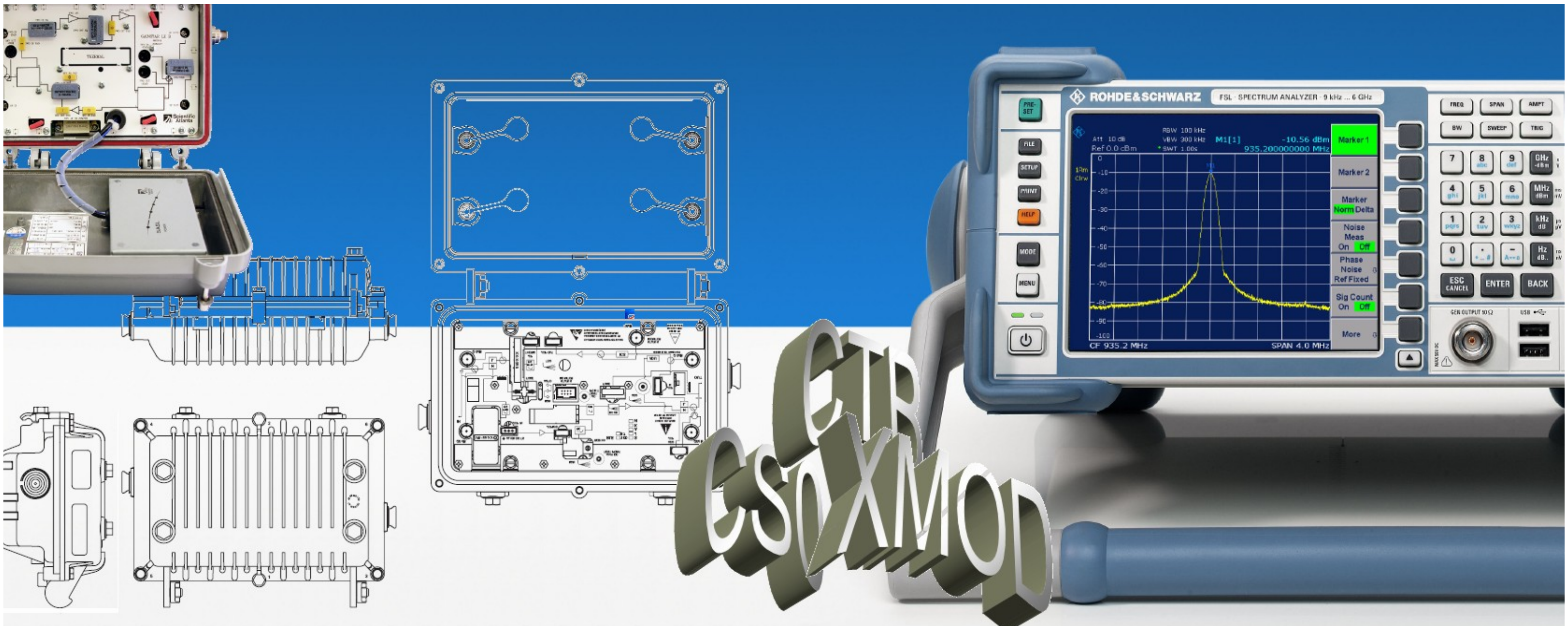

Products: Vector Signal Generator R&S® SMU200A, IQ Modulation Generator R&S® AFQ100A, Vector Signal Generator R&S® SMV, Spectrum Analyzer R&S® FSL

CSO, CTB & XMOD characterisation of CATV line extenders with the aid of vector signal generators

Application Note

The fact that cable TV networks are generally located in densely populated areas or extend over large geographical regions makes the presence of line extenders at regular intervals a necessity. Cascading large numbers of amplifiers however calls for excellent noise, SWR and intermodulation distortion specifications for the integrated amplifiers in order to avoid quality of service dropping below minimum acceptable levels. Composite second order, composite triple beat & cross modulation are commonly used figures to specify the performance of CATV equipment. In this application note we describe how to determine these figures with the aid of R&S® SMU200A or AFQ100A/SMV vector signal generators.

Subject to change – H.Gielen 06.2006 – RAC-0605-016

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1 Overview

Since that CATV line extenders predominantly reside in locations with very unfavorable environmental conditions (Pollution, moisture, temperatures ranging from -30 to +40 degrees Celsius, humidity, etc.) determines that the mechanical quality of these devices must be excellent. Furthermore the electronic components used in line extenders must also have a wide environmental operating range as well as a high degree of reliability.

Apart from these environmental conditions, CATV systems are usually located in densely populated cities or spread over large geographical areas in places with a high level of CATV penetration and low population density. Such inevitably leads to extensive cabling and therefore high signal losses. To avoid signal levels from disappearing into the noise floor at the outer ends, line extenders must be inserted at regular intervals to *"beef up"* signal levels. The large number of extenders which can run into hundreds, also suggests stringent electrical requirements and the latest developments to include digital TV, fixed line telephone, and data services on CATV systems doesn't make the situation any simpler.

Indeed, excellent SWR and group delay figures must prevent reflection and therefore the appearance of *"ghost images"* while the large number of frequency channels present on a CATV system (Often more than 100), together with the cascading effect of the line extenders may lead to equally large inter-channel interference if the linearity of the amplifiers used inside the line extenders isn't outstanding. To specify the electrical quality of CATV equipment several parameters were introduced. Though most are used to specify RF amplifiers in general, CTB, CSO and XMOD are rather typical for CATV equipment.

- Gain & frequency response
- Noise figure
- Phase & group delay
- Hum modulation
- Intermodulation distortion (IMD)
- Standing wave ratio (SWR)
- Composite triple beat (CTB)
- Composite second order (CSO)
- Cross modulation distortion (XMOD)

Over the years multiple methods have been proposed to perform CTB, CSO, or XMOD tests either for lab or in-service use. The latter often make use of the modulated TV carriers present in operational systems. Lab tests instead use well-defined modulated or un-modulated signals. Therefore, comparing lab and field test results must be done with care since data originating from the field doesn't necessarily represent the overall modulation distortion of all line extenders alone. Figures could well include unwanted modulation caused by oxidised connections & soldering, functioning as non-linear detectors. In this application note we describe a procedure suitable for lab use which makes use of multiple R&S® SMU200A or AFQ100A/SMV Vector Signal Generators and a spectrum analyzer.

2 The origin of IMD, CSO, CBT and XMOD products

2.1 *“Two-tone”* intermodulation distortion

“Two-tone” intermodulation is the result of two sinusoidal or non- sinusoidal signals interacting with each other in devices with a non-linear transfer characteristic. This interaction produces additional unwanted or in case of mixers, wanted signals. Unwanted intermodulation usually takes place in active devices such as amplifiers, filters and to a lesser extent, in passive devices found in RF transmission systems. For example, RF connectors on transmission feeds may become corroded over time resulting in them behaving as non-linear semiconductors. The same can apply at the junction of different metals like the contact between solder & the copper clad of PCBs or magnetic materials like ferrite cores used in coils.

CATV line extenders are in essence bi-directional amplifiers shown in the figure below.

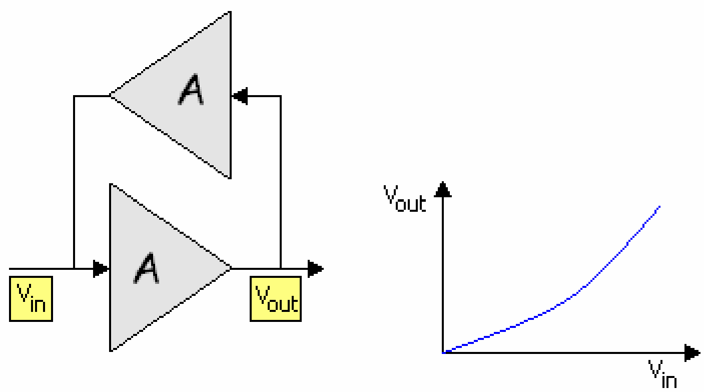


Figure 1 Non-ideal bi-directional amplifier

The transfer characteristic or relationship between the output signal V_{out} and input signal V_{in} of any non-ideal amplification device can be expressed as a polynomial of order N :

$$V_{\text{out}} = \sum_{i=0}^{N} A_i V_{\text{in}}^{i}$$

Where:

$i = 0$: The DC component in the output signal.

If we expand the above summation we get:

$$V_{\text{out}} = A_0 + A_1 V_{\text{in}} + A_2 V_{\text{in}}^2 + A_3 V_{\text{in}}^3 + \ldots..$$

Let’s assume that:

- The input signal V_{in} is the sum of 2 pure sine waves with frequencies f_1 and f_2 and with unity as amplitude.
- The DC component in the output signal can be omitted through AC coupling
- The only significant factors are A_1 and A_2 .

We obtain:

$$V_{\text{out}} = A_1(\sin\omega_1 \text{t} + \sin\omega_2 \text{t}) + A_2(\sin\omega_1 \text{t} + \sin\omega_2 \text{t})^2$$

$$V_{\text{out}} = A_1 \sin\omega_1 \text{t} + A_1 \sin\omega_2 \text{t} + A_2(\sin^2\omega_1 \text{t} + \sin^2\omega_2 \text{t} + 2\ \sin\omega_1 \text{t} \sin\omega_2 \text{t})$$

If we expand and simply the formula we'll obtain the following relationship

$$V_{\text{out}} = A_1 \sin\omega_1 \text{t} + A_1 \sin\omega_2 \text{t} + \frac{A_2}{2}\left(2\text{-}\ \sin 2\omega_1 \text{t-}\ \sin 2\omega_2 \text{t} + \cos(\omega_1 \text{-} \omega_2)\text{t}\ \text{-}\ \cos(\omega_1 + \omega_2)\text{t}\right)$$

The behavior of the amplifier has created 5 different additional components at its output called *"two- tone 2nd order"* intermodulation products:

- $2f_1$: A component with twice the frequency of f_1
- $2f_2$: A component with twice the frequency of f_2
- $f_1 + f_2$: The sum frequency
- $f_2 - f_1$ or $|\ f_1 - f_2\ |$: The difference frequency.
- A_2 : A DC component proportional to the 2nd order term. In reality this DC component has a superimposed low frequency signal due to small frequency fluctuations between the original input signals f_1 and f_2 ,as well as non-linearity instabilities of the amplification device itself.

Observe the phase relationship between the components i.e. minus sign. Furthermore $f_1 - f_2$ and $|\ f_1 - f_2\ |$ are one and the same component and negative frequencies therefore must not be mistaken for an additional component. While calculating the location of *"multi-tone harmonics"* care must be taken not to count the same component twice. This is especially true for theoretical analysis of CSO & CTB where a multitude of carriers are used.

The frequency spectrum of the output signal is shown below.

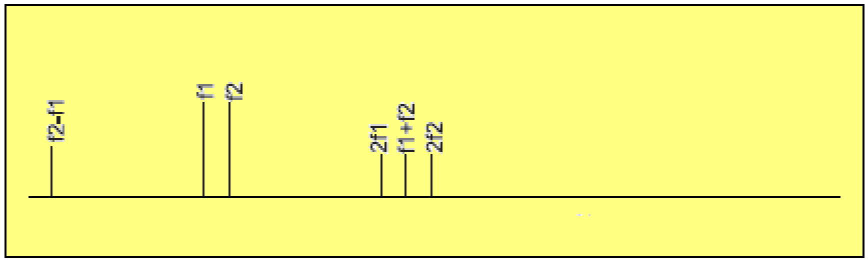


Figure 2 "Two-tone" 2nd order intermodulation products for a device with 1st and 2nd order terms in its transfer function

If we include the 3rd order term and repeat the above deduction:

$$V_{\text{out}} = A_0 + A_1 V_{\text{in}} + A_2 V_{\text{in}}^2 + A_3 V_{\text{in}}^3$$

$$V_{\text{out}} = A_1(\sin\omega_1 \mathrm{t} + \sin\omega_2 \mathrm{t}) + A_2(\sin\omega_1 \mathrm{t} + \sin\omega_2 \mathrm{t})^2 + A_3(\sin\omega_1 \mathrm{t} + \sin\omega_2 \mathrm{t})^3$$

We obtain, in addition to the previous *"two tone 2nd order"* products, the following *"two- tone 3rd order"* intermodulation products:

- $2f_1 - f_2$
- $2f_2 - f_1$
- $2f_1 + f_2$
- $2f_2 + f_1$
- $3f_1$
- $3f_2$

The frequencies $2f_1 - f_2$, $2f_2 - f_1$ are of particular importance because unlike the 2nd order distortion components $2f_1$ and $2f_2$ or the 3rd order products $3f_1$ and $3f_2$, these components appear in the close proximity to the original input signal and may interfere directly with the wanted signal and can't be filtered out easily due to their proximity with the input signals. If the input signal isn't a pure sine wave due to small distortions present inside the signal the second order intermodulation products may also be located in the proximity of the carrier in the same way the third order components do.

Note that the amplitudes of the 2nd and 3rd order components are proportional to the degree of non-linearity. However in case of *"multi-tone"* the total resulting amplitude can't be predicted easily. Depending on degree of non-linearity & the phase relationship between the second and third order intermodulation products may add as power or voltage and may add or reduce the final amplitude of the composite intermodulation product.

Refer to next chapter for details. The entire spectrum of 2nd and 3rd order intermodulation components is shown below.

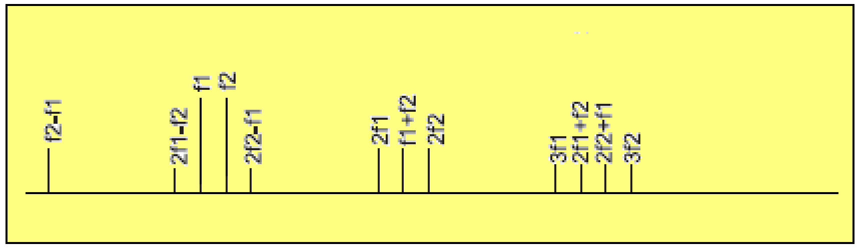


Figure 3 "Two-tone" 2nd & 3rd order intermodulation products for device with 1st, 2nd & 3rd order terms in its transfer function

Example: The *"two- tone"* 2nd and 3rd order intermodulation products for the adjacent *PAL-B* vision carriers channel $E8$ and $E9$ in the VHF band i.e. $196.25MHz$ and $203.25MHz$ are as follows:

Two-tone harmonic frequencies	Frequency (MHz)
2f1	*392.50*
2f2	*406.50*
f1+f2	*399.50*
f1-f2	*7.00*
3f1	*588.75*
3f2	*609.75*
2f1+f2	*595.75*
2f2+f1	*602.75*
2f2-f1	*210.25*
2f1-f2	*189.25*

Table 1 "Two tone" 2nd & 3rd order harmonics for the above-mentioned PAL vision carriers

Figure 4 Harmonics for 2 adjacent PAL carriers

Since a *PAL-B* channel occupies $7MHz$ of bandwidth i.e. $1.25MHz$ below and $5.75MHz$ above the vision carrier, harmonic frequency $2f2\text{-}f1$ will cause interference in channel $E9$.

2.2 *"Multi-tone"* intermodulation distortion

"*Multi-tone"* intermodulation takes place when more than 2 carriers interact with each other in a non-linear system. In the world of cable TV although, the term "*Multi-tone"* intermodulation isn't commonly used and instead the terms "*Composite Second Order"* or *CSO* and *"Composite Triple Beat"* or *CTB* describe the intermodulation performance of CATV equipment when subjected to multiple frequencies. As the terms suggest *CSO* is in fact the vector sum of all the 2nd order "*Two-tone"* intermodulation products at a certain location in the band of interest. The same counts for the *CTB* but instead for the 3rd order intermodulation products.

Even in a CATV operation with a medium load of around 40 TV channels it is far from a surprise that the number of 2nd & 3rd order intermodulation products runs in the hundreds. Seen the fixed spacing between the carrier frequencies (Depending on the TV standard 6.0, 7.0 or $8.0 MHz$) the likelihood of harmonics falling at the same location is high. Since most of the power in a TV channel is concentrated at the actual carrier frequency, the power of the *CSOs* and *CTBs* are concentrated at the location of the harmonic and sub-harmonic products of these carriers as well and therefore it makes sense to determine the intermodulation components in relation to the carrier.

In a PAL-B system the locations of the *PAL-B* vision carriers for a fully occupied CATV system are:

48.25, 55.75, 62.25, 119.25, 126.25, 133.25, 140.25, 147.25, 154.25, 161.25, 168.25,
175.25, 182.25, 189.25, 196.25, 203.25, 210.25, 217.25, 224.25, 231.25, 238.25, 245.25,
252.25, 259.25, 266.25, 273.25, 280.25, 287.25, 294.25, 303.25, 311.25, 319.25, 327.25,
335.25, 343.25, 351.25, 359.25, 367.25, 375.25, 383.25, 391.25, 399.25, 407.25, 415.25,
423.25, 431.25, 439.25, 447.25, 455.25, 463.25, 471.25, 479.25, 487.25, 495.25, 503.25,
511.25, 519.25, 527.25, 535.25, 543.25, 551.25, 559.25, 567.25, 575.25, 583.25, 591.25,
599.25, 607.25, 615.25, 623.25, 631.25, 639.25, 647.25, 655.25, 663.25, 671.25, 679.25,
687.25, 695.25, 703.25, 711.25, 719.25, 727.25, 735.25, 743.25, 751.25, 759.25, 767.25,
775.25, 783.25, 791.25, 799.25, 807.25, 815.25, 823.25, 831.25, 839.25, 847.25., 855.25

These positions determine at the same time the position of the *CSOs* and *CTBs*.

- *CSO* components

As we just mentioned the locations of the *CSOs* depend on the used frequency plan. A computer simulation or manual calculation shows that the *CSOs* for the above frequency plan must always be located at one or more of the following frequencies.

$$f_{\text{harm/sub-harm}} = f_{\text{carr}} + n/4 \text{ MHz}$$

Where n is a signed integer $\neq 0$.

