R&S®R&S ZVL-K1
Spectrum Analysis Options
Software Manual

1303.6573.42 – 05

Test and Measurement

Software Manual

ROHDE&SCHWARZ

This Software Manual describes the following options for the R&S® ZVL:

- R&S® ZVL-K1, stock no. 1306.0301.02
- The supplementary spectrum analysis options described in chapter 1, Introduction

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The following abbreviations are used throughout this manual:
R&S®ZVL is abbreviated as R&S ZVL.
R&S® FSL-xxx as R&S FSL-xxx.

Conventions Used in the Documentation

To visualize important information quickly and to recognize information types faster, a few conventions have been introduced. The following character formats are used to emphasize words:

Bold	All names of graphical user interface elements such as dialog boxes, softkeys, lists, options, buttons etc. All names of user interface elements on the front and rear panel such as keys, connectors etc.
Courier	All remote commands (apart from headings, see below)
Capital letters	All key names (front panel or keyboard)

The description of a softkey (Operating Manual and Online Help) always starts with the softkey name, and is followed by explaining text and one or more remote control commands framed by two lines. Each remote command is placed in a single line.

The description of remote control commands (Operating Manual and Online Help) always starts with the command itself, and is followed by explaining text including an example, the characteristics and the mode (standard or only with certain options) framed by two grey lines.

Contents of Chapter 1

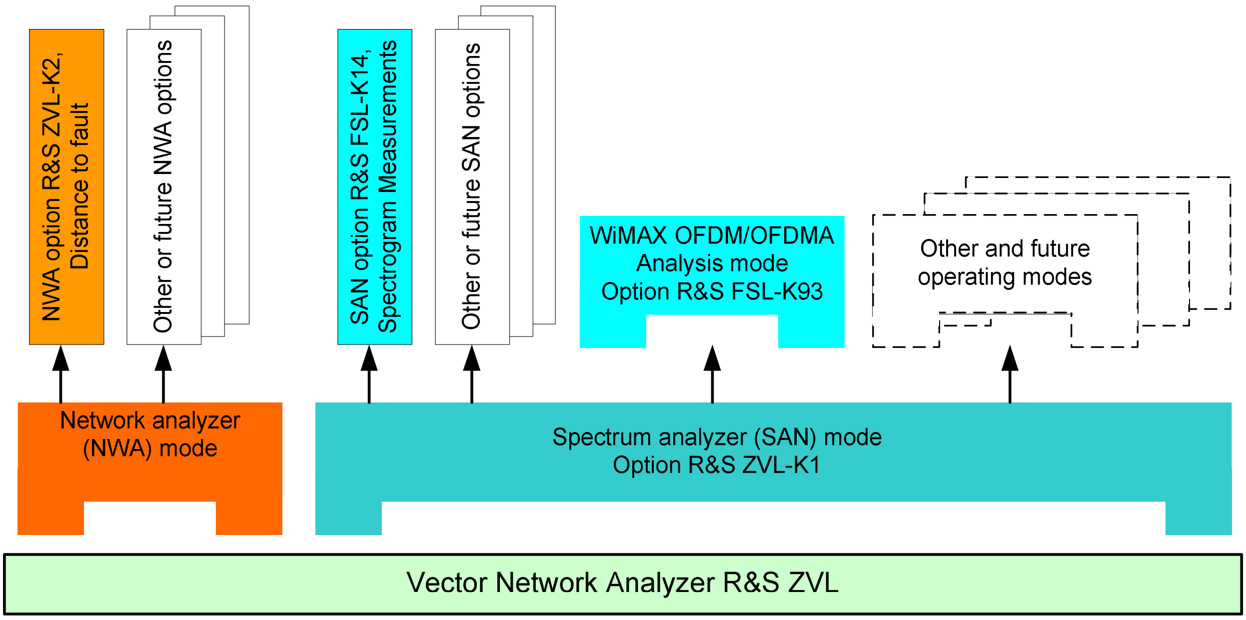
1 Introduction

The R&S ZVL network analyzer can be upgraded with various hardware and software options, providing enhanced flexibility and an extended measurement functionality. The available options are listed in the *SETUP – More – System Info – Versions + Options* dialog. Options can be enabled by means of a license key, to be entered in the SETUP menu after an appropriate firmware version has been installed. The new supported options for each firmware version are listed in the "What's New..." section of the network analyzer help system.

The R&S ZVL options can be grouped as follows:

- Measurement modes: The option enables a special operating mode. Only one measurement mode can be active at a given time. The basic instrument modes are *Network Analyzer* (NWA, no option required) and *Spectrum Analyzer* (SAN, with option R&S ZVL-K1). The SAN mode is described in this operating manual; it provides a number of supplementary measurement modes, e.g. *WiMAX OFDM/OFDMA Analysis* mode (with option R&S FSL.K93). The supplementary SAN modes also require option R&S ZVL-K1.
- Additional measurements: The option extends a particular measurement mode, providing additional measurement functionality. The analyzer provides additional measurements for the NWA and the SAN modes.

The relationship between the R&S ZVL options and measurement modes is shown below.



Accessing measurement modes, remote control

All measurement modes are accessed by means of the MODE front panel key. When a new mode is selected, the appearance of the user interface and the control elements change. At the same time, the instrument adjusts its remote-control command set to the functionality of the selected operating mode.

While a particular measurement mode is active, the functionality of the other modes is generally not available. The same applies to the remote-control commands. Basic instrument functions, i.e. the softkeys associated with the FILE, SETUP, PRINT, and MODE front panel keys and the related commands, are available in all operating modes.

The present manual describes the SAN modes and options listed below. For a complete list of options, accessories, and extras refer to the R&S ZVL product brochure.

Option	Option Type	Functionality
ZVL-K1, Spectrum Analysis	SAN option, measurement mode	Basis spectrum analyzer functions providing the frequency spectrum of the measured RF signal. The option also provides a wide range of pre-configured power measurements.
FSL-B6, TV Trigger	SAN option	TV trigger, especially for service in the analog TV field.
FSK-B8, Gated Sweep	SAN option	Gated sweep, especially for the modulation spectrum of GSM signals or bursted WLAN signals.
FSL-K7, AM/FM/φM Measurement Demodulator	SAN option	Analog modulation analysis for amplitude, frequency or phase modulated signals.
FSL-K8, Bluetooth Measurements	SAN option	Bluetooth transmitter (TX) tests in line with the Bluetooth® RF test specification, including EDR tests.
FSL-K14, Spectrogram Measurements	SAN option	Spectrogram display and trace recording for general spectrum measurements.
FSL-K20, Cable TV Measurements	SAN option, measurement mode	Transmitter (TX) tests on analog and digital TV signals.
FSL-K30, Noise Figure and Gain Measurements)	SAN option, measurement mode	Noise figure and noise temperature measurements, especially suited for manufacturers of amplifiers.
FSL-K72, WCDMA Measurements (3GPP/FDD BTS)	SAN option, measurement mode	Transmitter (TX) tests on 3GPP/FDD downlink signals including HSDPA and HSUPA channels.
FSL-K82 CDMA2000 BTS Analysis	SAN option, measurement mode	Transmitter (TX) tests on CDMA2000 forward link signals.
FSL-K84 1xEV-DO BTS Analysis	SAN option, measurement mode	Transmitter (TX) tests on 1xEV-DO forward link signals.
FSL-K91/K91n, WLAN OFDM Analysis	SAN option, measurement mode	Transmitter (TX) tests on WLAN signals in line with the WLAN standards IEEE 802.11a/b/g/j and n.
FSL-K93, WiMAX OFDM/OFDMA Analysis	SAN option, measurement mode	Transmitter (TX) tests on WLAN signals in line with standard IEEE 802.16-2004 and IEEE 802.16e-2005 for mobile WiMAX-Signals including WiBro.

The following sections provide a short introduction to the software options.

Spectrum Analysis (R&S ZVL-K1)

The spectrum analysis option provides the basic functionality for measuring an arbitrary RF signal in the frequency domain. Evaluation tools such as markers and limit lines allow a refined analysis of the measurement results. A wide range of predefined power measurements cover typical RF measurement tasks, in particular:

- Zero span power measurements
- Channel and adjacent channel power measurement
- Measurement of occupied bandwidth
- CCDF measurement (amplitude statistics of signals)

Option R&S ZVL-K1 is a prerequisite for all supplementary spectrum analyzer (SAN) options; see table and figure above.

TV Trigger (R&S FSL-B6)

Option R&S FSL-B6 adds a TV trigger to option R&S ZVL-K1, in order to select different sections of a TV video signal for display and facilitate the analysis. This option is especially suited for all doing any service in the analog TV field.

Gated Sweep (R&S FSL-B8)

The gated sweep mode removes switching transients from the spectrum. This is advantageous for the analysis of pulsed-carrier signals, e. g. to investigate the modulation spectrum of GSM signals or WLAN signals.

AM/FM/φM Measurement Demodulator (R&S FSL-K7)

The AM/FM/φM Measurement Demodulator option R&S FSL-K7 converts the R&S ZVL into an analog modulation analyzer for amplitude, frequency or phase modulated signals. It measures not only characteristics of the useful modulation, but also factors such as residual FM or synchronous modulation.

Bluetooth Measurements (R&S FSL-K8)

Option R&S FSL-K8 provides measurements on Bluetooth transmitters. All measurements are carried out in line with the Bluetooth® RF test specification Rev. 2.0+DER and cover basic rate as well as Enhanced Data Rate (EDR) packets.

Spectrogram Measurements (R&S FSL-K14)

Option FSL-K14 adds a spectrogram display and trace recording to the R&S ZVL. The spectrogram view gives a history of the spectrum and helps to analyze intermittent problems or variations in frequency and level versus time.

Cable TV Measurements (R&S FSL-K20)

Option R&S FSL-K20 provides Transmitter (TX) tests on analog and digital TV signals. The option provides predefined measurements for a variety of results which characterize the signal power, modulation accuracy, and spectrum. Measurements may be performed on single channels or on a group of channels collected in a table.

Noise Figure and Gain Measurements (R&S FSL-K30)

Option R&S FSL-K30 adds the capability to measure noise figure and noise temperature. This enables manufacturers of amplifiers to analyze all necessary characteristics, e.g. noise figure, nonlinear parameters such as harmonics, intermodulation or ACPR, as well as S-parameters.
In addition to the spectrum analyzer option R&S ZVL-K1, option R&S FSL-K30 also requires option R&S FSL-B5, Additional Interfaces (providing the noise source control voltage), and an external preamplifier to specify the measurement uncertainties. DC supply for the external preamplifier can be derived from the probe power socket; a matching connector can be ordered as spare part (1065.9480.00).
Noise source: E.g. NC 346 types from Noisecom.

WCDMA Measurements (3GPP/FDD BTS) (R&S FSL-K72)

The R&S FSL-K72 adds transmitter (TX) measurements on 3GPP downlink signals including HSDPA/HSUPA signals. The measurement types comprise code domain power, signal channel power, adjacent channel power, and spectrum emission mask.

CDMA2000 Base Station Measurements (R&S FSL-K82)

The R&S FSL-K82 provides test measurements on CDMA2000 forward link signals. The measurement types comprise code domain power, signal channel power, adjacent channel power, and spectrum emission mask.

1xEV-DO Base Station Measurements (R&S FSL-K84)

The R&S FSL-K84 provides test measurements on 1xEV-DO forward link signals. The measurement types comprise code domain power, signal channel power, adjacent channel power, and spectrum emission mask.

WLAN OFDM Analysis (R&S FSL-K91)

Option R&S FSL-K91 provides transmitter (TX) tests, especially spectrum and modulation measurements, on signals in line with the WLAN standards IEEE 802.11a/b/g/j.

WiMAX OFDM/OFDMA Analysis (R&S FSL-K93)

Option R&S FSL-K93 provides transmitter (TX) tests, especially spectrum and modulation measurements on signals in line with IEEE 802.16-2004 and IEEE 802.16e-2005 for mobile WiMAX-Signals including WiBro.

Contents of Chapter 2

2 Advanced Measurement Examples

This chapter explains how to operate the R&S ZVL-K1 using typical measurements as examples. Additional background information on the settings is given.

Test Setup

All of the following examples are based on the standard settings of the R&S ZVL-K1. These are set with the **PRESET** key. A complete listing of the standard settings can be found in chapter "Instrument Functions", section "Initializing the Configuration – PRESET Key".

In the following examples, a signal generator is used as a signal source. The RF output of the signal generator is connected to the RF input of R&S ZVL-K1.

If a 65 MHz signal is required for the test setup, as an alternative to the signal generator, the internal 65 MHz reference generator can be used:

1. Switch on the internal reference generator.
   - Press the **SETUP** key.
   - Press the **Service** softkey.
   - Press the **Input RF/Cal/TG** softkey, until **Cal** is highlighted.

