

## MEASUREMENT TIPS

# Simplify the Generation of High-Quality IQ Signals



### Introduction

**In-phase quadrature modulation**, or IQ modulation, is by far the dominant modulation scheme in communication applications for transmitting and receiving data. Its popularity is due to its efficient use of bandwidth, which continues to be a critical bottleneck in our data-hungry world. Because IQ modulation designers face a continual bandwidth crunch in a spectrum that is filled with interference, test via signal simulation is critical. In particular, designers need to generate a high-quality known-good signal and be able to easily add real-world non-ideal characteristics to the signal to test the limitations of their designs. In this application brief, we will look at how you can use the 33500B Series waveform generators with the IQ Signal Player option for generating ideal as well as non-ideal IQ signals.

We will first discuss the 33500B's performance and how its exclusive Trueform waveform generation technology can help you produce more accurate signals. From there, we will look at how easy it is to move your IQ signals from software to a 33500B Series waveform generator for play back. Finally, we will look at the 33500B Series' built-in features for simulating quantitative non-ideal conditions on an IQ signal for testing the limits of your design.

### Snapshot

A start-up company designs monitoring devices for the smart grid that offer two different ways to communicate over the smart grid: power line communication (PLC) and a proprietary wireless standard using the 900-MHz ISM band. The start-up company has cost and time constraints for testing its design, which strongly influenced the development team's choice of test equipment. For testing the communication portions of the design, the team chose the Agilent 33522B waveform generator with an IQ Signal Player for its low cost, ease of use, signal quality, and flexibility. The 33522B waveform generator and the Agilent N9310 signal generator were used as a complete IQ baseband-to-RF carrier solution for testing the wireless communication module design, and the 33522B was used alone for generating carrier and baseband IQ signals for testing the PLC module design. Since the design operates around power lines, which is an electrically noisy environment, the features on the 33522B waveform generator that allow you to simulate non-ideal signal conditions were invaluable for verifying correct operation of the design in its real-world operating environment.



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## Trueform waveform generation technology

The 33500B Series provides an analog waveform bandwidth with a flat amplitude response to 30 MHz with a sample rate of 250 MS/s. The exclusive Trueform waveform generation technology found in the 33500B Series provides a true representation of a waveform, not an approximation like the widely used waveform generation technology direct digital synthesis (DDS), which can skip and repeat points. Trueform technology provides extremely low waveform jitter, typically less than 5 ps of RMS jitter. In **Figure 1**, you can see an example of a jitter measurement made on a 10-MHz pulse signal from a 33522B using a high-performance oscilloscope.



**Figure 1. Jitter measurement on the 33522A waveform generator**

The histogram function of the scope was used to measure the jitter on the pulse signal. The standard deviation of the histogram represents the RMS jitter of the signal. The RMS jitter in Figure 1 (highlighted above) is only 4.1 ps. Trueform waveform generation technology ensures you generate a high-quality known-good IQ signal.

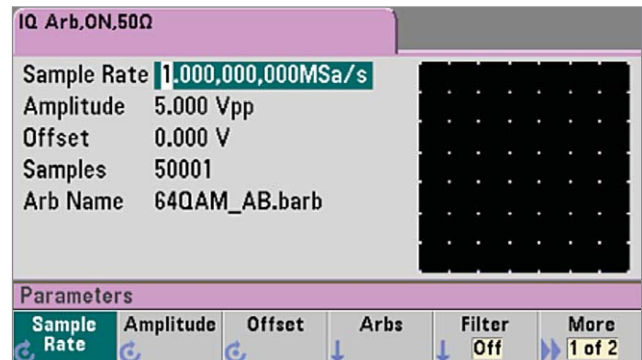
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With a sample rate of 250 MS/s, the 33500B Series waveform generators' usable IQ signal bandwidth can go well beyond the specified analog bandwidth of 30 MHz. To generate IQ signals above the specified bandwidth, you just need to compensate for the amplitude roll off at higher frequencies when you build your waveform in software. The 33500B Series' roll off above 30 MHz is fairly gradual, for instance, at 50 MHz you will see about a 6-dB drop in amplitude.

## Transferring and generating IQ baseband signals to the 33522B

The 33500B Series provides USB, LAN, and GPIB I/O interfaces and supports major drivers such as IVI for transferring IQ waveforms remotely from software. If you want to avoid having to connect to the waveform generator remotely, you can upload waveforms via the USB connector on the front panel from a USB storage device. You can easily upload waveforms from file formats such as comma-separated value (CSV) files, data (DAT) files, and ActionScript Communication (ASC) files. These file formats are typically supported in communication/signal engineering software packages such as MATLAB.

