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Upstream challenges with DOCSIS 3.1 implementation

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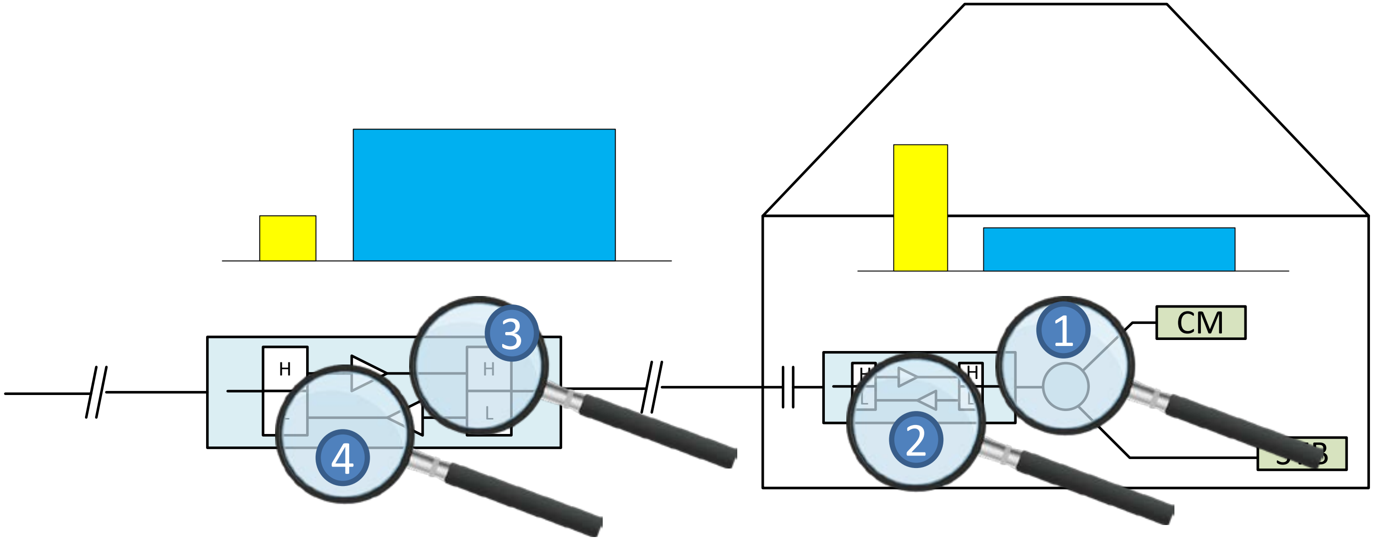
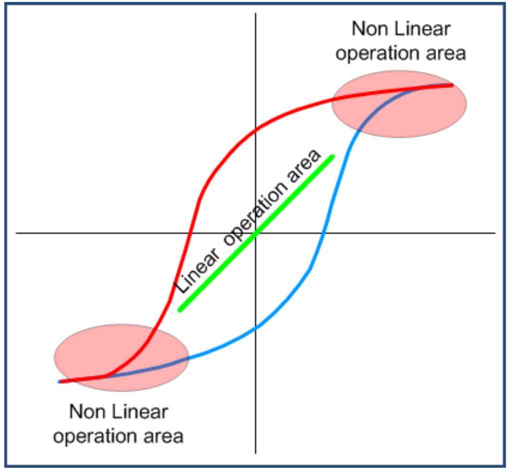
Upstream Challenges

