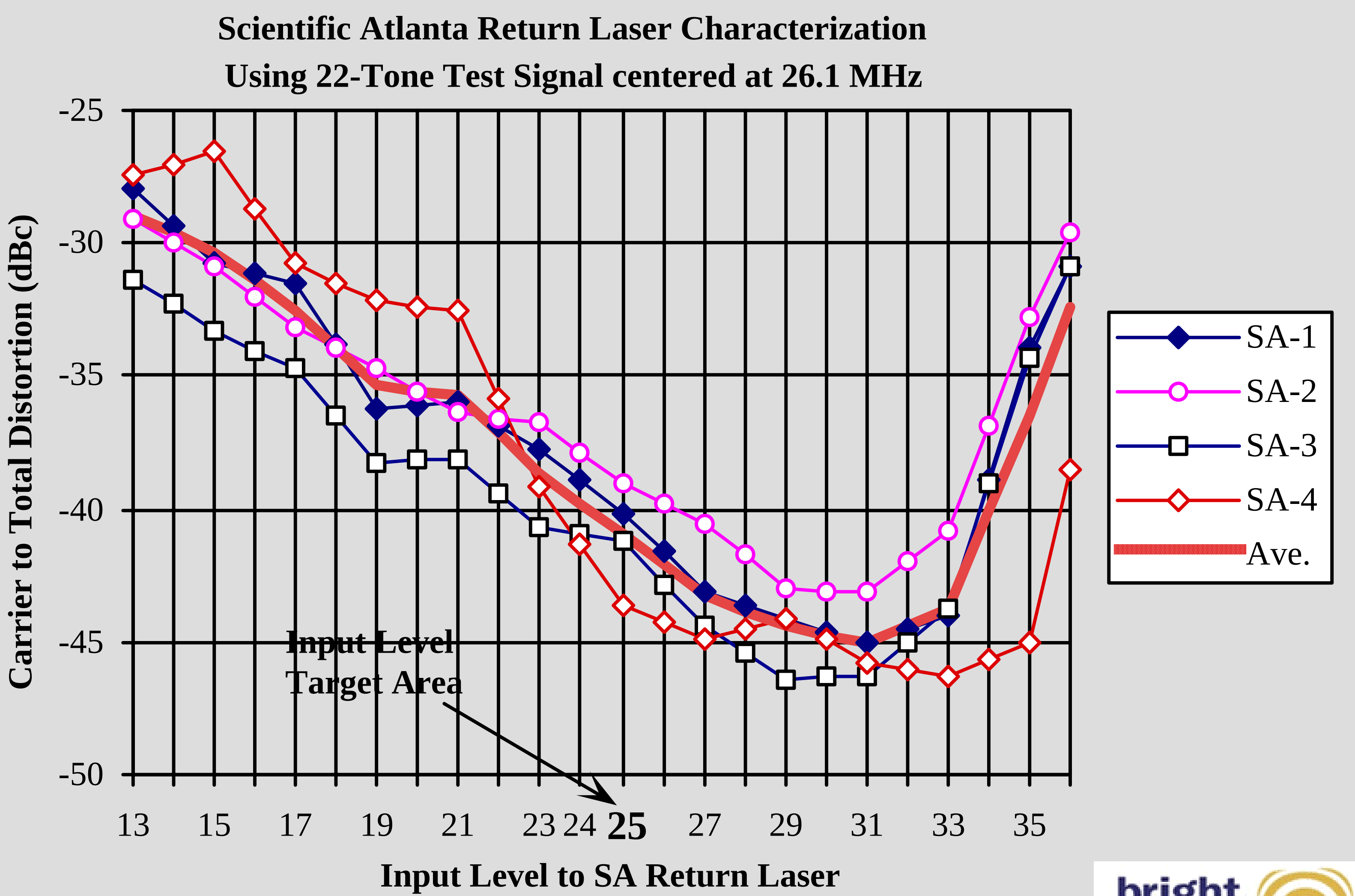
The Reverse Optical Link

- The goal is to RF drive the reverse laser as hard as possible without driving it nonlinear. (clipping)
- The carrier drive level should also be achievable by all customer premise equipment installed at any location in your plant.

