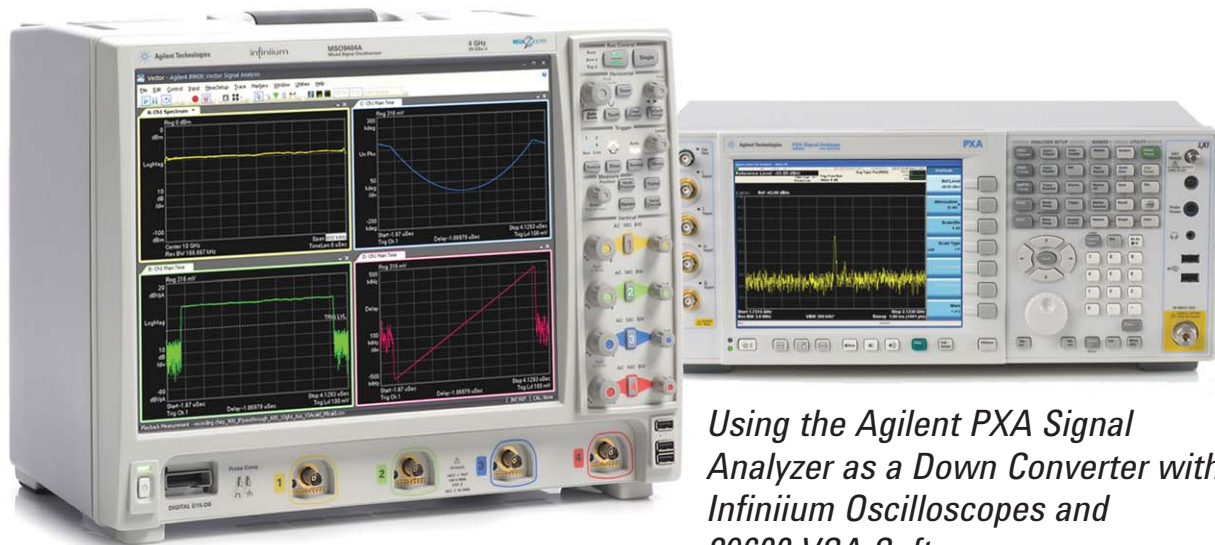# Making Wideband Measurements
Application Note

Using the Agilent PXA Signal Analyzer as a Down Converter with Infiniium Oscilloscopes and 89600 VSA Software

Many applications in digital communications and radar require demodulation and analysis of wideband signals in the microwave region. Some of these applications can be handled by using a modern wideband oscilloscope, such as the Agilent Infiniium oscilloscopes, to directly digitize the signal for analysis with the Agilent 89600 VSA software. However, many times it is more convenient and economical to use a broadband down converter or tuner to translate the desired microwave signal down to an intermediate or IF frequency prior to digitization with an oscilloscope.

This paper will discuss using the Agilent PXA signal analyzer as a microwave down converter for an Infiniium oscilloscope or Acqiris digitizer running the 89600 VSA software. This method provides the user with the advantages of both a full featured signal/spectrum analyzer and high-resolution vector signal analyzer, as well as a wideband system to address wideband demodulation requirements.

A discussion of system-level interconnection will be presented, as well as required options for the PXA and methods to correct the IF frequency response of the PXA over a wide frequency range.

Agilent Technologies

PXA Configuration

Frequency range

The first issues to consider are is the frequency range and bandwidth requirements of the proposed measurement. The frequency range of the N9030A PXA signal analyzer is determined by specifying an option. Options that determine the highest frequency of operation are as follows:

Model-option	Maximum frequency (GHz)
N9030A-503	3.6 GHz
N9030A-508	8.4 GHz
N9030A-513	13.6 GHz
N9030A-526	26.5 GHz
N9030A-550	50 GHz

Table 1. PXA signal analyzer frequency options

Another point of consideration is the minimum frequency. The minimum RF frequency for the PXA signal analyzer is 3 Hz. The frequency range between the minimum frequency and the maximum frequency is divided into two bands, namely, low-band and high-band. Low-band covers from 3 Hz to 3.6 GHz. In this frequency band, the PXA offers an IF bandwidth of 150 MHz. In most cases it would be preferable to use the PXA internal 160 MHz digital IF (Option B1X) for vector signal analysis in low-band; however, an external digitizer, such as an Infiniium oscilloscope, could be used.