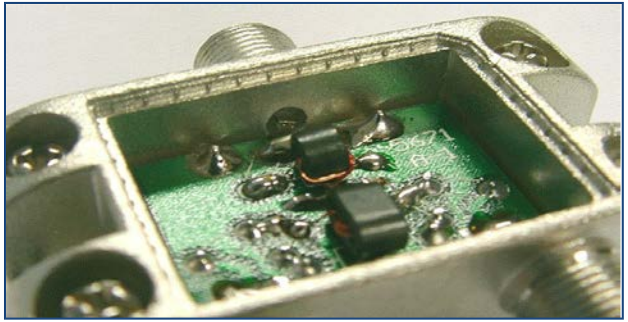


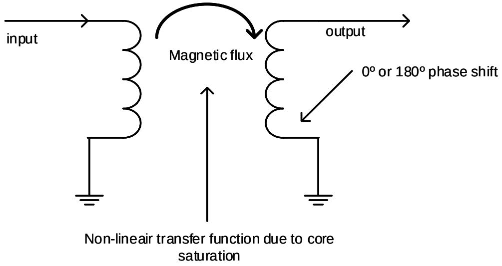
1. Passive intermodulation in splitters
2. 2nd order intermodulation in in-home amplifiers
3. Isolation in access amplifiers
4. Overloading of upstream amplifiers in the access amplifier

Passive modulation (PIM) in splitters

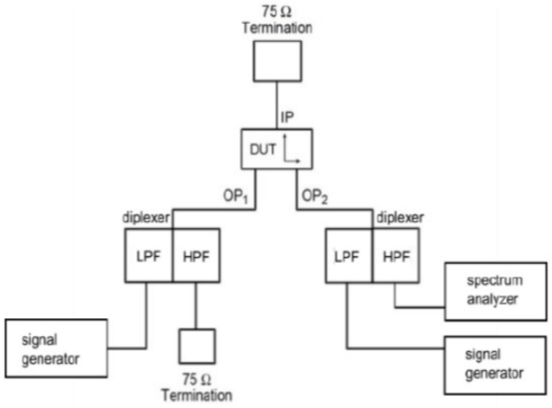
- Upstream signals that destroy downstream signals

