

R&S®R&S ZVL-K1

Spectrum Analysis Options

Software Manual



1303.6573.42 – 05

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	1.1
Spectrum Analysis (R&S ZVL-K1).....	1.3
TV Trigger (R&S FSL-B6)	1.3
Gated Sweep (R&S FSL-B8)	1.3
AM/FM/φM Measurement Demodulator (R&S FSL-K7)	1.3
Bluetooth Measurements (R&S FSL-K8).....	1.3
Spectrogram Measurements (R&S FSL-K14)	1.4
Cable TV Measurements (R&S FSL-K20)	1.4
Noise Figure and Gain Measurements (R&S FSL-K30)	1.4
WCDMA Measurements (3GPP/FDD BTS) (R&S FSL-K72).....	1.4
CDMA2000 Base Station Measurements (R&S FSL-K82)	1.4
1xEV-DO Base Station Measurements (R&S FSL-K84)	1.4
WLAN OFDM Analysis (R&S FSL-K91).....	1.5
WiMAX OFDM/OFDMA Analysis (R&S FSL-K93)	1.5

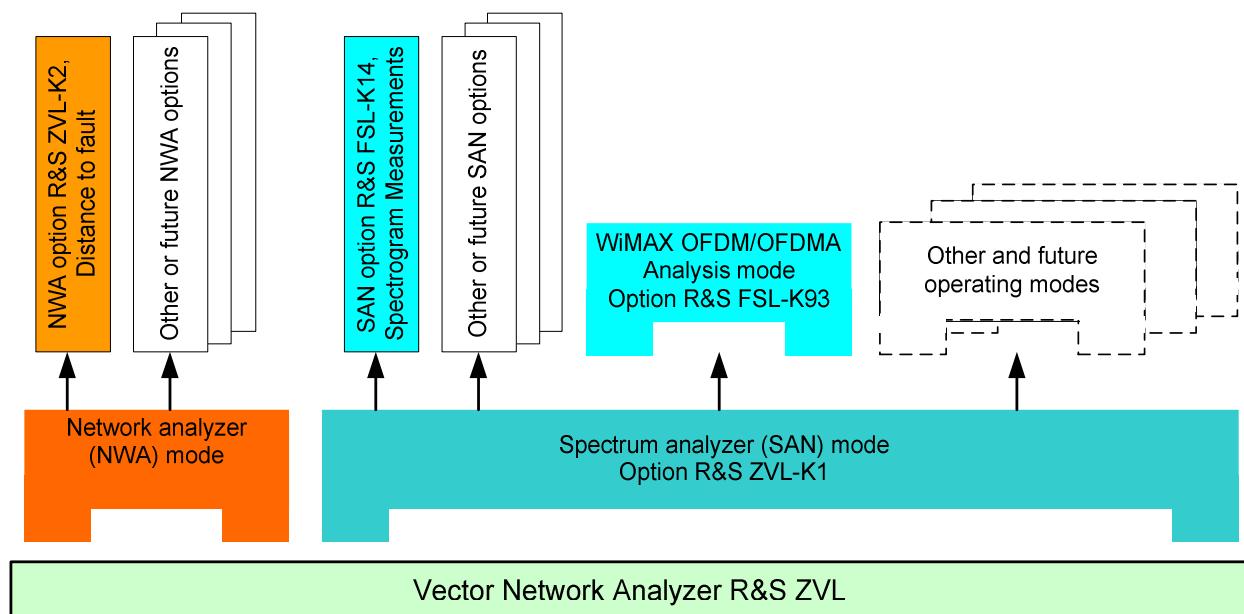
1 Introduction

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/ φ M 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/i 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/ φ M Measurement Demodulator (R&S FSL-K7)

The AM/FM/ φ M 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	2.1
Test Setup	2.1
Measurement of Harmonics	2.1
High-Sensitivity Harmonics Measurements	2.3
Measuring the Spectra of Complex Signals	2.5
Separating Signals by Selecting an Appropriate Resolution Bandwidth	2.5
Intermodulation Measurements	2.6
Measurement example – Measuring the R&S ZVL-K1's intrinsic intermodulation	2.8
Measuring Signals in the Vicinity of Noise	2.11
Measurement example – Measuring level at low S/N ratios.....	2.12
Noise Measurements	2.15
Measuring Noise Power Density.....	2.15
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	2.15
Measurement of Noise Power within a Transmission Channel	2.17
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.....	2.18
Measuring Phase Noise.....	2.21
Measurement example – Measuring the phase noise of a signal generator at a carrier offset of 10 kHz	2.21
Measurements on Modulated Signals	2.23
Measuring Channel Power and Adjacent Channel Power	2.23
Measurement example 1 – ACPR measurement on an CDMA 2000 signal.....	2.24
Measurement example 2 – Measuring adjacent channel power of a W-CDMA uplink signal.....	2.28
Amplitude Distribution Measurements	2.32
Measurement example – Measuring the APD and CCDF of white noise generated by the R&S ZVL-K1	2.32
Bluetooth Measurements (Option K8).....	2.35
Bluetooth Overview.....	2.35
Bluetooth technical parameters	2.35
Power classes	2.36
Structure of a Bluetooth data packet	2.36
Supported Tests	2.37
Overview of Transmitter Tests.....	2.38
Functional Description – Block Diagram.....	2.39
Bandwidths	2.40
Measurement Filter (Meas Filter On).....	2.40
Oversampling	2.41
Determining Average or Max/Min Values	2.42
Impact of the sweep count on the measurement results	2.43
Trigger Concepts	2.43
Cable TV Measurements (Option K20)	2.45

Analog TV Basics	2.45
Analog TV Measurement Examples	2.46
Analog TV settings.....	2.47
Analog TV test setup.....	2.47
Spectrum measurement.....	2.48
Carriers measurement	2.49
Video Scope measurement.....	2.51
Vision Modulation measurement	2.52
Hum measurement	2.53
C/N measurement.....	2.54
CSO measurement	2.59
CTB measurement.....	2.62
Digital TV Basics.....	2.63
Digital TV Measurement Examples	2.68
Digital TV settings	2.69
Digital TV test setup.....	2.70
Spectrum measurement.....	2.70
Overview measurement.....	2.71
Constellation Diagram measurement (modulation analysis)	2.73
Modulation Errors measurement (modulation analysis)	2.74
Echo Pattern measurement (channel analysis)	2.75
Channel Power measurement	2.77
APD measurement.....	2.78
CCDF measurement	2.79
TV Analyzer Measurements	2.80
Tilt measurement	2.80
Channel Tables and Modulation Standards	2.81
Channel tables	2.82
Modulation standards.....	2.83
Example: Creating a channel table	2.88
Example: Restoring the default channel tables	2.94
Performing a Measurement without a Channel Table	2.94
Performing a Measurement Using a Channel Table	2.96
Noise Figure Measurements Option (K30).....	2.100
Direct Measurements.....	2.100
Basic Measurement Example	2.100
DUTs with very Large Gain.....	2.102
Frequency-Converting Measurements	2.103
Fixed LO Measurements.....	2.103
Image-Frequency Rejection (SSB, DSB).....	2.103
3GPP Base Station Measurements (Option K72).....	2.106
Measuring the Signal Channel Power	2.106
Measuring the Spectrum Emission Mask	2.108
Measuring the Relative Code Domain Power.....	2.109
Synchronization of the reference frequencies	2.110
Behavior with deviating center frequency setting	2.111

Behavior with incorrect scrambling code	2.111
Measuring the Relative Code Domain Power Triggered	2.111
Trigger offset.....	2.112
Setup for Base Station Tests	2.113
Standard test setup.....	2.113
Basic settings	2.113
CDMA2000 Base Station Measurements (Option K82).....	2.114
Measuring the Signal Channel Power	2.114
Measuring the Spectrum Emission Mask	2.116
Measuring the Relative Code Domain Power and the Frequency Error	2.117
Synchronization of the reference frequencies	2.119
Behavior with deviating center frequency setting	2.119
Measuring the triggered Relative Code Domain Power	2.120
Adjusting the trigger offset.....	2.122
Behaviour with the wrong PN offset.....	2.122
Measuring the Composite EVM	2.123
Measuring the Peak Code Domain Error and the RHO Factor	2.124
Displaying RHO	2.125
Test Setup for Base Station Tests	2.125
WLAN TX Measurements (Option K91 / K91n)	2.127
Signal Processing of the IEEE 802.11a application	2.127
Abbreviations	2.127
Literature	2.132
Signal Processing of the IEEE 802.11b application	2.133
Abbreviations	2.133
Literature	2.137
802.11b RF carrier suppression	2.137
Definition	2.137
Measurement with the R&S ZVL-K1	2.137
Comparison to IQ offset measurement in K91 / K91n list mode.....	2.138
IQ Impairments	2.139
IQ Offset.....	2.139
Gain Imbalance	2.139
Quadrature Error	2.140
WiMAX, WiBro Measurements (Options K93)	2.141
Basic Measurement Example	2.141
Setting up the measurement.....	2.141
Performing the level detection	2.143
Performing the main measurement	2.143
Signal Processing of the IEEE 802.16–2004 OFDM Measurement Application	2.143
Analysis Steps	2.147
Subchannelization.....	2.148
Synchronization	2.148
Channel Results.....	2.148
Frequency and Clock Offset	2.149
EVM	2.149

IQ Impairments	2.150
RSSI.....	2.151
CINR	2.151
Literature	2.151
Signal Processing of the IEEE802.16–2005 OFDMA/WiBro Measurement Application.....	2.152
Introduction	2.153
Signal Processing Block Diagram.....	2.154
Synchronization	2.154
Channel Estimation / Equalization	2.155
Analysis.....	2.155
Literature	2.157

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 **RESET** 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.

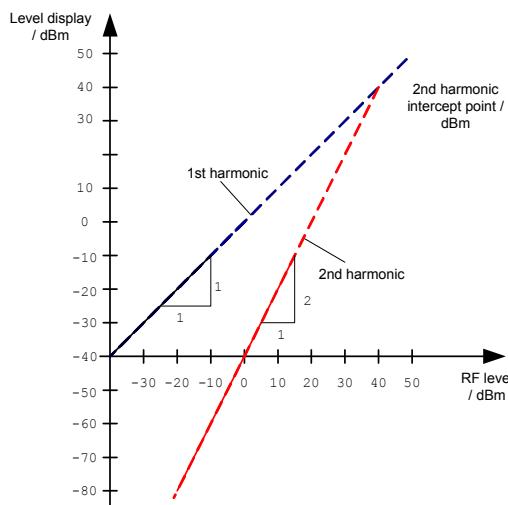


Fig. 2-1 Extrapolation of the 1st and 2nd harmonics to the 2nd harmonic intercept at 40 dBm

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

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

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:

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

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:

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

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.

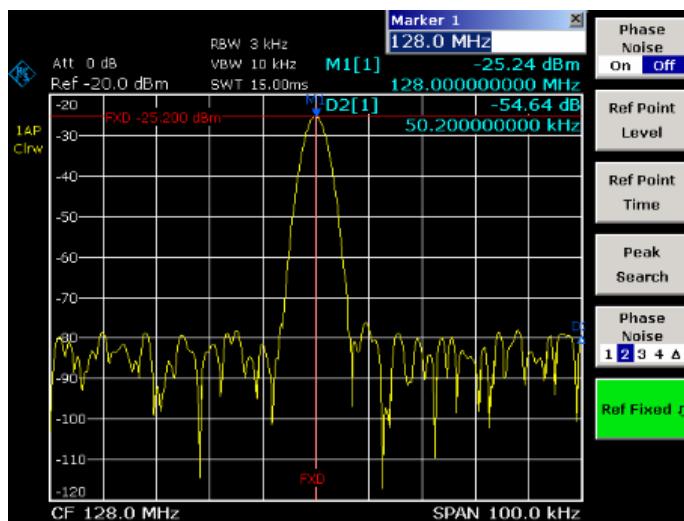


Fig. 2-2 Fundamental wave and the frequency and level reference point

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 2nd 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 2nd harmonic.

7. Place the delta marker on the 2nd harmonic.

- Press the **MKR->** key.

- Press the **Peak** softkey.

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

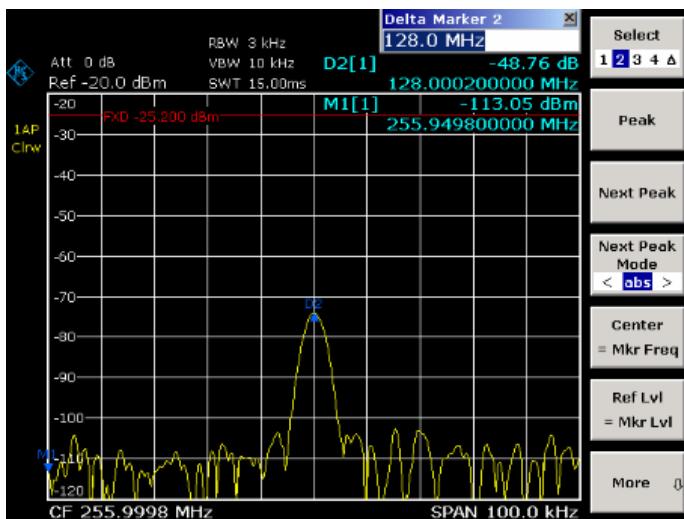


Fig. 2-3 Measuring the level difference between the fundamental wave (= reference point level) and the 2nd harmonic

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.

$$\text{SWT} = k \cdot \text{Span}/\text{RBW}^2 \quad (4)$$

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:

$$SWT = k \cdot \text{span}/\text{RBW} \quad (5)$$

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} .

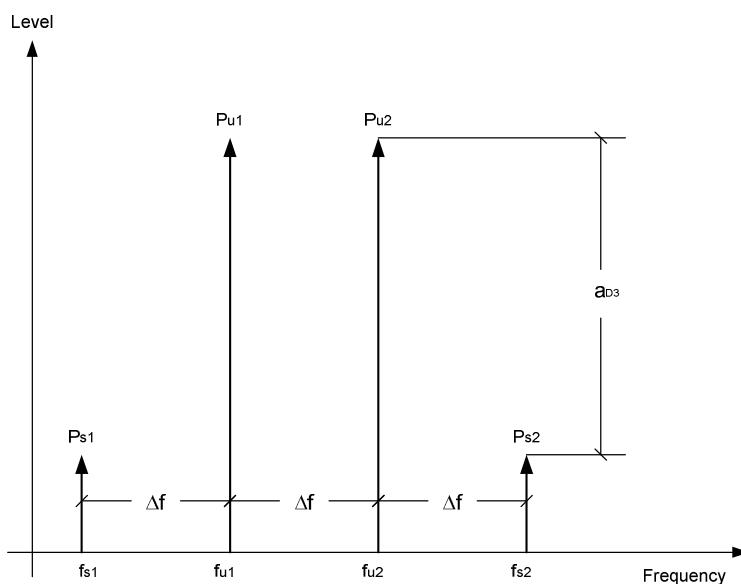


Fig. 2-4 Intermodulation products P_{U1} and P_{U2}

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.

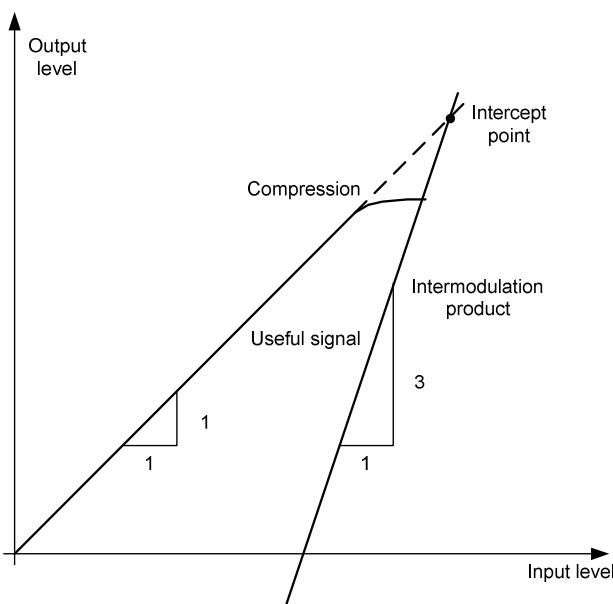


Fig. 2-5 Dependence of intermodulation level on useful signal level

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.

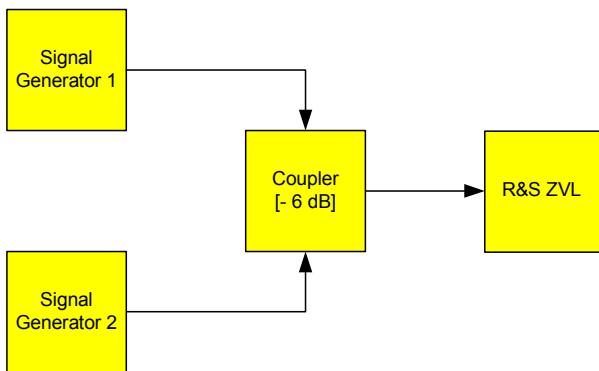
$$IP3 = \frac{a_{D3}}{2} + P_N \quad (8)$$

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:

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

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 **RESET** 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:

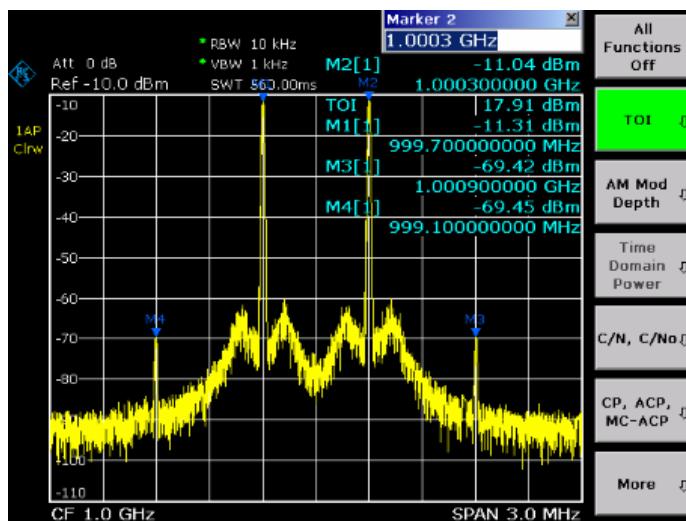


Fig. 2-6 Result of intrinsic intermodulation measurement on the R&S ZVL-K1. The 3rd order intercept (TOI) is displayed at the top right corner of the grid.

