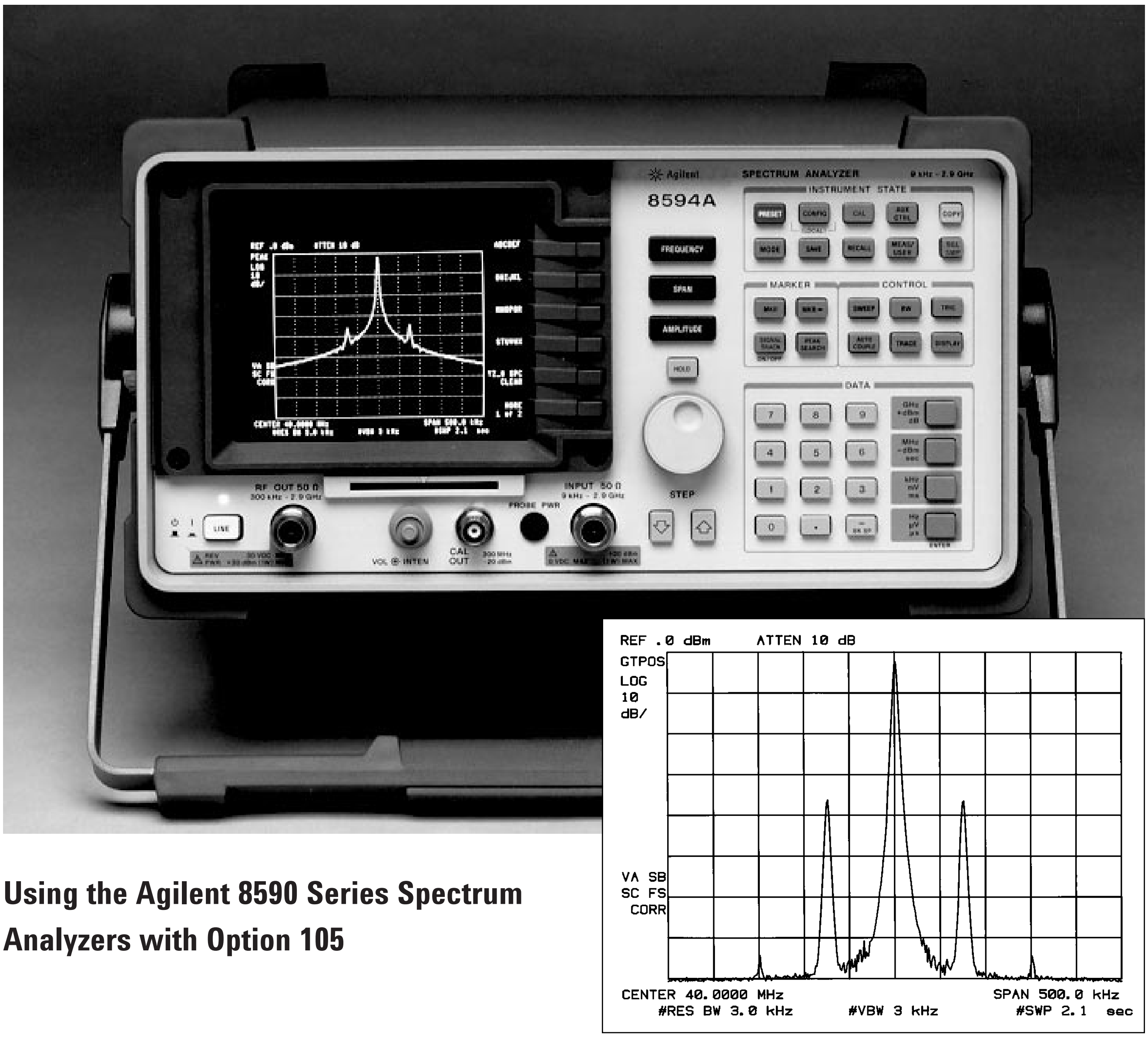
Agilent PN 8590-2

Time-Gated Spectrum Analysis: New Measurement Fundamentals

Product Note



Using the Agilent 8590 Series Spectrum Analyzers with Option 105

Agilent Technologies

Innovating the HP Way

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Chapter 1
Introduction–what to expect from this product note

Time-gated spectrum analysis allows you to obtain spectral information about signals in the frequency domain that are separated in the time domain. Using an external trigger signal to separate these time-varying signals, you can perform the following operations:

- Measure any one of several signals separated in time; for example, you can separate the spectra of two radios time-sharing a single frequency.
- Exclude interfering signals, such as periodic pulse edge transients that exist for only a limited time.

This product note serves as the primary operator's reference for Option 105, time-gated spectrum analysis capability, of the Agilent Technologies 8591A, 8593A, 8594A, and 8595A portable spectrum analyzers. A brief description of Option 105 can also be found in the Installation Manual, Operating Manual, or Programming Manual (each having print dates after November 1, 1990) of the Agilent 8590 series spectrum analyzers.

Note regarding use of oscilloscope:
Most examples in this product note show the spectrum analyzer being used with a multi-channel oscilloscope. Since time-gated spectrum analysis helps bridge the gap between the time and frequency domains, viewing signals on spectrum analyzers and oscilloscopes may be useful.

If you already know some of the time-domain parameters of the signal, you may be able to successfully perform time-gated spectrum measurements using an oscilloscope. However, if you are unsure of the time-domain characteristics of the signal, or uncertain of how it is synchronized with the timing trigger signal, you may find it very helpful to begin using both an oscilloscope and a spectrum analyzer until you have determined certain signal parameters. Chapter 6 describes the signal parameters you'll need to know.

Note regarding calibration, markers, and detectors:
When performing the front-panel calibration routines, be sure that nothing is connected to the gate trigger connector on the back panel of the spectrum analyzer; Chapter 7 provides more information. Most marker functions are available with time gating, with the exception of MARKER NOISE, which requires a sample detector. During swept frequency measurements, only the GTPOS detector should be used.

Chapter 2
Why time gating is needed

Traditional frequency-domain spectrum analysis provides only limited information for certain signals. Examples of these difficult-to-analyze signals include the following signal types:

- Pulsed RF
- Time multiplexed
- Time domain multiple access (TDMA)
- Interleaved or intermittent
- Burst modulated

In some cases, time-gating capability enables you to perform measurements that would otherwise be very difficult, if not impossible. For example, consider Figure 2-1, which shows a simplified digital mobile-radio signal in which two radios, #1 and #2, are time-sharing a single frequency channel. Each radio transmits a single 1 ms burst, then shuts off while the other radio transmits for 1 ms.

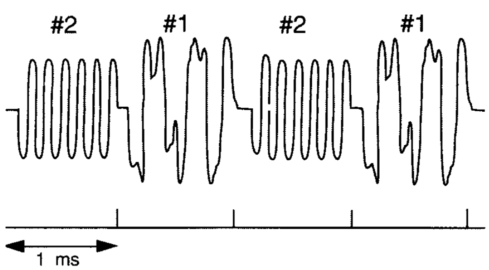

Figure 2-1 Simplified digital mobile-radio signal in time domain

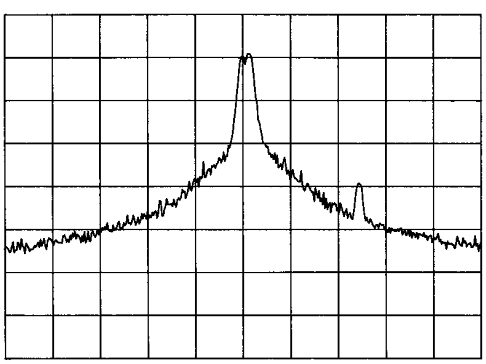

Figure 2-2 Frequency spectrum of combined signals. Which radio produces the spurious emissions?

What if you wanted to measure the unique frequency spectrum of each transmitter? Unfortunately, a traditional spectrum analyzer cannot perform that measurement. By the time the spectrum analyzer has completed its measurement sweep, which lasts approximately 20 ms, the radio transmissions will have switched back and forth ten times. Since the radios are both transmitting at the same frequency, their frequency spectra will overlap, as in Figure 2-2. The spectrum analyzer shows the combined spectrum; you will not be able to tell which part of the spectrum results from which signal.

Using the time-gate capability and an external trigger signal, you can see the separate spectrum of radio #1 (or radio #2 if you wished) and identify it as the source of the spurious signal shown, as in Figure 2-3.

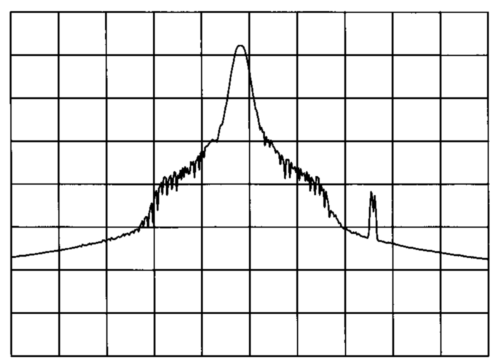

Figure 2-3a Time-gated spectrum of signal #1 identifies it as the source of spurious emission.

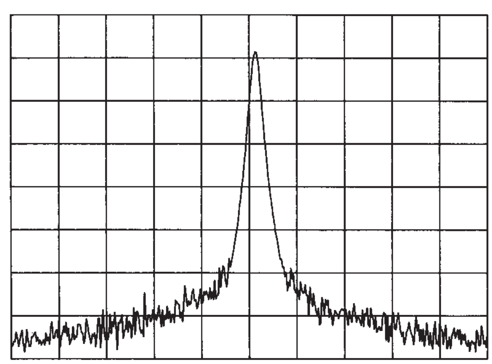

Figure 2-3b Time-gated spectrum of signal #2 shows it is free of spurious emissions.