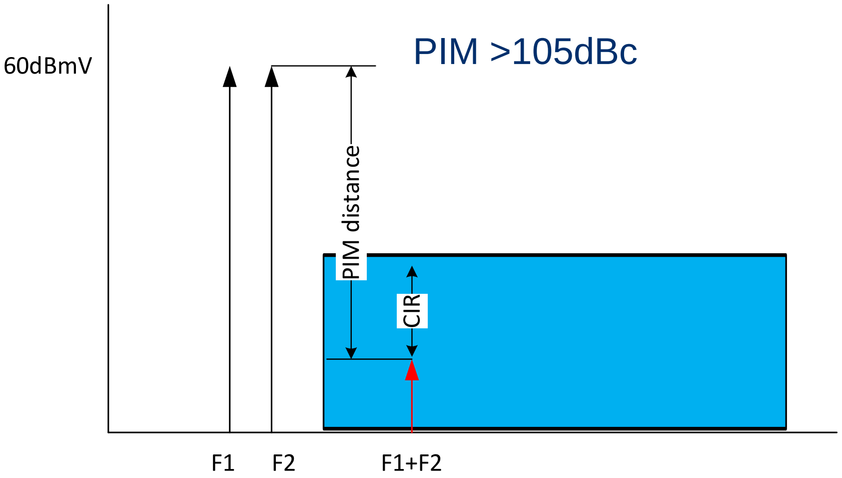






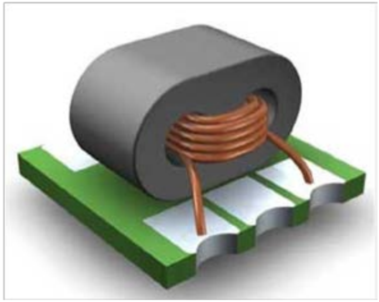
Testing PIM

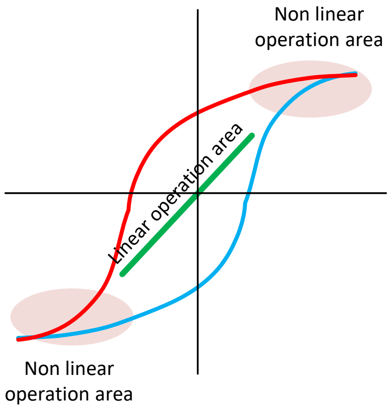




Standard	Level upstream 2 channels	Level downstream	Intermod @ 105 dBc PIM	CIR downstream	CIR downstream @ 115 dBc PIM	CIR downstream @ 90 dBc PIM
DOCSIS 3.0	54 dBmV	-6 dBmV	-57 dBmV	51 dBc	61 dBc	36 dBc
DOCSIS 3.1	60 dBmV	-6 dBmV	-45 dBmV	39 dBc	49 dBc	24 dBc

