

# RF AMPLIFIER TESTING – FROM WAFER TO DESIGN-IN

We help you reach your target:

- ▶ Improve efficiency
- ▶ Ensure RF performance
- ▶ Increase throughput

**ROHDE & SCHWARZ**

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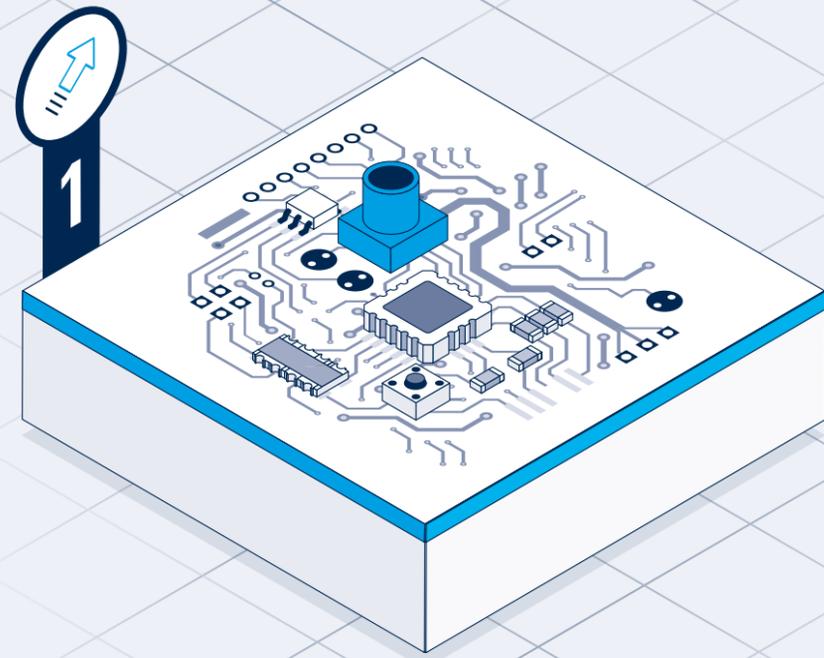


# YOUR CHALLENGE ...

The design must be verified – from the first development sample to final production. High throughput without any compromise to RF specifications is crucial in automated testing.

The requirements define the basic design parameters for an RF power amplifier in terms of frequency coverage, bandwidth, linearity and output power of the power transistor and the power amplifier. The true differentiators between solutions are energy efficiency, heat dissipation and footprint.

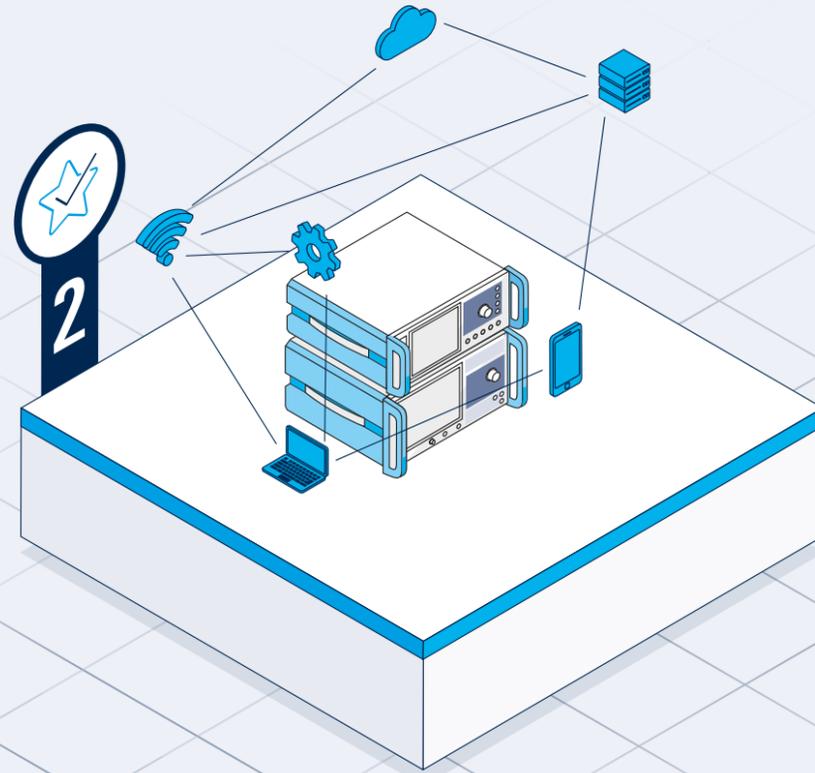
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## 1. Improve efficiency

