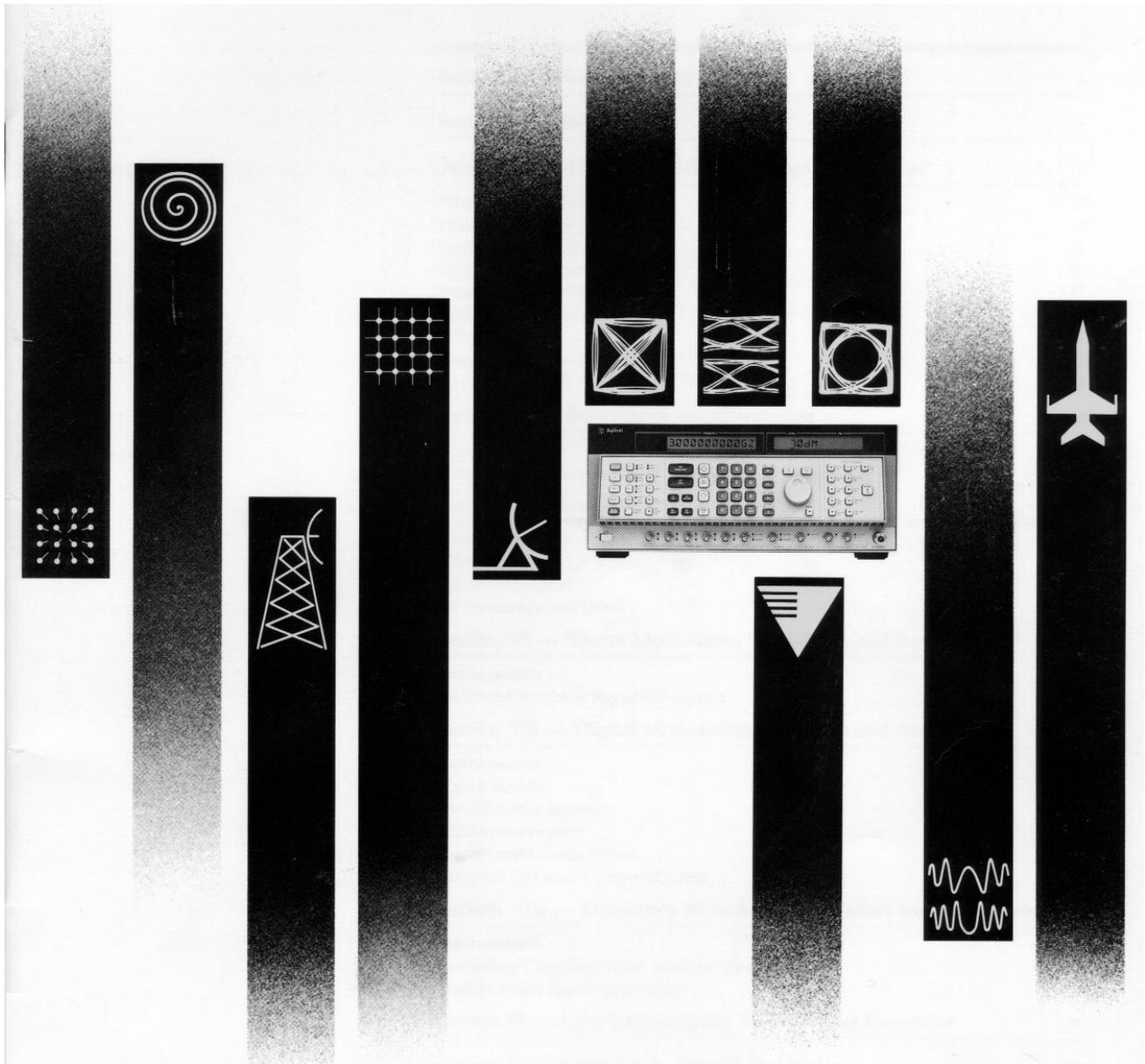


Agilent PN 8780A-1

Introductory Operating Guide to the Agilent 8780A Vector Signal Generator

Product Note



Agilent Technologies

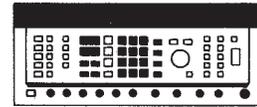
Innovating the HP Way

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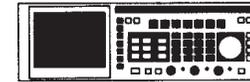
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Block Diagram Key

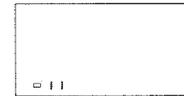
Agilent 8780A Vector Signal Generator



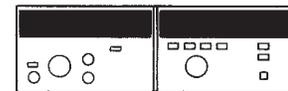
Agilent 8980A Vector Analyzer



Agilent 8770A Arbitrary Waveform Synthesizer



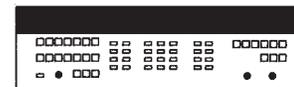
Agilent 8671B Synthesized Signal Generator



Agilent 8656B Synthesized Signal Generator



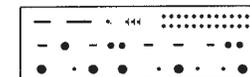
Agilent 8165A Programmable Signal Source



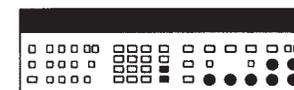
Agilent 8116A Pulse/Function Generator



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Agilent 9000 Series Controller



Introduction

This Product Note contains detailed information about the use and application of the Agilent Technologies 8780A Vector Signal Generator.

Being sure that a product like the vector signal generator meets your measurement needs sometimes requires more information than what's in a data sheet or brochure. This document describes important application concerns and should help you use the vector signal generator to satisfy your measurement requirements.

The first two sections describe the vector signal generator's main features and familiarize you with the controls and connectors on the front and rear panels. Sections 3, 4, and 5 describe basic operation and application of the vector, digital, and FM modulation modes respectively. The Appendix contains supplementary information about the instrument's special functions and GPIB commands.

While this Product Note covers the general use and application of the 8780A Vector Signal Generator, there are other publications that may help to address the measurement needs of specific systems. The following publications are available from your Agilent field engineer.

Product Note 8980A-1 Introductory Operating Guide to the Agilent 8980A Vector Analyzer. The vector analyzer is a companion product to the vector signal generator, and they are often used together in measurement systems. The 8980A Product Note contains information necessary to understand its use and evaluate its suitability for specific measurements.

AN 343-1 Measurement Applications In Digital Microwave Radio. Digital microwave radios (DMRs) are increasingly chosen for both satellite and terrestrial applications. Application Note 343-1 outlines some of the measurements and test procedures critical to measuring the analog signals in DMR systems. It provides a good starting point for the engineer or technician called upon to design measurements for these applications.

AN 343-3 Coherent Pulsed Tests of Radar and Electronic Warfare Systems. Almost all radars and electronic warfare equipment now coherently transmit and detect their signals. This Application Note describes methods of testing the microwave and IF portions of radar and EW equipment using a vector measurement system.

I-Q Tutor: The Agilent Digital Communications Tutorial. Sometimes it's best to start at the beginning. I-Q Tutor is a tutorial manual and computer program that simulates many of the signals in real digital microwave radios to help develop an understanding of the fundamental concepts of digital communication. The computer program runs on IBM-PC™ compatibles (HP 11736B), and HP 9000 series models 216, 217, 236, and 236C (HP 11736A).

If your particular application is not covered by one of the documents listed, consult your Agilent field engineer for the latest list of product and application notes.

The Agilent 8780A Vector Signal Generator

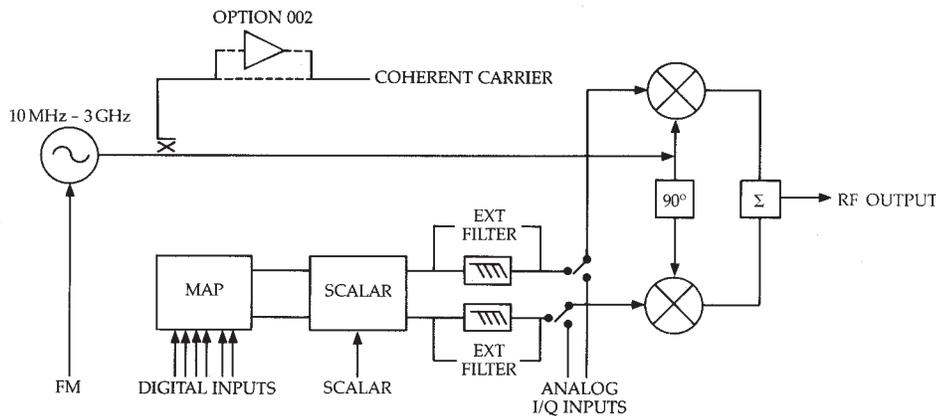
What Is The Agilent 8780A?

The Agilent 8780A Vector Signal Generator is a 10 MHz to 3 GHz synthesized microwave signal generator with exceptional modulation capabilities. Its name, “vector”, comes from the way it achieves its modulation: by using a “vector” or I/Q modulator. The vector modulator gives the generator modulation bandwidths much wider than those previously available. In addition to vector modulation, the vector signal generator can do many phase shift keyed (PSK) and quadrature amplitude modulations (QAM) using its digital inputs. This simplifies generation of digital microwave radio (DMR), phase-coded radar and other digitally modulated signals. The 8780A can also be frequency or amplitude modulated with analog signals.

Vector modulation allows arbitrary phase and amplitude modulation with bandwidths up to 700 MHz peak-to-peak. The modulation capability is complemented by a coherent carrier available at the rear panel. This reference signal simplifies demodulation and enables pulsed phase measurements.

For convenient generation of common modulation formats, the 8780A has digital inputs for switching between preset generator output phase-amplitude states.

The 8780A also provides very wideband linear frequency modulation. FM deviation is specified to 50 MHz p-p at up to 12 MHz rates. Simultaneous modulations can simulate radar chirps and antenna scan patterns.

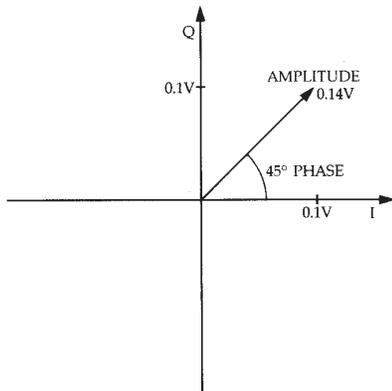


Simplified vector signal generator block diagram

Vector Modulation

Vector modulation represents a significant departure from traditional signal generator modulation techniques. Initially used in communication systems because of its ability to efficiently utilize transmission bandwidth, vector modulation now provides increased modulation bandwidths in a microwave signal generator.

Vector modulation, or I/Q modulation as it is sometimes called, is a method of modulating a carrier with two base-band signals called the in-phase (I) and quadrature-phase (Q) components. The I and Q signals effectively “move” the carrier signal (or vector) about the I/Q plane. In the I/Q plane, the phase of a signal is the angle of its vector with respect to the I axis, and the magnitude is the length of the vector from the origin. The diagram below illustrates the relationship of the generator’s output phase and amplitude to given I and Q voltages.