Methods to improve PIM

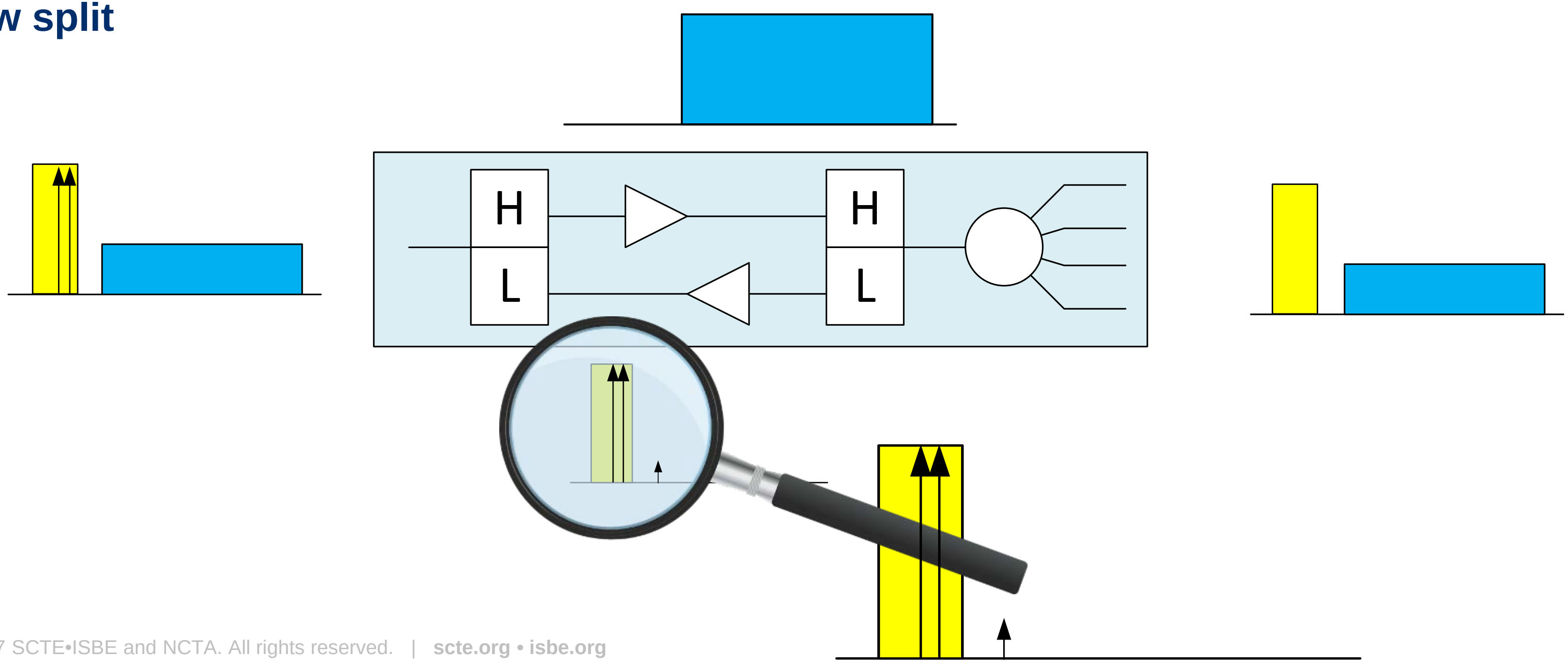




- Better ferrite performance is required but this is not easy:
  - To get better high frequency performance, the ferrite needs to be lower (shorter transmission lines on the ferrite)
  - To get better intermodulation performance, the ferrite needs to be higher (more energy needed to magnetize)
  - **DOCSIS 3.1 means degrading the insertion loss performance or degrading the IMD performance!**
- Stop this issue with a protection circuit so that surge energy can't reach the ferrite
  - Use protected ferrite with good insertion loss performance without degrading IMD performance.

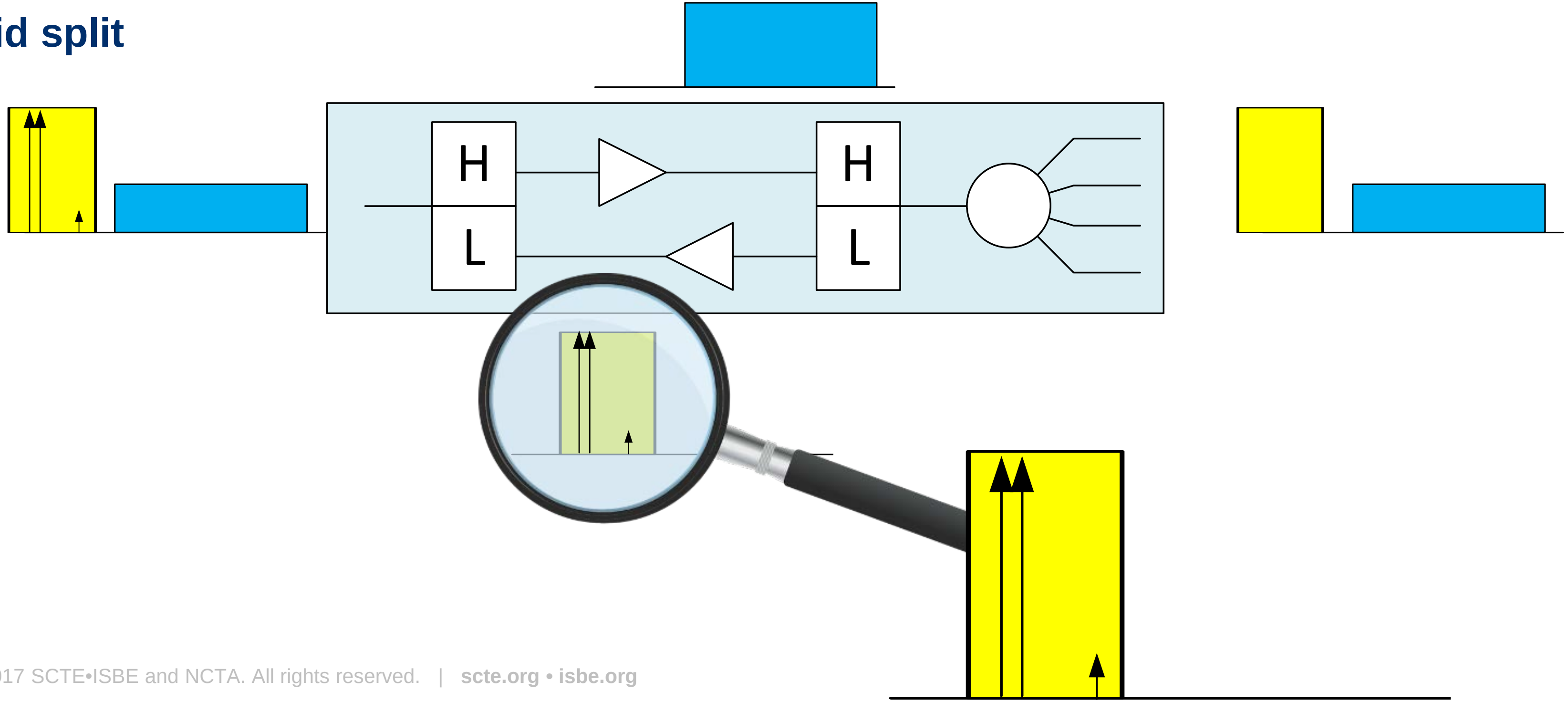
2^{nd} order intermodulation in in-home amplifiers