The following simulation data shows the 2nd order sum and difference intermodulation products of a fully occupied PAL-B CATV system which fall within a $7MHz$ bandwidth of UHF channel 37 (Located @ 599.25 MHz)

Difference frequencies f1-f2 :

f1=161.25 f2=759.25 f2 - f1 |f1-f2|)=598.00

f1=217.25 f2=815.25 f2 - f1 (|f1-f2|)=598.00

f1=48.25 f2=647.25 f2 - f1 (|f1-f2|)=599.00

f1=168.25 f2=767.25 f2 - f1 (|f1-f2|)=599.00

f1=224.25 f2=823.25 f2 - f1 (|f1-f2|)=599.00

f1=55.25 f2=655.25 f2 - f1 (|f1-f2|)=600.00

f1=119.25 f2=719.25 f2 - f1 (|f1-f2|)=600.00

f1=175.25 f2=775.25 f2 - f1 (|f1-f2|)=600.00

f1=231.25 f2=831.25 f2 - f1 (|f1-f2|)=600.00

f1=62.25 f2=663.25 f2 - f1 (|f1-f2|)=601.00

f1=126.25 f2=727.25 f2 - f1 (|f1-f2|)=601.00

f1=182.25 f2=783.25 f2 - f1 (|f1-f2|)=601.00

f1=238.25 f2=839.25 f2 - f1 (|f1-f2|)=601.00

f1=133.25 f2=735.25 f2 - f1 (|f1-f2|)=602.00

f1=189.25 f2=791.25 f2 - f1 (|f1-f2|)=602.00

f1=245.25 f2=847.25 f2 - f1 (|f1-f2|)=602.00

f1=140.25 f2=743.25 f2 - f1 (|f1-f2|)=603.00

f1=196.25 f2=799.25 f2 - f1 (|f1-f2|)=603.00

f1=252.25 f2=855.25 f2 - f1 (|f1-f2|)=603.00

f1=147.25 f2=751.25 f2 - f1 (|f1-f2|)=604.00

f1=203.25 f2=807.25 f2 - f1 (|f1-f2|)=604.00

f1=154.25 f2=759.25 f2 - f1 (|f1-f2|)=605.00

f1=210.25 f2=815.25 f2 - f1 (|f1-f2|)=605.00

Sum frequencies f1+f2 :

f1=55.25 f2=543.25 f1+f2=598.50

f1=119.25 f2=479.25 f1+f2=598.50

f1=175.25 f2=423.25 f1+f2=598.50

f1=231.25 f2=367.25 f1+f2=598.50

f1=287.25 f2=311.25 f1+f2=598.50

f1=48.25 f2=551.25 f1+f2=599.50

f1=168.25 f2=431.25 f1+f2=599.50

f1=224.25 f2=375.25 f1+f2=599.50

f1=280.25 f2=319.25 f1+f2=599.50

f1=161.25 f2=439.25 f1+f2=600.50

f1=217.25 f2=383.25 f1+f2=600.50

f1=273.25 f2=327.25 f1+f2=600.50

f1=154.25 f2=447.25 f1+f2=601.50

f1=210.25 f2=391.25 f1+f2=601.50

f1=266.25 f2=335.25 f1+f2=601.50

f1=147.25 f2=455.25 f1+f2=602.50

f1=203.25 f2=399.25 f1+f2=602.50

f1=259.25 f2=343.25 f1+f2=602.50

f1=140.25 f2=463.25 f1+f2=603.50

f1=196.25 f2=407.25 f1+f2=603.50

f1=252.25 f2=351.25 f1+f2=603.50

f1=133.25 f2=471.25 f1+f2=604.50

f1=189.25 f2=415.25 f1+f2=604.50

f1=245.25 f2=359.25 f1+f2=604.50

Some of the intermodulation products, not shown in the above list but are nevertheless present, fall at the edges of the $7MHz$ TV channels and don't cause any interference. It is clear that the *CSOs* are always at least $250kHz$ away from the carrier and can only appear at the frequencies defined by the above formula. Remember that the formula is only valid for *PAL-B* schemes. *NTSC* and other frequency plans may have *CSOs* at different locations. In fact for *NTSC* systems the sum frequencies fall $1.25MHz$ above and the difference frequencies $1.25MHz$ below the carrier according to the following relationship:

$$f_{harm} = 6.n+2.5\ \text{MHz}$$

$$f_{sub\text{-}harm} = 6.n\ \text{MHz}$$

Where n is an unsigned integer.

- *CTB* components

Again we can simulate or calculate the locations of the 3rd order components for the *PAL-B* frequency plan and determine that these must be located at the following frequencies.

$$f_{harm} = f_{carr} + n/2\ \text{MHz}$$

$$f_{sub\text{-}harm} = f_{carr} - n/2\ \text{MHz}$$

Where n is an unsigned integer including 0.

The previous formula shows us that the *CTBs* are always located on the carrier itself or $500kHz$ away from the carrier.

The following simulation data show the 3rd order components $2f2\text{-}f1$ and $2f1+f2$ that fall within a $7MHz$ bandwidth of UHF channel 37 (Located @ 599.25 MHz)

Intermodulation products 2f2+f1:

f1=55.25	f2=273.25	2f1+f2=601.75
f1=126.25	f2=238.25	2f1+f2=602.75
f1=140.25	f2=231.25	2f1+f2=602.75
f1=154.25	f2=224.25	2f1+f2=602.75
f1=168.25	f2=217.25	2f1+f2=602.75
f1=182.25	f2=210.25	2f1+f2=602.75
f1=196.25	f2=203.25	2f1+f2=602.75

Intermodulation products 2f2-f1:

f1=168.25	f2=383.25	2f2-f1=598.25
f1=280.25	f2=439.25	2f2-f1=598.25
f1=55.25	f2=327.25	2f2-f1=599.25
f1=119.25	f2=359.25	2f2-f1=599.25
f1=231.25	f2=415.25	2f2-f1=599.25
f1=311.25	f2=455.25	2f2-f1=599.25
f1=327.25	f2=463.25	2f2-f1=599.25
f1=343.25	f2=471.25	2f2-f1=599.25
f1=359.25	f2=479.25	2f2-f1=599.25
f1=375.25	f2=487.25	2f2-f1=599.25
f1=391.25	f2=495.25	2f2-f1=599.25
f1=407.25	f2=503.25	2f2-f1=599.25
f1=423.25	f2=511.25	2f2-f1=599.25
f1=439.25	f2=519.25	2f2-f1=599.25
f1=455.25	f2=527.25	2f2-f1=599.25
f1=471.25	f2=535.25	2f2-f1=599.25
f1=487.25	f2=543.25	2f2-f1=599.25
f1=503.25	f2=551.25	2f2-f1=599.25
f1=519.25	f2=559.25	2f2-f1=599.25
f1=535.25	f2=567.25	2f2-f1=599.25
f1=551.25	f2=575.25	2f2-f1=599.25
f1=567.25	f2=583.25	2f2-f1=599.25
f1=583.25	f2=591.25	2f2-f1=599.25
f1=182.25	f2=391.25	2f2-f1=600.25
f1=294.25	f2=447.25	2f2-f1=600.25
f1=133.25	f2=367.25	2f2-f1=601.25
f1=245.25	f2=423.25	2f2-f1=601.25
f1=196.25	f2=399.25	2f2-f1=602.25
f1=147.25	f2=375.25	2f2-f1=603.25
f1=259.25	f2=431.25	2f2-f1=603.25
f1=210.25	f2=407.25	2f2-f1=604.25

An additional observation is that the number of 3rd order intermodulation products that end-up at the same location is higher at the band edges than in the centre of the band. The same is true for the 2nd order sum frequencies which pile up towards the upper edge of the band while the difference frequencies pile up at the lower edge of the band.

The 3 graphs on the following page tell us the relative strength and position of *CSOs* & *CTBs* in case the 42 carriers defined in the EN50083-3 test standard for cable TV systems are used. The graphs display the quantity vs. position of four 2nd and 3rd order intermodulation products in the proximity of the vision carrier of 3 TV channels one at a low-band frequency, one mid-band, and respectively one upper-band frequency.

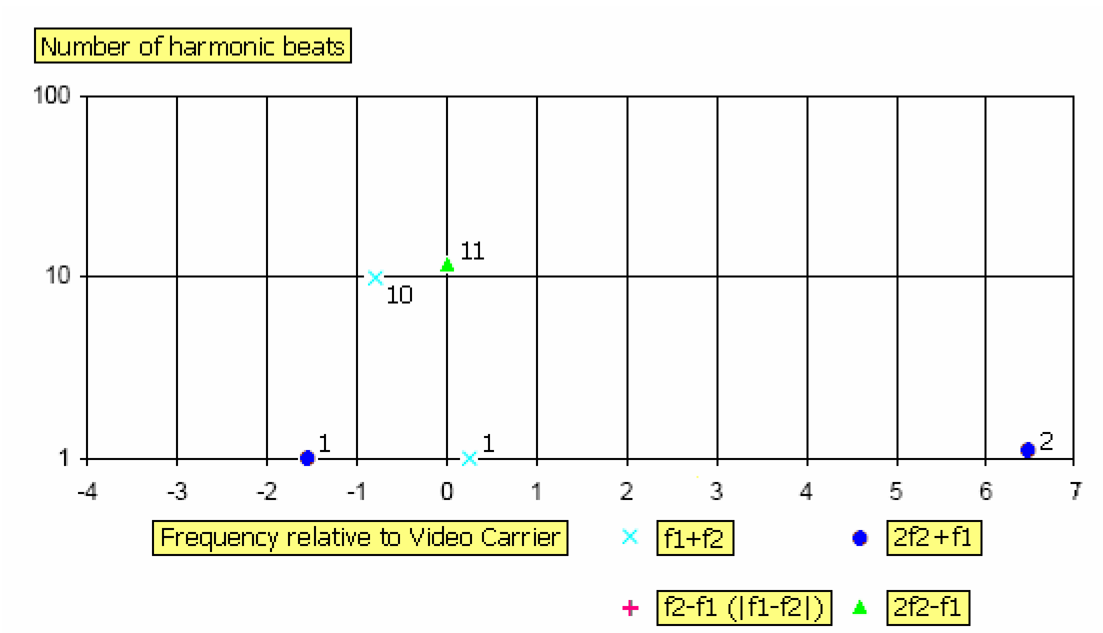


Figure 5 Some important 2nd & 3rd order harmonics of EN50083-3 test carriers @ upper band edge UHF channel 69 or 855.25 MHz

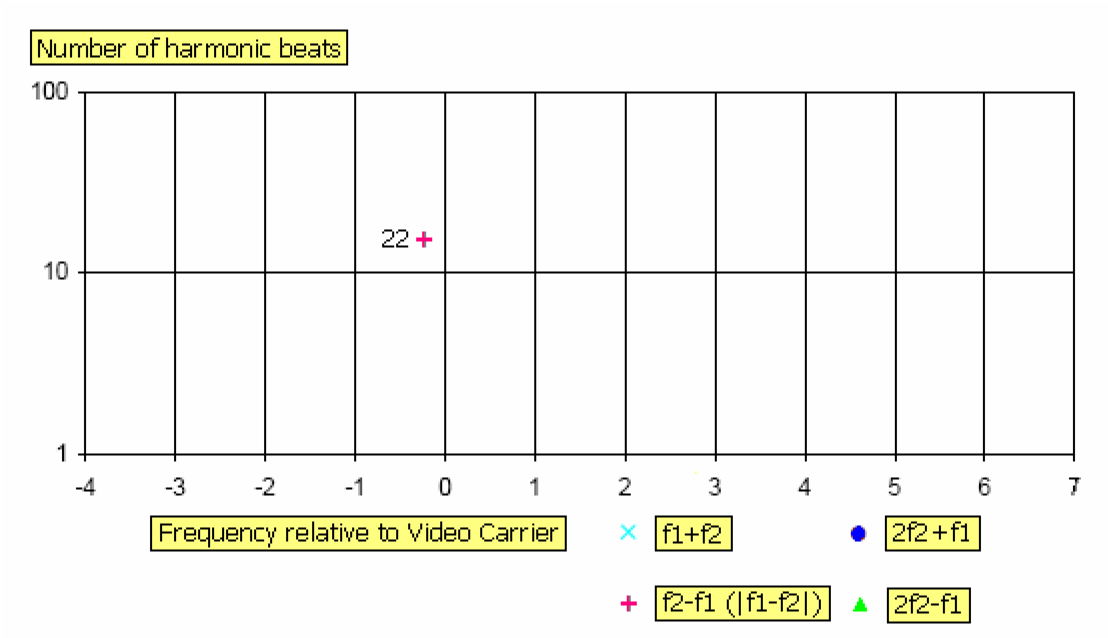


Figure 6 Same @ lower band edge VHF channel E2 or 48.25MHz

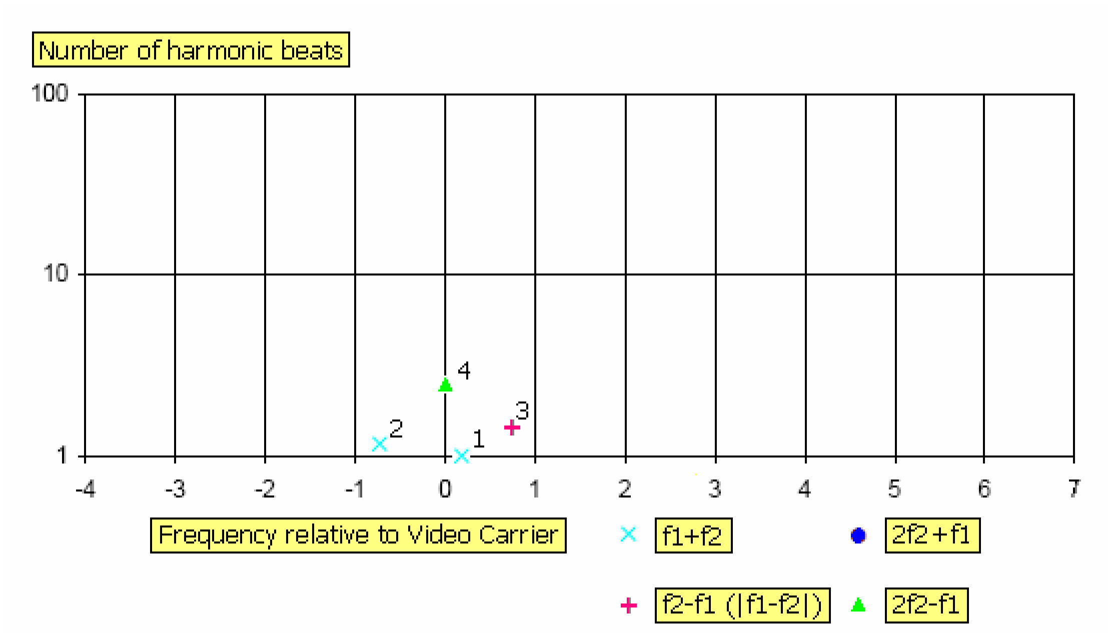
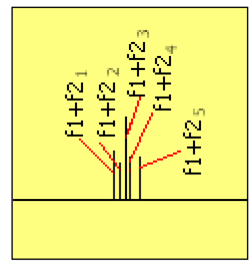


Figure 7 Same @ mid-band channel UHF S36 or 423.25MHz

2.3 Some notes on the magnitude of intermodulation products

2.3.1 Noise-like behavior



At first it may seem odd that the topic of noise is mentioned in an application note related to the measurement of intermodulation distortion, however when we have a closer look at the way the large number of required carrier signals are generated to perform *CSO* and *CTB* tests, one may observe that the generated intermodulation products have noise-like behavior. In a real laboratory test set-up the first approach that comes to mind to generate the test signal is the use of discrete generators each set at a different frequency.

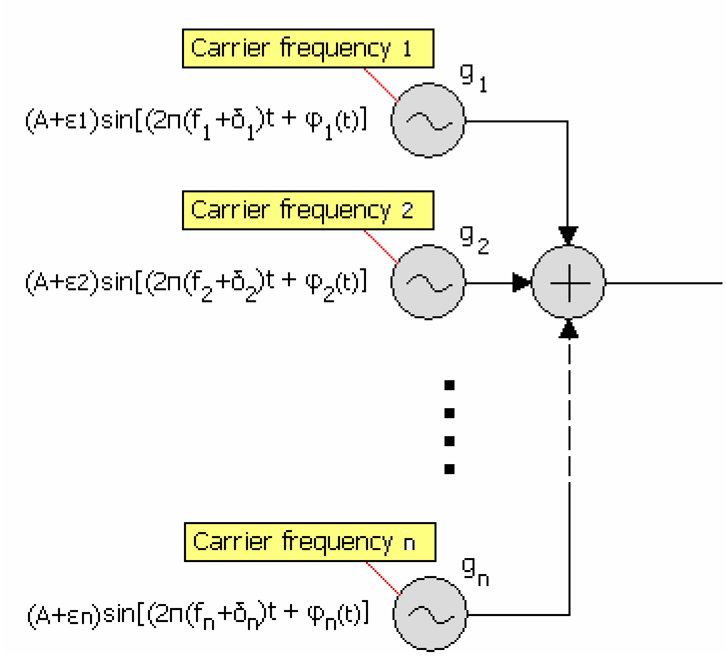


Figure 8 Multiple carrier signal generated with discrete oscillators

Because of imperfections in the oscillators inside the generator spacing between the different carriers deviates from its theoretical value, both in time as well as by fixed offsets: Imperfections mean:

- Frequency jitter or phase noise $\varphi_n(t)$ affects the spacing between carriers over time.
- Fixed offsets δ_n in the spacing between carriers affect the exact location.

In practice this means that the intermodulation products of the carrier signals

$$A_n \sin\left[2\pi(f_n + \delta_n)t + \varphi_{n(t)})\right]$$

which should have fallen at discrete locations don't do so in practice but instead fall within a finite bandwidth centered on the theoretical location of the intermodulation product. If the number of used carriers is large enough the probability distributions of $\varphi_n(t)$ and δ_n are Gaussian, and so are $\varphi_n(t)$ and δ_n of the intermodulation products. This also indicates that if we want to measure the power of the intermodulation products at a specific location with a spectrum analyzer we need a finite resolution bandwidth *(RBW)* as well. This however introduces some additional problems.

Which *RBW* should we use for the spectrum analyzer's IF filter?

Any measurement is in fact the sum of the intermodulation products and noise.

$$P_{tot} = P_{imd} + P_n$$

Where: P_n : Noise power within the chosen RBW

P_{imd} : Power of the intermodulation products within the RBW.

Depending on the chosen *RBW* the instrument's power reading around the theoretical frequency of the intermodulation product P_{tot} may be under or overweighed. If the *RBW* of the spectrum analyzer is set too narrow certain intermodulation components aren't included in P_{imd} effectively reducing the reading, while at the other hand if the *RBW* is set too wide the noise power P_n will add to the actual reading. This is shown below.