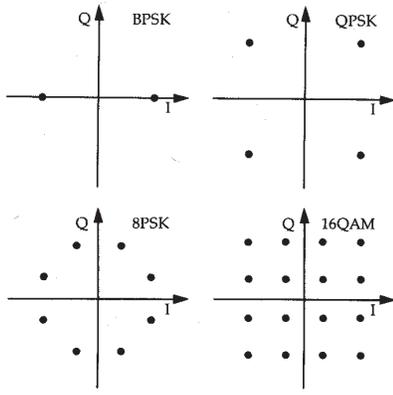
Vector modulation is the most wide-band arbitrary way of using the Agilent 8780A. The vector inputs have bandwidths of 350 MHz and can be used to generate phase, amplitude, and frequency modulation. These capabilities are explained in more detail in Chapter 4—Vector Modulation Operation and Applications.

Digital Modulation

The digital inputs of the 8780A Vector Signal Generator provide a convenient way of generating phase-shift-keyed and quadrature amplitude modulations. Built-in mapping circuitry converts digital inputs into analog I and Q voltages to drive the vector modulator and generate the following modulations: BPSK, QPSK, 8PSK, 16QAM, and 64QAM (with Option 064). Besides these standard modulations, the digital modulation circuitry allows several variations which are particularly valuable in performing receiver tests.

There are six digital inputs on the standard vector signal generator; four data inputs, and two clock inputs¹. These inputs are the modulation source lines for all digital modulations. The data lines determine which of the I/Q (or phase-amplitude) states the generator will output. Changing the digital signals at these inputs changes the phase and amplitude of the output and generates the desired QAM or PSK modulation.

1. Option 064 adds one data input and deletes one of the clocks.



Vector signal generator standard modulations; Option 064 adds 64QAM.

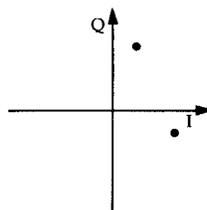
The clock inputs can be used to latch the analog I and Q voltages into the modulator. Although modulation can be done asynchronously (i.e., without a clock input), the two clock inputs can be used to latch I and Q signals independently, or one clock can be used to latch both I and Q. Synchronous operation ensures data symmetry and fast rise times at high clock rates (>50 MHz). At lower rates, synchronous operation may be used to clean up data asymmetry, remove slow rise times, or provide staggered modulations.

In addition to the preset modulations (BPSK, QPSK, 8PSK and 16QAM), the 8780A can modulate between any two user-defined states. TWO STATE uses a digital input line to switch the output back and forth between two user-specified I/Q or phase-amplitude states.

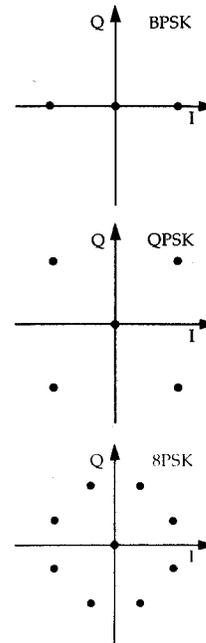
BURST, when used by itself, is analogous to pulse modulation on traditional generators. It simply switches the generator's CW output on and off as controlled by one of the digital input lines. The on/off ratio specified for BURST operation is 50 dB; typical performance is 55 dB. The on/off ratio is a function of how well the vector modulator is calibrated, and will be best after using the calibration key.

When BURST mode is used with another modulation like 8PSK, the BURST line gates the output of the generator. This facilitates easy simulation of time domain multiple access (TDMA) bursts, Barker coded radar signals, and other discontinuous signals.

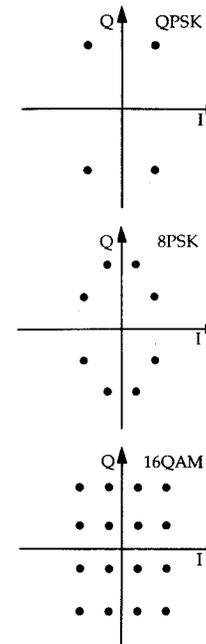
The basic modulations such as BPSK and QPSK can be modified to suit the needs of your particular system or to stress your receiver. One of the simplest ways that a modulation can be modified is by selectively attenuating the modulation format in the I direction. This is done by selecting the I<Q mode and can be used with any of the vector signal generator modulations.



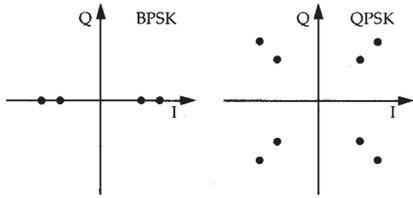
Two-state modulation



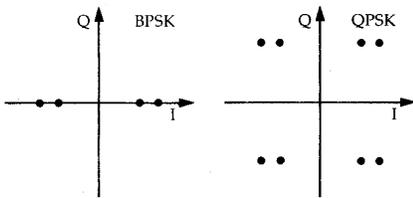
Burst modulations for TDMA simulation and phase-coded pulses



I < Q for circuit stress testing and unbalanced modulations



Alt Level — dynamically attenuates both I and Q.



Alt Level I — dynamically attenuates only I.

Other variations of digital modulations can be done dynamically such as ALT LEVEL and ALT LEVEL I. ALT LEVEL and ALT LEVEL I are used to selectively attenuate the output to alternate levels and are useful in simulating rapid amplitude changes in signals. After you specify the desired attenuation (0-40 dB) and enable ALT LEVEL, the ALT LEVEL digital line dynamically attenuates one of the selected modulation types (say QPSK). Similarly, ALT LEVEL I dynamically attenuates only the I component of the modulation being generated. This is the equivalent of squeezing the transmitted constellation in the I direction.

BURST, ALT LEVEL, and ALT LEVEL I can be used in combination with certain standard modulations shown below:

Mode	BPSK	QPSK	8PSK	16/64 QAM
BURST	Yes	Yes	Yes	No
ALT LEVEL	Yes	Yes	No	No
ALT LEVEL I	Yes	Yes	No	No

All standard digital modulations are specified to operate asynchronously up to 50 MHz and synchronously up to 150 MHz clock rates. Data skew and asymmetry are typically <1 ns for clocked operation and, without clocks, will be limited by the data lines' skew and asymmetry. This means that clocked operation will provide improved performance in applications where timing is critical, such as digital microwave radio tests.

Although clock and data line impedances are 50 Ω (into -2 V or ground), the signal threshold is selectable from -2.5 V to +2.5 V. This makes it possible to use 75 Ω lines without the need of special adapters or termination concerns in most cases.

Frequency Modulation

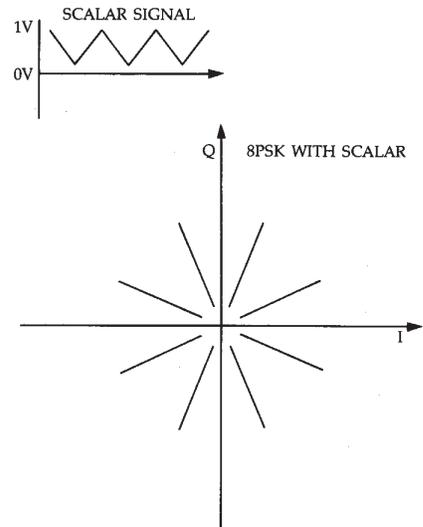
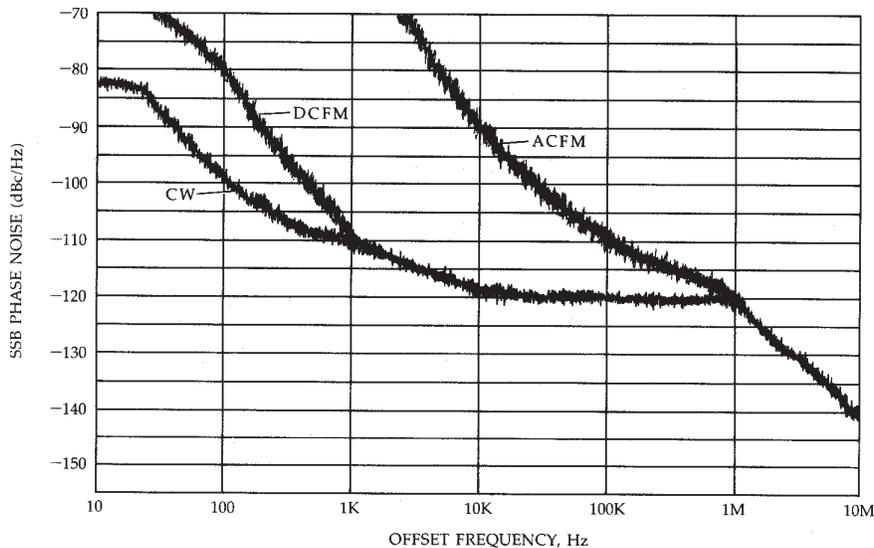
The exceptional frequency modulation capabilities of the Agilent 8780A

Vector Signal Generator are suitable for demanding applications like satellite video generation. The wideband modulation capabilities of the generator make wide frequency deviations and rates possible. In addition, the modulation is very linear and clean; differential gain and phase are typically <2% and <1°, respectively.

For applications requiring wide deviation high rate FM, the vector signal generator's ac FM provides deviations up to 50 MHz p-p and rates from 20 Hz to 12 MHz (3 dB points). In ac-coupled FM, phase noise performance is degraded from CW operation.

Where low phase noise is particularly important and maximum deviation and rate are not required, the vector signal generator's dc FM provides near CW phase noise performance with deviations up to 150 kHz p-p and rates to 10 kHz. This is especially valuable for simulating Doppler shifts on phase-sensitive modulations like QPSK and 8PSK. DC FM would also be the modulation type chosen for phase locking the vector signal generator.

A special wideband dc FM mode is also available which allows deviations up to 50 MHz with dc coupling. Linearity and distortion are not specified in this mode, and phase noise is comparable to that of ac coupled FM. For more information about wideband dc FM, see Appendix A.



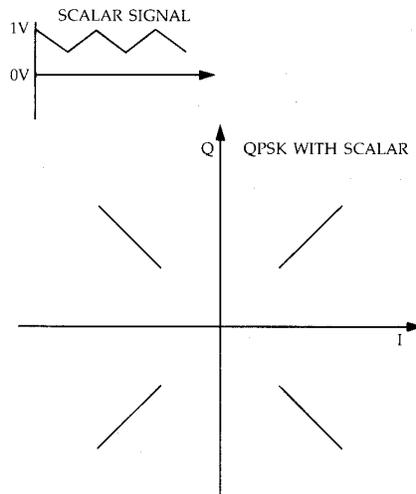
Measured Agilent 8780A CW, dc FM, and ac FM SSB phase noise at 1 GHz

Amplitude/Scalar Modulation

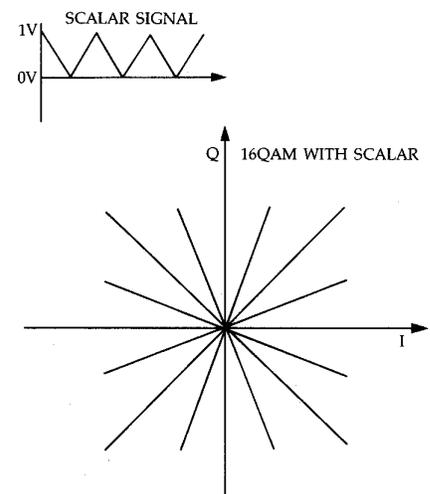
There are two methods of generating amplitude modulation with the vector signal generator. Wideband AM can be generated with vector modulation, or up to 500 kHz bandwidth AM can be generated simultaneously with digital modulations using Scalar modulation.

