Millimeter-Wave Receiver Calibration

MADE EASIER, CHEAPER, AND FASTER

KEYSIGHT TECHNOLOGIES

INTRODUCTION

Accurately Measure Your DUT at the Reference Plane

As bandwidths grow wider and frequencies soar to millimeter-wave and beyond, small margins for error on wideband measurements force RF engineers to look for new ways to reduce linear errors. Even short cables can cause tremendous losses at millimeter-wave frequencies. Correcting for magnitude and phase errors in your setup allows you to get the most out of your measurements and see your device's real performance. But receiver calibration methods are often expensive, complex, and time-consuming.

Until now, a single device to quickly and easily calibrate your signal analyzer did not exist. The Keysight U9361 RCal receiver calibrator represents a new paradigm in signal analyzer calibration. It brings accuracy, simplicity, and value to the calibration of your test receiver system. RCal allows you to correct for cable and path losses, accurately measure power at the device under test (DUT) reference plane, and generate flatness corrections in magnitude and phase up to 5 GHz IF bandwidths.

Don't sacrifice your time, energy, and budget to undergo complex signal analyzer calibration with multiple pieces of equipment. With a receiver calibration module, you can make measurements an order of magnitude more accurate than before.

Contents

CHAPTER 1

Challenges with Traditional Methods

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Wideband measurement challenges grow more complex by the day. Wider bandwidths, higher frequencies, and more complex modulation make your measurements more sensitive to nonlinearities. At higher frequencies, as the noise floor increases, the absolute amplitude accuracy becomes more important. While you know the accuracy of your instrument, the signal path can contribute unknown errors that degrade your overall measurement accuracy.

A complex measurement setup.

To get the most accurate measurements, you must calibrate at the measurement plane. Moving the reference plane to the output of your DUT can provide an order-of-magnitude improvement in your receiver (Rx) system accuracy by calibrating out the linear impairments from fixtures, cables, and adapters in your test system. **If vast measurement improvements are possible, why do many engineers forgo this process?**

Traditional receiver calibration methods

Performing receiver calibration for your signal analyzer is traditionally complex, expensive, and time-consuming. To make matters worse, an industry-standard approach does not exist. The responsibility has fallen entirely on the user to develop a process and execute the error correction efficiently to improve the accuracy of their measurements.

To get a sense of the challenges present in these methodologies, let us analyze several approaches commonly used to compensate for the external path between the DUT and the signal analyzer:

- A calibrated vector network analyzer (VNA) characterizes the external path over frequency. The VNA then saves this as an S2P file and applies it as a correction to the measured signal analyzer data. You can apply this correction using either custom automation software or the analyzer's complex user correction feature.
- A calibrated source measures the path. In this case, you would use a power sensor to flatten the signal generator's output power over frequency. You would then apply the calibrated signal to the DUT measurement plane and measure it using a signal analyzer. The difference becomes the correction value that you apply to your DUT's measured data.

Performing traditional calibration procedures presents several challenges:

Complex

- The calibration requires multiple instruments: a VNA, analog / vector signal generator, power meter, and power sensor.
- Users need to write 100% of the code to execute the calibration.

Expensive

- Performing the calibration requires costly instruments.
- Cost increases dramatically as frequency increases.

Time-Consuming

- In addition to the instrument setup time, traditional processes require significant time to develop system software for “home-brewed” approaches to calibrate and correct measurements.
- Users need additional time to debug and verify.

In addition to what we have mentioned so far, receiver calibration using a VNA will not improve the measurement error caused by the signal analyzer’s frequency response, which can be significant when making absolute amplitude measurements. It will also not improve the signal analyzer’s intermediate frequency (IF) flatness when making modulation accuracy measurements. Finally, it does not include the effects of the mismatch between the path and the signal analyzer.

CHAPTER 2

Today's Calibration Solution

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Today's Calibration Solution

Complex, expensive solutions to vector correct your signal analyzer input have driven engineers away from calibration. Today's unique solution, the Keysight U9361 RCal receiver calibrator, can help. RCal makes receiver calibration simple, cost-effective, and fast for any Keysight X-Series signal analyzer.