Chapter 3
A new approach: time-gated spectrum analysis

Spectrum analyzers have always allowed the operator to define a frequency window in which to perform measurements. Imagine being able to specify a time window in which your spectrum analyzer would measure a signal. Such a feature could be quite worthwhile, since it would provide your analyzer with unique capabilities:

- Measure the spectrum of a specific part of a signal; e.g., the middle of an RF pulse
- Separate and measure signals that are interleaved in time. For example, your analyzer could provide information about the spectrum of a radio channel that was time multiplexed between several users.
- Exclude or “mask-out” interfering signals that are pulsed or switched off at predictable times

Time-gate capability, Option 105 of the Agilent 8591E, 8593E, 8594E, and 8595E portable spectrum analyzers, allows you to define a time window, or time gate, during which a measurement will be performed. This permits you to specify the part of a signal that you want to measure, and exclude or mask out other signals that might interfere.

Time gating is achieved because the spectrum analyzer selectively interrupts the path of the detected signal, as shown in Figure 3-1. By opening and closing a switch relative to an externally supplied trigger signal, the analyzer controls the times at which it captures measurement data. Under the right conditions, the only signals that the analyzer measures are those present at the input to the analyzer when the gate is on. All other signals are masked out.[1]

The gate within the analyzer is opened and closed on four factors:

- An externally supplied trigger signal
- The gate control, or trigger mode (POS or NEG edge, or LEVEL)
- The GATE DELAY setting, which determines how long after the trigger signal the gate actually becomes active
- The GATE LENGTH setting, which determines how long the gate is on

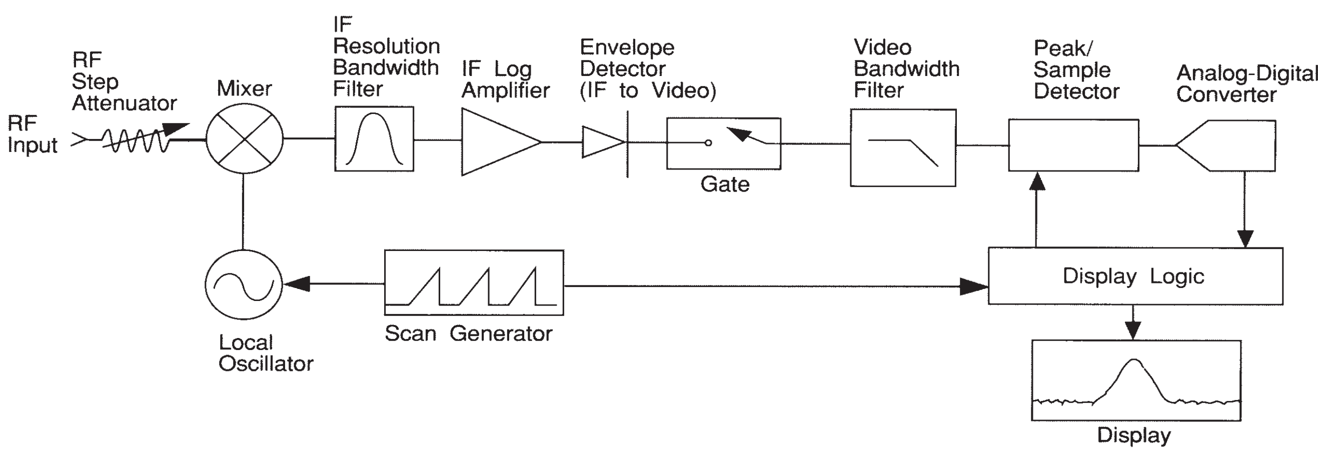

Figure 3-1 Block diagram of spectrum analyzer with time gate

1. Certain timing and bandwidth conditions must be met, as discussed in Chapter 6.

To better understand time gating, consider a spectrum measurement performed on two pulsed-RF signals. You need to consider the timing interaction of three key signals that are present during this measurement. The three signals are:

- The pulsed-RF signal under test
- The gate trigger signal, supplied from the signal source
- The gate output signal, available from a BNC connector on the rear panel of the spectrum analyzer. This transistor-transistor logic (TTL) signal is low when the gate is "off" (masking) and high when the gate is "on" (measuring).

The timing interactions between the three key signals are best understood if you observe them first on an oscilloscope. Figure 3-2 shows each of the signals as they would appear on the oscilloscope.

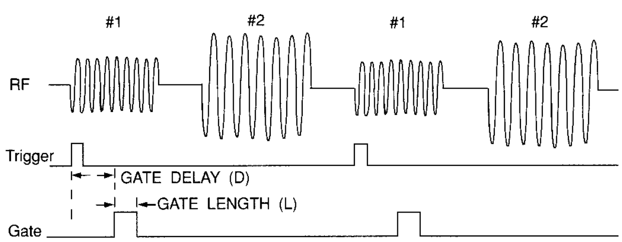

Figure 3-2 Timing relationship of signals during gating

Keep in mind the main goal: to measure the spectrum of pulse train #1 and determine if it has any low-level modulation or spurious signals. Since the pulse trains of signals #1 and #2 have almost the same carrier frequency, their frequency-domain spectra overlap. Further, the spectrum of pulse train #2 dominates because signal #2 has greater amplitude. Without gating, you won't see the spectrum of pulse train #1; it is masked by pulse train #2. The measurement result would appear like that shown in Figure 3.3.

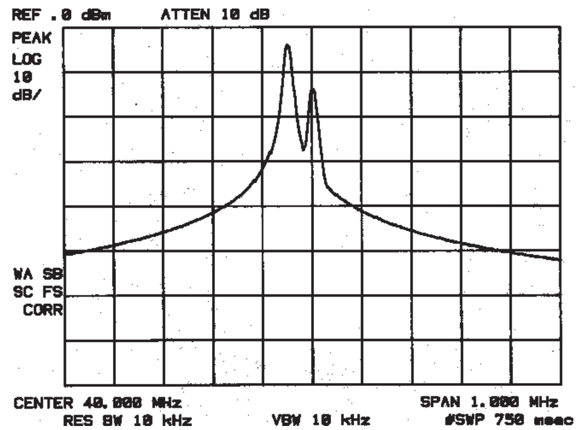

Figure 3-3 Without gating, a spectrum analyzer can only show the combined spectra of both pulse trains.

To measure pulse train #1, the gate must be on only during those pulses. The gate will be off at all other times, thus excluding all other signals. To position the gate, set the gate delay and gate length, as shown in Figure 3-2, so that the gate is on only during some central part of the pulse. Carefully avoid positioning the gate over the rising or falling pulse edges. When gating is activated, the gate output signal will indicate actual gate position in time, as shown in the line labeled "Gate."

Now that you've set up the spectrum analyzer to perform the gated measurement, you'll see, as shown in Figure 3-4a, the spectrum within the pulses of pulse train #1 only; the spectrum of pulse train #2 is excluded. In addition, when viewing pulse train #1, you also will have eliminated the pulse spectrum generated from the pulse edges. Gating has allowed you to view spectral components that otherwise would be hidden. (Chapter 6 provides a detailed measurement procedure.)

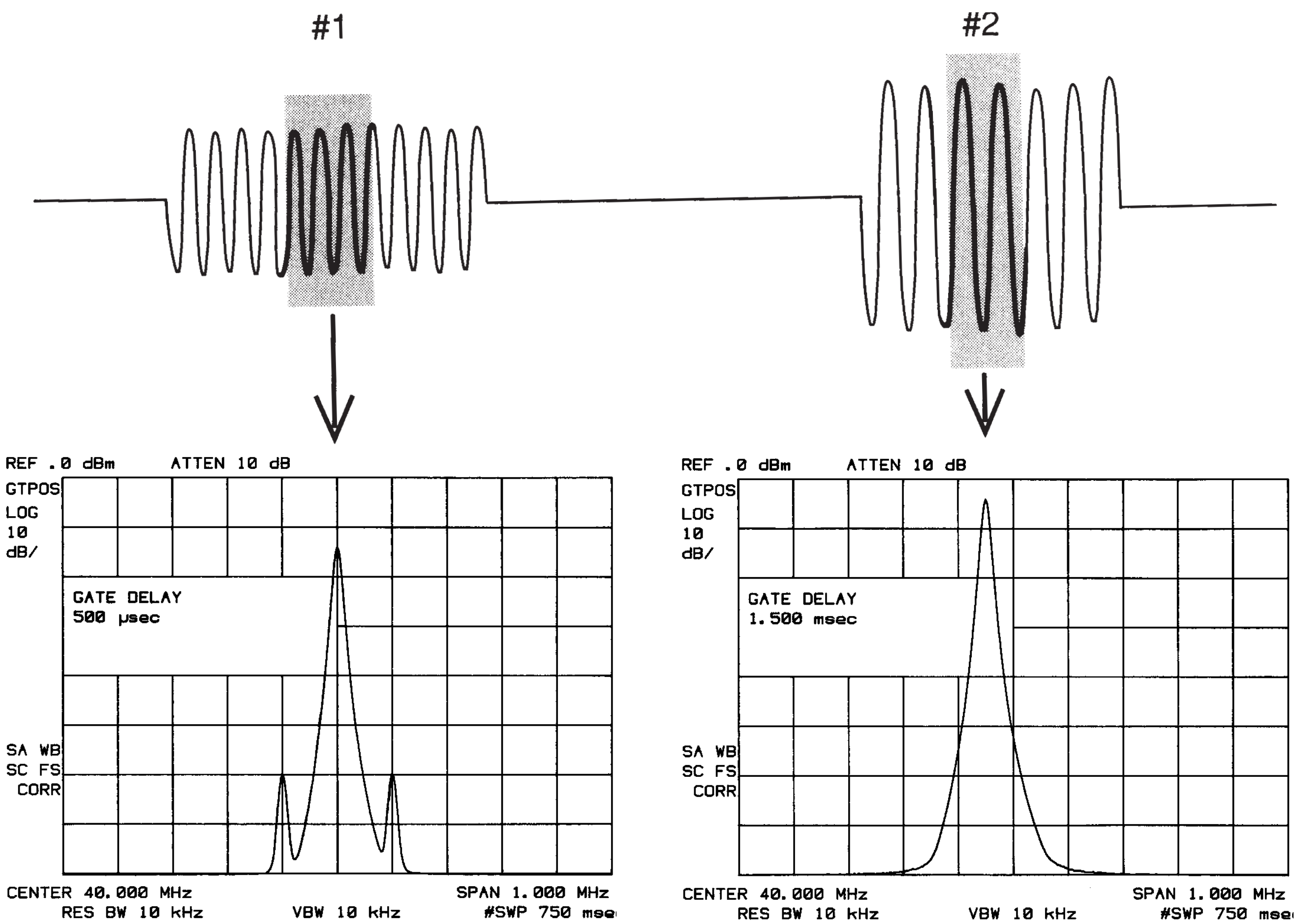

Figure 3-4a With time-gating the spectrum of signal #1 shows components that were previously hidden.

