

Keysight Technologies

Baseband Up-Conversion to Desired
Intermediate Frequency with Regard
to Signal Quality and Play Time

Application Note



Introduction

Comparing Different Up-Conversion Methods

New generations of communication applications – such as radar, communication systems, or electronic warfare and SIGINT equipment – need to be tested as realistically as possible, to ensure a strong foundation for reliable transmission. Realistic signal scenarios that simulate transmission, including interference, fading and more, can push designs to the limit while reducing test costs, by minimizing the need for the high cost of flight-testing.

Critical needs are

- Getting the best signal quality in the desired frequency range,
- Having the flexibility to simulate the different real-world distortions, and
- Long playtime for different signal scenarios.

This means the modulation bandwidth needs are constantly increasing. At the same time, excellent signal fidelity remains as necessary as ever, and distortions have to be kept to a minimum.

Generating a radio frequency signal: the process in general

Generating a final signal takes several steps.

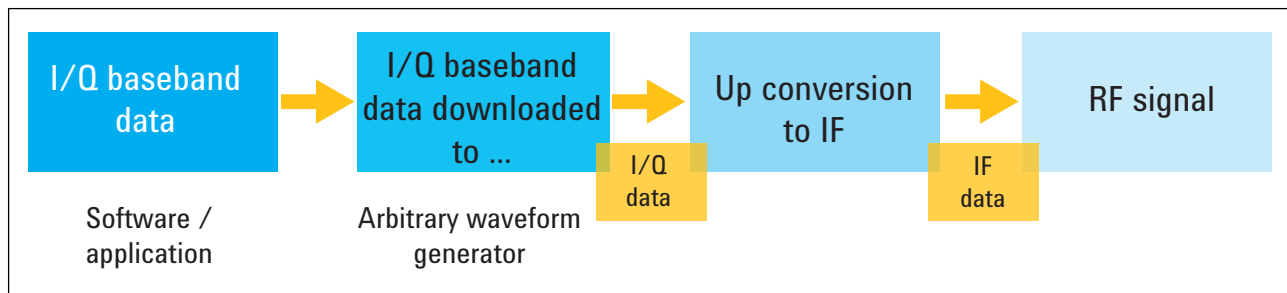


Figure 1. Signal generation

Let us now look at the different stages.

Creating baseband data

Different software tools are available to produce I/Q baseband data. They range from development tools such as MATLAB to applications such as the Keysight Technologies, Inc. N7620B Signal Studio for Pulse Building.

Arbitrary Waveform Generator

An arbitrary waveform generator is an ideal instrument to generate complex, real-world signals. The range of signals they can produce range from high precision continuous wave signals, to multi-tone signals, digital modulations, to pulsed radar signals. There are many types of arbitrary waveform generator, from those with low resolution and wide bandwidth, to instruments with high resolution and low bandwidth. For the application described in this paper, an arbitrary waveform generator needs both high resolution and a wide bandwidth.

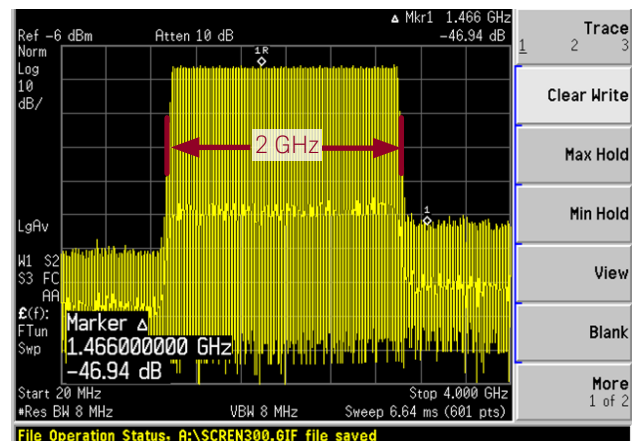


Figure 2. Pulsed radar linear chirp spanning 2 GHz, Pulse width: 6 μ s, FS = 7.2 GHz with amplitude correction

Up-conversion methods

The baseband signal is converted to an intermediate frequency and radio frequency (IF and RF) using an up-converter. There are three principal up-conversion methods:

- Analog up-conversion
- Software up-conversion
- Digital up-conversion

Analog up-conversion

This is the traditional method of up-conversion. As with other methods, software is used to produce an I/Q baseband signal, which can then be downloaded to an arbitrary waveform generator. This I/Q data is used as an input to a vector signal generator with wide bandwidth I/Q inputs. Typically the input accepts I/Q modulated signals up to 2 GHz. Looking at the resulting RF signal shows that the analog

modulator causes distortions. The tones are asymmetric about the carrier frequency. There are images and carrier feed through. Careful adjustments can reduce such distortions, such as by:

- Adjusting the offset of the I and Q signals to reduce the carrier feed-through.
- Adjusting the frequency response to flatten amplitude variation to less than 0.5 dB.
- Adjusting the skew and the relative amplitude between I and Q signals to reduce the images (typically to about 30 to 40 dBc).

