How to Select an Analog Signal Generator

Primer

Today's microwave and wireless communications market is expanding at an incredible rate. Along with this growth comes an increasing need for test equipment, such as an analog signal generator, that can help verify the performance of devices and systems.

The signal generator's wide frequency range, high output power and variety of modulations make it a flexible tool for a broad scope of applications. Signal generators with a minimum frequency of 9 kHz permit applications in Electromagnetic Compatibility or EMC measurements. Frequency coverage up to 12.75 GHz covers ISM bands as well as all important mobile radio bands. Microwave signal generators may cover or support frequencies up to 20 GHz, 40 GHz and even 110 GHz.

This primer provides an overview of analog signal generators including their key specifications, modulation capabilities and applications, thus providing helpful information in determining which analog signal generator is the best fit for your application. Throughout the document we'll be referring to the R&S®SMA / SMB / SMF Signal Generators from Rohde & Schwarz to illustrate typical key specifications.

www.rohde-schwarz.us

Primer
Lawrence Wilson
4.2015 - 1.1

ROHDE&SCHWARZ

Table of Contents

1 Analog vs. Vector

One of the most important factors to determine upfront is whether an analog or vector signal generators is best for your application. Let's start with a review of the basic signal equation and its parameters:

$$u(t) = A \times \cos(2\pi f t + \theta)$$

Where: A = amplitude

f= frequency

θ = phase

In addition to traditional CW signals, analog signal generators have the ability to vary each of these parameters to create different forms of modulation such as amplitude modulation (AM), frequency modulation (FM) and phase modulation (PM). Modulation formats may also be combined, such as adding FM onto an AM signal. Vector signal generators, on the other hand, have the ability to vary two or more of these modulation types – at the same time. **Figure 1** highlights these modulation capabilities.

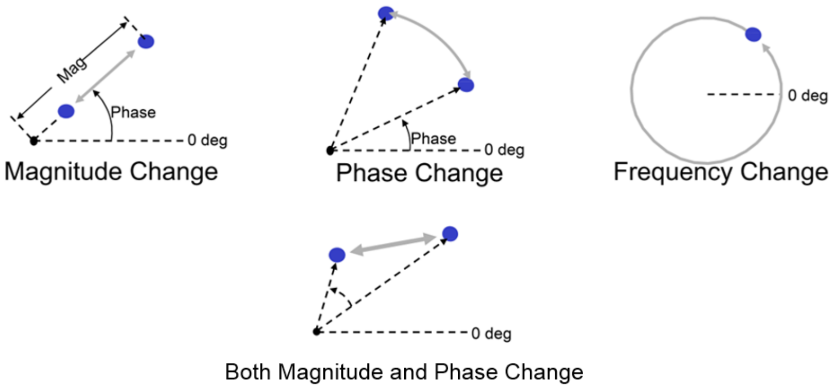


Figure 1.

Analog signal generators can modulate a signal by changing either the magnitude, phase or frequency. Vector signal generators have the ability to vary two or more modulation types at the same time.

At the highest level, the signal generator design architecture of either analog or vector products drives a few tradeoffs. **Table 1** highlights a few of the key differences between the two.

Table 1. Comparing Signal Generators

Description	Advantages	Disadvantages
Analog Signal Generator 	▪ Very good single sideband (SSB) phase noise ▪ High pulse on-off ratios ▪ Short rise and fall times ▪ Lower cost	▪ Only one single carrier per instrument ▪ Limited pulse shaping ▪ Limited to analog modulation (AM, FM, sweeps)
Vector Signal Generator 	▪ Any type of modulation and pulse shaping ▪ Arbitrary pulse trains possible ▪ Fast frequency within modulation bandwidth ▪ Large waveform memories ▪ One-box-solution	▪ Higher cost ▪ Limited on-off ratio available from I/Q modulator

2 Banner Specifications: What are they and what do they mean?

Frequency range, output power, phase noise, and harmonics are just a few of the key parameters when it comes to selecting the right analog signal generator. However, many real world measurements require focus on more than one aspect simultaneously.

This section provides an overview of many of the key signal generation specifications you will need to consider.

2.1 Definitions

Before we discuss the banner specifications it is important to provide a few definitions that will be helpful as you review test equipment data sheets to determine the best fit for your application.

In general, data sheet specifications apply under the following conditions:

- Three hours storage at ambient temperature followed by 30 minutes warm-up operation
- Specified environmental conditions met
- Recommended calibration interval adhered to
- All internal automatic adjustments performed, if applicable
- Level within specified level range

Note, when most manufacturers display typical data as well as nominal and measured values, these are not necessarily all warranted specifications.

Table 2 provides a summary of some of the common definitions together with their explanation.

Table 2. Common Data Sheet Specification Definitions	
Specifications with limits	Represent warranted product performance by means of a range of values for the specified parameter. These specifications are marked with limiting symbols such as <, ≤, >, ≥, ±, or descriptions such as maximum, limit of, minimum. Compliance is ensured by testing or is derived from the design. Test limits are narrowed by guard bands to take into account measurement uncertainties, drift and aging, if applicable.
Specifications without limits	Represent warranted product performance for the specified parameter. These specifications are not specially marked and represent values with no or negligible deviations from the given value (e.g. dimensions or resolution of a setting parameter). Compliance is ensured by design.
Typical data (typ.)	Characterizes product performance by means of representative information for the given parameter. When marked with <, > or as a range, it represents the performance met by approximately 80 % of the instruments at production time. Otherwise, it represents the mean value.
Nominal values (nom.)	Characterize product performance by means of a representative value for the given parameter (e.g. nominal impedance). In contrast to typical data, a statistical evaluation does not take place and the parameter is not tested during production.
Measured values (meas.)	Characterize expected product performance by means of measurement results gained from individual samples.
Uncertainties	Represent limits of measurement uncertainty for a given measurand. Uncertainty is defined with a coverage factor of 2 and has been calculated in line with the rules of the Guide to the Expression of Uncertainty in Measurement (GUM), taking into account environmental conditions, aging, wear and tear.

2.2 Frequency Range

When selecting a generator it is important to determine what your required maximum and minimum frequency needs are. To handle any out of band requirements, or future testing needs, be sure to select a generator that has a frequency beyond your minimum required frequency range.