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.

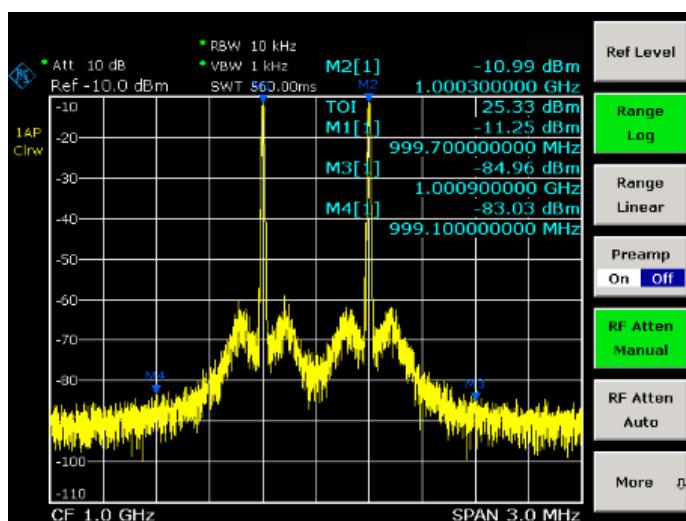


Fig. 2-7 If the RF attenuation is increased, the R&S ZVL-K1's intrinsic intermodulation products disappear below the noise floor.

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:

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

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.

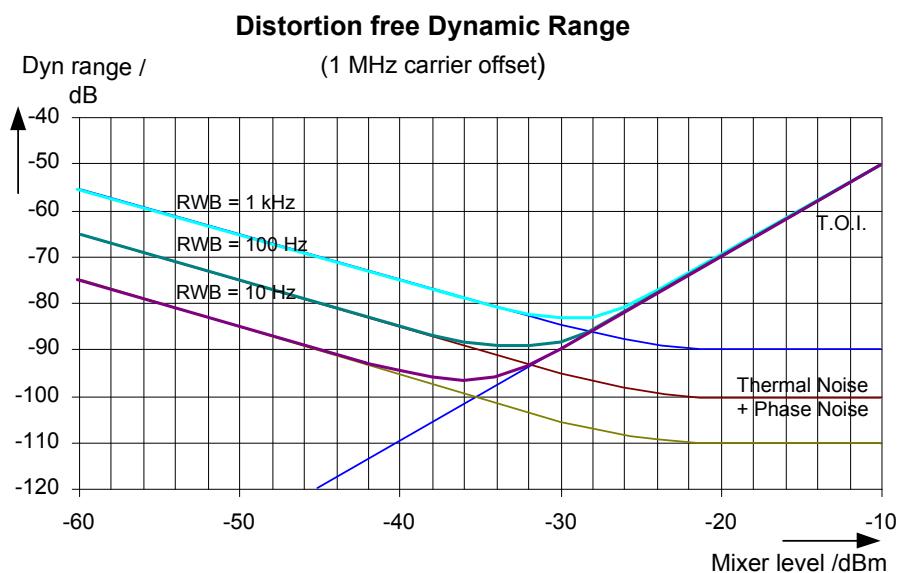


Fig. 2-8 Intermodulation–free range of the R&S ZVL-K1 as a function of level at the input mixer and the set resolution bandwidth (useful signal offset = 1 MHz, DANL = -145 dBm /Hz, TOI = 15 dBm; typical values at 2 GHz)

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.

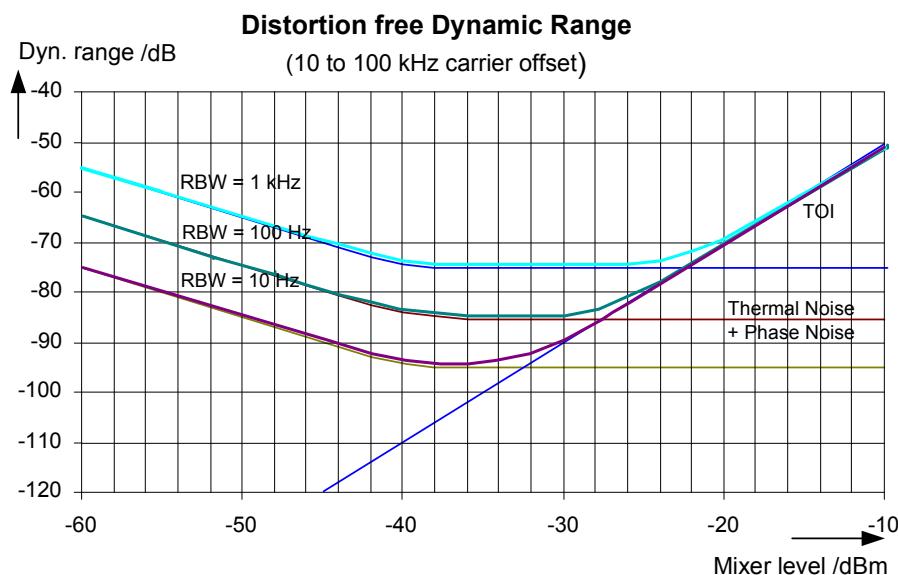


Fig. 2-9 Intermodulation-free dynamic range of the R&S ZVL-K1 as a function of level at the input mixer and of the selected resolution bandwidth (useful signal offset = 10 to 100 kHz, DANL = $-145 \text{ dBm}/\text{Hz}$, TOI = 15 dBm ; typical values at 2 GHz).



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 **RESET** 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.

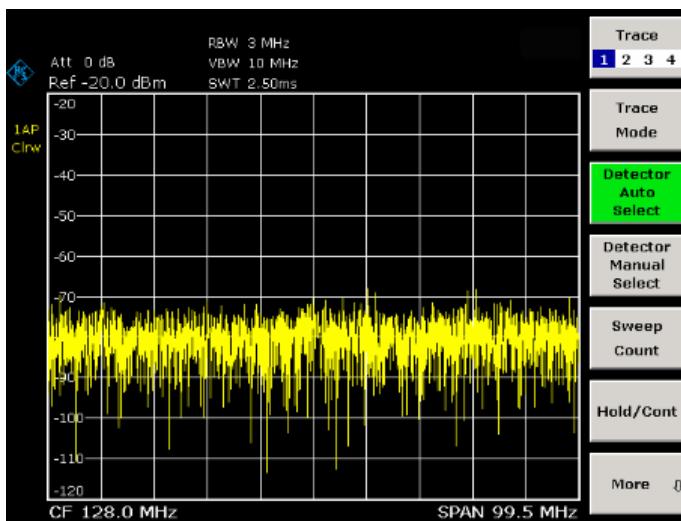


Fig. 2-10 Sinewave signal with low S/N ratio. The signal is measured with the auto peak detector and is completely hidden in the intrinsic noise of the R&S ZVL-K1.

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.

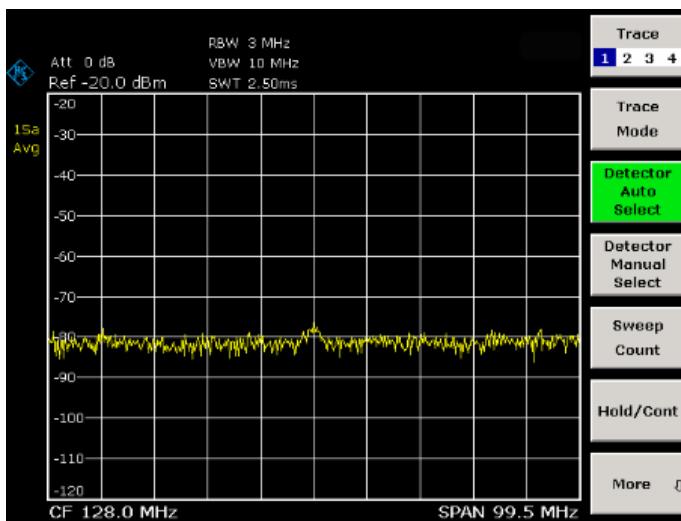


Fig. 2-11 RF sinewave signal with low S/N ratio if the trace is averaged.

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.

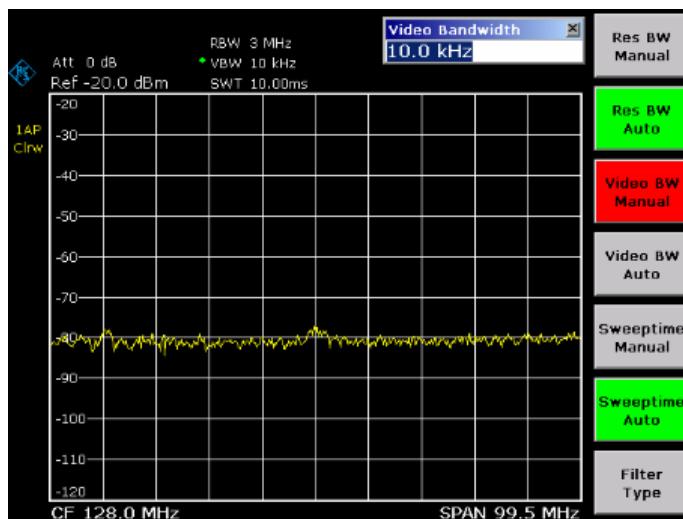


Fig. 2-12 RF sinewave signal with low S/N ratio if a smaller video bandwidth is selected.

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.

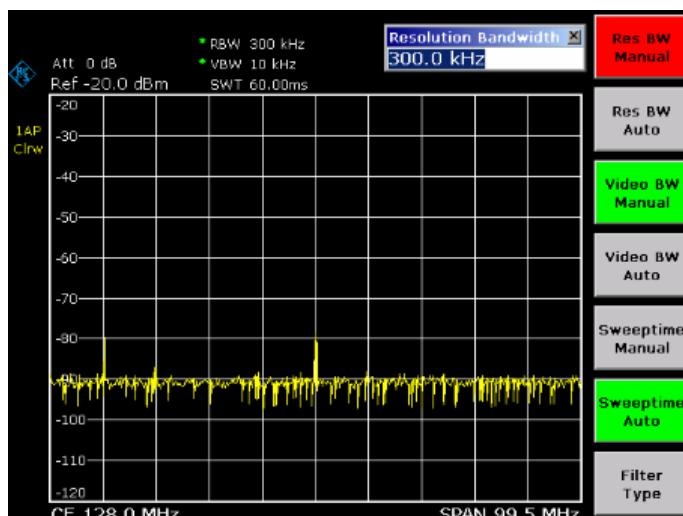


Fig. 2-13 Reference signal at a smaller resolution bandwidth

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 $50\ \Omega$.

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 $10 \cdot \log (\text{BW})$ 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.

$$P_{[1\text{kHz}]} = -150 + 10 * \log (1000) = -150 + 30 = -120 \text{ dBm} \text{ (1 kHz)}$$

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 $-10 * \log (\text{RBW}_{\text{noise}})$, with $\text{RBW}_{\text{noise}}$ 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 50Ω resistor at room temperature (-174 dBm (1Hz)) and the measured noise power P_{noise} the noise figure (NF) is obtained as follows:

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

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

$$NF = -143 + 174 = 31 \text{ dB}$$



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.

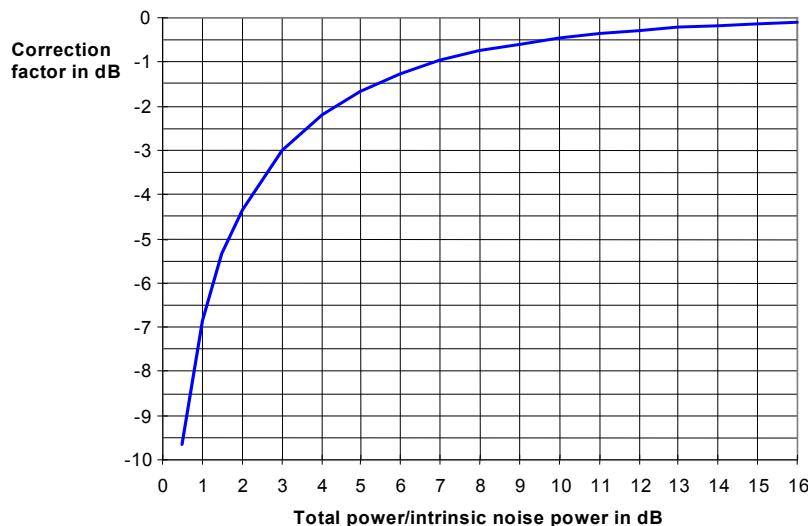


Fig. 2-14 Correction factor for measured noise power as a function of the ratio of total power to the intrinsic noise power of the spectrum analyzer

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 $50\ \Omega$.

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.

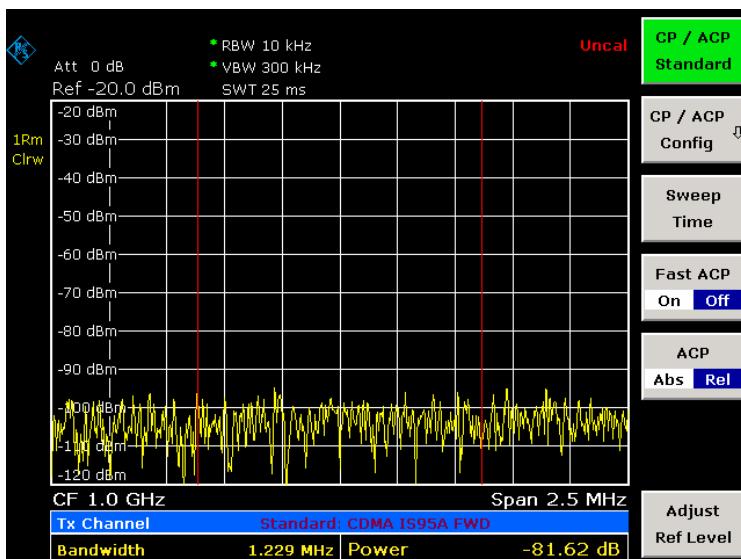


Fig. 2-15 Measurement of the R&S ZVL-K1's intrinsic noise power in a 1.23 MHz channel bandwidth.

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).

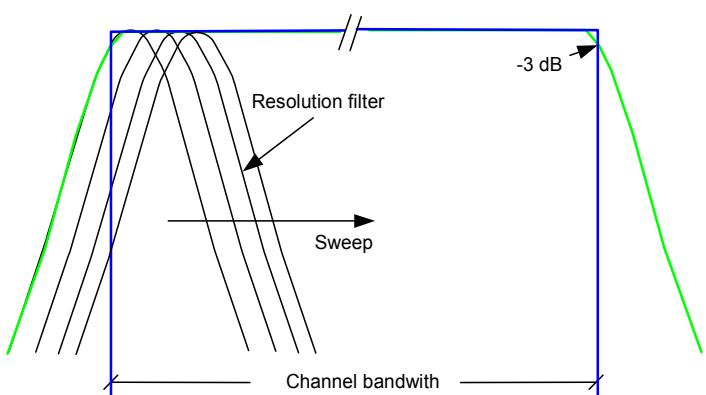


Fig. 2-16 Approximating the channel filter by sweeping with a small resolution bandwidth

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 (Integration Bandwidth 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:

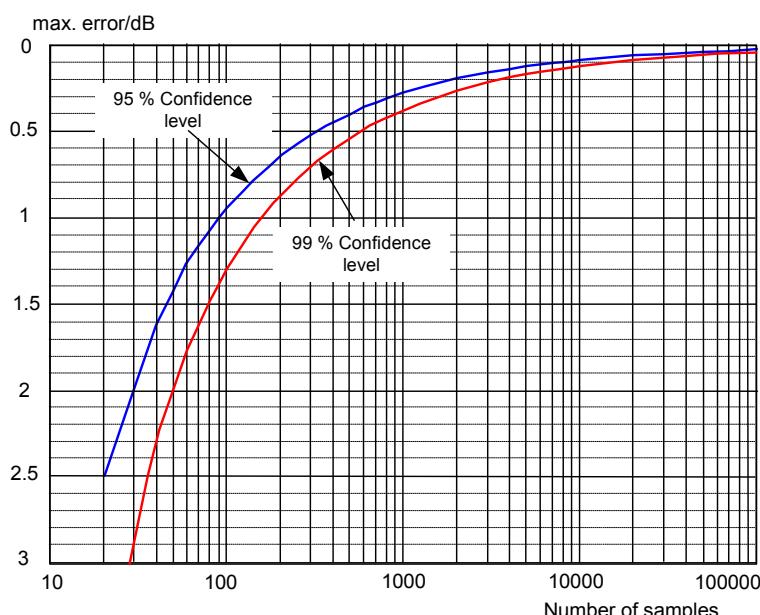


Fig. 2-17 Repeatability of channel power measurements as a function of the number of samples used for power calculation

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:

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

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

Example

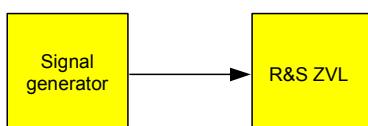
At a resolution bandwidth of 30 kHz and a sweep time of 100 ms, 3000 uncorrelated samples are obtained. If the channel bandwidth is equal to the frequency display range, i.e. all trace pixels are used for the channel power measurement, a repeatability of 0.2 dB with a probability of 99% is the estimate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

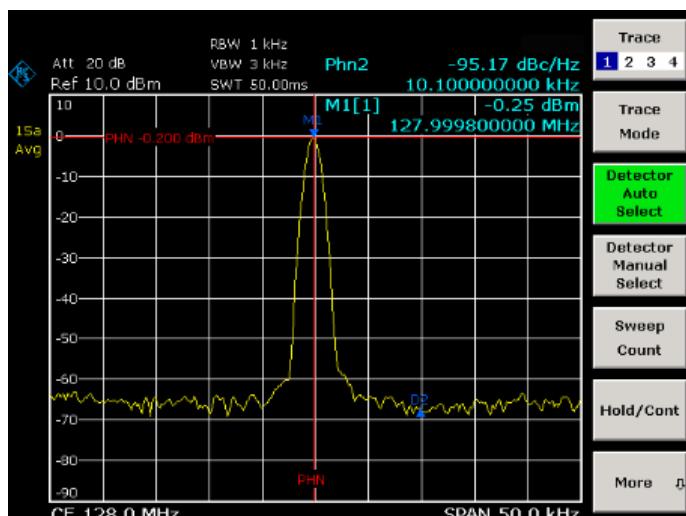


Fig. 2-18 Measuring phase noise with the phase-noise marker function

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 (Integration Bandwidth 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.