   The internal 65 MHz reference generator is now on. The R&S ZVL-K1's RF input is switched off.
2. Switch on the RF input again for normal operation of the R&S ZVL-K1. Two ways are possible:
   - Press the **PRESET** key
   - Press the **SETUP** key.
   - Press the **Service** softkey.
   - Press the **Input RF/Cal/TG** softkey, until **RF** is highlighted.

   The internal signal path of the R&S ZVL-K1 is switched back to the RF input in order to resume normal operation.

Measurement of Harmonics

Measuring the harmonics of a signal is a frequent problem which can be solved best by means of a spectrum analyzer. In general, every signal contains harmonics which are larger than others. Harmonics are particularly critical regarding high–power transmitters such as transceivers because large harmonics can interfere with other radio services.

Harmonics are generated by nonlinear characteristics. They can often be reduced by lowpass filters. Since the spectrum analyzer has a nonlinear characteristic, e.g. in its first mixer, measures must be taken to ensure that harmonics produced in the spectrum analyzer do not cause spurious results. If necessary, the fundamental wave must be selectively attenuated with respect to the other harmonics with a highpass filter.

When harmonics are being measured, the obtainable dynamic range depends on the second harmonic intercept of the spectrum analyzer. The second harmonic intercept is the virtual input level at the RF input mixer at which the level of the 2nd harmonic becomes equal to the level of the fundamental wave. In practice, however, applying a level of this magnitude would damage the mixer. Nevertheless the available dynamic range for measuring the harmonic distance of a DUT can be calculated relatively easily using the second harmonic intercept.

As shown in Fig. 2-1, the level of the 2nd harmonic drops by 20 dB if the level of the fundamental wave is reduced by 10 dB.

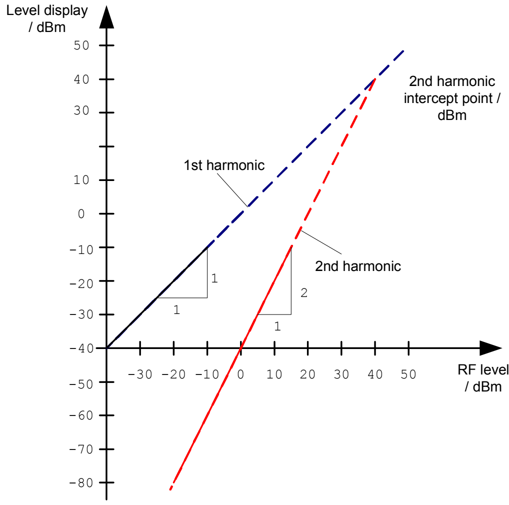


Fig. 2-1 Extrapolation of the 1st and 2nd harmonics to the 2nd harmonic intercept at 40 dBm

The following formula for the obtainable harmonic distortion d_2 in dB is derived from the straight–line equations and the given intercept point:

$$d_2 = S.H.I - P_I \qquad (1)$$

d_2 = harmonic distortion

P_I = mixer level/dBm

S.H.I. = second harmonic intercept

The mixer level is the RF level applied to the RF input minus the set RF attenuation.

The formula for the internally generated level P_1 at the 2nd harmonic in dBm is:

$$P_1 = 2 \cdot P_I - S.H.I. \qquad (2)$$

The lower measurement limit for the harmonic is the noise floor of the spectrum analyzer. The harmonic of the measured DUT should – if sufficiently averaged by means of a video filter – be at least 4 dB above the noise floor so that the measurement error due to the input noise is less than 1 dB.

The following rules for measuring high harmonic ratios can be derived:

- Select the smallest possible IF bandwidth for a minimal noise floor.
- Select an RF attenuation which is high enough to just measure the harmonic ratio.

The maximum harmonic distortion is obtained if the level of the harmonic equals the intrinsic noise level of the receiver. The level applied to the mixer, according to (2), is:

$$\boldsymbol{P_I = \frac{P_{noise} / dBm + IP2}{2}} \qquad (3)$$

At a resolution bandwidth of 10 Hz (noise level –143 dBm, S.H.I. = 40 dBm), the optimum mixer level is – 51.5 dBm. According to (1) a maximum measurable harmonic distortion of 91.5 dB minus a minimum S/N ratio of 4 dB is obtained.

If the harmonic emerges from noise sufficiently (approx. >15 dB), it is easy to check (by changing the RF attenuation) whether the harmonics originate from the DUT or are generated internally by the spectrum analyzer. If a harmonic originates from the DUT, its level remains constant if the RF attenuation is increased by 10 dB. Only the displayed noise is increased by 10 dB due to the additional attenuation. If the harmonic is exclusively generated by the spectrum analyzer, the level of the harmonic is reduced by 20 dB or is lost in noise. If both – the DUT and the spectrum analyzer – contribute to the harmonic, the reduction in the harmonic level is correspondingly smaller.

High–Sensitivity Harmonics Measurements

If harmonics have very small levels, the resolution bandwidth required to measure them must be reduced considerably. The sweep time is, therefore, also increased considerably. In this case, the measurement of individual harmonics is carried out with the R&S ZVL-K1 set to a small span. Only the frequency range around the harmonics will then be measured with a small resolution bandwidth.

Signal generator settings (e.g. R&S SMU):

Frequency: 128 MHz

Level: – 25 dBm

Procedure:

1. Set the R&S ZVL-K1 to its default state.
   – Press the **PRESET** key.
     The R&S ZVL-K1 is set to its default state.
2. Set the center frequency to 128 MHz and the span to 100 kHz.
   – Press the **CENTER** key.
     The frequency menu is displayed.
   – In the dialog box, enter *128* using the numeric keypad and confirm with the **MHz** key.
   – Press the **SPAN** key.
   – In the dialog box, enter *100* using the numeric keypad and confirm with the **kHz** key.
     The R&S ZVL-K1 displays the reference signal with a span of 100 kHz and resolution bandwidth of 3 kHz.
3. Switching on the marker.
   – Press the **MKR** key.
     The marker is positioned on the trace maximum.

4. Set the measured signal frequency and the measured level as reference values

   – Press the Phase Noise/Ref Fixed softkey.

     The position of the marker becomes the reference point. The reference point level is indicated by a horizontal line, the reference point frequency with a vertical line. At the same time, the delta marker 2 is switched on.

   – Press the **Ref Fixed** softkey.

     The mode changes from phase noise measurement to reference fixed, the marker readout changes from dB/Hz to dB.

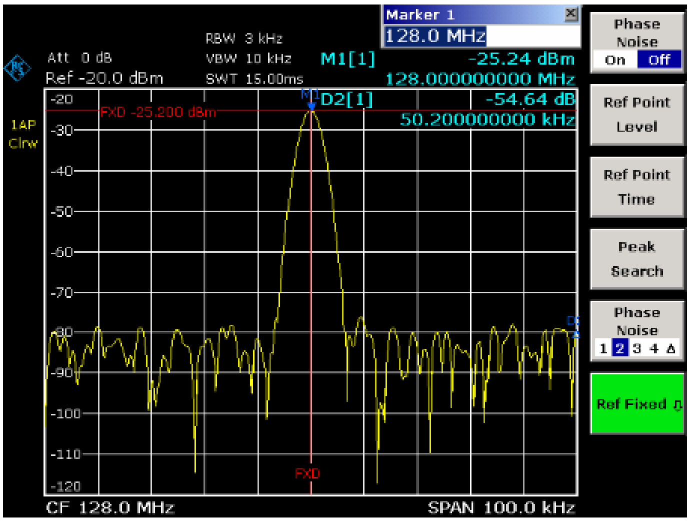


Fig. 2-2 Fundamental wave and the frequency and level reference point

5. Make the step size for the center frequency equal to the signal frequency

   – Press the **CENTER** key.

     The frequency menu is displayed.

   – Press the **CF–Stepsize** softkey and press the **= Marker** softkey in the submenu.

     The step size for the center frequency is now equal to the marker frequency.

6. Set the center frequency to the 2^{nd} harmonic of the signal

   – Press the **CENTER** key.

     The frequency menu is displayed.

   – Press the **UPARROW** key once.

     The center frequency is set to the 2^{nd} harmonic.

7. Place the delta marker on the 2^{nd} harmonic.

   – Press the **MKR–>** key.

   – Press the **Peak** softkey.

     The delta marker moves to the maximum of the 2^{nd} harmonic. The displayed level result is relative to the reference point level (= fundamental wave level).

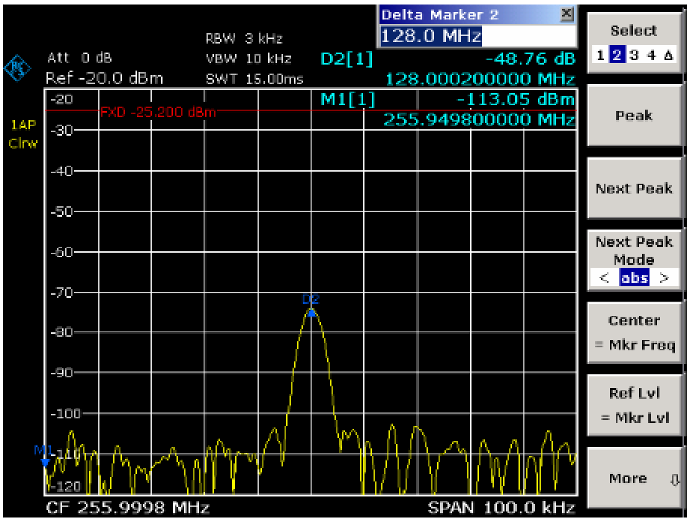


Fig. 2-3 Measuring the level difference between the fundamental wave (= reference point level) and the 2nd harmonic

The other harmonics are measured with steps 5 and 6, the center frequency being incremented or decremented in steps of 128 MHz using the **UPARROW** or **DNARROW** key.

Measuring the Spectra of Complex Signals

Separating Signals by Selecting an Appropriate Resolution Bandwidth

A basic feature of a spectrum analyzer is being able to separate the spectral components of a mixture of signals. The resolution at which the individual components can be separated is determined by the resolution bandwidth. Selecting a resolution bandwidth that is too large may make it impossible to distinguish between spectral components, i.e. they are displayed as a single component.

An RF sinusoidal signal is displayed by means of the passband characteristic of the resolution filter (RBW) that has been set. Its specified bandwidth is the 3 dB bandwidth of the filter.

Two signals with the same amplitude can be resolved if the resolution bandwidth is smaller than or equal to the frequency spacing of the signal. If the resolution bandwidth is equal to the frequency spacing, the spectrum display screen shows a level drop of 3 dB precisely in the center of the two signals. Decreasing the resolution bandwidth makes the level drop larger, which thus makes the individual signals clearer.

If there are large level differences between signals, the resolution is determined by selectivity as well as by the resolution bandwidth that has been selected. The measure of selectivity used for spectrum analyzers is the ratio of the 60 dB bandwidth to the 3 dB bandwidth (= shape factor).

For the R&S ZVL-K1, the shape factor for bandwidths is < 5, i.e. the 60 dB bandwidth of the 30 kHz filter is < 150 kHz.

The higher spectral resolution with smaller bandwidths is won by longer sweep times for the same span. The sweep time has to allow the resolution filters to settle during a sweep at all signal levels and frequencies to be displayed. It is given by the following formula.

$$SWT = k \bullet Span/RBW^2 \qquad (4)$$

SWT = max. sweep time for correct measurement

k	=	factor depending on type of resolution filter
		= 1 for digital IF filters
Span	=	frequency display range
RBW	=	resolution bandwidth

If the resolution bandwidth is reduced by a factor of 3, the sweep time is increased by a factor of 9.

The impact of the video bandwidth on the sweep time is not taken into account in (4). For the formula to be applied, the video bandwidth must be <3 x the resolution bandwidth.

FFT filters can be used for resolution bandwidths up to 30 kHz. Like digital filters, they have a shape factor of less than 5 up to 30 kHz. For FFT filters, however, the sweep time is given by the following formula:

$$SWT = k \cdot span/RBW \qquad (5)$$

If the resolution bandwidth is reduced by a factor of 3, the sweep time is increased by a factor of 3 only.

Intermodulation Measurements

If several signals are applied to a transmission two–port device with nonlinear characteristic, intermodulation products appear at its output by the sums and differences of the signals. The nonlinear characteristic produces harmonics of the useful signals which intermodulate at the characteristic. The intermodulation products of lower order have a special effect since their level is largest and they are near the useful signals. The intermodulation product of third order causes the highest interference. It is the intermodulation product generated from one of the useful signals and the 2nd harmonic of the second useful signal in case of two–tone modulation.

