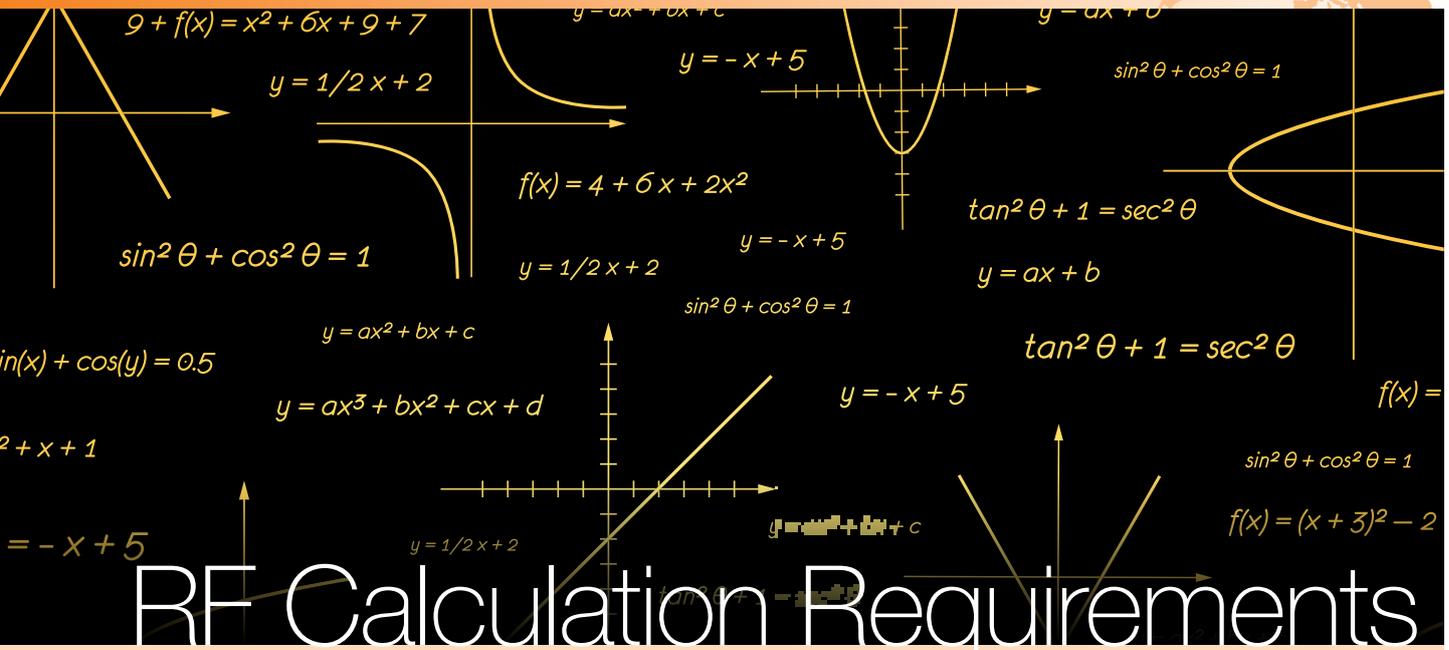


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# RF Calculation Requirements

for DOCSIS 3.1 and ACSO Networks

by Diarmuid Kelly, Director Global Sales, AND Solution GmbH

**This article presents an overview of AND network software, as well as the calculations needed for RF/DOCSIS cable networks and/or ACSO. These calculations allow users to effectively simulate their networks, providing them with a means of ensuring optimal performance of existing infrastructure as well as providing the necessary engineering support for future network upgrade projects to DOCSIS 3.1.**



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An accomplished and successful senior executive, Diarmuid Kelly is a veteran of the telecommunications industry with over 30 years' extensive international experience. Over the years has worked in the areas of global sales, business development, strategic sales & marketing, R&D product management, software development project management as well as quality assurance.