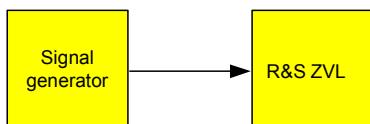
Measurement using a channel filter

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 **RESET** 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.

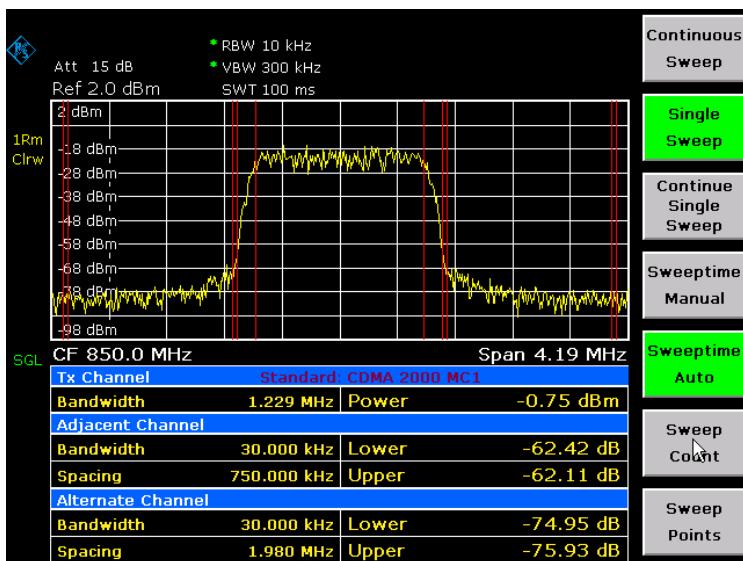


Fig. 2-19 Adjacent channel power measurement on a CDMA 2000 MC1 signal

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 are 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 $20000/33\mu s = 606$ samples per channel measurement compared to $600/33\mu s = 12.5$ 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.

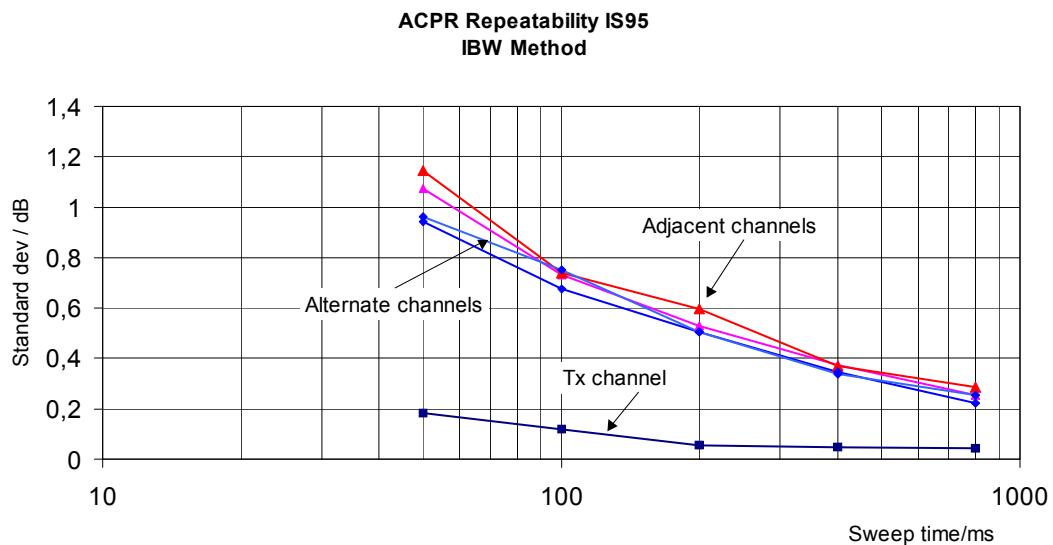


Fig. 2-20 Repeatability of adjacent channel power measurement on CDMA 2000 standard signals if the integration bandwidth method is used

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.

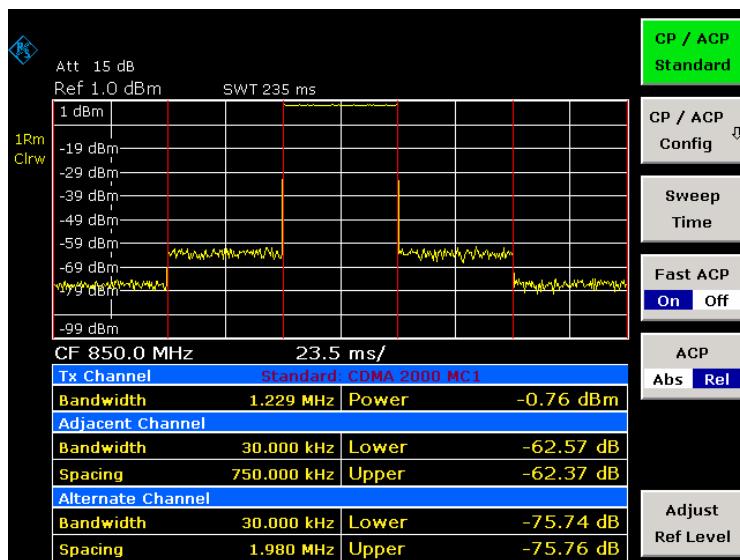


Fig. 2-21 Measuring the channel power and adjacent channel power ratio for 2000 MC1 signals with zero span (Fast ACP)

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.

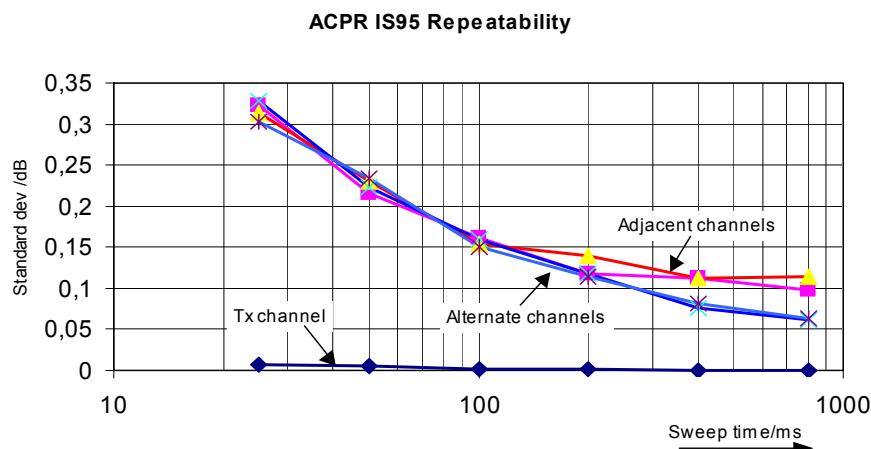


Fig. 2-22 Repeatability of adjacent channel power measurements on CDMA 2000 signals in the fast ACP mode



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.

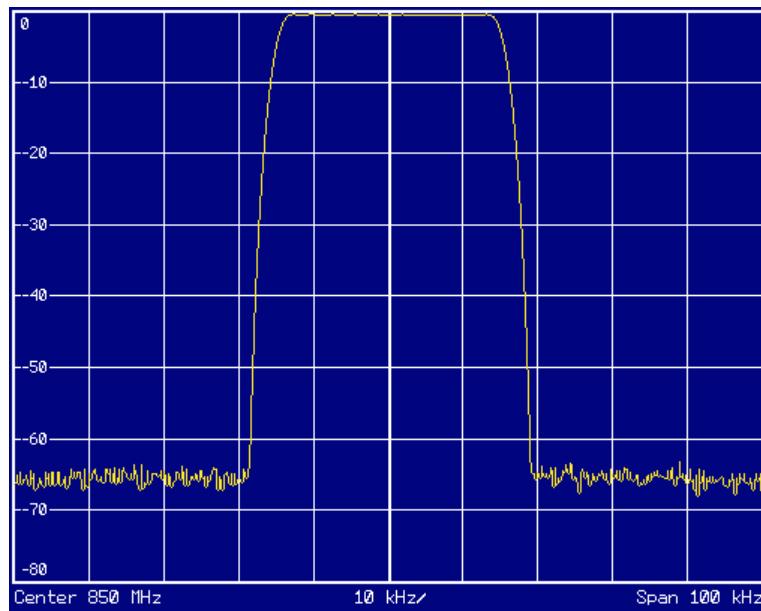
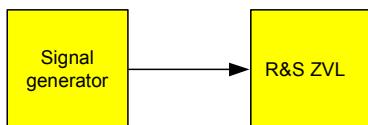


Fig. 2-23 Frequency response of the 30 kHz channel filter for measuring the power in the 2000 MC1 adjacent channel

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.

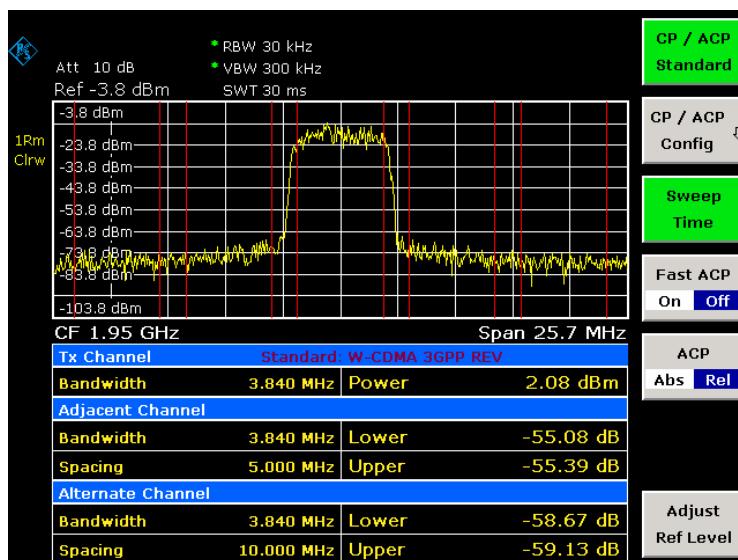


Fig. 2-24 Measuring the relative adjacent channel power on a W-CDMA uplink signal

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 $\alpha = 0.22$ and chip rate 3.84 Mcps (= receive filter for 3GPP W-CDMA) is used as channel filter.

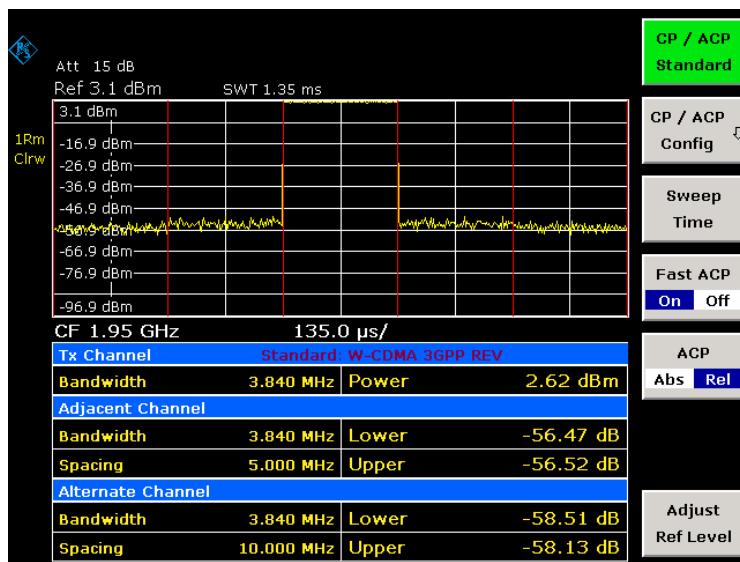


Fig. 2-25 Measuring the adjacent channel power of a W-CDMA signal with the fast ACP mode



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).

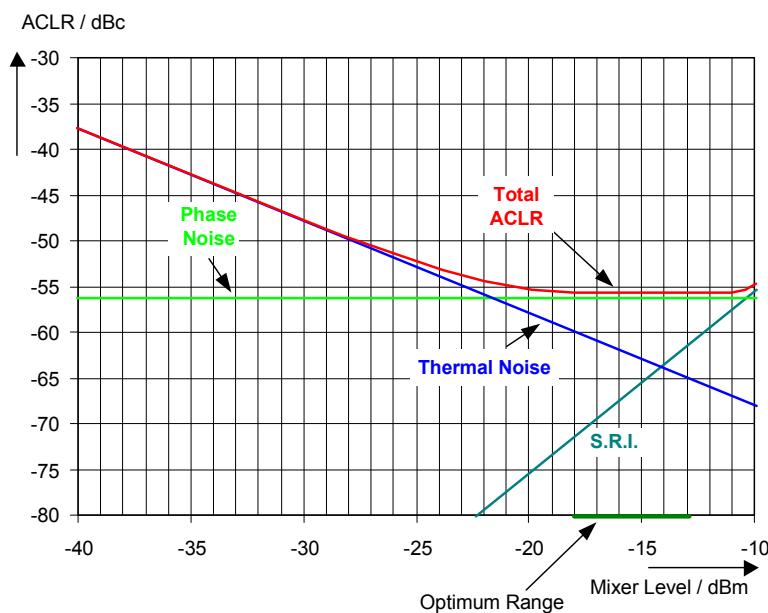


Fig. 2-26 The R&S ZVL-K1's dynamic range for adjacent channel power measurements on W-CDMA uplink signals is a function of the mixer level.

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 **RESET** 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.

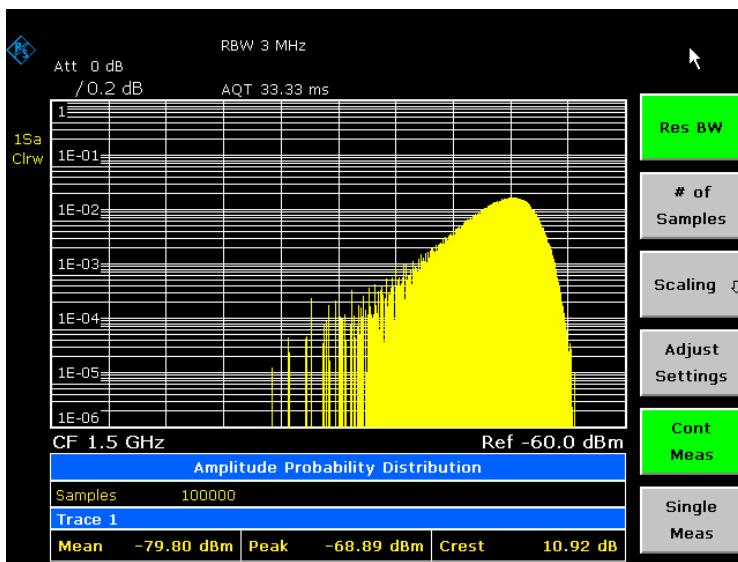


Fig. 2-27 Amplitude probability distribution of white noise

3. Switch to the CCDF display mode.
 - Press the **▲** key.
 - Press the **CCDF** softkey.
- The CCDF display mode is switched on.

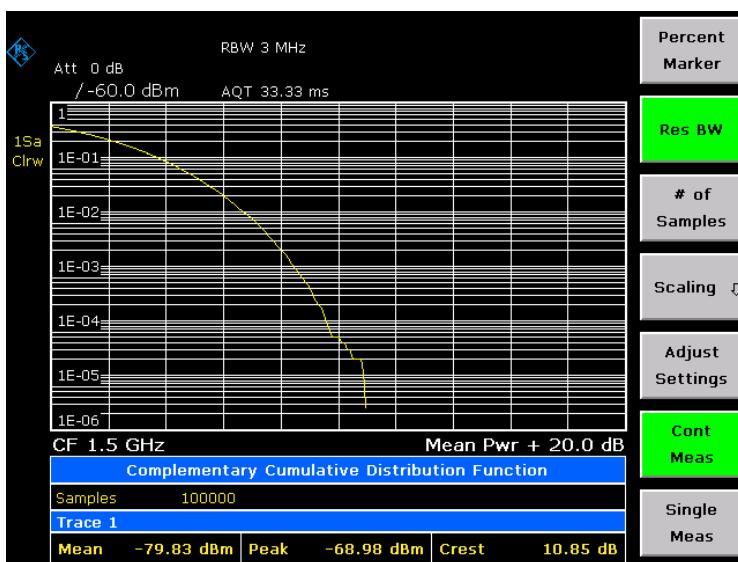


Fig. 2-28 CCDF of white noise

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

1

1xEV-DO BTS Analyzer mode (K84) 3.120
 1xEV-DO Measurements 1.4

3

3G FDD BTS mode (K72) 3.120

A

abbreviations

 3GPP Base Station measurements (K72) 3.251
 cable TV terms (K20) 3.191
 CDMA2000 BTS Analyzer (K82) 3.282
 WiMAX measurements (K93) 2.144
 WiMAX, WiBro measurements (K93) 2.153
 absolute grant channel (K72) 3.252
 Active Channels (K82) 3.303
 adjacent-channel power
 number of channels 3.87
 Adjacent-Channel Power measurement (K8) 3.145

adjustment

 attenuation (K20) 3.190
 AF trigger (K7) 3.125
 alias power (K82) 3.300, 3.306
 AM demodulation 3.55
 AM modulation depth 3.84
 AM/FM/ \square M Measurement Demodulator 1.3
 amplifier measurement (K30) 2.102
 amplitude imbalance (K20) 2.67
 amplitude menu
 base unit 3.13
 K20 option 3.207
 K7 option 3.136
 K72 option 3.258
 K8 option 3.155
 K82 option 3.314
 K84 option 3.366
 K91/K91n option 3.388
 K93 option 3.423
 AMPT / SCALE key 3.13

analog demodulation

 AF trigger (K7) 3.125
 bandwidth (K7) 3.125
 circuit description (K7) 3.124
 measurement results (K7) 3.125
 measurement time (K7) 3.126
 sample rate (K7) 3.126
 trigger offset (K7) 3.126
 analog demodulation (K7) 3.123
 analog demodulation menu (K7) 3.123, 3.126

