

Taking measurements at antenna systems



boosting wireless efficiency

A very important application area of the 9102 Handheld Spectrum Analyzer consists of antenna measurements for the purpose of antenna performance analysis during installation, maintenance and acceptance-testing of antenna systems. The three core components of mobile radio systems – base station, antenna system and connection to the core network or switching – are often installed by different companies. Every company has to perform an acceptance test and document the quality of their work. The following sections show how to test and document antenna system quality using the Willtek 9102 Handheld Spectrum Analyzer in conjunction with the 9130 VSWR/DTF Reflection Measurement Option and the 9160 VSWR/DTF Bridge.



Antenna system peculiarities

Modern transmitter sites for mobile networks consist of a base station, the connection to the core network (via a dedicated line or a radio link) and the antenna system. The antenna system in turn consists of flexible, thin jumper cables going from the base station to the tower, rigid feeder cables with a low loss going up the tower to the antennas, the antennas themselves as well as possibly additional devices like amplifiers and downtilt controls. The quality of the installed system is influenced by cables, connectors, integrated filters and amplifiers. Transmission quality is especially influenced by mechanical aspects. For example, if cable connectors are not properly bolted together or cables are squeezed or bent too tightly, this can have adverse effects on transmission quality.

Usually the antenna system is installed before the base station is delivered. The system can thus be tested starting from the antenna connectors. The system components are designed for transmission of high frequency signals with an impedance of 50Ω . Ideally, on applying such a signal to the antenna cable it will be transmitted via the antenna without any reflection. Any discontinuity in the cable, a short circuit or any other change in the impedance (e.g. by a tight bent in the cable) will cause at least part of the transmission power to be reflected. The reflected power is in this case no longer available to the mobile network's subscribers and will be returned to the power amplifier. The resulting standing waves cause an excess in voltage and may in the worst case damage or destroy the amplifier or integrated filters.

Apart from this there can also be other adverse effects which may be less dramatic, however still damaging the reputation and image of the mobile network provider. Less than optimal transmission on the antenna cable may cause calls to be dropped or handovers from one base station to the other to fail. This means that the mobile connection cannot be used which in turn leads to an avoidable loss of earnings for the network provider. Customer satisfaction on the other hand is crucial for a network operator's image and reputation. An even more serious scenario occurs, if networks operated or rented by government institutions or public safety organisations cannot be used due to bad antenna systems. This can result in damage of property or even loss of human lives.

An optimal antenna system construction is therefore crucial in order to ensure optimal coverage and prevent material fatigue.

Requirements

The reflection measurement mode is available on the 9102 Handheld Spectrum Analyzer in conjunction with the 9130 VSWR/DTF Reflection Measurement Option.

Measurement types

The most common antenna measurements performed during antenna system installation, maintenance and acceptance testing are the reflection and the distance-to-fault (DTF) measurements.

Reflection measurements

Using reflection measurements you can test transmission quality in the sender and receiver range and assess the match of the antenna system's components. Within the measurement instrument the reflection is measured via a Wheatstone measurement bridge. Willtek offers the 9160 VSWR/DTF Bridge for this purpose. Thus an impedance measurement is performed. Even a small impedance error causes a relatively high voltage change and can therefore easily be measured. The impedance measured will then be converted into a reflection factor and displayed on the instrument.

The two most common parameters are Voltage Standing Wave Ratio (VSWR) and return loss. Using the reflection measurement mode of the 9102 Handheld Spectrum Analyzer you can display the measured value either as return loss, VSWR or other custom units, e.g. reflection coefficient (ρ) or reflected power ratio.

The Voltage Standing Wave Ratio is often stated for high frequency devices. The measurement value is linear and higher than, or ideally equal to 1. The VSWR is displayed as a function of the frequency. For antenna systems limit values are usually specified for specific frequency ranges.

The course of the return loss is displayed as a logarithmic value in dB. In contrast to the linear display also smaller reflections are clearly visible on the graphical display. For a total power reflection of 10 % the measurement instrument will show a return loss of 10 dB. In mobile radio systems an antenna system with a return loss of 17 to 20 dB is considered to be of good quality.