Figure 3-4b The dominating spectrum of signal #2 can also be isolated.

Moving the gate so that it is positioned over the middle of pulse train #2 produces a result such as that shown in Figure 3-4b. Here, you see only the spectrum within the pulses of signal #2; both signal #1 and the pulse spectrum of signal #2 are excluded.

Time gating serves as a useful measurement tool for many different types of signals. However, the signal must be repetitive and have a TTL timing trigger signal available to synchronize the gate.

Test set-up and connection diagram

At this point, you'll probably want to take a brief look at the block diagram of the test setup, shown in Figure 3-5. Here, the signal source is treated as one block. The source produces a single RF-pulse train from one port and a TTL trigger signal from the other port. The other blocks represent a spectrum analyzer with time-gating capability and a multi-channel oscilloscope. As Figure 3-2 showed, the oscilloscope is very useful for illustrating the timing interactions of the signals.

The connections to the spectrum analyzer are as follows:

- RF input (the RF-pulse train from the signal source)
- Gate trigger input (the TTL timing trigger signal from the signal source)
- Gate output (the TTL voltage output indicating whether the gate is on or off)

The connections to the oscilloscope are as follows:

- Gate trigger (same signal as the analyzer's gate trigger input)
- Gate output (to graphically show gate status versus time)
- RF signal under test (Note: If the signal frequency is too high to view directly on the oscilloscope, see Appendix C.)

Using this measurement setup will allow you to view all signal spectra on the spectrum analyzer and all timing signals on the oscilloscope. The setup will prove to be very helpful when you perform gated measurements on unknown signals.

The next chapter presents a specific measurement example. Chapter 6 provides general guidelines on how to perform time-gated spectrum measurements.

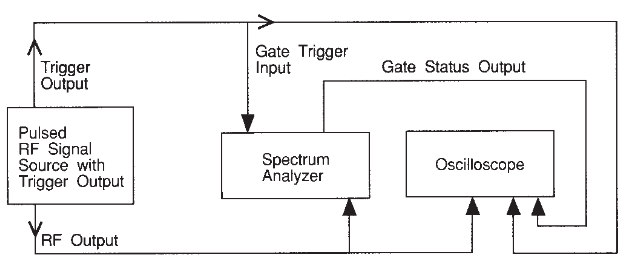

Figure 3-5 Connection diagram for performing time-gated spectrum-measurements

Chapter 4
Measurement example: single RF-pulse train

A measurement example will provide a closer look at time gating and will show even more clearly the advantages of this measurement capability. Since the example uses a simple pulsed-RF signal with specific parameters and shows specific instrument model numbers and control settings, you can duplicate the measurement using your own equipment.

The objective of this measurement is to eliminate the pulse spectrum and then view the spectrum of the carrier as if it were continually on, rather than pulsed. This will reveal low-level modulation components that were hidden by the pulse spectrum.

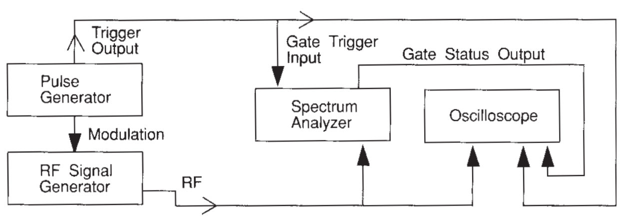

Figure 4-1 Connection diagram for measurement example

Shown below are the instrument configurations for the measurement:

PULSE GENERATOR: Agilent 8112A or equivalent

Pulse period	= 5 ms (or pulse frequency = 200 Hz)
Pulse width	= 4 ms
HIL	= 5 V
LOL	= 0 V (or AMPL = 5 V, OFFSET = 2.5 V)
Mode	= norm
Waveform	= pulse
Delay (if available)	= 0 or minimum

SIGNAL GENERATOR: Agilent 8642A or equivalent

Frequency	= 40 MHz
Amplitude	= 0 dBm
AM	= OFF
PULSE	= ON, modulation source = EXT DC
FM	= ON, 1 kHz deviation
FM MOD SOURCE	= INT
MOD FREQUENCY	= 100 kHz
RF	= ON

SPECTRUM ANALYZER: Agilent 8591E, 8593E, 8594E, or 8595E with Option 105 (time gating)

Center Freq	= 40 MHz
Span	= 500 kHz
Ref. Level	= 0 dBm
Sweep time	= 2.1 s
Resolution bandwidth	= 3 kHz
Video bandwidth	= 3 kHz
Gate	= OFF
Gate length	= 1 ms
Gate delay	= 2 ms
Gate control	= EDGE
Edge polarity	= POS

OSCILLOSCOPE: Agilent 54503A or equivalent with 3 or more input channels

Timebase	= 1 ms/div
Display	= Normal
No. of screens	= 4
Persistence	= minimum
Channel 1	= ON, 4 V/div, OFFSET = 2 V, DC coupled, 1 Mohm input, connect to external trigger signal. Adjust as necessary.
Channel 2	= ON, 400 mV/div, OFFSET = 0 V, DC coupled, 50 ohm input, connect to the pulsed-RF signal. Adjust as necessary.
Channel 3	= ON, 4 V/div, OFFSET = 2 V, DC coupled, 1 Mohm input, connect to the GATE OUTPUT status line from the spectrum analyzer. Adjust as needed when gate is active.
Channel 4	= OFF
Trigger	= TRIG'D, channel 1, level = 3.5 V, or as needed
System control	= running

Measurement results

Without time gating, the signals appear as shown in Figure 4-2.

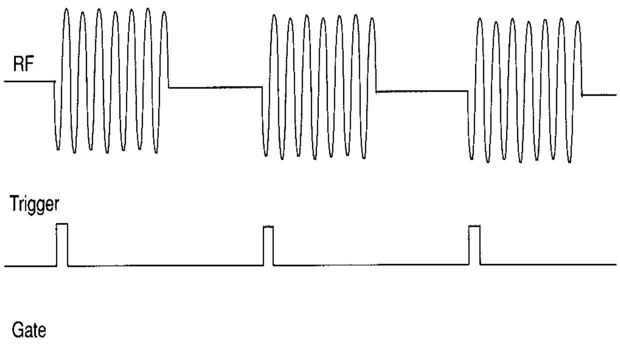

Figure 4-2a Time-domain view of RF and trigger signals without gating

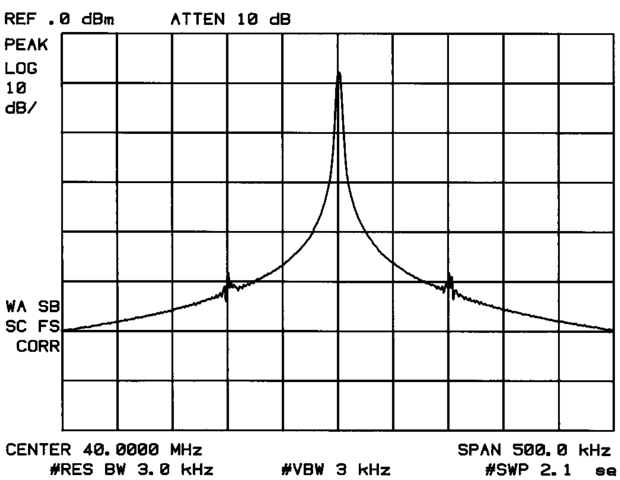

Figure 4-2b Frequency spectrum of signal without gating

To see the effect of time gating, follow the procedure described: Press the key on the front panel of the analyzer that is marked SWEEP, then press GATE so that ON is underlined (this activates the gate). Check the display of the oscilloscope to ensure that the gate is positioned under the pulse. (You might want to review Figure 3-2.) If adjustments are necessary, press GATE MENU, then set GATE DELAY and GATE LENGTH. The gate should be set to be on during approximately the third quarter of the pulse.

You should see the gate status on the oscilloscope as in Figure 4-3a; you should also see the gated spectrum on the screen of the spectrum analyzer as in Figure 4-3b. Notice that the gated spectrum is much cleaner than the ungated spectrum. The spectrum you see is the same as would be seen if the signal were on continually. To prove this, turn off the pulse modulation in the signal generator by pressing SHIFT PULSE OFF; the spectrum does not change. In both cases, you can see the two low-level modulation sidebands caused by the narrow-band FM. Without gating, these sidebands had been obscured by the pulse spectrum.