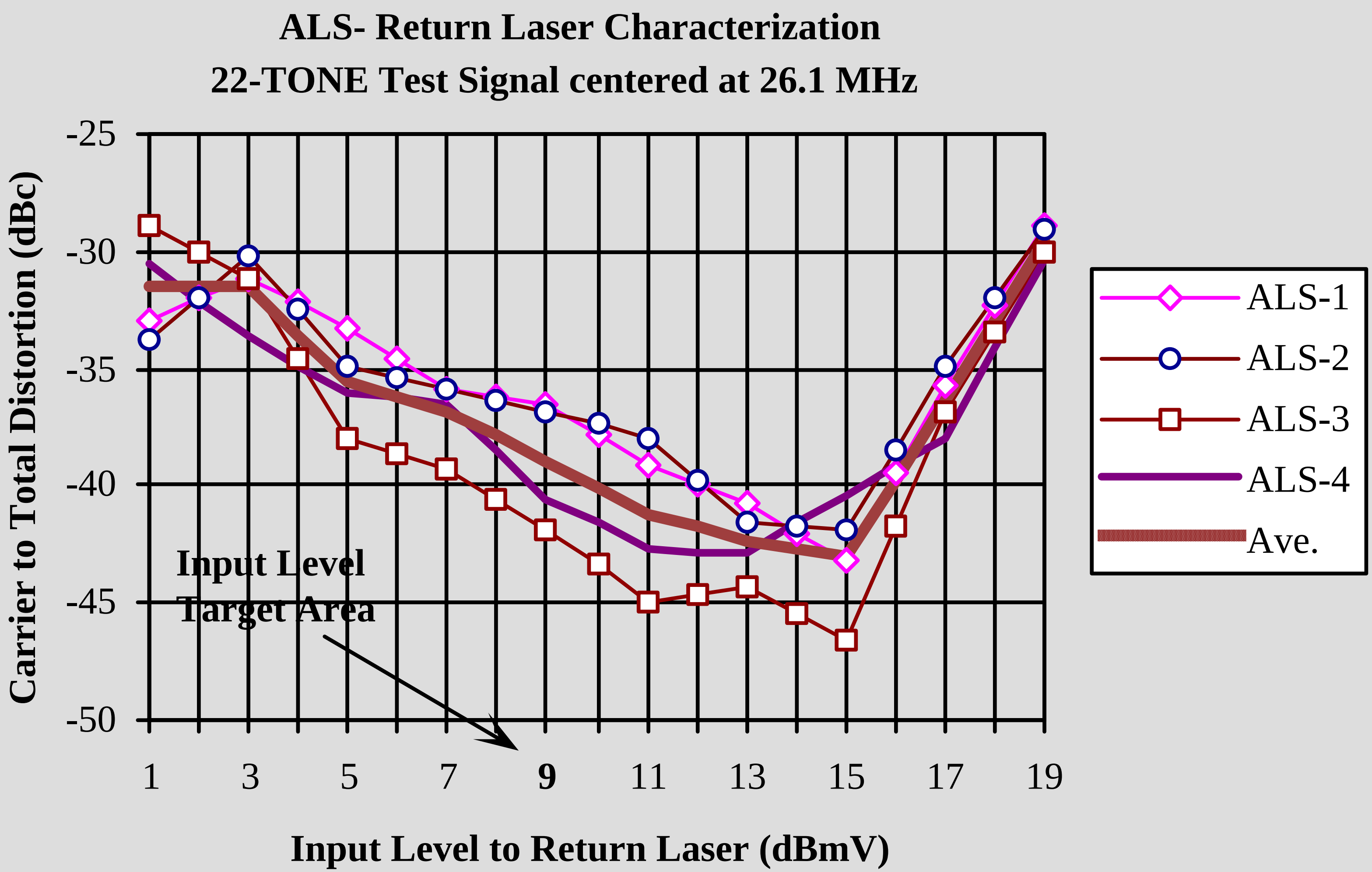
The Reverse Optical Link

- How do you know what that the laser drive level should be? You qualify the laser.
- Each manufacturer will have different drive levels for a given number of carriers
- You should understand how the test results are derived so that you can optimize levels based on your own system’s needs.

The Reverse Optical Link



The Reverse Optical Link



The Reverse Optical Link

- Lasers are qualified by number of carriers and drive level.
- For high speed data services the current trend is fewer carriers at wider bandwidths.
- DOCSIS 1.x maximum bandwidth is 3.2 MHz.
- DOCSIS 2.0 has a 6.4 MHz bandwidth!
  - This is wider than a forward carrier!

The Reverse Optical Link

Optical receiver setup

- The RF output for all optical receivers (of the same type) should be the same for all optical loss's.
- RF hub equipment can control level only, it just accepts the C/N that it receives after level ranging.
- The goal is to make sure the C/N headroom is good for all optical loss budgets and each type of service at a given number of nodes combined.
- CW carriers should be used for setup. No correction factors are needed with CW carriers.
- To maintain acceptable levels of data performance the number of nodes combined is reduced as more customers subscribe to advanced services

Headend and Hubs - RF

HFC Reverse Plant Goals

- Have enough performance “head room” to maintain performance and keep service calls down. (but don’t spend too much time or money doing it)
- Use frequencies that are best suited for each type of service. Stay above 20 Mhz for broadband data if possible.
- “Rule of thumb” for C/N for digital services - Take your minimum C/N specification and add 4 to 6 dB to it for reliable performance.

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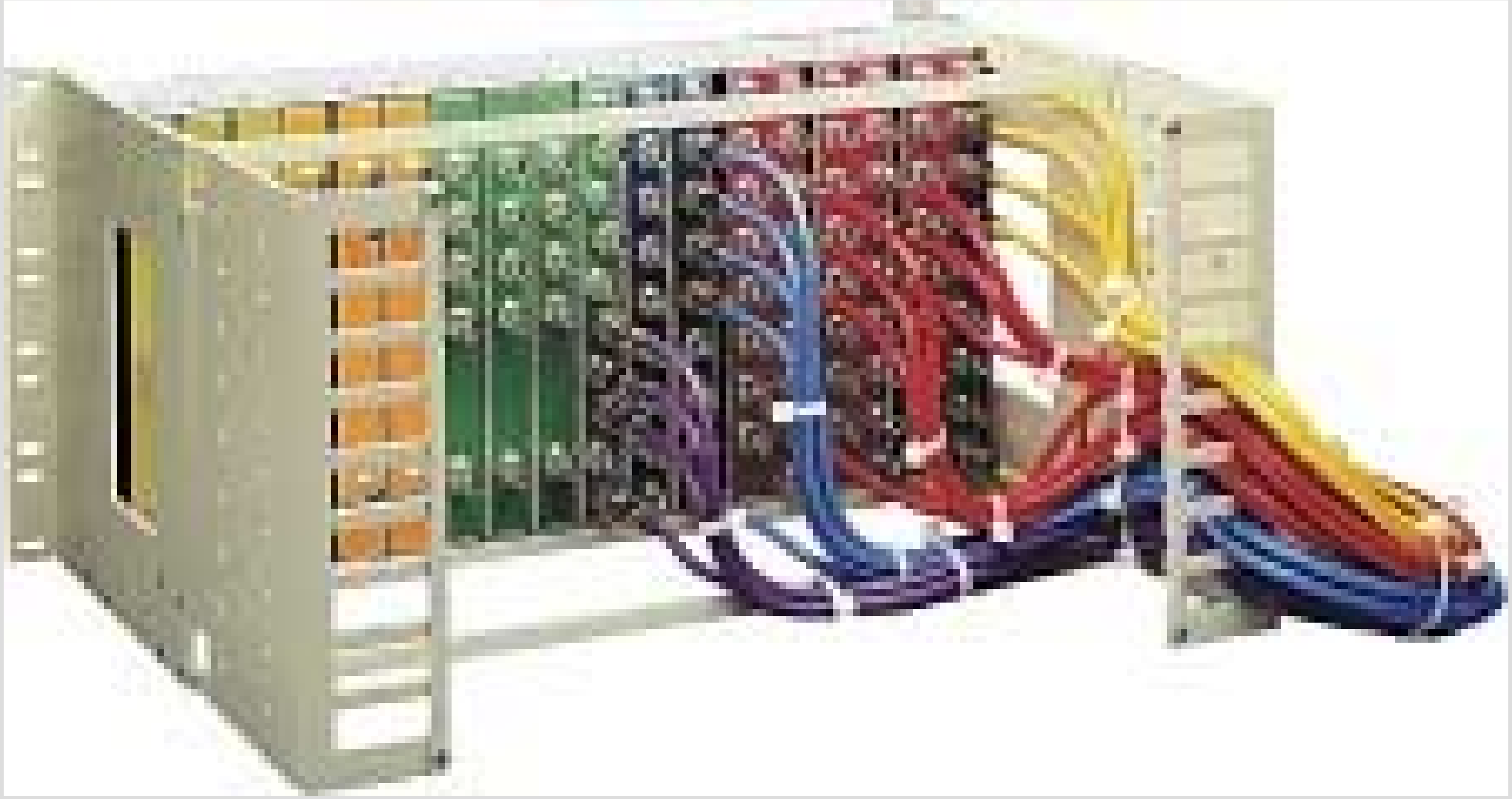
Headend and Hubs - RF

