

Using Agilent's PrecisionProbe Software on the Infiniium 9000 Series Oscilloscopes to Characterize and Correct for Probe Loss

Application Note



Introduction

Oscilloscope probes provide the vital link between an object to be measured and the oscilloscope. Because they are inherently lossy, probes influence both the accuracy of the measurement result and measurement repeatability. To compensate for the inherent loss, various techniques (e.g., probe correction via digital signal processing (DSP) or use of higher bandwidth probe heads) have been employed with mixed results. Over the last few years, waveform transformation software has made it possible

to minimize the errors caused by the probing system, but the process is long and arduous. This application note introduces an easier and quicker solution for addressing the loss due to the probing system and its impact on oscilloscope measurements. The solution—the Agilent PrecisionProbe software running on the Infiniium 9000 Series oscilloscopes—enables quick characterization of the entire probe system, making it increasingly more difficult for engineers to simply ignore the loss.



Agilent Technologies

Understanding the Problem

When it comes to the probe system, engineers don't typically know how the link to the oscilloscope input impacts their measurement results, and that's the problem. At times, the probe's inherent loss and response variation can be substantial. In other cases, it may be just different enough from the other similar probes to cause measurement variation. Either way, the result is the same—inaccurate, non-repeatable measurements, which ultimately means more time debugging and slower times to market.

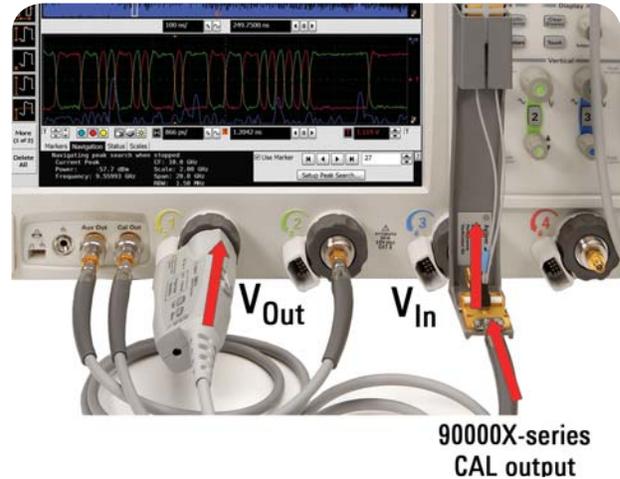
The goal of any measurement system is a flat frequency response, since the flatter the response, the more accurately the scope will depict the actual signal being probed. A flatter frequency response also means that measurements become more repeatable. Achieving a flat frequency response requires probe correction as probe hardware is not perfect and will have loss. Unfortunately, four key challenges work to complicate this process.

To better understand these challenges, it's important to first define the following terms:

- V_{Src} —The signal at the probe point before the probe is connected, which would be the signal at the probe point if an ideal probe with infinite input impedance were connected.
- V_{In} —As shown in Figure 2-1, V_{In} is the signal at the probe point while the signal is being loaded by the probe. Probe loading is caused by the input impedance of the probe making a voltage divider with the source impedance of the circuit being measured.
- V_{Out} —As shown in Figure 2-1, V_{Out} is the signal that is output from the probe.
- Voltage Transfer Function—The resulting response of the compensation of the probe

2.1 Probed Environment Challenges

The four key challenges presented by the probed environment include:



9000 X-Series CAL output

Figure 2-1. V_{In} is the signal at the probe point while the signal is being loaded by the probe.

Model-Based Correction

In an ideal world, probe compensation would be done for each individual probe, however due to time and file management this is not possible. Tips and probe head correction is typically based off a model, it does not accurately represent a specific probe employed. As an example, consider a probe amplifier. Oscilloscope vendors measure many probes and average all their characteristics to get a baseline probe characteristic that is converted into a characteristic file. Vendors use the file to create a model and ultimately, for probe compensation for all probe amplifiers. This same method is used for oscilloscope accessories.

One exception to the model-based compensation is the InfiniiMax III probe amplifier. With the introduction of the InfiniiMax III probe amplifier, Agilent now offers a better method. Instead of relying on model-based correction, each specific InfiniiMAX III probe amplifier is measured and the resulting S-parameter (the probe characteristic file) data stored on the amplifier. When the amplifier probe is plugged into the oscilloscope, the stored data is automatically downloaded. While the amplifier is no longer model based, all accessories and probe heads still use model-based characterization for their compensation.