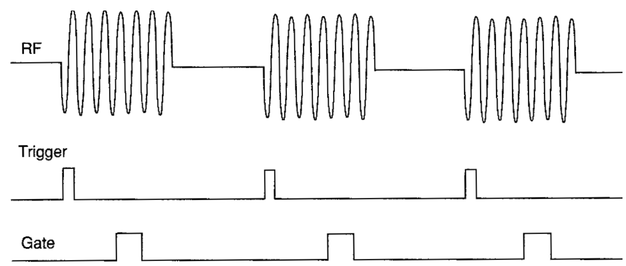

Figure 4-3a Time-domain view of RF and trigger signals with gating

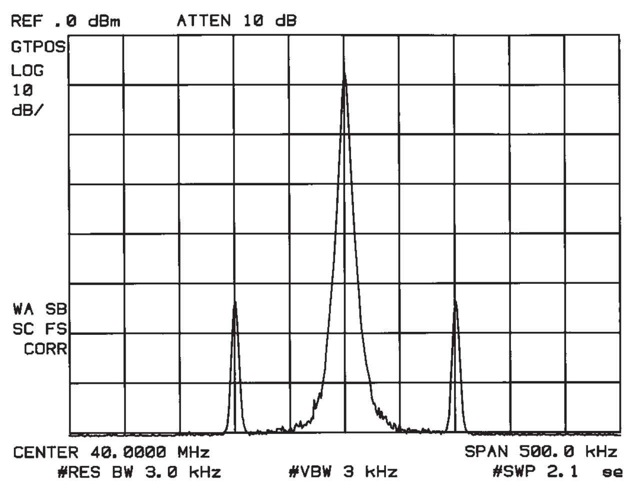

Figure 4-3b Frequency spectrum of signal with gating, showing low-level modulation sidebands previously hidden by pulse spectrum.

Chapter 5
Gate triggering: EDGE mode and LEVEL mode

Depending on the trigger signal that you are working with, you can trigger the gate in one of two separate modes: EDGE or LEVEL. This gate-trigger function is separate from the normal external trigger capability of the spectrum analyzer, which initiates a sweep of a measurement trace based on an external TTL signal.

EDGE mode:
EDGE mode allows you to position the gate relative to either the rising or falling edge of a TTL trigger signal. To trigger on the rising edge, press the following key sequence on the spectrum analyzer: SWEEP, GATE MENU, GATE CTL so that EDGE is underlined, and EDGE POL so that POS is underlined. With the equipment set up as in the previous example, the oscilloscope screen should appear as shown in Figure 5-1. By activating EDGE POL so that NEG is underlined, the screen should appear as shown in Figure 5-2, where the falling edge initiates the gate delay.

LEVEL mode:
In LEVEL gate-control mode, an external trigger opens and closes the gate directly, without any programmed delay. A TTL-high trigger signal turns the gate on; a TTL-low trigger signal turns the gate off. Therefore, the GATE DELAY and GATE LENGTH softkey control functions are not active. LEVEL mode is useful when your trigger signal occurs at exactly the same time as does the portion of the signal you want to measure.

When using LEVEL mode, you must set SWEEP TIME, RESOLUTION BANDWIDTH, and VIDEO BANDWIDTH, as described in Chapter 6, steps 2 and 5.

The GATE OUTPUT signal is not active in LEVEL mode, since it simply follows the trigger input. (If you're not sure whether the analyzer is triggering properly in LEVEL mode, try switching between GATE ON and GATE OFF.)

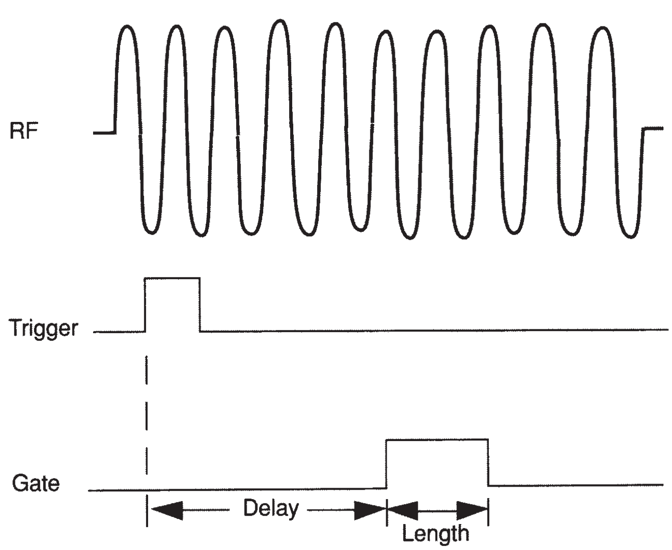

Figure 5-1 Edge POS triggering

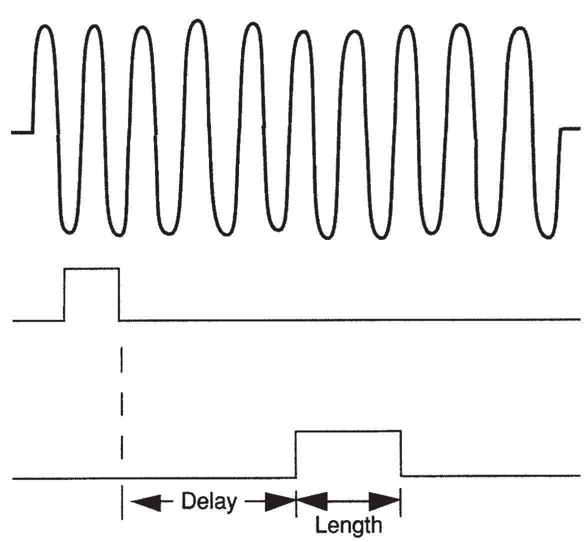

Figure 5-2 Edge NEG triggering

Chapter 6
Measurement procedure for time-gated spectrum analysis

The goal of this chapter is not only to help you learn the basic steps for performing time-gated measurements in the frequency domain, but also to help you understand the reasons for making each step. Appendix B discusses time gating for time-domain measurements.

Although time gating can be used on many different signal types, you probably will want to begin by viewing a simple pulsed-RF signal and adjusting the controls of the spectrum analyzer to perform specific measurements. After reading this chapter, you should be able to adapt the basic “rules” presented here to the specific signals you want to measure.

Most signals requiring time gating are fairly complex, so some extra steps are often required when performing measurements. Once you understand the basic steps of time-gated measurements and the reasons for taking these steps, you will be able to set up your instruments using just the summary of “rules” or the recommended control setting tables presented at the end of this chapter, whichever is easier. Then you can confidently take full advantage of the flexibility that time gating allows.

Detailed measurement procedure

Following is a detailed explanation of the measurement steps. A summary and a table of recommended settings are shown on pages 18 through 20.

Do not turn the gate on until step 4! Otherwise, the gate will “chop” the displayed trace and make it difficult to interpret until you have properly positioned the gate and adjusted the bandwidths.

1. Determine how your signal under test appears in the time domain and how it is synchronized to the trigger signal.

Since you position the time gate by setting the delay relative to the trigger signal, you need to know the timing relationship between the trigger and the signal under test. Unless you already have a good idea of how the two signals look in the time domain, you probably will want to examine them with an oscilloscope to determine the following parameters:

- Trigger type (POS or NEG edge of TTL signal)
- Pulse repetition interval (PRI), which is the length of time between trigger events.
- Pulse width, or τ. If your signal is not pulsed as in this example, τ could be as large as the PRI.
- Signal delay (SD), which is the length of time occuring between the trigger event and when the signal is present and stable. If your trigger occurs at the same time as the signal, SD will be zero. See Figure 6-1.
- The parameters of the signal you want to measure and the resolution bandwidth required to measure those parameters.

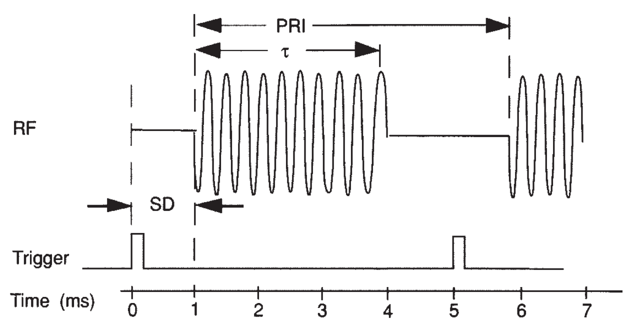

Figure 6-1 Time-domain parameters that you need to know in order to set gate controls properly

In the diagram shown above:

- Gate control = EDGE POS
- PRI = 5 ms
- Pulse width = 3 ms
- Signal delay = 1 ms

Note: If your signal of interest has too high a frequency to be displayed on the oscilloscope, you may want to use the spectrum analyzer as a downconverter to bring the signal to a 21.4 MHz intermediate frequency. Appendix C provides a description of this process in zero-span.

Will you be looking for low-level modulation components, spurious signals between pulses, or some other parameter? Determining the signal parameters that you wish to measure influences not only where you place the gate and how long the gate will be on, but also the bandwidth settings necessary to perform the measurement. These factors will be important considerations as you make trade-offs between different pairs of control settings in steps 4 and 5, particularly when you choose wider resolution bandwidths to allow for shorter set-up times.

In Chapter 4, you were looking for low-level 100 kHz modulation during the middle of a pulse, so you'll want to choose a resolution bandwidth considerably narrower than 100 kHz, such as 3 kHz.

2. Set analyzer SWEEPTIME to greater than 401 x PRI (pulse repetition interval), or longer if MEAS UNCAL appears on the screen.

