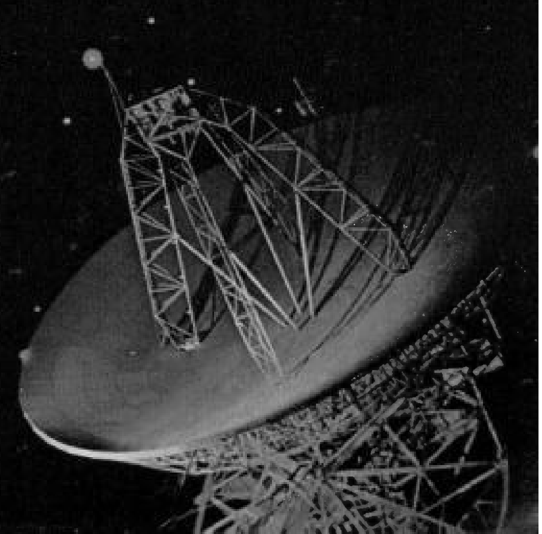
Application Note 218-1

Microwave Synthesizer Series

Feb 1977

Applications & Performance

of the 8671A and 8672A Microwave Synthesizers



HEWLETT PACKARD

HEWLETT hp PACKARD

Application Note 218-1

Applications & Performance

of the

8671A and 8672A

Microwave Synthesizers

Feb 1977

W1QG

COVER

ATS6 Satellite and Wallops Island Tracking Station courtesy of NASA; Galaxy photograph courtesy of Lick Observatory.

Contents

Introduction 1
- 8671A Microwave Frequency Synthesizer 1
- 8672A Synthesized Signal Generator 2

Frequency Control and Performance 3
- Frequency Control 3
- Indirect Synthesis 3
- Spectral Purity 4
  - Reference Oscillator Considerations
- Frequency Stability 5
  - Long Term Stability
  - Short Term Stability
- Switching Speed 7

Output Level Control and Performance 8
- Output Level Control 8
  - RF On/Off
  - ALC Controls
- Maximum Output Level 11
  - Peak/Norm Adjustment (8672A)
- Performance in Overrange (8672A) 13
  - Amplitude Modulation
  - Output Level Flatness
  - Spurious Output

Modulation Control and Performance 14
- Modulation Control 14
- Frequency Modulation 14
  - Maximum FM Deviation
  - Distortion
- Amplitude Modulation 16

Applications 17
- Satellite Communications 17
- Electronic Warfare 17
- Automatic Systems 18
- Component Test 18
- Bench Signal Sources 18
- Use With Other Instruments 18
  - Finer Frequency Resolution
  - 1 MHz to 18 GHz Systems
  - Higher Frequencies
  - Reduced Harmonics
  - Two Tracking Microwave Synthesizers
  - Pulse Modulation

(cont'd.)

Contents (cont'd.)

Remote Programming 24
Programming Format 24
Frequency Programming 25
Special Frequency Programming 26
Output Level (8672A Only) 27
Modulation 28
ALC 29
Service Request 29
Status Reporting 29
Programming Execution Time 30

Bus Commands 32
Output Subroutines 32
9825A
9830A
Programming Quick Reference Guide 34

8671A/8672A Familiarization Procedure 36

Theory of Operation 39

Reliability and Serviceability Features 41

Introduction

Recent advances in microwave technology have resulted in major performance improvements in many microwave systems. These have resulted in increased demands on components, sub-systems, and test equipment. Particularly in the area of frequency generation, the need for sources with better spectral purity, frequency stability, and frequency resolution has greatly increased.

Frequency synthesizers meet many of these requirements. General purpose synthesizers are widely used today in applications where frequency accuracy and resolution, speed of changing frequency, spectral purity, or programmability are requirements. In the past, these synthesizers have generally been limited to lower frequencies even though the requirement for improved performance has extended into the microwave area.

The technology advances which have improved microwave systems have also made possible general purpose microwave synthesizers. These offer excellent stability, accuracy, and spectral purity combined with wide frequency coverage and programmability. They offer a unique solution to many of today's problems.

In order to receive the full benefit the instruments can offer it is important to understand their features, applications, and operation. The intent of this note is to familiarize the user with these instruments so that their full potential can be realized. In particular, this note discusses two of these microwave synthesizers—the HP 8671A Microwave Frequency Synthesizer and the HP 8672A Synthesized Signal Generator.

Before discussing the operation and applications of the 8671A and 8672A in detail, a basic description of each is useful so that their basic similarities and differences will be apparent.

8671A Microwave Frequency Synthesizer

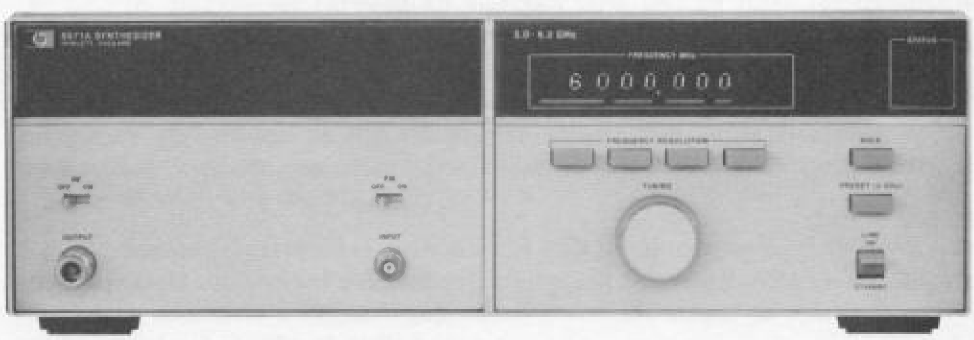


Figure 1. 8671A Microwave Frequency Synthesizer with frequency range of 2.0 to 6.2 GHz.

The 8671A Microwave Frequency Synthesizer (Figure 1) is an extremely pure frequency source which covers the frequency range of 2.0 to 6.2 GHz with 1 kHz frequency resolution and minimum output power of +8 dBm. The output is unleveled and is derived from a 2.0 to 6.2 GHz phase locked YIG-tuned oscillator (YTO). It is well suited for many local oscillator applications.

The 8671A also provides for frequency modulation at rates up to 10 MHz. Two calibrated but unmetered input sensitivity ranges are provided for convenience. The output frequency remains phase-locked while in the FM mode.

For automated applications, all functions can be remotely programmed via the Hewlett-Packard Interface Bus. This allows the 8671A to be used as a programmable frequency source or local oscillator.

8672A Synthesized Signal Generator

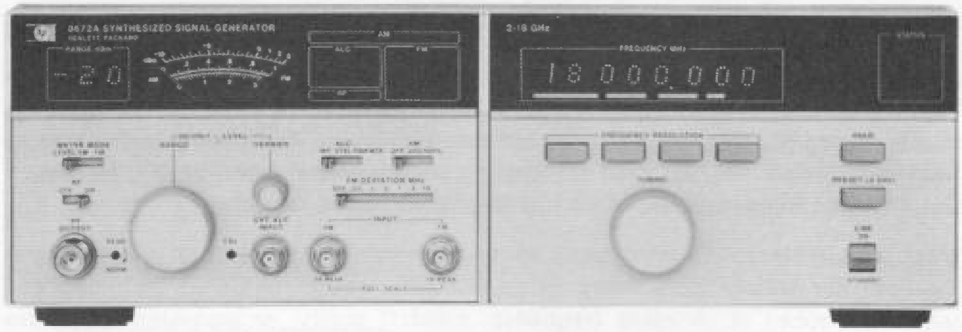


Figure 2. 8672A Synthesized Signal Generator with frequency coverage of 2 to 18 GHz, calibrated output level, and AM and FM.

The 8672A Synthesized Signal Generator (Figure 2) covers the entire 2.0 to 18.0 GHz frequency range with a single output. It not only has wide frequency coverage but also combines synthesizer accuracy, spectral purity, and programmability with the precise modulation and output level calibration of a signal generator. The 8672A has two ranges of metered amplitude modulation and six ranges of metered frequency modulation. The output frequency is always phase-locked while modulation is applied, and simultaneous AM and FM is possible. Output power is internally leveled and calibrated from +3 to −120 dBm for making receiver sensitivity tests and may also be externally leveled from either a diode detector or power meter.

To obtain the wide frequency coverage of the 8672A, a multiplication technique is used. A 2.0 to 6.2 YIG-tuned oscillator is phase locked to the reference. The output of the YTO drives a YIG-tuned multiplier (YTM) which multiplies and filters the YTO output to produce the 2.0 to 18.0 GHz frequency coverage with maximum output power of at least +3 dBm.

Frequency Control and Performance

Frequency Control

The 8670 Series synthesizers provide excellent frequency stability and spectral purity over a broad range of frequencies. In order to easily use this broadband frequency capability, the synthesizers incorporate a simple, convenient frequency tuning system. All frequencies can be either remotely programmed or entered manually by a rotary pulse generator. Because the tuning control is a rotary pulse generator, it can be tuned as far in any direction as desired without frustrating mechanical stops. Also, the faster it is turned the greater the frequency change per revolution. The convenience of this single control tuning (Figure 3) is further improved with selectable resolution. Resolution keys located above the tuning control are used to select 1 kHz, 10 kHz, 1 MHz, or 100 MHz resolution.

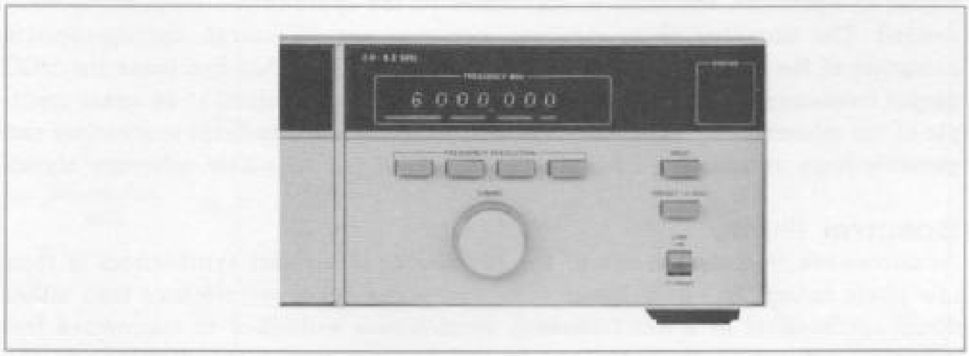


Figure 3. 8670 Series tuning controls.

The basic oscillator in the 8670 Series synthesizers is a 2.0 to 6.2 GHz YTO that is phase-locked in 1 kHz steps. For higher frequencies the YTM multiplies this signal by two for frequencies between 6.2 and 12.4 GHz and by three for frequencies above 12.4 GHz. This results in 1 kHz resolution between 2.0 and 6.2 GHz, 2 kHz resolution between 6.2 and 12.4 GHz, and 3 kHz resolution above 12.4 GHz. As a result of this, when making coarse frequency changes in the higher bands the kHz digit may also change as the synthesizer adjusts the output frequency to one compatible with its resolution. For example, 16 GHz would be adjusted to 15 999.999 MHz or 16 000.002 MHz.

Once a desired frequency has been set, the HOLD key can be used to disable the tuning control and prevent unintentional changes in frequency. Also associated with frequency control is a PRESET key which resets the output to 3 GHz for easily setting the least significant digits to zeros.

Whenever the synthesizers are turned off or have power removed, the last frequency entered is stored in memory. When the instrument is again turned on, the frequency returns to that previously set. This is very convenient because momentary power failures do not require the re-entry of the desired frequency. Even after extended periods without power, the last frequency is retained.

Indirect Synthesis

A basic consideration with any signal source is spectral purity. This is a critical parameter particularly for synthesizers where spectral purity is an important performance consideration in many applications.

The 8670 Series synthesizers use an indirect (phase-locked loop) method of frequency synthesis. This technique offers certain advantages over other techniques. In order to understand the performance of the 8670 synthesizers and the reason the indirect technique is used, a simple explanation of how phase-locked loops are used in synthesizing frequencies is important.

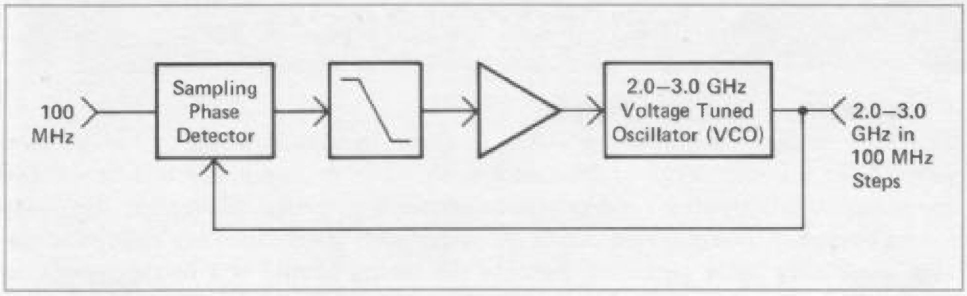


Figure 4. Simple 2 to 3 GHz indirect synthesizer.

The simple example of an indirect synthesizer shown in Figure 4 generates frequencies between 2 GHz and 3 GHz in 100 MHz steps. The output is generated by a voltage controlled oscillator (VCO) phase-locked to a harmonic of the reference signal. In operation, the VCO is first tuned to the approximate output frequency desired. The sampling phase detector compares the VCO with the appropriate harmonic of the reference and feeds back an error signal that fine tunes the VCO output frequency. The VCO output frequency is thus maintained at an exact multiple of the reference. By expanding this simple example the indirect synthesizer can generate large numbers of frequencies all derived from a single reference signal.

Spectral Purity

At microwave frequencies, one of the advantages of indirect synthesizers is their low phase noise. They have better wideband phase noise performance than either direct synthesizers or lower frequency synthesizers multiplied to microwave frequencies. Indirect synthesizers can do this because they take advantage of the difference in noise characteristics of the crystal reference and VCO for optimum noise performance.

With indirect synthesizers the output phase noise is that of the reference multiplied up to microwave frequencies within the phase-locked loop bandwidth. As the offset from the carrier increases, the effects of the phase-locked loop decrease and the noise performance approaches that of the VCO only. The result is an overall improvement in noise performance because close to the carrier the multiplied reference has the lower phase noise while at larger offsets the VCO is actually cleaner. The synthesizer then includes the best regions of both signals for optimum noise performance (Figure 5).

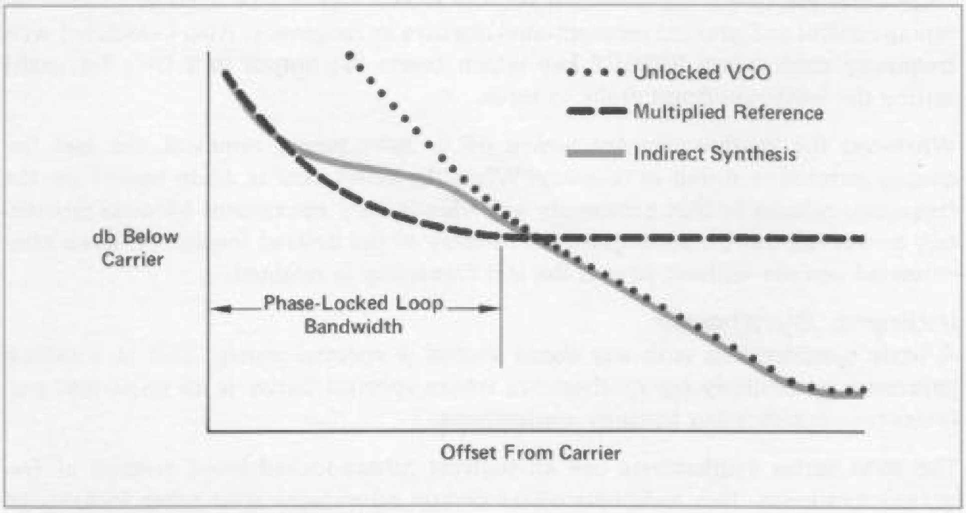


Figure 5. Indirect synthesizer phase noise.

Reference Oscillator Considerations

Many synthesizer applications require that the synthesizer be locked to an external reference. This can be a problem because spurious signals on this reference are multiplied along with the reference up to microwave frequencies. The multiplication process causes the relative amplitude of the spurious signals to increase in direct proportion to the amount of multiplication. Spurious signals on a 10 MHz reference used to generate a 6 GHz frequency increase in relative amplitude by approximately 56 dB. Thus an external reference can have no spurious signals higher than 126 dB below the primary signal in order for the spurious signals to be 70 dB below the carrier at 6 GHz. This kind of performance is difficult to achieve either because the reference frequency contains higher spurious or because spurious signals are picked up in the cable to the synthesizer.

To help solve this problem the 8670 synthesizers filter the external reference input. This filter reduces spurious signals that are greater than 200 Hz offset from the reference and allows otherwise unacceptable references with spurious above −126 dBc to be used (Figure 6).