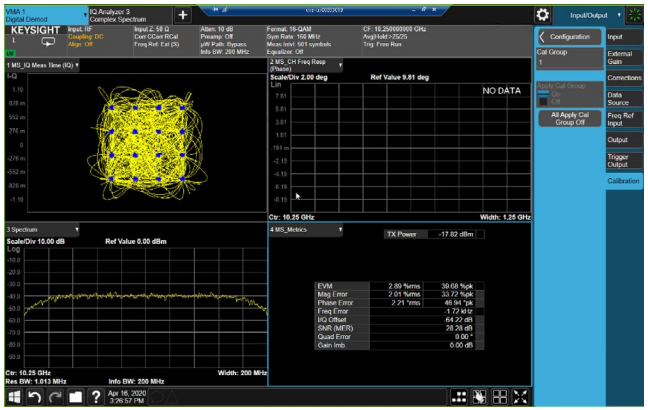
The U9361 is a compact, palm-size reference signal source that you can use to calibrate out linear impairments from the fixtures, cables, and adapters in the test receiver system. This enables you to establish a calibration plane equivalent to physically connecting the test receiver system to your DUT's output. The frequency range covers up to 110 GHz with up to 5 GHz of bandwidth, ensuring that you can calibrate on today's devices as well as tomorrow's emerging millimeter-wave applications.

The U9361 RCal receiver calibrator does the following:

- **moves the reference plane in the measurement system**, compensating for system path losses and frequency response to accurately measure transmitter characteristics at the output of your DUT
- **transfers absolute power accuracy** (dBm) to your signal analyzer — improving absolute amplitude
- **generates IF flatness corrections** (complex magnitude and phase, up to 5 GHz IF bandwidths) to help improve demodulation measurements

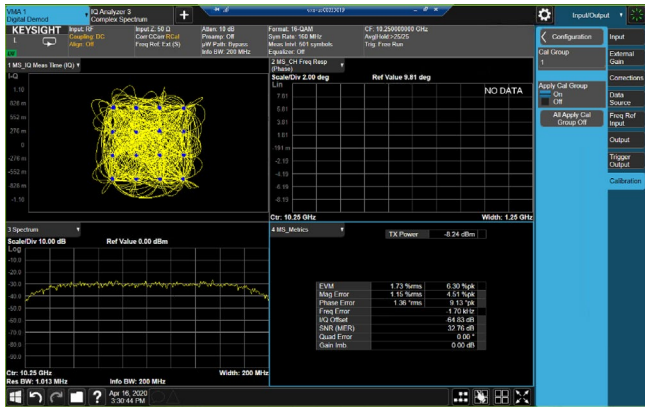
Observe the following screenshots of the vector modulation analyzer mode of a Keysight X-Series signal analyzer. They show demodulation results, including error vector magnitude (EVM) performance. For a 16QAM signal, the top screenshots show you the difference in EVM with and without RCal correction applied (2.89% versus 1.73%). In the bottom screenshots, you can see how RCal improves receiver flatness.