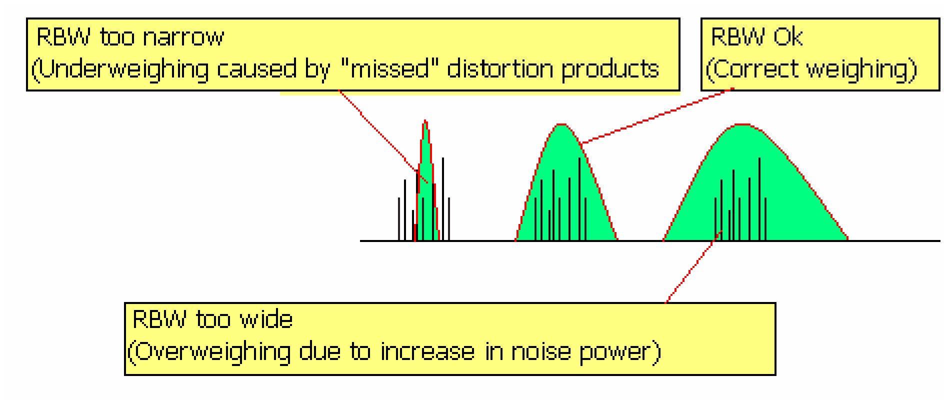


Figure 9 Effect of the RBW on the result of CSO & CTB measurements

The result is inaccuracies in the measurement. To ensure reproducibility & communality in the measurements the relevant test standards *EN50083-3, NCTA* and *EIJ ET-2301* mentioned in the subsequent chapter usually define a *RBW* of $30.0kHz$ when measuring *CSO* & *CTB*. This value has been determined empirically at the time. The share of noise power in the measurement can be calculated in the following way.

$$\mathrm{P_n = P_{danl} + 10log(NBW/Hz)}$$

Where:

P_n : The noise power reading

P_{danl} : Displayed average noise level *DANL* of the spectrum analyzer in dBm/Hz

NBW : Equivalent noise bandwidth (*NBW)* of the instrument in Hz

In our practical set-up we make use of an *R&S®FSL Spectrum Analyzer.* This instrument has a *DANL* below $-140\mathrm{dBm/Hz}$ within the frequency band of interest of $45\ \mathrm{MHz\ to\ 900\ MHz}$, while the *NBW* is 1.2 times the *RBW* resulting in the the following noise power:

$$\mathrm{P_n} = -140.0 + 10\log(3.6_{10}{}^4) \approx -94.5dBm$$

This means that intermodulation products below that level can't be measured anymore. One may ask why it is necessary to measure distortion products below the noise floor of the instrument, after all $-90dBm$ is comparatively low to the nominal signal levels of possible intermodulation levels of CATV amplifiers. The answer lies in the large number of cascaded amplifiers used in a real life scenario where a cable system extends over several kilometers and contains a multitude of cascaded amplifiers. Since the intermodulation products produced by the cascaded amplifiers have a constant phase relationship they add as voltage every time they pass through the amplifier. Noise however adds as powers eventually lifting the intermodulation distortion above the noise floor. Distortion products that were meaningless in the 1st amplification stage become considerable in the last stage emphasizing on the need to measure distortion product as low as possible.

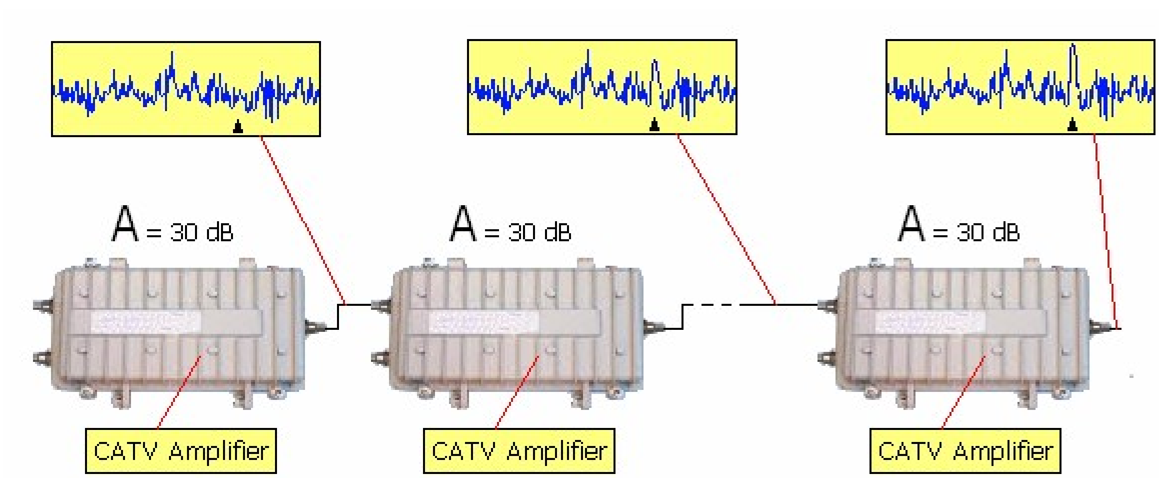
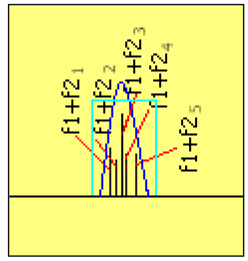
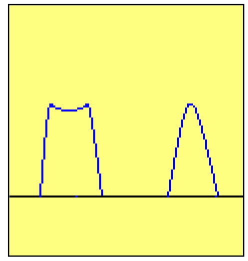


Figure 10 Cascading effect of amplifiers

- Correcting the effect of the non-rectangular shape of a spectrum analyzer's IF filter.

To measure the cluster of carriers correctly the IF filter of the spectrum analyzer must have the perfect rectangular shape represented by the cyan rectangle shown at the right. Such ideal filter shape isn't possible in reality and depending on the number of poles & type a practical filter has a shape closer to the ones shown below. This means that the signals that are further away from the center frequency are either underweighted or overweighted. Since the spectrum analyzer is only calibrated to measure sine waves correctly at center frequency this introduces measurement errors. To correct these errors, a parameter called *Equivalent Noise Bandwidth (NBW)* has been introduced. The *NBW* is the width of a filter with a hypothetical rectangular shape with the same area under its curve as the actual one. The *R&S®FSL Spectrum Analyzer* has a Gaussian filter in its IF (*RBW*) circuitry. The *NBW* for such filter is approximately $1.065 \times \mathrm{RBW}$ or $0.27\mathrm{dB}$. This means that if the power level is measured with a regular marker function the reading must be corrected by $\approx 0.79dB$. Many spectrum analyzers have a noise marker which does the required correction.





- Correcting the effect envelope detector.

In the first paragraph we determined that the cluster of discrete intermodulation products has a noise like behavior. To measure the power of noise-like signals we need to take the following into consideration. The probability density function or *PDF* of the amplitude of white Gaussian noise is a Rayleigh distribution. It is easy to understand that for a given δ, the $PDF = 0$ for $u = 0$ and $u = \infty$ and reaches is maximum for $u = \delta$.

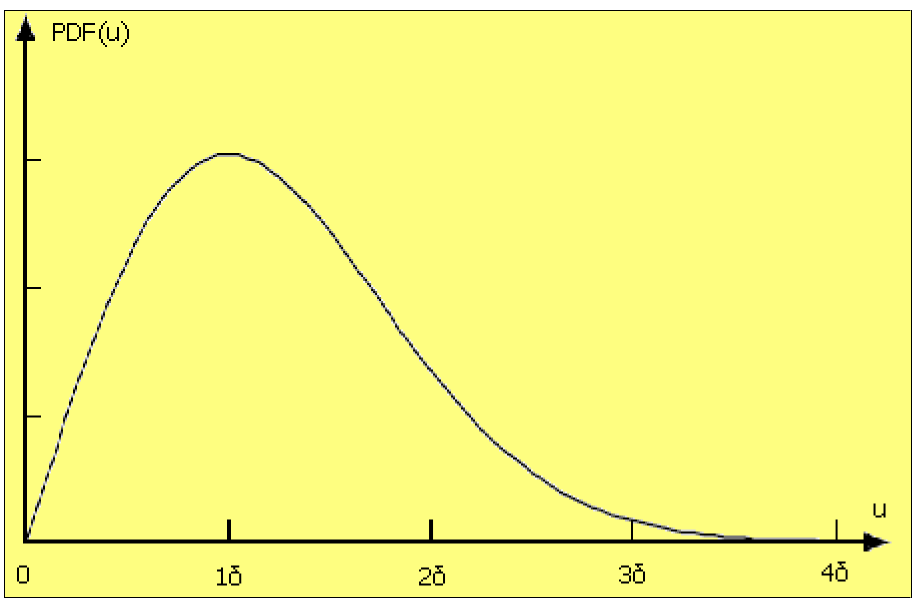


Figure 11Amplitude distribution of Gaussian noise

This is shown in the above figure. To find the average noise power $\overline{p}$ we need to find the average noise voltage $\overline{v}$ and subsequently calculate the power. For a 50Ω system the average power is:

$$\overline{p} = \left(\overline{v}\right)^2/50$$

So to determine the average voltage of white Gaussian noise we simply calculate the area under the distribution curve:

$$\overline{v} = \int_0^{\inf} vPDF(v)dv = \delta\sqrt{\pi/2}$$

Inserting the first equation into the previous equation gives us the average power $\overline{p}$:

$$\overline{p} = \int_0^{\inf} \left(\frac{v}{50}^2\right) PDF(v)dv = \frac{\delta^2}{25}$$

We know that the detector inside the spectrum analyzer is adjusted to correctly display the levels of a sine wave. This means that the power displayed on the spectrum analyzer's screen is the average voltage $\overline{v}$ which is squared (And then divided by 50), while to display the power of noise correctly we need to square the individual discrete frequency components inside the noise signal and than sum the squares. If we determine the ratio of both calculation methods we can determine the measurement error.

$$\text{err} = \frac{\left(\delta\sqrt{\pi/2}\right)^2/50}{\delta^2/25} = \frac{\pi}{4}$$

Or

$$\text{err}_{\text{dB}} = 10\log(\pi/4) = -1.05\text{dB}$$

This means that when noise is measured with a sample detector the reading is consistently underweighted by $-1.05dB$.

Summarized this means that when measuring a cluster of intermodulation products caused by a large amount of discrete signals we need to take the following factors into account:

1. Overweighting due to the non-rectangular shape of the spectrum's analyzer *IF* filter: Reduce the measurement by $0.79dB$
2. Underweighting due to non-sinusoidal nature of the noise signal: Add $1.05dB$ or when a logarithmic scale is used $2.51dB$ to the measurement.
3. Inability to measure composite distortion products below $-94.5+10 \approx -84.5dBm$.

2.3.2 What are the solutions?

Solutions for the above-mentioned shortcomings aren't readily available. Reducing the *RBW* of the spectrum analyzer reduces the noise contributions, but increases the risk of not capturing intermodulation products at the edges of the cluster ultimately resulting in little improvement.

- Increasing the carrier levels

One solution is to increase the carrier levels above the normal operation levels of the amplifier. Since the 2nd order modulation increases with the square & the 3rd intermodulation product with the cube i.e. it is possible to extrapolate the higher levels back to the normal operating levels of the amplifier. Care must be taken though that the amplifier isn't operating in its non-linear region. This method is only possible when the behavior of the amplifier is completely known outside of its normal operating region.

- Using modulated signal

Some engineers perform composite intermodulation tests with carriers that are amplitude modulated with a low frequency square wave at a modulation index of 100%. The intermodulation products experience the same modulation. Since a known relationship exists between the sidebands & the carrier levels it is possible to demodulate the intermodulation signals and measure the levels of the demodulated signal. This system uses a spectrum analyzer to convert the frequency down while the IF output of the instrument is then connected to an external detector to retrieve the modulation signal. The actual measurement takes place with a LF spectrum analyzer with a very narrow bandwidth between $1-2kHz$ leading to a reduced level of noise power. This method brings a lot of advantages but is complex to execute and requires certain experience.

- Vector generators

Vector or arbitrary waveform generators use FFTs to generate their output signal. The reference signal used by the FFT is derived from a free running oscillator. If we operate the instrument in multi-carrier mode the distance between the carriers is very accurate and only limited by the calculation resolution of the FFT. In case multiple generators are required to generate enough carriers we may opt to synchronise all instruments to the same clock reference. This leads to a multi-carrier signal with very accurate spacing and no jitter between the carriers. This however still doesn't solve the overall jitter of the reference oscillator. The latter can be solved by synchronizing the spectrum analyzer with the reference clock of the vector generator. With this method we are able to reduce the *RBW* of the spectrum analyzer to $3kHz$, dramatically decreasing the contribution of noise power. It is this method that we use in the subsequent chapters.

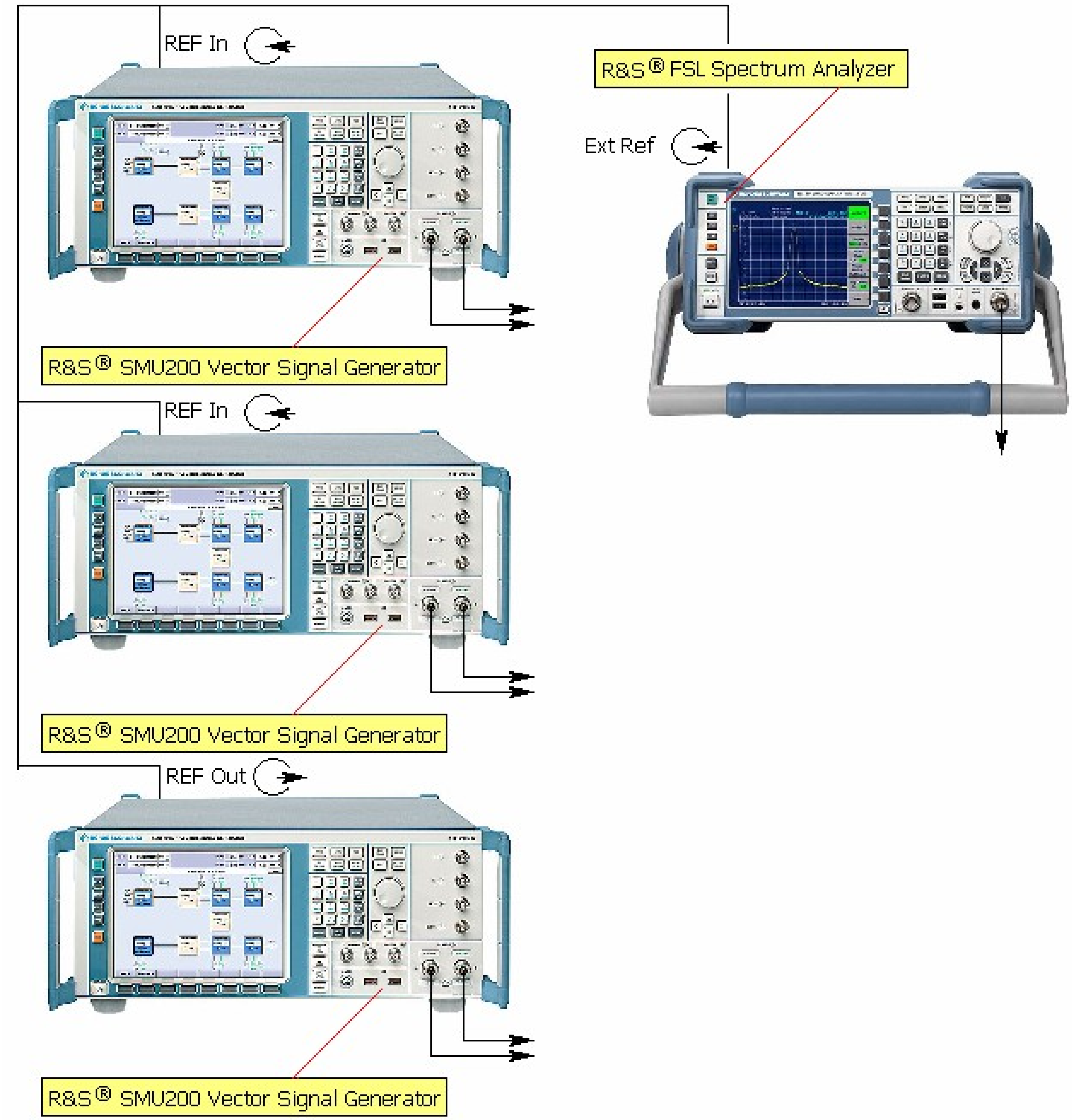


Figure 12 Set-up for improved composite intermodulation distortion measurements

3 Test standards

Although QA departments and R&D labs may determine in-house test procedures & maximum limits for *CSO*, *CTB* & *XMOD* figures to measure the quality of their CATV amplifiers, there in fact 4 existing test standards which refer to this matter. All 4 standards define measurement procedures & set limit values, however there are no common definitions for the terms *CSO*, *CTB* & *XMOD*. In addition there are also no uniform cross-standard measurement procedures and these procedures are furthermore not always binding. The table below lists 4 common test standards.

Geo-area	Test standard	CSO	CTB	XMOD
International	*IEC 728-1*	Yes	Yes	Yes
Europe	*EN 50083-3*	Yes	Yes	Yes
Japan	*EIJ ET-2301*	Yes	Yes	Yes
US	*NCTA / FCC (National Cable TV Association)*	Yes	Yes	Yes

Table 2 CATV performance test standards

We explain the differences in interpretation of the 3 terms across the different standards. For more details refer to the respective documents mentioned in Table 2.

- *EN50083-3* standard

(1) The *CTB* figure is expressed as the ratio of the level of the wanted carrier in the target channel under test to the mean level of largest 3rd order composite intermodulation product appearing within a 7 or $8 MHz$ TV channel.

$$\text{CTB} = \frac{\text{Level wanted carrier @ target channel}}{\text{Mean level of largest } 3^{\text{rd}} \text{order composite intermodulation product within 7/8 MHz band of target channel}}$$

(2) The *CSO* figure is expressed as the ratio of the level of the wanted carrier in the target channel under test to the mean level of largest 2nd order composite intermodulation product appearing within 7 or $8 MHz$ TV channel.

$$\text{CTB} = \frac{\text{Level wanted carrier @ target channel}}{\text{Mean level of largest } 2^{\text{nd}} \text{order composite intermodulation product within 7/8 MHz band of target channel}}$$

(3) *XMOD* is expressed as the ratio of the level of the wanted carrier at the target channel under test to the composite level of the unwanted intermodulation components in the proximity of the wanted carrier resulting from the modulation in other channels

$$\text{XMOD} = \frac{\text{Level wanted carrier @ target channel}}{\text{Level modulated components @ target channel from other channels}}$$

The specified measurement procedures for *CSO* & *CTB* define a *RBW* of $30kHz$ and *VBW* of $10Hz$ but no specific measures are suggested to handle the noise-like behavior of *CSO* & *CTB. "Equivalent"* measurement procedures are allowed. The standard specifies which carrier frequencies must be used and every carrier must be used as target carrier to locate the worst case value.