Other considerations like frequency resolution which determine how precise you can set the output signal to be. For example, to meet the high requirements of many applications in research and science, a frequency resolution of one-thousandth of a hertz (0.001 Hz) is typically standard. Additionally when evaluating the performance specifications it is good to review the product data sheets as the performance often varies across the complete frequency range of the signal generator.

The following are a few frequency related options to consider when selecting your signal generator.

2.2.1 Low Frequency Extensions

The price of a signal generator is often proportional to its maximum frequency. Microwave signal generators are often purchased for applications that are primarily focused on 1 GHz and above frequencies. In order to reduce costs and optimize performance microwave signal generators may offer a minimum frequency of 1 GHz.

For applications that also require lower frequencies, options are available which extend the frequency range of the microwave signal generator to cover below 1GHz.

2.2.2 Frequency Extensions to 110 GHz

Signals in the frequency range from 50 GHz to 110 GHz are used in both the civil sector and in aerospace & defense applications. They can be used in diverse applications, e.g. in the automotive sector with distance radars, in astronomy with sophisticated telescopes and in radar interferometry for analyzing the earth's surface.

Frequencies in the range from 50 GHz to 110 GHz can be generated with a signal generator plus an external frequency multiplier or mixer. The frequency multiplier is typically defined by the waveguide bands at these frequencies: 50 GHz to 75 GHz, 60 GHz to 90 GHz, 75 GHz to 110 GHz.

Some signal generators may directly control the frequency multiplier via USB for example. This combination operates as a single unit, allowing users to enter the wanted frequency and power level at the multiplier output directly in to the signal generator. Compared with conventional setups, an integrated solution significantly simplifies setup and operation. The signal generator receives all necessary data from the multiplier such as the configuration, the multiplication factor and in particular the pre-calibrated frequency response and is able to perform an automatic correction, which ensures that the frequency and power level values will actually be correct at the output of the multiplier. Costly, error-prone and time-consuming level measurements using level detectors or power sensors, which is common for conventional setups, are not required. This makes the integrated set up easier to use and delivers more accuracy, repeatable results.

Figure 2. Frequencies from 50 GHz to 110 GHz can be generated with a signal generator plus an external frequency multiplier.

2.2.3 Highly stable output frequency

Many applications, from calibration labs to leading edge design often require a higher level of precision to evaluate other test equipment and components. While all signal generators have an integrated reference oscillator that keeps the output frequency precise and low in drift, some applications need to meet the highest of requirements in precision and aging. In these cases higher stability reference oscillators may be selected as an option to meet these more demanding requirements.

2.3 Output Power

Signal generators can be used in many applications, ranging from supplying a low level interfering signal, to delivering a high power stable reference signal. As such, the demands on the output power of the generator are wide ranging. To accommodate this generators can have output power range of -145 dB to +30 dB, with a resolution capability of 0.01 dB.

The value of the power level or RF level is usually displayed in the level field in the header of the signal generator's display. This value normally refers to the power level of the signal coming out of the front panel connector on the generator. However, in many test set ups, there are cables, attenuators/amplifiers, splitters, etc between the generator and Device Under Test (DUT). In these cases, the power level coming out of the generator is quite different from the power level actually being applied to the DUT. To simplify this, some generators can compensate for these external components and display the power level which is actually being applied to the DUT. This simplifies the use of the generator and allows the operator to enter the desired power level at the DUT, directly into the generator. Section 4.2 discusses using a signal generator and power sensor to measure the effects of external components in the test set up.

2.3.1 Higher output levels

It is important to note that the actual maximum output level from the generator may be higher than its specified output power level. Most signal generators will allow users to enter values above the maximum specified power level as there is always additional performance beyond the specifications. As you move further and further beyond the specified limit, the output amplifier stage of the generator is likely to go into compression and the actual output power may not increase at the same rate as the displayed output power which is entered by the user. Power sensors maybe used in these cases to ensure accuracy beyond the specified maximum output power level. **Figure 3** shows an example of the actual maximum output power across the frequency range of an R&S®SMF with and without the high power option.

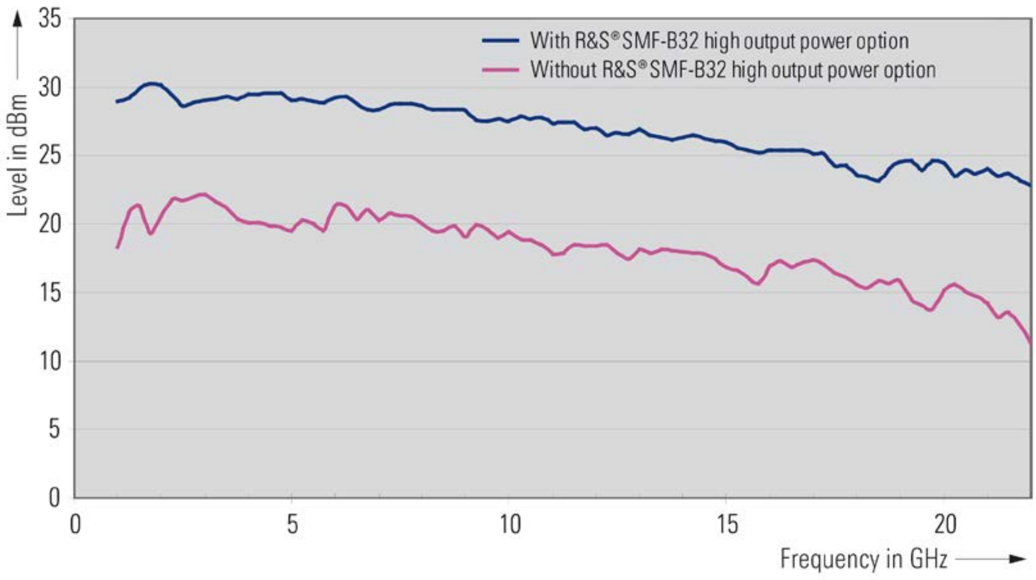


Figure 3. Actual maximum output power of a signal generator is often found in the products data sheet. Example of the R&S®SMF with and without the high output power option in the frequency range 1 GHz to 22.

Some DUTs require very high input power or drive levels. In some cases an external amplifier is required to meet this need. A high power option on the signal generator may also meet this need in many cases. The external amplifier adds complexity, hassle and may need to be calibrated with the signal generator. Using a signal generator with high enough output power removes complexity and provides a calibrated, specified solution that will deliver repeatable results.

