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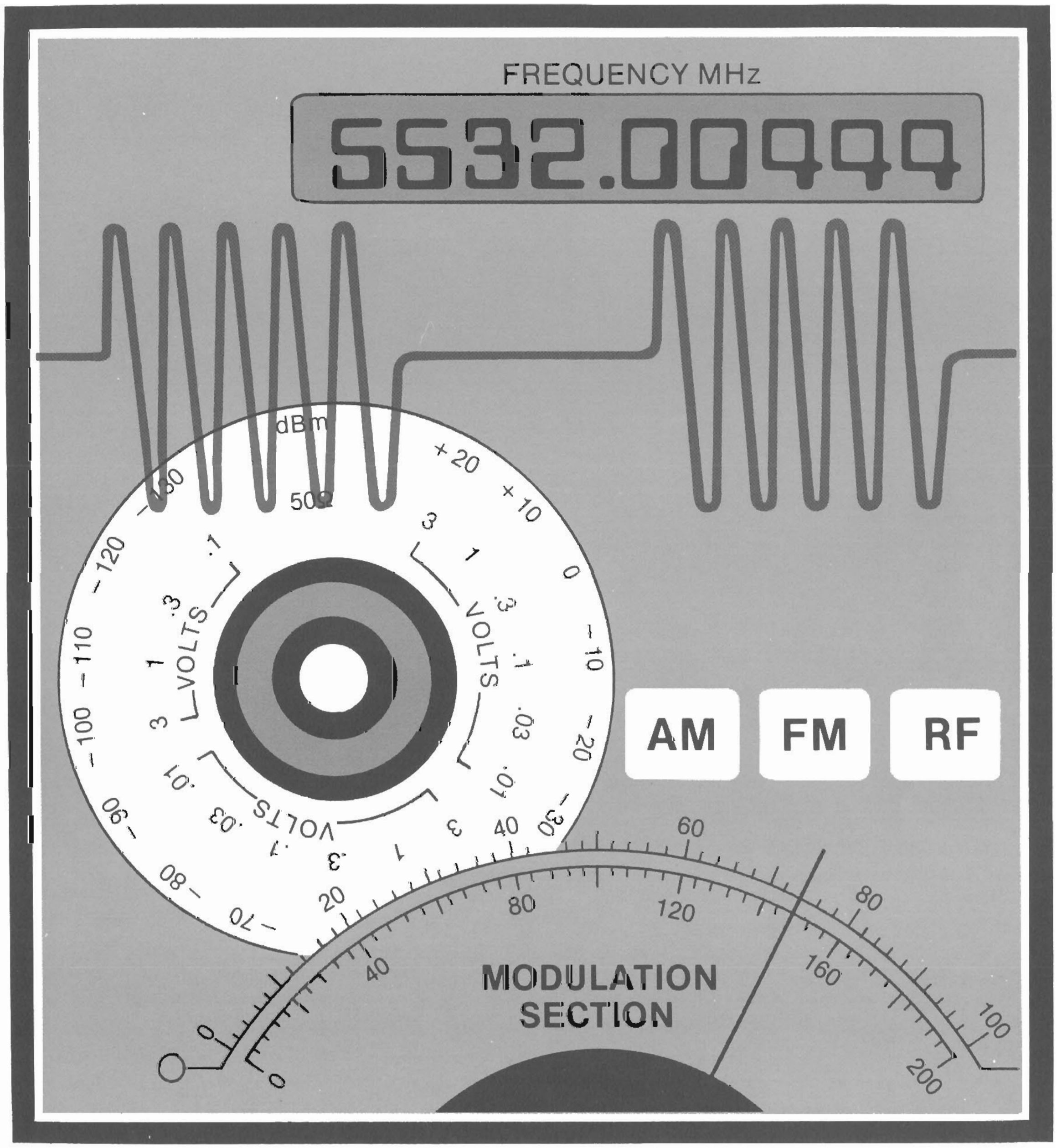
rf design



Signal Generator Specifications — Part I

To an engineer or technician faced with the requirement for an RF signal generator, a proliferation of instruments is available. The challenge is to purchase the signal generator which has the specified capacity to fulfill all of the applications requirements. To aid the user in this task a review of the important signal generator specifications and how they affect various applications is presented here.

By Rob Oeflein
Marketing Engineer
Hewlett-Packard

To be classified as a signal generator an instrument must have three basic characteristics:

1. Calibrated and variable frequency over a broad range.
2. Calibrated and variable output level over a wide dynamic range.
3. One or more forms of calibrated modulation.

It is important to notice that not all frequency sources or synthesizers are signal generators. Sweepers, test oscillators, and traditional frequency synthesizers cannot be classified as signal generators because they usually lack a calibrated output or some form of calibrated modulation.

The wide variety of applications addressed by signal generators and some of the critical specifications associated with each are listed in Figure 1. The primary application in today's market, however, is that for which the signal generator was originally designed — receiver testing. Most signal generators can be easily classified, therefore, according to their capacity to perform in-channel (sensitivity, audio bandwidth, squelch threshold) or out-of-channel (adjacent channel selectivity, intermodulation distortion, spurious attenuation) receiver tests. Figure 2 lists some of the typical receiver tests and the standard signal generator characteristics which are required to perform them.

Types of Signal Generators

Most oscillators only cover a single octave, but many applications require greater than one octave of frequency coverage. Three techniques are commonly used to obtain wide frequency coverage in RF signal generators — reactance band-switching, high frequency tuned resonators with dividers or heterodyne circuits, and synthesis.

The reactance band-switched signal generator was the earliest design. Most of the older tube-type generators used switched inductors with variable capacitors and many updated solid-state signal generators still employ this technique.

The advent of broadband output power amplifiers and solid-state high frequency oscillators led to the development of signal generators that use a single high frequency tuned resonator. Dividers or a heterodyne technique can then be used to obtain the lower frequencies.

