Application Note

PERFORM HIGH IMPEDANCE MEASUREMENTS WITH SPECTRUM ANALYZERS

Products:

- R&S®FSW
- R&S®FSWP
- R&S®FSMR3000
- R&S®FSV/FSVA3000
- R&S®RT-ZA9/ZA51
- R&S®RTO-ZZ80
- R&S®RTO-ZS10/20/30/40
- R&S®RTO-ZD10/20/30/40

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www.rohde-schwarz.com/appnote/1EF116

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1 Introduction

One of the challenges in circuit design and debugging is the lack of available test points, which can make it difficult to verify the performance of the circuit. RF design often requires measurements at multiple stages along the signal path. Traditionally, RF designers addressed this issue by incorporating RF connectors as test points along the path. However, with the continuous shrinking of component sizes and the limited space on circuit boards in modern designs, it has become increasingly challenging to incorporate sufficient RF test connections for accurate measurements.

To address these challenges, one potential solution is to use oscilloscope probes. The available space on surface-mounted components and printed circuit board tracks provides sufficient room to connect the probe tip. By directly probing the circuit, the need for test connectors at various points in the design can be avoided. However, accurate measurements with oscilloscope probes in conjunction with spectrum analyzers require an understanding of the interface between the circuit, the probe, and the analyzer. While most RF spectrum analyzers have an input with 50 Ω impedance, this may not fit to many oscilloscope probes. Nevertheless, modern oscilloscope probes offer high impedance, low capacitive loading, and a wide bandwidth of several GHz, making them an excellent tool for RF measurements with a spectrum analyzer.

Nowadays, it is feasible to conduct RF testing directly on the circuit board thanks to the availability of probe interfaces for spectrum analyzers. Active, high-impedance probes can be connected to spectrum analyzers, providing a practical and highly precise measurement solution to overcome an otherwise cumbersome RF testing issue. This application note provides information on how to use oscilloscope probes in RF measurements using spectrum analyzers.

2 R&S oscilloscope probes overview

There is a wide variety of probes available for oscilloscopes, ranging from simple passive probes to active, high impedance probes. It is important to select a probe that suits the circuit under test and which works well together with the test equipment. The following chapter gives a short overview about the available probes for R&S oscilloscopes. For each type of probe some characteristics are described and the possibility to use it with spectrum analyzers is explained.

2.1 Passive probes

Rohde & Schwarz passive probes are the perfect accessory for general measurement applications at low-frequencies. The very fine, spring-loaded tip allows precise and reliable contacting of signal lines.

Figure 1: Passive probe, the all-rounders for oscilloscopes

In order to get correct measurement results, passive probes must fit to the input impedance of the oscilloscope or spectrum analyzer. Most passive oscilloscope probes are designed to have an impedance of 1 MΩ at the probe output connector.

Note: Although these probes are compatible with most oscilloscopes, they are incompatible with the standard 50 Ω impedance RF input connector found on a typical spectrum analyzers.

This limitation due to the impedance limits the use of the general passive probe to some rare models of spectrum analyzers with high input impedance.

An illustration of this case is the R&S®FSMR3000 Measuring Receiver, which provides a low frequency input as an option (R&S®FSMR3-B3). This additional input allows the selection of either a 50 Ω or 1 MΩ input impedance. In addition, the low frequency input uses a BNC connector that perfectly matches most passive probes. The typical use case is to increase the level measurement range by using a passive probe. The maximum input level of the analyzer can be extended by the attenuation factor of the probe.

2.1.1 Broadband passive probes

In the past, incorporating test points with RF connectors along the path used medium impedance resistors to couple the test port to the signal path. This method enables accurate measurements with a moderate load on the circuit. Passive broadband probes leverage this approach, providing a convenient solution for measuring high-frequency signals on low impedance lines.

Figure 2: Passive probe, the all-rounders for oscilloscopes

The R&S®RT-ZZ80 probe provides an attenuation factor of 10:1 at an input impedance of 500 Ω. In contrast to active probes, the input impedance is low but remains practically constant over the entire frequency range that covers up to 8 GHz. This test approach works well with typical 50 Ω line impedance on single ended RF connections, as the 500 Ω input impedance puts only an additional load of about 10% on the signal line.

