



Products: NRV-Z, NRVD, NRVS, URV55

# Program for Measurement Uncertainty Analysis with Rohde & Schwarz Power Meters

## Application Note

The application note describes the Measurement Uncertainty Analysis Program NRV-Z. The program is used to determine measurement uncertainties that inevitably arise when using power meters. In particular, it covers the NRV-Z family of thermal sensors and diode sensors for high-precision power measurements, as well as the compatible basic units NRVD, NRVS and URV55.



## Contents

1 Overview.....	2
2 Hardware and Software Requirements .....	3
3 Installing the Software .....	3
4 Using the Software .....	4
5 Literature .....	7
6 Ordering Information.....	8

## 1 Overview

Independent of whether measurements are made in a production line, a calibration or test laboratory, or on the development workbench, it is common practice to calculate or at least to estimate the uncertainties related to the measurement. The calculation of measurement uncertainties is in general not easy. This is especially true for accurate instruments like power meters where many Influence Quantities have to be taken into account.

This program helps the users of Rohde & Schwarz NRV-Z power sensors to assess the measurement uncertainty quickly without any need to study the relevant data sheets and add up the contributions of the individual effects. All entries, such as parameter settings on the power meter, or signal level, or frequency, are made by means of selection fields and scrollbars. Since the program uses current settings for immediate calculation, every parameter change immediately yields a different result for measurement uncertainties. The handling of the program has been kept very simple and it is easy to see 'what will happen when'. For example, choose from a variety of different power sensors to find the one that is best suited for a measurement task.

The resulting measurement uncertainties are calculated in accordance with the internationally accepted 'Guide to the expression of uncertainties in measurement' [1]:

- Consideration of all relevant influence quantities
- Setting up a model function for the description of the technical problem
- Determination or at least estimation of distribution functions
- Calculation of the equivalent standard uncertainties
- Calculation of the sensitivity coefficients
- Calculation of the combined standard uncertainty
- Calculation of the expanded uncertainty

Reference [1], also known as GUM, is worth reading for general information on uncertainty analysis. For additional information on RF power meters and sensors, please refer to the 'Voltage and Power Measurements' brochure from Rohde & Schwarz [2] or to the relevant data sheets for specifications and characteristics of sensors and meters [3 to 7].

## **2 Hardware and Software Requirements**

### **Hardware Requirements**

The program will run on any IBM AT compatible computer with

- CPU: Pentium or better
- RAM: >32 MB (for Windows NT >48 MB)
- Monitor: colour VGA, minimum 800 x 600, recommended 1024 x 768

### **Software Requirements**

- Windows 95, 98 or Windows NT (version 4.0 or later), Windows 2000 or ME

## **3 Installing the Software**

The program 'Measurement Uncertainty Analysis NRV-Z' is supplied as a packed file. It includes the program itself, a runtime version of Visual Basic 6.0 and the Microsoft Installer.

### **Installing**

Copy the compressed file 1GP43\_0E.EXE to a temporary directory and execute the program. The WinZip Self-Extractor will guide you through the extraction process.

Then use the Microsoft Installer for installing the uncertainty analysis software. If you work under Windows 2000 or Windows ME, or if you have already installed software with the Microsoft Installer, you can execute NRZCalc.MSI directly. The MS Installer will guide you through the installation process.

Otherwise, install the MS Installer first:

- Under Windows 95: run InstMSIA.EXE
- Under Windows 98 and Windows NT 4.0: run InstMSIW.EXE

Then execute NRZCalc.MSI.

For quick access to the program an icon can be placed on the desktop of your PC. Please refer to your Microsoft Windows documentation.

Before installing the program files to a different directory you have to uninstall the software.

### **Uninstalling**

To remove the software from your PC, the Microsoft Windows uninstall software should be used. Please refer to your Microsoft Windows documentation.

To remove an icon for this program from the desktop of your PC, click on the icon, press the right mouse button and select 'Delete' from the menu.

## 4 Using the Software

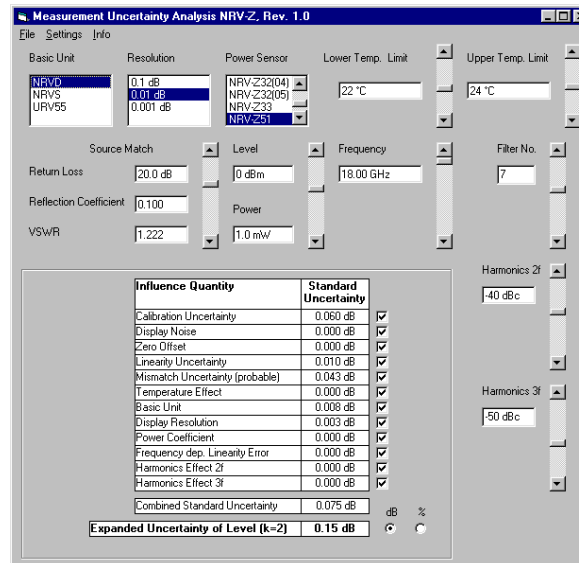
### Starting the Program

1. From the Windows Start menu select the Measurement Uncertainty Calculator.
2. After the start picture has disappeared, the main panel comes up and shows the current selection and setting options and gives the result of the uncertainty analysis in the bottom line.