- *NCTA* standard

(4) *CTB* figure is expressed as the ratio of the level of the wanted carrier at the target channel under test to the composite of the 3rd order intermodulation products dispersed around the target carrier.

$$\text{CTB} = \frac{\text{Level wanted carrier @ target channel}}{\text{Mean level of composite 3}^{\text{rd}}\text{order beats dispersed around target channel}}$$

(5) *CSO* is expressed as the ratio of the level of the wanted carrier at the target channel under test to the highest composite level of the 2nd order intermodulation components dispersed around $0.75MHz$ and $1.25MHz$ above and below the target channel.

$$\text{CSO} = \frac{\text{Level wanted carrier @ target channel}}{\text{Mean level of largest composite 2}^{\text{nd}}\text{order beats dispersed around 0.75MHz \& 1.75MHz below and above target channel}}$$

(6) *XMOD* is expressed as the ratio of the level of the wanted carrier at the target channel under test to the composite level of the unwanted intermodulation components in the proximity of the wanted carrier resulting from the modulation in other channels

$$\text{XMOD} = \frac{\text{Level wanted carrier @ target channel}}{\text{Level modulated components @ target channel from other channels}}$$

The specified measurement procedures for *CSO* & *CTB* define a *RBW* of $30kHz$ and *VBW* of $100Hz$ but no specific measures are suggested to handle the noise-like behavior of *CSO* & *CTB. "Equivalent"* measurement procedures are allowed. The standard specifies which carrier frequencies must be used and every carrier must be used as target carrier to locate the worst case value.

- *EIJ ET-2301* standard

(7) *CTB* figure is expressed as the ratio of the level of the wanted carrier at the target channel under test to the composite level of the 3rd order intermodulation products dispersed around the target carrier. The carriers for all channels available in the band must be switched on i.e. full occupation.

$$\mathrm{CTB} = \frac{\text{Level wanted carrier @ target channel}}{\text{Mean level of composite } 3^{\text{rd}}\text{order beats dispersed around target channel}}$$

(8) *CSO* figure is expressed as the ratio of the level of the wanted carrier in the target channel under test to the mean level of largest 2nd order composite intermodulation product appearing within the $6MHz$ TV channel. The carriers for all channels available in the band must be switched on i.e. full occupation

$$\mathrm{CTB} = \frac{\text{Level wanted carrier @ target channel}}{\text{Mean level of largest } 2^{\text{nd}}\text{order composite intermodulation product within 6 MHz band of target channel}}$$

(9) *XMOD* is expressed as the ratio of the level of the wanted carrier at the target channel under test to the composite level of the unwanted intermodulation components in the proximity of the wanted carrier resulting from the modulation in other channels

$$\mathrm{XMOD} = \frac{\text{Level wanted carrier @ target channel}}{\text{Level modulated components @ target channel from other channels}}$$

The carriers for all channels available in the CATV band must be switched on i.e. full occupation.

4 Performing an IMD test

4.1 Test set-up

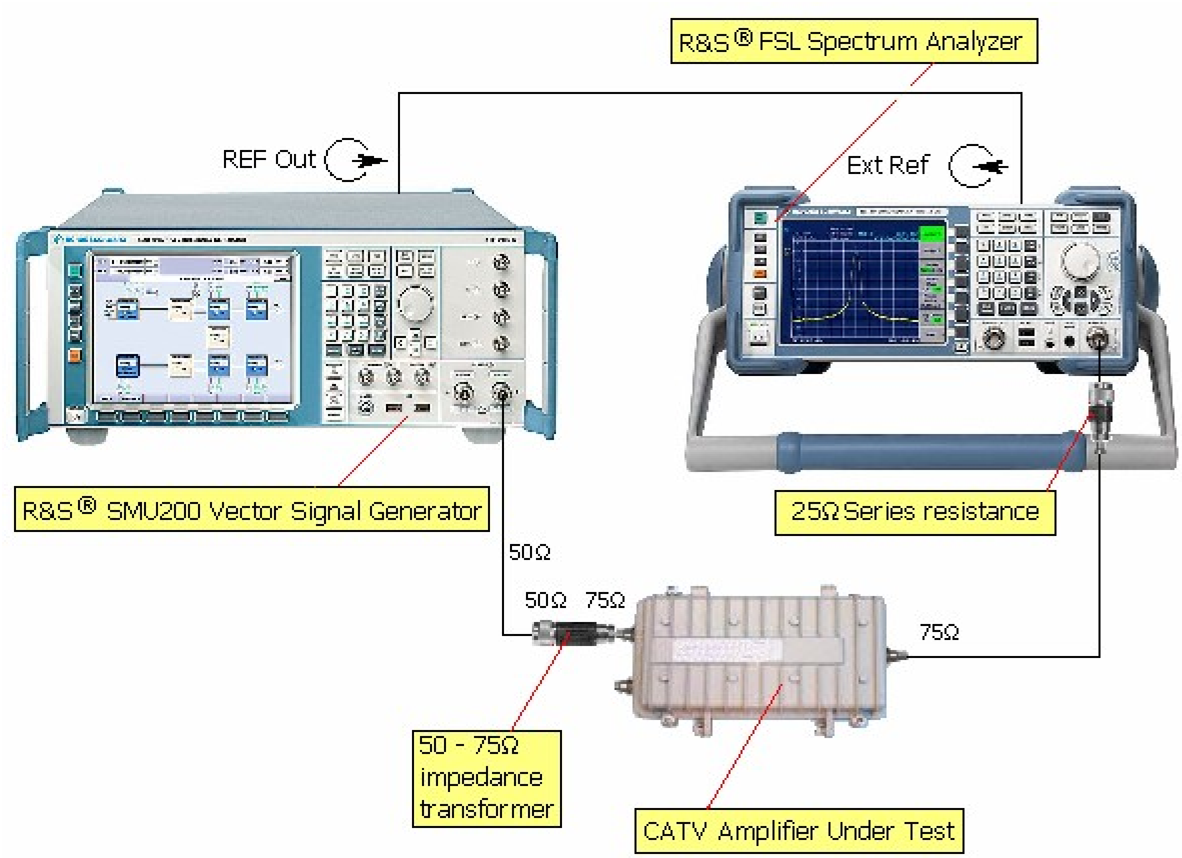


Figure 13 Test set-up for IMD test

Connect the instruments as shown in the previous figure. The commonly used standardised impedance for CATV systems is 75Ω instead of 50Ω commonly used for test & measurement equipment. This means that a matching pad is required to adapt the generator's output impedance to the input impedance of the CATV *Amplifier Under Test*. The output of the *Amplifier Under Test* however may be connected directly to the *R&S® FSL Spectrum Analyzer.* A series resistance of 25Ω at the input of the instrument (*R&S® RAZ*) converts the input impedance to 75Ω. The required correction of the spectrum analyzer's vertical scale by $10\log(50/75) = -1.76\text{dB}$ due to the attenuation caused by the series resistance is done automatically when the instrument is set to 75Ω. In our set-up we used a *Pico-Macom® PIDA-1000 Broadband Bi-directional Push-Pull Distribution Amplifier* meant for indoor usage to replace the lack of availability of an outdoor CATV line extender.

Figure 14 Pico-Macom® PIDA-1000 Broadband Bi-directional Push-Pull Distribution Amplifier

The nominal output level of this device is $40\mathrm{dBmV}$ or $-8.8\mathrm{dBm}$ in a 75Ω system while the intermodulation distortion figures are as follows

Figure	Forward path (dB)	Reverse Path (dB
CTB	*-53.0*	-60.0
CSO	*-56.0*	-60.0
XMOD	*-54.0*	-60.0
HUM	*-70.0*	-65.0
IMD	*N/A*	*N/A*

Table 3 Intermodulation specifications of the Amplifier Under Test

4.2 Test details

An *IMD* test determines the 2nd and 3rd order intermodulation products resulting from two or three non-modulated carriers. The *IMD* figure is the difference between the carrier level and the level of the intermodulation products expressed in dB.

$$S/I = l_{carr} - l_{dist} .$$

Where:

S/I_{imd} : The Intermodulation distortion in dBc

l_{carr} : Carrier level in dBm

l_{dist} : Level of distortion product

An *IMD* test is preferably done twice once with 2 adjacent channels in the respective band & subsequently with 2 signals which are located at the edges of the band. The intermodulation components that fall outside the operating range of the *Amplifier Under Test* must not be taken into account. Since 2nd order distortion products don't fall anywhere near other carriers they are only important for broadband devices with a range of more than one octave. 3rd order intermodulation products are important for narrowband as well as broadband amplifiers like the device we use in our set-up. In our example we use the following PAL-B VHF frequencies to perform the test.

	Carrier frequency 1 (MHz)	Carrier frequency 2 (MHz)
Adjacent channels	*175.25 (PAL-B VHF-III Ch E5)*	*182.25 (PAL-B VHF-III Ch E6)*
Far channels	*48.25 (PAL-B VHF-I Ch E2)*	*224.25 (PAL-B VHF-III Ch E12)*

Table 4 Carriers frequencies used in the IMD test

4.3 Preparations

On the R&S®SMU200

- Remove the *Amplifier Under Test* and connect the *R&S®SMU200* directly to the spectrum analyzer. Maintain the matching pad.
- Press the green Preset key
- Turn the Rotary knob clockwise or counterclockwise until the Baseband icon is active. Press the Rotary knob inwards to open the Context Menu and select Multicarrier in the Context Menu with the Rotary knob.

- Enter 2 in the Number of Carriers field and set the Carrier Spacing $@\,7.0MHz$, the channel spacing for PAL-B. Subsequently set the State to On and close the window. Keep the remaining settings at default setting as shown below.

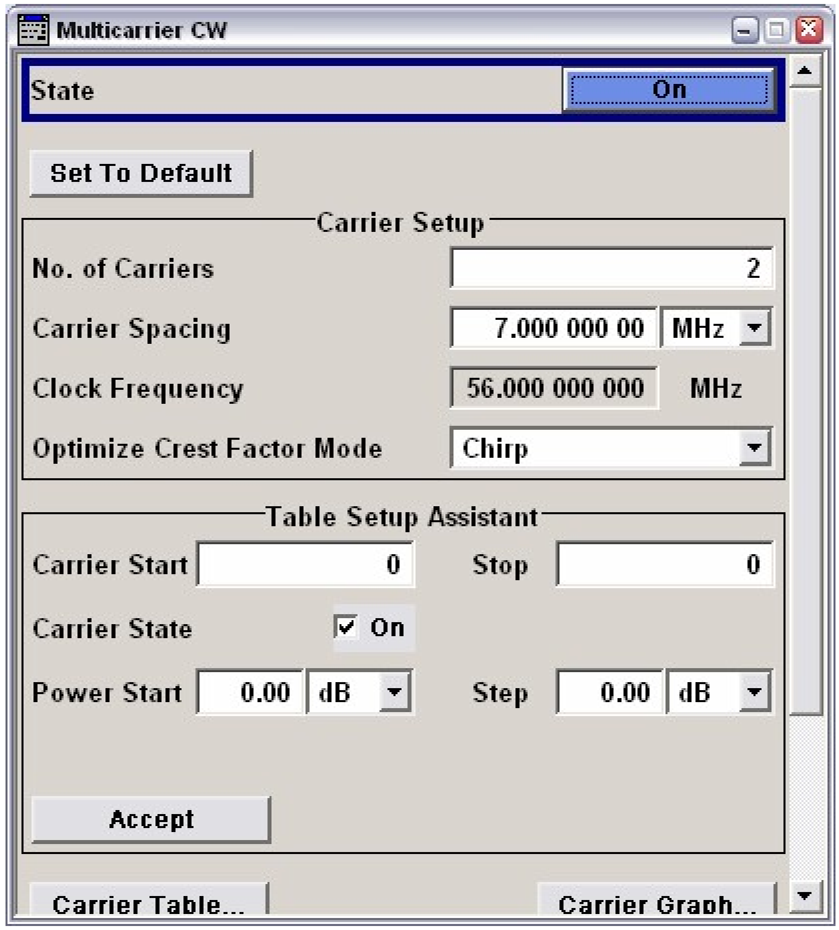
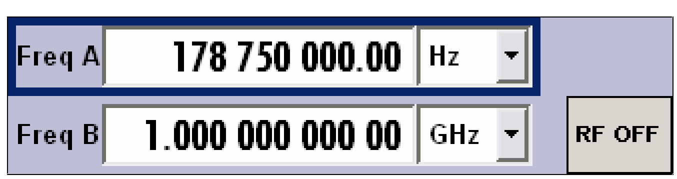


Figure 15 Multicarrier settings window

- Although the 2 carriers appear as 2 separate frequencies in the spectrum, the *R&S® SMU200 Vector Signal Generator* uses a FFT algorithm on the internal reference oscillator to generate the output signal. For this purpose the main generator Freq A must be set right in the centre of the 2 carrier frequencies that you want the generator to produce. i.e. $175.25 + 7.0/2 = 178.75MHz$. Press the Freq button on the front panel and enter the respective value.

- Press the Level key and set the output level of Output A provisionally to the nominal input level of the *Amplifier Under Test* which is in our case $-8.8dBm - 30dB = -38.8dBm$.
- Press the RF On/Off key and verify if the RF Off icon disappears. Follow the subsequent steps to verify the presence and correctness of the dual carrier signal with the spectrum analyzer.



On the R&S® FSL.

- Press the green Preset key
- Set the instrument to External Ref in the Setup menu.
- Press the Frequency key and set the Center Frequency to $178.75 MHz$. Subsequently press Span button and set to $10.0 MHz$. Both carriers should now be visible on the spectrum analyzer.
- Press the BW key and Res BW Manual softkey on the instrument's display and set this parameter to $100.0 kHz$. Press the Video BW Manual softkey and set to $5.0 kHz$
- Press the AMPT key and change the Reference Level until the top of the carriers are in the upper ¾ of the display. Observe the overflow IFOVL indicator at all times to avoid additional intermodulation distortion created by the spectrum analyzer. The display should look like the one below.

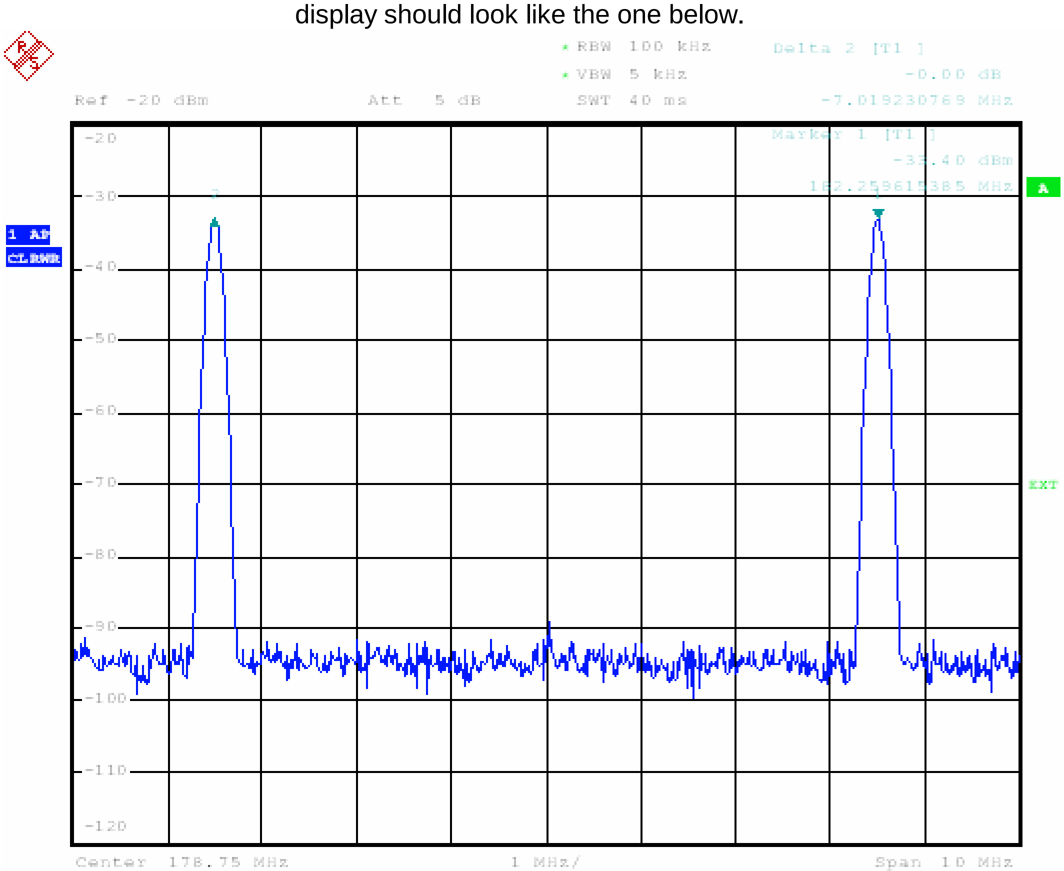


Figure 16 The level difference between both carriers must be within a certain margin to obtain accurate IMD measurements

- Press the MRK button and subsequently Marker2 softkey. The delta marker now indicates the difference between both carriers. To obtain an accurate *IMD* measurement the level of both carriers must not differ more than $0.25dB$. The accuracy of the FFT algorithm in the *R&S® SMU200 Vector Signal Generator* makes such unlikely nevertheless adjust the level of the individual carriers in the Carrier Table 

accessible via the Multicarrier CW configuration window, should such be the case.

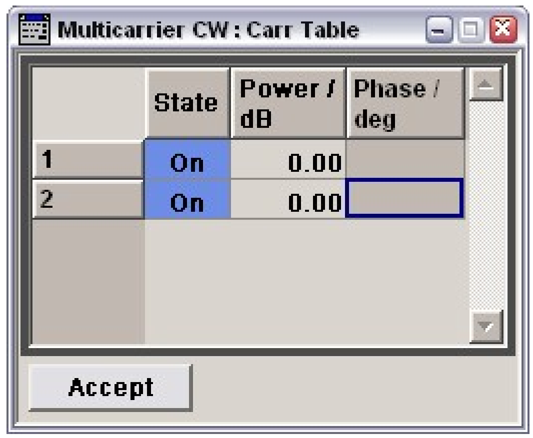


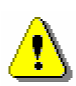
Figure 17 Multi-carrier Table

- Verify the presence of intermodulation products generated by the vector generator itself. Intermodulation products appear at the following frequencies.

	Frequency 1 (MHz)	Frequency 2 (MHz)	Location of intermodulation product (MHz)
f2 – f1	*175.25*	*182.25*	*7.00*
f1 + f2	*175.25*	*182.25*	*357.50*
2f1 – f2	*175.25*	*182.25*	*168.25*
2f2 – f1	*175.25*	*182.25*	*189.25*
2f2 + f1	*175.25*	*182.25*	*539.75*
2f1 + f2	*175.25*	*182.25*	*532.75*

Table 5 2nd & 3rd order harmonics for 175.25 & 182.25 MHz

Press the Frequency key and change the centre frequency to the values in the previous table. If necessary increase the sensitivity of the instrument to measure the lower level magnitudes.


Be aware that the level of the two carrier frequencies is far above that of potential harmonics generated by the generator and may drive the spectrum analyzer in saturation when sensitivity is increased. This creates harmonic distortions inside the analyzer that aren't present in the input signal. Alternatively a filter may be used in the set-up to avoid such from happening. The harmonic

components should be at least $10.0dB$ below the levels of the expected magnitude of the intermodulation products generated by the *Amplifier Under Test.* Refer to the next chapter *"How to perform a CSO test"* for details on a suitable filter. Also respect the *1dB compression point* of the *R&S® FSL* which lies around $5dBm$. For line extenders with a high output power insert an attenuator.