Distance-to-fault measurements

In addition to testing transmission quality in the sender and receiver range antenna system quality can also be assessed in view of fault locations. Cable kinks, bad connections at the transition between jumper and feeder cables as well as a partial short circuit may have adverse effects on transmission quality, especially in the longer term. With the distance-to-fault measurement you can determine cable faults of this kind. This measurement is based on the local impedance change caused by the cable fault. The measurement instrument performs an internal reflection measurement in the frequency range and transforms the result via inverse FFT into the time domain. If the propagation velocity of the cable is known, the instrument can then transform the results into the location domain. As a result the instrument graphically displays the reflection behaviour as a distance function. A cable kink can thus be easily be recognized, its position can be determined via the distance information displayed.

Performing antenna measurements using the 9102 in the field

The 9102 Handheld Spectrum Analyzer in conjunction with the 9130 VSWR/DTF Reflection Measurement Option and the 9160 VSWR/DTF Bridge offers VSWR/DTF measurement modes for performing the antenna measurements required for assessing the quality of an antenna system and described in the previous sections:

Using the reflection measurement mode all functional parameters relevant for reflection measurements are available at a glance. This mode enables you to test performance and match of antenna systems over the desired frequency range in one view.

The reflection measurement modes offers scalar and vector reflection measurements and displays all common reflection measurement units such as return loss, rho, VSWR and the reflected power ratio.

The distance to fault measurement mode enables a detailed analysis of the antenna feeder cables with a total length of up to 2000 m. Using this measurement mode you can easily detect and locate weak connectors, cable kinks, water ingress or other cable-related problems. Even small reflections are detected and result in a displayed distance to fault. For performing a distance to fault measurement the cable characteristics have to be entered. Willtek provides predefined cable parameter files for most known coaxial cables used for antenna installations. These parameter files can easily be uploaded to the 9102. However, the parameters for rare cable types can be set step by step on the instrument.

Preparative steps

Before you actually start a reflection or distance-to-fault measurement the following preparative steps are necessary.

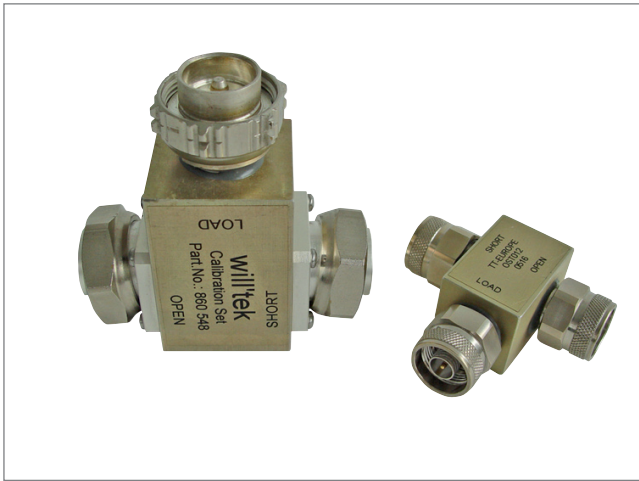
Connecting the 9160 VSWR/DTF Bridge

The 9102 in its Tracking or VSWR/DTF edition includes a tracking generator whose signal is transmitted via a separate port. For testing antenna and cable systems the sent and received signals are coupled via a measurement bridge. Thus measurements can be performed from the end of the cable connected to the base station. Willtek offers the 9160 VSWR/DTF Bridge as a tailor-made measurement bridge for the 9102. This bridge is a Wheatstone measurement bridge, an electrical bridge circuit for the precise comparison of resistances well suited for measuring small impedance changes. In order to prepare your 9102 for performing antenna measurements connect the 9160 Bridge to the RF in and RF out connectors as well as to the Multi Port connector on the top of the instrument as shown in the following picture.



Calibration

Before starting measurements the measurement instrument has to be calibrated using a highly precise terminator. For reference calibration a calibration standard with an open, short and load reference connector has to be connected. The purpose of this calibration procedure is for example to eliminate inaccuracies within the instrument and at the connector which can for example be caused by temperature changes. Willtek offers Open/Short/Load Type 7/16 male and Type N male calibration sets as well as test port extension cables with different connector standards (N and 7/16 DIN).



Calibration sets

Connecting the cable to be measured

The open end of a cable to be measured often has a 9/16 inch connector. Use an adapter cable to establish a connection between the cable to be measured and the N connector of the 9160 VSWR/DTF bridge.