Division of the higher frequencies improves the

Major Uses of Signal Generators	Important Parameters
1) Receiver Testing and Calibration	Spurious Output Level Accuracy Phase Noise Modulation Distortion
2) R&D Design of Amplifiers, Antennas and Filters	Frequency Range Output Level Accuracy
3) Component Testing	Sweep Capability Frequency Accuracy Output Level Range
4) Local Oscillator Substitution	Frequency Stability Spectral Purity
5) EMI/RFI Susceptibility Testing or Calibration of Equipment	Leakage Output Level Accuracy Frequency Range
6) Communication System Maintenance	Modulation Flexibility Frequency Range Output Level Range
7) Metrology Lab Standard	Frequency Accuracy Output Level Accuracy Modulation Accuracy
8) Test Equipment Calibration	Frequency and Output Level Range and Accuracy

Figure 1. The major uses of signal generators and the signal generator parameters associated with each application.

Typical Receiver Tests	Signal Generator Characteristics Required
Usable Sensitivity	Low Leakage/Accurate, Low Level Signals
Image and IF Rejection — Tests Primarily RF Selectivity	Low Spurious/Output Levels >IV for Testing Large Rejection Ratios/Coverage of Both IF and RF Frequencies
Adjacent Channel Selectivity — Tests Primarily IF Selectivity	Low Noise at Typical Channel Spacings
Intermodulation — Tests RF Selectivity and Linearity	Good Isolation Between Two Generators
AM Rejection (on FM Receivers) — Tests Receivers' Immunity to AM Noise	Low Incidental FM/Simultaneous AM and FM Modulation
AGC Characteristics Audio Hum and Noise	Accurate, Wide Range Output Level Low Residual AM and FM
Audio Harmonic Distortion — Tests IF Amplitude and Phase Response Plus Discriminator Linearity	Low Modulation Distortion (Particularly Stringent for FM Broadcast, Typically <.1%)
IF and Discriminator Alignment	Wide Modulation Bandwidth/Sweep

Figure 2. Typical receiver tests and the critical signal generator characteristics associated with each test.

noise performance of these generators by a factor of about 6 dB for each divide by two. The tradeoff here is FM deviation capability which is halved with every division of two. Division also requires additional design to eliminate spurious, harmonics and noise caused by the dividers themselves.

Heterodyning, on the other hand, preserves the primary band FM deviations at the lower frequencies. Noise performance at the lower frequencies, however, is not improved from that of the primary band. To insure that the signal to noise performance is not degraded, a clean stable reference must be provided in the heterodyne design to act as local oscillator (LO) to down convert the primary oscillator's output.

Depending on the design, the output of either of these fundamental signal generators can be phase-locked to an external synchronizer or an internal reference to improve its long term stability.

Synthesizer techniques have recently been employed to yield the third type of signal generator. The synthesized signal generator is a source in which all of the output frequencies are derived from a fixed frequency reference oscillator. In this manner, the long and short term stability of this reference oscillator can be translated to the output.

Two techniques are employed to synthesize a signal. Indirect synthesis uses a combination of phase-lock loops and their associated voltage controlled oscillators (VCO's) to generate the RF spectrum. A direct synthesizer has one or more fixed frequency oscillators and all of the output frequencies are arithmetically generated by mixing, multiplying, or dividing with suitable filtering.

The advantages of a synthesized signal generator over a fundamental signal generator are better resolution (settability), higher long and short-term stability, and programming capability. The disadvantages include the presence of spurious signals from the synthesis process and the lack of a continuous tuning since synthesizers must increment frequency in discrete steps.

Signal Generator Specifications

The numerous specifications needed to quantify signal generator performance can be grouped in six basic categories. Figure 3 illustrates that these categories are frequency, spectral purity, output level, modulation, switching speed, and control. Each of these functions plays an important role in determining the overall capability of a signal generator to perform in a specific application.

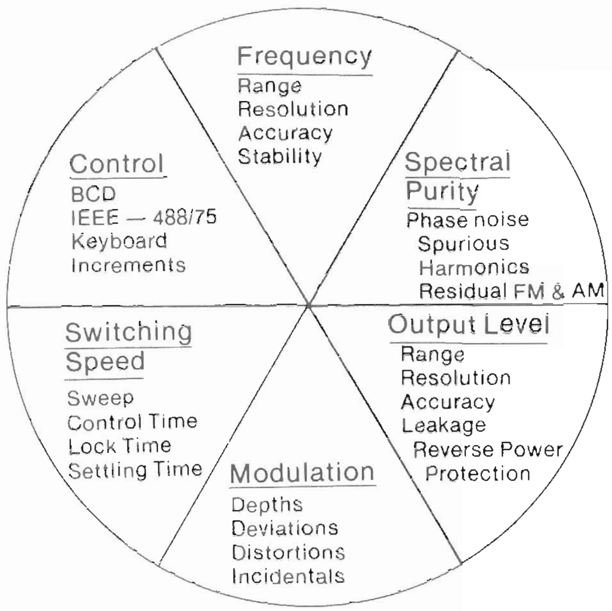


Figure 3. Six major categories for signal generator specifications.

Frequency

The choice of *frequency range* might at first seem fairly straightforward. In the maintenance of communication systems, however, it might be desirable for the generator to cover the IF, LO, and baseband frequencies as well as the RF. Image response testing, spurious checks and harmonic analysis all require RF capability greater than just the radio's receive frequency. In addition, the range of a fundamental generator's bands may restrict its usefulness if they are limited or divide certain commercial or military frequency groupings. In short, the versatility *of a signal generator depends to a large extent on* its frequency range.

