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Impact of CCAP on RF Management Isolation



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WHITE PAPER

Impact of CCAP on RF Management Isolation

References

[TR CCAP]	Converged Cable Access Platform Architecture Technical Report, CM-TR-CCAP-V03-120511, Cable Television Laboratories, Inc.
[QAM MOD]	QAM Bulks Up Once Again: Modulation to the Power of Ten, Robert L. Howard, Ph.D., Motorola
[CNR_SNR]	BROADBAND: CNR VERSUS SNR, Ron Hranac, Mar 2003 Communication Technologies

Scope

There are some common misconceptions regarding [TR CCAP], section 6.4 which mentions “The CCAP requires a minimum port-to-port isolation of ≥ 70 dB from 50 MHz to 550 MHz and ≥ 65 dB from 550 MHz to 1002 MHz”. It is clear to us that this specification is a requirement of the Converged Cable Access Platform itself, and in no way implies this specification on the external RF management gear used in conjunction with the CCAP.

It is imperative that ports on a CCAP, which are intended to provide different content per port, but on the same frequencies, appear as if they are physically separated from an RF stand point. However, to apply this specification on a module-by-module basis in the external RF lashup results in nearly double the net isolation required. Further, it is only achievable through active means (active = amplification = cost = unnecessary distortion = power consumption = lower MTBF) which inherently goes against some of the fundamental goals of CCAP advocates.

The reality is that RF lashup isolation requirements are driven by: a) a source CNR of >65 dB, b) an optical link typically near 50 dB CNR, c) an end of line CNR for each modulation scheme used, which is well published as 35 dB for 256 QAM (for pre-FEC BER $<10E-9$) and theoretically 41 dB for 1024 QAM.