The 33500B Series has an IQ Signal Player option that is ideal for IQ signal generation applications. The IQ Signal Player provides an easy-to-use interface that allows you to configure and control both channel 1 and channel 2 as if they were a single channel or waveform. **Figure 2** shows a screen shot from the 33500B Series with the IQ Signal Player option. In Figure 2, the waveform generator is outputting a 64-QAM IQ baseband signal at a sample rate of 1 MHz.



**Figure 2. 33500B IQ Signal Player screen view**

The resulting example IQ baseband signal was captured with a high-performance oscilloscope running signal analysis software, as shown in **Figure 3**. You can see the resulting constellation diagram in the top left display and the measured error vector magnitude (EVM) of only 0.3% in the bottom right display (circled in red). The two additional displays, from left to right, show the plotted magnitude error millipercent and the phase error in millidegrees.



**Figure 3. Constellation diagram and EVM of a 64-QAM baseband signal**

## Simulating non-ideal signal and channel conditions

When you need to understand the limits of your design, the goal is not to simulate an ideal signal, but to simulate a signal with quantitative non-ideal characteristics and test the response of the design to the non-ideal conditions. The 33500B Series has three features for simulating non-ideal IQ baseband signal conditions:

- 1. Balance adjust:** Allows you to specify the amplitude gain balance between the two channels and the amplitude offset adjustment for each channel. You can see the 33522B's balance adjust screen in **Figure 4**.
- 2. Skew adjust:** Allows you shift either the I or Q baseband signal in time with picoseconds of resolution.
- 3. Advanced modulation:** Modulation features such as sum or phase modulation allow you to add noise, random jitter, or deterministic jitter to the signal.

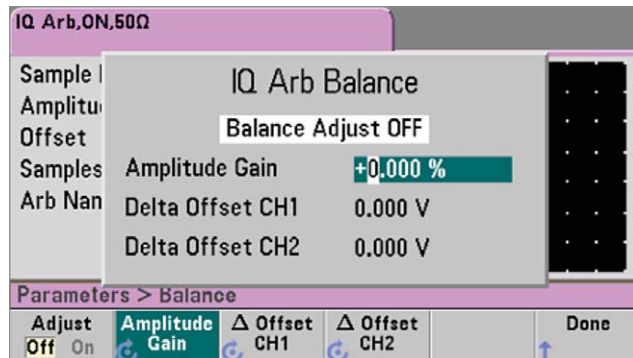


Figure 4. IQ balance adjust screen

Let's look at an additive noise example on the 64-QAM signal that we saw in Figure 3. The 33500B Series provides a built-in Gaussian noise waveform with a crest factor of 4.3 and adjustable bandwidth up to 30 MHz. The noise signal will not repeat for more than 50 years of continuous play. Using the "sum" modulation feature on the 33522B, 30-MHz bandwidth of noise at 10% of amplitude was added to the I and Q baseband signal. The results can be seen in **Figure 5**. If we compare Figure 3 with Figure 5, we can see the constellation points

are clearly larger and smeared. Also notice that the EVM, circled in red, has increased to about 1%. The noise amplitude adjust on the 33500B provides resolution down to 0.01% so you can zero in on the exact amount of error you would like to simulate.

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You may need to simulate noise or jitter on either the I or Q signal but not both. This can be accomplished by loading the I signal on channel 1 and the Q signal on channel 2 as individual arbs on the 33500B, not using the IQ Player mode. From there, you can use the 33522B's modulation capability on an individual channel basis for adding noise or any other non-ideal signal condition to an individual channel. Note that the output signals from the 33522B channels can still be phase synchronized like you would do if you were using it in the IQ Player mode.

## Conclusion

The 33500B Series with the IQ Signal Player provides an easy-to-use, low-cost solution for generating high-quality, low-EVM IQ signals. The exclusive Trueform waveform generation technology provides a true representation of all signal points with very low jitter and noise levels compared to the most common waveform generation technology on the market today, DDS. With no remote connection required to transfer your waveform from a PC to the waveform generator and a user interface built for playing IQ signals, the 33500B Series makes the process of turning a software waveform into a hardware waveform quick and easy. Finally, with features such as IQ balance settings, channel-to-channel skew adjust, and advanced modulation features, the 33500B Series allows you to simulate real-world non-ideal conditions on your IQ baseband signals for testing the limits of your design.



Figure 5. Constellation diagram and EVM of 64-QAM baseband signal with added noise



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