Frequency resolution determines the minimum frequency change which can be made. The resolution may depend on the output frequency, providing less settability as the frequency increases. Synthesized RF generators available today may offer resolutions as broad as 1 kHz or as narrow as 0.1 Hz at an output frequency of 500 MHz. Fine resolutions are important for checking narrowband filters and testing radios which have 12.5 kHz or less channel spacings. In addition, if the source is to be multiplied up in frequency the resolution is reduced and finer resolution will allow better settability at the higher frequencies.

Repeatability of the frequency setting is determined primarily by the *frequency accuracy.* On mechanically tuned generators this is usually specified as a percent of the frequency set or as dial accuracy. Synthesized or phase-locked sources which digitally display the generator frequency usually derive their accuracy from the accuracy and aging rate of the reference oscillator. These generators will have their accuracy specified in parts per million (ppm) or as parts times ten to a minus power ($x10^{-y}$).

The frequency accuracy is particularly important in applications such as component testing or when the signal generator is used as a meteorology lab standard. It is important to notice that the resolution of a generator does not determine its accuracy. If a synthesizer has a resolution of 100 Hz but has a time

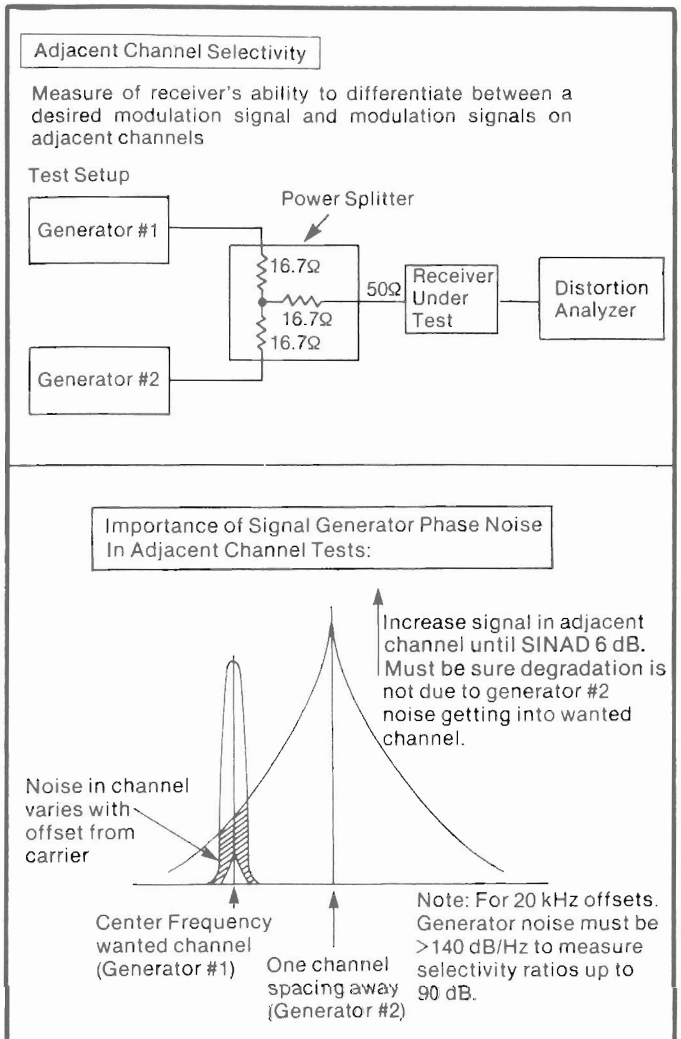


Figure 4. Effect of phase noise on adjacent channel selectivity tests.

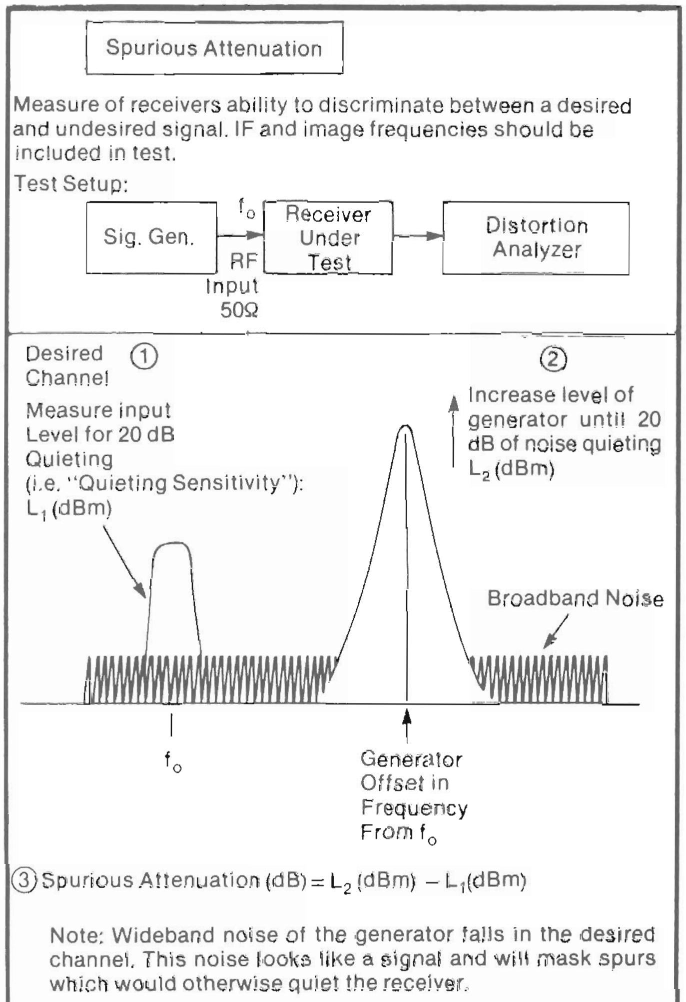


Figure 5. Effect of broadband noise on spurious attenuation tests.

base accuracy of 10ppm, the frequency accuracy at 500 MHz is ± 5 kHz.

