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FIG 1 **Power splitter and power sensor in one box: the new R&S®NRP-Z28/-Z98 level control sensors.**

R&S®NRP-Z28/R&S®NRP-Z98 Level Control Sensors

Integrated solution for feeding calibrated signals

Two new sensors place Rohde & Schwarz once again in the lead of power meter technology. The sensors convert any signal source into a highly accurate power reference.

Highly accurate and extremely convenient

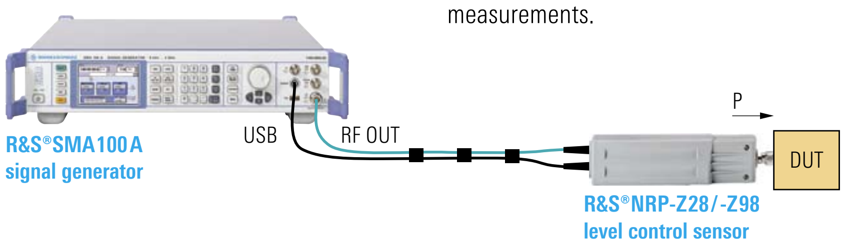
The two new products provide a one-box solution to replace the conventional power splitter / power sensor assembly previously needed for feeding signals to a DUT. They combine highly accurate measurements with ease of operation, particularly when used in conjunction with one of the R&S®SMU / R&S®SMJ / R&S®SMATE / R&S®SMA / R&S®SMB / R&S®SMF signal generators from Rohde & Schwarz. These signal generators can not only function as a power meter base unit, but will also improve their amplitude accuracy significantly by using a level control sensor. There are plenty of applications, starting with level calibration of spectrum and signal analyzers, and extending to the provision of calibrated levels for all types of receiver measurements.

Conventional power sensors are ideal for measuring the power available from an output. Due to excellent impedance matching they absorb the applied signal almost completely and reproducibly convert it into an easily measured physical quantity. If properly calibrated, they can measure the nominal power of a source very accurately.

In the past, the only commercially viable method used for measuring the applied power was to use directional power sensors. These sensors include an integrated directional coupler for signal tapping and can measure the power both of the wave incident on the DUT and of the wave reflected by it. Such power measurements are restricted to levels of more than 1 W.

To perform measurements in the more relevant level range below 100 mW (+20 dBm), users either had to configure their own small measurement system, consisting of a directional coupler or power splitter, one or two power sensors, and a connection cable – or settle for a significant decrease in accuracy.

FIG 2 **Test setup using level control sensors.**



The advantages of the new solution

The new R&S®NRP-Z28 and R&S®NRP-Z98 level control sensors (FIG 1) make these compromises unnecessary, because applied power levels are measured easily in the same way as with absorbing power sensors (FIG 2). In this case, the level control sensors are simply hooked up to the input of the DUT and then connected to either a signal generator or another signal source via a microwave cable. Either the signal generator itself (FIG 3), an R&S®NRP power meter, or a PC with USB interface can be used for displaying the measurement result. The measurement range for the applied level extends from –67 dBm to +20 dBm and the frequency range from 9 kHz to 6 GHz (R&S®NRP-Z98) or from 10 MHz to 18 GHz (R&S®NRP-Z28). The measurement uncertainty is comparable to that of commercial power sensors.

The advantages of the new solution can best be seen in comparison with a simple test setup, i.e. a direct cable connection between the signal generator and the DUT. In this case, the level applied to the DUT is read from the entry field of the signal generator; the cable loss typically is not taken into consideration. This can lead to a significant offset between the level that is set and the level that is actually applied (FIG 4). Level control sensors measure the applied power directly at the input of the DUT and therefore provide a clear advantage.

A further improvement is achieved with respect to impedance matching. In the case of direct cable connection, mismatch errors become apparent by the strong ripple of the trace, whereas this is barely noticeable when using level control sensors. This is because the level control sensors can be matched much better to 50 Ω than a signal generator. In addition, signal generator impedance matching is further impaired by the connection cable.

Of course, these disadvantages of direct cable connections are already well known, and a simple correction method is, therefore, frequently used. You simply premeasure the power at the DUT input using an absorbing power sensor (substitution) and use the measurement result as a "user correction" on the signal generator. As shown by the yellow trace in FIG 4, this does indeed compensate for the cable loss, and the amplitude accuracy of the signal generator level only plays a minor role. However, because this has little effect on the ripple, this method is only partially successful. Moreover, it would also be necessary to connect a very well matched attenuator to the cable output in order to somewhat reduce the ripple – or you could simply use a level control sensor.

