DOCSIS® 3.1 Component Tests
Application Note

Products:

- R&S®CLGD
- R&S®SFD
- R&S®FSW

The need for higher data rates and flexibility for IP and Cable TV (CATV) has led to the introduction of DOCSIS®3.1. With channel bandwidths up to 192 MHz and 96 MHz on the downstream and upstream respectively as well as the cable network frequency extension up to 1.2 GHz (1.8 GHz as a future extension) the technical requirements of cable components have increased significantly. This application note describes a test scenario tor testing cable components with an R&S®CLGD Cable Load Generator for DOCSIS 3.1 or R&S®SFD DOCSIS 3.1 Generator and an R&S®FSW Signal & Spectrum Analyzer.

Note:

Please find the most up-to-date document on our homepage
http://www.rohde-schwarz.com/appnote/1MA285.

This document is complemented by software. The software may be updated even if the version of the document remains unchanged

Application Note
O.Gerlach
3.2017 – 3e

ROHDE&SCHWARZ

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1 Introduction

Wideband cable networks were originally designed as a feeder system for terrestrial broadcast receivers and networks. Nowadays these consist of hybrid optical / electrical components and are still partially used as a radio and television distribution network. In addition to this many operators also offer fast internet and telephony on the same networks, so called “triple play”.

With traditional single-carrier signals such as DOCSIS 1.0 to 3.0, EURO-DOCSIS, the transmission quality strongly depends on the frequency and phase response of the transmission chain. This led to the OFDM based standards DVB-C2 and DOCSIS 3.1 which are more immune against frequency and phase distortion.

With spectrum bandwidths up to 192 MHz for downstream and 96 MHz for upstream the technical requirements of cable components have increased significantly.

This application note describes a test scenario tor testing cable components with an R&S®CLGD Cable Load Generator for DOCSIS 3.1 or R&S®SFD DOCSIS 3.1 Generator and an R&S®FSW Signal & Spectrum Analyzer with FSW-K192 DOCSIS 3.1 downstream analysis option. Since DOCSIS 3.1 components must also be backward compatible to preceding standards this application note also contains the tests scenarios for determining Composite Second Order (CSO) / Composite Triple Beat (CTB), Carrier to Noise (C/N), Amplitude Modulation – Intermodulation (AM-XMod), Noise Power Ratio (NPR) and Bit Error Rate (BER) with the same test equipment.

- The R&S®CLGD Cable Load Generator for DOCSIS 3.1 is referred to as CLGD.
- The R&S®SFD DOCSIS 3.1 Generator is referred to as SFD.
- The R&S®FSWxx Spectrum Analyzer is referred to as FSW.
- The R&S®RAM is referred to as RAM.
- R&S® means Rohde & Schwarz GmbH und Co KG
- DOCSIS® is a registered trademark of **Cable**Labs®

2 CATV Network Components

A CATV network consists of numerous sections with different components:

- Network section 3: Fiber, 75 Ohm coax technology using CATV amplifiers
- Network section 4: distribution network inside the homes
- Network section 5: connection between access point and end user equipment

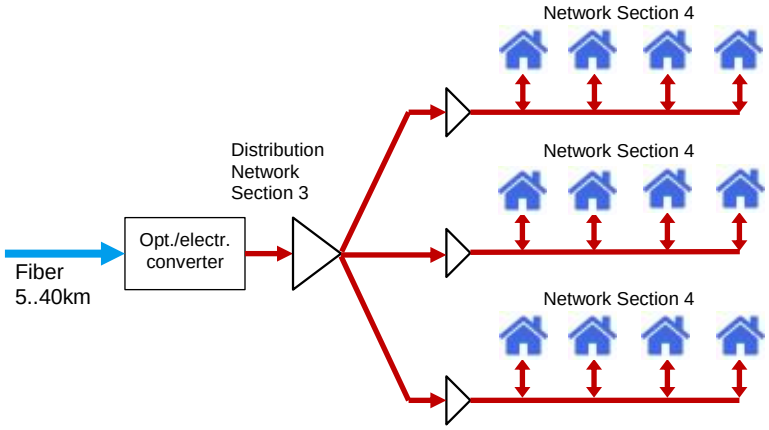


Fig. 2-1: CATV network sections 3 and 4

The network section 3 contains **A-LINE** and **B-LINE** amplifiers that supply city districts, **C-LINE** amplifiers that supply streets and **D-LINE** (drop cable) amplifiers that supply houses.

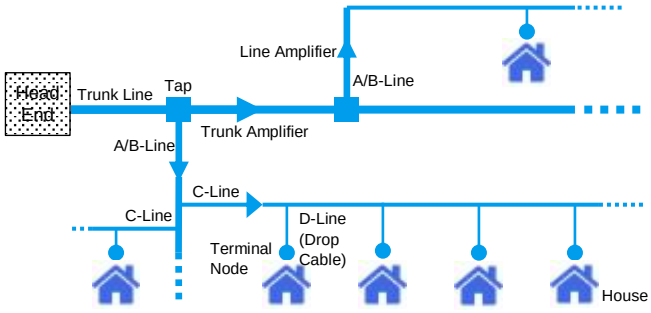


Fig. 2-2: CATV Architecture

Furthermore CATV network also consists of filters, splitters, taps and cables which all contribute to the power spectrum, signal-to-noise-ratio (SNR) and distortion, ultimately affecting the signal quality and maximum data throughput.

3 DOCSIS 3.1 and CATV Specifications

The **DOCSIS 3.1** measurements in the following sections are based on the DOCSIS 3.1 Pocket Guide, Physical Link Layer by CableLabs. The most common tests are implemented in the FSW-K192 option.

- **MAGNITUDE CAPTURE** (see 3.1.1) - Magnitude vs. time
- **POWER SPECTRUM** (see 3.1.2) - Power density (power/Hz) vs. frequency
- **RESULT SUMMARY** (see 3.1.3) - Numerical results for the main DOCSIS 3.1 parameters
- **CONSTELLATION** (see 3.1.4) - In-phase / quadrature phase results for the currently selected frame.
- **MER VS SYMBOL X CARRIER** (see 3.1.5) - Modulation error ratio per carrier and symbol for the currently selected frame.

The **CATV** measurements described in the following chapters (CSO/CTB, AM-XMod etc.) are based on SCTE standards which can be downloaded from the SCTE website.

- **CSO/CTB** (Composite Second Order / Composite Third Beat, see 5.3) – The sum of all products that happen to fall at the same nominal frequency in a multi-tone system.
- **CNR** (Carrier to Noise Ratio, see 5.4) – Measures the ratio of carrier to thermal noise and “noise-like” interference for broadband telecommunications system components.
- **AM-XMOD** (Amplitude Modulation Cross Modulation, see 5.5) – Cross modulation is the transfer of modulation from one signal, typically a much stronger one, to another signal, typically a weaker one, due to non-linearity in the receiver chain.
- **NPR** (Noise Power Ratio, see 5.6) – The NPR measurement technique can characterize the linearity of a wide band amplifier over a custom frequency range.
- **BER DS** (Bit Error Rate Downstream, see 5.7) – This test measures BER of downstream (forward path) broadband telecommunications QAM signals.

4 Measurement Setup

4.1 CLGD and FSW

The controller PC and CLGD can be directly connected with a LAN cable or via LAN switch. The FSW can optionally be connected to the LAN switch in case of remote use. The LAN switch can be connected to a DHCP server e.g. company network which allows the use of IP address independent symbolic instrument names, e.g. RSCLGD-123456 or FSW26-123456.

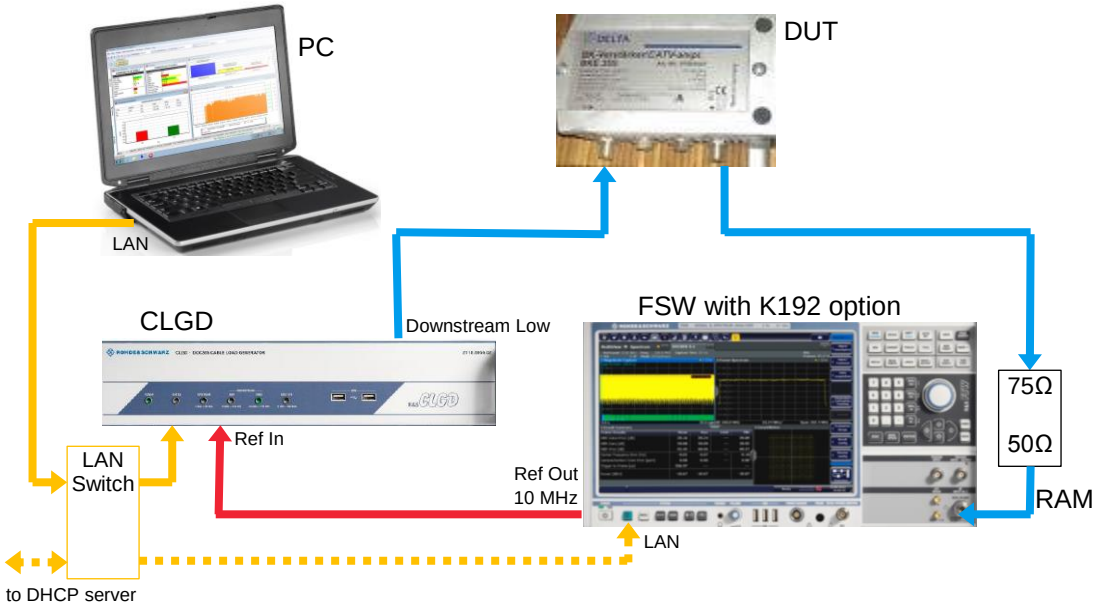
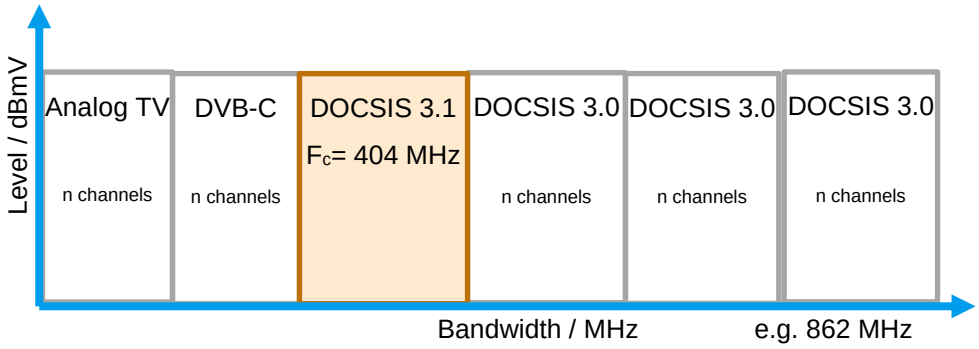


Fig. 4-1: Component test setup with CLGD and FSW

Under real conditions the bulk of the DUT (line amplifier, etc.) bandwidth is used by various signals. In order to simulate real world conditions it is necessary to feed additional DOCSIS 3.1, DOCSIS 3.0, DVB-C and analog TV signals to the DUT.



The CLGD and FSW with K192 option is an all-in-one solution for generating and analyzing all types of CATV signals (FSW-K70 option must be used in case of measuring DOCSIS 3.0 or single-carrier signals) used in this application note.

In Mixed Mode the CLGD can generate up to 3 DOCSIS 3.1 channels (4 with extended frequency license), DOCSIS 3.0 or ARB signals. The DOCSIS 3.x signals can contain a real data stream fed into LAN input or simulate it. In this example it is convenient to generate 3 adjacent DOCSIS 3.1 channels at 204 MHz, 404 MHz and 604 MHz and fill up the unused bandwidth with DOCSIS 3.0 and DVB-C channels.

4.2 SFD and FSW

The controller PC and the SFD can be directly connected with a LAN cable or via LAN switch. The FSW can optionally be connected to the LAN switch in case of remote use. The LAN switch can be connected to a DHCP server e.g. company network which allows the use of IP address independent symbolic instrument names, e.g. RSSFD-123456 or FSW26-123456.

The combination of an SFD with an FSW with K192 option is an alternative for expanding existing CATV measurement systems with DOCSIS 3.1. The SFD can generate one DOCSIS 3.1, DOCSIS 3.0 or DVB-C signal at a time and must be added to an existing measurement system via external combiner (Fig. 4-2).

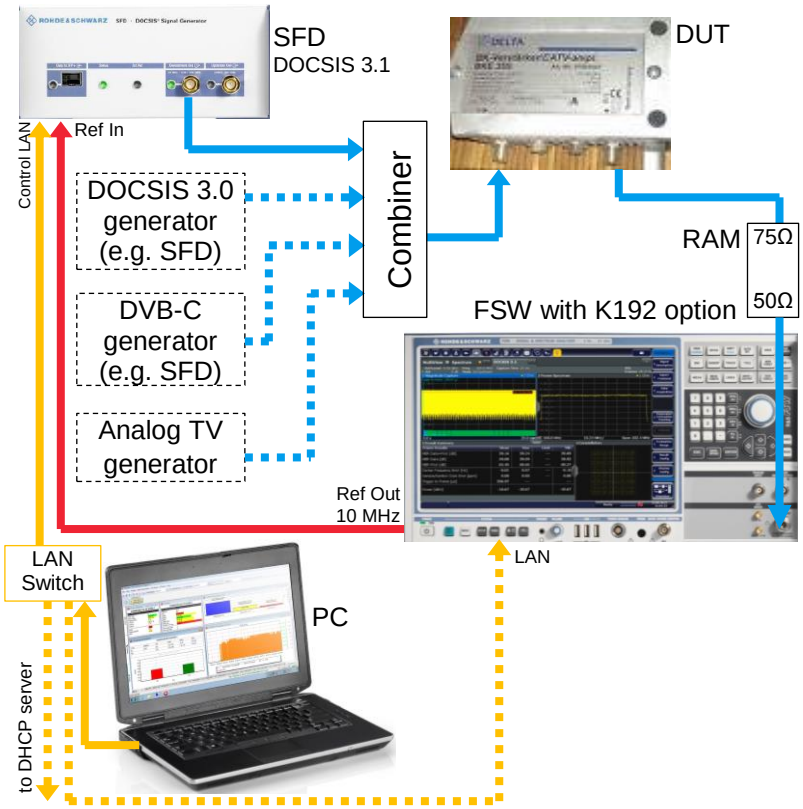


Fig. 4-2: Component test with SFD and FSW

When using an external combiner the resulting output level + DUT gain (e.g. 41 dB) should not exceed the specified DUT maximum output level (e.g. 126 dBµV = 66 dBmV).

The unit for levels used in **Europe** is usually **dBµV** which can be also chosen in the CLGD and SFD menu. The **remote commands** of these instruments only support **dBmV**. In order to have similar results with manual and remote measurements it is convenient to use dBmV which is the default unit used by SFD and CLGD.

4.2.1 Compensating R&S®RAM Matching Pad

The RAM Matching Pad is specified with e.g. 7.5 dB attenuation in the 75 Ω to 50 Ω direction. Compensate the attenuation on the FSW by pressing **AMPT** → **AMPLITUDE CONFIG** → **OFFSET** = **7.5 dB**.

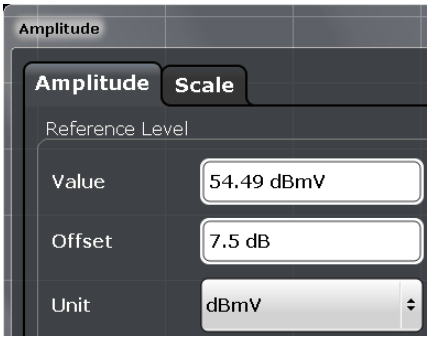


Fig. 4-3: Compensate matching pad on FSW

4.2.2 Network Configuration of CLGD, SFD and FSW

If all devices are to be connected to a specified network, it is necessary to use **DHCP** in order to obtain an IP address from the name server.

With CLGD or SFD perform following steps:

- Disconnect your PC from the company network.
- Set the PC to a fixed LAN address, e.g. **192.168.10.20**.

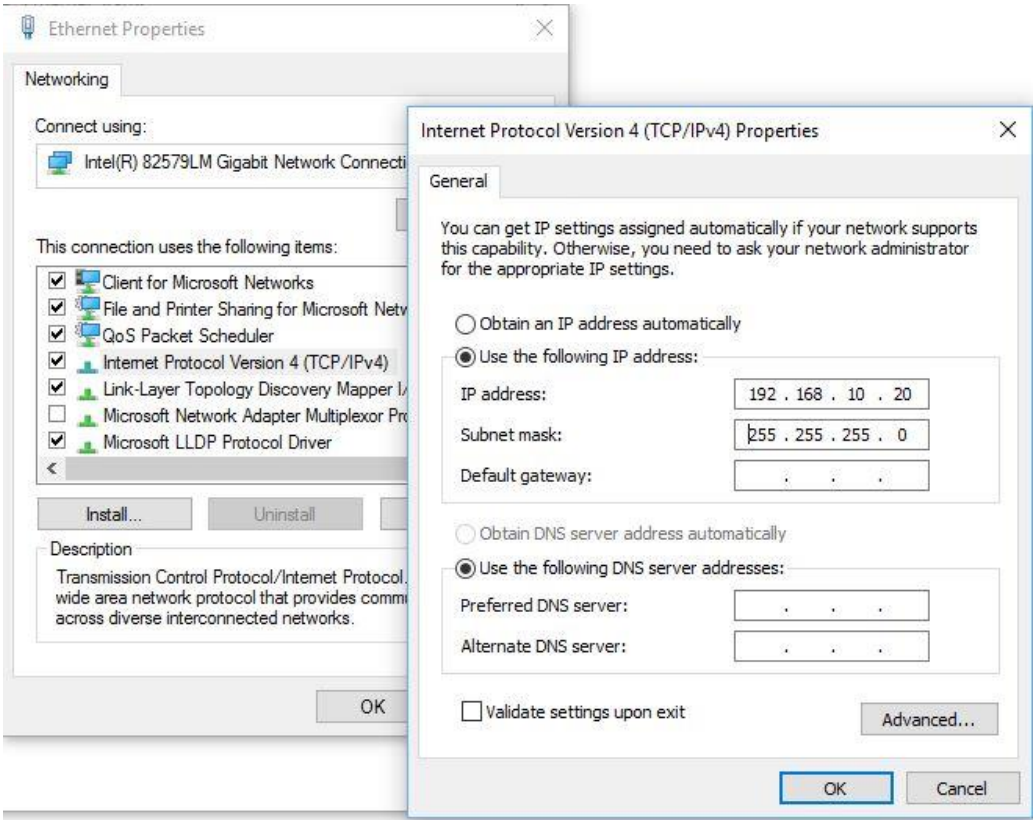


Fig. 4-4: Set PC to fixed IP address

- Open the browser on the PC and type in the CLGD or SFD default IP address **192.168.10.1**. The CLGD or SFD web interface appears.
- Select **NETWORK** → **NETWORK TYPE** = **DHCP** and press **APPLY**.