The frequencies of the intermodulation products are above and below the useful signals. Fig. 2-4 shows intermodulation products P_{I1} and P^{I2} generated by the two useful signals P_{U1} and P_{U2}.

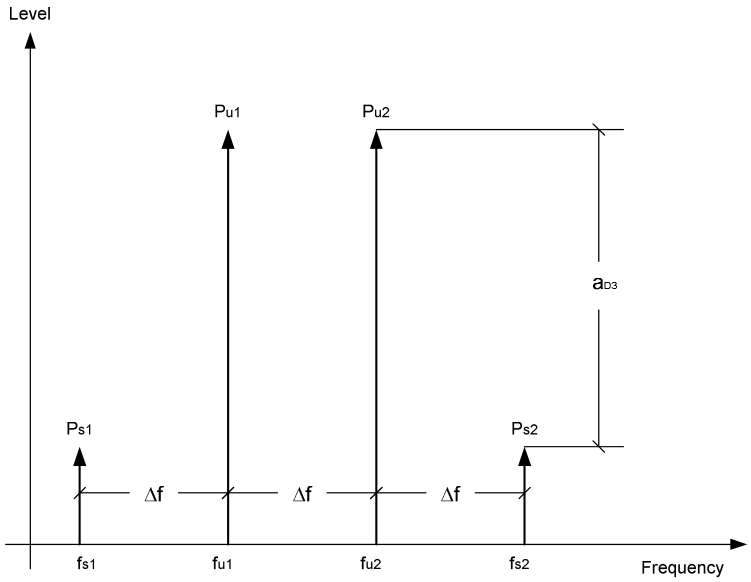


Fig. 2-4 Intermodulation products P_{U1} and P_{U2}

The intermodulation product at f_{I2} is generated by mixing the 2nd harmonic of useful signal P_{U2} and signal P_{U1}, the intermodulation product at f_{I1} by mixing the 2nd harmonic of useful signal P_{U1} and signal P_{U2}.

$$f_{i1} = 2 \times f_{u1} - f_{u2} \quad (6)$$

$$f_{i2} = 2 \times f_{u2} - f_{u1} \quad (7)$$

The level of the intermodulation products depends on the level of the useful signals. If the two useful signals are increased by 1 dB, the level of the intermodulation products increases by 3 dB, which means that spacing a_{D3} between intermodulation signals and useful signals are reduced by 2 dB. This is illustrated in Fig. 2-5.

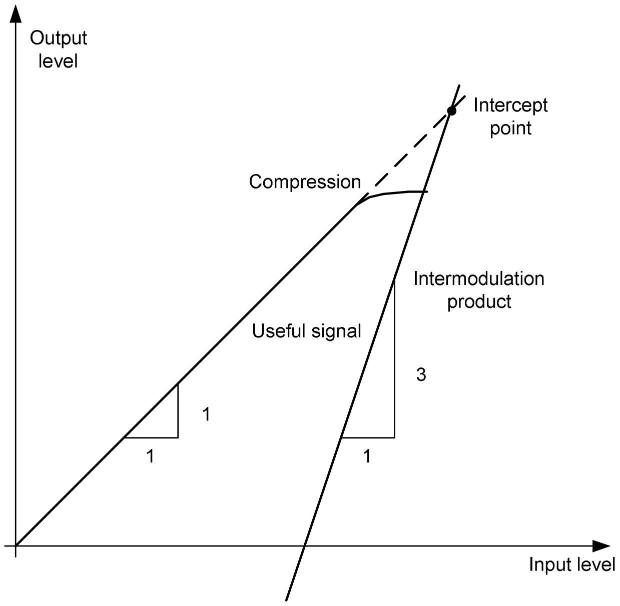


Fig. 2-5 Dependence of intermodulation level on useful signal level

The useful signals at the two–port output increase proportionally with the input level as long as the two–port is in the linear range. A level change of 1 dB at the input causes a level change of 1 dB at the output. Beyond a certain input level, the two–port goes into compression and the output level stops increasing. The intermodulation products of the third order increase three times as much as the useful signals. The intercept point is the fictitious level where the two lines intersect. It cannot be measured directly since the useful level is previously limited by the maximum two–port output power.

It can be calculated from the known line slopes and the measured spacing a_{D3} at a given level according to the following formula.

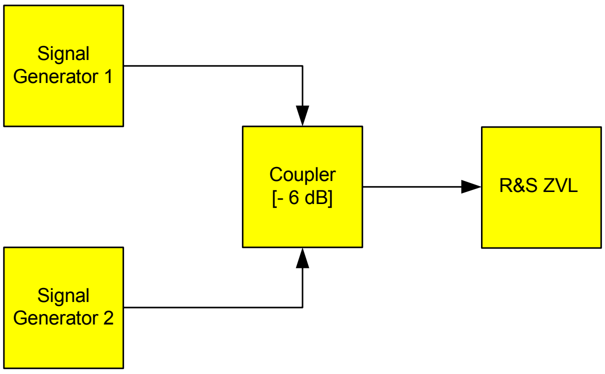
$$IP3 = \frac{a_{D3}}{2} + P_N \quad (8)$$

The 3rd order intercept point (TOI), for example, is calculated for an intermodulation of 60 dB and an input level P_U of –20 dBm according to the following formula:

$$IP3 = \frac{60}{2} + (-20dBm) = 10dBm \quad (9)$$

Measurement example – Measuring the R&S ZVL-K1's intrinsic intermodulation

Test setup:



Signal generator settings (e.g. R&S SMU):

	Level	Frequency
Signal generator 1	–4 dBm	999.7 MHz
Signal generator 2	–4 dBm	1000.3 MHz

Procedure:

1. Set the R&S ZVL-K1 to its default settings.
   - Press the **PRESET** key.

     The R&S ZVL-K1 is in its default state.

2. Set center frequency to 1 GHz and the frequency span to 3 MHz.
   - Press the **CENTER** key and enter *1 GHz*.
   - Press the **SPAN** key and enter *3 MHz*.

3. Set the reference level to –10 dBm and RF attenuation to 0 dB.
   - Press the **AMPT** key and enter *–10 dBm*.
   - Press the **RF Atten Manual** softkey and enter *0 dB*.

4. Set the resolution bandwidth to 10 kHz.
   - Press the **PWR BW** key.
   - Press the **Res BW Manual** softkey and enter *10 kHz*.

     The noise is reduced, the trace is smoothed further and the intermodulation products can be clearly seen.
   - Press the **Video BW Manual** softkey and enter *1 kHz*.

5. Measuring intermodulation by means of the 3rd order intercept measurement function
   - Press the **MEAS** key.
   - Press the **TOI** softkey.

The R&S ZVL-K1 activates four markers for measuring the intermodulation distance. Two markers are positioned on the useful signals and two on the intermodulation products. The 3rd order intercept is calculated from the level difference between the useful signals and the intermodulation products. It is then displayed on the screen:

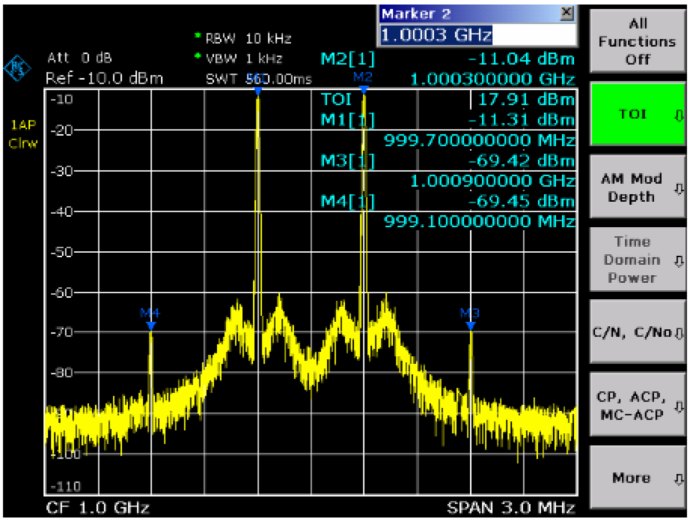


Fig. 2-6 Result of intrinsic intermodulation measurement on the R&S ZVL-K1. The 3rd order intercept (TOI) is displayed at the top right corner of the grid.

The level of a spectrum analyzer's intrinsic intermodulation products depends on the RF level of the useful signals at the input mixer. When the RF attenuation is added, the mixer level is reduced and the intermodulation distance is increased. With an additional RF attenuation of 10 dB, the levels of the intermodulation products are reduced by 20 dB. The noise level is, however, increased by 10 dB.

6. Increasing RF attenuation to 10 dB to reduce intermodulation products.

   – Press the **AMPT** key.

   – Press the **RF Atten Manual** softkey and enter *10 dB*.

   The R&S ZVL-K1's intrinsic intermodulation products disappear below the noise floor.

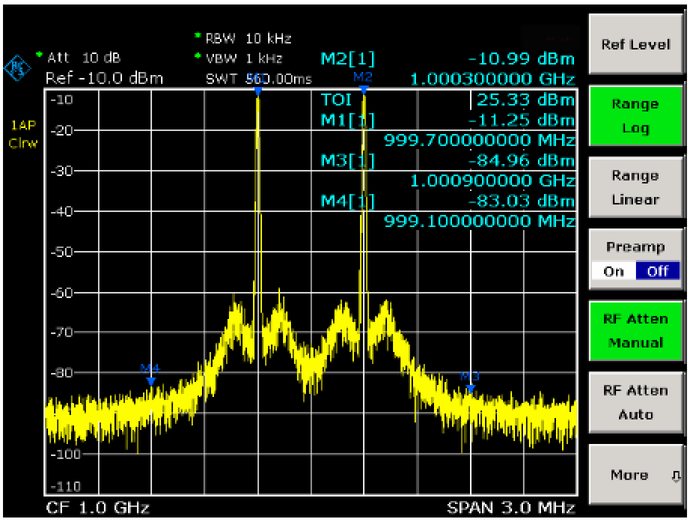


Fig. 2-7 If the RF attenuation is increased, the R&S ZVL-K1's intrinsic intermodulation products disappear below the noise floor.

Calculation method:

The method used by the R&S ZVL-K1 to calculate the intercept point takes the average useful signal level P_u in dBm and calculates the intermodulation d_3 in dB as a function of the average value of the levels of the two intermodulation products. The third order intercept (TOI) is then calculated as follows:

$$TOI/dBm = \frac{1}{2} d_3 + P_u$$

Intermodulation– free dynamic range

The **Intermodulation – free dynamic range,** i.e. the level range in which no internal intermodulation products are generated if two–tone signals are measured, is determined by the 3rd order intercept point, the phase noise and the thermal noise of the spectrum analyzer. At high signal levels, the range is determined by intermodulation products. At low signal levels, intermodulation products disappear below the noise floor, i.e. the noise floor and the phase noise of the spectrum analyzer determine the range. The noise floor and the phase noise depend on the resolution bandwidth that has been selected. At the smallest resolution bandwidth, the noise floor and phase noise are at a minimum and so the maximum range is obtained. However, a large increase in sweep time is required for small resolution bandwidths. It is, therefore, best to select the largest resolution bandwidth possible to obtain the range that is required. Since phase noise decreases as the carrier–offset increases, its influence decreases with increasing frequency offset from the useful signals.

The following diagrams illustrate the intermodulation–free dynamic range as a function of the selected bandwidth and of the level at the input mixer (= signal level – set RF attenuation) at different useful signal offsets.

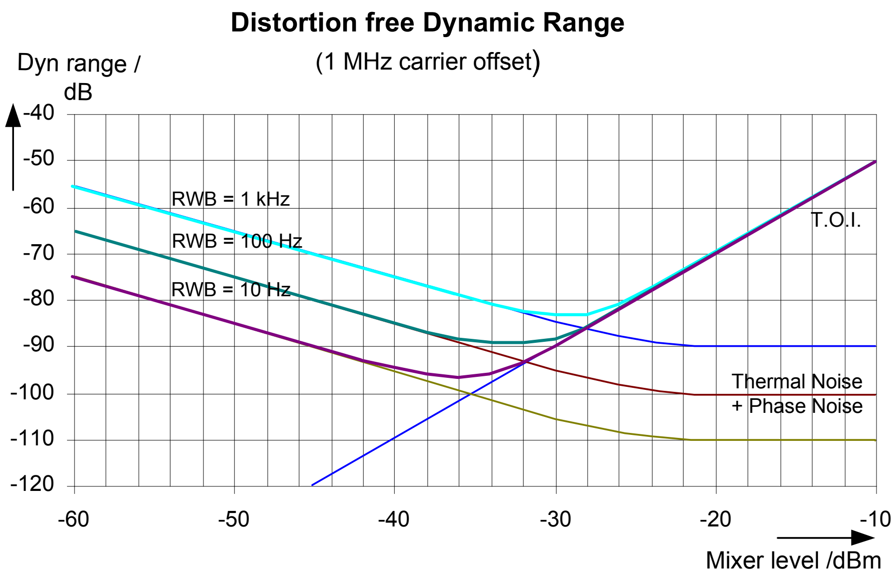


Fig. 2-8 Intermodulation–free range of the R&S ZVL-K1 as a function of level at the input mixer and the set resolution bandwidth (useful signal offset = 1 MHz, DANL = –145 dBm /Hz, TOI = 15 dBm; typical values at 2 GHz)

The optimum mixer level, i.e. the level at which the intermodulation distance is at its maximum, depends on the bandwidth. At a resolution bandwidth of 10 Hz, it is approx. –35 dBm and at 1 kHz increases to approx. –30 dBm.

