Generating Multiple Digitally Modulated Carriers Using an AWG

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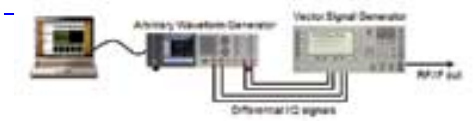
When testing wideband RF components and systems, it is necessary to stimulate the device under test (DUT) with a wideband signal that is as close to the “real” signal as possible. For some measurements, wideband noise or a multi-tone signal might be appropriate. In other cases, a stimulus signal that consists of a large number of digitally modulated carrier signals is required in order to emulate the same spectral characteristics as the real application signal.

[1]

Each of the modulated carriers might be only a few Megahertz wide, but the whole band is often spread across a bandwidth of up to 1 GHz or more. Traditionally, these kinds of signals were generated by combining the outputs of several signal generators – which works well, but can be very costly. The main limitation is that signal generators usually provide modulation bandwidths of less than 100 MHz.

This article describes an approach to generate such a wide-band signal using an arbitrary waveform generator (AWG). Depending on the highest frequency that is required in the stimulus signal and the capabilities of the AWG, there are two alternatives to generate the desired signal.

If the highest frequency is less than the bandwidth of the AWG, the RF signal can be generated directly by the AWG. In this case, the I/Q modulation is performed in software before downloading the waveform or in a digital signal processing circuit inside the AWG (this is also known as “digital I/Q modulation”). This setup is shown in Figure 1. The benefit of this approach is that digital I/Q modulation does not produce any distortions or carrier feed-through as it is the case with analog I/Q modulators.



[2]

In the other case, the AWG generates wideband I and Q signals that are fed into a vector signal generator with wideband I/Q inputs (see Figure 2).

The RF/IF signal is generated by a vector signal generator in this case. The range of frequencies that can be reached by this solution is much wider, but I/Q modulators in vector signal generators also add signal distortions.

Calculating Waveform Data

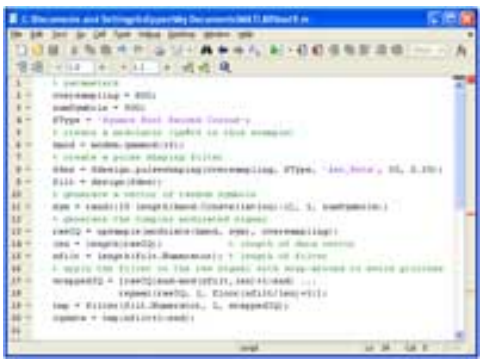
Many AWG vendors offer software applications to calculate I/Q signals. The generated waveforms range from single carrier with analog and digital modulation schemes to waveforms that emulate signals for specific wireless transmission standards.

Another possibility to calculate waveform data for an AWG is to use programming environments such as MATLAB®. One of the benefits of a programming language like MATLAB® versus a dedicated waveform generator software application is the flexibility to create signals that fit specific or proprietary needs. It is also possible to add pre-distortion to the signal in order to compensate distortion effects such as non-flatness of the signal path. A certain disadvantage on the other hand is the initial effort to learn the language.

[3]

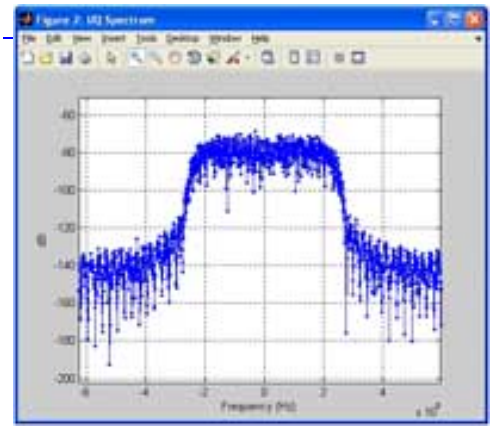
Figure 3 shows an example MATLAB® routine that calculates a multi-tone signal. At the end of this routine, “iqdata” contains a vector of complex numbers that represents the multi-tone signal which can be downloaded into an AWG. The “tones” vector (line 4) can be an arbitrary list of frequencies between –Fs/2 and +Fs/2; it is not limited to an equidistant list of tones as shown in the example.

The signal is calculated by setting up a complex frequency domain vector with the desired tones and then performing an inverse FFT (line 17). One important property of the generated signal is that it does not contain any phase-discontinuities for any of the tones when the signal is repetitively output by an AWG.