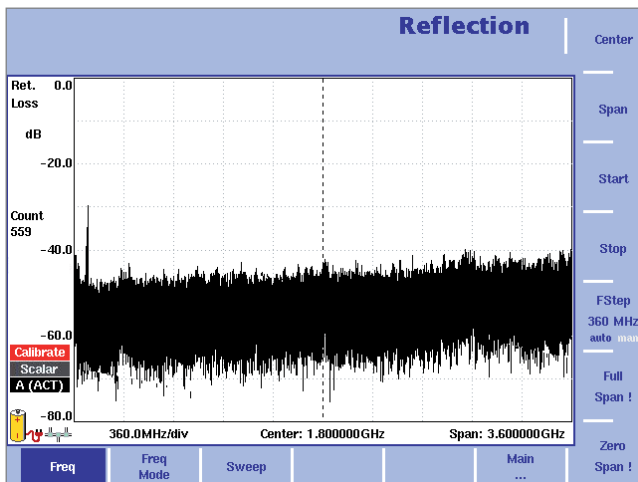
Test port extension cable

A detailed description of the calibration processes for reflection and DTF measurements is included in the relevant step by step measurement description.

Performing reflection measurements

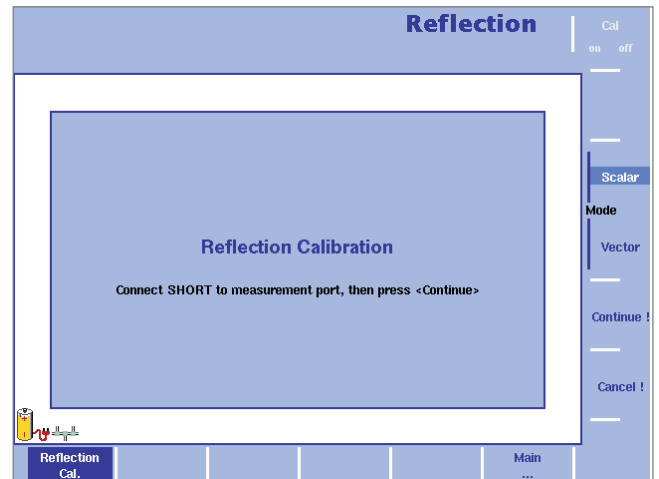
In order to perform a reflection measurement proceed as follows:

1. Press the Mode function key. The Mode menu is displayed.
2. Select the reflection measurement mode by pressing VSWR/Tracking... > Reflection. The Reflection main menu appears.
3. The next step is specifying the frequency. Press the Freq softkey to select the desired frequency band. The Frequency menu is displayed.



Frequency menu

4. There are different methods to set the frequency range to be measured; the range can be expressed by either the start and stop frequencies (i.e. first and last frequencies on the display), or by center frequency and span (i.e. the center and the frequency range), or by other combinations of center frequency, span, start and stop frequencies. For further details on setting the frequency, refer to the 9102 user's guide delivered with your instrument.
5. After specifying the frequency the next step is reflection calibration. First, connect the test port extension cable to the 9160 VSWR/DTF Bridge.
6. In the Reflection main menu press Reflection Cal. softkey. The Reflection Calibration menu is displayed.
7. Select the mode to be used for your measurement by pressing the Scalar or Vector softkey. The scalar measurement measures the level of the reflected signal. The vector measurement is even more precise and also measures the phase of the reflected signal. It increases measurement accuracy as well as the return loss measurement range.



Reflection Calibration menu

The 9100 will guide you through the calibration process by onscreen messages as shown in the figure above. When prompted as shown connect the calibration set to the test port extension cable and press Continue. You can abort the calibration process by pressing the Cancel ! softkey.

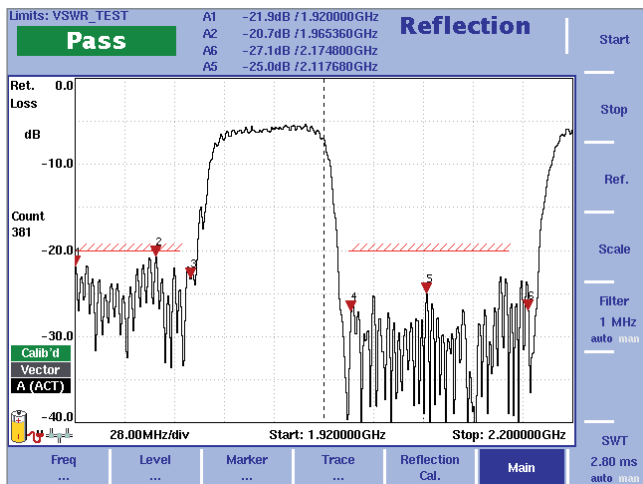
8. When calibration is completed the Reflection main menu will be displayed again. On the left-hand side of the results display the calibration icon will now be displayed in green and read "Calib'd" (Calibrated). The measurement graph shows full reflection (0 dB return loss) as soon as the calibration set is removed. The instrument is now ready for starting the actual reflection measurement.
9. The next step is to set the unit to be used for your reflection measurement. The reflection mode supports all common reflection measurement units: return loss, VSWR, reflection factor or reflected power.