RCal Off



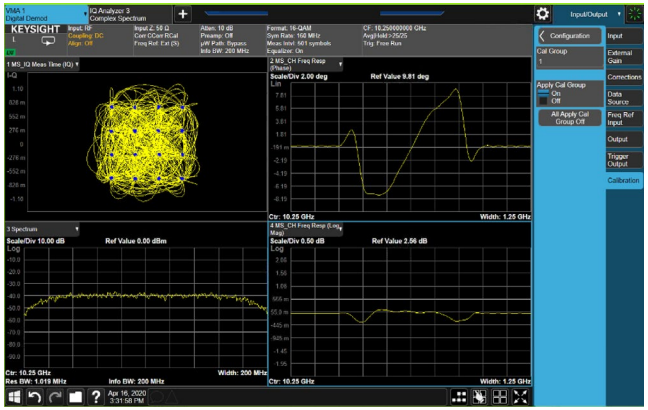
EVM = 2.89%

RCal On



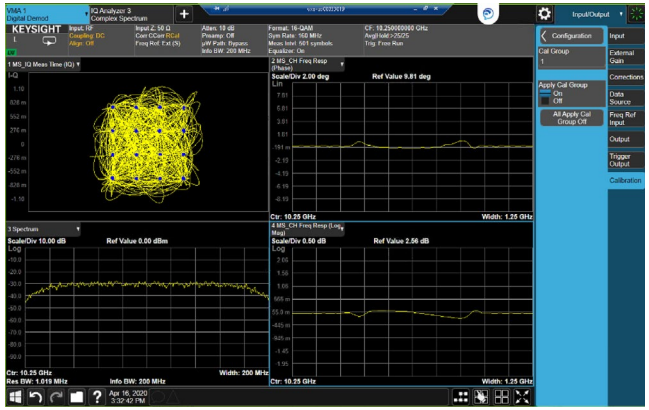
EVM = 1.73%

RCal Off

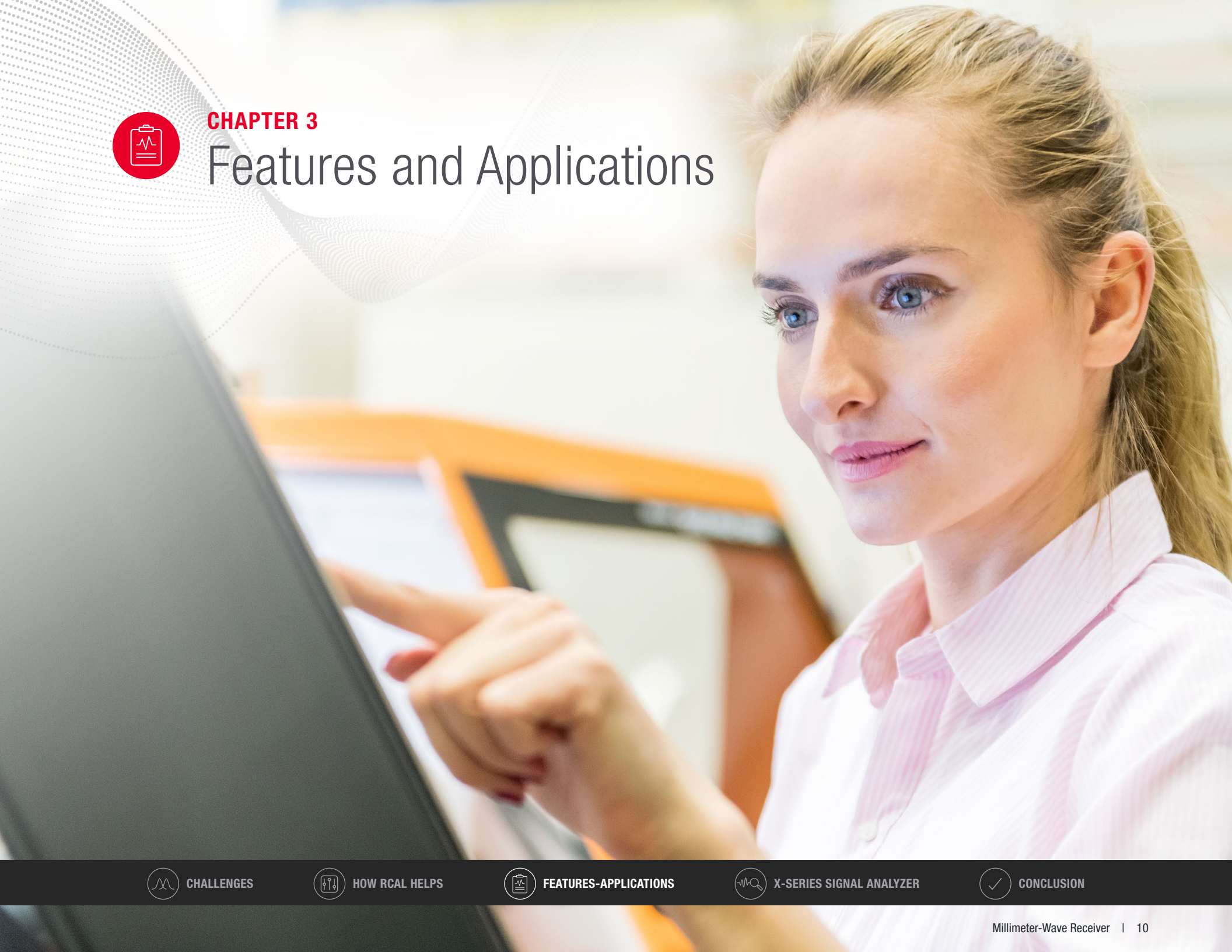


Phase = +/- 8 degrees

RCal On



Phase = +/- 0.5 degrees



CHAPTER 3

Features and Applications

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Applications

While you can apply wideband receiver calibration to numerous industries and applications, three key applications are at the forefront of this signal trend:

Wide-bandwidth applications > 100 MHz

As we move to more complex modulation schemes, applications require higher bandwidths.

High-frequency applications — millimeter-wave

With the proliferation of satellites, radar systems, and communication networks, demand for higher frequencies and data rates soars.

Complex measurement systems

Test setups include cables, switches, antennas, and adapters that introduce errors into the system.

Benefits of the U9361 RCal receiver calibrator include:

- the industry's first traceable receiver calibration standard
- helps you improve your test Rx system accuracy by an order of magnitude
- lets you seamlessly move the reference plane to the output of your DUT with an easy-to-use command structure and automation
- models up to 110 GHz
- compact, palm size, and USB-powered and controlled
- ultra-stable and repeatable, with precision factory calibration data inside
- provides magnitude and phase corrections with tunable, BPSK comb modulation
- has a US patent for BPSK modulation calibrator

Improve your test Rx system accuracy by an order of magnitude.

CHAPTER 4

Keysight's X-Series Signal Analyzer Portfolio

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Keysight's X-Series Signal Analyzer Portfolio

The U9361 RCal receiver calibrator works with the following Keysight X-Series signal analyzers.