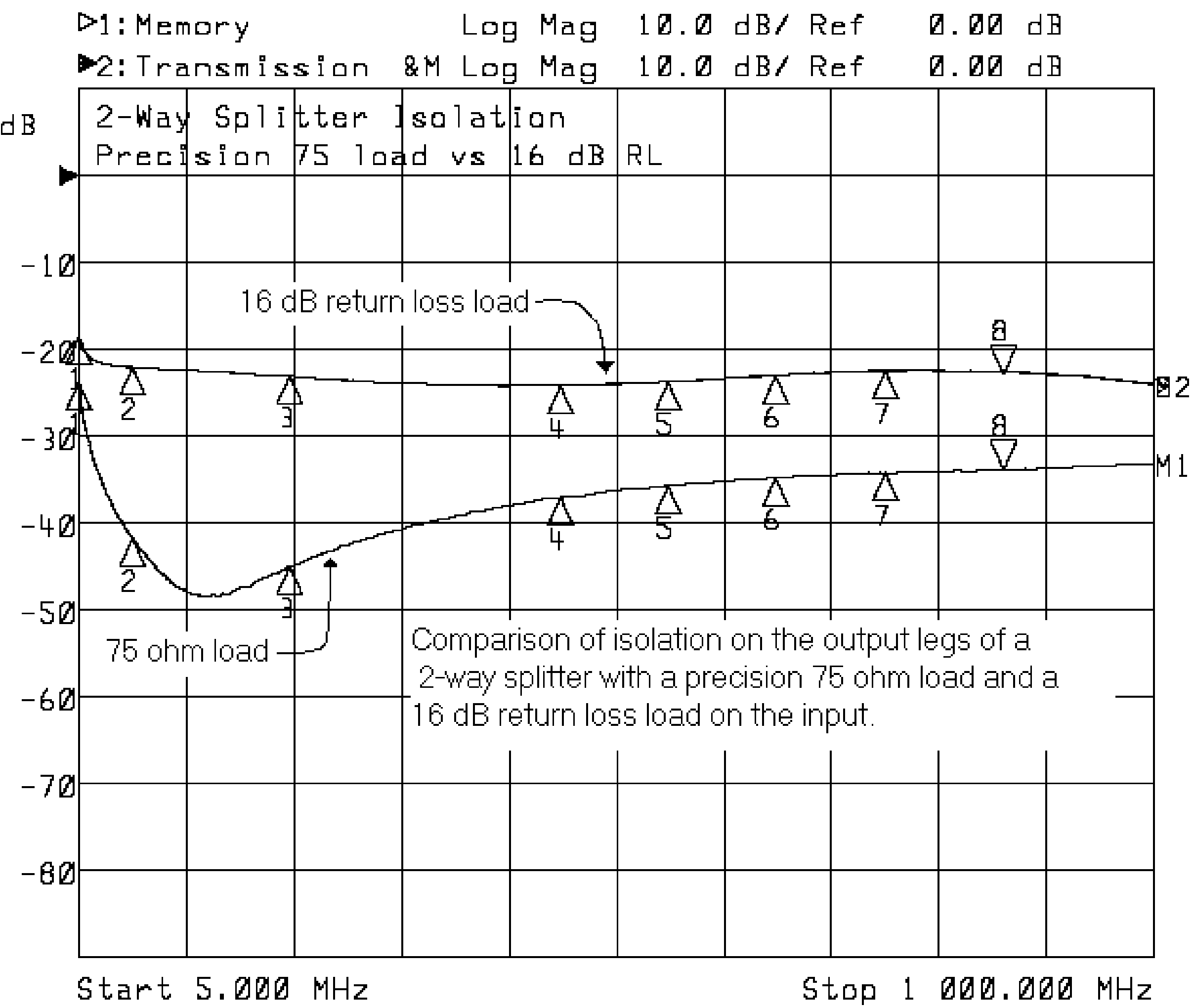
- A system should be in place to track node grouping for troubleshooting.
- RF wiring by service can be color coded.
- A system should be in in place to manage both forward and reverse RF carriers. All cables should be labeled.
- Data tools should be in place to track customers and data loading numbers by node group to indicate when its time to regroup or add ports. Review them regularly.

RF Management hardware



Headend and Hubs - RF

- Make sure you have enough RF isolation from service group to service group.
- The standard for analog video carrier isolation is 60 dB. This is not necessary for digital video and data but it is a good goal because there will be so many modulators using the same frequency. They will power add by as much as 8 to 10 db due to many separate service groups.



1:Mkr	(MHz)	dB	2:Mkr	(MHz)	dB
1:	5.0000	-23.660	1:	5.0000	-18.396
2:	55.2500	-41.797	2:	55.2500	-22.082
3:	200.0000	-44.964	3:	200.0000	-23.110
4:	450.0000	-37.069	4:	450.0000	-24.209
5:	550.0000	-35.730	5:	550.0000	-23.733
6:	650.0000	-34.843	6:	650.0000	-23.019
7:	750.0000	-34.256	7:	750.0000	-22.558
8>	860.0000	-33.850	8>	860.0000	-22.665

You will not get the same isolation performance in a real world deployment as the ones you see on the specification sheet.

The return loss of most equipment is 16 dB in the 550 to 860 Mhz range.

Precision loads are used for testing when specifications are published.

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HFC Reverse Plant Noise

- Two main components - coaxial plant and optical link
- Average reverse coaxial plant noise for about 30 System Amp-II and LE-II devices = 56dB C/N

  at 4 MHz bandwidth.
- Average optical link noise for 7dB link with 20 carriers - 41dB C/N (4db is an average reverse link)
- The combined “rounded down” performance of the two should be about 40 dB C/N for a 4 MHz occupied bandwidth. Most links will be better.

HFC Reverse Plant C/N Specifications

Service	C/N Specification	C/N goal to receiver input after combining
DOCSIS	25 dB-1.6 MHz QPSK	31 dB (4 to 5 nodes)
DOCSIS	25 dB-3.2 MHz QPSK	31 dB (4 to 5 nodes)
Pegasus/Data	18 dB-1 MHz QPSK	25 dB (8 to 10 nodes)
C-Cor.Net	15 dB-0.4 MHz FSK	21 dB(30 to 40 nodes)
WaveTek sweep	15 db-0.1 MHz FSK	21 dB(40 to 80+nodes)

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How do we get all these different carrier to noise numbers with the same RF path?

- Carrier to Noise changes with occupied bandwidth.

- The wider the bandwidth of the receive system the more noise.

- The narrower the bandwidth of the receive system the less noise.