Phase noise has a considerable influence on the intermodulation–free range at carrier offsets between 10 and 100 kHz (Fig. 2-9). At greater bandwidths, the influence of the phase noise is greater than it would be with small bandwidths. The optimum mixer level at the bandwidths under consideration becomes almost independent of bandwidth and is approx. –40 dBm.

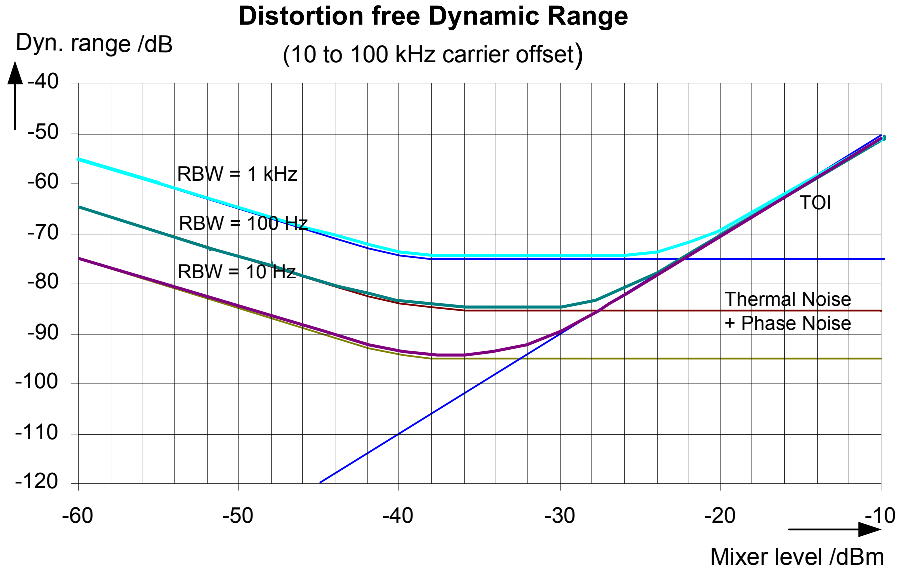


Fig. 2-9 Intermodulation–free dynamic range of the R&S ZVL-K1 as a function of level at the input mixer and of the selected resolution bandwidth (useful signal offset = 10 to 100 kHz, DANL = –145 dBm /Hz, TOI = 15 dBm; typical values at 2 GHz).

If the intermodulation products of a DUT with a very high dynamic range are to be measured and the resolution bandwidth to be used is therefore very small, it is best to measure the levels of the useful signals and those of the intermodulation products separately using a small span. The measurement time will be reduced– in particular if the offset of the useful signals is large. To find signals reliably when frequency span is small, it is best to synchronize the signal sources and the R&S ZVL-K1.

Measuring Signals in the Vicinity of Noise

The minimum signal level a spectrum analyzer can measure is limited by its intrinsic noise. Small signals can be swamped by noise and therefore cannot be measured. For signals that are just above the intrinsic noise, the accuracy of the level measurement is influenced by the intrinsic noise of the spectrum analyzer.

The displayed noise level of a spectrum analyzer depends on its noise figure, the selected RF attenuation, the selected reference level, the selected resolution and video bandwidth and the detector. The effect of the different parameters is explained in the following.

Impact of the RF attenuation setting

The sensitivity of a spectrum analyzer is directly influenced by the selected RF attenuation. The highest sensitivity is obtained at a RF attenuation of 0 dB. The attenuation can be set in 10 dB steps up to 70 dB. Each additional 10 dB step reduces the sensitivity by 10 dB, i.e. the displayed noise is increased by 10 dB.

Impact of the resolution bandwidth

The sensitivity of a spectrum analyzer also directly depends on the selected bandwidth. The highest sensitivity is obtained at the smallest bandwidth (for the R&S ZVL-K1: 10 Hz, for FFT filtering: 1 Hz). If the bandwidth is increased, the reduction in sensitivity is proportional to the change in bandwidth. The R&S ZVL-K1 has bandwidth settings in 1, 3, 10 sequence. Increasing the bandwidth by a factor of 3 increases the displayed noise by approx. 5 dB (4.77 dB precisely). If the bandwidth is increased by a factor of 10, the displayed noise increases by a factor of 10, i.e. 10 dB.

Impact of the video bandwidth

The displayed noise of a spectrum analyzer is also influenced by the selected video bandwidth. If the video bandwidth is considerably smaller than the resolution bandwidth, noise spikes are suppressed, i.e. the trace becomes much smoother. The level of a sinewave signal is not influenced by the video bandwidth. A sinewave signal can therefore be freed from noise by using a video bandwidth that is small compared with the resolution bandwidth, and thus be measured more accurately.

Impact of the detector

Noise is evaluated differently by the different detectors. The noise display is therefore influenced by the choice of detector. Sinewave signals are weighted in the same way by all detectors, i.e. the level display for a sinewave RF signal does not depend on the selected detector, provided that the signal–to–noise ratio is high enough. The measurement accuracy for signals in the vicinity of intrinsic spectrum analyzer noise is also influenced by the detector which has been selected. For details on the detectors of the R&S ZVL-K1 refer to chapter "Instrument Functions", section "Detector overview" or the Online Help.

Measurement example – Measuring level at low S/N ratios

The example shows the different factors influencing the S/N ratio.

Signal generator settings (e.g. R&S SMU):

Frequency: 128 MHz

Level: – 80 dBm

Procedure:

1. Set the R&S ZVL-K1 to its default state.
   - Press the **PRESET** key.

     The R&S ZVL-K1 is in its default state.

2. Set the center frequency to 128 MHz and the frequency span to 100 MHz.
   - Press the **CENTER** key and enter *128 MHz*.
   - Press the **SPAN** key and enter *100* MHz.

3. Set the RF attenuation to 60 dB to attenuate the input signal or to increase the intrinsic noise.
   - Press the **AMPT** key.
   - Press the **RF Atten Manual** softkey and enter *60 dB*.

     The RF attenuation indicator is marked with an asterisk (*Att 60 dB) to show that it is no longer coupled to the reference level. The high input attenuation reduces the reference signal which can no longer be detected in noise.

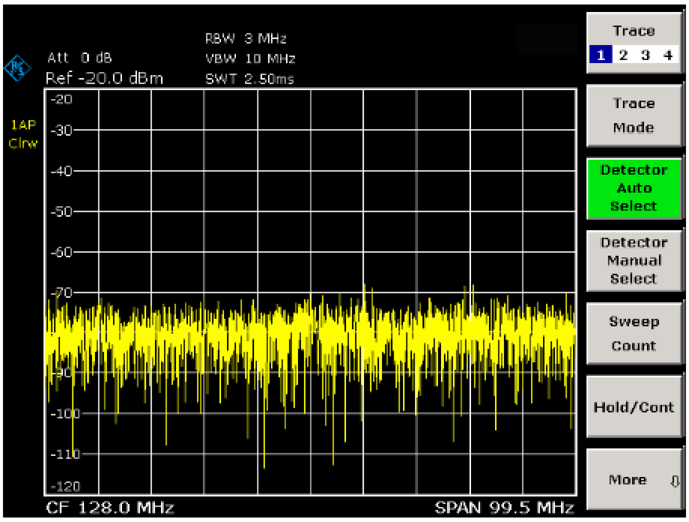


Fig. 2-10 Sinewave signal with low S/N ratio. The signal is measured with the auto peak detector and is completely hidden in the intrinsic noise of the R&S ZVL-K1.

4. To suppress noise spikes the trace can be averaged.
   – Press the **TRACE** key.
   – Press the **Trace Mode** key.
   – Press the **Average** softkey.

   The traces of consecutive sweeps are averaged. To perform averaging, the R&S ZVL-K1 automatically switches on the sample detector. The RF signal, therefore, can be more clearly distinguished from noise.

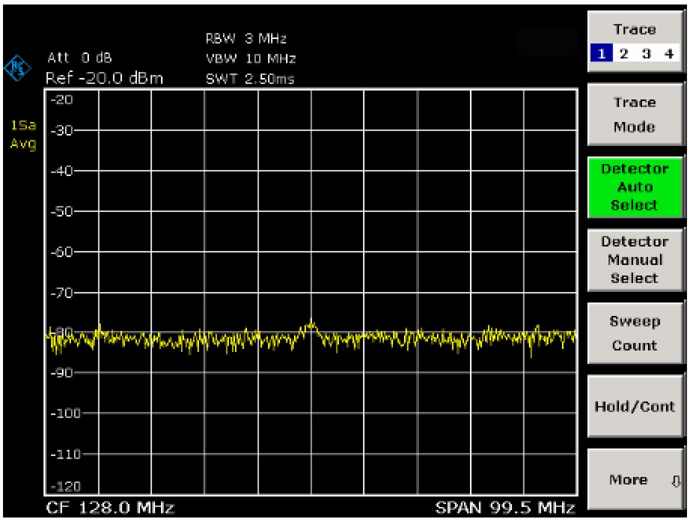


Fig. 2-11 RF sinewave signal with low S/N ratio if the trace is averaged.

5. Instead of trace averaging, a video filter that is narrower than the resolution bandwidth can be selected.
   – Press the **Trace Mode** key.
   – Press the **Clear Write** softkey.

– Press the **PWR BW** key.

– Press the **Video BW Manual** softkey and enter *10 kHz*.

The RF signal can be more clearly distinguished from noise.

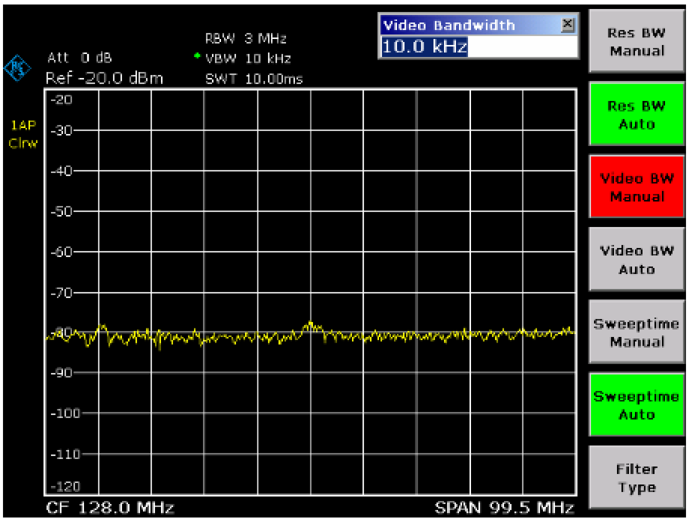


Fig. 2-12 RF sinewave signal with low S/N ratio if a smaller video bandwidth is selected.

6. By reducing the resolution bandwidth by a factor of 10, the noise is reduced by 10 dB.

– Press the **Res BW Manual** softkey and enter *300 kHz*.

The displayed noise is reduced by approx. 10 dB. The signal, therefore, emerges from noise by about 10 dB. Compared to the previous setting, the video bandwidth has remained the same, i.e. it has increased relative to the smaller resolution bandwidth. The averaging effect of the video bandwidth is therefore reduced. The trace will be noisier.

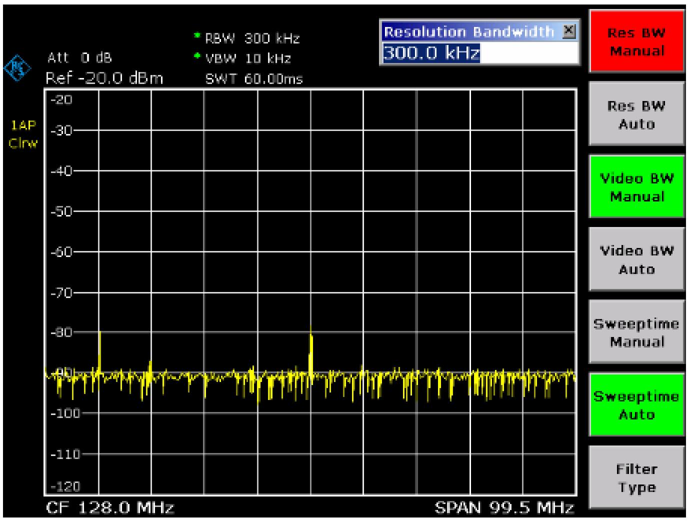


Fig. 2-13 Reference signal at a smaller resolution bandwidth

Noise Measurements

Noise measurements play an important role in spectrum analysis. Noise e.g. affects the sensitivity of radio communication systems and their components.