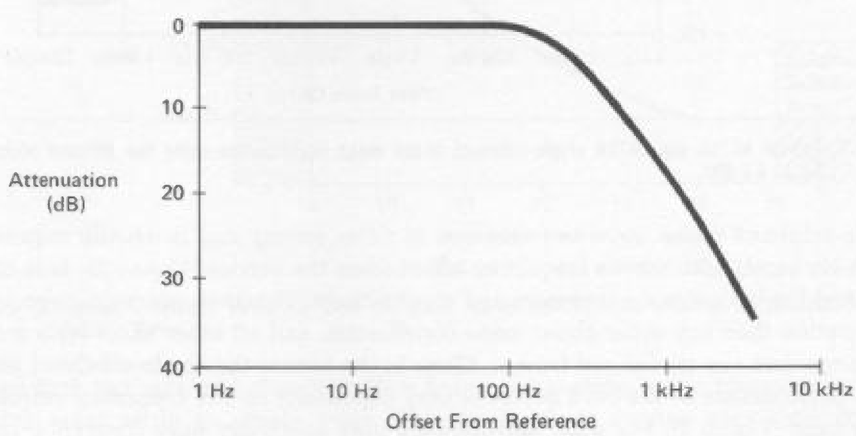


Figure 6. 8670 Series synthesizer reference filter characteristics.

When the internal reference oven is cold, the frequency error of the reference is large enough so that the signal is outside the filter passband. When this occurs the synthesizer cannot phase lock. As a result, when the internal reference is cold it may take several minutes after power is applied to the reference for it to stabilize within the filter bandwidth and the synthesizer to acquire phase lock. This minor inconvenience only occurs when the instruments have been disconnected from the power line, but the result is better spectral purity with external references.

Frequency Stability

Among signal sources, frequency synthesizers offer exceptionally high frequency stability. This is one of the characteristics of synthesizers that makes them very useful. Many applications require the greatest stability possible, both long and short term.

Long Term Stability

Long term stability refers to the slow change in the average frequency with time and is usually expressed as a ratio, $\Delta f/f$ over a given period of time. The long term stability of the 8671A and 8672A is determined by the reference being used. The internal standard in the 8670 Series is a high quality quartz oscillator with a long term stability of 5×10^{-10}/day.

When using external frequency standards, the long term stability of the synthesizer is that of the external reference. By using rubidium standards, long term stabilities of 1×10^{-11}/month are possible. For maximum long term stability a cesium standard can be used with no systematic drift and absolute accuracies of parts in 10^{-12}.

Output Level Control and Performance

Output Level Control

The 8672A Synthesized Signal Generator is calibrated over a wide range of output power from +3 to −120 dBm. There are two controls that are normally used to set the output power of the 8672A. These are the output level range and vernier controls (Figure 10). The actual output level is the sum of the setting of both controls.

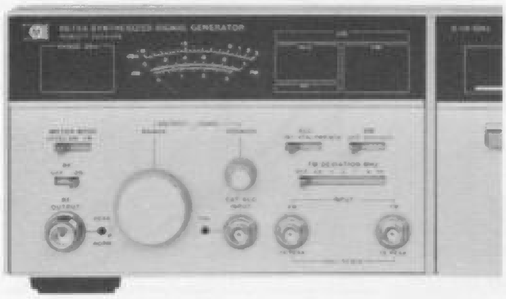


Figure 10. 8672A output level controls and displays.

The range control varies the output level in 10 dB steps from 0 dBm to −110 dBm in twelve ranges which are indicated by the LED digits in the upper left corner of the front panel. This display makes recognition of the output range easy even when the instrument is operating in the remote mode. When higher output powers are needed, there is a +10 dBm overrange setting that allows the instrument to output the maximum power available, up to +13 dBm over part of the band with internal leveling.

While the range control determines the output level in large steps, the vernier allows finer resolution within each range. The vernier covers 13 dB from +3 to −10 dB about the range setting. The meter located next to the range indicator displays the vernier setting when the meter mode switch is in the LEVEL position. The output can easily be determined by summing these two adjacent displays.

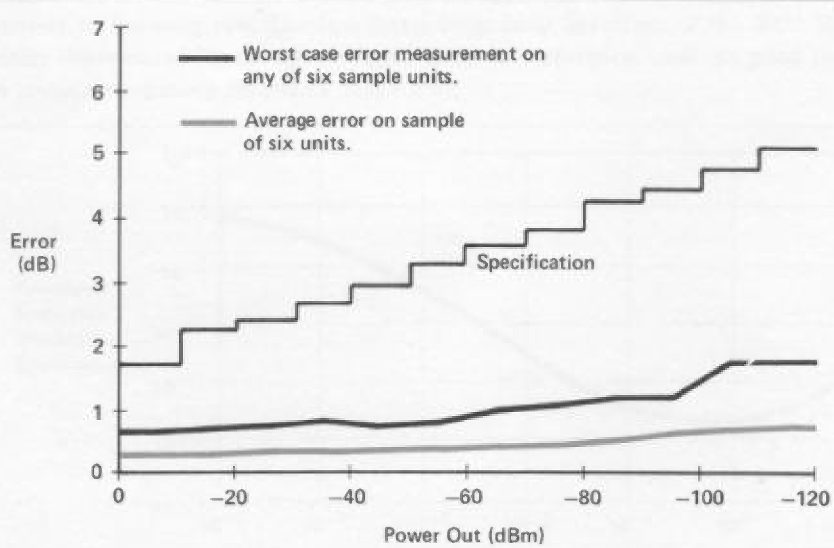


Figure 11. Typical output level accuracy on the 2.0 to 6.2 GHz frequency band. Data is based on a random sample of six units.

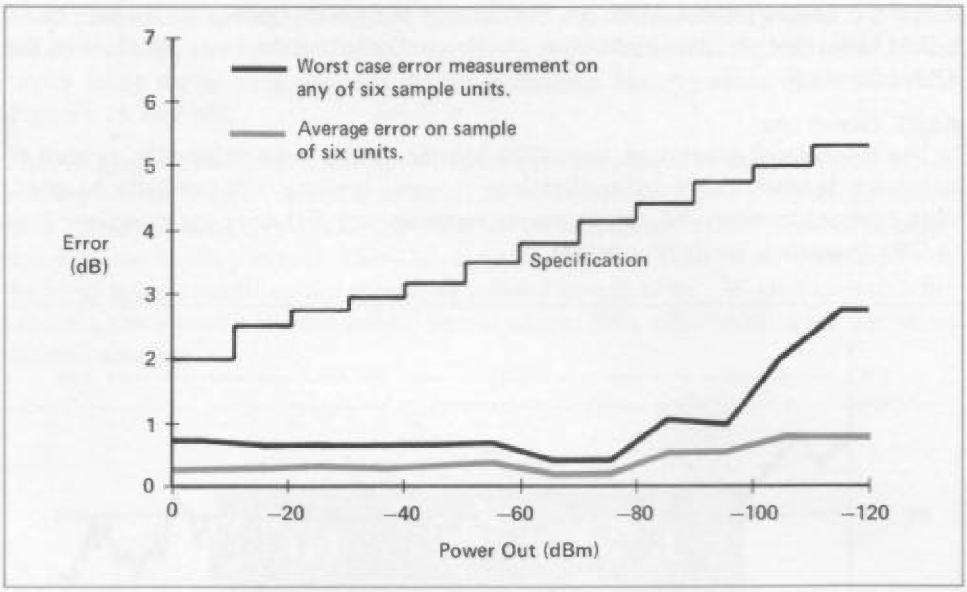


Figure 12. Typical output level accuracy on the 6.2 to 12.4 GHz frequency band. Data is based on a random sample of six units.

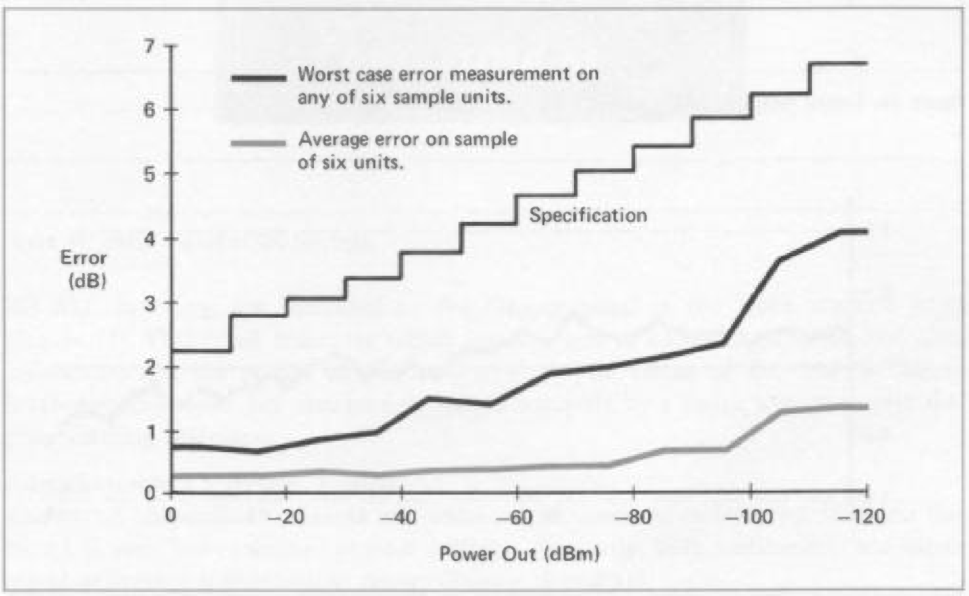


Figure 13. Typical output level accuracy on the 12.4 to 18 GHz frequency band. Data is based on a random sample of six units.

In the manual mode the vernier can be varied continuously over the full 13 dB. When the 8672A is remotely controlled, the vernier can be programmed in fourteen 1 dB steps from +3 to −10 dB. Because the vernier can be controlled over greater than 10 dB in both local and remote, it is possible to overlap range settings by 3 dB. This is very useful in applications such as receiver testing where the ability to vary the output power continuously about a given level is critical.

RF On/Off

The RF on/off switch provides a convenient way of turning off the output in both the 8671A and 8672A. This is very useful when calibrating detectors, zeroing power meters, or making noise measurements on receivers with no input signal. With the switch in the "off" position the 2.0 to 6.2 GHz YTO is biased off so no signal is present at the output.

The display panel has an indicator to show whether the RF is on or off. This is extremely useful when the instrument is remotely controlled so that instrument status can be determined. With no YTO output the synthesizer is no longer phase-locked or leveled, so these conditions are also indicated on the front panel when the RF is turned off.

ALC Controls

Unlike most signal generators, the 8672A has the ability to be externally, as well as internally, leveled. For most applications internal leveling will normally be used. With internal leveling the output power remains very flat over the complete 2 to 18 GHz frequency range (Figure 14).

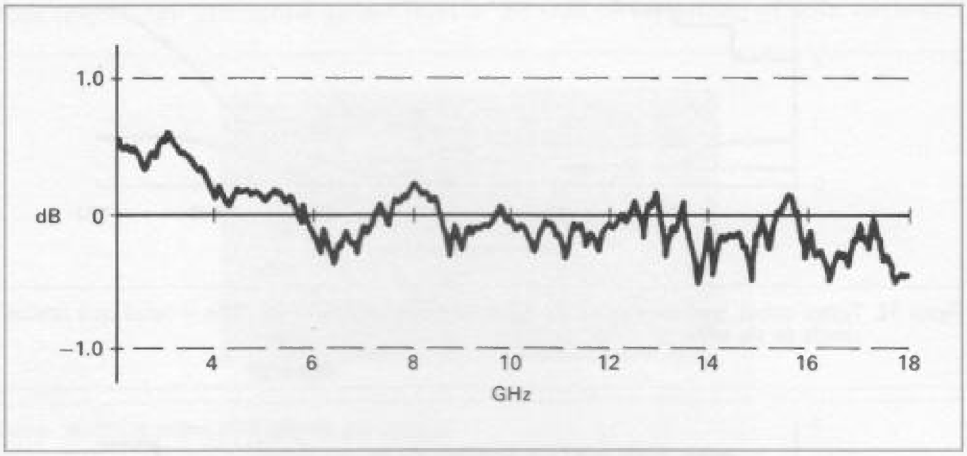


Figure 14. Typical measured 8672A output flatness with internal leveling.

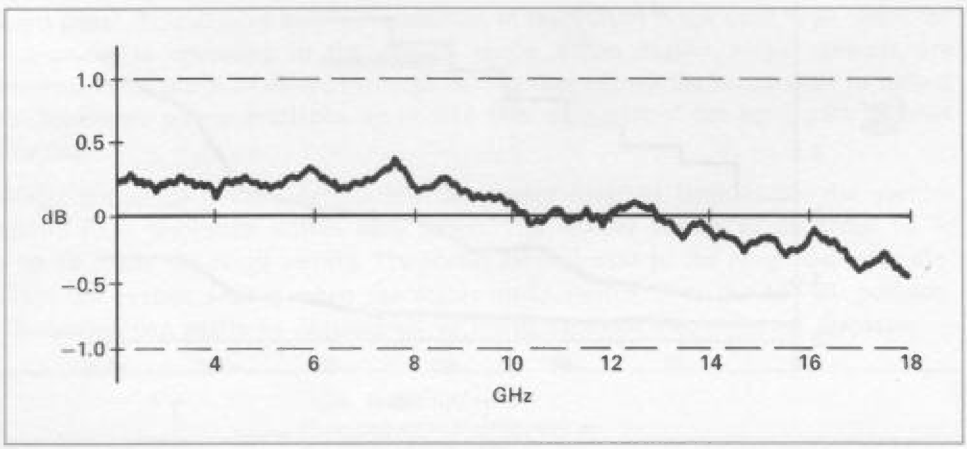


Figure 15. Typical measured 8672A output flatness using external diode leveling and power splitter.

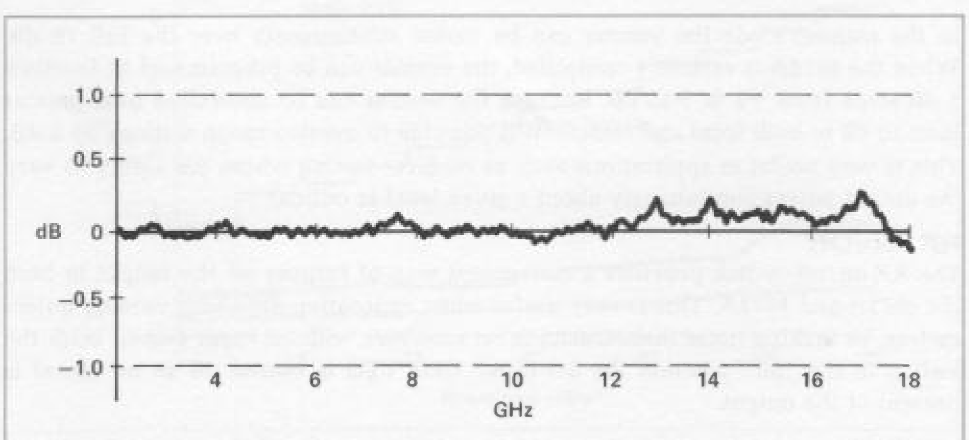


Figure 16. Typical measured 8672A output flatness using power meter leveling and a power splitter.

When external leveling is required the 8672A can be leveled by either a diode detector or a power meter. This allows the power to be leveled at the input to the device being tested thus reducing power variations due to cables and connectors (Figures 15 and 16).

The ALC (automatic level control) switch on the front panel is used to select which leveling source is used: internal, external diode detector, or power meter. So that a wide variety of detectors can be used, the 8672A will accept either positive or negative external leveling inputs. There is also a screwdriver calibration adjustment on the front panel permitting the externally leveled power to be adjusted to match the vernier setting over a limited output power range. This adjustment does not affect internal leveling.

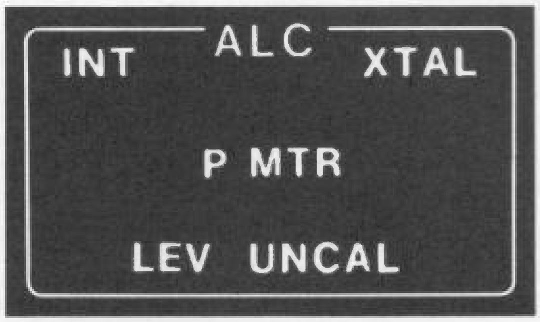


Figure 17. 8672A display of ALC functions.

All ALC functions are indicated on the display panel in the block marked ALC (Figure 17). This block indicates which leveling source has been selected and also indicates when the 8672A output is unleveled. The status of the ALC, whether leveled or unleveled, can also be determined remotely by a status byte sent over the programming interface.

