Signal Integrity eSeminar Series Q&A: Jitter Analysis: What Works, What Doesn't and Why

The following Questions and Answers were created from the live eSeminar broadcast of March 30, 2005. You can view the archived eSeminar by going to **www.agilent.com/find/archives** and selecting it from the list of archived eSeminars.

Q: What is the effect of bandwidth on the jitter analyzers?

A: In the tests we made, we set the data rate to 2.5 Gb/s, which should have been a nice comfortable data rate for the bandwidths of all of the analyzers that we studied. Generally speaking, the effect of bandwidth works both ways. First of all, you want plenty of frequency bandwidth so that you can accurately feed the signal. If you don't have enough bandwidth then you'll roll off the signal and see only a few of the harmonics. That will change the rise/fall time. When you do that, you won't get an accurate jitter measurement. On the other hand, if the bandwidth is really huge, it's possible that you could introduce more jitter analyzer noise. Though, for the results we saw here the highest bandwidth analyzer, the 86100C DCA-J at 20 GHz, still gave the most accurate results. But generally that's something you want to look out for.

Q: Was the jitter baseline created against a bit error ratio of the test set?

A: No. The calibration of the precision jitter transmitter is documented on the Agilent website by our DesignCon 2005 paper. We used a lot of different techniques for the calibration. For example, for periodic jitter we used the Bessel null method, which is traceable, for inter-symbol interference. We measured the S-parameters to calculate the inter-symbol interference. And then, to calibrate the level of total jitter, at 10^{-12}, the TJ was calculated by convolving the distributions of the different conditions that were included. So in other words, if we had random jitter, periodic jitter, inter-symbol interference and duty cycle distortion, we convolved the independent distributions and then integrated those to calculate what the total jitter at 10^{-12} was. This was one of the reasons that it was of utmost importance that our random jitter distribution faithfully follow a Gaussian all the way down to a bit error ratio of 10^{-12}. We compared our calculation of the total jitter with the complete measurements performed on a bit error ratio tester. We saw quite nice consistency at a level of around 5%, except near the noise floor of the BERT. For the uncertainties in total jitter, we propagated the uncertainties of each source through the calculation.

Q: What sample rate did you use on the real-time scopes?

A: 20 GSa/s with all the 6 GHz real-time scopes.

Q: Have you tested the Agilent real-time oscilloscopes since JitterFest?

A: Yes. They have been tested but I don't have results to show you. The results I've seen look very promising. If you ask your Agilent field engineer, they should be able to provide some information very soon.

Q: What does DCA-J stand for?

A: Digital Communications Analyzer with Jitter Analysis. The Agilent 86100C DCA-J is a wide bandwidth sampling scope with a special acquisition system optimized for jitter analysis.

Q: What about other sampling scopes? Were they tested?

A: No. We did not test any other sampling scope other than the 86100C DCA-J. We used all the equipment we could get our hands on, and it would certainly be nice if we could get a precision jitter transmitter out in public and have everybody test their analyzers. That's not currently planned and I don't know if it will be. I think if there's an outcry from customers we could probably arrange it.

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Q: If voltage noise is a problem for making measurement on real-time scopes, why didn't Agilent compare the Tektronix CSA8000 and other BERTs?

A: The test required the ability to do jitter separation, which was not available with the Tektronix CSA at the time.

Q: Did you compare this jitter analysis with that which is performed by the Omni BER?

A: The OmniBER is an Agilent product that is a SONET tester and tests the SONET flavor of jitter. It basically uses a mixer to demodulate the jitter from the signal. That's a much different type of jitter analysis than any of these jitter analyzers use. It's different in a lot of ways. Primarily it's different because the jitter frequency bandwidth is limited. The amount of jitter frequency that's analyzed by SONET is fixed. And in enterprise/digital jitter it's not. They're very different measurements, so it's difficult to compare them. There are cases where what they call jitter generation in SONET, which is the jitter generated by a transmitter, might correspond to what we call random jitter. There are also jitter transfer and jitter tolerance measurements required in SONET. When you're having jitter problems, performing these SONET style jitter analyses can be very helpful. I would recommend that if you're in deep trouble, then try everything at your disposal. These are complementary techniques, and I can't map the results from enterprise jitter analysis, something like total jitter at a bit error ratio, onto the space of SONET analysis results.

Q: Does the precision jitter transmitter represent the sort of jitter conditions I see in my lab?

A: I don't know. The jitter conditions that the precision jitter transmitter applies are ideal, they meet all of the industry assumptions. Since all the jitter analyzers are based on those assumptions we required that they be valid. We didn't ask the jitter analyzers to do anything that they didn't claim to be capable of. The advantage is that we had a level playing field. We could tell which analyzers worked and which didn't in those situations where they claimed to work. The disadvantage is that it's possible to have some jitter from sources that don't follow the industry-wide assumptions. Crosstalk, for example, yields a distribution that cannot be generally defined – it varies too much from circuit to circuit. So it's a yes and no. The precision jitter transmitter should accurately portray the vast majority of jitter conditions that you'll see, though maybe you'll see them at different levels than those that we looked at. Hopefully we covered the space pretty well. But you'll have other effects. You might have effects that are rare, that are real hardware like things. For example, if you were analyzing jitter on a bus in a computer, and the computer did something like a page swap, something that happens within a period of milliseconds at worst, seconds more likely, it is an event that none of these jitter analyzers are going to see.

Q: Total Jitter was defined as a well-defined peak-to-peak relationship between jitter and bit error ratio. What does that mean?