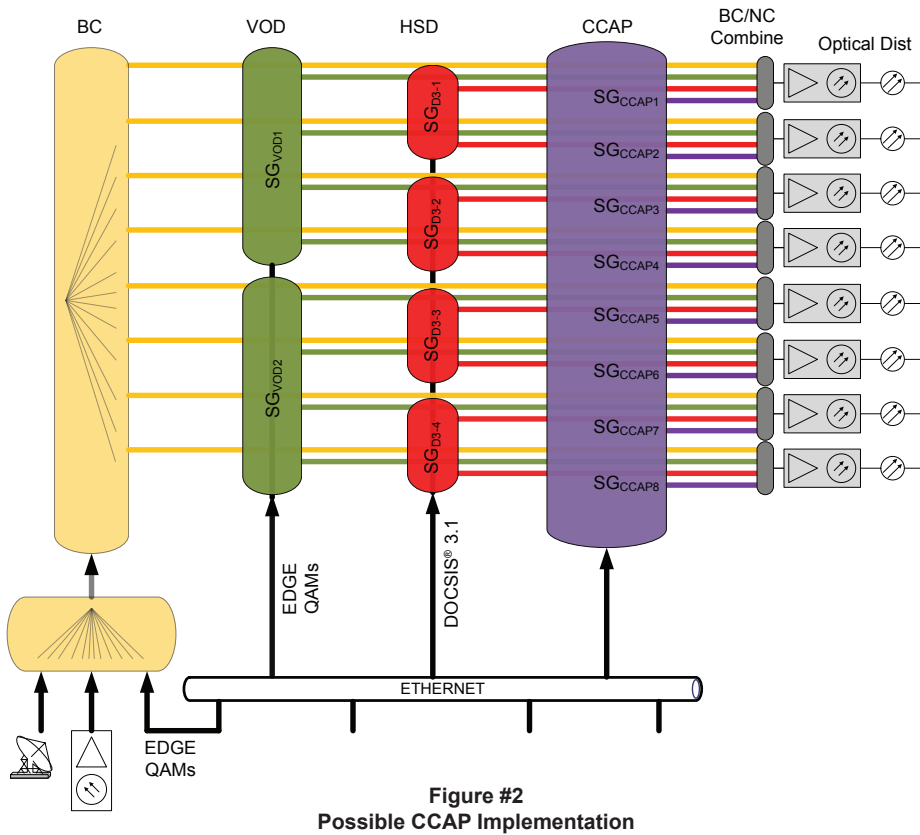
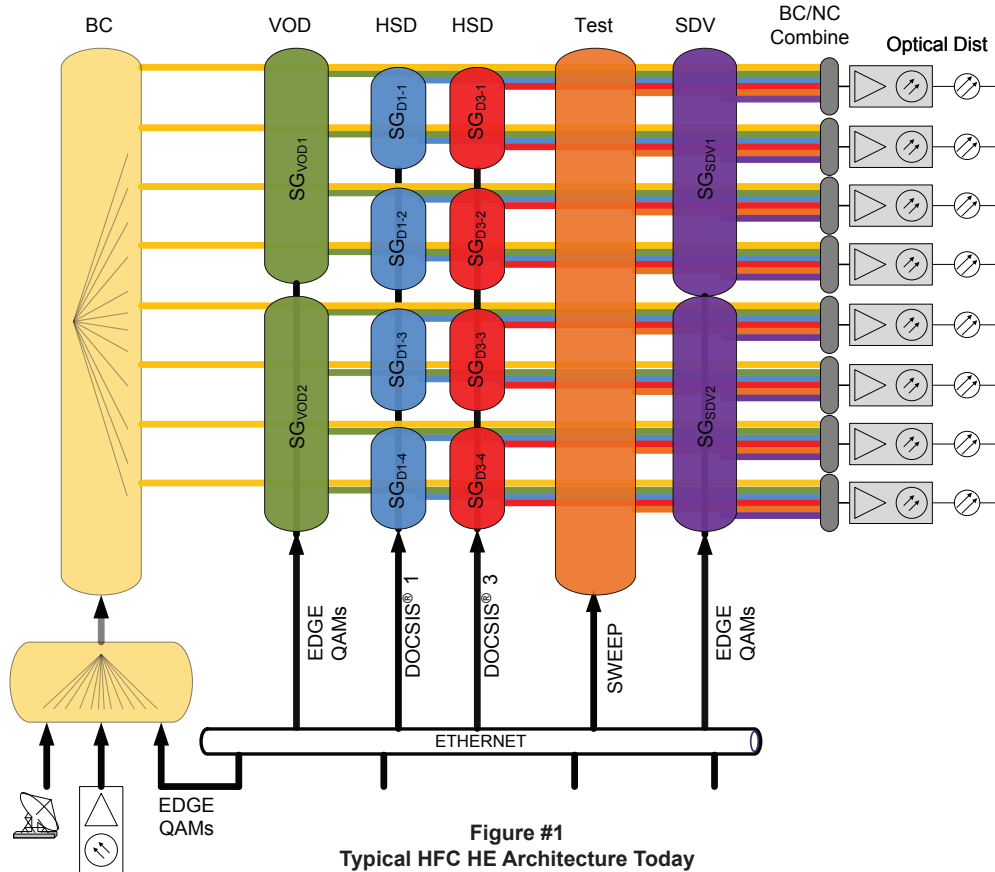
This is very important and very good news for operators looking to transition CCAP into their networks. The same passive RF splitter and combiner modules (with 30 dB port-port isolation) used in pre-CCAP networks do not need to change.

An Example Transitional Architecture to CCAP

Downstream architectures are commonly based on the basic concept of combining two distinct RF spectrums just before each optical transmitter.

- A common broadcast (BC) series of channels. The same video channels sent to all node segments at the same moment in time.
- A narrowcast (NC) series of channels can be unique content to each node segment or group of node segments as consumer demand and budget for more source equipment dictates. Each type of service (DOCSIS®, SDV, VOD, status monitoring, set top box control, etc) can use RF management gear to combine to create service groups and split to any desired number of optical transmitters to be sent to the node segment. To best achieve this flexibility, each transmitter must have a NC RF combiner, with enough ports to satisfy the particular operator’s variety of NC service groups.

The example below shows one possible transition from a traditional RF management architecture (Figure 1) into CCAP (Figure 2). By combining DOCSIS and edge QAM channels into a single device, CCAP allows simplification and reduction of RF management. The basic structure changes little though and the NC combiner is still recommended to leverage CAPEX already invested in stand-alone edge QAMs and CMTS’s, as well as to account for any new/existing narrowcast service which CCAP may not be capable of today. History has shown that if we claim that the services, speeds and bandwidth conceived of today will be enough, we will always be wrong. Having a BC combine port on this NC combiner is only necessary if the optical transmitter does not already have usable BC and NC insertion ports. If the CCAP device is providing the entire BC lineup, then this can be connected to the BC port of TX or BC/NC combiner with little difference to overall architecture.