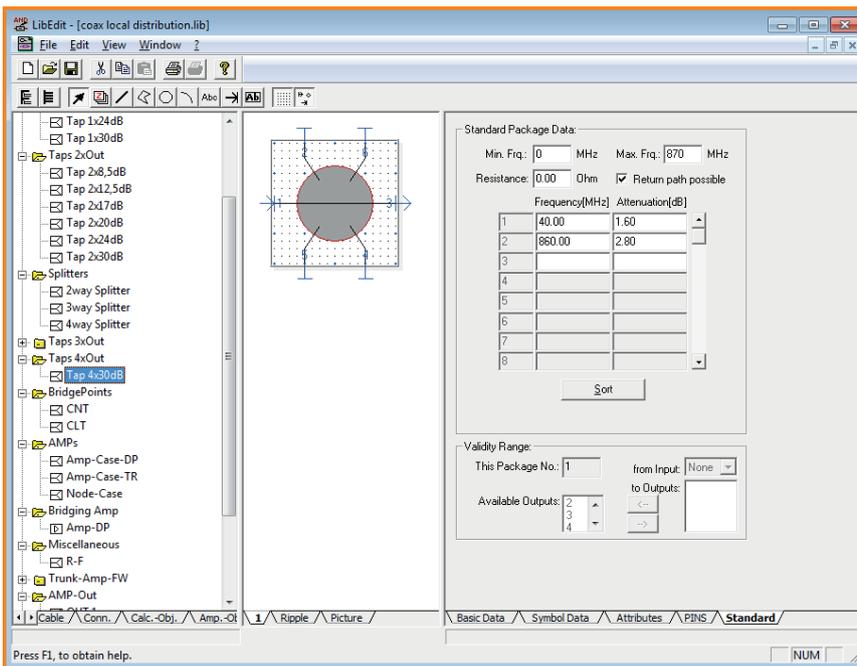
Originally from Dublin, Ireland he moved to England in 1981 to study computer engineering at Staffordshire University where he graduated in the summer of 1985. Several weeks later he was on the move again, this time to Munich, Germany, where he joined Siemens' public network division until 1998. Following a short period in its mobile network division, he left Siemens for COM21 (acquired since by ARRIS), which specialised in voice and data solutions over the cable networks. Since 2003 he has been working at AND Solution. Now, as global sales director of this European specialist in network planning and documentation, he helps shape the development of the industry.

The introduction of DOCSIS 3.1 with extended downstream and upstream, along with improved spectral efficiency, provides cable network operators with the opportunity to satisfy ever-increasing bandwidth demands for the foreseeable future. If we also consider the normally considerably lower investments costs for cable operators to upgrade, rather than migrating to FTTH, then there is a compelling argument for DOCSIS 3.1.

Certainly, the upgrade process throws up considerable engineering, as well as logistical, challenges. The AND system solution, however, provides the operator with the necessary tools during the planning process as well as supporting network engineers throughout the actual upgrade process.

### Brief overview

AND is a highly intuitive, easy-to-use integrated and scalable solution for all types of networks including FTTH, FTTx as well as HFC/RFoG. Its ability to manage the in-building means it is also suitable for data centres, OLAN and most types of campus networks.



Screenshot 1

Network components such as DOCSIS 3.1 amplifiers, along with coaxial and fibre cables, are documented in the AND libraries according to their technical specifications. Complex objects, such as cabinets, hubs and even apartment blocks, can be created as templates for later usage.

Taking equipment characteristics into account, AND models the network to a high degree of accuracy. This enables it to calculate the optical power throughout the network for both directions as well as calculating the complete DOCSIS 3.1 spectrum.

AND provides field technicians who use Android tablets, iPads, notebooks etc. with interactive web solutions which include redlining functions, fibre breakage location functionality, photo and QR code management, as well as signal tracing. Integrated test and measurement devices enable efficient and practical comparisons between AND calculations and measurements as well as the automatic upload of reports to the documentation.

An interface to monitoring solutions provides near real-time display of states in the documentation while showing the common point of failure.

Civil works planning is fully integrated into AND software. Flexibility and user-friendliness are of the utmost importance. AND also supports the realignment of trench paths including contents such as ducts and cables for the as-built documentation without the need to delete and redraw them.

## Planning the upgrade

The actual planning of the upgrade is comparatively straightforward assuming the network is already documented in AND. **Note:** A migration API is now available for operators with legacy documentation.

Having decided which components are required for the upgrade, the user sets about drawing up a “translation table” of existing material to be replaced by DOCSIS 3.1 components.

Using the DesignAlternative function, the planner creates a virtual copy of the documentation for the target area. By doing so, the future network can be simulated without affecting existing documentation needed by the service colleagues.