Noise power is specified either as the total power in the transmission channel or as the power referred to a bandwidth of 1 Hz. The sources of noise are, for example, amplifier noise or noise generated by oscillators used for the frequency conversion of useful signals in receivers or transmitters. The noise at the output of an amplifier is determined by its noise figure and gain.

The noise of an oscillator is determined by phase noise near the oscillator frequency and by thermal noise of the active elements far from the oscillator frequency. Phase noise can mask weak signals near the oscillator frequency and make them impossible to detect.

Measuring Noise Power Density

To measure noise power referred to a bandwidth of 1 Hz at a certain frequency, the R&S ZVL-K1 provides marker function. This marker function calculates the noise power density from the measured marker level.

Measurement example – Measuring the intrinsic noise power density of the R&S ZVL-K1 at 1 GHz and calculating the R&S ZVL-K1's noise figure

Test setup:

➢ Connect no signal to the RF input; terminate RF input with 50 Ω.

Procedure:

1. Set the R&S ZVL-K1 to its default state.
   – Press the **PRESET** key.
     The R&S ZVL-K1 is in its default state.
2. Set the center frequency to 1.234 GHz and the span to 1 MHz.
   – Press the **CENTER** key and enter *1.234 GHz*.
   – Press the **SPAN** key and enter *1 MHz*.
3. Switch on the marker and set the marker frequency to 1.234 GHz.
   – Press the **MKR** key and enter *1.234 GHz*.
4. Switch on the noise marker function.
   – Switch on the **Noise Meas** softkey.
     The R&S ZVL-K1 displays the noise power at 1 GHz in dBm (1 Hz).

Since noise is random, a sufficiently long measurement time has to be selected to obtain stable measurement results. This can be achieved by averaging the trace or by selecting a very small video bandwidth relative to the resolution bandwidth.

5. The measurement result is stabilized by averaging the trace.
   - Press the **TRACE** key.
   - Press the **Trace Mode** key.
   - Press the **Average** softkey.

     The R&S ZVL-K1 performs sliding averaging over 10 traces from consecutive sweeps. The measurement result becomes more stable.

Conversion to other reference bandwidths

The result of the noise measurement can be referred to other bandwidths by simple conversion. This is done by adding 10 · log (BW) to the measurement result, BW being the new reference bandwidth.

Example

A noise power of –150 dBm (1 Hz) is to be referred to a bandwidth of 1 kHz.
$P_{[1kHz]}$ = –150 + 10 * log (1000) = –150 +30 = –120 dBm (1 kHz)

Calculation method for noise power

If the noise marker is switched on, the R&S ZVL-K1 automatically activates the sample detector. The video bandwidth is set to 1/10 of the selected resolution bandwidth (RBW).

To calculate the noise, the R&S ZVL-K1 takes an average over 17 adjacent pixels (the pixel on which the marker is positioned and 8 pixels to the left, 8 pixels to the right of the marker). The measurement result is stabilized by video filtering and averaging over 17 pixels.

Since both video filtering and averaging over 17 trace points is performed in the log display mode, the result would be 2.51 dB too low (difference between logarithmic noise average and noise power). The R&S ZVL-K1, therefore, corrects the noise figure by 2.51 dB.

To standardize the measurement result to a bandwidth of 1 Hz, the result is also corrected by –10 * log (RBW_{noise}), with RBW_{noise} being the power bandwidth of the selected resolution filter (RBW).

Detector selection

The noise power density is measured in the default setting with the sample detector and using averaging. Other detectors that can be used to perform a measurement giving true results are the average detector or the RMS detector. If the average detector is used, the linear video voltage is averaged and displayed as a pixel. If the RMS detector is used, the squared video voltage is averaged and displayed as a pixel. The averaging time depends on the selected sweep time (=SWT/501). An increase in the sweep time gives a longer averaging time per pixel and thus stabilizes the measurement result. The R&S ZVL-K1 automatically corrects the measurement result of the noise marker display depending on the selected detector (+1.05 dB for the average detector, 0 dB for the RMS detector). It is assumed that the video bandwidth is set to at least three times the resolution bandwidth. While the average or RMS detector is being switched on, the R&S ZVL-K1 sets the video bandwidth to a suitable value.

The Pos Peak, Neg Peak, Auto Peak and Quasi Peak detectors are not suitable for measuring noise power density.

Determining the noise figure

The noise figure of amplifiers or of the R&S ZVL-K1 alone can be obtained from the noise power display. Based on the known thermal noise power of a 50 Ω resistor at room temperature (–174 dBm (1Hz)) and the measured noise power P_{noise} the noise figure (NF) is obtained as follows:

$$NF = P_{noise} + 174 - g,$$

where g = gain of DUT in dB

Example

The measured internal noise power of the R&S ZVL-K1 at an attenuation of 0 dB is found to be –143 dBm/1 Hz. The noise figure of the R&S ZVL-K1 is obtained as follows

NF = –143 + 174 = 31 dB

If noise power is measured at the output of an amplifier, for example, the sum of the internal noise power and the noise power at the output of the DUT is measured. The noise power of the DUT can be obtained by subtracting the internal noise power from the total power (subtraction of linear noise powers). By means of the following diagram, the noise level of the DUT can be estimated from the level difference between the total and the internal noise level.

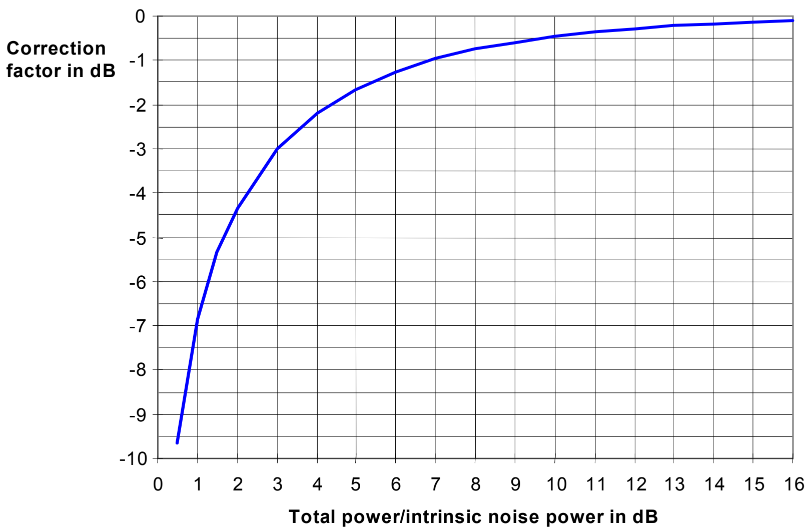


Fig. 2-14 Correction factor for measured noise power as a function of the ratio of total power to the intrinsic noise power of the spectrum analyzer

Measurement of Noise Power within a Transmission Channel

Noise in any bandwidth can be measured with the channel power measurement functions. Thus the noise power in a communication channel can be determined, for example. If the noise spectrum within the channel bandwidth is flat, the noise marker from the previous example can be used to determine the noise power in the channel by considering the channel bandwidth. If, however, phase noise and noise that normally increases towards the carrier is dominant in the channel to be measured, or if there are discrete spurious signals in the channel, the channel power measurement method must be used to obtain correct measurement results.

Measurement example – Measuring the intrinsic noise of the R&S ZVL-K1 at 1 GHz in a 1.23 MHz channel bandwidth with the channel power function

Test setup:

- Leave the RF input of the R&S ZVL-K1 open–circuited or terminate it with 50 Ω.

Procedure:

1. Set the R&S ZVL-K1 to its default state.
   - Press the **PRESET** key.

     The R&S ZVL-K1 is in its default state.

2. Set the center frequency to 1 GHz and the span to 1 MHz.
   - Press the **CENTER** key and enter *1 GHz.*
   - Press the **SPAN** key and enter *2 MHz*.

3. To obtain maximum sensitivity, set RF attenuation on the R&S ZVL-K1 to 0 dB.
   - Press the **AMPT** key.
   - Press the **RF Atten Manual** softkey and enter *0 dB*.

4. Switch on and configure the channel power measurement.
   - Press the **MEAS** key.
   - Press the **CP, ACP, MC–ACP** softkey.

     The R&S ZVL-K1 activates the channel or adjacent channel power measurement according to the currently set configuration.
   - Press the **CP/ACP Config** softkey.

     The submenu for configuring the channel is displayed.
   - Press the **Channel Settings** softkey.

     The submenu for channel settings is displayed.
   - Press the **Channel Bandwidth** softkey and enter *1.23 MHz*.

     The R&S ZVL-K1 displays the 1.23 MHz channel as two vertical lines which are symmetrical to the center frequency.
   - Press the **Adjust Settings** softkey.

     The settings for the frequency span, the bandwidth (RBW and VBW) and the detector are automatically set to the optimum values required for the measurement.

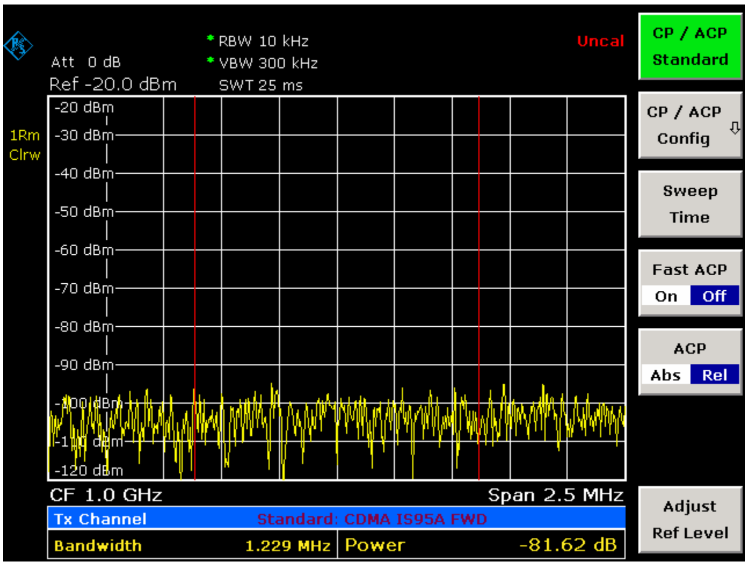


Fig. 2-15 Measurement of the R&S ZVL-K1's intrinsic noise power in a 1.23 MHz channel bandwidth.

5. Stabilizing the measurement result by increasing the sweep time
   - Press the ▲ key twice.

     The main menu for channel and adjacent channel power measurement is displayed.
   - Press the **Sweep Time** softkey and enter *1 s*.

     The trace becomes much smoother because of the RMS detector and the channel power measurement display is much more stable.

Method of calculating the channel power

When measuring the channel power, the R&S ZVL-K1 integrates the linear power which corresponds to the levels of the pixels within the selected channel. The spectrum analyzer uses a resolution bandwidth which is far smaller than the channel bandwidth. When sweeping over the channel, the channel filter is formed by the passband characteristics of the resolution bandwidth (see Fig. 2-16).

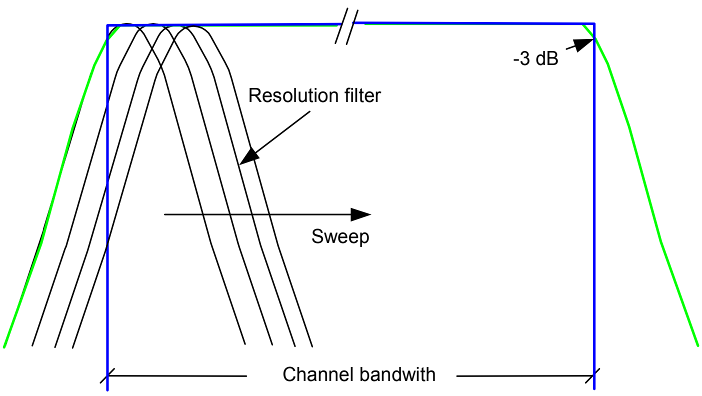


Fig. 2-16 Approximating the channel filter by sweeping with a small resolution bandwidth

The following steps are performed:

- The linear power of all the trace pixels within the channel is calculated.

