# Generating and Applying High-Power Output Signals

## Design and application of the Agilent E8257D PSG signal generator with Option 521

In RF testing, an essential attribute of every signal generator is the maximum output power it can supply to a device under test (DUT). To ensure valid measurement results, it must be capable of maintaining spectral purity and level accuracy while delivering output power of +25 dBm or more. Delivering a pure, accurate signal at those levels not only ensures improved measurement accuracy but also enables testing with greater dynamic range and at extreme or unusual operating conditions.

The Agilent E8257D PSG analog signal generator delivers those capabilities when equipped with its ultra-high output power option (Option 521, 10 MHz to 20 GHz). In that configuration, the PSG ensures measurement accuracy by addressing three key areas: spectral purity, impedance matching and automatic level control (ALC). ALC in particular plays a key role in correcting for mismatches and frequency-response variations, ensuring level accuracy that provides meaningful test results.

This application note describes both the inner workings of the PSG with Option 521 and the applications of its high-power output signals. With Option 521 installed, the PSG can help you simplify the testing of high-power amplifiers, overcome losses within automated test equipment (ATE) systems, and address the attenuation of signals within long cable runs. Ultimately, the benefits of using the PSG with Option 521 include reduced cost, size and weight of the resulting test configuration or test system.

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# Creating a better high-power signal generator

The Agilent E8257D PSG is a fully synthesized signal generator with high output power, low phase noise and optional ramp sweep capability. When equipped with Option 521, it can produce output power of greater than +30 dBm (typical) up to 14 GHz and greater than +27 dBm (typical) up to 20 GHz. The internal design of the PSG ensures the delivery of spectrally pure signals with stable level accuracy at high output levels.

## Designing for spectral purity

In any signal generator design, the levels of the harmonics present in the output signal are a function of the actual output power. The lower the output power, the lower the harmonics; the higher the output power, the higher the harmonics.

One possible solution is to add filters that reduce harmonics across specific frequency ranges. In the PSG, for example, Option 521 includes selectable harmonic filters for carrier signals below 2 GHz. This reduces the level of harmonics, but at the expense of a lower maximum output level.

Within the signal generator block diagram, the placement of the filters affects the tradeoff between harmonic rejection and maximum output power. In the PSG block diagram **(Figure 1)** the harmonic filters are placed at the input of the high-power amplifier stage. This is the appropriate choice when higher output power is the main goal; however, the level of the harmonic components will be higher than if the filtering was performed closer to the output of the power amp.
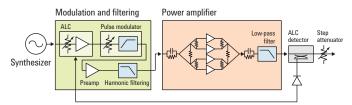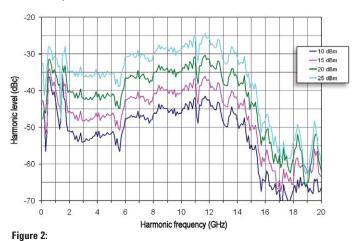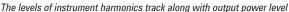


**Figure 1:**
*Inside the PSG, filtering attenuates harmonic signals at the input of the power amplifier*
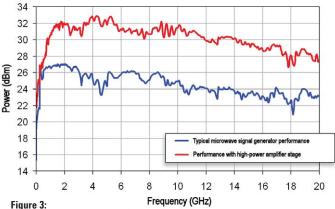
Adding a high-power amplifier to the signal generator introduces another tradeoff in spectral purity: it affects the instrument's broadband noise floor. This will appear as several decibels of additional phase noise at offsets greater than 1 MHz from the carrier frequency. Adding the amplifier will also affect spurious response, though not necessarily in terms of higher levels. Instead, the spurs may shrink due to changes in gain flatness or shift up or down in frequency due to impedance changes that affect the time constants within the various subcircuits.

As shown in **Figure 2,** the harmonic performance is relatively consistent at different power levels.



**Figure 2:**
*The levels of instrument harmonics track along with output power level*

## Ensuring accurate impedance matching

One key challenge in the design of the power amplifier stage of Option 521 was ensuring proper impedance matches at two critical points: between the output of the preamp-and-filtering stage and the input of the power amp; and between the power amp output and the input of the ALC detector and step attenuator. As shown in **Figure 3,** impedance mismatches with the power amplifier can cause output power to roll off rather significantly at low frequencies.



**Figure 3:**
*As shown by the upper trace, impedance mismatches associated with the addition of an internal power amplifier can have a negative effect on output power performance (notice low-frequency rolloff)*

Matching issues often arise due to the structure of the combining network for the multiple amplifiers that comprise a power amp. There are two ways to mitigate these problems. One is to use parallel RC circuits at the input and output of the power amplifier to create closer impedance matches (refer back to Figure 1). The other is to amend the combiner network (also called a Wilkinson combiner or divider) with additional segments that accommodate the long wavelengths of lower frequencies. Because both approaches cause losses in the RF path, they must be applied with care.

