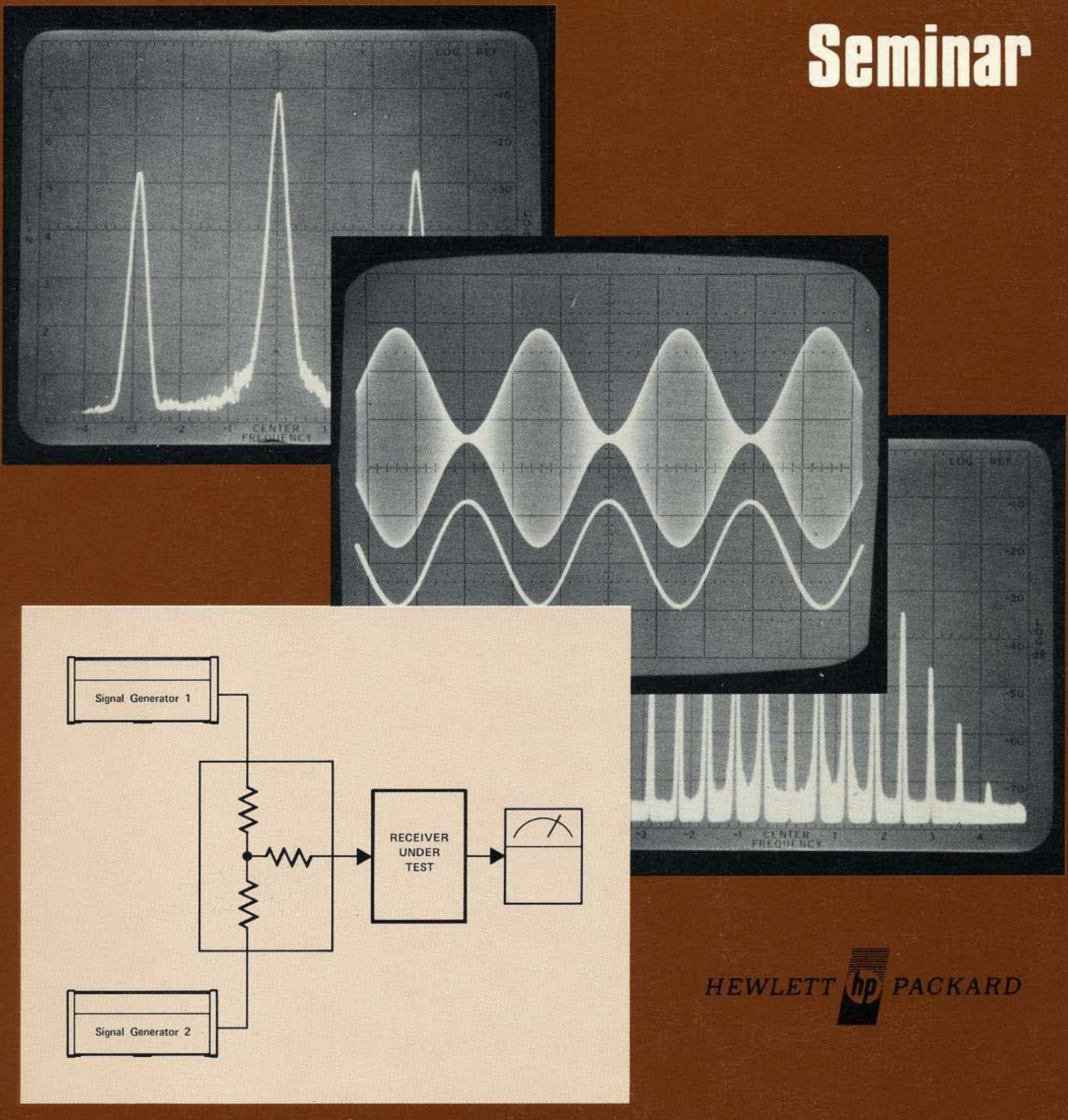
Signal Generator Seminar



HEWLETT hp PACKARD

Signal Generator Seminar

HEWLETT PACKARD

REVISED SEPT 1974

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INTRODUCTION

A BASIC SIGNAL GENERATOR MUST HAVE:

1. Calibrated and Variable Output Frequency
2. Calibrated and Variable Output Amplitude
   (Over a Wide Dynamic Range)
3. One Or More Forms Of Modulation

A basic signal generator is an energy source whose output frequency and output level (amplitude) are variable over a wide range, yet are always known. Also signal generators must include some provision for calibrated modulation.

OTHER TYPES OF SIGNAL SOURCES

A. Sweep Oscillators

B. Function Generators

C. Test Oscillators

D. Frequency Synthesizers

Other sources which don't meet this definition are often mistakenly called signal generators.

Sweepers have uncalibrated output levels.

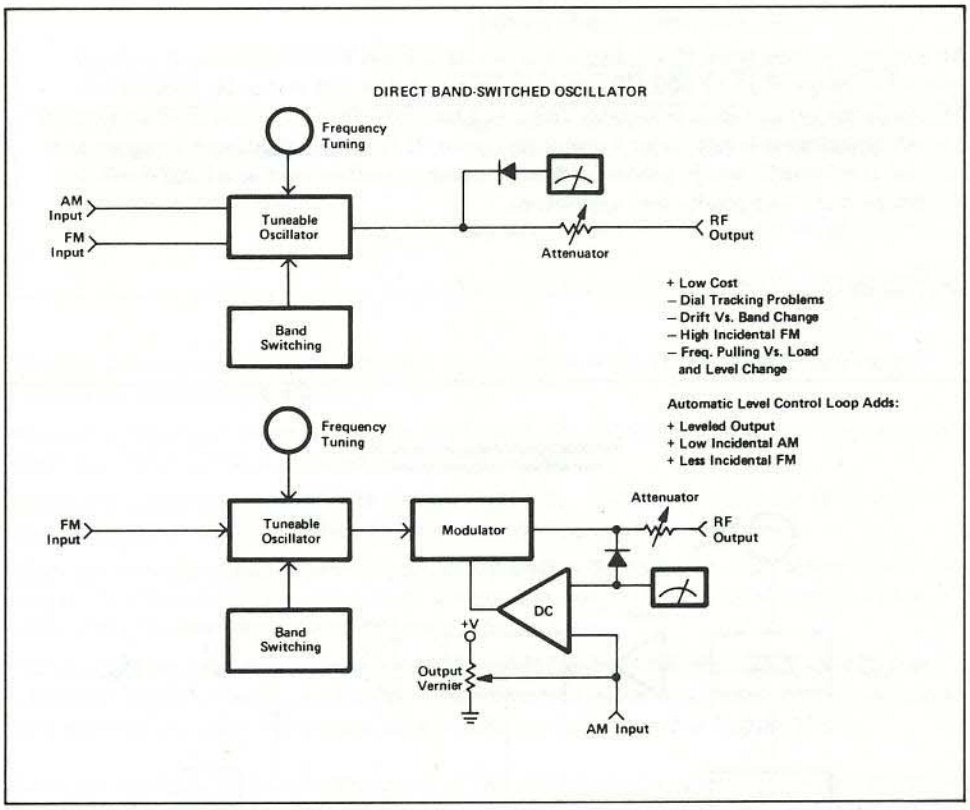
Function generators lack output leveling and modulation.

Test oscillators lack modulation and usually lack calibrated output levels.

Synthesizers generally do not have modulation or calibrated output.

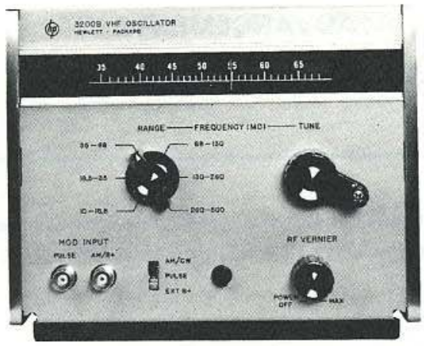
ADVANCEMENTS IN SIGNAL GENERATOR DESIGN

To best appreciate the advances in signal generator design let's run through a quick evolution in signal generator complexity. This will not necessarily be a chronological evolution.



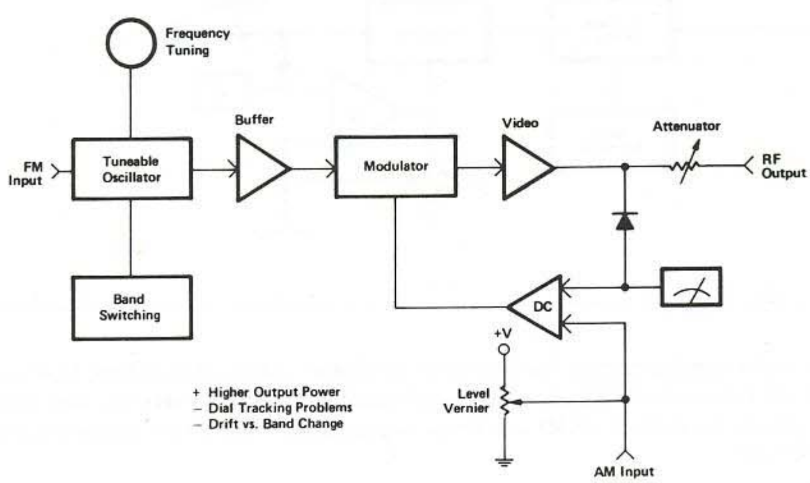
The most basic signal generator has a variable oscillator with band switching to extend the range, an output level indicator, and a calibrated attenuator to vary the output level. Both amplitude modulation (AM) and frequency modulation (FM) are applied directly to the oscillator.

Along with *calibrated* output level, the user would probably like to have a *constant* output level as frequency is changed. The automatic level control (ALC) loop in the lower block diagram provides a constant level output with the added bonus of reduced pulling of the oscillator frequency by the AM signal.



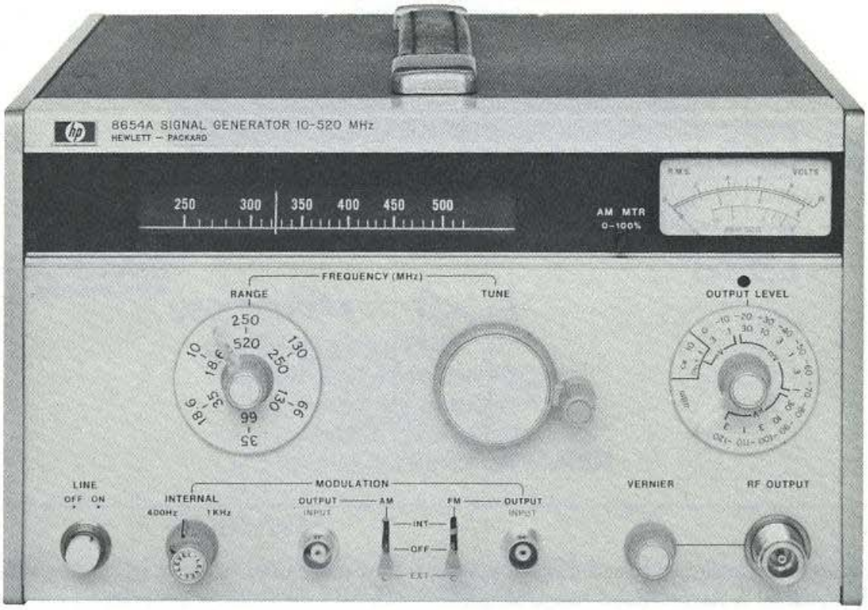
An example of this basic block diagram is the HP 3200B VHF Oscillator. It covers a frequency range of 10 to 500 MHz and can be externally AM and pulse modulated. Although the output level is variable from +13 to −107 dBm, it is unleveled and uncalibrated, therefore it is not really a signal generator. It is simple, light, and compact and because it provides enough power to drive a mixer it is often used as a local oscillator for design work and production test setups.

BANDSWITCHED OSCILLATOR WITH BROADBAND AMPLIFICATION



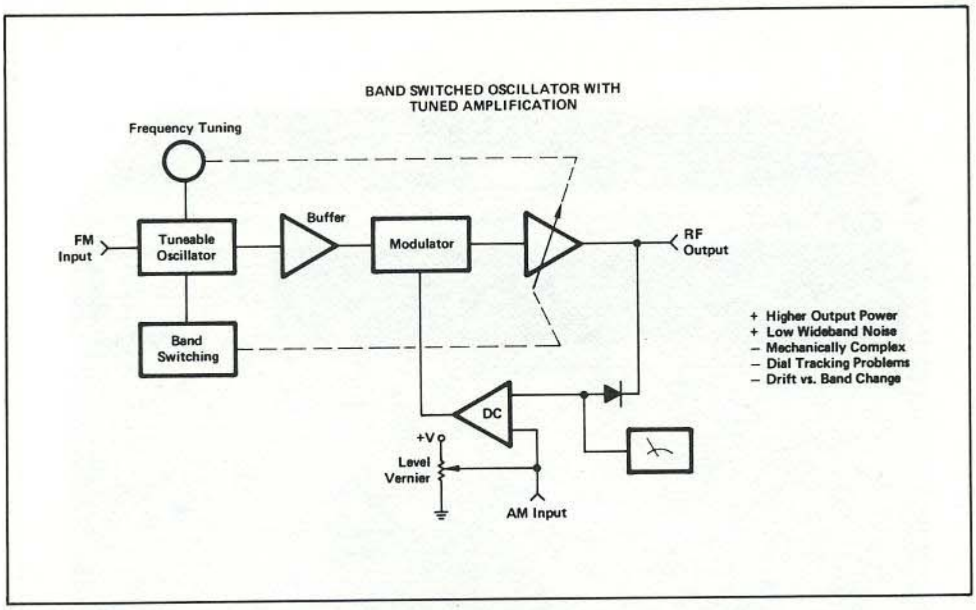
When the application calls for better frequency stability, a buffer amplifier can be added between the oscillator and modulator to further reduce any pulling of the oscillator frequency by the modulation.

When more power is required an output amplifier can be added. Older tube-type generators commmonly used tuned power amplifiers. In modern generators these have been replaced with broadband (video) amplifiers made possible by recent advancements in solid state design.

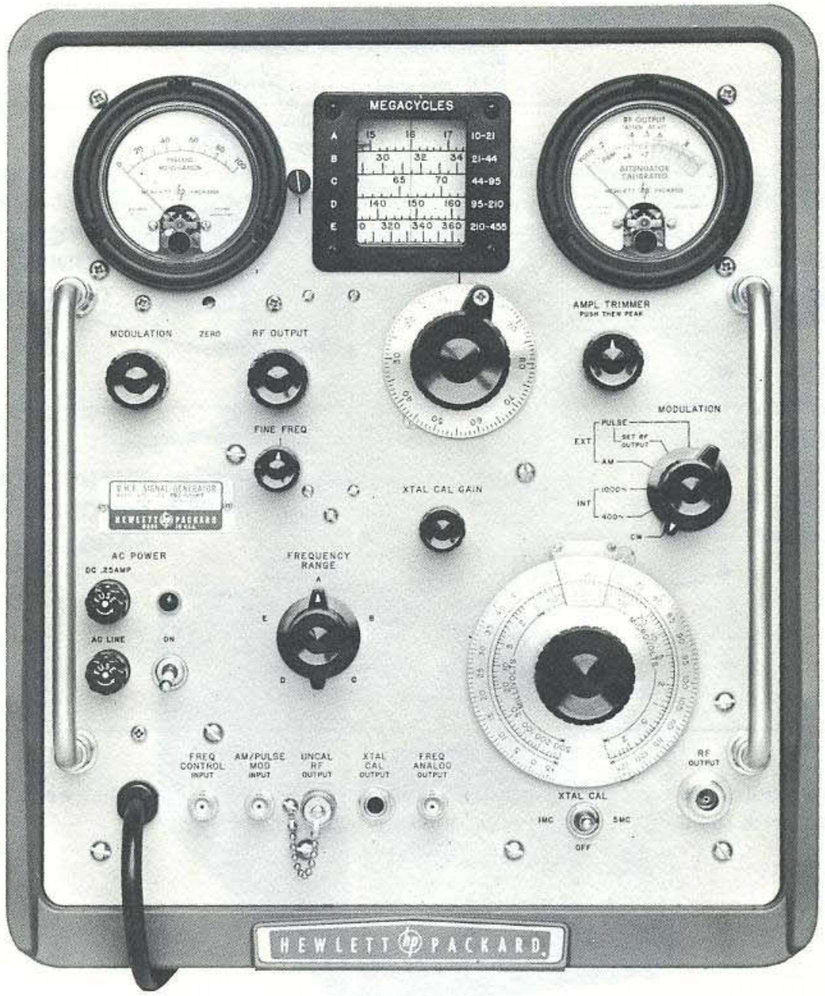


The HP 8654A economy signal generator uses the broadband amplifier technique. It covers a frequency range of 10 to 520 MHz and has a calibrated output range of +10 to −130 dBm. It has AM and FM capability (internal 400 Hz and 1 kHz tones or external signals).

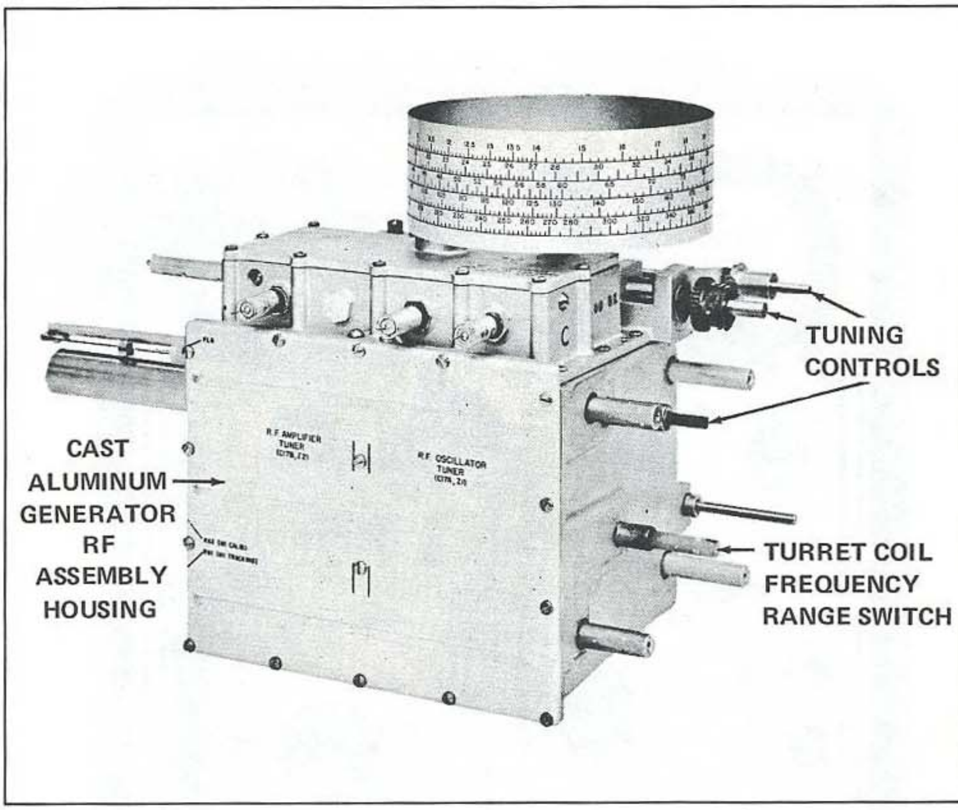
Low cost, solid-state generators of this type offer a lot of performance per dollar. They are more than adequate for many service shops, production lines, school labs and even R&D labs where their low cost makes "one on every bench" practical. Their small size and light weight also makes them attractive for field "Go -- No Go" receiver testing, where only a few basic tests are performed.



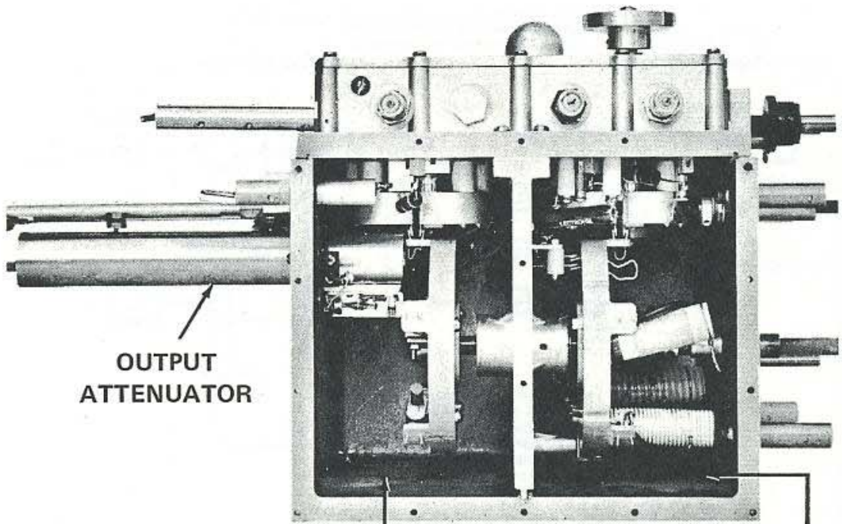
In vacuum tube designs a tuned output amplifier is usually used in place of the broadband video amplifier. A narrowband tuned amplifier with gain only at the generator's output frequency, coupled with the large signal available from a tube-type oscillator, results in a generator with excellent signal-to-noise ratio. However, this advantage is achieve at the expense of significantly greater mechanical complexity and more frequent maintenance requirements.



The HP 608E and 608F are examples of generators that use the tuned output amplifier technique. With a frequency range of 10 to either 455 or 480 MHz, their output is accurate and continuously variable from +13 to −127 dBm. They can be AM and pulse modulated with both internal and external signals. Their tube-type design has high stability, excellent signal-to-noise ratio and spectral purity, and low AM distortion. As such these generators have until recently been considered standards of the communications industry.



Let's take a quick look at the oscillator/amplifier assembly of the 608 so that we can later compare it with the new generation of all solid-state generators.

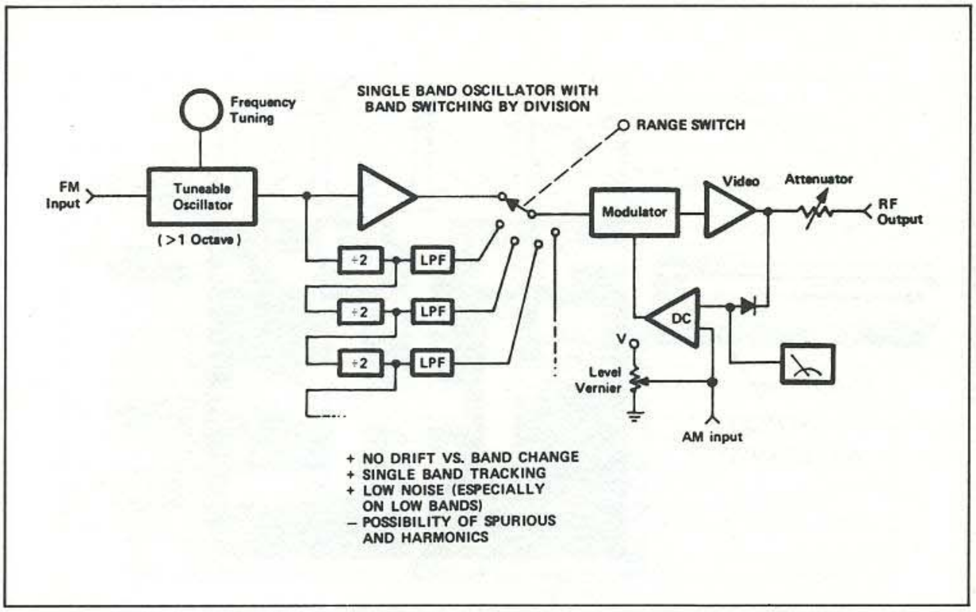


With the cover removed we can see the band switching coils for the oscillator in the right section. The switchable coils for the tuned output amplifier are in the left section.

