Integrated RF calculations in AND

24 May 2017

The emergence of DOCSIS 3.1 has given cable networks a new lease of life.

Using existing network infrastructure relevant components can be swapped out extending the downstream up to a possible 1.8 GHz and the upstream to 200MHz. Improved spectral efficiency in comparison to the current DOCSIS 3.0 standard along with increased available bandwidth will enable operators to offer as much as 1 Gigabit/s. Indeed, it is expected that eventually up to 10 Gigabit/s will be possible on the same infrastructure without making further physical changes.

The upgrade projects will nevertheless present considerable engineering challenges, which, if not properly executed, could have serious repercussions on network performance as well as having a negative impact on “bits per dollar”. In addition, the upgrade tasks will have to be carried out with military precision causing as little disruption to services as possible.

This document presents an overview of the integrated AND calculations for RF/DOCSIS cable networks. These calculations allow you to effectively simulate your network providing you a means of ensuring optimal performance of your existing infrastructure as well as providing you with the necessary engineering support for future network upgrade projects, e.g. to DOCSIS 3.1.

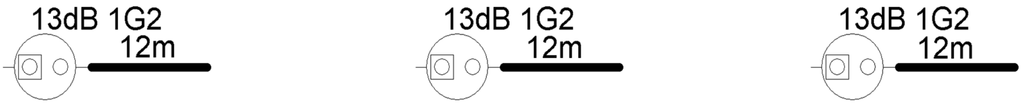
Not only does AND consider the complete network spectrum for both upstream and downstream, it also considers the end-to-end network, i.e. from the headend right to each and every home, regardless of whether this is a single-family building or part of a large apartment complex.

Note: AND provides very precise calculations of intermodulation products (2^{nd} and 3^{rd} order) caused by channels of narrow bandwidth. These consider nonlinearities of active components such as amplifiers. Consequently, AND comprehends the rate of intermodulations within each channel regardless of its bandwidth.

Recently implemented additional RF calculation improvements have been included in this paper; these will be available with the AND SystemSolution release scheduled for August 2017.

Units

To cater for the various signal level unit formats commonly deployed AND allows the user to select either dBµV, dBmV, or dBm. This can be done during normal operations.



266,00 MHz: 61,1 dBµV 792,00 MHz: 64,8 dBµV 1122,00 MHz: 66,6-67,6 dBµV	266,00 MHz: 1,1 dBmV 792,00 MHz: 4,8 dBmV 1122,00 MHz: 6,6-7,6 dBmV	266,00 MHz: -47,6 dBm 792,00 MHz: -43,9 dBm 1122,00 MHz: -42,1--41,2 dBm

Figure 1: Supported unit levels in AND

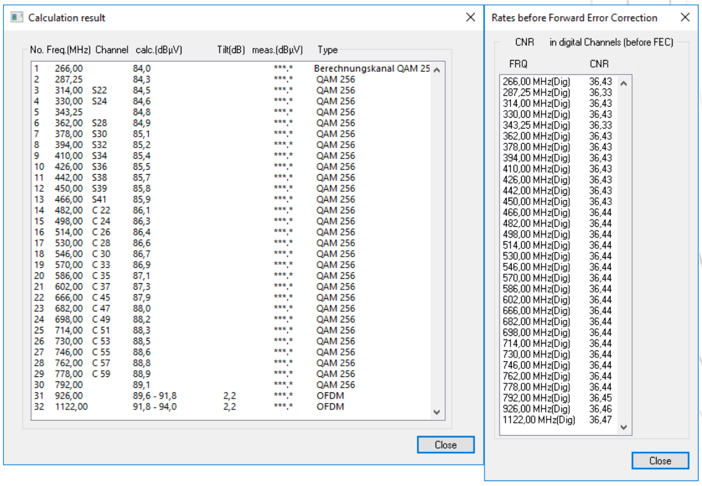
Levels are converted automatically.

Frequency routing

Each frequency is routed separately meaning that the channel raster is known at each point in the network.