Low split

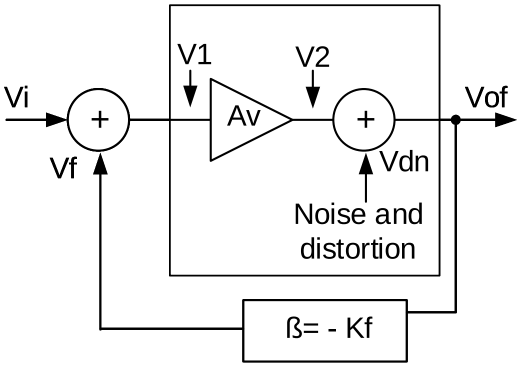


2nd order intermodulation in in-home amplifiers

Mid split



Negative feedback



$Vof = V2 + Vdn$

$Vof = Av \cdot V1 + Vdn$

$Vof = Av\,(Vi + Vf) + Vdn$

$Vof = Av\,(Vi - Kf \cdot Vof) + Vdn$

$Vof = Av \cdot Vi - Av \cdot Kf \cdot Vof + Vdn$

$Vof\,(1 + Av \cdot Kf) = Av \cdot Vi + Vdn$

$$Vof = \left[\frac{Av}{1 + Av \cdot Kf}\right] Vi + \left[\frac{1}{1 + Av \cdot Kf}\right] Vdn$$

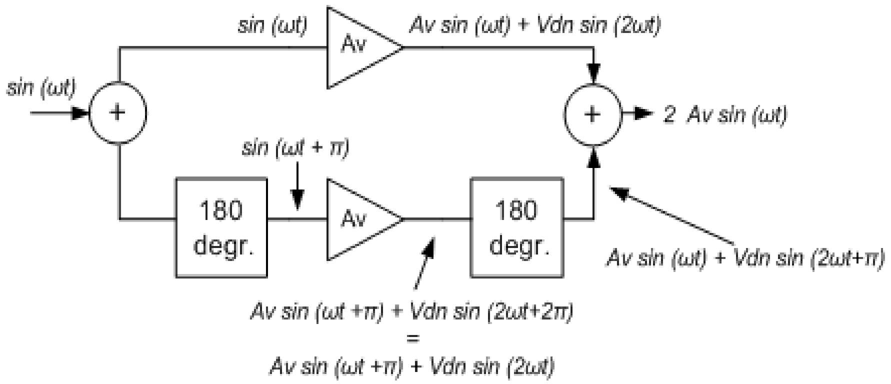
The conclusion is twofold:

- first part of the equation shows that the gain is reduced
- second part of the equation shows that the noise and distortion is reduced

The equation shows that more feedback results in lower gain and lower distortion.