If you do not want to run the program from the 'Start' folder but from a different folder, e.g. Programs (without changing the location of the program files), please refer to your Microsoft Windows documentation.

### Changing Selections and Settings

Select either the sensor type, type of basic unit, level, or frequency, or enter the Influence Quantity values, such as temperature or harmonics, directly. The parameters can be modified in different ways:



Basic unit, resolution and sensor type are selected by clicking on the appropriate list. To select a power sensor that is not visible in the first four lines of the list, use the scrollbar on the right.

All other parameters are changed by scrolling the bars on the right until the desired value appears. Please note that overwriting the displayed values by placing a cursor on them and entering numbers is disabled.

An Influence Quantity is represented by the standard deviation of its effect on the measurement result, called standard uncertainty. By default all standard uncertainties are combined by adding the squares of the individual standard uncertainties and taking the square root of the result. Sometimes it may be desirable to totally exclude one or more of the standard uncertainties from the analysis. Therefore each Influence Quantity can be excluded by means of a check box:

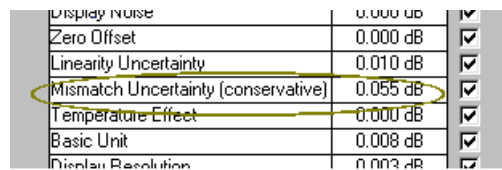
- included
- excluded

The unit for the uncertainty information can be switched to dB or % by clicking on either the 'dB' or the '%' button. dB is valid for level measurements and % is used for relative uncertainties of power measurements.

### Special Case 'Mismatch Uncertainty'

Optionally, select either a 'probable' or a 'conservative' approach to Mismatch Uncertainty.

According to the conservative approach the magnitude of the reflection coefficient of the power sensor equals specified limits, and its phase and the phase of the source reflection coefficient are equally distributed. This approach is very common and therefore selected by default.



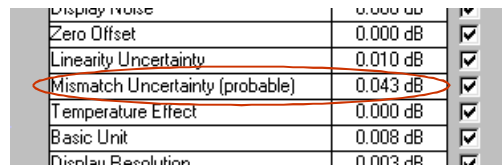
Display Noise	0.000 dB	<input checked="" type="checkbox"/>
Zero Offset	0.000 dB	<input checked="" type="checkbox"/>
Linearity Uncertainty	0.010 dB	<input checked="" type="checkbox"/>
Mismatch Uncertainty (conservative)	0.055 dB	<input checked="" type="checkbox"/>
Temperature Effect	0.000 dB	<input checked="" type="checkbox"/>
Basic Unit	0.008 dB	<input checked="" type="checkbox"/>
Display Resolution	0.002 dB	<input checked="" type="checkbox"/>

Fig. 4-1 Mismatch Uncertainty (conservative)

In reality, the magnitude of the reflection coefficient of the power sensor varies from unit to unit around a mean value that is a reasonable amount smaller than the specified limits. Therefore the real contribution of the mismatch to the measurement uncertainty is often much smaller than the (conservatively) calculated value.

In the 'probable' approach, the magnitude of the reflection coefficient of the power sensor is equally distributed between the specified reflection coefficient and half the value. The phase of both the source and the sensor reflection coefficient is assumed to be equally distributed.

Click on the row for Mismatch Uncertainty to toggle between the 'probable' and the 'conservative' approaches:



Display Noise	0.000 dB	<input checked="" type="checkbox"/>
Zero Offset	0.000 dB	<input checked="" type="checkbox"/>
Linearity Uncertainty	0.010 dB	<input checked="" type="checkbox"/>
Mismatch Uncertainty (probable)	0.043 dB	<input checked="" type="checkbox"/>
Temperature Effect	0.000 dB	<input checked="" type="checkbox"/>
Basic Unit	0.008 dB	<input checked="" type="checkbox"/>
Display Resolution	0.002 dB	<input checked="" type="checkbox"/>

Fig. 4-2 Mismatch Uncertainty (probable)

### Interpretation of Results

Besides the combined standard uncertainty the program outputs twice the value, i.e. the expanded uncertainty  $U$  with a coverage factor of 2:

Expanded Uncertainty of Level (k=2)	0.15 dB
-------------------------------------	---------

The expanded uncertainty describes a symmetric interval of  $\pm U$  around the measured value which contains all the values that could reasonably be assigned to the measurand. Assuming a normal distribution of the measurement results (depending on the various influence quantities), the 'true value' can be found within this interval with a level of confidence of about 95 %. The expanded uncertainty should be part of the measurement result, given as  $\pm U$  with respect to the measured value.