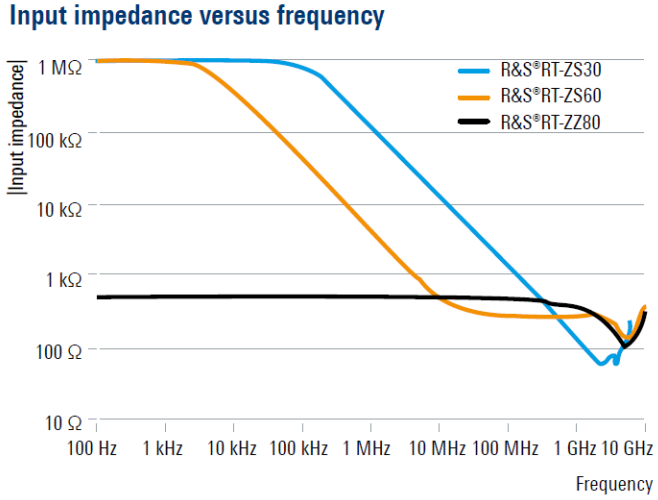

Figure 3: R&S®RT-ZZ80 input impedance

The SMA plug at the probe output is directly connected to the spectrum analyzer RF input. The 10:1 ratio of the probe can be easily considered like an external attenuator using the reference level offset function in the spectrum analyzer. And with this simple step, the instrument is configured to perform precise RF level measurements at any point in the RF circuit.

Note: The broadband passive probe is the ideal solution for in-circuit debugging along the 50 Ω impedance of most RF circuits where no test connectors are available. Due to it´s passive design it will not add any distortion or noise in the test.

2.2 Active probes

Rohde & Schwarz offers an extensive range of active broadband probes with high input impedance and low input capacitance. This includes single-ended active probes with a maximum bandwidth up to 6 GHz, and a wide range of differential broadband probes with excellent common mode suppression.

Figure 4: Active oscilloscope probe R&S ® RT-ZS30

When measuring the high frequency signals used in modern designs, the load from the probe must be kept low. Rohde & Schwarz active probes meet this requirement with 1 MΩ input impedance and an input capacitance of < 1 pF. As a result, the probe's influence on the circuit during measurement is minimized.

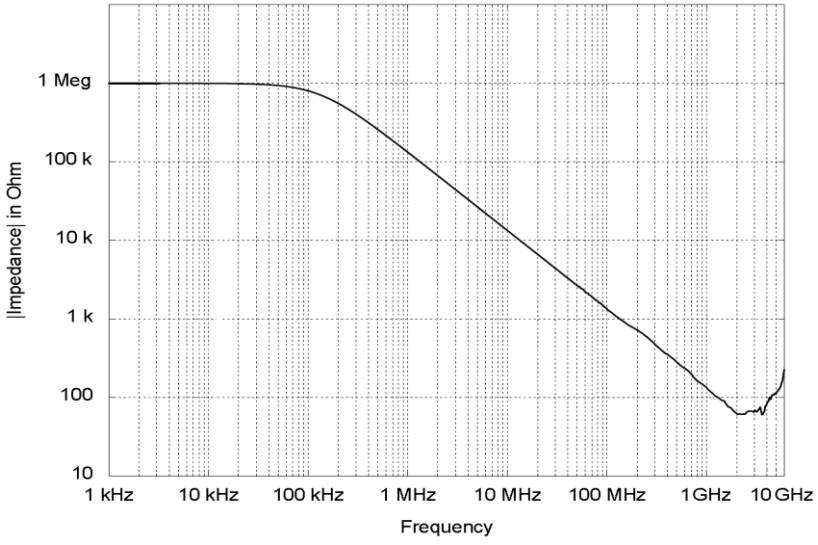

Figure 5: Plot of the Input Impedance versus frequency for active probe R&S RT-ZS30

The design of the contact accessories also permits a high measurement bandwidth for various contacting methods, including manual contacting, solder-in and plug-in connections. The compact probe head allows measurements even on densely populated printed boards, and the low weight ensures a minimal load at the contact point.

2.2.1 Differential Active probes

The typical RF design was for a long time dominated by single ended, coaxial circuits throughout the signal path. The availability of high performance, differential RF components today makes the use of differential circuit architectures possible. Good examples for this technology are A/D and D/A converters; mixers and amplifiers are also available. While differential circuits outperform most single ended design, the technology creates a problem for making accurate measurements. Most RF test instruments such as spectrum analyzers use a single ended RF connector. The two parts of a differential signal need to be combined into a single line before they can be connected to a spectrum analyzer. A BALUN (BALanced/UNbalanced) circuit was previously often used to make the combination. The disadvantage of a BALUN is that the frequency range is limited, and the impedance must be matched to the test point.