For very wideband AM without simultaneous digital modulation, vector modulation should be used with the envelope signal on either the I or Q channel. Using the vector inputs, AM signals can be simulated with up to 350 MHz single sided bandwidths.

Scalar modulation is used to amplitude modulate the digital and FM signals of the 8780A Vector Signal Generator. The scalar input can be used to simulate fades, test AGC loops, or simulate antenna patterns with any of the vector signal generator modulations except vector modulation.



Scalar modulation works by multiplying the vector signal generator's output by the Scalar Input. To do traditional AM, a dc offset must be added to the modulating signal at the Scalar Input so a 0 V dc input corresponds to the average RF output level.



The Scalar Input impedance is nominally 10 kΩ with a range of 0.0 V to +1.0 V; A 1.0 V input signal causes full power output, and 0.0 V causes no output signal. It is dc coupled and has a 500 kHz bandwidth.

Simultaneous Modulation

It is often advantageous to be able to combine various modulations to create signals which either better represent the real world or help stress devices being tested. Because of this, the Agilent 8780A Vector Signal Generator does several different simultaneous modulations. The permissible combinations are shown below:

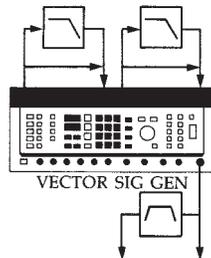
Modulation	Digital	Scalar	FM	Vector
Digital	—	Yes	Yes	No
Scalar	Yes	—	Yes	No
FM	Yes	Yes	—	Yes
Vector	No	No	Yes	—

External Filters

The 8780A Vector Signal Generator automatically selects internal spectral limiting filters for digital modulations to avoid aliasing or spectral folding that results when single-sided modulation bandwidths exceed the generator's tuned frequency. The internal filters are low pass filters with very flat passband response. If the selected filter doesn't meet your needs, there are two alternatives available. You can choose a different internal filter (see Appendix A for details), or you can use your own external filters.

The 8780A Vector Signal Generator accepts baseband external filters between its connectors on the rear panel. If dc-coupled filters are used, the generator's calibration routines will calibrate out small dc gain imbalances between the I and Q filters. For ac-coupled filters, gain differences may be manually specified using one of the special functions.

Either of these techniques will ensure good amplitude balance with a minimal loss of vector accuracy provided the overall filter gain or loss is less than 2 dB. If active filters are used, they must also have smaller than 20 mV dc offsets. DC offsets in the filters cause a loss of resolution in the calibration routines, which reduces the vector accuracy achievable.



The vector signal generator gives you the choice of filtering I and Q baseband signals or the modulated output.

Frequency Range

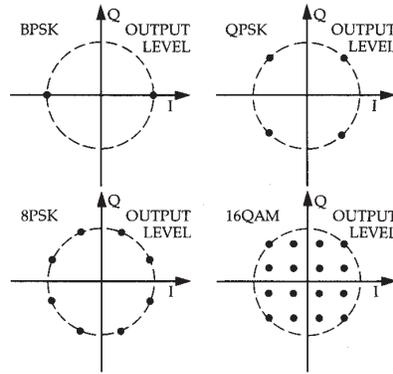
The vector signal generator is specified between 10 MHz to 3 GHz and can be tuned with 1 Hz resolution. The generator can also be tuned outside the 10 MHz to 3 GHz range, but performance is not specified.

In fact, the generator can generate signals down to about 4 MHz where the output starts to roll off. Some of the specifications that may degrade at these lower frequencies are amplitude flatness, output power, and spur and harmonic levels. If you need to ensure a certain level of performance in this range, you should verify the important specifications by measuring the vector signal generator's performance first.

RF Output

The RF Output of the Agilent vector signal generator has a wide dynamic range and achieves very good flatness through the use of software correction tables. Output level is controlled from the front panel keypad or knob and can be varied from +12 dBm to -110 dBm in 0.1 dBm steps. Maximum available output level is specified to be +10 dBm for 10 MHz to 2.5 GHz and +4 dBm to 3 GHz. When output level is set using the front panel keys or knob, the instrument automatically selects the step attenuator and vernier settings necessary for the desired level. In some cases, particularly when testing phase locked systems, the automatic switching of step attenuator settings may interfere with the measurement. The vector signal generator has an extended vernier mode for these situations.

In the extended vernier mode the step attenuator doesn't switch and the level vernier range is extended. With the "Lock Step, Extend Range" special function, the RF output level typically can be tuned over a 20 dB range (from roughly 10 dB below the low attenuator switch point to just over the high attenuator switch point). This is wide enough to provide ample tuning range for receiver sensitivity tests and similar measurements. Extended vernier operation is not specified, and at the extremes of the vernier range, the vector signal generator's vector accuracy may degrade slightly.



Agilent 8780A level always corresponds to the maximum modulation states.

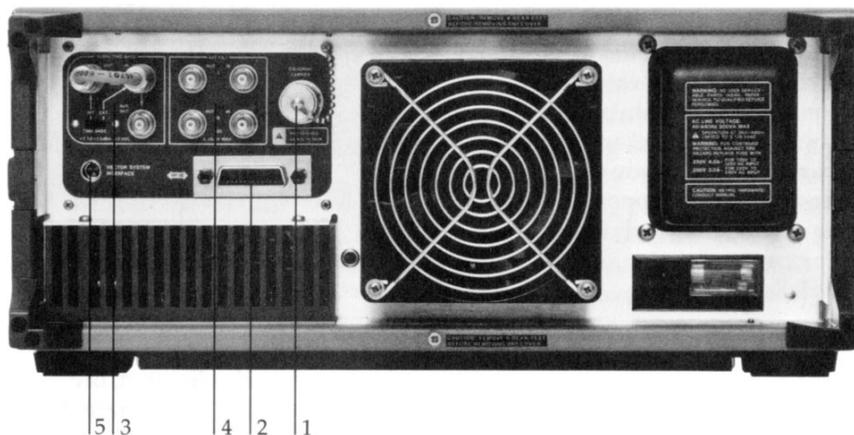
For vector modulations and digital modulations, the definition of output level must be carefully understood. The level set using RF Output level controls always refers to the magnitude of the largest state in these modes. The maximum level corresponds to a vector of magnitude 0.5 V at the vector inputs, which is the magnitude of the largest state of the digital modulation selected. For example, if 16QAM modulation is selected, and the RF Output level is -4.0 dBm, then the magnitude of the outermost states of the 16QAM constellation will be -4.0 dBm. Similarly, if vector modulation is selected, and the RF Output level is -4.0 dBm, then the output will only be -4.0 dBm for an I input of +0.5 V and no Q input, or some other vector of the same magnitude.

10. RF Output—This is the 8780A Vector Signal Generator’s primary output. It is the test signal generated with all modulation, level, and frequency control. For demodulation purposes, a coherent output, which has no modulation except for FM, is provided on the rear panel.

The Phase Bump special function can be used to shift the RF Output and Coherent Carrier phase with respect to the 10 MHz frequency reference. This makes it possible to change the vector signal generator’s phase with respect to another synthesizer. Phase Bump does not change the phase of the Coherent Carrier with respect to the RF Output.

11. Output Control—This section of the front panel toggles different modulations and the RF output on and off. LEDs in the keys indicate which modulations are on and whether the RF output is enabled. Simultaneous modulations can be selected provided they are compatible. For example, QPSK and Scalar may both be selected, but 16QAM and Burst may not (since there aren’t enough data lines). Any modulation can be turned off in the same way that it was turned on—by pressing that modulation key.

The RF OUT ON key toggles the Coherent Carrier on and off along with the RF output.



Rear Panel Connections

1. Coherent Carrier—The Coherent Carrier provides a reference signal for demodulating the RF output or output of a test device. It is an unmodulated (except for FM) and unlevelled version of the RF output at the front panel. It has a 50 Ω impedance and its level is nominally >-20 dBm. Coherent Carrier level can be increased to +9 dBm with Option 002.

The Phase Bump special function can be used to shift the Coherent Carrier and RF Output phase with respect to the 10 MHz frequency reference. This makes it possible to change the Coherent Carrier phase with respect to another synthesizer. Phase Bump does not change the phase of the Coherent Carrier with respect to the RF Output.

2. GPIB—Allows remote operation with GPIB controllers. For a brief description of the GPIB codes, see Appendix C.

3. 10 MHz Timebase Reference—The 8780A can be phase locked to other stable frequency references using the 10 MHz timebase reference, or other test equipment can be phase locked to it. In either mode the reference selection switch must be appropriately set.

4. External Filter Connectors—External filter connectors are provided which let you use your own baseband filters with the 8780A. To use them, you remove the jumpers supplied and insert your own I and Q baseband filters in their place. External filters are selected on the front panel with the EXT FILTER ON key. I and Q impedances are 50 Ω and full scale signals are +0.1 V to -0.1 V.

5. External System Interface—The external system interface provides a convenient system connection to let the 8780A communicate with future complementary products.

Getting Started

This chapter describes the basic operation of the vector signal generator. It covers calibration and the selection of modulation, frequency, output level, and other parameters which you will have to change for general operation. The details of operating different modulations are covered in the chapters that follow.



Instrument Preset

To establish a known setup prior to entering new data, press the green INSTR PRESET key. Preset sets the 8780A to the following configuration:

- Modulation: Off
- Frequency: 70 MHz
- Amplitude: -110 dBm
- RF Out: On
- DC FM: Off
- Special Functions: Off
- Digital Lines: Not Inverted
- Clock and Data: ECL Levels
- Knob: Off
- No External Clocks
- No External Filters

Calibration

The vector signal generator should be calibrated by pressing the CAL button before using the instrument. The calibration routine makes several critical adjustments to the vector modulator, digital mapping, and FM circuits. Aside from doing an initial adjustment of the modulation components, calibration should also be used to remove component drift that occurs during warm-up.

Select Modulation

Once preset and calibrated, the Agilent 8780A is ready to generate the desired modulation.

To select vector modulation, press the VECTOR ON button. The VECTOR ON LED and the LEDs next to the I and Q inputs will light, indicating that vector modulation has been selected.

To select digital modulations, press the digital modulation key that corresponds to the basic modulation desired (BPSK, QPSK, 8PSK, or 16QAM). If a modified modulation is desired, select the second modulation also. The output ON/OFF section of the keyboard will indicate the modulation(s) selected by lighting the LEDs in the appropriate keys. Also, the LEDs next to the required digital inputs will light.

To select frequency modulation, press the FM ON button. If dc FM is desired (usually in a phase locked application), press the DC COUP FM button also.

Set Frequency and Level

Use either the SET FREQUENCY or SET LEVEL keys to set your desired operating frequency or RF output level. The display will indicate which has been selected by showing a cursor under one digit of either the level or frequency.

You can change the value selected by typing a new value using the keypad, increasing and decreasing the value with the up and down arrows, or by using the knob. If the keypad is used, the entry must be terminated with one of the units keys at the right of the entry section. If using the increment/decrement method, the SET INCR key sets the amount that is added or subtracted each time the up or down arrow is pressed.