2.3.2 Lower output levels

For high sensitivity measurements on receivers, very low power levels are needed. Signal generators include, either standard or as an option, step attenuators to allow the lower level limit to be shifted from –20 dBm without the attenuator down to around –130 dBm with attenuator.

2.3.3 Step Attenuators -- Electronic vs. Mechanical

There are typically two types of attenuators used in signal generators, electronic and mechanical. Depending on your application you may have a choice of which to use. **Table 3** highlights the advantages and disadvantages of each.

Table 3. Electronic vs. Mechanical Step Attenuators

Description	Advantages	Disadvantages
Mechanical step attenuator 	▮ High dynamic range ▮ Low temperature drift of the mechanical attenuator ▮ Low insertion loss of the mechanical step attenuator ▮ Low VSWR ▮ **Cover high microwave frequencies**	▮ Long switching time (> 20 ms) ▮ Not wear and tear free ▮ Noisy when operated (could be an issue in case of level sweeps)
Electronic step attenuator 	▮ High dynamic range ▮ Short switching time of the CMOS electronic step attenuator ▮ Wear and tear free ▮ Excellent level settling behavior of CMOS switches ▮ Additional overvoltage protection ▮ Low temperature drift due to analog temperature compensation ▮ No switching transients	▮ Not available for > 12.75 GHz ▮ Extra components (PA)

2.4 Harmonics

The harmonic and non-harmonic levels of a signal generator are specified and measured in dBc or dB relative to the carrier frequency power level. Both are unwanted frequencies generated in addition to the desired output frequency of the signal generator.

Harmonic frequencies are present at integer multiples of the signal generator output frequency. Harmonics are essentially non-harmonic frequencies that occur at the known multiples of the output frequency. Non harmonic signals appear to be random, but are not random, they are systematic of a given signal generator. Within the design of a signal generator there are a wide variety of causes for non-harmonic signals, but they are usually well defined and adhere to the specified performance.

Devices which are affected by harmonics emission from generators are, for example, wideband receivers. During blocking tests, the harmonics of the signal generator could fall into the desired band and interfere with the measurement result. Another critical application is the total harmonic distortion (THD) measurement of a power amplifier. The setup comprises a signal generator generating the input signal, the DUT and a spectrum analyzer for measuring the amplifier performance. Here, the harmonics must be low enough to ensure that the harmonic distortion of the DUT is measured and not the harmonics of the signal source. And last but not least: for scalar network analysis, good dynamic range of the overall setup is essential. Bad harmonics from the signal source will limit this, since the harmonics are unintentionally measured, too.

2.4.1 Wideband Noise

Wideband noise is the sum of wideband phase noise and wideband amplitude noise. For wideband noise, which is normally assumed for offset frequencies > 10 MHz, the amplitude- and phase-noise contribution is equal and uniformly distributed versus frequency. Therefore, the overall wideband noise is normally 3 dB higher than the wideband phase noise.

Both the signal generator's harmonic performance and wideband noise floor will vary somewhat versus the set output frequency and level. The wideband noise performance can be optimized by increasing the level at the RF output stage, which will then degrade the harmonic performance of the signal generator.

When selecting a signal generator, the following factors must be taken into account:

- The generator's non-harmonic distortion products should be far below the distortion products of the DUT.
- Since the demands placed on a signal source may become higher in future challenges, the performance of a generator should ideally already have enough margin to meet these future requirements.

2.4.2 Harmonic filtering

Some signal generators offer optional internal low harmonic filters to further lower their harmonics. The low harmonic filter generally improves measurement accuracy in the entire setup for the specified filter frequencies.

2.5 Phase Noise

In the frequency domain, an ideal carrier would appear as an infinite small thin line. The typical carrier signal however, will have skirts whose amplitudes generally follow (1/f) distribution **(Figure 4).** These skirts are the envelope of side bands due to modulations of the carrier and are both FM and AM in nature, random in frequency and amplitude. This is caused by various phenomena relating to the physics of the particular oscillator. We specify phase noise as single sideband (SSB) power in relation to the fundamental RF output frequency measured at various offset frequencies from the carrier, normalized to a one hertz measuring bandwidth.

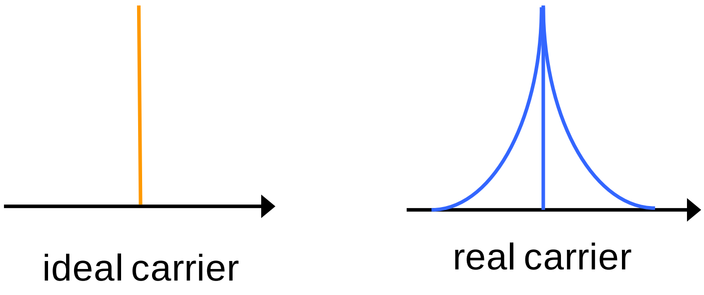


Figure 4. An ideal carrier would have no phase noise, however a typical carrier will have skirts whose amplitudes generally follow (1 / f) distribution.

Designers care about phase noise because it influences the signal quality. As shown, in the frequency domain phase noise appears as noise sidebands on the carrier. In the time domain, phase noise is exhibited as a jitter in the zero crossings of a sine wave.

Accurate understanding of phase noise performance is essential for getting reliable results when testing receivers and transmitters. But – substantial for some applications – the SSB phase noise is not only determined by a specific offset at 10 kHz. For small offsets, the SSB phase noise becomes worse, whereas for bigger offsets the phase noise is lower and reaches the broadband noise floor for offsets more than several megahertz. Several signal generators offer options to improve the SSB phase noise which provides an even cleaner signal for improved performance.

For low phase noise measurements a clean signal source is required. Normally, the performance of the signal source must show a considerable margin in order not to introduce additional errors from SSB phase noise, harmonics, non-harmonics and wideband noise into the measurement.

2.5.1 Effect in Frequency Multiplier Application

When frequency multiplication is employed to achieve the required output frequency, the phase noise of the output signal increases by 20 log (multiplication factor). This results in noise degradation of approximately 6 dB for frequency doubling, 10 dB for frequency tripling and 20 dB for decade multiplication.

For example, the R&S®SMF100A offers -75 dBc for 5 GHz and 30 Hz offset. When a carrier frequency of 80 GHz is needed, one can externally multiply it with 16. In this case, the phase noise becomes worse by 24 dB **(Figure 5)**.