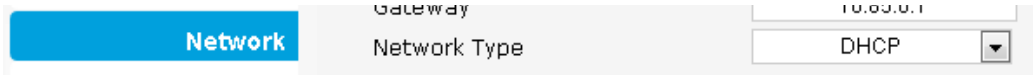


Fig. 4-5: Select Network Type DHCP

- Close the browser, set your PC to **DHCP** (**OBTAIN AN IP ADDRESS AUTOMATICALLY**) again and reconnect it with the company network.
- Open your browser and type in the default name of the device "**http://<Devtype>-<Serial number>.local**", e.g. http://rsclgd-101682.local/ or http://rssfd-101431.local/ to open the CLGD or SFD web interface.

The FSW is set to DHCP by default. You can either open the web interface by typing e.g. http://FSW26-101794.local/ or using the significantly faster **WINDOWS REMOTE DESKTOP**.

In order to control the CLGD or SFD press **TAKE CONTROL** first.

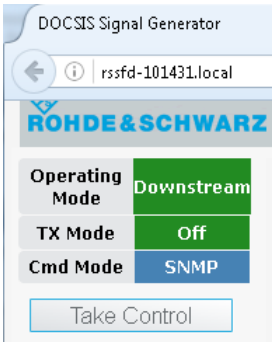


Fig. 4-6: Press Take Control

5 Measurements

Some measurement require additional configuration or data files to be uploaded to the CLGD, SFD or FSW. After downloading **1MA285_FORUM_SCRIPTS.ZIP** from http://www.rohde-schwarz.com/appnote/1MA285.html and unzipping it, these files can be found in **<USER DIRECTORY>/1MA285 – FORUM SCRIPTS/REQUIRED FILES**.

5.1 Measuring DUT Output Power (CLGD / SFD)

5.1.1 Generating DOCSIS 3.1 Signals with CLGD

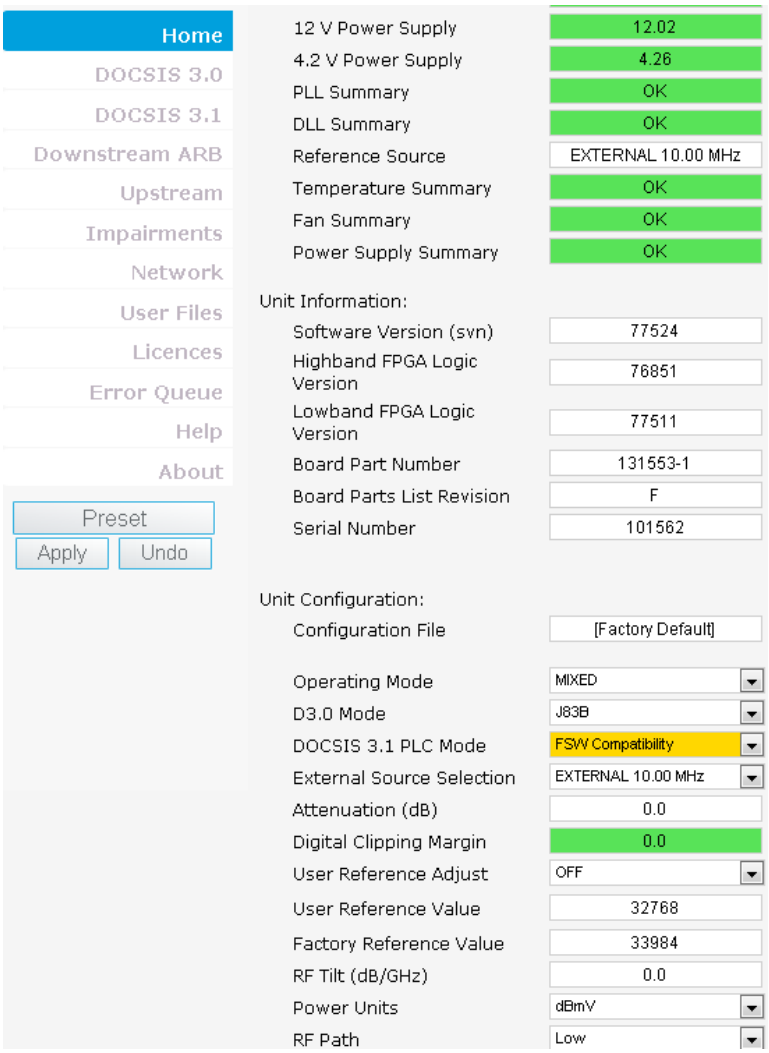


Fig. 5-1: CLGD Home configuration

The yellow colored control values differ from default. They change to white after pressing **APPLY**.

Select DOCSIS 3.1 menu.

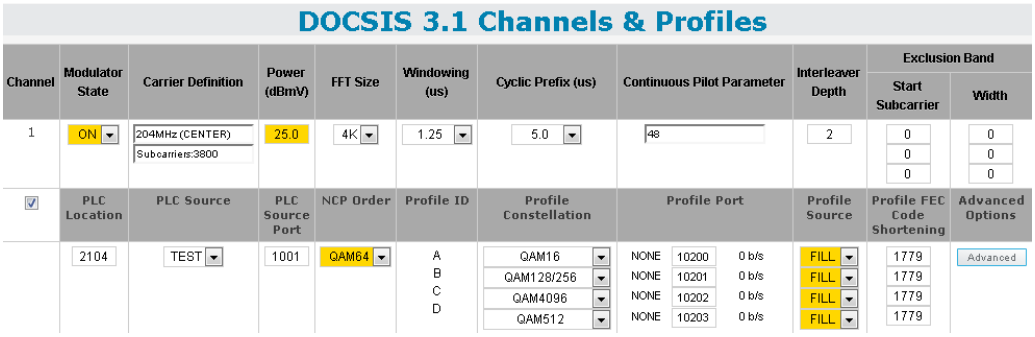


Fig. 5-2: CLGD Downstream configuration

In the **DOWNSTREAM** menu set the **CARRIER DEFINITION** (e.g. Channel = 204 MHz Center), the **NCP ORDER** (e.g. QAM64), the **PROFILE CONSTELLATION** for each **PROFILE ID** and each **PROFILE SOURCE** to **FILL**. Do the same for Channel 2 = 404 MHz and Channel 3 = 604 MHz

After setting up the **POWER** (25 dBmV + 41 dB (DUT gain) = 66 dBmV = 126 dBµV) turn **MODULATOR STATE** = **ON** and press **APPLY**.

5.1.2 Generating DOCSIS 3.1 Signal with SFD

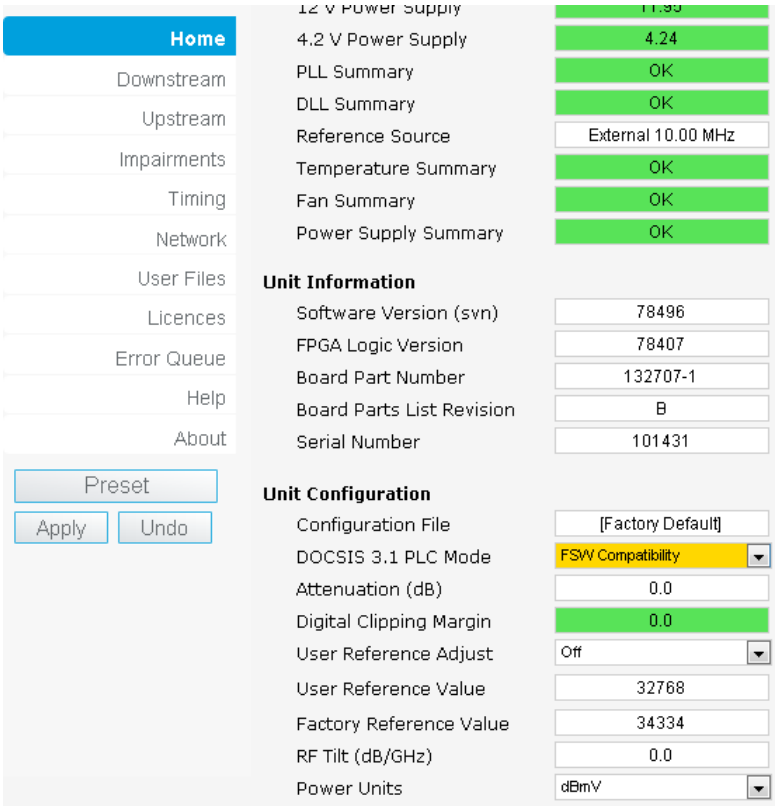


Fig. 5-3: SFD Home configuration

Select the menu item **DOWNSTREAM**.

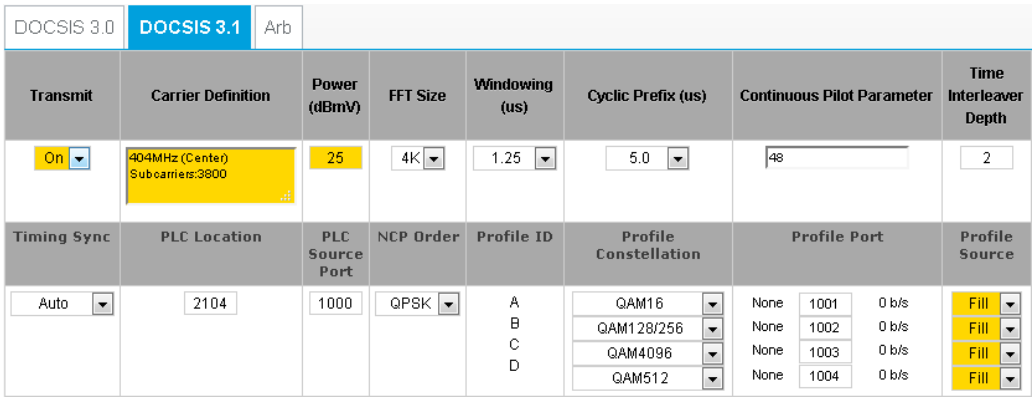


Fig. 5-4: SFD Downstream configuration

In the **DOWNSTREAM** menu set the **CARRIER DEFINITION** (e.g. 404 MHz Center), the **NCP ORDER** (e.g. QAM64), the **PROFILE CONSTELLATION** for each **PROFILE ID** and each **PROFILE SOURCE** to **FILL**.

After setting up the **POWER** (25 dBmV + 41 dB (DUT gain) = 66 dBmV = 126 dBµV) turn **TRANSMIT** = **ON**. Then press **APPLY** to activate the changes.

5.1.3 FSW Configuration and Measurement

For determining the DUT output power over the full bandwidth use the **CHANNEL POWER ACLR** function of the FSW.

- Switch to **SPECTRUM** mode.
- Set Start and Stop Frequency according to the required regional network lower band limit. Typical band limits are 48 MHz, 85 MHz and 105 MHz. 204 MHz is used for extended DS frequency up to 1.8 GHz. In this example we will stick to the DUT limits, fstart= 4 MHz, fstop = 864 MHz.
- Set **AMPLITUDE** → **UNIT** to dBmV.
- Select **MEASUREMENT** → **CHANNEL POWER ACLR**.

Fig. 5-5: Select Channel Power ACLR measurement

- In **CHANNEL SETTINGS** set **CHANNEL COUNT** Tx = 1 and Adj = 0.

- The Tx 1 channel occupies the full DUT bandwidth (e.g. 860 MHz).

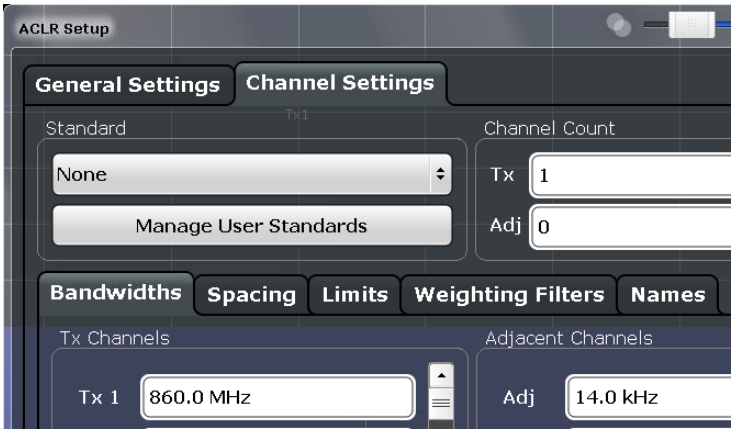


Fig. 5-6: ACLR Setup

Tx1(Ref) displays the DUT output power which should not exceed e.g. 66 dBmV = 126 dBµV. In this example the cables leading to and from the DUT have not been compensated which result in the measured power being lower than the expected 66 dBmV.

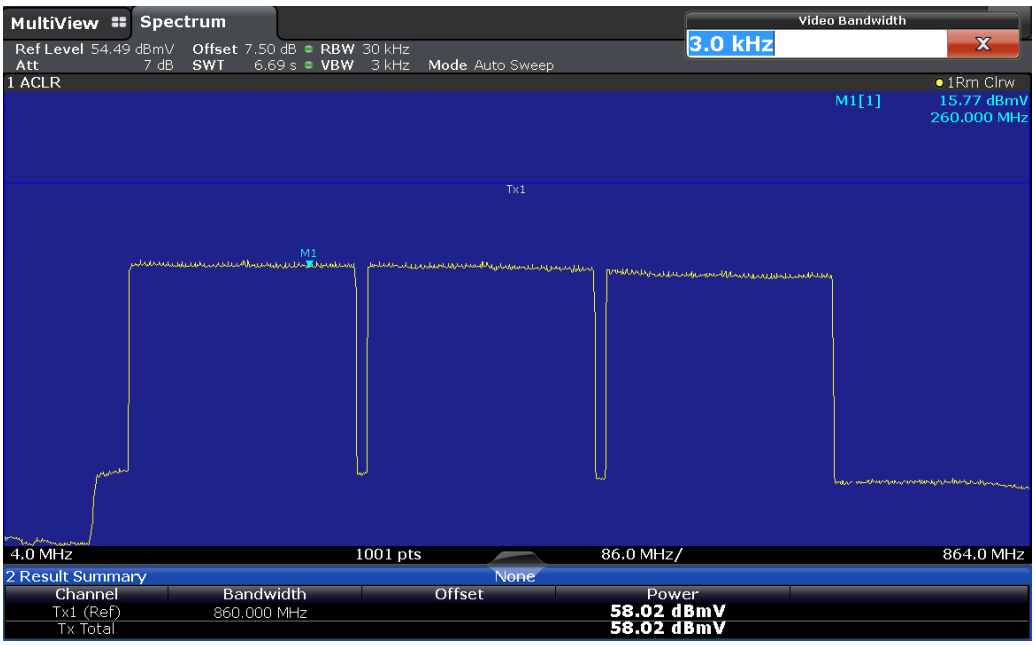


Fig. 5-7: Spectrum view of DUT bandwidth

5.2 DOCSIS 3.1 Measurements with FSW-K192 Option (CLGD / SFD)

- For first time use it is recommended to preset the FSW.
- Press the **MODE** button and select **DOCSIS 3.1**.

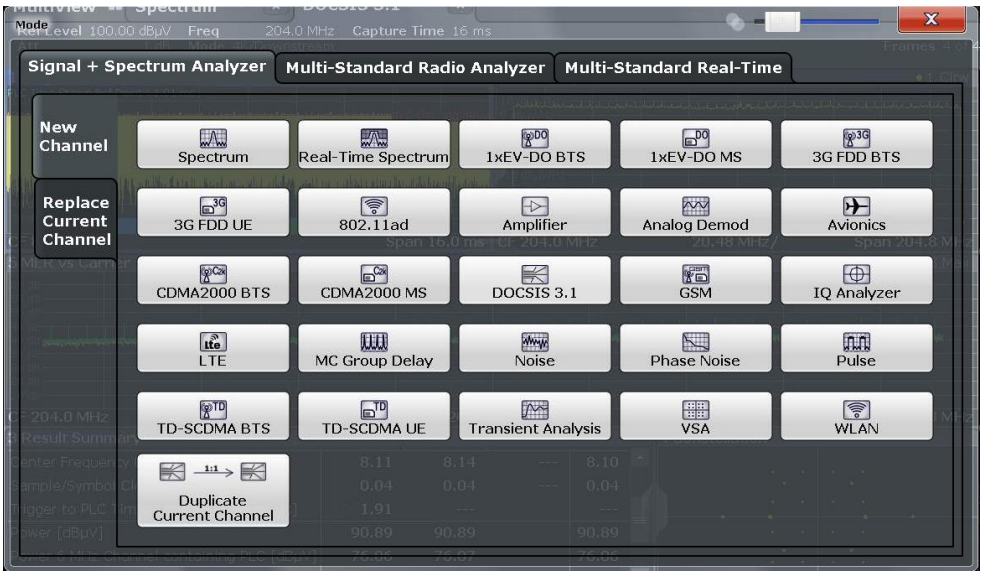


Fig. 5-8: FSW modes

- If **PRESET** had been performed shortly before, the DOCSIS 3.1 panel will appear with 4 measurement windows, **MAGNITUDE CAPTURE**, **POWER SPECTRUM**, **RESULT SUMMARY** and Constellation. Add **MER VS. SYMB X CARRIER**.