In the single source/sources of each channel input parameters can be entered for:

- Noise
- RF level
- Frequency
- Modulation type
- Level reduction



Calculation result

No.	Freq.(MHz)	Channel	calc.(dBµV)	Tilt(dB)	meas.(dBµV)	Type
1	266,00		84,0		***,*	Berechnungskanal QAM 25
2	287,25		84,3		***,*	QAM 256
3	314,00	S22	84,5		***,*	QAM 256
4	330,00	S24	84,6		***,*	QAM 256
5	343,25		84,8		***,*	QAM 256
6	362,00	S28	84,9		***,*	QAM 256
7	378,00	S30	85,1		***,*	QAM 256
8	394,00	S32	85,2		***,*	QAM 256
9	410,00	S34	85,4		***,*	QAM 256
10	426,00	S36	85,5		***,*	QAM 256
11	442,00	S38	85,7		***,*	QAM 256
12	450,00	S39	85,8		***,*	QAM 256
13	466,00	S41	85,9		***,*	QAM 256
14	482,00	C 22	86,1		***,*	QAM 256
15	498,00	C 24	86,3		***,*	QAM 256
16	514,00	C 26	86,4		***,*	QAM 256
17	530,00	C 28	86,6		***,*	QAM 256
18	546,00	C 30	86,7		***,*	QAM 256
19	570,00	C 33	86,9		***,*	QAM 256
20	586,00	C 35	87,1		***,*	QAM 256
21	602,00	C 37	87,3		***,*	QAM 256
22	666,00	C 45	87,9		***,*	QAM 256
23	682,00	C 47	88,0		***,*	QAM 256
24	698,00	C 49	88,2		***,*	QAM 256
25	714,00	C 51	88,3		***,*	QAM 256
26	730,00	C 53	88,5		***,*	QAM 256
27	746,00	C 55	88,6		***,*	QAM 256
28	762,00	C 57	88,8		***,*	QAM 256
29	778,00	C 59	88,9		***,*	QAM 256
30	792,00		89,1		***,*	QAM 256
31	926,00		89,6 - 91,8	2,2	***,*	OFDM
32	1122,00		91,8 - 94,0	2,2	***,*	OFDM

Close

Rates before Forward Error Correction

CNR in digital Channels (before FEC)

FRQ	CNR
266,00 MHz(Dig)	36,43
287,25 MHz(Dig)	36,33
314,00 MHz(Dig)	36,43
330,00 MHz(Dig)	36,43
343,25 MHz(Dig)	36,33
362,00 MHz(Dig)	36,43
378,00 MHz(Dig)	36,43
394,00 MHz(Dig)	36,43
410,00 MHz(Dig)	36,43
426,00 MHz(Dig)	36,43
442,00 MHz(Dig)	36,43
450,00 MHz(Dig)	36,43
466,00 MHz(Dig)	36,44
482,00 MHz(Dig)	36,44
498,00 MHz(Dig)	36,44
514,00 MHz(Dig)	36,44
530,00 MHz(Dig)	36,44
546,00 MHz(Dig)	36,44
570,00 MHz(Dig)	36,44
586,00 MHz(Dig)	36,44
602,00 MHz(Dig)	36,44
666,00 MHz(Dig)	36,44
682,00 MHz(Dig)	36,44
698,00 MHz(Dig)	36,44
714,00 MHz(Dig)	36,44
730,00 MHz(Dig)	36,44
746,00 MHz(Dig)	36,44
762,00 MHz(Dig)	36,44
778,00 MHz(Dig)	36,44
792,00 MHz(Dig)	36,45
926,00 MHz(Dig)	36,46
1122,00 MHz(Dig)	36,47

Close

In the next release (E6/2017) AND will support individual CNR limit values for each channel modulation type as different signal usage requires different carrier to noise ratio limits. For example, QAM 64 might need a 27db ratio whereas QAM 256 might require a 32.5dB ratio.

Up to now the AND user has only been able to set a single limit in the warning settings. As a workaround, the input levels and noise ratios had to be adapted at the signal source. With the next release (E6/2017) the warning settings will be extended allowing the user to enter an individual CNR limit for each modulation type. This can be selected on a per channel-basis at the signal source.

The *net-check* function will consider these limits for each channel individually.

Attenuation

Cable

Cable attenuation is entered for selected frequencies. AND uses these values to calculate the attenuation for the frequency spectrum using square root interpolation. This returns an attenuation curve as shown in the diagram below.