Maximum Output Level

The 8671A is specified to have a minimum output power of at least +8 dBm and the 8672A is specified to deliver at least +3 dBm. Typically, both instruments are capable of delivering higher output power (Figure 18 and 19).

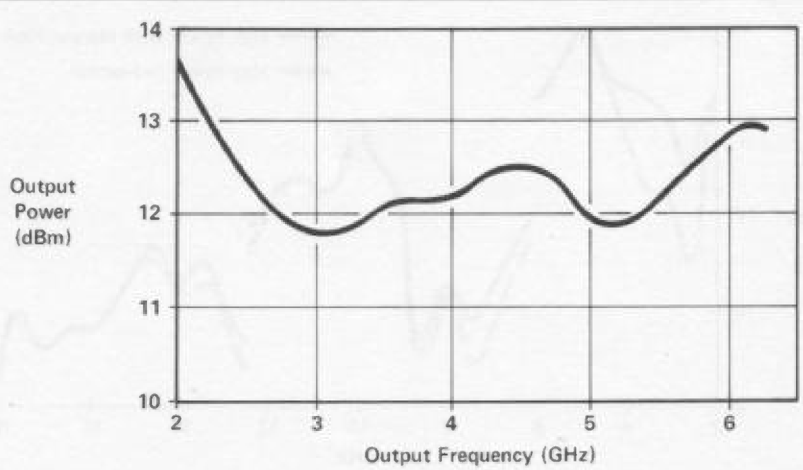


Figure 18. Typical output power available from the 8671A.

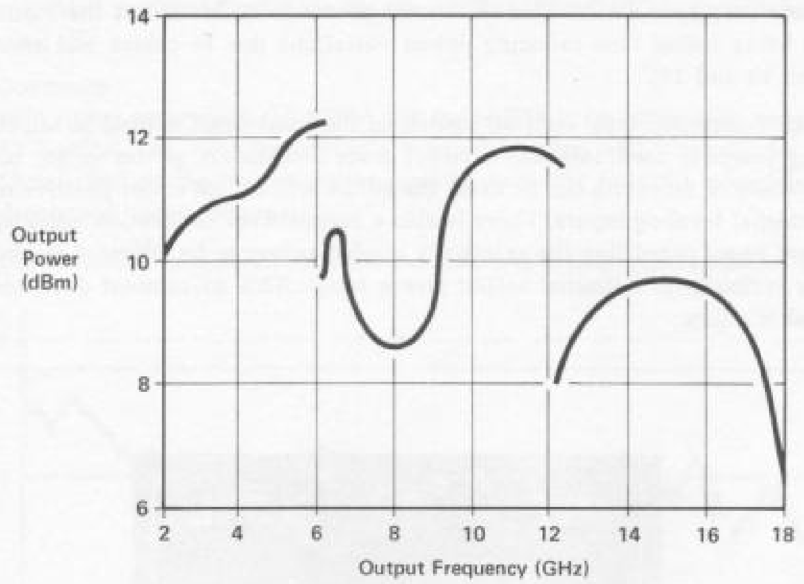


Figure 19. Maximum power typically available from the 8672A.

Peak/Norm Adjustment (8672A)

A factor on the 8672A that determines the maximum available power is the YTM (YIG-Tuned Multiplier) tracking of the YTO (YIG-Tuned Oscillator). Because the YTM not only multiplies but also filters it is necessary that the YTM accurately track the output of the YTO, or much of the possible power will be attenuated by the YTM filter action.

On the front panel of the 8672A next to the RF output is a screwdriver adjustment labeled PEAK/NORM. When in the normal, detent position the YTM is biased to track the YTO across the entire frequency range of 2 to 18 GHz. This results in the maximum average power across the band, but it may be possible when operating at a single frequency to further tune the YTM for more power. The PEAK/NORM adjustment allows the operator to manually center the YTM at a given operating frequency for maximum power. This manual adjustment can result in a small increase in power at certain frequencies (Figure 20).

Because the 8671A covers only up to 6.2 GHz and does not have a YTM, tracking in the 8671A is not a factor, and it does not have a PEAK/NORM adjustment.

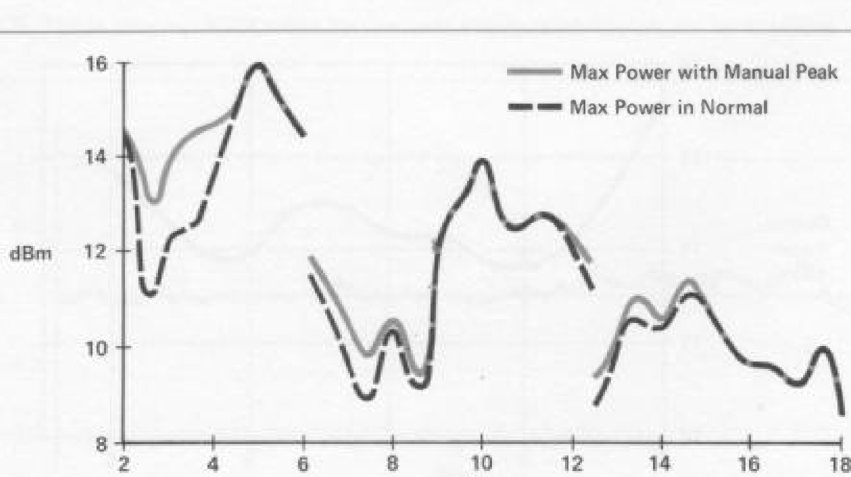


Figure 20. Typical maximum power improvement possible using the PEAK/NORM adjustment.

Performance in Overrange (8672A)

Most 8672A performance characteristics remain almost unchanged when operating on the +10 dBm overrange output setting. However there are certain parameters that may be affected: amplitude modulation, output level flatness, and spurious output signals.

Amplitude Modulation

An amplitude modulated signal may contain more peak power than the same unmodulated CW signal. When the 8672A is operating near the maximum output power, it may not have sufficient reserve to deliver the peak power necessary for amplitude modulation. In the +10 dBm overrange setting this condition may exist and cause AM distortion to increase significantly. In this case, reducing modulation depth or output power will reduce the distortion.

Output Level Flatness

Output level flatness is dependent on the ALC circuitry and the maximum available power. In order to have a leveled output from the 8672A it is necessary for the ALC circuitry to continuously control the output level. This can only occur if the selected output power is below that available at each frequency. For leveled output power on the +10 dBm overrange setting it is necessary that the unleveled indicator remains off.

Spurious Output

In the overrange setting, there is a slight possibility of spurious oscillations resulting in sidebands on the carrier at approximately 250 MHz offset and at a level of 30 to 50 dB below the carrier. These are caused by parametric oscillations of the YTM under maximum power conditions and occur over only very small fractions of the frequency band.

In general these oscillations may be eliminated by either adjusting the peak-normal adjustment for maximum output power at the desired frequency or by reducing the output level vernier. With reduction in power of only 1 or 2 dB the oscillations usually cease. These oscillations do not occur on most instruments, and even in the few instruments where they do occur, it is usually only at output levels above +7 dBm.

Modulation Control and Performance

Modulation Control

The 8671A and 8672A can both be modulated using externally applied signals. The 8671A has two unmetered FM sensitivity ranges. The 8672 has six metered FM ranges and two metered AM ranges. On each range, the modulation depth or peak deviation is linearly controlled by varying the input signal level between 0 and 2 V_{peak} into the 8671A and 0 to 1 V_{peak} into the 8672A. The meter mode switch on the 8672A selects which function is monitored—AM depth, FM peak deviation, or output power. With separate controls and input connectors on the 8672A, simultaneous AM and FM is practical.

Frequency Modulation

The 8670 Series synthesizers are designed to allow broadband frequency modulation while maintaining synthesizer stability and spectral purity. Frequency modulation is accomplished in such a way that all loops remain phase-locked, so the long-term stability and accuracy of the carrier frequency is preserved. Also, because all loop bandwidths remain constant, phase noise performance in FM is almost the same as in CW.

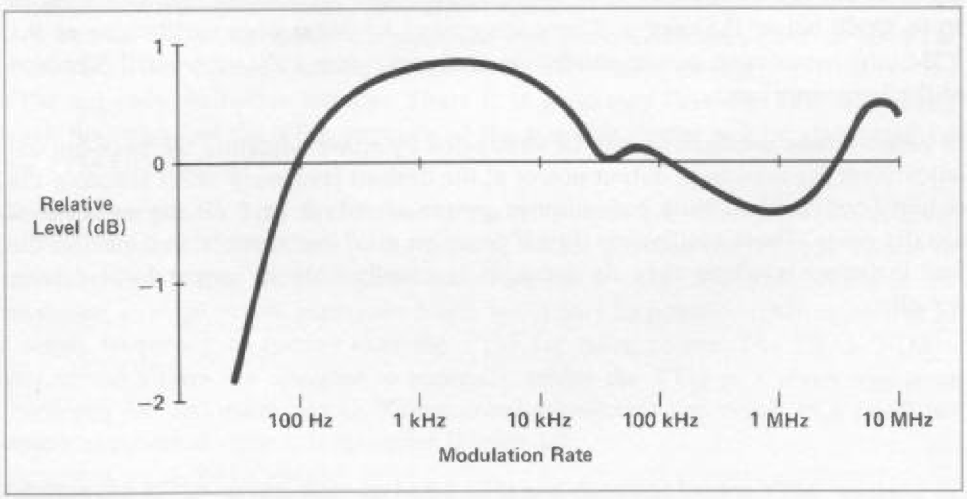


Figure 21. Typical 8672A FM frequency response (30 and 100 kHz/V ranges).

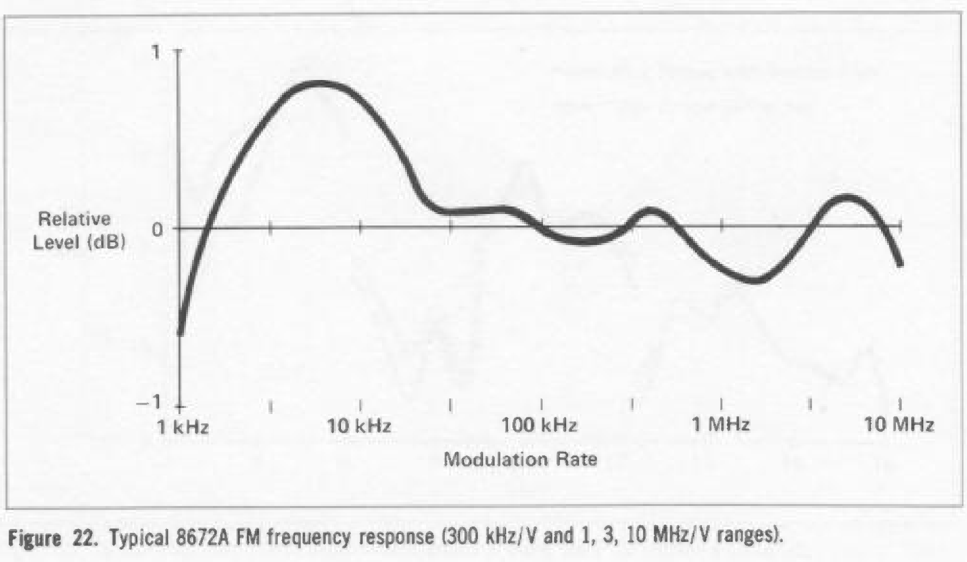


Figure 22. Typical 8672A FM frequency response (300 kHz/V and 1, 3, 10 MHz/V ranges).

Maximum FM Deviation

With 8670 Series synthesizers the maximum possible peak frequency deviation is not constant but is a function of the modulating frequency (Figure 23). At low rates the peak frequency deviation is modulation index limited while at high rates the peak deviation is limited to a maximum of 10 MHz. This occurs because at high modulation indexes the synthesizers can no longer remain phase-locked. The maximum specified modulation index is 5 on the 2.0 to 6.2 GHz band, 10 between 6.2 and 12.4 GHz, and 15 between 12.4 and 18 GHz, but typically normal operation is maintained up to modulation indexes of 7, 14, and 21 depending on the band.

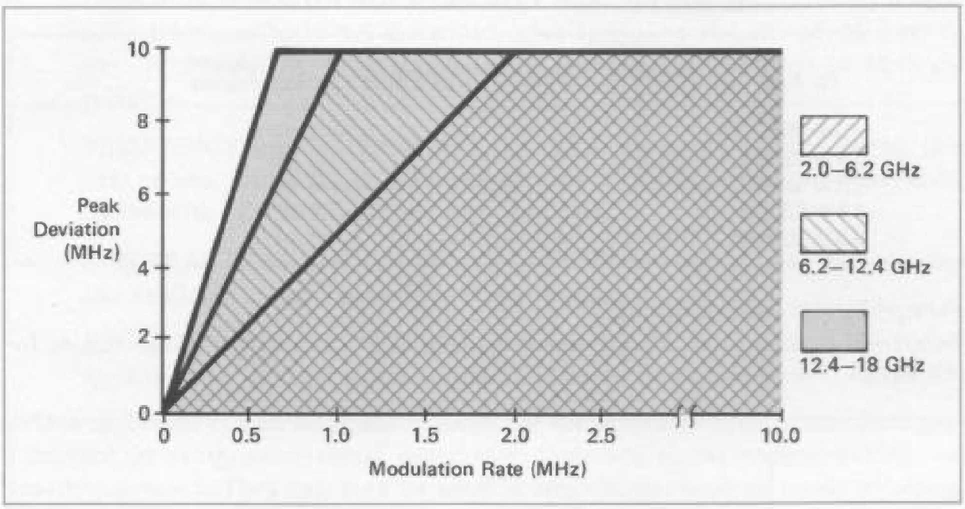


Figure 23. Possible rates and frequency deviations using the 8671A and 8672A frequency modulation.

Distortion

FM distortion can be separated into two components, harmonic and nonharmonic. In the 8671A and 8672A harmonic distortion is the largest of the two components. This is the most typical distortion in signal generators and is due mostly to nonlinearities in the modulator or drive circuitry. Unlike most signal generators, in the 8671A and 8672A the highest distortion occurs at low modulation rates and low peak deviation (Figure 24). This occurs because the modulation falls inside the YTO loop bandwidth where fine-grain non-linearity in the phase detector results in increased distortion.

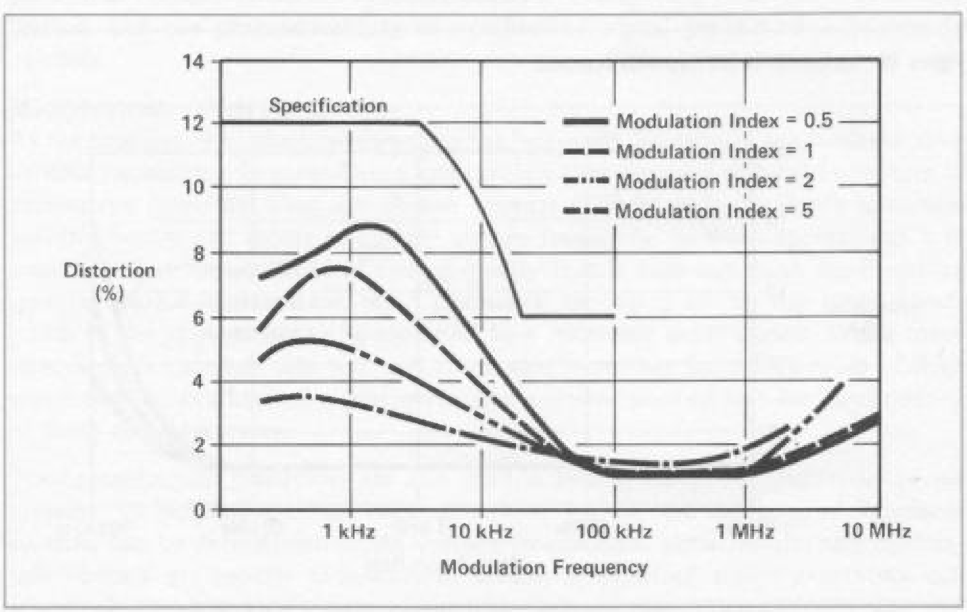


Figure 24. Typical distortion using the 8671A and 8672A.

Non-harmonic distortion is usually only significant at high modulation rates. When modulating with certain frequencies, spurious FM signals can occur. These result when a multiple of the modulating frequency occurs at almost the same frequency as the sampling rate of the YTO loop (less than 500 kHz difference). The spurious modulation frequency is the difference between the multiple of the modulating frequency and the sampling rate and is a result of the sampling process. They may contain significant energy but result in relatively little frequency deviation because of their low rate. The following table shows the typical ratio of spurious FM to desired modulation after demodulation in an external FM discriminator.

Table 1. Typical FM non-harmonic distortion.