LIMITATIONS OF MULTIBAND TUBE-TYPE SIGNAL GENERATORS

- Microphonics
- Restabilization Time After Band Change
- Tube Aging
- Size and Weight
- FM Capability Not Included In Many Generators

Although multiband tube-type signal generators have excellent signal quality, they do have several limitations. These are microphonics (sensitivity to mechanical vibration), restabilization time after band change, tube aging, size and weight. Also, many generators designed during this period did not include FM capability.



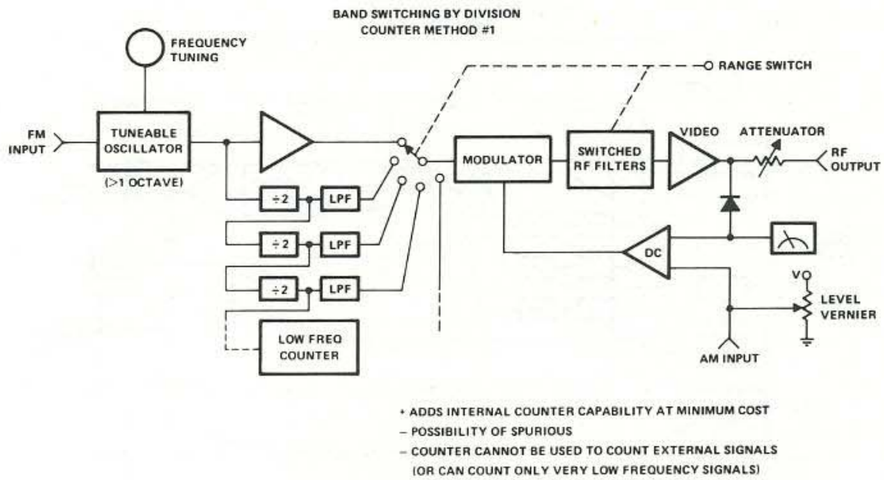
The latest advancement in signal generator design has been the use of a single-band oscillator to tune over the highest band of the generator, with solid-state dividers switched in to obtain the lower bands. This technique has several advantages . . .

- the oscillator can be optimized for best FM performance and spectral purity over a single band
- as dividers are switched in for lower bands they divide down the noise output as well as the frequency
- frequency drift after band change is virtually eliminated

. . . and a coupler of trade-offs

- maximum FM deviation varies with the band
- the dividers are potential sources of harmonics and subharmonics in the output.

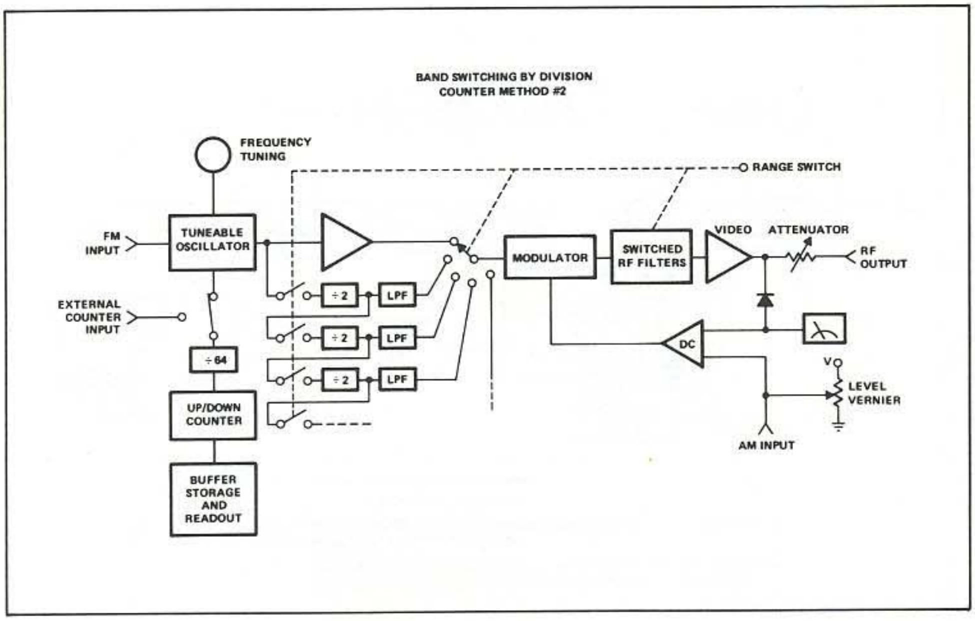
  The harmonics can be controlled with switchable highpass filters. The subharmonics could be reduced by cutting off any low frequency dividers below the band in use.



A recent trend in signal generator design has been to include a built-in counter for greatly improved frequency resolution and accuracy. When the divider-type block diagram is used, one way to do this is to simply add a low frequency counter at the end of the RF divider chain. This technique is relatively straightforward and inexpensive, but has a couple of drawbacks:

(1) Dividers below the band in use cannot be cut off to reduce subharmonic distortion because they are still needed to drive the counter.

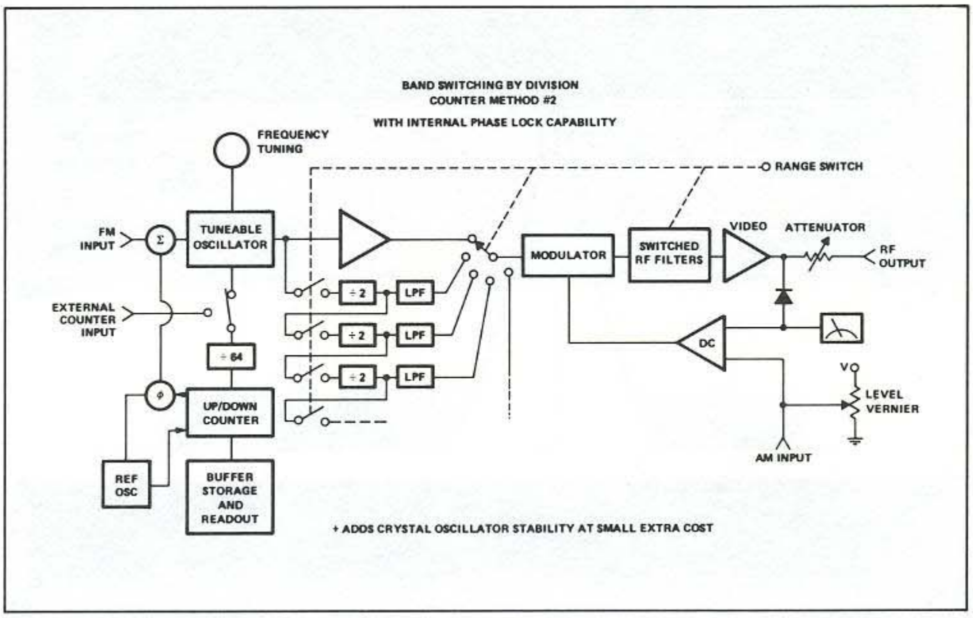
(2) Since a very low-frequency counter is used, it normally cannot be used to count external signals.



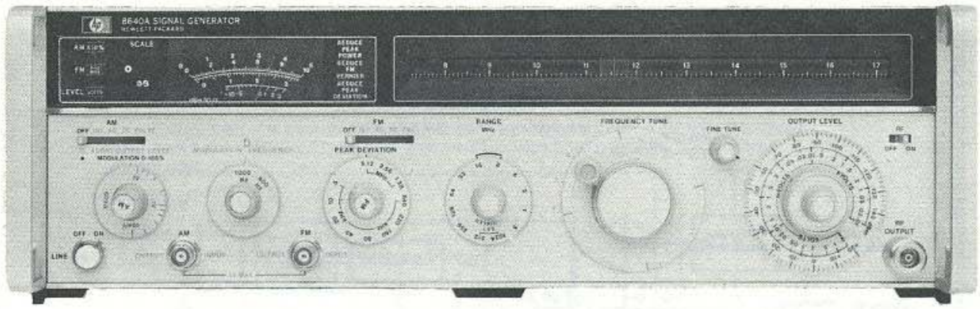
An attractive compromise is to provide a separate divider to drive the counter. While being slightly more expensive, this method allows cutting off any of the output dividers not in use, reducing the possible spurious and subharmonic outputs.

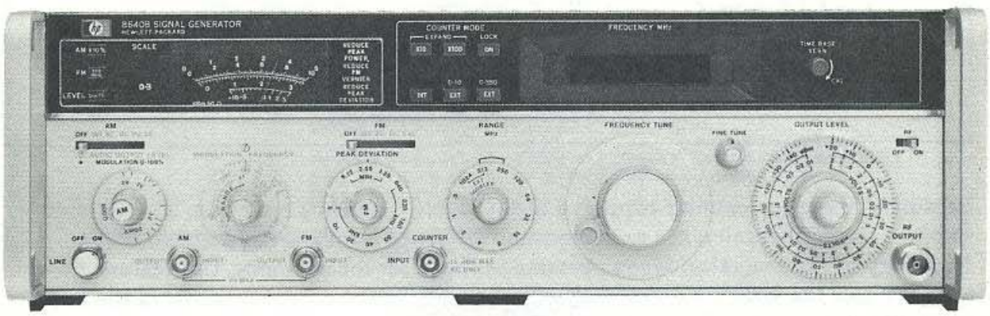
A second advantage of this technique is that the internal counter can also be used to count external signals over the full frequency range of the signal generator.

Finally, the completely independent internal counter with its own dividers is useful for self-test and servicing, i.e., the counter can be used to test the generator output and vice versa.

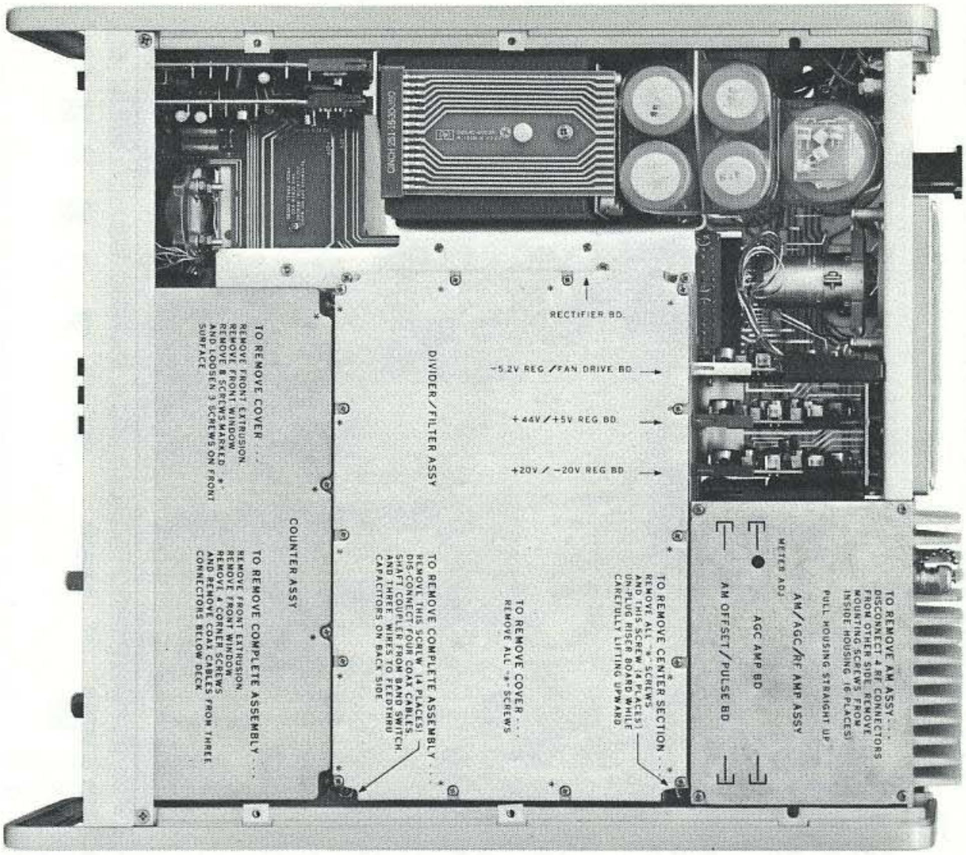


Because a frequency counter requires a highly stable frequency reference, it's a natural step to also use that reference as a frequency reference for phase-locking the output frequency of the generator. When operated in the phase-locked mode, this feature gives the generator the same long-term frequency stability as the crystal timebase in the counter (typically on the order of parts in 10^8 per hour).





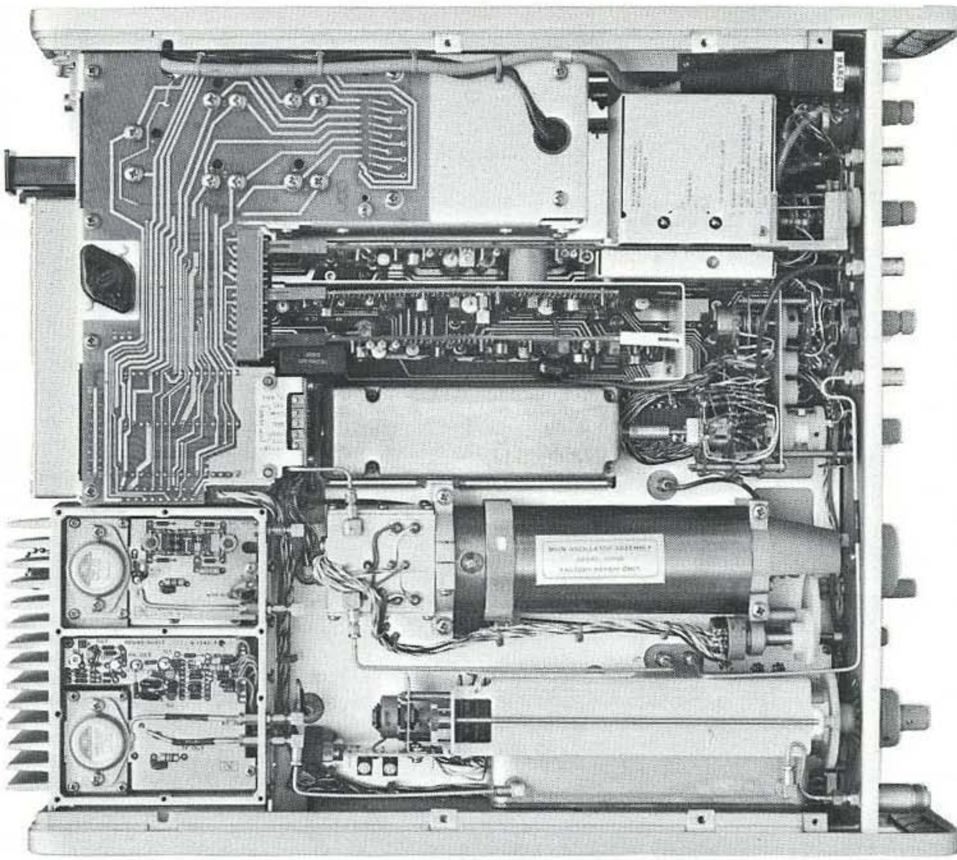
This is exactly the technique used in the HP 8640B high performance signal generator, the lower unit in this picture. The upper unit, the 8640A, uses identical circuitry without the counter and phase-lock circuits. These instruments have a frequency range of 450 kHz to 550 MHz and a calibrated and leveled output range of +19 to −145 dBm. They can be AM, FM, and pulse modulated with both internal and external signals. This type of high quality general purpose AM/FM generator is used whenever full performance tests are required such as in stringent receiver testing. The inclusion of a counter (8640B) adds high resolution, crystal stability, and external count to 550 MHz.



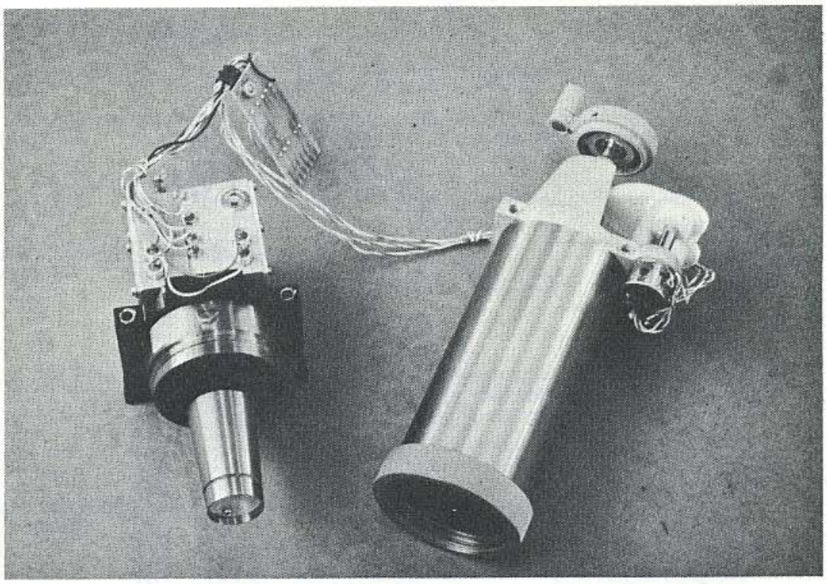
A few minutes ago we looked at the HP 608's oscillator and amplifier assembly. Now for comparison let's look inside the HP 8640B to see how modern technology has affected internal instrument layout. The most notable difference is that while the 608 had oscillator, amplifier, range switching, etc. built into one large casting, the modern generator has each major function built as an individual module. This modular design greatly facilitates access for troubleshooting and adjustment and also allows individual shielding of each functional circuit -- an important consideration in today's more densely packed generators.

The major functional assemblies in the 8640B pictured are as follows:

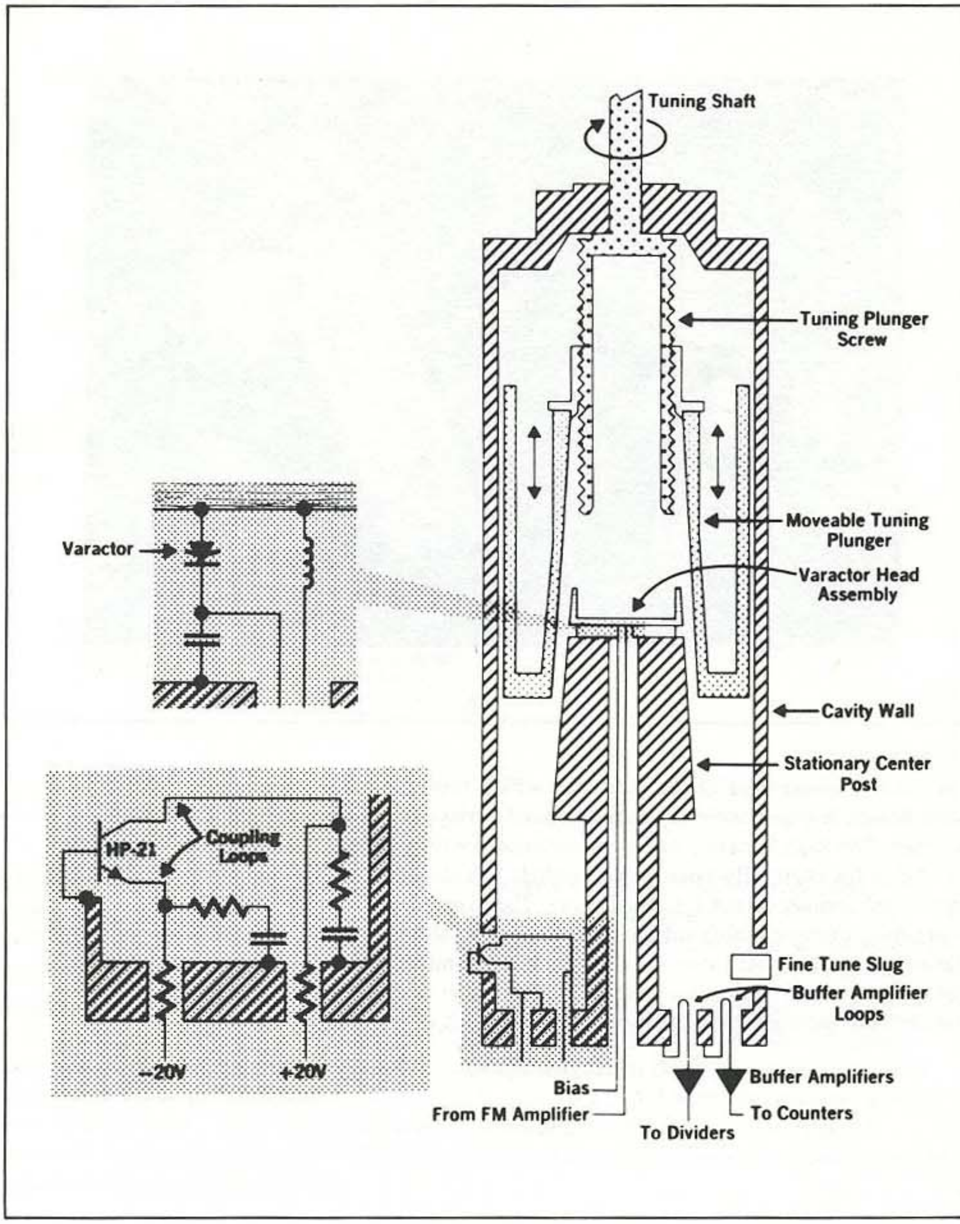
The power supplies are at the top left. The counter unit is seen on the bottom left and the divider network is the unit on the bottom center. The output amplifier is on the bottom right with its integral heat sink extending out the rear of the instrument.



Turning the instrument around we see the optional variable frequency oscillator on the upper right. The oscillator cavity is just above the step attenuator which is in the lower right corner.