## Enhancing ALC and level controlt

Within the PSG signal generator the ALC system continuously monitors and controls the average output level of the carrier signal. The goal of the ALC is to hold the output power constant by countering the effects of circuit drift caused by temperature variation with time.

As shown in **Figure 4,** a coupler and detector are used to sense the RF power at the amplifier output before the signal reaches the step attenuator. The detected power level is fed back to the ALC system to control its modulator. By changing the gain of the RF path in real time, this feedback loop adjusts the ALC modulator to retain a precisely controlled output level.
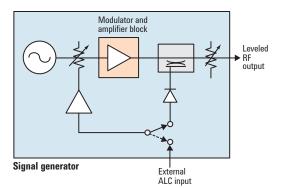


**Figure 4:**
*This simplified block diagram illustrates the structure of the PSG's ALC feedback system*

## Optimizing level accuracy

The ability to achieve precise level accuracy depends on leveling techniques that correct for mismatches and frequency-response variations. The two most commonly used methods are static leveling and dynamic leveling. Static leveling is performed prior to a measurement while dynamic leveling is performed during a measurement.

Static leveling relies on an array of user-created calibration factors that ensure the delivery of flat power at an interface beyond the signal generator's RF output connector. The calibration array can be generated by an Agilent power meter under the control of the PSG signal generator. The two instruments step through a list of user-defined key frequencies, generating and measuring the associated power levels. The PSG will interpolate the required power-offset values for frequencies between measured points, enabling flat output power levels across the signal generator's  frequency range.

Dynamic leveling corrects for impedance mismatches by using an external detector that provides a DC feedback signal to the PSG's external ALC input (Figure 4). This approach makes it possible to level the PSG's output power based on a signal that is farther downstream from its RF output. The PSG provides adjustments to optimize inputs from diode-based detectors.

In general, external dynamic leveling uses either a power meter or a crystal-diode detector. The key difference is a tradeoff between speed and accuracy: The power meter-based approach is often more accurate while the diode-based approach is usually faster.

In most cases, a combination of static and dynamic leveling is the most effective approach. Working in concert, the static flatness correction removes frequency response errors, including those from the coupler and diode detector, while dynamic leveling will correct for mismatches that vary with frequency and signal level.

### Protecting the DUT

To prevent damage to unique or high-value DUTs such as satellite systems and components, the PSG with Option 521 includes a power clamp feature with a typical response time of less than 30 μs. It allows the user to set and fix the maximum allowable power levels, ranging from +15 dBm to +33 dBm (factory preset is +25 dBm).

We used a highly failsafe approach by implementing this capability in hardware rather than software: If the instrument is inadvertently reset, the hardware implementation ensures that it will not return to a state of maximum power. Linking the power clamp feature to external or internal power leveling provides additional protection.

For further protection, the clamp value can be saved in a user-defined preset and as part of a saved instrument state.
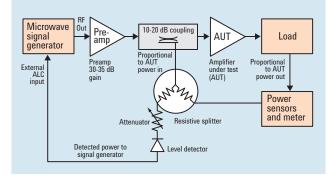
# Applying high-power signals

As shown in the following examples, the capabilities built into a PSG signal generator equipped with Option 521 can help you simplify the testing of high-power amplifiers, overcome losses within automated test equipment (ATE) systems, and address the attenuation of signals within long cable runs. In many applications, the resulting measurement configuration or test system will be smaller, lighter and less costly because you can eliminate external equipment such as preamps, couplers and detectors.

## Simplifying amplifier testing

Traveling wave tube (TWT) microwave amplifiers are a classic example: They produce more than 100 W or +50 dBm of output power and require input levels of +25 dBm or greater. Unfortunately, most of today's microwave signal generators don't provide leveled outputs with that much power. As a result, the only option is to connect the signal generator to an external microwave preamplifier and the support equipment necessary to monitor, level and calibrate the signal delivered to the TWT.

**Figure 5** shows a commonly used configuration for the testing of high-power amplifiers. The signal generator output, which is typically +10 to +23 dBm, is fed into a preamp with 30 to 35 dB of gain. The preamp can be either a broadband device or one that matches the frequency range of the amplifier under test (AUT).