To ensure that the gate is on at least once during each of the 401 digital trace points on the spectrum analyzer, you may need to decrease the sweep rate of the analyzer. In Figure 6-1, the PRI is 5 ms, so you should set the sweep time to at least 401 x 5 ms = 2005 ms, or 2.005 s. (The next higher setting is 2.1 s). If the sweep time is too fast, some trace points may show values of zero or other incorrectly low readings. If the signal has an intermittent or variable repetition interval, use the longest PRI for calculating sweep time. If the trace seems incomplete or erratic, try a longer sweep time.

Leave SWEEPTIME in MAN mode, not AUTO, so that it will retain the value you have set.

3. Locate the signal under test on the display of the spectrum analyzer. Set CENTER FREQ and SPAN so that you can view the signal characteristics that you are interested in measuring.

Although the analyzer is not yet configured for correct gated measurements, you will want to determine the approximate frequency and span in which to display the signal of interest. If the signal is erratic or intermittent, you may want to press TRACE, then MAX HOLD to determine the frequency of peak energy.

Set SPAN narrow enough to show the signal characteristics that you want to measure. For example, if you wanted to look for spurious signals within a 200 kHz frequency range, you might set SPAN to just over 200 kHz, or if you just wanted to measure peak amplitude during the gate, you could leave the SPAN wider.

4. Activate GATE ON, and position the gate over the part of the signal that you want to measure by adjusting GATE CONTROL (triggering), GATE DELAY, and GATE LENGTH. Determine the setup time (SUT) (See Figure 6-2).

If you want to trigger on the rising edge of your trigger signal, select GATE CONTROL EDGE, and EDGE POLARITY POS. (NEG polarity triggers on the falling edge of the TTL trigger signal.) See Chapter 5 for triggering information.

GATE DELAY determines the length of time from the trigger event until the gate is on, and GATE LENGTH controls the length of time that the gate remains on. Together, these parameters determine the gate position relative to the trigger signal.

For this case, choose EDGE POS triggering so the gate delay begins from the rising edge of the trigger pulse. Since you are looking for modulation during the pulse, delay the start of the gate until roughly the center of the pulse.

Generally, you should position the gate over a part of the signal that is stable, not over a pulse edge or other transition that might disturb the spectrum. Starting the gate at the center of the pulse gives a "setup time" of approximately 1/2 the pulse width. Setup time (SUT) describes the length of time during which the signal is present and stable before the gate comes on. Generally, you should maximize SUT. Signal delay (SD) is the delay inherent in the signal; that is, SD is the length of time after the trigger, but before the signal of interest occurs and becomes stable. If the trigger event occurs simultaneously with the signal of interest, SD = 0, and SUT = gate delay. Otherwise, SUT = gate delay-SD.

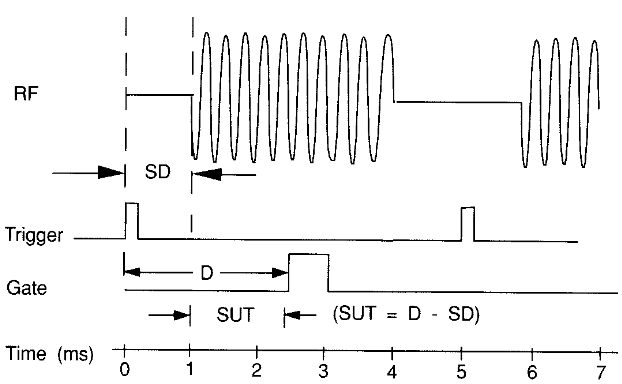

Figure 6-2 Setup time and signal delay for time gating

Notice that in Figure 6-2:
Signal delay (SD) = 1.0 ms
Gate delay (D) = 2.5 ms
Setup time (SUT) = 1.5 ms

You have much flexibility in positioning the gate, but some positions offer a wider choice of resolution bandwidths. A good rule of thumb is to start the gate in the middle of the pulse and have it remain on for one-fourth the pulse duration. Doing so provides a reasonable compromise between setup time and gate length, but it is only a starting point–you can actually position the gate almost anywhere you wish.

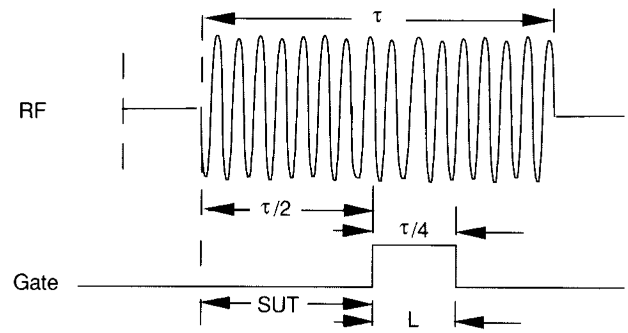

Figure 6-3 Suggested initial gate positioning

Notice that in Figure 6-3:
Pulse width (τ) = 3.0 ms
Setup time (SUT) = 1.5 ms
Gate length (L) = 0.75 ms

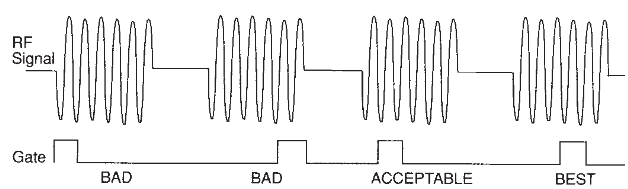

Figure 6-4 Gate should generally be positioned over the later part of pulse, but it should avoid pulse edges.

As a general rule, you will obtain the best measurement results if you position the gate relatively late within the signal of interest, but without extending the gate over the trailing pulse edge or signal transition. Doing so maximizes setup time and provides the resolution-bandwidth filters of the spectrum analyzer the most time to settle before a gated measurement is made. "Relatively late," in this case, means allowing a setup time of greater than 2/RBW, where RBW is the –3 dB width of the resolution-bandwidth filter used.

As an example, if you want to use a 1 kHz RBW for measurements, you will need to allow a setup time of at least 2 ms. Or, if you want to turn on the gate as early as possible, you could use the widest specified resolution bandwidth in the analyzer, which is 3 MHz. Minimum setup time, 2/(3 MHz), equals 0.67 µs, so you could have a setup time as short as 0.67 µs, although the minimum settable GATE DISPLAY is 1 µs.

You can set the gate length to any value you desire that enables you to select the proper portion of the signal of interest to measure. Choosing a narrower gate length forces you to select a wider video bandwidth, as will be discussed in step 5.

Note that the signal need not be an RF pulse. It could be simply a particular period of modulation in a signal that is continuously operating at full power, or it could even be during the off time between pulses. Depending on your specific application, adjust the gate position to allow for progressively longer setup times (ensuring that the gate is not left on over another signal change such as a pulse edge or transient), and select the gate delay and length that offer the best signal-to-noise ratio on the display.

If you were measuring the spectrum occuring between pulses, you should use the same (or longer) setup time after the pulse goes away, but before the gate goes on. This allows the resolution-bandwidth filters to fully discharge the large pulse before the measurement is made on the low-level interpulse signal.

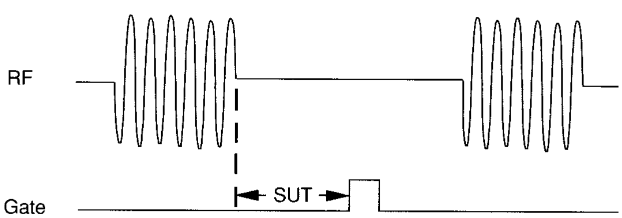

Figure 6-5 Setup time for interpulse measurement

5a. Adjust spectrum analyzer settings:

RESOLUTION BANDWIDTH: Adjust to greater than 2/setup time. Do you want a narrower resolution bandwidth? If so, you can increase the setup time, which returns you to step 4.

VIDEO BANDWIDTH: Adjust to greater than 1/GATE LENGTH

5b. Leave RBW and VBW in MANUAL mode, not autocoupled.

Resolution bandwidth

The resolution bandwidth you can choose is determined by the gate position, so you can trade off longer setup times for narrower resolution bandwidths. This trade-off is due to the time required for the resolution-bandwidth filters to fully charge before the gate comes on. Setup time, as mentioned, is the length of time that the signal is present and stable before the gate comes on.

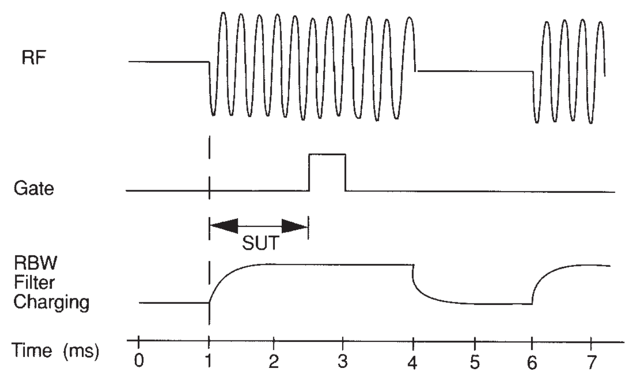

Figure 6-6 Resolution-bandwidth filter charge-up effects

Since the resolution-bandwidth filters are bandlimited devices, they require a finite amount of time to react to changing conditions. Specifically, the filters take time to fully charge after the analyzer is exposed to a pulsed signal. Although the charge-up is asymptotic, you can consider it to be complete after the length of time defined by 2/RBW, where RBW is the –3 dB resolution bandwidth being used.

Since setup time should be greater than filter charge time, be sure that:

SUT >2/RBW, or RBW >2/SUT
where, in this example, RBW >2/1.5 ms; that is RBW >1300 Hz.