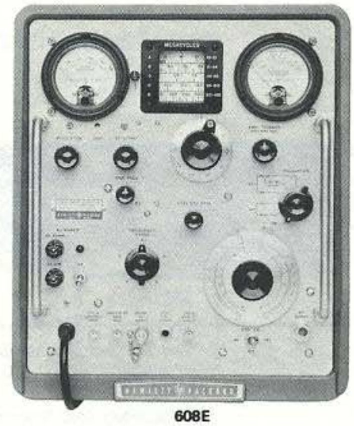
Let's take a closer look at the oscillator which forms the heart of this generator. The basic design is a mechanically tuned coaxial cavity, tuned by a non-contacting sliding plunger. The high Q cavity has been optimized with the use of a low noise microwave transistor for spectrally pure output signals (on the order of 15 - 20 dB better than an equivalent transistorized L-C oscillator). The housing on the right contains the non-contacting plunger which rides on Teflon guides and is mechanically positioned over the stationary center post (seen on the left) to determine the resonant frequency. The housing on which the center post is mounted also contains the buffer amplifiers which connect the separate pick-off loops to the output divider and counter.



The separate pick-off loops allow the cavity to act as a feedback filter protecting the output divider network from possible spurious developed in the counter network.

We can see from this comparison that oscillator design has come a long way since the HP 608.

8640A



608E

- Wider Frequency Range
- Output Power to +19 dBm
- Internal/External FM
- High Quality AM Generator - Lower Incidental FM and Distortion

- Output Accuracy ± 1 dB (Continuous Output Attenuator)

A comparison of the HP 8640A (dial tuned) high performance signal generator with the older HP 608 reveals that the modern design exceeds the 608 in almost all categories. Besides the obvious size difference, it is significant to note that the modern generator has a greater frequency range, higher power output and FM capability.

8640	8654
- Wider Frequency Range (down to 450 kHz)	- Low Price
- Output Power to +19 dBm	- Compact and Portable
- Exceptionally Good Spectral Purity and Noise Performance	- Limited FM Capability
- A True FM Generator	
- High Quality AM Generator - Lower Incidental FM and Distortion	
- Various Options Plus "B" Version For Expanded Capability	

Comparing the 8640A (dial tuned) high performance signal generator with the 8654A economy signal generator, it becomes obvious that the modern advances we have discussed make possible the choice of stringent performance when it is needed or the option of satisfactory performance with an excellent price/performance ratio where the application dictates.

ADVANCEMENTS

Design Advancement	Affect on Signal Generator Performance
All Solid-State Design	– Smaller and Lighter – Eliminates Aging Problems
Internal AGC	– Constant Level v.s. Frequency (not just *calibrated*)
Broadband Output Amplifiers	– Less Mechanical Complexity – Less Frequency Pulling & Incidental FM
Improved Oscillator Designs and High Frequency Dividers	– Lower Noise and Residual FM
Internal Frequency Counter	– Better Resolution and Accuracy – Possible External Counter Capability
Internal Phase-Lock on Counter Designs	– Improved Frequency Stability
Modular Construction and Design	– Improved Serviceability

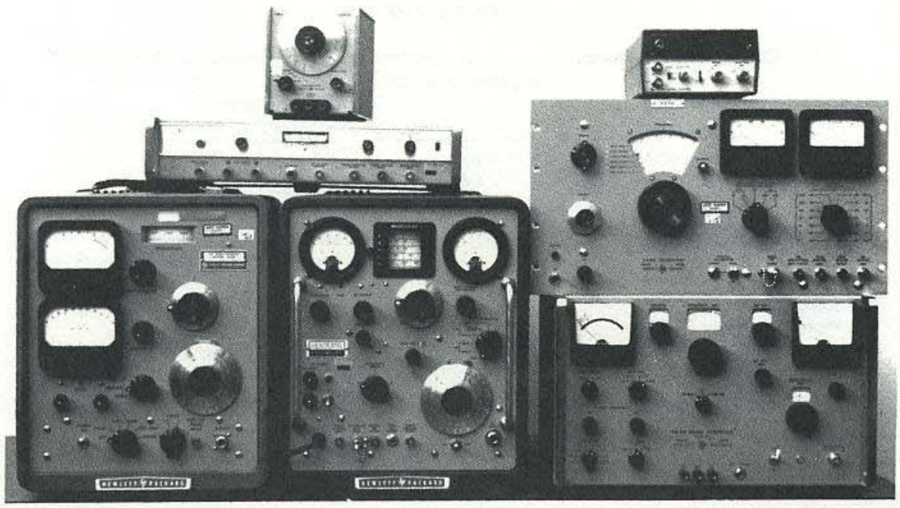
TECHNOLOGICAL ADVANCES MAKING THIS POSSIBLE

High Frequency Transistors for Solid-state Oscillators and Amplifiers

High Frequency Monolithic Dividers (>500 MHz)

Thin Film Broadband Amplifiers (450 kHz – 550 MHz)

In summary, we see that solid-state designs, including broadband output amplifiers and improved oscillators, have provided signal generators that are smaller, lighter, longer lasting, more stable and more spectrally pure. The inclusion of internal counters and phase-lock techniques have greatly improved resolution, accuracy and stability. And finally, modern construction and design have improved serviceability.



To dramatically illustrate how far signal generator design has come in the last decade, here is the equipment replaced or partially replaced by the new HP 8640B high performance signal generator plus a frequency doubler. (Left to right, top to bottom: 204 function generator, 5300 counter, 8708A synchronizer, 606 signal generator, 612 and 608 AM signal generators, and 202 FM signal generator.)

HOW TO READ DATA SHEETS

In this section we will briefly discuss most of the specifications on a signal generator data sheet. However, the emphasis will be on the newer specs and on those that are most complicated and commonly misunderstood.

SIGNAL GENERATOR SPECIFICATIONS

- FREQUENCY CHARACTERISTICS
- OUTPUT CHARACTERISTICS
- MODULATION CHARACTERISTICS

The specifications on signal generators are divided into three major categories: FREQUENCY, OUTPUT and MODULATION. The application of the instrument determines the relative importance of these characteristics.

FREQUENCY CHARACTERISTICS

→ **Frequency Range:**

→ **Frequency Accuracy:**

Frequency Stability With . . .

A. Time

B. Temperature

C. Line Voltage

D. Load Change

E. Band Switching

Short-Term Stability:

Harmonics:

Spurious

A. Non-Harmonic Spurious

B. Subharmonic Spurious

We have a rather complete list of Frequency Characteristics here. Though we won't talk about all of them, they should all be included on the data sheet of a high performance signal generator. An economy signal generator will naturally have fewer specifications.

The FREQUENCY RANGE specification of a signal generator is self-explanatory, but one caution -- in many applications the frequency range of the generator must be considerably greater than that of the device being tested in order to check harmonic rejection, intermod and spurious responses, etc.

FREQUENCY ACCURACY is a spec that has changed a lot in the past few years due to the addition of counters in signal generators. Generators with internal counters generally have much better frequency resolution, better settability and better resettability. In some of today's generators the internal counter also gives external counting capability and in many cases internal phase lock capability at the same time. However, one caution: The number of digits in the counter implies that the output frequency from the generator has that accuracy, but in fact the accuracy of the counter is only as good as the counter time base. As an example, a counter with 100 Hz resolution at 500 MHz might only have an accuracy of ±500 Hz if its time base accuracy is 1 ppm.

FREQUENCY CHARACTERISTICS

Frequency Range:

Frequency Accuracy:

→ **Frequency Stability With . . .**

- A. Time
- ➧ B. Temperature
- C. Line Voltage
- D. Load Change
- E. Band Switching

→ **Short-Term Stability:**

Harmonics:

Spurious

- A. Non-Harmonic Spurious
- B. Subharmonic Spurious

Long-term STABILITY specs (stability over minutes and hours) cover the effects of TIME, changes in TEMPERATURE, LINE VOLTAGE, LOAD, and BAND SWITCHING on output frequency. Though these effects are usually observed in combination, their contributions are spec'd individually on the data sheet. In newer solid-state generators the most significant parameter is TEMPERATURE. The degree of effect is a function of the thermal mass of the generator. Generators with a large thermal time constant (large thermal mass) take longer to warm up but are least affected by short term temperature changes.

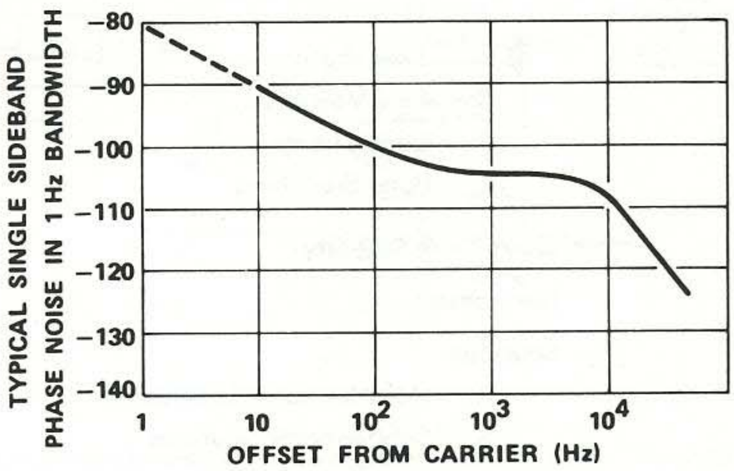
The addition of internal phase lock, as in the HP 8640B, virtually eliminates all these long-term drift factors. You can turn on an 8640B, set the frequency, and push the phase lock button for a frequency stability equal to that of the reference crystal ($\pm 5 \times 10^{-8}$/hr.).

SHORT-TERM STABILITY is measured over periods which are fractions of a second. In older generators the largest source of short-term instability was 60 Hz pickup. In modern generators this problem is almost entirely eliminated and short-term stability is a function of noise either modulating the oscillator or added along the signal path.

The short-term instability of a generator limits its use in FM applications. It can also cause problems in an AM system if the instability is excessive (e.g., FM's out of the passband of the device under test) or if the AM system is also FM sensitive.

METHODS OF SPECIFYING SHORT-TERM STABILITY

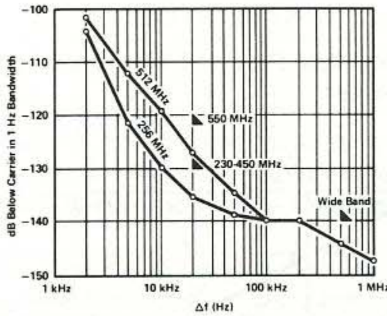
→ 1) SSB Phase Noise Plot In 1 Hz Bandwidth vs. Offset From Carrier*



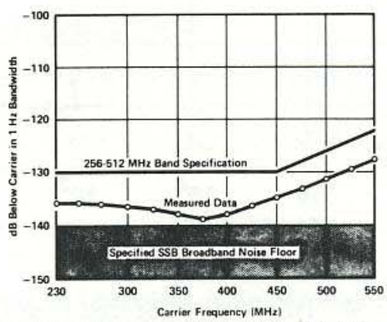
2) Residual FM: Hz, RMS In Stated Post Detection Bandwidth

*Basic Short-Term Stability Measurement. All Others May Be Derived From This Plot.

There are several ways to specify SHORT-TERM STABILITY. The most fundamental method is to plot single sideband phase noise in a 1 Hz bandwidth against offset from the carrier. This is a graphical representation of the phase noise distribution on one side of the carrier. The assumption is made that the distribution on the other side of the carrier is identical. From the curve it is possible to compute the other short-term stability specs (although the calculations are difficult and often measured instead).



SSF Phase Noise Plot in 1 Hz Bandwidth vs. Offset From Carrier



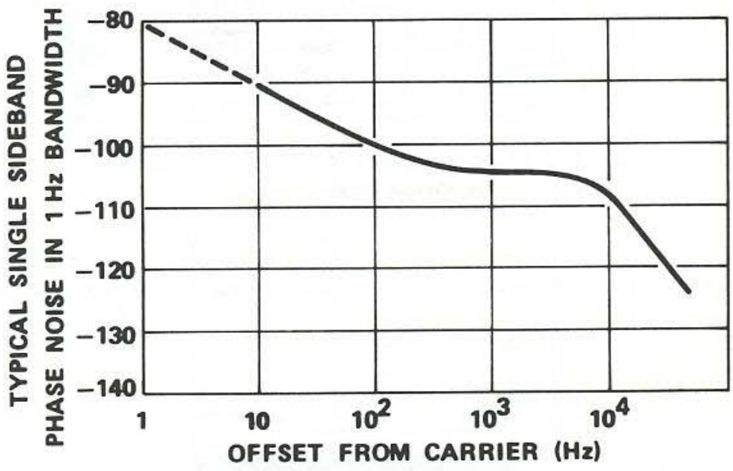
Signal-to-Phase Noise Ratio at 20 kHz Offset vs. Carrier Frequency (MHz)

Some examples of SSB phase noise plots from the 8640 high performance signal generator data sheet. The top figure is the SSB phase noise curve. It shows the noise on one side of the carrier. These plots are for carrier frequencies of 512 and 256 MHz.

The lower figure is a plot of signal-to-phase noise ratio at 20 kHz offset from the carrier vs. the carrier frequency, i.e., it is a plot of one point on the phase noise curve vs. different carrier frequencies. The top line is the specification and the lower line is actual measured data.

METHODS OF SPECIFYING SHORT-TERM STABILITY

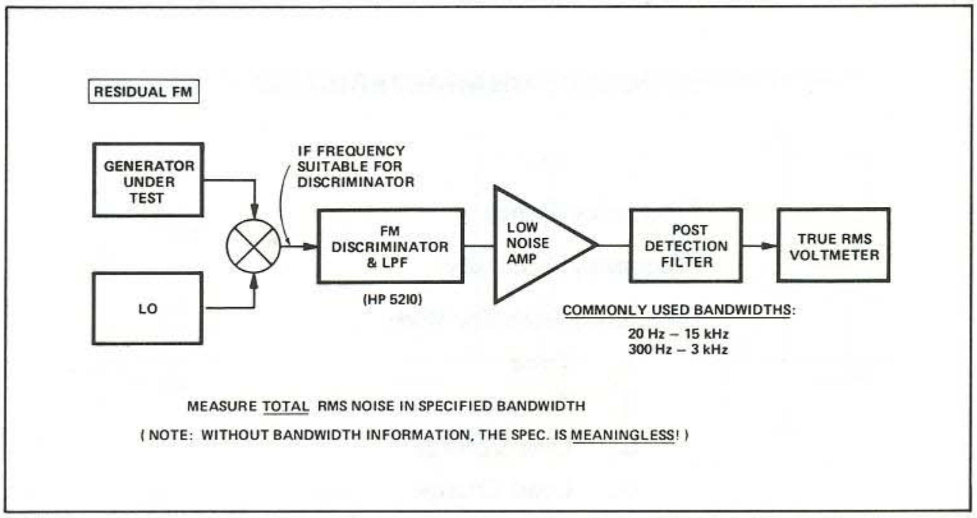
1) SSB Phase Noise Plot In 1 Hz Bandwidth vs. Offset From Carrier*



→ 2) Residual FM: Hz, RMS In Stated Post Detection Bandwidth

*Basic Short-Term Stability Measurement. All Others May Be Derived From This Plot.

RESIDUAL FM is the other common method used to specify short-term stability. It is a measure of the small amount of FM inherent in the generator in the CW mode with all modulation turned off. Residual FM is due to the combined effect of all the noise shown on the phase noise curve out as far as the bandwidth of the FM measurement setup. It is measured in RMS deviation because today residual FM is virtually all noise related.



RESIDUAL FM is usually measured by beating the generator under test against a local oscillator (cleaner than or at least equivalent to the generator under test) to develop an IF suitable for use in an FM discriminator. The discriminator output is amplified and passed through a low-pass filter to a true RMS voltmeter. Since the FM is noise related, filter bandwidth is the key to the spec. Without specifying the bandwidth a residual FM spec is meaningless. Almost any desired value can be obtained by changing bandwidth if bandwidth is not specified.

FREQUENCY CHARACTERISTICS

Frequency Range:

Frequency Accuracy:

Frequency Stability With . . .

A. Time

B. Temperature

C. Line Voltage

D. Load Change

E. Band Switching

Short-Term Stability:

→ **Harmonics:**

→ **Spurious**

A. Non-Harmonic Spurious

B. Subharmonic Spurious

The Harmonics spec is straightforward and does not need discussion here. SPURIOUS has gained significance with the introduction of synthesized signal generators and subharmonics with the trend toward divider type sources. Nonharmonic spurs are often cause by mixers and/or dividers. Subharmonic spurious are 1/2, 1/4, 1/8, etc. of the output frequency. These develop in dividers and scalers for counters. Extra care is needed in shielding an internal counter to avoid trouble from this source. This spec warrants notice on new data sheets.

OUTPUT CHARACTERISTICS

→ **Output Level Range:**

A. Volts and dBm Into 50 Ohms

or

B. EMF

→ **Output Accuracy:**

A. Meter

B. Attenuator (Trend Toward Step Attenuators Because of Less Insertion Loss)

C. Flatness (Frequency Response): Modern Generators Should be Leveled

Output Level Stability With . . .

A. Time

B. Temperature

C. Line Voltage

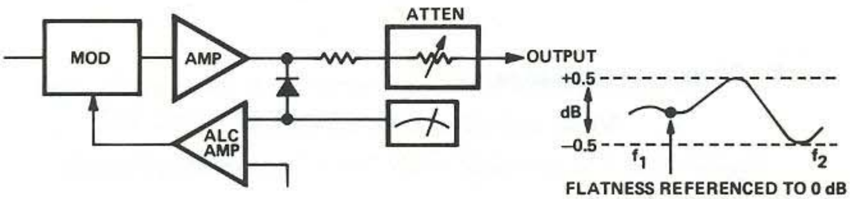
Source Impedance:

Leakage:

Looking at OUTPUT characteristics, there are two methods commonly used to specify LEVEL RANGE. The most common is to spec voltage into a 50 ohm resistive load. The other is to spec voltages into an open circuit (EMF). Sometimes EMF is stated as a level "behind" 50 ohms. In this case the stated voltage specification will be twice what it would be if specified into a matched load.

OUTPUT ACCURACY is a source of confusion because in recent years it has been divided into its component parts and spread all over the data sheet. It's easy, for example, to look at the output attenuator accuracy and assume it to be total output accuracy when actually three or four other error factors need to be added to obtain the total accuracy.

OUTPUT LEVEL ACCURACY



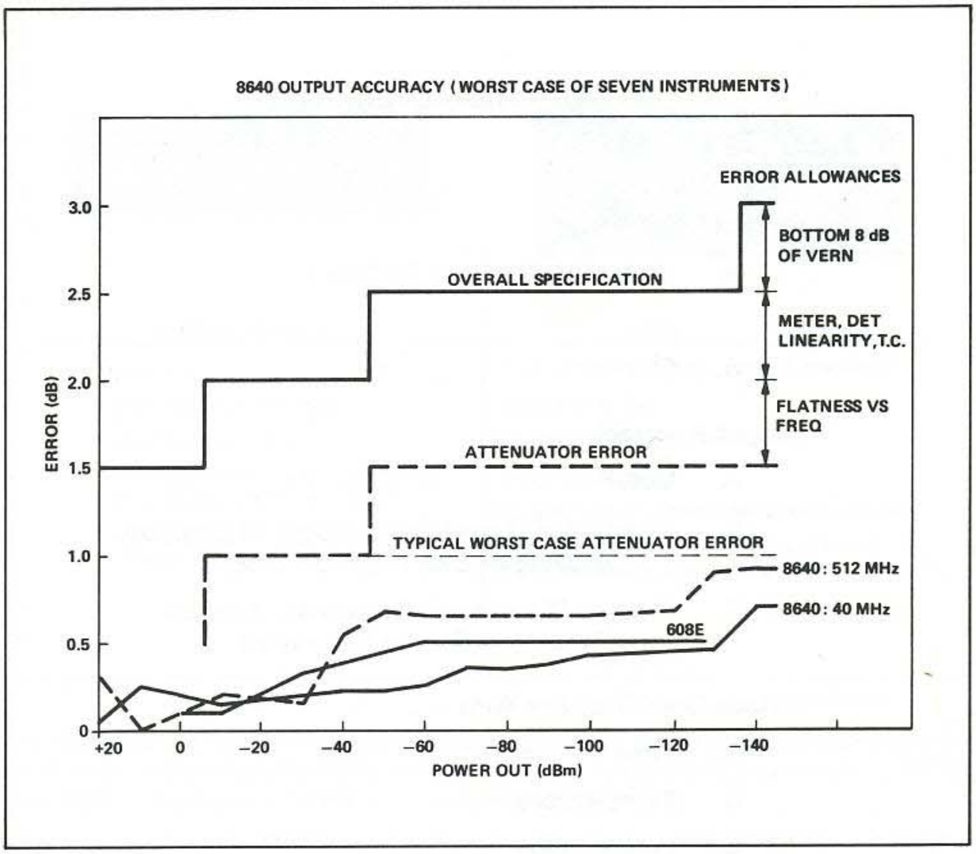
FLATNESS REFERENCED TO 0 dB AT SPECIFIED FREQUENCY

SOURCES OF ERROR: LEVEL FLATNESS
LEVEL VARIATIONS WITH TEMPERATURE (DUE TO DETECTOR)
DETECTOR AND METER LINEARITY
ATTENUATOR
MEASUREMENT UNCERTAINTY DURING CALIBRATION

OLDER GENERATORS SPECIFIED ERRORS SEPARATELY.

MODERN DATA SHEETS SHOULD INCLUDE TOTAL ABSOLUTE ACCURACY AT ANY LEVEL SETTING AND INCLUDE ALL SOURCES OF ERROR.

Looking at the sources of output accuracy error -- level flatness is added to the affect of temperature on the detector and to detector and meter linearity error to determine the accuracy of the power applied to the attenuator. These are then added to the attenuator inaccuracies (which vary for each step) and the attenuator frequency response. Finally there are measurement uncertainties in calibration. A complete data sheet should give a figure for total output accuracy and then list at least the major items that make up that total.



This graph shows how the errors in a sig gen would accumulate. It is for the HP 8640 high performance generator. We see the attenuator error is added to flatness, meter and detector linearity, the temperature coefficient, and finally on the lowest output range, to the error in the bottom 8 dB of the vernier, to give a total output accuracy spec. As output level decreases attenuator error increases as more pads are used. The curves at the bottom represent the typical measured error. They represent the worst case of several instruments that were measured at room temperature. Later, a method to calibrate out the majority of these output errors will be discussed.

For comparison the same data on some HP 608's is included. The 608 uses a waveguide-beyond-cutoff attenuator which is inherently very accurate. However, it also has 15 to 20 dB of insertion loss which cannot be tolerated in new solid-state generators. Therefore, most new generators use step attenuators (less loss) with 10 dB steps and a 9 dB vernier in the AGC loop.