Nevertheless the signal is not ideal.

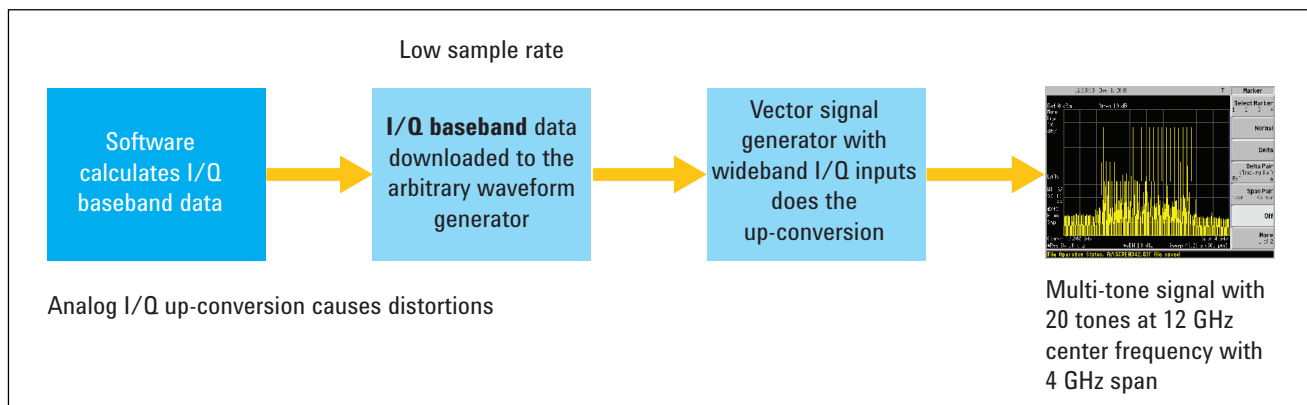


Figure 3. Low sample rate

Preparing a baseband signal

A high quality baseband signal is the foundation for further up-conversion. But just having an excellent baseband signal isn't enough. The signal quality needs to be right in the desired frequency range.

For example, a spectrum analyzer can measure the magnitude of each tone resulting from the original MATLAB signal. The frequency response can then be used to calculate compensation for any distortion the modulator introduces. That is, analyzing the initial result from a spectrum analyzer and calculating the necessary pre-distortion based on the results, this is used to adjust the baseband signal which is then applied to produce the corrected IF signal.

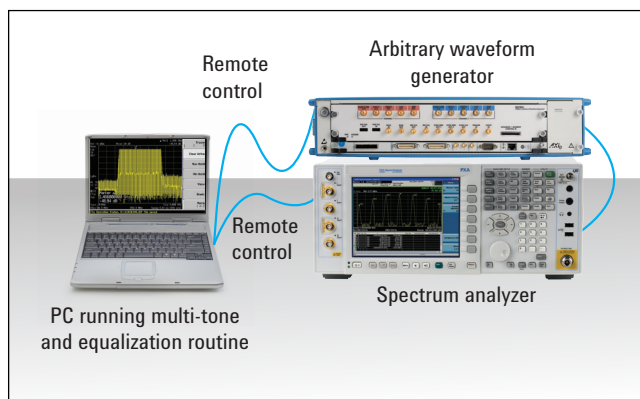


Figure 4. Set up for up-conversion

Software up-conversion

Software tools such as MATLAB can produce the data for the IF directly. The software calculates the I/Q baseband data and up converts it to IF.