Drift, or *long-term stability,* is usually defined over a period of time greater than one second. Specifications are usually given in ppm/hour or parts x 10^{-y}/day or year. An RF signal generator used to simulate a local oscillator in a deep space probe needs exceptional stability since the bandwidths of the receivers are typically very narrow.

For fundamental generators, which do not have frequency or phase-lock circuitry, temperature change is the primary cause of instability. Typical values may be 20 to 50ppm per ten minutes for an L-C oscillator, even after a two hour warm-up. This type of drift can become unacceptable for FM mobile radio testing, particularly with the new UHF 800-900 MHz radios that have 25 kHz channel spacings.

Phase-locked or synthesized sources rely on their internal reference oscillators for their long-term stability as well as frequency accuracy. Typical values may range from parts x 10^{-6}/day for a standard temperature controlled crystal to parts x 10^{-10}/day for an oven controlled oscillator. Oscillator drift improves as the temperature stabilizes during warm-up, so extrapolating specifications from per hour to per day or year will not usually yield accurate values for comparison. Other factors besides temperature, such as line voltage, output load variations and output level changes, may affect the generator's stability to a lesser degree.

Short-term stability of a signal generator is normally defined for averaging times less than one second, since it refers to changes in frequency which have negligible long-term effects. These instabilities result from noise modulating the carrier and are best characterized under the heading of spectral purity.

Spectral Purity

All oscillators exhibit noise which is made up of random nondeterministic signals. Thermal noise, shot noise, and 1/f or flicker noise contribute to time-dependent phase and amplitude fluctuations on the signal. These fluctuations manifest themselves as various amounts of amplitude and angular modulation on the carrier and may limit a signal generator's capability to perform in many applications.

Figures 4 and 5 illustrate how this noise can mask the true performance of a receiver during such critical tests as adjacent channel selectivity or spurious attenuation. If the signal is multiplied up in frequency, the maximum amplitude of the FM noise sidebands increases in direct relation to the multiplication ratio. This naturally limits the signal-to-noise performance at the higher frequencies.

A useful measure of *short-term frequency stability* must allow the performance of the signal generator to be predictable in a wide variety of applications and serve as a basis to allow comparisons among signal generators. Single-sideband phase noise, residual FM, and fractional frequency deviation are all terms used to describe a generator's short-term stability. Either the time domain (using digital frequency counters) or the frequency domain (using spectrum analyzers) may be used to characterize this performance. The actual measurement procedures are well described in references 2 and 4.

Fractional frequency deviation can be measured in the time domain with a frequency counter. It is based on the statistical distribution of the output frequency which results from the random noise modulation. The statical measurement, more commonly known as the Allan variance after its developer, is expressed as the square of the standard deviation (σ) of the fractional frequency fluctuations over a measurement averaging time interval (τ). When the averaging time is varied a plot of $\sigma(\tau)$ versus τ may be generated.

It is evident that for a single point the averaging time must be the same for a comparison between any two sources to be valid. The plot of the fractional frequency deviation is helpful for many applications such as doppler radar or high stability crystal oscillator analysis. As the averaging time decreases, however, the measurement becomes difficult and a detailed characterization of the signal generator's performance is complicated. As measurement averaging times increase and the deviations become correspondingly smaller, the randomness of the fluctuations becomes obscured since the average must approach the nominal output frequency drift in the long run.

The most common and meaningful method of specifying short-term stability is a plot of the signal generator's *single-sideband (SSB) phase noise* in a 1 Hz bandwidth versus the offset from the carrier. This is illustrated in Figure 6. The SSB phase noise is expressed in dB relative to the carrier (dBc). A 1 Hz bandwidth is used since the noise in other bandwidths can then be easily calculated (a times 10 increase in bandwidth yields a 10 dB increase in the noise power).

This plot is a graphical representation of the phase noise distribution on one side of the carrier with the assumption that the distribution on the other side is identical. From this curve it is possible to calculate the other two principle methods of specifying short-term stability — fractional frequency deviation and residual FM. These calculations are described in detail in reference 3.

For SSB phase noise in a 1 Hz bandwidth to

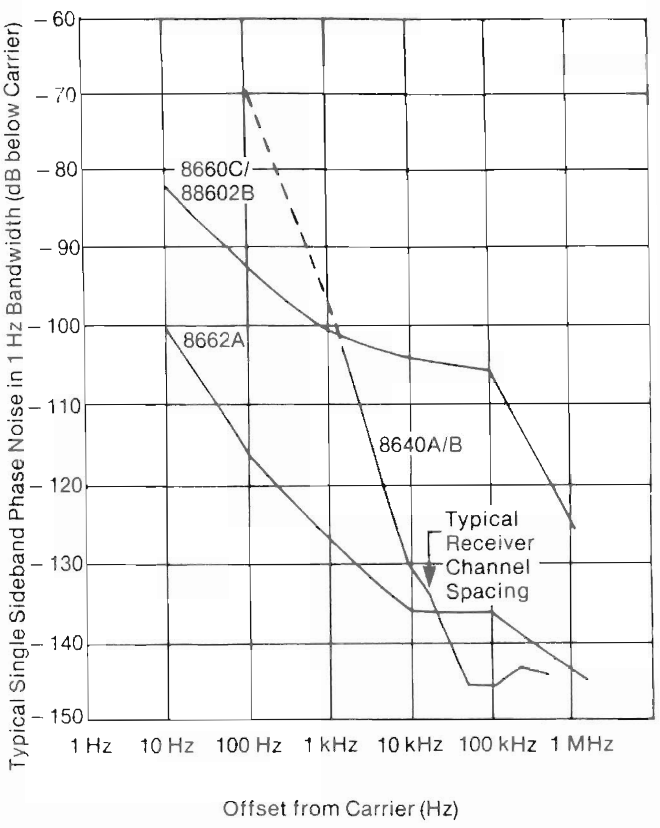


Figure 6. SSB phase noise plots of a cavity-tuned generator (8640A/B) and two synthesized generators. $F_c = 500$ MHz.

serve as a basis for comparison among signal generators, three parameters must be known: the phase noise, the offset, and the output frequency. All are important, and the specification becomes meaningless if one of them is missing. The need to specify the offset is clearly illustrated in Figure 6, while the need to indicate the generator's output frequency is apparent if one recalls that roughly a 6 dB improvement in noise performance is gained if the output frequency is divided by two.