OUTPUT CHARACTERISTICS

Output Level Range:

A. Volts and dBm Into 50 Ohms

or

B. EMF

Output Accuracy:

A. Meter

B. Attenuator (Trend Toward Step Attenuators Because of Less Insertion Loss)

C. Flatness (Frequency Response): Modern Generators Should be Leveled

→ **Output Level Stability With . . .**

A. Time

B. Temperature

C. Line Voltage

→ **Source Impedance:**

→ **Leakage:**

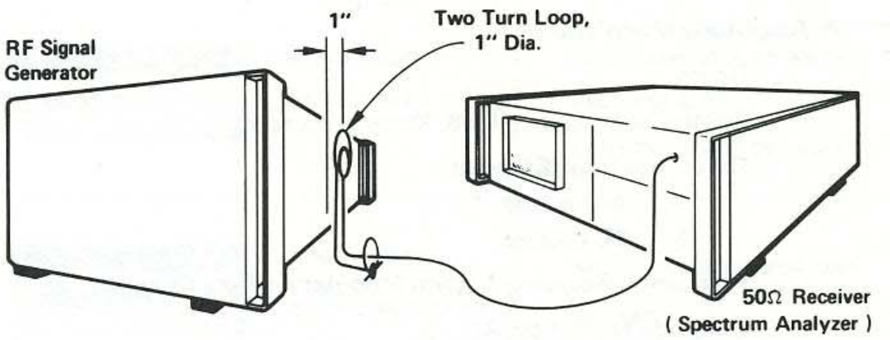
OUTPUT LEVEL STABILITY with time, temperature and line voltage is affected much the same way frequency stability is. Temperature is again the major parameter.

When looking at the OUTPUT IMPEDANCE spec, it is important to realize that the spec may be worse on the highest output level setting where there is no output attenuation to improve the match. Also the spec may apply only at the frequency of the carrier and not at frequencies far away from the carrier.

The final output spec is LEAKAGE. Rigorous leakage tests are quite time consuming and require expensive equipment and facilities. Therefore, we also use a common method to spec leakage . . .

LEAKAGE

A Common Test Setup



. . . seen here. This is a two turn loop of wire one inch in diameter held one inch from the generator. The loop is connected to a 50 ohm receiver (usually a spectrum analyzer) which acts as the detector. This practical method is not absolute, but is easily duplicated and gives a good rough indication of leakage.

MODULATION CHARACTERISTICS

→ **Amplitude Modulation**

Depth:

Depth Calibration: (Mod. Meter Accuracy)

Rate: (Internal/External)

A. AC Coupled
B. DC Coupled

Frequency Response: (With Modulation Rate Change)

Envelope Distortion At . . .

30%
70%
90%

Incidental FM: (Incidental Phase Modulation in Many Cases)

Frequency Modulation

Deviation: (Internal/External)

Deviation Calibration: (DC Voltage Sometimes Used)

Rate: (Internal/External)

A. AC Coupled
B. DC Coupled

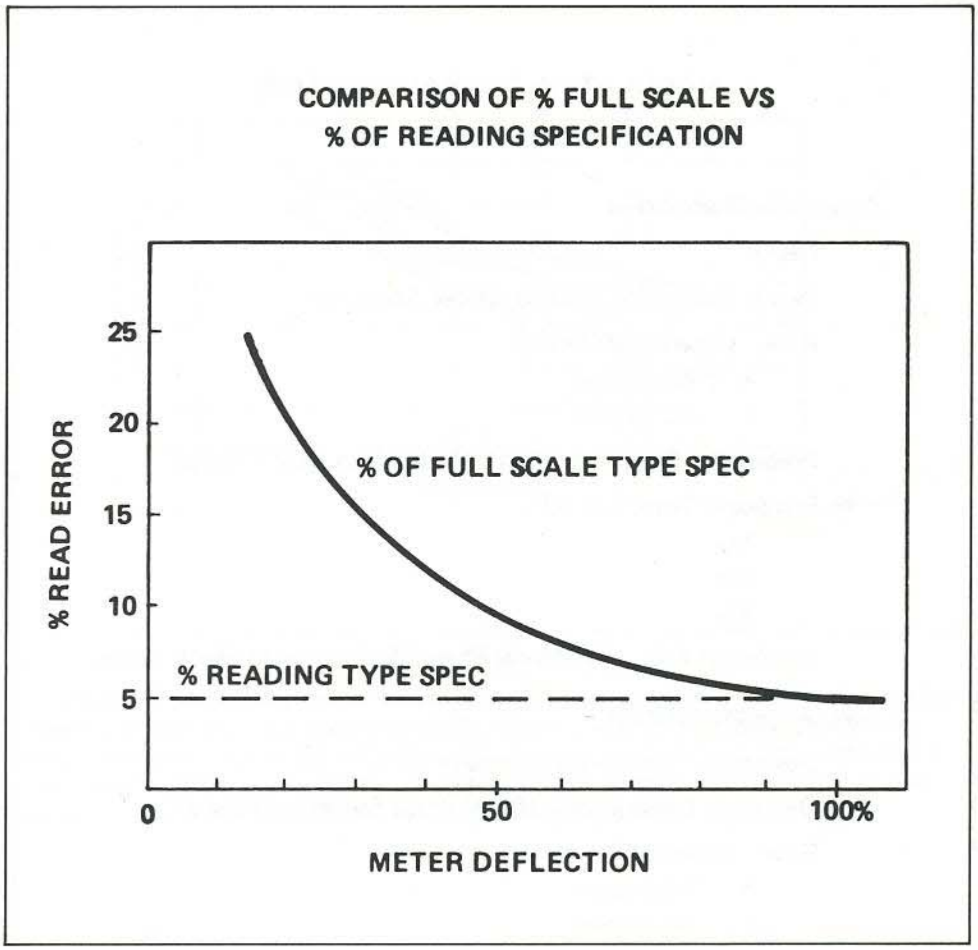
Frequency Response (With Modulation Rate Change)

Distortion:

Incidental AM:

Pulse Modulation
Video Modulation } Special Cases of AM

The final category of specification is MODULATION characteristics. Most specs in this category are quite straightforward. Concerning RATE, DC coupling is important not only for low modulating rates, but also in some applications where it is necessary to have very little phase shift between the audio modulating signal and the final envelope of the carrier. This is especially true in certain forms of avionics testing.



Two common ways to spec mod meter accuracy are % of full scale and % of reading. The "% of reading" spec'd meter has the same percent accuracy regardless of the meter deflection. On a "% of full scale" spec'd meter percent of error increases greatly for small meter deflections. It's therefore important to pay attention to the exact wording of the specification.

MODULATION CHARACTERISTICS

Amplitude Modulation

Depth:

Depth Calibration: (Mod. Meter Accuracy)

Rate: (Internal/External)

A. AC Coupled

B. DC Coupled

Frequency Response: (With Modulation Rate Change)

→ Envelope Distortion At . . .

30%

70%

90%

Incidental FM: (Incidental Phase Modulation in Many Cases)

Frequency Modulation

Deviation: (Internal/External)

Deviation Calibration: (DC Voltage Sometimes Used)

Rate: (Internal/External)

A. AC Coupled

B. DC Coupled

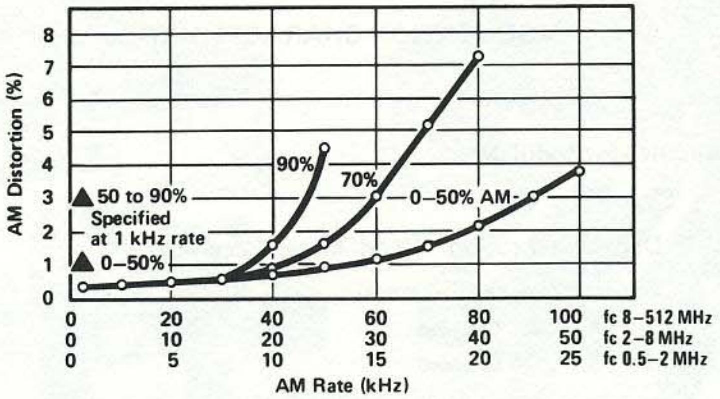
Frequency Response (With Modulation Rate Change)

Distortion:

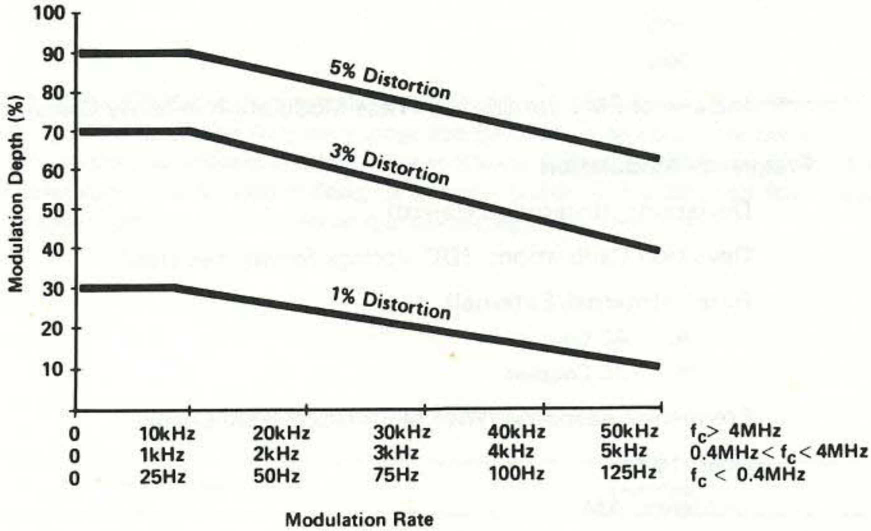
Incidental AM:

Pulse Modulation }
Video Modulation } Special Cases of AM

AM ENVELOPE DISTORTION varies both with modulation rate and depth.



AM DISTORTION VS. AM RATE MEASURED AT 200 MHz AND + 13 dBm, REPRESENTATIVE OF ALL BANDS.



86601A AM DISTORTION CURVES

Here are two different methods of showing AM DISTORTION on the data sheet. The top figure shows distortion at three depths as rate is varied. The bottom curve shows combinations of rate and depth which give 1%, 3%, and 5% distortion. With either type of graph it is possible to extrapolate between the curves to get an estimate of distortion at other settings.

MODULATION CHARACTERISTICS

Amplitude Modulation

Depth:

Depth Calibration: (Mod. Meter Accuracy)

Rate: (Internal/External)

A. AC Coupled

B. DC Coupled

Frequency Response: (With Modulation Rate Change)

Envelope Distortion At . . .

30%

70%

90%

→ Incidental FM: (Incidental Phase Modulation in Many Cases)

Frequency Modulation

Deviation: (Internal/External)

Deviation Calibration: (DC Voltage Sometimes Used)

Rate: (Internal/External)

A. AC Coupled

B. DC Coupled

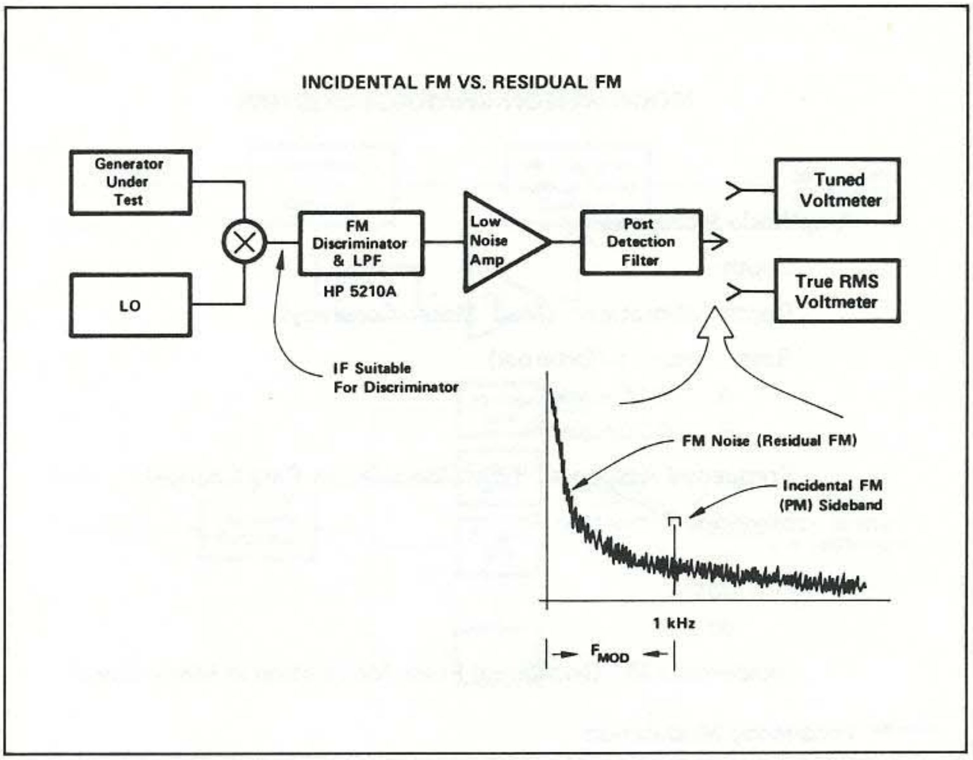
Frequency Response (With Modulation Rate Change)

Distortion:

Incidental AM:

Pulse Modulation }
Video Modulation } Special Cases of AM

When amplitude modulation (AM) is applied, a small amount of FM occurs at the same rate as the modulating frequency. Because it is incidental to the AM, this is called INCIDENTAL FM.



This is a graphic illustration of how incidental FM would look on a low frequency spectrum analyzer at the output of the discriminator in this test setup. It shows the relationship between residual FM and incidental FM. Residual FM is caused by noise when no modulation is applied. Then when the AM is applied a small incidental FM sideband also appears.

In most new generators the actual mechanism is incidental phase modulation (PM) not incidental FM. If this is the case, the resulting FM deviation will increase as the modulating rate increases. Since this deviation might get quite large at high modulation rates, the actual INCIDENTAL PM is also often specified. From this it is possible to calculate the incidental FM deviation at high rates according to the relationship

$$\Delta \phi \text{ peak} = \frac{\Delta f \text{ peak}}{f \text{ mod}}$$

MODULATION CHARACTERISTICS

Amplitude Modulation

Depth:

Depth Calibration: (Mod. Meter Accuracy)

Rate: (Internal/External)

A. AC Coupled

B. DC Coupled

Frequency Response: (With Modulation Rate Change)

Envelope Distortion At . . .

30%

70%

90%

Incidental FM: (Incidental Phase Modulation in Many Cases)

→ **Frequency Modulation**

Deviation: (Internal/External)

Deviation Calibration: (DC Voltage Sometimes Used)

Rate: (Internal/External)

A. AC Coupled

B. DC Coupled

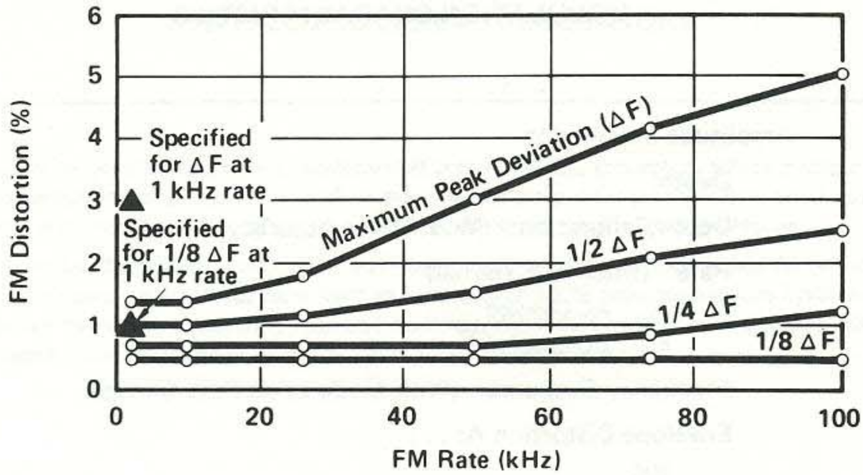
Frequency Response (With Modulation Rate Change)

Distortion:

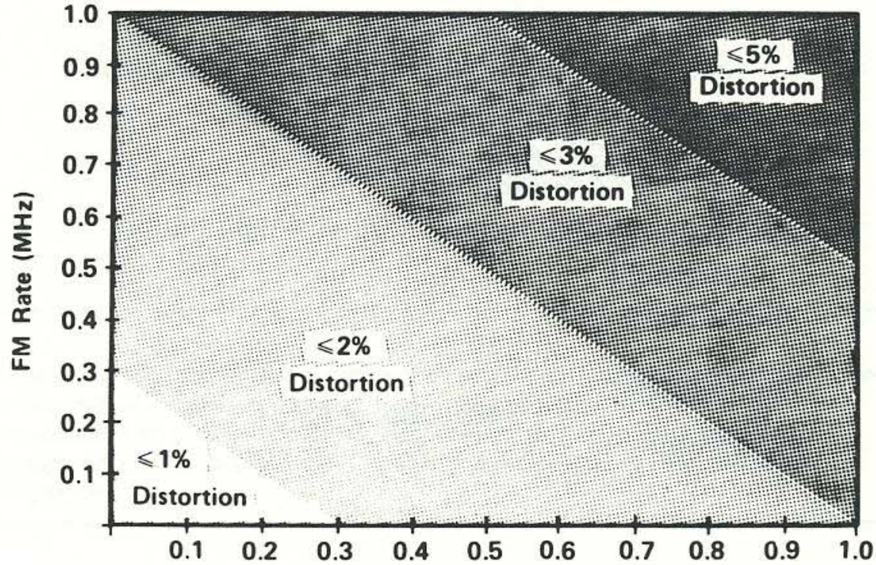
Incidental AM:

Pulse Modulation
Video Modulation } Special Cases of AM

FM specs are quite straightforward as in the AM case.



FM DISTORTION VS. FM RATE MEASURED IN THE 8–16 MHz BAND, REPRESENTATIVE OF ALL BANDS.



86601A FM DISTORTION CURVE

Here are two different methods of showing FM DISTORTION on the data sheet. The top figure shows distortion at four peak deviations as rate is varied. The bottom figure shows combinations of rate and peak deviation which give ≤1%, ≤2%, ≤3%, and ≤5% distortion. With either type of graph it is possible to extrapolate between the curves to get an estimate of distortion at other settings. The specs are confined to the graph through, i.e., with plots of this type, values cannot be safely extrapolated *beyond* the limits of the data shown.

MODULATION CHARACTERISTICS

Amplitude Modulation

Depth:

Depth Calibration: (Mod. Meter Accuracy)

Rate: (Internal/External)

A. AC Coupled

B. DC Coupled

Frequency Response: (With Modulation Rate Change)

Envelope Distortion At . . .

30%

70%

90%

Incidental FM: (Incidental Phase Modulation in Many Cases)

Frequency Modulation

Deviation: (Internal/External)

Deviation Calibration: (DC Voltage Sometimes Used)

Rate: (Internal/External)

A. AC Coupled

B. DC Coupled

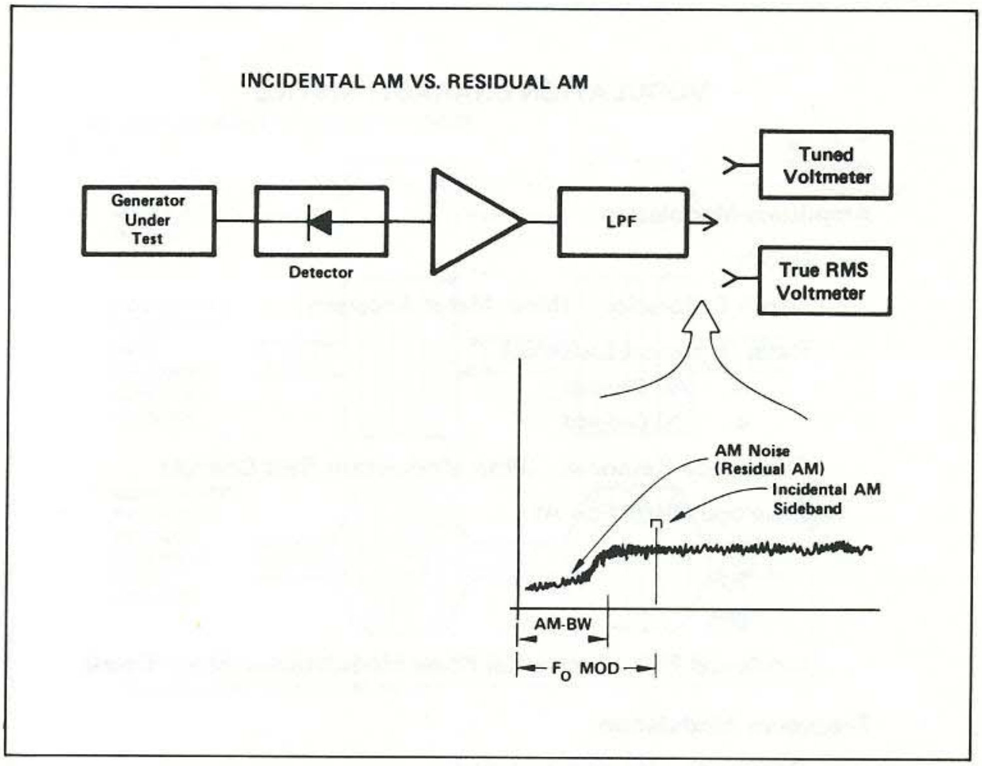
Frequency Response (With Modulation Rate Change)

Distortion:

→ Incidental AM:

Pulse Modulation }
Special Cases of AM
Video Modulation }

INCIDENTAL AM is similar to the incidental FM case. When frequency modulation (FM) is applied, a small amount of AM also occurs at the same rate. Because it is incidental to the FM, it is called incidental AM.



This is a graphic illustration of the detected AM compared to residual AM. Residual AM is that AM appearing on the carrier in the CW mode. It is mostly noise related. When FM is applied we can have incidental AM at the same rate.

Note that close to the carrier, the AM noise decreases. This is due to the action of the AGC loop.

If we FM within the bandwidth of the AGC loop, it will also reduce incidental AM. At low rates, older generators without AGC loops had higher incidental AM.

MODULATION CHARACTERISTICS

Amplitude Modulation

Depth:

Depth Calibration: (Mod. Meter Accuracy)

Rate: (Internal/External)

A. AC Coupled

B. DC Coupled

Frequency Response: (With Modulation Rate Change)

Envelope Distortion At . . .