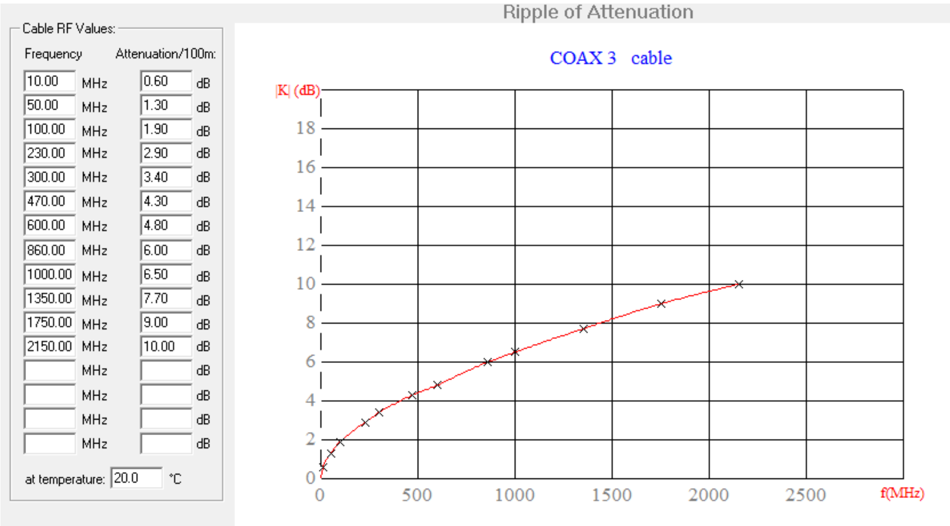


Figure 2: Attenuation curve for coaxial cable

AND also calculates cable attenuation for different temperatures when considering AGC alterations.

Passive Components

Attenuation is entered for selected frequencies. Using these values the attenuation for individual frequencies is calculated by linear interpolation. This returns an attenuation curve as shown in the diagram below.

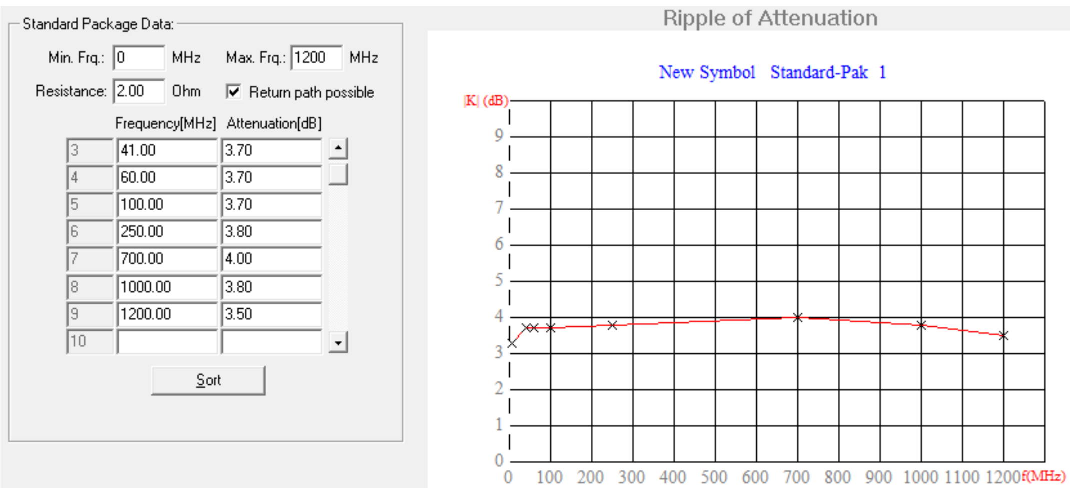


Figure 3: Attenuation curve for passive components

Equalizer

The equalizer is a so called *ideal component*, nevertheless real-world devices have basic attenuation and this is considered by AND.

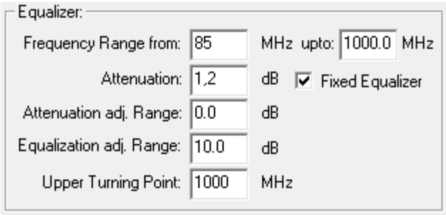


Figure 4: Equaliser settings

The User enters the following values:

- Basic attenuation
- Nominal slope
- Lower frequency
- Turning point

  e.g. 10 dB slope between 85 and 1000 MHz.

AND assumes a combination of linear response (att(f) = af+b) and square root-like response (att(f) = $a\sqrt{f}+b$). The mixing ratio can be entered as a project setting that is applied to all equalisers of the current project. By default, a mixture of 25% linear and 75% square root-like is used.