Noise floor refers to the signal generators broadband SSB phase and AM noise. It is desirable to have the noise floor as close to the thermal noise level (kTB) as possible for receiver tests such as image rejection or spurious response testing (see Figure 5). It is also preferable to reach the noise floor as close to the carrier as possible, since the SSB phase noise is a limiting factor in many applications.

Residual FM specifies undesired angular modulation. It is measured on a CW signal in a given bandwidth and includes the effects of both spurious and phase noise. It is essentially the integral of the phase noise curve (including spurious) whose limits represent the post-detection bandwidth of interest. The units are in RMS deviation and again the generator output frequency must be given since residual FM varies with both bandwidth and frequency. Typical bandwidths used to measure residual FM are 300 Hz to 3 kHz and 20 Hz to 15 kHz. Without the bandwidth or the output frequency specified, residual FM is meaningless as a basis for comparison.

The residual FM specification gives the signal generator user an idea of the noise present on the signal which will limit his ability to measure the quieting of a receiver or the receiver's signal-to-noise ratio. It also acts as a figure of merit that indicates the signal generator's capability to be used as a local oscillator or a source that is to be multiplied. Because the actual distribution of the noise is not readily apparent, residual FM does not give a good indication of the generator's ability to make out-of-channel receiver measurements or to perform in narrowband applications which require the close-in phase noise to be very low.

Residual AM is similar to residual FM in that it results from noise modulating the carrier, but it is only concerned with that noise which causes undesired fluctuations in the signal amplitude. Residual AM does not affect short-term frequency stability, but it is an important aspect of the overall spectral purity. Besides limiting the signal generator's performance in AM systems, residual AM sidebands increase the total noise. The post-detection bandwidth is again critical to the specification, and the units are generally dBc for an average RMS value (this includes both sidebands).

Discrete spectral lines not harmonically related to the carrier are commonly referred to as *spurious outputs*. Spurious outputs are a direct result of mixing and dividing, so they are generally of more concern in synthesizers than fundamental generators. Spurs can appear symmetrically around the carrier, as in the case of power line related noise, or they can move rapidly relative to the carrier as the frequency is varied if they result from mixing in the synthesis process. Through judicious design these line related and assymmetrical spurs can be reduced in effect, but not eliminated.

Since spurs not only mask the performance of the system under test but also contribute to residual AM and FM, they can drastically effect many applications. Spurious attenuation, for example, is the ability of a receiver to discriminate between a desired signal and an undesired one, including IF and image responses. If the generator used to measure spurious attenuation has spurs larger than the specified performance of the radio, the test is meaningless. When the signal generator is used as a local oscillator, spurious signals will cause the desired output to vary in phase at the IF frequency, and they are a possible source of intermodulation products. Figure 7 illustrates how a 1 kHz spur of −80 dBc will contribute −86 dBc sidebands to residual AM and ØM at a 1 kHz rate.

The total *harmonic content* of the CW signal can be a key specification in some applications. If the harmonics are specified at −20 dBc, one percent of the total output power resides in them. The harmonics will restrict the users ability to make linearity tests and broadband power measurements. Subharmonics which result from a doubling process are also undesirable signals on the output, but in most cases they can be externally filtered out. The harmonic content of the output may vary across the signal generator's frequency range and increase at high output levels.

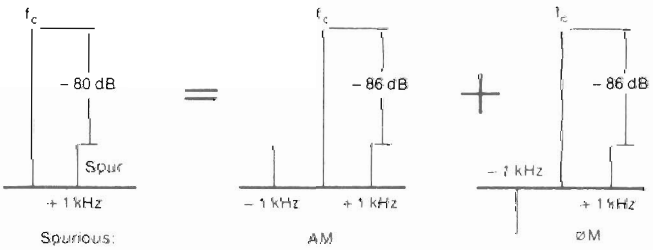
Figure 7. The effect of spurious outputs from a signal generator.

Spurious

Problems Caused by Spurious:
1) When the Synthesizer Is Used Directly Into a Mixer or as an LO Spurious Result in Intermodulation Products at the Output of the Mixer.

2) In Receiver Testing Set-Ups, Spurious Can Feed Directly into the IF of the Receiver

3) Spurious Also Contribute to Residual AM and FM.



Residual AM and ØM Contribution of a Spurious Signal −80 dB and 1 kHz from the Carrier

Signal Generator Specifications — Part II

Output Level

To be useful, the signal generator *output level* must be calibrated in some unit over a specified range into a characteristic impedance. The nominal output impedance of most RF signal generators is 50 ohms. For CATV and some telecommunications applications which require 75 ohms, an impedance transformer or resistive adaptor can be used. High output levels are desirable for driving mixers or overcoming system losses. Low output levels are important for receiver sensitivity measurements and to calibrate RFI measurements.

The most common output level unit is dB referenced to one milliwatt (dBm) into a 50 ohm resistive load. In many applications it is desirable to set the output directly in volts and this capability is normally provided. Several other output units have become popular in the receiver test market. These include E.M.F. or open circuit voltage, dB referenced to one microvolt (dBuV), and dB referenced to one femtowatt (dBf).

Amplitude resolution determines the settability of the output level. For relative output settings high resolution is beneficial and .1 dB may be desired. In an automatic system one-half the resolution is the maximum amplitude correction which can be made, but it should be stressed that this resolution does not determine the absolute accuracy of the setting. Figure 8 illustrates the sources of absolute accuracy error.