To use the knob, first turn it on by pressing the KNOB button. The knob button LED shows the knob is active. The knob always increments or decrements the digit of the value being entered that is directly above the cursor. The cursor is moved by using the left and right arrow keys found just above the knob.

Vector Modulation Operations and Applications

Fundamentals

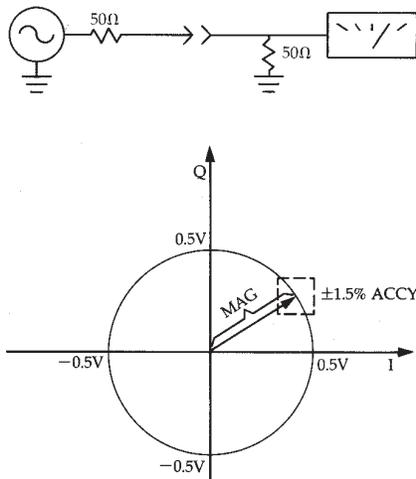
The vector modulation in the 8780A makes arbitrary phase and amplitude modulation possible with up to 700 MHz bandwidths. This is valuable in a large number of applications where standard modulation techniques are insufficient. Variable rise time pulses, high complexity digital modulations, some spread spectrum communications, and other non-standard modulations can all be accomplished with vector modulation on the 8780A Vector Signal Generator.

The Modulation Source

For Vector Modulation, two sources will usually be used; one each for the I and Q modulation inputs. The sources should have 50 Ω impedances.

Full scale I or Q signals are ±0.5 V into 50 Ω. However, vector accuracy is only specified within a circular I/Q space with a radius of 0.5 V. This means that although I and Q signals may independently be ±0.5 V, the square root of the sum of the squares of I and Q voltages must not be larger than 0.5 V to achieve the specified accuracy.

The best way to check the I and Q signal levels is to connect an accurate 50 Ω load to the source output and measure the voltage across the load as shown below.



$$Mag < 0.5 V \text{ or } \sqrt{I^2 + Q^2} < 0.5 V$$

When using vector modulation with the 8780A, filtering can be done with baseband filters at the modulation inputs or with bandpass filters at the RF output. If filters are used at the vector inputs, they should have as small a dc offset as possible since dc offsets cause carrier leakage in the final modulation.

Wideband Arbitrary Signal Generation Applications

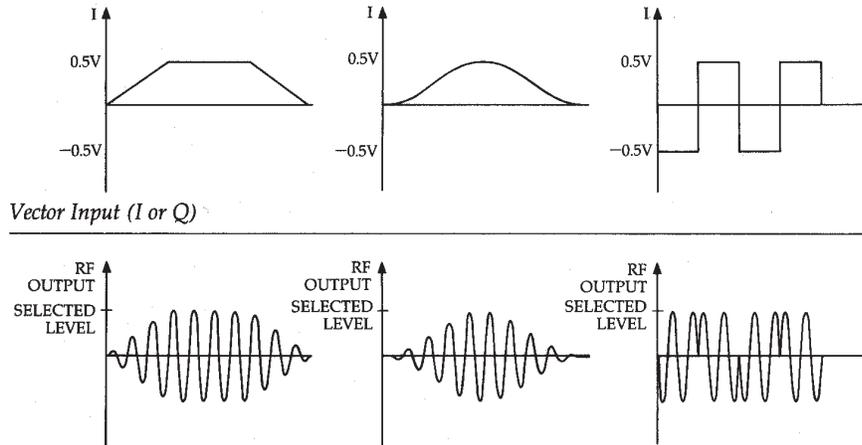
Vector modulation is done with the I and Q analog inputs. The two signals essentially “steer” the carrier around the I/Q plane when vector modulation is selected. In the I/Q plane, phase modulation (which includes frequency modulation) is represented as circular motion of the carrier about the center, and amplitude modulation appears as movement of the carrier toward and away from the center. From these basic ideas, we can generate a large number of arbitrary modulations by carefully selecting I and Q driving signals to create the modulation, or combination of modulations, desired.

The following examples help to show how appropriate I and Q driving signals are chosen:

Example 1: Shaped Pulses

If the envelope of a purely amplitude modulated signal is known, then that modulation is easily generated by applying the envelope to either the I or Q channel.

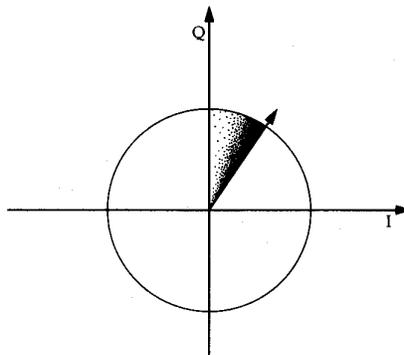
To generate a pulse with the modulation envelope shown, the modulating signal is applied to either the I or Q vector inputs of the 8780A. Since pulse modulation only varies the amplitude of the output, and not the phase, the driving signal should be entirely positive or negative.



RF output with vector modulation. Note example where I going negative causes a phase change.

Example 2: Frequency Hopping

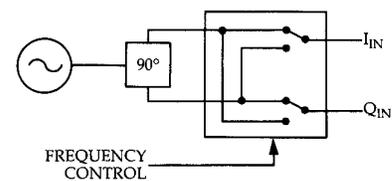
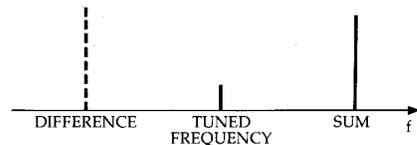
Frequency hopping may not seem at first to be the type of modulation that is easily generated using vector modulation, but in fact, frequency changes in the vector domain are little more than rotating vectors. The I and Q signals required to generate a rotating vector of constant magnitude are sine and cosine signals (or two sine waves that are 90 degrees apart). The rate at which the vector rotates is the frequency offset from the reference. The direction of rotation determines whether the modulated output frequency is the sum or difference of the reference and modulation frequencies.



Rotating vector represents a frequency shift

These ideas suggest a simple method for rapidly hopping the vector signal generator output between two frequencies. A tunable RF source and a 90 degree hybrid splitter can be used to produce the I and Q driving signals. When the 0 and 90 degree signals are applied to the I and Q inputs of the generator, the output is its tuned frequency plus the frequency of the modulation source. When the I and Q

inputs are exchanged using a PIN switch, the output frequency “hops” twice the frequency of the modulating source. If a 350 MHz source is used, the vector signal generator’s output can be hopped 700 MHz in a matter of nanoseconds.

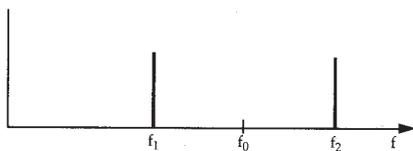


Frequency domain representation of frequency hop, and frequency hop block diagram

Example 3: MSK Signals

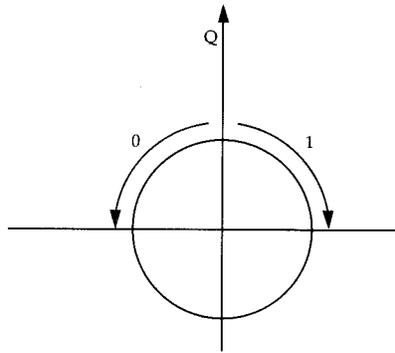
Minimum shift keying (MSK) is often used in satellite communications and other systems where nonlinear amplification is prevalent. MSK signals are frequency shift keyed (FSK) signals whose shift-frequency is a function of the clock rate of the data to be sent. The frequency shift is plus and minus one fourth the clock rate of the data. The generation of MSK signals with the vector signal generator is very similar to the frequency hopped signal just discussed.

If we use the same approach that was taken in the frequency hopped example, and use the data to switch the I and Q channels, the most important remaining concern is the precise generation of the shift frequency. This can easily be done by dividing the clock frequency by four using digital circuits. Once divided, the square wave output can be filtered to provide the sine wave needed for the frequency shift. Using this technique and good components, MSK can be done using the vector signal generator at rates up to several hundred MHz.

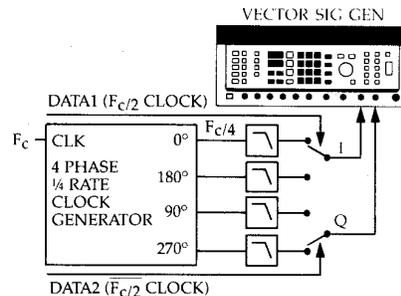


$$\begin{aligned}
 f_0 &= \text{tuned frequency} \\
 f_c &= \text{data clock rate} \\
 f_1 &= f_0 - f_c/4 \\
 f_2 &= f_0 + f_c/4
 \end{aligned}$$

MSK spectrum



MSK vector diagram



Block diagram for generating MSK

Example 4: Arbitrary Signals—The General Case

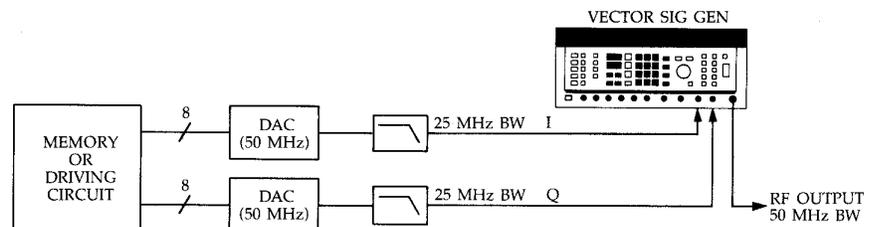
Almost any modulation can be simulated with the vector inputs of the 8780A, provided the modulation is defined in amplitude and phase or in terms of I and Q.

One way of generating a very wide range of I and Q driving signals is to use digital-to-analog converters (DACs). Using DACs allows I and Q driving signals to be generated from digital

signal definitions stored in memory. Theoretically, any conceivable type of modulation known could be generated using this basic technique.

If DACs are used to drive the I and Q vector inputs, the maximum theoretical IF modulation bandwidth will be equal to the clock rate of the DAC, provided it doesn't exceed the capabilities of the vector signal generator. Usually a clock rate twice the signal bandwidth is required to reconstruct a signal, but the vector modulation technique lets us use two lower rate sources to generate a signal with a bandwidth equal to the clock rate. Another way of putting it is that the modulation bandwidth is twice what it would be for a simple up-conversion and filter. For example, if two DACs with a maximum clock rate of 50 MHz are available, modulations can be simulated with bandwidths up to 50 MHz.

In the DAC application illustrated, two 50-MHz DACs are used to generate I and Q driving signals with 25-MHz bandwidths. Filters are used to eliminate the higher frequency components of the DAC outputs. The bandwidth of the vector signal generator output is 50 MHz since it combines the two 25 MHz bandwidths in the modulation process.