High-band for the PXA covers from 3.6 GHz to the highest frequency defined by the options listed in Table 1, above. In high-band, the PXA supports several hundred MHz of IF bandwidth. Therefore, this configuration will be the central topic of discussion for this paper. Lastly, for this discussion, we will only consider PXA signal analyzers equipped with Options 508, 513, 526, or 550 because there is no appreciable advantage in using a low-band only analyzer for this application due to limited IF bandwidth.

IF output

When using the PXA as a down converter, the rear-panel 2nd IF output connector will be connected to the oscilloscope's input. The PXA must be configured with Option CR3 to invoke the IF output functionality. Table 3 lists a summary of Option CR3 performance characteristics.

Description	Supplemental information
Second IF out	
Output center frequency	
SA mode	322.5 MHz
I/Q analyzer mode	
IF path ≤ 25 MHz	322.5 MHz
IF path 40 MHz	250 MHz
IF path 160 MHz	300 MHz
Conversion gain at 2nd IF output center frequency	–1 to +4 dB (nominal) plus RF frequency response [1]
Bandwidth	
Low band	Up to 160 MHz (nominal)
High band	
With preselector	Depends on RF center frequency [2]
Preselector bypassed (Option MPB)	Up to 900 MHz nominal
Residual output signals	–94 dBm or lower (nominal)

Table 2. Second IF output

Two parameters of particular importance are the IF output center frequency and the specified IF bandwidth. First, the IF output center frequency is shown to be from 250 MHz through 322.5 MHz. When using the PXA as a down converter, Agilent recommends using the analyzer in the swept-tuned spectrum analyzer mode, which will produce a normal IF output at 322.5 MHz. In addition, Agilent recommends setting the frequency span to 0 Hz, which stops the normal swept operation of the local oscillator and parks the receiver at the frequency selected in the center frequency menu.

1. *Conversion gain is defined from RF input to IF output with 0 dB mechanical attenuation and the electronic attenuator off. The nominal performance applies in zero span.*
2. *The YIG-tuned preselector bandwidth nominally varies from 46 MHz to 74 MHz depending on the center frequency and the analyzer's frequency option. The preselector effect will dominate the passband width.*

The second parameter that should be reviewed from the Table 2 is the specified IF bandwidth. When used in high-band, the bandwidth is specified with a preselector and with the preselector bypassed. For this application we will want to bypass the preselector to obtain the maximum IF bandwidth possible. The preselector is a tracking band-pass filter that is placed in front of the first mixer, when the analyzer is used in the high-band. This tracking filter greatly improves the performance of the swept-tuned spectrum analyzer, but can severely limit the available bandwidth when the analyzer is used as a down converter. However, keep in mind that when the preselector is bypassed, there is no image protection and the user must ensure that there are no input signals in the instrument's image band that could inadvertently be down converted to the IF frequency. This may require filters at the analyzer input to block interfering signals.

Therefore, to obtain the best broadband down converter, Option MPB, preselector bypass, must also be included in the PXA configuration.

Configuration summary

Based on the above discussion, and assuming that it is desired to cover the microwave frequency range from 3.6 to 26.5 GHz, the following minimum configuration would be recommended:

Model/Option	Description
N9030A	PXA X-Series signal analyzer
Option 526	Maximum frequency range of 26.5 GHz
Option CR3	2nd IF output connector on rear-panel
Option MPB	Microwave preselector bypass

Table 3. PXA signal analyzer recommended configuration

The configuration shown in Table 3 would be a minimum configuration for a signal analyzer that could also be used as a broadband down converter. Also, it may be desired to add other options, such as a preamplifier to improve small signal performance.