In the Reflection main menu select Level > Units. The Unit menu is displayed on the right-hand side of the screen.

10. Select Return Loss, VSWR, Refl. Factor or Refl. Power by pressing the respective softkey followed by Enter. The selected unit will be displayed on the left-hand side of the results display.
11. After specifying the unit for your reflection measurement you can adjust the level parameters. Depending on the unit you specified via the Units menu the display of the Level menu changes to enable you to set the level parameters for the individual units. For a detailed description on the procedure of setting the level parameters, refer to the 9102 user's guide delivered with your instrument.

After specifying the reflection measurement parameters you can use the 9102's trace, marker and limit line functionality to further analyze and document measurement results. For a detailed description of these functionalities, refer to the 9102 user's guide.

The following picture shows a reflection measurement results display after selecting return loss as a unit and applying markers and limit lines to the measurement. Due to the activation of limit lines the 9102 provides a simple Pass verdict and shows the limit lines on screen. If the reflection is higher than the limit, the test result is displayed as "Fail".



Reflection measurement results display

Performing distance-to-fault measurements

In order to perform a distance-to-fault measurement proceed as follows:

1. Press the Mode function key. The Mode menu is displayed.
2. Select the distance to fault measurement mode by pressing VSWR/Tracking... > Distance to Fault.

The Distance to Fault main menu appears.

Setting the unit

1. The first step is to set the unit for reflection. In the Distance to Fault main menu select Level > Units. The Unit menu is displayed on the right-hand side of the screen.
2. Select dB or mRho by pressing the respective softkey followed by Enter. The selected unit will be displayed on the left-hand side of the results display: "Ref." and "dB", if you select dB. "Refl. factor" and "mRho", if you select Rho.

Setting the cable length

1. The next step is to set the length of the cable to be tested. First, you have to specify the unit of the cable length. To do so press the Distance Unit softkey in the Distance to Fault main menu.
2. Toggle the softkey to the required unit, metre or feet, and press Enter. The unit will be displayed in the cable length field of the results display as well as on the Cable Length input field.
3. In the Distance to Fault main menu press the Cable Length softkey. The Cable Length input field is displayed.
4. Enter the cable length in the unit specified and press Enter.

Specifying the cable settings

1. The next step is specifying the cable settings. For most known coaxial cables Willtek provides predefined parameter files which are included in the delivery of the 9100 Data Exchange Software which is supplied with your instrument. The files can be easily transferred to the instrument to be available for selection during DTF measurements. For information on transferring predefined cable types to your instrument, refer to the 9100 Data Exchange Software chapter in your 9102 user's guide. If the cable to be tested is a common cable type contained in the predefined parameter file you can select its settings for use within the DTF measurement after transferring the parameter file. To choose predefined parameter files stored on the instrument for your measurement select Cable > Cable Memory. The Cable Memory menu is displayed.
2. Press the Recall Cable Type softkey. A dropdown list containing all cable types stored on the system is displayed.
3. Select the required cable type using the Up/Down arrow keys and press Enter. The settings of the selected cable type are now automatically used for the DTF measurement.
4. If you intend to test a rare cable type you can also specify the cable parameters step by step and save them collectively as a userdefined cable type for later use on the instrument. For the values to be entered, refer to the manufacturer's information for the cable to be tested. To specify the cable settings manually select Cable > Cable Setting in the „Distance to Fault“ main menu. The Cable Setting menu is displayed.
5. Either press the Cable Dielec. softkey to specify the cable's dielectric which is linked to the velocity factor and specifies the isolation between the cable's conductors. The Cable Dielectric input field is displayed. Enter the value specified for the cable and press Enter. Or press the Cable Velocity Factor softkey to specify the propagation velocity of the cable. The Cable Velocity Factor input field is displayed. Enter the velocity factor specified for the cable to be tested and press Enter.
6. Press the Cut Off Freq. softkey to specify the cable's cut off frequency, which is the frequency up to which the cable transmits. The Cut Off Frequency input field is displayed. Enter the frequency specified for the cable to be tested and press Enter.