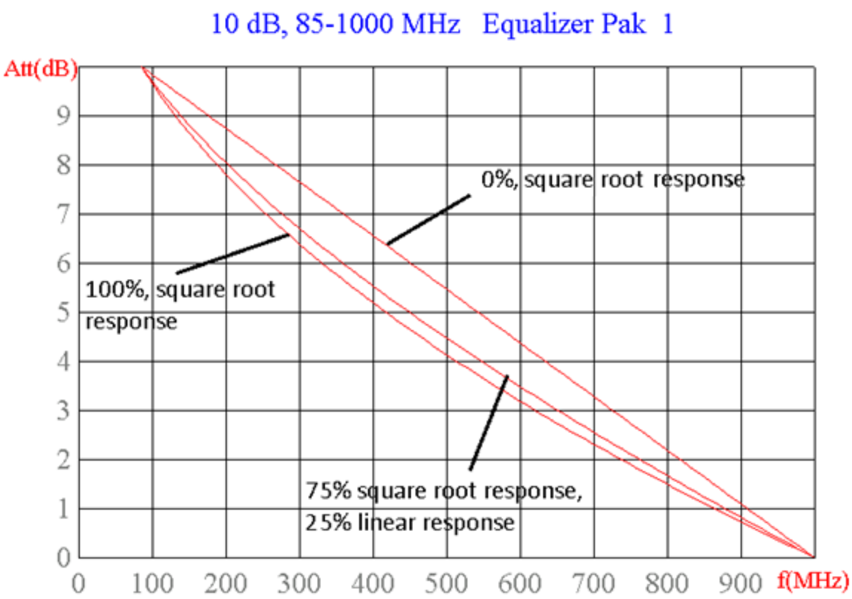


Figure 5: Comparison of the frequency response of a 10db equaliser for ratios 0%, 75%, 100%

It is also possible to enter attenuations for a list of frequencies when deploying equalisers designed as standalone components with fixed equalisation. Attenuation is then calculated by linear interpolation as with other passives.

Downstream Level

The downstream level is calculated as following:

> *"signal source level minus attenuation plus amplification".*

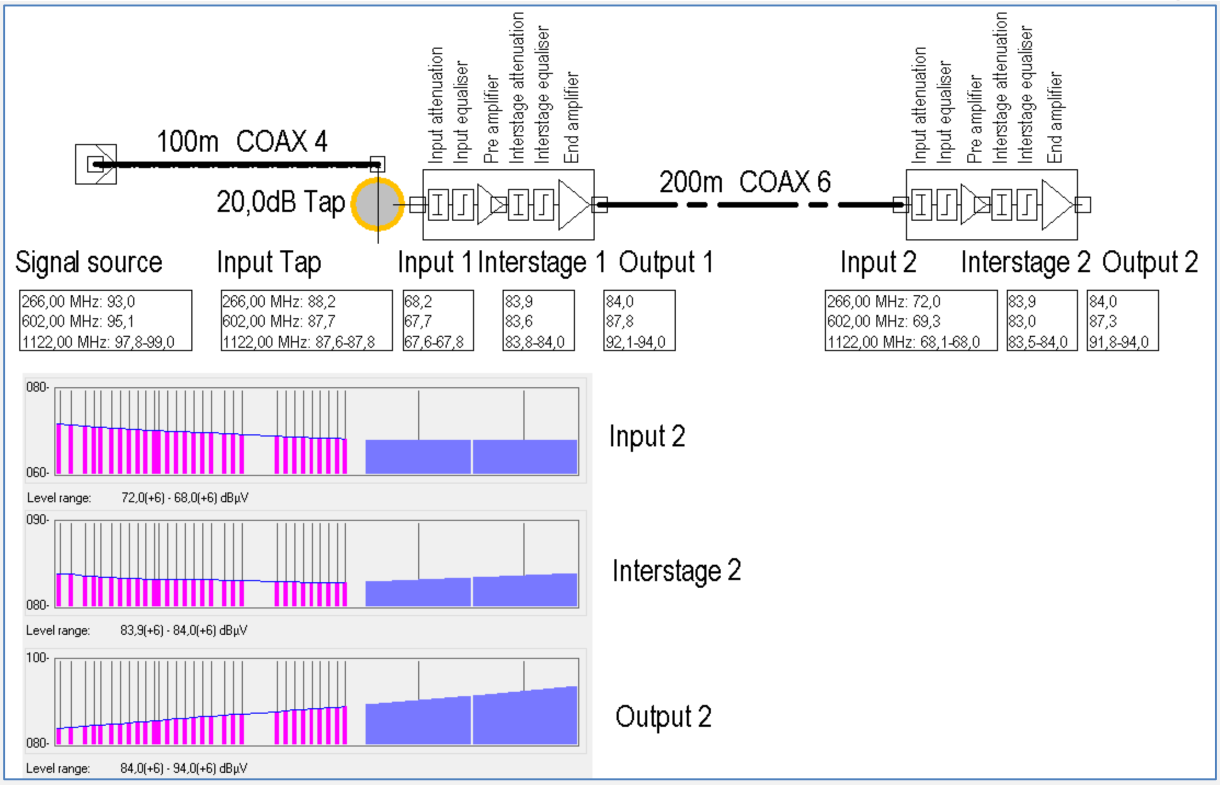


Figure 6: Signal path with amplification and attenuation

Attenuation is calculated for all frequencies of all signal sources. This allows calculation of each frequency at any given point. Attenuation can be regulated using adjustable components.