Bandwidth considerations

The next area to be considered is that of bandwidth. The question at hand is, how much bandwidth is required for a specific measurement and how much bandwidth can the analyzer provide? The short answer, regarding the available bandwidth, is that in high-band operation with the preselector bypassed, the PXA can provide up to 1 GHz of bandwidth, depending on fidelity requirements. Better IF flatness is available for reduced bandwidths of 600 to 900 MHz. Assuming a bandwidth of 1 GHz, one could assume a 322.5 MHz IF center frequency, with the local oscillator (LO) frequency parked above the microwave frequency band to be down converted. Considering that half of the IF bandwidth would be equal to 500 MHz, this would place the bottom of the IF band at −177.5 MHz, which would result in a severe case of IF fold-over.

Therefore, it is recommended that maximum IF bandwidth to be considered for the standard IF configuration with a center frequency of 322.5 MHz not exceed 500 MHz. This bandwidth restriction would then provide a guard band of 72.5 MHz between the LO and the desired measurement band.

If greater bandwidth is desired, a simple adjustment to the PXA can be made to shift the IF to a higher center frequency, thereby increasing the spacing between the LO frequency and the measurement band. This adjustment is accomplished by adding a frequency offset to the analyzer.

How much bandwidth can be achieved using the above technique? Agilent would recommend a maximum IF bandwidth of 900 MHz, with an IF center frequency of 700 MHz. This can be accomplished by using a frequency offset of −377.5 MHz. In this case, the desired frequency offset can be calculated as follows:

$$F_{Offset} = F_{Normal\ IF} - F_{Desired\ IF}$$

For the example above, the desired frequency offset would be:

$$322.5\ MHz - 700\ MHz = -377.5\ MHz$$

In the following example we will assume an IF bandwidth of 900 MHz using an IF center frequency of 700 MHz.

PXA Setup

When using the PXA as a down converter with a 700 MHz IF center frequency and up to 900 MHz of IF bandwidth, use the following instrument setup:

Note: In the following setup, as well as all others in this document, a bold command enclosed in brackets indicates a hard key, while a bold command not enclosed in brackets indicates a soft key.

1. Verify that the instrument is in the spectrum analyzer mode by pressing **[Mode]** and verifying that **Spectrum Analyzer** is highlighted.

2. Preset the instrument by pressing the green mode preset button in the upper right corner of the instrument front-panel. The instrument should now be making a full band sweep from 10 MHz to the highest frequency possible (option dependent).

3. Set the analyzer to the desired center frequency by pressing **[FREQ] > Center Freq**. For this example assume the desired frequency is 10.0 GHz.

4. Set the span to zero-span, by pressing **[SPAN] > Zero Span**.

5. Enter the desired frequency offset, as described above, by pressing **[FREQ] > Freq Offset**, and entering the desired offset. For this example, enter –377.5 MHz. This will cause the center frequency to shift by the offset entered.

6. Reset the center frequency to the desired frequency by repeating step 3, above. Again, 10 GHz was used in this example.

7. Next, the IF output configuration needs to be set-up, by pressing **[Input / Output] > More > Output Config > Aux IF Out > Second IF (322.5 MHz)**.

8. Invoke the preselector bypass function by pressing **[AMPTD] > More > µW Path Ctrl > µW Preselector Bypass**.

9. Turn off the analyzer auto alignment functions by pressing **[System] > Alignments > Auto Align > Off**. This will ensure that the instrument doesn't try to perform an auto alignment in the middle of your measurement.

10. Finally, place the instrument in single-sweep mode by pressing **[Single]**. This will prevent any internal, between sweep, calibrations that may interfere with your measurement. Remember, when the instrument is in single sweep mode, it will not update parameters like frequency changes until a sweep completes. Therefore, remember to press **[Single]** after any configuration changes.

After completing the sequence above, the analyzer will be configured as a down converter and is tuned to 10 GHz with an IF output centered at 700 MHz. The IF output could be verified by connecting another spectrum analyzer to the IF output connector or by using the VSA to observe performance. Remember that since the local oscillator frequency is higher than the measurement band, the IF spectrum will be inverted (low frequencies will be high and high frequencies will be low).