Custom Probes

Custom probes have no automatic vendor provided correction (in other words you get what the hardware gives you). An example of characteristics of one such custom probe is shown in Figure

2-2. As the graph illustrates, the response on this probe has a 3 dB down point at 4 GHz, even though the probe and scope are rated to 13 GHz



Figure 2-2. This custom probe system has a response that is far from flat.

Differing Compensation Techniques

Oscilloscope vendors employ different frequency response correction methods to account for probing. The two frequency response correction methods used to compensate for loss and nonlinearities are V_{Out}/V_{In} and V_{Out}/V_{Src} (Figure 2-3). Each method poses a number of pros and

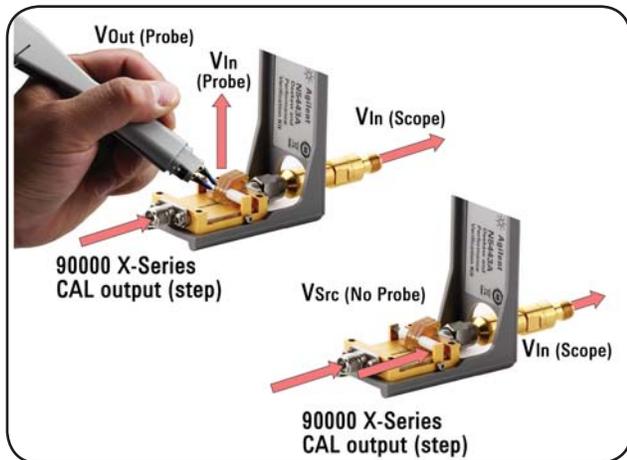


Figure 2-3. Pictured here are the two frequency response correction methods employed by Agilent's 9000 Series oscilloscope to account for probing.

With the V_{Out}/V_{In} , the goal is for V_{Out} to equal V_{In} . In this case, the signal at the output of the probe offers an accurate representation of the signal that currently exists as it is being probed; it doesn't hide the fact that the probe loaded the signal. This method is best used for receiver sensitivity.

With V_{Out}/V_{Src} , the goal is for V_{Out} to equal V_{Src} . When the system source impedance is known, this method more accurately depicts the signal before it was probed (V_{Src}). It is best used for transmitter test since it does an exceptional job of estimating the signal coming out of the transmitter. With receiver type testing, errors occur since the signal that is actually there while being probed isn't shown. Additionally, this hides the effect that probe loading has on the signal being probed.

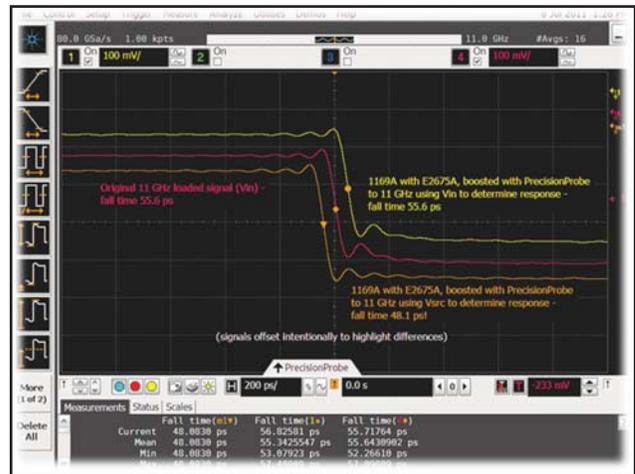


Figure 2-4. Shown here is a comparison of the two probe compensation methods.

The graph in Figure 2-4 compares the two probe compensation methods (V_{Out}/V_{Src} and V_{Out}/V_{In}). Notice that while the V_{Out}/V_{In} correction accurately tracks with the cabled connection, the V_{Out}/V_{Src} correction overemphasizes the rise time. The V_{Out}/V_{In} function is the definitive voltage transfer function of the probe, but it is not a function of the probe's input impedance. The V_{Out}/V_{Src} function is not the definitive voltage transfer function of the probe. Rather, it is a function of the probe's input impedance and the source impedance of the system being probed.