In cases where even level control sensor matching isn't enough, it is possible to make use of another improvement referred to as gamma correction. This involves a numeric compensation of the influences resulting from impedance mismatch. FIG 4 gives an example of the residual ripple (blue trace) eliminated by gamma correction. However, although effective, this method does ▶

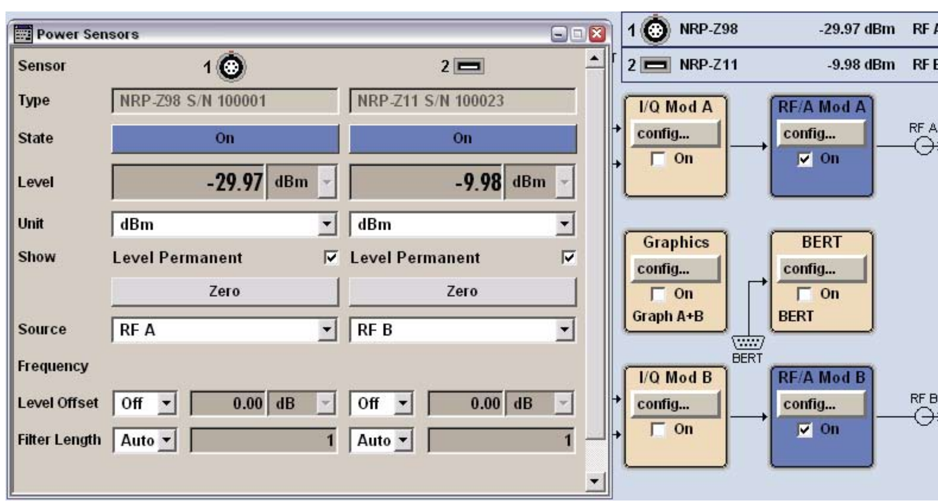


FIG 3 Menu for power measurements using the R&S®SMU/R&S®SMJ signal generators and display of measurement results in the block diagram.

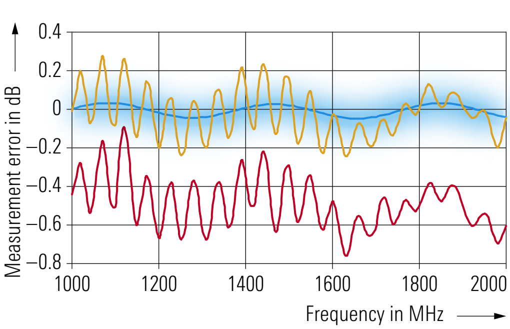


FIG 4
Level accuracy with a configuration like in FIG 2 compared to an equally long cable connection. The traces show the signal level on the DUT:
- **(blue) relative to the measurement results of the level control sensor (the blue trace shows the measurement uncertainty);**
- **(red) relative to the level setting of the signal generator for a cable connection;**
- **(yellow) relative to the level setting of the signal generator following a "user correction" (with power sensor at end of cable).**

The measurements were carried out with an R&S®SMATE signal generator, an R&S®NRP-Z28 level control sensor and a dummy load (SWR 1.6).

Two power sensors that are equal to the task

The new level control sensors use a broadband, resistive power splitter as a signal divider; for detection, they use a tried-and-tested power sensor with a USB interface (FIG 5). To this extent, they are very similar to the R&S®NRP-Z27 and R&S®NRP-Z37 power sensor modules. The difference lies in their configuration and calibration. While the R&S®NRP-Z27 and -Z37 measure the applied power (i.e. they act as absorbing power sensors), the two level control sensors measure the power that is output. To do this, one of the two outputs of the power splitter is connected to the power sensor and the other to the test port.

By virtue of its symmetrical configuration and its two 50 Ω resistors used for signal division, the power splitter ensures that the power applied to the power sensor and the power applied to the DUT are approximately the same, even if there is a significant mismatch on the side of the DUT. This type of configuration is well known and frequently used worldwide for feeding calibrated signals to DUTs. But this still falls far short of the accuracy achieved with a power meter. To achieve this level of accuracy, any residual asymmetry of the power splitter would have to be eliminated; this could be done, for example, by using a second power sensor for a calibration. The power ratio of the two sensors would then have to be taken into account during the subsequent measurement on the DUT. Since this is a time-consuming process, particularly when measuring at several frequencies, it is used only in exceptional cases to improve accuracy.

Rohde & Schwarz demonstrates a better way with the new level control sensor. Above and beyond the integration of all components in a single box, it is primarily the following measures that ensure the high degree of accuracy and simple handling:

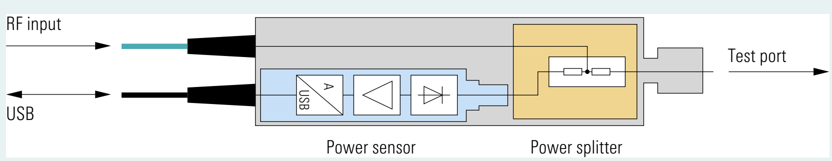


FIG 5 Block diagram of the R&S®NRP-Z28 / -Z98 level control sensors.

Gamma correction during test port calibration at the factory

Just like with the other R&S®NRP-Zxx sensors, calibration uncertainties resulting from impedance mismatch are widely eliminated during production. Since the complex reflection coefficients on both sides of the calibration interface must be known, this is also called a gamma correction. Only by this correction method can the specified measurement uncertainty reach the levels associated with power meters.