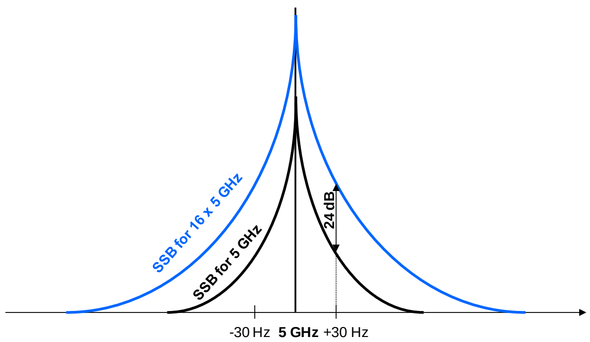


Figure 5. An application that multiples a 5 GHz signal up to 80 GHz increases the phase noise by 24 dB.

2.6 Frequency Setting Time

Frequency setting time is the amount of time it takes for a signal generator to stabilize at a given frequency for an accurate measurement. In a production test environment the speed at which a product can be tested may depend on the required number of test frequencies to accurately characterize the device or system under test. Typically the frequency setting times maybe a handful of milliseconds.

There are a few techniques available for reducing the frequency setting time and thus overall throughput. The most common is known as list mode. In list mode extremely fast frequency and level settings can be made. The signal generator typically provides a user-friendly editor for defining lists, which contain frequency and level value pairs and if required user-defined level corrections. The lists are saved to files and may thus have any length. The file name of the lists and the directory to which the files are saved are user-selectable. In order to further increase speed, in list mode neither the current frequency nor level is displayed, the display is dimmed and the combined result is that frequency setting times may be reduced several hundred microseconds. Another major advantage in list modes is that frequency and linearity errors can be eliminated via the user-defined corrections.

2.7 Level Setting Time

Level setting time is the amount of time it takes for a signal generator to stabilize at a given output power level for an accurate measurement. Typically the level setting times maybe just a couple milliseconds.

2.8 Level accuracy and repeatability

Precise and stable output levels are essential in a signal generator. It is important that the signal generator has the ability to operate over a wide range of power settings with very low errors in the desired output power level **(Figure 6)**. It is important to understand how the level accuracy varies at different power levels, as well as, how it varies at different output frequencies. In addition, production environments require not only level accuracy, but also repeatability over time as well **(Figure 7)**.

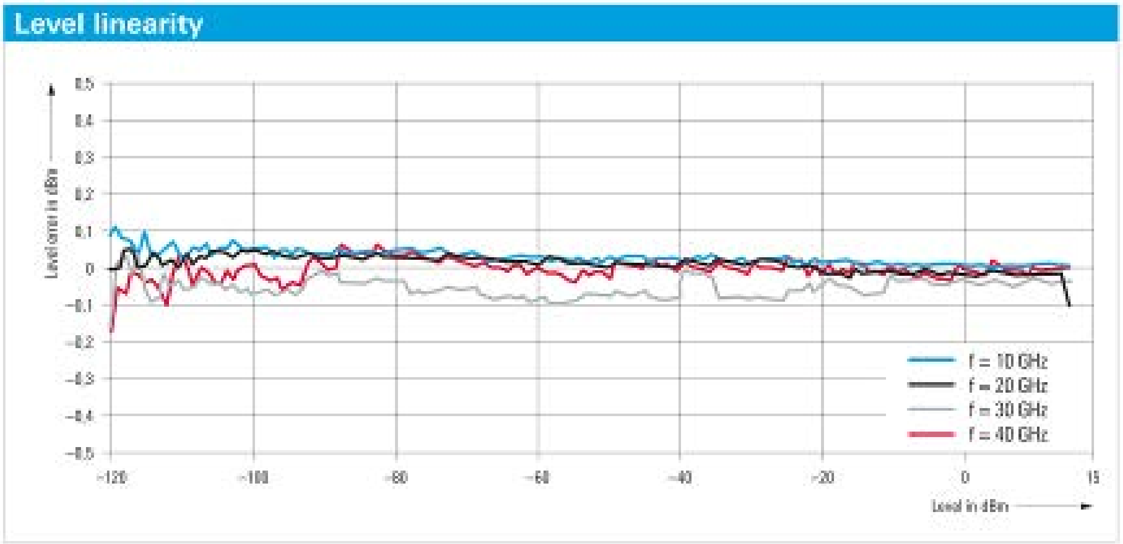


Figure 6. Signal linearity becomes an important specification to watch as the power level and frequency changes.

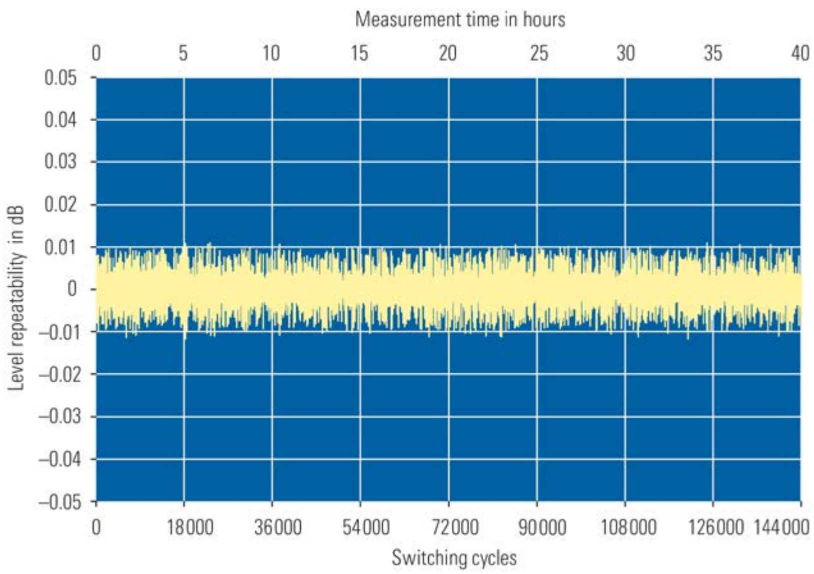


Figure 7. Level repeatability over time (with random frequency and level changes between measurements)

3 Modulation

Analog al generators typically provide the following types of modulation: amplitude, frequency, phase, pulse and chirp. In addition, the RF signal can also normally be modulated with a wide variety of internal sources, e.g. sine waves, triangle/rectangular/trapeze waveforms, and noise. In some cases specific test signals for specific applications can be also be generated such as VOR (VHF Omnidirectional Range), ILS-GS (Instrument Landing System - Glide Slope), ILS-LOC (Instrument Landing System -Localizer) and Marker Beacon).