$P_i = 10^{(L_i/10)}$

where P_i = power of the trace pixel i

L_i = displayed level of trace point i

- The powers of all trace pixels within the channel are summed up and the sum is divided by the number of trace pixels in the channel.
- The result is multiplied by the quotient of the selected channel bandwidth and the noise bandwidth of the resolution filter (RBW).

Since the power calculation is performed by integrating the trace within the channel bandwidth, this method is also called the IBW method (**I**ntegration **B**and**w**idth method).

Parameter settings

For selection of the sweep time, see next section. For details on the parameter settings refer to chapter "Instrument Functions", section "Settings of the CP / ACP test parameters" or the Online Help.

Sweep time selection

The number of A/D converter values, N, used to calculate the power, is defined by the sweep time. The time per trace pixel for power measurements is directly proportional to the selected sweep time.

If the sample detector is used, it is best to select the smallest sweep time possible for a given span and resolution bandwidth. The minimum time is obtained if the setting is coupled. This means that the time per measurement is minimal. Extending the measurement time does not have any advantages as the number of samples for calculating the power is defined by the number of trace pixels in the channel.

If the RMS detector is used, the repeatability of the measurement results can be influenced by the selection of sweep times. Repeatability is increased at longer sweep times.

Repeatability can be estimated from the following diagram:

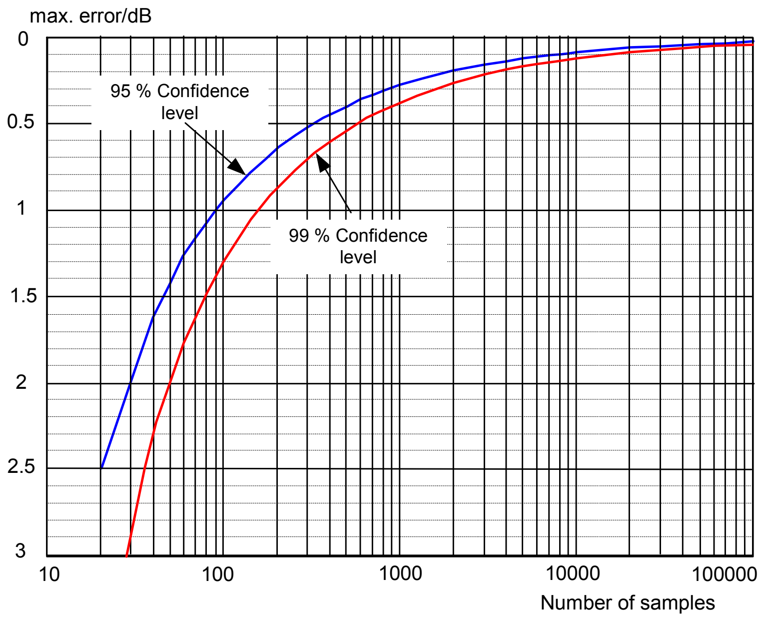


Fig. 2-17 Repeatability of channel power measurements as a function of the number of samples used for power calculation

The curves in Fig. 2-17 indicate the repeatability obtained with a probability of 95% and 99% depending on the number of samples used.

The repeatability with 600 samples is ± 0.5 dB. This means that – if the sample detector and a channel bandwidth over the whole diagram (channel bandwidth = span) is used – the measured value lies within ± 0.5 dB of the true value with a confidence level of 99%.

If the RMS detector is used, the number of samples can be estimated as follows:

Since only uncorrelated samples contribute to the RMS value, the number of samples can be calculated from the sweep time and the resolution bandwidth.

Samples can be assumed to be uncorrelated if sampling is performed at intervals of 1/RBW. The number of uncorrelated samples is calculated as follows:

$N_{decorr} = SWT \cdot RBW$ *(N_{decorr} means uncorrelated samples)*

The number of uncorrelated samples per trace pixel is obtained by dividing N_{decorr} by 501 (= pixels per trace).

Example

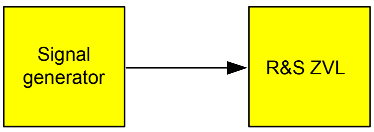
At a resolution bandwidth of 30 kHz and a sweep time of 100 ms, 3000 uncorrelated samples are obtained. If the channel bandwidth is equal to the frequency display range, i.e. all trace pixels are used for the channel power measurement, a repeatability of 0.2 dB with a probability of 99% is the estimate that can be derived from Fig. 2-17.

Measuring Phase Noise

The R&S ZVL-K1 has an easy–to–use marker function for phase noise measurements. This marker function indicates the phase noise of an RF oscillator at any carrier in dBc in a bandwidth of 1 Hz.

Measurement example – Measuring the phase noise of a signal generator at a carrier offset of 10 kHz

Test setup:



Signal generator settings (e.g. R&S SMU):

Frequency: 100 MHz

Level: 0 dBm

Procedure:

1. Set the R&S ZVL-K1 to its default state.
   – Press the **PRESET** key.

     R&S ZVL-K1 is in its default state.

2. Set the center frequency to 100 MHz and the span to 50 kHz.
   – Press the **CENTER** key and enter *100 MHz*.
   – Press the **SPAN** key and enter *50 kHz*.

3. Set the R&S ZVL-K1's reference level to 0 dBm (=signal generator level).
   – Press the **AMPT** key and enter *0 dBm*.

4. Enable phase noise measurement.
   – Press the **MKR** key.
   – Press the Phase Noise/Ref Fixed softkey.

   The R&S ZVL-K1 activates phase noise measurement. Marker 1 (=main marker) and marker 2 (= delta marker) are positioned on the signal maximum. The position of the marker is the reference (level and frequency) for the phase noise measurement. A horizontal line represents the level of the reference point and a vertical line the frequency of the reference point. The dialog box for the delta marker is displayed so that the frequency offset at which the phase noise is to be measured can be entered directly.

5. Set the frequency offset to 10 kHz for determining phase noise.
   – Enter *10 kHz*.

   The R&S ZVL-K1 displays the phase noise at a frequency offset of 10 kHz. The magnitude of the phase noise in dBc/Hz is displayed in the delta marker output field at the top right of the screen (Phn2).

6. Stabilize the measurement result by activating trace averaging.
   – Press the **TRACE** key.
   – Press the **Trace Mode** key.
   – Press the **Average** softkey.

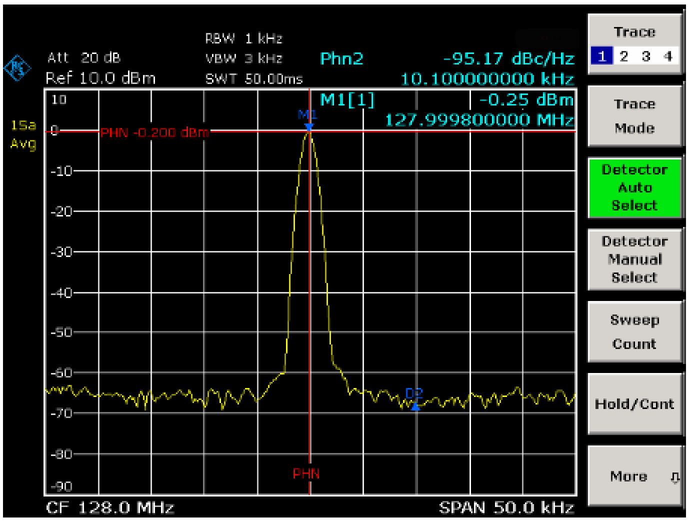


Fig. 2-18 Measuring phase noise with the phase–noise marker function

The frequency offset can be varied by moving the marker with the rotary knob or by entering a new frequency offset as a number.

Measurements on Modulated Signals

Measuring Channel Power and Adjacent Channel Power

Measuring channel power and adjacent channel power is one of the most important tasks in the field of digital transmission for a spectrum analyzer with the necessary test routines. While, theoretically, channel power could be measured at highest accuracy with a power meter, its low selectivity means that it is not suitable for measuring adjacent channel power as an absolute value or relative to the transmit channel power. The power in the adjacent channels can only be measured with a selective power meter.

A spectrum analyzer cannot be classified as a true power meter, because it displays the IF envelope voltage. However, it is calibrated such as to correctly display the power of a pure sinewave signal irrespective of the selected detector. This calibration cannot be applied for non–sinusoidal signals. Assuming that the digitally modulated signal has a Gaussian amplitude distribution, the signal power within the selected resolution bandwidth can be obtained using correction factors. These correction factors are normally used by the spectrum analyzer's internal power measurement routines in order to determine the signal power from IF envelope measurements. These factors apply if and only if the assumption of a Gaussian amplitude distribution is correct.

Apart from this common method, the R&S ZVL-K1 also has a true power detector, i.e. an RMS detector. It correctly displays the power of the test signal within the selected resolution bandwidth irrespective of the amplitude distribution, without additional correction factors being required. The absolute measurement uncertainty of the R&S ZVL-K1 is < 1.5 dB and a relative measurement uncertainty of < 0.5 dB (each with a confidence level of 95%).

There are two possible methods for measuring channel and adjacent channel power with a spectrum analyzer:

- IBW method (**I**ntegration **B**and**w**idth Method)
  The spectrum analyzer measures with a resolution bandwidth that is less than the channel bandwidth and integrates the level values of the trace versus the channel bandwidth. This method is described in section "Method of calculating the channel power".
- Using a channel filter
  For a detailed description, refer to the following section.

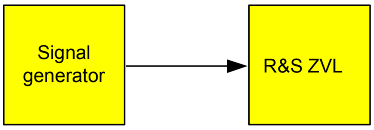
Measurement using a channel filter

In this case, the spectrum analyzer makes zero span measurements using an IF filter that corresponds to the channel bandwidth. The power is measured at the output of the IF filter. Until now, this method has not been used for spectrum analyzers, because channel filters were not available and the resolution bandwidths, optimized for the sweep, did not have a sufficient selectivity. The method was reserved for special receivers optimized for a particular transmission method. It is available in R&S FSQ, FSU, FSP, FSL and ESL series.

The R&S ZVL-K1 has test routines for simple channel and adjacent channel power measurements. These routines give quick results without any complex or tedious setting procedures.

Measurement example 1 – ACPR measurement on an CDMA 2000 signal

Test setup:



Signal generator settings (e.g. R&S SMU):

Frequency: 850 MHz

Level: 0 dBm

Modulation: CDMA 2000

Procedure:

1. Set the R&S ZVL-K1 to its default state.
   – Press the **PRESET** key.

     The R&S ZVL-K1 is in its default state.

2. Set the center frequency to 850 MHz and span to 4 MHz.
   – Press the **CENTER** key and enter *850 MHz*.
   – Press the **SPAN** key and enter *4 MHz*.

3. Set the reference level to +10 dBm.
   – Press the **AMPT** key and enter *10 dBm*.

4. Configuring the adjacent channel power for the CDMA 2000 MC1.
   – Press the **MEAS** key.
   – Press the **CP, ACP, MC–ACP** softkey.
   – Press the **CP / ACP Standard** softkey.
   – In the standards list, mark **CDMA 2000 MC1** using the rotary knob or the arrow keys and confirm pressing the rotary knob or the **ENTER** key.

     The R&S ZVL-K1 sets the channel configuration according to the 2000 MC1 standard for mobile stations with 2 adjacent channels above and below the transmit channel. The spectrum is displayed in the upper part of the screen, the numeric values of the results and the channel configuration in the lower part of the screen. The various channels are represented by vertical lines on the graph.

     The frequency span, resolution bandwidth, video bandwidth and detector are selected automatically to give correct results. To obtain stable results – especially in the adjacent channels (30 kHz bandwidth) which are narrow in comparison with the transmission channel bandwidth (1.23 MHz) – the RMS detector is used.

5. Set the optimal reference level and RF attenuation for the applied signal level.
   – Press the **Adjust Ref Level** softkey.

The R&S ZVL-K1 sets the optimal RF attenuation and the reference level based on the transmission channel power to obtain the maximum dynamic range. Fig. 2-19 shows the result of the measurement.