The resolution bandwidth should be set to the next larger value, 3 kHz.

Video bandwidth

Just as the resolution-bandwidth filter needs a finite amount of time to charge and discharge, so does the video filter, which is a post-detection filter that is used mainly to smooth the measurement trace. Regardless of the length of the real RF pulse, the video filter sees a pulse no longer than the gate length, and the filter will spend part of that time charging up. In order to ensure that a true peak value is obtained before the gate goes off, the video filter must have a charge time of less than the gate length. For this purpose, you can approximate the charge time of the video filter as 1/VBW, where VBW is the –3 dB bandwidth of the video filter. Therefore, you'll want to be sure that:

GATE LENGTH >1/VBW, or VBW >1/GATE LENGTH

For example, if you use a 1 kHz video bandwidth for noise smoothing, you need a gate length that is greater than 1 ms. Alternatively, if you use a gate as narrow as 1 µs, you should use a video filter of at least 1 MHz.

Reducing the video-bandwidth filter too far causes the signal to appear to drop in amplitude on the screen.

If you're in doubt about the proper video bandwidth to choose, set it to 3 MHz and reduce it gradually until the detected signal level drops slightly. Then reset it to the value it was at just before the signal dropped.

Leave both RBW and VBW in MANUAL mode, not AUTO; this is important so that they will not change if SPAN is changed. Press the BW hardkey, then press RES BW or VID BW once or twice until MAN is underlined. The setting readout on the bottom line of the analyzer screen should show a # sign next to the function names ("#RES BW", "#VBW", and "#SWP"), indicating that they have been manually set.

6. Adjust span as necessary, and perform your measurement.

Now your spectrum analyzer is set up to perform accurate measurements. Freeze the trace data by either activating SINGLE SWEEP (press SGL SWP hardkey) or by placing your active trace in VIEW mode (press the TRACE hardkey, then press VIEW A). Use the markers to measure the signal parameters you chose in step 1. If necessary, adjust SPAN, but do not decrease RESOLUTION BAND-WIDTH, VIDEO BANDWIDTH, or SWEEPTIME. If MEAS UNCAL shows on the screen after increasing SPAN, you must increase SWEEPTIME further.

Most normal trace functions are still available with gating, including VIDEO AVG (but using peak detection only) and limit lines. Most marker functions also are available, except MARKER NOISE. MARKER COUNT is unaffected by gating, but many signals that require gating are not appropriate for counting due to their intermittent nature.

Summary of measurement procedure

Following is a description of the steps required to perform a time-gated spectrum measurement.

1. Determine how your signal under test appears in the time domain and how it is synchronized to the trigger signal. You need to determine:

- Trigger type (POS or NEG EDGE)
- Pulse repetition interval (PRI)
- Pulse width (τ)
- Signal delay (SD)
- The parameters of the signal that you want to measure and the resolution bandwidth required to measure those parameters

2. Set the analyzer SWEEPTIME to greater than 401 x PRI (pulse repetition interval), or longer if MEAS UNCAL appears on the screen. Leave in MANUAL mode, not autocoupled.

3. Locate the signal under test on the display of the spectrum analyzer. Set CENTER FREQ and SPAN so that you can view the signal characteristics in which you are interested.

4. Activate GATE ON, and position the gate over the part of the signal that you want to measure by adjusting GATE CONTROL (triggering), GATE DELAY, and GATE LENGTH. Determine the setup time (SUT). (View oscilloscope screen while positioning gate. Do not read measurement results from spectrum analyzer yet, since the bandwidths have not been adjusted for gate settings.)

5a. Adjust spectrum analyzer settings:

RESOLUTION BANDWIDTH: Adjust to greater than 2/setup time. Do you want a narrower resolution bandwidth? If so, you can increase the setup time, which returns you to step 4.

VIDEO BANDWIDTH: Adjust to >1/GATE LENGTH

5b. Leave RBW and VBW in MANUAL mode, not autocoupled.

6. Adjust span and amplitude as necessary, and perform your measurement.

Summary of "rules" for making time-gated spectrum measurements

A. Position gate over the late part of pulse, not at its edge. Start with GATE DELAY = τ/2 + signal delay GATE LENGTH = τ/4

B. SWEEPTIME >401 x PRI

C. RESOLUTION BANDWIDTH >2/SUT (setup time)

D. VIDEO BANDWIDTH >1/GATE LENGTH

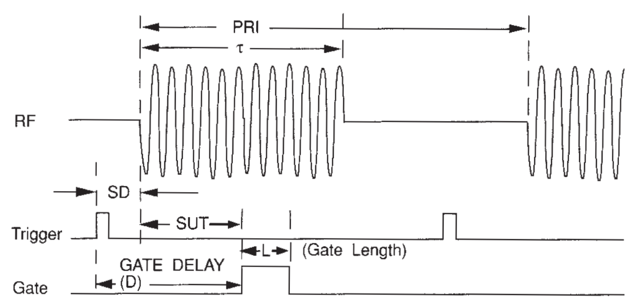

Figure 6-7 Gate positioning parameters

Most control settings are determined by two key parameters of the signal under test: the pulse repetition interval (PRI) and the pulse width (τ). If you know these parameters, you can begin by picking some standard settings. Tables 6-8 and 6-9 summarize the parameters for a signal whose trigger event occurs at the same time as the beginning of the pulse (i.e., SD = 0). If your signal has a non-zero signal delay, just add it to the recommended GATE DELAY.

PULSE WIDTH (τ)	GATE DELAY (SD + τ/2), (also = SUT since SD = 0)	MIN. RES. BANDWIDTH (>2/SUT), (i.e., >4/τ)	GATE LENGTH (τ/4)	MIN. VIDEO BANDWIDTH (>1/GATE LENGTH), (i.e., >4/τ)
4 μs	2 μs[2]	1 MHz	1 μs	1 MHz
10 μs	5 μs	1 MHz	3 μs	1 MHz
50 μs	25 μs	100 kHz	13 μs	100 kHz
63.5 μs	32 μs	100 kHz	16 μs	100 kHz
100 μs	50 μs	100 kHz	25 μs	100 kHz
500 μs	250 μs	10 kHz	125 μs	10 kHz
1 ms	500 μs	10 kHz	250 μs	10 kHz
5 ms	2.5 ms	1 kHz	1.25 ms	1 kHz
10 ms	5 ms	1 kHz	2.5 ms	1 kHz
16.6 ms	8.3 ms	1 kHz	4 ms	1 kHz
33 ms	16.5 ms	1 kHz	8 ms	1 kHz
50 ms	25 ms	1 kHz	13 ms	1 kHz
100 ms	50 ms	1 kHz	25 ms	1 kHz
≥130 ms	65 ms	1 kHz	33 ms	1 kHz

Table 6-8 Suggested initial control settings for known pulse width (τ) and zero signal delay

2. Up to 1 μs delay jitter is due to internal clock rate of 1 MHz and asynchronous trigger. This may be visible for short delay times.

PULSE REPETITION INTERVAL (PRI)	PULSE REPETITION FREQ. (PRF = 1/PRI)	MIN. SWEEPTIME (>401 x PRI)
≤50 μs	≥20 kHz	21 ms
100 μs	10 kHz	41 ms
500 μs	2 kHz	210 ms
1 ms	1 kHz	410 ms
5 ms	200 Hz	2.1 s
10 ms	100 Hz	4.1 s
16.7 ms	60 Hz	6.7 s
33.3 ms	30 Hz	14 s
50 ms	20 Hz	21 s
100 ms	10 Hz	41 s
200 ms	5 Hz	81 s
249 ms	4 Hz	100 s

For PRI >249 ms, use MAX HOLD trace function and repeated sweeps because the longest sweep time of the analyzer is 100 s.

Table 6-9 Suggested sweep times for known pulse repetition interval (PRI) or pulse repetition frequency (PRF)

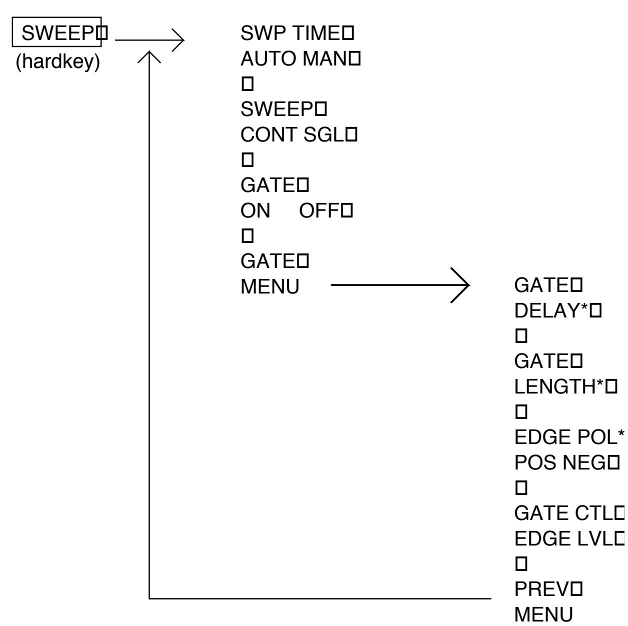

Figure 6-10 Softkey menu structure

* These keys are blank while in LVL mode.

Chapter 7
Troubleshooting; questions and answers

If the functions of your Option 105 do not seem to be working properly, consult the Operation Manual for your specific instrument. It contains a brief section verifying Option 105 operation. Following is a summary of that procedure.

1. Allow the instrument to come to a stable operating temperature.

2. Be sure that the rear panel BNC connector labeled GATE TRIGGER INPUT is not connected to anything. It should be left open.