Analog Demodulation mode (K7) 3.119
 analog TV basics (K20) 2.45
 Analog TV Settings dialog box (K20) 3.218
 analysis of measurement variables (K93) 2.155
 analysis steps (K93) 2.148
 antenna gain (K8) 3.151
 APICH 3.282
 ASCII file export 3.46
 ATDPCH 3.282
 attenuation
 adjustment (K20) 3.190
 automatic 3.15
 manual 3.15, 4.146
 auto level detection
 K93 option 2.143
 Auto Peak detector 3.38
 Average detector 3.38
 average or peak values (K8) 2.42
 Average trace mode 3.36
 averaging
 continuous sweep 3.37
 single sweep 3.37
 sweep count 3.37
 AWGN noise (K20) 2.68

B

bandwidth

 K8 option 2.40
 occupied 3.70
 occupied (K20) 2.87
 resolution 3.20
 resolution (K7) 3.138
 video 3.20

bandwidth menu

 base unit 3.20
 K7 option 3.138
 K8 option 3.157
 K82 option 3.315
 K84 option 3.368

base station measurements (K72) 2.106
 base station measurements (K82) 2.114

base station tests

 basic settings (K72) 2.113
 test setup (K72) 2.113
 test setup (K82) 2.125

BCH 3.282

BD_ADDR (K8) 3.152

Bit Reverse Code Order (K82) 3.297

Bitstream (K84) 3.360

Blank trace mode 3.37

Bluetooth device address (K8) 3.152

Bluetooth measurement

average or peak values (K8)	2.42
bandwidths (K8)	2.40
data packet structure (K8)	2.36
filter (K8)	2.40
functional description (K8)	2.39
oversampling (K8)	2.41
supported tests (K8)	2.37
transmitter tests (K8)	2.38
trigger concept (K8)	2.43
Bluetooth Measurements	1.3
Bluetooth menu (K8)	3.141, 3.150
Bluetooth mode (K8)	3.119
menus	3.141
BTS (K72)	3.251
C	
C/N Setup dialog box (K20)	3.214
Cable TV Analyzer menu (K20)	3.183, 3.202
Cable TV Analyzer mode (K20)	3.120
menus	3.183
cable TV measurement	
analog TV basics (K20)	2.45
analog TV measurement examples (K20)	2.46
analog TV settings (K20)	2.47
analog TV test setup (K20)	2.47
APD – digital TV (K20)	3.200
APD (K20)	2.78
C/N – analog TV (K20)	3.193
Carriers – analog TV (K20)	3.192
Carriers (K20)	2.49
CCDF – digital TV (K20)	3.201
CCDF (K20)	2.79
Channel Power – digital TV (K20)	3.200
Channel Power (K20)	2.77
Constellation Diagram – digital TV (K20)	3.198
Constellation Diagram (K20)	2.73
CSO – analog TV (K20)	3.194
CTB – analog TV (K20)	3.195
digital TV basics (K20)	2.63
digital TV measurement examples (K20)	2.68
digital TV settings (K20)	2.69
digital TV test setup (K20)	2.70
display labels (K20)	3.191
Echo Pattern – digital TV (K20)	3.199
Echo Pattern (K20)	2.76
Hum – analog TV (K20)	3.197
Hum (K20)	2.53
measurement overview (K20)	2.45
measurement with channel table (K20)	2.96
measurement without channel table (K20)	2.94
Modulation Errors – digital TV (K20)	3.199
Modulation Errors (K20)	2.74
Overview – digital TV (K20)	3.198
Overview (K20)	2.71
Spectrum – analog TV (K20)	3.192
Spectrum – digital TV (K20)	3.197
Spectrum (K20)	2.48, 2.70
status bar information (K20)	3.189
Tilt – TV analyzer (K20)	3.201
Tilt (K20)	2.80
TV analyzer measurement examples (K20)	2.80
Video Scope – analog TV (K20)	3.196
Video Scope (K20)	2.51
Vision Modulation – analog TV (K20)	3.196
Vision Modulation (K20)	2.52
with channel table (K20)	3.188
without channel table (K20)	3.188
CACH	3.282
calibration (K30)	2.101, 3.227
Carr Freq Error (K82)	3.303
Carrier Frequency Drift measurement (K8)	3.147
carrier frequency error (K20)	2.68
Carrier Frequency Stability and Modulation	
Accuracy measurement (K8)	3.149
carrier suppression	2.68
CATV network (K20)	2.82
CCCH	3.282
CCIR 473–4	3.33
CDEP	3.282
CDMA2000 BTS Analyzer mode (K82)	3.120
CDMA2000 Measurements	1.4
CDP	3.282
center frequency	3.7
K8 option	3.150
step size	3.8
CENTER key	3.5
channel	
active (K72)	3.256
active (K82)	3.292
active (K84)	3.347
bandwidth	3.86, 3.88, 3.93
inactive (K82)	3.292
inactive (K84)	3.347
K20 option	2.82
number	3.87
spacing	3.88
threshold (K82)	3.292
threshold (K84)	3.347
channel (K72)	3.252
channel assignment table (K72)	3.263
parameters	3.263
Channel Bitstream (K82)	3.310
Channel Constellation (K82)	3.308
channel estimation (K93)	2.155
channel filter, list of	3.18
channel number (K8)	3.150
Channel Power Rel / Abs (K82)	3.304
Channel Results (K84)	3.357
channel results (K93)	2.148
channel table	
result display (K82)	3.300
channel table (K20)	2.81, 3.189
creating	2.88
default	2.94

measurement with channel table	2.96
measurement without channel table	2.94
channel table (K82)	
Add Channel	3.294
auto search	3.291
Cancel	3.295
Copy	3.292
Delete	3.292
delete channel	3.294
Edit	3.293
Meas	3.294
name	3.292
New	3.292
predefined	3.291
Reload	3.295
Restore default channel tables	3.295
Save	3.295
Sort	3.295
channel table (K84)	
Add Channel	3.348
auto search	3.346
Cancel	3.349
Copy	3.349
Delete	3.349
delete channel	3.348
Edit	3.349
Meas	3.348
name	3.347
New	3.347
predefined	3.346
Reload	3.349
Restore default channel tables	3.350
Save	3.348
Sort	3.348
Channel Table (K84)	3.359
Channel Table dialog box (K20)	3.185
Channel Table Settings (K84)	3.346
Channel Table Settings dialog (K82)	3.291
Channel Tables dialog box (K20)	3.189
channel width (K20)	2.82
characters	
special	4.3
Chip Rate Error (K82)	3.303
CINR (K93)	2.151, 2.156
Clear Write trace mode	3.36
clock offset (K93)	2.149
Code Domain Analyzer menu (K82)	3.273
Code Domain Error (K82)	3.305
Code Domain Error (K84)	3.361
Code Domain Power (K82)	3.299
Code Domain Power (K84)	3.354
command	
description	4.2
programming examples	5.1
common commands	4.6
common pilot channel (K72)	3.251
Composite Constellation (K82)	3.309
Composite Constellation (K84)	3.362
Composite EVM	3.282, 3.359
Composite EVM (K82)	3.304, 3.307
continuous sweep	3.23
coupling	
resolution bandwidth	3.20
sweep time	3.21
video bandwidth	3.21
CPCCH	3.282
CPICH (K72)	3.251
Crest factor	3.282
CSO Setup dialog box (K20)	3.216
CTB Setup dialog box (K20)	3.217
D	
data packet	
structure (k8)	2.36
dedicated physical channel (K72)	3.252
default scalings of x– and y-axis	3.95
definition of transducer factors	5.20
delay	
gate signal	3.32
delta marker	3.48
Demod Settings (K84)	3.344
Demod Settings dialog (K82)	3.288
Demod Settings dialog box	
K91/K91n option	3.389
K93 option	3.424
demodulation bandwidth (K7)	3.125
detector	
Auto Peak	3.41
auto select	3.41
Average	3.42
IF overload (K20)	3.190
Negative Peak	3.41
Positive Peak	3.41
Quasi Peak	3.42
RF overload (K20)	3.190
RMS	3.41
Sample	3.41
detector overview	3.38
dialog	
Channel Table Settings (K84)	3.346
Demod Settings (K84)	3.344
Frontend Settings (K84)	3.342
IQ Capture Settings (K84)	3.343
Result Settings (K84)	3.350
dialog box	
Edit Power Classes (remote control)	4.45
Differential Phase Encoding measurement (K8)	3.149
digital TV basics (K20)	2.63
Digital TV Settings dialog box (K20)	3.222
direct measurement (K30)	2.100, 3.241
display lines	3.113, 3.116
display range	
frequency	3.7
level	3.14
distance-to-fault measurement (K20)	2.76
DPCH (K72)	3.251

E	
error messages	
3GPP Base Station measurements (K72)	6.3
device-specific	6.1
noise figure measurements (K30)	6.2
WiMAX, WiBro measurements (K93)	6.5
WLAN TX measurements (K91)	6.4
EUT (K8)	3.152
EVM (K20)	2.68
EVM (K93)	2.149, 2.155
EVM vs Symbol (K82)	3.309
EVM vs Symbol (K84)	3.362
external trigger	3.28
F	
FDD (K72)	3.251
filter	
K8 option	2.40
root raised cosine (K20)	2.65
RX (K20)	2.65
TX (K20)	2.65
fixed reference	3.54
FM demodulation	3.55
frequency	
axis	3.5
band (K8)	3.150
center	3.7
line	3.117
offset	3.9
power meter	3.169
specify frequency axis	3.5
start	3.7
stop	3.8
frequency menu	
base unit	3.7
K20 option	3.205
K30 option	3.231
K7 option	3.133
K72 option	3.257
K8 option	3.154
K82 option	3.312
K84 option	3.364
K91/K91n option	3.388
K93 option	3.423
frequency offset (K93)	2.149
frequency plan (K20)	2.81
Frequency Settings dialog box (K30)	3.231
frequency-converting measurement (K30)	
.....	2.103, 3.241
Frontend Settings (K84)	3.342
Frontend Settings dialog (K82)	3.286
FSL-B6	1.3
FSL-B8	1.3
FSL-K14	1.4
FSL-K30	1.4
FSL-K7	1.3
FSL-K72	1.4
FSL-K8	1.3
FSL-K82	1.4
FSL-K91	1.5
FSL-K93	1.5
functional description (K8)	2.39
G	
gate	
delay	3.32
external/internal	3.31
length	3.32
mode	3.32
Gated Sweep	1.3
General Results (K84)	3.355
General Settings dialog box	
K91/K91n option	3.388
K93 option	3.423
Graphic dialog box (K30)	3.233
H	
Hadamard Code Order (K82)	3.297
harmonics measurement	3.107
high speed physical downlink shared channel (K72)	3.252
high speed shared control channel (K72)	3.252
horizontal sync signal	3.33
hybrid acknowledgement indicator channel (K72)	3.252
I	
I/Q data acquisition	5.21
I/Q imbalance (K93)	2.156
IEC/IEEE bus	
command description	4.2
image-frequency rejection (K30)	2.103
impedance	
cable TV networks (K20)	3.208
input	3.16
Inactive Channel Threshold	3.282
Initial Carrier Frequency Tolerance	
measurement (K8)	3.146
initial configuration	3.4
initial configuration (K82)	
Code Domain Analyzer	3.276
instrument functions	3.1
INSTrument[\$NSElect] (K20)	4.467
interference	
inter-symbol K20	2.65
intermodulation product	2.6
inter-symbol interference K20	2.65
IQ Capture Settings (K84)	3.343
IQ Capture Settings dialog (K82)	3.287
IQ Imbal / Offset (K82)	3.304
IQ impairments (K93)	2.150
K	
key	
AMPT / SCALE	3.13
BW	3.17

ESC	4.29
FREQ	3.5
LINES	3.109
MEAS	3.67
MENU	3.121
MKR	3.48
MKR->	3.59
MODE	3.119
MODE (remote control)	4.149
PRESET	3.3, 4.8, 4.243
SPAN	3.11
SWEEEP	3.22
TRACE	3.35
TRIG / FORMAT	3.25
L	
LAP (K8)	3.152
level	
axis	3.16
display range	3.14
range	3.14
reference	3.14
trigger	3.30
level detection	
K93 option	2.143
limit	
ACP measurement	3.90
evaluation range	3.85
limit check	
ACP measurement	3.90
Limit Check (remote control)	4.45
limit line	3.113
copying	3.116
deleting	3.116
editing	3.116
new	3.115
scaling	3.110, 3.111
shift	3.112
span setting	3.110
unit	3.111
Limit Lines dialog box (K30)	3.227
line	
display	3.113
frequency (Frequency Line 1, 2)	3.117
limit	3.113
system	3.34
threshold	3.65
time (Time Line 1, 2)	3.117
linear averaging	3.45
LINES key	3.109
lines menu	
base unit	3.114
K30 option	3.246
K91/K91n option	3.412
K93 option	3.461
literature	
K93 option	2.151, 2.157
LO exclude	3.66
logarithmic averaging	3.44
Loss dialog box (K30)	3.237
lower-case (commands)	4.3
M	
marker	3.48
center frequency to	3.64
peak	3.63
reference level to	3.64
search limit	3.65
signal track	3.10
to trace	3.55
zoom	3.57
marker field	
base unit	3.48
K14 option	3.174
K72 option	3.252
marker menu	
base unit	3.52
K14 option	3.177
K30 option	3.245
K72 option	3.259
K82 option	3.319
K84 option	3.371
K91/K91n option	3.411
K93 option	3.460
marker-> menu	
base unit	3.62
K14 option	3.178
K30 option	3.246
K72 option	3.260
K82 option	3.320
K84 option	3.372
K91/K91n option	3.412
K93 option	3.461
Max Hold trace mode	3.36
maximum search	3.63
maximum value	3.84
MC1	3.282
MC2	3.282
mean power (GSM burst)	3.84
MEAS key	3.67
measurement	
Adjacent-Channel Power (K72)	3.270
Adjacent-Channel Power (K8)	3.145
Bitstream (K84)	3.360
Bluetooth (K8)	3.141
cable TV (K20)	3.184
Carrier Frequency Drift (K8)	3.147
Carrier Frequency Stability and Modulation Accuracy (K8)	3.149
Channel Bitstream (K82)	3.310
Channel Bitstream (remote control, K84)	4.615
Channel Constell (K82)	3.308
Channel Constell (remote control, K84)	4.615
Channel Results (K84)	3.357
Channel Table (K82)	3.300
Channel Table (K84)	3.359
Channel Table (remote control, K84)	4.615

Code Dom Power (K72) ..	3.263, 3.264, 3.265, 3.266	2.47
Code Domain Analyzer (K82) ..	3.298, 3.322	2.78
Code Domain Analyzer (K84) ..	3.354, 3.374	2.100
Code Domain Error (K82) ..	3.305	2.141
Code Domain Error (K84) ..	3.361	2.49
Code Domain Error (remote control, K84)	4.615	2.79
Code Domain Power (K82) ..	3.299	2.77
Code Domain Power (K84) ..	3.354	Code Domain Power measurement (K72)
Code Domain Power (remote control, K84)	4.615	2.111
Composite Constell (K82) ..	3.309	Composite EVM measurement (K82) ... 2.123
Composite Constell (remote control, K84)	4.615	Constellation Diagram (K20) 2.73
Composite Constellation (K84) ..	3.362	digital TV (K20) 2.68
Composite EVM	3.359	digital TV settings (K20) 2.69
Composite EVM (K82) ..	3.307	Echo Pattern (K20) 2.76
Composite EVM (remote control, K84) ..	4.615	harmonics 2.1
Differential Phase Encoding (K8) ..	3.149	Hum (K20) 2.53
distance-to-fault (K20) ..	2.76	intermodulation 2.6
EVM vs Symbol (K82) ..	3.309	modulated signals 2.23
EVM vs Symbol (K84) ..	3.362	Modulation Errors (K20) 2.74
EVM vs Symbol (remote control, K84) ..	4.615	noise 2.15
functions	3.47	Overview (K20) 2.71
General Results (K84) ..	3.355	Peak Code Domain Error measurement (K82) 2.124
Initial Carrier Frequency Tolerance (K8) ..	3.146	relative Code Domain Power measurement (K72) 2.109
Modulation Characteristics (K8) ..	3.145	relative Code Domain Power measurement (K82) 2.117
Occupied Bandwidth (K82) ..	3.326	relative Code Domain Power measurement triggered (K82) 2.120
Occupied Bandwidth (K84) ..	3.378	RHO factor (K82) 2.124
Output Power (K8) ..	3.144	Signal Channel Power measurement (K72) 2.106
parameters	3.2	Signal Channel Power measurement (K82) 2.114
Peak Code Domain Error (K82) ..	3.308	signals in the vicinity of noise 2.11
Peak Code Domain Error (K84) ..	3.361	spectra of complex signals 2.5
Peak Code Domain Error (remote control, K84) ..	4.615	Spectrum (K20) 2.48, 2.70
Power (K72) ..	3.267	Spectrum Emission Mask measurement (K72) 2.108
Power vs Chip (K84) ..	3.358	Spectrum Emission Mask measurement (K82) 2.116
Power vs PCG (K82) ..	3.301	test setup 2.1
Power vs PCG (remote control, K84) ..	4.615	Tilt (K20) 2.80
Power vs Symbol (K82) ..	3.310	TV analyzer (K20) 2.80
Power vs Symbol (K84) ..	3.358	Video Scope (K20) 2.51
Relative Transmit Power (K8) ..	3.147	Vision Modulation (K20) 2.52
Result Summary (K82) ..	3.302	with channel table (K20) 2.96
Result Summary (remote control, K84) ..	4.615	without channel table (K20) 2.94
Signal Channel Power (K82) ..	3.323	measurement forms (K30) 3.228
Signal Channel Power (K84) ..	3.375	measurement menu
Spectrum Emission Mask (K72) ..	3.270	base unit 3.80
Spectrum Emission Mask (K82) ..	3.278, 3.324	K20 option 3.209
Spectrum Emission Mask (K84) ..	3.376	K30 option 3.238
Spurious Emissions (K8) ..	3.148	K72 option 3.261
Symbol Constellation (K84) ..	3.362	K8 option 3.163
time	3.170	K82 option 3.322
WiMAX 802.16 OFDM/OFDMA/WiBro (K93)	3.415	K84 option 3.373
WLAN TX (K91/K91n) ..	3.383	K91/K91n option 3.387
measurement example		K93 option 3.421
amplitude distribution	2.32	
analog TV (K20)	2.46	