Probe characteristics differ from one probe to the next. For example, an InfiniiMax II series probe amplifier with a browser will have a different voltage transfer function than an InfiniiMax III series probe amplifier with a browser. Two InfiniiMax II's with an identical browser model number will not be identical in their characteristics. Even a task as simple as changing the span on a browser changes the entire probe's voltage transfer function.

3.0 An Easier, More Accurate Solution

Realizing accurate, repeatable measurements in the presence of probe loss requires a solution that understands the characteristics of the probing system and is able to adequately compensate for any response nonlinearities caused by loss or phase nonlinearities. The recently introduced PrecisionProbe software running on the Infiniium 9000 Series oscilloscope (N2808A) offers just such a solution, enabling higher measurement accuracy and repeatability.

3.1 PrecisionProbe Software and the 9000 Series Oscilloscope

PrecisionProbe software quickly and easily characterizes and corrects the frequency response (V_{Out}/V_{In}) or (V_{Out}/V_{Src}) magnitude and phase of any probe and probe head combination using only the Infiniium 9000 Series oscilloscope (Figure 3-1), the individual probe and its accessories (meaning no more model-based inaccuracies). It also ensures that the frequency response is the same for every oscilloscope probe. In particular, it allows the engineer to:

- measure the input impedance and response of any probe (gaining valuable insight),
- quickly correct for probe loss (without extra instruments such as VNA or TDR),
- correct probing issues such as phase nonlinearity, magnitude non-flatness, and see the effect of probe loading; and
- quickly gain insight into the impedance/capacitance that defines the connection.



Figure 3-1. The Infiniium 9000 Series scopes comprise three instruments in one: a scope, logic analyzer and protocol analyzer. It offers the same powerful features as any Infiniium oscilloscope, but is specifically engineered with a broad measurement capability in bandwidths up to 4 GHz and a 20 GSa/s sample rate to meet a full range of needs.

The software characterizes and corrects a probe by first measuring only a cabled connection and the E2655A desk fixture to create a baseline measurement. The probe is then added to the deskew fixture and the characteristics of the system measured. The resulting S-parameter data is stored on the oscilloscope. When the probe is plugged into the oscilloscope, the stored data is automatically recalled. This simple method of measurement allows the PrecisionProbe software to measure V_{src} (the voltage at the DUT before the probe is connected), V_{in} (the voltage at the DUT with probe loading), and V_{out} (the voltage at the end of the probe).

Combining PrecisionProbe with the 9000 Series oscilloscope enables a number of key benefits. To begin with, every probe in the system can have the exact same response probe-to-probe without the inaccuracies that using one model can produce, as all probes are measured and compensated to the individual probe. Custom probes can now be properly characterized and unwanted loss and nonlinearities removed. Characterization of custom probes can now be done without needing a Vector Network Analyzer (VNA). Additionally, engineers can characterize their probing system and then immediately use the compensation in real time, without having to load more software.

When combining Infiniimax probes with switches between the amplifier and the probe head, PrecisionProbe allows for full correction and automation of each probe's path, including the switch. Full automation is then available to allow for quick swapping of the inputs with each input fully characterized and corrected. No longer does one need to worry about the path-to-path variation that can cause inaccuracies. In addition to increased measurement accuracy, such capabilities translate into a significant time and cost savings as accurately depicted measurements mean faster time to market.

4.0 Probe Characterization: Final Results

With PrecisionProbe, engineers can choose to utilize either the V_{Out}/V_{Src} or V_{Out}/V_{In} method for probe correction. In the latter case, PrecisionProbe corrects the V_{Out}/V_{In} response to be flat with frequency and phase to the engineer's defined bandwidth limit. Regardless of the chosen correction method, PrecisionProbe cannot correct the loading effects of the probe. Note that Agilent's probe frequency response corrections are typically defined using V_{Out}/V_{In} , which does not ignore probe loading.

The final result of a probe characterization using the V_{Out}/V_{In} method is shown in Figure 4-1. In this case, PrecisionProbe is used to correct "V_{Out} is directly on top of V_{In}." The corrected V_{Out}/V_{In} transfer function is indicated by the light blue line. Notice that the transfer function is now flat for the entire bandwidth of the probe. In addition, 6 dB of loss has been compensated.