With the help of the translation table, the planner sets about semi-automatically upgrading node for node. On the completion of each node, the plan can be verified using the network check function. This considers the following:

- RF-Attenuation of cables, passive components and equalisers.
- Optical budget at fibre-nodes.
- Automatic amplifier adjustment, including AGC.
- Downstream and upstream levels.
- Amplifier input levels.
- Max. number of amplifiers permitted in cascade.
- Noise.
- Remote supply.
- Amplifier cumulative load.

Errors and warnings are listed, enabling the planner to revise the upgrade design until all issues have been resolved.

On completion of the target area, the bill of material can be generated with the planner able to move onto the next project.

## Achieving the network upgrade

Somewhere down the line, the actual upgrade itself will take place. Plans are in place, corresponding components are in stock and end-users are informed of the pending upgrade.



Out in the network field, technicians can access current AND documentation and upgrade plans on their mobile devices e.g. using GPS or QR codes. Photos taken before the upgrade are uploaded (admin-free) to the AND database.

Having switched from documentation to the upgrade plan, the HW changes are then carried out. On completion, the network engineers, with the help of the AND Verify function, can compare AND's RF calculations with measurement results from, for example, the integrated KWS VAROS 107i test and measurement device. If there are discrepancies, these can be immediately rectified, otherwise the measurement report (along with photos documenting the build) are uploaded to AND.

Any necessary redlinings can be made, with corresponding tasks generated for the documentation staff responsible for completing the as-builts.

## Highlights

- Integrated DOCSIS 3.1 engineering for complete spectrum (GPON is similarly supported).
- Function available to allow virtual copy of documentation to be used for planning of future network.
- Network component swap-out functionality for upgrade projects e.g. D3.0 – D3.1 with validation check.
- Interactive mobile applications (HTML-5 based) for field staff with redlining and photo-upload (admin-free); user can switch between documentation and plans.
- Integrated test and measurement device allowing measured results to be compared with AND calculations; admin-free upload of report to data system.
- Amplifier settings as calculated by AND are available to remote management systems, avoiding manual adjustment of amplifiers.
- Migration API allows data to be migrated from legacy to AND data model
- Interface available to network monitoring.

The access of data containing amplifier instances and generic attribute-value pairs enabling amplifier management systems to remotely adjust the amplifiers (according to AND calculations) is supported for the rollout of amplifiers.

## RF calculation requirements for DOCSIS 3.1 and ACSO networks

The emergence of DOCSIS 3.1 and ACSO (Analogue Channel Switch-Off) have undoubtedly 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 1.8GHz and the upstream to 200MHz. Improved spectral efficiency in comparison to the 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.

Here, we present an overview of the integrated AND software calculations for RF/DOCSIS cable networks and/or ACSO. These calculations allow users to effectively simulate their networks, providing them with a means of ensuring optimal performance of existing infrastructure as well as providing the necessary engineering support for future network upgrade projects to DOCSIS 3.1.

AND software considers the complete network spectrum for both upstream and downstream, as well as the end-to-end network i.e. from the headend right to each home, regardless of whether this is a single-family building or part of a multi-storey apartment complex.

With the introduction of DOCSIS 3.1, additional RF calculation improvements were implemented in AND software and

**Note:** AND also provides precise calculations of intermodulation products (2nd and 3rd order) caused by channels of narrow bandwidth. These calculations consider nonlinearities of active components such as amplifiers. Consequently, AND comprehends the rate of intermodulations within each channel regardless of its bandwidth. These calculations are not considered in this article.

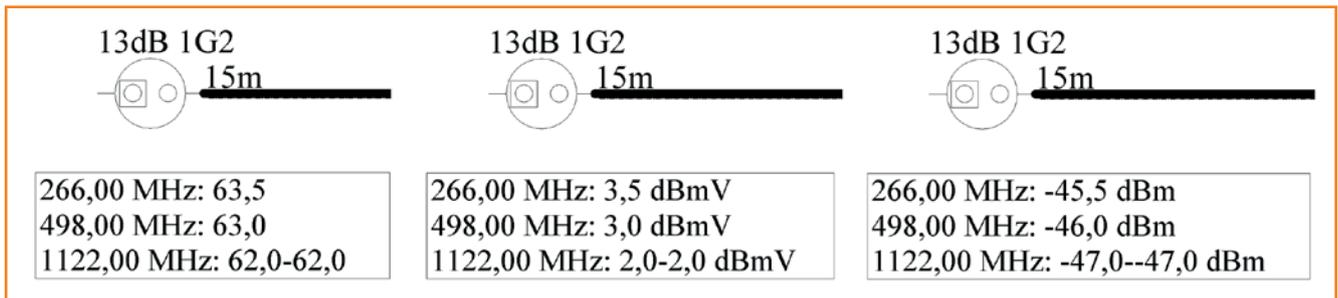


Figure 1: Supported unit levels in AND software

these are described in this article. These enhancements are available as from AND SystemSolution V4.12.