Table 4. Simultaneous Operation of Several Modulations or Other Operating Modes

	AM	FM	dig FM	PhiM	dig PhiM	Pulse	VOR	ILS	MB	ADF	DME
Amplitude modulation (AM)	/	+	+	+	+	-	-	-	-	-	-
Frequency modulation (FM)	+	/	-	-	-	+	+	+	+	+	+
Digital Frequency modulation (FM)	+	-	/	-	+	+	+	+	+	+	+
Phase modulation (PHiM)	+	-	-	/	+	+	+	+	+	+	+
Digital Phase modulation (PhiM)	+	-	-	-	/	-	-	-	-	-	-
Pulse modulation	-	+	+	+	+	/	-	-	-	-	-
VOR modulation	-	+	+	-	+	-	/	-	-	-	-
ILS modulation	-	+	+	-	+	-	-	/	-	-	-
Marker Beacon modulation (MB)	-	+	+	-	+	-	-	-	/	-	-
ADF modulation	-	+	+	-	+	-	-	-	-	/	-
DME modulation	-	+	+	-	+	-	-	-	-	-	/

** The table shows the modulations and operating modes which can be activated simultaneously (+) or which deactivate each other (-).*

3.1 AM/FM/PM

Amplitude modulation (AM) can be achieved either through an internal or external source. R&S®SMA signal generators for example have two LF modulation generators and a noise generator available as the internal source. Two-tone AM and FM is possible by simultaneously switching on the external and internal or both internal sources. For frequency and phase modulation the generator has to be equipment with a FM/PhiM Modulator. Similar to the AM described above, an internal and/or external source can be selected.

3.2 Pulse Generation

Pulsed signals are frequently required in aerospace and defense applications to test radar systems. In the past an external pulse generator was often required to supply the RF generator with a pulse that could be used to modulate the RF signal. Today, signal generators can be equipped with an integrated pulse modulator option and a pulse generator option. This offers the ideal solution as it makes high quality pulse modulation possible in a single box solution. However, today's signal generators can still use external pulses to modulate the RF which is useful when, for example, the test requires that the pulsed RF signal be synchronized to part of a larger test system.

3.3 Pulse Modulation

Similar to amplitude modulation an internal or external source can be selected for pulse modulation. In case of the external source, the external signal is input via a connector at the rear of the instrument. R&S signal generators offer a pulse generator option for internal modulation which enables extended features, e.g. generation of single or double pulse.

3.4 Pulse Trains, Sequencing

Pulse trains are commonly utilized in radar systems to help identify the intended target and to reduce noise and other interference. Some signal generators offer an optional feature to expand their pulse generation capabilities to include the generation of pulse trains. An example of a pulse train is shown in **Figure 8**. In contrast to a single or double pulse, a pulse train is a combination of different pulses, which can be a periodical or non-periodical set of pulses. Pulse width, ON/OFF can be set independently and separately for each pulse. This makes it possible to generate staggered pulses, vary pulse width and simulate "missing" pulses.

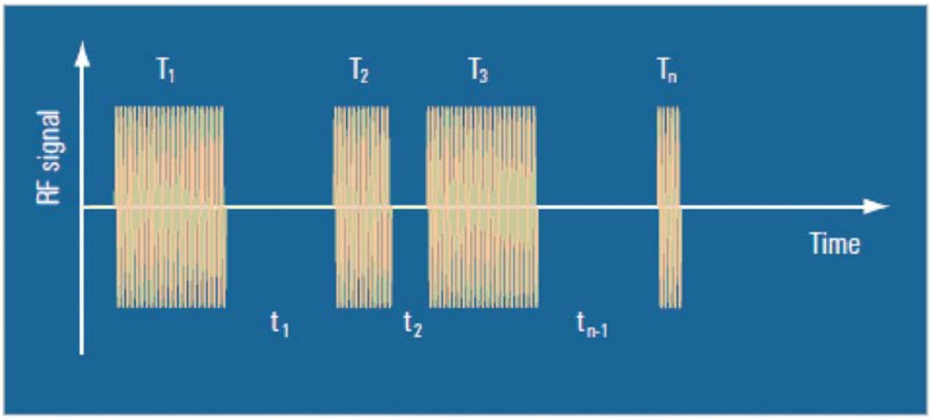


Figure 8. Pulse trains are combinations of pulses with different pulse widths and pulse pauses.

3.5 Chirp Modulation

Chirp modulation is a useful radar technique to achieve pulse compression. Pulse compression increases the sensitivity and resolution of radar systems by modifying transmitted pulses to improve their auto-correlation properties. To chirp the radar signal is one way of accomplishing this. A chirp is a signal in which the frequency increases or decreases over time.

R&S signal generators use chirp modulation together with pulse modulation. The modulation signals for FM and Pulse modulator are generated and synchronized internally. The internal pulse generator is used as the modulation source for the pulse modulator and the internal LF generator as source for the frequency modulation. Normal FM mode is used.

3.6 VOR Modulation

VOR systems (VHF Omnidirectional Range) provide directional information for air planes in flight. The VOR stations transmit a carrier which is modulated with two separate 30 Hz modulations. One of the 30 Hz signals (Reference signal) remains in the same phase at all reception positions around the VOR station. The other 30 Hz signal received (Variable signal) will differ in phase by exactly the angular displacement of the receiver around the VOR from the Zero radial. The aircraft receiver demodulates the two 30 Hz signals and compares their phase difference.

R&S signal generators provide four different modes for the VOR test signal:

- Norm - VOR modulation + optional COM/ID tone
- VAR - Amplitude modulation of the output signal with the 30 Hz signal content of the VOR signal
- Subcarrier - Amplitude modulation of the output signal with the unmodulated 9960 Hz FM carrier of the VOR signal
- Subcarrier + FM - Amplitude modulation of the output signal with the frequency-modulated 9960 Hz FM carrier of the VOR signal

3.7 ILS-GS Modulation

ILS-GS modulation (Instrument Landing System - Glide Slope) systems provide information relating to the position of the air plane relative to the runway during landing. The ILS-GS system indicates if the air plane is above, below or on the glide path. The carrier is modulated by a 90 Hz and a 150 Hz tone and sent to a separate directional antenna system. The antenna array is arranged so that the 90 Hz signal is stronger above of the glide path, and the 150 Hz signal is stronger below the glide path. The information on position is provided after demodulation of the signals by evaluating the difference in depth of modulation (DDM).