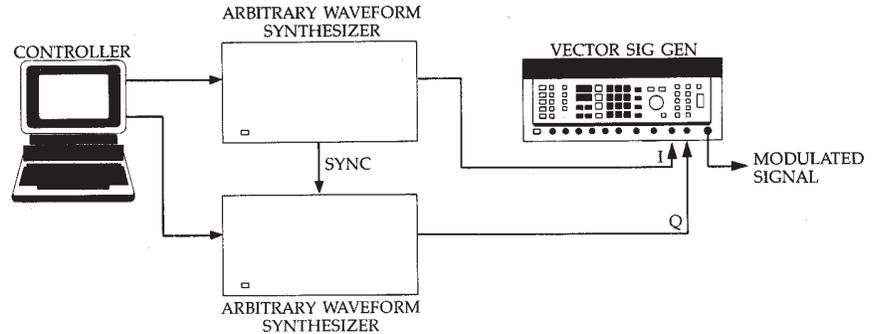


The vector signal generator's RF output bandwidth is twice the bandwidth of the I and Q signals when generating arbitrary modulations.

Measurement Considerations

The most important consideration when setting up the Agilent 8780A for vector modulation is that the I and Q amplitudes are appropriate. They must not exceed ± 0.5 V into 50Ω and operation is only specified for combinations of I and Q voltages whose square root of the sum of the squares is less than or equal to 0.5 V. Since the I and Q lines are dc coupled, dc offsets in the driving signals will degrade performance by “pushing” the I-Q pattern off center.

Another major concern is the synchronization of the I and Q driving signals. The output amplitude and phase at any instant are dependent on both the I and Q voltages, so delay of either signal with respect to the other will cause erroneous results. Generally, synchronization can be ensured by using the same clock for both the I and Q sources if they are digital, or the same trigger for both sources if they are analog.



An off-the-shelf solution for generating arbitrary modulations with up to 100 MHz bandwidth

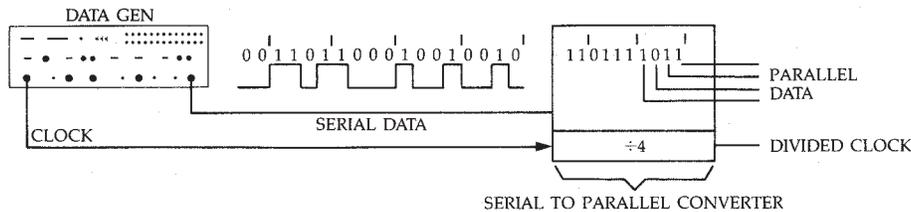
Agilent 8780A General Solution

To generate an arbitrary test signal using vector modulation, the appropriate I and Q signals must first be defined. For some simple signals, function generators can be used, but for more complicated waveforms, the I and Q signals must either be mathematically defined or generated from acquired waveforms. Since mathematical definition of waveforms can be a difficult task, a special software product is available to simplify the process. The Waveform Generation Language (WGL) is a software package that runs on the HP 9000 series 200 and 300 computers and is used to define waveforms for arbitrary waveform synthesizers like the 8770A Arbitrary Waveform Synthesizer. It allows definition of signals in the time or frequency domain and can be used to quickly generate a wide variety of I and Q vector signals.

If WGL is used to define I and Q signals, two 8770A Arbitrary Waveform Synthesizers can be used to generate the I and Q driving signals. The 8770A can generate arbitrary signals with 50 MHz bandwidths from the I and Q signal definitions generated using WGL.

A very comprehensive general method for generating I and Q signals using the 8770A Arbitrary Waveform Synthesizer is shown. In many cases, such as pulse generation, much simpler equipment will suffice. Using this general technique, almost any signal with modulation bandwidths up to twice the waveform synthesizer bandwidth (2×50 MHz = 100 MHz for the 8770A) can be generated. Of course, the maximum bandwidth capability of the vector signal generator will limit output bandwidth to 700 MHz (2×350 MHz) regardless of the waveform generator used.

Digital Modulation Operation and Applications



Some digital modulations require two or more parallel data lines, which can be derived using a serial-to-parallel converter.

Fundamentals

Digital modulation in the 8780A makes the generation of a variety of quadrature amplitude and phase shift keyed modulations easy. Digital signals at the vector signal generator's input control the phase and amplitude of the output signal making the generation of modulated test signals as easy as connecting the cables. Some of the applications where digital modulation will be appreciated are terrestrial and satellite digital communications as well as in phase-coded Radar/EW systems.

The Modulation Source

For digital modulations, the most common modulation source will be a data generator. Depending on the modulation chosen, you may need some additional hardware.

The digital inputs are essentially parallel inputs to the I-Q modulation map. For BPSK, QPSK, 8PSK, and 16QAM, there will be 1, 2, 3, or 4 digital modulation source lines required respectively. With Option 064 you have the choice of providing 6 parallel inputs or one serial input at a six times rate and a word clock for 64QAM. All other modulations still require parallel inputs. Since data generators usually have only one or two lines, we need a way of driving more inputs for modulations requiring more than two inputs.

One way of getting more data lines without using additional data generators is to use a serial-to-parallel converter. This takes one high data rate signal and divides it into two, three, or more lower rate data lines. If a clock is to be used, the clock must also be divided down to the new data rate.

Mapping

For the digitally modulated signal to be decoded properly in a particular system it must have the correct mapping.

Digital modulation mapping refers to the way the I-Q modulated states are determined from the digital word at the map inputs (in the case of the 8780A, the word at the digital input lines). Because mapping conventions vary, signals from similar systems may be incompatible. Because of this, the 8780A allows some flexibility in its mapping. By inverting, and/or switching selected digital input lines, many different mappings are possible.

Consult the 8780A data sheet for specific details regarding mapping.

TDMA Signals

The vector signal generator can generate signals typical of those used in most time domain multiple access (TDMA) applications. When the vector signal generator is used to generate TDMA signals, many valuable receiver and system tests are possible. The wide dynamic range of the generator's output facilitates simple receiver sensitivity testing, and the generator dc FM can be used to simulate Doppler shifts commonly seen in satellite communications.

Generating the correct modulation for TDMA signals involves two modulation processes: generation of the envelope, and generation of the modulation within the envelope or the frame of data. The pulse envelope can be generated using the vector signal generator's Burst digital modulation input, and the modulation within the pulse can be generated using one of the generator's digital modulations. Simultaneous burst operation ensures synchronous burst and data transitions and the same envelope and data rise times. The BPSK, QPSK, and 8PSK modulation modes of the generator will cover the modulation requirements of most TDMA signals.

Measurement Considerations

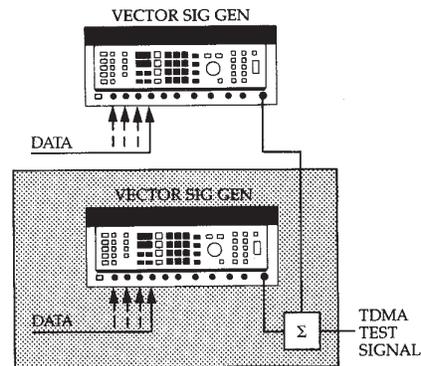
The most important aspect of generating TDMA signals, whether they be for terrestrial or satellite systems, is obtaining the correct modulation signals to drive the modulation source lines. You will have to provide the right digital signals depending on your modulation technique.

The signals consist of a Burst line, data lines (1 for BPSK, 2 for QPSK, and 3 for 8PSK), and possibly a clock.

Another possible concern in generating TDMA signals is the pulse on/off ratio. The vector signal generator's on/off ratio is specified to be > 50 dB (typically 55 dB). For greater dynamic range, an external pulse modulator like the 8730 series can be used, providing an 80 dB on/off ratio with rise times of 30 nanoseconds.

The Agilent 8780A Solution

An example that addresses most of the major concerns of TDMA signal generation is shown below. Since the data and burst lines vary with different applications, their generation is left to the user. Once the data lines are connected correctly, and the modulation types are selected, the vector signal generator is a versatile measurement source for TDMA communications receivers and subsystems.



If only one vector signal generator is used, the basic modulation will have to be modified to be representative of typical TDMA signals. TDMA systems have to quickly respond to changes in transmitter frequency, phase, level and even clock rate. One vector signal generator can simulate some of these changes by using dc FM, ALT LEVEL modulation, and varying the data clock frequency. These techniques will provide very rapid level switching and fluctuations of the clock and radio frequencies, but are not exactly like TDMA signals.

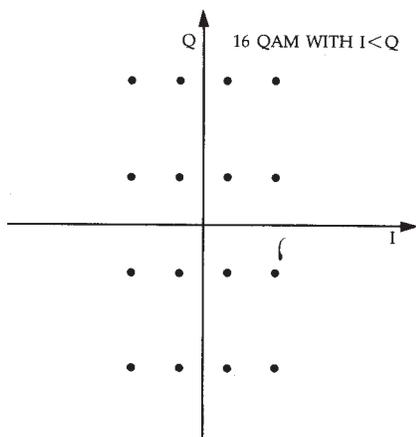
By using two generators, TDMA signals can be more accurately simulated. All of the variations in transmitters can be quickly simulated by simply changing the generators' front panel settings. Frequency variations can be precisely selected and the phase of successive transmissions from each signal generator will be the same. If only phase discontinuity is important without any frequency change, the Phase Bump special function can be used to shift one generator's phase with respect to the other in 0.1 degree increments.

There are several measurements possible with the 8780A Vector Signal Generator when generating TDMA signals. Modulation errors can even be introduced for receiver testing. By using the vector signal generator's Coherent Carrier, system components can be dynamically characterized using techniques described in the component test section of this chapter. BER measurements can also be made as described in the next section.

BER Measurements

Application

Bit error rate (BER) tests are the most direct way to measure how well a digital microwave radio is working. By measuring the number of errors received for a given number of transmitted bits, the radio's ability to communicate information can be assessed. When the 8780A Vector Signal Generator is used to generate a benchmark digitally modulated signal, BER measurements can be used to determine a receiver's tolerance to a wide variety of degradations including quadrature error, Doppler frequency shifts, amplitude imbalances, and fades.



Simulating "unbalanced" modulations is possible with the 8780A I<Q modulation.

Measurement Considerations

Aside from selecting your modulation format on the 8780A, the most important consideration in making BER measurements is getting the Vector Signal Generator's modulation states for a given digital input to match those of the radio to be tested. To set up the 8780A to perform the correct mapping, the digital input lines may be inverted and switched with one another. The default mappings are shown in the vector signal generator data sheet, and are easy to change by exchanging and/or inverting data lines.

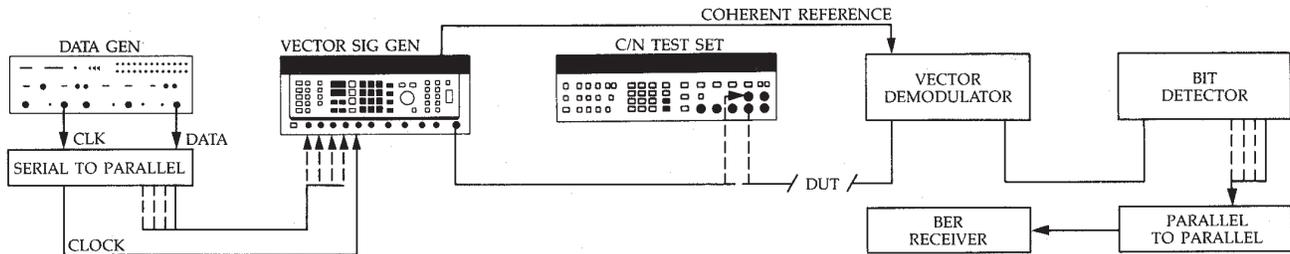
Once the correct mapping and modulation types have been chosen, there may still be some fine tuning required to make the 8780A modulation match the system under test. Some radios use modulation formats which are rectangular instead of square. This just means that either the I or Q signal level is attenuated with respect to the other. These modulations may be generated with the 8780A by using SET I<Q to select the appropriate attenuation for the I signal. Once the I signal attenuation is chosen, the I<Q modulation key is pressed to activate I<Q for the modulation selected.