30%

70%

90%

Incidental FM: (Incidental Phase Modulation in Many Cases)

Frequency Modulation

Deviation: (Internal/External)

Deviation Calibration: (DC Voltage Sometimes Used)

Rate: (Internal/External)

A. AC Coupled

B. DC Coupled

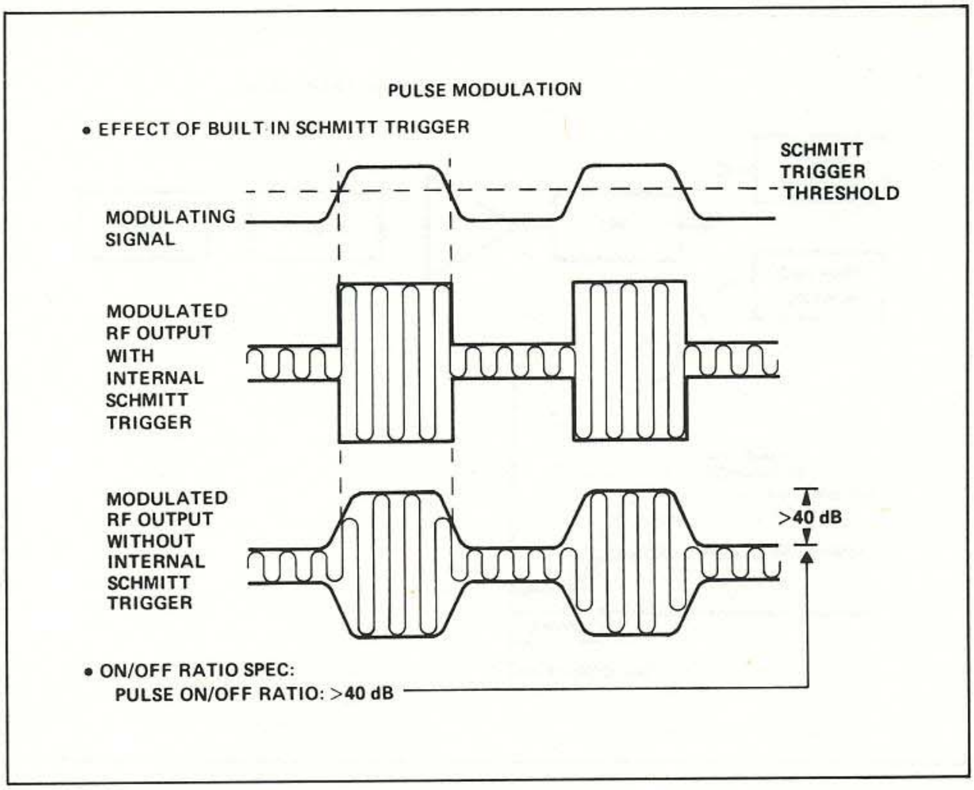
Frequency Response (With Modulation Rate Change)

Distortion:

Incidental AM:

→ **Pulse Modulation**
→ **Video Modulation**
} Special Cases of AM

PULSE and VIDEO MODULATION are special cases of AM. Pulse modulation is beginning to appear on many signal generator data sheets while video modulation (extremely wide-band AM) appears only in a few generators.



Here's an important point about external pulse modulation that isn't always obvious from the data sheet:

In some generators the input pulse is applied directly to the pulse modulator so that the RF pulse has essentially the same shape as the applied modulating signal. However, in other generators the external input is used to fire a Schmitt Trigger that controls the modulator. With this type of design the RF pulse shape will always be rectangular and only its width will be controlled by the applied modulating signal. This difference is significant in some applications.

Another commonly misunderstood specification is pulse ON/OFF ratio:

$$\text{ON/OFF RATIO} = \frac{\text{power present when RF is pulsed on}}{\text{power present when RF is off}}$$

The ratio is expressed in dB on the data sheet.

SYNTHESIZED SIGNAL GENERATORS

So far we've been talking about fundamental types of signal generators where a single oscillator inside the generator is used to generate the output frequency. Now we'll talk about a relatively new type of signal generator, the synthesized signal generator.

Traditionally, frequency synthesizers have been used primarily as very stable frequency sources. Typical applications have been as local oscillators in communications systems and as lab frequency standards. Recently however, calibrated output level and modulation capabilities been added to create synthesized signal generators.

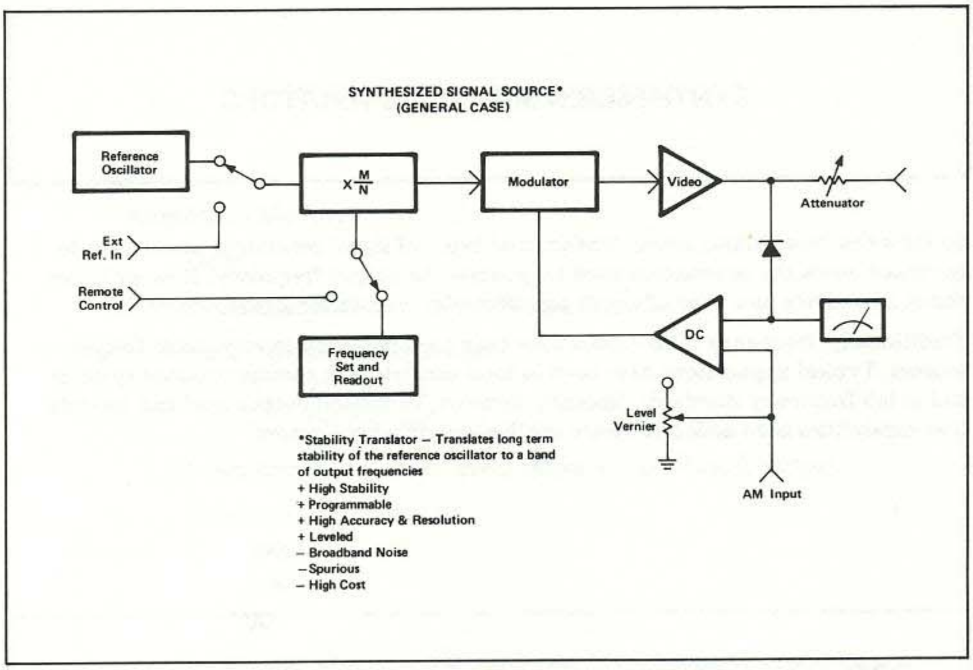
UNIQUE SYNTHESIZED SIGNAL GENERATOR CHARACTERISTICS

HIGH RESOLUTION (Typically 1 Hz Steps)

HIGH STABILITY (Typically Parts in 10^8 or 10^9)

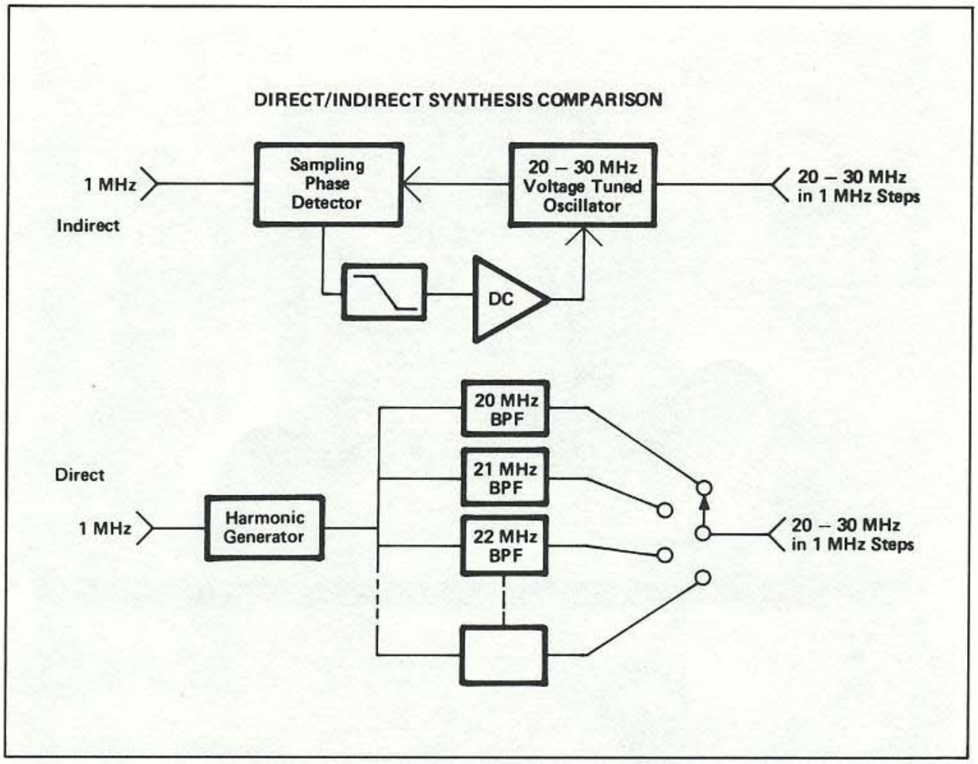
PROGRAMMABILITY

The combination of a synthesized source with calibrated output and modulation capability has created a signal generator with some unique characteristics. For example, high resoluation (typically 1 Hz steps), high stability (typically parts in 10^8 or 10^9), and programmable frequency, output level and modulation. Let's see how this is accomplished . . .



The synthesized signal generator differs from a fundamental signal generator primarily in the method used to generate the RF output signal. From the modulator to the right hand side of the figure this block diagram is the same as it has been in our fundamental oscillator block diagrams. However, on the left the method of generating the RF signal is different. We start with a high quality crystal reference oscillator (either internal or external). The reference frequency is then fed through a block called "X M/N" which translates the reference frequency to a broad range of output frequencies. The translation is done in a manner so as to provide the frequency out of the "X M/N" with the same stability as the crystal reference. The objective -- a crystal oscillator translated to a broad range of output frequencies.

Obviously the "X M/N" block has to be sophisticated to do this. Let's look at how the translation is accomplished.



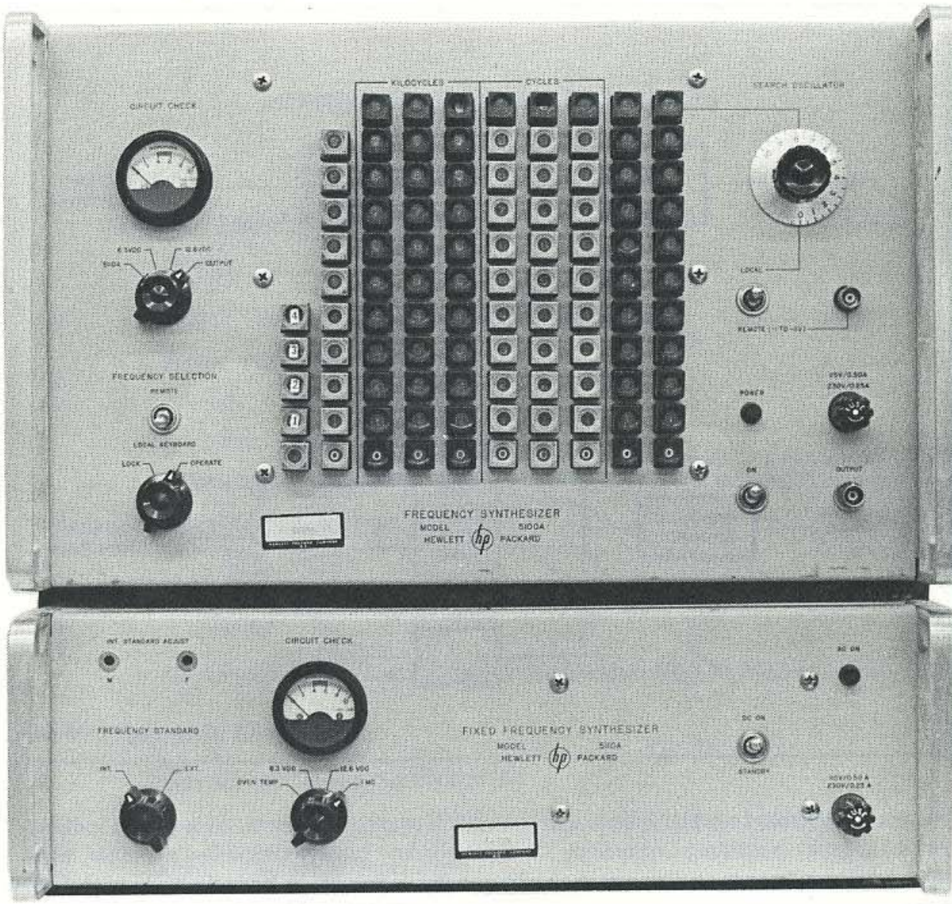
There are basically two techniques used to translate the frequency -- direct and indirect (or phase-lock) synthesis. Comparing the methods in a greatly simplified example, we'll use a 1 MHz reference and translate the frequency to the 20 to 30 MHz band with 1 MHz steps.

The direct method would put the 1 MHz reference through a harmonic generator to generate a comb of output signals at 1 MHz increments. These signals pass through a bank of bandpass filters at 1 MHz increments. The desired frequency is selected by switching to the filter with the appropriate output.

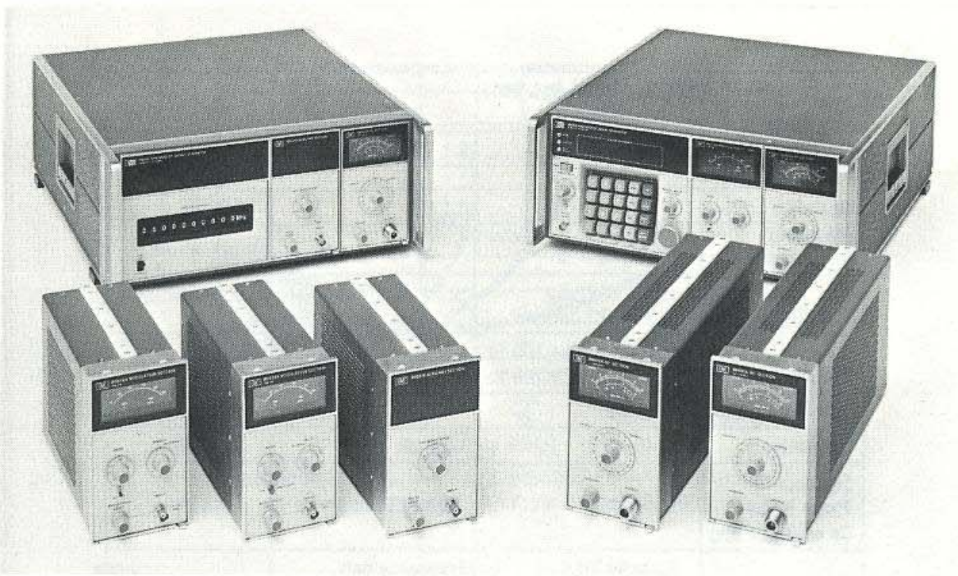
The indirect or phase-lock method uses a sampling phase detector to compare the appropriate harmonic of the 1 MHz reference with the output of a voltage tuned oscillator which has been course-tuned to the desired frequency. The error output from the phase detector is passed through a feedback network to tune and lock the voltage tuned oscillator to the exact frequency desired.

Comparing the two methods, direct synthesis is more expensive and bulky than indirect synthesis due to the need for many filters. Also extensive shielding is needed as many frequencies exist in the direct synthesizer at the same time. Finally, the switch isolation must be good to reduce the possibility of spurious outputs. The advantage of direct synthesis is switching speed (i.e., speed in changing frequency) on the order of 20 μsec.

On the other hand, due to the extensive use of IC's in phase-lock designs, indirect synthesis is generally smaller and less expensive than direct synthesis. Also the possibility of spurious is less as there is only one frequency at a time generated in each phase-lock loop. However, switching speed is slower in indirect synthesis as you must break lock, retune the oscillator, capture and relock to change frequency. Typically it's on the order of 1 to 2 msec.

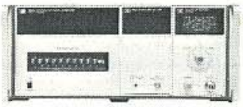
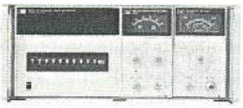
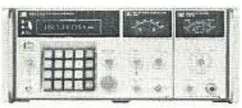


An example of a direct synthesizer made at HP is the 5100B. It covers dc to 50 MHz in 0.01 Hz steps. The 5110B on the bottom contains the reference oscillator and generates some of the intermediate frequencies used in the direct synthesis process. The large size and weight of the HP 5100B/5110B is typical of direct synthesizers.



Let's look at the HP 8660 as an example of an indirect synthesis design. Since the 8660 utilizes plug-ins to determine frequency range and modulation capability we can configure the system as either an indirect synthesizer or synthesized signal generator to demonstrate the characteristics of each. (Plug-in design is a unique feature of the HP 8660 family and is not typical of indirect synthesizers or synthesized sig gens in general).

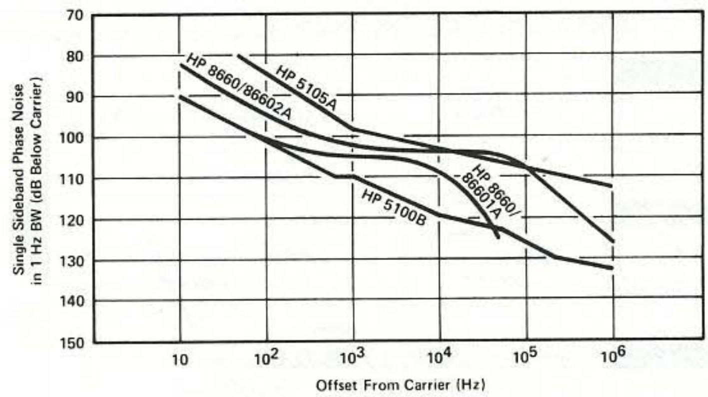
EXAMPLE 8660 SERIES CONFIGURATIONS

Configuration		Capability
	Frequency Synthesizer	0.01-110 MHz or 1-1300 MHz Frequency Range 1 Hz Steps ±3 x 10^{-8}/Day Stability (±3 x 10^{-9} Optional) -80 dB Spurious TTL Programmable
	Synthesized Signal Generator	Adds . . . AM/FM Modulation Capability 150 dB Calibrated Attenuator
	Bench Synthesized Signal Generator	Adds . . . Keyboard Control * Digital Sweep * Synthesized Search * Frequency Stepping

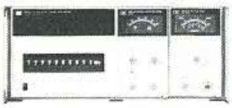
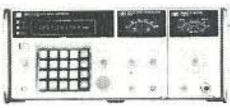
Let's begin by configuring the 8660 as an indirect synthesizer (source only) without modulation capability or output attenuator. It is fairly typical with a 1 Hz steps, ±3 x 10^{-8}/ day stability, —80 dB spurious and programming capability.

	8660A/86601A Opt. 001/ 86631B	5105A/5110B	5100B/5110B
Frequency Range	0.01 - 110 MHz	0.1 - 500 MHz	DC - 50 MHz
Maximum Frequency Resolution	1 Hz	0.1 Hz	0.01 Hz
Stability	$\pm 3 \times 10^{-8}$/day $\pm 3 \times 10^{-9}$ optional	$\pm 3 \times 10^{-9}$/day	$\pm 3 \times 10^{-9}$/day
Switching Time	5 ms to within 100 Hz 100 ms to within 5 Hz	20 μs typical	20 μs typical
Spurious	—80 dB	—70 dB	—90 dB
Harmonics	—40 dB	—25 dB	—30 dB
Signal-to-Phase Noise (in a 30 kHz BW)	—50 dB	—40 to —48 dB	—54 dB
Programming	Directly TTL compatible, incl. output level & modulation	Frequency only. Hold —12.6 V on selected line	Same as 5105A

Comparing the 8660 as an indirect synthesizer with the HP 5100B and 5105A direct synthesizers we see that stability, spurious, and phase noise are very comparable for the two different methods. However, the significant differences are that the direct synthesizer has two orders of magnitude faster switching time and costs more than twice as much as the indrect approach.



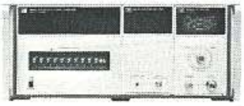
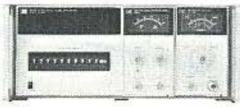
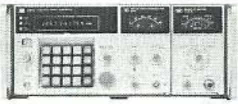
Looking at the phase noise curves for the two synthesizers we see that while they are roughly comparable they each have characteristically different shapes. The phase noise of the direct synthesizer tends to fall off more or less linearly, while the indirect synthesizer's noise tends to flatten out within the phase-lock loop bandwidth (about 10 kHz in this example) and then fall very rapidly outside the loop bandwidth.

EXAMPLE 8660 SERIES CONFIGURATIONS		
Configuration		**Capability**
	Frequency Synthesizer	0.01-110 MHz or 1-1300 MHz Frequency Range 1 Hz Steps ±3 x 10^{-8}/Day Stability (±3 x 10^{-9} Optional) -80 dB Spurious TTL Programmable
	Synthesized Signal Generator	**Adds . . .** AM/FM Modulation Capability 150 dB Calibrated Attenuator
	Bench Synthesized Signal Generator	**Adds . . .** Keyboard Control * Digital Sweep * Synthesized Search * Frequency Stepping

Adding AM/FM modulation and a calibrated output attenuator converts the indirect synthesizer to a complete synthesized signal generator suitable for testing synthesized communications equipment or for use in computer controlled automatic receiver testing systems.

When the synthesized signal generator is used in an automatic test system, thumbwheel switches for manual frequency control are adequate for occasional testing, but when the generator is used exclusively on the bench, such controls are at best inconvenient. Recognizing this problem, HP has gone one step farther to develop a totally new concept -- keyboard control. In addition to providing much more flexible and convenient frequency control the 8660B keyboard shown at the bottom of the figure also adds many unique new capabilities to the synthesized signal generator such as frequency stepping, digital sweep, and synthesized search.

8660 SERIES CONFIGURATION VS. APPLICATIONS

CONFIGURATION		APPLICATION
	FREQUENCY SYNTHESIZER	PROGRAMMABLE RF SOURCE RECEIVER L.O. LAB FREQUENCY STANDARD
	SYNTHESIZED SIGNAL GENERATOR	AUTOMATIC RECEIVER TEST EXCITER
	BENCH SYNTHESIZED SIGNAL GENERATOR	BENCH RECEIVER TEST ULTRA-STABLE SWEEPER

Now let's review the applications for synthesizers and synthesized signal generators. Once again using the 8660 configuration as an example, we see that basic indirect synthesizers are used as programmable sources, L.O.'s or frequency standards. Adding modulation and calibrated output the synthesized sig gen is built into automatic test systems as a programmable signal generator and used as an exciter in transmitters. Finally, adding keyboard control for bench applications the synthesized signal generator is ideal for testing very narrowband or crystal controlled receivers and for use as an ultra-stable precision sweeper for evaluating very narrowband devices.

8660 SYNTHESIZED SIGNAL GENERATOR APPLICATIONS

- L.O. For VHF TV Transmitter (FCC Type Acceptance Granted)
- L.O. For Mobile Satellite Terminal
- Precision Source For Radio Astronomy
- L.O. For Long-Range Radio Relay
- Used With Power Amp As AM Transmitter
- Used With Power Amp As Missile Destruct Transmitter
- Automatic Mobile Receiver Testing
- Automatic Avionics Testing
- Simulator For FSK Transmitter (For 1975 Mars Lander)
- Mobile Radio Production Testing
- Source For NMR Decoupler

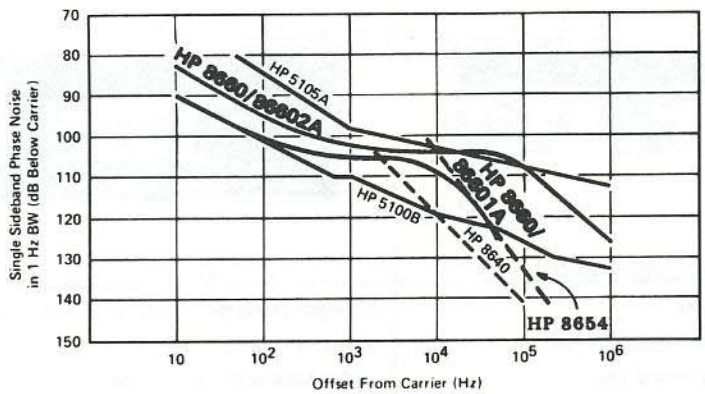
Here are examples of some of the applications HP synthesized signal generators have been used for to demonstrate the broad range of possiblities.