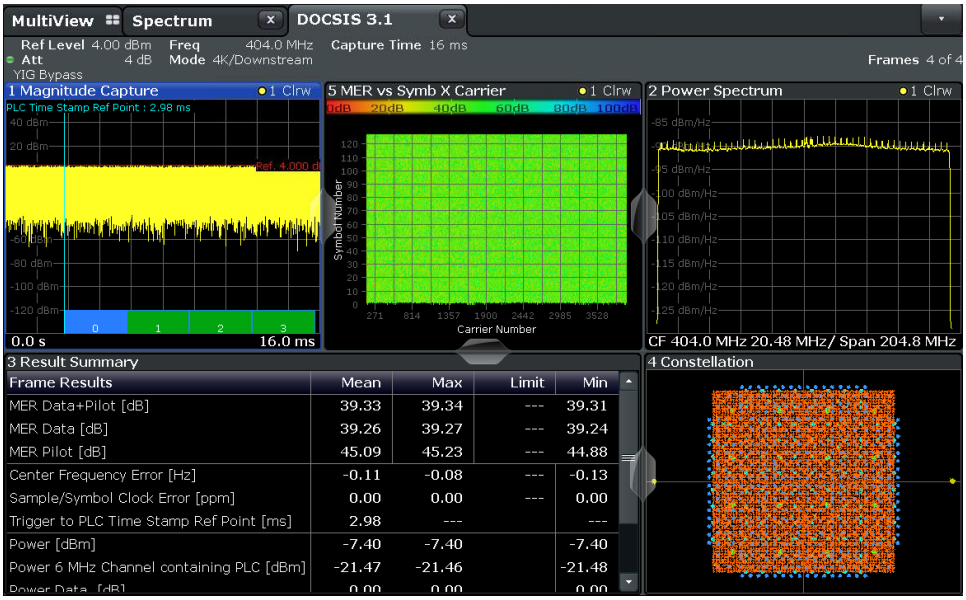


Fig. 5-9: Selected DOCSIS 3.1 measurements

- Set the **FREQUENCY** to the generator's center frequency, e.g. 404 MHz.
- The quality of the measurement results depends on perfectly set input gain. Press **AUTO SET** → **AUTO LEVEL**, then **AUTO SET FROM PLC & RUN** to optimize the input gain.

Fig. 5-10: Auto Level soft button

5.2.1 Magnitude Capture

The Magnitude Capture display shows the magnitude vs time data captured in the last measurement. Green bars at the bottom of the Magnitude Capture display indicate the individual detected frames with their frame number. The blue bar indicates the currently Selected Frame which is evaluated for graphical result displays. Increasing MER Frame Results and a more clearly defined Constellation indicate better signal quality.

5.2.2 Power Spectrum

This result display shows the power density (power/Hz) vs frequency values obtained using an FFT. The evaluation is performed over the complete data in the current capture buffer, without any correction or compensation. The power unit depends on the Unit setting.

5.2.3 Result Summary

The result summary provides the numerical results for the main DOCSIS 3.1 parameters summarized over a specified number of frames or for a single frame. This is the currently Selected Frame as indicated in the "Magnitude Capture" display. If more than one frame is evaluated (if analyzing a single frame is disabled), a statistical evaluation of the specified "Frame Statistic Count / Number of Frames to Analyze" or for all detected frames in the capture buffer is also performed. In this case, the minimum, maximum and mean values are displayed, as well as the defined limit, if available.

5.2.4 Constellation

This result display shows the in-phase and quadrature phase results for the currently Selected Frame as indicated in the "Magnitude Capture" display. The Tracking/Channel Estimation according to the user settings is applied. The inphase results (I) are displayed on the x-axis, the quadrature phase (Q) results on the y-axis.

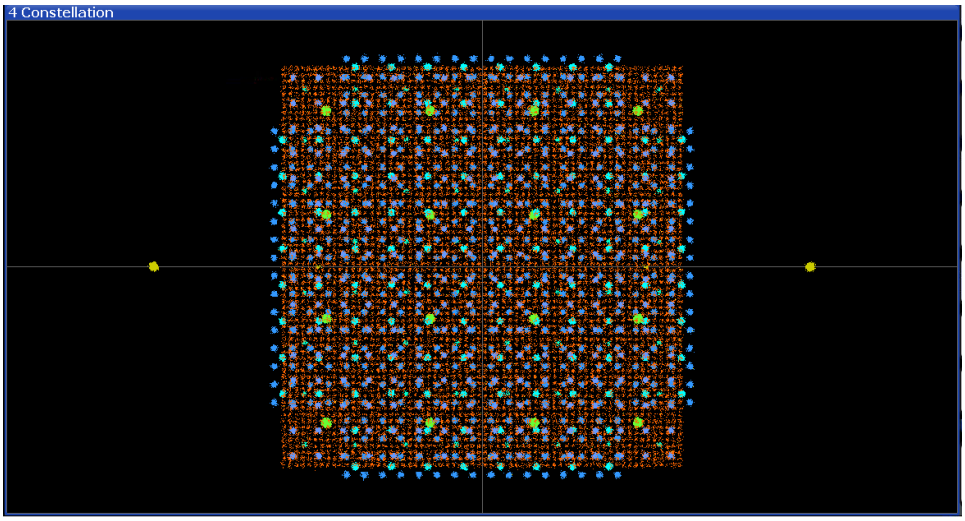


Fig. 5-11: Full sized Constellation view with NCP, PLC, 4 active profiles and pilot

5.2.5 MER vs Symbol X Carrier

Displays the modulation error ratio per carrier and symbol for the currently selected frame as indicated in the "Magnitude Capture" display. The carriers are displayed on the x-axis and the symbols on the y-axis. The MER is color-coded according to its level and is indicated as a colored dot for each symbol and carrier. The legend for the color coding is provided by a color bar at the top of the diagram.

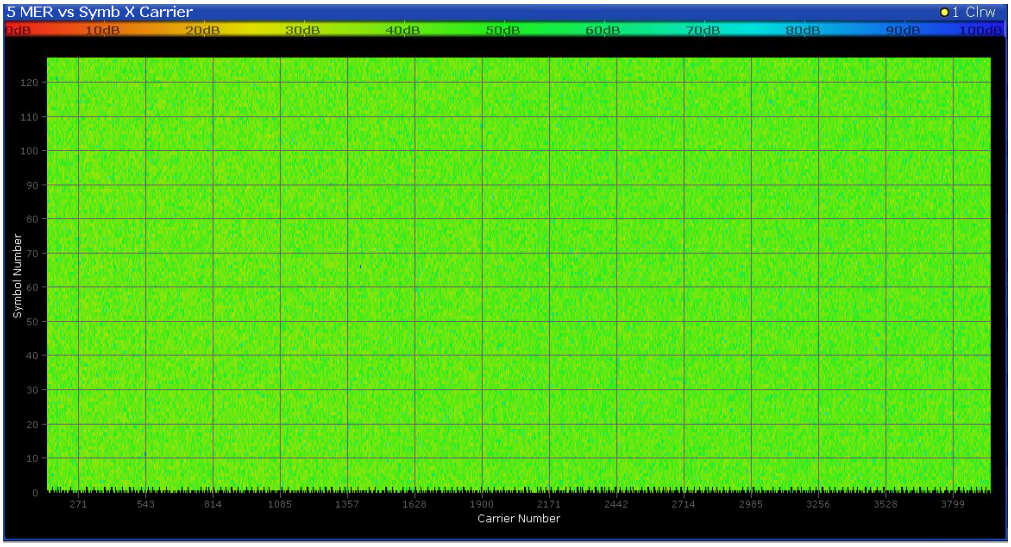


Fig. 5-12: MER vs. Symb X Carrier

5.3 CSO / CTB Measurements (CLGD)

COMPOSITE SECOND ORDER (CSO):

DISCRETE SECOND ORDER (DSO) is an individual, second order intermodulation product, produced when one or two carriers pass through a non-linear component. The sum of all DSO products that happen to fall at the same nominal frequency in a multi-tone system. CSO is defined as the difference, in dB, between the RMS voltage of the carrier measured at its peak and the RMS voltage of this sum. This procedure describes a technique for measuring this difference using a spectrum analyzer (SA) in the LOG mode. For consistency with existing measurements and specifications, the results of measurements made using any other technique must be correlated with the results from this technique.

COMPOSITE TRIPLE BEAT (CTB):

DISCRETE THIRD ORDER (DTO) is an individual, third order intermodulation product, produced when one, two or three carriers pass through a non-linear component. The sum of all DTO products in a multi-tone system that happen to fall at the same nominal frequency in a multi-tone system. CTB is defined as the difference, in dB, between the RMS voltage of the carrier measured at its peak and the RMS voltage of this sum. As with CSO, this procedure describes a technique for measuring this difference using a SA in the LOG mode. For consistency with existing measurements and specifications, the results of measurements made using any other technique must be correlated with the results from this technique.

This measurement requires multiple DOCSIS 3.0 channels which is a feature of the CLGD. Use the test setup as shown in Fig. 4-1.

On the CLGD load the configuration file **CSO_CTB_80CW_PORT_LOW_ON.CFG**. This defines the frequency plan of 80 CW channels, sets Modulator State of Channel 1 to 80 ON and Power = 0 dBmV. It is convenient to use its **DOWNSTREAM LOW** output because it requires no setup change for all further measurements. Set all channels to Power = 30 dBmV (A-Line amplifier) or 25 dBmV (C-Line amplifier).

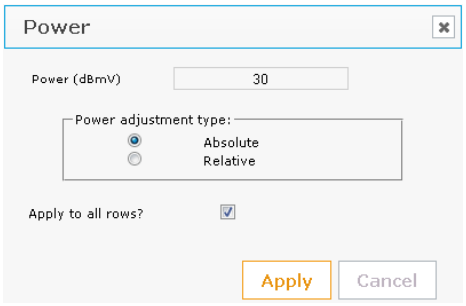


Fig. 5-13: Set level of marked channels

Channels | Blocks

Channel	Block	Modulator State	Source	Data Rate	Center Frequency (MHz)	Power (dBmV)
1	1	ON	CW	0 b/s	55.25	25.00
2	1	ON	CW	0 b/s	61.254168	25.00
3	1	ON	CW	0 b/s	67.246588	25.00
4	1	ON	CW	0 b/s	73.252731	25.00
5	1	ON	CW	0 b/s	79.247873	25.00
6	1	ON	CW	0 b/s	85.251597	25.00
7	1	ON	CW	0 b/s	91.248856	25.00
8	1	ON	CW	0 b/s	97.250765	25.00

Fig. 5-14: DOCSIS 3.0 channel definition

Press Apply to upload the settings to the CLGD.

The **ANSI/SCTE 06** standard for Composite Distortion Measurements (CSO & CTB) defines the analyzer settings as follows:

Center Frequency	Carrier Frequency under test
Span	3 MHz
Detector	Peak
RBW	30 kHz
VBW	30 Hz
Attenuation	≥ 10 dB
Vertical Scale	10 dB/div

5.3.1 CSO

The CSO measurement must be made for each of the major distortion products at each measured frequency. Every possible combination of two frequencies result in 4 CSO distortion products surrounding the carrier f that need to be measured, **f – 1.25 MHz**, **f – 0.75 MHz**, **f + 0.75 MHz** and **f + 1.25 MHz**. In some cases a distortion product may overlap the carrier which makes it necessary to turn it OFF.

This example focuses on **CHANNEL 37** = **271.25362 MHz**.

5.3.1.1 C-Line Amplifier

In the first example a C-Line amplifier is used.

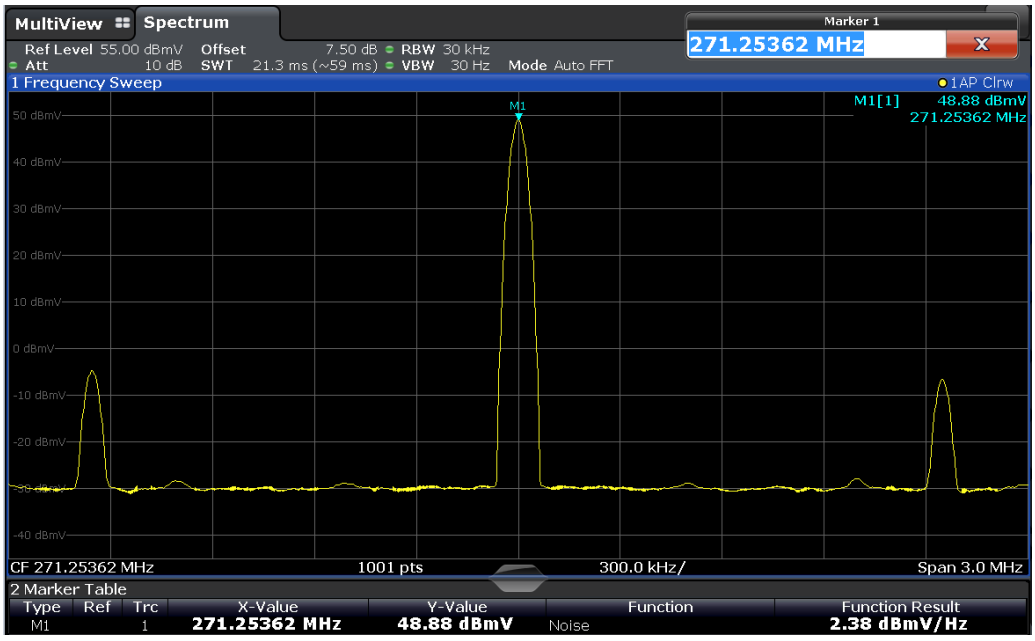


Fig. 5-15: Set center frequency = Channel 37 (C-Line Amplifier)

Carrier Level = **48.88 dBmV**

- Turn Channel 37 OFF.

Fig. 5-16: Channel 37 OFF

The alleged carrier drops > 49 dB, indicating that there is also a distortion product.

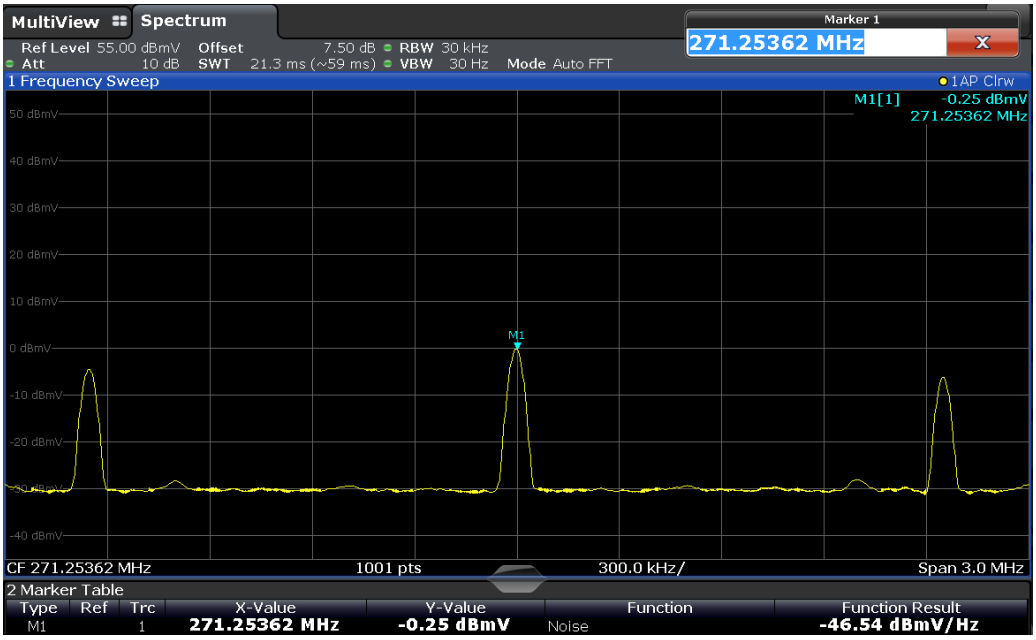


Fig. 5-17: Channel 37 OFF (C-Line Amplifier)

- Define Marker 1 to 4 and read out level:

  f_{M1} = 271.25362 MHz – 1.25 MHz = **270.00092 MHz**, Y_{M1} = **-4.58 dBmV**

  f_{M2} = 271.25362 MHz – 0.75 MHz = **270.50362 MHz**, Y_{M2} = **-29.64 dBmV**

  f_{M3} = 271.25362 MHz + 0.75 MHz = **272.00362 MHz**, Y_{M3} = **-29.92 dBmV**

  f_{M4} = 271.25362 MHz + 1.25 MHz = **272.50042 MHz**, Y_{M4} = **-6.35 dBmV**

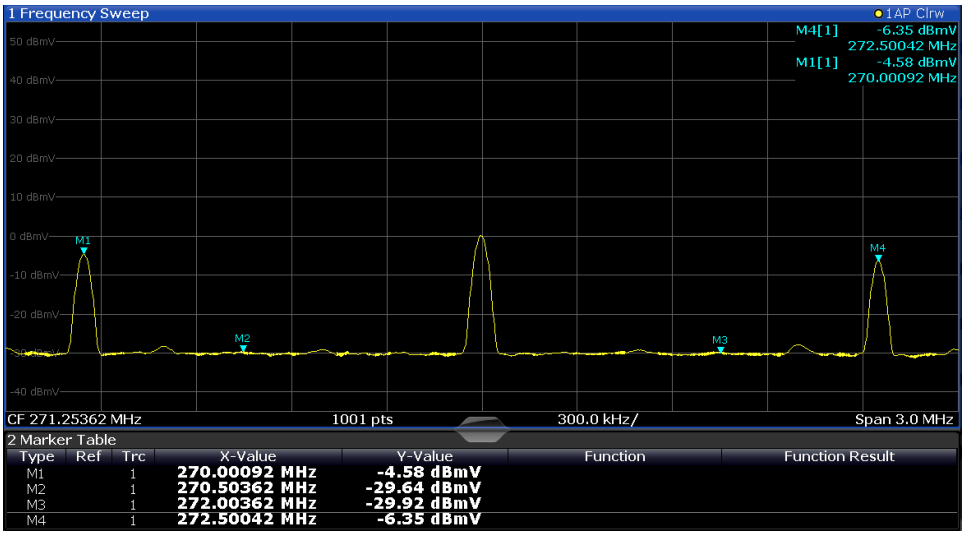


Fig. 5-18: Markers at fc ± 1.25 MHz and fc ± 0.75 MHz (C-Line Amplifier)

- Measure noise floor level.