measurement mode	
1xEV-DO BTS Analyzer (K84)	3.120
3G FDD BTS (K72)	3.120
Analog Demodulation (K7)	3.119
available modes	3.119
Bluetooth (K8)	3.119
Cable TV Analyzer (K20).....	3.120
CDMA2000 BTS Analyzer (K82).....	3.120
changing.....	3.119
displaying main menus.....	3.121
K30 option	3.227
Noise (K30)	3.120
Spectrum Analyzer	3.119
WiMAX/WiBro (92).....	3.120
WLAN (K91/K91n)	3.120
measurement result	
Active Channels (K82)	3.303
Carr Freq Error (K82).....	3.303
Channel Power Rel / Abs (K82)	3.304
Chip Rate Error (K82)	3.303
Composite EVM (K82)	3.304
IQ Imbalance (K82).....	3.304
Modulation (K82).....	3.304
Offset (K82).....	3.304
Phase Offset (K82)	3.304
Pilot PWR (K82).....	3.303
RHO (K82)	3.303
Symbol EVM rms / Pk (K82)	3.304
Timing Offset (K82).....	3.304
Total PWR (K82).....	3.303
Trg to Frame (K82)	3.303
measurement results (K30)	3.228
Measurement Settings dialog box (K30)....	3.238
measurement variables	
CINR (K93).....	2.151, 2.156
EVM (K93).....	2.149, 2.155
I/Q imbalance (K93)	2.156
IQ impairments (K93).....	2.150
K93 option	2.155, 2.157
RSSI (K93)	2.151, 2.156
menu	
amplitude.....	3.13
amplitude (K20).....	3.207
amplitude (K7).....	3.136
amplitude (K72).....	3.258
amplitude (K8).....	3.155
amplitude (K82).....	3.314
amplitude (K84).....	3.366
amplitude (K91/K91n)	3.388
amplitude (K93).....	3.423
analog demodulation (K7)	3.123, 3.126
bandwidth	3.20
bandwidth (K7)	3.138
bandwidth (K8)	3.157
bandwidth (K82)	3.315
bandwidth (K84)	3.368
Bluetooth (K8)	3.141, 3.150
Cable TV Analyzer (K20).....	3.183, 3.202
Code Domain Analyzer (K82).....	3.273
frequency.....	3.7
frequency (K20).....	3.205
frequency (K30)	3.231
frequency (K7)	3.133
frequency (K72)	3.257
frequency (K8)	3.154
frequency (K82)	3.312
frequency (K84)	3.364
frequency (K91/K91n).....	3.388
frequency (K93)	3.423
lines	3.114
lines (K30)	3.246
lines (K91/K91n).....	3.412
lines (K93)	3.461
marker	3.52
marker (K14)	3.177
marker (K30)	3.245
marker (K72)	3.259
marker (K82)	3.319
marker (K84)	3.371
marker (K91/K91n).....	3.411
marker (K93)	3.460
marker->	3.62
marker-> (K14)	3.178
marker-> (K30)	3.246
marker-> (K72)	3.260
marker-> (K82)	3.320
marker-> (K84)	3.372
marker-> (K91/K91n).....	3.412
marker-> (K93)	3.461
measurement (K14).....	3.174
measurement (K20).....	3.209
measurement (K30)	3.238
measurement (K7).....	3.126
measurement (K72).....	3.261
measurement (K8).....	3.163
measurement (K82)	3.322
measurement (K84)	3.373
menu.....	3.121
noise figure measurements (K30)	3.226, 3.230
power measurement.....	3.80
power meter (K9).....	3.168, 3.169
settings (K72)	3.249, 3.253
span	3.11
span (K7)	3.135
span (K82)	3.313
span (K84)	3.365
spectrogram (K14).....	3.172, 3.174
sweep	3.22
sweep (K14)	3.176
sweep (K30)	3.243
sweep (K7)	3.138
sweep (K8)	3.159
sweep (K82)	3.316
sweep (K84)	3.369
sweep (K91/K91n)	3.410
sweep (K93)	3.459
trace.....	3.39

trace (K20)	3.208
trace (K30)	3.244
trace (K82)	3.318
trace (K84)	3.370
trace (K91/K91n)	3.413
trace (K93)	3.462
trigger	3.29
trigger (K7)	3.139
trigger (K72)	3.259
trigger (K8)	3.163
trigger (K82)	3.317
trigger (K84)	3.370
trigger (K91/K91n)	3.388
trigger (K93)	3.423
WiMAX (K93)	3.415, 3.421
WLAN (K91/K91n)	3.382, 3.387
MENU key.....	3.121
menu menu.....	3.121
MER (K20).....	2.68
Min Hold trace mode.....	3.36
minimum search	3.64
MKR key	3.48
MKR-> key	3.59
mode	
see also measurement mode.....	3.119
trigger	3.30
MODE key	3.119
model.....	3.122
Modulation (K82)	3.304
Modulation Characteristics measurement (K8)	
.....	3.145
modulation depth	3.84
modulation standard (K20)	2.82, 2.83, 3.190
< unused >	2.83
Modulation Standard Options dialog box (K20)	
.....	3.186
modulation standards (K20)	
analog TV.....	2.84
assigning.....	2.93
creating	2.90
digital TV	2.86
N	
Negative Peak detector	3.38
noise	
measurement (K30)	3.226
Noise Figure and Gain Measurements	1.4
noise figure measurements menu (K30)	3.226, 3.230
Noise mode (K30).....	3.120
O	
occupied bandwidth	3.70
K20 option	2.87
offset	
frequency	3.9
gate signal.....	3.32
reference level.....	3.15
trigger	3.31
option	3.122
1xEV-DO Base Station Test (K84)	3.332
3GPP Base Station Measurements (K72)	
.....	3.249
Additional Interfaces (B5)	3.168
Analog Demodulation (K7)	3.123
Bluetooth Measurements (K8)	3.141
Gated Sweep (B8)	3.25
Noise Figure Measurements (K30)	3.226
Power Meter (K9)	3.168
RF Preamplifier (B22)	3.15
Spectrogram Measurement (K14)	3.172
TV Trigger (B6)	3.28
WiMAX IEEE 802.16e, WiBro Measurements (K93)	3.414
WLAN TX Measurements (K91/K91n)	3.382
OTD.....	3.282
Output Power measurement (K8)	3.144
oversampling (K8)	2.41
oversampling factor (K8)	3.154
overview	
Bluetooth measurements (K8)	2.35
overwrite mode.....	3.36
P	
p0 bit (K8).....	2.43, 3.143
paging indication channel (K72)	3.252
parameter	
technical (K8)	2.35
PCCPCH (K72)	3.251
PCG	3.282
PCH	3.282
PDCCH	3.283
PDCH	3.283
Peak Code Domain Error (K82)	3.308
Peak Code Domain Error (K84)	3.361
peak envelope power (K20)	2.68
peak search	3.63
phase jitter (K20)	2.68
physical layer (K20)	2.82
PICH	3.283
PICH (K72)	3.251
Pilot PWR (K82)	3.303
polarity	
external trigger/gate	3.30
trigger edge	3.30
video	3.34
Positive Peak detector	3.38
power	
3GPP FDD signal (K72)	3.267
bandwidth percentage	3.93
mean	3.84
power classes	
bluetooth (K8)	2.36
power measurement	3.67
occupied bandwidth	3.70
trace	3.91
zero span	3.69
power measurement menu	

base unit.....	3.80
power meter (K9).....	3.168
frequency	3.169
menu	3.168, 3.169
power sensor support (K9)	3.168
Power vs Chip (K84).....	3.358
Power vs PCG (K82)	3.301
Power vs Symbol (K82)	3.310
Power vs Symbol (K84)	3.358
preset instrument.....	3.3
PRESET key.....	3.3
preset spectrum analyzer	3.3
pre-trigger	3.31
primary common control physical channel (K72)	3.251
primary synchronization channel (K72).....	3.251
programming examples	
averaging I/Q data.....	5.23
channel power measurement.....	5.11
I/Q data	5.21
level measurement.....	5.19
limit lines and limit test	5.9
occupied bandwidth measurement	5.13
power ramp measurement.....	5.15
service request.....	5.1
Spectrum Emission Mask measurement	5.24
Spurious Emissions measurement	5.28
time domain power measurement.....	5.14
transducers	5.20
WiMAX, WiBro measurements (K93)	5.35
WLAN TX measurements (K91)	5.32
PWR BW key.....	3.17
Q	
QAM (K20).....	2.86
quadrature error (K20).....	2.68
R	
RC.....	3.283
reference	
fixed.....	3.54
level to marker level	3.64
value	3.171
reference level	3.14
channel power	3.92
offset	3.15
to marker level.....	3.64
reference noise bandwidth (K20).....	2.54
reference point	
frequency	3.54
level	3.54
peak search.....	3.54
time	3.54
relative grant channel (K72).....	3.252
Relative Transmit Power measurement (K8)	3.147
remote control	
programming examples	5.1
reset	
switch on or off	3.42
resolution bandwidth	3.20
K7 option	3.138
result display	
Code Dom Channel Table (K72)	3.263
Code Dom Power Diagram (K72).....	3.264
Code Dom Result Summary (K72).....	3.265, 3.266
Result Settings dialog (K82).....	3.295
Result Summary (K82).....	3.302
RHO (K82)	3.303
RMS detector	3.38
RMS value.....	3.84
roll-off factor (K20)	2.65
root raised cosine	2.87
filter (K20)	2.65
RSSI (K93).....	2.151, 2.156
RX filter (K20).....	2.65
S	
Sample detector	3.38
sample number	3.94
scaling	3.14
level axis	3.16
x– and y–axis (signal statistic)	3.94
SCH (K72).....	3.251
SCPI	
conformity information	4.2
search	
bandwidth	3.10
minimum	3.64
peak	3.63
range	3.65
secondary common control physical channel (K72)	3.251
secondary synchronization channel (K72)	3.251
Select Limit Line dialog box	3.112
sensitivity	
APD measurement	3.95
CCDF measurement	3.95
Settings (K82)	3.284
Settings (K84)	3.341
settings menu (K72)	3.249, 3.253
Settings Overview dialog (K82)	3.285
Settings Overview dialog (K84)	3.341
SF	3.283
sideband suppression (K30)	2.103
signal count	3.55
signal level (K20).....	3.190
signal processing	
block diagram (K93)	2.154
IEEE 802.11a (K91)	2.127
IEEE 802.11b (K91)	2.133
IEEE 802.16 OFDMA (K93)	2.153
IEEE 802.16–2004 OFDM (K93)	2.144
signal tracking	3.10
search bandwidth	3.10
softkey	
# of Adj Chan	3.87

# of Adj Chan (remote control).....	4.205	Adjust Ref Level (K72).....	3.256, 3.272
# of Samples	3.94	Adjust Ref Level (K82)....	3.312, 3.314, 3.324,
# of Samples (K82)	3.327	3.327	
# of Samples (K84)	3.379	Adjust Ref Level (K84)....	3.364, 3.366, 3.376
# of Samples (remote control).....	4.111	Adjust Ref Level (remote control).....	4.208
# of TX Chan	3.87	Adjust Ref Level (remote control, K72) 4.569,	
# of TX Chan (remote control)	4.211	4.572	
% Power Bandwidth	3.93	Adjust Ref Level (remote control, K82) . 4.600	
% Power Bandwidth (K82)	3.326	Adjust Ref Lvl	3.93
% Power Bandwidth (remote control)....	4.211	Adjust Settings.....	3.86, 3.91, 3.95, 3.107
(remote control, K14)	4.375, 4.377	Adjust Settings (K82).....	3.327, 3.328
= Center	3.9	Adjust Settings (K84).....	3.379, 3.380
= Chan Spacing (K8).....	3.155	Adjust Settings (remote control) . 4.112, 4.207	
= Marker.....	3.9	Adjust X-Axis	3.106
= Marker (remote control)	4.69	AF Center (K7)	3.134
0.1 * RBW	3.8	AF Center (remote control, K7)	4.284
0.1 * RBW (remote control).....	4.187, 4.188	AF Coupling AC/DC (K7)	3.130
0.1 * Span	3.8	AF Coupling AC/DC (remote control, K7)	
0.1 * Span (remote control).....	4.187, 4.188	.....	4.284
0.1*Chan Spacing (K8)	3.155	AF Filter (K7)	3.131
0.1*Demod BW (K7)	3.134	AF Full Span (K7)	3.135
0.5 * RBW	3.8	AF Full Span (remote control, K7)	4.285
0.5 * RBW (remote control).....	4.187, 4.188	AF Range (K7).....	3.129
0.5 * Span	3.8	AF Span Manual (K7)	3.135
0.5 * Span (remote control).....	4.187, 4.188	AF Span Manual (remote control, K7)... 4.285	
0.5*Demod BW (K7)	3.134	AF Spectrum (K7).....	3.128
30kHz/1MHz Transition (K72)	3.272	AF Start (K7).....	3.134
30kHz/1MHz Transition (remote control, K72)		AF Start (remote control, K7)	4.286
.....	4.555	AF Stop (K7).....	3.134
ACP (K72)	3.270	AF Stop (remote control, K7).....	4.286
ACP (remote control, K72).....	4.560	AF Time Domain (K7).....	3.128
ACP Abs/Rel	3.92	All Functions off	3.83
ACP Abs/Rel (remote control).....	4.207	All Functions off (remote control)	4.95
ACP Ref Setting (remote control)	4.209	All Marker Off	3.57
ACP Ref Settings	3.89	All Marker Off (K30)	3.245
ACP Ref Spacing (remote control).....	4.209	All Marker Off (remote control, K30)	4.514
ACP Rel/Abs (K91/K91n)	3.406	AM	3.55
ACP Rel/Abs (remote control, K91)	4.676, 4.682	AM (remote control).....	4.69
ACPR Abs/Rel (K93)	3.454	AM Mod Depth	3.84
ACPR Abs/Rel (remote control, K93).....	4.816, 4.817, 4.818	AM Mod Depth (remote control) 4.72, 4.73	
ACPR Abs/Rel (K93)	3.453	Analog TV (K20)	3.211
ACPR Abs/Rel (remote control, K93)....	4.758, 4.768, 4.769	Analog TV (remote control, K20)	4.456
Activate (K20).....	3.202	Analog TV Settings (K20)	3.218
Activate (remote control, K20).....	4.458	Analog TV Settings (remote control, K20)	
Add Channel (K82).....	3.294	.....	4.491, 4.502, 4.503, 4.504
Add Channel (K84).....	3.348	Annotation On/Off (remote control)	4.125
Adjacent Channel Power (K82).....	3.323	Antenna Diversity (K82).....	3.289
Adjacent Channel Power (K84).....	3.375	Antenna Diversity On/Off (K72)	3.256
Adjacent Channel Power (remote control, K82)	4.592	Antenna Diversity On/Off (remote control, K72)	4.568
Adjacent Channel Power (remote control, K84)	4.629	Antenna Gain (K8).....	3.151
Adjust Attenuation (K20)	3.205	Antenna Gain (remote control, K8).....	4.353
Adjust Gate (K8).....	3.160	Antenna Number 1/2 (K72)	3.256
Adjust Gate (remote control, K8)	4.342	Antenna Number 1/2 (remote control, K72)	
Adjust Ref Level	3.92	.....	4.568
ASCII File Export		APD	3.93
APD (K20)		APD (remote control).....	4.110, 4.111
ASCII File Export		ASCII File Export	3.43, 3.58, 3.104

ASCII File Export (remote control)	4.161	Capture Length (K84)	3.343
Auto Level (K91/K91n)	3.410	Carr Freq Drift (K8)	3.166
Auto Level (K93)	3.459	Carr Freq Drift (remote control, K8)	4.317, 4.318
Auto Level (remote control, K93)	4.772	Carr Freq Stability (K8)	3.167
Auto Level&Code (K72)	3.262	Carr Freq Stability (remote control, K8)	4.318, 4.319, 4.320, 4.321, 4.322
Auto Level&Code (remote control, K72)	4.569	Carrier Selection (K91/K91n)	3.404
Auto Lvl (remote control, K91)	4.685	Carrier Selection (K93)	3.447
Auto Max Peak	3.66	Carrier Selection (remote control, K91)	4.678
Auto Max Peak (remote control)	4.59	Carrier Selection (remote control, K93)	4.764
Auto Min Peak	3.66	Carriers (K20)	3.212
Auto Min Peak (remote control)	4.61	Carriers (remote control, K20)	4.418
Auto Range (K20)	3.219, 3.225	CCDF	3.95
Auto Range (remote control, K20)	4.460	CCDF (K20)	3.224
Auto Scale Once (K82)	3.315, 3.319	CCDF (K82)	3.327
Auto Scale Once (K84)	3.367	CCDF (K84)	3.379
Average	3.40	CCDF (K91/K91n)	3.407
Average Length (K91/K91n)	3.399	CCDF (K93)	3.455
Average Length (remote control, K91)	4.681	CCDF (remote control)	4.110, 4.111
Average Mode	3.44	CCDF (remote control, K82)	4.592
Average Mode (remote control)	4.106	CCDF (remote control, K84)	4.629
Band Class (K82)	3.323, 3.325	CCDF (remote control, K91)	4.684
Band Class (K84)	3.375, 3.377	CCDF (remote control, K93)	4.772
Band Class (remote control, K82)	4.591	CDP Average (K84)	3.353
Band Class (remote control, K84)	4.628	Center	3.7
Base SF (K82)	3.288	Center (K8)	3.155
Bit Selection (K93)	3.458	Center (remote control)	4.186
Bit Selection (remote control, K93)	4.762, 4.763	Center =Mkr Freq	3.64
Bitstream (K91/K91n)	3.408	Center =Mkr Freq (remote control)	4.69
Bitstream (K93)	3.456	CF Stepsize	3.8
Bitstream (remote control, K91)	4.684	CF Stepsize (remote control)	4.186
Bitstream (remote control, K93)	4.771	CF–Stepsize (K8)	3.155
Blank	3.41	Chan Pwr/Hz	3.89
Block Count (K8)	3.160	Chan Pwr/Hz (remote control)	4.89
Block Count (remote control, K8)	4.340	Chan Type (K84)	3.363
Build Tbl (K30)	3.242	Channel (Code) Number (K82)	3.296
Burst Fit On/Off (K84)	3.381	Channel (K20)	3.206
Burst Offset (K8)	3.153	Channel (K8)	3.150
Burst Offset (remote control, K8)	4.357	Channel (remote control, K20)	4.487
Burst Selection (K93)	3.439	Channel (remote control, K8)	4.340
Burst Selection (remote control, K93)	4.768	Channel Analysis (K20)	3.221
Burst Summary (K93)	3.457	Channel Bandwidth	3.86, 3.88, 3.93
Burst Summary (remote control, K93)	4.771	Channel Bandwidth (K82)	3.326
C/N	3.85	Channel Bandwidth (remote control)	4.206
C/N (K20)	3.213	Channel Bitstream (K82)	3.310
C/N (remote control)	4.86, 4.87, 4.90	Channel Bitstream (remote control, K82)	4.582, 4.605
C/N (remote control, K20)	4.419	Channel Constell (K82)	3.308
C/N Setup (K20)	3.214	Channel Constell (remote control, K82)	4.582, 4.605
C/N Setup (remote control, K20)	4.470, 4.471, 4.473	Channel List Start (K8)	3.162
C/N, C/No	3.85	Channel No (K20)	3.212
C/No	3.86	Channel Power (K20)	3.223
C/No (remote control)	4.86, 4.87, 4.90	Channel Settings	3.88
Cal (K30)	3.243	Channel Setup (K20)	3.202
Cal (remote control, K30)	4.517	Channel Spacing	3.88
Cal Type Sine/Comb (remote control)	4.121	Channel Spacing (remote control)	4.210, 4.211
Cancel (K82)	3.295		
Cancel (K84)	3.349		
Capture Length (K82)	3.287		