4.4 Measurement procedure

Your system is now ready to perform the actual measurement.

- Re-insert the *Amplifier Under Test* and switch it on.
- Press the Frequency key and set the Center Frequency of the spectrum analyzer back to the original $178.75MHz$. Press the Level key on the *R&S® SMU* and adjust Level A if required until the amplifier reaches its nominal output level ($-8.8dBm$).Press the MRK button and read the marker value. Record this value as l_{carr}.
- Press the Frequency key and change the centre frequency settings to the first intermodulation frequency stated in the table 5. Set the Span to $20.0kHz$.
- The level of the intermodulation products is very low and to avoid overweighing caused by noise we must reduce the Resolution BW. Press the BW key and set the Resolution BW and Video bandwidth to $1.0kHz$ respectively $10.0-100.0Hz$

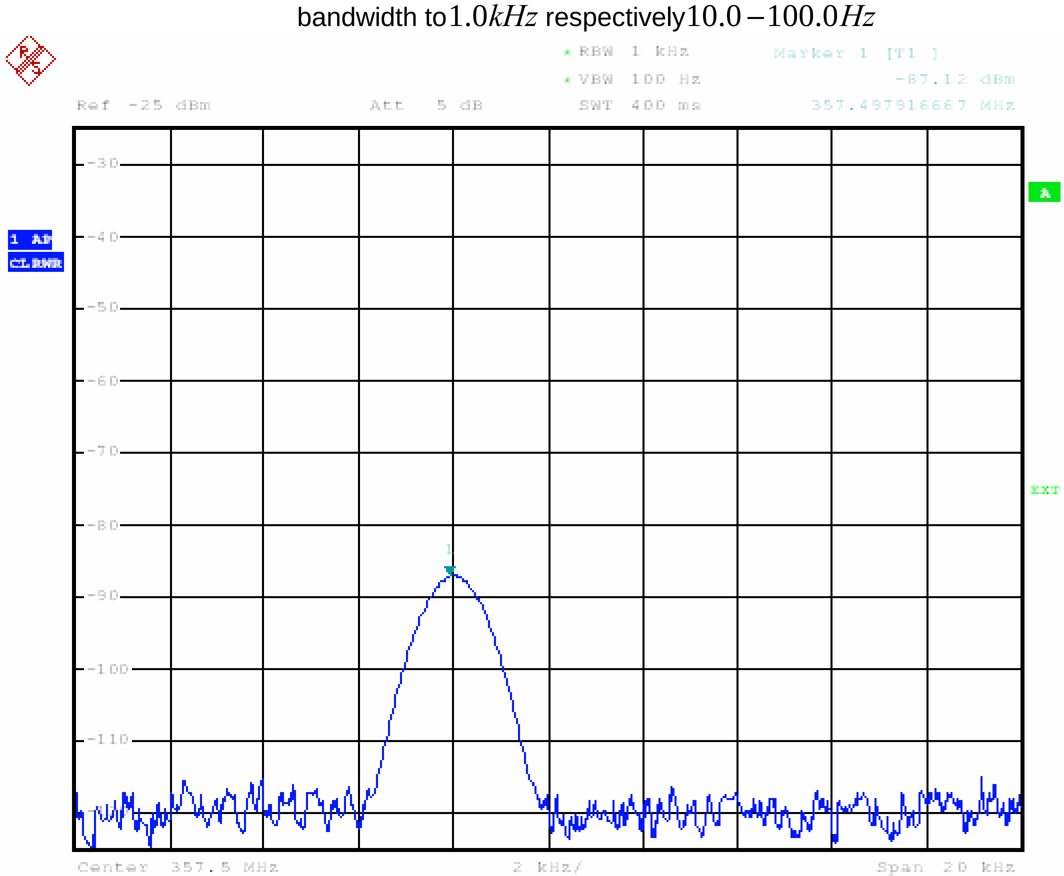


Figure 18 Intermodulation component

- Switch the marker on and off (Press MRK button twice) and read the marker value again. Record this value as l_{dist}.
- Repeat the previous steps at the location of the remaining intermodulation products listed in table 5. Intermodulation products that are located outside the frequency range of the amplifier or outside the used TV band don't need to be taken into account.

  Again be aware that the level of the two carrier frequencies is far above that of potential harmonics generated by the generator and may drive the spectrum analyzer in saturation when sensitivity is increased. This creates harmonic distortions inside the analyzer that aren't present in the input signal. Alternatively a band pass filter or CATV pre-selector may be used in the set-up to avoid such from happening.
- The *IMD* figure is the difference of the carrier level in dBm and the level of the intermodulation products. Unless the obtained figures are used for R&D purposes only the worst-case value is reported in data & specification sheets.

$$S/I = l_{carr} - l_{dist}\ .$$

Where:

S/I_{imd} : The Intermodulation distortion in dBc

l_{carr} : Carrier level in dBm

l_{dist} : Level of distortion product in dBm

5 Performing a CSO test

5.1 Test set-up

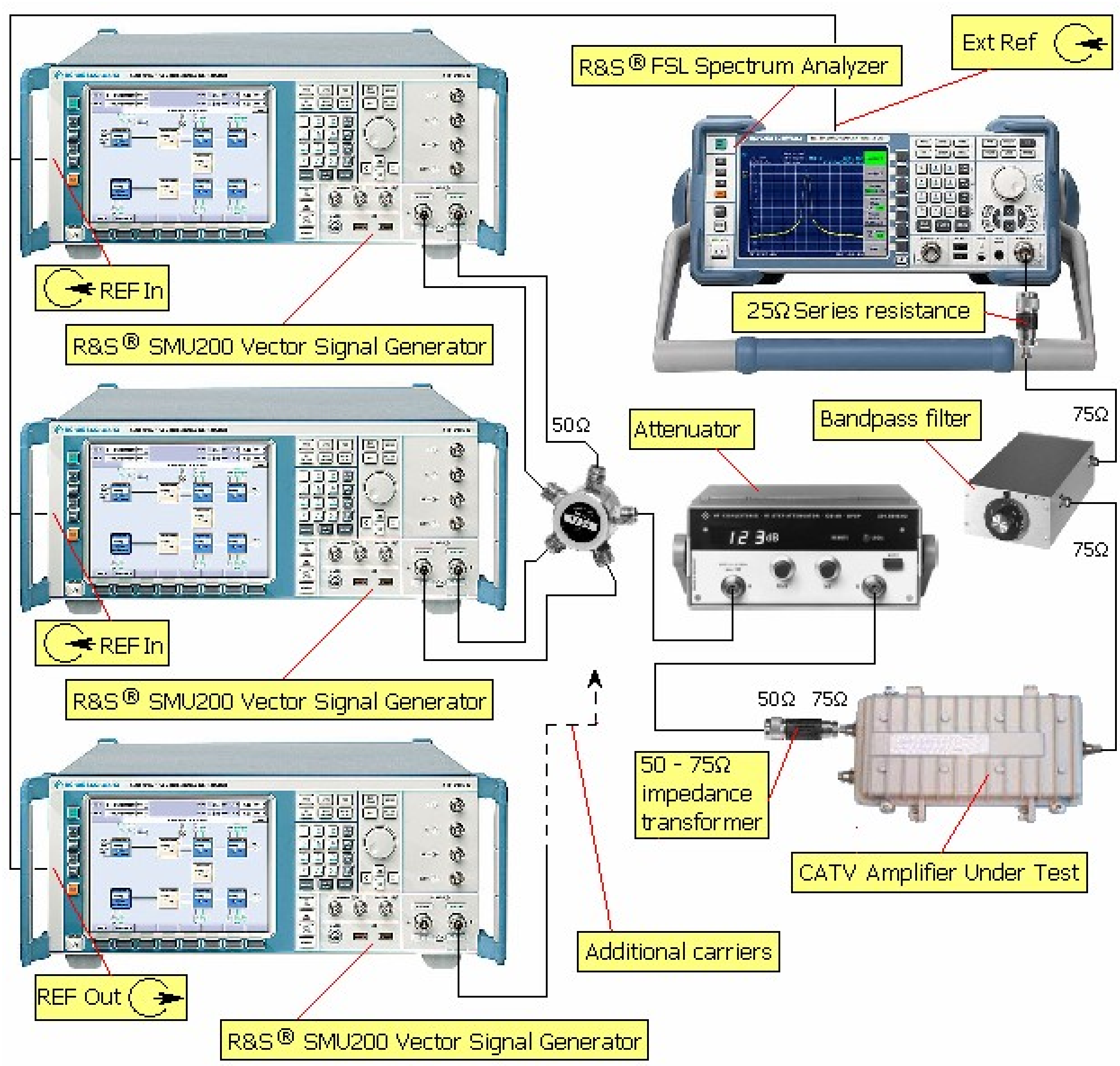


Figure 19 Test set-up for CTB test

Connect the instruments as shown in figure 19. While in reality the number of *R&S® SMU200A Vector Signal Generators* needed depends on the amount of carriers you would like to generate, we only use 2 generators in our set-up. The next paragraph shows how to calculate the number of generators. If more generators are to be connected use a RF power combiner with more inputs and connect them in the same manner as the other generators. Terminate eventually unused inputs with 50Ω terminators. Since resistive RF power combiners are fully symmetrical and don't provide any isolation between the inputs (The isolation loss from one input to another input is only $6dB$), the generator output signals may influence each other and create unwanted intermodulation products at the source in addition to the intermodulation generated by the *Amplifier Under Test.* If these intermodulation products show unacceptably high magnitudes, measures must be taken to reduce them. Discrete or lumped component combiners have a much higher isolation loss (Up to $40dB$) and should be the preferred choice to resolve the problem. Impedance matching can again be achieved via a $50\Omega / 75\Omega$ matching pad.

- Attenuator

Any attenuator with a frequency range of $40MHz - 1GHz$ and attenuation range of $40dB$ is adequate. Suitable models include the *R&S®RSG, RSP, DPSP & DPS* attenuators*.* The use of an attenuator is strictly speaking not required since output levels can be set on the generators however it greatly simplifiers the test procedure since all carrier levels can be adjusted at the same time with one single operation.

-

A bandpass filter is required at the output of the CATV *Amplifier Under Test* to avoid overdriving the spectrum analyzer when measuring low level intermodulation components. Any bandpass filter with the correct bandwidth ($8.0MHz$ for PAL-B) is suitable however most practical is the use of CATV pre-selectors like the *Trilithic Inc® VF or DCF-5* series or a *Wavetek® PP75.* These devices are available for PAL as well as NTSC frequency schemes and come with 75Ω standardised impedance. The channel/frequency can be set via a selector switch or for the models with electronic control via a keypad or interface.

5.2 Test details

- Number of required generators

The *R&S® SMU200A* incorporates 2 fully independent RF generators, both with frequency ranges than cover the entire VHF/UHF spectrum. However only Output A has the ability to generate multiple carriers. Furthermore the number of carriers for Output A is restricted to the instrument's bandwidth which is currently $80.0\,MHz$. To determine the maximum number of un-modulated carriers use the following formulas:

$$n_{\mathrm{maxOutA}} = \frac{80}{\Delta f} + 1 \quad .$$

$$n_{\mathrm{maxOutB}} = 1$$

Where:

$n_{\max}$: Maximum number of carriers that can be generated

Δ_f : Carrier spacing in MHz

Example: At a $8MHz$ carrier spacing the instrument is able to generate $11 + 1 = 12$ carriers.

If you make use of fully equipped *R&S® SMU200A* generators with 2 baseband modules (Options *R&S® SMUB10/11)* you can further increase the number of carriers per generator i.e:

$$n_{\text{maxOutA}} = \frac{80}{\Delta f} + 1$$

$$n_{\text{maxOutB}} = \frac{80}{\Delta f} + 1$$

or in the above example a total of 22 at $8MHz$ carrier spacing.

Alternatively a combination of

- *R&S® AFQ100A IQ Modulator*
- *R&S® SMV03 Vector Signal Generator*

may be used to generate the necessary carriers. The *R&S® AFQ100A* has a bandwidth of $100MHz$ allowing $200MHz$ of RF bandwidth. This results in a total of 26 carriers @ $8MHz$ frequency spacing.

The *R&S® AFQ100A* doesn't have any front panel controls and is to be controlled via an IEEE bus & remote control software *WinIQSim.* This software can be downloaded free of charge from the *Rohde & Schwarz* website. To emulate an *R&S® SMU200A Vector Signal Generator* in the above set-up connect one of the instrument's I/Q-outputs to the I/Q-inputs of the *R&S® SMV03* generator. This is shown below. The RF output of the generator may then be connected in the same way as shown in figure 19.

Figure 20 AFQ100A/SMV03 combination as an alternative to SMU200A

The maximum number of carriers can be calculated as follows:

$$n_{\max} <= \frac{200}{\Delta f} + 1.$$

Where:

$n_{\max}$: Maximum number of carriers that can be generated

Δ_f : Carrier spacing in MHz

Although it is up to the discretion of the test engineer to determine the number & location of the carriers used in a *CSO* test, relevant test standards like the *EN50083-3* in fact do specify carriers for the purpose of making plausible comparisons between different amplifiers specifications. *EN50083-3* specifies the number and location of the carriers to be used in the table on the following page. The *EIJ ET-2301* and *NCTA* standards specify similar test carrier plans. Refer to the respective standard for the necessary details.

One additional hurdle is the fact that the carriers in the test plan aren't equidistantly spaced from each other. This increases the number of required generators. All test carriers are located on a $8\,MHz$ raster except the first one. We creatively make use of the second generator output (output B) to create this carrier. This configuration allows us to switch carriers without the cost of additional generators since the above formula guarantees a constant ratio between carrier spacing & number of carriers as long as the carriers are located on a fixed raster.

Test carrier No	Frequency (MHz)	Frequency Raster (MHz)	*R&S®* SMU200A	*R&S® AFQ100A/ SMV03 & 1 SML03*
1	*48.25*	*71.00*	*Generator 1 B*	*Generator 1*
2	*119.25*	*56.00*	*Generator 2 B*	*Generator 2*
3	*175.25*	*16.00*	*Generator 3 B*	
4	*191.25*	*16.00*	*Generator 4 B*	
5	*207.25*	*16.00*	*Generator 5 B*	
6	*223.25*	*16.00*	*Generator 6 B*	
7	*231.25*	*8.00*	*Generator 7 B*	
8	*247.25*	*16.00*	*Generator 1A*	*Generator 3*
9	*263.25*	*24.00*		
10	*287.25*	*48.00*		
11	*311.25*	*16.00*	*Generator 2A*	
12	*327.25*	*16.00*		
13	*343.25*	*16.00*		
14	*359.25*	*32.00*		
15	*375.25*	*16.00*	*Generator 3A*	
16	*391.25*	*16.00*		
17	*407.25*	*16.00*		
18	*423.25*	*32.00*		*Generator 4*
19	*439.25*	*8.00*		
20	*447.25*	*16.00*	*Generator 4A*	
21	*463.25*	*16.00*		
22	*479.25*	*16.00*		
23	*495.25*	*16.00*		
24	*511.25*	*16.00*		

25	527.25	16.00		
26	543.25	24.00	Generator 5A	
27	567.25	16.00		
28	583.25	16.00		
29	599.25	16.00		
30	663.25	16.00		Generator 5
31	679.25	16.00	Generator 6A	
32	695.25	16.00		
33	711.25	16.00		
34	727.25	16.00		
35	743.25	16.00		
36	759.25	16.00		
37	775.25	16.00	Generator 7A	
38	791.25	16.00		
39	807.25	16.00		
40	823.25	16.00		
41	839.25	16.00		
42	855.25	16.00		

Table 6 Generator allocation plan for EN50083-3 (SMU200A with one baseband unit SMU-B10)

With a fully equipped *R&S® SMU200* the amount of generators needed can be reduced to 4.

The effectiveness of the *R&S® AFQ100A/SMV03* combination becomes immediately clear from the figures in table 7. Since we are able to allocate a total of 26 carriers to one single generator combination the required number of instruments reduces dramatically.

In our test we follow the *EN50083-3* test plan. Since we only have 2 *R&S® SMU200* generators to our disposal we know that by applying the above formula we can only assign 6 carriers to the 1st generator as well as another 6 for the 2nd generator. This rather low figure is due to the fact that the spacing between 2 carriers is considerable $16\,MHz$ in fact. The table below shows the carrier allocation plans for both generators.

Test carrier No	Frequency (MHz)	Frequency Raster (MHz)
Generator 1/ A		
37	775.25	16.00
38	791.25	16.00
39	807.25	16.00
40	823.25	16.00
41	839.25	16.00
42	855.25	16.00

Generator 1/ B		
1	*48.25*	*71.00*
Generator 2/A		
31	*679.25*	*16.00*
32	*695.25*	*16.00*
33	*711.25*	*16.00*
34	*727.25*	*16.00*
35	*743.25*	*16.00*
36	*759.25*	*16.00*
Generator 2/ B		
2	*119.25*	*56.00*

Table 7 Carrier allocation plan used in our test

- Combiners

RF combiners provide a simple way to combine the output signals of several RF sources. The theoretical insertion loss of regular resistive combiner can be calculated as follows:

$$\mathrm{A_{nom}} = 3.0\,(\mathrm{n}\text{-}1)$$

Where:

A_{nom} : Insertion loss from input to output in dB

n : Number of ports

For a 3-port device this is $6.0\,dB$. On its own this doesn't need to be a problem however the $6\,dB$ isn't fully dissipated in the combiner but in practice half of it flows to the other input. Without some form of isolation, the two sources can modulate with each other, either by the non-linear characteristics of the source output circuitry or leakage into the phase lock or level control circuits. These modulation products fall at the exact same frequencies as the one we want to measure and are indistinguishable from them. The result is measurement errors.

Unless a generator can be found that is able to produce enough carriers we can only minimize the problem. One solution is to make use of discrete component combiners which provide a considerable isolation improvement over regular resistive combiners i.e. $40\,dB$ and more. Further enhancements are possible by including a directional device or filter in front of the combiners however this increases the complexity of the set-up tremendously. The following picture shows an intermodulation component $f_1 + f_2$ of $60.77\,dBc$ generated by combining output A and B of an *R&S® SMU200A*. The one below shows a $10\,dB$ improvement when another type of combiner is used.