Note: If the required bandwidth is 500 MHz or less it is recommended that you use the standard 322.5 MHz IF output center frequency. For this case, omit steps 5 and 6 in the procedure above.

Setting Up the 89600 VSA Software

Connect the IF output on the rear-panel of the PXA signal analyzer to the Channel 1 input of the Infiniium oscilloscope being used. Note that the scope should, as a minimum, support 2 GHz of bandwidth. Start the VSA software. When the software has initialized and a sweep is displayed, proceed with the following set up:

1. Turn on a signal generator and connect it to the PXA signal analyzer input connector. Set the generator to produce a CW signal with an amplitude of 0 dBm. The center frequency should be the same as that used in the analyzer setup, for our example it is 10 GHz. It may also be beneficial to use the same amplitude as the signal under test. This could improve dynamic range since the frequency response would be measured at the same power level as the signal that will eventually be measured.

    Note: This would be a good point to consider the attenuation value set on the PXA. For an input signal level of 0 dBm you should have at least 10 to 16 dB of input attenuation. The 1 dB gain compression specification for the PXA ranges from -3 to +4 dBm (at the input mixer). To avoid gain compression issues, 10 dB of drive level backoff would be recommended.

2. Using the VSA spectrum display you should see a CW carrier at 700 MHz (or whatever IF frequency you have specified). If you don't see this signal, something isn't set up correctly.

3. Adjust the VSA range control to 0 dBm.

4. Now configure the 89601B VSA for use with an external down converter by selecting **Input menu > User Correction > Frequency Converter**. If you are using the 89601A VSA select Utilities **Menu > Calibration**. In the Calibration Properties window, select the Frequency tab and configure the down converter menu by selecting **Use Frequency Converter**.

5. Enter the external center frequency. In our example it is 10 GHz.

6. Enter the intermediate frequency (IF). In our example it is 700 MHz.

7. Enter the external bandwidth. In our example it is 900 MHz.

8. Finally, under Spectrum, select **Inverted**. If you are using the 89601A VSA, select **Mirror Frequency**. This will invert the spectrum and correct the spectral inversion problem mentioned above.

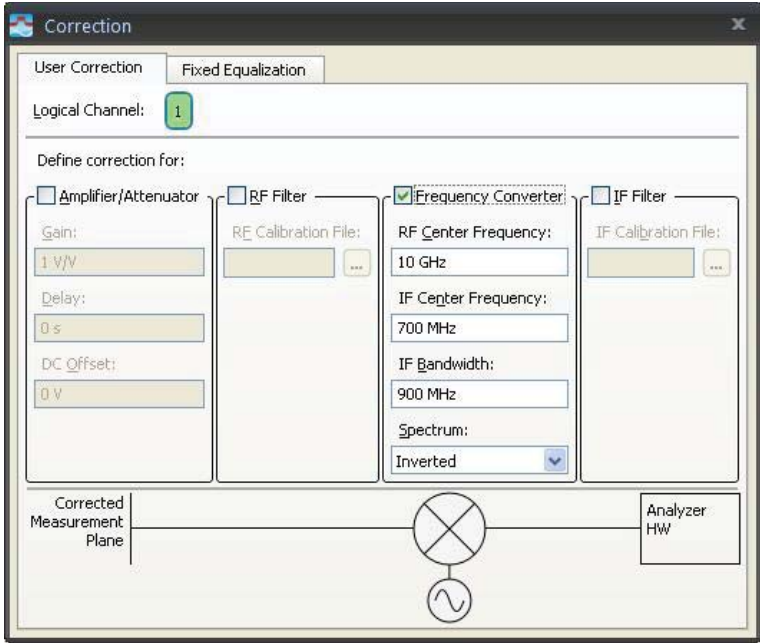The frequency Correction properties box should look like this:

With the VSA configured for use with an external down converter, you should now see your 10 GHz CW signal correctly represented in the center of the VSA spectrum window. The displayed span may not be set correctly. If this is the case, set the span to agree with the external bandwidth, as shown in the Calibration Properties Frequency menu in Figure 1.