Temperature, level flatness, indicator accuracy, detector linearity, attenuator accuracy, and measurement error all contribute to the signal generator's ***absolute output level accuracy*** specification. The accuracy specification (usually given as ± dB) should include allowances for all of these factors if an absolute value is indicated. The importance of this specification is evident in receiver usable sensitivity measurements where an error of a few dB might cause a misrepresentation of many miles in the radio's reception capability. Also, if the signal generator is used to verify ALC characteristics or squelch thresholds the output level accuracy is the key specification involved.

Temperature primarily affects the sensitivity of the detector. This error can be minimized by designing the signal generator with a large thermal mass and by maintaining a relatively constant ambient temperature. *Level flatness* is a measure of the flatness of the insertion loss of both the detector and the attenuator as well as a measure of the signal generator's ALC capability. Level flatness must be specified over the frequency range of interest. *Indicator accuracy* and *detector linearity* refer to the tracking between the actual output and the level that the detector sees and the indicator displays. The indicator is commonly a meter, but may now be a digital readout.

At a single frequency these errors (temperature, flatness, detector linearity, and indicator accuracy) can be calibrated out using a power meter and a fixed vernier setting on the signal generator. Reference 1 describes this technique.

Attenuator accuracy for step attenuators is directly proportional to the accuracy of each pad involved in setting the output level. The total error is cumulative so that if a generator has 5 pads and each is specified at ±0.3 dB, the worst case error would be ±1.5 dB. Some synthesized signal generators use their internal microprocessor to calibrate out this error. Waveguide beyond cutoff attenuators are still used in some generators because of their inherent accuracy and ability to provide a continuously variable output. The drawback is the inability to program them and their large insertion loss.

Measurement error refers to the uncertainty of the absolute error which results from the signal generator calibration. The primary source of this error is the impedance mismatch or VSWR of the signal generator and the instrument used to calibrate it. The VSWR of a signal generator is normally given for both high and low levels since the VSWR is degraded at high output levels when the attenuator is not being utilized.

When the signal generator is used in an application which requires low level signals, like measuring the sensitivity of pocket pagers, *leakage* can cause serious inaccuracies. This specification is a measure of the signal generator's EMI and RFI. It is normally sufficient to indicate whether the signal generator complies with one or more of the universally accepted standards such as MIL STANDARD 461 or VDE 0871. A qualitative and easily measured specification indicates the voltage induced in a two-turn 2.4 cm. loop held 2.4 cm. from any surface on the generator. This method provides an easily measured value for comparison among signal generators.

Reverse power protection with automatic reset (or an in-line fuse) helps prevent serious damage to the generator's attenuator or circuitry in the case of an accidental transmission from a transceiver. This type of protection should specify the reverse power handling capability and indicate any degradation of the level accuracy caused by the circuits involved.

Modulation

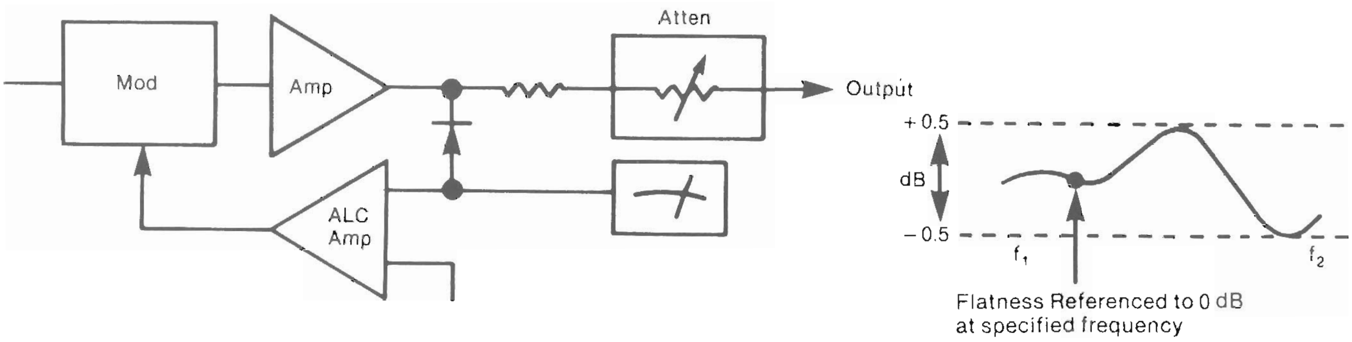
Without the ability to pass information modulated onto the carrier, an instrument cannot be classified as a signal generator. There are a variety of modulation formats in use today, but normally each method can be classified as either amplitude or angular modulation. In general, the signal generator's modulation specifications are concerned with its ability to precisely apply the internally or externally supplied information onto the carrier. Sufficient bandwidth and fidelity are the two primary concerns.

Amplitude modulation requires that the signal generator provide for a variable percentage of depth over some specified range of rates. In standard AM receiver tests the amount of depth required may be only 30 percent. However, for VOR/ILS avionics testing and other complex modulation schemes, total depths up to 100 percent AM may be necessary.

AM bandwidth available may depend on the RF carrier frequency as well as the amount of depth selected. Both internal and external rates should be specified as well as whether external DC coupling is available. DC coupling is important not only for low frequency modulation with minimal phase shifts but also for some applications where it is desired to program the output level in a continuous manner.

Figure 8. Sources of absolute output level error.

Output Level Accuracy



Sources of Error: Level Flatness
Level Variations with Temperature (Due to Detector)
Detector and Meter Linearity
Attenuator
Measurement Uncertainty During Calibration

Modern Data Sheets Should Include Total Absolute Accuracy At Any Level Setting and Include All Sources of Error.

Normally 1 kHz and 400 Hz rates are supplied internally. An optional selection of other fixed rates or a continuously variable internal oscillator may be offered.