  Load the configuration file **CSO_CTB_80CW_PORT_LOW_OFF.CFG** in the CLGD to turn OFF all channels.

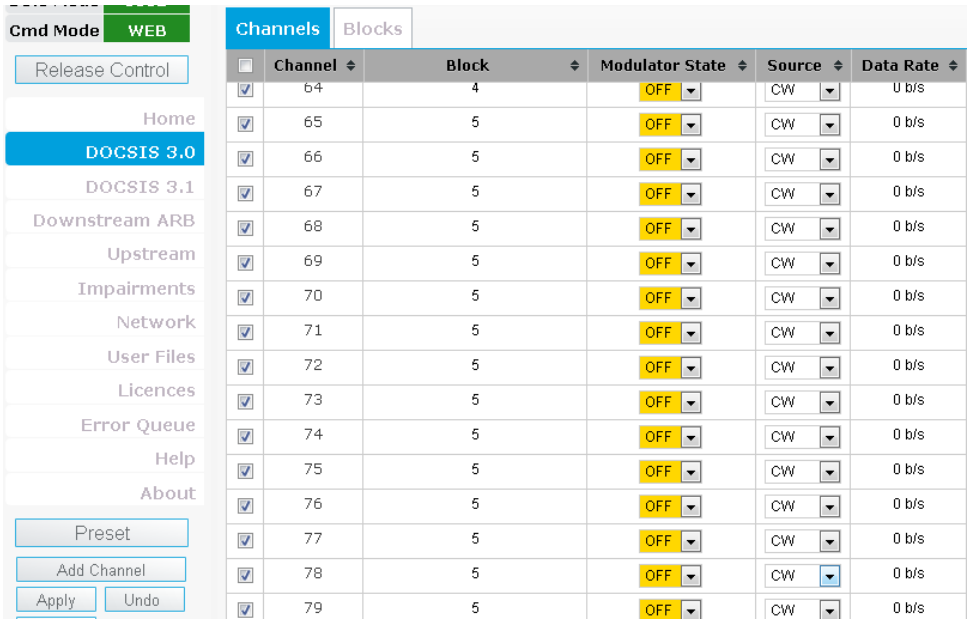


Fig. 5-19: Set Modulator State of checked channels

Use the ACLR function to measure the noise floor level. Set Channel Count Tx = 1 and Tx1 Bandwidth = 3.MHz.

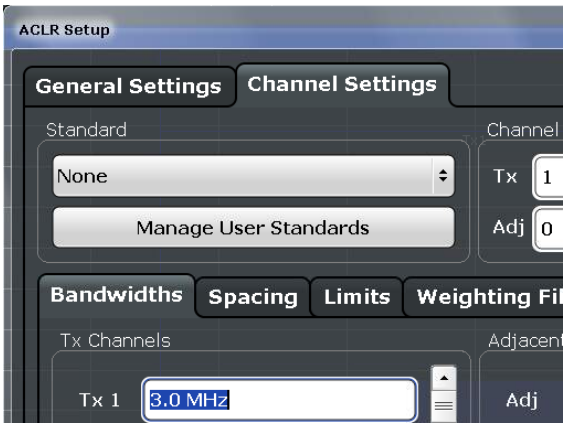


Fig. 5-20: ACLR Setup

The Noise Floor Level = Tx1 (Ref) = **-22.00 dBmV**

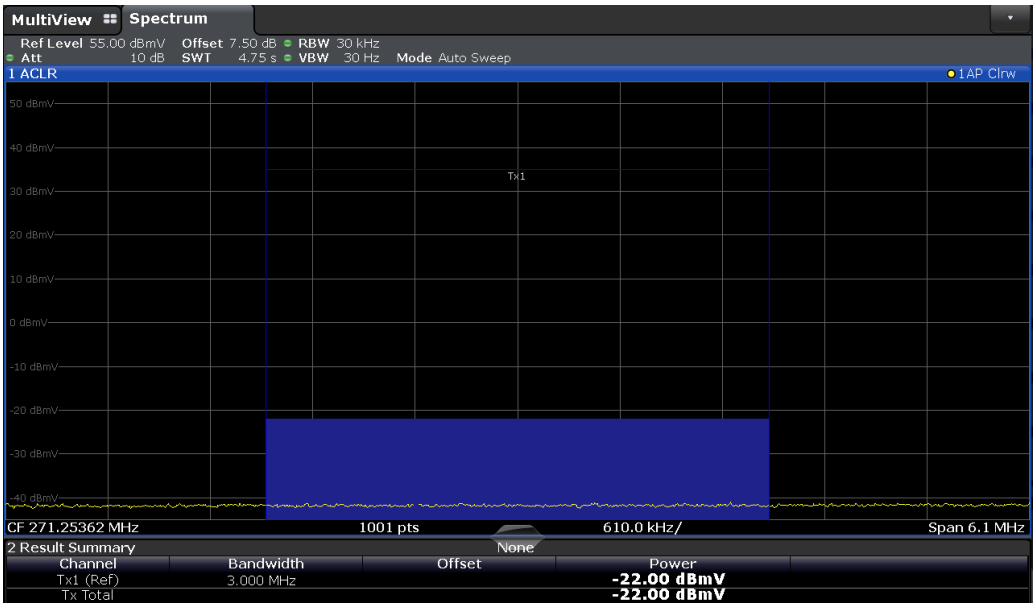


Fig. 5-21: Noise Floor Level (C-Line Amplifier)

- Compute Noise Floor Delta:

  $$Noise\ Floor\ Delta = CSO\ Level - Noise\ Floor\ Level$$

  The CSO Level can be determined by adding the de-logarithmized marker levels and logarithmizing the sum.

  $$M = 20 * \log(\frac{U}{1mV})$$

  $$U = 10^{\frac{M}{20}} * 1mV$$

  $U1_C$ = 0.59 mV, $U2_C$ = 0.033 mV, $U3_C$ = 0.032 mV, $U4_C$ = 0.481 mV

  $\sum U_C$ = 1.136 mV

  CSO Level = $\sum$M = **1.108 dBmV**

  $$Noise\ Floor\ Delta = 1.108\ dBmV + 22.000\ dBmV = \mathbf{23.108\ dB}$$

- If Noise Floor Delta < 2 dB add post-amplifier to system and repeat measurement.
- If Noise Floor Delta ≥ 2dB calculate following Noise Floor Correction factor

  $$Noise\ Floor\ Correction\ Factor = 10 * \left|\log\left(1 - 10^{-\left(\frac{Noise\ Floor\ Delta}{10}\right)}\right)\right| = \mathbf{0.0218\ dB}$$

- Compute Corrected CSO for each product:

  $$Corrected\ CSO = Carrier\ Level - CSO\ Level + Noise\ Floor\ Correction\ Factor$$
  $$= 48.88\ dBmV - 1.108\ dBmV + 0.0218\ dB = \mathbf{47.7938\ dBc}$$

5.3.1.2 A-Line Amplifier

The following measurement was performed with an **A-LINE** amplifier.

- Measure Carrier Level = **45.40 dBmV**

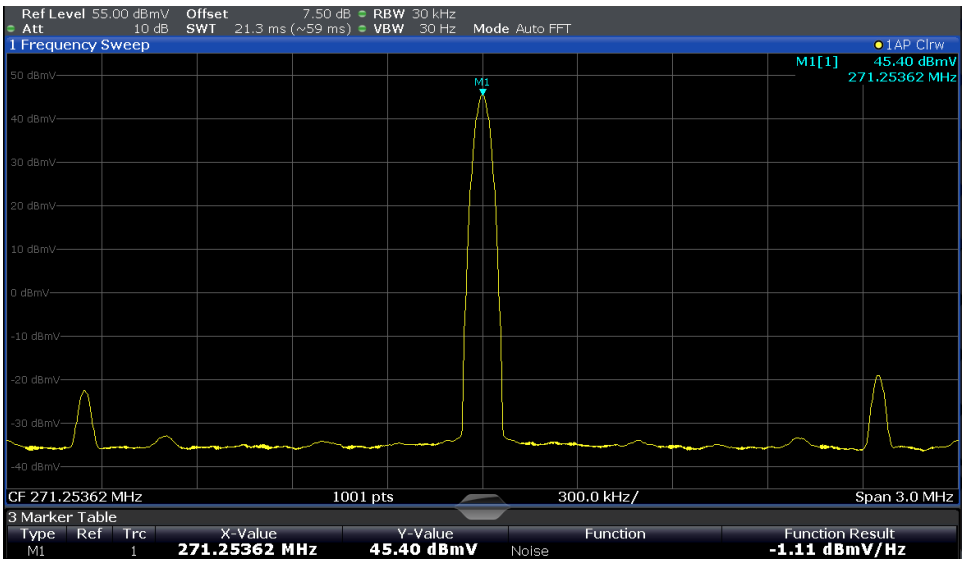


Fig. 5-22: Set center frequency = Channel 37 (A-Line Amplifier)

- Turn Channel 37 OFF
- Set markers at fc ± 1.25 MHz and fc ± 0.75 MHz

  If necessary, decrease Ref Level and Range for better readability.

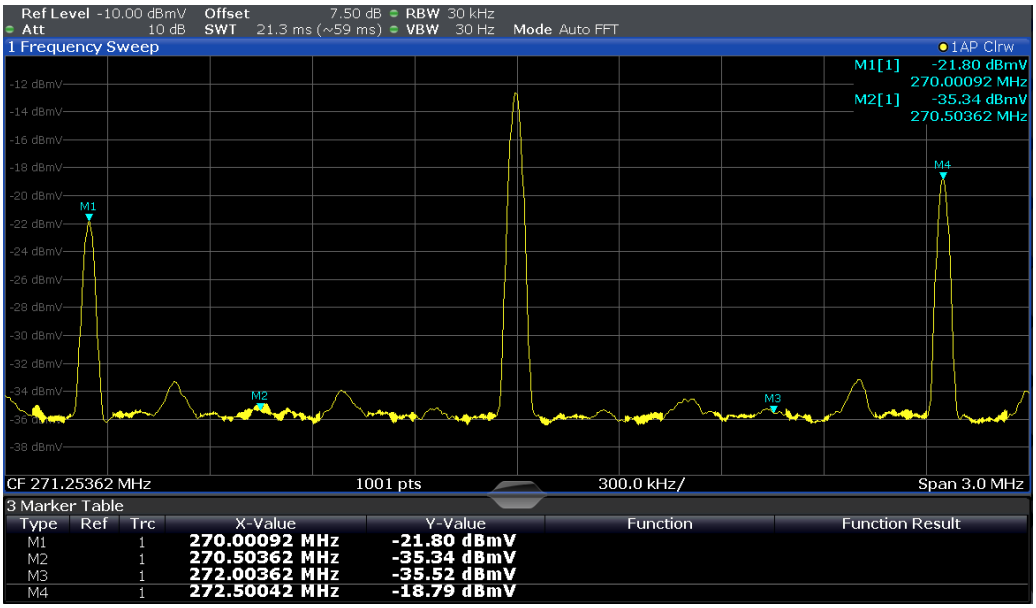


Fig. 5-23: Markers at fc ± 1.25 MHz and fc ± 0.75 MHz (A-Line Amplifier)

Y_{M1} = **-21.80 dBmV,** Y_{M2} = **-35.34 dBmV,** Y_{M3} = **-35.52 dBmV,** Y_{M4} =**-18.79 dBmV**

- Load the configuration file **CSO_CTB_80CW_PORT_LOW_OFF.CFG** in the CLGD to turn OFF all channels and measure Noise Floor level = **-25.25 dBmV**.

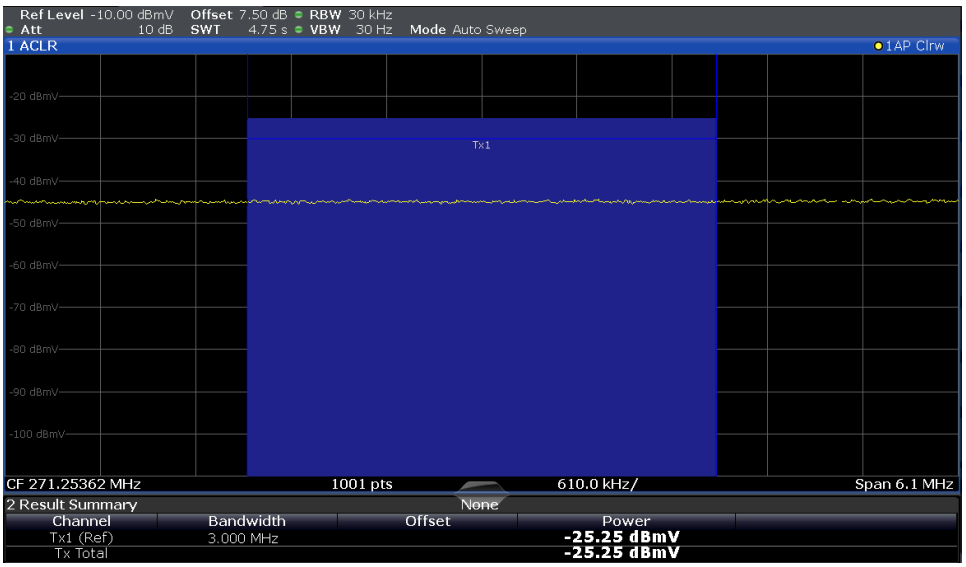


Fig. 5-24: Noise Floor Level (A-Line Amplifier)

- Compute Noise Floor Delta:

  Y_{M1} = -21.80 dBmV, Y_{M2} = -35.34 dBmV**,** Y_{M3} = -35.52 dBmV**,** Y_{M4} = -18.79 dBmV

  U1 = 0.0813 mV, U2 = 0.0171 mV, U3 = 0.0167 mV, U4 = 0.1149 mV,

  ∑U = 0.23 mV, CSO Level = ∑M = **-12.765 dBmV**

$$Noise\ Floor\ Delta = CSO\ Level - Noise\ Floor\ Level$$
$$= -12.765\ dBmV + 25.250\ dBmV = \mathbf{12.485\ dB}$$
$$Noise\ Floor\ Correction\ Factor = 10 * \left|\log\left(1 - 10^{-\left(\frac{Noise\ Floor\ Delta}{10}\right)}\right)\right| = \mathbf{0.252\ dB}$$

- Compute Corrected CSO for each product:

$$Corrected\ CSO = Carrier\ Level - CSO\ Level + Noise\ Floor\ Correction\ Factor$$
$$= 45.4\ dBmV + 12.765\ dBmV + 0.252\ dB = \mathbf{58.417\ dBc}$$

5.3.2 CTB

CTB products are located at the carrier under test frequency, except channels 5 and 6 where the CTB products are located 2 MHz higher. The DUT is a C-Line amplifier.

- Turn off the carrier under test.

Fig. 5-25: Channel 37 OFF

5.3.2.1 C-Line Amplifier

- Use SA marker to measure CTB product of interest (CTB level).

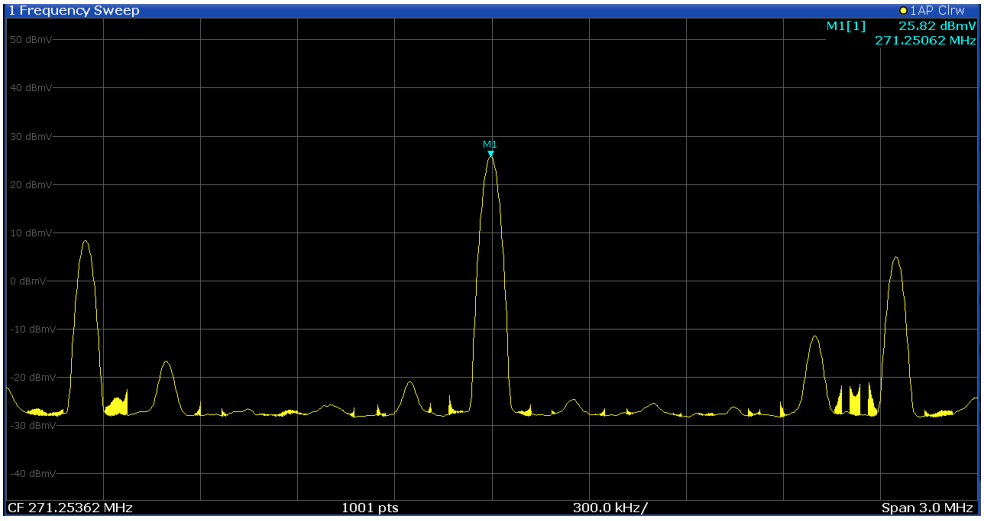


Fig. 5-26: Set marker on CTB product of interest

$$CTB\ Level = \mathbf{25.82\ dBmV}$$

- Measure Noise Floor Level and calculate

$$Noise\ Floor\ Delta = CTB\ Level - Noise\ Floor\ Level = 25.82\ dBmV + 22.51\ dBmV = \mathbf{48.33\ dB}$$

- If Noise Floor Delta < 2 dB add optional post-amplifier to system
- If Noise Floor Delta ≥ 2 dB calculate:

$$Noise\ Floor\ Correction\ Factor = 10 * \left| log\left(1 - 10^{-\left(\frac{Noise\ Floor\ Delta}{10}\right)}\right)\right| = \mathbf{0.001\ dB}$$

- Calculate Corrected CTB:

$$Corrected\ CTB = Carrier\ Level - CTB\ Level + Noise\ Floor\ Correction\ Factor = 48.88\ dBmV - 25.82\ dBmV + 0.001\ dB = \mathbf{23.061\ dBc}$$

The resulting unit is –dBc.

