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MILLIMETER WAVE MEASUREMENTS WITH EXTERNAL HARMONIC MIXERS

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I. INTRODUCTION

In order to observe the spectrum of a signal at frequencies above the maximum frequency capability of a spectrum analyzer, an external harmonic mixer may be used with a spectrum analyzer configured to display the spectrum of the signal with a compatible mixer. Usually this is accomplished in the external mixer by using a harmonic of the L.O. output from the spectrum analyzer to produce an output signal at the IF frequency of the spectrum analyzer which processes the IF signal and displays the spectrum of the mixer input signal at the actual frequencies and amplitudes of the input signal.

There are two major drawbacks to the use of an external harmonic mixer: high conversion loss and the production of image and other unwanted signals. The mixer input signal is displayed by the spectrum analyzer at the actual amplitude by correcting for the conversion loss. But using a correction factor does not change the signal to noise ratio. Also many unwanted signals, including image signals, appear on the display. This can make it difficult to recognize and make measurements of the desired signal spectrum. The conversion loss of a typical external mixer can be of the order of 30 to 40 dB in the V and W millimeter wave bands and increases at higher frequencies. This requires that the amplitude of the mixer input signal be high enough to overcome the conversion loss and produce a spectral display on the analyzer which permits making the desired measurements. There are several ways of dealing with unwanted signals in the display. Typically an analyzer configured to work with an external harmonic mixer has two built-in functions: image shift and image suppression. The image shift function permits the identification of the desired signal in the presence of the image signal. When selected, image shift causes the desired signal and the image signal to alternately appear on the display with the image signal shifting in horizontal position while the desired signal remains fixed. Image suppression eliminates the image and displays only the desired signal. However, when implementing either of these functions, some other functions of the analyzer may be disabled and measurements may not be accurate. Another way to deal with unwanted signals is the use of a preselected external harmonic mixer at the cost of higher conversion loss.

II. PULSED SIGNALS

Figure 1 shows the spectrum of a pulsed signal produced by a 100 nsec pulse at a PRF of 1 MHz using an external harmonic mixer. The image appears at twice the analyzer's IF frequency of 321.4 MHz. By using an image suppression function, the desired signal can also be viewed as shown in Figure 2. Since the bandwidth of the desired signal is significantly less than the IF bandwidth, it is not difficult to identify and perform measurements on the desired signal.

However, when the signal bandwidth approaches twice the IF frequency, the desired signal and image spectrums begin to overlap as shown in Figure 3 for a 10 nsec pulse, which has a wider bandwidth. Figure 4 shows the spectrum of the same signal with the image suppressed. Figure 5 shows the desired signal spectrum superimposed on the spectrum with no image suppression. Figure 6 shows a computer simulated harmonic mixer spectrum of a 1 nsec pulse. Since the bandwidth of the main lobe of the sinx/x spectrum of a 1 nsec wide pulse is 2 GHz, which is more than twice the IF frequency, there is significant overlap of the image and the desired signal spectrum. The figure shows the desired and the image spectrum and the sum of the two. Only the sum actually appears on the spectrum analyzer display so measurements of the desired signal cannot be made without the use of image suppression.

III. WIDEBAND SIGNALS

Figure 7 shows the spectrum produced by a harmonic mixer with an approximately 1.7 GHz wide signal. Since this is nearly three times twice the IF frequency, there is significant overlap of the desired and the image spectrum which makes it difficult to make accurate measurements. Figure 8 shows the spectrum obtained of the desired signal by use of the image suppression function and Figure 9 shows this spectrum superimposed on the signal with the image unsuppressed.

One way of eliminating the problem of images is the use of a preselected harmonic mixer. Figure 10 shows the spectrums produced by a preselected and an unpreselected mixer with the same CW signal input. The preselected spectrum has been shifted slightly to permit better display of the two plots. Although the amplitude of the desired signal at 60 GHz is nominally the same, the noise level with the preselected mixer is greater than with the unpreselected mixer because of the higher conversion loss. Figure 11 shows the results of measuring the same signal at a lower amplitude with the two different types of mixers. The signal is detectable with the unpreselected mixer but is below the noise level with the preselected mixer. Figure 12 shows the difference when using a preselected and an unpreselected mixer with image suppression with a wideband signal. The spectrum of the desired signal between 59.5 and 61.5 GHz is essentially the same but there are unwanted out-of-band emissions appearing in the unpreselected spectrum which do not appear when using the preselected mixer. However, as previously shown, the signal to noise ratio for the preselected mixer is less. The problems of high conversion loss and images and other unwanted signals can be reduced by the use of a downconverter instead of a harmonic mixer. A downconverter translates the signal to a lower frequency which can be applied to the RF input of the spectrum analyzer within its frequency range capability. Figure 13 is a block diagram of a downconverter assembled from components to downconvert a signal with up to a 4 GHz bandwidth in the 75 to 85 GHz band to 10 GHz for measurement with a spectrum analyzer.