### Design

To streamline the process from electronic design to real hardware, we are collaborating with Cadence. Checking compliance with design targets for frequency behavior, linearity and output power on the real device is an important step. This is followed by optimizing performance and efficiency, which is also vital for amplifier manufacturers.



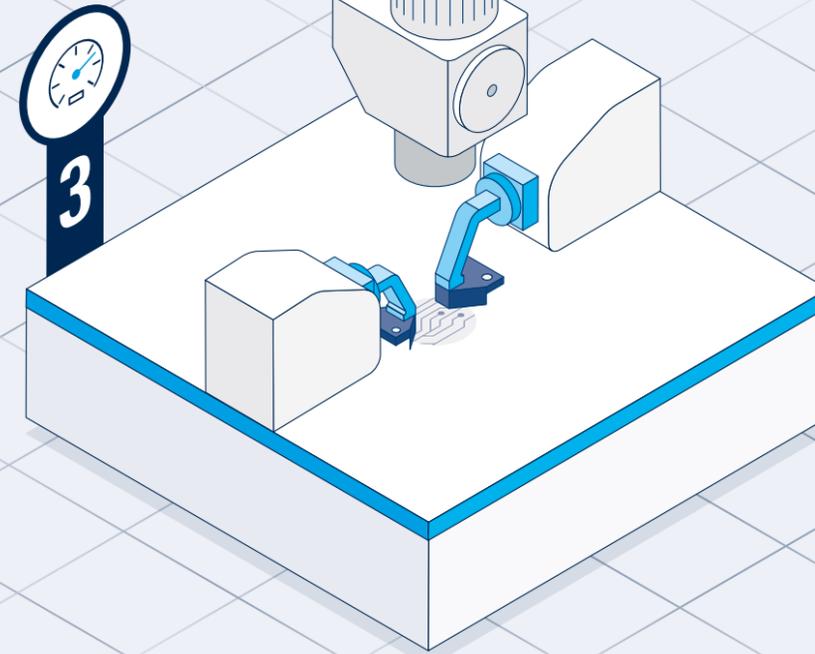
## 2. Ensure RF performance

### Quality lab

In the quality lab, designs are tested under real-world conditions to ensure reliable operation.

### Integration of RF amplifiers into the target design

Once the product hits the market, users will design the amplifier into a larger system or a module such as an RF frontend (RFFE) for mobile devices. In highly integrated systems, it may not be possible to connect to the module for testing since its antenna is fully integrated.



## 3. Increase throughput

### Characterization

Before a new product goes to market, its specifications need to be verified. Extensive testing is performed on a series of devices to determine the product's behavior under various conditions.

### Production: on-wafer testing

On-wafer testing is performed to verify that the wafer run was successful.

### Production: final test after assembly

Packaging has a significant effect on the RF characteristics. Final RF tests such as harmonic distortion, EVM and ACLR are therefore performed after packaging. These tests call for repeatability and speed.

# BENEFIT FROM 85 YEARS OF EXPERIENCE

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Our wide range of T&M instruments and solutions, including oscilloscopes, spectrum analyzers, signal generators, vector network analyzers, power meters and power supplies, are the result of our technological passion and high-quality engineering in development and production. Combined with strong customer commitment, this is our inspiration and motivation for industry-leading solutions and expertise in digital, analog and RF design.

Rohde & Schwarz offers a large portfolio of solutions for electronic and RF design. The company has more than 70 subsidiaries with highly specialized engineers and representatives around the world, providing local support and service worldwide.