[4]

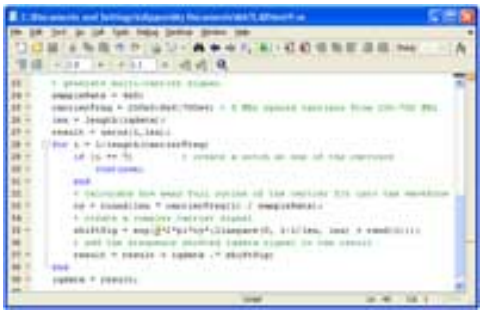
However, this requires that the tone frequencies are rounded in order to fit an integer number of cycles into the given number of samples. As it can be seen from the formula in line 10, tone frequencies that are a multiple of sampleRate/numSamples (12.5 MHz in the example) can be generated exactly and don't require any rounding. For a better frequency resolution the number of samples has to be increased.



[5]

The routine to download the data is not shown here (Figure 3) because it depends on the specific AWG. For Agilent's 81180A 4.2 GS/s AWG (which was used for the development of this paper), several MATLAB routines including a script to download I/Q signals can be found at [1] under "Demos".

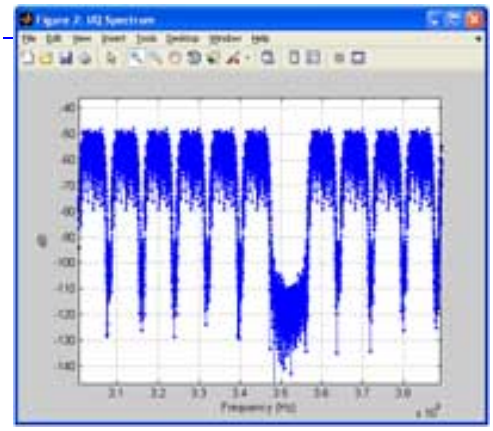
Digital Modulation



[6]

Generating a digitally modulated multi-carrier signal is equally straight forward. The script shown in figure 4 generates a complex I/Q signal that with a QAM16 modulation on 500 random symbols. A large oversampling factor of 800 has been chosen in this example in order to achieve a sample rate of 4 GSa/s with a symbol rate of 5 MSymbols/s. The high sample rate is required in order to allow digital up-conversion later on. Similar to the multi-tone routine, the “iqdata” vector contains the complex signal at the end of the routine.

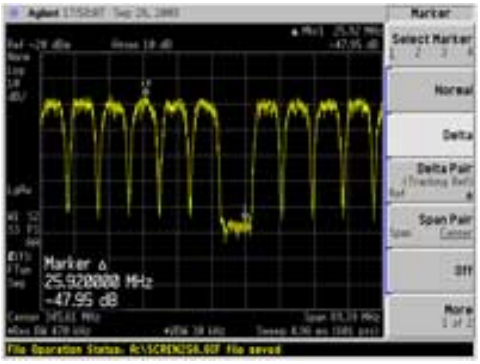
Figure 5 shows the theoretical spectrum of this (single carrier) I/Q signal. The diagram was created by performing an FFT on the iqdata vector and plotting the result in MATLAB.



[7]

In order to generate a multi-carrier signal, a number of frequency-shifted copies of the “iqdata” signal must be added up. Mathematically, a frequency shift is performed by element-wise multiplication of the complex IQ signal vector with a complex carrier signal vector. A MATLAB script that perform this frequency shift is shown in Figure 6.

Notice the notch that is generated in lines 29...31. I.e. one of the carriers is left out. Such a gap is typically used to perform noise-power-ratio (NPR) measurements. The simulated result is shown in Figure 7.



[8]

Finally, Figure 8 shows the previously calculated signal generated by an Agilent 81180A 4.2 GS/s AWG. It was captured with an Agilent PSA spectrum analyzer in “MAX HOLD” mode. The screenshot shows 10 of the 50 carriers and the gap.

Note the noise-power-ratio of about 48 dB that was achieved here because of the 12 bit resolution of the Agilent 81180A 4.2 GS/s AWG, which is unique in the industry for this speed class.

References:

[1] http://www.agilent.com/find/81180 - Agilent 81180A - 4.2 GS/s Arbitrary Waveform Generator

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