### Units

To deal with the various signal level unit formats commonly deployed, AND allows the user to select either dBμV, dBmV or dBm. This selection can be done during normal operations. 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, the following input parameters can be entered for:

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

AND supports 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 require a 27db ratio, whereas QAM 256 might require a 32.5dB ratio.

Previously, AND users were only 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. The warning settings have since been extended to allow the user to enter an individual CNR limit for each modulation type. These can be selected on a per channel-basis at the signal source.

The Network-Check function considers 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.

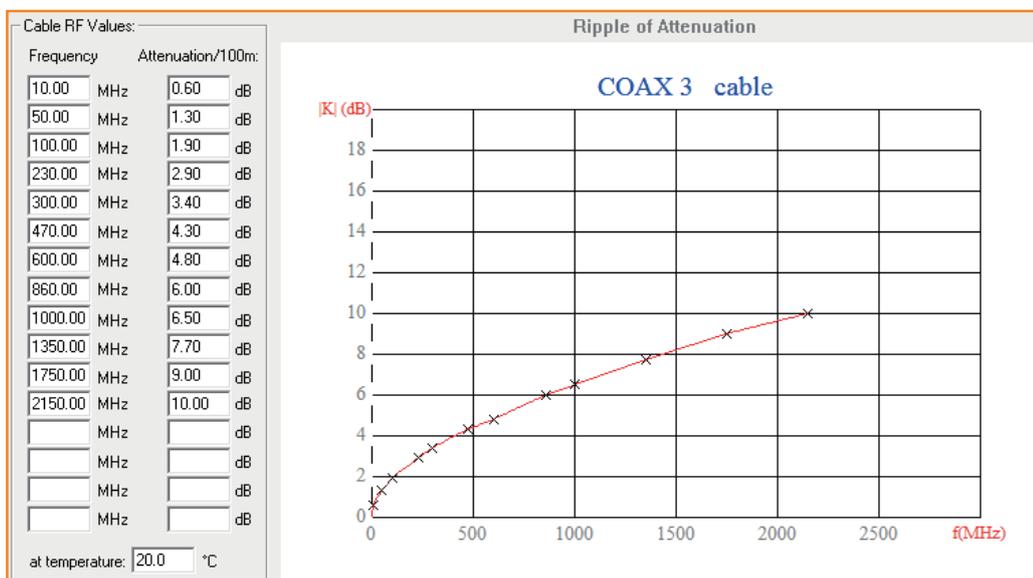
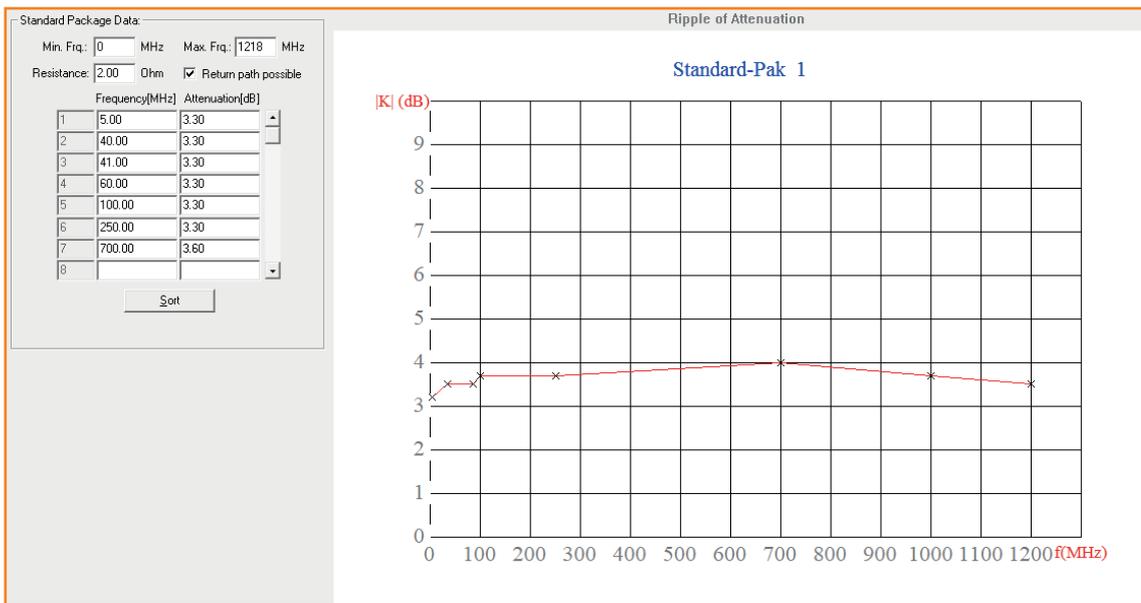