If everything is working correctly, you should have a VSA screen that looks like this:
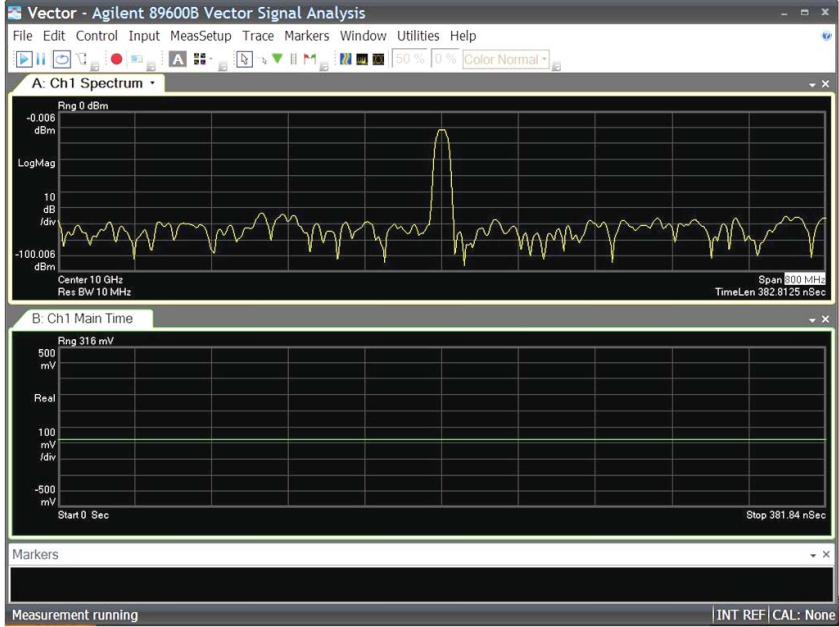
Figure 2. VSA screen— showing spectrum of the 10 GHz carrier

Correcting for the Down Converter Frequency Response

With the PXA configured as a down converter and the VSA displaying the correct CW spectrum, you are ready to start correcting for the frequency response characteristics of the down converter, cables, and scope combination. The correction will consist of measuring the system frequency response; using a swept RF source, saving the frequency response data, and then applying it as a correction file within the VSA software.

Before getting into configuring the signal generator to provide a calibration signal, the amplitude accuracy of the signal generator's signal should be discussed. Normally, when sweeping over a broad frequency range like 800 MHz to 1 GHz, one could expect the signal generator's amplitude to vary within about 2 dB. This amplitude ripple will adversely affect the proposed calibration. If better amplitude flatness is desired, it may be necessary to use an external leveling loop to improve performance. Please refer to your signal generator's user's guide for a discussion on leveling. Also, you can measure the generator's performance with a spectrum analyzer or power meter to determine if it meets your requirements.

Refer to Figure 3 for a typical external leveling setup, using a directional coupler and crystal detector. If you intend to use a resistive power splitter instead of a directional coupler you can achieve better performance with a 2-resistor splitter, rather than a 3-resistor splitter.

Figure 3. Typical signal generator external leveling loop
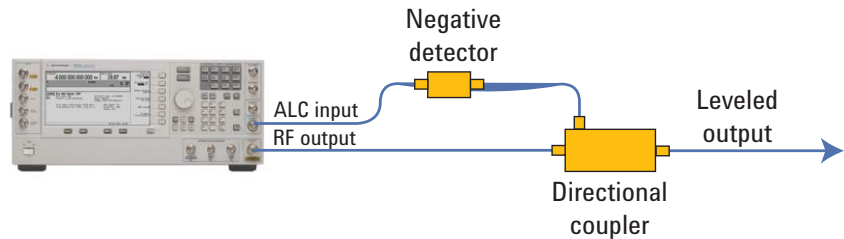
Using external leveling, amplitude flatness could be expected to be better than 1 dB over a 1 GHz bandwidth, depending on the quality of the components used.