FM Rate	Ratio of spurious FM to desired modulation after demodulation
<1.0 MHz	<−70 dB
1.0 to 2.8 MHz	<−60 dB
2.8 to 4.5 MHz	<−55 dB
4.5 to 9.5 MHz	<−50 dB
9.5 to 10.0 MHz	<−45 dB

Amplitude Modulation

Figures 25 and 26 show typical AM frequency response and distortion curves for the 8672A.

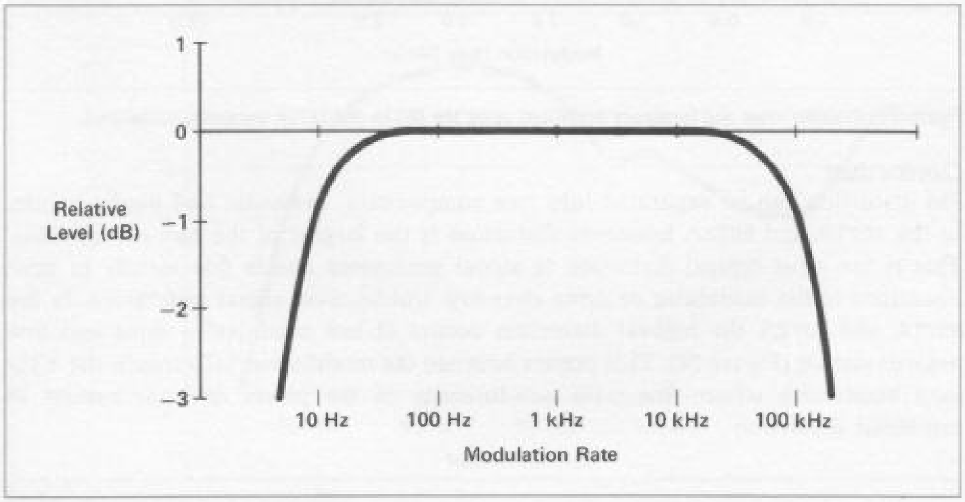


Figure 25. Typical 8672A AM frequency response.

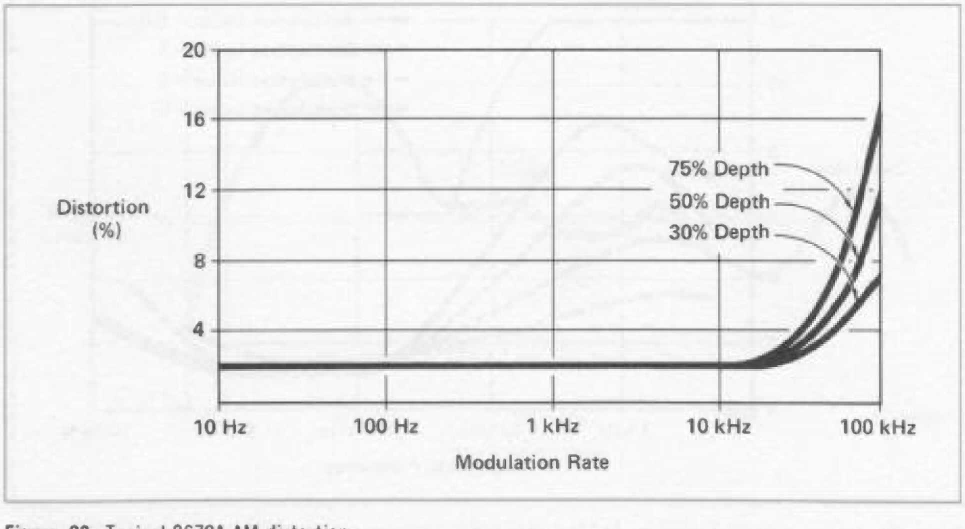


Figure 26. Typical 8672A AM distortion.

Applications

The use of frequency synthesizers has increased greatly because of the need for improved signal performance. Synthesizers feature unique frequency characteristics and allow measurements to be made that would be difficult to make with any other instrument. They are used in applications where one or more of the following characteristics is required:

- LONG-TERM FREQUENCY STABILITY AND ACCURACY. With their internal references, the 8671A and 8672A have frequency stability of $\pm 5 \times 10^{-10}$/day. With external references, stability and accuracy of parts in 10^{-12} are possible.
- FREQUENCY RESOLUTION. The resolution of the 8671A and 8672A is 3 kHz or less. Resolution of fractions of hertz is possible when used in combination with other synthesizers. (See page 18.)
- SPECTRAL PURITY. Synthesizers have the lowest phase noise near the carrier available in general-purpose signal sources.
- PROGRAMMABILITY AND SWITCHING SPEED. Synthesizers allow frequency to be changed easily and quickly under remote control.

When calibrated output level and modulation are added to basic synthesizer performance in synthesized signal generators, their usefulness and versatility are greatly increased. They can then be used in applications such as receiver testing, component testing, etc.

Some of the major applications that require these synthesizer capabilities are satellite communications, electronic warfare, automatic systems, component test, and bench signal sources.

Satellite Communications

In satellite communications, frequency accuracy, frequency resolution, and spectral purity are critical. When synthesizers are used as local oscillators, they provide the long term stability and spectral purity required in receivers while allowing the frequency to be easily changed for channel selection or doppler correction. Synthesized signal generators are used extensively to test the receivers in ground stations for similar reasons. Often the time available for testing these receivers is extremely limited, and the programmability of synthesized signal generators is extremely valuable.

Electronic Warfare

As the complexity of electronic warfare has increased, broadband synthesizers have become necessities. In surveillance applications they are used as local oscillators in heterodyne receivers. They are chosen because of their wide frequency coverage, spectral purity, and ability to quickly change frequency. In these applications it is important that the signal be of such a quality that it does not mask the incoming signal's characteristics. Also, rapid frequency switching allows the broad bandwidth of the synthesizer to be searched in a relatively short period. When these receivers are airborne, size and weight are also important factors. Because of their signal quality, synthesized signal generators are also used to test the performance of these same receivers.

Synthesized signal generators are also used in testing electronic counter measures systems. By simulating threat radar and other signals, the response of defensive systems can be determined. When various frequencies, signal levels, and modulation formats are rapidly programmed, several synthesized signal generators can effectively simulate an operational electronic environment. This reduces cost and system complexity.

Automatic Systems

Automatic systems are used where many measurements are required or testing speed is important. In these applications, synthesizers are used because of their programmability and rapid response time. By reducing test time they help reduce cost by increasing throughput. They also provide the accuracy necessary for repeatable measurements. Because of their signal quality they can be used as components in even the most sophisticated systems, and are used as both local oscillators and stimuli. When used as stimuli, synthesized signal generators provide programmable, calibrated output level and modulation as well as accurate frequencies.

Component Test

Because of their frequency stability, accuracy, and resolution, synthesizers fill needs currently not met by sweepers in component testing applications. Sweepers lack the frequency accuracy required in many measurements. Also, due to higher residual FM, sweepers cannot be used to accurately measure abrupt changes in response with respect to frequency such as those in high Q components.

Bench Signal Sources

A key requirement for R&D bench equipment is versatility. The greater use an instrument is put to the more valuable it becomes. In this environment, initial cost of test equipment is less important than cost per year of useful life. Because of their superior frequency performance, calibrated output, and modulation, synthesized signal generators can be used for a broad range of current applications, and it is reasonable to assume they will meet future needs as well. They can be used as precision frequency sources, spectrally-clean local oscillators, signal generators for receiver testing, etc. In the case of the 8672A, it can replace many signal generators because of its wide frequency coverage. When used in temporary, bench-top, programmable HP-IB systems, measurement speed can be greatly increased, thus helping reduce engineering cost.

Use With Other Instruments

When used in applications with other instruments, the capabilities of the 8671A and 8672A can be greatly increased. Here are some examples.

Finer Frequency Resolution

For greatly increased frequency resolution, the 8672A can be used with either the HP 8660A/C Synthesized Signal Generator or the HP 3330B Automatic Synthesizer. A frequency resolution of 1, 2, or 3 Hz up to 18 GHz results when the 8672A Option H04 or H05 is used in combination with the 8660A/C. Using the 3330B and 8672A Option H05 results in 0.1, 0.2, or 0.3 Hz resolution up to 18 GHz.

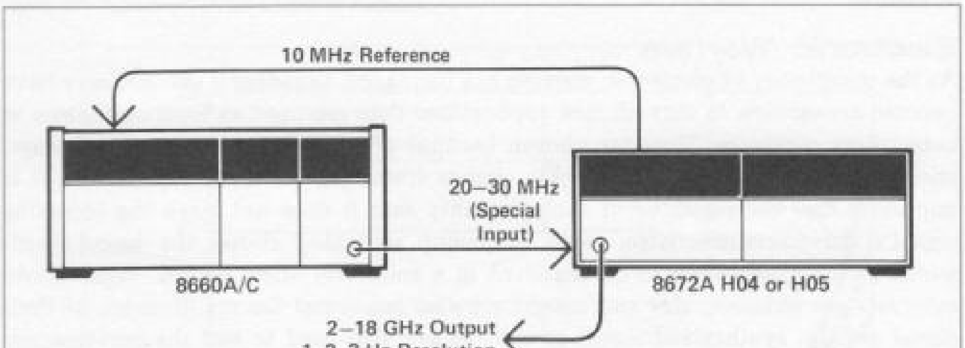


Figure 27. System configuration for 1, 2, or 3 Hz resolution using an HP 8660A/C Synthesized Signal Generator.

This type of performance is possible because the least significant digits of the 8672A (1 MHz and lower) are determined by a synthesized 20 to 30 MHz internal signal. The 8672A Options H04 and H05 allow the instrument to operate either normally or with a 20 to 30 MHz external signal with finer resolution substituted for the internal signal. The result is a microwave signal with the resolution of the 20 to 30 MHz signal. In the case of the 3330B the 20 - 30 MHz signal appears at the auxiliary output and is 20 MHz higher than the 3330B display or 20 to 33 MHz.

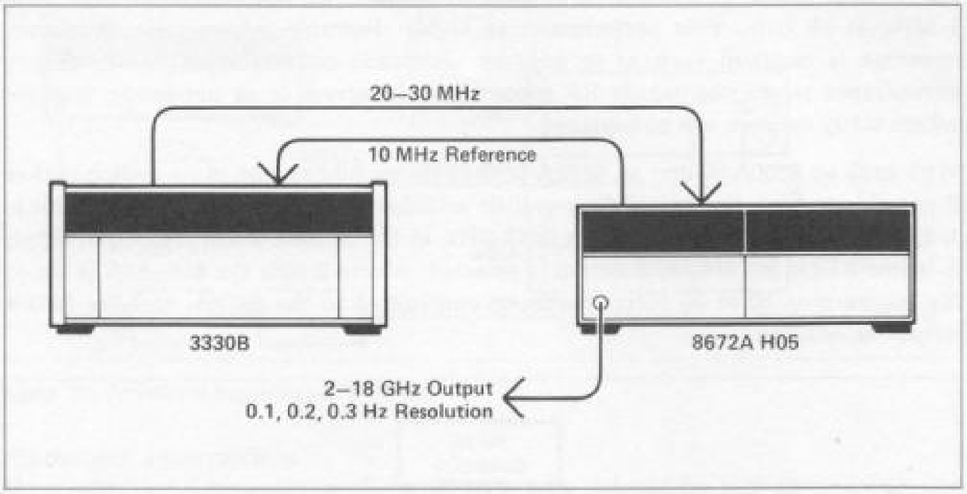


Figure 28. System configuration for 0.1, 0.2. or 0.3 Hz resolution using an HP 3330B Automatic Synthesizer.

For any desired output frequency the necessary 20 to 30 MHz signal and 8672A setting can be readily determined.

First the fundamental frequency of the 8672A (2.0 to 6.2 GHz) must be determined. If the desired frequency is not in the fundamental band, the fundamental frequency is one half of frequencies between 6.2 and 12.4 GHz and one third of frequencies between 12.4 and 18 GHz. The required 20 to 30 MHz signal is then the 1 MHz and less significant digits of the fundamental frequency subtracted from 30 MHz. Then the 8672A is set to the desired output frequency with digits 100 kHz or less significant set to zero. For example: To generate a frequency of 10 003.735 058 MHz the fundamental frequency is one half of the desired frequency or 5001.867 529. The 1 MHz and lesser digits are 1.867 529. When subtracted from 30 MHz the required 20 to 30 MHz signal is 28.132 471, and the 8672A setting is 10 003.000 MHz. Any rounding in the last digit of the 8672A now has no effect.

In practice it is relatively easy to calculate the required frequencies for any output. However, if the frequency is changed very often, it might become tedious to continually make calculations. In this case an HP-IB controller could automatically calculate the necessary frequencies and control the synthesizers. When using an HP-IB controller the algorithms for the required frequencies are:

F = desired output frequency in MHz
F_1 = required 20 to 30 MHz signal in MHz
F_2 = 8672A frequency setting in MHz
INT (X) = the integer value $\leq$ the value of X
Example: INT (9.7) = 9

For frequencies between 2.0 and 6.2 GHz
$F_1 = 30 - [F - 10 \times (\text{INT}(F/10))]$
$F_2 = \text{INT}(F)$

For frequencies between 6.2 and 12.4 GHz
$F_1 = 30 - [F/2 - 10 \times (\text{INT}(F/20))]$
$F_2 = \text{INT}(F)$

For frequencies between 12.4 and 18 GHz
$F_1 = 30 - [F/3 - 10 \times (\text{INT}(F/30))]$
$F_2 = \text{INT}(F)$

1 MHz to 18 GHz Systems

The HP 8660A/C Synthesizer used with the HP 86603A RF Section has frequency coverage of 1 MHz to 2.6 GHz. This is an obvious complement to the 8672A. By multiplexing the signals from these two synthesizers using a coaxial switch such as the HP 8761A, it is possible to have a signal output with frequency coverage from 1 MHz to 18 GHz. This performance is highly desirable where wide frequency coverage is required such as in military electronic countermeasures or military surveillance where the whole RF spectrum is involved or in automatic systems where many sources can be replaced.

With both an 8660A/C and an 8672A in the system, adding one more switch makes it possible to have finer resolution at little additional cost (Figure 29). The result is 1, 2, or 3 Hz resolution from 1 MHz to 18 GHz. In this system when the output signal is below 2 GHz the 8660A/C output is selected. Above 2 GHz the 8660A/C is set to the appropriate 20 to 30 MHz frequency and routed to the 8672A, and the 8672A output is selected.

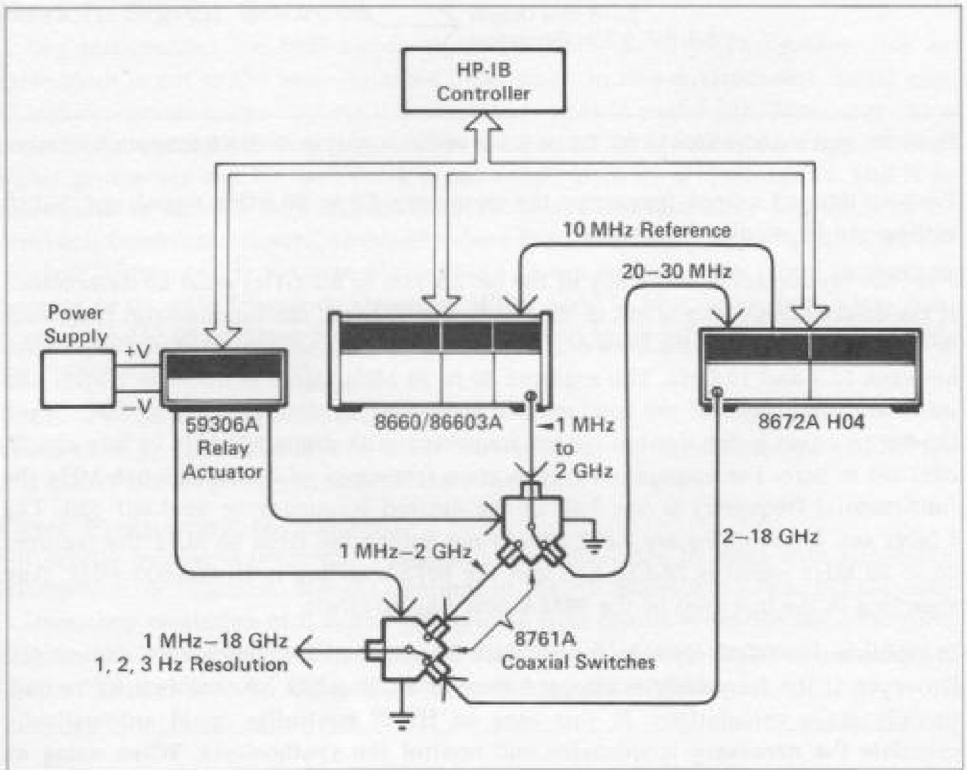


Figure 29. Automatic 1 MHz to 18 GHz system using an HP 8660/86603A and 8672A.