Channel Table (K82)	3.300
Channel Table (remote control, K82)	4.582, 4.588, 4.589, 4.591, 4.599, 4.605
Channel Table (remote control, K84)	4.624, 4.625, 4.627, 4.628, 4.637
Channel Table settings (K82).....	3.291
Channel Table Settings (K84)	3.346
Channel Type (K84)	3.351
Channel Width (K20).....	3.206
Clear All Messages (remote control)....	4.239, 4.240
Clear Write	3.40
Clear/Write	3.91
Close Sweep List	3.101
Code Dom Channel Table (K72).....	3.263
Code Dom Channel Table (remote control, K72)	4.553, 4.560
Code Dom Overview (K84)	3.353
Code Dom Power Diagram (K72)	3.264
Code Dom Power Diagram (remote control, K72)	4.553, 4.560
Code Dom Result Summary (K72)	3.265
Code Dom Result Summary (remote control, K72)	4.553, 4.558, 4.560
Code Domain Analyzer (K82).....	3.322
Code Domain Analyzer (K84).....	3.374
Code Domain Analyzer (remote control, K82)	4.592
Code Domain Analyzer (remote control, K84)	4.629
Code Domain Error (K82)	3.305
Code Domain Error (remote control, K82)	4.582
Code Domain Power (K82)	3.299
Code Domain Power (remote control, K82)	4.582, 4.605
Code Order (K82).....	3.297
Code Power (K82).....	3.297
Code Power Abs Rel (K84)	3.353
Code Power Abs/Rel (K72)	3.254
Code Power Abs/Rel (remote control, K72)	4.553
Color (K14)	3.175
Color (remote control, K14).....	4.388
Color On/Off (remote control)	4.140
Composite Constell (K82)	3.309
Composite Constell (remote control, K82)	4.582
Composite EVM (K82)	3.307
Composite EVM (remote control, K82) .	4.582, 4.605
Const Diagram (K20)	3.221
Constell Selection (K93).....	3.447
Constell Selection (remote control, K93)	4.763, 4.765
Constell vs Symbol/Carrier (K91/K91n)	3.403
Constell vs Symbol/Carrier (K93).....	3.446
Constell vs Symbol/Carrier (remote control, K91)	4.679
Constell vs Symbol/Carrier (remote control, K93)	4.764
Cont Demod	3.56
Cont Demod (remote control).....	4.68
Cont Meas (remote control).....	4.143, 4.144
Continue Frame On/Off (K14)	3.177
Continue Frame On/Off (remote control, K14)	4.388
Continue Single Sweep	3.23
Continue Single Sweep (remote control).....	4.143
Continue Test (K8)	3.160
Continuous Sweep	3.23
Continuous Sweep (K8).....	3.160
Continuous Sweep (remote control).....	4.143, 4.144
Continuous Sweep Start/Stop (remote control, K14).....	4.392
Copy (K20)	3.204
Copy (K82)	3.292
Copy (K84)	3.349
Copy (remote control).....	4.153
Copy (remote control, K82)	4.589
Copy (remote control, K84)	4.625
Copy Channel (K20)	3.203
Copy to	3.116
Copy to (remote control).....	4.30
Copy Trace	3.42
Copy Trace (remote control)	4.247
Copy Trace (remote control, K20)	4.501
Copy Zone/Burst (K93).....	3.437
Corr Data On/Off (remote control).....	4.119
CP / ACP Config.....	3.87
CP / ACP Standard.....	3.86
CP / ACP Standard (remote control).....	4.86
CP, ACP, MC-ACP	3.86
CP, ACP, MC-ACP (remote control).....	4.86, 4.87, 4.90
CPICH (K72).....	3.261
CPICH (remote control, K72)	4.551, 4.557
CSO (K20)	3.216
CSO (remote control, K20).....	4.419
CSO Setup (K20).....	3.216
CSO Setup (remote control, K20)	4.474, 4.475, 4.476
CTB (K20).....	3.217
CTB (remote control, K20)	4.420
CTB Setup (K20)	3.217
CTB Setup (remote control, K20).....	4.478, 4.480
Data → Mem1 (K30).....	3.244
Data → Mem1 (remote control, K30)....	4.517
Data → Mem2 (K30).....	3.244
Data → Mem2 (remote control, K30)....	4.517
Data → Mem3 (K30).....	3.244
Data → Mem3 (remote control, K30)....	4.517
Data On/Off (K30)	3.245
Data On/Off (remote control, K30)	4.519, 4.521
dB per Division (K7).....	3.129
dB per Division (K72).....	3.258

dB per Division (remote control, K7)	4.278
dB per Division (remote control, K72)	4.561
Decim Sep.....	3.43
Decim Sep (remote control)	4.135
Deemphasis (K7)	3.132
Deemphasis (remote control, K7)	4.305
Default All (K91/K91n).....	3.413
Default All (K93)	3.461
Default Colors 1 (remote control)	4.126
Default Colors 2 (remote control).....	4.126
Default Current (K91/K91n).....	3.413
Default Current (K93)	3.461
Default Settings.....	3.95
Default Settings (remote control) 4.111, 4.113	
Delete	3.116
Delete (K20)	3.203, 3.204
Delete (K30)	3.242, 3.247, 3.248
Delete (K82)	3.292
Delete (K84)	3.349
Delete (remote control)	4.30, 4.154, 4.158
Delete (remote control, K82)	4.590
Delete (remote control, K84)	4.627
Delete Channel (K20).....	3.203
Delete Channel (K82).....	3.294
Delete Channel (K84).....	3.348
Delete File (remote control).....	4.152
Delete Line (K20)	3.215
Delete Range	3.102
Delete Range (remote control)	4.178
Delete Value.....	3.116
Delete Zone/Burst (K93)	3.437
Demod Bandwidth (K7)	3.135
Demod BW (K7).....	3.128
Demod BW (remote control, K7).....	4.304
Demod Settings (K7)	3.130
Demod Settings (K82).....	3.288
Demod Settings (K84).....	3.344
Demod Settings (remote control, K82)	4.598, 4.601, 4.602, 4.603
Demod Settings (remote control, K84)	4.641
Demod Settings (remote control, K91 / K91n)	4.707, 4.708, 4.709, 4.710, 4.711, 4.712, 4.713, 4.714, 4.718, 4.719
Deselect All	3.115
Details On/Off.....	3.106
Detector Auto Peak	3.41
Detector Auto Select	3.41
Detector Auto Select (remote control)	4.173
Detector Average	3.42
Detector Manual Select	3.41
Detector Manual Select (remote control)	4.173
Detector Manual Select (remote control, K8)	4.341
Detector Negative Peak	3.41
Detector Positive Peak	3.41
Detector Quasi Peak	3.42
Detector RMS	3.41
Detector Sample	3.41
Dev per Division (K7)	3.129
Deviation Lin/Log (K7)	3.130
Deviation Lin/Log (remote control, K7)	4.279
Device 1/2 (remote control)	4.156
Device Setup (remote control)	4.139, 4.140, 4.142, 4.237, 4.238
Diagram Full Size (K7)	3.128
Diagram Full Size (remote control, K7)	4.278
Diff Phase (K8)	3.167
Diff Phase (remote control, K8)	4.322, 4.323
Digital TV (K20)	3.220
Digital TV (remote control, K20)	4.457, 4.458
Digital TV Settings (K20)	3.222
Digital TV Settings (remote control, K20)	4.484, 4.485, 4.486
Disable all Items (remote control)	4.160
Discard Changes (K20)	3.204
Disconnect Network Drive (remote control)	4.157
Display Graph/Display List (K93)	3.438
Display Graph/Display List (remote control, K93)	4.788
Display Line 1	3.117
Display Line 1 (remote control)	4.23
Display Line 2	3.117
Display Line 2 (remote control)	4.23
Display Lines	3.116
Display List/Graph (K30)	3.233
Display List/Graph (K91/K91n)	3.397
Display List/Graph (remote control, K30)	4.520
Display List/Graph (remote control, K91)	4.689
Display Pwr Save (remote control)	4.127, 4.128
Display Settings (K30)	3.233
Display Settings (remote control, K30)	4.520, 4.521, 4.522, 4.524
DPSK Start (K8)	3.162
DPSK Start (remote control, K8)	4.345
DPSK Stop (K8)	3.162
DPSK Stop (remote control, K8)	4.346
Echo Pattern (K20)	3.221
Edit	3.116
Edit (K20)	3.204
Edit (K30)	3.247
Edit (K82)	3.293
Edit (K84)	3.349
Edit (remote control)	4.29, 4.32, 4.41, 4.42, 4.43, 4.49, 4.50, 4.51, 4.52, 4.53
Edit ACP Limit	3.90
Edit ACP Limit (remote control)	4.33, 4.34, 4.35, 4.37, 4.38, 4.39
Edit Comment	3.115
Edit Margin	3.115
Edit Name	3.115
Edit Path (remote control)	4.151, 4.156
Edit Power Classes	3.104
Edit Reference Range	3.102

Edit Reference Range (remote control)	4.175,	3.255
4.185		
Edit Table (K20)	3.212	Format Hex/Dec (remote control, K72)
Edit Table (remote control, K20)	4.399, 4.400,	4.570,
4.401, 4.402, 4.403, 4.404, 4.405, 4.406,		4.571
4.426, 4.427, 4.428, 4.429, 4.430, 4.431,		3.321
4.432, 4.433		F-PICH (K82).....
EDR (K8).....	3.166	F-PICH (remote control, K82).....
Enable all Items (remote control)	4.158	4.585
Enable/Disable (K30)	3.248	Frame Count (K14).....
ENR Settings (K30).....	3.236	Frame Count (remote control, K14).....
ENR Settings (remote control, K30).....	4.533,	4.389
4.537		Freeze (K20).....
Error Frequency/Phase (K91/K91n).....	3.402	3.221
Error Frequency/Phase (K93)	3.445	Freeze (remote control, K20)
Error Frequency/Phase (remote control, K91)	.....	4.459
.....	4.680	Freq Axis Lin/Log (remote control)
Error Frequency/Phase (remote control, K93)	.....	4.131
.....	4.766, 4.767	Freq Settings (K30)
EVM Constell (K91/K91n)	3.401	3.231
EVM Constell (K93).....	3.442	Freq Settings (remote control, K30)
EVM vs Symbol (K82)	3.309	4.534,
EVM vs Symbol (remote control, K82)	4.582,	4.538, 4.539, 4.540, 4.541
4.605		Frequency Abs/Rel (K20)
EVM vs Symbol/Carrier (K91/K91n).....	3.401	3.206
EVM vs Symbol/Carrier (K93)	3.442	Frequency Abs/Rel (remote control, K20)
EVM vs Symbol/Carrier (remote control, K91)	.....	.....
.....	4.679, 4.680	4.490
EVM vs Symbol/Carrier (remote control, K93)	.....	Frequency Coupling (K9).....
.....	4.766	3.170
Exclude LO	3.66	Frequency Coupling (remote control, K9)
Exclude LO (remote control)	4.58	.....
Exit (K30)	3.242, 3.247	4.369
Export (K91/K91n).....	3.400	Frequency Line 1
Export (K93)	3.442	3.117
Export (remote control, K91 / K91n)	4.704	Frequency Line 1 (remote control)
Export (remote control, K93)	4.809	4.26
Ext Att (remote control, K91 / K91n)	4.702	Frequency Line 2
Ext Att (remote control, K93)	4.790	3.117
Ext Power Trigger (K9)	3.171	Frequency Line 2 (remote control)
Ext Power Trigger (remote control, K9)	4.371	4.26
Fast ACP On/Off	3.92	Frequency Manual (K9)
Fast ACP On/Off (remote control)	4.212	3.169
Field 1/2 (K20)	3.219	Frequency Manual (remote control, K9)
Field 1/2 (remote control, K20)	4.503	4.368
File Manager (K93)	3.458	Frequency Offset
Filter Type	3.21	3.9
Filter Type (K8)	3.158	Frequency Offset (remote control)
Filter Type (remote control)	4.170	4.188
Find Burst On/Off (K8)	3.152	Frontend Settings (K82)
Find Burst On/Off (remote control, K8)	4.356	3.286
Find Sync (K8)	3.151	Frontend Settings (K84)
Find Sync On/Off (K8)	3.151	3.342
Find Sync On/Off (remote control, K8)	4.357	F-TDPICH (K82).....
Firmware Update (remote control)	4.240	3.321
Fix Freq (K30)	3.243	F-TDPICH (remote control, K82)
Fix Freq (remote control, K30)	4.518, 4.539	4.586
FM	3.55	Full Burst (K91/K91n)
FM (remote control)	4.69	3.398
		Full Burst (K93)
		3.438
		Full Burst (remote control, K91)
		4.682
		Full Burst (remote control, K93)
		4.768
		Full Size Diagram
		3.108
		Full Size Diagram (remote control)
		4.128
		Full Span
		3.12
		Full Span (K7)
		3.135
		Full Span (remote control)
		4.189
		Full Span (remote control, K7)
		4.302
		Full Subframe (K93)
		3.439
		Gate Delay
		3.32
		Gate Delay (K8)
		3.162
		Gate Delay (remote control)
		4.216
		Gate Length
		3.32
		Gate Length (K8)
		3.162
		Gate Length (remote control)
		4.216
		Gate Mode Lvl/Edge
		3.32
		Gate Mode Lvl/Edge (remote control)
		4.217
		Gate Settings
		3.32
		Gated Trigger
		3.31
		Gated Trigger (remote control)
		4.215, 4.217
		Gating Settings On/Off (K91/K91n)
		3.399
		Gating Settings On/Off (K93)
		3.440
		Gating Settings On/Off (remote control,
		K91 / K91n)
		4.716, 4.717
		Gating Settings On/Off (remote control, K93)
	
		4.822, 4.823, 4.824

General Settings (remote control, K91 / K91n).....	4.702, 4.707, 4.715, 4.716, 4.718, 4.729, 4.730, 4.731	3.256
General Settings (remote control, K91) 4.685, 4.686, 4.690		3.287
GFSK Start (K8)	3.162	3.343
GFSK Start (remote control, K8).....	4.346	3.461
GFSK Stop (K8)	3.162	3.599, 4.602
GFSK Stop (remote control, K8).....	4.347	4.638, 4.641
GPIB Address (remote control).....	4.237	3.152
GPIB Terminator LFEOL/EOI (remote control)	4.237	4.357
Grid Abs / Rel.....	3.16	3.12
Grid Abs / Rel (remote control).....	4.132	3.65, 3.85
Grid Abs / Rel (remote control, K20).....	4.460	4.64
Hardware Info (remote control).....	4.7, 4.120	3.90
Harmonic Distort	3.107	3.90
Harmonic On/Off	3.107	4.33, 4.36, 4.39
Harmonic RBW Auto.....	3.107	3.271
Harmonic Sweep Time.....	3.107	4.583
High Pass AF Filter (K7)	3.131	4.617
High Pass AF Filter (remote control, K7)4.306		4.554
History Depth (K14).....	3.175	3.271
History Depth (remote control, K14).....	4.390	4.583
Hold/Cont	3.42	4.617
Hor Sync.....	3.33	4.554, 4.555
Hor Sync (remote control).....	4.263	4.584
HSDPA/HSUPA On/Off (K72).....	3.257	4.618
HSDPA/HSUPA On/Off (remote control, K72)	4.569	Limit Line Select dialog box (remote control)
Hum (K20).....	3.219	4.47, 4.53
Hum (remote control, K20).....	4.421	3.272
IF Output IF/Video (remote control)	4.164	4.583
IF Power Retrigger Holdoff.....	3.33	4.617
IF Power Retrigger Holdoff (remote control)	4.259	4.554
IF Power Retrigger Hysteresis	3.33	3.85
IF Power Retrigger Hysteresis (remote control).....	4.260	4.64
Import (K91/K91n).....	3.400	3.44
Import (K93)	3.442	3.218
Import (remote control, K91 / K91n).....	4.704	4.503
Import (remote control, K93)	4.808	3.34
Inactive Channel Threshold (K72).....	3.256	4.263
Inactive Channel Threshold (remote control, K72)	4.570	3.103
Init Carr Freq Tol (K8)	3.166	3.103
Input 50 Ω / 75 Ω	3.16	3.435
Input 50 Ω / 75 Ω (remote control)	4.147	3.44
Input RF/Cal/TG (remote control)	4.121	4.127
Insert (K30)	3.242, 3.247	3.237
Insert after Range	3.101	4.534, 4.536
Insert after Range (remote control).....	4.181	3.131
Insert before Range	3.101	4.306, 4.307
Insert before Range (remote control)....	4.181	3.9
Insert Line (K20).....	3.215	4.186
Insert Value	3.116	3.214
Insert Zone/Burst (K93).....	3.437	
Installed Options (remote control)...4.7, 4.120		