5.3.2.2 A-Line Amplifier

The same measurement with an A-Line amplifier.

- Turn Channel 37 OFF.
- Set marker on product of interest.

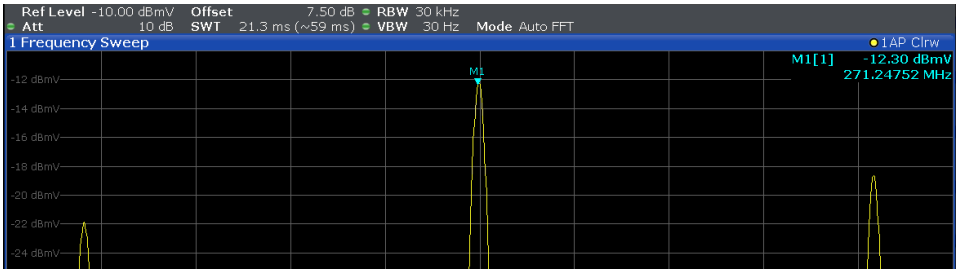


Fig. 5-27: Set marker on CTB product of interest

$$CTB\ Level = \mathbf{-12.30\ dBmV}$$

- $Noise\ Floor\ Delta = CTB\ Level - Noise\ Floor\ Level = -12.30\ dBmV + 25.25\ dBmV = \mathbf{12.95\ dB}$
- $Noise\ Floor\ Correction\ Factor = 10 * \left|log\left(1 - 10^{-\left(\frac{Noise\ Floor\ Delta}{10}\right)}\right)\right| = \mathbf{0.22596\ dB}$
- $Corrected\ CTB = Carrier\ Level - CTB\ Level + Noise\ Floor\ Correction\ Factor = 45.4\ dBmV + 12.30\ dBmV + 0.22596\ dB = \mathbf{57.926\ dBc}$

  The resulting unit is –dBc.

5.4 Carrier to Noise Measurements (CLGD)

This section describes how to measure the ratio of carrier to thermal noise and “noise-like” interference for broadband telecommunications system components according to **ANSI/SCTE 17**. It consists of measuring noise level or combined noise plus “noise-like” intermodulation product levels relative to the carrier level of a CW signal. The share of noise provided by the test equipment must also be measured in order to correct readings near the test equipment noise floor.

This example uses Channel 37 as carrier (see Fig. 3-16). In this example the initial setup for the spectrum analyzer is:

Center Frequency	Carrier frequency of channel under test
Span	30 MHz
RBW	30 kHz
VBW	10 kHz
Video Averaging	Off
Input Attenuation	Auto (minimum 10 dB)
Vertical Scale	10 dB/div
Detector	Peak

On the CLGD load the configuration file **CSO_CTB_80CW_PORT_LOW_ON.CFG**. This defines the frequency plan of 80 CW channels, sets **MODULATOR STATE** of Channel 1 to 80 ON and Power = minimum. It is convenient to use its **DOWNSTREAM LOW** output because it requires no setup change for all further measurements. Set the marked channels 1 to 80 to Power = 30 dBmV.

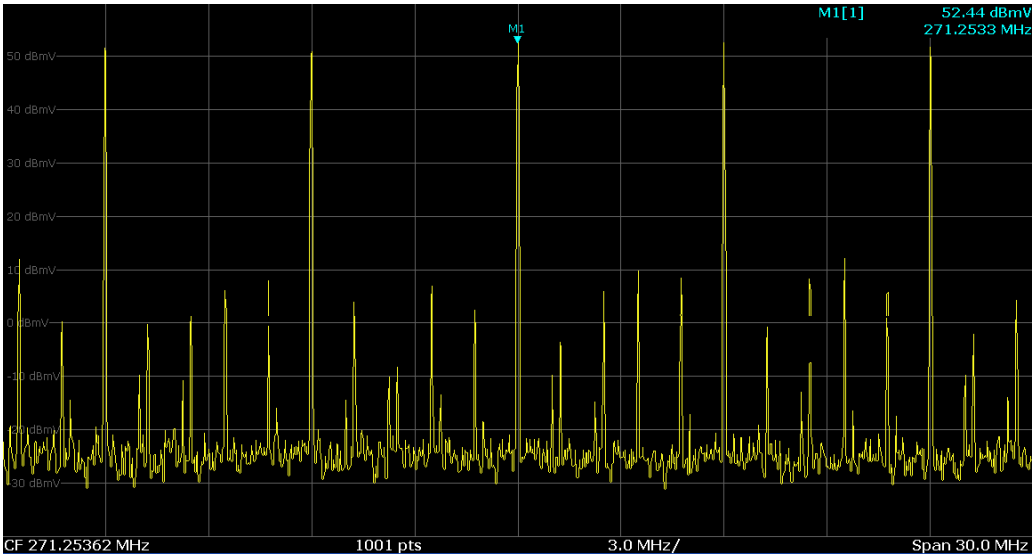


Fig. 5-28: Neighbor channels ON

- Turn OFF the neighbor channels 35, 36, 38 and 39.

Channel	Block	Modulator State	Source
34	3	ON	CW
35	3	OFF	CW
36	3	OFF	CW
37	3	ON	CW
38	3	OFF	CW
39	3	OFF	CW

Fig. 5-29: Turn OFF neighbor channels

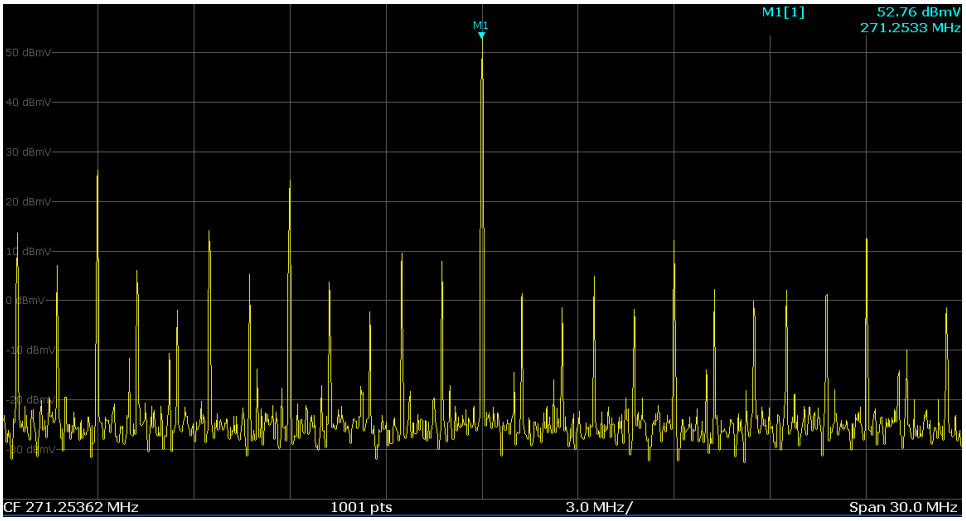


Fig. 5-30: Suppressed neighbor channels

- Re-adjust the spectrum Analyzer as follows:

Span	3 MHz
VBW	30 Hz (or lower if SWT is tolerable)

The noise floor appears flat across the display.

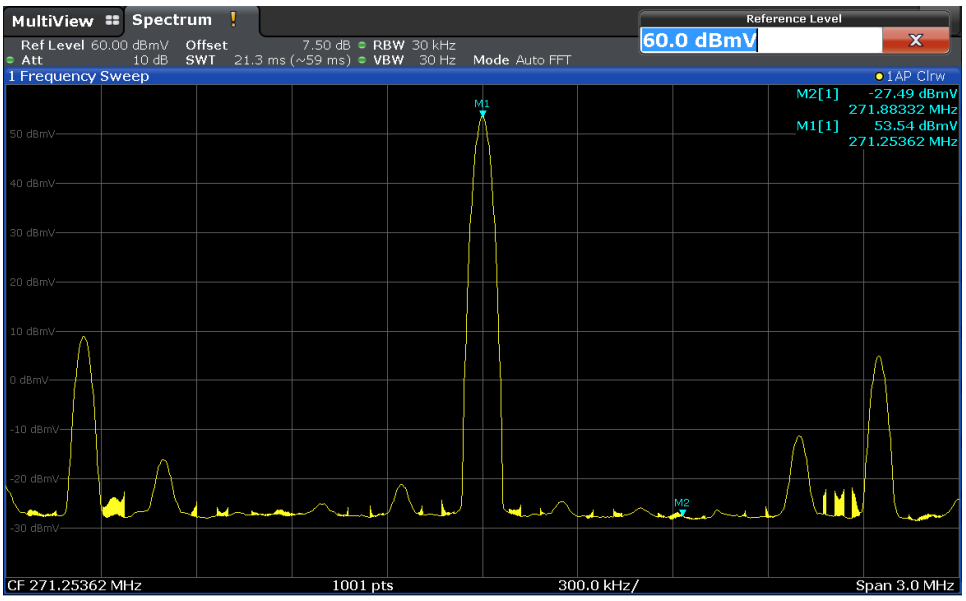


Fig. 5-31: Noise floor

- Disconnect the cable at the DUT output and terminate it with 75 Ω or disconnect the cable after the matching pad and terminate it with 50 Ω.

  If the noise floor drops less than 10 dB, reduce the FSW input attenuator and re-check the noise drop. Compare the "signal" to test equipment noise with the same attenuator setting. In this example there is a noise drop of approx. 20 dB so there is no need to take further actions.

- Re-connect the cable.

- Re-Adjust the FSW as follows:

Span	3 MHz
VBW	10 kHz

- Read carrier peak $\mathbf{C_p}$ = **53.44 dBmV** (= **113.44 dBµV**)

Fig. 5-32: Carrier peak

- Turn OFF the carrier under test.

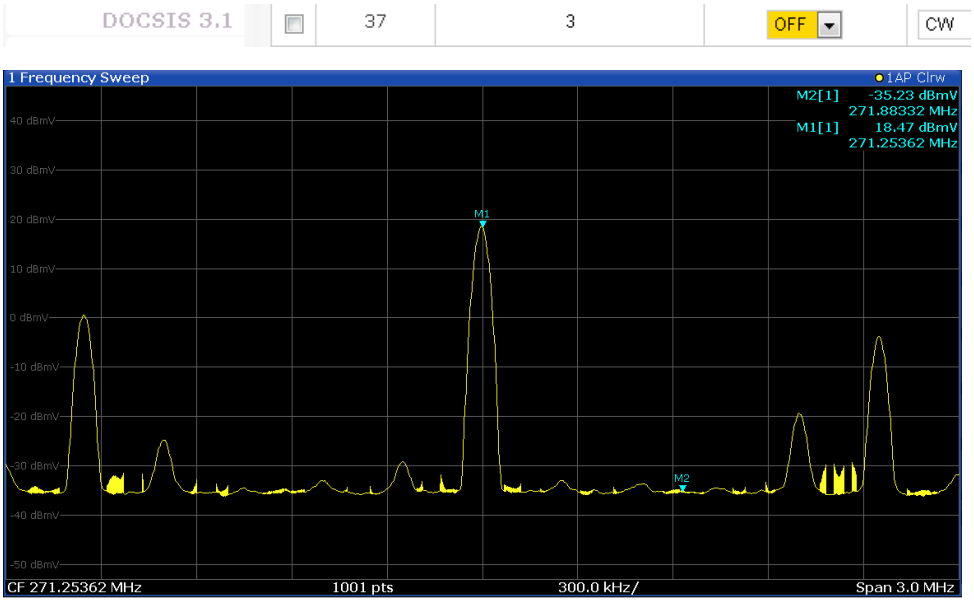


Fig. 5-33: Raw Composite Noise

Raw Composite Noise **$N_{COMP\text{-}raw}$ = -35.23 dBmV (= 24.77 dBµV)**

- Turn OFF the digital source.

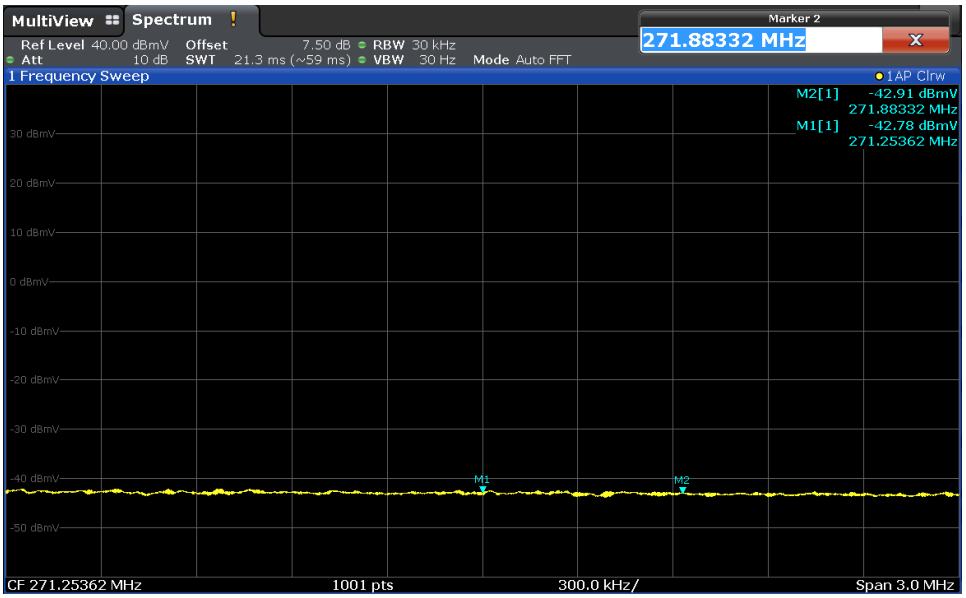


Fig. 5-34: Raw Thermal Noise $N_{TH\text{-}raw}$

Raw Thermal Noise **$N_{TH\text{-}raw}$ = -42.91 dBmV (= 17.09 dBµV)**

- Disconnect the cable at the DUT output and terminate it.

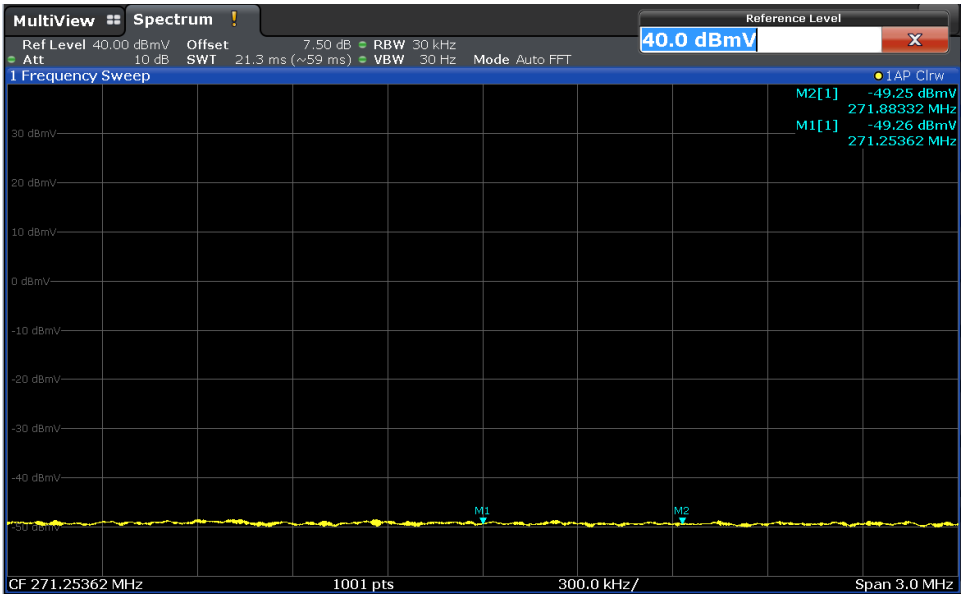


Fig. 5-35: Test Equipment Noise Floor N_{TE}

Test Equipment Noise floor **N_{TE} = -49.25 dBmV (= 10.75 dBµV)**

5.4.1 Carrier to Noise (C/N)

The term Carrier to Noise is generally the ratio of the carrier peak level to the noise floor of the transmission system, which includes thermal and undesired noise and noise-like signals. CCN, CIN, and CTN specify the components of the noise floor more clearly. CW carriers are substituted at equivalent levels to the peak visual carrier levels.