By adding an HP-IB controller, HP 59306A HP-IB Relay Actuator, and power supply the whole system can be automated so that for any frequency the correct source, switch positions, and frequencies are automatically selected. The result is a fully automatic source with a single output connector that covers 1 MHz to 18 GHz with 1, 2, or 3 Hz resolution, has calibrated, wide range output level, allows calibrated AM, FM, and ϕM; and the whole system uses less than 500 mm (20 inches) of rack space.

Higher Frequencies

For synthesized frequencies above 18 GHz the 8672A can be used with the HP 938A and HP 940A Frequency Doubler Sets to extend its capabilities up to 36 GHz (37.2 GHz with the 8672A overrange). The 938A can be used for frequencies between 18 and 26.5 GHz, and the 940A can be used from 26.5 to 36 GHz. All that is needed is a coax to waveguide adapter and a waveguide adapter at the input to each doubler. When used with the 8672A, conversion loss is typically less than 18 dB so that maximum available output power is typically −10 dBm. At these higher frequencies the spectral purity of the signal is maintained and resolution is 6 kHz. Amplitude modulation is greatly distorted but frequency modulation will remain unchanged except that FM deviations will double giving a maximum peak deviation of 20 MHz.

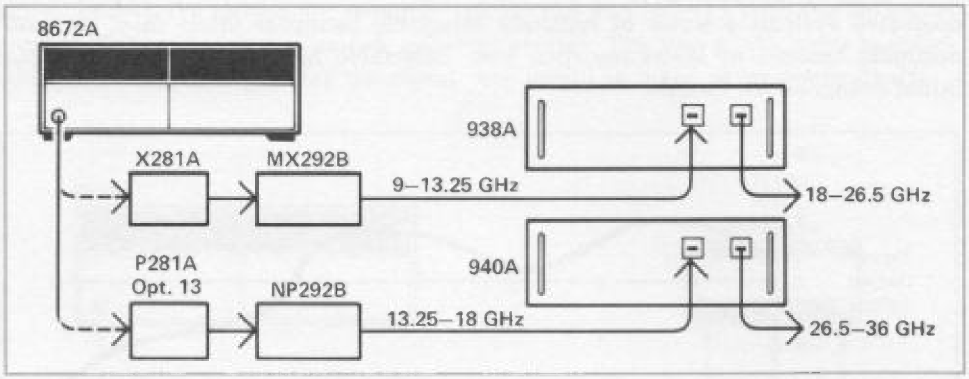


Figure 30. Synthesized frequencies up to 36 GHz.

Reduced Harmonics

Harmonics and subharmonics of the 8672A can be reduced by >70 dB to <−95 dBc using the HP 8445B Option 004, 005 Tracking Preselector. The 8445B is a YIG-tuned filter whose pass-band can be externally tuned with a 2 to 18 Vdc level. For applications where harmonics or subharmonics are undesirable this combination results in excellent performance for a source whose frequency coverage is much greater than one octave.

Because the 8445B has a narrow pass band, its tracking of the signal is critical. Manually, this is easily accomplished by setting the 8672A frequency and adjusting the dc voltage to maximize the output signal. For automatic operation a system such as that shown in Figure 31 can be used. In this system, proper tracking is accomplished using the following procedure:

1. Program the input voltage to the 8445B to 2 V and the 8672A to +3 dBm internal leveling and 2 GHz. Adjust the 8445B FREQ OFFSET to maximize the signal through the system.
2. Program the input voltage to 18 V and the 8672A to 18 GHz. Adjust the 8445B TRACKING for maximum signal through the system.
3. Repeat steps 1 and 2 until no improvement can be made.
4. Periodic readjustment may be necessary for minimum insertion loss.

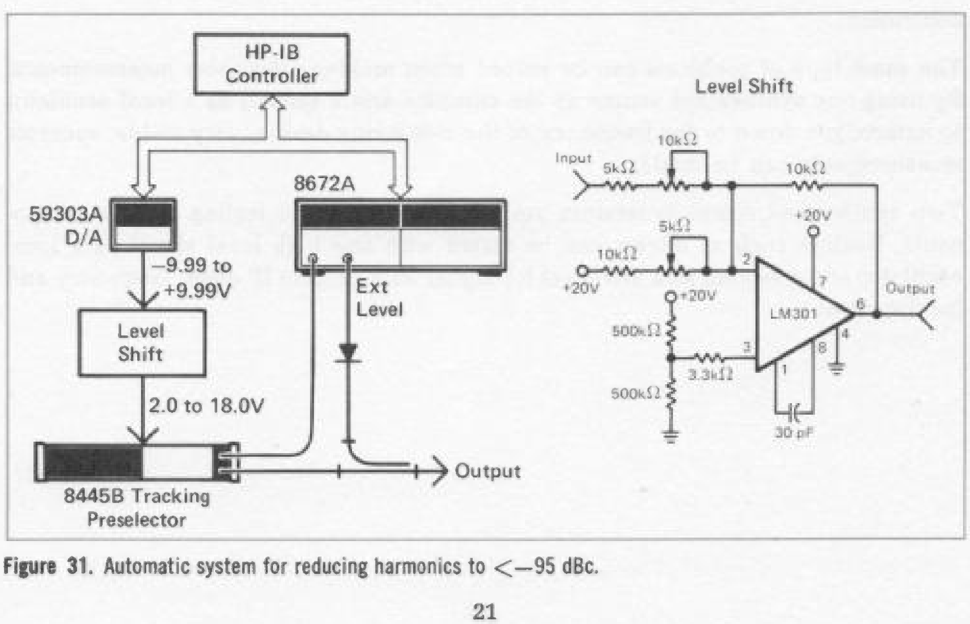


Figure 31. Automatic system for reducing harmonics to <−95 dBc.

Because of hysteresis, whenever a new frequency is selected the voltage to the 8445B should first be programmed to 2 volts and then to the new level.

The 8445B limits for input signals >+5 dBm. This limits the maximum output level even though the 8672A typically has much higher available power (Figure 32). For dedicated systems a series of remotely selectable bandpass filters may be more desirable because of lower insertion loss. Selectable filters would require some initial design effort, though.

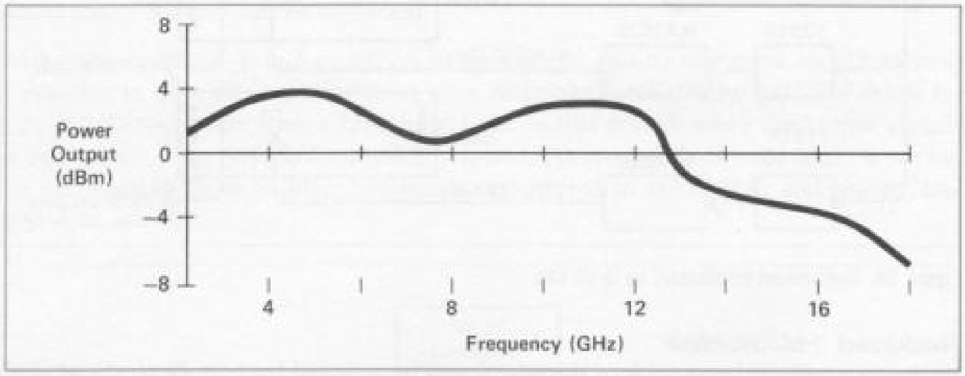


Figure 32. Typical maximum power using the 8672A and 8445B Tracking Preselector.

Two Tracking Microwave Synthesizers

Accurately measuring low level signals at microwave frequencies is difficult. When using broadband detectors the system residual noise limits the sensitivity of the measurement. If detectors with narrow bandwidths are used to increase sensitivity, measurement times can become extremely long. When using an unstabilized source, it can be frustrating to first search for the signal and then try to track it long enough to make an accurate measurement.

Using two 8672A Synthesized Signal Generators to make intermodulation measurements on microwave receivers is a good example of how precise frequency and excellent stability can speed measurements. In many receivers intermodulation products may be over 100 dB below the primary signals. Using unstabilized sources intermodulation products may drift at rates almost as fast as the measuring device can scan. This makes them difficult to find and even harder to measure. By using two 8672A Synthesized Signal Generators, precise signals can be input to the receiver. Because of the signal accuracy the exact frequency of the intermodulation products can be calculated and then rapidly measured. This technique is especially useful because frequencies can be easily changed and amplitudes accurately controlled.

The same type of problems can be solved when making attenuator measurements. By using one synthesized source as the stimulus and a second as a local oscillator to heterodyne down to the frequency of the measuring device, very stable, accurate measurements can be made.

Two synthesized signal generators are also very useful in testing certain components. Devices such as mixers can be tested with one high level signal as a local oscillator and a second as a low level RF signal with precise IF offset frequency and level control.

Pulse Modulation

The 8672A can be used with the HP 11720A Pulse Modulator where high performance pulse modulation is required. The 11720A covers the full 2 to 18 GHz frequency band, provides short rise and fall times, and has a high on-off ratio. When pulsed microwave signals are required, the 11720A can be used with the 8672A to provide high performance, pulsed, coherent signals. The low phase noise coupled with pulse modulation makes the signal very useful in many radar applications.

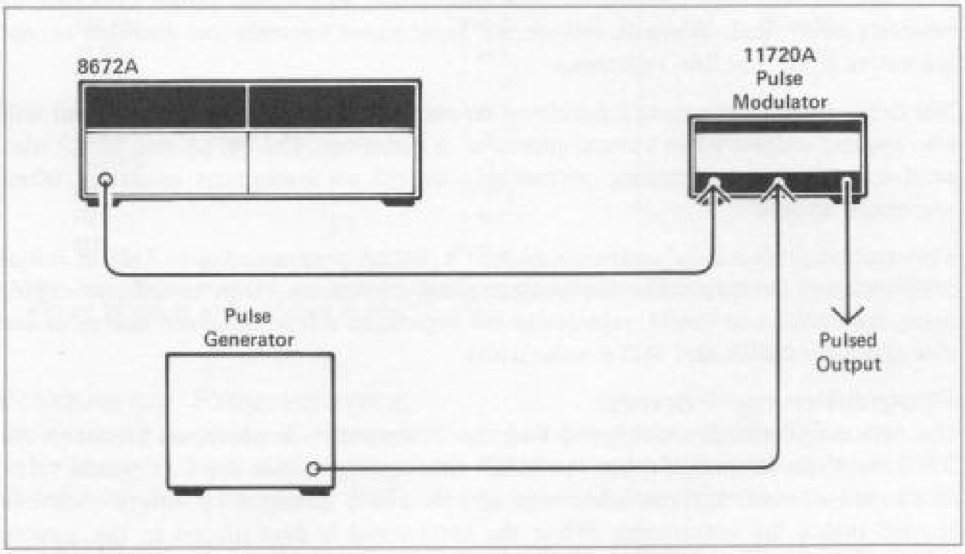


Figure 33. Pulse modulation using the HP 11720A Pulse Modulator.

Remote Programming

The 8671A and 8672A are both fully programmable. All front panel functions except the line switch can be HP-IB controlled. Frequency can be programmed to the same resolutions as in manual mode. The output level is programmable over its full range in 1 dB steps, or it can be programmed OFF. The leveling source (Int., Ext., Xtal., etc.) can be remotely controlled. The modulation mode and range can also be remotely controlled. When in remote, all front panel controls are disabled except the meter mode and line switches.

Not only can the instrument's functions be remotely controlled, the instrument will also request service when normal operation is disrupted. The 8671A and 8672A also send a status byte containing critical information on instrument operation when addressed to talk.

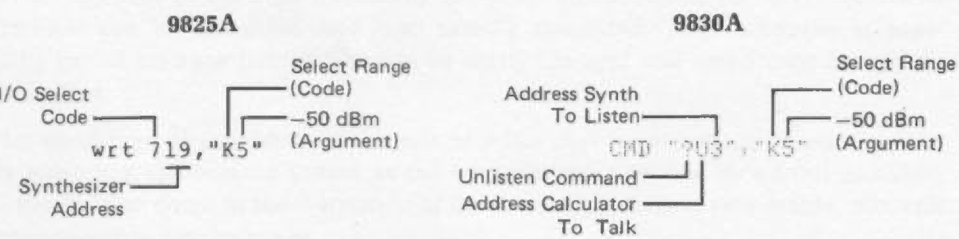
This section gives a brief overview of 8671A/8672A programming to help in initial programming. To help make the programming statements clear, specific examples using the 9825A and 9830A calculators are shown. In a few instances examples are also given for 9820A and 9821A calculators.

Programming Format

The 8671A and 8672A are shipped with the listen and talk addresses preset to the ASCII symbols "3" and "S." For the 9825A this corresponds to a 5-bit decimal value of 19. When needed, these addresses can be easily changed by rotary switches located inside the instrument. When the instrument is first placed in the remote mode, all instrument functions and frequency output remain unchanged except power output vernier which is set to +3 dB. The 8671A and 8672A remain in local mode until they are first addressed to listen.

Once the 8671A or 8672A have been addressed to listen, the programming format consists of a program code and argument. The program codes consist of a single character which determines the function being programmed (see Table 2). The argument is a single character that determines the value of the function being programmed. Program codes with appropriate arguments may be sent in arbitrary order with the exception of frequency data and the "frequency execute" command.

Example:



When using multiple program codes to change several functions simultaneously, all program codes after the first may be deleted if the program codes are in alphabetical order.

Example: These statements are equivalent.

9825A

```
wrt 719,"P1Q2R3S4T5U6V7W8Z9"

wrt 719,"P12345678Z9"
```

9830A

```
CMD "?U3","@1R2B3C4D5E6F7G8J0"*

CMD "?U3","@12345678J0"
```

* @ is obtained by [shift] [result] key strokes on the 9830 and [GO TO] on the 9820A and 9821A.

Table 2. Program codes.

FUNCTION	PROGRAM CHARACTERS*	
	ASCII	DECIMAL
10 GHz	@ or P	64 or 80
1 GHz	A or Q	65 or 81
100 MHz	B or R	66 or 82
10 MHz	C or S	67 or 83
1 MHz	D or T	68 or 84
100 kHz	E or U	69 or 85
10 kHz	F or V	70 or 86
1 kHz	G or W	71 or 87
FREQUENCY EXECUTE	J or Z	74 or 90
RANGE	K or [	75 or 91
VERNIER	L or \	76 or 92
AM	M or]	77 or 93
FM	N or ^	78 or 94
ALC	O or _	79 or 95

* More than one program code for each function is provided for convenience because some controllers may not be able to easily generate all possible codes.

Frequency Programming

Programming frequency is extremely simple and easy to accomplish. There are three basic steps: 1) input the program code for the largest digit being programmed; 2) input the actual frequency digits; and 3) input the frequency execute command.

The 8671A and 8672A will accept any programmed frequency within their output range to 1 kHz resolution. Above 6.2 GHz the 8672A will round randomly up or down if the programmed frequency is not compatible with the 2 or 3 kHz resolution actually possible.

The output frequency does not change until the frequency execute command is sent. This command must be sent sometime after the frequency data has been sent. In order to complete the programming syntax, a dummy argument must follow the frequency execute program and can be any number.

Example:

9825A

10 GHz (Code) — "P"; Freq. Exec. — "J"; Dummy Argument For Syntax — "8"

```
wrt 719,"P12345678J8"      Results in 12345.678 MHz

wrt 719,"A9847600J2"       Results in 9847.600 MHz

wrt 719,"P98476000J2"      Results in an out of range
                           indication of 98.476 GHz
```

9830A

10 GHz (Code) — "@"; Freq. Exec. — "J"; Dummy Argument For Syntax — "0"

```
CMD "?U3","@12345678J0"    Results in 12345.678 MHz

CMD "?U3","A9847600J2"     Results in 9847.600 MHz

CMD "?U3","P98476000J2"    Results in an out of range
                           indication of 98.476 GHz
```

Special Frequency Programming

The 8671A and 8672A have special features which can simplify programming in many situations:

1. Decimal points are ignored by the instruments. This allows a single output statement to be used for all frequencies above and below 10 GHz when programming with variables on many controllers. The necessity of determining whether a 10 GHz or 1 GHz program code is required can be eliminated.

Example:

9825A

```
ent "Frequency in MHz",F
fmt "P",fz9.3,"Z9";wrt 719,F
```

For 13 500 MHz the actual digits output are "P13500.000Z0"
For 8000 MHz the actual digits output are "P08000.000Z0"

Example:

9830A

```
150 CMD "?U3"
160 DISP "INPUT FREQUENCY IN MHZ";
170 INPUT F
180 FORMAT "P",F1000.7,"Z0"
190 OUTPUT (13,180)F/1E+04
```

For 13 500 MHz the actual digits output are "P1.3500000Z0"
For 8000 MHz the actual digits output are "P0.8000000Z0"

Example:

9820A/9821A

```
0:
CMD "?U3"⊦
1:
ENT "FREQ IN MHZ
",X⊦
2:
FMT "P",FXD *.8,
"Z0";WRT 13,X/1E
5⊦
```

For 13 500 MHz the actual digits output are "P.13500000Z0"
For 8000 MHz the actual digits output are "P.08000000Z0"

2. Within the 8671A and 8672A frequency information is stored in two blocks of four digits each. One block is for the 10 GHz through 10 MHz digits, the other is for the 1 MHz through 1 kHz digits. Programming within one block does not change the other block unless it is necessary for the instrument to round the 1 kHz digit for frequencies above 6.2 GHz.