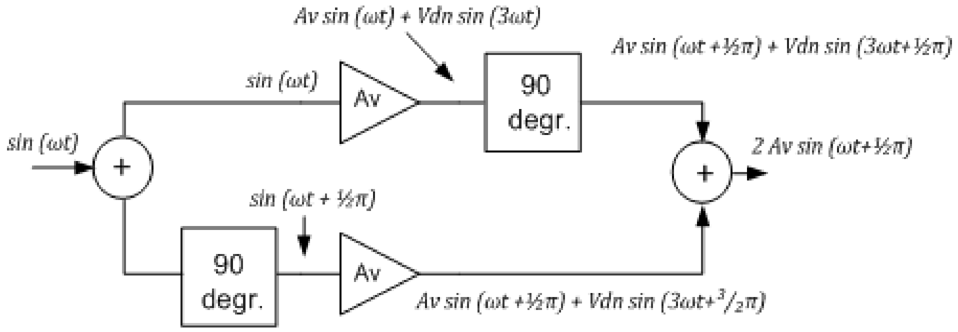
Push pull

- It is assumed the divider/combiner is lossless therefore the gain of the circuit equals *2 Av*. In the real world, the divider loss is 3 dB and therefore the gain of the circuit equals *Av.*
- From the figure above, it can be seen that even (2nd, 4th, …) order intermodulation products are cancelled. Uneven (3rd, 5th, ..) order intermodulation performance improvement is only marginal with two amplifiers in parallel.



Balanced amplifier

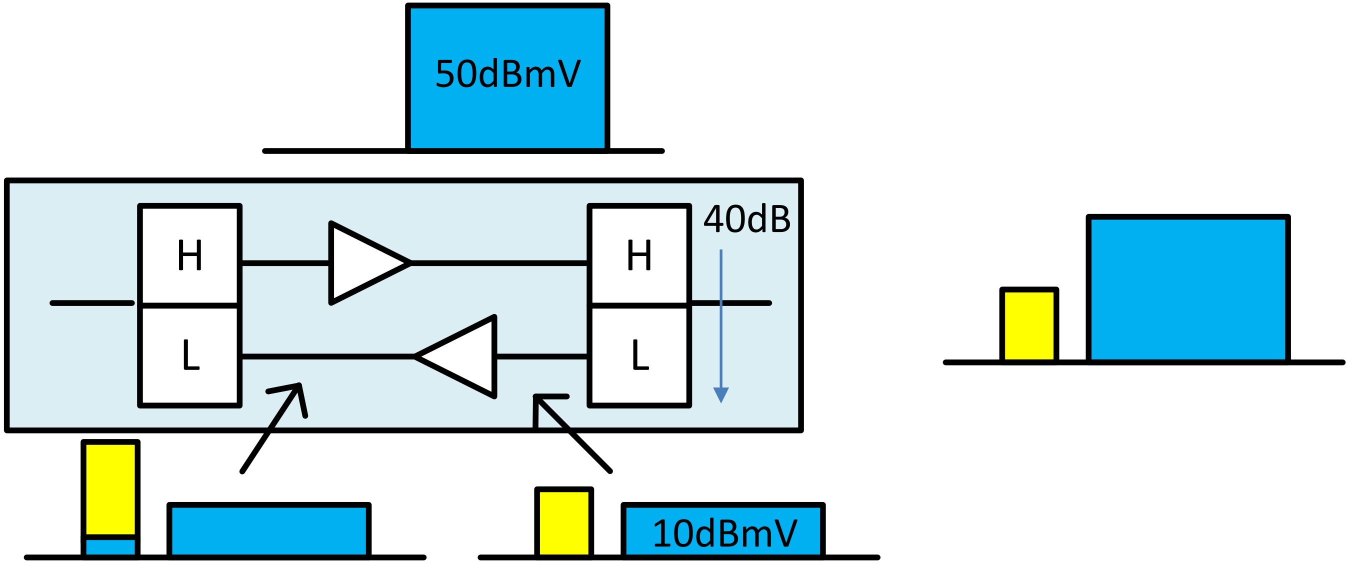
- The 90 degree delay lines used are frequency dependent, limiting the usable bandwidth of the amplifier.
- This type of amplifier is commonly used in microwave applications or in narrowband RF applications.