So how much does C/N change with bandwidth?

$$10 \times \log \frac{\text{Bandwidth 1}}{\text{Bandwidth 2}}$$

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“Field Factor” weighting of carrier to noise in plant performance

- In Forward plant – Low weighting numbers are used due to forward HFC plant characteristics being stable and very easy to predict.

  We use 1 dB for forward plant.
- In Reverse plant- Large weighting numbers used due to reverse plant characteristics being very volatile and changing optical loss on reverse links. We use 10 dB for reverse plant.

C/N change with bandwidth Conversion Chart with 4.2 MHz as a zero reference

256 QAM	-1.06 dB	5.36 MHz wide forward
64 QAM	-0.80 dB	5.05 MHz wide forward
Standard video	0.00 dB	4.2 MHZ reference for CATV
DOCSIS	1.18 dB	3.2 MHz - QPSK reverse
DOCSIS	4.19 dB	1.6 MHz - QPSK reverse
SA Digital Data	6.23 dB	1.0 MHz - QPSK forward & reverse
C-Cor.net Data	10.21dB	0.4 MHz - FSK forward & reverse
WaveTek Data	16.23dB	0.1 MHz - FSK forward & reverse

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DOCSIS RR 3.2 MHz noise model

Reverse link to HUB		+40 dB
Number of nodes mixed	**4**	- 6 dB
Field factor		- 10 dB
Noise power correction		+1.18dB
Calculated carrier to noise		25.18dB
C/N equipment specification		25 dB (DOCSIS Spec)

DOCSIS RR system headroom 0.18 dB at 3.2 MHz

DOCSIS RR 1.6 MHz noise model

Reverse link to HUB		+40 dB
Number of nodes mixed	**4**	- 6 dB
Field factor		- 10 dB
Noise power correction		+4.2dB
Calculated carrier to noise		28.2dB
C/N equipment specification		25 dB (DOCSIS Spec)

DOCSIS RR system headroom 3.2 dB(more on this later)

SA digital data carriers noise model

Reverse link to HUB		+40 dB
Number of nodes mixed	**8**	- 9 dB
Field factor		- 10 dB
Noise power correction		+6.25 dB
Calculated carrier to noise		27.25 dB
C/N equipment specification		18 dB
SA data carriers headroom		**9.25 dB**

C-Cor.net HMS data carriers noise model

Reverse link to HUB	+40 dB
Number of nodes mixed 32	- 15 dB
Field factor	- 10 dB
Noise power correction	+10.25 dB
Calculated carrier to noise	25.25 dB
C/N equipment specification	15 dB
C-Cor.Net carriers headroom	**10.25 dB**

WaveTek data carriers noise model

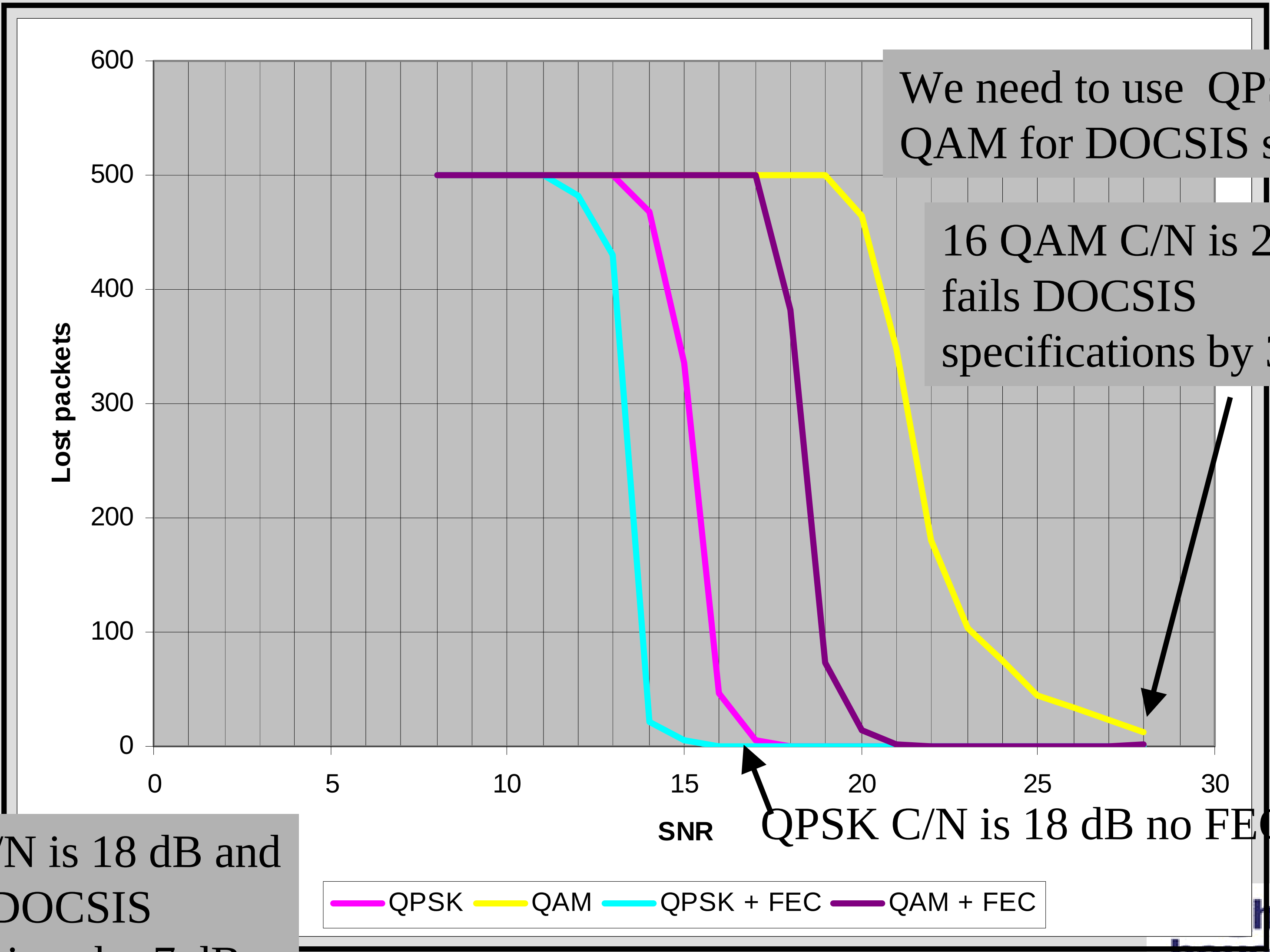
Reverse link to HUB		+40 dB
Number of nodes mixed	**96**	- 19.75 dB
Field factor		- 10 dB
Noise power correction		+16.25 dB
Calculated carrier to noise		26.5 dB
C/N equipment specification		15 dB
WaveTek carriers headroom		**11.5 dB**

Carrier to Noise “headroom” by service summary

DOCSIS RR system headroom 3.2 MHz	0.18 dB
SA data carriers headroom	9.25 dB
C-Cor.Net carriers headroom	10.25 dB
WaveTek data carriers headroom	11.5 dB

Lets talk about DOCSIS. It’s better than it looks if you use the right modulation profile.