Stored calibration data

The power ratios between the internal and external power sensor derived during calibration in the factory are offset against the calibration data of the internal sensor and then stored in the sensor itself. As a result, the power applied to the DUT can be measured immediately – without further corrections.

Power sensors in patented three-path technology

For the level control sensor from 10 MHz to 18 GHz, the tried-and-tested R&S®NRP-Z21 is used, which also permits simple analysis of the power envelope with a video bandwidth of 100 kHz. In the level control sensor for lower frequencies, an R&S®NRP-Z91 average power sensor is used. Both sensors provide a very wide dynamic range and a high degree of sensitivity plus the ability to measure accurately regardless of the waveform.

Gamma correction by the user

Gamma correction is ideal for significantly reducing measurement uncertainty with a strongly mismatched DUT. Therefore, Rohde & Schwarz also provides users with the equivalent reflection coefficients obtained during the production of the level control sensors.

Embedding

Since there are at least three types of RF connectors just for the frequency range below 4 GHz, the use of adapters is hard to avoid. But something that is not critical at all for a signal generator or spectrum analyzer can quickly lead to the specified measurement uncertainty being vastly exceeded on a power sensor. Therefore, Rohde & Schwarz has taken the following precautions with regard to the level control sensors:

First, the test port uses a male N connector instead of a female connector, permitting a direct connection to most measuring instruments. This already provides a major advantage over commercial power splitters that use only female N connectors. If adapters must be used, such as when converting to the 7/16 or SMA systems, the user can embed the adapter in the application. To do this, the four S-parameters of the adapter have to be determined using a vector network analyzer and then stored in the sensor (up to 1000 frequency points). The advantages: The high degree of measurement accuracy is maintained, in particular in connection with active gamma correction, and the process is foolproof. Comparable advantages can be achieved by embedding an attenuator that is hooked up to the test port, e.g. in order to apply very small signals outside the measurement range of the level control sensors.

not see much practical use because the complex reflection coefficients of the DUT and the source would have to be measured to make this correction. That's not the case for level control sensors. Rohde & Schwarz ensures highly accurate measured values for the equivalent source reflection coefficients of level control sensors. You then simply have to provide the reflection coefficients of the DUT – a standard measurement task – and the sensor does the rest. The remaining mismatch uncertainty is typically small enough so as to be considered negligible (FIG 6).

From signal generator to level calibrator

Even if it is clearly sufficient in many cases to know the exact level applied to the DUT, there are applications for which a small deviation from a nominal value is needed. Because the alternating measurement and correction of a level setting is cumbersome and time-consuming, these tasks are frequently performed by level calibrators, which set the desired level value immediately and highly accurately.

The introduction of the level control sensors now makes this functionality also available for signal generators of the R&S®SMU / SMJ / SMATE / SMA / SMB / SMF family. The "user correction" function on the signal generator is used for this purpose, and the signal generator is run through a training sequence while the DUT is connected. This is done before the nominal level is set. The level setting on the signal generator is then corrected so that the desired nominal level is present on the DUT. Except for the DUT-specific training sequence, this level calibrator is almost identical to conventional instruments of this type. In terms of accuracy, it can even be superior (FIG 7).

Outlook

The R&S®NRP family is continually being enhanced. As always, the focus remains on benefits for the user: high quality at a reasonable price, leading-edge technology, and true to the motto "plug in and measure".

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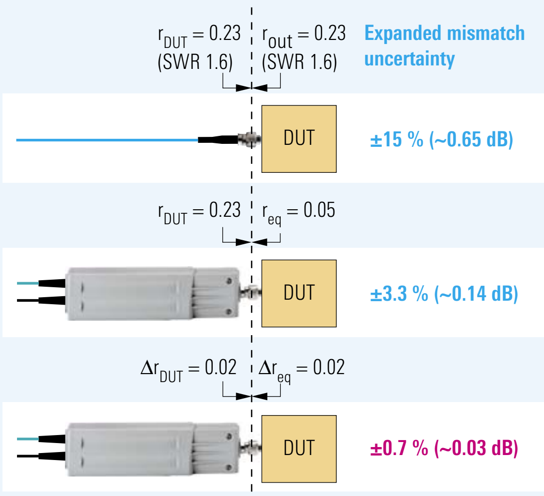
FIG 6 Mismatch uncertainty using a DUT featuring an SWR of 1.6:
❶ with cable (source with an SWR of 1.6);
❷ with the R&S®NRP-Z28 / -Z98 in the frequency range up to 4 GHz without gamma correction;
❸ like ❷, but with gamma correction. The measurement uncertainties for the complex reflection coefficients relevant for the gamma correction were assumed to be 0.02.



More information at www.rohde-schwarz.com (search term: NRP-Z28)

FIG 7 Amplitude accuracy for a level calibrator when feeding a DUT with an SWR of ≤1.5.
Red: Competitor.
Blue: The R&S®SMU / R&S®SMJ / R&S®SMATE generators after user correction with the R&S®NRP-Z28 / -Z98 (reproducibility in relation to the training sequence is taken into consideration).