Figure 2: Attenuation curve for coaxial cable



**Figure 3:** Attenuation curve for passive components

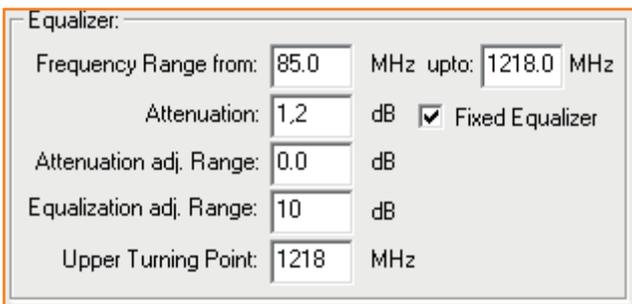
AND software also calculates cable attenuation for different temperatures when considering AGC alterations.

### 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 above.

### Equaliser

The equaliser is a so-called ideal component, nevertheless real-world devices have basic attenuation that is considered by AND.



**Figure 4:** Equaliser settings

The User enters the following values:

- Basic attenuation.
- Nominal slope.
- Lower frequency.
- Turning point e.g. 10dB slope between 85 and 1000MHz.

AND assumes a combination of linear response ( $att(f) = af+b$ ) and square root-like response ( $att(f) = \sqrt{f}$ ). 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.

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 follows:

*“Signal source level minus attenuation plus amplification”.*

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 wide OFDM channels (see Figure 7).

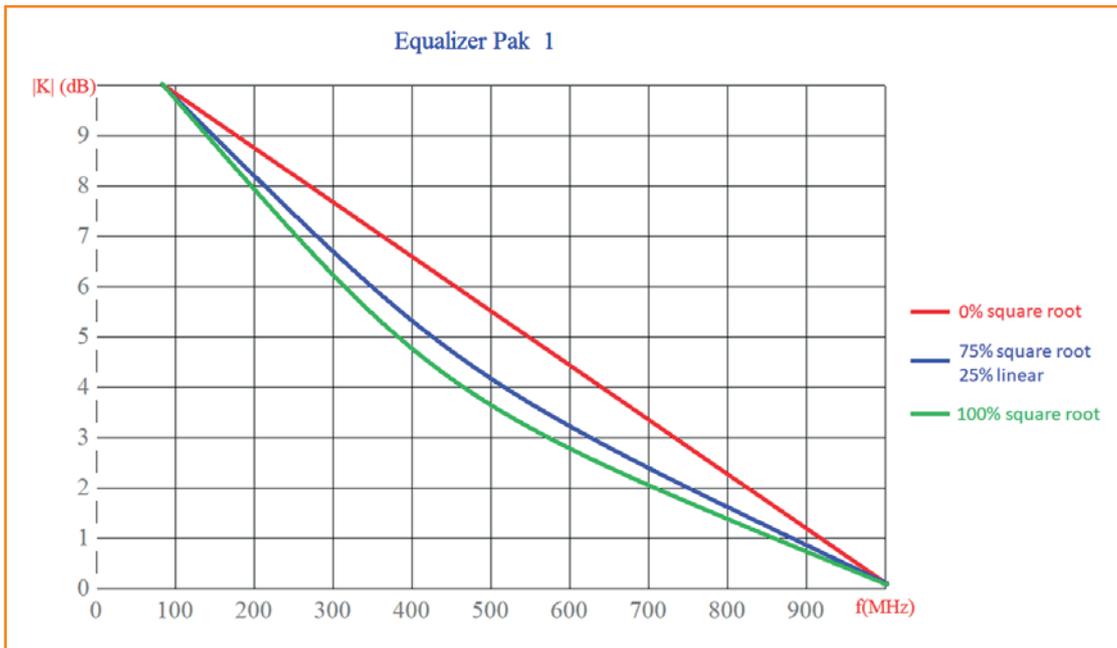


Figure 5: Comparison of the frequency response of a 10db equaliser for ratios 0%, 75% and 100%