A: I would refer you to some of the documentation that's on the resource page for this eSeminar, or consult the 86100C DCA-J web page at **www.agilent.com/find/dca**. This is defined in great and rigorous detail.

Q: Is data dependent jitter only attributed to signal levels?

A: No. Data dependent jitter comes in as a vector quantity. So it changes the signal levels, the amplitude. It also changes the timing. So data dependent jitter, primarily through inter-symbol interference, is caused by the filtering and attenuation effects of the transmission path. So it's got two effects. The amplitude effect seems to be the one that causes noisy analyzers to interpret data dependent jitter as random jitter.

Q: Why didn't you measure the 10^{-12} TJ with a BERT for all jitter present instead of having wide uncertainty bars?

A: The uncertainty of TJ (10^{-12}) measurements performed on a BERT are much larger than the uncertainties from our calculations. The main source of BERT TJ (10^{-12}) uncertainty, at least in high quality modern BERTs, are the error detector sensitivities. Older BERTs have much greater trouble with the timebase linearity/accuracy. The Agilent N4901B Serial BERT has the best error detector sensitivity of any BERT available, better than 50 mV, but still doesn't give TJ measurements more accurate than our calculations.

Q: What is DDJ (4, xxx) on slide 11?

A: The jitter signals constructed had several levels that could be generated. DDJ 4 would represent one of the 4 levels of DDJ that could be set.

Q: Is DDJ only attributed to the voltage levels?
A: No. DDJ is a combination of Inter-Symbol Interference (ISI) and Duty-Cycle Distortion (DCD). The former has both time and voltage components, the latter (usually) has only a time component. The trick is that they are not independent so one must take care in combining them.

Q: If one were to measure jitter on a clock, would there be a DDJ component?
A: Yes. Duty-Cycle Distortion would be present on a clock signal.

Q: You being an expert on the DCA-J and Serial BERT, should it really be surprising that they had less error? Each instrument has many settings and tweaks to optimize measurements and without experts from each company present, how can you ensure that there weren't measurement setup options?
A: The 86100C DCA-J requires no set-up whatsoever. You push the button and get the results. The BERT was configured in one way for all the tests using a BER threshold (10^{-4}) and number of transmitted bits (3×10^{-9}) that really didn't have a big affect on the results. We configured all the other equipment as the user manuals suggested to get the most accurate results. Some of those configurations required minutes per test, too. Remember, this was an internal study, we wanted the most accurate results that every analyzer could give. JitterFest was not a marketing game. Ultimately, if the set-up of the equipment is so complicated that a company expert is required to get an accurate measurement, the equipment probably isn't very useful anyway. Still, the precision jitter transmitter is well documented and was built from parts available to anyone. I agree that every company should properly debug their equipment with a known signal. Frankly, I was shocked that no one else has done this – it seemed kind of obvious to me, which is why I suggested it.

Q: Why were two IQ modulators required to produce a truly random jitter distribution?
A: To generate RJ that faithfully follows a Gaussian with tails out to $BER=10^{-12}$, two IQ modulators are required to provide sufficient memory.

Q: Is it possible to measure jitter using the DCA-J on a differential signal?
A: Yes.

Q: If the voltage noise being translated to Jitter causes all the analyzers to overestimate the Jitter, why was the brown real-time analyzer "Z" underestimating Jitter at some points?
A: Evidence suggests that they made mistakes in tuning the parameters of their algorithm. The most annoying thing about the whole study was trying to figure out how the different analyzers work. Let me re-iterate: if you don't know what your equipment is doing, then you can't understand the results. You should always know what you're doing. The methods used by the Agilent equipment are described in detail for this reason.

Q: The 86100C DCA-J is a 20 GHz scope. What is the best scope to use for a 4 GHz signal? I believe the ratio is that the scope should be 3x the signal correct?
A: Using 3 times the signal gets you the 5^{th} harmonic of the fundamental frequency. I would say that you need at least 3x the data rate but should have as much as you can unless the voltage noise increases with bandwidth.

Q: Can the DCA-J show the frequencies of PJ?
A: Yes. A clever technique is used to determine the actual spectrum from the aliased spectrum that the DCA-J (which under-samples the signal) actually measures.

Q: What level of BER did you start your BERT dual Dirac analysis at? Did you start deeper to reduce mistaking DDJ for RJ?
A: All tests had a BER threshold of 10^{-4}.

Q: Can the TJ reported numbers from all the respective jitter analyzers be considered accurate, or is the TJ number reported just the addition of RJ and DJ?
A: No. They can't all be considered accurate. Unfortunately most of the manufacturers of jitter analyzers don't provide descriptions of how their measurements are made so it's impossible to make intelligent decisions about where a given analyzer is likely to fail. The Agilent techniques are described in detail.

Q: In all of your studies and expertise, you have surely developed white papers on correct design rules to minimize jitter. Is that something you will share with the industry?
A: They are available on the web. Go to **www.agilent.com/find/dca** and look at the library information.

Q: Can I get a copy of the presentation or find the resource page with the links for the white papers?

A: Yes, go to eSeminar archive. When the window opens there will be a pull-down menu selection at the bottom left of the window labeled "-- Print Documents and View Links --". If you select "Additional Resources", the Agilent Resource page will be displayed, where you can get a copy of the presentation plus find many valuable links for more information on the subject. There is also a Digital discussion forum (**www.agilent.com/find/forums**) if you would like to pose/review other questions.

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