Amplifiers are automatically adjusted by AND to a value specified by the planner considering the reduction set at signal source for each channel so that the input attenuators and equalisers set the signal as flat as possible and the required slope is generated in the interstage. Noise-reducing attenuation is also taken into account in the interstage.

Slopes (tilts) within channels are also calculated; this is particularly important for broadband OFDM channels:

	Cha...	Program	Frq [MHz]	dBµV	Tilt[dB]	Type	Ban...	Red.	C/N	Mux
			926,00	90,9	2,0	OFDM	192,00	6,0	36,5	None
			1122,00	93,0	2,0	OFDM	192,00	6,0	36,5	None

Figure 7: Channel list with OFDM channels and tilt within the channel bandwidth

Upstream Level

The following values must be defined for the calculation of the upstream:

- Reception levels at the receiver or the signal source, e.g. 70 dBµV
- Level range in which the cable modems can send, e.g. 100-112 dBµV.

The upstream level for any given point after the cable modem is calculated as follows:

"receiving level + attenuation of the cable and passives".

Attenuation is calculated for all return path frequencies in 1 MHz steps. Slope of cables and return path equaliser are considered. The return path amplifier settings also consider the upstream equaliser.

As the frequency band in DOCSIS 3.1 is more than three times larger than that in DOCSIS 3.0 the inclusion of cable attenuation calculation is of utmost significance. (Basically, the longer the cable the greater the slope.) The physical properties of the cable are stored in AND, making it possible to calculate attenuation with respect to frequency.

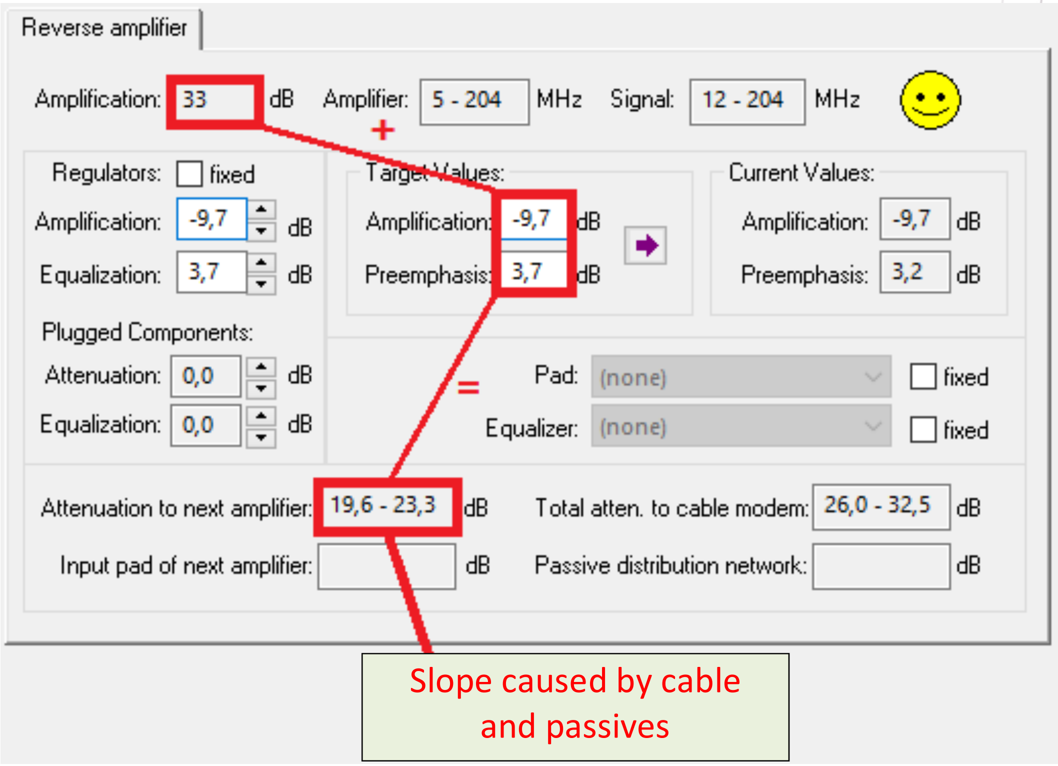


Figure 8: Reverse path amplifier settings

The amplifier can be adjusted in order to compensate for attenuation and slope.