Measured Cisco uBR C/N performance at 1.6 MHz Reverse



We need to use QPSK not QAM for DOCSIS services

16 QAM C/N is 28 dB and fails DOCSIS specifications by 3 dB

QPSK C/N is 18 dB no FEC

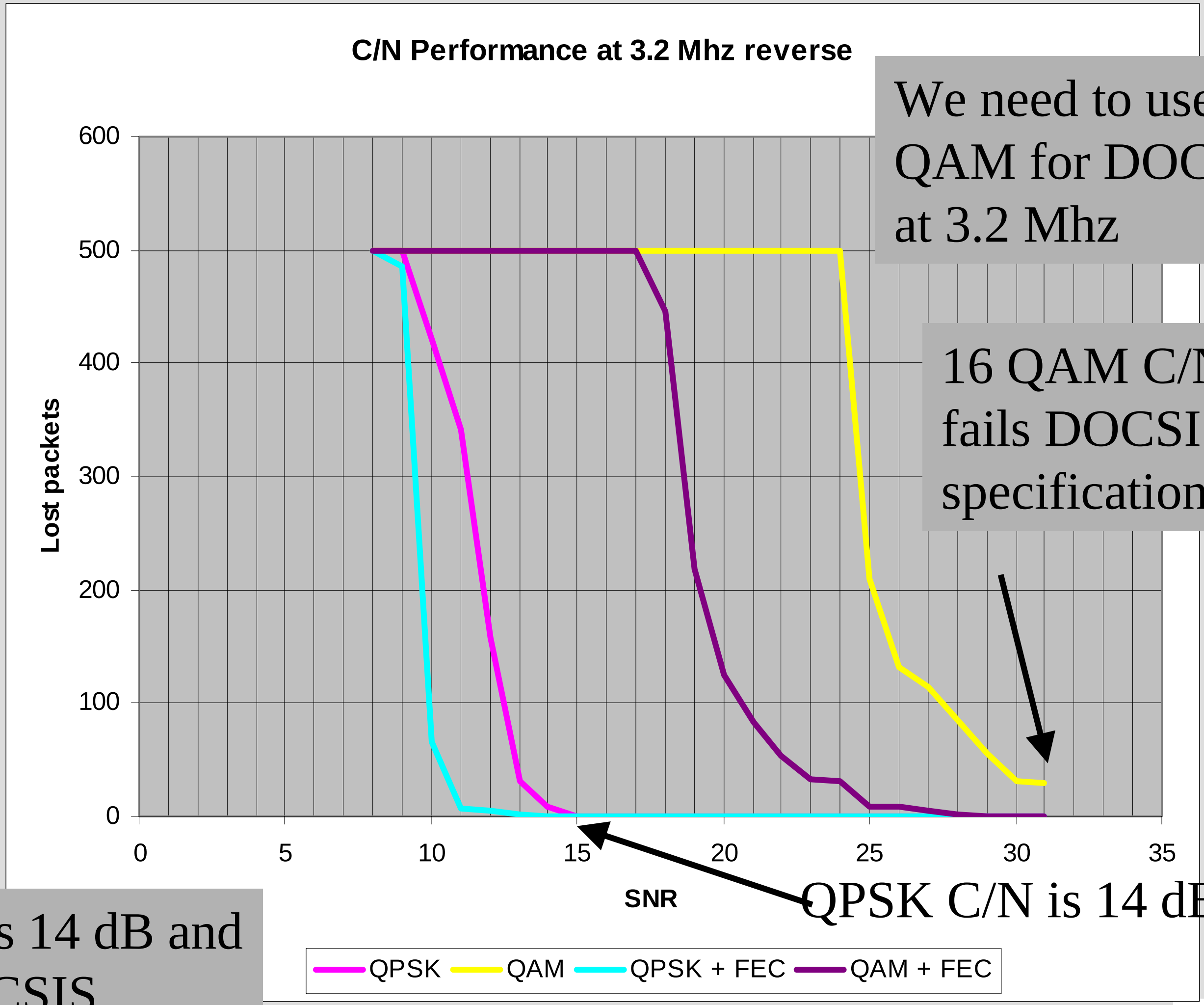
QPSK C/N is 18 dB and exceeds DOCSIS specifications by 7 dB

DOCSIS 1.6 MHz QPSK RR noise model

Reverse link to HUB		+40 dB
Number of nodes mixed	4	- 6 dB
Field factor		- 10 dB
Noise power correction		+4.2dB
Calculated carrier to noise		28.2dB
C/N equipment specification		18 dB (QPSK Measured)

DOCSIS RR system headroom **10.2 dB**
at 1.6 MHz Bandwidth

Measured Cisco uBR C/N performance at 3.2 MHz Reverse



We need to use QPSK not QAM for DOCSIS service at 3.2 Mhz

16 QAM C/N is 32 dB and fails DOCSIS specifications by 7 dB

QPSK C/N is 14 dB with no FEC

QPSK C/N is 14 dB and exceeds DOCSIS specifications by 11 dB

DOCSIS 3.2 MHz QPSK RR noise model

Reverse link to HUB	+40 dB
Number of nodes mixed 4	- 6 dB
Field factor	- 10 dB
Noise power correction	+1.18dB
Calculated carrier to noise	28.2dB
C/N equipment specification	14 dB (QPSK Measured)