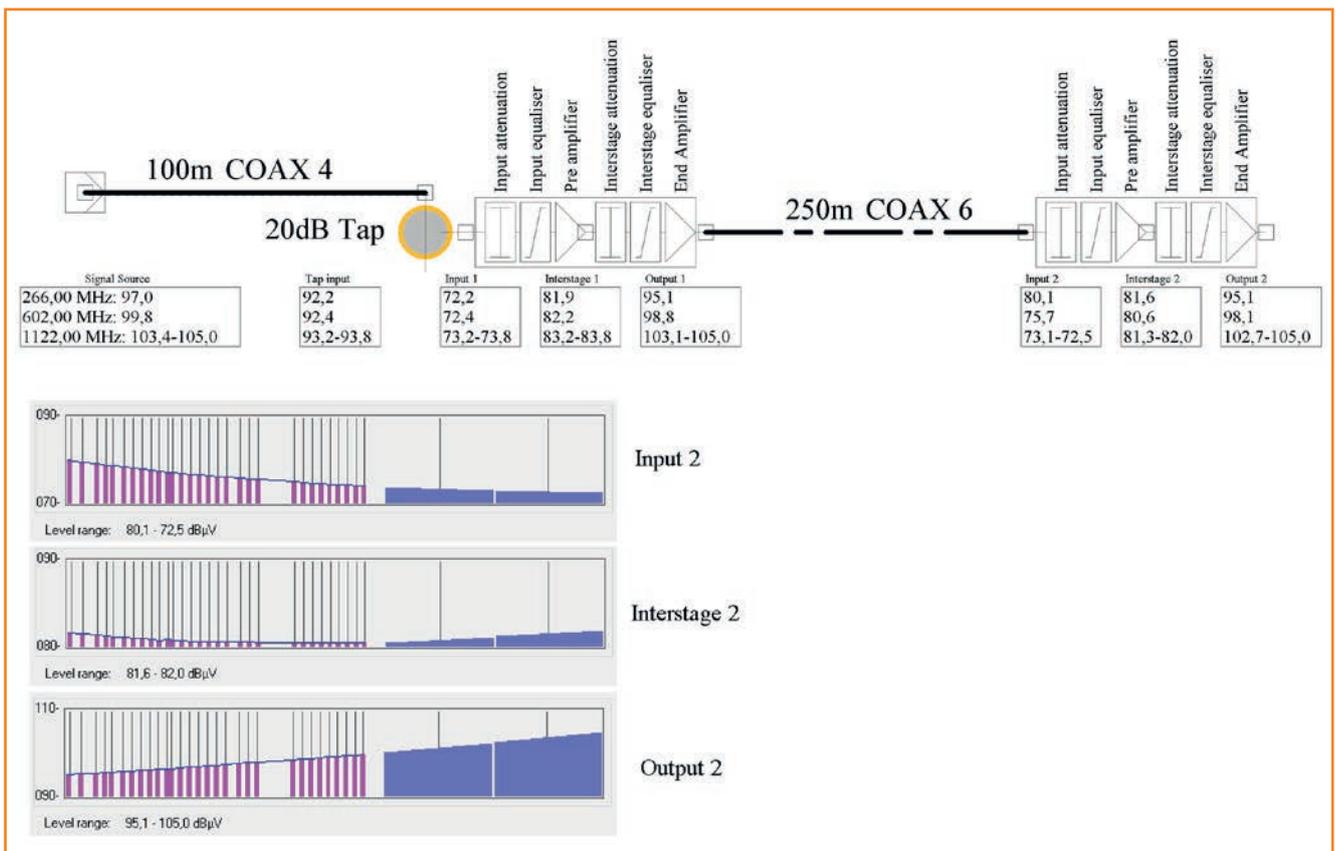


Figure 6: Signal path with amplification and attenuation

Ch...	Program	Frq [M...]	dB $\mu$ V	- [dB]	+ [...]	Tilt[dB]	Type	Ban...	Red.	C/N	Mux	CTB	CSO
		926,00	102,5	0,0	0,0	1,6	OFDM	192,00	0,0		None	57,0	57,5
		1122,00	104,2	0,0	0,0	1,6	OFDM	192,00	0,0		None	57,0	57,5