To set up the frequency response measurement, follow this sequence:

1. Configure your signal generator (Agilent PSG or MXG) to sweep over the frequency range of interest. In our example, a 10 GHz center frequency was used with a 900 MHz measurement span. Therefore, you will need to set the signal generator start frequency to 9.55 GHz and the stop frequency to 10.45 GHz. The amplitude should be set for 0 dBm or close to the amplitude of the signal you plan to measure.

2. Set the sweep time of the signal generator to a fairly slow sweep. For example, you could set it to 10 to 20 seconds.

3. With the signal generator sweeping, you should see the CW tone sweep through the VSA frequency span. In our example, it should sweep over the 900 MHz span shown above in Figure 2.

4. Watch the upper right corner of the spectrum display and look for the OV (over voltage) symbol. If this warning is present, the VSA is being over-driven. If you see the OV warning, adjust the VSA range up in small steps until the warning goes away. The simplest way to make this adjustment is to Press the range value displayed in the upper right hand corner of the spectrum display to highlight the range value. Now that range is the active function, you can use your keyboard up and down arrow keys to increment the range parameter. If you do not see the OV warning, decrease the range until the warning appears and then back off until it is no longer visible.

5. Next, change the VSA averaging to continuous peak hold. This is accom-plished by selecting the MeasSetup menu and selecting **Average**. Under the Average Type scroll-down menu select **Continuous Peak Hold**.

6. With continuous peak hold invoked, you should see the frequency response of the system drawn out on the spectrum display. You can decrease the dB/div control and adjust the display to get a better view of the frequency response.

7. Allow the sweep generator to sweep through the frequency band several times to clean up any holes that may appear in the frequency response plot. Once you are satisfied with the displayed frequency response, place the VSA in pause pressing double-bar symbol just below the Edit menu.

Your frequency response plot may look something like this:

Figure 4. VSA and down converter frequency response (uncorrected)

8. Next, store your measured frequency response by selecting **File > Copy Trace**. The default storage register is Register D1. Use this choice.

9. With the frequency response saved in Register D1 you are ready to apply it as a correction to the VSA. This is accomplished by selecting **Input > Fixed Equalization**. This will bring up the VSA Correction Properties dialog box.

10. Under the Fixed Equalization tab of the Correction Properties dialog box, select **Fixed Equalization**. Ensure that Register D1 is selected as the data register where the correction file is stored. Close the dialog box.

11. Restart the VSA (following the pause, above) and adjust the scale/div control for a usable display. The VSA should now display a corrected frequency response curve (allow a couple of sweeps).

Your VSA system is now corrected for the frequency response of the down converter; however, the amplitude has not been calibrated. This can be accomplished by entering a fixed amplitude offset into the VSA software to correct the amplitude readings.

You should have a display that looks something like the following:
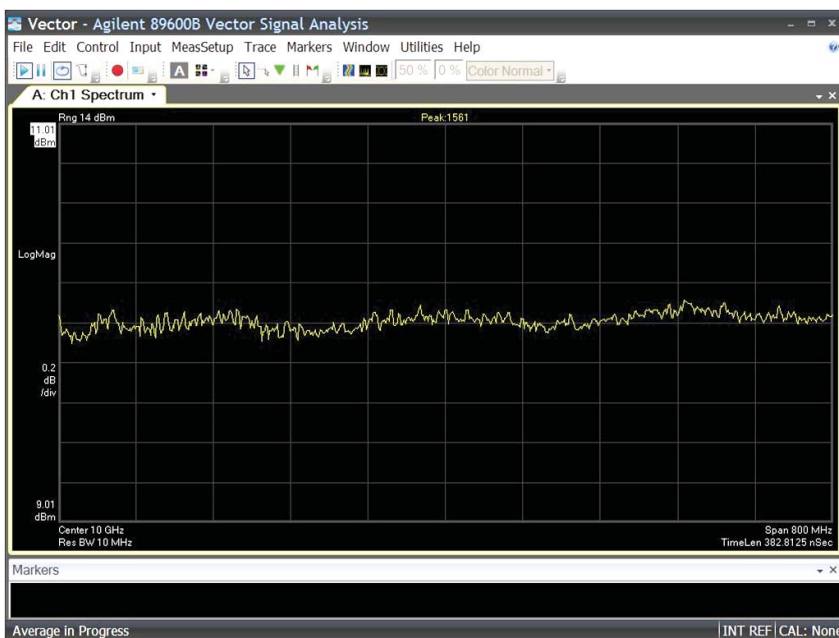
Figure 5. Down converter frequency response (corrected)