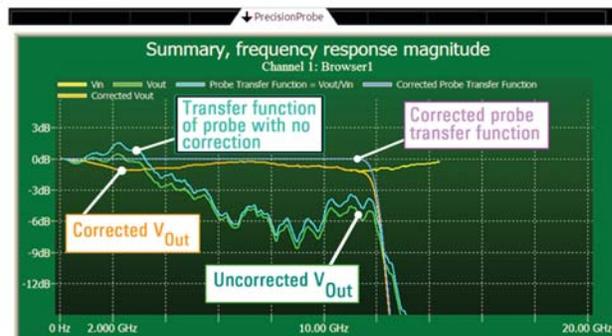


Figure 4-1. A probe that has a perfect transfer function shows an exact copy of a signal at the input. A probe that has a perfect system response shows the signal at the input of probe boosted by the estimate amount of loading due to the probe.

5.0 Conclusion

Despite the absolute best efforts from oscilloscope vendors, probes are lossy and, as a result, can cause measurement errors. Over the last few years, waveform transformation software has made minimizing the errors possible; however until software/hardware was introduced on scopes it was still a long process. Scope vendors are now making probe correction much easier and making the decision to ignore the probe systems inherent loss much more difficult. Agilent's PrecisionProbe software runs on the Infiniium 9000 Series oscilloscopes to provide a means for engineers to quickly and easily characterize and correct for the insertion loss caused by probing systems. Using PrecisionProbe, they can now further increase their margins without adding significant time or extra equipment, and also realize accurate and repeatable measurements.



Agilent Technologies Oscilloscopes

Multiple form factors from 20 MHz to >90 GHz | Industry leading specs | Powerful applications

 **Agilent Email Updates**

www.agilent.com/find/emailupdates
Get the latest information on the products and applications you select.



www.axiestandard.org
AdvancedTCA[®] Extensions for Instrumentation and Test (AXIe) is an open standard that extends the AdvancedTCA for general purpose and semiconductor test. Agilent is a founding member of the AXIe consortium.



www.lxistandard.org
LAN eXtensions for Instruments puts the power of Ethernet and the Web inside your test systems. Agilent is a founding member of the LXI consortium.



www.pxisa.org
PCI eXtensions for Instrumentation (PXI) modular instrumentation delivers a rugged, PC-based high-performance measurement and automation system.

Agilent Channel Partners

www.agilent.com/find/channelpartners
Get the best of both worlds: Agilent's measurement expertise and product breadth, combined with channel partner convenience.



Agilent Advantage Services is committed to your success throughout your equipment's lifetime. We share measurement and service expertise to help you create the products that change our world. To keep you competitive, we continually invest in tools and processes that speed up calibration and repair, reduce your cost of ownership, and move us ahead of your development curve.

www.agilent.com/find/advantageservices



Windows[®] is a U.S. registered trademark of Microsoft Corporation.

For more information on Agilent Technologies' products, applications or services, please contact your local Agilent office. The complete list is available at:
www.agilent.com/find/contactus

Americas

Canada	(877) 894 4414
Brazil	(11) 4197 3600
Mexico	01800 5064 800
United States	(800) 829 4444

Asia Pacific

Australia	1 800 629 485
China	800 810 0189
Hong Kong	800 938 693
India	1 800 112 929
Japan	0120 (421) 345
Korea	080 769 0800
Malaysia	1 800 888 848
Singapore	1 800 375 8100
Taiwan	0800 047 866
Other AP Countries	(65) 375 8100

Europe & Middle East

Belgium	32 (0) 2 404 93 40
Denmark	45 45 80 12 15
Finland	358 (0) 10 855 2100
France	0825 010 700*
	*0.125 €/minute
Germany	49 (0) 7031 464 6333
Ireland	1890 924 204
Israel	972-3-9288-504/544
Italy	39 02 92 60 8484
Netherlands	31 (0) 20 547 2111
Spain	34 (91) 631 3300
Sweden	0200-88 22 55
United Kingdom	44 (0) 118 927 6201

For other unlisted countries:

www.agilent.com/find/contactus

Revised: January 6, 2012

Product specifications and descriptions in this document subject to change without notice.

© Agilent Technologies, Inc. 2012
Published in USA, January 22, 2012
5990-9465EN