For R&S signal generators three different modes are offered for the ILS-GS test signal:

- Norm - Standard localizer/glideslope signal
- 90 Hz - Suppression of the 150 Hz modulation tone
- 150 Hz - Suppression of the 90 Hz modulation tone

3.8 DME Modulation

DME (Distance Measurement Equipment) is a radar system which determines the slant distance between the aircraft and the ground station **(Figure 9)**. On the aircraft, the time is measured which the radio signal takes to travel from the aircraft to the ground station and back. The aircraft is equipped with an interrogator and the ground station with a transponder.

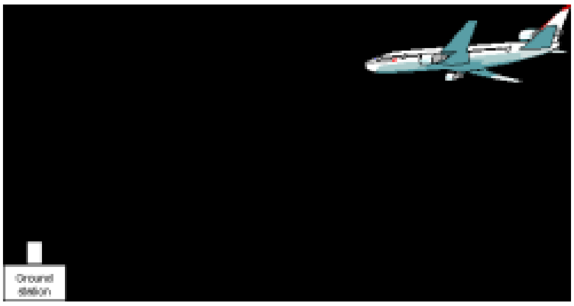


Figure 9. DME (Distance Measurement Equipment) radar systems determine the slant distance between the aircraft and the ground station.

The DME channels are paired with the VOR frequencies, they are in the range between 1025 to 1150 MHz for the interrogator and 962 and 1213 MHz for the transponder. The spacing for all channels is 1 MHz, X and Y channels differ in the spacing between the two pulses of the pulse pair and in the delay for the reply pulse. The interrogator transmits a stream of pulse pairs with fixed duration and spacing. The ground based transponder receives the pulse train and re-transmits them after a defined delay on a frequency which is +/-63MHz from the interrogation frequency. The airborne interrogator identifies its own stream of pulses and measures the time between the start of interrogation and response from the ground transponder in order to evaluate the slant distance. The distance is given in nautical miles (nm). 1 nm is 1852.01 meters and corresponds to a run time of 12.359 µs.

For R&S signal generators two different modes are offered for the DME test signal:

- DME Interrogation - pulse stream from the interrogator, X or Y channel (simulation of aircraft interrogator)
- DME Reply - reply pulses from the transponder + optional ID signal, X or Y channel (simulation of ground station)

4 Example Applications

4.1 Power Measurements

A unique feature for some signal generators is that they allow you to directly connect a power sensor to the front panel **(Figure 10)**. Basic power measurements can be performed on the instruments without the need to use an additional power meter base unit which simplifies the test set up and saves space. Since the power sensor makes all the power measurements itself the signal generator only provides the display. The sensor can be operated from the generator's front panel, USB keyboard or mouse, or via remote control.

Beyond saving bench space, the sensor can be integrated and controlled by the generator to, enable several applications, such as

- Power analysis – measure and monitor: power vs. frequency, power vs. power, power vs. time
- Power monitoring – the signal generator can measure its own output power via the attached power sensor and report out any significant variations

Figure 10. Basic power measurements can be performed on the instruments without the need to use an additional power meter basic unit.

4.2 Scalar Network Analysis

The transmission characteristics of RF components such as filters, amplifiers, or frequency converters are normally measured with a scalar network analyzer or a spectrum analyzer with tracking generator. Scalar measurements can also be carried out using a signal generator, a power sensor and an external control program. R&S for example offers a free Visual Basic (VB) sample program that allows accurate measurements of the transmission characteristics over a large frequency and dynamic range. This provides a solution for network analysis that is more cost-effective than the use of a scalar network analyzer.

The high speed required for scalar network analysis is achieved by utilizing the List Mode in the signal generators. Such a setup can be useful for applications in a production environment where fast, reproducible and cost-effective measurement applications are important.

Typical applications for the scalar network analysis procedure include the following:

- Characterizing components such as amplifiers, filters, and converters. This procedure is especially useful for conducting measurements on converters such as satellite TV converters. Unlike the selective measurements performed by a network analyzer, power meter measurements are broadband, and for example, a DUT with an unstable local oscillator frequency will not adversely affect measurement accuracy when a power sensor is used.
- Balancing and documenting the transmission characteristics of filters
- Calibrating measurement setups. Complicated setups for measurements usually include filters, attenuators, cables, etc whose frequency response must be known.
- Determining the compression point in amplifiers. The List Mode can also be used in conjunction with the power sensor to conduct a fast power sweep in order to measure compression behavior in amplifiers, for example.

Figure 11. Scalar measurements can be carried out using a signal generator and a power sensor for a more cost-effective solution than the use of scalar network analyzer.

4.3 Mixed‑Signal IC Testing

Tests on integrated RF circuits frequently require a pure clock signal in addition to the RF signal. In the past, an extra signal generator was usually necessary in this case. R&S offers a low-jitter clock signal option which can be set independently of the RF output signal. The clock signal is available as a differential signal in the frequency range from 100 kHz to 1.5 GHz at two separate connectors. It enables, for example, A/D converter tests using only a single signal generator.

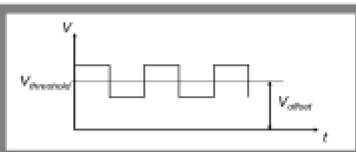
Frequency range	100 kHz to 1.5 GHz
Output voltage	0.5 Vpp into 50 ohm (differential output)
Jitter	typ. 140 fs (1 kHz to 5 MHz offset)
DC Offset: Resolution:	-5 V to +5 V 10 mV  shift clock signal to switching threshold of logic devices
Applications	▪ additional clock source in test set ▪ test of A/D converters ▪ test of differential DUTs

Figure 12. Tests on integrated RF circuits frequently require a pure clock signal in addition to the RF signal. The low-jitter clock signal option can be set independently of the RF output signal.

4.4 Phase Coherent

Phase coherence of RF signals designates a defined, constant delta phase between two or more RF carrier signals with the same frequency or a multiple of the frequency **(Figure 13)**. It is commonly used in radar, active array antenna and beamforming applications.