You are now ready to use your VSA for signal analysis. Before continuing, be sure and return to the MeasSetup Average menu and turn off the continuous peak hold function.

Amplitude Corrections

Up to this point we have corrected our VSA for frequency response errors introduced by the down converter, any cables we may be using, and the oscilloscope we are using for a digitizer, but there has been no effort to correct our display to provide correct signal amplitude measurements. Each of the above contributions to frequency response errors also contribute to amplitude accuracy issues; however, the biggest factor is generally the conversion-loss of the down converter and any attenuation that may have been selected in the PXA setup.

In Table 2, nominal conversion gain is specified at –1 to +4 dB. This specification assumes that the PXA attenuator is set to 0 dB. For the signal levels discussed previously in this paper a typical attenuation would be at least 10 to 16 dB. Therefore, we could expect to see at least 10 dB of RF to IF conversion loss for the down converter.

Correcting for signal losses can be a simple matter, depending upon the desired accuracy level. In the simplest, case a 0 dBm CW signal can be set up on a signal generator that is connected to the RF input of the spectrum analyzer being used as a down converter. Next, the user can measure the signal level on the VSA spectrum display using a marker. The measured power can then be negated (multiply by –1) and applied as an amplifier/attenuator gain in the VSA User Correction menu, as follows:

1. Input a known power level at the center frequency of the VSA span, in our example 10 GHz CW tone at 0 dBm.

2. Measure the signal's power using a marker on the VSA spectrum display. Assume a marker amplitude of –10 dBm, as an example.

3. The required correction factor can be calculated by subtracting the input signal power from the measured signal power. $Ac = Pin - Pm$. For this example, $Ac = 0\ dBm - (-10\ dBm) = 10\ dB$.

4. Go to the 89601B Input menu and select **User Correction > Define Correction for > Amplifier/Attenuator.**

5. Enter the correction factor calculated in step 3, above.

Now the 89600 VSA should display correct power levels. The above procedure can be improved by connecting a power splitter to the input of the down converter, with the input to the splitter connected to the signal generator, and the unused output port connected to a power meter. In this way, a more accurate measurement of the power at the input to the down converter can be determined. Likewise the splitter and power sensor could be moved to the end of a cable to also correct for the loss of an input cable.

Measurements

Finally, Figure 6 shows the end result of the corrections procedure described above. In this figure, the VSA is being used to demodulate a linear FM chirp radar signal with a chirp bandwidth of 800 MHz. Four display panels are used to show the signal information. First, in the upper left panel the RF spectrum is displayed. Immediately below the spectrum is the power versus time display showing a 5 µs pulse at a scale factor of 10 dB/div. In the upper right panel the signal's phase versus time is displayed, and directly below the phase plot is the frequency versus time. The frequency versus time display shows the actual frequency modulation applied to the pulse and can be used to determine chirp linearity.

Figure 6. Example of 750 MHz chirp radar signal demodulation

In conclusion, we have demonstrated how to use the PXA signal analyzer as a broadband down converter for use with the 89600 VSA software, to demodulate and analyze radar and communications signals. A procedure has been provided to allow the user to correct for the RF to IF frequency response of the down converter and any cables or test fixtures that may be included in the test system. Using the PXA as described in this paper allows technicians and engineers to enjoy maximum reuse of their test equipment, and avoid the inconvenience of having to build their own down converter for wideband measurements.