Manual Reference Power (remote control, K20)	4.472, 4.475, 4.479
Map Network Drive (remote control)	4.157, 4.158
Mapping Auto (K84)	3.352
Mapping Complex (K84)	3.352
Margin	3.103
Margin (remote control)	4.24
Marker 1	3.53
Marker 1 (K30)	3.245
Marker 1 (K82)	3.319
Marker 1 (K84)	3.372
Marker 1 (K91/K91n)	3.411
Marker 1 (K93)	3.460
Marker 1 (remote control)	4.12
Marker 1 (remote control, K30)	4.514, 4.515
Marker 1 (remote control, K91)	4.671, 4.672, 4.673, 4.674, 4.675
Marker 1 (remote control, K93)	4.752, 4.753, 4.754, 4.756
Marker 1 to 4 (remote control)	4.21, 4.56, 4.63, 4.66
Marker 2	3.53
Marker 2 (K82)	3.319
Marker 2 (K84)	3.372
Marker 2 (remote control)	4.12
Marker 3	3.53
Marker 3 (K82)	3.319
Marker 3 (K84)	3.372
Marker 3 (remote control)	4.12
Marker 4	3.53
Marker 4 (K82)	3.319
Marker 4 (K84)	3.372
Marker 4 (remote control)	4.12
Marker Demod	3.55
Marker Demod Volume	3.121
Marker List (remote control)	4.70
Marker Norm/Delta	3.53
Marker Norm/Delta (K82)	3.319
Marker Norm/Delta (K84)	3.372
Marker Norm/Delta (remote control)	4.12
Marker Off (K91/K91n)	3.412
Marker Off (K93)	3.460
Marker Off (remote control, K91)	4.671
Marker Off (remote control, K93)	4.753
Marker Peak List	3.57
Marker Search Type (K14)	3.181
Marker StepSize	3.58
Marker StepSize (remote control)	4.65
Marker to Trace	3.55
Marker to Trace (K30)	3.245
Marker to Trace (remote control)	4.20, 4.63
Marker to Trace (remote control, K20)	4.424, 4.449
Marker to Trace (remote control, K30)	4.515
Marker Zoom	3.57
Marker Zoom (K72)	3.260
Marker Zoom (K91/K91n)	3.411
Marker Zoom (K93)	3.460
Marker Zoom (remote control)	4.79
Marker Zoom (remote control, K91)	4.677
Marker Zoom (remote control, K93)	4.759
Max Hold	3.40, 3.91
Maximize Size (K14)	3.175
Maximize Size (remote control, K14)	4.390
Mean	3.84
Mean (remote control)	4.96, 4.97
Meas (K82)	3.294
Meas (K84)	3.348
Meas Carrier (K20)	3.213
Meas Carrier (remote control, K20)	4.454, 4.455
Meas Filter (K8)	3.159
Meas Filter (remote control, K8)	4.356
Meas Settings (K30)	3.238
Meas Settings (remote control, K30)	4.523, 4.524, 4.532, 4.541, 4.547
Meas Single/Cont (K91/K91n)	3.410
Meas Single/Cont (remote control, K91 / K91n)	4.701
Meas Start/Stop	3.105
Meas Start/Stop (remote control)	4.145
Meas Time (K7)	3.129
Meas Time (remote control, K7)	4.295, 4.309
Meas Time Auto (K8)	3.157
Meas Time Manual (K8)	3.157
Meas Time/Average (K9)	3.170
Meas Time/Average (remote control, K9)	4.369
Meas to Ref (K9)	3.170
Meas to Ref (remote control, K9)	4.362
Mem1 On/Off (K30)	3.245
Mem1 On/Off (remote control, K30)	4.519
Mem2 On/Off (K30)	3.245
Mem2 On/Off (remote control, K30)	4.519
Mem3 On/Off (K30)	3.245
Mem3 On/Off (remote control, K30)	4.519
Min	3.64
Min (K14)	3.181
Min (K30)	3.246
Min (K91/K91n)	3.412
Min (remote control)	4.18, 4.60
Min (remote control, K14)	4.376, 4.378, 4.382, 4.384
Min (remote control, K30)	4.516
Min (remote control, K91)	4.673
Min Hold	3.40
MKR → Trace (K91/K91n)	3.412
MKR → Trace (K93)	3.461
MKR → Trace (remote control, K91)	4.674
MKR → Trace (remote control, K93)	4.755
Mkr Demod On/Off	3.55
Mkr Demod On/Off (remote control)	4.68
Mkr List On/Off (remote control)	4.70
Mkr Stop Time	3.56
Mkr Stop Time (remote control)	4.68
Modulation AM/FM/PM (remote control, K7)	4.269

Modulation Analysis (K20).....	3.220	Noise Src On/Off (remote control).....	4.122
Modulation Char (K8)	3.166	Normalize (K82).....	3.298
Modulation Char (remote control, K8) ...	4.326,	Normalize (K84).....	3.353
4.327, 4.328		Normalize On/Off (K72).....	3.256
Modulation Errors (K20).....	3.221	Normalize On/Off (remote control, K72)	4.572
Modulation FM/PM/AM (K7).....	3.127	Number of Readings (K9).....	3.171
Modulation Options (K20)	3.203	Number of Readings (remote control, K9)	
Modulation Options (remote control, K20)		.....	4.370
..... 4.485, 4.486, 4.491, 4.492, 4.494, 4.495		OBW	3.93
Multi Carrier (K82).....	3.290	OBW (remote control)	4.86, 4.90
Multi Carrier (K84)	3.345	Occupied Bandwidth (K82).....	3.326
Multi-Carrier Filter Settings (remote control,		Occupied Bandwidth (K84).....	3.378
K82)	4.592	Occupied Bandwidth (remote control, K82)	
Multi-Carrier Filter Settings (remote control,		.....	4.592
K84)	4.629	Occupied Bandwidth (remote control, K84)	
n dB down	3.56	.....	4.629
n dB down (remote control)....	4.74, 4.75, 4.76	Output Power (K8).....	3.165
Name (remote control)	4.31	Output Power (remote control, K8).....	4.329,
Name (remote control, K30).....	4.509	4.330	
New	3.115	Overview (K20).....	3.220
New (K20)	3.203	Packet Bytes SCO (K8).....	3.151
New (K30)	3.246	Packet Bytes SCO (remote control, K8)	4.343
New (K82)	3.292	Packet Type (K8).....	3.150
New (K84)	3.347	Packet Type (remote control, K8).....	4.345
New (remote control)....	4.29, 4.32, 4.41, 4.42,	Password (remote control)	4.243
4.43, 4.49, 4.50, 4.51, 4.52, 4.53		PCCPCH (K72).....	3.261
New (remote control, K30)	4.510	PCCPCH (remote control, K72)	4.551, 4.558
New (remote control, K82)	4.590	Peak	3.63, 3.84
New (remote control, K84)	4.626	Peak (K14)	3.179
New Folder (remote control)	4.155	Peak (K30)	3.246
New Search.....	3.57	Peak (K91/K91n)	3.412
New Segment (K93).....	3.437	Peak (remote control). 4.17, 4.58, 4.99, 4.100	
New Zone/Burst (K93).....	3.437	Peak (remote control, K14)	4.376, 4.377,
Next Meas Frequency (K20)	3.215	4.382, 4.383	
Next Meas Frequency (remote control, K20)		Peak (remote control, K30)	4.516
..... 4.470, 4.474, 4.478		Peak (remote control, K91)	4.673
Next Min	3.64	Peak Code Domain Error (K82)	3.308
Next Min (K14)	3.182	Peak Code Domain Error (remote control,	
Next Min (remote control)	4.19, 4.61, 4.62	K82)	4.582, 4.605
Next Min Mode < abs >	3.64	Peak Excursion	3.66
Next Min X Search < abs > (K14)	3.180	Peak Excursion (remote control)	4.62
Next Min Y Search up/abs/dn (K14).....	3.180	Peak List Off	3.57
Next Min Y Search up/abs/dn (remote		Peak Search	3.54
control, K14)	4.379, 4.385, 4.386	Peak Search (remote control)	4.14, 4.70,
Next Peak.....	3.63	4.71, 4.72	
Next Peak (K14).....	3.179	Peaks per Range	3.106
Next Peak (remote control) ...	4.17, 4.18, 4.19,	Percent Marker	3.94
4.59, 4.60, 4.61, 4.62		Percent Marker (K82)	3.320, 3.327
Next Peak Mode < abs >.....	3.63	Percent Marker (K84)	3.372, 3.379
Next Peak Y Search up/abs/dn (K14)	3.179	Percent Marker (remote control)	4.66
Next Peak Y Search up/abs/dn (remote		Ph Noise On/Off (remote control)... 4.13, 4.16	
control, K14)	4.377, 4.378, 4.383, 4.384	Ph Noise/Ref Fixed (remote control)	4.13,
No of Halfslots (K84)	3.380	4.16	
No. of ACP Chan (K8).....	3.161	Phase Noise 1 2 3 4	3.54
No. of ACP Chan (remote control, K8)	4.338,	Phase Noise On/Off	3.54
4.342		Phase Noise/Ref Fixed	3.54
No. of Harmonics	3.107	Phase Unit Rad/Deg (K7)	3.132
Noise Meas On/Off	3.53	Phase Unit Rad/Deg (remote control, K7)	
Noise Meas On/Off (remote control).....	4.77	.....	4.313

Phase Wrap On/Off (K7).....	3.132
Phase Wrap On/Off (remote control, K7)	
.....	4.270
PLCP Header (remote control, K91)	4.684
PN Offset.....	3.345
PN Offset (K82).....	3.290
Points / Symbol (K8)	3.154
Points / Symbol (remote control, K8)	4.345
Power (Average Mode)	3.45
Power (K72)	3.267
Power (K82)	3.323
Power (K84)	3.375
Power (remote control, K72)	4.560
Power (remote control, K82)	4.592
Power (remote control, K84)	4.629
Power Avg Start (K8)	3.161
Power Avg Stop (K8).....	3.161
Power Class (K8)	3.151
Power Control Group (K82).....	3.296
Power Level (remote control, K91 / K91n)	
.....	4.731
Power Meter.....	3.121
Power Mode	3.90
Power Mode (remote control).....	4.86
Power Ref TOT/CPICH (K72)	3.254
Power Ref TOT/CPICH (remote control, K72)	
.....	4.573
Power Reference (K82).....	3.297
Power vs PCG (K82)	3.301
Power vs PCG (remote control, K82)....	4.582,
4.605	
Power vs Symbol (K82).....	3.310
Powermeter On/Off (K9)	3.169
Powermeter On/Off (remote control, K9)	
.....	4.368
Preamp On/Off	3.15
Preamp On/Off (remote control)	4.147
Predefined Colors (remote control).....	4.126,
4.138	
Print Screen (remote control).....	4.136, 4.137,
4.141, 4.156	
PvT (K84).....	3.380
PVT (K91/K91n)	3.397
PVT (K93)	3.438
PVT (remote control, K91)	4.681
PVT (remote control, K93)	4.767
R&S Support (K91/K91n)	3.400
R&S Support (K93)	3.442
Ramp Up/Down/Up & Down (K91/K91n).....	3.399
Ramp Up/Down/Up & Down (remote control,	
K91)	4.682
Range (K8).....	3.156
Range (remote control, K8).....	4.351
Range Lin. Unit	3.14
Range Lin. Unit (remote control).....	4.131
Range Linear.....	3.14
Range Linear %	3.14
Range Linear % (remote control).....	4.131
Range Linear (K7).....	3.136
Range Log	3.14
Range Log (K7)	3.136
Range Log (remote control)	4.131, 4.132
Range Log (remote control, K20)	4.460
Recall File (remote control)	4.155
Ref Level	3.14
Ref Level (K8).....	3.156
Ref Level (remote control)	4.113, 4.132
Ref Level (remote control, K20)	4.461
Ref Level Offset.....	3.15
Ref Level Offset (remote control)	4.133
Ref Level Offset (remote control, K20)	4.461
Ref Level Position.....	3.15
Ref Level Position (remote control)	4.133
Ref Level Position (remote control, K20)	4.461
Ref Lvl =Mkr Lvl.....	3.64
Ref Lvl =Mkr Lvl (remote control)	4.78
Ref Point Frequency	3.54
Ref Point Frequency (remote control)	4.14
Ref Point Level	3.54
Ref Point Level (remote control)	4.15
Ref Point Time (remote control)	4.14
Ref Pow Max/Mean (K91/K91n)	3.399
Ref Pow Max/Mean (remote control, K91)	
.....	4.681
Ref Value (remote control)	4.134
Ref Value Position (remote control)	4.133
Ref Value Position (remote control, K20)	
.....	4.461
Reference Channel (K20).....	3.213
Reference Channel (remote control, K20)	
.....	4.472, 4.475, 4.479
Reference Fixed	3.54
Reference Fixed On/Off	3.55
Reference Int/Ext (remote control)	4.213,
4.220	
Reference Manual	3.381
Reference Mean Power (K84)	3.381
Reference Mean Power (remote control, K84)	
.....	4.630
Reference Position (K7)	3.129
Reference Position (K8)	3.156
Reference Position (remote control, K7)	4.279
Reference Position (remote control, K8)	4.351
Reference Power (K20)	3.213
Reference Power (remote control, K20)	4.473,
4.476, 4.479	
Reference Value (K7)	3.130
Reference Value (K8)	3.156
Reference Value (K9)	3.171
Reference Value (remote control, K7)	4.279
Reference Value (remote control, K8)	4.351
Reference Value (remote control, K9)	4.362
Refresh (K91/K91n)	3.411
Refresh (K93)	3.459
Refresh (remote control, K93)	4.805
Rel TX Power (K8)	3.166
Rel TX Power (remote control, K8)	4.332,
4.333	

Reload (K82)	3.295
Reload (K84)	3.349
Rename (remote control)	4.155
Repetition Intervall.....	3.31
Res BW	3.94
Res BW (K7)	3.138
Res BW (K82)	3.327
Res BW (K84)	3.379
Res BW (remote control)	4.169
Res BW (remote control, K7)	4.300
Res BW Auto	3.20
Res BW Auto (K8).....	3.158
Res BW Auto (remote control)....	4.169, 4.170
Res BW Auto (remote control, K8)	4.339
Res BW Manual	3.20
Res BW Manual (K8)	3.158
Res BW Manual (remote control)	4.169
Res BW Manual (remote control, K8)	4.338
Restart on Fail (K84)	3.381
restart on Fail (remote control, K84)	4.630
restor STD Lines (K84)	3.381
Restore Default Tables (K20)	3.204
Restore Default Tables (K82)	3.295
Restore Default Tables (K84)	3.350
Restore Default Tables (remote control, K82)	4.593
Restore Default Tables (remote control, K84)	4.628
Restore FSL K82 Files (K82)	3.326
Restore FSL K82 Files (remote control, K82)	4.583
Restore FSL K84 Files (K84)	3.378
Restore FSL K84 Files (remote control, K84)	4.617
Restore Standard Files	3.105
Restore Std Lines (K72)	3.272
Restore Std Lines (remote control, K72)	4.554
Result (remote control, K82)	4.598, 4.600, 4.601, 4.602
Result (remote control, K84)	4.637
Result Display (K7)	3.127
Result Settings (K82)	3.295
Result Settings (K84)	3.350
Result Summary (K82)	3.302
Result Summary (remote control, K82)	4.582, 4.585, 4.605
Result Summary Extended (K72)	3.266
Result Summary Extended (remote control, K72)	4.573
Result Summary Normal (K72)	3.265
Revision 0 A (remote control, K84)	4.631
Revision 0/A (K84)	3.344
RF	
SLOT (remote control, K84)	4.631
RF (K20)	3.205
RF (remote control, K20)	4.487
RF Atten Auto	3.15
RF Atten Auto (remote control)	4.146
RF Atten Manual	3.15
RF Atten Manual (K20)	3.208
RF Atten Manual (remote control)	4.146
RF Slot Full Idle (K84)	3.380
RF Spectrum (K7)	3.128
RF StepSize (K20)	3.206
RF Time Domain (K7)	3.128
Right Limit	3.65, 3.85
Right Limit (remote control)	4.65
Rising & Falling (K91/K91n)	3.398
Rising & Falling (remote control, K91)	4.682
Rising/Falling (K93)	3.440
RMS	3.84
RMS (remote control)	4.101, 4.103
Run Single/Cont (K93)	3.459
Same as Meas Channel (K20)	3.214
Save (K82)	3.295
Save (K84)	3.348
Save (remote control)	4.163
Save As Standard	3.105
Save Changes (K20)	3.204
Save Evaluation List	3.103
Save Evaluation List (remote control)	4.161
Save File (remote control)	4.162
Save Limit Line	3.116
Scaling	3.94
Scaling (K82)	3.314, 3.319, 3.327
Scaling (K84)	3.367, 3.379
Schematic (K30)	3.241
Scrambling Code (K72)	3.254, 3.255
Scrambling Code (remote control, K72)	4.570, 4.571
Scrambling Code Autosearch (K72)	3.255
Scrambling Code Autosearch (remote control, K72)	4.571
Screen A/B (K91/K91n)	3.413
Screen A/B (remote control, K82)	4.594
Screen A/B (remote control, K84)	4.633
Screen A/B (remote control, K91)	4.688
Screen Colors (remote control)	4.126, 4.137, 4.138
Screen Focus A/B (K82)	3.298
Screen Focus A/B (K84)	3.353
Screen Focus A/B (K93)	3.462
Screen Focus A/B (remote control, K93)	4.787, 4.788
Screen Full/Split (K91/K91n)	3.413
Screen Full/Split (remote control, K91)	4.688
Screen Size (remote control, K82)	4.594
Screen Size (remote control, K84)	4.633
Screen Size Full/Split (K82)	3.298
Screen Size Full/Split (K84)	3.353
Screen Size Full/Split (K93)	3.462
Screen Size Full/Split (remote control, K93)	4.787
Screen Title (remote control)	4.129
Search Len Auto (K8)	3.153
Search Len Manual (K8)	3.154
Search Len Manual (remote control, K8)	4.358, 4.359