8640B LOCKED MODE	8660B
- Lower Cost	- Programmable Frequency, Level, & Modulation
- Lower Spurious >5 Hz Away	- Resolution to 1 Hz
- Lower Wideband S/N	- Digital Steps and Precision Tuning
- No "Noise Pedastal"; i.e., Superior For Receiver Adjacent Channel Tests	- Sweep Capability
- Counter Usable For External Inputs to 550 MHz	- Plug-in Output Frequency Range and Modulation
	- Output Frequency Always Locked to Standard; i.e., Can Continuously Adjust Output Without Re-Locking

In applications which don't require remote programming the conventional signal generator with built-in phase-lock capability is often compared to a synthesizer, so using the HP 8640 and 8660 as examples let's look at the unique features of each.

The advantages of the 8640B signal generator in the locked mode are a lower wideband noise floor, lower spurious >5 Hz away from the carrier, and a counter usable to count external signals.

On the other hand, the 8660B synthesized signal generator is programmable, has 1 Hz settability, and does not have to be unlocked, tuned, and relocked at each new frequency. The 8660B also has the advantages of plug-in design and keyboard control features such as sweep and frequency stepping.



Comparison of SSB Signal-to-Phase Noise Ratio of HP 86601A, HP 86602A, HP 5100B, HP 5105A, HP 8654A, and HP 8640 (86602A and 5105A at 500 MHz, 86601A at 100 MHz, 5100B at 50 MHz, 8654 at 400 MHz and 8640 at 512 MHz).

Finally, the phase noise curves of the synthesized signal generator and fundamental generator have characteristically different shapes which may indicate the choice of one over the other in a particular application. The synthesizer has lower noise <1 kHz or so from the carrier, but has a higher wideband noise floor. On the other hand, the signal generator has higher noise <1 kHz from the carrier, but has a lower wideband noise floor due to the high "Q" of the oscillator cavity or tank circuit. (A phase noise curve for the HP 8654A economy signal generator has also been added for comparison. The 8654A uses an LC tuned oscillator in place of the cavity tuned oscillator in the 8640.)

ADDITIONAL SYNTHESIZER AND SYNTHESIZED SIGNAL GENERATOR SPECIFICATIONS

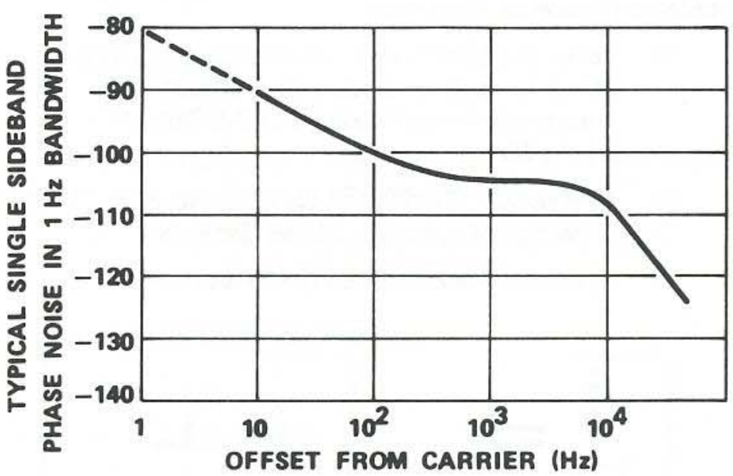
1. Short-Term Stability
2. Spurious Outputs
3. Remote Programming
4. Switching Time

Some additional specs that apply to synthesizers and synthesized signal generators which we haven't discussed are:

1. Short term stability (particularly signal to phase noise ratio in a 30 kHz BW)
2. Spurious outputs
3. Remote programming
4. Switching time

METHODS OF SPECIFYING SHORT-TERM STABILITY

1) SSB Phase Noise Plot In 1 Hz Bandwidth vs. Offset From Carrier*



2) Residual FM: Hz, RMS In Stated Post Detection Bandwidth

→ 3) Signal To Phase Noise Ratio In a 30 kHz Bandwidth Excluding 1 Hz Centered on the Carrier

*Basic Short-Term Stability Measurement. All Others May Be Derived From This Plot.

We use basically the same techniques in specifying short term stability in synthesizers that we use in fundamental signal generators with the addition of signal to phase noise ratio in a 30 kHz bandwidth excluding 1 Hz centered on the carrier. This is a wideband measurement used to roughly compare the short-term stability of one synthesizer with another.

This specification is measured by putting a signal from the source under test and a signal at the same frequency from a reference source of equal or better quality into a double balanced mixer in phase quadrature. The mixer acts as a phase detector in this mode. The detected signal is passed through a low pass filter to be read on an AC voltmeter. The bandwidth of the low pass filter determines the band over which the measurement is made. This most commonly is 30 kHz (±15 kHz).

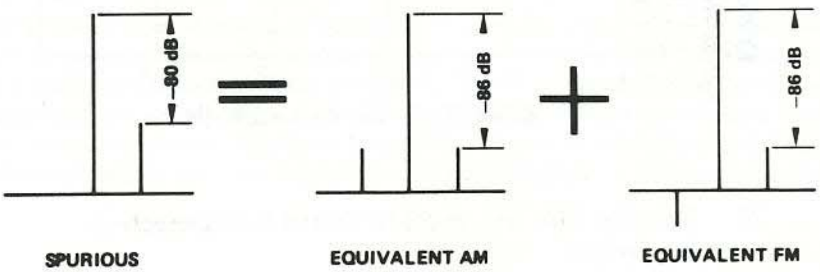
SPURIOUS

This, More Than Any Other Specification Determines The Cost of a Synthesizer.

A Good Synthesizer Should Have Spurious at Least –80 dB.

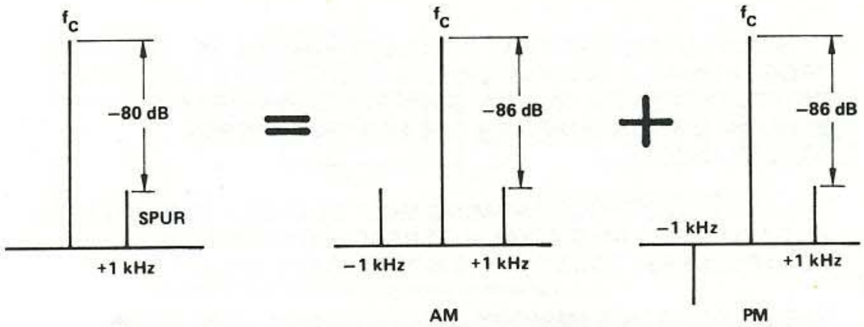
Problems Caused by Spurious:

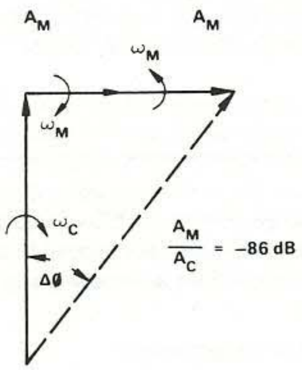
1) When the Synthesizer Is Used Directly Into a Mixer or as an L.O., Spurious Result in Intermodulation Products at the Output of the Mixer.
2) In Receiver Testing Set-Ups, Spurious Can Feed Directly Into the I.F. of the Receiver.
3) Spurious Also Contribute to Residual AM and FM.



Spurious outputs receive more attention in synthesized signal generators because they are much more likely to occur in the synthesis process. Here are some examples of the problems they can cause in various applications.

Residual FM Contribution of a Spurious Signal - 80 dB and 1 kHz from the Carrier





FOR SMALL ANGLES . . .

$$\Delta\phi_{PK} \text{ (In Radians)} \approx \text{TAN } \Delta\phi_{PK}$$

$$\Delta\phi_{PK} \approx \frac{2A_M}{A_C} = -80 \text{ dB}$$

$$\Delta\phi_{PK} \approx 10^{-4} \text{ Radians}$$

FOR ANGLE MODULATION . . .

$$\Delta\phi_{PK} = \frac{\Delta f_{PK}}{f_M}$$

$$\text{SO} \quad 10^{-4} \text{ Radian} = \frac{\Delta f_{PK}}{10^3 \text{Hz}}$$

$$\boxed{\Delta f_{PK} = 0.1 \text{ Hz}}$$

Here is a sample calaculation to demonstrate the magnitude of the residual FM contribution of spurious. If we have 1 spurious 80 dB down and 1 kHz away from the carrier coming out of synthesizer it will represent an equivalent FM peak deviation of 0.1 Hz. For comparison, all of the phase noise on the output of the HP 8660 synthesizer contributes on the order of 0.3 Hz peak deviation. Therefore this one spurious output would contribute 1/3 as much residual FM as all the phase noise on the oscillator. If the spur were down only 60 dB instead of 80 dB, it would contribute 10 times as much peak FM deviation. So when buying a synthesizer for very good frequency stability and low residual FM, it's important to look at the level of the spurious as well as the level of the phase noise.

GENERAL PROGRAMMING CONSIDERATIONS

1. IT IS NOT SUFFICIENT THAT FREQUENCY ALONE BE PROGRAMMABLE IN MANY APPLICATIONS. MODULATION AND OUTPUT LEVEL MUST ALSO BE PROGRAMMABLE TO ELIMINATE THE NEED FOR A SKILLED OPERATOR IN ATTENDANCE.
2. THE METHOD OF PROGRAMMING MUST BE EASILY IMPLEMENTED AND NOT REQUIRE SPECIAL INTERFACES OR COMPLEX CONTROLLERS. TODAY TTL IS MOST WIDELY USED.
3. THE INFORMATION MEMORY SHOULD BE INCLUDED IN THE SIGNAL GENERATOR. THE REMOTE CONTROLLER SHOULD NOT BE REQUIRED TO HOLD INFORMATION ON THE CONTROL LINES SO THAT IT CAN CONTROL OTHER INSTRUMENTS ON THE CONTROL LINES.

Since synthesized signal generators are the only signal generators that are programmable, they are used in a lot of applications where their stability, etc. is not needed but the programmability is. Here are some important points to consider in choosing a generator for a programmable application:

1. Frequency, modulation and output level must be programmable.
2. The method of programming must be easily implemented (TTL most common).
3. The information memory should be in the signal generator.

EXAMPLE OF REMOTE PROGRAMMING SPECS (HP 8660A/B)

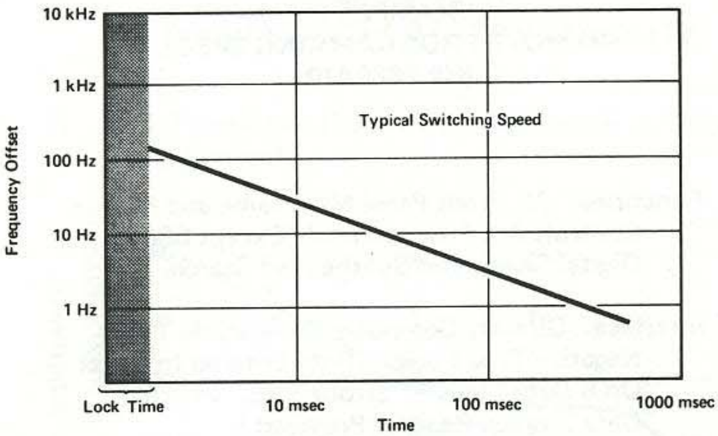
Functions: All Front Panel Mainframe and Plug-In Controls Are Programmable Except 8660B Digital Sweep and Synthesized Search.

Interface: Directly Computer Compatible TTL Negative True Logic. (Data Entered In Serial On 8 Data Lines +1 Strobe Line. Internal Data Storage Register Provided.)

11671A Interface Kit –

Contains 16 Line Microcircuit I/O Card and Cable For Direct Connection to HP Model 2114, 2115, 2116 and 2100 Computers.

The HP 8660 is an example of a generator designed with the above considerations in mind. Frequency, output level and modulation are programmable. Also it has TTL logic and internal data storage. Going one step further, an interface kit is available which provides all of the hardware necessary to interface the HP 8660 with HP 2100 series computers.



Switching Time:

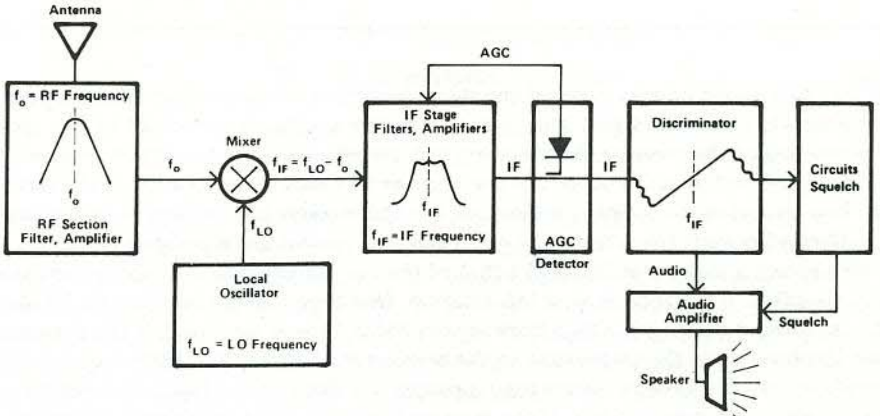
Less than 5 ms to be within 100 Hz of any new frequency selected.
Less than 100 ms to be within 5 Hz of any new frequency selected.

The final new specification we'll discuss is switching time. The switching time for an indirect synthesizer consists of two components: lock time and settling time. Both are not always specified. Lock time is the time it takes the phase lock loop to capture after a frequency change. This is usually specified and will be on the order of 1 - 2 msec. When lock occurs there is still a finite phase error in the phase lock loop which must settle to zero. This small phase change over time $\left(\frac{d\phi}{dt}\right)$ actually represents a frequency error from the desired output. The time it takes the oscillator to settle to the exact output frequency is called settling time. This is not always specified and may take as long as 100-500 msec for ±1 Hz accuracy. So, particularly in automatic system applications where switching time becomes significant, it is important to make sure exactly what is included in the switching time spec given.

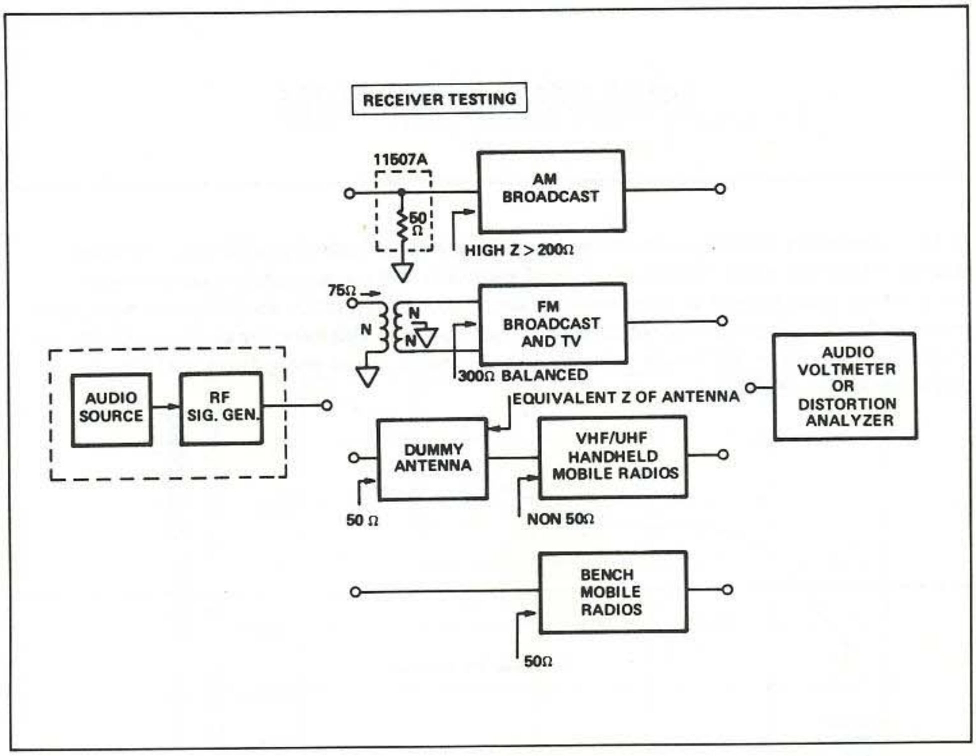
USING SIGNAL GENERATORS

In this section we will concentrate on the primary use of signal generators -- receiver testing. There are many different types of receivers and we cannot discuss each one in detail so we have chosen as a common denominator a frequency modulated land mobile receiver. Let's talk about the set of tests which apply to this receiver to illustrate the use of a signal generator. We'll talk primarily about the EIA test procedures with some reference to the IEEE tests.

Simplified FM Receiver

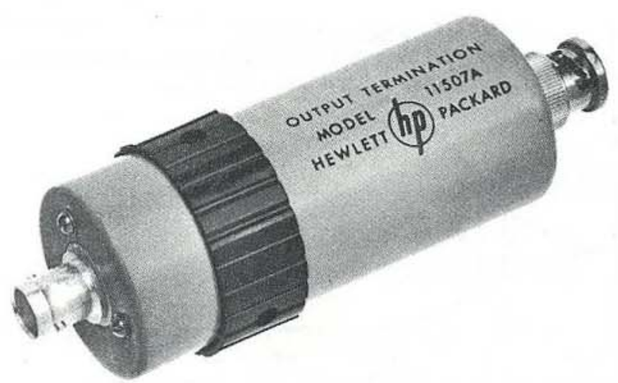


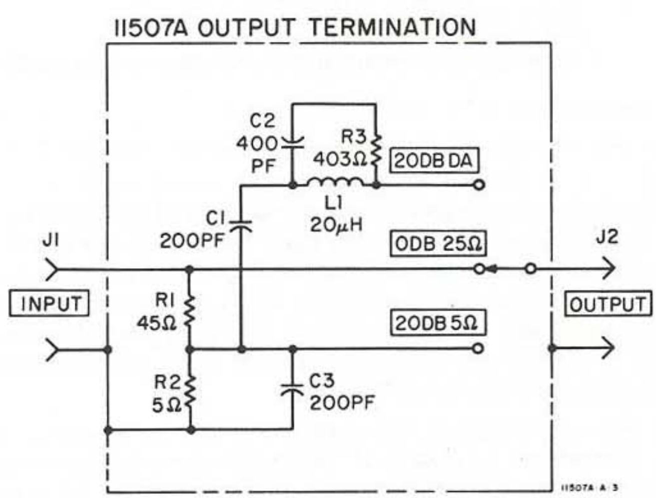
Let's look quickly at a simplified block diagram of an FM receiver. The first stage is the tuned RF section which in theory lets only one station at a time into the mixer of the receiver. Actually the RF section is fairly coursely tuned and the fine tuning is accomplished by the bandwidth of the IF section. Next the local oscillator beats down the incoming RF to an IF. The IF amplifiers are followed by an AGC detector which controls the gain of one of the IF amplifiers. The signal then goes through a discriminator, or FM detector, where the audio is demodulated and fed to the audio amplifier and speaker. The squelch circuits monitor the audio and when no audio is present they cut off the audio amplifier so the user does not have to listen to noise.



First, let's talk about how to connect the signal generator to the receiver. The purpose of all these tests is to use the signal generator to simulate a signal received out of free space by the antenna of the receiver. A measuring instrument, usually a distortion analyzer, is then connected to the audio outout of the receiver to measure the quality of the received signal. It is important to couple the generator to the receiver in a manner such that we have calibrated output from the signal generator and present an impedance to the receiver's antenna input that looks like that of the normal antenna. Dummy antennas are usually specified in the receiver test information. One type that is common is a 50 ohm resistor to ground used with a high impedance (>500Ω) receiver. This lets the generator see see 50 ohms while the impedance to the receiver is 25 ohms. For FM broadcast and TV receivers with balanced antenna inputs coupling is done with a balun or a resistive divider to give a balanced output. If the receiver has some other impedance a complex dummy antenna is used. FM land mobile receivers we'll be talking about usually have 50 ohm antenna inputs so the signal generator can be directly coupled to them.

TERMINATION model 11507A





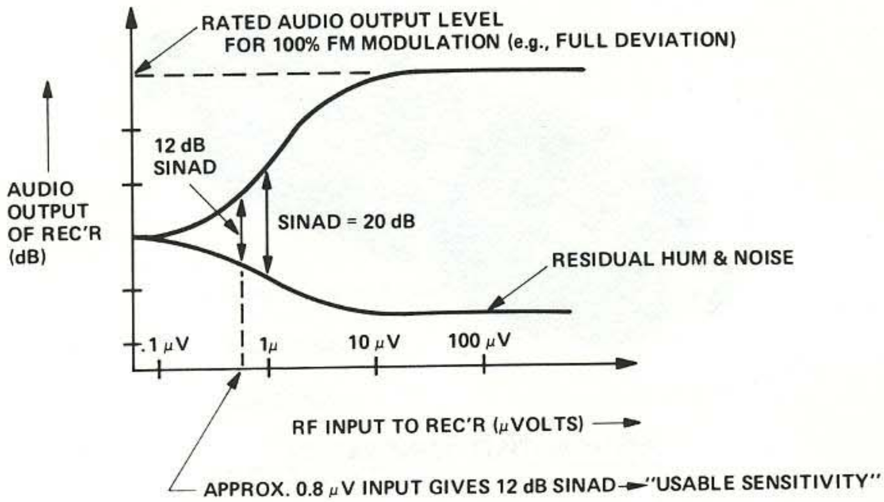
Hewlett-Packard does make one dummy antenna, the 11507A. It is typical of the dummy antennas used for low frequency AM receivers. It has three outputs. We'll only talk about the top output as it's the most commonly used. The signal generator is connected to the top of the resistive divider. It sees a 50 ohm load (45 + 5 ohms). Because the divider has approximately a 10 to 1 division ratio, it has 20 dB of insertion loss. We couple off of the 5 ohm resistor which makes the generator look like a low impedance source to the receiver. The reactive elements simulate the reactive elements of the antenna. This particular dummy antenna configuration is out of a 1948 IRE standard for AM broadcasting.

This device also has 5 ohm and 25 ohm output impedance ports used with other receivers.

MOBILE RADIO TESTS

DEFINITION "SINAD" = RATIO OF SIGNAL + NOISE + DISTORTION TO NOISE + DISTORTION

$$\text{SINAD [DB]} = 10 \log_{10} \frac{S + N + D}{N + D}$$



The tests that we will be talking about are written in terms of SINAD ratio. This is a figure of merit used to describe what a usable signal out of a receiver is. SINAD is the ratio of the signal plus noise plus distortion at the output of a receiver to the noise plus distortion at that same output. This is essentially the type of measurement a distortion analyzer makes. A broadband voltmeter measures everything out of the receiver then a notch filter takes out the desired signal and what's left (noise plus distortion) is measured. The ratio of the two measurements is SINAD.