**Figure 5:**
*Example configuration for testing of high-power amplifiers*

To keep the input power as flat as possible, the preamp output is fed into a leveling coupler, which provides a proportional sampling point that is fed into the external input of the signal generator's ALC. This type of dynamic mismatch correction is necessary due to the high likelihood of variation in the frequency response of the preamp. To adequately characterize the AUT gain, the coupler's output signal must have a level accuracy of at least ±0.5 dB at the amplifier input.

The amplifier drives a load that is usually water- or oil-cooled to handle the high-power output of the AUT. As with the coupler, the output of the load is proportional to the AUT output, bringing the signal into a range that is easily measured with commercial power sensors and power meters.

Unfortunately, this widely used approach has three noteworthy shortcomings: the configuration is somewhat complicated; it requires costly test accessories capable of handling high power; and its overall accuracy depends on the cumulative precision of every element within the system. Cost and complexity will increase if multiple narrowband preamps are needed to maintain proper input power across the AUT frequency range.

The PSG with Option 521 enables the simpler test configuration shown in **Figure 6.** Because the PSG with Option 521 is capable of providing +25 dBm or more of output power, then the preamp and external leveling coupler can be removed. This reduces system cost and also improves system performance.
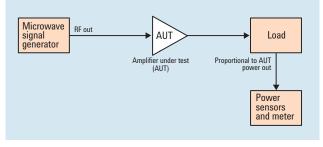


**Figure 6:**
*Simplified configuration for amplifier testing with high-power signal generator*

To maintain the desired ±0.5 dB level accuracy across the AUT frequency range, the PSG can obtain correction factors from the power meter (static leveling). For greater level accuracy, the external leveling coupler can be added to this configuration (dynamic leveling). This makes it possible to accurately measure AUT input power and enables external power leveling for the PSG **(Figure 7).** This retains some of the cost and complexity of the original configuration (Figure 5); however, it eliminates the cost of either one broadband preamp or multiple narrowband preamps.
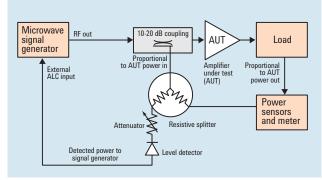


**Figure 7:**
*Simplified configuration with high-power signal generator and external dynamic leveling*

**Overcoming signal losses within an ATE system**

A typical ATE system accumulates signal-power losses throughout a variety of system elements: cabling; switches; and the passive couplers, combiners, isolators, and so on, that enable signal sharing. The availability of greater power from the PSG can overcome these losses and thereby ensure greater measurement accuracy. Extra power also makes it possible to insert filters and signal monitors, improving overall measurement quality.

The decision to include a high-power signal generator brings wide-bandwidth and relatively low-noise amplification of stimulus signals to the ATE system. Ultimately, the use of the PSG with Option 521 reduces system cost by eliminating narrowband amplifiers and the associated switching systems.

**Addressing attenuation in long cable runs**

When testing antennas or satellite subsystems the signal source may reside a significant distance from the DUT. On an antenna test range, for example, the transmit antenna may be placed on a tower that is 15 to 80 feet tall **(Figure 8).** During indoor testing, satellite subsystems may be placed into a thermal/vacuum chamber but the test system will be outside the chamber, which may be quite large. To further complicate the situation, the access ports may be far above the floor in a high-bay building.
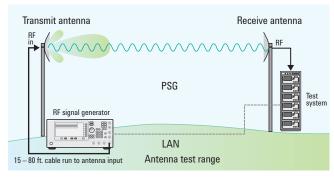


**Figure 8:**
*A high-power signal generator can overcome cable attenuation in antenna testing*

In such cases, the most common solution is to use long runs of coaxial cable; however, these cause considerable losses in RF power and, of course, the attenuation increases dramatically at higher frequencies. Although the losses can vary widely depending on cable quality, typical values for 100 feet of coax are 45 dB at 12 GHz and 70 dB at 20 GHz. One solution is the Heliax type of coaxial cable, which is inherently low loss; however, it can be difficult to work with because it is rigid and not meant for the frequent movement and reconfiguration of a typical test environment.

An alternative solution is additional amplification within the signal source. With the extra output power integrated into the source, there will be savings in cost, space and weight.

## Conclusion

The PSG with Option 521 provides multiple advantages, ranging from simplified test configurations to reduced size, weight and cost of a test system. The ability to deliver a pure, accurate signal at +30 dBm or greater can ensure improved measurement accuracy and also enable testing with wider dynamic range and at extreme or unusual operating conditions.

## Related information

Data sheet: Agilent E8257D PSG analog signal generator, publication 5989-0698EN

Data sheet: Agilent EPM Series power meters, publication 5965-6382EN

Application note: *Agilent Radar Measurements,* publication 5989-7575EN

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