Search Lim Off	3.65
Search Lim Off (remote control) ...	4.64, 4.115
Search Limits	3.65
Search Limits (remote control).....	4.64
Search Mode (K14).....	3.179
Search Signals	3.83
Select 1 2 3 4	3.63
Select 1 2 3 4 (K14)	3.178
Select 1 2 3 4 (K82)	3.321
Select 1 2 3 4 (K84)	3.373
Select 1 2 3 4 (remote control).....	4.56, 4.66
Select 1 2 3 4 (remote control, K14)	4.375, 4.381
Select Ch/PCG (K82)	3.304
Select Channel (K72)	3.253
Select Channel (remote control, K72)....	4.569
Select Code Slot (K84).....	3.351
Select CPICH Slot (K72)	3.254
Select CPICH Slot (remote control, K72)	.....
	4.574
Select Frame (remote control, K14).....	4.389
Select Items (remote control)....	4.159, 4.160, 4.161
Select Meas (K82).....	3.298
Select Meas (K84).....	3.354
Select Print Color Set (remote control) ..	4.137
Select Search Area (K14)	3.181
Select Search Area (remote control, K14)	.....
	4.375, 4.381
Select Slot (remote control, K84)	4.642
Select Trace	3.10, 3.91
Select Trace (K7)	3.128
Select Trace (K8)	3.154
Select Trace (remote control)	4.92, 4.212
Select Traces to check	3.114
Select Traces to check (remote control) .	4.31, 4.32
Self Align (remote control).....	4.118
Selftest (remote control).....	4.9
Selftest Results (remote control).....	4.123
SEM Settings (K93).....	3.441
Service Function (remote control).....	4.122
Set Mean To Manual (K84)	3.381
Set Standard	3.105
Set Standard (remote control).....	4.176
Set to Default (remote control) ...	4.126, 4.137
Settings (K82)	3.284
Settings (K84)	3.341
Settings General/Demod (K91/K91n)....	3.388
Settings General/Demod (K93)	3.423
Settings General/Demod (remote control, K93).....	4.768, 4.772, 4.773, 4.774, 4.775, 4.776, 4.777, 4.778, 4.779, 4.780, 4.781, 4.782, 4.783, 4.784, 4.785, 4.786, 4.790, 4.811, 4.812, 4.813, 4.814, 4.815, 4.816, 4.821, 4.822, 4.824, 4.825, 4.830, 4.838, 4.839, 4.840, 4.843
Settings General/Demod (remote control, K93)	4.820, 4.821
Settings Overview (K82).....	3.285
Settings Overview (K84).....	3.341
Shift X Limit Line (remote control).....	4.43
Shift Y Limit Line (remote control) ..	4.49, 4.53
Shoulder Atten On/Off (K20)	3.212
Show Align Results (remote control)	4.118, 4.119
Show List (K72)	3.255
Show List (remote control, K72)	4.571
Show Peaks.....	3.103
Show Peaks (remote control)	4.25
Sig Count On/Off	3.55
Sig Count On/Off (remote control)..	4.56, 4.57
Signal Field (K91/K91n).....	3.409
Signal Field (remote control, K91)	4.684
Signal Level (K20)	3.207
Signal Track	3.9
Signal Track (remote control)	4.91
Single Meas (remote control)	4.143, 4.144
Single Sweep	3.23
Single Sweep (K8)	3.160
Single Sweep (remote control) ...	4.143, 4.144
Soft Frontpanel (remote control)	4.239
Sort (K82)	3.295
Sort (K84)	3.348
Sort Mode Freq/Lvl	3.57
Sort Mode Freq/Lvl (remote control)	4.71
Span Manual	3.12
Span Manual (K7).....	3.135
Span Manual (remote control).....	4.189
Span Manual (remote control, K7)	4.302
Spectrogram	3.121
Spectrogram Clear (K14)	3.177
Spectrogram Clear (remote control, K14)	.....
	4.387
Spectrogram On/Off (K14)	3.175
Spectrogram On/Off (remote control, K14)	.....
	4.387
Spectrum (K20)	3.211, 3.220
Spectrum (K91/K91n)	3.404
Spectrum (K93)	3.448
Spectrum ACPR (K91/K91n).....	3.406
Spectrum ACPR (remote control, K91)	4.676, 4.682
Spectrum Emission Mask	3.96
Spectrum Emission Mask (K72)	3.270
Spectrum Emission Mask (K82)	3.324
Spectrum Emission Mask (K84)	3.376
Spectrum Emission Mask (remote control, K72)	4.560
Spectrum Emission Mask (remote control, K82)	4.592
Spectrum Emission Mask (remote control, K84)	4.629
Spectrum ETSI/IEEE (K91/K91n).....	3.405
Spectrum ETSI/IEEE (K93)	3.450
Spectrum FFT (K91/K91n)	3.406
Spectrum FFT (K93)	3.452
Spectrum FFT (remote control, K91)	4.682

Spectrum FFT (remote control, K93)	4.769	Sweeptime Manual (K8)	3.158
Spectrum Flat./Diff./Group Delay (K93)	3.448	Sweeptime Manual (remote control)	4.218
Spectrum Flat./Diff./Group Delay (remote control, K93)	4.769, 4.770	Sweeptime Manual (remote control, K8)	4.348
Spectrum Flatness (K91/K91n)	3.404	Sync Offset (K8)	3.152
Spectrum Flatness (remote control, K91)	4.683	Sync Offset (remote control, K8)	4.358
Spectrum IEEE/ETSI (remote control, K91)	4.683	Sync Type CPICH/SCH (K72)	3.257
Spectrum IEEE/ETSI (remote control, K93)	4.770, 4.771	Sync Type CPICH/SCH (remote control, K72)	4.574
Spectrum Mask (K91/K91n)	3.405	System Messages (remote control)	4.239, 4.240
Spectrum Mask (remote control, K91)	4.683	Threshold	3.65
Spurious Emissions	3.106	Threshold (remote control)	4.115
Spurious Emissions (K8)	3.166	Tilt (K20)	3.224
Spurious Emissions (remote control, K8)	4.324, 4.325	Tilt Setup (K20)	3.224
Start	3.7, 3.12	Tilt Setup (remote control, K20)	4.492
Start (K82)	3.312	Time / Phase Estimation (K82)	3.290
Start (K84)	3.364	Time / Phase Estimation (K84)	3.345
Start End (K93)	3.439	Time Domain Power	3.84
Start End (remote control, K93)	4.768	Time Domain Power (remote control)	4.94
Start Test (K8)	3.160	Time Line 1	3.117
Startup Recall (remote control)	4.154	Time Line 1 (remote control)	4.116
Statistics (K91/K91n)	3.407	Time Line 2	3.117
Statistics (K93)	3.455	Time Line 2 (remote control)	4.116
Std Dev	3.85	Time Stamp On/Off (K14)	3.175
Std Dev (remote control)	4.103, 4.105	Time Stamp On/Off (remote control, K14)	4.390
Stepsize Standard	3.58	Time+Date (remote control)	4.238, 4.244
Stepsize Standard (remote control)	4.65	Time+Date On/Off (remote control)	4.129
Stepsize Sweep Points	3.58	TOI	3.83
Stepsize Sweep Points (remote control)	4.65	TOI (remote control)	4.78
Stop	3.8, 3.12	Trace 1 2 3 4 5 6	3.40
Stop (K82)	3.312	Trace 1 2 3 4 5 6 (remote control)	4.130
Stop (K84)	3.365	Trace 1 2 3 4 5 6 (remote control, K20)	4.459
Swap IQ (K82)	3.287	Trace 1 2 3 4 5 6 (remote control, K8)	4.350
Swap IQ (K84)	3.343	Trace Math	3.43
Sweep Count	3.24, 3.42	Trace Math (remote control)	4.106, 4.107
Sweep Count (K8)	3.161	Trace Math Position	3.43
Sweep Count (remote control)	4.214	Trace Mode	3.40
Sweep Count (remote control, K8)	4.347	Trace Mode (K82)	3.318
Sweep List	3.96	Trace Mode (K84)	3.370
Sweep List (remote control)	4.177, 4.178, 4.179, 4.180, 4.181, 4.182, 4.183, 4.184, 4.196, 4.197, 4.198, 4.199	Trace Mode (remote control)	4.95, 4.96, 4.97, 4.98, 4.99, 4.101, 4.102, 4.103, 4.104, 4.130, 4.132
Sweep Points	3.24	Trace Mode (remote control, K20)	4.459, 4.460
Sweep Points (remote control)	4.218	Trace Mode (remote control, K8)	4.349
Sweep Single/Cont (K30)	3.243	Track BW	3.10
Sweep Single/Cont (remote control, K30)	4.518	Track BW (remote control)	4.91
Sweep Time	3.32, 3.91	Track On/Off	3.10
Sweep Time (remote control)	4.218	Track On/Off (remote control)	4.91
Sweeptime Auto	3.21, 3.23	Track Threshold	3.10
Sweeptime Auto (K8)	3.158	Track Threshold (remote control)	4.92
Sweeptime Auto (K82)	3.21	Trg / Gate Level	3.30
Sweeptime Auto (remote control)	4.219	Trg / Gate Level (remote control)	4.261
Sweeptime Auto (remote control, K8)	4.348	Trg / Gate Polarity Pos/Neg	3.30
Sweeptime Manual	3.21, 3.23	Trg / Gate Polarity Pos/Neg (remote control)	4.216, 4.261
Sweeptime Manual (K20)	3.219	Trg / Gate Source	3.30

Trg / Gate Source (remote control)	4.217,
4.260, 4.261	
Trg/Gate Level (K8)	3.163
Trigger Level (K9)	3.171
Trigger Offset	3.31
Trigger Offset (K20)	3.219
Trigger Offset (K7)	3.140
Trigger Offset (remote control)	4.259
Trigger Polarity (K82)	3.288
Trigger Polarity (K84)	3.343
Trigger Polarity Pos/Neg (K82)	3.318
Trigger Polarity Pos/Neg (K84)	3.370
Trigger Source (K7)	3.139
Trigger Source (K72)	3.259
Trigger Source (K8)	3.163
Trigger Source (K82)	3.287, 3.318
Trigger Source (K84)	3.343, 3.370
Trigger Source (remote control, K7)	4.312
Trigger Source (remote control, K72)	4.580
TV Analyzer (K20)	3.224
TV Free Run On/Off	3.34
TV Free Run On/Off (remote control)	4.262
TV Trig Settings	3.33
TX Spec ACP (K8)	3.165
TX Spec ACP (remote control, K8)	4.316, 4.317
Unit	3.16
Unit (K20)	3.208, 3.222
Unit (remote control)	4.117, 4.265
Unit (remote control, K20)	4.422, 4.445, 4.446, 4.447, 4.453, 4.505
Unit/Scale (K9)	3.170
Unit/Scale (remote control, K9)	4.363, 4.372
Unzoom (K91/K91n)	3.411
Unzoom (K93)	3.460
Unzoom (remote control, K91)	4.677
Unzoom (remote control, K93)	4.759
Update Path (remote control)	4.240
Use Ref Lev Offset (K9)	3.171
Use Ref Lev Offset (remote control, K9)	4.370
User Defined Colors (remote control)	4.137, 4.138
Value	3.115
Value (remote control)	4.41, 4.47, 4.51
Velocity Factor (K20)	3.222
Velocity Factor (remote control, K20)	4.482
Versions+Options (remote control)	4.7
Vert Sync	3.33
Vert Sync (remote control)	4.263
Vert Sync Even Field	3.33
Vert Sync Even Field (remote control)	4.263
Vert Sync Odd Field	3.33
Vert Sync Odd Field (remote control)	4.263
Video BW Auto	3.21
Video BW Auto (K8)	3.158
Video BW Auto (remote control)	4.171, 4.172
Video BW Auto (remote control, K8)	4.340
Video BW Manual	3.20
Video BW Manual (K8)	3.158
Video BW Manual (remote control)	4.171
Video BW Manual (remote control, K8)	4.339
Video Pol Pos/Neg	3.34
Video Pol Pos/Neg (remote control)	4.264
Video Scope (K20)	3.218
View	3.40
Vision Modulation (K20)	3.219
Vision Modulation (remote control, K20)	4.421
Volume	3.56
Volume (remote control)	4.245
X * RBW	3.9
X * RBW (remote control)	4.187, 4.188
X * Span	3.9
X * Span (remote control)	4.187, 4.188
x Offset (remote control)	4.42
x*Demod BW (K7)	3.134
x-Axis Range	3.94
x-Axis Range (remote control)	4.112
x-Axis Ref Level	3.94
x-Axis Ref Level (remote control)	4.113
XML Export (K82)	3.326
XML Export (K84)	3.378
XML Export (remote control)	4.177, 4.604
XML Import (K82)	3.325
XML Import (K84)	3.377
y Offset (remote control)	4.48, 4.52
y-Axis Max Value	3.95
y-Axis Max Value (remote control)	4.114
y-Axis Maximum (K82)	3.315, 3.319
y-Axis Maximum (K84)	3.367
y-Axis Min Value	3.95
y-Axis Minimum (K82)	3.315, 3.319
y-Axis Minimum (K84)	3.367
Y-Axis/Div (K91/K91n)	3.401
Y-Axis/Div (K93)	3.447
Y-Axis/Div (remote control, K91)	4.689
Y-Axis/Div (remote control, K93)	4.789
y-Unit %/Abs	3.95
y-Unit %/Abs (remote control)	4.113
Zero (K9)	3.170
Zero (remote control, K9)	4.364
Zero Phase Reference Point (K7)	3.132
Zero Phase Reference Point (remote control, K7)	4.298
Zero Span	3.12
Zero Span (remote control)	4.189
Zoom (K20)	3.220, 3.221, 3.222
Zoom (K7)	3.133
Zoom (K8)	3.161
Zoom (remote control, K20)	4.461, 4.462, 4.463
Zoom (remote control, K7)	4.303
SOURce<1|2>§EXternal<1|2>§ROSCillator[§S OURce]	4.220
SOURce§TEMPerature§APRobe?	4.220
SPAN key	3.11
span menu	
base unit	3.11
K7 option	3.135

K82 option	3.313
K84 option	3.365
special characters	4.3
spectrogram (K14)	
menu	3.172
Spectrogram Measurements	1.4
spectrogram menu (K14)	3.174
Spectrum Analysis	1.3
Spectrum Analyzer mode	3.119
Spectrum Emission Mask (K82)	3.278
Spurious Emissions measurement (K8)	3.148
start frequency	3.7
status bar	
K30 option	3.230
K91/K91n option	3.387
K93 option	3.421
step size	
center frequency	3.8
stop frequency	3.8
subchannelization (K93)	2.148
supported tests (K8)	2.37
sweep	
continue single sweep	3.23
continuous	3.23
count	3.24, 3.42
Free Run	3.28
gated	3.25, 3.31
single	3.23
time	3.23
SWEEP key	3.22
sweep menu	
base unit	3.22
K14 option	3.176
K30 option	3.243
K7 option	3.138
K8 option	3.159
K82 option	3.316
K84 option	3.369
K91/K91n option	3.410
92 option	3.459
sweep time	
coupling	3.21
Symbol Constellation (K84)	3.362
Symbol EVM rms / Pk (K82)	3.304
symbols	
WiMAX, WiBro measurements (K93)	2.152
SYNC	3.283
sync signal	3.33
sync word (K8)	2.43, 3.151
synchronization	
K93 option	2.148, 2.154
T	
TD	3.283
TDPICH	3.283
test	
supported (K8)	2.37
transmitter (K8)	2.38
test setup	
analog TV (K20)	2.47
base station tests (K72)	2.113
base station tests (K82)	2.125
digital TV (K20)	2.70
threshold	
line	3.65
signal tracking	3.10
Tilt Setup dialog box (K20)	3.224
time	
line	3.117
Timing Offset (K82)	3.304
title bar	
K91/K91n option	3.387
K93 option	3.421
Total PWR (K82)	3.303
trace	
Clear Write	3.36
power measurement	3.91
signal tracking	3.10
TRACE key	3.35
trace menu	
base unit	3.39
K20 option	3.208
K30 option	3.244
K82 option	3.318
K84 option	3.370
K91/K91n option	3.413
K93 option	3.462
trace mode	3.40
Average	3.36, 3.40
Blank	3.37, 3.41
Clear Write	3.36, 3.40
Max Hold	3.36, 3.40
Min Hold	3.36, 3.40
View	3.36, 3.40
transmitter tests (K8)	2.38
Trg to Frame (K82)	3.303
TRIG / FORMAT key	3.25
trigger	
concepts (K8)	2.43
extern (K8)	2.43
external	3.28
external gate	3.31
gated sweep	3.32
level	3.30
offset	3.31
slope	3.30
trigger menu	
base unit	3.29
K7 option	3.139
K72 option	3.259
K8 option	3.163
K82 option	3.317
K84 option	3.370
K91/K91n option	3.388
K93 option	3.423
trigger mode	3.30
External	3.28
Free Run	3.28

IF power	3.28
TV.....	3.28
Video	3.28
TV trigger	3.33
TV Trigger.....	1.3
TX filter (K20).....	2.65
U	
unit	3.170
upper-case (commands).....	4.3
V	
velocity factor (K20).....	2.75
vertical sync signal.....	3.33
video bandwidth	3.20
video polarity.....	3.34
video triggering	3.28
View trace mode	3.36

W

Walsh code	3.283
WCDMA Measurements	1.4
WiMAX menu (K93)	3.415, 3.421
WiMAX mode (92)	3.120
WiMAX OFDM/OFDMA Analysis	1.5
WLAN menu (K91/K91n)	3.382, 3.387
WLAN mode (K91/K91n)	3.120
WLAN OFDM Analysis	1.5

Z

zero span	3.12
zeroing (K9).....	3.168
zoom	3.57
amplitude	3.37
ZVL-K1	1.3