The Agilent 8780A Solution

Setting up the 8780A Vector Signal Generator for BER tests involves three basic steps: generating the digital input signals, setting up the mapping, and connecting the BER detector. The mapping concerns are described earlier in this section, and the BER interface concerns are addressed below. Degradations may also be added to the signal to stress the receiver under test.

A serial-to-parallel converter may be needed to increase the number of data lines available. For BER testing, the BER receiver will expect the initial serial line pattern, so a parallel to serial conversion will also be required at the receiver output. Sometimes this is already done in the receiver, but if it isn't, a parallel-to-serial converter will have to be built that complements the serial-to-parallel converter.

The clock input lines should not be neglected. Although the 8780A Vector Signal Generator can generate modulations without external clock inputs, a clock reduces the amount of jitter and data asymmetry in the modulated signal and should be used whenever possible. When serial-to-parallel converters are used, the clock must also be divided down with the data rate, and multiplied up in the case of the parallel-to-serial converter.



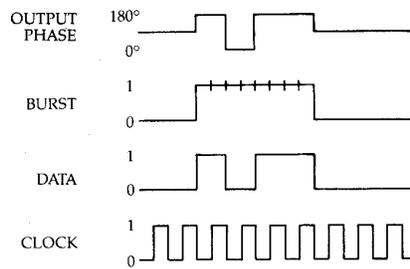
Measurement setup for automated BER versus C/N curves

Many realistic tests can be done by frequency modulating the test signal to simulate Doppler shifts, scalar modulating to simulate fades, introducing some amplitude imbalance with I<Q, or testing carrier recovery range by varying the test signal frequency using dc FM. Other degradations which may be introduced using the special functions include quadrature errors, and carrier leakage. (See Appendix A for details.) With the addition of the Agilent 3708A Noise and Interference Test Set, residual BER, BER vs. carrier to noise (C/N), and BER vs. carrier to interference (C/I) tests can all be easily made.

For more information about BER measurements refer to AN 343-1 "Measurement Applications in Digital Microwave Radio" and "Additive White Noise and Interference Testing of Digital Radio Systems with Noise of Finite Crest Factor" (Agilent literature number 5954-2007).

Phase-Coded Radar Pulses Application

The vector signal generator can generate a wide range of phase-coded radar pulses including Barker codes. By using Burst and digital modulation simultaneously, several complex modulations can be included within pulses for testing radar receivers and other system components.



Example burst, data, and clock signals for generating a phase-coded pulse

Generating the correct modulation for complex radar signals usually involves two modulation processes: generation of the pulse envelope, and generation of the modulation within the pulse. The pulse envelope can be generated using the vector signal generator's Burst digital modulation input, and the modulation within the pulse can be generated using the digital modulation of the vector signal generator. Simultaneous burst operation ensures synchronous burst and data transitions and the same envelope and data rise times. The BPSK, QPSK, and 8PSK modulation modes of the generator will cover the modulation requirements of most phase-coded radar signals.

Measurement Considerations

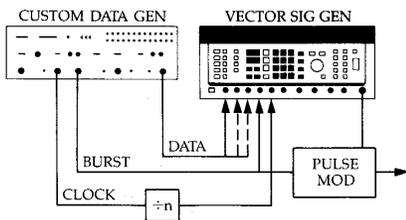
The most important aspect of generating phase-coded radar pulses, whether they be Barker codes or some other type of coding, is obtaining the correct modulation signals to drive the modulation source lines. You will have to provide two, three, four, or five digital signals depending on your modulation technique. The signals consist of a Burst (pulse) line, data lines (1 for BPSK, 2 for QPSK, and 3 for 8PSK), and possibly a clock. The 8780A data sheet will tell you how the digitally modulated states correspond to the correct digital words at the inputs.

The other major concern in generating phase-coded pulses is the pulse on/off ratio. The vector signal generator's on/off ratio is specified to be >50 dB (typically 55 dB). For greater dynamic range, an external pulse modulator like the Agilent 8730 series or 11720A can be used, providing an 80 dB on/off ratio with rise times of 30 ns.

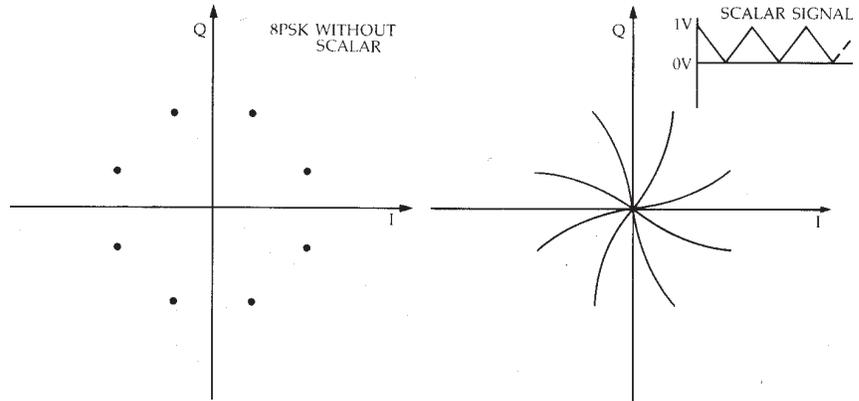
The Agilent 8780A Solution

A simple example of the technique for generating phase-coded radar pulses is shown below. Since the data and Burst signals vary with different applications, their generation is left to the user. Once the data lines are connected correctly, and the modulation types are selected, the vector signal generator is a versatile measurement source for applications involving phase-coded radar signals.

There are several measurements possible with the 8780A Vector Signal Generator when generating phase-coded radar signals. Errors in level, frequency, and even modulation can be introduced for receiver testing. By using the vector signal generator's Coherent Carrier, system components can be dynamically characterized using techniques described in the next section.



Example setup for generating phase-coded pulses



Vector Analyzer display of AM-PM

Coherent Dynamic Component Test Application

Component test requirements are rapidly outgrowing the low bandwidth measurement solutions that were used in the past. Phase and amplitude distortions now need to be dynamically measured over wide modulation bandwidth channels for modern phased array radar as well as for digital communications components. The vector signal generator, with its Coherent Carrier, is well-suited to generating test signals for dynamic component test systems.

The biggest advantage of dynamic component test over low modulation bandwidth network analysis measurements is that the test signal can be the same as the signal that the components will see in actual use. For some components, this is a necessity. Phased array radar amplifiers often overheat when tested under CW operation, so they have to be tested using pulsed signals.

Communication TWTs and solid state amplifiers on the other hand may not perform the same under low bandwidth or CW operation as they do with wideband signals, making dynamic characterization attractive.

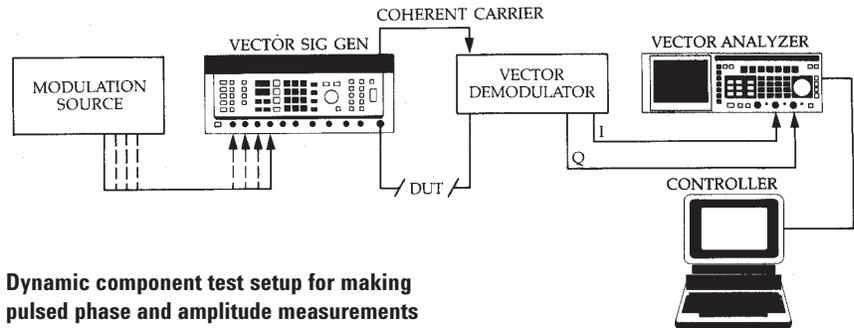
Example: AM-PM Measurements.

The dynamic component test using vector techniques is well suited to the measurement of amplitude modulation to phase modulation conversion (AM to PM) in non-linear amplifiers. This measurement is made with a vector signal generator signal that is digitally modulated and Scalar modulated simultaneously. (See Chapter 1 for details on Scalar.) The DUT is used to amplify the test signal before demodulation using a vector demodulator. The demodulated I and Q signals are displayed on a vector analyzer.

Any AM to PM conversion shows up as curving of the amplitude fluctuation lines. Using the vector analyzer's calibrated markers, the AM to PM characteristics can be easily quantified at several points. For a more complete analysis, a desktop computer can be used to calculate AM to PM curves from the vector analyzer data.

Measurement Considerations

Dynamic component test is much like network analysis. The vector signal generator is used to generate a test signal that is representative of the modulation bandwidth, frequency, and amplitude that the device under test (DUT) will see in normal operation. The Coherent Carrier is used with a vector demodulator to demodulate the output of the excited DUT into I and Q components. By using a vector analyzer to display the I and Q signals, phase and amplitude response of the channel can be deduced. A computer can be added to perform frequency transforms, and to calculate transfer functions and S-parameters of the DUT.



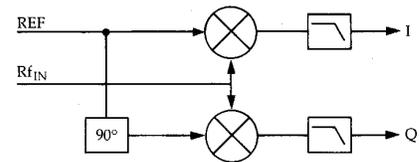
Dynamic component test setup for making pulsed phase and amplitude measurements

The Agilent 8780A Solution

The general dynamic component test setup is shown above. The measurement equipment consists of a modulation source, the vector signal generator, a vector demodulator, a vector analyzer, and a computer. All of the required equipment can be purchased off the shelf with the exception of the vector demodulator, which can be built from readily available parts.

The modulation source and modulation type chosen for the measurement will depend on the application or the component. The three most frequently used signal types for dynamic component test are pulse (or Burst), digital modulation, and a combination of the first two (or phase-coded pulses). For a detailed description of the techniques used to generate digital modulation and phase-coded pulses, see the BER and phase-coded pulse sections of this section.

More information about specific dynamic component test and measurement procedures can be found in AN 343-2 "Dynamic Component Tests Using Vector Modulation Analysis."



Simplified vector demodulator block diagram

Building a Vector Demodulator

The vector demodulator consists of two mixers and a quadrature splitter with some necessary low pass filters. It performs the complementary function to the vector modulator that is in the 8780A Vector Signal Generator: it demodulates a signal into its I and Q components.

Building a vector demodulator is not difficult. Care must be taken to be sure that all of the components have wide enough bandwidth for the signals to be tested. Aside from bandwidth, special care must be taken to ensure that the filters are flat within the range of frequencies of interest, yet roll off fast enough to eliminate the sum frequency components.

Finally, I and Q dc offsets, quadrature error, and amplitude imbalances may occur. If this is the case, they may either be removed in hardware or compensated for using the calibration functions of the vector analyzer and a reference signal from the vector signal generator.