DOCSIS RR system headroom **11.18 dB**
at 3.2 MHz Bandwidth

Carrier to Noise "headroom" by service summary

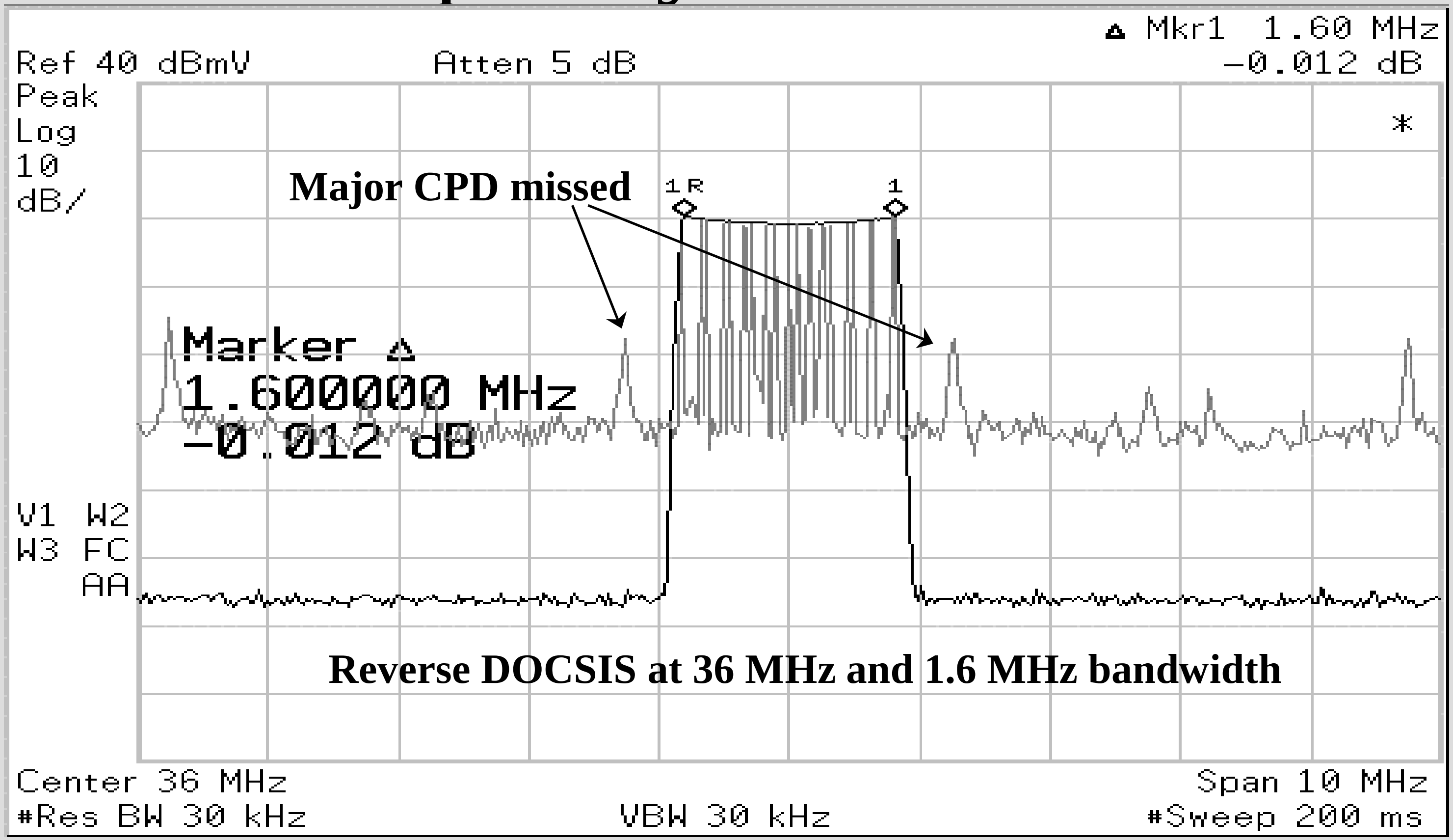
DOCSIS RR system headroom (1.6 MHz QPSK)	**10.2** dB
DOCSIS RR system headroom (3.2 MHz QPSK)	**11.18 dB**
SA data carriers headroom (QPSK)	**9.25** dB
C-Cor.Net carriers headroom (FSK)	**10.25** dB
WaveTek data carriers headroom(FSK)	**11.5** dB

These are all respectable numbers. Maybe we could trade some C/N for dynamic range in our outside plant.

Headend and Hubs – RF
Frequency Selection

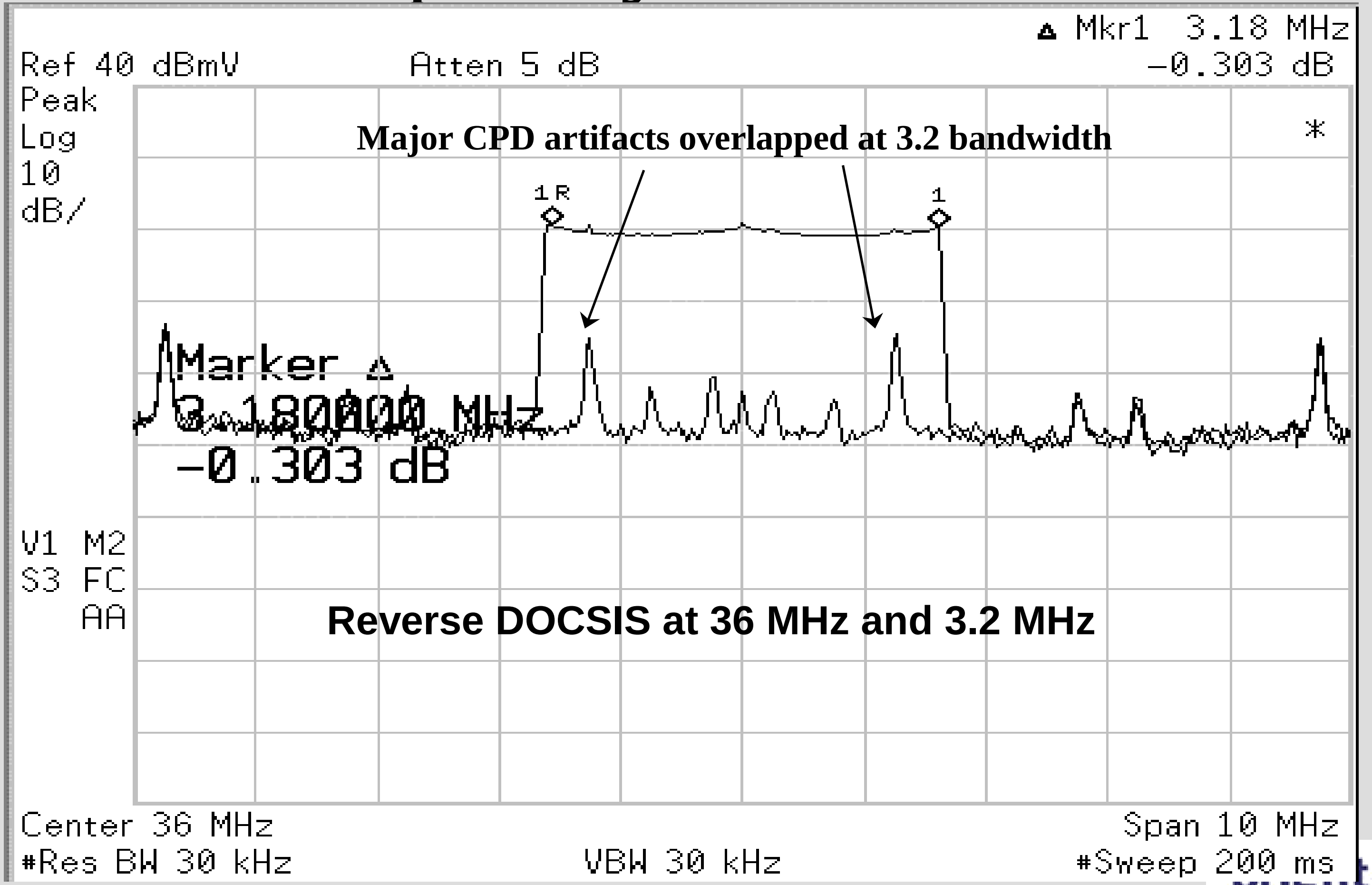
- Select frequencies that avoid problems. This includes Ham and CB bands
- Common path distortion can be avoided. (…but still needs to be fixed)
- Beware of group delay using 16-QAM.