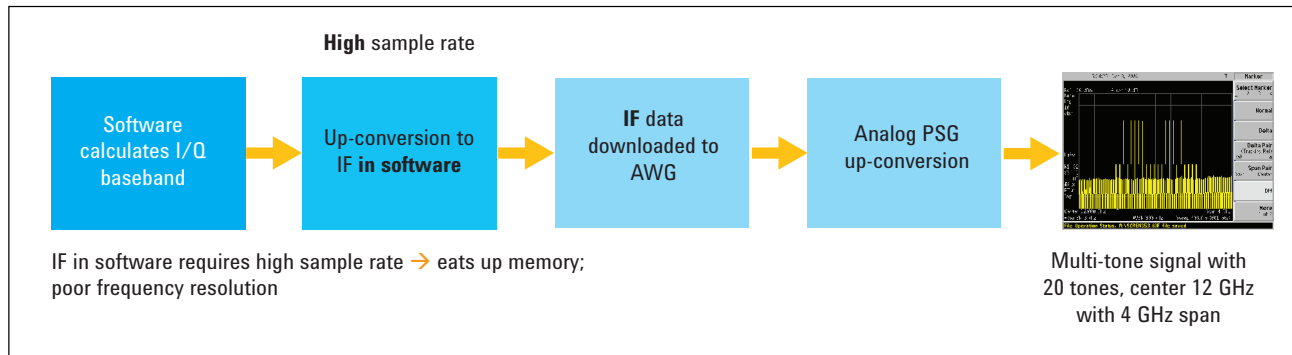


Figure 5. High sample rate

The first drawback of this approach is that the overall frequency resolution is poor.

Also the signal downloaded to the arbitrary waveform generator needs to be at the sampling rate of the IF signal. As this is very high, it uses a lot of memory. If, for example, an arbitrary waveform generator has memory for 2 GSa, at a sampling rate of 12 GSa/s, this corresponds to a playtime of between 1/180 and 1/6 of a second. That is, the signal quality of this approach is excellent, but compromises the playtime.

Digital up-conversion

Digital up-conversion avoids a few of the problems associated with analog IQ modulator:

- There is no (in-band) carrier feed-through
- There are no (in-band) images

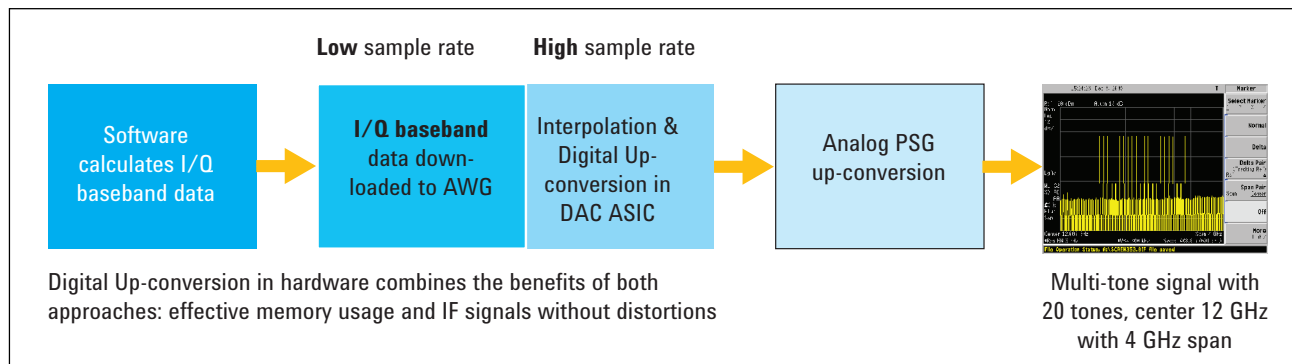


Figure 6. Digital up-conversion for the benefits of both low and high sample rates

Using digital up-conversion to create the IF avoids a few of the problems associated with analog I/Q modulators: there is no in-band carrier feed-through, and there are no images. The final radio frequency can be generated, as before, using a mixer and a local oscillator.

A flat frequency response can be prepared using the same method as described for the analog up-conversion.

Digital Up-Conversion Architecture

Solutions for digital up-conversion include FPGAs with reference designs, but also complete solutions built into the arbitrary waveform generator. The baseband signal is fed to an interpolator followed by a complex multiplier, which is also supplied by a numerically controlled oscillator (NCO). The quality of the NCO is critical for the accuracy, phase and amplitude.

Proposed solution

A wide bandwidth arbitrary waveform generator can generate the IF directly. If the arbitrary waveform generator can perform digital up-conversion, this makes it possible to use the available memory effectively, by downloading baseband I/Q data and generating the high-sampling IF signal. The Keysight M8190A Arbitrary Waveform Generator provides digital up-conversion as an option, using a Keysight proprietary ASIC.