Model	N9010B EXA	N9020 / 21B MXA	N9030B PXA	N9040B UXA	N9041B UXA	N9042B UXA
						
Maximum frequency	44 GHz	50 GHz	50 GHz	50 GHz	110 GHz	110 GHz
Maximum analysis bandwidth	40 MHz	160 / 510 MHz	510 MHz	1 GHz	1 GHz / 5 GHz	4 GHz / 11 GHz
DANL @ 1 GHz	-172 dBm	-172 dBm	-174 dBm	-174 dBm	-172 dBm	-174 dBm
Phase noise @ 1 GHz (10 kHz offset)	-109 dBc/Hz	-114 / -129 dBc/Hz	-136 dBc/Hz	-135 dBc/Hz	-135 dBc/Hz	-135 dBc/Hz
	MORE INFO	MORE INFO MORE INFO	MORE INFO	MORE INFO	MORE INFO	MORE INFO

CONCLUSION

Reach New Levels of Accuracy

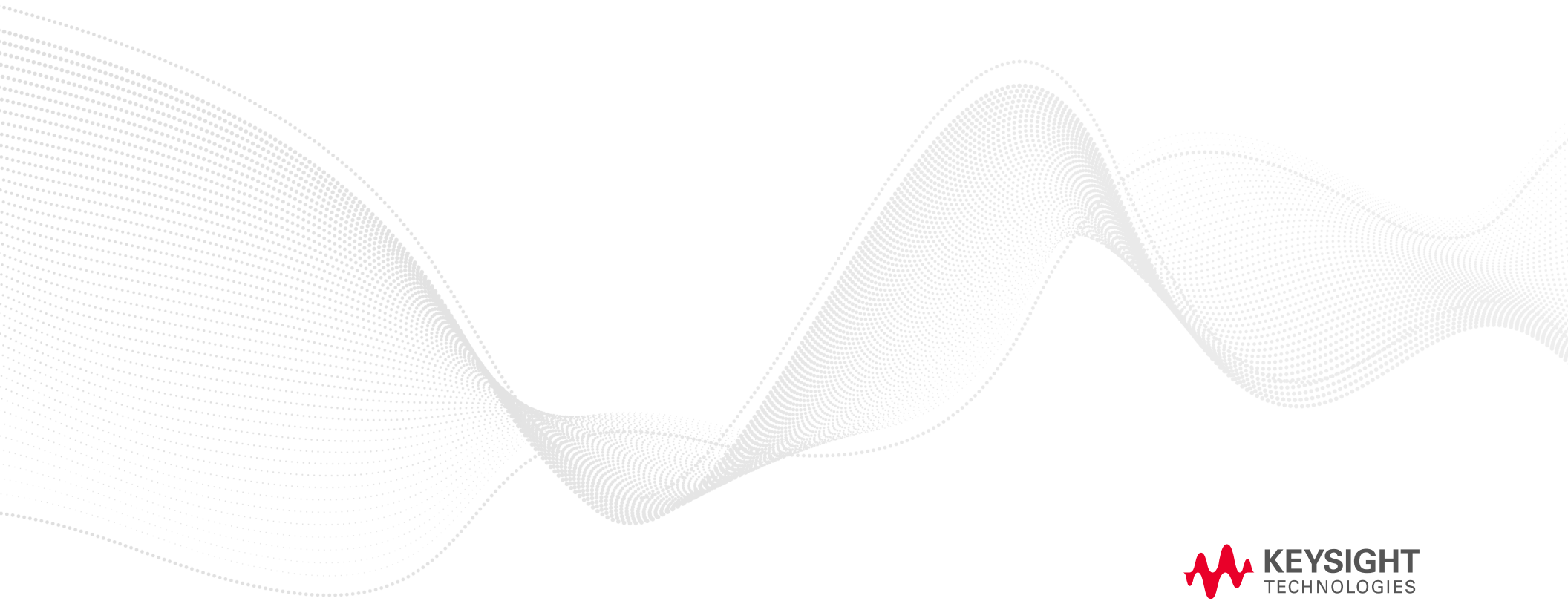
With an easier, less expensive, and faster option available, calibrating your receiver measurement path is no longer a daunting task. The standard approach used to include expensive setups, forced you to write automation code, and manage complex methodologies. Today's solution eliminates the hassle along with errors. With the U9361 RCal, the instrument handles everything for you.

Incorporating a receiver calibration module into your signal analyzer measurement setup can improve your test Rx system accuracy by an order of magnitude.

FOR MORE INFORMATION

For more insights on the U9361 RCal Receiver Calibrator, see the following resources:

- **Website**
- **Technical Overview**



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