Log Amp Factor = **2.5 dB**, Noise BW = **4.0 MHz** (NTSC), Noise BW = **5.0 MHz** (PAL), FSW Shape Factor 60 dB: 3 dB ≤ **2**, COR_{drop2} = **0.0 dB**

$$COR_{BW} = 10 * log\left(\frac{Noise\ BW}{Filter\ Shape\ factor * Res\ BW}\right) + Log\ Amp\ Factor$$

$$= 10 * log\left(\frac{4\ MHz}{2 * 30\ kHz}\right) + 2.5\ dB = \mathbf{20.739\ dB}$$

5.4.2 Carrier to Thermal Noise (CTN)

The ratio of the CW carrier to the thermal noise floor of the transmission system, specifically excluding any contribution from digital intermodulation products.

$$N_{TH} = N_{THraw} + COR_{BW} - COR_{drop2} = -42.91\ dBmV + 20.739\ dB = \mathbf{-22.171\ dBmV}$$

$$CTN = C_p - N_{TH} = 53.44\ dBmV + 22.171\ dBmV = \mathbf{75.611\ dB}$$

5.4.3 Carrier to Composite Noise (CCN)

CCN is the ratio of the CW carrier to the combined noise plus noise-like signals of non-thermal origin. This includes the thermal noise (CTN), combined with the noise-like intermodulation products created by beat products of analog and digital signals (CIN).

$$N_{COMP} = N_{COMPraw} + COR_{BW} - COR_{drop2} = -35.23\ dBmV + 20.739\ dB$$
$$= \mathbf{-14.491\ dBmV}$$

$$CCN = C_p - N_{COMP} = 62.59\ dBmV + 14.491\ dBmV = \mathbf{62.59\ dB}$$

5.4.4 Carrier to Intermodulation Noise (CIN)

The ratio of the CW carrier to the noise-like signals generated by the non-linearity of a broadband transmission system with analog and digitally modulated signals. These distortion products are comparable to CSO and CTB products produced by analog carriers, but appear as noise-like interference due to the pseudo random nature the digital modulated signals,. When CIN products fall within the analog portion of the spectrum, their effect on the analog signal is similar to increasing thermal (random) noise. Since CIN is a distortion product, its contribution depends on the output level.

$$N_{DIG} = 10 * \log\left(10^{\left(\frac{N_{COMP}}{10}\right)} - 10^{\left(\frac{N_{TH}}{10}\right)}\right) = 10 * log(0.03555\ \mathrm{m}V - 0.006\ mV)$$
$$= \mathbf{-15.29\ dBmV}$$

$$CIN = C_p - N_{DIG} = 53.44\ dBmV + 15.29\ dBmV = \mathbf{68.73\ dB}$$

The following figure show the relationship between CCN, CTN and CIN.

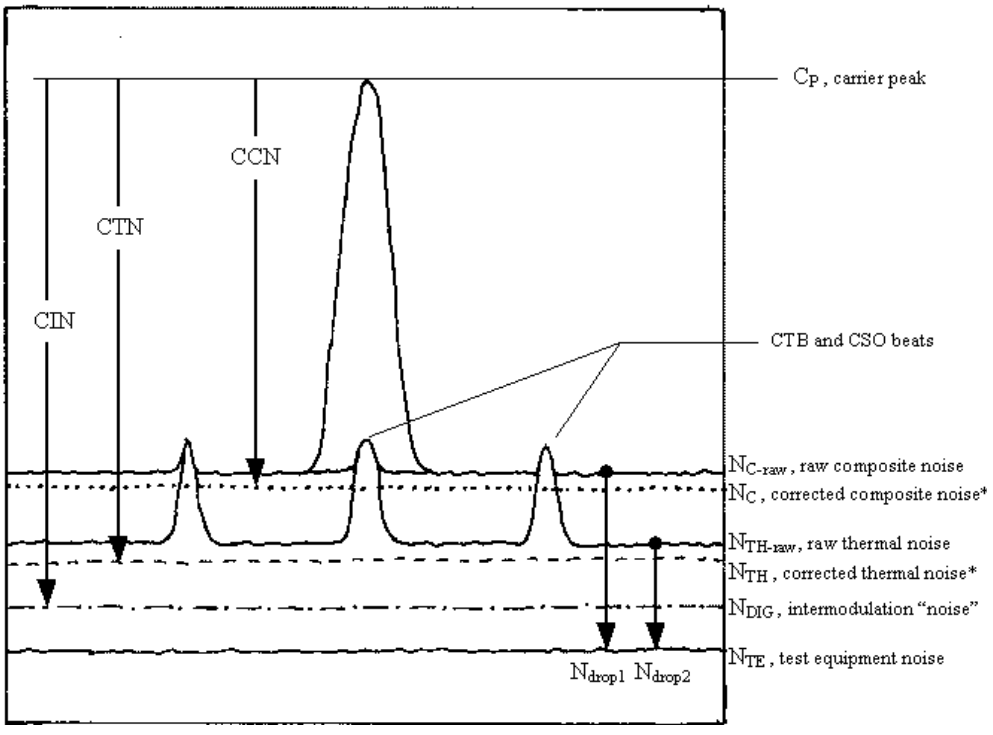


Fig. 5-36: Relationship between CCN, CTN and CIN

5.5 Amplitude Modulation Cross Modulation (AM-XMod) (CLGD)

This chapter describes a test procedure for the laboratory and production measurement of Amplitude Modulation Cross Modulation (or AM-XMOD) that is present in Broadband Systems which carry Frequency Division Multiplexed (FDM), amplitude modulated, analog video channels.

For this measurement load the configuration file **CSO_CTB_80CW_PORT_LOW_OFF.CFG** to turn OFF all DOCSIS 3.0 channels. Then upload the data file AM-XMod_15625Hz.wv or AM-XMod_15750Hz.wv to the CLGD.

- Select **USER FILES** menu.
- Drag and drop the file into the **FILE UPLOAD** area.
- Press **START UPLOAD** to copy it from the PC to the CLGD home directory

Fig. 5-37: File copy from PC to CLGD

- Select **DOWNSTREAM ARB** menu and click on the **ARB FILE** field of the **LOW FREQUENCY NARROWBAND CHANNELS** area and select the file that has previously been imported.

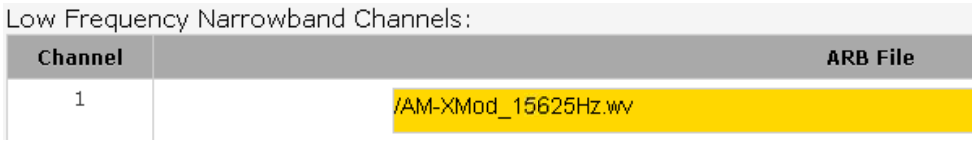


Fig. 5-38: Set ARB file

After pressing **APPLY** this AM modulated signal is now assigned to ARB1 and shall be referred to as f_{AM}.

- Go to the **DOCSIS 3.0** menu and set **CHANNEL 37** to **CENTER FREQUENCY** = **271.25362 MHz**, **POWER** = **30.0 dBmV** (= **90.0 dBµV**), **SOURCE** = **ARB1** and press **APPLY**.

Fig. 5-39: Modulate Channel 37 with ARB1

- Set the FSW analyzer to the carrier frequency (= 271.25362 MHz).

  The analyzer must be set to

Center Frequency	Carrier Frequency under test
Span	100 kHz
Detector	RMS
RBW	30 Hz
VBW	3 Hz
Input Attenuation	≥ 10 dB
Sweep Time	Auto

  On the FSW turn **MARKER 1** ON and press PEAK SEARCH. Press **MARKER 2** to add a 2nd marker that will automatically position itself on one of the sideband carriers. Set **MKR TYPE** = **NORM**. Read M2 peak level which is referred to as Reference Sideband Level (**39.99 dBmV = 99.99 dBµV**).

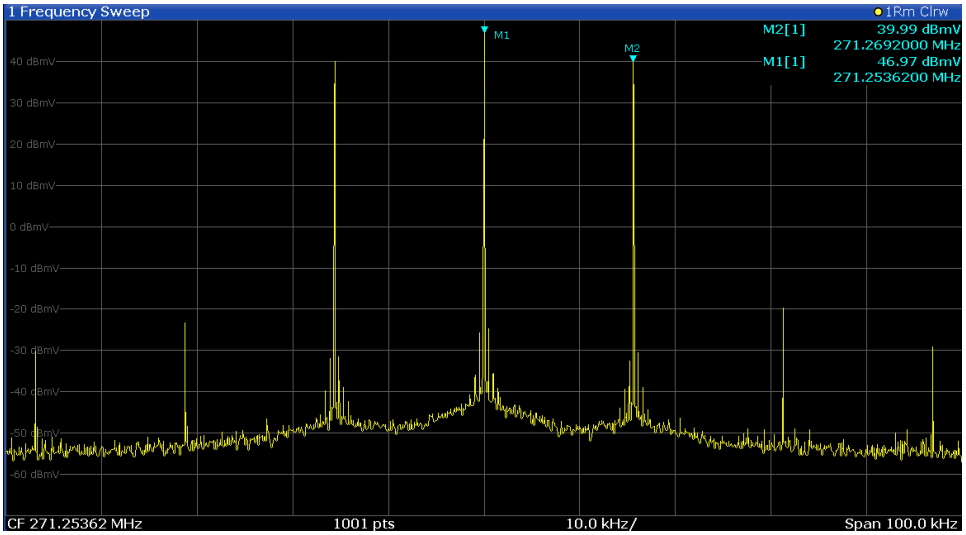


Fig. 5-40: Reference Sideband Level

- Turn OFF the AM modulation by changing the **MODULATION SOURCE** of **CHANNEL 37** to **CW**.

Fig. 5-41: Turn AM modulation OFF

The M2 peak level is the Raw AM-XMod level = **-50.31 dBµV (= 110.31 dBµV)**.

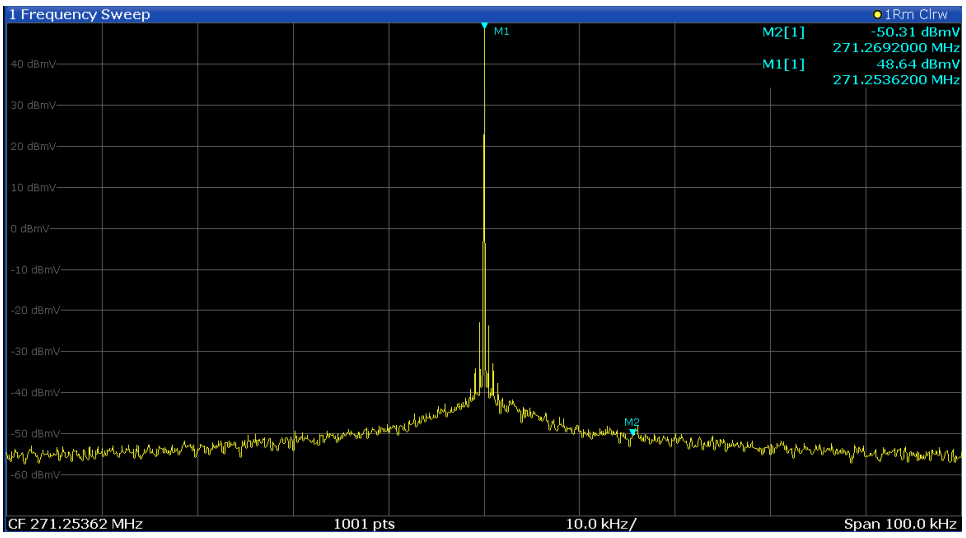


Fig. 5-42: Raw AM-XMod Level

- Turn ON **MARKER 3**, move it to the flat portion of the noise floor and set **MKR TYPE** = **NORM**. This is the Noise Floor Level = **-54.04 dBmV (= 14.04 dBµV)**.

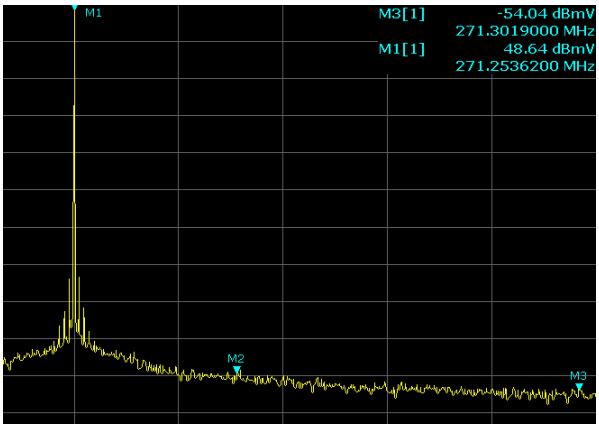


Fig. 5-43: Noise Floor level

- Calculate Noise Floor Delta as:

$$Noise\ Floor\ Delta = Raw\ AMXModLev - Noise\ Floor\ Lev$$
$$= -50.31 + 54.04\ dBmV = \mathbf{3.73\ dB}$$

- Since Noise Floor Delta > 2 dB you need to calculate the Noise Floor Correction Factor:

$$Noise\ Floor\ Correction\ Factor = 10 * \left|\log\left(1 - 10^{-\left(\frac{Noise\ Floor\ Delta}{10}\right)}\right)\right|$$
$$= 10 * |\log(1 - 10^{-0.373})| = \mathbf{2.393\ dB}$$

- Compute the “corrected AM Cross Modulation” as:

$$\begin{aligned}&\textit{Corrected AM Cross Modulation, referenced to sideband}\\&\quad = \text{Reference Sideband Level} - \text{Raw AMXMod Level}\\&\quad + \text{Noise Floor Correction Factor} + (6\ \text{dB, if using and RMS detector})\\&\quad = 95.5 - 4.28 + 2.393 + 6 = \mathbf{99.613\ dB}\end{aligned}$$

5.6 Noise Power Ratio - NPR (CLGD / SFD)

This procedure defines a method of measurement for Noise Power Ratio (NPR) of active Cable Telecommunications equipment. It is intended for measurement of 75 Ω devices having type "F" or 5/8-24 KS connectors. The NPR test examines the amount of noise and intermodulation distortion in a channel which characterizes the linearity of a wide band amplifier over a custom frequency range. The test signal consists of Gaussian white noise with the same bandwidth as the range to be measured (e.g. 200 MHz) containing a notch with zero energy. A handy tool for generating custom NPR files is the application note 1MA029 – Noise Power Ratio.

Generate a noise signal with 200 MHz sample rate and one notch 10 MHz wide with 5 MHz offset so the notch is not affected by the carrier.

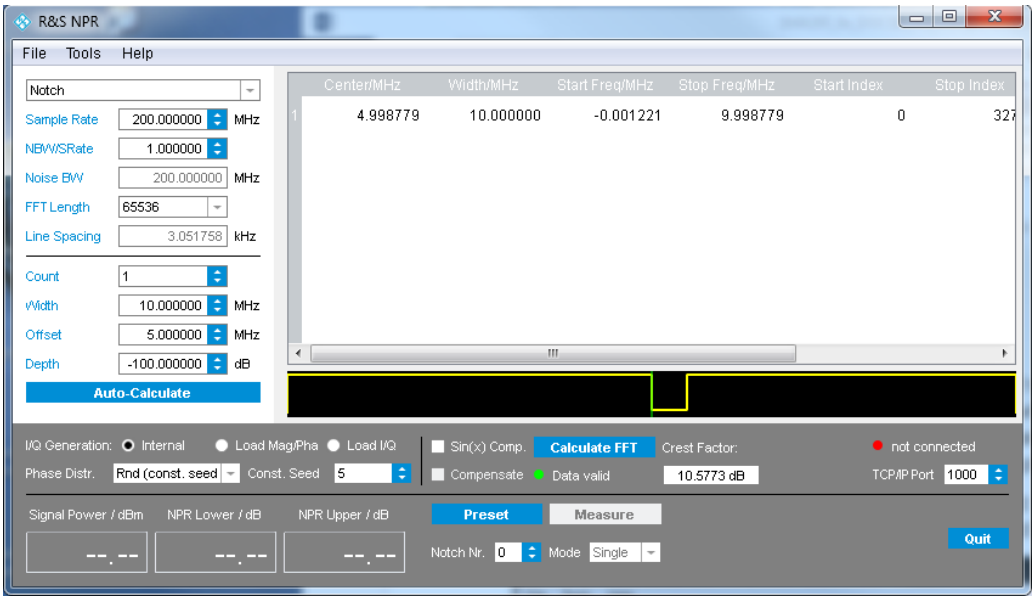


Fig. 5-44: Generate NPR test signal with R&S NPR

Press **Calculate FFT** to generate the IQ waveform. Save the waveform with **FILE** → **SAVE DATA FILE (*.WV)**.

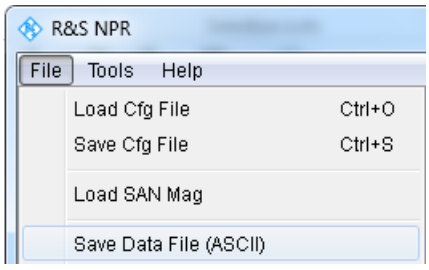


Fig. 5-45: Save IQ data to *.wv

Upload the *.wv file to the CLGD or SFD in the **USER FILES** menu. Drag & drop the *.wv file in the **FILE UPLOAD** area. Then press **START UPLOAD** to copy the file from your PC to the CLGD or SFD hard drive.