Active differential probes are a commonly used with oscilloscopes. The positive and negative inputs of these probes are connected to a high-performance differential amplifier, which converts the inputs to a single-ended coaxial output signal.

Figure 6: Active differential probe R&S ® RT-ZD30

The high input impedance puts a very low load on the signal test point and can consequently be directly connected to a differential signal line or a high impedance output of an integrated circuit. With the availability of active, differential probes and methods to use these probes together with a spectrum analyzer, a big obstacle is solved that made measurements difficult to perform in the past.

2.2.2 Modular Active probes

The R&S®RT-ZM modular probe system meets the demands for high probing bandwidth and dynamic range in conjunction with the need for low capacitive load. The modular probe system is available with amplifier modules offering bandwidths from 1.5 GHz to 16 GHz. These modules come with a Rohde & Schwarz probe interface that allows automatic probe detection and configuration on Rohde & Schwarz spectrum analyzers. The modular probe system also offers multimode functionality, enabling users to switch between different measurement modes like single ended or differential mode.

Figure 7: R&S®RT-ZM probe amplifier module with Rohde & Schwarz probe interface and a double-socket SMP connector

The amplifier is equipped with a miniaturized high-quality and high-frequency coaxial double-socket SMP connector for flexible snap-on use with various probe tips modules (see figure below). The system includes probe tip modules for various measurement tasks and conditions. Examples include semi-permanent solder-in probe tips for physically small probing areas or a solution for environmental tests in climatic chambers.

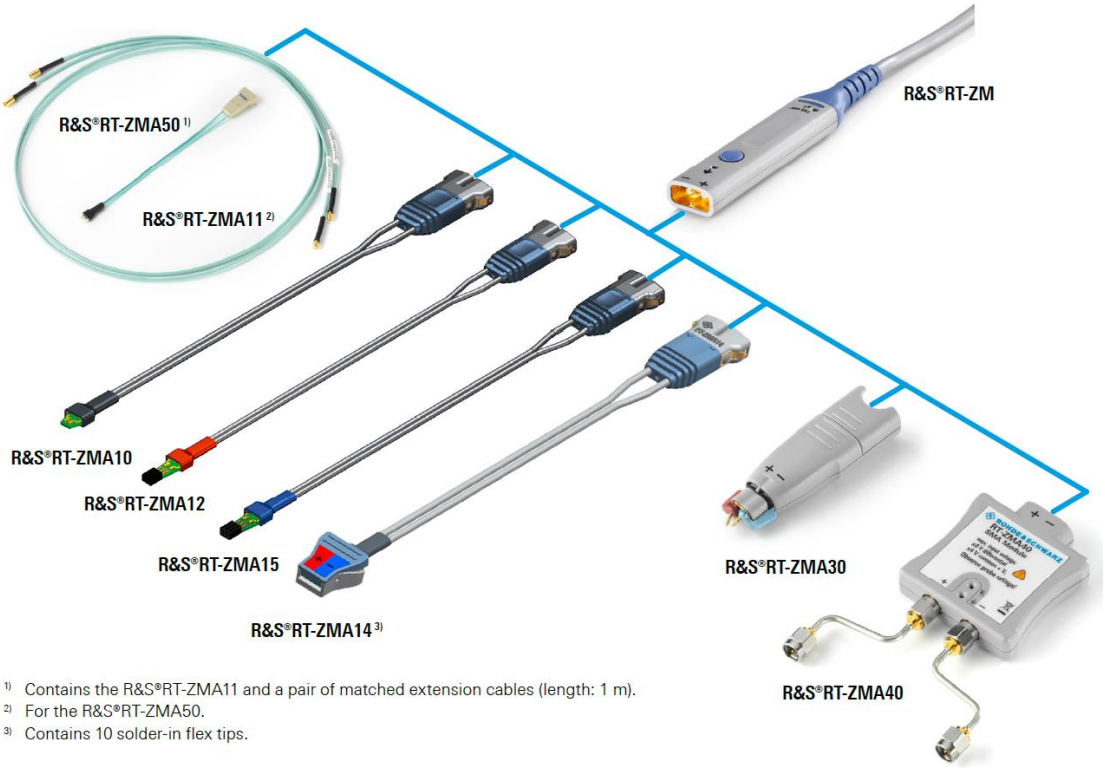

Figure 8: R&S Probe tip modules for the R&S®RT-ZM. For detailed information, see R&S®RT-ZM flyer

3 Probe interfaces for R&S Spectrum Analyzers

Active probes for oscilloscopes offer the advantage of a very high input impedance and low capacitive load, typically achieved by a wide bandwidth FET amplifier. The probe amplifier output has 50 Ω impedance which perfectly matches the spectrum analyzer`s RF input. The difficulty using active probes with spectrum analyzers is the interface that connects the probe and supplies the built-in amplifier with power.