Understanding the CCAP Isolation Specification

“...there is no question that the CCAP port-to-port isolation spec of ≥ 70 dB applies to a CCAP chassis and its line cards.”
 Ron Hranac, Cisco

This isolation requirement makes sense for any source gear, whether it is CCAP, edge QAM or CMTS. If two neighbouring ports on any device are outputting QAMs on overlapping frequency spectrums the 65 dB isolation specification is a reasonable baseline for the best CNR that will be possible throughout the system before RF management, the optical link and other impairments start introducing noise/impairments.

The goal for the RF lashup is to attenuate all leakage paths enough to not noticeably degrade this performance at end of line. These paths are later shown to always pass through at least 2 RF module’s port-to-port isolation, requiring only half the net isolation from each module.

Absolute Minimum SNR/CNR Requirement

What is important here is that RF outputs with different content (I_a, I_b, \dots) in the same frequency range (f_x) must not overlap with less than a minimum delta in power. This delta is expressed in dB and since the unintended (interfering) QAM content is noise-like in nature, this delta is synonymous with SNR (and also CNR and MER, see [CNR_SNR]).

The SNR requirement increases as QAM modulation scheme increases, because the constellation grid becomes denser and a given amount of noise/MER degradation is more likely to cause bit error (BER) issues.

The chart below from [QAM MOD] gives SNR values that are well substantiated in other similar publications. To get no noticeable degradation of pre-FEC BER, we should aim for headend SNR performance of 35 dB for 256 QAM and 41 dB for 1024 QAM. FEC is not considered because we should never design architectures relying upon this safety margin.

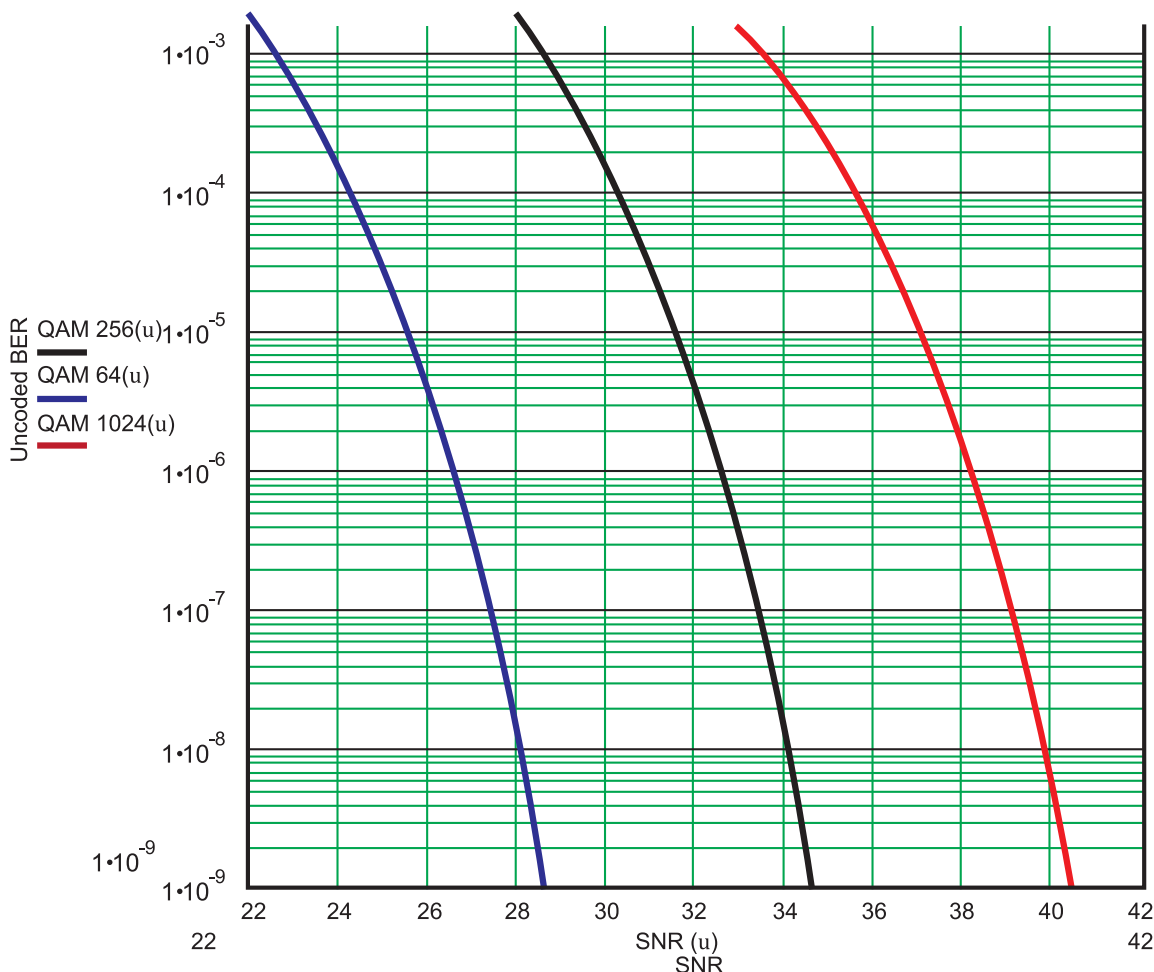


Figure #3
 Theoretical QAM BER, excerpt from [QAM MOD]

Where does Isolation Matter?

