Agilent
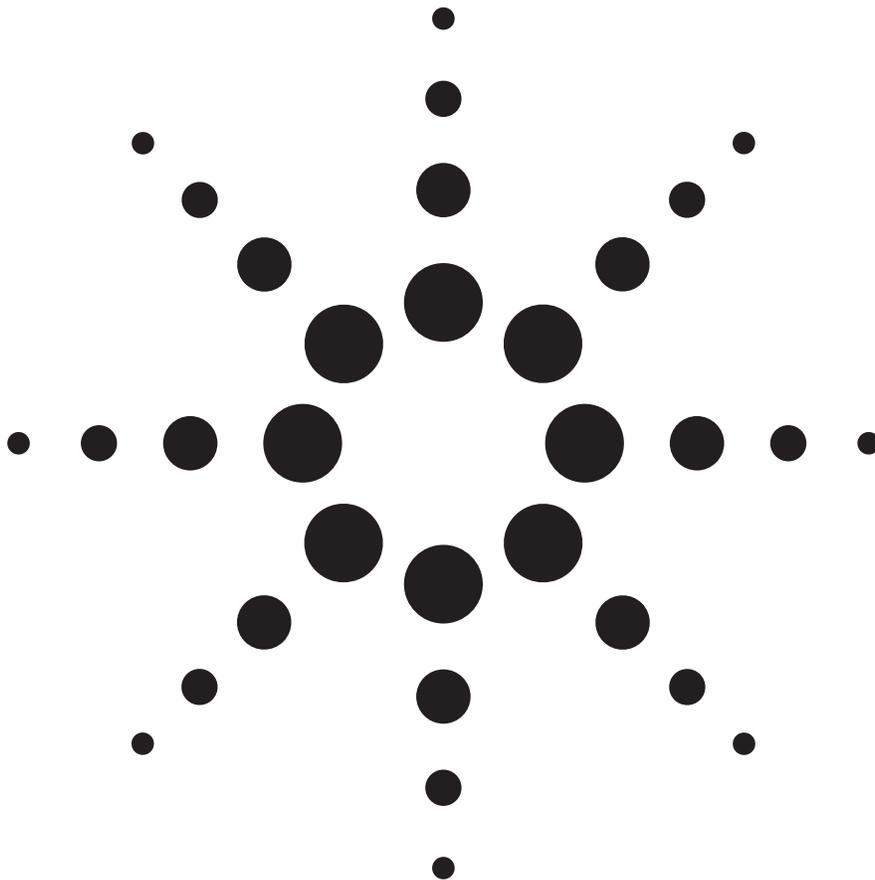# Creating Multi-tone Signals With the N7509A Waveform Generation Toolbox

Application Note

Introduction

Of all the signal engines in the N7509A, the most complex is the multi-tone engine. This application note provides some tips on how to get the engine to act correctly, given the number of parameters over which the user has control.

Figure 1 shows the Multi-tone signal form with some example parameters. This generates both I and Q vectors centered around zero (the carrier.) The tones start 260 MHz to the left of the carrier and produce 5200 tones spaced 100 kHz apart. This should yield 520 MHz of evenly spaced tones at whatever carrier frequency to which we set the E8267D.
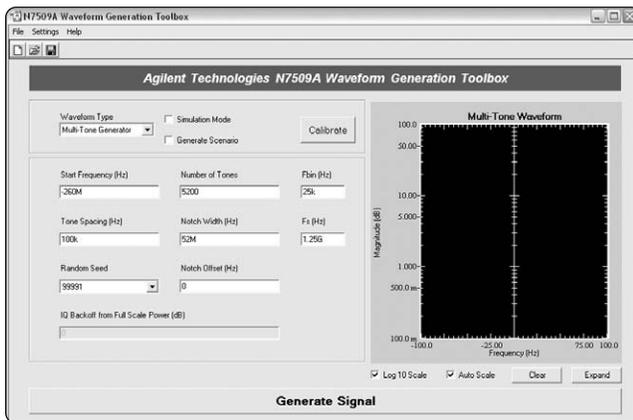

Figure 1. Multi-tone generator signal form

Also specified is a 52 MHz notch in the tones, appearing in the center (no offset.)

The last parameters are the Random Seed, Fs, the sampling clock (1.25 GHz), and F_{bin}, the frequency domain waveform resolution. This note will cover several topics related to these parameters and their correct use.

Differences Between I/Q and IF

The following information is true for all waveform types. The N7509A application allows the user to choose either the I/Q mode of generation or IF mode. All waveforms are available in both modes, but there are some important considerations for both. The default mode is I/Q mode. This mode calculates the correct I and Q vectors for the chosen waveform based on the driving parameters. The I vector is downloaded into channel 1 and the Q vector is downloaded into channel 2. Since each channel has 500 MHz of instantaneous bandwidth the composite bandwidth of both channels is 1 GHz.

In I/Q mode, the center of the waveform is always zero. That is the carrier frequency. The I/Q modulator in the E8267D mixes these two vectors with the carrier frequency, producing a waveform that is symmetrical about the carrier. The waveform is normalized to the carrier frequency. The display of the N7509A software shows 0 Hz at the center and ±600 MHz or so from left to right.