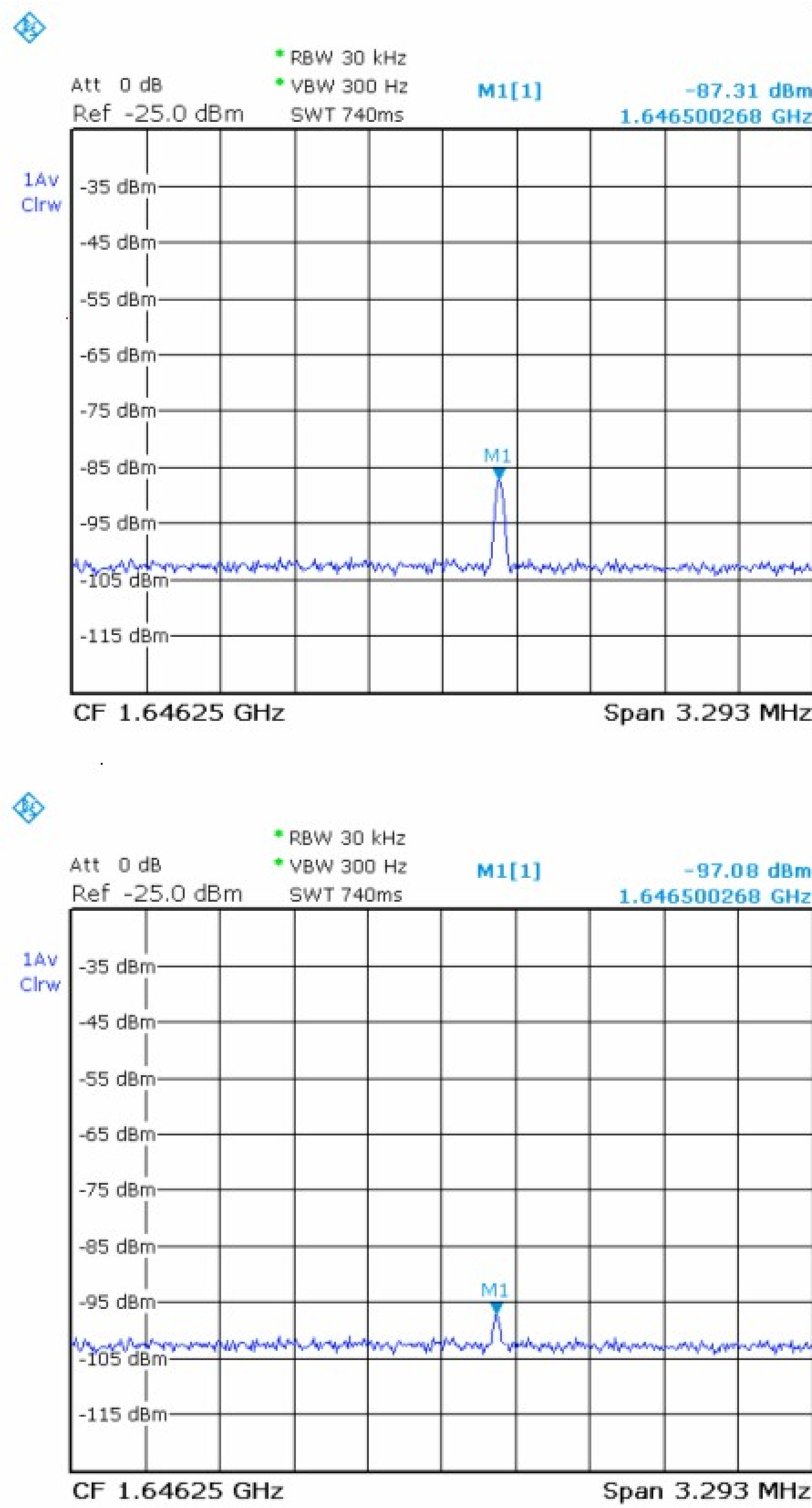


Figure 21 Modulation @ source with 2 different RF combiner types

Some additional tips on the use of combiners.

- Hybrid combiners & splitters offer excellent isolation & good frequency response but don't cover the full CATV frequency band. **They can only be used for CATV UHF line extenders** but not for VHF devices.
- Resistive RF power-combiners/dividers have excellent frequency flatness over a very wide band but only provide $6dB$ isolation between inputs i.e. the same as the actual insertion loss for 2 discrete frequencies from one port to another. Ranges starting from DC to several GHz aren't uncommon. **If resistive power combiners are used the intermodulation products at the source must be verified. They are also best used in combination with isolation whenever possible i.e. narrowband filters.**
- Discrete or lumped-component splitters/combiners offer excellent isolation if matching is properly done and have a flat response over several octaves. **They are the preferred type for this application.**

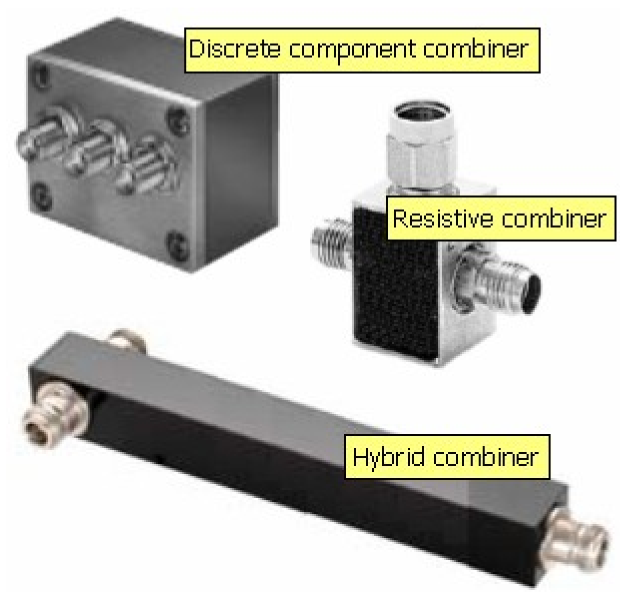


Figure 22 Different RF combiner types

- To increase isolation cascade discrete power-combiners or use 4-port combiners/splitters and only use the conjugate inputs.
- Ferrite isolators are only available for narrow frequency bands. In the best case they can be used for *IMD* tests with 2 or 3 carriers. They aren't suitable for *CTB*, *CSO* or *XMOD* applications except within a very complex setting.
- Additional bandpass filters between the generator & RF-combiner may improve isolation but increases complexity.

5.3 Preparations

On the R&S® SMU200 generators

- Remove the *Amplifier Under Test* and bandpass filter or CATV pre-selector and connect the output of the attenuator directly to the *R&S® FSL.* Maintain the $50/75\Omega$ matching pad.
- Press the green Preset key
- Turn the Rotary knob clockwise or counterclockwise until the Baseband icon is active. Press the Rotary knob inwards to open the Context Menu and select Multicarrier in the Context Menu with the Rotary knob.
- Enter 6 in the No of Carriers field and set the Carrier Spacing $@16.0MHz$, the channel spacing required for the PAL-B test carriers defined in appendix A of *EN50083-3*. Subsequently set the State to on and close the window. The remaining settings must be kept at the default value.

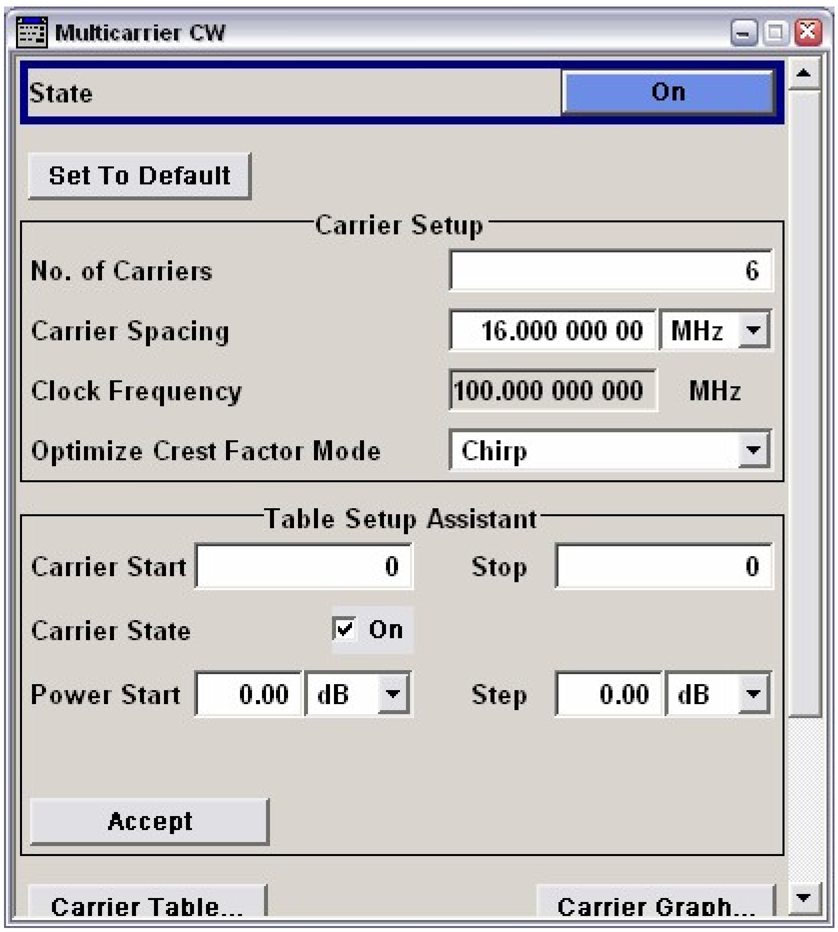


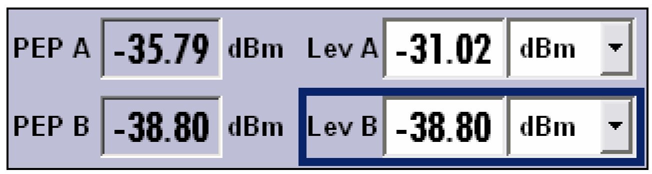
Figure 23 Multi-carrier settings window

- Although the 6 carriers appear as 6 discrete frequencies in the spectrum, the *R&S® SMU200 Vector Signal Generator* uses a FFT algorithm on the reference oscillator to generate the output signal. For this purpose the main generator i.e. Freq A must be set right in the centre of the 6 carrier frequencies i.e.

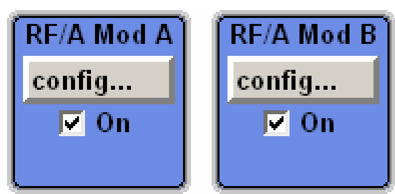
$775.25 + (855.25 - 775.25)/2 = 815.25 MHz$. Press the Freq button on the front panel and enter the respective value.

- Press the Freq key again and set Freq B to $48.25 MHz$.

- Press the Level key and set the output level of output A provisionally to the nominal input level of the *Amplifier Under Test,* in this case $-8.8 dBm + 7.78 dB - 30.0 dB = -31.02 dBm$ The $7.78 dB$ comes from the fact that the overall level setting of the instrument is spread over 6 carriers or $10\log(1/6) \approx 7.78 dB$. Press the Level key again and set the level of output B to $-8.8 dBm - 30.0 dB = -38.80 dBm$. Later in test we adjust the overall level with the attenuator whenever required.



- Press RF On/Off key and verify if the RF Off icon disappears. Repeat for output B.



- Repeat the previous procedure for the second vector signal generator but now with the carrier frequencies in table 8 defined for generator 2.

On the R&S®FSL

- Verify the presence and accuracy of the 14 carrier signals with the spectrum analyzer through the following steps.
- Set the attenuator level at $-10.0 dB$
- Press the green Preset key
- Press the Frequency key and set the Center Frequency to $815.25 MHz$. Subsequently press Span button and set to $100.0 MHz$. 6 carriers should now be visible on the display.
- Press the BW key and Res BW Manual softkey on the instrument's display and set the resolution bandwidth to $1.0 MHz$. Subsequently press the Video BW Manual softkey and set to $3.0 kHz$
- Smoothen the trace if necessary by using trace average .
- Press the AMPT key and change the Reference Level until the top of the carriers are in the upper ¾ of the display. Observe the overflow indicator at all times to avoid overdriving the

spectrum analyzer. The display should now resemble the one below.

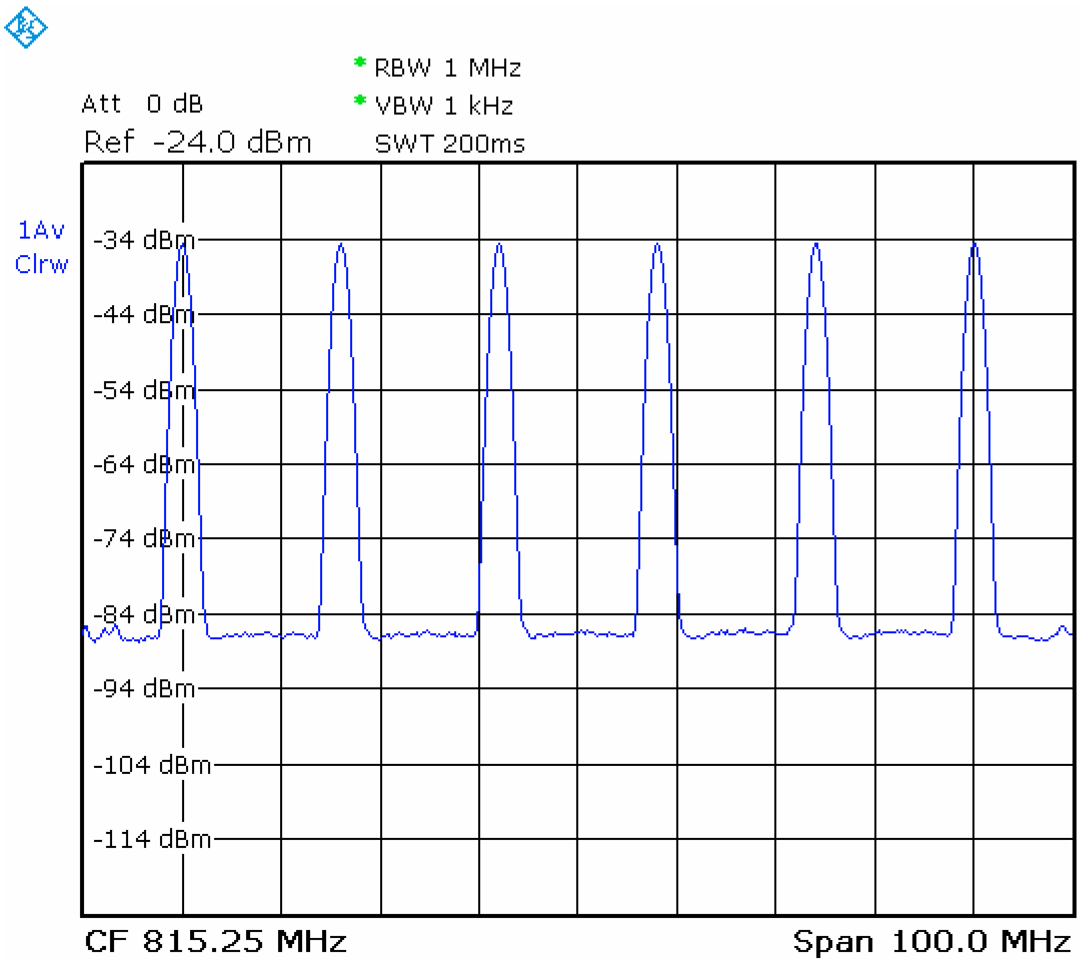
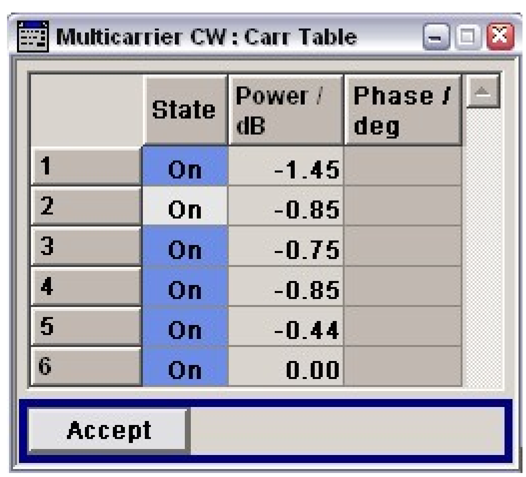


Figure 24 CATV multi-carrier signal with 6 carriers

- Press the MRK button and subsequently Marker2 softkey. The delta-marker now indicates the difference between 2 carriers. To make accurate *CSO* measurements all carriers levels must not differ more than $0.25dB$. To iron out power combiner and attenuator inaccuracies as well as the inaccuracies of the *R&S®SMU200 Vector Signal Generator* it is possible that the level of the individual carriers need adjustment. This takes place in the Carrier Table Carrier Table... accessible via the Multicarrier CW


Multicarrier CW : Carr Table

	State	Power / dB	Phase / deg
1	On	-1.45	
2	On	-0.85	
3	On	-0.75	
4	On	-0.85	
5	On	-0.44	
6	On	0.00	

Accept

configuration window, should such be the case. Set Marker2 at the peak of the different carriers with the Rotary knob or Next Peak softkey and verify if all carriers are within a $0.25dB$ margin. The picture on the previous page shows an adjusted Carrier Table.

- Verify the presence of intermodulation products generated by the vector generator itself or intermodulation caused by the interaction between the 4 generators. Refer to paragraph 2.2 for the location of 2nd and 3rd order modulation products. Eventual intermodulation products should be at least $10.0dB$ below the expected magnitude of the intermodulation products caused by the *Amplifier Under Test.*

5.4 Measurement procedure

Your system is now ready to perform the actual measurement.

- Re-insert the bandpass filter or CATV pre-selector and *Amplifier Under Test*. Switch both devices on.
- Tune the centre frequency of the bandpass filter to the 1st measurement frequency or set the CATV pre-selector to the 1st channel to be tested i.e. $775.25MHz$ or channel 37 . See table 9.
- Press the Frequency key and set the Center Frequency of the spectrum analyzer to the same frequency.
- Press the BW key and Res BW Manual softkey on the instrument's display and set the resolution bandwidth to $3.0kHz$. Subsequently press the Video BW Manual softkey and set this parameter to $10Hz$
- Set the Span to $20kHz$
- Adjust the attenuator setting if necessary until the output of the amplifier reaches its normal operation level i.e. $-8.8\ \mathrm{dBm}$. Deduct the insertion loss of the matching pad $\approx 4.0\mathrm{dB}$ and filter should this be considerable. Adjust the Reference Level of the spectrum analyzer as well should this be required.
- Press the MRK button and read the level of the carrier. Record this level as l_{carr}
- Switch the carrier off. If this particular carrier is generated by Output A you must use the State flag in the Carrier Table window. If the respective carrier was generated by Output B uncheck the On flag in the main user interface.