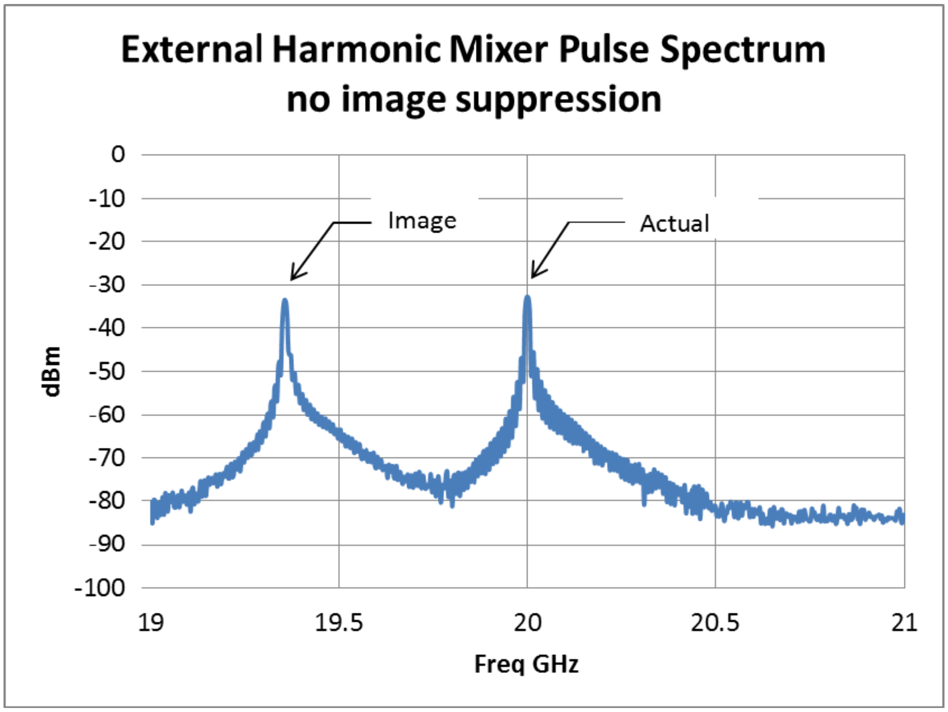

Figure 1

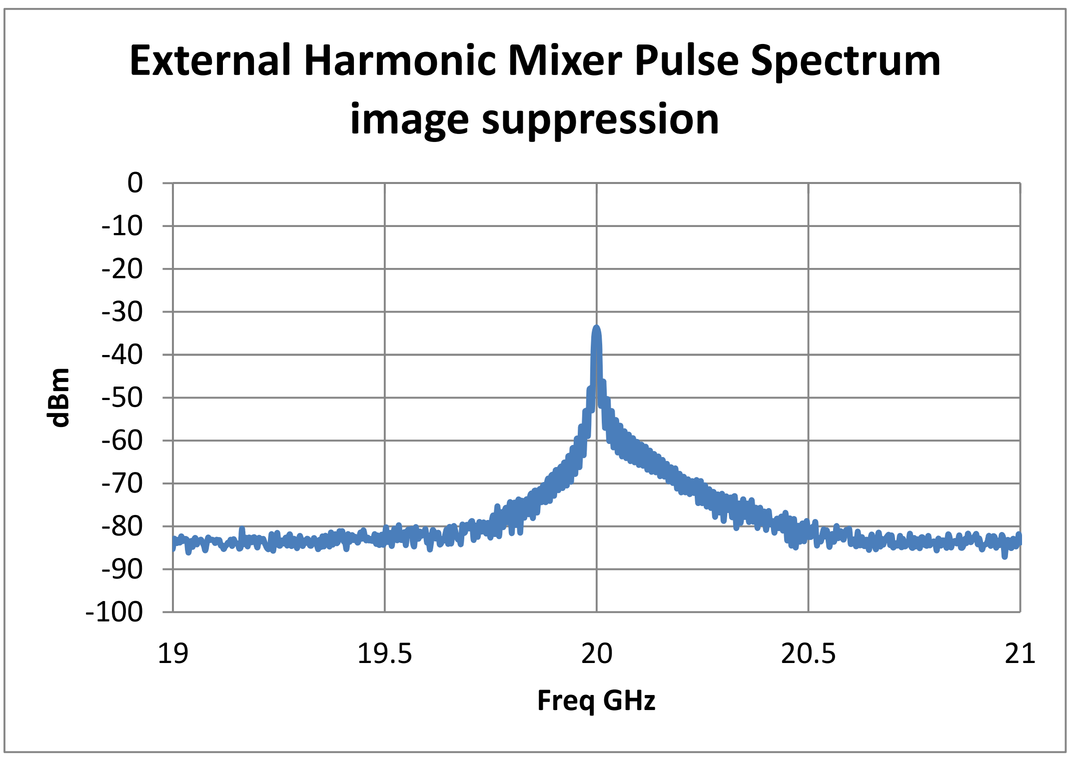

Figure 2

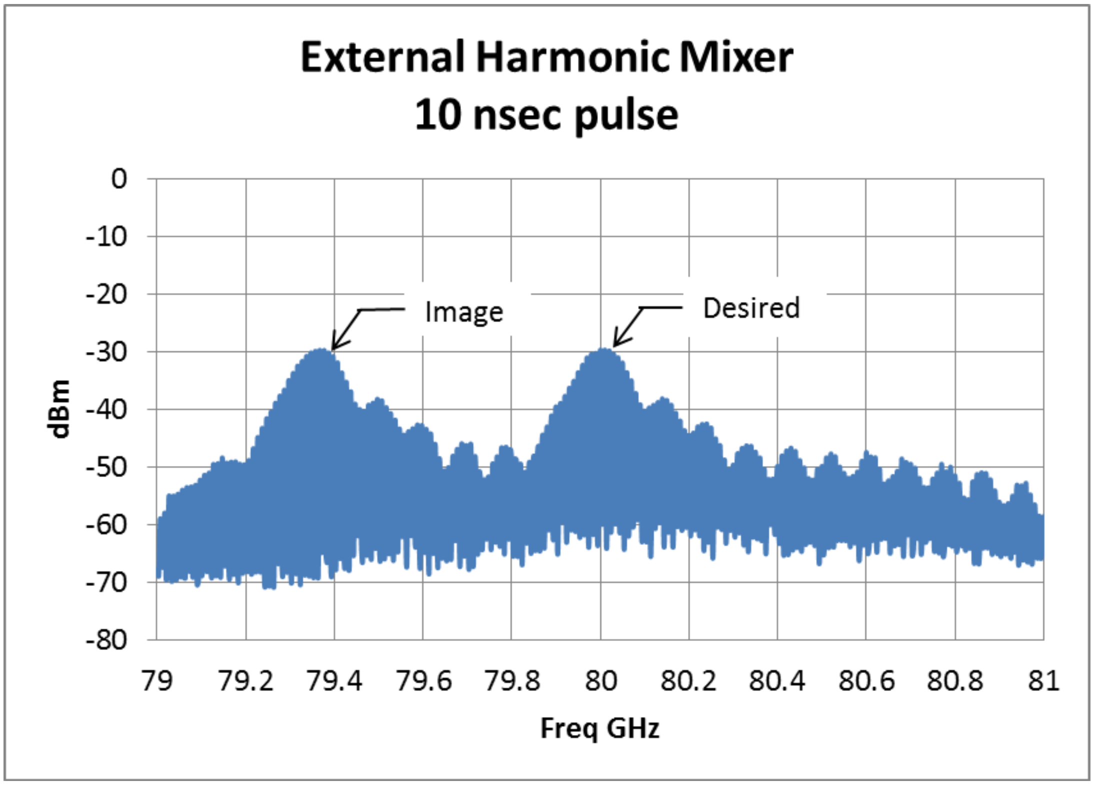

Figure 3

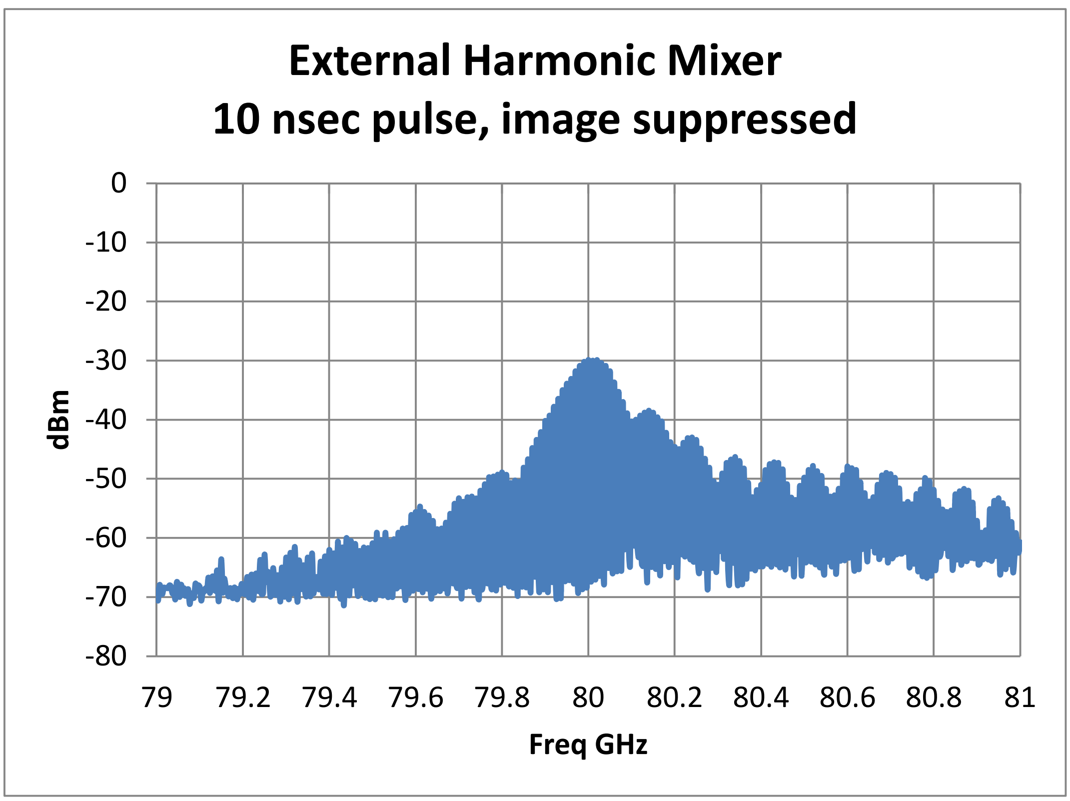

Figure 4

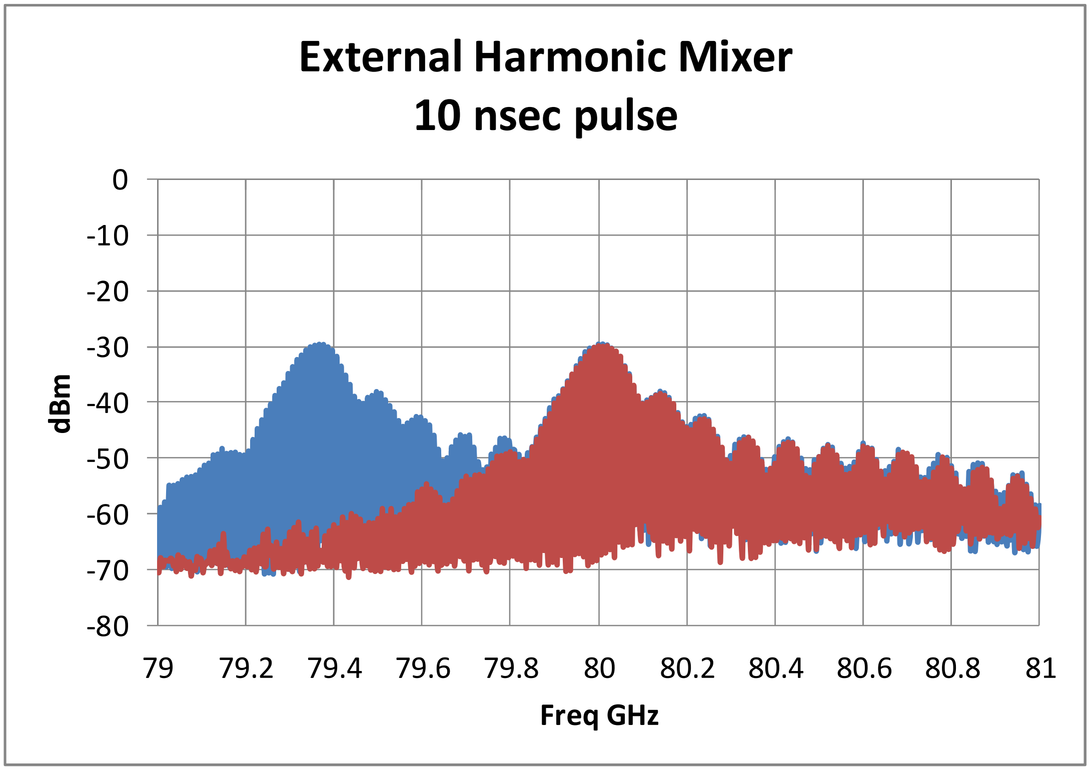

Figure 5

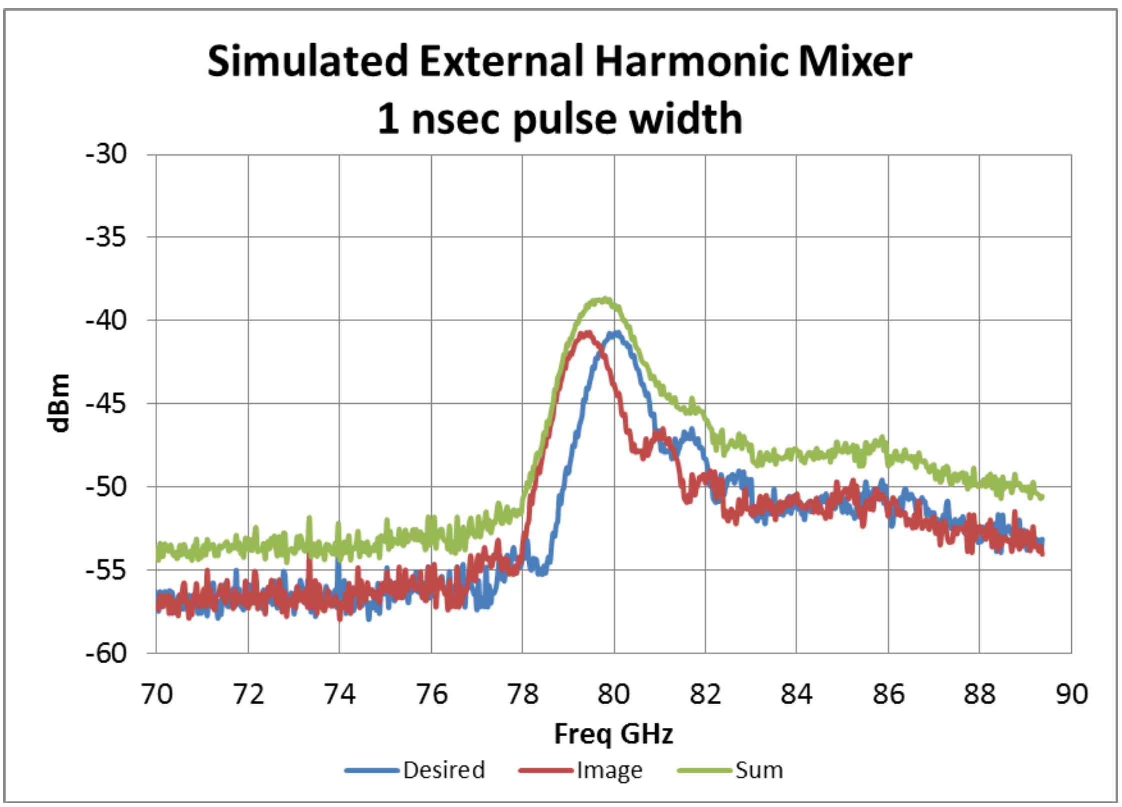