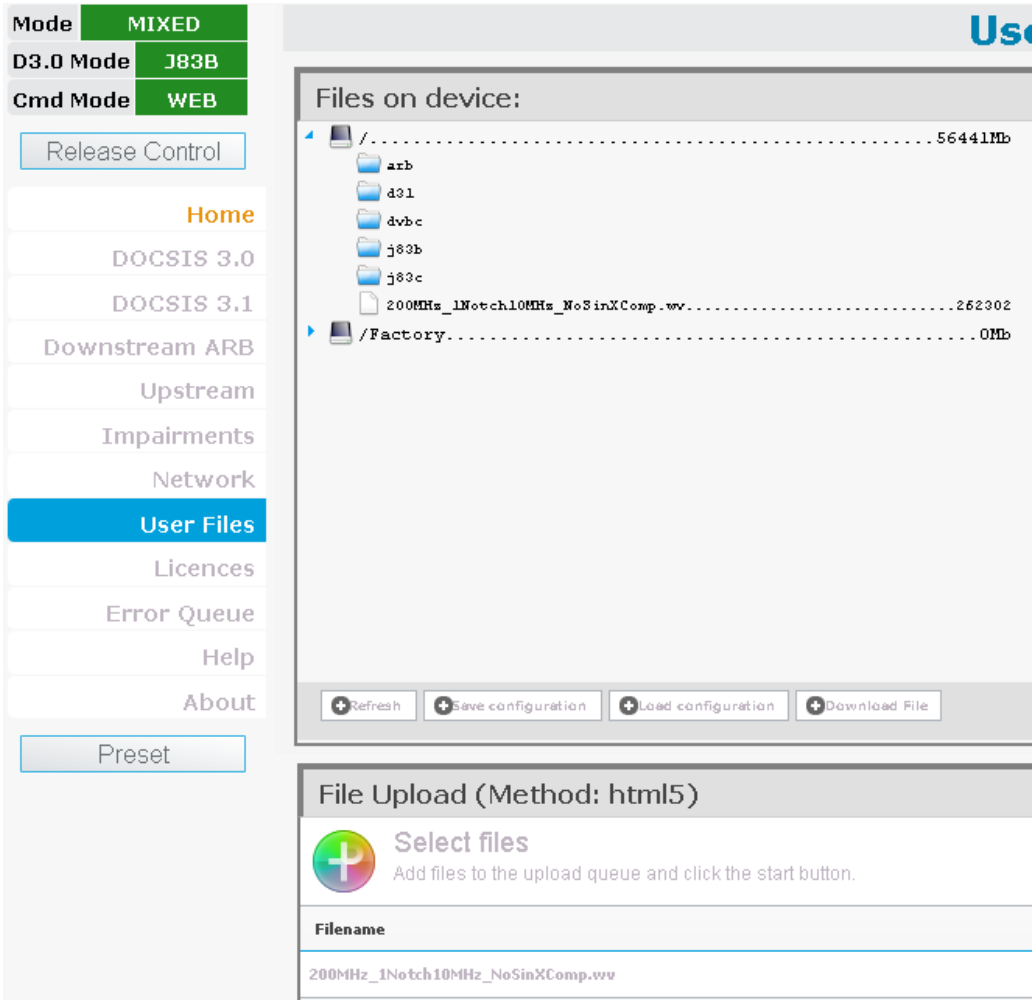


Fig. 5-46: User Files menu

Switch to the **DOWNSTREAM ARB** menu. In **LOW FREQUENCY WIDEBAND CHANNELS** → **CHANNEL 1** choose the ARB file and press **OK**.

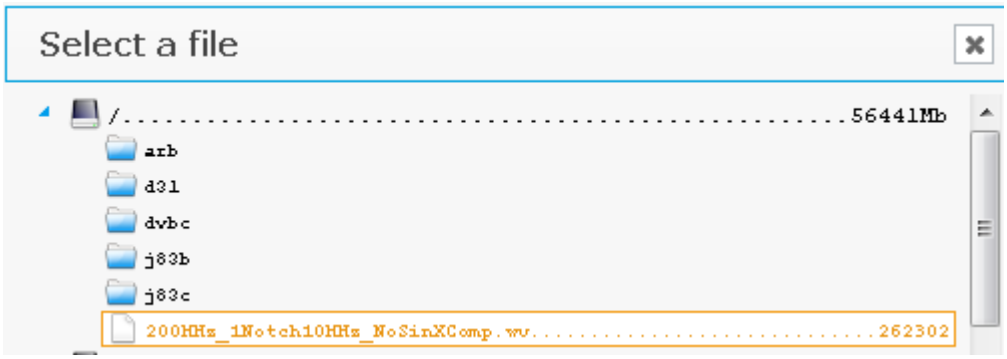


Fig. 5-47: Select ARB file

Set **POWER**, **FREQUENCY,** turn **TRANSMIT** ON and press **APPLY**.

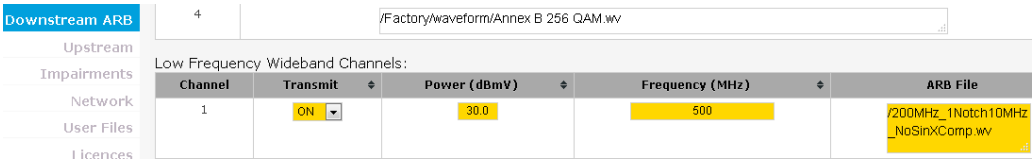


Fig. 5-48: Import NPR file to CLGD ARB

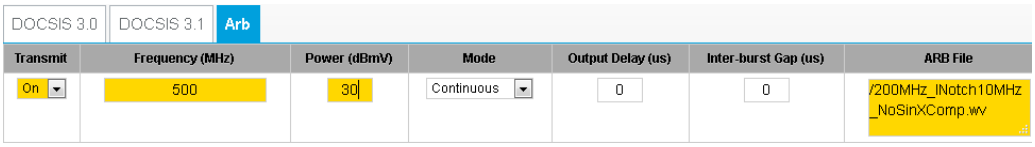


Fig. 5-49: Import NPR file to SFD ARB

Switch to Spectrum Mode on the FSW and set **FREQUENCY** = CLGD Channel 1 Frequency, **SPAN** = 250 MHz, **DETECTOR** = RMS to get a stable readout.

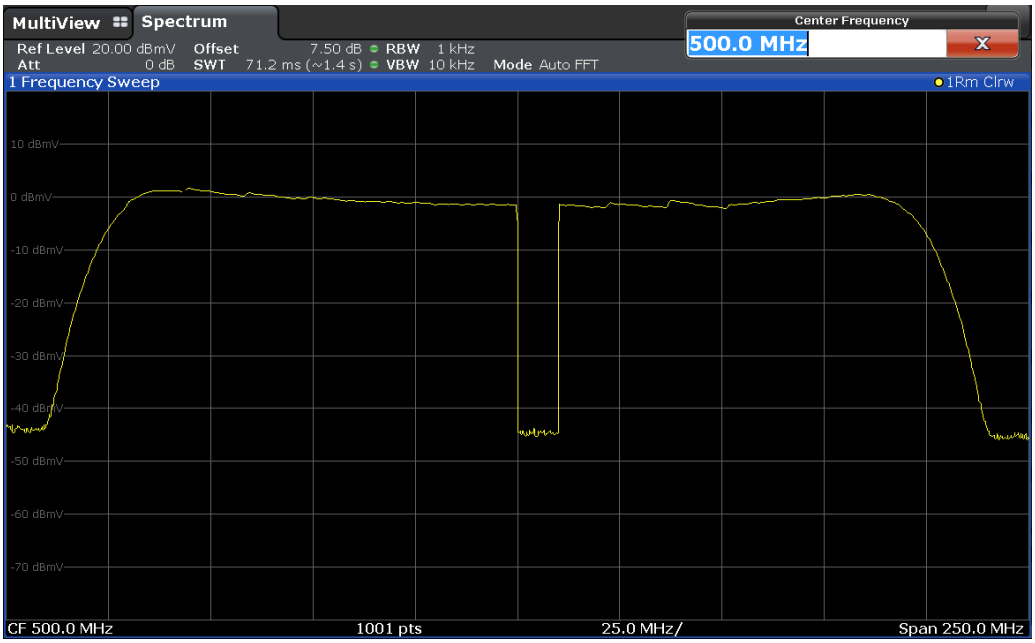


Fig. 5-50: Output spectrum of a typical C-Line amplifier (100 MHz to 800 MHz) fed with NPR signal

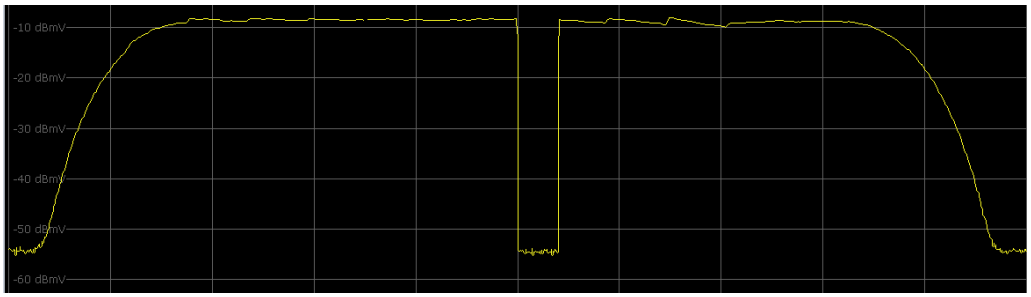


Fig. 5-51: Output spectrum of a typical A-Line amplifier fed with NPR signal

The **MEAS → POWER MEASUREMENTS → CHANNEL POWER ACLR** can be used for NPR measurements.

Set **CP / ACLR CONFIG → GENERAL SETTINGS** as shown below:

Fig. 5-52: CP / ACLR General Settings

Set **CP / ACLR CONFIG → CHANNEL SETTINGS** as shown below:

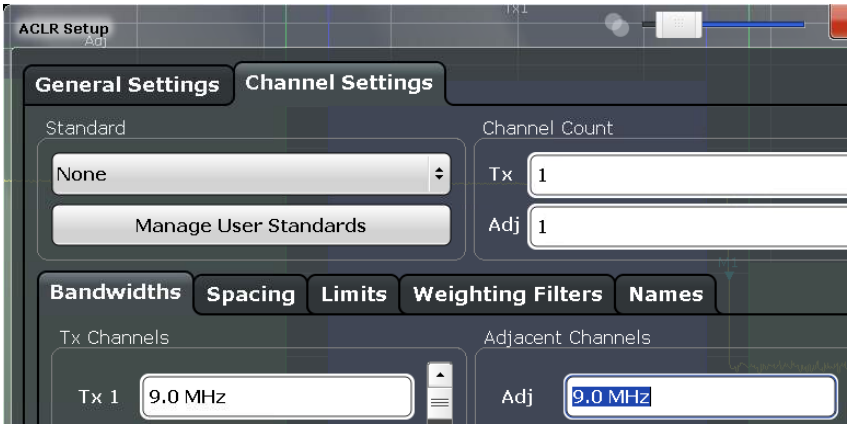


Fig. 5-53: CP / ACLR → Channel Settings

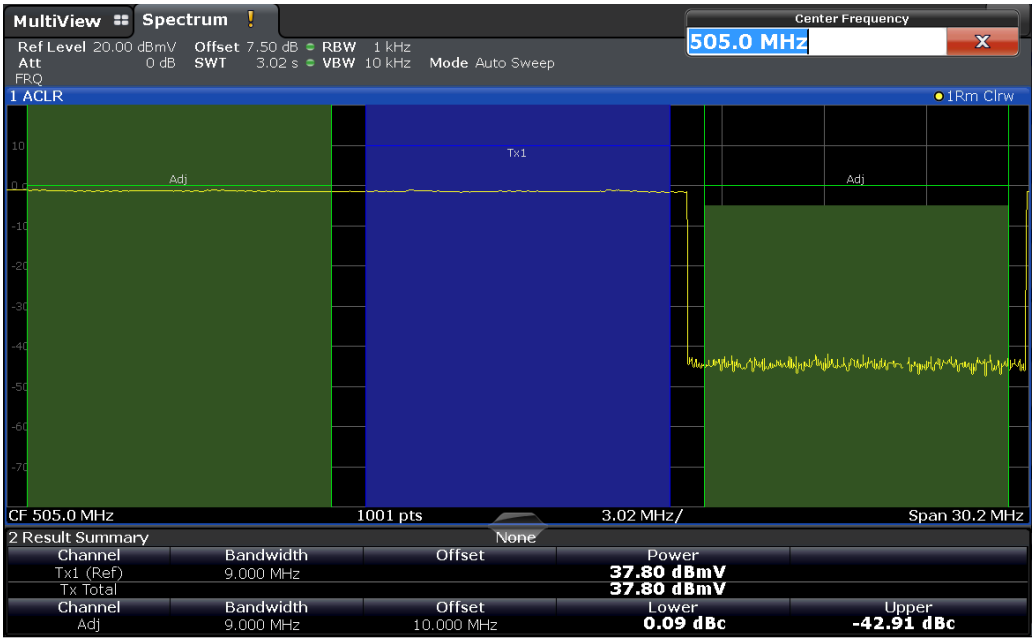


Fig. 5-54: NPR of a typical C-Line amplifier calculated with ACLR

$$NPR = Lower - Upper = 0.09\ dBc + 42.91\ dBc = \mathbf{43.00\ dB}$$

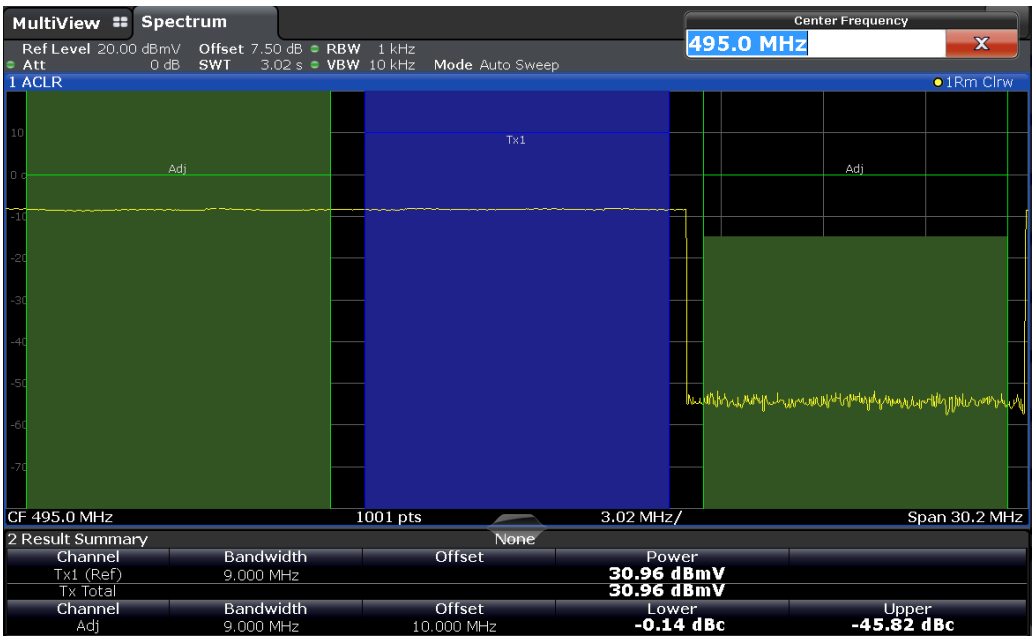


Fig. 5-55: NPR of a typical A-Line amplifier calculated with ACLR

$$NPR = Lower - Upper = -0.14\ dBc + 45.82\ dBc = \mathbf{45.68\ dB}$$

You can vary the NPR signal, for instance by defining a wider notch or multiple notches.

5.7 BER Downstream (CLGD / SFD)

The purpose of this test is to measure Bit Error Rate (BER) of downstream (forward path) broadband telecommunications QAM signals. This procedure will address mainly pre-Forward Error Correction BER results for 64 and 256 QAM.

BER is an important specification for component manufacturers. For measuring BER the data sequence sent by the CLGD / SFD must be known by the FSW in advance. The analyzer then compares the measured, demodulated data with the available reference information and can calculate the BER itself. The FSW has a recording tool app which records sequences in VSA mode. The BER measurement is usually performed at the lower, mid and upper frequency of the DUT.

5.7.1 CLGD / SFD Configuration

- Connect the CLGD Downstream Low / SFD Downstream output with R&S RAM 75 to 50 Ohm impedance converter directly to the FSW RF input.
- Upload the file **DVBC-6.9MSPS-256QAM-PN11.WV** to the CLGD or SFD in the **USER FILES** menu (see section 3.2.5).

  Note: An SFD with firmware up to version 1.1 requires replacing the K2 license for compatibility with the waveform used in this chapter.

  1. Navigate to https://www.rohde-schwarz.com/firmware/clgd/ and download the file "**CLGD-K2_V01_10.zip**".
  2. Unzip the file "**RSCLGD-999999-K2_encrypted.lic**" from the zip file.
  3. Select the **LICENSES** menu on the SFD.
  4. Drag and drop the file "**RSCLGD-999999-K2_encrypted.lic**" in the **LICENSE UPLOAD** area and press the **UPLOAD AND INSTALL** button to install the license.

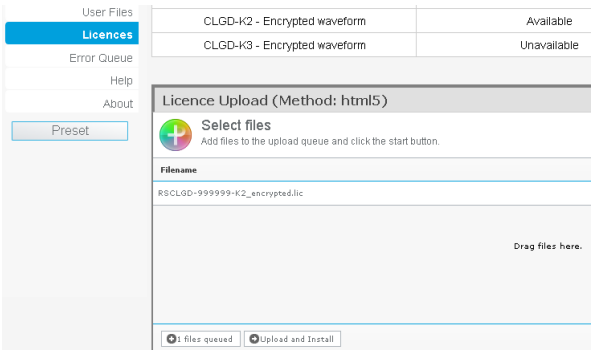


Fig. 5-56: Hot fix encrypted waveform license

- The arbitrary wave file **DVBC-6.9MSPS-256QAM-PN11.WV** can be used in 2 different ways.

  1. Upload it to **LOW FREQUENCY WIDEBAND CHANNEL 1**.Use this file In the **DOWNSTREAM ARB** menu and turn **TRANSMIT** ON.