7. Press the Cable Attn. softkey to specify the cable attenuation. You can enter the value in dBm per 100 m or dBm per 100 ft, depending on the unit you specified for the cable length. The Cable Attn. softkey can be toggled accordingly and Cable Attenuation input field will be displayed with showing the units specified. Enter the attenuation specified for the cable to be tested and press Enter.

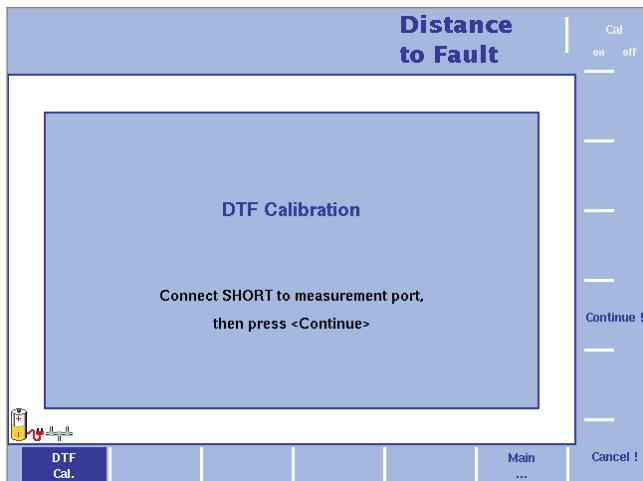
Setting center frequency and span

1. The next step is to set the center frequency and span. Push the Cent function key or the Center softkey in the Distance to Fault main menu. The vertical softkeys include Center and Span. An entry field appears, indicating the center frequency currently set and the step size for the up/down cursor keys.
2. Enter a new frequency using the numeric keys, the cursor keys and the Backspace key.
3. Conclude the entry by pushing an enter key for the unit (GHz/dBm for gigahertz, MHz/dB μ s for megahertz, kHz/dB μ V/ms for kilohertz, or Enter for hertz).
4. Push the Span softkey. If you intend to set the span manually, enter the frequency for the range from the left to the right end of the display. If you want the span to be set automatically, toggle the Span softkey to auto.

If you specify the same value for the center frequency as for the cable cutoff frequency, your measurement becomes invalid as the cutoff frequency is the maximum frequency up to which the cable transmits signals. In this case the measurement would not make any sense.

Calibrating

1. The next step is performing the distance-to-fault calibration process. First connect the test port extension cable to the 9160 VSWR/DTF Bridge.
2. In the Distance to Fault main menu press the DTF Cal. softkey. The distance to fault Calibration menu is displayed.
3. The 9102 will guide you through the calibration process by onscreen messages as shown in the figure below. When prompted as shown connect the calibration set to the test port extension cable and press Continue. You can abort the calibration process by pressing the Cancel ! softkey.
4. When calibration is completed the Distance to Fault main menu will be displayed again. On the left-hand side of the results display the calibration icon will now be displayed in green and read "Calib'd" (Calibrated).



DTF Calibration menu

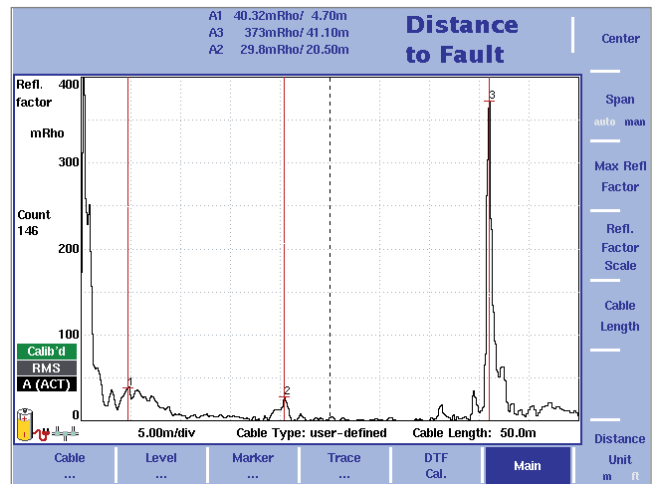
Specifying level parameters

As the last step of specifying the parameters for your DTF measurement you can now adjust the level parameters. Depending on the unit you specified via the Units menu the display of the Level menu changes to enable you to set the level parameters for the individual units. For a detailed description on the procedure of setting the level parameters, refer to the 9102 user's guide delivered with your instrument.