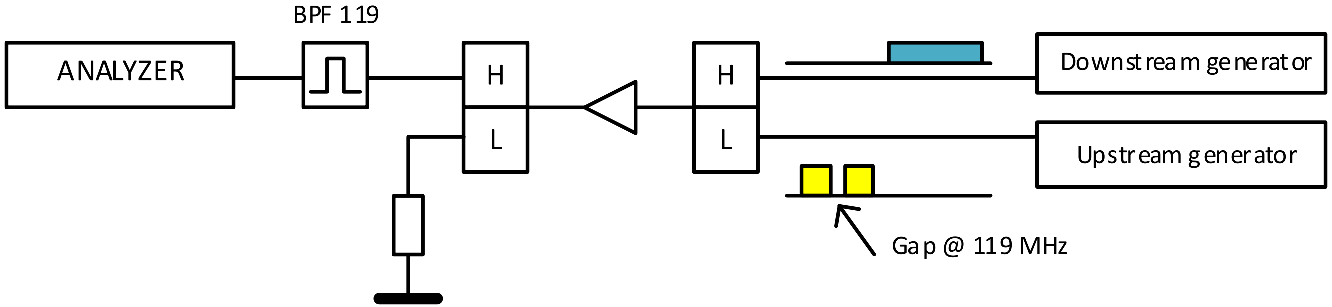
Methods to improve 2nd order intermodulation

- Mid and high split drive the complexity of upstream gain stages in the in-home amplifiers.
- The DPF in the in-home amplifier will stop some of the intermodulation products but this also raises the importance of a good DPF.
- There are different styles of gain stages and all have their pros and cons.
- Push pull design has the best performance, 2nd order IMD of 80dB is feasible.

Isolation in access amplifiers



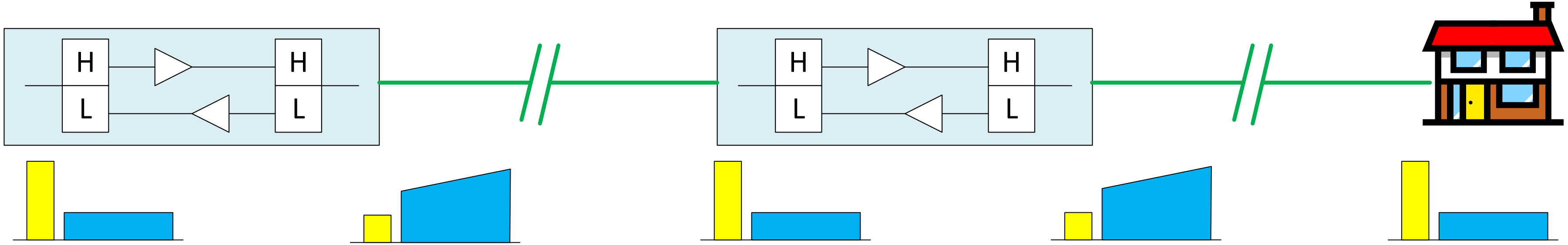
Measuring: Isolation in access amplifiers



- Low isolation in diplex filters will reduce the quality of the upstream due to loading of the upstream amplifier with downstream signals.
- Normal isolation of 50 dB in the diplex filters should not be a problem for the upstream.

downstream signal (dBmV/6MHz)	CINR
-10	42.01
-8	42.01
-6	42.01
-4	42.01
-2	42.01
0	42.01
2	42.01
4	42.01
6	42.01
8	41.61
10	40.41
12	38.91
14	35.91
16	30.51
18	23.21
20	17.41
22	9.81

Overloading of upstream amplifiers in the access amplifier



6.4MHz to √Hz = 10log6,400,000 = 68 dB

P out = 6dBuV/√Hz + 12 dB (BW) + 28 dB (gain) + 68 dB (6.4MHz)