	<p>OUTPUT 1 I_A, F_x</p> <p>OUTPUT 2 I_B, F_y</p> <p>OUTPUT 3 I_C, F_z</p> <p>eQAM</p>	<p>OUTPUT 1 I_A, F_x</p> <p>OUTPUT 2 I_B, F_x</p> <p>OUTPUT 3 I_C, F_x</p> <p>CCAP</p>
<p>Consider a standard RF passive with 30 dB port-to-port isolation</p>	<p>Used in an application where non-overlapping channels are combined. Port-to-port isolation is acceptable because channels are intentionally being combined.</p>	<p>There is no practical application, (CCAP or otherwise), to intentionally combine channels of overlapping frequency, so P-P iso is not relevant to even discuss in this context.</p>

Leakage paths CAN occur whenever combiner ports connect to splitter ports, and an isolation loop path is created. It is the NET-isolation which is important, and is basically related to 2x [individual port-to-port isolation plus any padding or cable loss]. This is shown in the examples below.

A broadcast network is not shown below under the assumption either CCAP is providing it, or there is a separate BC port on the transmitter. Adding it into the BC/NC combiner below also would not change the concept of where isolation leakage can occur.

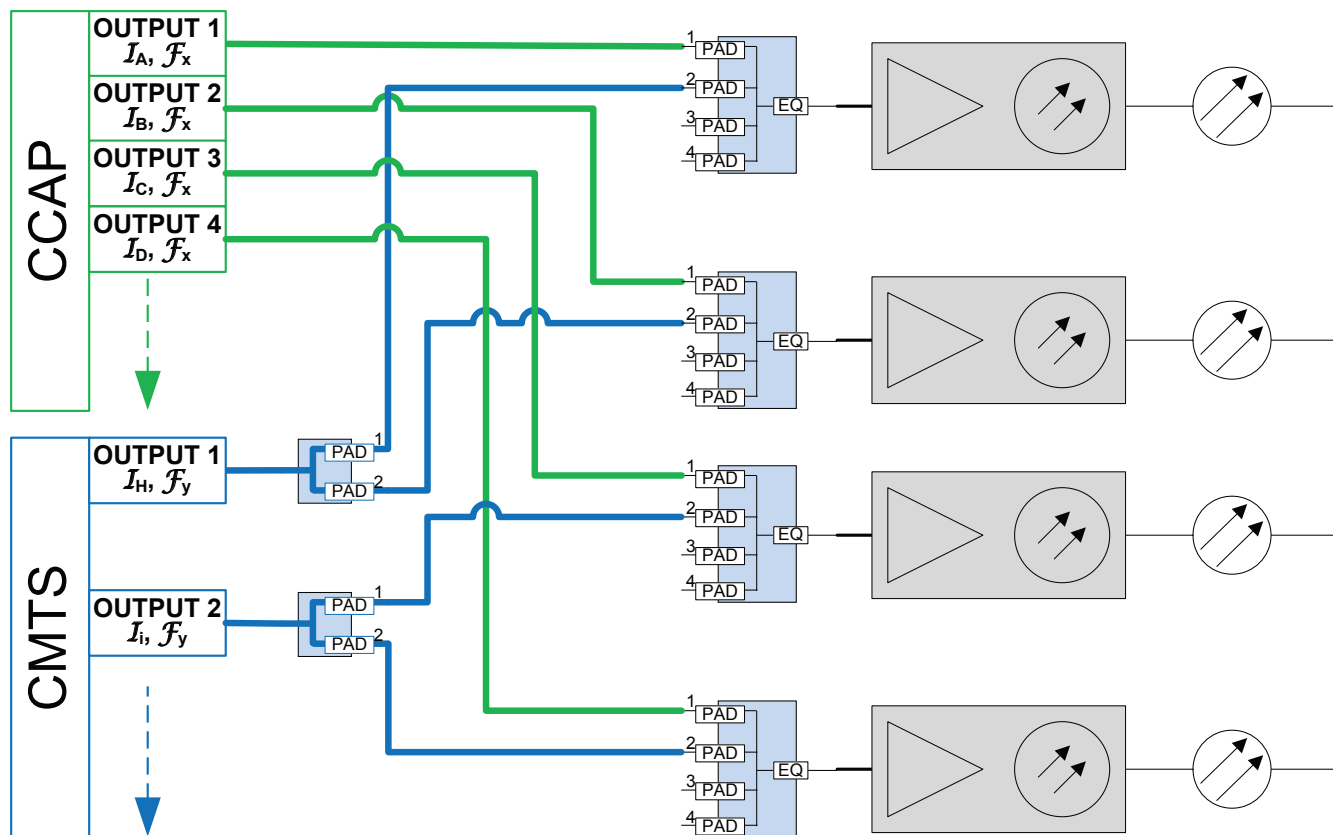


Figure #4
Example of CCAP/DOCSIS® 3.1 System

Consider the simple system in Figure 4, with CCAP ports connected 1:1 to transmitters and another service such as DOCSIS 3.1 CMTS connected at 1:2 ratio (1 CMTS port per 2 TX/nodes). This could be any other narrowcast service and not affect the argument. CCAP ports each produce a large block of QAMs that are intended for one TX only. So, we look for the path that one of these could reach an unintended TX. Figure 5 clearly shows one such example applied to the second transmitter. In green is an intended CCAP block of channels at starting power P (channel power of each QAM), passing through cable loss, plug in padding and insertion loss of the combiner. An interfering block of channels in same spectrum, also starting at Power P , reaches TX#2 through the red isolation path passing through many elements including two paths of isolation on RF passives, each at 30 dB. This is the key point.

α_{c1} = cable loss from CCAP to NC combiner

α_{c2} = cable loss from D3.1 to NC combiner

α_p = plug in padding value for CCAP input to NC combiner

α_q = plug in padding value for D3.1 input to NC combiner

Port-to-Port isolation of NC combiner ≥ 30 dB (though typically better at most frequencies and typically better as ports becomes further spaced on a module)