Frequency Modulation Operation and Applications

Fundamentals

The FM capabilities of the vector signal generator serve two purposes in generating test signals. For many applications, the linearity and low distortion specifications of the FM circuitry make it the perfect primary modulation source. Where another modulation type is primary (like a digital vector modulation), the vector signal generator's low phase noise FM capabilities can be used to simulate Doppler shifts or to test carrier recovery loop bandwidths.

The Modulation Source

Frequency modulation requires one modulation source. The specified full scale range is ± 0.5 V for dc coupled FM and 1 V_{p-p} for ac coupled FM. FM sensitivity is selected with the SET FM key, and the value selected corresponds to the peak-to-peak deviation that will be generated by full scale inputs. FM sensitivity has a range of 50 kHz to 50 MHz for ac FM and 150 Hz to 150 kHz for dc FM. Allowable rates for ac FM and dc FM are 20 Hz to 12 MHz and dc to 10 kHz respectively.

AC coupled FM will normally be the modulation type desired. DC coupled FM was designed primarily for phase locking the vector signal generator. dc FM has very low modulation bandwidths and preserves the vector signal generator's low phase noise characteristics. If ac coupled deviations are desired with dc coupling, there is a special dc FM mode that allows up to 50 MHz p-p deviations at rates up to 10 kHz.

Generating Chirps For Radar Receiver Measurements

Application

The vector signal generator's FM and simultaneous Burst are suited to generating chirp radar test signals.

There are two components in a chirp modulation: the amplitude envelope and the frequency modulation. A chirp can be generated with an FM source and a Burst source. Normally, the FM part of the pulse is a linear ramp and the pulse envelope is square. Both of these signals have to be synchronized, and if turn-on phase is important, the amplitude and frequency envelope should be synchronized to the vector signal generator carrier signal.

When generating chirp signals, the generator is a versatile measurement source for radar receiver testing. Level, frequency, and many other parameters can be changed to stress the receiver.

Measurement Considerations

The three most important parameters of a chirp signal are length of the pulse, frequency deviation, and on/off ratio. Using function generators as modulation sources allows easy adjustment of all three parameters. Chirp length can be controlled by varying pulse width and sawtooth rate. FM deviation is set with the SET FM and level of the FM input. Pulse depth on the vector signal generator is specified to be >50 dB (typically 55 dB) and can be improved with an external pulse modulator.

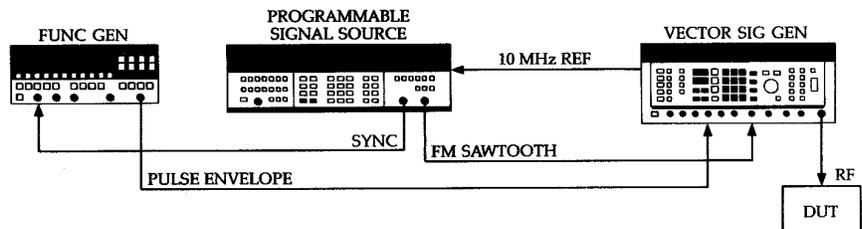
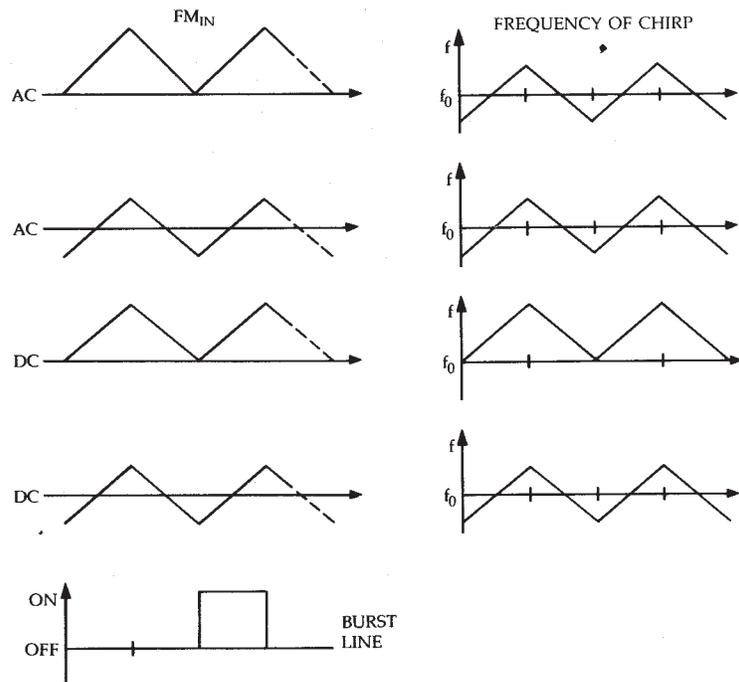
The FM ramp may be generated with either ac coupled or special function Wideband dc FM. AC coupled FM generates a chirp signal centered at the vector signal generator's tuned frequency. With dc FM the chirp signal generated will start and stop at the frequencies determined by the FM input signal, but in the Wideband dc FM mode dc offsets may affect frequency accuracy (typically <1 MHz offset).

Since radar chirps are often very wideband, it may be necessary to overdrive the FM input of the vector signal generator to achieve wide enough deviations. Although the full-scale FM inputs are specified to be ± 0.5 V and 1 Vp-p for dc and ac coupling, respectively, greater deviations are possible by exceeding these levels. The FM input is protected by a relay which will prevent damaging the FM circuitry, but it won't disconnect the input until levels reach 5 Vp-p or 2.5 V average. By overdriving the FM input, peak-to-peak deviations up to 250 MHz are typically possible using ac coupled FM or special function Wideband dc FM.

The Agilent 8780A Solution

To generate a chirp pulse with the vector signal generator, two external modulation sources are required: an FM and a Burst source. These signals can be generated with function generators such as the Agilent 8165A and 8116A. With the function generator timebase locked to the 8780A, the start phase of successive chirps will be within a couple of degrees of one another.

If greater than 50 dB depth is required, an external modulator such as the Agilent 8730 series can be used to provide an 80 dB on/off ratio with rise times of 30 nanoseconds.



Example setup for generating wideband chirps with the same starting phase with respect to the Coherent Carrier

Satellite Video Signal Generation Application

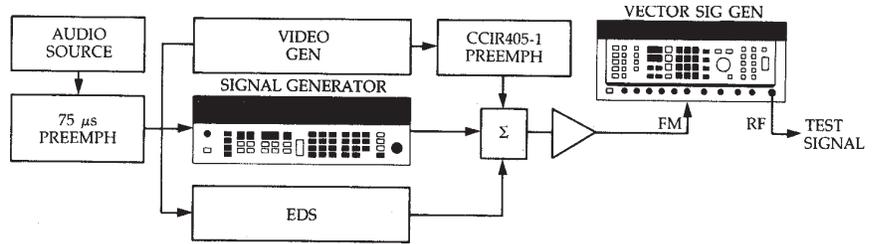
The ac FM portion of the vector signal generator was designed to exceed the strictest requirements of satellite video signal generation. Although there are many different ways to generate satellite video signals, the approach outlined in this section addresses most of the concerns that one might encounter using the vector signal generator.

The vector signal generator's FM modulator provides good performance for a wide range of modulating signals, but performance is optimized for deviations of 27.6 MHz p-p, covering the deviation of most satellite video signals. At this deviation the vector signal generator's typical differential gain and phase are <2% and <1°, respectively. Other characteristics which set the FM capabilities of the instrument apart are given below:

Frequency Response
(50 Hz to 8 MHz): <±0.5 dB

Field Time Distortion: <1%
Luminance to Chrominance Delay:
<20 ns

Luminance to Chrominance Gain:
<±0.3 dB



Complete satellite video signal simulation block diagram

Measurement Considerations

There are three components to a satellite video signal: the video signal, the audio signal, and the energy dispersal signal (EDS). To generate a satellite video signal, the sum of these three signals is applied to the FM input of the vector signal generator.

The video signal will usually come from a standard video source or a dedicated video pattern generator. Before the video portion of the signal can be added to the other two components, it must be passed through a CCIR 405-1 video preemphasis filter.

The audio portion of the signal is usually modulated onto a subcarrier between 5.5 to 7.5 MHz before being added to the FM input. It is also filtered first with a 75 μs pre-emphasis filter.

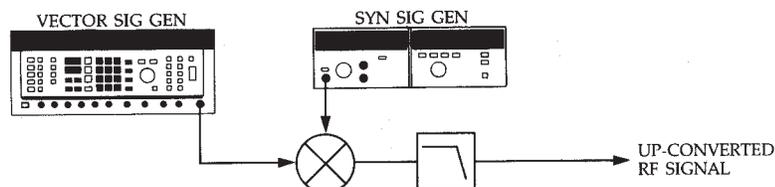
The EDS portion of the modulating signal is derived from the video signal and has no filtering before addition to the modulating signal.

Following the summer used to add the three components, an amplifier may be required. The maximum input sensitivity of the 8780A is 50 MHz p-p/1 Vp-p, which means that about a 0.55 Vp-p signal level is needed for 27.6 MHz p-p deviations.

The Agilent 8780A Solution

A block diagram of the components needed for satellite video signal generation is shown. Since measurement needs vary, the diagram serves only as an example that addresses all of the basic requirements of satellite video generation. For some applications, the audio or EDS generators may not be required, and the output of the vector signal generator may need additional conditioning (e.g., up-conversion or the addition of noise) before being applied to the device under test.

Up-Converting The Vector Signal Generator



Simple up-conversion of the vector signal generator to microwave frequencies

For many measurements, the tunable RF output of the vector signal generator will have to be shifted up in frequency. The vector signal generator covers a 10 MHz to 3 GHz range, but with a few readily available parts and an up-conversion source, it can produce microwave test signals as well.

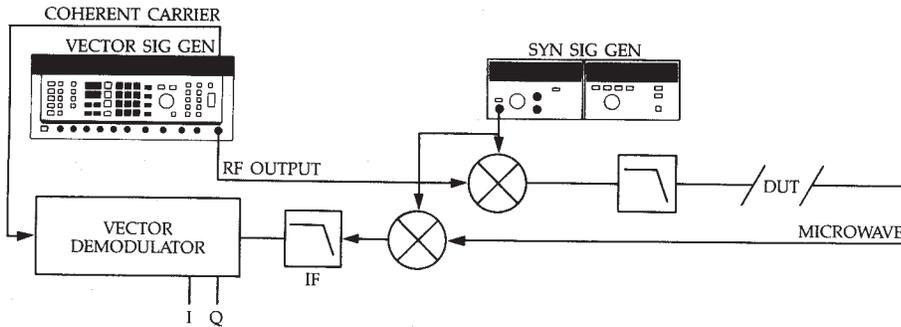
Up-Converting The RF Output

There are three parts of an up-conversion system: an up-conversion source, a mixer, and a filter. In some cases, the filter will not be needed because the device under test will have its own input filter.