If two signal generators are coupled via their 10 MHz reference, they are generating exactly the same frequency but only from the long term perspective. Having a closer look into the instantaneous differential phase (“delta phase”) of these two RF signals, shows that they are quite unstable with respect to each other. This is due to:

- The phase noise of the two synthesizers
- “Weak” coupling at 10 MHz and a long synthesis chain up to the RF domain
- Temperature differences which cause a change of the effective electrical length of some synthesizer components

Most critical for a stable delta phase is the RF phase fluctuation between multiple RF synthesizers. These fluctuations can be minimized by using a common synthesizer meaning a common local oscillator (LO) signal for all RF carrier. Only if this LO signal is the same for all carriers, a stable phase relationship can be achieved between the RF signals. R&S offers signal generators with an option to share LOs to achieve phase coherence.

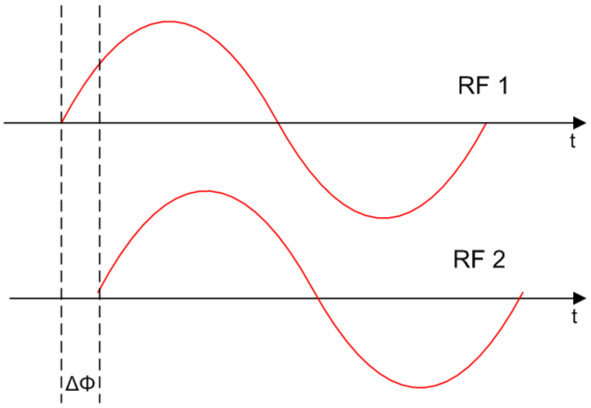


Figure 13. Phase coherence of RF signals designates a defined, constant delta phase between two or more RF carrier signals with the same frequency or a multiple of the frequency.

5 Usability Considerations

5.1 Intuitive Operating Guide

The User Interface of R&S signal generators provide a signal flow that is shown by a straightforward block diagram on their color display. Thus, the user can immediately see the activated and deactivated generator blocks as well as where settings can be made. The entire operating manual for the signal generator is integrated into the instrument's help system. At the press of a button, the user can access details about the function currently being used. For example, this makes it very easy to find the associated remote-control command for any given parameter on the generator. To make settings, the rotary knob, the cursor and function keys or a USB mouse and/or keyboard can be used. The above features combine to make operation easy and intuitive.

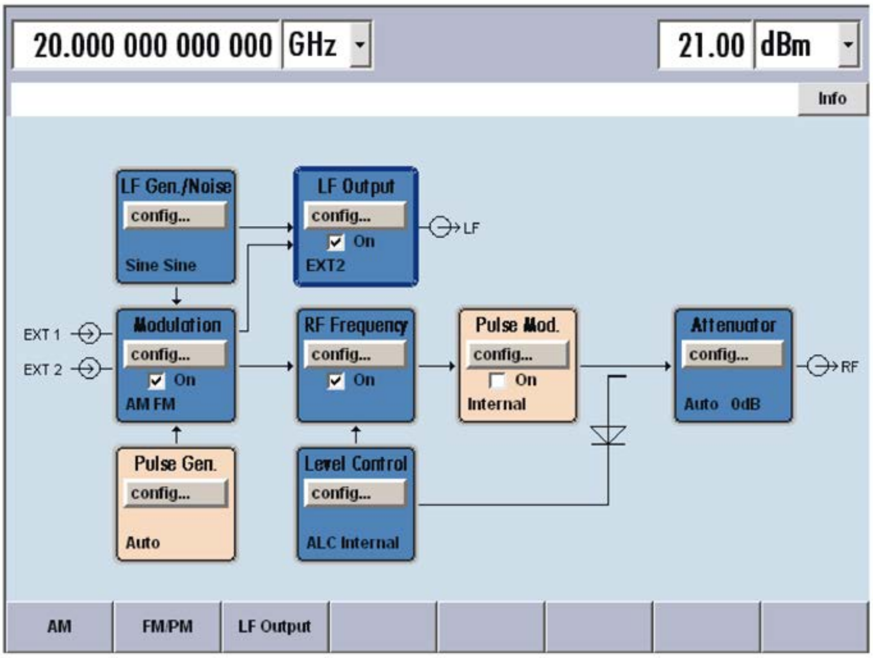


Figure 14. R&S signal generators display a block diagram image which shows numerous settings, the signal flow, as well as active inputs and outputs in a straightforward manner.

5.2 Local Bench or Remote Test

If the user will be pushing the buttons and looking at the instrument display all day a traditional signal generator may be the right choice. On the other hand if the signal generator is located in a test rack which is typically automated then a more compact minimalist design may be a better solution.

For generators being used in a test rack, the front panels can have a minimalist design. They may only offer status LEDs as well as all of the keys necessary for controlling generator operation. However these types of signal generators can also be used in a benchtop environment, as they can be controlled from PC which is running software that simulates the front panel of an instrument.

Figure 15. Will the signal generator be used on a bench or in a remote rack?

5.3 Code Compatibility

Signal generators are often used in automated test environments. Replacing them from time to time could be necessary for a variety of reasons, including:

- The signal generator is broken and cannot be serviced any more
- The performance of the signal generator in the application must be improved
- New signal generator functionalities are needed

The old generator being replaced and the new generator must be compatible at least in terms of electrical features and remote control features. Legacy instruments often use a proprietary remote control language. Direct replacement therefore requires language emulation capability in the software of the new generator. To meet these requirements, the R&S signal generators come with a language emulation feature. By selecting the desired generator that is to be emulated, the new signal generator acts as the original replaced instrument.

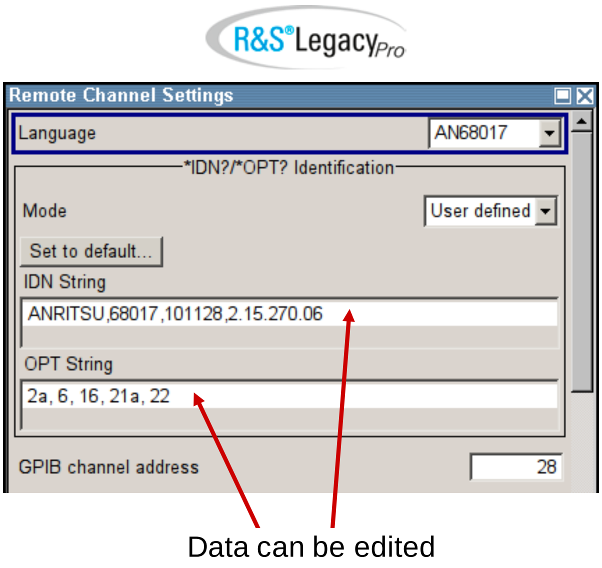


Figure 16. R&S signal generators have a language emulation feature which allows you to select the desired language emulation and then the signal generator acts as the original replaced instrument.