= 114dBuV = 54dBmV

204MHz has 30 channels,

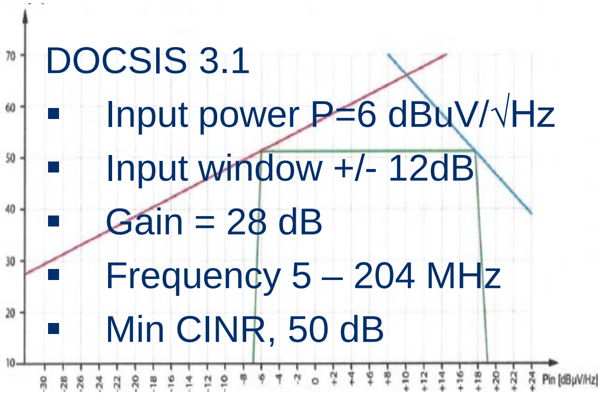
Pout = 54 dBmV + 10log30

= 69 dBmV

DOCSIS 3.0

- Input power P=6 dBuV/√Hz
- Input window = +/- 12 dB
- Gain = 25 dB
- Frequency 5 – 65 MHz
- Min CINR, 50 dB

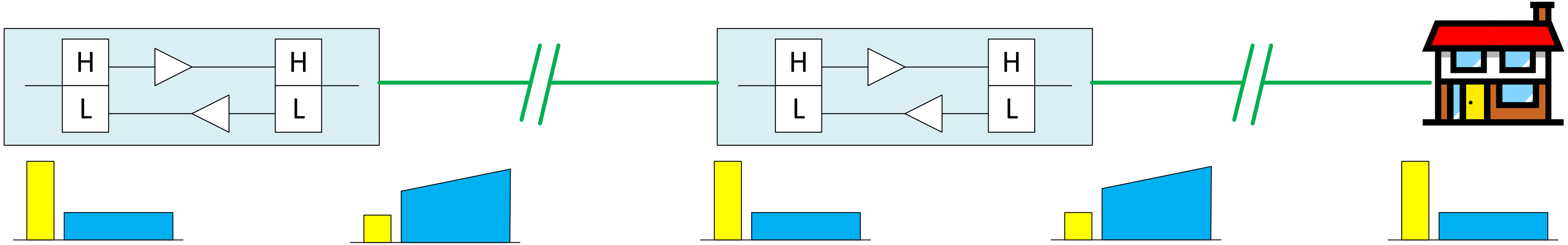
total composite power



DOCSIS 3.1

- Input power P=6 dBuV/√Hz
- Input window +/- 12dB
- Gain = 28 dB
- Frequency 5 – 204 MHz
- Min CINR, 50 dB

Overloading of upstream amplifiers in the access amplifier



- An amplifier with mid or high split will always have a tilted output
- The level on the input of the upstream amplifier can be greatly reduced
- With 10 amplifiers behind an optical node
- NF of 8dB and NP (thermal noise) of 2dBuV
- C/N towards the node of the 10 amplifiers together is:

C/N upstream = Input level - (8 db (NF) + 2 dBuV (NP)) – 10log10 (Number of amplifiers)

= Input level – 20 dBuV

With an input level of 10 dBmV, the C/N from the access network is still 50 dB.

Conclusion

There are several challenges when driving the upstream through the existing CATV network but these can be solved with the latest technology including:

- **PIM in splitters**

  PIM are intermodulation products from the upstream signals that can reduce the quality of the downstream signals.

  Standards drive the measurability.

  PIM can be reduced by using better ferrites (but take care of insertion loss) or special protection circuits.

- **2nd order in-home amplifiers**

  Intermodulation products in in-home amplifiers are products created by upstream signals reducing the quality of upstream signals.

  The 2nd order problem in upstream amplifiers becomes critical with mid and high split.

  From the amplifier styles researched, the push pull amplifier has the best potential.

Conclusion

- **Overloading of the upstream amplifier in access amplifiers**

  Overloading of the upstream amplifier in the access network can be solved by using a new way of specifying and alignment of the upstream signals.

  Due to the segmentations, the input level of the upstream amplifiers can be reduced.

- **Downstream reduces the quality of the upstream in the access amplifiers**

  The upstream amplifier can be overloaded by the downstream signals that will reduce the quality of the upstream signals.

  This problem can be solved by good DPF and the latest state-of-the-art amplifier technologies.

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THANK YOU!

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