Figure 6

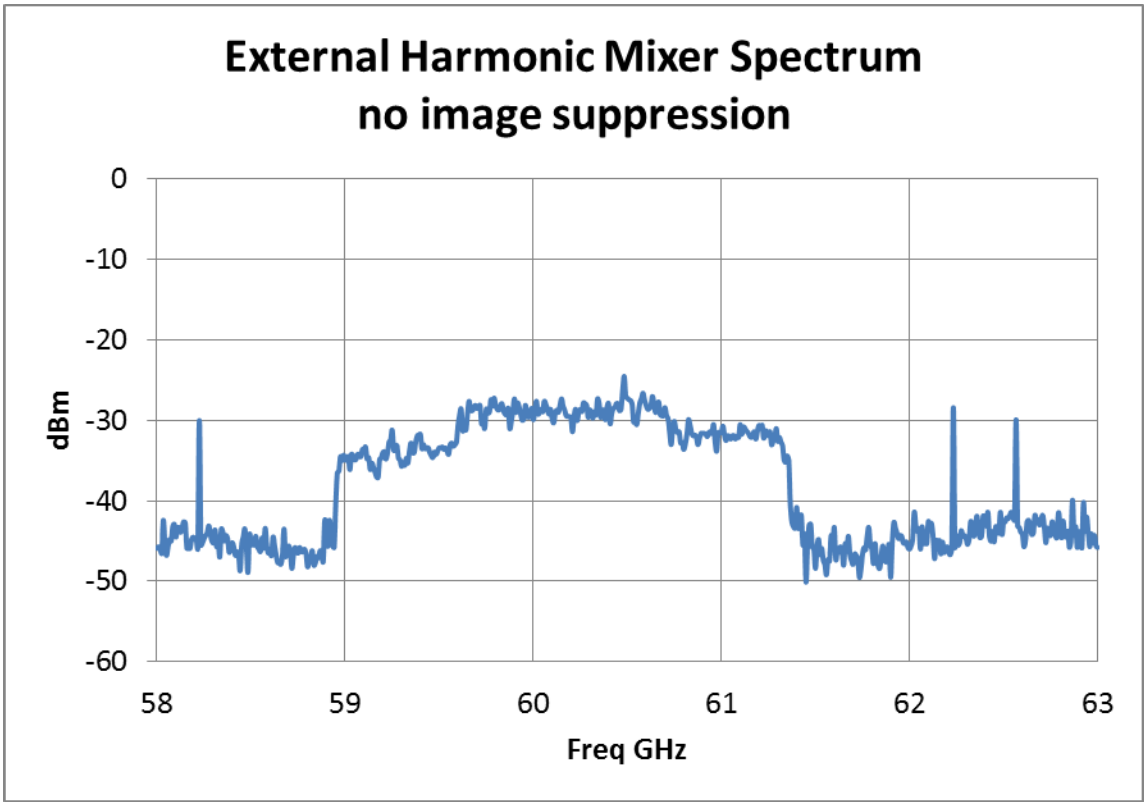

Figure 7

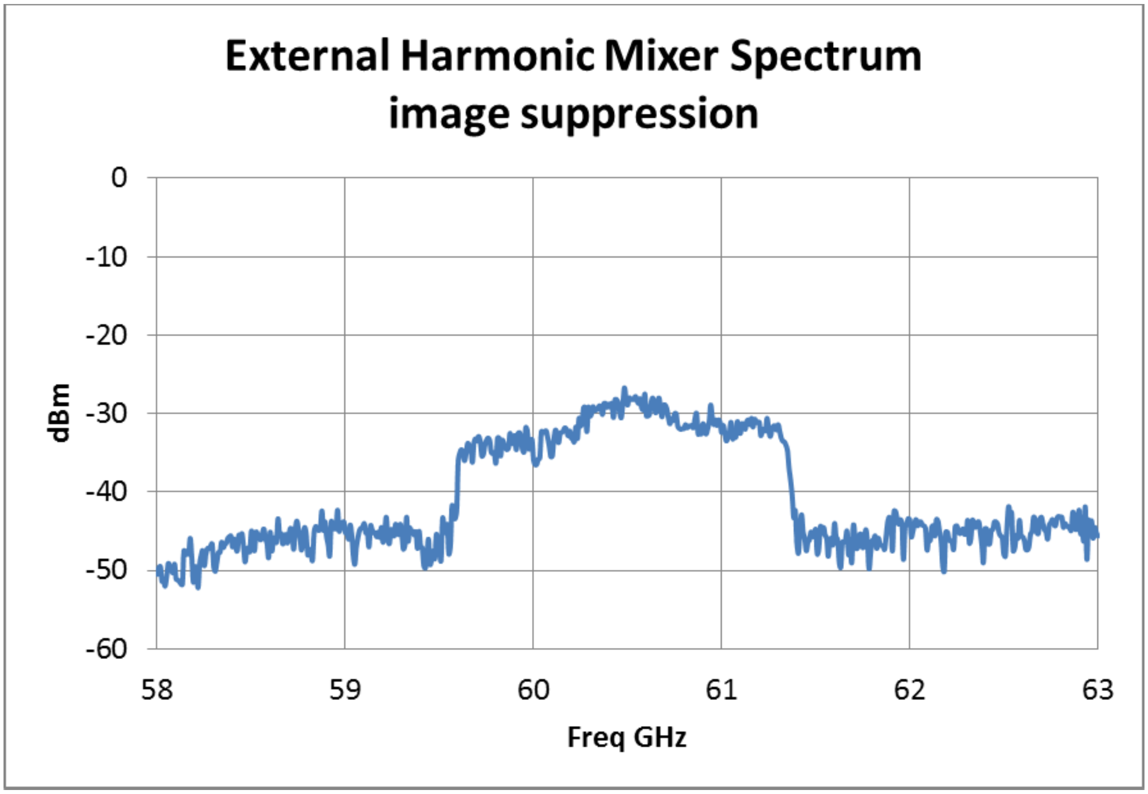

Figure 8

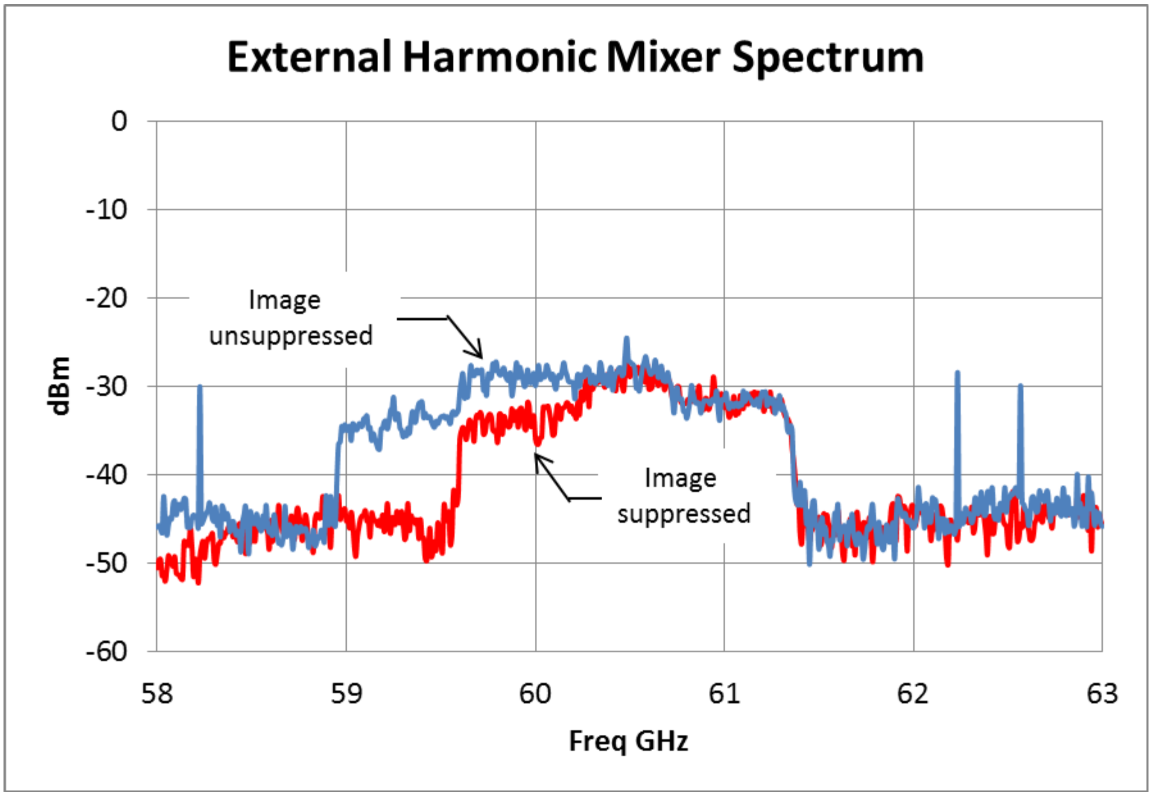

Figure 9

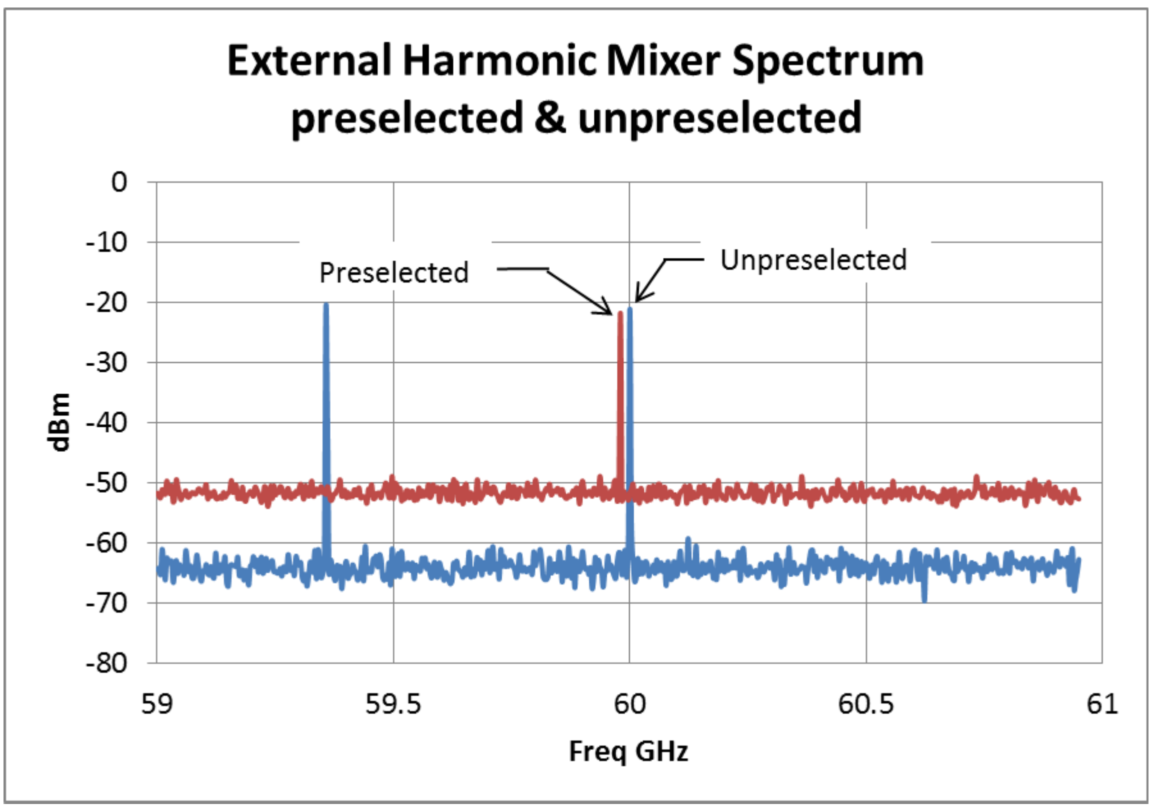

Figure 10

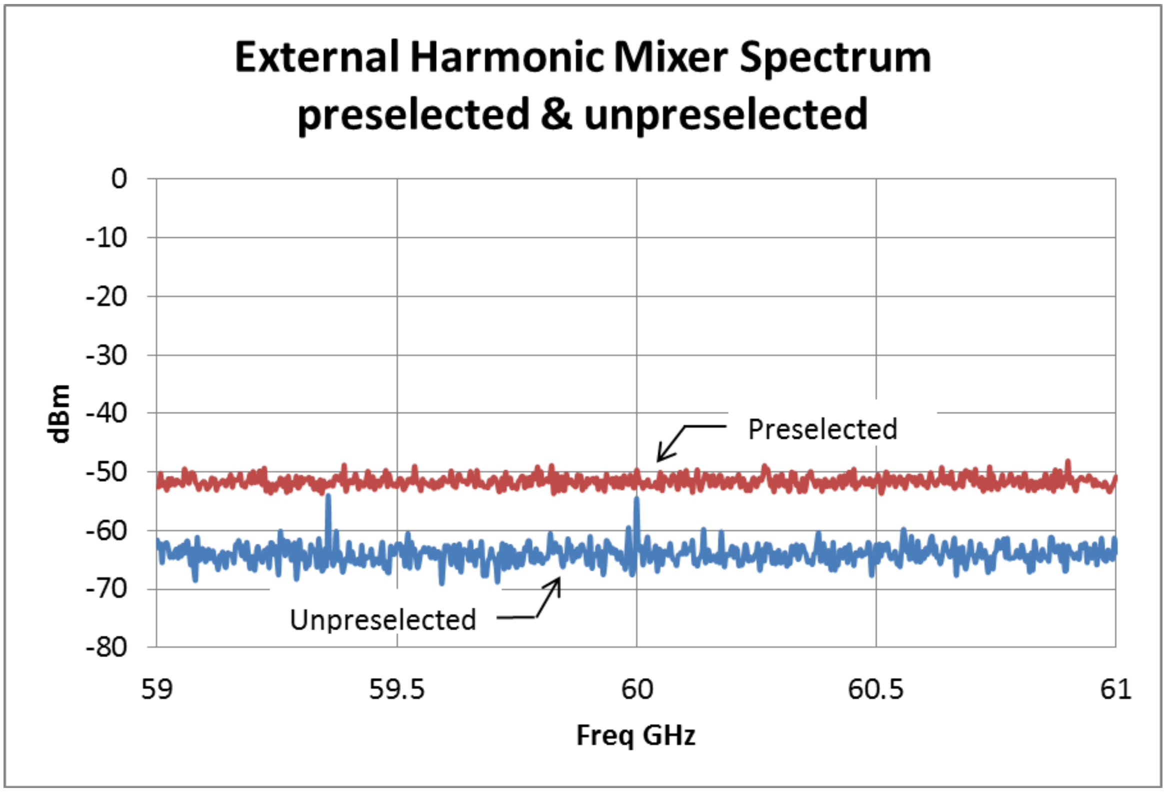