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

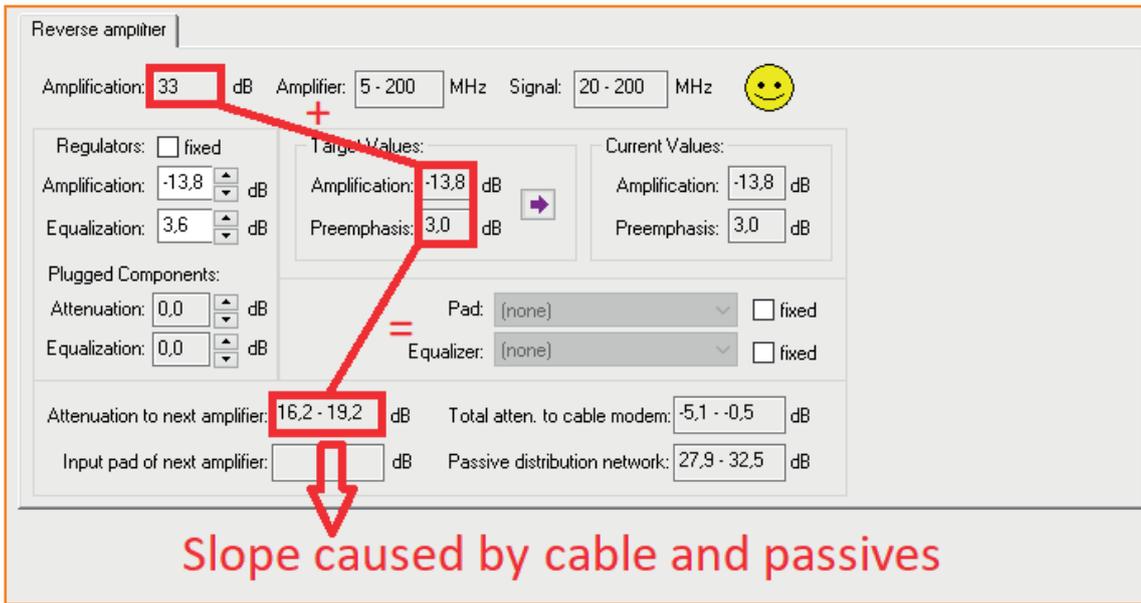


Figure 8: Reverse path amplifier settings

### 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 1MHz 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.

The amplifier can be adjusted 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. Additional limits and checks for amplifier input were introduced for DOCSIS 3.1; these are described below.

### Default level window in library

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

### 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 Network-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 Network-Check function if the calculated input level falls outside the permitted level range.

### 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 Network-Check function.

This is carried out for the following:

- **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 is shown in the case where there are valid values in the library and where the user has overwritten these resulting in possible performance issues.

### Check on max. amplifiers in cascade

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

In the warning settings, the user has the following checkbox: “Check on number of amplifiers in cascade”. A limit for the number of permitted amplifiers can be modified as required. If the function is activated, the Network-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:

$CNR_{out}$ = CNR at output	
$CNR_{in}$ = CNR at input	
$Z = Pin[dB\mu V] - R[dB] - kT\Delta f[dB\mu V]$	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	$\Delta$ = 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.

Calculate and check the distortion at bridgepoints

Warn, if the distortion ratio at a bridge point is out of the following limits:

Terrestrial analog:

CTB (modulated):	60 dB	CTB:	55 dB
CSO (modulated):	62,5 dB	CSO:	57 dB

Terrestrial digital:

C / (max{CSO,CTB}): 32,5 dB

These values can be specified for both digital and analogue channels; digital channel-only networks are also possible.

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

AND allows 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.

### Remote powering

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.