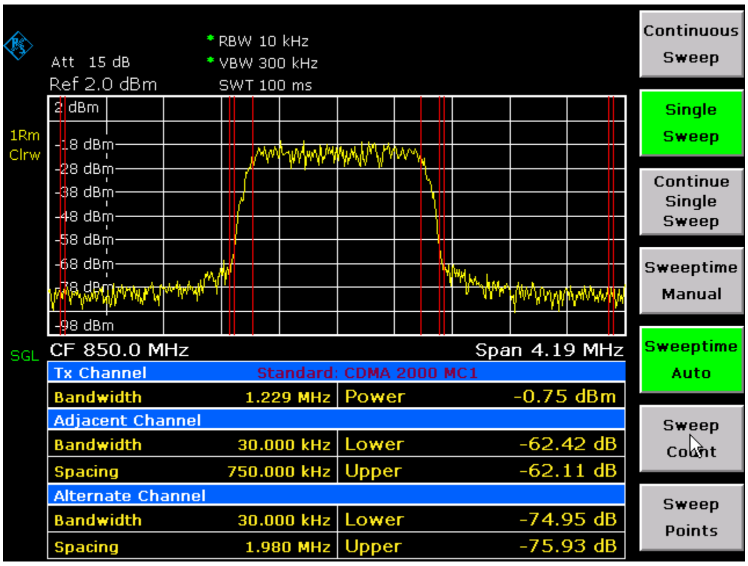


Fig. 2-19 Adjacent channel power measurement on a CDMA 2000 MC1 signal

The repeatability of the results, especially in the narrow adjacent channels, strongly depends on the measurement time since the dwell time within the 30 kHz channels is only a fraction of the complete sweep time. A longer sweep time may increase the probability that the measured value converges to the true value of the adjacent channel power, but this increases measurement time.

To avoid long measurement times, the R&S ZVL-K1 measures the adjacent channel power with zero span (fast ACP mode). In the fast ACP mode, the R&S ZVL-K1 measures the power of each channel at the defined channel bandwidth, while being tuned to the center frequency of the channel in question. The digital implementation of the resolution bandwidths makes it possible to select filter characteristics that is precisely tailored to the signal. In case of CDMA 2000 MC1, the power in the useful channel is measured with a bandwidth of 1.23 MHz and that of the adjacent channels with a bandwidth of 30 kHz. Therefore the R&S ZVL-K1 changes from one channel to the other and measures the power at a bandwidth of 1.23 MHz or 30 kHz using the RMS detector. The measurement time per channel is set with the sweep time. It is equal to the selected measurement time divided by the selected number of channels. The five channels from the above example and the sweep time of 100 ms give a measurement time per channel of 20 ms.

Compared to the measurement time per channel given by the span (= 5 MHz) and sweep time (= 100 ms, equal to 0.600 ms per 30 kHz channel) used in the example, this is a far longer dwell time on the adjacent channels (factor of 12). In terms of the number of uncorrelated samples this means 20000/33 µs = 606 samples per channel measurement compared to 600/33µs = 12.5 samples per channel measurement.

Repeatability with a confidence level of 95% is increased from ± 1.4 dB to ± 0.38 dB as shown in Fig. 2-17. For the same repeatability, the sweep time would have to be set to 1.2 s with the integration method. Fig. 2-20 shows the standard deviation of the results as a function of the sweep time.

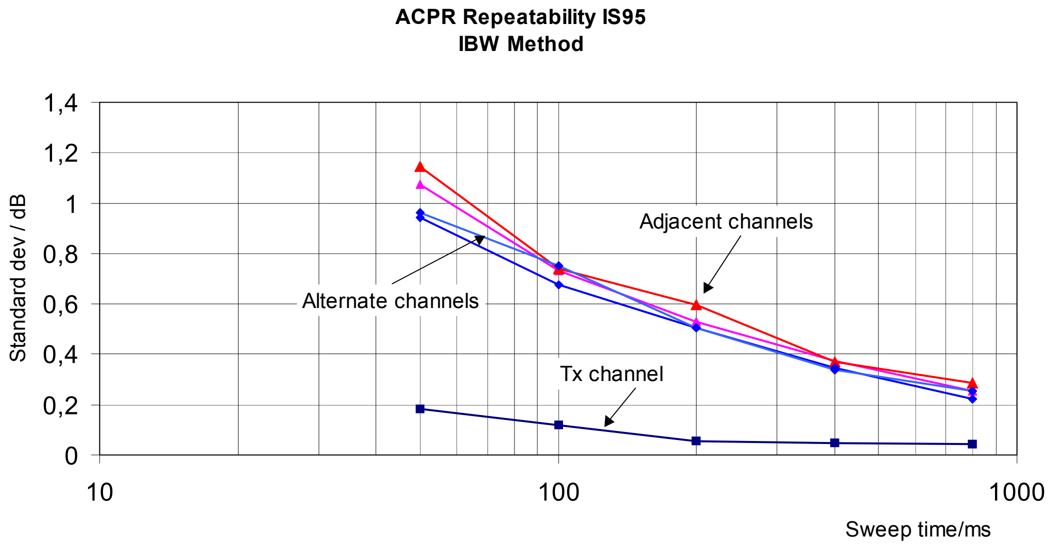


Fig. 2-20 Repeatability of adjacent channel power measurement on CDMA 2000 standard signals if the integration bandwidth method is used

6. Switch to fast ACP mode to increase the repeatability of results.

   – Switch the **Fast ACP** softkey to **On**.

   The R&S ZVL-K1 measures the power of each channel with zero span. The trace represents power as a function of time for each channel (see Fig. 2-23). The numerical results over consecutive measurements become much more stable.

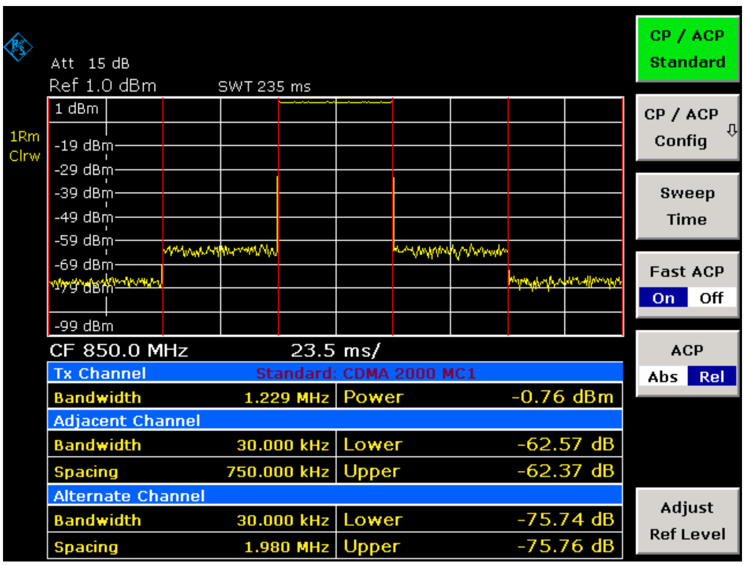


Fig. 2-21 Measuring the channel power and adjacent channel power ratio for 2000 MC1 signals with zero span (Fast ACP)

Fig. 2-22 shows the repeatability of power measurements in the transmit channel and of relative power measurements in the adjacent channels as a function of sweep time. The standard deviation of measurement results is calculated from 100 consecutive measurements as shown in Fig. 2-22. Take scaling into account if comparing power values.

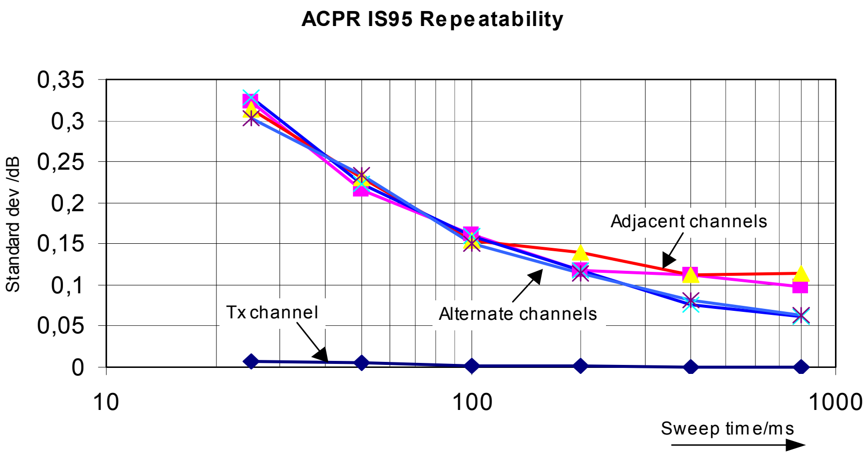


Fig. 2-22 Repeatability of adjacent channel power measurements on CDMA 2000 signals in the fast ACP mode

Note on adjacent channel power measurements on 2000 MC1 base–station signals:

When measuring the adjacent channel power of 2000 MC1 base–station signals, the frequency spacing of the adjacent channel to the nominal transmit channel is specified as ± 750 kHz. The adjacent channels are, therefore, so close to the transmit channel that the power of the transmit signal leaks across and is also measured in the adjacent channel if the usual method using the 30 kHz resolution bandwidth is applied. The reason is the low selectivity of the 30 kHz resolution filter. The resolution bandwidth, therefore, must be reduced considerably, e.g. to 3 kHz to avoid this. This causes very long measurement times (factor of 100 between a 30 kHz and 3 kHz resolution bandwidth).

This effect is avoided with the zero span method which uses steep IF filters. The 30 kHz channel filter implemented in the R&S ZVL-K1 has a very high selectivity so that even with a ± 750 kHz spacing to the transmit channel the power of the useful modulation spectrum is not measured.

The following figure shows the passband characteristics of the 30 kHz channel filter in the R&S ZVL-K1.

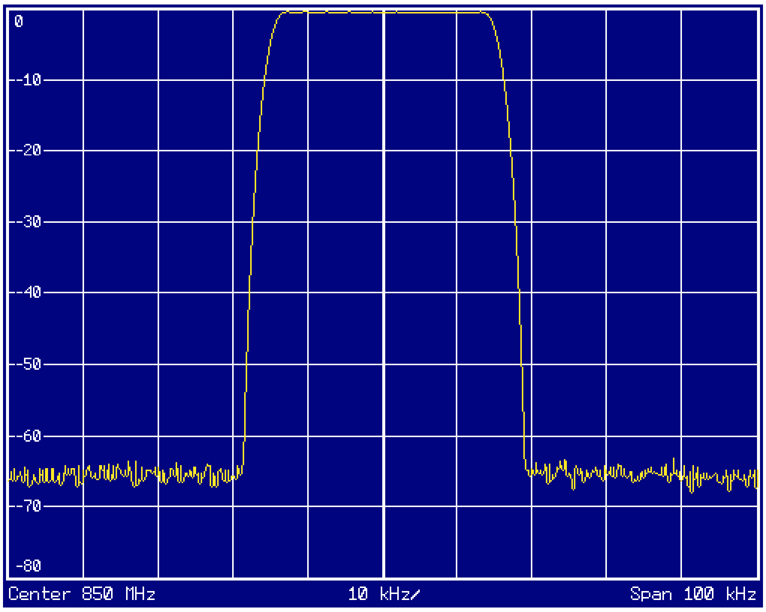
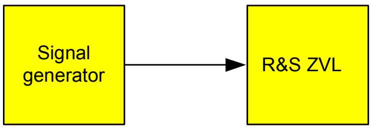


Fig. 2-23 Frequency response of the 30 kHz channel filter for measuring the power in the 2000 MC1 adjacent channel

Measurement example 2 – Measuring adjacent channel power of a W–CDMA uplink signal

Test setup:



Signal generator settings (e.g. R&S SMU):

Frequency: 1950 MHz

Level: 4 dBm

Modulation: 3 GPP W–CDMA Reverse Link

Procedure:

1. Set the R&S ZVL-K1 to its default state.
   – Press the **PRESET** key.
     The R&S ZVL-K1 is in its default state.
2. Set the center frequency to 1950 MHz.
   – Press the **CENTER** key and enter *1950 MHz*.

3. Switch on the ACP measurement for W–CDMA.
   - Press the **MEAS** key.
   - Press the **CP, ACP, MC–ACP** softkey.
   - Press the **CP / ACP Standard** softkey.
   - In the standards list, mark **W–CDMA 3GPP REV** using the rotary knob or the arrow keys and confirm pressing the rotary knob or the **ENTER** key.

   The R&S ZVL-K1 sets the channel configuration to the 3GPP W–CDMA standard for mobiles with two adjacent channels above and below the transmit channel. The frequency span, the resolution and video bandwidth and the detector are automatically set to the correct values. The spectrum is displayed in the upper part of the screen and the channel power, the level ratios of the adjacent channel powers and the channel configuration in the lower part of the screen. The individual channels are displayed as vertical lines on the graph.

4. Set the optimum reference level and the RF attenuation for the applied signal level.
   - Press the **Adjust Ref Level** softkey.

   The R&S ZVL-K1 sets the optimum RF attenuation and the reference level for the power in the transmission channel to obtain the maximum dynamic range. The following figure shows the result of the measurement.