5.4 Upgrades

Today, modern signal generators often have software capabilities that enable the end user to upgrade their instrument themselves. Software options can normally be activated with the use of a key code. Retrofitting hardware options can be more complicated. While some upgrades can be performed in the Field, other can require the generator to be recalibrated or send back to a service center.

5.5 Size, Weight and Power

Signal generators come in a variety of form factors to suit the needs of the many locations that RF and microwave signal generation is required. While size and power consumption has always been important in production environments, today it can be an issue even in traditional R&D labs as bench top real estate is valuable and more people are sharing test benches.

Compact designs are particularly useful in all applications that require multiple RF signal sources, such as phased array antenna systems because they provide multiple RF channels without taking up a lot of room.

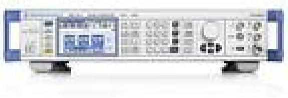
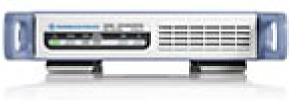
Low power consumption and effective heat dissipation reduces expenditures for cooling in a production line test rack making it possible to place the instruments close to one another. This saves space and can have a positive impact on the MTBF of the test rack.

6 Summary

This primer has highlighted that selecting an analog signal generator is not entirely straight forward. Careful considerations have to be taken into account when evaluating specifications and the functionality required for the application the generator will be used for. Additional considerations should include future needs and usability.

6.1 R&S Analog Signal Generator Overview

Rohde & Schwarz offers test equipment that will verify your designs from prototypes through manufacturing and even field operations. This test equipment can be used to verify not only the total performance of the system, but can also be used to replace parts of the system which may not be available at test time. The following is a brief overview of the analog signal generators available from R&S.

Analog Signal Generators from Rohde & Schwarz		
Model	**Description**	**Key Facts**
R&S®SMF100A Microwave Signal Generator 	Signal quality, speed, and flexibility - these are decisive properties for a signal generator in the microwave range. The R&S®SMF100A microwave signal generator is a first-rate, state-of-the-art microwave signal generator that sets standards.	▪ Up to 110 GHz with R&S®SMZ frequency multiplier ▪ Excellent SSB phase noise of typ. –120 dBc (at 10 GHz; 10 kHz carrier offset) ▪ Very high output power of typ. +25 dBm ▪ Unique pulse generation capabilities
R&S®SMA100A Signal Generator 	Signal quality, speed and flexibility – these are the criteria by which signal generators are measured today. The R&S®SMA100A perfectly meets these criteria, and thus is a premium-class analog generator that sets standards due to its outstanding characteristics.	▪ Frequency options from 9 kHz to 3 GHz/6 GHz ▪ Very low SSB phase noise of typ. -141 dBc (at 1 GHz, 20 kHz offset, 1 Hz measurement bandwidth) with option ▪ Nonharmonics <-96 dBc (f < 750 MHz, carrier offset > 10 kHz) with option
R&S®SMB100A RF and Microwave Signal Generator 	The compact, versatile R&S®SMB100A RF and microwave signal generator with a frequency range up to 40 GHz provides outstanding spectral purity and high output power. In addition, it features easy operation, comprehensive functionality and low cost of ownership.	▪ Wide frequency range from 9 kHz to 6 GHz or from 100 kHz to 40 GHz ▪ Excellent signal characteristics with low SSB phase noise of typ. –128 dBc (at 1 GHz, 20 kHz offset)
R&S®SMC100A Signal Generator 	The analog R&S®SMC100A sets standards for attractively-priced signal generators. It has the smallest size and the best price/performance ratio in its class.	▪ Frequency range 9 kHz to 1.1 GHz or 3.2 GHz ▪ Maximum output level of typ. > +17 dBm ▪ Optional high-stability reference oscillator ▪ Analog modulation modes (AM/FM/φM/pulse) integrated as standard
R&S®SGS100A SGMA RF Source 	The R&S®SGS100A is an RF source designed to meet the requirements of automated test systems. It is available as a CW source or as a vector signal generator with an integrated I/Q modulator.	▪ Small design ideal for system integration ▪ Enables high throughput due to very short frequency and level setting times of typ. 280 µs via PCIe interface
R&S®SGU100A SGMA Upconverter 	The R&S®SGU100A SGMA Upconverter offers a frequency extension to 40 GHz. Equipped with the R&S®SGU100A, the R&S®SGS100A covers the entire frequency range from 10 MHz to 40 GHz.	▪ Frequency extension to 40 GHz with the R&S®SGU100A upconverter ▪ Two instruments integrated into one, providing a small compact 40 GHz generator ▪ Seamless integration into existing user interfaces

About Rohde & Schwarz

The Rohde & Schwarz electronics group is a leading supplier of solutions in the fields of test and measurement, broadcast and media, secure communications, cyber security, and radiomonitoring and radiolocation. Founded more than 80 years ago, this independent global company has an extensive sales network and is present in more than 70 countries. The company is headquartered in Munich, Germany.

Regional contact

North America
1 888 TEST RSA (1 888 837 87 72)
customer.support@rsa.rohde-schwarz.com

Europe, Africa, Middle East
+49 89 4129 12345
customersupport@rohde-schwarz.com

Latin America
+1 410 910 79 88
customersupport.la@rohde-schwarz.com

Asia Pacific
+65 65 13 04 88
customersupport.asia@rohde-schwarz.com

China
+86 800 810 82 28 |+86 400 650 58 96
customersupport.china@rohde-schwarz.com

Sustainable product design

- Environmental compatibility and eco-footprint
- Energy efficiency and low emissions
- Longevity and optimized total cost of ownership

Certified Quality Management
ISO 9001

Certified Environmental Management
ISO 14001

PAD-T-M: 3573.7380.02/02.04/EN/