The high-quality NCO in Keysight's proprietary ASIC ensures a precise resolution for frequency, phase and amplitude. Keysight's implementation stores the waveform independently of waveform parameters, such as amplitude and frequency. That is, instead of storing the waveform repeatedly, the basic waveform itself is stored only once, and the variations are stored independently in tables.

There is no need to store the phase of the waveform, as the Keysight proprietary ASIC takes care of the phase setting. The sequencer controls merging the parameters with the waveform in real-time. This makes it possible to store waveforms more efficiently, especially repetitive waveforms, such as radar signals.

Summary

Generating radar and electronic warfare signals is typically done in several steps. An arbitrary waveform generator such as the Keysight M8190A AWG simplifies the generation of high quality signals. Digital up-conversion, using Keysight's proprietary ASIC, lets you combine the 14 bit vertical resolution with wide bandwidth to generate high fidelity IF signals with long playtimes. This unique combination let you create signal scenarios that push your designs to the limit and bring you new insight.

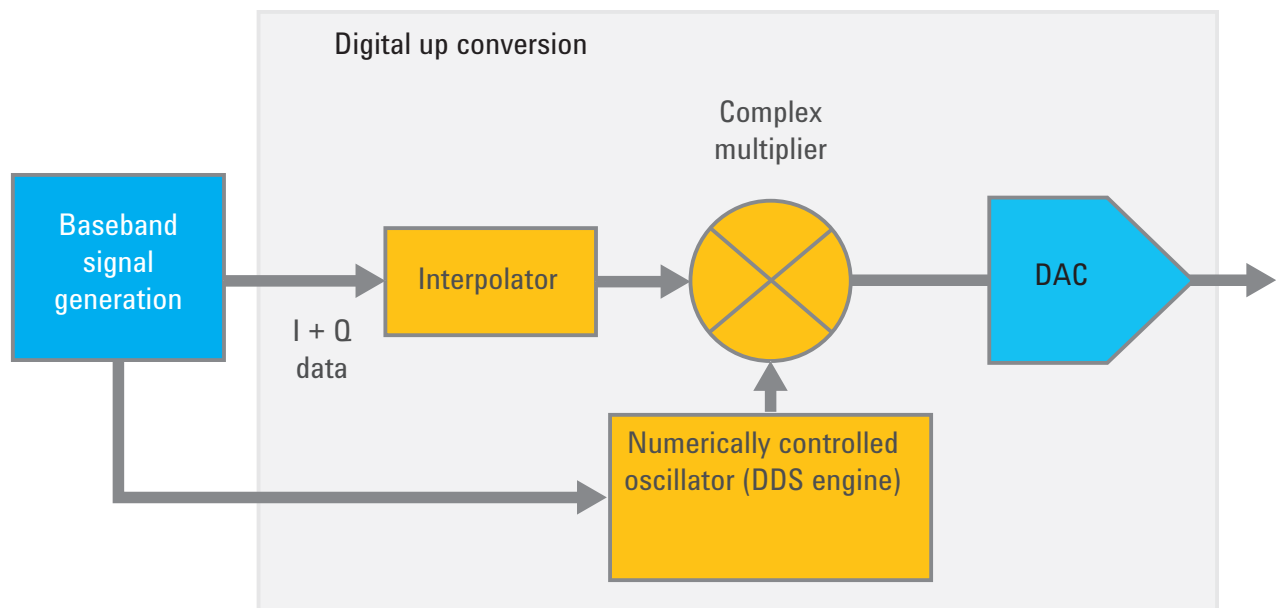
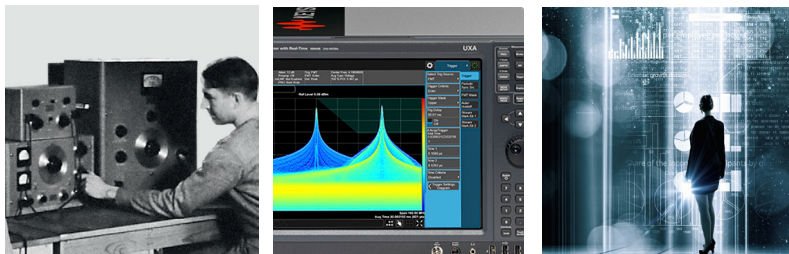


Figure 6. Digital up-conversion for the benefits of both low and high sample rates

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Published in USA, December 1, 2017
5991-1649EN
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