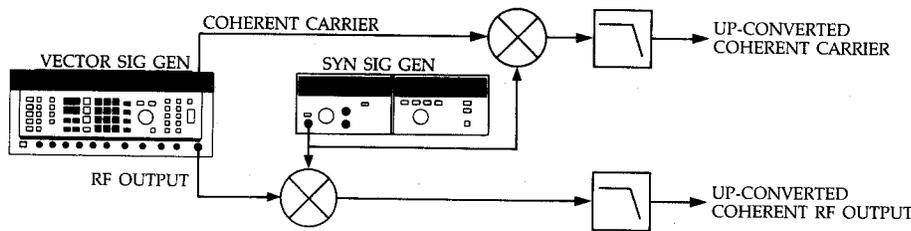
The most important part in the up-conversion process is the up-conversion source. The final output frequency will be the sum or difference of the vector signal generator's frequency and the up-conversion source's frequency, and any noise inherent in the up-conversion signal (phase noise in particular) will be transferred onto the test signal. Since the systems that the vector signal generator is used to test are particularly sensitive to phase noise, a very clean source should be chosen for up-conversion. The Agilent 8671B Synthesized CW Generator is a good choice offering synthesizer performance at an economical price.

The other two parts of the upconversion system, the mixer and the filter, should also be carefully selected. The most important characteristic of these components, aside from operating at the correct frequencies, is their bandwidth. The mixer and the filter should have bandwidths that exceed those of the signals to be generated by the vector signal generator. For the mixer, the IF and RF ports should have wide bandwidths, but the LO port doesn't have to—provided it covers the LO frequency. The filter should also have a flat response through the passband so it doesn't degrade the signal.

To reduce the complexity of the filter, the vector signal generator and LO frequencies should be chosen to separate the sum and difference frequencies as much as possible.



Using the Coherent Carrier with the up-converted RF Output



Up-conversion of Coherent Carrier with the RF Output

The Coherent Carrier And Up-Conversion

There are some special considerations when using the Coherent Carrier with up-converted signals. If these considerations are observed, component tests, demodulator tests, and others that require the reference can also be done at higher microwave frequencies.

After the RF output has been up-converted to perform a measurement at a microwave frequency, it can be down-converted using the same LO that was used in the up-conversion. When this is done, the Coherent Carrier can be used normally to demodulate the down-converted test signal.

If demodulation has to be done at microwave frequencies, both the RF output and the Coherent Carrier will have to be up-converted. The same technique used to up-convert the RF output applies to the Coherent Carrier. But, because the Coherent Carrier is a narrow-band signal, the demands on the mixers and filters used to up-convert it are less stringent. The same LO used to up-convert the RF output may also be used to up-convert the Coherent Carrier, simplifying the setup. Calibrating a vector demodulator at higher microwave frequencies is one example of the need for an up-converted Coherent Carrier.

When using the Coherent Carrier as a demodulator LO signal, the high power Coherent Carrier option (Option 002) will ensure sufficient power for driving mixers. Option 002 increases the Coherent Carrier output power from -20 dBm to typically >+10 dBm.

Appendix A. Special Functions

Special functions might be called hidden features. They represent the efforts of the design team to provide as much versatility as possible by preserving some of the most arbitrary control capabilities of the instrument. Special functions don't usually appear on the front panel of the instrument; this is done to simplify front panel design and to make the instrument easier to use. As a consequence, though, some of the capabilities of an instrument like the Agilent 8780A are "hidden." Please read this section and see if the needs of your application are addressed by one or more of the special functions.

Show Active Specials (0.0)

This special function displays on the LCD the other special functions that are currently selected.

Lock Step, Extend Range (1.0–1.1)

This special function locks the step attenuator and extends the output level range tunable with the vernier. This is important when performing sensitivity measurements near a step attenuator switch point when the step attenuator switching might interfere with the measurement. Typical range extension is about 10 dB lower and 0.1 dB higher than the unextended range.

At the high and low ends of the extension, some performance degradation is expected, and vector accuracy is unspecified.

Wideband dc FM (2.0–2.1)

Wideband dc FM is an unspecified frequency modulation mode that allows up to ± 50 MHz deviations at up to 10 kHz rates. Higher deviations are possible by over-driving the FM input with average signal values typically up to ± 2.5 V (up to 250 MHz p-p deviations). The input is protected with a relay which disconnects the driving input if the driving signal's average value is too high.

BB Filter Override (3.0–3.1)

BB Filter Override is used to select one of the four built-in spectral limiting filters for use with digital modulations. Normally the 8780A selects a spectral limiting filter that has a passband less than half the tuned frequency to avoid the spectral folding that happens when modulation bandwidths greater than the generator's frequency are combined. BB filter override allows either higher or lower passband filters to be selected from those in the instrument.

The four low pass BB filters available in the 8780A have the following approximate 3 dB frequencies: 40 MHz, 90 MHz, 180 MHz, and 250 MHz. The 3 dB roll off frequency for the I and Q channels without filters is >350 MHz.

External Filter Correction Factors (4.0–5.1)

Although the vector signal generator can calibrate through external dc coupled filters, you may want to enter your own correction factors for ac coupled or dc coupled filters. This special function allows you to do that. You can select losses in the range of 0 to 3 dB with a resolution of 0.1 dB. Filters with loss or gain out of this range are not recommended for use with the 8780A.

Carrier Leakage (6.0–6.1)

Permits the addition of some amount of carrier to a digitally modulated signal; it lets you “spike” a signal. Carrier leakage is selected in dBc and can be from -40 to -3 dBc. Carrier leakage is always added in the I channel. Digital modulation accuracy may be adversely affected, especially for large amounts of carrier leakage.

Internal PRBS Generation (7.0–7.1)

The vector signal generator can use its own microprocessor to generate pseudo random bit sequences to drive its digital input lines. Although too slow for BER testing (typically 5 kHz), the internal PRBS signals simplify generation of test patterns. Since all of the digital lines are driven by different taps of the same $2^{15} - 1$ sequence, any vector signal generator digital modulation can be generated.

Fast Frequency Switching (8.0–8.1)

This function decreases the typical time required to switch the output frequency of the vector signal generator to 100 ms. The reduced switching time is achieved by not readjusting the output level each time a new frequency is selected. For automated tests where many measurements have to be made quickly over a narrow band, this special function can cut total measurement time in half.

All Modulation Off (11.0)

Provides a convenient way to turn off all modulations presently active. It is especially useful when several modulations are being used simultaneously.

Blank Display (12.0–12.1)

Used to turn the vector signal generator’s LCD display off to prevent possibly sensitive information from being shown. This is especially valuable for secure system measurements where frequencies and modulations must be kept secret.

Phase Bump (13.0–13.1)

Shifts the RF output phase with respect to another synthesizer’s output, provided that the two synthesizers are phase locked. Phase Bump can introduce phase shifts up to ± 360 degrees in 0.1 degree increments. Phase Bump does not shift the phase between the vector signal generator’s RF output and Coherent Carrier. Since the phase of any synthesizer may drift slightly with respect to its reference, Phase Bump stability is not specified.

DAC Control (14.0–15.2)

This function lets you directly set any of the vector signal generator’s thirteen internal digital-to-analog converters from the front panel. You can control the digital states within the I/Q plane, the quadrature of the modulator, and I and Q channel attenuation.

Selective Calibrations (20.0–20.3)

These functions calibrate only the baseband, output, or FM sections of the instrument instead of the complete calibration that is done by the front panel CAL key. This may be important in automated test systems where many measurements have to be made quickly and calibration time can be costly. By performing only the calibration pertinent to the measurement being made, you can save time and ensure accurate operation of the vector signal generator.

Set GPIB Address (25.0)

The 8780A GPIB address is set or changed using this special function from the front panel.

Service Voltmeter (52.0–52.8)

Acts like a service probe that can measure critical signal voltages in the instrument to isolate failures or otherwise assure correct operation. One of eight test points is selected, then the voltage at that point is displayed on the vector signal generator front panel.

Direct Control (53.0–53.3)

Used to program any of the 8780A’s internal control latches. These latches control all DAC, attenuator, filter, and other hardware settings. In fact, most other specials represent a simplified way of doing what could have been done using Direct Control.

Hard Reset (99.9)

Used to set the vector signal generator to its original configuration. It erases all user-set frequencies, instrument configurations, and recent calibration information.

Appendix B. GPIB Commands

PR	Presets the instrument	RO	Sets the R1 state	QP0	Turns off QPSK
SP0	Turns off all special functions	RT	Sets the R2 state	QP1	Turns on QPSK
SY, ST	Stores current instrument setting	AO	Sets the phi1 state	QA0	Turns off 16QAM
SSP	Sets special function	AT	Sets the phi2 state	QA1	Turns on 16QAM
RC	Recalls an instrument setting	SFM	Sets FM deviation	STQ0	Turns off 64QAM
CL	Calibrates instrument	SAL	Sets alternate level	STQ1	Turns on 64QAM
EC0	Selects asynchronous operation	SIQ	Sets I<Q	AL0	Turns off alternate level
EC1	Selects one clock operation	AI	Sets alternate level I	AL1	Turns on alternate level
EC2	Selects two clock operation	VA	Sets variable data level	BR0	Turns off Burst
CK0	Sets clock level to 'auto'	IS	Sets increment value	BR1	Turns on Burst
CK1	Sets clock level to 'ECL'	GZ	GHz terminator	SC0	Turns off Scalar
CK2	Sets clock level to 'GND'	MZ	MHz terminator	SC1	Turns on Scalar
DL0	Sets data level to 'VAR'	KZ	kHz terminator	IQ0	Turns I<Q off
DL1	Sets data level to 'ECL'	HZ	Hz terminator	IQ1	Turns I<Q on
DL2	Sets data level to 'GND'	DBM	dBm terminator	RF0	Disables RF output
EF0	Unselects external filters	VL	Volts terminator	RF1	Enables RF output
EF1	Selects external filters	MV	Millivolts terminator	CR	Moves cursor in set modes
DF0	Selects AC FM coupling	UV	mvolts terminator	RM	Enables service request mask response
DF1	Selects DC FM coupling	DBR	dB terminator	CS	Sets status byte to zero
IFM	Inverts or uninverts FM input	PC	Percent terminator	LP1	Enables system configuration response
IPI	Inverts a digital input	EN	Enter terminator	LP2	Enables system status response
IPN	Sets input to not inverted	KN0	Disables the knob	DE	Turns LCD display on
UP	Adds the increment to current set value	KN1	Enables the knob	DD	Turns LCD display off
DN	Subtracts the increment from current set value	CW	Turns off all modulations	DA	Turns on all LCD display segments
FR	Sets frequency	FM0	Turns off FM	@1	Accepts next character as 'binary request service mask'
CF	Enters set frequency state	FM1	Turns on FM	?ID	Enables GPIB address response
LV, LE, AP, PL	Enters set level state	BP0	Turns off BPSK	?CL	Enables "still calibrating?" response
IO	Sets the I1 state	BP1	Turns on BPSK	SM	Enables system status message response
IT	Sets the I2 state	EP0	Turns off 8PSK		
Q0	Sets the Q1 state	EP1	Turns on 8PSK		
QT	Sets the Q2 state	TS0	Turns off two-state		
		TS1	Turns on two-state		
		VM0	Turns off vector modulation		
		VM1	Turns on vector modulation		

Service Request Mask:

8	7	6	5	4	3	2	1
not used	RQS	soft error	ready	power fail	hard error	not used	cal done

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Printed in U.S.A. 10/00

5954-6368



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