AM distortion results from the inability of the ALC loop to track the AM envelope. For this reason, the distortion will increase with greater depths and higher rates. A specification for the internal 1 kHz or 400 Hz rates with a single depth can be misleading. Figure 9 illustrates two methods of more completely specifying AM distortion. Obviously, if the fidelity of a receiver or other system is to be measured the limiting factor is the distortion inherent in the signal generator and the audio source.

The *accuracy* of the AM depth depends primarily on the quality of the modulator utilized and the indicator used to display the setting. If a meter is used to indicate the depth it is important to know whether the accuracy is specified as percent of reading or percent of full scale. The error is constant for percent of reading but increases with lower deflections for percent of full scale.

When AM is applied to a carrier a small amount of FM generally appears at the same rate as the modulating frequency. This *incidental FM* in contrast with residual FM is not present on the CW signal. In stringent AM applications such as stereo AM incidental FM adds to the noise and distortion. The actual mechanism involved is commonly incidental phase modulation and in this case the FM deviation increases with the modulation rate. Incidental FM equals the peak incidental ØM times the modulation rate.

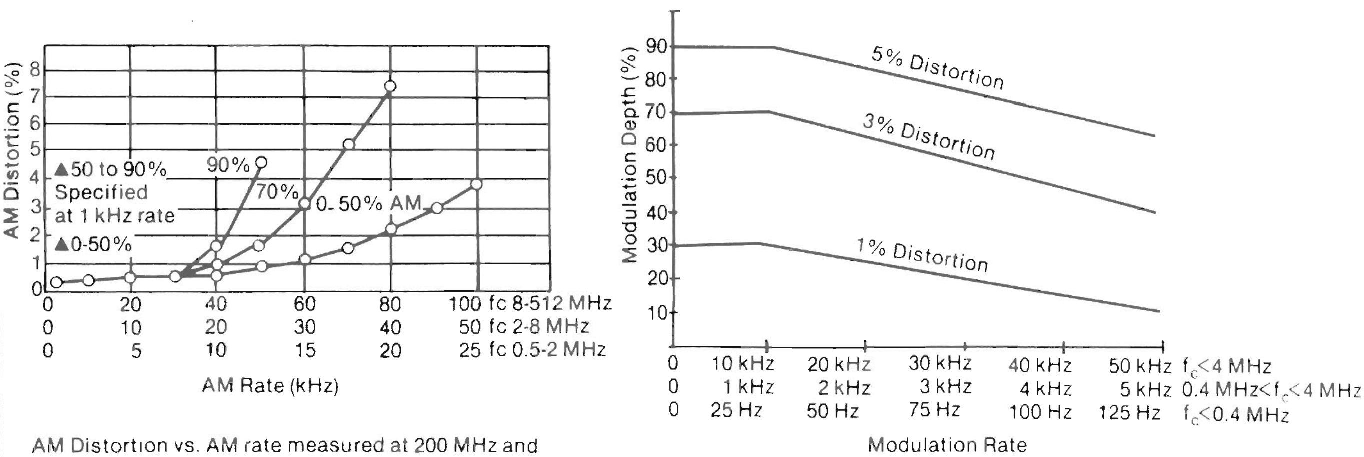
Pulse modulation (Pm) is a form of amplitude modulation. Many of the specifications are similar with the exception of the pulse parameters and the pulse on/off ratio. Fast *rise/fall times* help the input pulse to be faithfully reproduced. Pulse repetition rate and minimum pulse width further identify the type of pulses which may modulate the carrier. The *on/off ratio* defines the power present when the RF is pulsed on to the power present when it is pulsed off. High resolution radar systems may require rise/fall times less than .1μs and on/off ratios of greater than 80 dB at the IF frequencies. Other applications for pulse modulation include avionics DME radars, IF filter characterization, and EW or ECM work.

Frequency modulation requires that the signal generator provide for a variable amount of FM deviation over some specified range of rates. Although most FM mobile receivers have audio bandwidths less than 5 kHz, the entertainment FM band requires from 75 to 100 kHz of peak deviation from 88 to 108 MHz. As mentioned previously, the available peak deviation is preserved in the heterodyne process but reduced by half with each division by two. Thus the amount of available peak deviation may decrease at lower frequencies and it is important to know the specification for the carrier frequency of the application. In addition, the resolution of the FM deviation may vary depending on the carrier frequency.

FM bandwidth, like AM bandwidth, should be specified for both internal and external rates. In older generators a 3 dB bandwidth was common, but today many manufacturers are giving the 1 dB bandwidth. External DC FM is desirable to provide an analog DC sweep capability for testing IF filters or discriminators, and to allow the generator to act as the VCO in a phaselocked loop. DC FM may also be required for certain squelch formats if low rate AC coupling is not provided.

FM distortion will depend on the rate and deviation selected. Figure 10 illustrates two methods of displaying FM distortion. Although 1 percent distortion is normally sufficient for most applications, some FM stereo receivers now specify better than .05 percent distortion. Again, the distortion is commonly specified at the internal rates of 1 kHz and 400 Hz for a particular amount of deviation.

Incidental AM is the small amount of AM which occurs at the same rate as the FM. It is not present



AM Distortion vs. AM rate measured at 200 MHz and + 13 dBm, representative of all bands.

Figure 9. Two methods of specifying AM Distortion on a data sheet for various Rates and Depths.

on the CW signal, but normally becomes more pronounced with greater FM deviation. Incidental AM impairs the ability of the signal generator to make FM rejection measurements on an AM receiver, and can effect Bessel null calibrations.

The specification is normally given in percent AM, but the AM sidebands may be specified in dBc. When the power in both sidebands is measured the dBc specfication may be converted to percent AM by the formula:

$$10^{\frac{-XdBc + 40}{20}}$$

When the power in only a single sideband is indicated (as on a spectrum analyzer) a 6 dB correction factor is necessary since at 100 percent AM each sideband has 25 percent of the power in the carrier. This correction can be made by adding 46 dB instead of 40 dB.