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# 1. IMPROVE EFFICIENCY

While the target application dictates the RF requirements, efficiency and cost are the main differentiating factors for RF power amplifier solutions. Various techniques can be used to improve efficiency, e.g. technologies such as GaN with increased energy density. Envelope tracking and digital predistortion (DPD) extend the linear range of amplifiers. Classic multipath structures such as Doherty and outphasing amplifiers are experiencing a comeback in current designs because amplification of two separate components allows the signal to be reconstructed in a different and potentially more efficient way.

## One setup, many possibilities

The R&S®SMW200A vector signal generator together with the R&S®FSW signal and spectrum analyzer form a flexible and powerful test solution for RF amplifiers. The dedicated R&S®FSW K18 amplifier measurement application provides a complete test environment from one GUI since it fully controls the signal generator. It evaluates all important parameters in a single measurement run: EVM and ACLR, linearity with AM/AM, AM/PM, and gain compression as well as power added efficiency (PAE).

For envelope tracking, the R&S®SMW200A vector signal generator internally creates the envelope signal on the fly for any test scenario, simplifying test preparation. Equalization is used to optimize ET tracker performance based on the measurement in the analyzer and applied in realtime in the signal generator.

The solution allows two DPD modes. The realtime polynomial approach is ideal for mobile devices. Direct DPD provides ideal predistortion, including memory effect, by correcting the signal on a sample-by-sample basis.

A memory polynomial DPD model with user defined complexity as well as a Hammerstein model can be derived based on the Direct DPD result for implementation in a real-time system.

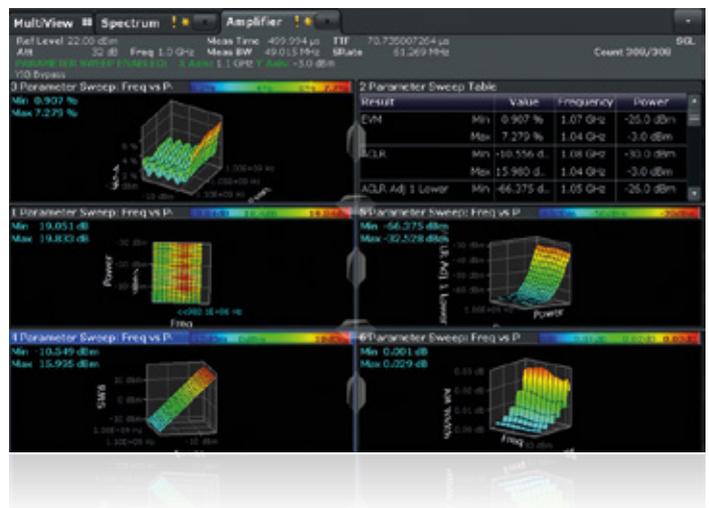
Parameter sweeps are ideal for larger test campaigns over frequency and level, collecting data in one run. The unique two-path concept of the R&S®SMW200A, with two fully integrated, yet independent baseband and RF sections, is perfect for testing multipath designs such as Doherty and outphasing amplifiers with fixed and settable phase relationships.

## The solution offers:

- ▶ Frequency coverage up to 67 GHz for all important 5G bands plus conversion to D-band for 6G research
- ▶ Wide signal bandwidth up to 4 GHz covering modern wideband signals
- ▶ Simultaneous evaluation of multiple inputs for PAE simplifies the test setup
- ▶ Display of all results on one large screen provides a quick overview
- ▶ Realtime envelope tracking and DPD
- ▶ Built-in signal generation and analysis for all advanced standards, including 5G, to shorten the preparation time
- ▶ Fully integrated and remote programmable test environment for easy automation

Various test functions paired with high dynamic range. The R&S®SMW200A vector signal generator and the R&S®FSW signal and spectrum analyzer cover all needs to verify and characterize your DUT.

All results delivered by the amplifier measurement application (R&S®FSW K18) at a glance.



# 2. ENSURE RF PERFORMANCE

When designing and using an RF power amplifier in a dedicated application such as a 5G base station, the system requirements for RF performance concerning EVM, ACLR, linear, harmonics and output power are given. However, compliance with system requirements needs to be ensured.