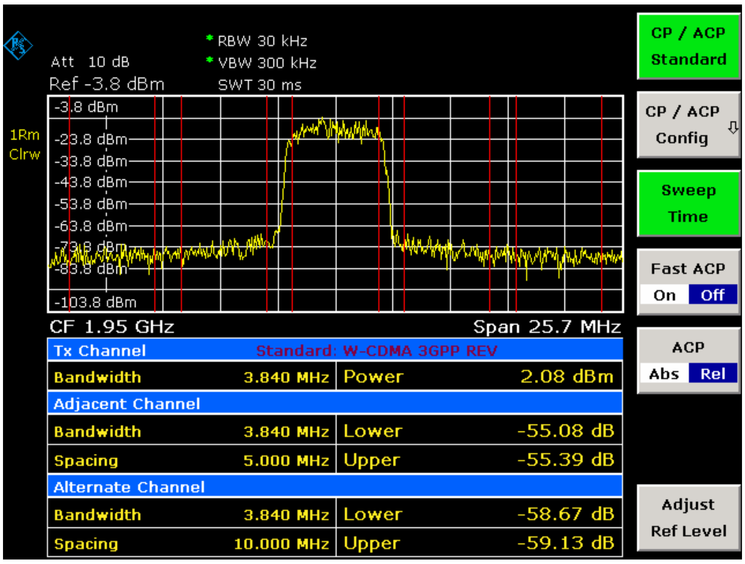


Fig. 2-24 Measuring the relative adjacent channel power on a W–CDMA uplink signal

5. Measuring adjacent channel power with the fast ACP mode.
   - Set **Fast ACP** softkey to **On**.
   - Press the **Adjust Ref Level** softkey.

   The R&S ZVL-K1 measures the power of the individual channels with zero span. A root raised cosine filter with the parameters α = 0.22 and chip rate 3.84 Mcps (= receive filter for 3GPP W–CDMA) is used as channel filter.

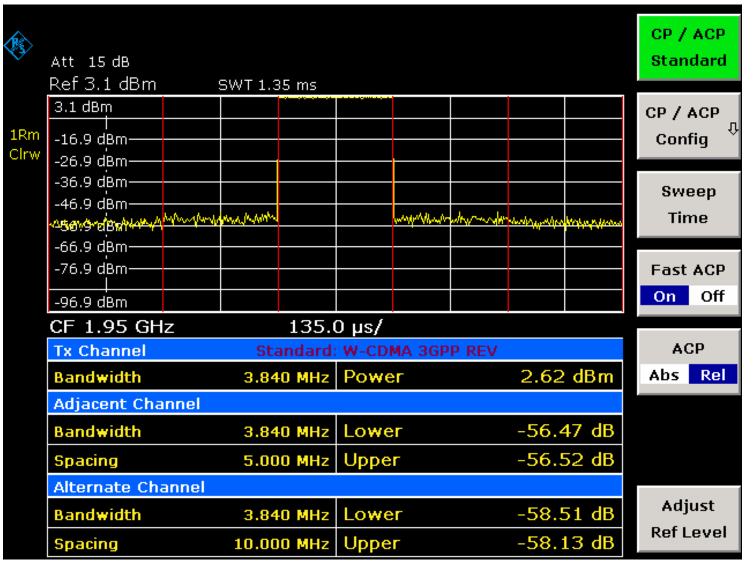


Fig. 2-25 Measuring the adjacent channel power of a W–CDMA signal with the fast ACP mode

With W–CDMA, the R&S ZVL-K1's dynamic range for adjacent channel measurements is limited by the 12–bit A/D converter. The greatest dynamic range is, therefore, obtained with the IBW method.

Optimum Level Setting for ACP Measurements on W–CDMA Signals

The dynamic range for ACPR measurements is limited by the thermal noise floor, the phase noise and the intermodulation (spectral regrowth) of the spectrum analyzer. The power values produced by the R&S ZVL-K1 due to these factors accumulate linearly. They depend on the applied level at the input mixer. The three factors are shown in the figure below for the adjacent channel (5 MHz carrier offset).

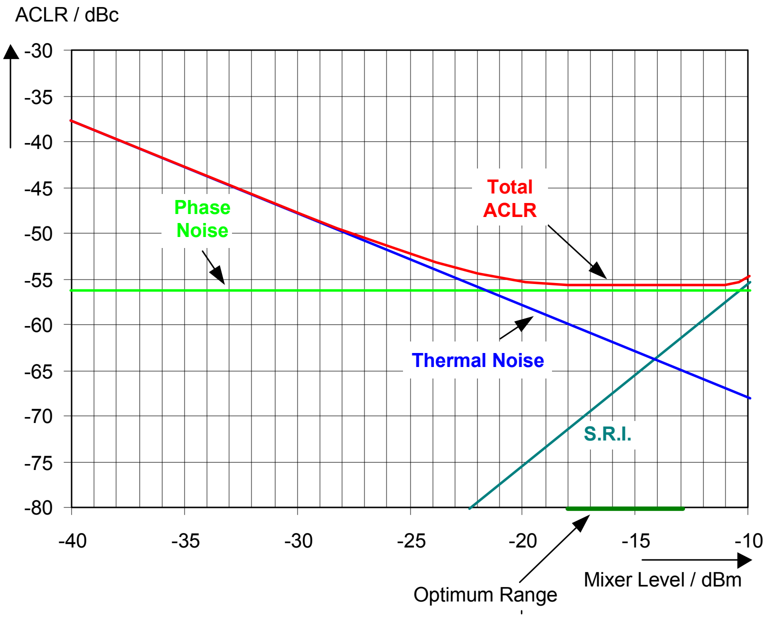


Fig. 2-26 The R&S ZVL-K1's dynamic range for adjacent channel power measurements on W–CDMA uplink signals is a function of the mixer level.

The level of the W–CDMA signal at the input mixer is shown on the horizontal axis, i.e. the measured signal level minus the selected RF attenuation. The individual components which contribute to the power in the adjacent channel and the resulting relative level (total ACPR) in the adjacent channel are displayed on the vertical axis. The optimum mixer level is –21 dBm. The relative adjacent channel power (ACPR) at an optimum mixer level is –65 dBc. Since, at a given signal level, the mixer level is set in 10 dB steps with the 10 dB RF attenuator, the optimum 10 dB range is shown in the figure: it spreads from –16 dBm to –26 dBm. In this range, the obtainable dynamic range is 62 dB.

To set the attenuation parameter manually, the following method is recommended:

- Set the RF attenuation so that the mixer level (= measured channel power – RF attenuation) is between –11 dBm and –21 dBm.
- Set the reference level to the largest possible value where no overload (IFOVL) is indicated.

This method is automated with the **Adjust Ref Level** function. Especially in remote control mode, e.g. in production environments, it is best to correctly set the attenuation parameters prior to the measurement, as the time required for automatic setting can be saved.

To measure the R&S ZVL-K1's intrinsic dynamic range for W–CDMA adjacent channel power measurements, a filter which suppresses the adjacent channel power is required at the output of the transmitter. A SAW filter with a bandwidth of 4 MHz, for example, can be used.

Amplitude Distribution Measurements

If modulation types are used that do not have a constant zero span envelope, the transmitter has to handle peak amplitudes that are greater than the average power. This includes all modulation types that involve amplitude modulation –QPSK for example. CDMA transmission modes in particular may have power peaks that are large compared to the average power.

For signals of this kind, the transmitter must provide large reserves for the peak power to prevent signal compression and thus an increase of the bit error rate at the receiver.

The peak power or the crest factor of a signal is therefore an important transmitter design criterion. The crest factor is defined as the peak power / mean power ratio or, logarithmically, as the peak level minus the average level of the signal.

To reduce power consumption and cut costs, transmitters are not designed for the largest power that could ever occur, but for a power that has a specified probability of being exceeded (e.g. 0.01%).

To measure the amplitude distribution, the R&S ZVL-K1 has simple measurement functions to determine both the APD = Amplitude Probability Distribution and CCDF = Complementary Cumulative Distribution Function.

In the APD display mode, the probability of occurrence of a certain level is plotted against the level.

In the CCDF display mode, the probability that the mean signal power will be exceeded is shown in percent.

Measurement example – Measuring the APD and CCDF of white noise generated by the R&S ZVL-K1

1. Set the R&S ZVL-K1 to its default state.
   – Press the **PRESET** key.
     The R&S ZVL-K1 is in its default state.

2. Configure the R&S ZVL-K1 for APD measurement
   – Press the **AMPT** key and enter **–***60 dBm*.
     The R&S ZVL-K1's intrinsic noise is displayed at the top of the screen.
   – Press the **MEAS** key.
   – Press the **More** softkey.
   – Press the **APD** softkey.
     The R&S ZVL-K1 sets the frequency span to 0 Hz and measures the amplitude probability distribution (APD). The number of uncorrelated level measurements used for the measurement is 100000. The mean power and the peak power are displayed in dBm. The crest factor (peak power – mean power) is output as well.

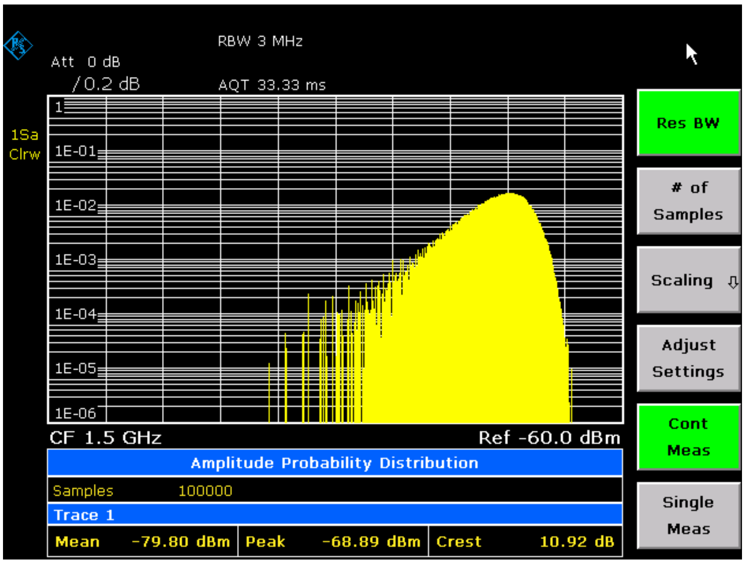


Fig. 2-27 Amplitude probability distribution of white noise

3. Switch to the CCDF display mode.
   – Press the ▲ key.
   – Press the **CCDF** softkey.

   The CCDF display mode is switched on.

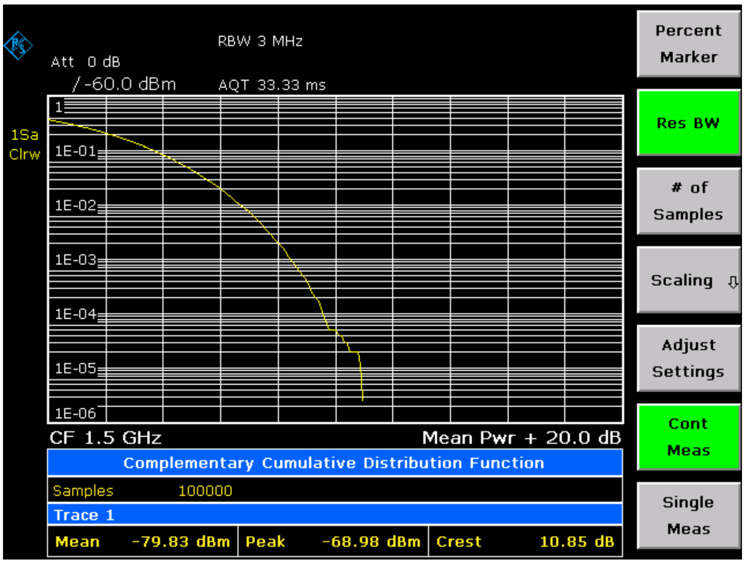


Fig. 2-28 CCDF of white noise

The CCDF trace indicates the probability that a level will exceed the mean power. The level above the mean power is plotted along the x–axis of the graph. The origin of the axis corresponds to the mean power level. The probability that a level will be exceeded is plotted along the y–axis.

4. Bandwidth selection

   When the amplitude distribution is measured, the resolution bandwidth must be set so that the complete spectrum of the signal to be measured falls within the bandwidth. This is the only way of ensuring that all the amplitudes will pass through the IF filter without being distorted. If the resolution bandwidth which is selected is too small for a digitally modulated signal, the amplitude distribution at the output of the IF filter becomes a Gaussian distribution according to the central limit theorem and so corresponds to a white noise signal. The true amplitude distribution of the signal therefore cannot be determined.

5. Selecting the number of samples

   For statistics measurements with the R&S ZVL-K1, the number of samples $N_{Samples}$ is entered for statistical evaluation instead of the sweep time. Since only statistically independent samples contribute to statistics, the measurement or sweep time is calculated automatically and displayed. The samples are statistically independent if the time difference is at least 1/RBW. The sweep time SWT is, therefore, expressed as follows:

   $SWT = N_{Samples} / RBW$

Index

E

F

G

H

I

K