In some synthesizers the carrier will shift in frequency when the generator is switched from the CW to the FM mode. This carrier shift is especially undesirable in narrowband applications and should be specified if the shift occurs.

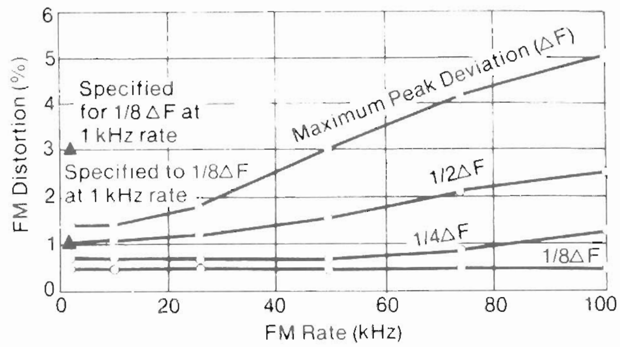
Phase modulation ∅m is another form of angular modulation. Here the important specifications are similar to FM with the exception that the deviations are expressed in degrees or radians. Although most ∅M applications occur above 1 GHz, such as satellite communications, it is desirable for checking the phase characteristics of subassemblies or to analyze phase-lock loops.

Finally, if the signal generator has the ability to perform *simultaneous modulation* it should be specified. Simultaneous AM and FM can be utilized to check the FM rejection of an AM receiver or vice versa, and is required for stereo AM applications. Also, if a demodulated AM output is provided it should be noted. This feature is used to check the accuracy of percent AM settings and is desired primarily in avionics applications.

Switching Speed

With the advent of synthesized signal generators, both direct and indirect, *switching speed* has become an important specification to understand. Indirect synthesizers generally switch slower than direct synthesizers due to the indirect synthesis process. Switching speed on an indirect synthesizer is comprised of three factors, control time, lock time, and settling time.

Control time is the time required for the synthesizer to receive the command, process the change information, and send out the appropriate data to the RF section. *Lock time* refers to the time required for the phase locked loops to capture a new frequency after a change is initiated by the controller. The time it takes for the phase error in the loop to decrease to within a specified value from the final frequency is *settling time.*



FM Distortion vs. FM Rate Measured in the 8-16 MHz Band Representatives of All Bands.

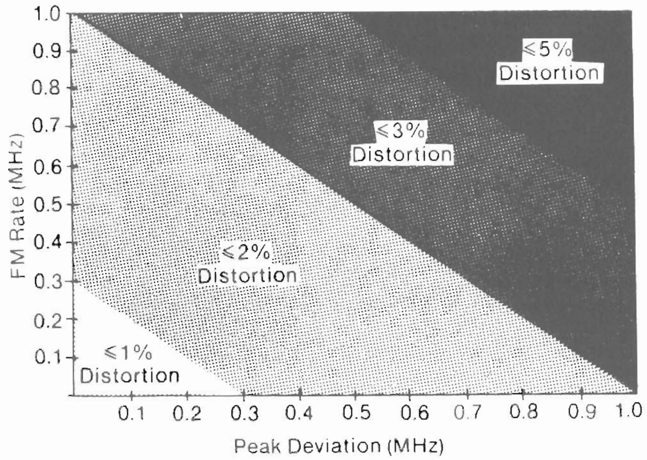


Figure 10. Two methods of illustrating FM Distortion on a data sheet for various Rates and Deviations.

A direct synthesizer can change frequency essentially as fast as its internal switches. Control time is the limiting factor in their design since they do not utilize any phase-lock loops and their settling times are normally short.

For all signal generators, the switching speed should be specified as the time from the initialization of the change to when the output is within a certain number of hertz from the desired final frequency.

Faster switching synthesizers can also incorporate a precision *digital sweep* capability into their design. The time saving advantage of this feature is readily evident during the analysis of filters, antennas, or amplifiers. With the resolution of 0.1 Hz available in some signal generators the digital point to point nature of the sweep becomes almost unnoticeable.

Control

Programmability in signal generators has led to their widespread use in Automatic Test Equipment (ATE) systems. Several types of interfaces are available today and care should be taken to select the one which offers the most flexibility for the application.

Binary coded decimal (BCD) interfaces have existed on signal generators for quite a few years. Since this is usually a full parallel interface it offers speed and simultaneous control of several functions. It is important to know the number of lines required by the interface and the decimal weighting of the 4 bit code. Although "8421" is the most commonly used today, "4221" and "1248" have been popular in the past.

The *IEEE 488-75* interface is quickly gaining in popularity. This 16 line bit-parallel, byte-serial interface features standardized interface connectors and a handshake type of control format. This interface bus cannot operate at the speed of a full parallel interface, but it is sufficient for the majority of ATE applications.

Control features have also improved the manual operation of today's signal generators through the use of internal microprocessors. Such features as full keyboard control, store/recall of front panel settings, and the ability to define increments for all functions can greatly reduce test set-up and measurement times.

Conclusion

The challenge of selecting a signal generator which will fulfill all of the critical requirements in a particular application can be simplified if the specifications involved are thoroughly understood. Once it has been determined which of the six specification categories (frequency, spectral purity, output level, modulation, switching speed, and control) are critical to the signal generator's performance, the various instruments available may be more easily evaluated. All future or anticipated requirements should be included in this analysis.

Comparison of the data sheet specifications should then be undertaken carefully. Widespread differences in measurement methods and the existence of "specmanship" can lead to the purchase of equipment unable to meet all the requirements. The contrasting specifications should be converted to units which can be easily compared, and particular attention should be paid to all of the qualifications associated with each specification. For example, a specification given as typical does not guarantee that every unit manufactured will have the stated performance.

Astute examination of the application followed by prudent selection of the signal generator will ensure that the equipment purchased will match the performance required. □

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