Example:

9825A	9830A	
wrt 719,"8000000J8"	CMD "?U3","A8000000J8"	Results in 8000.000 MHz
wrt 719,"D0050Z7"	CMD "","D005020"	Converts 8000.000 MHz to 8000.050 MHz
wrt 719,"D4000J6"	CMD "","D4000J0"	Converts 8000.050 MHz to 8004.000 MHz

Caution must be used when programming in only one block because rounding can cause totally unexpected errors in output frequency when only the most significant block is programmed.

3. When digits are programmed in consecutive order, within a block being programmed all digits not programmed are set to zero.

Example:

9825A	9830A	
wrt 719,"A400Z25"	CMD "?U3","A400220"	Results in 4002.000 MHz

The least significant digit, "2" in this case, is stored in the second block and causes zeros to be stored in the rest of the block.

Output Level (8672A Only)

Programming of output level is divided into two independent parts. One program code controls the range in 10 dB steps; the other program code controls the vernier in 1 dB steps. They can be used together when both range and vernier are to be changed or separately when only one needs to be varied.

The output level range can be controlled over all ranges from 0 dBm to −110 dBm. The output level vernier can be controlled over 13 dB of range from +3 dB to −10 dB. The 13 dB programming range of the vernier is very useful in applications where switching 10 dB ranges at certain output levels may be undesirable. The programmer now has greater control over when output level ranges are changed. Table 3 lists the arguments required for each range and vernier setting.

Like frequency programming, any program codes after the first one can be deleted. That is, to obtain an output level of −56 dBm the argument for range would be 5 and that for vernier 9. The program sequence could be either "K5L9" or "K59". This is easiest to identify as 59 dB below +3 dBm.

Example:

9825A	9830A	
wrt 719,"K03"	CMD "?U3","K03"	Results in 0 dBm
wrt 719,"K:7"	CMD "?U3","K:7"	Results in −104 dBm

Table 3. Arguments for output level.

Output Range (dBm)	Vernier (dB)	Argument	
		ASCII	DECIMAL
0	+3	Ø	48
−10	+2	1	49
−20	+1	2	50
−30	Ø	3	51
−40	−1	4	52
−50	−2	5	53
−60	−3	6	54
−70	−4	7	55
−80	−5	8	56
−90	−6	9	57
−100	−7	:	58
−110	−8	;	59
—	−9	<	60
—	−10	=	61

Modulation

There are two ranges of amplitude modulation and six ranges of frequency modulation that can be remotely selected on the 8672A. Two ranges of unmetered frequency modulation can be selected on the 8671A. These can be selected with the appropriate program codes (see Table 2) and the argument that corresponds to each range (see Tables 4 and 5).

Example:

9825A	9830A	
`wrt 719,"M0N7"`	`CMD "?U3","MØN7"`	Results in no modulation with the 8672A
`wrt 719,"M3N2"`	`CMD "?U3","M3N2"`	Results in 30% AM and 1 MHz FM with the 8672A

Table 4. Amplitude modulation arguments (8672A only).

Range	Argument
Off	Ø or 1
100%	2
30%	3

Table 5A. Frequency modulation arguments (8672A only).

Range	Argument
Off	6 or 7
30 kHz	5
100 kHz	4
300 kHz	3
1 MHz	2
3 MHz	1
10 MHz	Ø

Table 5B. Frequency modulation arguments (8671A only).

Range	Argument
Off	Ø
100 kHz	1
10 MHz	2

ALC

This program code controls the function of three front panel switches on the 8672A. These are the RF ON/OFF switch, the ALC switch, and the +10 dBm range of output power. On the 8671A this program code controls RF ON/OFF only.

The argument for the program code is decoded in a binary format by the 8672A. The argument is an ASCII character which corresponds to the sum of the weighting of the functions desired.

RF is ON and has a weight of one.
+10 dBm range has a weight of two.
External leveling has a weight of four.
Power meter leveling has a weight of eight.

Table 6A. ALC arguments (8672A only).

Function	Argument
RF OFF	Ø, 2, 4, 6, 8, :, <, >
INT LEVELING, NORMAL RANGE	1
INT LEVELING, +10 dBm RANGE	3
EXT. XTAL LEVELING, NORMAL RANGE	5
EXT. XTAL LEVELING, +10 dBm RANGE	7
PWR MTR LEVELING, NORMAL RANGE	= (Decimal 61)
PWR MTR LEVELING, +10 dBm RANGE	? (Decimal 63)

Table 6B. ALC arguments (8671A only).

Function	Argument
RF On	1
RF Off	Ø

For proper instrument operation, whenever the +10 dBm overrange output is selected for the ALC program code the argument for the output level range program code should be zero.

Service Request

When normal instrument operation is disrupted for any one of four reasons the 8671A and 8672A will request service via the interface SRQ line (Service request line). The four conditions that will cause a request for service are:

1. If a programmed frequency is outside the instrument's capability. (OUT OF RANGE.)
2. If the synthesizer is unlocked when the RF is on. (NOT PHASE LOCKED.)
3. If the output is unleveled with the RF on, or an output level below −120 dBm is programmed. (LEVEL UNCALIBRATED.)
4. If the FM is being overmodulated with the RF on. (FM OVERMOD.)

When changing output level or frequency, several of the above conditions could occur for an instant during normal operation. This will not cause a request for service unless the condition persists for more than 50 ms. Also the request for service persists only as long as normal operation is disrupted or until a serial or parallel poll is initiated.

Status Reporting

When addressed to talk the 8671A and 8672A send a status byte of eight bits which contains critical information on instrument operation. The coding of the status byte is shown in Table 7.

Example:

9825A

```
rdb(719)→S    ← Enter Status Byte From Bus
prt S
```

9830A

```
CMD "?S5"     ← "?" Address Calculator To Listen; "S5" Address Synth To Talk
S=RBYTE13     ← Enter Status Byte From Bus
PRINT S
```

Table 7. Status byte.

Bit	8	7	6	5	4	3	2	1
Function	Crystal Oven Cold	RSV Request Service	Out of Range (Frequency)	RF Off	Not Phase Locked	Level Uncali-brated*	FM Over-mod	+10 dBm Over-range*
* Not used on 8671A.								

The RSV Request Service bit is a one whenever any of the four conditions that cause a request for service exists (even during the first 50 ms after a programming change). Once the instrument is addressed to talk the RSV line is fixed even though instrument operation may have changed.

The status byte is very useful for determining when a given programming change has been executed. For example, if the synthesizer is addressed to talk immediately after a frequency change, the status byte can be used to determine when the synthesizer has re-acquired lock. A frequency change might be followed by decimal status bytes of 72, 72, 64 indicating the synthesizer is now locked.

For increased flexibility the 8671A and 8672A are capable of performing both serial and parallel polls. In serial poll, the synthesizer responds with its status byte when the bus is placed in serial poll mode and the synthesizer is addressed to talk. Using serial poll, instruments are polled sequentially until the instrument requesting service is located.

In parallel poll the synthesizer is assigned one of the eight bus data lines on which to respond. A switch inside the synthesizer determines on which line it will respond. A second switch determines whether it will respond with a one or zero, or ignore parallel poll. With parallel poll the bus controller can poll up to eight instruments simultaneously. With each instrument responding on a separate data line, the controller can rapidly determine which instrument requested service.

Programming Execution Time

Programming execution time is determined by two parameters: the rate at which data can be input into the synthesizer over the interface and the time it takes the synthesizer to reach the desired output state.

The 8671A and 8672A can typically accept data at rates up to 80 kbytes/second. This is generally a much shorter time than it then takes the synthesizer to reach the desired output state. If the controller and all other instruments on the bus are fast enough, data transfer is then only a small fraction of the total program execution time.

Typical execution times for the various functions of the 8671A and 8672A are as follows:

Frequency Switching

The time it takes to switch from one frequency to the next depends on the largest frequency digit being changed. Generally, the smaller the digit being changed the shorter the switching time.

Typical switching times by largest digit being changed on 2.0 to 6.2 GHz bands: (For higher bands, actual digits being changed in fundamental frequency must be determined by dividing output frequency by 2 on 6.2 to 12.4 GHz band, and 3 on 12.4 to 18 GHz band.)

Largest Digit Changed	100 MHz	10 MHz	1 MHz	100 kHz	10 kHz	1 kHz
Time to be Within 1 kHz	10 ms	10 ms	10 ms	5 ms	3 ms	1.5 ms

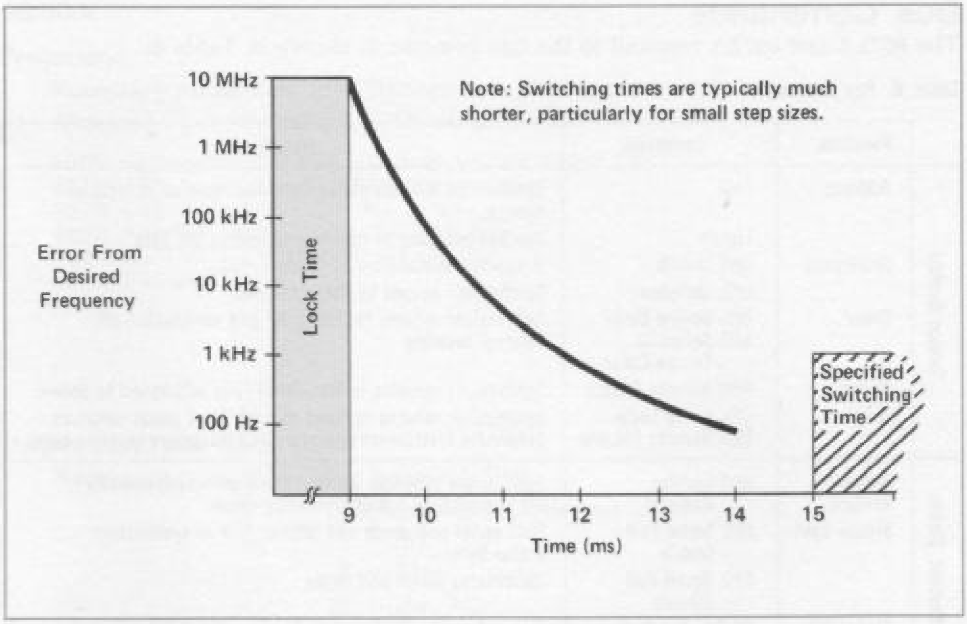


Figure 34. Typical frequency switching time for 8670 Series synthesizers showing worst case lock and settling times.

Output Level Programming

Output range switching (10 dB steps) .... <20 ms
Output vernier switching (1 dB steps) .... <10 ms
RF ON/OFF switch ON .... <30 ms
OFF .... < 5 ms

Modulation Programming

FM range change and frequency changes in FM mode .... <50 ms
AM range change .... <15 ms

Actual Program Execution Times

9825A

```
for F=2000 to 18000 by A
fmt "P",fz9.3,"Z9";wrt 719,F
jmp 1-bit(3,rdb(719))
next F
beep
end
```

In this program line 1 addresses the synthesizer to listen and increments the frequency. Line 2 addresses the synthesizer to talk and continually monitors the NOT PHASE-LOCKED bit and halts frequency changes until the synthesizer is phase-locked. Without line 2 the program execution time is 4 ms per step. The following table gives the average execution time per step depending on step size (A).

Step Size A	1 GHz	100 MHz	10 MHz	1 MHz	100 kHz	10 kHz	1 kHz
Execution Time per Step (ms)	10.8	9.8	9.6	9.4	6.5	6.4	6.4

9830A

```
10 CMD "?U3"
20 FOR F=2000 TO 18000
30 FORMAT "P",F1000.7,"Z0"
40 OUTPUT (13,30)F/1E+04
50 NEXT F
60 END
```

Lines 30 and 40 output the frequency. Execution time is 32 ms per step so there is no need to check for lock before incrementing the frequency.

Bus Commands

The 8671A and 8672A respond to the bus commands shown in Table 8.

Table 8. Bus commands.

	Function	Command	Response
Device Control	Address	Talk	Synthesizer outputs status byte and remains in local or remote.
		Listen	Synthesizer goes to remote and listens for data.
	Unaddress	UNT Untalk	If talking, synthesizer is unaddressed.
		UNL Unlisten	Synthesizer ceases to listen to data.
	Clear	DCL Device Clear SDC Selective Device Clear	Synthesizer returns to 3 GHz, RF and modulation off, internal leveling.
	Remote	REN Remote Enable	Synthesizer remains in local until first addressed to listen.
	Local	GTL Go To Local REN Remote Disable	Synthesizer returns to local control, front panel switches determine instrument operation and frequency remains same.
Interrupt/Status	Require Service	SRQ Service Request	Synthesizer requests service when unlocked, unleveled, FM overmod, or out of frequency range.
	Status Byte	SPE Serial Poll Enable	Sets serial poll mode and latches RSV in synthesizer status byte.
		SPD Serial Poll Disable	Terminates serial poll mode.
	Status Bit	PP Parallel Poll	Internal synthesizer switches determine if it will respond, with which sense, and on which line.
Abort	Abort	IFC Interface Clear	Synthesizer ceases to talk or listen.

Output Subroutines

9825A

Frequency:

Necessary parameters: F = frequency in MHz

Accessed by the command gsb "Freq"

```
"Freq":fmt "P",fz9.3,"Z9";wrt 719,F;ret
```

Output Level and ALC:

Necessary parameters: P = power in dBm

A determines ALC Source

1 – Int

5 – Xtal

13 – Pwr Mtr

Accessed by the command gsb "Power"

```
"Power":fmt 9,"K",2b,"O",b;if P>13;13→P
if P>3;wrt 719.9,48,61-P,A+50;ret
if P<=-120;wrt 719.9,59,61,A+48;ret
int(abs(P/10))→Q;wrt 719.9,Q+48,51-10Q-P,A+48;ret
```

In this subroutine arguments are output in decimal code rather than ASCII code for convenience of outputting data greater than 9. The first line sets a format statement for control of output level range and vernier, and ALC control. It also sets the upper power limit at 13 dBm. The second line checks to see if the output overrange setting is necessary and if so outputs the necessary range, vernier, and ALC commands. Line three sets the lower power limit at −120 dBm and sets the 8672A to that level if a power level of −120 dBm or below is requested. Line four outputs range, vernier, and ALC commands for all power settings between +3 and −119 dBm.

9830A

Frequency:

Necessary parameters: F = frequency in MHz
Accessed by the command "GOSUB 4000"

```
4000 REM-----------8671A AND 8672A FREQUENCY CONTROL
4010 REM-----------F=FREQUENCY IN MHZ
4020 CMD "?U3"
4030 FORMAT "P",F1000.7,"Z0"
4040 OUTPUT (13,4030)F/1E+04;
4050 RETURN
```

Output Level and ALC:

Necessary parameters: P = power in dBm
A determines ALC Source
1 – Int
5 – Xtal
13 – Pwr Mtr

Accessed by the command "GOSUB 5000"

```
5000 REM------8672A OUTPUT LEVEL AND ALC CONTROL
5010 REM------P=OUTPUT LEVEL IN DBM
5020 REM------A=1 IF INT ALC, 5 IF XTAL,13 IF PWR MTR
5030 FORMAT "K",2B,"O",B
5040 K=48
5050 CMD "?U3"
5060 IF P <= 13 THEN 5080
5070 P=13
5080 IF P>-120 THEN 5110
5090 OUTPUT (13,5030)59,61,A+K;
5100 GOTO 5170
5110 IF P>3 THEN 5150
5120 P1=INT(ABS(P/10))
5130 OUTPUT (13,5030)P1+48,51-10*P1-P,A+48;
5140 GOTO 5170
5150 K=50
5160 OUTPUT (13,5030)48,13-P,A+K;
5170 RETURN
```

In this subroutine arguments are output in decimal code rather than ASCII code for convenience of outputting data greater than 9. Line 5030 is the format statement used to control output range and vernier, and ALC. In line 5040 and 5150, K is used to convert the ALC digits to their binary equivalent. Line 5050 addresses the synthesizer to listen. Lines 5060 and 5070 set the upper power limit at 13. Lines 5080-5100 set the lower limit at −120 dBm and programs the 8672A to that level if a power level of −120 dBm or below is requested. Lines 5120 and 5130 output the range, vernier, and ALC commands for all power settings between +3 and −119 dBm. Line 5160 outputs the range, vernier, and ALC commands for power levels between +4 and +13 dBm.