To connect the R&S oscilloscope active probes to spectrum analyzers, R&S offers two different solutions:

- ► Probe adapters R&S RT-ZA9 and R&S RT-ZA51
- ► Analog baseband inputs, option R&S FSW-B71

Both solutions include the power supply for the amplifier in the active probes, and the probe is automatically recognized and correction factors are applied to the measurement.

3.1 Probe adapters

R&S offers adapters to connect active probes designed for R&S oscilloscopes to the spectrum analyzer`s RF input port. Depending on the adapter model, it converts the R&S active probe interface to a standard N-connector or 3.5 mm connector type.

Figure 9: Probe adapter R&S RT-ZA9 with USB-cable and active probe amplifier attached

In addition to the RF connector, the probe adapter is connected to the spectrum analyzer with an USB cable. The following functions are performed via the USB interface:

- ► Power supply for Probe amplifiers
- ► Automated recognition of connected probe
- ► Data connection used to transfer Probe factor and Micro button action

3.1.1 Probe adapter R&S RT-ZA9

The R&S RT-ZA9 probe adapter converts the probe plug of an R&S active probe to a standard N-type male RF connector. The power and data connection to the spectrum analyzer is done with a Mini-USB connection on the side of the adapter.

Figure 10: Probe adapter R&S RT-ZA9 in front- and rear-view

A USB cable is supplied together with the adapter to connect it with a standard USB type A socket. The adapter RT-ZA9 is best suited for all spectrum analyzers with N-type RF input connectors.

Order info: R&S®RT-ZA9; N(m) adapter for R&S®RT-Zxx oscilloscope probes, 1417.0909.02.

3.1.2 Probe adapter R&S RT-ZA51

The R&S RT-ZA51 is a probe adapter with R&S probe interface, USB-C connector, 3.5 mm female RF connector and a DC jack. The adapter uses a USB type C connector for the power supply and control of the probe. The adapter is shipped with a short USB-C to USB-A cable to perform the data and power connection to the spectrum analyzer. The additional DC jack is not required for the active probes RT-ZSxx (single ended) or RT-ZDxx (differential) and will not be used.

Figure 11: Probe adapter R&S RT-ZA51

Due to the 3.5mm female connector, the adapter RT-ZA51 is best suited for all spectrum analyzers with 3.5 mm or 2.9 mm male RF input connectors (i.e. FSW26, FSW43, FSV3030, FSV3044, etc.). For spectrum analyzers with different connectors RF adapters must be used (FSW50, FSW67, etc.).

Order info: R&S®RT-ZA51 adapter, 2.92 mm/3.5 mm/SMA to R&S probe interface: 1803.5365.02

3.2 Probe interface in the analog baseband inputs (R&S FSW-B71)

The R&S FSW High Performance Signal & Spectrum Analyzer family offers optional baseband inputs on the front panel of the analyzer (Option R&S FSW-B71). The baseband input consists of 4 BNC connectors (I/Q and inverted I/Q), each with 50 Ω input impedance. Typically, the baseband inputs of a spectrum analyzer are utilized for connecting I/Q baseband signals in order to demodulate and evaluate various types of signals.

The upper two baseband input connectors include the power and data interface for R&S active probes. Once a probe is connected, the R&S FSW will automatically identify the probe type and apply correction factors for accurate readings.

Figure 12: Baseband and Probe inputs on the R&S FSW spectrum analyzer front panel

As an additional feature, the baseband input can be used as RF input for the R&S FSW spectrum analyzer. This feature is implemented with an internal RF switch between the I input and the RF input. The input is selected in the Input Source dialog:

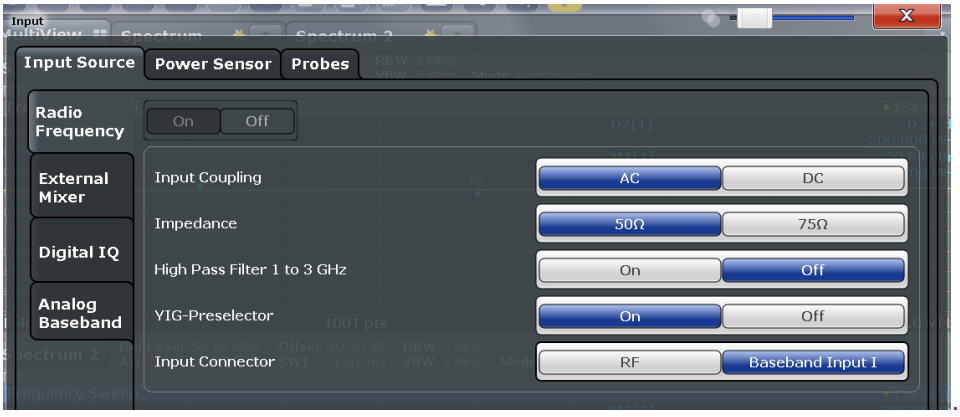

Figure 13: RF input selection dialog on the R&S FSW spectrum analyzer with baseband inputs

When a probe is connected to the baseband input, it allows for RF measurements to be conducted up to 6 GHz. The measurement results take into consideration the automatic adjustment for the loss of both the probe and the switch.

Note: For spectrum analyzers with installed baseband input option (R&S FSW-B71) the probe adapter RT-ZA9 or RT-ZA51 is not needed to connect active probes.

3.3 Probe correction factor and Micro button action

Once a probe is connected, the FSW will automatically identify the probe type and applies correction factors for accurate readings.

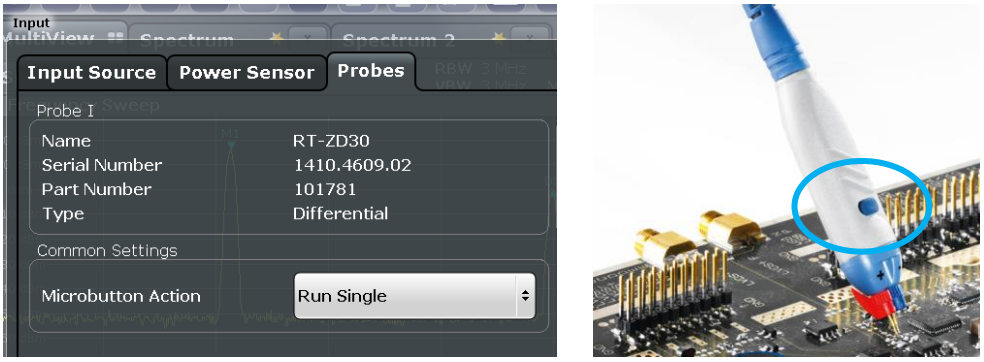

Figure 14: Probe information and configuration dialog and Micro button on the R&S probe

In probing situations with limited access to the test point, the micro-button on the active probes from R&S helps the user to keep his fingers on the probe and initiate a sweep on the spectrum analyzer without the requirement to move his hand away from the probe, which helps to capture exactly the result screen of interest.

4 Conclusion

Active probes for oscilloscopes offer new possibilities for spectrum analyzer measurements. Compared to previous setups with additional test connectors or additional special test circuits like a BALUN, the use of active probes makes quick, accurate measurements possible on signals over a wide frequency range with a spectrum analyzer at any point within a printed circuit board.

R&S probes, the congenial companion for spectrum analyzers

Table 1-1: Supported Rohde & Schwarz probes

Type	Model	Adapter/Comments
Passive	R&S RT-ZP10	Not suited for spectrum analyzers
Broadband passive	R&S®RT-ZZ80	No adapter needed, SMA connector
Single Ended active	R&S RT-ZSxx	RT-ZA9 or RT-ZA51
Differential active	R&S RT-ZDxx	RT-ZA9 or RT-ZA51
Modular active	R&S RT-ZMxx	RT-ZA9 or RT-ZA51

Rohde & Schwarz

The Rohde & Schwarz electronics group offers innovative solutions in the following business fields: test and measurement, broadcast and media, secure communications, cybersecurity, monitoring and network testing. Founded more than 80 years ago, the independent company which is headquartered in Munich, Germany, has an extensive sales and service network with locations in more than 70 countries.

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PAD-T-M: 3572.7186.00/01.00/EN

1EF116 | Version | 05.2023
Application Note | Perform High impedance measurements with spectrum analyzers
Data without tolerance limits is not binding | Subject to change

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