3. Connect the front panel CAL OUT to the front panel INPUT.

4. Press the CAL hardkey, then press CAL FREQ & AMPTD. Wait for the calibration routine to finish and show CAL DONE with no error messages. Press CAL STORE.

5. Press CAL, MORE, MORE, SERVICE DIAG, DISPLAY CAL DATA. Check to see that the number in the left column, ninth row down, is between 0.98 and 1.00. If it is not, check again to be sure that nothing was connected to the GATE TRIGGER INPUT on the rear panel during the successful CAL procedure.

If Option 105 functions still do not operate properly, check the symptoms and solutions shown in Table 7-1 to see if these suggestions help.

Symptom	Possible Cause	Suggested Solution
Can't find GATE softkeys under SWEEP hardkey	Analyzer may not have Option 105 installed or may have improper firmware.	Press CONFIG, MORE, SHOW OPTIONS. If the display does not show "105: Gate," then Option 105 is not properly installed. Contact your nearest Agilent Technologies Service Center.
Erratic analyzer trace with random vertical lines or dropouts extending below the peak trace amplitude	Sweep rate too fast to ensure at least one gate occurrence per trace point, or GTSMP detector used	Increase SWEEP TIME until dropouts disappear, and be sure GTPOS detector is active.
Erratic analyzer trace with dropouts that are not removed by increasing analyzer sweep time; oscilloscope view of gate output signal jumps erratically in time domain	GATE DELAY may be greater than trigger repetition interval.	Reduce GATE DELAY until it is less than trigger interval.
Vertical lines on trace, extending either above or below graticule marks, or both. Present only when GATE ON is active	Gate trigger applied during CAL, or CAL not run since installation of gate card	Remove GATE TRIGGER INPUT connection during CAL.
Gate does not trigger	Gate trigger voltage may be too low, or gate may not be activated.	Ensure gate trigger reaches 5.0 volts. Check to see if other connections to trigger signal may be reducing voltage. If using oscilloscope, check that all inputs are high impedance, not 50 ohms. Ensure that GTPOS shows in upper left corner of screen.
Displayed spectrum does not change when GATE ON softkey is activated	Insufficient setup time	Increase setup time for current RBW, or increase RBW.
Displayed spectrum too low in amplitude	RBW or VBW filters not charging fully	Widen RBW or VBW, or both
Display changed drastically during operation	Gate functions have been turned off by changing detector path (e.g. setting MKR NOISE or DETECTOR SAMPL).	Check to see that GTPOS still shows in upper left of screen while in frequency spans, or GTPOS or GTSMP while in zero-span. Do not change detector while using gate functions.

Table 7-1 Troubleshooting chart

Questions and answers

Q: Can Option 105 turn a pulsed-RF signal into a continuous wave (CW) signal for measurement purposes?
A: Almost. You can view the spectrum as if it were CW, provided that you have chosen a resolution bandwidth wide enough to charge fully on the pulse before the gate comes on. See Chapter 6 for a description of recommended resolution bandwidths, based on the signal to be measured.

Q: Is "time-gated spectrum analysis" the same as "gated sweep" available in other analyzers?
A: Option 105 uses a technique called "gated video," as shown in Figure 3-1. The internal circuitry is very different from that used in "gated sweep," but Option 105 allows you to perform similar measurements. The main differences are in parameters such as programmable gate delay and gate length.

Q: Do I need to use an oscilloscope with Option 105?
A: Not necessarily, although most people find one very helpful. If you are very sure about the time-domain nature of your signal under test and its relationship to the timing trigger signal, you should be able to set the gate parameters directly, without using an oscilloscope.

Q: Are the Option 105 functions programmable?
A: Yes. For more information, see the *Agilent 8590 Series Spectrum Analyzers Programming Manual* with print dates later than November 15, 1990.

Q: Can I use other analyzer functions while I use the time gate?
A: Mostly yes, but there are a few exceptions, including MARKER NOISE, quasi-peak detection, and sample detection (while in frequency span mode). MARKER COUNT is not directly affected, but most signals that require time gating are not appropriate for MARKER COUNT due to their intermittent nature. AM and FM demodulation functions are restricted. Also, in zero-span sweeps of less than 20 ms, you will see approximately 20 dB of sensitivity degradation, i.e., the noise floor increases, when using the 3 MHz video bandwidth filter. This degradation can be avoided by using another VBW setting or increasing sweeptime to greater than 20 ms.

Q: Can Option 105 time gating be retrofit?
A: Yes, although some earlier models may require internal modifications to accept Option 105. Contact your local Agilent Technologies Sales Office for the specific retrofit number. The number will depend on the serial number of your spectrum analyzer (on rear panel) and firmware revision (shown on screen after power-up).

Q: What options should I order along with Option 105?
A: Consider ordering Option 101, which provides fast zero-span sweeps. It provides a 1,000-fold reduction in zero-span sweeptime, from 20 ms to 20 µs, while retaining digital storage. You can order any other option, but remember that you can only choose up to four internal option boards, and that the 2.9 GHz built-in tracking generator also uses a board slot.

Appendix A
Product technical information

Summary characteristics of Option 105

This appendix summarizes information on the characteristics of Option 105 time-gate functions. The information is superceded by the Installation Manual for the specific spectrum analyzer to be used.

These figures assume CAL AMPTD & FREQ has been executed, passed, and stored. Data subject to change.

	Range	Resolution	Accuracy
Gate Length (L)[3]	1 µs to 65.535 ms	1 µs	±(0.2 µs + [0.01% x Gate Length Readout])
Gate Delay (D)[4]	1 µs to 65.535 ms	1 µs[5]	±[1 µs + (0.01% x Gate Delay Readout)]

Table A-1 Gate parameters for EDGE trigger mode

Additional Amplitude Error[6]
Log scale: ±0.3 dB
Linear scale: ±0.4% of reference level

Gate Control (Trigger) Modes: EDGE POS, EDGE NEG, or LEVEL

In LEVEL MODE, gate status is controlled directly by GATE TRIGGER INPUT.
TTL High causes gate on.
TTL Low causes gate off.
Open input is treated as TTL high.

For sweep times <20 ms with video bandwidth of 3 MHz, only upper 6 screen divisions are usable when GATE ON key is activated, but gate is in off position.

When using gate functions in non-zero frequency spans, detector mode should be GTPOS (positive peak, gate on). Functions that require other detectors may not produce calibrated measurement data. Examples include SAMPLE and QUASI-PEAK detectors and MARKER NOISE readout.

3. From positive edge to negative edge of gate output
4. From gate trigger input to positive edge of gate output
5. Up to 1 µs jitter is due to 1 µs resolution of gate delay clock
6. With GATE ON enabled and triggered, CW signal, peak detector mode

INPUTS and OUTPUTS

GATE TRIGGER INPUT

Connector:	BNC female, located on rear panel
Trigger level:	Minimum pulse width >30 ns (TTL)

GATE OUTPUT (indicates status of gate while in EDGE mode)

Connector:	BNC female, located on rear panel
Output level:	High indicates gate on (TTL) Low indicates gate off (TTL)

Programmability: all front panel gate settings are programmable via GPIB (Option 021) or RS-232 (Option 023).
Operating temperature: 0 to +55 °C
Storage temperature: –40 to +75 °C

EMI Compatibility: Conducted and radiated interference per CISPR Pub. 11 and FTZ 526/527/79.

Ordering information

Time-gated spectrum analysis capability is available on the Agilent 8591E, 8593E, 8594E, and 8595E portable spectrum analyzers as Option 105. For more information about these spectrum analyzers, see individual data sheets and the *Agilent 8560 and 8590 Series Spectrum Analyzers and Accessories Ordering Guide.*

Option 101 (Fast Time-Domain Sweeps) is recommended for zero-span measurements.

The time-gated spectrum analysis circuit board occupies one of the four internal board slots and two of the four rear-panel BNC connector holes of the 8591E, 8593E, 8594E, and 8595E analyzers.

For retrofit information, contact your Agilent Technologies sales and support office.

Agilent 8594A rear panel

Appendix B
Time-domain measurements and zero-span delay triggering

Although spectrum analyzers are primarily frequency-domain devices, they can also show signals in the time domain. The simplest way to do this is to set the SPAN of the analyzer to 0 Hz so that it becomes a fixed-tuned receiver. The display of the analyzer then shows received power versus time, which allows you to determine the shape of the envelope of an RF or microwave signal, as shown in Figure B-2. The zero-span display represents the power detected at the center frequency of the analyzer, within the bandwidth of the resolution-bandwidth filter.

In both the time and frequency domains, the measurement sweep is initiated following a valid sweep-trigger condition. The sweep-trigger condition differs from the gate trigger discussed in Chapter 5; they use different connections and circuits, and each can be set independently. Sweep trigger can be set by pressing the TRIGGER hardkey, then selecting between several choices.

Sweep Trigger Mode	Trigger Condition
FREE RUN	As soon as analyzer is ready to start another sweep
LINE	AC power cycle
EXTERNAL	External trigger input (TTL positive edge)
VIDEO	Internal video signal reaches level set by user

Non-gated spectrum analyzers can show a zero-span display, but there is a limitation since the time window that can be shown has only one dimension of adjustment. The sweep starts immediately after a valid trigger and lasts as long as the SWEEPTIME setting indicates. The only adjustment that can be made is to increase or decrease the length of the sweep. The sweep always begins immediately after a valid trigger condition, which limits the amount of detail that can be seen for events that do not occur immediately after the trigger event, as in Figure B-3.