Looking at the curves, the top curve is the audio output from the receiver (S+N+D). As the RF input is reduced that curve falls off. The bottom curve is the residual hum and noise. It is in a sense a plot of the AGC tracking of the receiver. As RF input is reduced the AGC adds gain and level of residual hum and noise increases. SINAD is the dB difference between the two curves. The level of RF input where SINAD (the difference in the curves) is 12 dB is by definition the threshold of "usable sensitivity".

TYPICAL RECEIVER TESTS:

USABLE SENSITIVITY

QUIETING SENSITIVITY

SQUELCH THRESHOLD

SPURIOUS ATTENUATION (INCLUDING IMAGE & IF REJECTION)

ADJACENT CHANNEL SELECTIVITY

INTERMODULATION SPURIOUS ATTENUATION

AUDIO FREQUENCY RESPONSE

IF FILTER AND DISCRIMINATOR ALIGNMENT

These are the tests we will be talking about:

Usable Sensitivity
Quieting Sensitivity (another way of measuring sensitivity)
Spurious Attenuation (including image and IF rejection)
Adjacent channel selectivity
Intermodulation Spurious Attenuation
Audio Frequency Response
IF Filter and Discriminator Alignment

USABLE SENSITIVITY

DETERMINE RF INPUT LEVEL WHICH PRODUCES ⩾50% OF RATED OUTPUT WITH A 12 dB SINAD (EIA RECOMMENDATION)

TEST SETUP:

TEST PROCEDURE:
1. APPLY TEST SIGNAL MODULATED WITH 1 kHz TONE AT 2/3 MAXIMUM RATED DEVIATION.
2. SET GENERATOR OUTPUT LEVEL FOR ~ 1 MV AND ADJUST RECEIVER VOLUME CONTROL FOR MAX. RATED OUTPUT.
3. REDUCE RF INPUT SIGNAL UNTIL:
   a. SINAD = 12 dB
   b. AUDIO OUTPUT FALLS TO 50% OF RATED VALUE

   } WHICHEVER OCCURS FIRST

IMPORTANT SIG. GEN. SPECS: ATTENUATION RANGE
ATTENUATION ACCURACY
LEAKAGE
FM DISTORTION

Usable Sensitivity: Determines the RF level which produces ⩾50% of rated output with a 12 dB SINAD. The signal generator is connected to the receiver antenna input. The receiver output is connected to a distortion analyzer used to measure SINAD. The test signal is modulated with a 1 kHz tone at 2/3 maximum rated deviation (IEEE uses 60%). The distortion analyzer is tuned to 1 kHz. The generator RF output level is then reduced until SINAD = 12 dB or audio output falls to 50% of rated value, whichever occurs first. This is the usable sensitivity of the receiver.

Important sig gen specs:

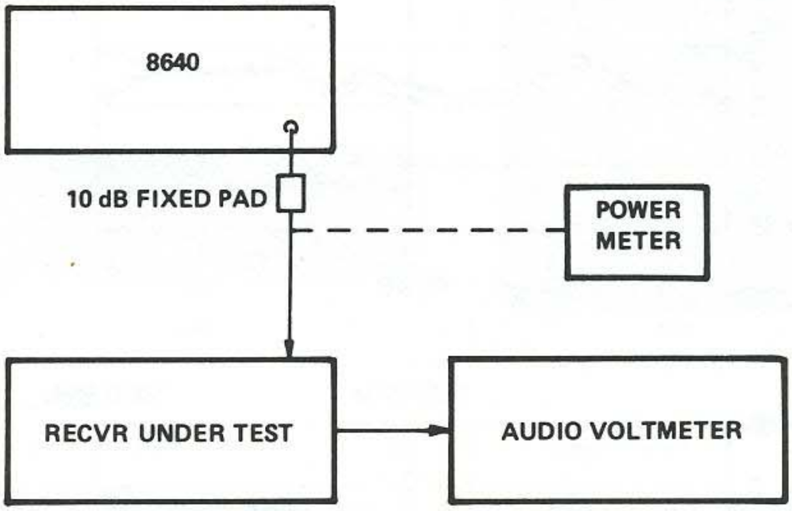
Attenuation Range:
must have calibrated output at least to sensitivity of receiver under test.

Attenuation Accuracy:
(example: a 3 dB error could make the difference on whether a radio is usable in a 20 or 24 mile radius. The 24 mile circle covers approximately 1.4 times the area of a 20 mile circle).

Leakage:
the only signal to enter the receiver should be the one coming out of the generator RF port to make the test meaningful.

FM Distortion:
the distortion analyzer can't tell the difference between distortion from the generator or receiver. Generator distortion would cause a measurement error.

OUTPUT ACCURACY IMPROVEMENT PROCEDURE



PROCEDURE –1 ADJUST 8640 FOR PROPER RCVR SENSITIVITY CRITERION – READ LEVEL

–2) DISCONNECT RECVR AND CONNECT POWER METER

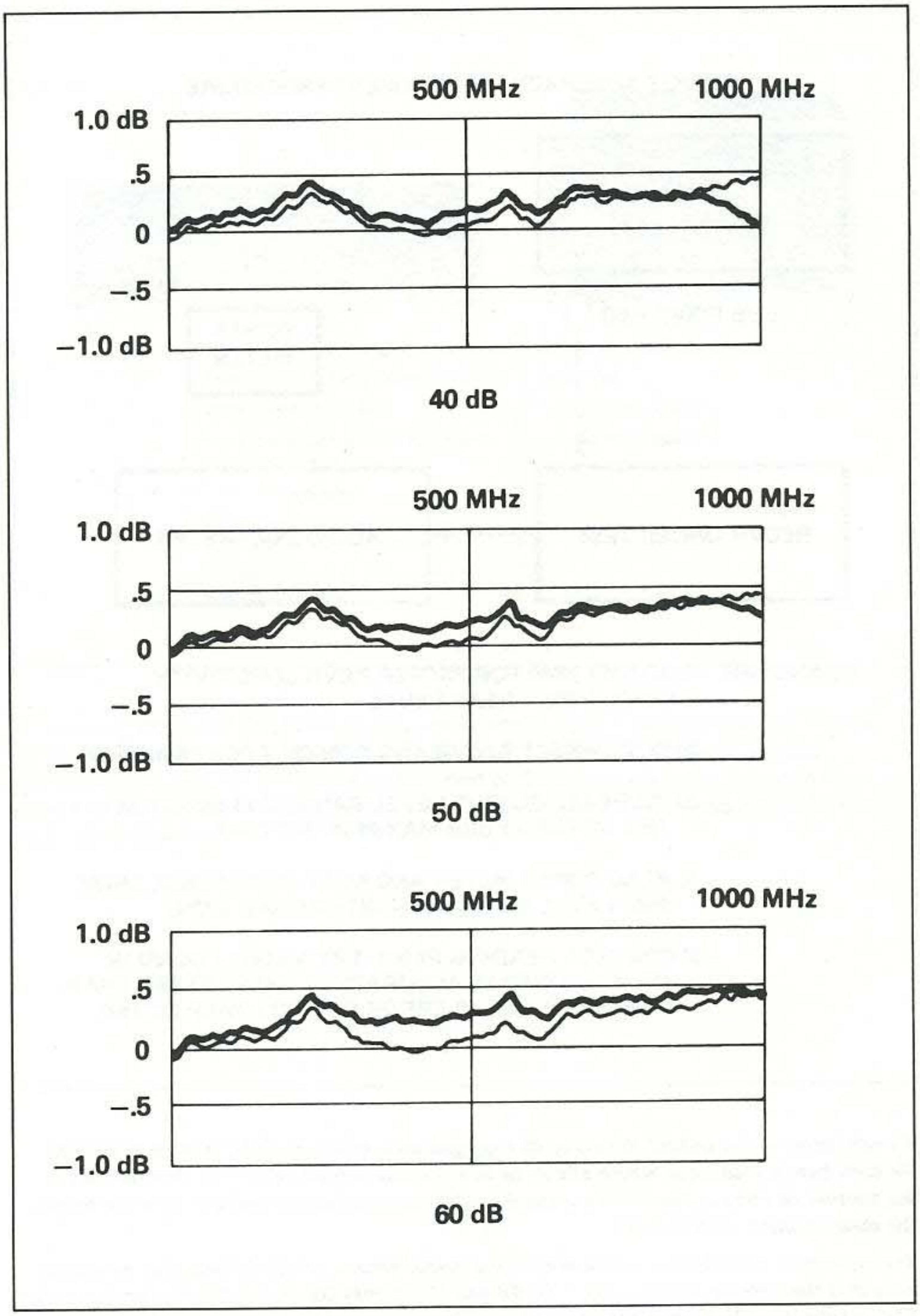
–3) INCREASE OUTPUT LEVEL RANGE ATTENUATOR TILL IN THE –7 dBm MAXIMUM SETTING

–4) READ POWER METER AND NOTE DIFFERENCE FROM 8640 LEVEL METER (MAGNITUDE AND SIGN)

–5) CORRECT READING IN NO. 1 BY VALUE FOUND IN NO. 4 –– OVERAL ACCURACY IS THEN BETTER THAN ± 1 dB PLUS ± .25 dB ERROR DUE TO POWER METER

We can improve the output accuracy of a sig gen such as the 8640 by using a few tricks. We have here a technique which allows us at a specific vernier setting to eliminate all of the sources of error in the 8640 except the attenuator accuracy spec and to some degree the measurement uncertainty.

The procedure is to do the usable sensitivity measurement just described. The generator output is then connected through a 10 dB pad (used only for matching) to a power meter. The output level from the generator is then adjusted using the attenuator only (do not touch the vernier) to a level in the operating range of the power meter. The power meter is read and the difference (magnitude and sign) between it and the generator level meter is noted. This difference is the correction factor applied to the reading obtained in the sensitivity test. The overall accuracy is now better than ±1.25 dB (±1 dB attenuator error and ±0.25 dB power meter error). We have calibrated out the errors due to detector and meter linearity, frequency response and detector temperature coefficient.



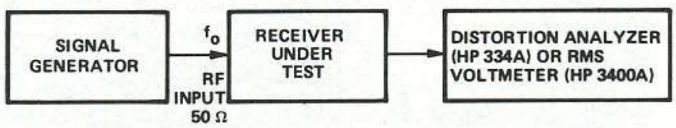
The only error left is the error in the output attenuator plus a small amount of measurement uncertainty. To show how good these output attenuator are, here are some actual curves of the worst of seven HP 8640 attenuators measured on our production line. The heavy line is the zero line, that represents in this case exactly 40 dB. The light line is the output attenuator pad. The actual error in the pad is the difference between these two lines. The worst case, seen on the 60 dB curve, is on the order of 0.3 dB. The errors are cumulative as pads are added, however (up to five pads for the −130 dB range).

QUIETING SENSITIVITY

"QUIETING" → OUTPUT NOISE OF RECEIVER IS REDUCED AS UNMODULATED RF SIGNAL IS APPLIED.

QUIETING SENSITIVITY — RF INPUT LEVEL REQUIRED TO REDUCE NOISE OUTPUT BY 20 dB (EIA RECOMMENDATION)

TEST SETUP:



TEST PROCEDURE:

1. TURN-OFF OR TUNE AWAY RF OUTPUT OF SIGNAL GENERATOR, UNSQUELCH RECEIVER, AND ADJUST VOLUME CONTROL FOR NOISE OUTPUT EQUAL TO 25% OF RATED OUTPUT POWER.
2. APPLY UNMODULATED SIGNAL AND INCREASE GENERATOR OUTPUT VOLTAGE UNTIL NOISE OUTPUT IS REDUCED BY 20 dB.

IMPORTANT SIG. GEN. SPECS:
ATTENUATOR RANGE
ATTENUATOR ACCURACY
LEAKAGE
RESIDUAL FM

Quieting sensitivity is another method of measuring the sensitivity of the receiver. When there is no carrier applied to a receiver the AGC loop increases the gain of the receiver as much as possible, tending to cause maximum noise at the audio output of the receiver. As soon as a carrier appears in the IF of the receiver, the AGC reduces the gain of the receiver to keep the level of the carrier constant, the limiters in an FM receiver begin to act, and the noise component at the output reduces accordingly. This is quieting.

Quieting sensitivity uses the same test setup as before. With the carrier off or full attenuation dialed in, the receiver volume is adjusted for a noise output level equal to 25% of the rated receiver output power. The generator output is then increased until the receiver output voltage (noise) is reduced by 20 dB. This carrier level is the quieting sensitivity level. Important signal generator specs for this test are:

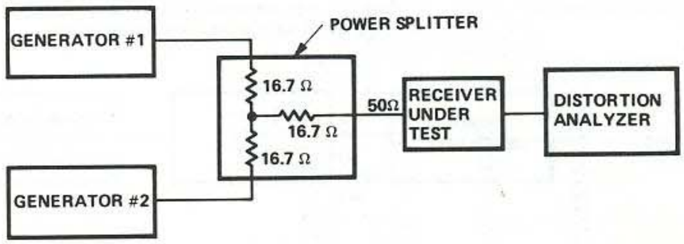
Attenuator range:, Attenuator accuracy:, Leakage: } same as for the usable sensitivity tests

Residual FM: results in small amount of detected noise which the distortion analyzer would add to the receiver noise. (Too small to be significant in SINAD test.)

ADJACENT CHANNEL SELECTIVITY

MEASURE OF RECEIVER'S ABILITY TO DIFFERENTIATE BETWEEN A DESIRED MODULATION SIGNAL AND MODULATION SIGNALS ON ADJACENT CHANNELS

TEST SETUP



TEST PROCEDURE:

1. TURN GENERATOR #2 OFF, SET GENERATOR #1 TO f_0 AND MODULATE WITH 1 kHz TONE AT 2/3 MAXIMUM RATED DEVIATION. SET LEVEL FOR 12 dB SINAD
2. TURN GENERATOR #2 ON AND MODULATE WITH 400 Hz TONE AT 2/3 MAX RATED DEVIATION.
3. TURN GENERATOR #2 TO ADJACENT CHANNEL AND ADJUST ITS LEVEL FOR 6 dB SINAD WITH DISTORTION ANALYZER NULLING 1000 Hz TONE.
4. RECORD RATIO OF GENERATOR #2 AMPLITUDE TO GENERATOR #1 AMPLITUDE.

IMPORTANT SIG. GEN. SPECS: PHASE NOISE
SPURIOUS
FM DISTORTION
FREQUENCY STABILITY

Adjacent channel selectivity is a measure of a receiver's ability to differentiate between a desired signal and other signals in adjacent channels. Two generators are used in this test, one to simulate the desired signal and the other to simulate the signal in the adjacent channel.

With the 2nd generator off the 1st generator is set to f_0 and modulated with a 1 kHz tone at 2/3 maximum rated deviation. The level is set for 12 dB SINAD. The 2nd generator is turned on, modulated with a 400 Hz tone at 2/3 maximum deviation, tuned to either adjacent channel, and adjusted in level to produce 6 dB SINAD with the analyzer nulling the 1 kHz tone (i.e., any 400 Hz that gets detected adds to the noise). The ratio of generator #2 level to generator #1 level is the adjacent channel selectivity. Looking at the important signal generator specs:

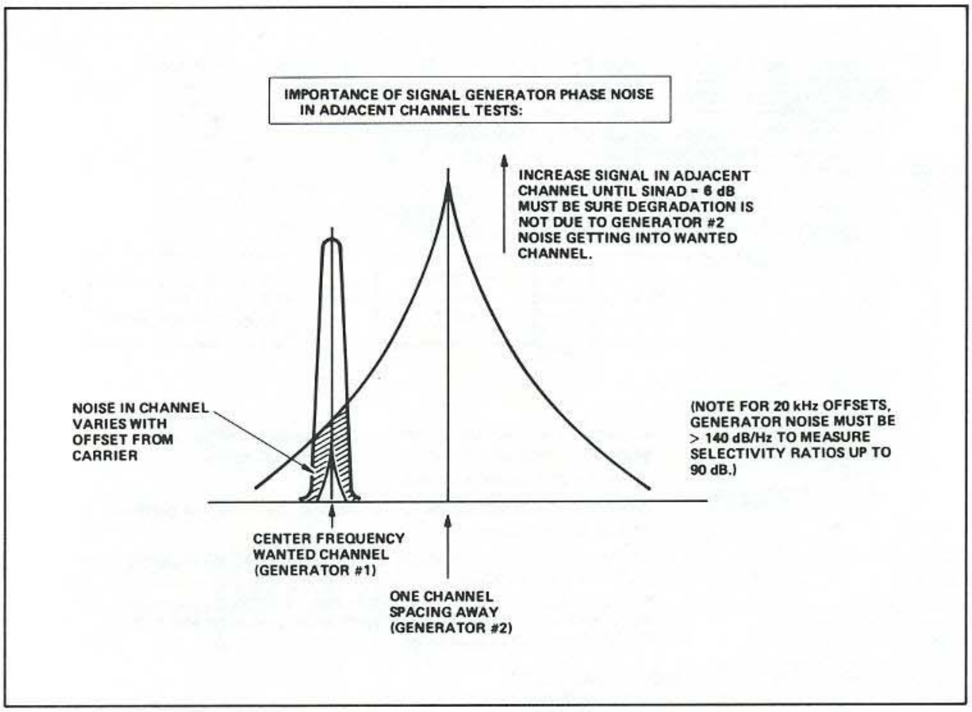
Spurious:
can feed directly into the IF of the receiver contributing to the distortion.

FM Distortion:
distortion on 1 kHz tone from generator #1 would show up on distortion analyzer.

Intermods from coupling 2 generators:
danger of products close to f_0 being seen as distortion.

Frequency stability:
with channel spacing as close as 12.5 kHz, drift would be intolerable.

Phase noise:
see next slide.

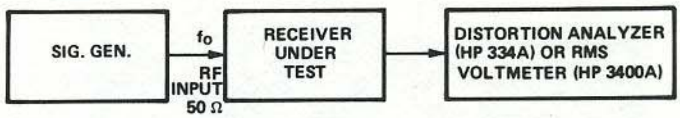


Phase noise is probably the most important spec for signal generators used in adjacent channel tests. As the level of generator #2 is increased, if it has much phase noise that phase noise would be seen within the bandwidth of the wanted channel and would contribute to the distortion being measured. As an example, for a receiver with approximately 10 kHz bandwidth, generator noise must be >140 dB/Hz to measure selectivity ratios up to 90 dB.

SPURIOUS ATTENUATION

MEASURE OF RECEIVERS ABILITY TO DISCRIMINATE BETWEEN A DESIRED AND UNDESIRED SIGNAL. IF AND IMAGE FREQUENCIES SHOULD BE INCLUDED IN TEST.

TEST SETUP:



TEST PROCEDURE:

1. TURN OFF OR TUNE AWAY SIGNAL GENERATOR, UNSQUELCH RECEIVER, AND ADJUST VOLUME CONTROL FOR NOISE OUTPUT = 25% RATED OUTPUT.
2. APPLY UNMODULATED SIGNAL AND ADJUST GENERATOR OUTPUT FOR 20 DB QUIETING.
3. VARY GENERATOR FREQUENCY WHILE INCREASING OUTPUT LEVEL AND NOTE RESPONSES.
4. RATIO BETWEEN GENERATORS VOLTAGE FOR 20 DB QUIETING AT f_o AND VOLTAGE FOR 20 DB QUIETING AT A SPURIOUS FREQUENCY IS "SPURIOUS ATTENUATION"

IMPORTANT SIG. GEN. SPECS:
- SPURIOUS
- ATTENUATION RANGE
- LEAKAGE
- NOISE FLOOR
- RF FREQUENCY RANGE

Spurious attenuation is a measure of the receiver's ability to discriminate between a desired and undesired signal, i.e., it's a figure of merit of the RF filters of the receiver. IF and image frequencies are included in the test. The test setup is the same as for quieting sensitivity. In fact the object of the first two steps is to obtain and note the quieting sensitivity. Then the generator output is turned to maximum and the generator is tuned over the frequency range of the receiver (*no* changes are made on the receiver settings). Whenever a signal is noted on the analyzer, the generator level should be reduced until 20 dB of quieting is observed. The ratio of the generator levels for 20 dB of quieting at f_o and 20 dB of quieting at the spurious frequency is the "spurious attenuation". Let's look at the important signal generator specifications:

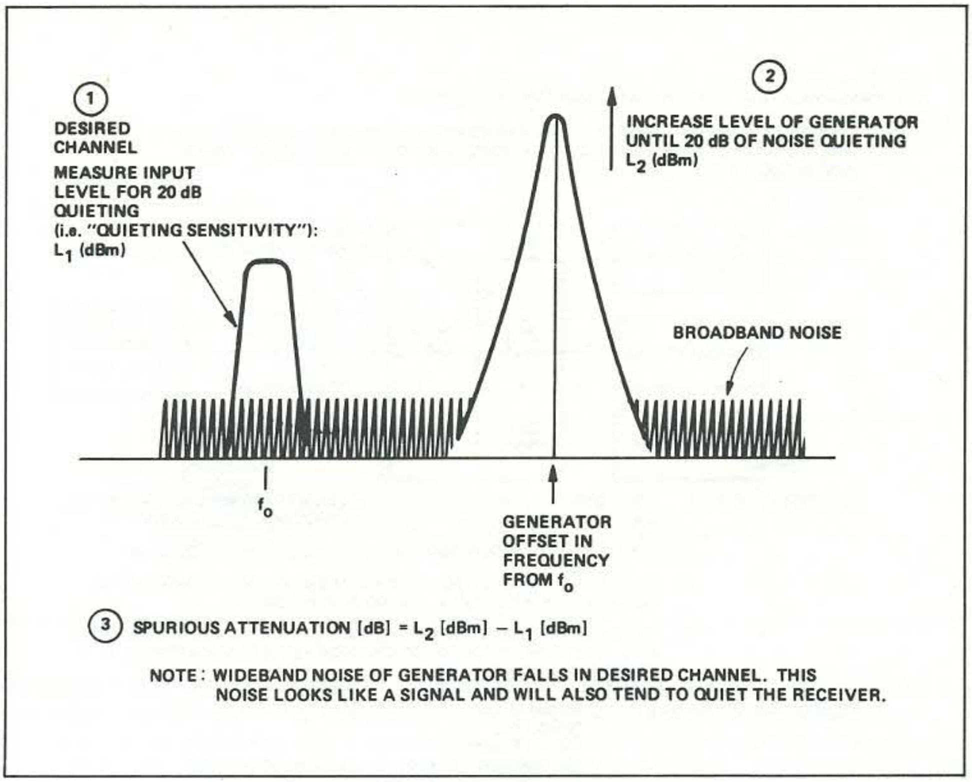
Spurious:
: very important. The distortion analyzer cannot separate spurious outputs of *generator* from spurious responses of the *receiver.*

Attenuator range:
: must have a range beyond the receiver sensitivity and output power high enough to allow 20 dB quieting with spurious response.