The measurement result

As for reflection measurements you can use the 9102's trace, marker and limit line functionality to further analyze and document measurement results after entering all DTF measurement parameters. For a detailed description of these functionalities refer to the 9102 user's guide.

The following picture shows a distance to fault measurement results display for a userdefined cable type after selecting the reflection unit mRho and the cable length unit m. Markers (in the distance to fault mode the markers appear in line style) have been applied to mark the peak reflection values, i.e. the impedance changes measured and converted into the reflection factors. Cable faults can thus easily be identified.



Distance to fault measurement results display

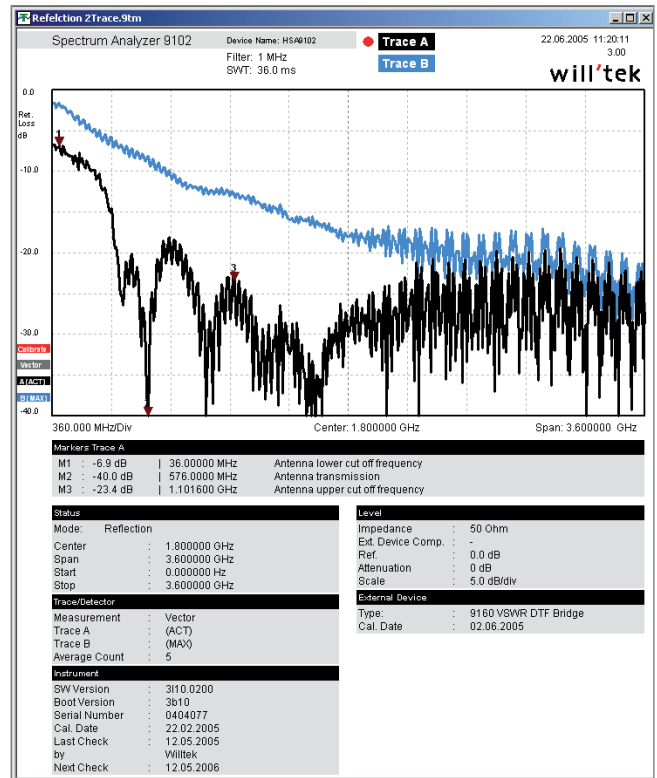
Analyzing and documenting quality measurement results in the office

Typically, you would want to document the tasks performed during antenna system installation, maintenance and acceptance-testing after returning to the office. Documented return loss and DTF measurements are required for final acceptance of an antenna system. You can transfer the results of the measurements performed with your 9102 Handheld Spectrum Analyzer via a LAN or RS-232 interface and using the 9100 Data Exchange Software, which is included in the delivery of your 9102, to your PC. The results are displayed on the PC as they are displayed on the instrument.

The 9100 Data Exchange Software offers special methods for documenting your measurement results. In addition to the six markers that can be set on the 9102 you can include up to four additional markers in the measurement result display on your PC and have comment fields assigned to them. Thus up to ten markers can be used on each trace. Using the additional four markers with their comment fields you can mark and comment on values that are within tolerance limits although critical. The measurement values at the marker positions are of course included in the display. Using the limit line functionality result values can be assessed at a glance. You can also include measurement parameters in the display to document the measurement conditions.

Following is an example of a distance to fault measurement results display edited within the 9100 Data Exchange Software. In this display trace A has been selected, markers have been added and comments assigned to them. The comments are displayed below the measurement trace alongside the marker result values under the heading Markers Trace A. For a detailed description of the usage of the 9100 Data Exchange Software, refer to your 9102 user's guide.

After adjusting the measurement results display to your requirements using the 9100 Data Exchange Software you can transfer it to your word processing program for inclusion into your test documentation. You can save the display in a file selecting one of nine possible graphical formats (e.g. TIF, JPEG etc.) or copy it to the clipboard. Then you can paste the file or picture into your test documentation. You can now provide your client with a comprehensive documentation on the quality of your work reinforced by a combination of graphics and numerical measurement values (markers).



Commented measurement results on the PC



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