Programming Quick Reference Guide

Bus Commands

	FUNCTION	COMMAND	RESPONSE
DEVICE CONTROL	Address	Talk	Synthesizer outputs status byte and remains in local or remote.
		Listen	Synthesizer goes to remote and listens for data.
	Unaddress	UNT Untalk	If talking, synthesizer is unaddressed.
		UNL Unlisten	Synthesizer ceases to listen to data.
	Clear	DCL Device Clear SDC Selective Device Clear	Synthesizer returns to 3 GHz, RF and modulation off, internal leveling.
	Remote	REN Remote Enable	Synthesizer remains in local until first addressed to listen.
	Local	GTL Go to Local $\overline{\text{REN}}$ Remote Disable	Synthesizer returns to local control, front panel switches determine instrument operation and frequency remains same.
INTERRUPT/STATUS	Require Service	SRQ Service Request	Synthesizer requests service when, unlocked, unleveled, FM overmod, or out of frequency range
	Status Byte	SPE Serial Poll Enable	Sets serial poll mode and latches RSV in synthesizer status byte.
		SPD Serial Poll Disable	Terminates serial poll mode.
	Status Bit	PP Parallel Poll	Internal synthesizer switches determine if it will respond, with which sense, and on which line.
ABORT	Abort	IFC Interface Clear	Synthesizer ceases to talk or listen.

Listen

Function	Model	Program Codes		Arguments	
Frequency		10 GHz	@ or P	Ø Through 9	
		1 GHz	A or Q		
		100 MHz	B or R		
		10 MHz	C or S		
		1 MHz	D or T		
		100 kHz	E or U		
		10 kHz	F or V		
		1 kHz	G or W		
		Execute	J or Z		
FM	8672A	N or ⌒		OFF	6 or 7
				30 kHz	5
				100 kHz	4
				300 kHz	3
				1 MHz	2
				3 MHz	1
				10 MHz	Ø
	8671A			OFF	Ø
				100 kHz	1
				10 MHz	2
ALC	8672A	O or _		RF Off	Ø, 2, 4, 6, 8
				Int, Normal	1
				Int, +10 Range	3
				Xtal, Normal	5
				Xtal, +10 Range	7
				Mtr, Normal	=
				Mtr, +10 Range	?
	8671A			RF On	1
				RF Off	Ø

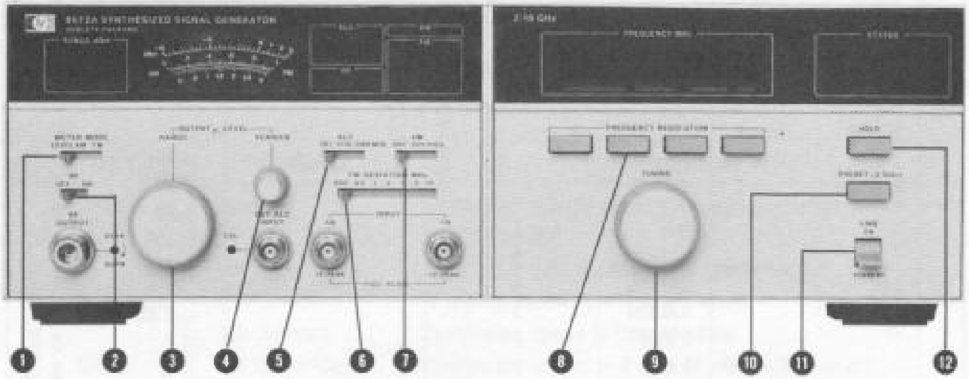
Function	Model	Program Codes	Arguments	
Output Power Range	8672A	K or [	0 dBm	Ø
			−10	1
			−20	2
			−30	3
			−40	4
			−50	5
			−60	6
			−70	7
			−80	8
			−90	9
			−100	:
			−110	;
Output Power Vernier	8672A	L or \	+3 dB	Ø
			+2	1
			+1	2
			0	3
			−1	4
			−2	5
			−3	6
			−4	7
			−5	8
			−6	9
			−7	:
			−8	;
			−9	<
			−10	=
AM	8672A	M or]	Off	Ø or 1
			100%	2
			30%	3

Talk

	Status Byte							
Bit	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
Function	Crystal Oven Cold	RSV Request Service	Out of Range (Frequency)	RF Off	Not Phase Locked	Level Uncalibrated*	FM Overmod	+10 dBm Overrange*

*Not used on 8671A

8671A/8672A Familiarization Procedure



Equipment Required

- **8671A or 8672A**
- **Audio Oscillator**

Frequency Selection

The 8670 Series synthesizers combine the simplicity of single control tuning with the convenience of selective resolution. To select a frequency momentarily depress the desired FREQUENCY RESOLUTION key (1 kHz, 10 kHz, 1 MHz, 100 MHz) (8) and rotate the TUNING control (9). The lighted bars under the LED display indicate the resolution that has been selected.

Tune the synthesizer through its full range using 100 MHz resolution, and note the ease with which the frequency can be tuned across the whole band. Select 1 kHz resolution and fine tune the synthesizer. The frequency resolution is 1 kHz below 6.2 GHz, 2 kHz between 6.2 GHz and 12.4 GHz, and 3 kHz above 12.4 GHz. Selective tuning resolution allows large frequency changes to be made rapidly while making fine tuning easy.

The HOLD (12) key disables the TUNING control (9) so that once a desired frequency is reached the operator need not worry about accidentally changing frequency. Push the HOLD key (12) and note that the TUNING control (9) is deactivated.

Note the frequency indicated in the display and set the synthesizer LINE switch (11) to STANDBY and then return it to the ON position. The frequency remains constant. Even with the power cable removed the synthesizer remembers the last frequency and returns to it when turned on. Thus all controls return to their last settings when the instrument is first turned on.

Momentarily depress the PRESET key (10). The synthesizer frequency is changed to 3000.000 MHz. This key is very convenient for rapidly changing all the right-most frequency digits to zeros without manual tuning.

Output Level (8672A Only)

The output level RANGE (3) and VERNIER (4) controls determine the output power level. With the METER MODE switch (1) in the LEVEL position the output is the sum of the LED range reading and vernier meter reading. This allows easy determination of output power from the display panel. Vary the RANGE (3) and VERNIER (4) settings and note the ease of output level selection.

The RF switch (2) permits the output to be easily turned off for making certain measurements. Turn the RF switch (2) on and off and notice that its status is indicated on the display panel.

The 8672A also allows external leveling, using a crystal or power meter, as well as internal leveling. By switching the ALC switch ❺ you can see the type of leveling indicated on the display panel. Also notice that the LEV UNCAL indicator lights whenever the output is unleveled.

Modulation (8672A Only)

Connect an audio source to the AM input. Switch the METER MODE switch ❶ to AM and the AM switch ❼ to 30%. The AM depth is displayed on the meter and the range is indicated on the display panel. In this mode, a one volt peak input results in 30% AM. Vary the modulation source level and observe that this controls the actual modulation depth. For the 100% position, one volt peak results in 100% AM.

Connect the audio source to the FM input. Switch the METER MODE switch ❶ to FM and vary the FM switch ❻ position. There are six FM peak deviation ranges; on each, one volt peak input results in a full scale deviation. When the selected deviation exceeds the 8672A's capability the FM OVERMOD indicator lights. This can be seen by overdriving the modulation input.

Separate inputs and controls for AM and FM allow the output signal to be simultaneously amplitude and frequency modulated.

Status Indicators

The six status indicators on the display panel in the "status" box make operation of the synthesizer much easier and help reduce possible operator errors.

OVEN warns that the crystal oscillator oven is not at the proper operating temperature. This normally occurs only when power has been removed from the instrument and it is first turned on.

OUT OF RANGE is a programming aid that indicates a frequency below 2 GHz or above 18.6 GHz has been programmed.

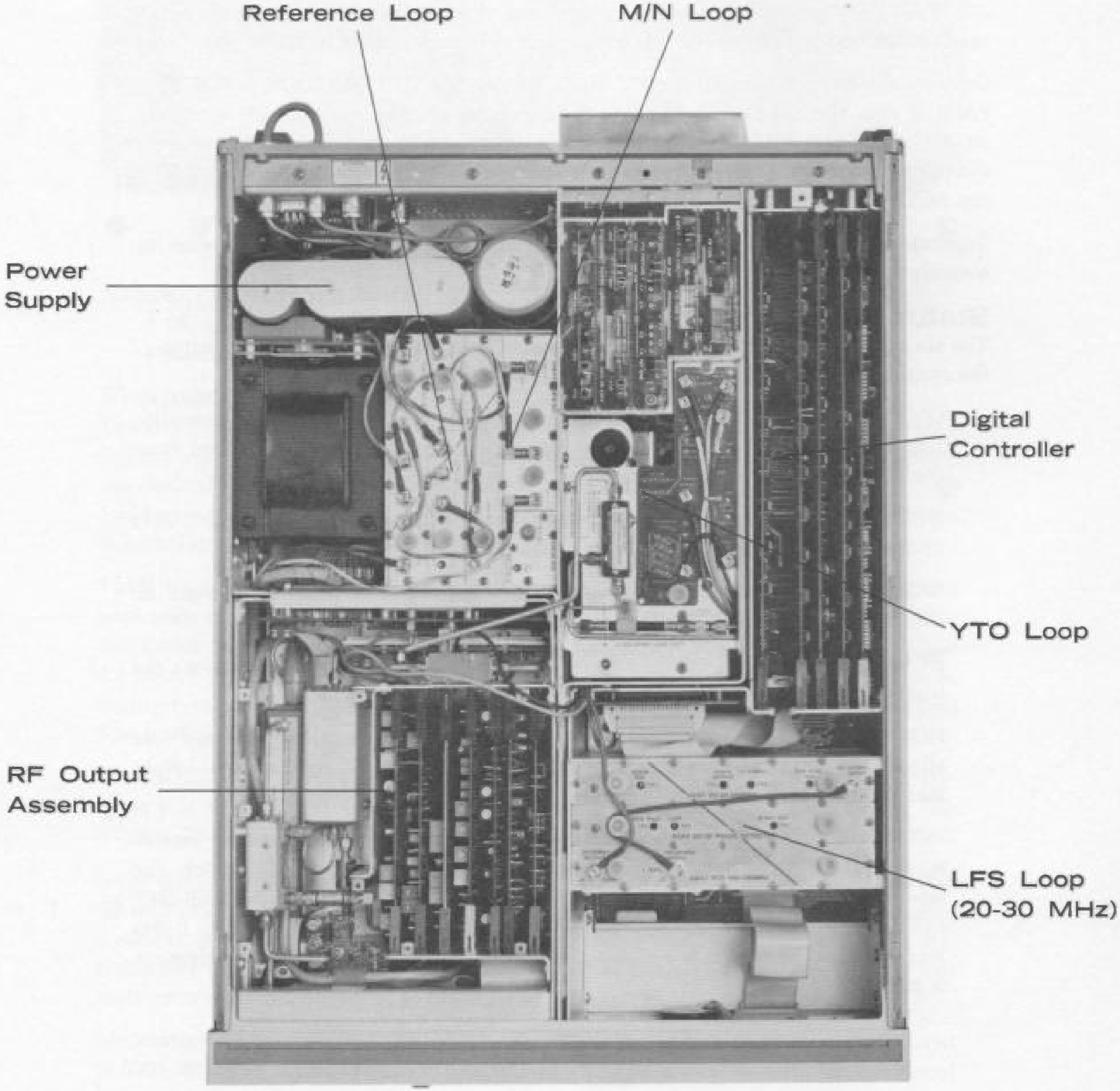
REMOTE indicates that the instrument is being remotely programmed and all controls but the line and meter mode switches are disabled.

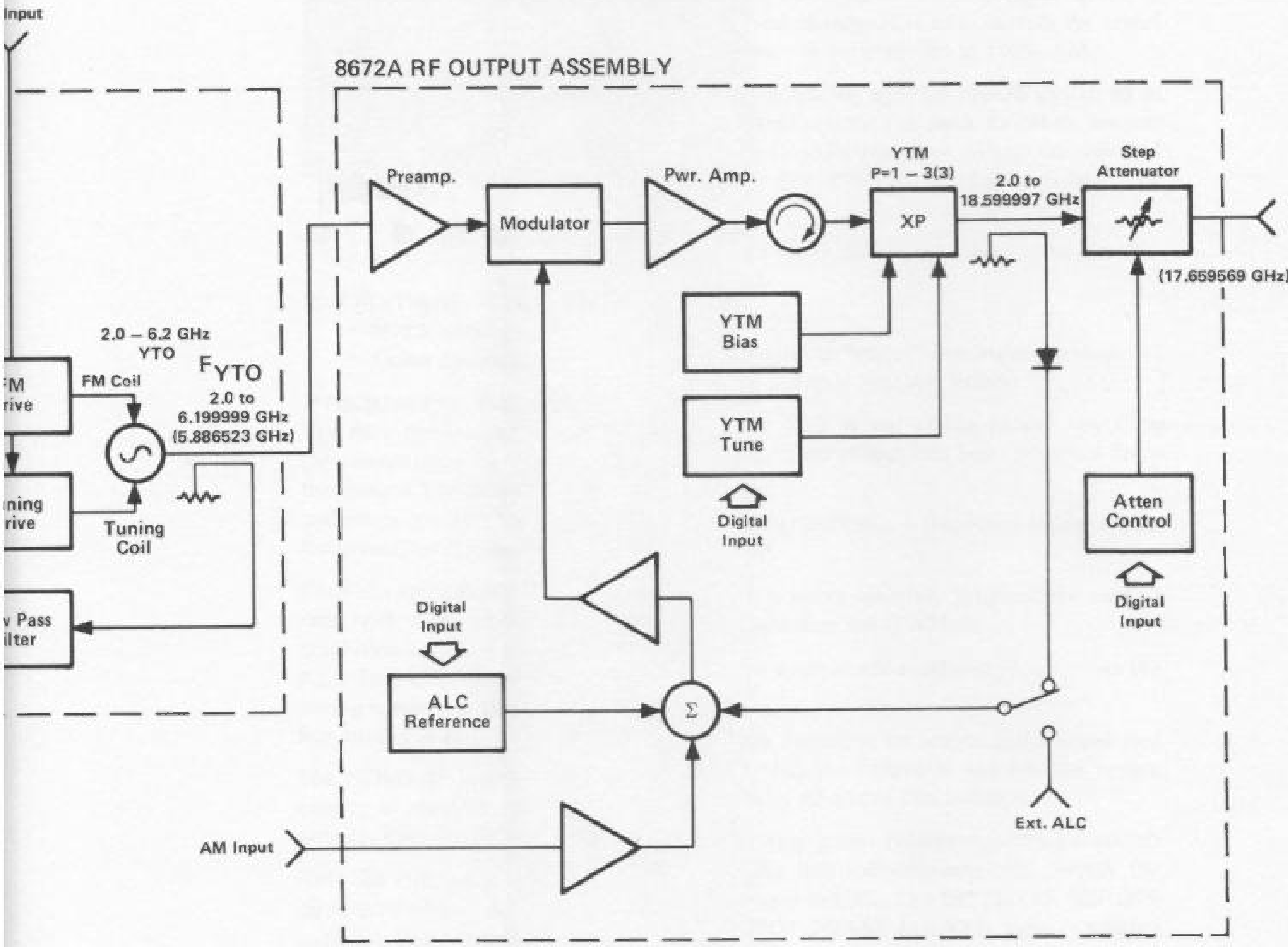
STANDBY makes it possible to know the oven is still receiving power when the line switch is in standby.

NOT PHASE LOCKED warns when the output is no longer synthesized and allows the operator to visually verify that the output is synthesized before making tests. Switch the RF switch on and off to see this indicator.

INTERNAL REF OFF lights when the rear panel reference selection switch is in the EXT position which turns the internal reference off. Switch the reference selection switch on the rear panel to EXT. The INTERNAL REF OFF light comes on. Also notice that the NOT PHASE LOCKED indicator lights warning that the output is no longer synthesized because no external reference is present.