Leakage:
: Any signal other than the one from the generator output port might contribute to measurement error.

RF frequency range:
: must tune over a much greater range than the receiver range to cover images, etc.

Noise floor:
: see the next slide.



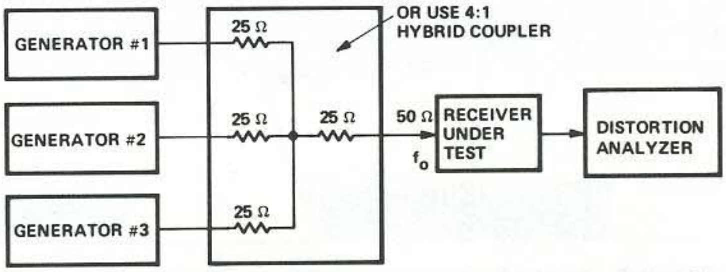
The broadband noise floor of the generator is also very important in the spurious attenuation measurement as illustrated in this example . . .

If the receiver has for example a 12 kHz bandwidth and the noise floor of the generator is 150 dB/Hz, then the noise received in a 12 kHz bandwidth would be 42 dB higher or −108 dB relative to the carrier. As such, if the receiver has very good spurious attenuation then the generator must have a very very low broadband noise floor or the generator's noise floor will actually be seen before spurious generated in the receiver as the RF level is increased.

INTERMODULATION SPURIOUS ATTENUATION

MEASURES ABILITY OF RECEIVER TO DISTINGUISH BETWEEN A DESIRED SIGNAL AND CERTAIN COMBINATIONS OF 2 OR MORE UNDESIRED SIGNALS AT OTHER FREQUENCIES.

TEST SETUP:



TEST PROCEDURE:

1. TUNE GENERATOR #1 TO f_0 AND MODULATE WITH 1 kHz TONE AT 2/3 MAX RATED DEVIATION. ADJUST OUTPUT FOR 12 dB SINAD.
2. TUNE UNMODULATED GENERATOR #2 TO ADJACENT CHANNEL.
3. TUNE GENERATOR #3 TO NEXT ADJACENT CHANNEL WITH 400 Hz MODULATION AT 2/3 MAX. RATED DEVIATION.
4. INCREASE LEVELS OF #2 AND #3 EQUALLY UNTIL SINAD DEGRADES 6 dB. RATIO OF LEVEL OF GENERATOR #2 TO GENERATOR #1 IS INTERMOD ATTENUATION.

IMPORTANT SIG. GEN. SPECS:

PHASE NOISE
SPURIOUS
FM DISTORTION
INTERMODS FROM COUPLING 3 GENERATORS
FREQUENCY STABILITY

Intermodulation spurious attenuation measures the ability of a receiver to distinguish between a desired signal and certain combinations of two or more undesired signals at other frequencies. Generator #1 is set to f_0 and modulated with a 1 kHz tone at 2/3 maximum rated deviation. The level is adjusted for 12 dB SINAD. Generator #2 is tuned to the adjacent (high or low) channel and *not* modulated. Generator #3 is tuned to the next adjacent channel (same side as #2) and modulated with a 400 Hz tone at 2/3 maximum rated deviation. The levels of generators #2 and #3 are increased together until SINAD degrades to 6 dB. The ratio of the level of generator #2 or #3 (they are the same) to generator #1 is the intermodulation spurious attenuation.

The important signal generator specs are the same as for the adjacent channel tests:

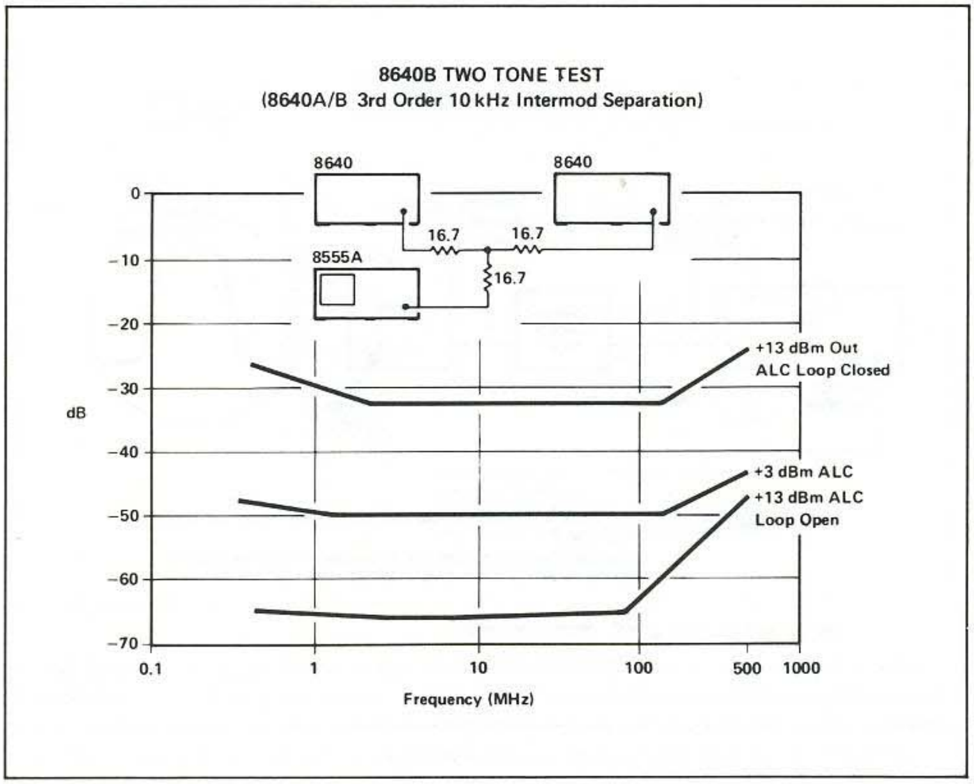
Phase noise:
: as the levels of generators #2 and #3 are increased the phase noise would be seen within the bandwidth of the wanted channel contributing to the distortion being measured.

Spurious:
: can feed directly into the IF of the receiver contributing to the distortion being measured.

FM distortion:
: would be more significant in generator #1's contribution than in #2 or #3's contribution thus causing a measurement error.

Frequency stability:
: with channel spacing as close as 12.5 kHz, drift would be intolerable.

Intermods from coupling 3 generators:
: generators have been intentionally set up so that intermods will fall in-band for this test and any intermods generated in the generators can't be separated from those occuring in the receiver.



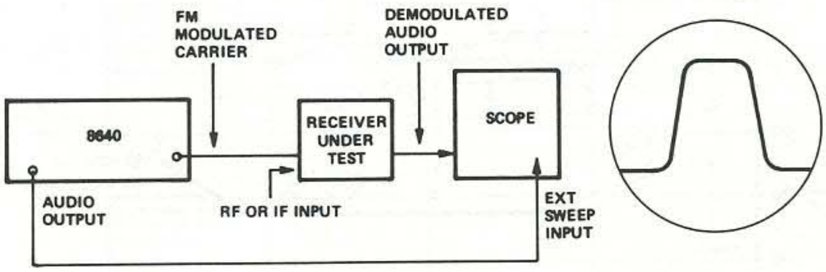
In making intermodulation spurious attenuation tests, intermods created by coupling two or more generators together cannot be separated from intermods caused by the receiver. To show this we have a plot of the intermodulation distortion outputs of two 8640 high performance generators. They are set up on either of the two top operating bands and combined through a normal 6 dB power splitter. The vertical scale is how far down the intermods are. The horizontal scale is the output frequency of the two generators. With both ALC loops closed the intermods vary from about −32 dB down over the mid-frequencies up to only −22 or −23 dB down at the high and low ends.

A trick to reduce these intermods is to open the ALC loops. The 8640 has an internal switch which allows the user to do this. With the loops open the worst case intermods are down −50 dB. Below 100 MHz, they are about −65 dB down.

On some generators it is necessary to physically remove a connection to open the loop and improve the intermod performance. With the HP 8660 synthesized signal generator a technique would be to go to the pulse modulation mode which opens the loop. (This also biases the RF off so you would have to put a +10 volt signal on the external pulse modulation input to bias the RF on again.)

Another method of reducing intermodulation products is the use of hybrid couplers with some reverse isolation to connect two or more generator.

IF FILTER/DISCRIMINATOR ALIGNMENT



<u>TEST PROCEDURE:</u> 1. TUNE RECEIVER AWAY FROM STATION AND SET 8640 AT THIS FREQUENCY.

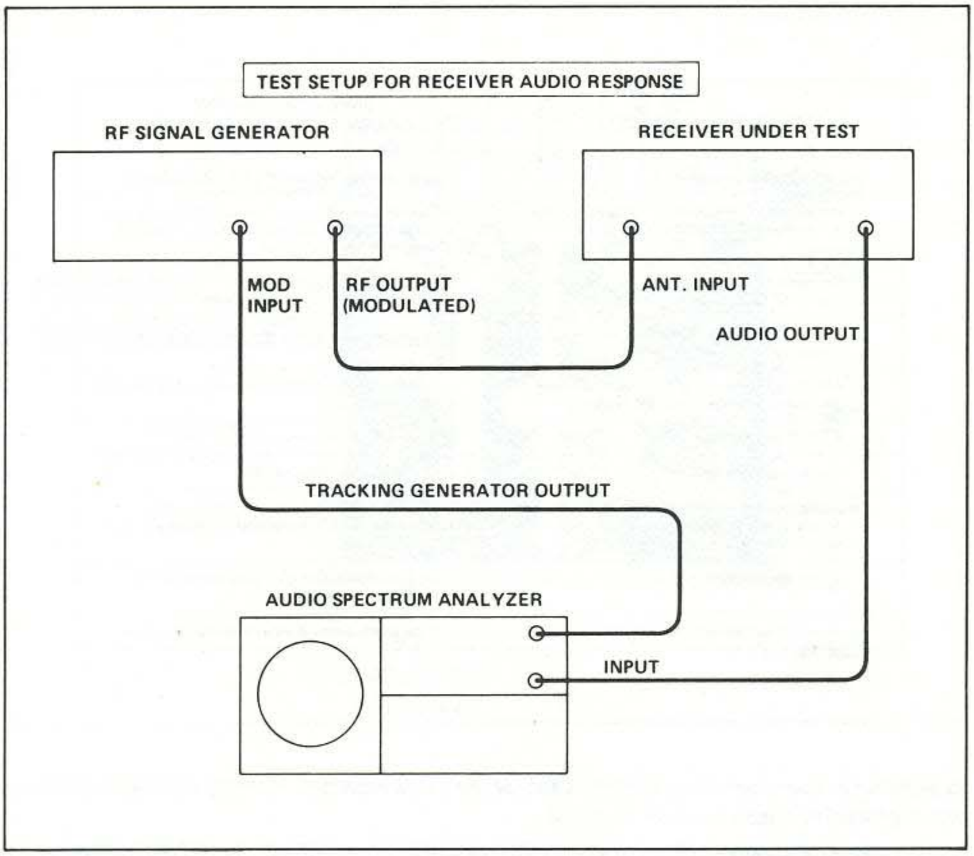
2. SET MAXIMUM DEVIATION >> IF BANDWIDTH OF RECEIVER AND FM OUTPUT TO EXTERNAL SWEEP INPUT ON SCOPE.

<u>IMPORTANT SIG. GEN. SPECS:</u> WIDE DEVIATION
LINEAR FM

IF Filter/discriminator alignment is not a receiver test, but rather is a procedure done in production testing and after some repairs.

The generator is connected to the receiver and the RF tuned away from a station. The receiver is tuned to the same frequency as the generator. The generator is then FM'ed internally at a very low rate, say 40 or 50 Hz (this can be done in an 8640 with the optional built in variable frequency oscillator). The maximum deviation is set much greater than the IF bandwidth of the receiver. The FM output is also used to externally sweep the scope. If the optional internal oscillator is not available then an external sawtooth can be used to externally FM the generator and sweep the scope.

It is important that the generator has provision for wide enough FM deviation so that it can be used as a sweeper for IF and discriminator alignments. Also the FM should be linear to insure that the only distortions seen come from the receiver and are not introduced to the receiver by the generator.



Here is a special technique using a signal generator with an HP Audio Spectrum Analyzer (141T/8552/8556) to look at the total audio response of a receiver. The tracking generator output of the audio frequency spectrum analyzer (which tracks the analyzer input frequency) is used to externally modulate the signal generator. The modulated RF output is applied to the receiver's antenna. The audio output of the receiver is applied to the input of the audio spectrum analyzer. This gives a swept frequency response of the total receiver. This is particularly useful for analyzing the audio circuits of receivers with multiple channels on the same carrier (e.g., multi-channel SSB receivers).

TYPICAL RECEIVER TESTS	SIGNAL GENERATOR CHARACTERISTICS REQUIRED
– Least Usable Sensitivity	– Low Leakage/Accurate, Low Level Signals
– Image and IF Rejection – Tests Primarily RF Selectivity	– Low Spurious/Output Levels ⩾1V for Testing Large Rejection Ratios/Coverage of Both IF and RF Frequencies
– Adjacent Channel Selectivity – Tests Primarily IF Selectivity	– Low Close-In Noise
– 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	– Accurate, Wide Range Output Level
– Audio Hum and Noise	– 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 ⩽.5%)
– Audio Bandwidth	– DC Coupled FM/High Linearity/Wide FM Deviation Capability
– IF and Discriminator Alignment	– Wide Modulation Bandwidth/Flat Response

In summary, then, here is a simplified list of the most common receiver tests with pertinent signal generator characteristics required . . .

Sensitivity tests require low leakage and accurate, low level signals. Image and IF rejection tests require low spurious and output levels ⩾1V. Adjacent channel tests require low close-in noise. Intermodulation tests need good isolation between generators. Audio bandwidth tests require high linearity and wide FM deviation capability. And finally the IF and Discriminator alignment requires wide modulation bandwidth and flat response.

CHOOSING THE RIGHT SIGNAL GENERATOR

We'll conclude by summarizing the signal generator types available and the uses they are best suited for. Before we do this though, let's take a second to review some examples of special purpose signal generators which are for specialized applications.

8601A GENERATOR/SWEEPER

FREQUENCY RANGE: 0.1–110 MHz

MODULATION: AM, FM (No Mod-Meter)

MAJOR APPLICATIONS:

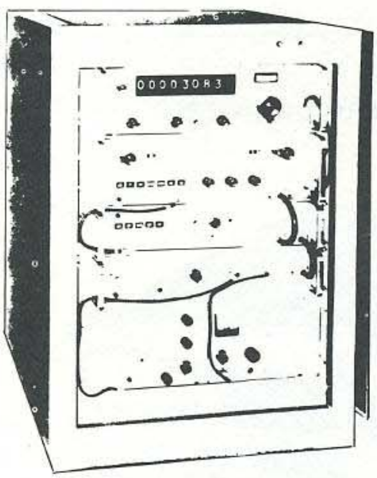
- –Swept Alignment of Receivers in Production or Field Repair Shops
- –Receiver Operational Readiness Tests
- –General Purpose Lab Sweeper

The first type of special purpose generator we want to look at is the generator/sweeper. The HP 8601A is an example. It is actually a very good precision sweep oscillator that also has some signal generator characteristics. It has a calibrated output attenuator and limited AM and FM capability. It is useful for IF and discriminator alignment on a receiver and has enough modulation and calibrated output capability to do sensitivity and audio distortion measurements to insure that the receiver is working correctly. It is not usually used for full receiver testing.

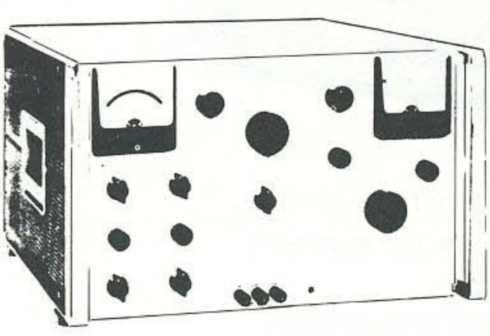
SPECIAL PURPOSE SIGNAL GENERATORS

DESCRIPTION/APPLICATION

- **8640B Option 004**
  NAV/COM Signal Generator
  450 kHz - 550 MHz
  Calibration of Aircraft
  ILS (Marker Beacon, Localizer
  and Glide Slope), VOR and VHF
  Communcation Equipment



- **8925A DME/ATC Test Set**
  962 - 1213 MHz
  Calibration of Aircraft
  DME and ATC Transponder
  Equipment



- **202H FM-AM Signal Generator**
  54 - 216 MHz
  FM Broadcast, VHF-TV,
  Mobile Radio

Other special purpose signal generators include avionics generators such as the HP 8640 Option 004. Generators of this type are used for testing aircraft instrument landing systems (ILS), navigation systems (VOR), and communications systems, both VHF and UHF.

The HP 8925 is actually a package of instruments used to calibrate aircraft distance measuring equipment (DME) and air traffic control (ATC) radar transponders.

An example of special purpose FM-AM signal generators designed for use in FM broadcast, VHF-TV and mobile radio is the HP 202H. It covers the 54 - 216 MHz band and has a very broadband FM capability.

8640B Option 004 NAV/COM Signal Generator

0.5 to 512 MHz

DESCRIPTION:

STANDARD 8640B PLUS:

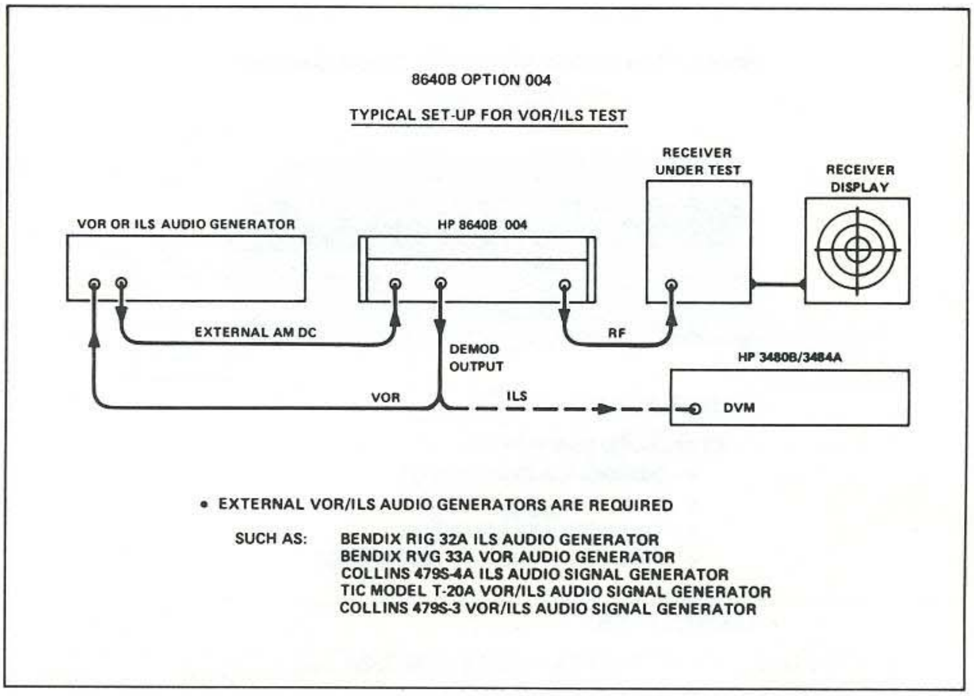
- DEMODULATED OUTPUT
- MODIFIED AM CIRCUITRY
- 1 dB STEP ATTENUATOR
- 2 kΩ EXT AM INPUT IMPEDANCE

OBJECTIVES:

- REPLACES HP 211A AND 232A
- TEST VOR/ILS RECEIVERS
- TEST VHF COMMUNICATIONS RECEIVERS
- MEET NEW, STRINGENT REQUIREMENTS
- RETAIN GENERAL PURPOSE FEATURES

Let's look at how an avionics generator such as the HP 8640B Option 004 differs from a general purpose signal generator. The NAV/COM version of the 8640B is a standard HP 8640B high performance signal generator with some special additions so it can be used in ILS testing. For calibration of the glide slope (part of the ILS) a very accurate AM (to fractions of a percent) is required. To monitor this a very linear AM detector and demodulated output were added. The output vernier is limited to a couple of dB to preserve the AM detector linearity so a 1 dB-step output attenuator is also added. In addition, the external AM input was increased to 2 kΩ to facilitate the use of specialized VOR and ILS Audio Generators.

These modifications allow the HP 8640B Option 004 to replace two older instruments (HP 211A and HP 232A) in testing VOR and ILS receivers. The same instrument can also be used to test VHF communications receivers as it still retains all of its general purpose signal generator features.



This is a typical setup using the HP 8640B Option 004 for testing VOR/ILS receivers. On the left is the external audio generator required for the precise external AM to the signal generator. The demodulated output from the signal generator is fed back to the audio generator as a negative feedback and acts as a modulation monitor. The output of the RF generator is connected to the receiver under test and the output of the receiver is observed on the receiver display.

GENERATOR	USES
8654A VHF Signal Generator 10 - 512 MHz	- Use for "operational readiness" tests; i.e., for "Go-No Go" receiver checkout in field installations. - Use as low cost laboratory generator.
8601A Generator/Sweeper 100 kHz - 110 MHz	- Sweeper with some sig gen characteristics - use for IF discriminator alignment in production or field. - Use for non-critical receiver tests or "operational readiness".
8640A/B AM/FM Signal Generator 450 kHz - 550 MHz	- Use where full performance tests must be performed; e.g., lab design, production test, and depot level repairs and recalibration. - Use for most stringent bench receiver tests; e.g., adjacent channel interference, etc. - Use on wide variety of high performance receivers.
8660B Synthesized Signal Generator 10 kHz - 1300 MHz (with appropriate plug-ins)	- Ideally suited for testing synthesizer based communication equipment (e.g., SSB where high stability and precision settability is required). - Programmable - for use in automatic test applications. - A precision sweep oscillator for narrowband applications.

Finally, let's summarize the basic types of generators we've covered with their major characteristics and applications . . .

Economy signal generator such as the HP 8654A (10 - 512 MHz) - used for "operational readiness" tests and as a low cost laboratory generator.

Generator/sweeper such as the HP 8601A (100 kHz - 110 MHz) - used for IF discriminator alignment and non-critical receiver tests or "operational readiness".

High performance signal generator such as HP 8640A/B (450 kHz - 550 MHz) - used for full performance tests (e.g., lab design, production test, and depot level repairs and recalibration) and for most stringent bench receiver tests.

Synthesized signal generator such as HP 8660B (10 kHz - 1300 MHz with appropriate plug-ins) - used for testing synthesizer based communcation equipment and in automatic test applications. Also a precision sweep oscillator for narrowband applications.

Now that we have looked at the variety of signal generators available, their characteristics, specifications and applications, we hope that you feel well prepared to confidently select the best generator for *your* application.

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