In IF mode, the same I and Q vectors are calculated and the N7509A digitally modulates a carrier with these vectors at the specified IF. The waveform is downloaded into channel 1 and an equal length waveform of zeros is downloaded into channel 2 (This is required by the N6030A in order to operate normally.) In this mode, there is only 500 MHz of alias-free bandwidth. Eq.1.1 shows the method used for this mode:

$$V(t) = I\cos(2\pi f_c t) - Q\sin(2\pi f_c t) \qquad (1.1)$$

Where f_c = IF frequency and t = a linear ramp of length I or Q divided by the sample rate. (The I and Q vectors are, by definition, of equal length.)

In order to prevent aliasing and distortion, the bandwidth of I and Q must be less than ±(500 – IF) MHz and the minimum IF must be greater than BW(i) or BW(q).

Using N6030A Corrections

The correction algorithm for the N6030A AWG is a pre-emphasis filter created from the impulse response of the channel reconstruction filter and the sample and hold characteristic of the DAC. (The latter is often referred to as a *sin(x)/x* correction.) This filter is convolved with the I and Q vectors to correct for the channel response. The result is a waveform correct in both magnitude and phase at the output of the N6030A. This correction is by default applied to each of the I and Q vectors generated by each waveform type. One potential problem with this method is that by its nature it may reduce the carrier to noise level of any intentional notch in the multi-tone signal. For this reason, the corrections can be disabled with a selection in the settings menu.

Setting the F_{bin} Parameter

This is the least understood parameter in this waveform type and the most crucial. It is called F_{bin} from its legacy use, but it is really the frequency domain waveform resolution parameter. For speed and accuracy the multi-tone signal is first calculated in the frequency domain and transformed into the time domain by use of an Inverse Fast Fourier Transform. To calculate the position of the tones in the frequency domain, a parameter describing the size of the waveform relative to the sampling rate must be used to create the initial arrays used to contain tones. This is F_{bin}. The length of the I and Q vectors is equal to F_s/F_{bin}. F_{bin} is also related to Nyquist because it states how closely tones may be placed adjacent to one another and still be correctly resolved in frequency. For example, if the desired tone spacing (in I/Q mode) is 100 kHz then F_{bin} must be less than or equal to100 kHz /2, or 50 kHz. F_{bin} may be set to much less than F_{space} /2 as long as there is enough memory to contain the waveform. This may be desirable to give the display in the N7509A more resolution so that when zoomed it looks more like a real signal. There is no advantage as far as actually generating the downloaded waveform to making F_{bin} arbitrarily small, as long as it satisfies the Nyquist criterion.

IF mode is a little different, as can be demonstrated in the N7509A tool. Because we are folding the I and Q vectors onto a carrier within the bandwidth of a single channel, the minimum ratio of F_{space} /F_{bin} is 4, not 2. As an exercise, one can set this ratio to 2 and see what happens to the waveform upon generation.

Lastly, it was earlier stated that an Inverse Fast Fourier Transform is used to transform the frequency domain data into the time domain for use by the N6030A. *FFTs* are particular in their coefficients in order to work best. It is best to always make the Fspace / Fbin ratio equal to an integer power of 2. Otherwise, unpredictable results will occur if the ratio is small. Decimal ratios of 1000 or greater are required to get a cleanly resolved waveform. If F_{space} /F_{bin} is relatively prime, or irrational, the waveform may take forever to generate. So, take care when setting F_{bin}.

These two IF multi-tone waveforms both have 100 kHz tone spacing. The multi-tone waveform on the left has an F_{bin} of 25 kHz and the one on the right has an F_{bin} of 10 kHz. Even though it has more resolution, the one on the right is undesirable due to an inappropriate F_{bin} setting.
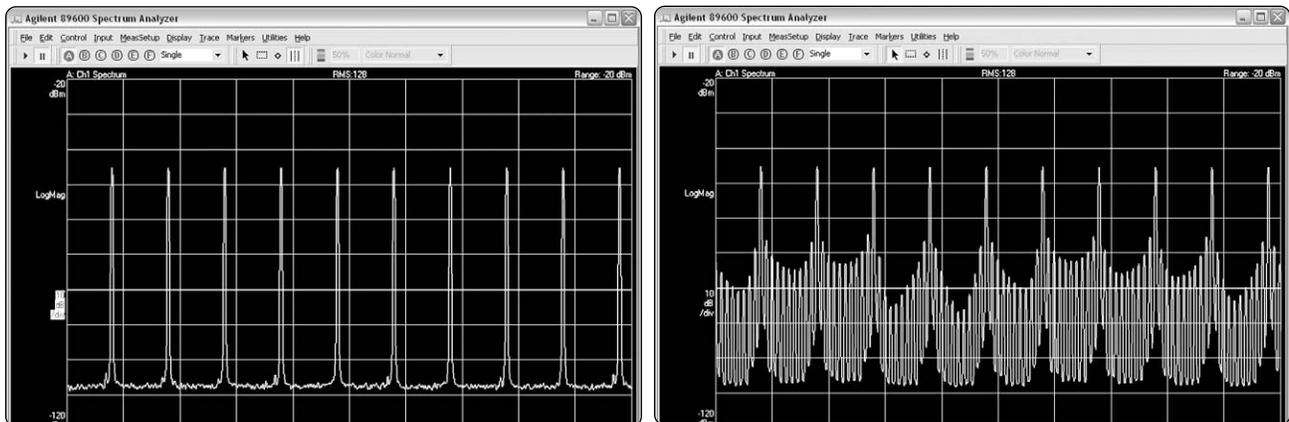