### Special Case: Frequency-Dependent Linearity Error

Whereas most of the influence quantities produce errors that are random in magnitude and sign, one effect that is typical of diode sensors causes a more systematic error. Since this error can be of considerable order, it is sometimes more convenient not to treat it statistically but to calculate its real impact on the measurement result. The effect is called varactor effect, since it is due to changes in the junction capacitance of the varactor diode, which lead to frequency-dependent nonlinearities outside the square-law region of the sensor (for more information see [2] and [3]).

The uncertainty analysis program copes with this effect in two ways:

#### Version 1: To GUM

By default, frequency-dependent linearity errors are treated like all other influence quantities, i.e. statistically in accordance with GUM [1]. The uncertainty analysis delivers only the combined uncertainty and the expanded uncertainty.

Power Coefficient	0.000 dB	<input checked="" type="checkbox"/>
Frequency dep. Linearity Error	0.160 dB	<input checked="" type="checkbox"/>
Harmonics Effect 2f	0.058 dB	<input checked="" type="checkbox"/>
Harmonics Effect 3f	0.017 dB	<input checked="" type="checkbox"/>
Combined Standard Uncertainty	0.204 dB	
<b>Expanded Uncertainty of Level (k=2)</b>	<b>0.41 dB</b>	<input checked="" type="radio"/> <input type="radio"/>

#### Version 2: Separate Systematic Error

The program extracts the systematic component of the effect and outputs it in the bottom line. Normally, it is positive, which means that the measured value is higher than it should be. Consequently it should be subtracted from the measured value to give a more accurate result. The systematic component is excluded from uncertainty calculations, only the expected variation with respect to the systematic error being taken into account. The combined and expanded uncertainty of the measurement result calculated this way will naturally be smaller than the value calculated according to version 1.

Click on the line for the Frequency-Dependent Linearity Error to toggle between Version 1 and Version 2:

Power Coefficient	0.000 dB	<input checked="" type="checkbox"/>
Frequency dep. Linearity Error	0.080 dB	<input checked="" type="checkbox"/>
Harmonics Effect 2f	0.058 dB	<input checked="" type="checkbox"/>
Harmonics Effect 3f	0.017 dB	<input checked="" type="checkbox"/>
Combined Standard Uncertainty	0.150 dB	
<b>Expanded Uncertainty of Level (k=2)</b>	<b>0.30 dB</b>	<input checked="" type="radio"/> <input type="radio"/>
<b>Systematic Error of Level</b>	<b>0.16 dB</b>	

## 5 Literature

- [1] Guide to the expression of uncertainty in measurement. International Organization for Standardization, Geneva, Switzerland, 1995. ISBN 92-67-10188-9
- [2] Brochure Voltage and Power Measurements PD 757.0835.23
- [3] Data sheet Power Sensors NRV-Z PD 756.9797.22
- [4] Data sheet Dual-Channel Power Meter NRVD PD 756.3176.23
- [5] Data sheet Power Meter NRVS PD 756.3182.23
- [6] Data sheet Level Meter URV35 PD 756.9497.23
- [7] Data sheet Millivoltmeter URV55 PD 756.3453.22

## 6 Ordering Information

### High-Sensitivity Diode Sensors

Name of instrument	range	Ordering number
NRV-Z1	20 mW, 50 $\Omega$ , 18 GHz	0828.3018.02
NRV-Z3	13 mW, 75 $\Omega$ , 2.5 GHz	0828.3418.02
NRV-Z4	20 mW, 50 $\Omega$ , 6 GHz	0828.3618.02
NRV-Z6	20 mW, 50 $\Omega$ , 26.5 GHz	0828.5010.02
NRV-Z15	20 mW, 50 $\Omega$ , 40 GHz	1081.2305.02

### Medium-Sensitivity Diode Sensors

NRV-Z2	500 mW, 50 $\Omega$ , 18 GHz	0828.3218.02
NRV-Z5	500 mW, 50 $\Omega$ , 6 GHz	0828.3818.02

### Thermal Power Sensors

NRV-Z51	100 mW, 50 $\Omega$ , 18 GHz	0857.9004.02
NRV-Z52	100 mW, 50 $\Omega$ , 26.5 GHz	0857.9204.02
NRV-Z53	10 W, 50 $\Omega$ , 18 GHz	0858.0500.02
NRV-Z54	30 W, 50 $\Omega$ , 18 GHz	0858.0800.02
NRV-Z55	100 mW, 50 $\Omega$ , 40 GHz	1081.2005.02

### Peak Power Sensors

NRV-Z31	20 mW, 50 $\Omega$ , 6 GHz	
	– Standard model	0857.9604.02
	– High-speed model	0857.9604.03
NRV-Z32	– TDMA model	0857.9604.04
	2 W, 50 $\Omega$ , 6 GHz	
	– TDMA model	1031.6807.04
NRV-Z33	– Universal model	1031.6807.05
	20 W, 50 $\Omega$ , 6 GHz	
	– High-speed model	1031.6507.03
	– TDMA model	1031.6507.04

### Basic Units

NRVD	Dual-Channel Power Meter	0857.8008.02
NRVS	Power Meter	1020.1809.02
URV55	Millivoltmeter	1029.1707.02
URV35	Level Meter	1020.0002.02
		1020.0002.03