Figure 11

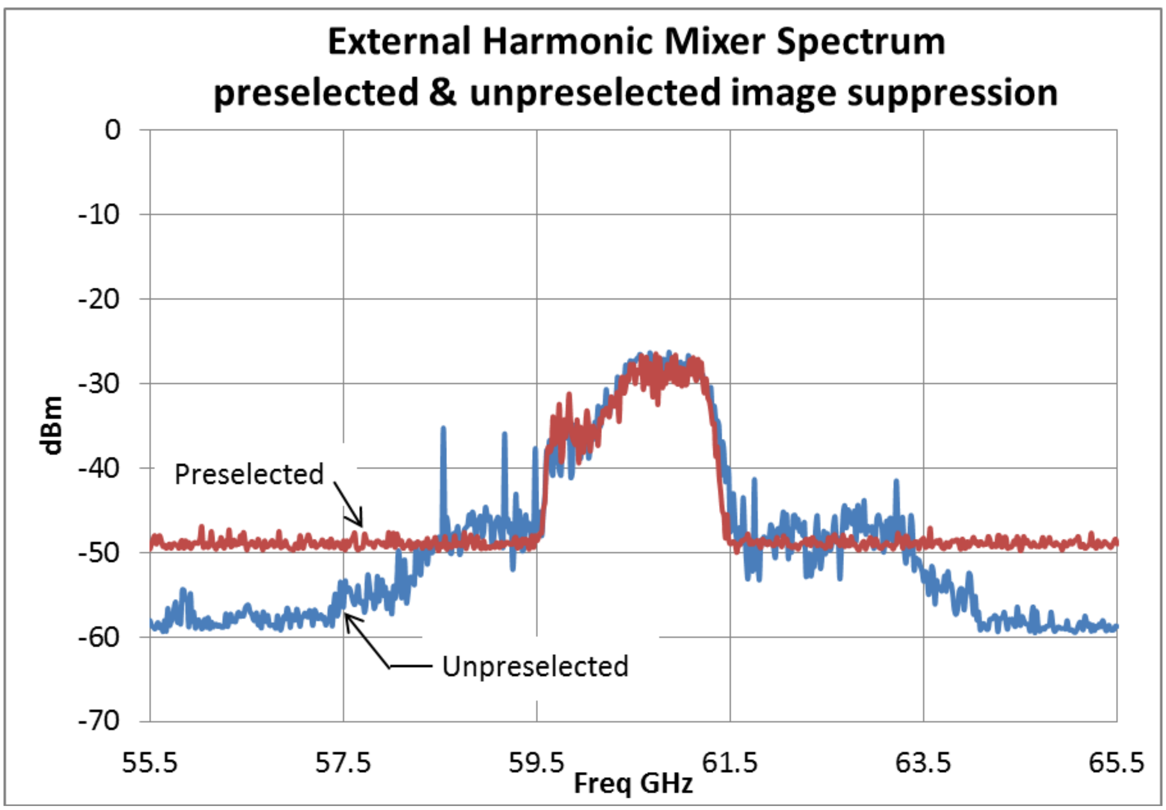

Figure 12

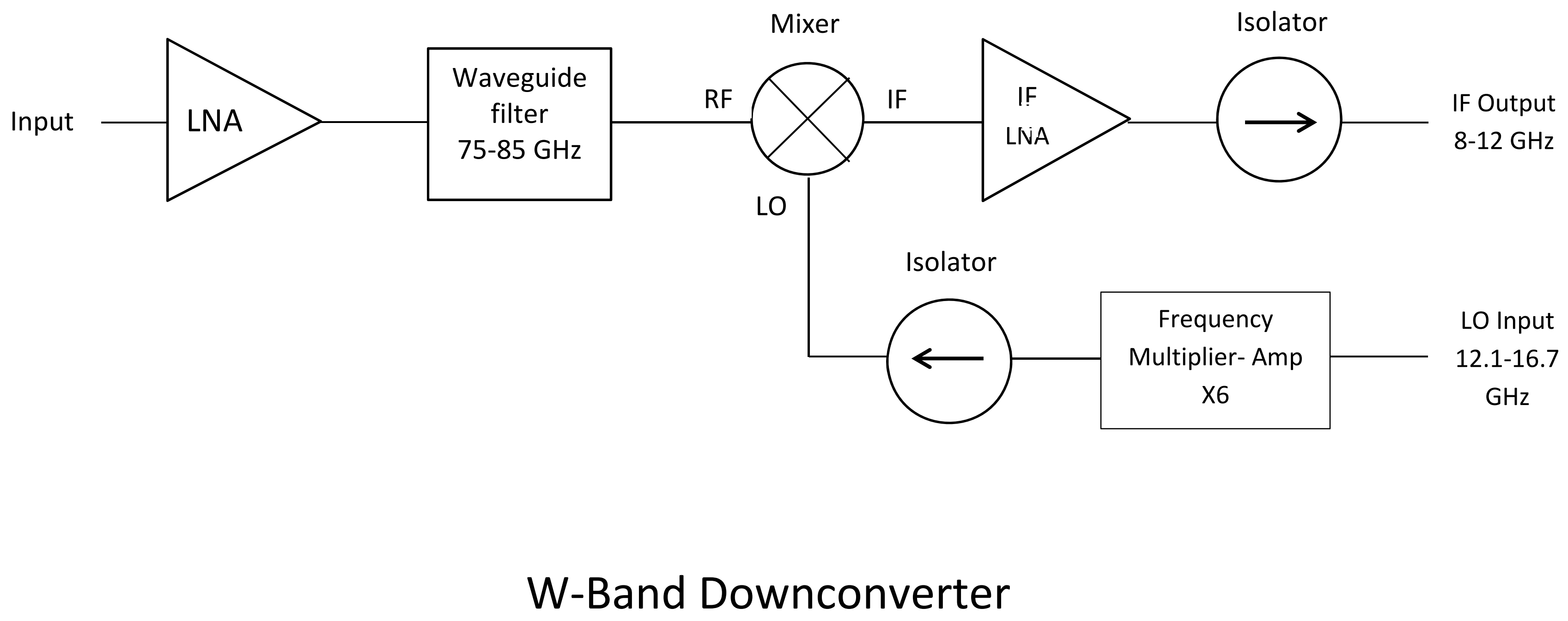
Input
LNA
Waveguide filter 75-85 GHz
RF
Mixer
IF
LO
IF LNA
Isolator
IF Output 8-12 GHz
Isolator
Frequency Multiplier- Amp X6
LO Input 12.1-16.7 GHz
W-Band Downconverter

Figure 13

IV. CONCLUSIONS

The use of an external harmonic mixer to make measurements of millimeter wave signals with a spectrum analyzer requires careful attention to the capabilities and limitations of this method. The signal strength with respect to the conversion loss must be sufficient to provide enough signal to noise to permit the desired measurements and the effect of images and other unwanted signals must not interfere with the ability to identify the desired signal. Images are especially a problem in the case of wideband signals where the bandwidth is equal to or greater than twice the IF frequency of the spectrum analyzer. This problem can be significantly diminished if an image suppression function is available or a preselected mixer is used and the higher conversion loss is acceptable. Better results can be obtained with a downconverter but commercial test equipment for compliance testing of equipment such as LPRs in the 75 to 85 GHz band is generally not available. However, the components to design and assemble a downconverter which will provide superior performance to an external harmonic mixer are readily available.