- Tune Center Frequency of the spectrum analyzer to the 1st *CSO* location and observe the presence of a *CSO* component. Adjust the Reference Level of the instrument if necessary. The bandpass filter should prevent spectrum analyzer overdrive.
- Press the MRK button and read the level. Record this value as l_{cso} . If you perform this test according to *EN50083-3* record the level of the other *CSOs* within the channel. Refer to chapter 2.2 for the location of the *CSO*s.
- The final figure to be used is the worst case value.
- Calculate the *CSO* value with the formula below.

$$CSO = l_{carr} - l_{cso}.$$

Where:

CSO : *CSO* in dBc

l_{carr} : Carrier level in dBm

l_{cso} : Level of *CSO* reading in dBm

- Repeat the previous procedure for all *Carriers Under Test*. The final *CSO* to be reported is the worst case figure for all carriers.

Channel Under Test	*Frequency (MHz)*
37	*775.25*
38	*791.25*
39	*807.25*
40	*823.25*
41	*839.25*
42	*855.25*
1	*48.25*
31	*679.25*
32	*695.25*
33	*711.25*
34	*727.25*
35	*743.25*
36	*759.25*
2	*119.25*

Table 8 Carriers Under Test

If the ripple or flatness (Insertion loss variation) of the bandpass filter isn't sufficiently low so must the calculation of the *CSO* be corrected with the value of the attenuation at the location of the *CSO*.

$$CSO = l_{carr} - l_{cso} + A_r$$

6 Performing a CTB test

6.1 Test set-up

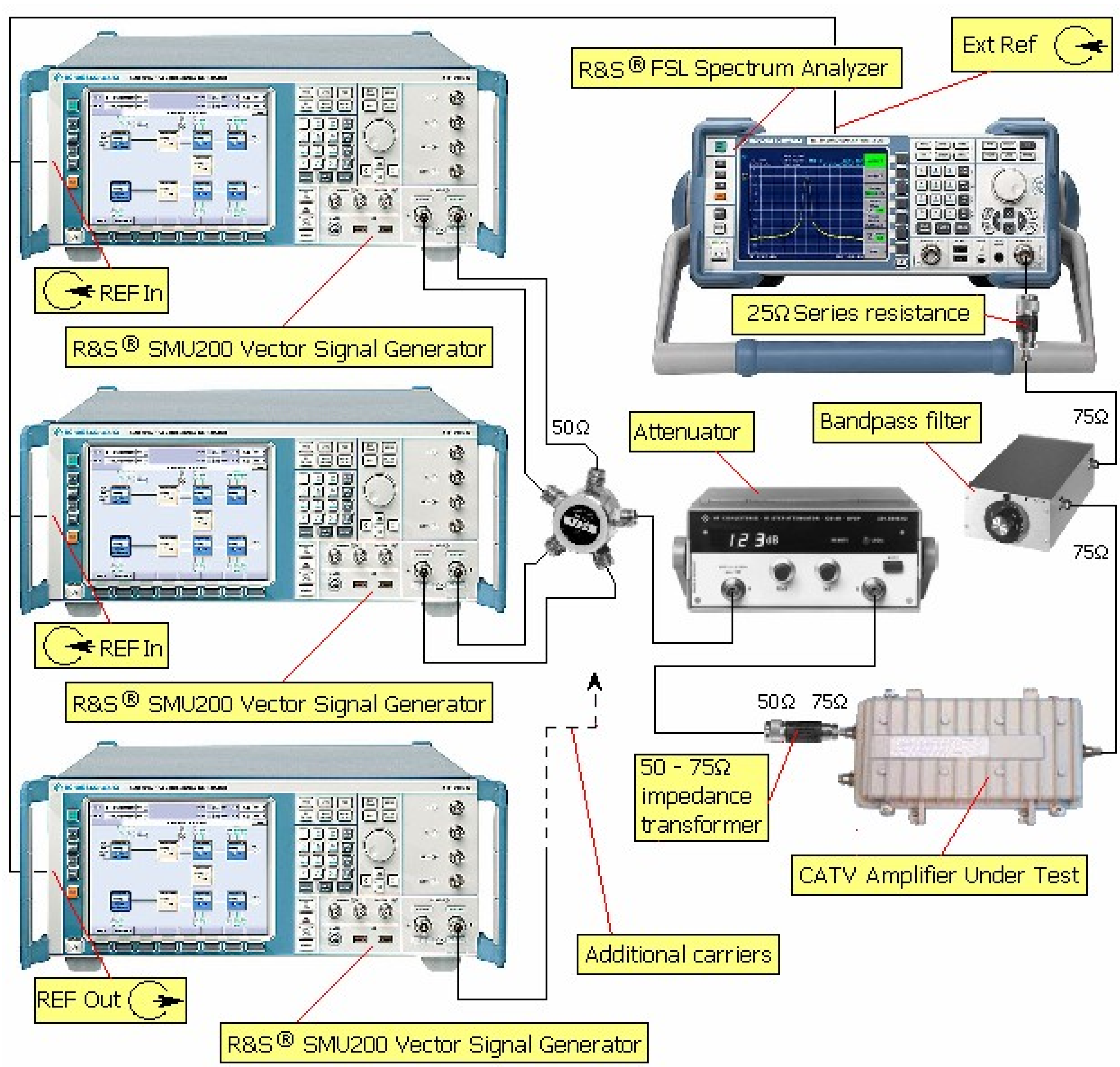


Figure 25 Test set-up for CBT measurement

Use the *CSO* test set-up defined in chapter 5.

6.2 Test details

Refer to the *CSO* test details in chapter 5.

6.3 Measurement preparations

Refer to the *CSO* test details in chapter 5.

6.4 Measurement procedure

The measurement procedure is largely the same as the one used to perform a *CSO* test with the exception that *CTB* products are located at different frequencies.

- Re-insert the bandpass filter or CATV pre-selector and *Amplifier Under Test*. Switch both devices on.
- Tune the centre frequency of the bandpass filter to the 1st measurement frequency or set the CATV pre-selector to the 1st channel to be tested i.e. $775.25MHz$ or channel 36. See table 9.
- Press the Frequency key and set the Center Frequency of the spectrum analyzer to the same frequency.
- Press the BW key and Res BW Manual softkey on the instrument's display and set the resolution bandwidth to $3.0kHz$. Subsequently press the Video BW Manual softkey and set this parameter to $10Hz$
- Set the Span to $20kHz$
- Adjust the attenuator setting if necessary until the output of the amplifier reaches its normal operation level i.e. $-8.8\ \mathrm{dBm}$. Deduct the insertion loss of the matching pad $\approx 4.0\mathrm{dB}$ and filter should this be considerable. Adjust the Reference Level of the spectrum analyzer as well should this be required.
- Press the MRK button and read the level of the carrier. Record this level as l_{carr}
- Switch the carrier off. If this particular carrier is generated by Output A you must use the State flag in the Carrier Table window. If the respective carrier was generated by Output B uncheck the On flag in the main user interface.

- Observe the presence of a *CTB* component at the location of the carrier frequency. Adjust the Reference Level of the instrument if necessary and press the MRK button to read the level. Record this value as l_{ctb}. If you perform this test according to *EN50083-3* you must record the levels of the other *CTBs* within the channel. For this tune the Center Frequency of the spectrum analyzer to the *CTB* locations and measure the magnitude. *CTBs* are located at:

$$f_{harm} = f_{carr} + n/2 \text{ MHz}$$

$$f_{sub\text{-}harm} = f_{carr} - n/2 \text{ MHz}$$

Where n is an unsigned integer including 0. The final figure to be used is the worst case value.

- Calculate the *CTB* value with the formula below.

$$CTB = l_{carr} - l_{ctb} .$$

Where:

CTB : *CTB* in dBc

l_{carr} : Carrier level in dBm

l_{ctb} : Level of *CTB* reading in dBm

- Repeat the previous procedure for all *Carriers Under Test*. The final *CTB* to be reported is the worst case figure for all carriers.

If the ripple or flatness (Insertion loss variation) of the bandpass filter isn't sufficiently low so must the calculation of the *CTB* be corrected with the value of the attenuation at the location of the *CTB*.

$$CTB = l_{carr} - l_{ctb} + A_r$$

7 Performing a XMOD test

7.1 Test set-up

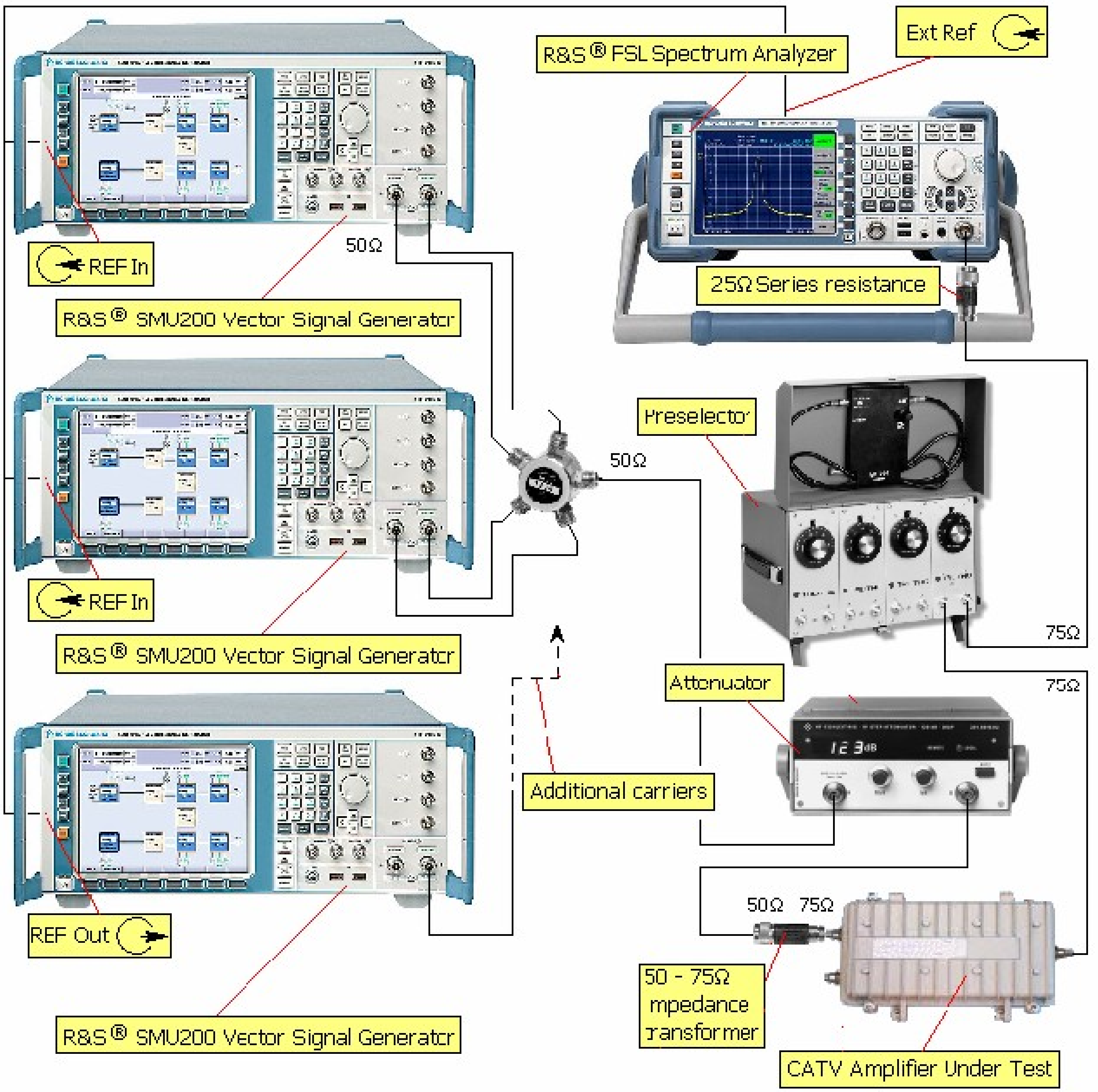


Figure 26 Test set-up for XMOD test

Use the *CSO* test set-up defined in chapter 5.

7.2 Test details

Refer to the *CSO* test details in chapter 5.

7.3 Measurement preparations

On your PC

- For a cross modulation test, the *Carriers Under Test* need to be modulated with a frequency close or identical to the horizontal line frequency of a TV receiver. This is $15625Hz$ for the *PAL* & *SECAM* TV standards and $15750Hz$ for the *NTSC* standard in the US, Japan & other countries who employ this standard. The modulation signal & method to be used depend on the test standard. If fact *EN50083-3* allows you some leeway on the modulation method and only states that:
    - The frequency used mustn't be a multiple of the $50Hz$ line frequency.
    - Every symmetrical modulation method may be used with the exception of pulse modulation.

  Both *EIJ ET-2301* and *NCTA* however specify a square wave that is amplitude modulated with an index of 100%.

  In our test set-up here we use a sinewave that is amplitude modulated (AM) with $m = 100\%$. Direct configuration of such a waveform via the front panel of the *R&S® SMU200* isn't possible and we must use the following external software applications to compile a waveform for the arbitrary waveform generator inside the instrument:
    - *R&S® WinIQSIM* software
    - *R&S® FM-ARB* software

  Both products can be downloaded free of charge from the www.rohde-schwarz.com website. Go to Downloads -> Application Notes and search for the respective product. Follow the steps below to compile the waveform.
- Install the *R&S® WinIQSIM* & *R&S® FM-ARB* software on your PC.
- If the installation was successful and you open *R&S® FM-ARB* the main user interface should look like figure 26. Select SMU-B10 in the Device list. Set the modulation Type to AM, the Modulation Depth to 100% and the Modulation Frequency to $15.625kHz$.

  Click the Save  button and store the compiled waveform in AM.IBN. The filename must have the specified extension *.IBN in order for *R&S® WinIQSIM* to recognise the file format. Remember the storage location.

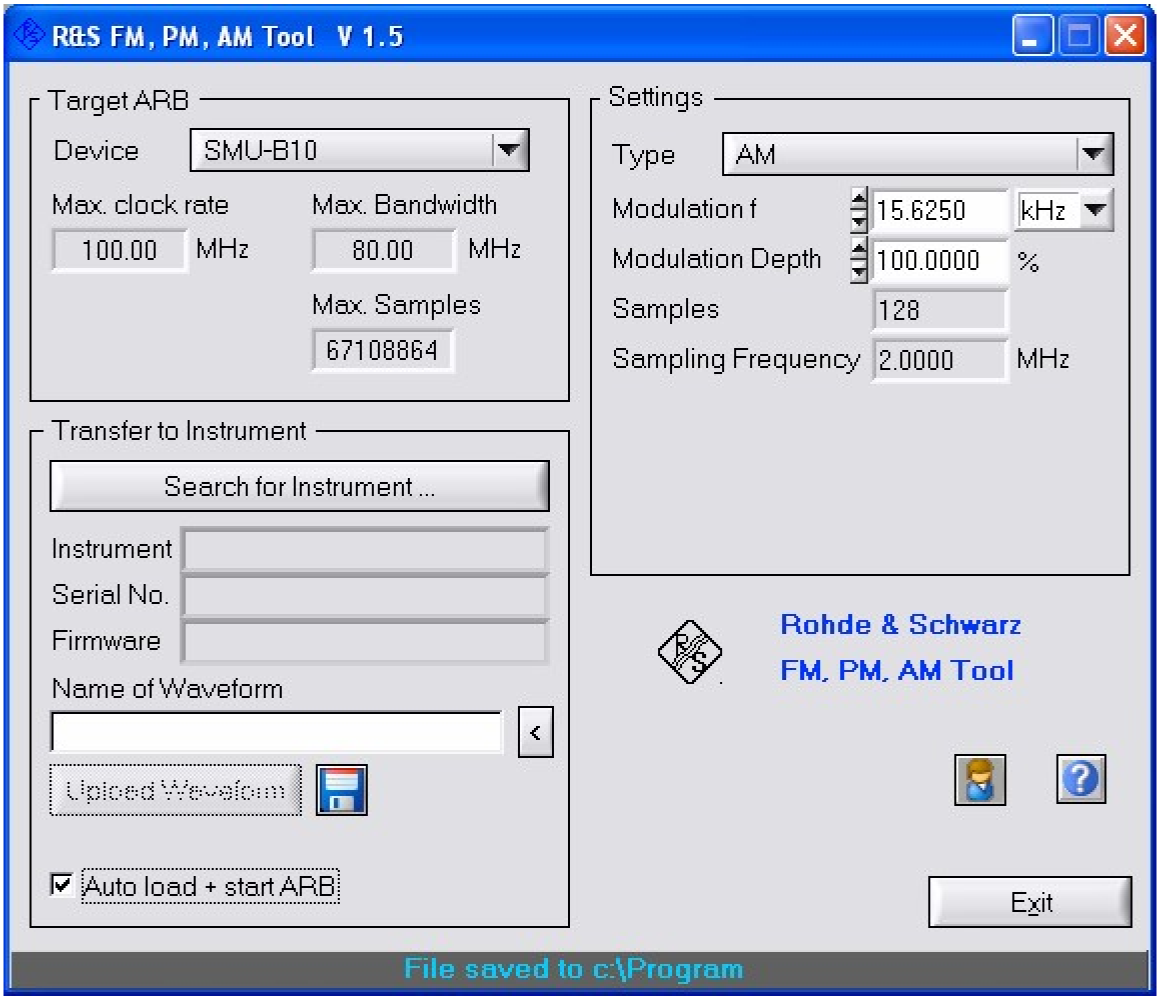


Figure 27 R&S® FM-ARB software

- Launch the *R&S® WinIQSIM* software
- Prior to making any settings changes you must set the target arbitrary waveform generator type. In the ARB menu on the main menu bar you'll find Set Target ARB.... Click on it and set the Target ARB list to SMU-B10, SMJ-B10, SMATE-B10. Click the Ok button to save the new settings.

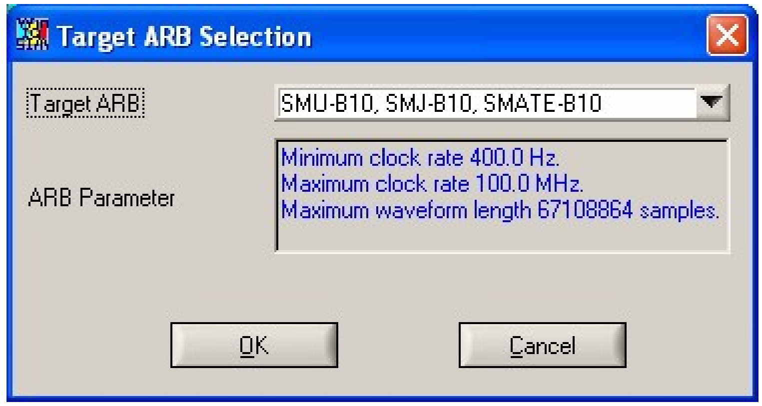


Figure 28 Target ARB selection window

- Select the System item in the main menu. Choose the Multi Carrier Mixed Signal option and close the window with the Ok button.