Rohde&Schwarz offers the right tools with the capabilities to do so in an easy and efficient way. 5G extends the frequency range into the mmWave region, focusing on the 28 GHz and 39 GHz bands. The R&S®SMW200A vector signal generator and the R&S®FSW signal and spectrum analyzer extend the frequency range coverage while maintaining ease of use and highest signal purity. This also applies to the covered signal bandwidth. With both instruments offering up to 4 GHz bandwidth, the combined solution is perfectly prepared for the 5G bands. 5G FR1 up to 7.125 GHz bands, the signal bandwidths will be smaller, but DPD demands coverage of multiples of the signal bandwidth, where the up to 4 GHz bandwidth again comes in handy.

Realtime deembedding as offered on the R&S®SMW200A vector signal generator and the R&S®FSW signal and spectrum analyzer makes it possible to compensate for the effects of connecting and cabling between the test equipment and the DUT.

The impedance network around the amplifier is designed using network analyzers such as the R&S®ZNB. To test the effect caused by varying loads, load pull systems are deployed. Rohde&Schwarz works with industry partners Focus Microwaves and Maury Microwave to offer a complete load pull system around the network analyzer R&S®ZNA.

## Quality testing

To make sure the RF amplifier remains stable under stress conditions and has a long lifetime, the RF performance is verified while the device is driven up to and beyond maximum input power. The operating mode of the R&S®BBA130 broadband amplifier can be tuned for maximum flexibility and linearity. The compact R&S®SAM100 extends the frequency range in the amplifier portfolio.

## Design-in

Once the RF amplifier is integrated into an RF frontend module, for example, performance verification is needed. Especially in 5G, integration can be very complex. Tests need to be performed over the air (OTA) since the antennas might also be integrated. Rohde&Schwarz is the only T&M vendor who is backed by extensive expertise in antenna testing and can offer complete turnkey solutions, including variation of ambient temperature for the DUT inside the test chamber.

Vector-receiver load pull application



OTA testing made easy for 5G modules and more. Simply carry out RF performance tests on a frontend module with amplifier and integrated antenna reusing the R&S®SMW200A vector signal generator and the R&S®FSW signal and spectrum analyzer together with the R&S®ATS1000 antenna test system.



# 3. INCREASE THROUGHPUT

## On-wafer testing for production

The earlier testing can qualify a device, the less it will cost if something does not function as planned. Testing starts at the wafer level by verifying either the device structure itself or a dedicated test structure on the same wafer for simplified testing.

Key characteristics include impedance and isolation. Network analyzers cover these quickly using S parameter measurements. True multipath solutions such as the R&S®ZNBT vector network analyzer allow parallel multisite testing. The network analyzer also provides amplifier tests such as gain transfer, and other RF tests such as group delay, since it is a complete test system by itself.

To connect to the wafer, Rohde&Schwarz partners with MPI Corporation for their wafer probers. Appropriate calibration techniques ensure accurate results. A dedicated calibration substrate or on-wafer calibration standards allow deembedding during on-wafer calibration.

## Comprehensive testing for characterization and production

For characterization, full testing is performed to verify designs and first samples against target specifications. Since a large volume of data is collected, speed is an essential requirement. Ideally, the test setup is comparable to and correlated to the production test solution.

In production, RF testing takes place after the RF amplifier is assembled and housed. It is critical to minimize the cost per device and therefore the total test time. Rohde&Schwarz offers the R&S®PVT360A optimized for speed and throughput.

The compact yet fully integrated R&S®PVT360A offers two transceivers, so two pairs of vector signal generators and analyzers for parallel testing. Thanks to the 16 RF ports, which can act as transmit, receive or duplex ports, many devices can be connected for faster tests minimizing handling needs. The internal synchronization and execution engine enables fastest test runs through different tests points without external control.

The wireless manufacturing test (WMT) service helps to implement test plans from paper to action. It ensures most efficient instrument usage, and allows to control the test device putting it into the right condition for each test. The service provides the flexibility needed for test automation in characterization and verification while enabling highest throughput for production.

Completing the on-wafer test solution with the cost-effective MPI Corporation probe system.



Maximized speed, minimized effort. The R&S®PVT360A performance vector tester integrates 2 transceivers for parallel testing. The internal switch matrix connects to multiple test devices. All powered by an integrated test sequence control enables fastest production runs with maximizes throughput.



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