Interior Layout

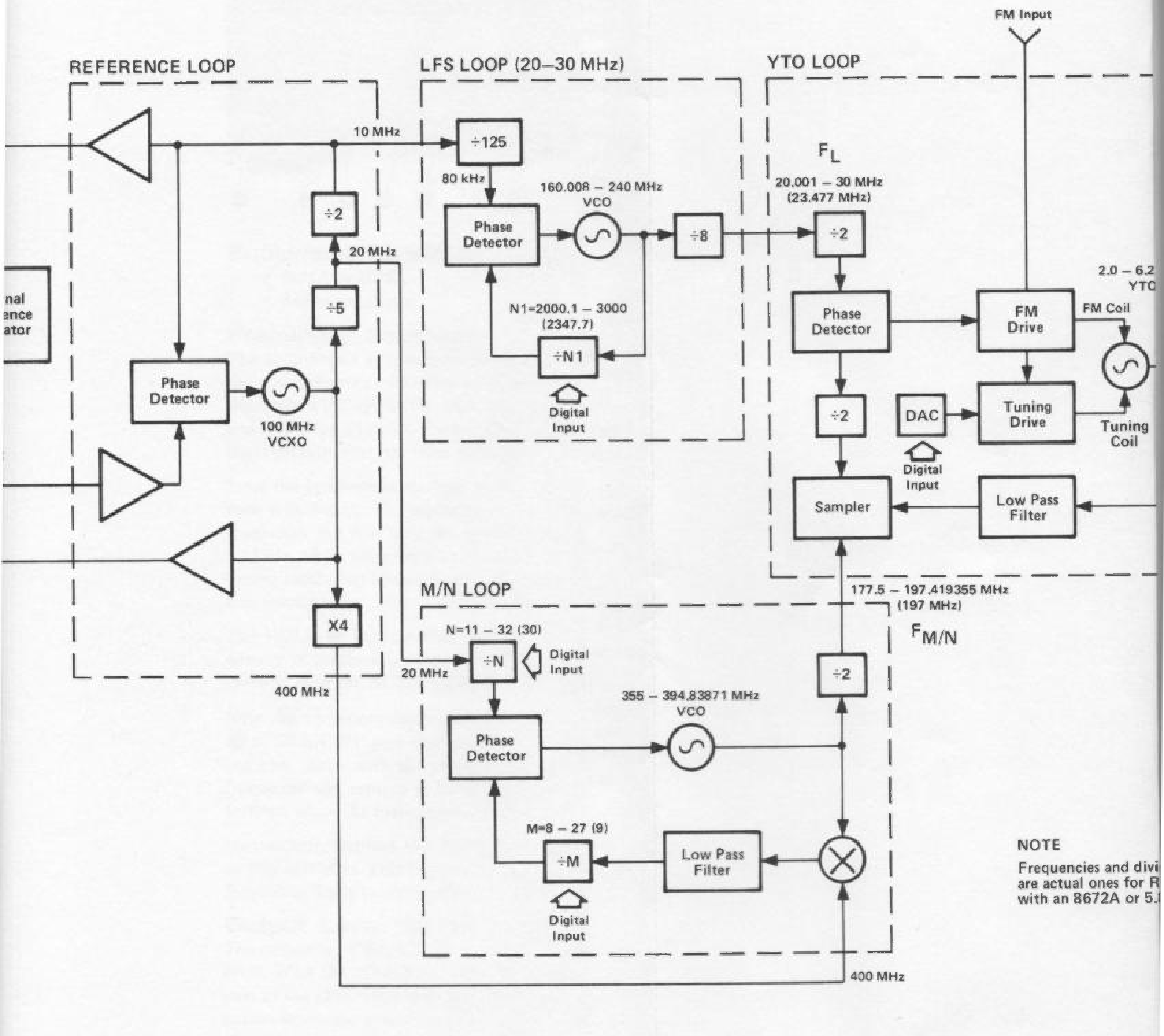




NOTE

Frequencies and divide numbers in parentheses are actual ones for RF Output of 17.659569 GHz with an 8672A or 5.886523 GHz with an 8671A.

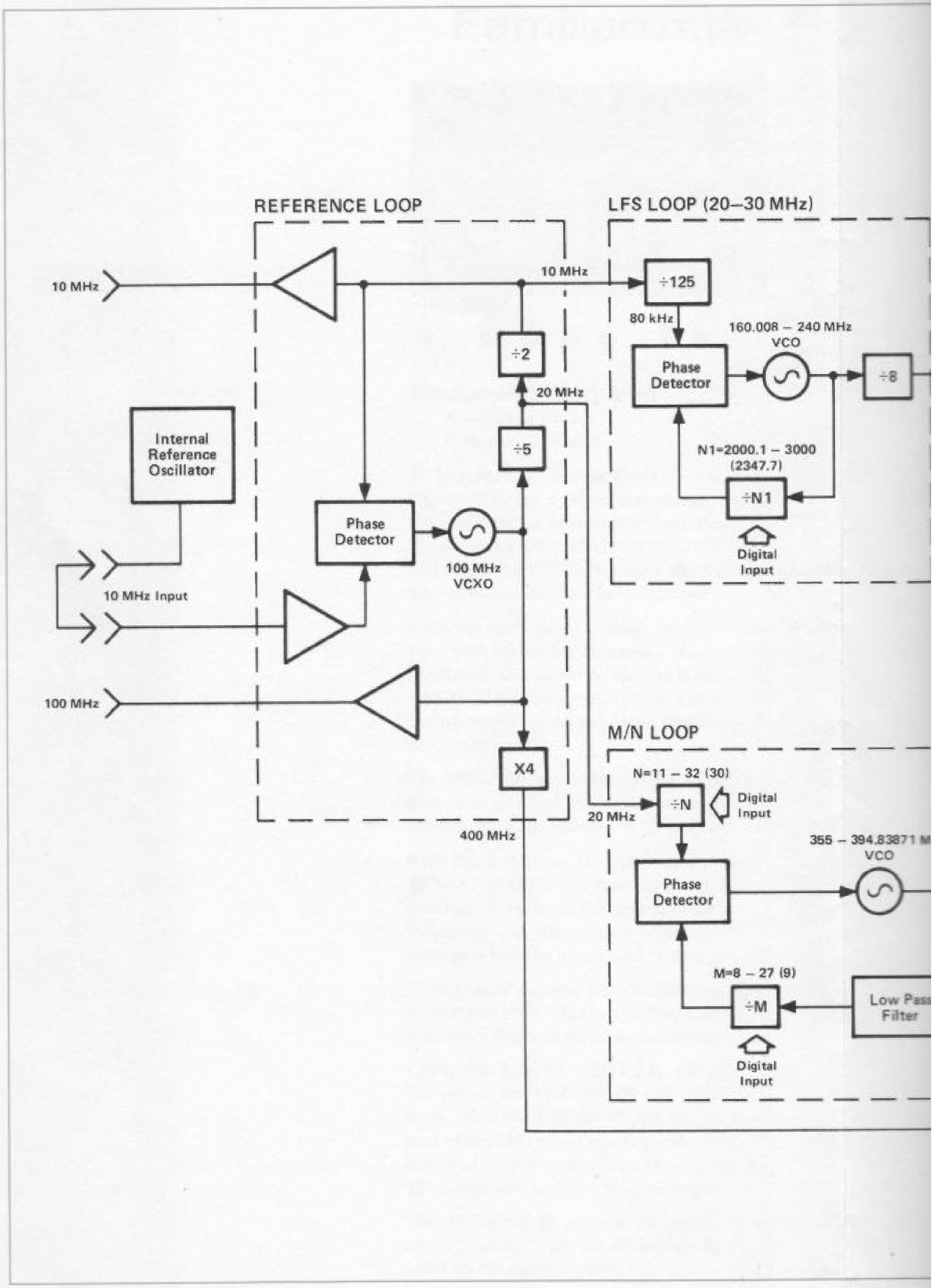
iagram



NOTE

Frequencies and divi
are actual ones for R
with an 8672A or 5.

8672A Block Diagram



Theory of Operation

(Refer to Block Diagram)

The 8671A and 8672A employ four phase-locked loops to generate the fundamental 2.0 to 6.2 GHz synthesized signal. The reference loop generates the basic signals to be used in the other phase-locked loops. The LFS loop determines the four least significant digits of the fundamental frequency, and the M/N loop determines the three most significant digits. The YTO loop uses signals from the LFS and M/N loop to phase-lock the final 2.0 to 6.2 GHz oscillator. A discussion of the operation of each of these loops and the RF output assembly follows. The instrument also includes a digital controller whose operation will not be discussed but which controls all functions and allows remote programming.

Reference Loop

A 100 MHz voltage controlled crystal oscillator is phase-locked to the internal 10 MHz reference oscillator or external reference signal. The output of this oscillator is multiplied by four to obtain a 400 MHz reference signal, and is divided to obtain 20 MHz and 10 MHz reference frequencies. The 100 MHz and 10 MHz reference signals are output to the back panel.

LFS Loop (20-30 MHz)

This loop determines the four least significant digits of the synthesizer output frequency. The loop operates from the 10 MHz reference loop output which when divided by 125 results in 80 kHz. A 160 to 240 MHz VCO is phase-locked to this 80 kHz signal. Digital inputs from the controller set the divide number, N1, which determines the VCO frequency. N1 varies between 2000.1 and 3000.0 and can be set in steps of 0.1. The result is a 160 to 240 MHz signal with 8 kHz resolution which when divided by eight results in a 20 to 30 MHz signal with 1 kHz resolution.

The output frequency of the LFS loop is related to the divide number, N1, by the formula $F_L = 10\text{ kHz} \times N1$ and to the YTO frequency, F_{YTO}, by $F_L = (30\text{ MHz} - Z)$ where Z is the four least significant digits of the YTO frequency.

M/N Loop

The M/N loop utilizes the 20 MHz and 400 MHz signals from the reference loop. These are used to produce a signal that varies between 177.5 and 197.5 MHz and determines the 1 GHz, 100 MHz, and 10 MHz digits of the YTO frequency.

In this loop the output from a 355 to 395 MHz VCO is mixed with the 400 MHz reference signal to generate a 5 to 45 MHz signal which is filtered and divided by the number M, set by the controller. The divided output is then phase compared with a signal generated by dividing the 20 MHz reference signal by N. The phase detector output corrects the VCO frequency to maintain phase-lock. The VCO output is divided by two to obtain the 177.5 to 197.5 MHz output signal. The resolution of this loop is $\frac{10\text{ MHz}}{N}$ where N varies between 11 and 32.

The output frequency of the M/N loop is related to the divide numbers, M and N, by the formula $F_{M/N} = 200\text{ MHz} - 10\text{ MHz} \times \frac{M}{N}$, and to the YTO frequency by $F_{M/N} = (F_{YTO} - F_L)/N$.

YTO Loop

The YTO loop synthesizes the basic microwave signal in the 8671A and 8672A. It uses the output signals from both the LFS loop and M/N loop to generate a 2.0 to 6.2 GHz signal with 1 kHz resolution.

Digital inputs to the digital-to-analog converter, DAC, from the controller generate a precise dc voltage on the YTO main coil to pretune the YTO close to the desired frequency. Part of the YTO output is coupled-off, filtered, and fed to the sampler.

The sampler is gated by the signal from the M/N loop and converts the microwave signal to an intermediate frequency which is the difference between the YTO frequency and the Nth harmonic of the M/N output frequency. This N is identical to the N of the M/N loop. The signal from the sampler is divided by two and phase compared to the LFS loop output which has also been divided by two.

The dc component from the phase detector is summed with the tuning voltage of the YTO tuning coil, and the ac component is applied to the YTO FM coil phase-locking the YTO. Frequency modulation is also accomplished in this loop by summing a modified form of the modulating signal with the phase detector output to frequency modulate the YTO.

The YTO frequency is related to N1, N, and M by the formula
$F_{YTO} = 200\text{ MHz} \times N - 10\text{ MHz} \times M - 10\text{ kHz} \times N1$.

8671A RF Output Assembly

In the 8671A RF output assembly the synthesized YTO output is passed through a circulator and then delivered to the front panel connector. The result is a 2.0 to 6.199 999 GHz source with frequency modulation capability.

8672A RF Output Assembly

In the 8672A output assembly the synthesized YTO output is amplified and then multiplied by the YIG-tuned multiplier, YTM. The digital inputs to the YTM tuning determine which harmonic is selected. The result is a 2.0 to 18.599 997 GHz signal. Output leveling, amplitude modulation, and output attenuation are also accomplished in the 8672A RF output assembly.

Reliability and Serviceability Features

Reliability and serviceability were major considerations in the design of the 8671A and 8672A. The goal has been to design extremely dependable, easily repaired microwave synthesizers. As a result, the mechanical and electrical designs of the 8671A and 8672A incorporate many features to assure high reliability and serviceability that are not apparent from either the specifications or block diagram.

Reliability

Everything during the design was examined from a reliability standpoint. Reliability considerations ranged from the selection of an overall block diagram to the selection of individual components. Every effort has been made to eliminate circuits or components susceptible to failure.

All circuits have been thoroughly analyzed for proper operation over the full operating environment and worst case combination of component tolerances. Components have also been analyzed for stress under worst case conditions and values have been chosen that allow for significant margin.

Internal temperature rise is another example of this effort. Because heat greatly shortens semiconductor life, it received special attention. The temperature rise of major components was checked in an operating instrument. Measures were taken to more effectively dissipate heat from some components, and often components with reduced dissipation incorporated. In addition, controlled air flow to dissipate this heat minimizes the internal temperature rise.

Serviceability

The ability to rapidly repair an instrument that fails is almost as important as preventing it from failing. When servicing is required the 8671A and 8672A are designed for easy access to all circuits and displays. Many circuits have built-in indicators to identify proper operation. These indicators along with front panel displays allow most failures to be quickly diagnosed to an individual circuit. The operating and service manuals also contain a large amount of servicing information to help in repairing instruments.

Easy access, indicators, numerous test points, labels, and a thorough manual allow most failures to be rapidly isolated and repaired. A few examples of these features are listed and shown in Figure 35.

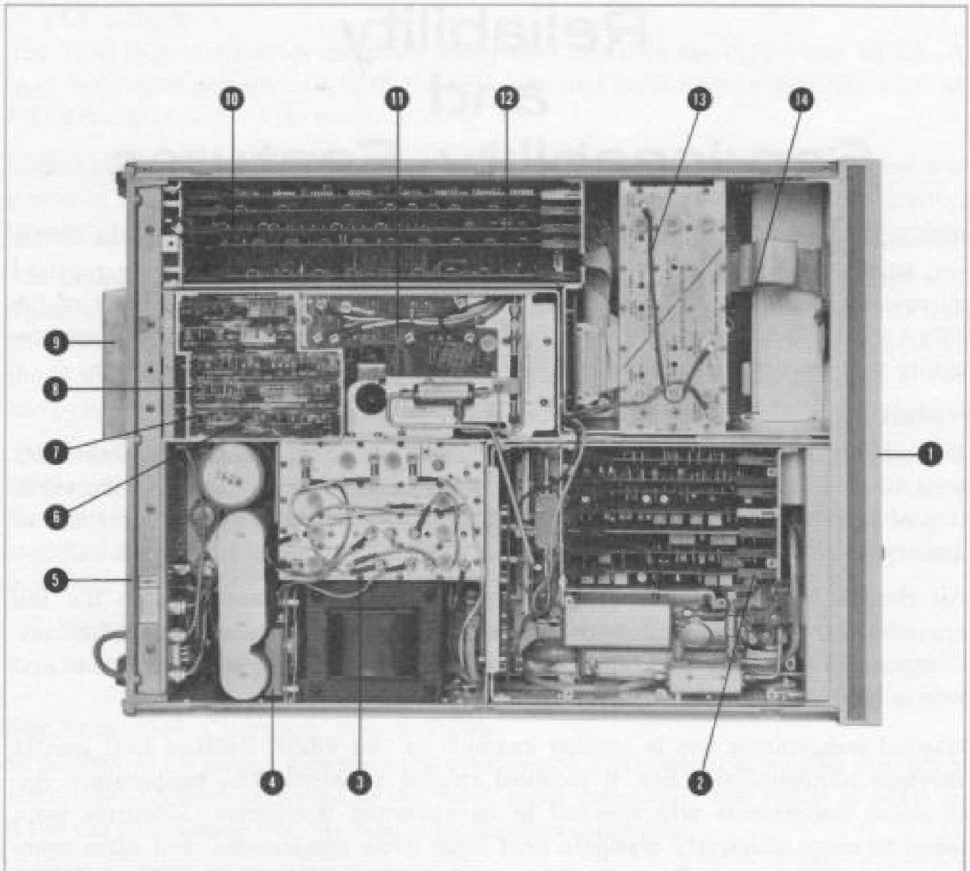


Figure 35. Reliability and serviceability features.

❶ Front panels swing out for easy access to switches and indicator lights

❷ Color coded circuit board tabs correspond to guides for ease of re-assembly

❸ Color coded cables match labelling by connectors to reduce errors

❹ Top, bottom, and side covers removable for easy access

❺ Section of rear panel removes easily to service power transistors

❻ Thermal over-load protection eliminates over-heating

❼ LED indicators for power supplies allow rapid troubleshooting

❽ Hinged power supply cover with labels and test points reduces possibility of power supply damage during repair

❾ Controlled air flow keeps internal temperature rise to $<10°C$

❿ Built-in logic probe for analyzing controller

⓫ Upper loop assembly swings up for easy access to components beneath it

⓬ Phase-lock indicators for each phase-locked loop allow rapid troubleshooting

⓭ Cables long enough to be used with extender boards eliminate need for special cables

⓮ Battery-protected frequency memory

HEWLETT hp PACKARD

5952-8168

Printed in U.S.A.