Headend and Hubs – RF Frequency Selection

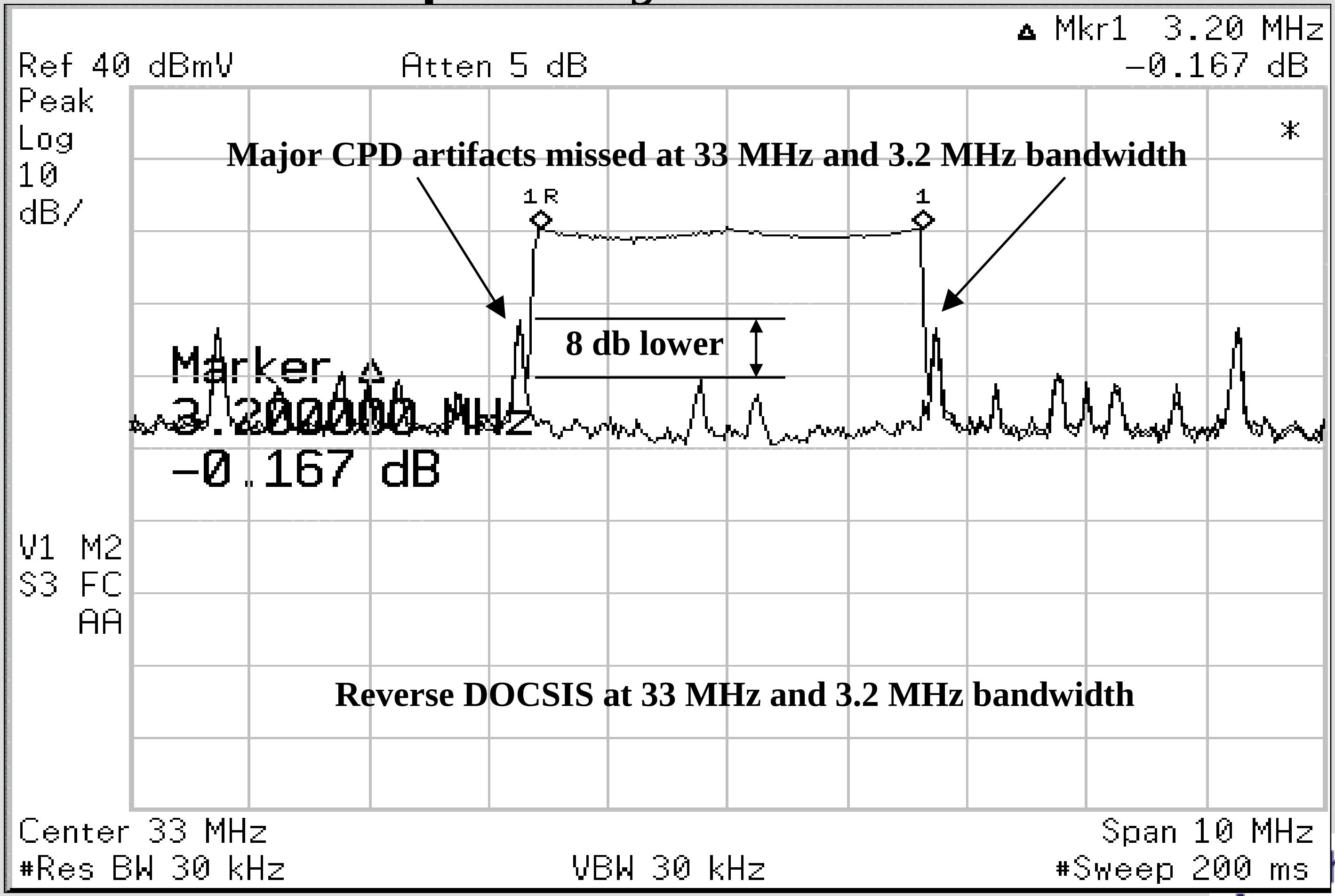


Headend and Hubs – RF

Frequency Selection



Headend and Hubs – RF
Frequency Selection



Headend and Hubs – RF
Frequency Selection- Group Delay

Two-way RF coaxial amplifiers are able to separate by frequency and direct the RF energy by band using diplex filters. These filters isolate RF amplifier stages in the forward and reverse directions from each other. This is to prevent energy from the output of an amplifier stage in one direction from overloading the input gain stage of the amplifier in the other direction.

These Diplex Filters, like all filters, alter the frequency and phase characteristics of RF signals that pass thru them. This effect increases at the band pass edges of the filters and can degrade network performance depending on modulation format and bandwidth. In the 5 to 40 MHz reverse path group delay increases below 8 MHz and above 36 MHz.