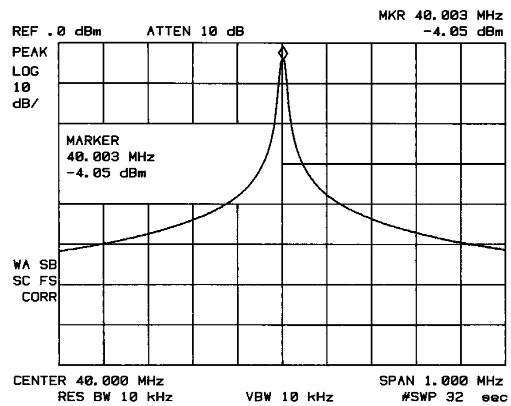

Figure B-1 Pulsed-RF signal in frequency domain, viewed on spectrum analyzer in normal swept-frequency display.

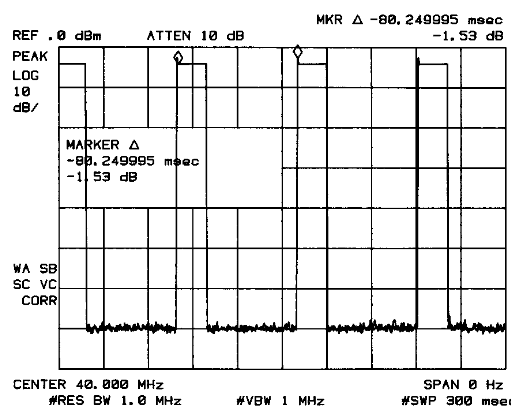

Figure B-2 Pulsed-RF signal in time domain, viewed on spectrum analyzer using zero-span technique and wide RBW and VBW.

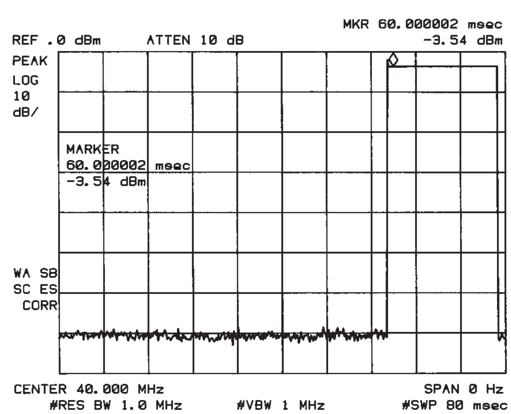

Figure B-3 Zero-span display of RF pulse that occurs 60 ms after the external sweep trigger signal. Without time gating, very little detail is visible.

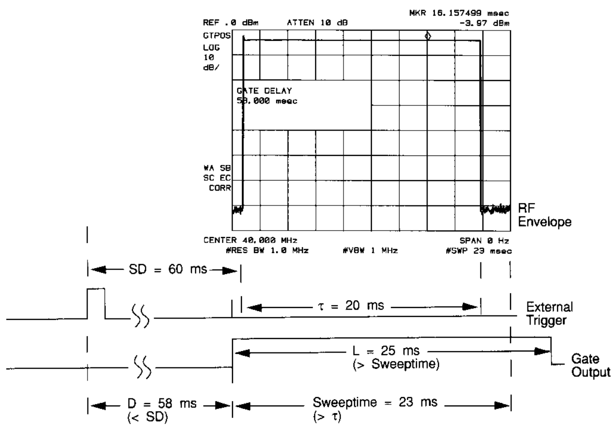

Figure B-4 Zero-span display of the same delayed RF pulse. Time gating allows display of the pulse with full display resolution.

The time-gating circuitry of Option 105 allows you to delay the start of a measurement sweep by up to 65 ms after an external trigger signal is received. This allows you to "zoom-in" on the event of interest, as shown in Figure B-4, showing greater detail.

To use Option 105 for delayed zero-span sweeps:

1. Turn GATE OFF.

2. Set CENTER FREQ to the signal of interest.

3. Set RBW and VBW wider than the spectral width of the signal of interest. If possible, choose a value wide enough so that the RBW filter is fairly flat over the width of your signal (screen readout of RBW indicates the –3 dB width of the filter).

4. Set SPAN to 0 Hz.

5. Connect the TTL trigger signal from the device under test to the BNC connector labeled GATE TRIGGER INPUT on rear panel of analyzer.

6. Connect GATE OUPUT to EXT TRIG INPUT (both on rear panel) via a BNC cable. This allows the rising edge of the GATE OUTPUT to act as an external trigger input for the sweep trigger.

7. Press TRIG hardkey, then press EXTERNAL.

8. Press SWEEP hardkey and set GATE ON, then adjust GATE DELAY, GATE CONTROL, and EDGE POLARITY so that the gate comes on slightly before the signal of interest. GATE DELAY should be less than signal delay, SD. This will start the sweep slightly before the signal of interest appears.

9. Adjust GATE LENGTH so that gate is on for at least as long as the signal of interest. GATE LENGTH should be greater than the pulse width, τ.

10. Set SWEEPTIME to be slightly less than GATE LENGTH. This setting will finish the sweep before the gate goes off. During this measurement, the Option 105 circuitry acts as a delay timer for the EXTERNAL TRIGGER INPUT, not actually gating on and off repeatedly during a single sweep.

11. Perform your measurement.

Summary "rules" for delayed zero-span measurements:
A. RBW and VBW >spectral width of signal

B. SPAN = 0 Hz

C. Connect trigger as shown in Figure B-5

D. GATE DELAY <Signal Delay

E. τ (duration of signal) <SWEEPTIME <GATE LENGTH

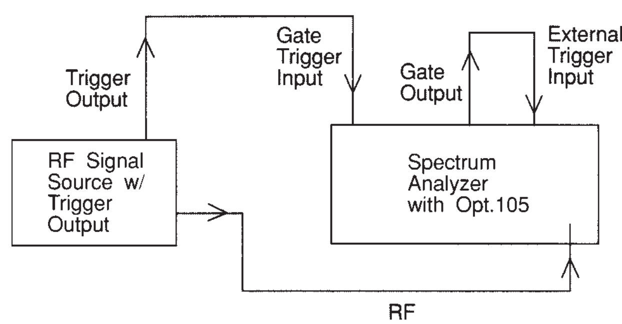

Figure B-5 Connection diagram for delayed zero-span measurement

Appendix C
How to view a high-frequency signal on an oscilloscope by using the spectrum analyzer as a downconverter to 21.4 MHz

If the signal that you want to measure with time gating is at too high a frequency to be displayed directly on the oscilloscope, you'll need to use another method to determine the time-domain behavior of the signal, including the information that follows:

- Pulse repetition interval (PRI)
- Pulse width (τ)
- Delay relative to trigger (SD, or signal delay)

If you already know these parameters, just sketch a picture of your signal as a reference and proceed as described in Chapter 6, step 2.

If you still need to determine these parameters, you may be able to use the spectrum analyzer as a downconverter and view the 21.4 MHz auxiliary intermediate frequency (AUX IF) signal on the oscilloscope. Follow this procedure:

1. Connect the AUX IF OUT from the back panel of the spectrum analyzer to one of the input channels of the oscilloscope.

2. Connect the trigger signal to one of the other oscilloscope channels and set the oscilloscope to trigger on this signal. Ensure that this oscilloscope channel has a high-impedance input, not 50 ohms. Also, connect this external trigger signal to the GATE TRIGGER INPUT of the analyzer.

3. Connect the GATE OUTPUT from the back panel of the spectrum analyzer to another channel of the oscilloscope, and adjust as necessary to view a TTL signal when the gate is turned on later. Your equipment configuration should resemble Figure C-1.

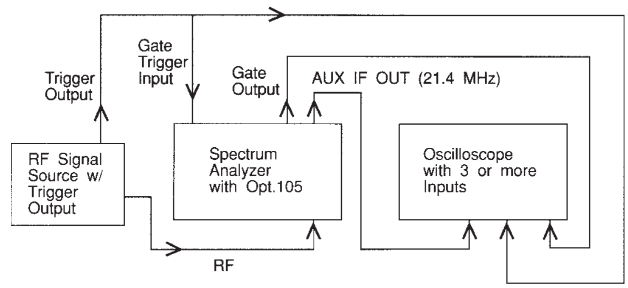

Figure C-1 Equipment configuration using spectrum analyzer as downconverter to view high frequency signal on oscilloscope

4. Set the CENTER FREQUENCY of the spectrum analyzer to that of the signal under test.

5. Set the RESOLUTION BANDWIDTH of the spectrum analyzer to be wider than the occupied spectral width of the signal under test, so that all of its modulation components are captured by the RBW filter.

6. Set the analyzer SPAN to 0 Hz so that it is no longer sweeping in frequency, but only downconverting the signal to the 21.4 MHz IF.

7. Adjust the REFERENCE LEVEL so that the signal is displayed near the top of the screen. This provides maximum IF signal level.

8. Set the oscilloscope to show several pulse cycles of the 21.4 MHz IF signal. Since this signal is just a lower-frequency version of the original input signal, you can now determine the pulse parameters shown above and determine where to position the gate.

9. To position the gate in time, press SWEEP, then set GATE ON, and adjust GATE DELAY and GATE LENGTH as described in Chapter 6, step 4. At this point, the spectrum analyzer is still in zero-span, so you can't see the gated spectrum, but you can ensure that the gate is occuring during the desired portion of the pulse by viewing the pulse and gate on the oscilloscope. At this stage, do not try to make a measurement on the spectrum analyzer because the sweep and gate are not necessarily synchronized for zero-span measurements.

10. Adjust the spectrum analyzer settings of SWEEP TIME, RESOLUTION BANDWIDTH, and VIDEO BANDWIDTH as described in Chapter 6.

11. Set the SPAN of the analyzer to cover the desired range, and proceed to perform gated spectrum-analysis measurements.

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Printed in U.S.A. 7/00
5952-3685

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