Amplifier input levels

AND checks the target levels at the amplifier output. In conjunction with CNR calculation for each stage amplifiers can be checked that they are operating in accordance with specified thresholds.

New additional limits and checks for amplifier input are being introduced in the next release (E06/2017); these are described below.

NEW: Default level window in library

A default level window with minimal and maximal values for the input of each amplifier stage is now available in the library editor. Normally the user will only enter these values for the input of the first amplifier stage.

NEW: Amplifier Input Level Check

When input limit values are set in the AND library they will be added to a newly drawn amplifier. The amplifier-package dialogue in AND will be extended by the new input level min/max values. The user can edit/overwrite the library values.

The warnings settings provide a checkbox and a tolerance parameter allowing the user to make a verification configuration for the net-check function.

Assuming the function has been activated and an amplifier has valid min/max values set then a warning will be shown during the execution of the net-check function if the calculated input level falls outside the permitted level range.

NEW: Warning if amplifier target values are higher than in library

Checkboxes and tolerances are included in the warning settings allowing the user to activate the library limit check within the net-check function.

This will be carried out for:

- Input level – if the amplifier Input Level window has been increased by the user
- Target level – if the amplifier target level has been increased by the user

A warning will be shown in a case where there are valid values in the library and where the user has overwritten these resulting in possible performance issues.

NEW: Check on max. amplifiers in cascade

Users may want to verify if the number of amplifiers in cascade exceeds a pre-defined limit.

The warning settings will get a checkbox “check on number of amplifiers in cascade” and an editable limit for the number of permitted amplifiers.
If the function is activated the *net-check* function will issue a warning for the amplifiers in a cascade where the limit has been exceeded.

Noise

The CNR value is entered for each channel of the signal source.

Degradation at each amplifier stage is calculated using the following formula:

$$10^{\frac{-CNRout}{10}} = 10^{\frac{-CNRin}{10}} + 10^{\frac{-Z}{10}}$$

CNR_{out} = CNR at output	
CNR_{in} = CNR at input	
Z = P_{in}[dBµV] - R[dB] - kTΔf[dBµV]	R = Noise number of the amplifier stage
P_{in} = Level at input of the amplifier stage	k = Boltzmann-constant
T = Temperature, e.g. 293 K	Δ = Bandwidth of a channel in Hz

The default value for the logarithmic noise factor is 10. As this is now editable the user can change this value, e.g. to 11. This value will then be considered in the noise calculation.

CNR is calculated for each individual channel which can be compared against threshold values in the warning settings. These values can be specified for both digital and analogue channels; digital channel-only networks are also possible.

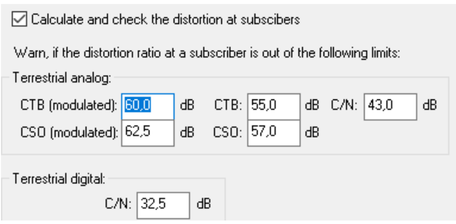


Figure 9: Warning settings (excerpt)

As stated earlier, different signal usage requires different carrier to noise ratio limits.

AND will allow the user to enter an individual CNR limit for each modulation type in the next release (E6/2017). This can be selected on a per channel-basis at the signal source.

Remote Powering

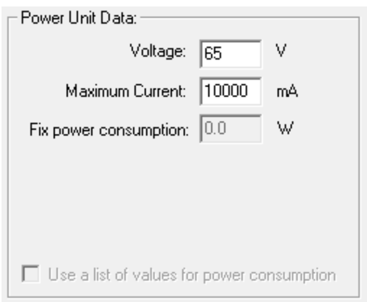


Figure 10: Power unit data

Electrical properties for remote supply are catered for in the library object. The ohmic resistance of the power supply cables and the current caused by active remote powered components are calculated as a voltage drop. AND checks whether the necessary supply is ensured for each component and also if the power unit is able to provide the network with enough current/power. In addition, AND checks the maximum permitted current of component(-ports) and if there are shortcuts or components that shouldn't be supplied.