Power Unit Data:

Voltage: 65 V

Maximum Current: 10000 mA

Fix power consumption: 0.0 W

Use a list of values for power consumption

### Testing the cumulative load of an amplifier

#### Motivation

In modern networks, it is often the case that channels are entirely digital. As result, CSO/CTB are no longer relevant. Instead, some manufacturers specify the maximum level at full load. This corresponds to a limitation of the cumulative load i.e. the sum of all signal levels. AND can check the cumulative load of the amplifiers using the Network-Check function.

#### LibEdit

A list of full load maximum levels for different frequency ranges can be entered for the data of an amplifier package.

“ A warning appears if the calculated load exceeds the max. allowed load by more than the tolerance value. ”

FrqMin[MHz]	FrqMax[MHz]	Umax[dBμV]
110	1006	110
200	1218	108
110	862	112

Figure 9: Umax for various frequency ranges (QAM, 8MHz)

The Umax value entered refers to a dense allocation of the entire frequency range using 8MHz QAM channels. LibEdit calculates the maximum value of the cumulative load for each line.

For example, for the second line of the list it looks as follows:

- 126 8MHz QAM channels fit into the frequency range  $(126=(1218-200)/8)$ .
- Max. cumulative load =  $108\text{dB}\mu\text{V} + 10 \cdot \log(126) = 129.0\text{dB}\mu\text{V}$ .

In some data sheets, you will find information such as:

- "Umax (112xQAM channels) @1GHz = 113dBμV".
- 112 channels cover a range of  $112 \cdot 8 = 896\text{MHz}$ .

In practice, it is almost irrelevant whether you enter 104-1000MHz or 110-1006 as the frequency range here. Of greatest importance is that the width of 896MHz is correct.

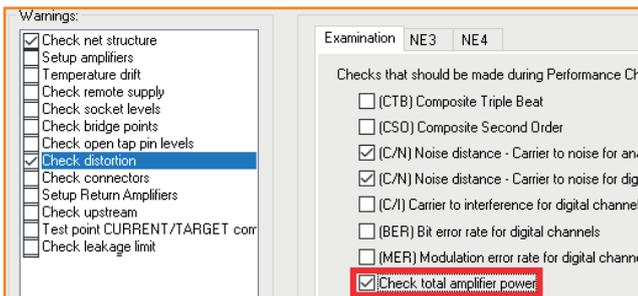


Figure 10: Setting warnings in Network-Check function

### Cumulative load test in AND

The cumulative load test can be switched on and off via the warning settings in the Distortion Products section.

If both "Check distortion products" and "Check amplifier total load" are activated, then the cumulative load for all amplifiers is checked during the Network-Check function.

**Note:** Only amplifiers for which maximum loads have been entered in LibEdit are checked.

### Calculating the cumulative load

For narrow channels, the cumulative load is simply the sum of all signal levels (considering the logarithmic dBμV scale).

For wide channels (e.g. OFDM) the levels refer to the measurement bandwidth from the calculation settings. If the slope is zero, the OFDM level counts x times, where  $x = \text{bandwidth}/\text{measuring bandwidth}$ . If the slope is not equal to zero, the wide channel is divided into narrow strips and the overall level of the channel is determined by integration.

### Comparison of the total load with the maximum allowed

For the frequency range of the signal, a search is made for the most suitable entry in the library list. Its total load is used as the maximum allowed.

A warning appears if the calculated load exceeds the max. allowed load by more than the tolerance value. The "level tolerance" for the amplifier setting is used as the tolerance value.

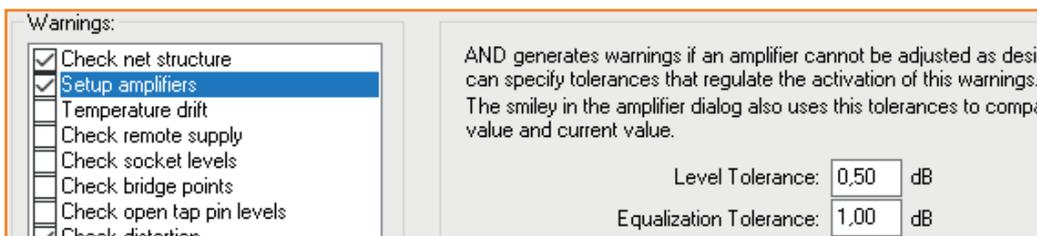


Figure 11: Setting warnings for Network-Check function