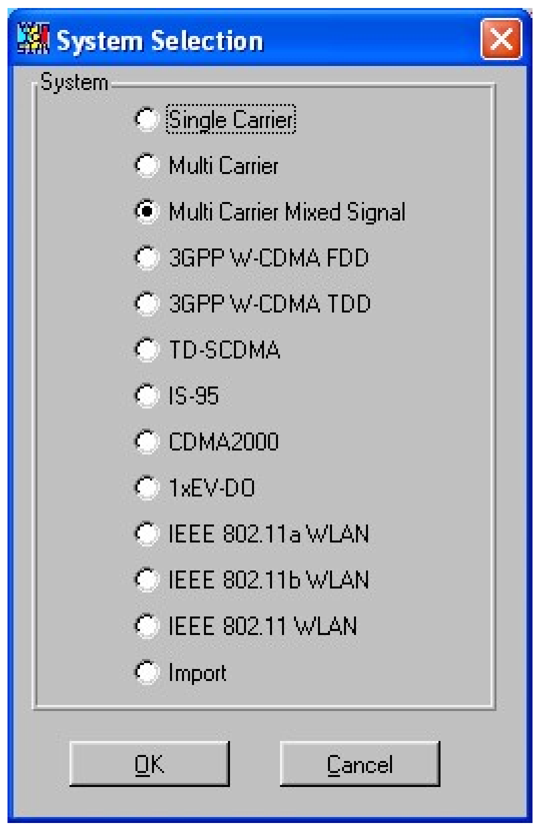


Figure 29 System Selection window in WinIQSim

- When you activate the Multi Carrier Mixed Signal mode, the main user interface settings are reduced to the ones shown in figure 29 i.e. Carrier settings and IF-Generation. Click the Carrier Settings.

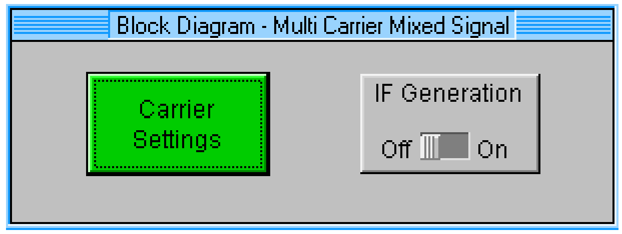


Figure 30 Main user interface for multi-carrier mode

- Make the following changes in the Carrier Settings window. Set the No of Carriers to 4. Due to the additional modulation the number of carriers per *R&S® SMU200 Vector Signal Generator* is now restricted to 4. In addition set the Carrier spacing to $16.0MHz$ just like in the *CSO* or *CTB* test. Leave the remaining settings in the General group unchanged.

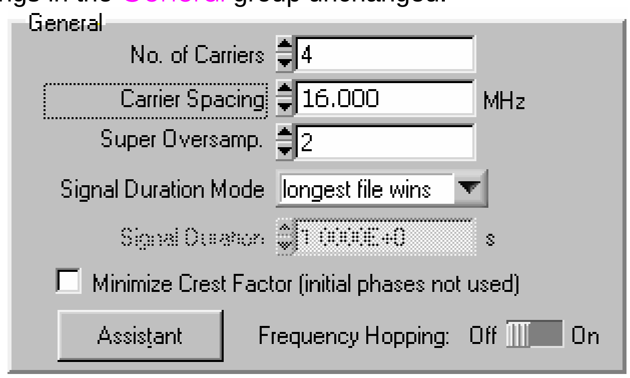


Figure 31 General carrier settings

- Click carrier No 0 in the in the Individual carrier definition group. Click subsequently onto the IQ file field, browse for the previously compiled AM.IBN file and click the Ok button in the Open File dialog. Click the On indicator to switch the respective carrier on. Leave the remaining settings at the default value. Repeat the above for the other 3 carriers.
- Leave the IF Generation in Off state.
- The settings for *R&S® SMU200 Vector Signal Generator* are identical. If you want to generate all the carriers *EN50083-3* some generators have a carrier spacing of $8.0MHz$ instead. In that case save the configurations under different files onto your hard disk for easy retrieval and downloading. The Save As function is available in the File menu.

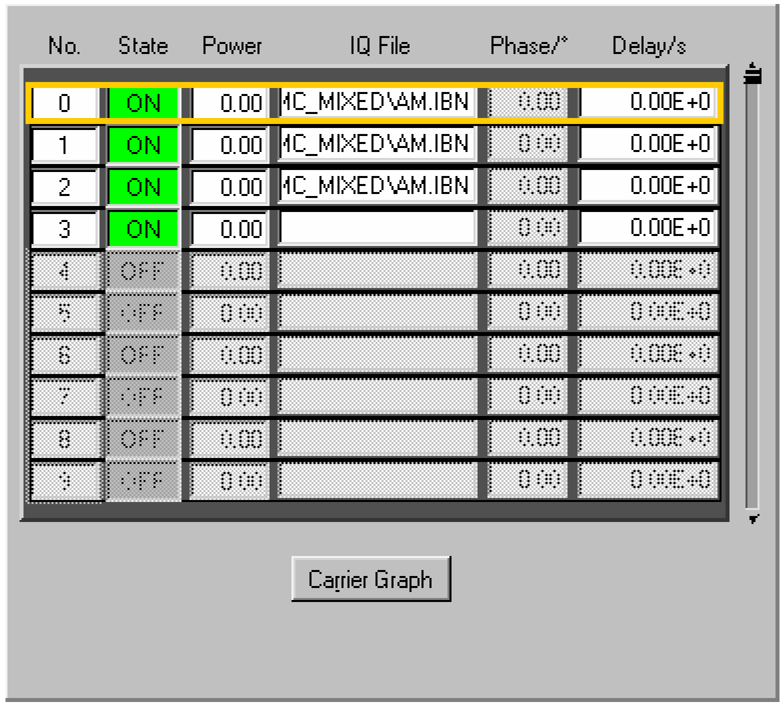


Figure 32 Carrier definitions

- The new configuration only takes effect after a transfer to the instrument. Click ARB -> SMU, SMJ, SMATE->Transmission. This opens the SMU Waveform Transmission window shown below.

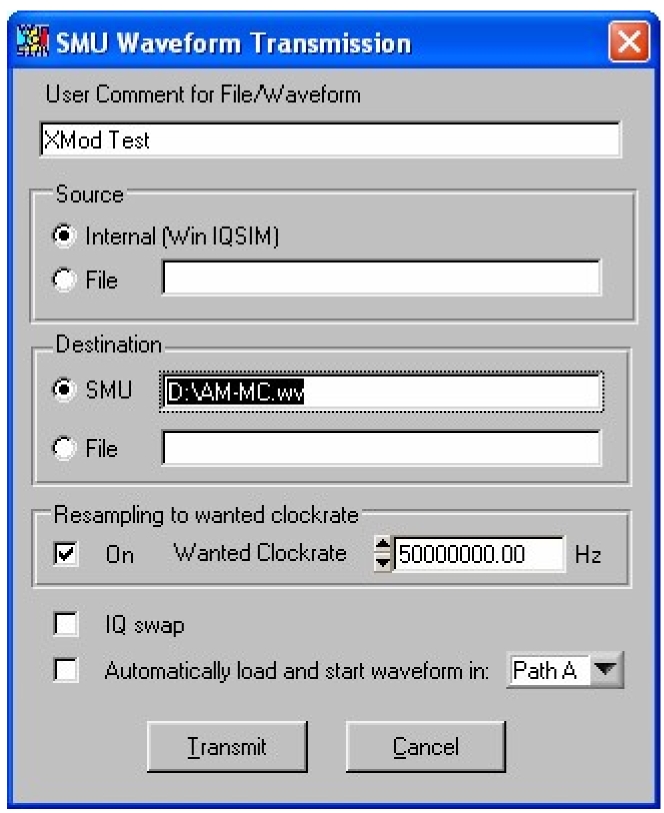


Figure 33 Waveform transmission

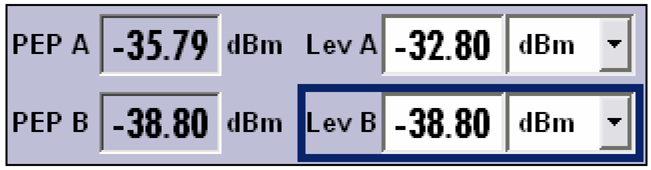
- Tick the Internal (WinIQSIM) option in the Source field and enter an appropriate comment in the User comment for File/Waveform field. Enter the name of the file under which you want the waveform to be stored in the SMU field of the destination group. Leave the other fields at their respective default values and click the Transfer button. If the transfer was successful the Multicarrier window in the vector signal generator should display the downloaded waveform.
- Remove the *Amplifier Under Test* and bandpass filter or CATV pre-selector and connect the attenuator directly to the *R&S® FSL.* Maintain the $50/75\Omega$ matching pad.

On the R&S® SMU200 generators

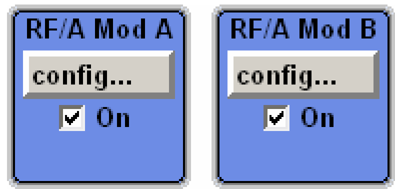
- Press the Preset button.
- Turn the Rotary knob clockwise or counterclockwise until the Baseband icon is active. Press the Rotary knob inwards to open the Context Menu and select Arbitrary Waveform in the Context Menu with the Rotary knob
- Click Load Waveform and browse for the waveform you just downloaded with the *WinIQSim* software. Subsequently set the State to On.
- Set the centre frequency of the main generator i.e. Freq A in the middle of the 4 carrier frequencies. This is: $807.25 + (855.25 - 807.25)/2 = 831.25MHz$. Press the Freq button on the front panel and enter the respective value.
- Press the Freq key again and set Freq B at $48.25MHz$.

- Select the RF/A Mod B icon with the Rotary knob and open the context menu. Select Amplitude Modulation in the context menu and subsequently set the Modulation depth at 100% and the LF Generator frequency at $15.625kHz$ .Switch the modulation On and close the window with the Esc button.

- Press the Level key and set the output level of output A provisionally to the nominal input level of the *Amplifier Under Test,* in our case $-8.8dBm + 6.02dB - 30.0dB = -32.78dBm$ The $6.02dB$ is the adjustment needed to compensate for the energy spreading over 4 carriers or $10\log(1/4) \approx 6.02dB$. The AM in addition disperses the energy over the 2 sidebands, however this is automatically adjusted by the instrument.
- Press the Level key again and set the level of output B to $-8.8dBm - 30.0dB = -38.80dBm$. Since this is a single carrier we don't need to take any energy dispersal into account. Later in the test we adjust the overall level with the attenuator whenever required.



- Press RF On/Off key and verify if the RF Off icon disappears. Repeat for output B.



- Repeat the previous procedure for the second vector signal generator but now with the carrier frequencies in table 8 defined for generator 2.

On the R&S®FSL

- Verify the presence and accuracy of the 10 carrier signals in the same manner as the described in the *CSO* test procedure. Make the required adjustments in the Carrier Table if required.

7.4 Measurement procedure

Your system is now ready to perform the actual measurement.

- Re-insert the bandpass filter or CATV pre-selector and *Amplifier Under Test*. Switch both devices on.
- Switch all carriers off with the exception of the *Channel Under Test* i.e. $775.25 MHz$. The modulation of the *Channel Under Test* must be switched on.
- Tune the centre frequency of the bandpass filter to the 1st measurement frequency or set the CATV pre-selector to the 1st *Channel Under Test* i.e. $775.25 MHz$ or channel 37. See table 9.
- Press the Frequency key and set the Center Frequency of the spectrum analyzer to the same frequency.
- Press the BW key and Res BW Manual softkey on the instrument's display and set the resolution bandwidth to $1.0 kHz$. Subsequently press the Video BW Manual softkey and set this parameter to $10 Hz$
- Set the Span to $50.0 kHz$ and Sweep Time to $50.0 \sec$. You should have approx. $25.0 kHz$ at both sides of the carrier.
- Adjust the attenuator setting if necessary until the output of the amplifier reaches its normal operation level i.e. $-8.8\ \mathrm{dBm}$. Deduct the insertion loss of the matching pad $\approx 4.0 \mathrm{dB}$ and filter should this be considerable. Adjust the Reference Level of the spectrum analyzer as well should this be required. The top of the sidebands must be in the upper ¾ of the screen.
- Press the MRK button and read the level of the wanted sideband component at $15.625 kHz$ from the carrier. Record this level as l_{sb}

- Switch all the other carriers on and swith the modulation of carrier of the *Channel Under Test* off. If this particular carrier is generated by Output A you must use the State flag in the Carrier Table window. If the respective carrier was generated by Output B uncheck the On flag in the main user interface.
- Press the MRK button and read the level of the unwanted sideband components located at either side of the carrier at $15.625 kHz$ distance. Record the maximum of the two readings as l_{unwsb}.
- Calculate the *XMOD* value with the formula below.

$$\text{XMOD} = \text{l}_{\text{sb}} - \text{l}_{\text{xmod}} .$$

Where:

$XMOD$: *XMOD* figure in dBc

l_{sb} : Level of wanted sideband in dBm

l_{unwsb} : Level of composite unwanted sidebands in dBm

- Repeat the previous procedure for all *Carriers Under Test*. The final *XMOD* to be reported is the worst case figure for all carriers.

Channel Under Test	*Frequency (MHz)*
37	*775.25*
38	*791.25*
39	*807.25*
40	*823.25*
41	*839.25*
42	*855.25*
1	*48.25*
31	*679.25*
32	*695.25*
33	*711.25*
34	*727.25*
35	*743.25*
36	*759.25*
2	*119.25*

Table 9 Carriers Under Test

8 Summary

In this application note we show that the scope of use of the *R&S® SMU200 Vector Signal Generator* and *R&S® AFQ100 IQ Modulation Generator* extends far beyond its typical deployment in wireless & mobile communication like Bluetooth, GSM and other wireless communication technologies. The instruments' abilities to generate multiple carriers with our without modulation with great ease allow RF and broadcasting engineers to characterise the behavior of amplifiers. Since the huge amounts of carriers typically required for such tests make it very expensive if not unfeasible to deploy discrete generators *R&S®* its wide range of vector generators may well provide the solution.

9 Literature

User manuals

[1] R&S® FSL Spectrum Analyzer Operating Manual Rohde & Schwarz Test & Measurement Division Ref 1300.2519.12-04

[2] R&S® SMU200A Vector Signal Generator Operating Manual Volume 1 Rohde & Schwarz Test & Measurement Division Ref 1007.9845.32-08-1

[3] R&S® AFQ100A IQ Modulation Generator Manual Rohde & Schwarz Test & Measurement Division Ref 1401.3084.32-01

[4] Cisco® Cisco uBR7200 Series Universal Broadband Router Hardware Installation Guide Appendix E Frequency Allocation Tables OL-5421-1

Articles & books:

[5] CCIR and FCC TV standards Rohde & Schwarz Sound and TV Broadcasting Rohde & Schwarz Munich PD0756.6981.21

[6] Characterisation of cable amplifiers for broadband network applications, Jodi Steel, Anthony Parker & David Skellern, Electronics Department Macquarie University New South Wales 2109, Australia.

[7] Common Path Distortion in Cable Networks and the Impact on the Quality of transported Services Findings and Solutions, December 2004, Jan Arts Integan kabelcommunicatie Antwerp Belgium

[8] Measurement Techniques for CNR, CSO, CTB and Spurious signals Technical Note 981110, Dr. Seidenberg BKTEL Germany.

[9] TV Picture Performance related to CNR, CSO, CTB and Spurious signals Technical Note 981117 Dr. Seidenberg BKTEL Germany

[10] Cable Television System Measurements Handbook NTSC Systems Ref 5091-8037E February 1994 Hewlett-Packard

Application notes

[11] R&S® FM-ARB, PC Software for generating AM/PM/FM signals in the ARB Application note 1GP59_5E, Thomas Roeder, February 2006.

*[12] R&S® WinIQSim I/Q-Simulation for SMU/SMJ/SMATE internal ARB SMx-B10/SMx-B11, I/Q Modulation Generator AMIQ,
ARB Option SMIQB60and AM300*

Standards & recommendations

[13] European norm EN50083-3 Kabelverteilsysteme für Ton- und Fernsehrundfunk-Signale Teil 3: Aktive Breitbandgeräte für koaxiale Verteilnetze, VDE-VERLAG GMBH, 10625 Berlin, June 1995.

Datasheets

[14] R&S® FSL Spectrum Analyzer Specifications April 2006 PD 0758.2790.12

[15] Gainstar® TM 862 Line Extender 862MHz with 65/87MHz split Scientific Atlanta Part Number 7008106 Rev A May2006 Scientific Atlanta Inc.

[16] Aeroflex Weinschel® Model 1515 & 1515-1 Broadband Resistive Power Divider Revision Date: 12/15/04

[17] Mini-Circuits® Power Splitters/Combiners 2–Way ZESC-2-11 10MHz-2GHz Datasheet Minicircuits Inc.

[18] Pico Macom® PIDA Series Broadband Bi-directional Push-pull Amplifiers Datasheet Pico-Macom Inc. 2003

10 Ordering information

Type of instrument		
Name of instrument	range	Ordering number
Vector Signal Generator R&S® SMU200A		1141.2005.02
Options:		
RF Path A: 100 kHz to 2.2 GHz R&S® SMU-B102	100 kHz to 2.2 GHz	1141.8503.02
RF Path B 100 kHz to 2.2 GHz R&S® SMU-B202	100 kHz to 2.2 GHz	1141.9400.02
Baseband Generator with ARB (64 Msamples) and Digital Modulation R&S® SMU-B10		1141.7007.02
Multicarrier CW Signal Generation R&S® SMU-K61		1160.8505.02
Baseband Main Module R&S® SMU-B13		1141.8003.02
Type of instrument		
Spectrum Analyzer R&S® FSL3	9.0 kHz-3.0GHz	1300.2502.03
Options:		
Cable-TV and TV measurements R&S® FSL-K20		1301.9675.02
Spectrum Analyzer R&S® FSP3		1164.4391.03
Type of instrument		
IQ Modulation Generator R&S® AFQ100A		1401.3003.02
Options:		
Waveform Memory 256 Msample R&S® AFQ-B10		1401.5106.02
Waveform Memory 1 Gsample R&S® AFQ-B11		1401.5206.02
WinIQSIM2™Multicarrier CW Signal Generation R&S® AFQ-K261		1401.6802.02
Type of instrument		
Vector Signal Generator R&S® SMV03	9 kHz – 3.3 GHz	1147.7509.13
Type of instrument		
RF Step Attenuator R&S® RSP	0.0 Hz – 2.7GHz	0831.3515.02
RF Step Attenuator R&S® DPSP	0.0 Hz – 2.7GHz	0334.6010.02
RF Step Attenuator R&S® DPS	0.0 Hz – 2.7GHz	0334.7217.02
Type of instrument		
50/75 Ohms matching pad R&S® RAM	0.0 Hz – 2.7GHz	0358.5414.02
25 Ohms series resistance R&S® RAZ		0358.5714.02

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