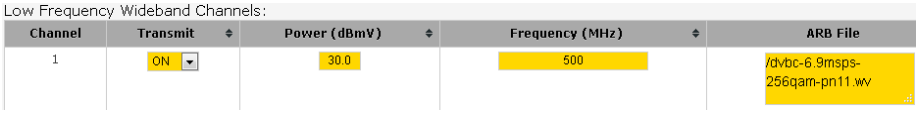


Fig. 5-57: Set ARB file in Low Frequency Wideband Channel menu on CLGD

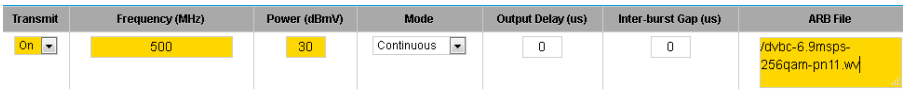


Fig. 5-58: Assign ARB file in Low Frequency Wideband Channel menu on SFD

  2. Upload it to Low Frequency Narrowband Channel 1

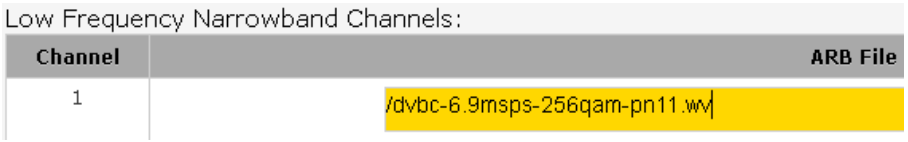


Fig. 5-59:

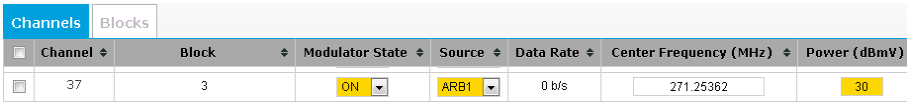


Fig. 5-60: Assign it to e.g. DOCSIS 3.0 Channel 37

- Press **APPLY** to generate the signal.

5.7.2 FSW BER Measurement:

- Select **MODE** → **VSA** on the FSW.
- Set **CENTER FREQUENCY** = generator frequency
- Select **OVERVIEW** → **SIGNAL DESCRIPTION** → **MODULATION** and set the parameters according to the generator settings.

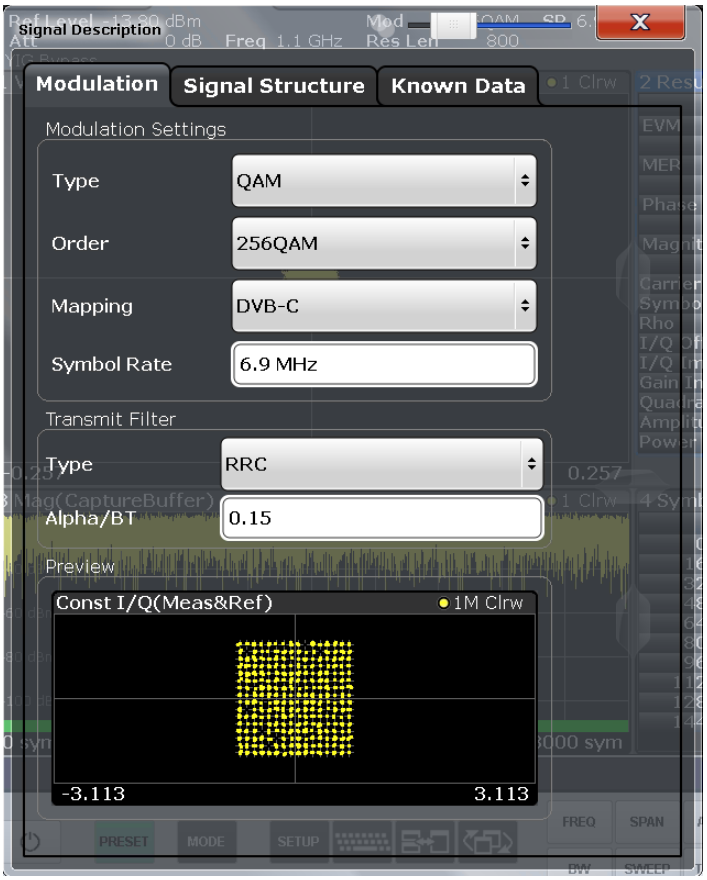


Fig. 5-61: Set modulation parameters

- Record the known data by pressing **START** → **VSA SEQUENCE RECORDING** on the FSW.

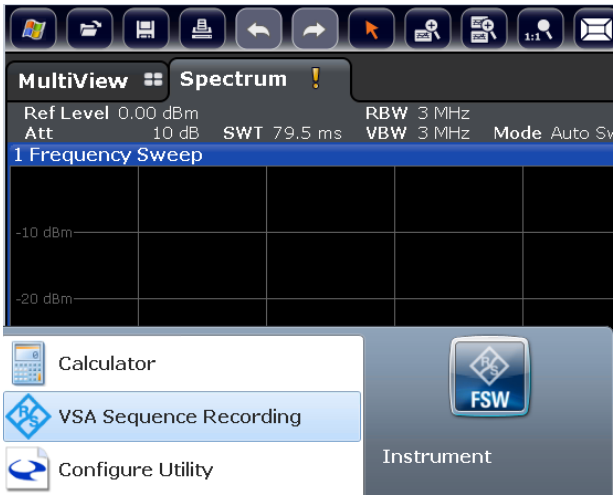


Fig. 5-62: Start VSA Sequence Recording tool

Press **RUN** to start the recording.

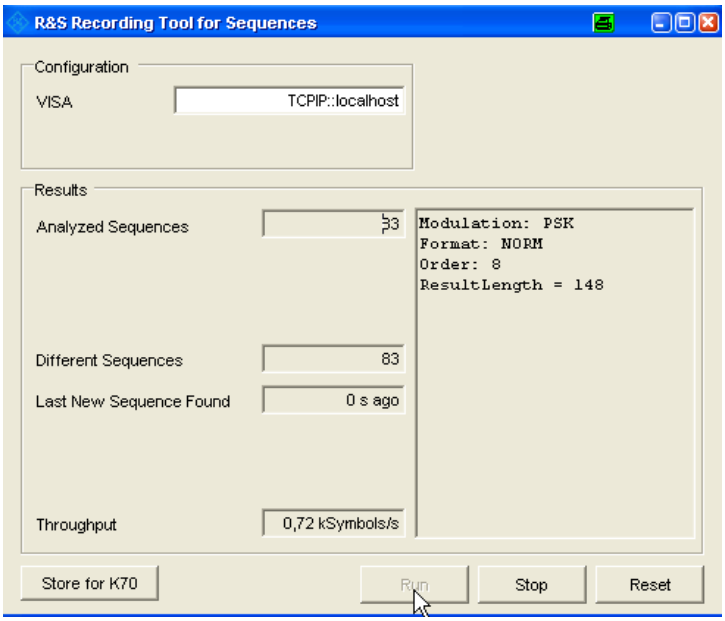


Fig. 5-63: VSA Sequence Recording tool

Stop the recording after approx. 20 secs and press **STORE FOR K70**. Select a file name, e.g. **REC_PN11_DVBC_256QAM.XML**.

- Switch to **KNOWN DATA** tab, check the **KNOWN DATA** checkbox, press the **LOAD DATA FILE** button and select the recently recorded file **REC_PN11_DVBC_256QAM.XML** which contains the de-modulated data of the ARB file.

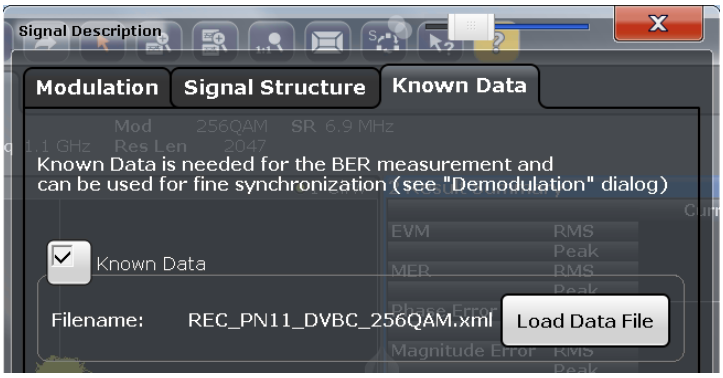


Fig. 5-64: Load Known Data file

- Make **RESULT SUMMARY** window active by clicking on it.
- Press **MEAS CONFIG** → **WINDOW CONFIG** and check **BIT ERROR RATE** radio button.

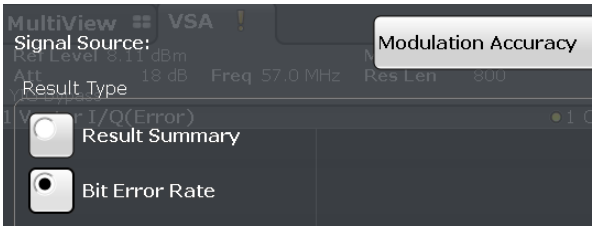


Fig. 5-65: Select Bit Error Rate

- Set the generator level so the specified max. DUT output level will not be exceeded.
- Re-connect the DUT input to the generator output and the DUT output to the FSW RF input.
- The BER can now be read out directly.

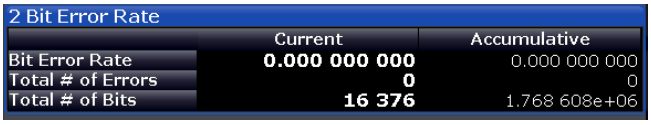


Fig. 5-66: Perfect BER

- The reference signal can be degraded by adding AWGN in the Impairment Settings menu. The Amplitude is absolute depends on the Bandwidth (dBc).

Fig. 5-67: Add AWGN with absolute amplitude

If the ARB file was modulated on a DOCSIS 3.0 channel it is convenient to select AWGN Mode **LOCKED**. The AMPLITUDE is relative (dB) to the **POWER** of the according DOCSIS channel.

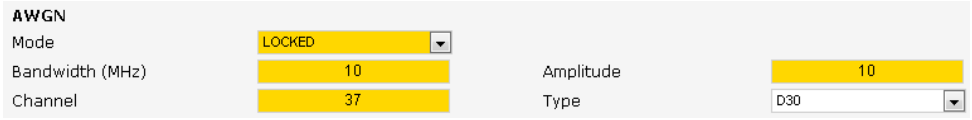


Fig. 5-68: Add AWGN with relative amplitude

This leads to increased BER.

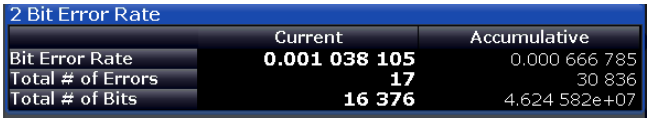


Fig. 5-69: Increased BER

- The impairments simulate various effects on the signal chain before the DUT.

6 Automatic Configuration and Measurement with R&S®Forum Scripts

The royalty-free R&S® Forum Software Tool allows custom creation of scripts for controlling measurement instruments remotely and displaying and storing the results. For the 1st time use of Forum it is necessary to define the instruments involved in the test, e.g. CLGD and FSW. Open the Devices menu with **SETTINGS** → **INSTRUMENTS** and add these instruments as shown below.

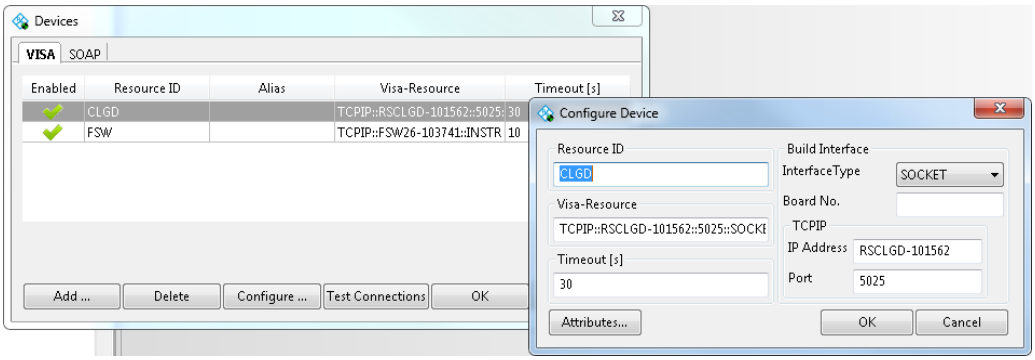


Fig. 6-1: Configure devices

The CLGD needs a socket connection with port 5025. The FSW uses VXI-11. Set the FSW timeout to 30 seconds because it takes approx. 20 seconds to load the known file for the BER measurement.

Download **1MA285_FORUM_SCRIPTS.ZIP** from http://www.rohde-schwarz.com/appnote/1MA285.html and unzip it to your user directory.

Load a script with **FILE** → **OPEN** → **<NAME.IE3>**

Remote commands to CLGD / SFD involving levels always have the unit

dBmV = **dBµV** – **60**

6.1 CSO / CTB

The Forum script **1_1MA285_EXAMPLE_CSO_CTB_CLGD_FSW.I3E** automatically performs a CSO / CTB measurement as described in 5.3 with a user-defined number of channels. The calculated test results are displayed on the PC screen.

6.2 Carrier to Noise

The Forum script **2_1MA285_EXAMPLE_C2N_CLGD_FSW.I3E** semi-automatically performs a C/N measurement as described in 5.4. It occasionally requests user interaction and displays the calculated results on the PC screen.

6.3 AM-XMod

The Forum script **3_1MA285_EXAMPLE_AM-XMOD_CLGD_FSW.I3E** automatically performs an AM Cross Modulation measurement as described in 5.5 with a user-defined number of channels and displays the calculated results on the PC screen.

6.4 NPR

The Forum script **4_1MA285_EXAMPLE_NPR_CLGD_FSW.I3E** automatically performs a Noise Power Ratio measurement as described in 5.6. The Noise Power Ratio is displayed on the FSW.

6.5 BER

The Forum script **5_1MA285_EXAMPLE_BER_DS_CLGD_FSW.I3E** automatically performs a BER DS measurement as described in 5.7. The BER result can be read out on the FSW.

7 References

[1] **American National Standard. 2015.** *ANSI/SCTE 06 (CSO/CTB).* 2015.

[2] **—. 2011.** *ANSI/SCTE 119 (NPR).* 2011.

[3] **—. 2011.** *ANSI/SCTE 121 (BER DS).* 2011.

[4] **—. 2010.** *ANSI/SCTE 133 (ACPR).* 2010.

[5] **—. 2007.** *ANSI/SCTE 17 (C/N).* 2007.

[6] **—. 2012.** *ANSI/SCTE 58 (AM-XMod).* 2012.

[7] **Gielen, H. 2006.** *RAC-0605-016 CSO, CTB & XMOD Characterisation of CATV Line Extenders. Application Note.* 2006.

[8] **Harald Ibl, Christiane Klaus. 2015.** *DOCSIS 3.1.* Munich : Rohde & Schwarz GmbH & Co KG, 2015. Application Note.

[9] **Rohde & Schwarz. 2014.** *7BM88 - DVB-C2 Receiver Tests in a Simulated Cable TV Network with Full Channel Load; Application Note.* 2014.

[10] **Test & Measurement.** *R&S®FSW-K70 Measuring the BER and the EVM for Signals with Low SNR.* Munich : Rohde & Schwarz GmbH & Co KG. Application Sheet.

8 Ordering Information

DOCSIS 3.1 Generator		
R&S®CLGD	DOCSIS 3.1 Generator, 8-channels, 47 MHz to 1218 MHz	2118.6956.02
R&S®CLGD-K3018	47 MHz to 1794 MHz Range Ext.	2118.6985.02
R&S®CLGD-K1050	Signal impairments simulation (SL)	2118.6991.02
R&S®CLGD-K201	Enhanced Functions	2118.7789.02
R&S®CLGD-K200	Downstream full channel load generator (SL)	2118.6962.02
R&S®CLGD-K300	Optional upstream cable modem emulator (SL)	2118.6979.02
R&S®SFD	DOCSIS 3.1 Generator 1-channel	2118.7400.02
R&S®SFD-K3018	47 MHz to 1794 MHz Range Ext.	2118.7452.02
R&S®SFD-K1050	Signal Interference Simulation	2118.7446.02
R&S®SFD-K201	Enhanced Functions	2118.7830.02
R&S®SFD-K200	Downstream full channel load generator (SL)	2118.7423.02
R&S®SFD-K300	Optional upstream cable modem emulator (SL)	2118.7430.02
Spectrum Analyzer		
R&S®FSWxx	2 Hz to 85 GHz	1312.8000.xx
R&S®FSW-K192	DOCSIS 3.1 OFDM Downstream	1325.4138.02
R&S®FSW-K70	Vector Signal Analysis (VSA)	1313.1416.02
R&S®FSW-B320	320 MHz Analysis Bandwidth	1325.4867.04
R&S®FSW-B512	512 MHz Analysis Bandwidth	1313.4296.04
Accessories		
R&S®RAM	0 Hz to 2.7 GHz 75 → 50 Ω Matching Pad	358.5714.02

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Regional contact

Europe, Africa, Middle East
+49 89 4129 12345
customersupport@rohde-schwarz.com

North America
1 888 TEST RSA (1 888 837 87 72)
customer.support@rsa.rohde-schwarz.com

Latin America
+1 410 910 79 88
customersupport.la@rohde-schwarz.com

Asia Pacific
+65 65 13 04 88
customersupport.asia@rohde-schwarz.com

China
+86 800 810 82 28 |+86 400 650 58 96
customersupport.china@rohde-schwarz.com

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- Energy efficiency and low emissions
- Longevity and optimized total cost of ownership

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Certified Environmental Management ISO 14001

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Rohde & Schwarz GmbH & Co. KG
Mühldorfstraße 15 | 81671 Munich, Germany
Phone + 49 89 4129 - 0 | Fax + 49 89 4129 – 13777

www.rohde-schwarz.com