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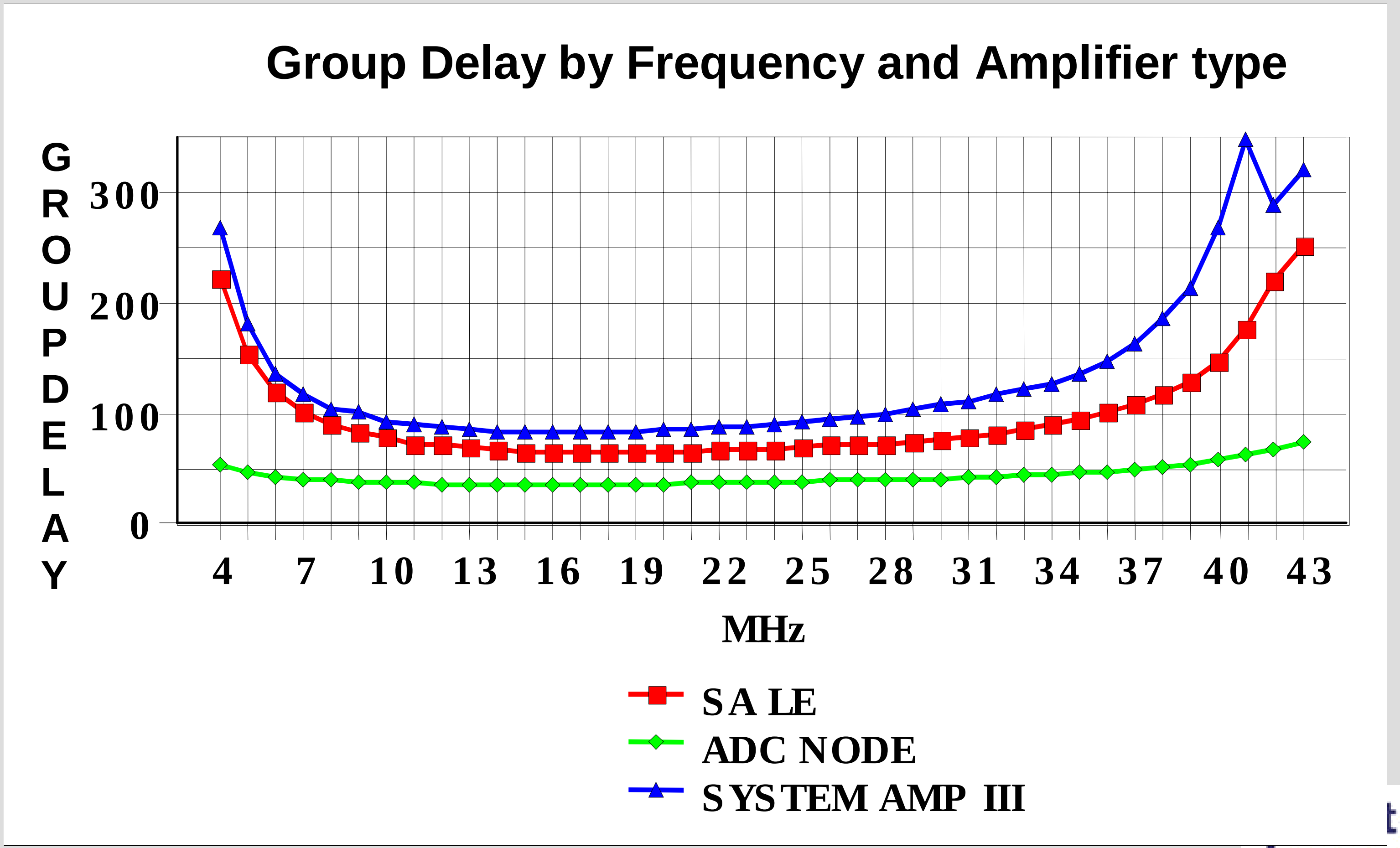
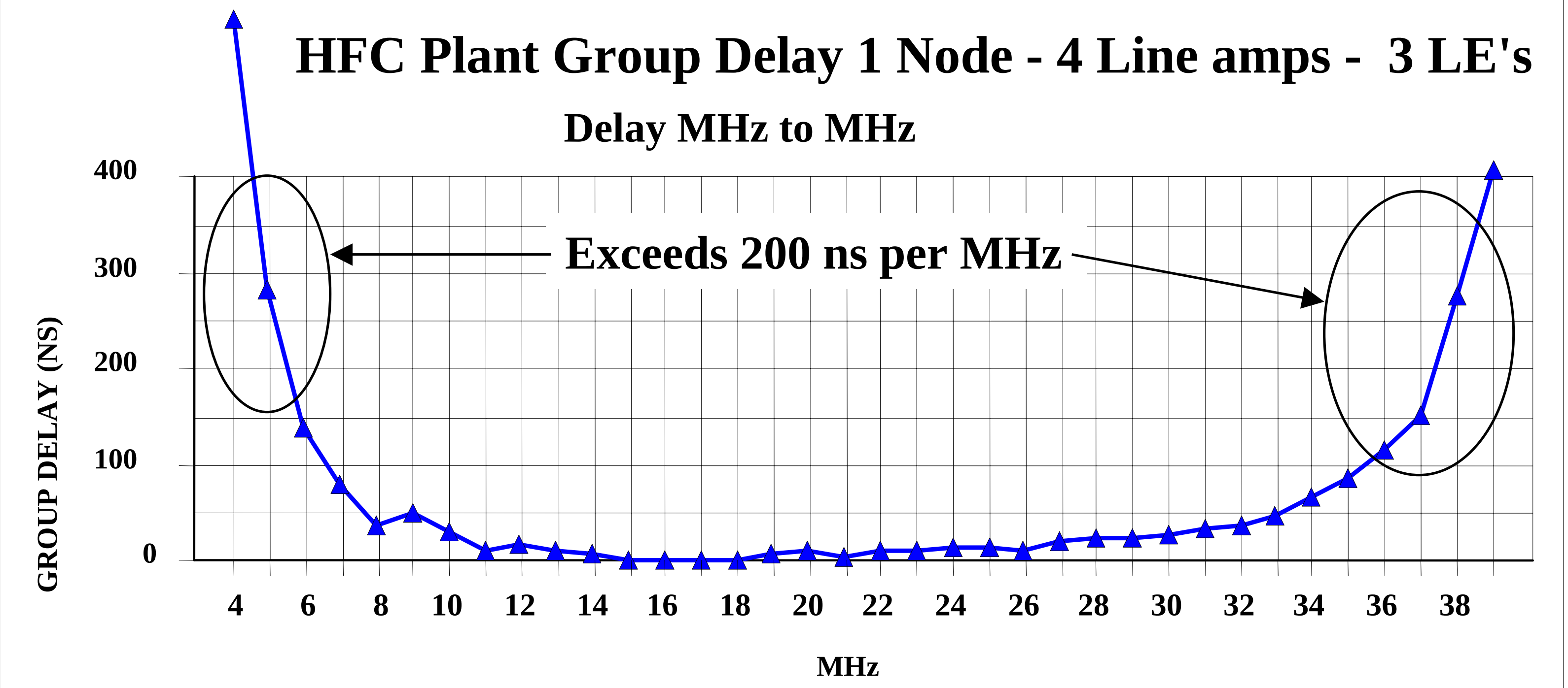
Headend and Hubs – RF

Frequency Selection - Group Delay



Headend and Hubs – RF
Frequency Selection - Group Delay



DOCSIS limit is 200 ns per MHz

Remember:
"Situational Awareness"

- Choose reverse frequencies wisely.
- Choose modulation formats with C/N in mind.
- Drive the laser hard for Carrier-to-Noise but avoid clipping.
- Design HFC reverse RF plant with reverse RF levels in mind.
- Establish minimum reverse plant Carrier-to-Noise goals by service
- Establish reverse combining standards by node numbers to achieve proper Carrier-to-Noise
- You can trade C/N for reverse RF level dynamic range if you have the headroom.

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Thank You for attending today

Any Questions?