Figure 2. Good multitone waveform on the left. Undesirable waveform on the right

The Random Seed

When generating multi-tones, it is customary to randomize the phases of the tones relative to each other. This has the effect of minimizing the crest factor (peak to average ratio) of the waveform. This is done to more accurately load broadband receivers, transponders, and transmitters to correctly emulate real traffic and real-world conditions. This phase relationship can be either random or parabolic to achieve this effect. The N7509A supports only randomly phased tones. Since these tones are created digitally in the N6030A, they are a snapshot of a random phase that repeats as long as that tone set is used. In order to approach the true performance of the broadband device, several sets of randomly phased tones may be necessary. These sets of phased tones, or "phase sets" have an aggregate Gaussian distribution statistically. Their responses may be averaged together over many measurements to most closely approximate the true response of the device under load. This is where the Random Seed enters the equation. There are 30 5-digit prime numbers that can be selected. Each is used to "seed" the random number generator used to create the phase relationships of each phase set. Because they are prime, no two phase sets will give correlated results. This guarantees at least 30 different uncorrelated phase sets can be averaged together to determine the true response. In practice, only 3 to 8 phase sets are required to converge onto the average response.

Use of Notch Width and Notch Offset

Noise Power Ratio measurements have become popular for measuring the intermodulation distortion of amplifiers and transponders in both terrestrial and satellite communications. The N7509A Multi-tone Engine has input parameters for notch width in Hz, and Notch Offset in Hz. Any combination of notch width and notch offset are allowed as long as they fall within the signal bandwidth. At this time, only one notch is allowed per waveform.

To position a notch in a waveform (Figure 3), use the notch offset to place the notch either to the left or right of the carrier frequency. The notch offset specifies the position of the **center** of the notch relative to the carrier frequency. For example, let's look at our current multi-tone waveform:
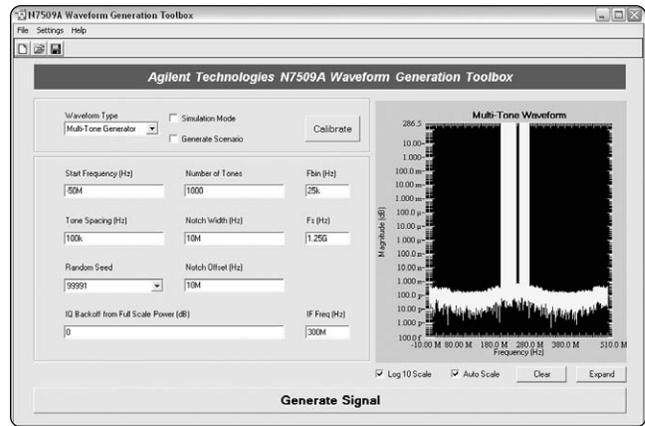

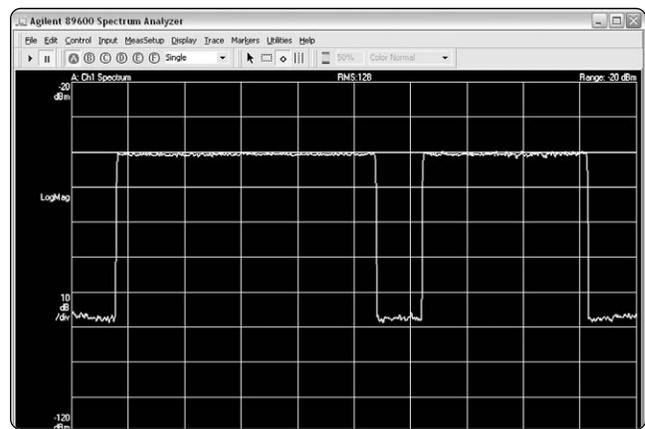**Figure 3. Multi-tone notch specified in N7509A**

Figure 4.Notched multi-tone waveform viewed with an 89600 spectrum analyzer

We specify a group of 1000 tones spaced evenly 100 kHz apart. They start at –50 MHz relative to our 300 MHz IF frequency. We therefore expect the bandwidth of tones to range from 250 MHz to 350 MHz. For our notch we specify a 10 MHz wide notch with a 10 MHz offset. This gives us a notch that starts at 305 MHz and ends at 315 MHz (Figure 4). A notch offset of –20 MHz would place the notch between 275 MHz and 285 MHz.

The IQ Backoff Parameter

This parameter is a placeholder in the current revision and has no operation.

Web Resources

For more information, go to:
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Printed in USA, July 20, 2005
5989-3172EN

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