IL_4 = Insertion loss of 4-way combiner

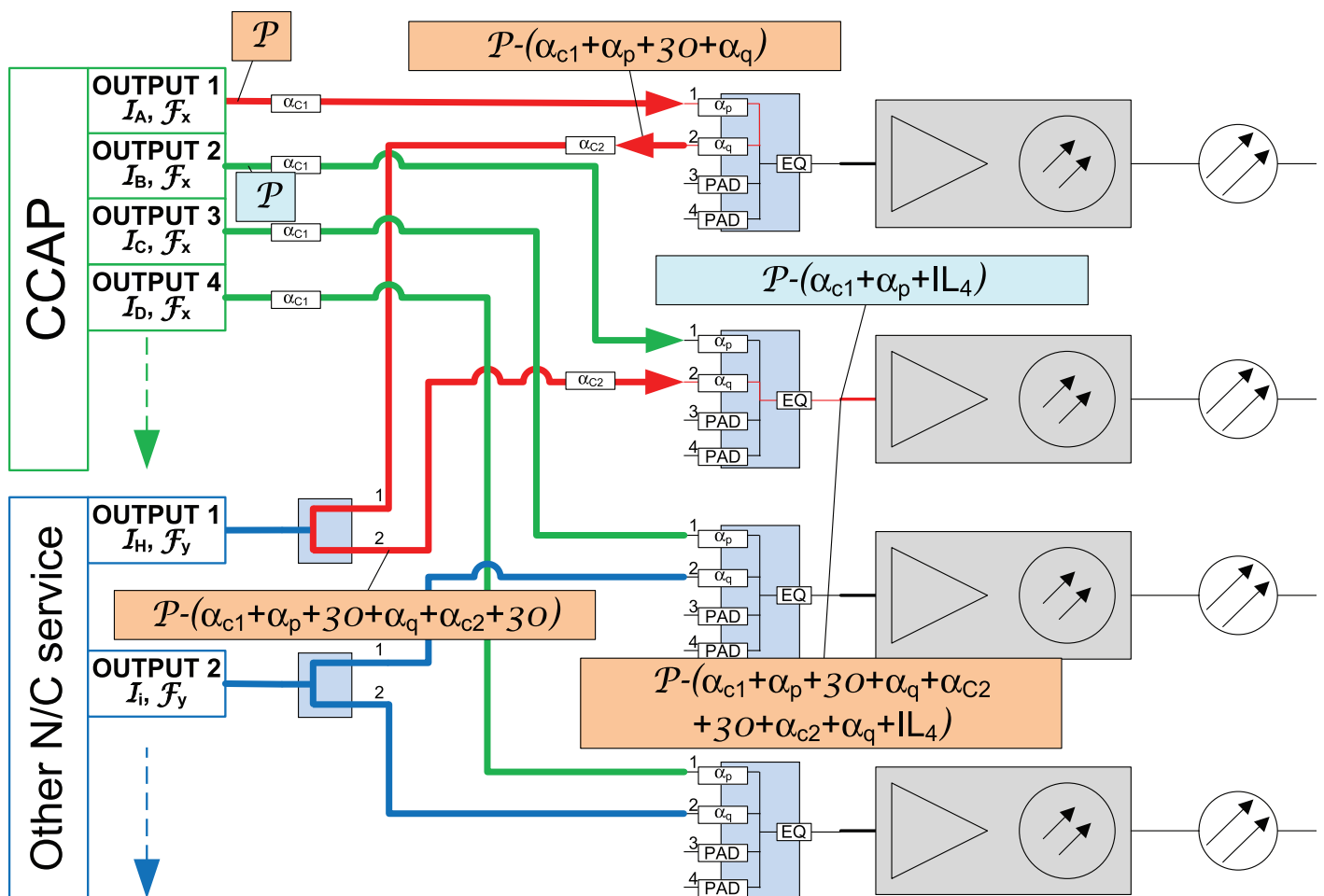


Figure #5
Isolation Path of Concern

Calculating the difference (delta) power between intended and unintended signals, many common terms cancel each other out.

$$\begin{aligned} \text{Isolation}_{\text{NET}} &= [\mathcal{P}-(\alpha_{c1}+\alpha_p+|L_4)] - [\mathcal{P}-(\alpha_{c1}+\alpha_p+30+\alpha_q+\alpha_{c2}+30+\alpha_{c2}+\alpha_q+|L_4)] \\ &= - [30+\alpha_q+\alpha_{c2}+30+\alpha_{c2}+\alpha_q] \\ &= - [60+2\alpha_q+2\alpha_{c2}] \end{aligned}$$

Even if there were 0 dB pads and trivial cable loss, this configuration still yields 60 dB isolation on a single path. Now there are multiple parallel paths that need to be considered and add to the total noise. Physical distance between ports inherently increases port to port isolation beyond the minimum 30 dB specification, so this multi-path impact drops off rapidly in practical scenarios. We can subtract the sum of interfering channel power from the net isolation by:

$$\text{Isolation}_{\text{NET}, n \text{ paths}} = - [60+2\alpha_q+2\alpha_{c2}] + 10*\log(n)$$

Refer again to the SNR vs BER table above where 41 dB SNR is required for 1024 QAM. We have 19 dB of headroom here to account for multi-path interference and safety margin. (25 dB headroom for 256 QAM). There are hundreds of installations globally using 256 QAM and RF passives with only slightly less than 30 dB port to port isolation in similar configurations. If 1024 QAM becomes deployed this increases the net isolation requirement by only 6 dB, which means just 3 dB of cable loss or plug in padding on each BC/NC combiner port is all that is required. A net isolation of 65 dB is a far different requirement than a per-module one.

Isn't more Isolation Better?

No. Leading RF management products used in the CATV headends today specify port to port isolation of a basic passive 2-way circuit of at least 30 dB up to 1 GHz. This basic building block is just repeated multiple times for 4-ways, 8-ways, etc without degrading port-to-port isolation and often increasing it as ports get physically further apart in a single device.

To get significantly higher isolation, it would be suggested to add much passive loss to combiner ports, and then overcome this loss by adding amplification.

While it may be advantageous for a manufacturer to do this and claim ultra-high isolation requirements (to gain increased revenue) this comes with clear costs to the cable operator as compared to all-passive approaches.

- CAPEX on initial purchase of active gear
- OPEX to supply power to run the gear and exhaust BTU's of heat generated
- Worse MTBF
- Distortions generated by more amplifiers
- CNR degradation due to excessive loss and noise figure of any amplifier.

In situations where insertion loss is too high and signals are not reaching the transmitter at sufficient levels, then active solutions may be unavoidable. This is a very different situation than intentionally throwing away RF power to increase isolation far beyond what is required for the foreseeable future.

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