# Optimize External Mixer Operation for Improved Conversion Loss Performance.

## Introduction

Harmonic mixers can overcome the inherent microwave limitation in spectrum analyzers for millimeter wave measurements. As a modern convenience, high performance spectrum analyzers are available that offer a standard external mixer option with standard predetermined frequency plans (i.e., multipliers) to simplify millimeter wave measurements. In contrast, many other spectrum analyzers do not offer this functionality due to connectivity limitations (i.e., LO & IF access).

Given the increasing popularity of external mixer techniques, this note will describe a generic architecture for millimeter wave measurements using any spectrum analyzer. Furthermore, the presented architecture offers opportunities to optimize operation for lower and flatter conversion loss characteristics, which may be especially beneficial for applications requiring modulation analysis (e.g., WiGig).

Generic external mixer requirements for conducting millimeter wave spectrum analysis,

1. A spectrum analyzer (e.g., Keysight PSA or PXA)
2. A signal generator with low phase noise and high power characteristics (e.g., Keysight PSG)
3. A harmonic mixer (e.g., OML MxxHWD), including self-bias attenuator (1 dB)
4. A suitable diplexer (e.g., OML DPL-518)

## Overview

The harmonic mixer down converts the RF signal by mixing the nth harmonic of the LO to generate a predefined IF that satisfies the equation of n(LO) – (RF). Using this equation as guidance, engineers can setup a generic architecture that satisfies a variety of millimeter wave measurement scenarios.

The obvious trade-off of this approach is the spectrum analyzer’s display will readout the discrete IF instead of the RF frequency. In contrast, the advantages are in flexibility to choose the desired IF and harmonic multiplier. Once the frequency plan is chosen, the measurements are straightforward to conduct.

# Hardware Connection

Referring to Figure 1, connect the spectrum analyzer, signal generator, diplexer, self-bias attenuator (1dB) and harmonic mixer as shown.

**Note:** Time base synchronize the two instruments for accurate frequency readout.

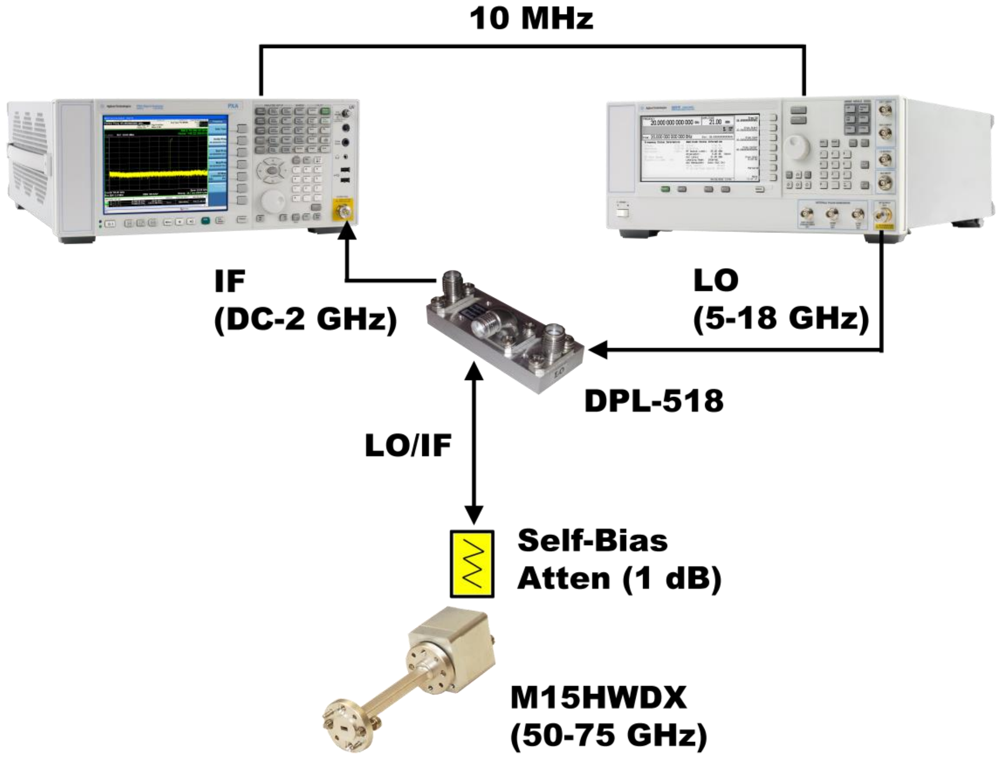



***Figure 1 – Generic setup for external harmonic mixer measurements consisting of spectrum analyzer, signal generator, diplexer, self-bias attenuator (1 dB) and harmonic mixer.***

# Frequency Planning

Generally speaking, lower conversion loss is possible with lower multipliers. For reference, the following table in Figure 2 shows the standard harmonic multipliers by waveguide band for the Keysight PSA and PXA signal analyzers, which has predetermined IF of 321.4 MHz and 322.5 MHz, respectively. Using this summary, engineers have the opportunity to replicate the measurement conditions before further optimizing their generic setup.

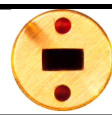
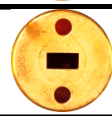
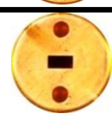
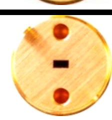
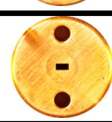
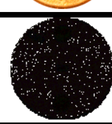
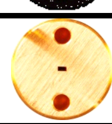
| **Waveguide Spectrum** | **$TE_{10}$ Cutoff Frequency (GHz)** | **Rectangular Waveguide Interface View** | **Internal Dimensions (mils)** | **Keysight PSA Multiplier Factor, n** | **Keysight PXA Multiplier Factor, n** |
|---|---|---|---|---|---|
| 50 – 75 GHz<br>**WR-15**<br>V-Band | 39.9 GHz |  | 148.0 x 74.0 | 14 | 10 |
| 60 – 90 GHz<br>**WR-12**<br>E-Band | 48.4 GHz |  | 122.0 x 61.0 | 16 | 12 |
| 75 – 110 GHz<br>**WR-10**<br>W-Band | 59 GHz |  | 100.0 x 50.0 | 18 | 8 |
| 90 – 140 GHz<br>**WR-08**<br>F-Band | 73.8 GHz |  | 80.0 x 40.0 | 22 | 10 |
| 110 – 170 GHz<br>**WR-06**<br>D-Band | 90.8 GHz |  | 65.0 x 32.5 | 26 | 14 |
| 140 – 220 GHz<br>**WR-05**<br>G-Band | 115.7 GHz |  | 51.0 x 25.5 | 32 | 16 |
| 170 – 260 GHz<br>**WR-04**<br>Y-Band | 137.2 GHz |  | 43.0 x 21.5 | 38 | 20 |
| 220 – 325 GHz<br>**WR-03**<br>H (J)-Band | 173.6 GHz |  | 34.0 x 17.0 | 48 | 24 |

*Figure 2 – Table summarizes Keysight's PSA & PXA harmonic multipliers versus waveguide band. Higher harmonic multipliers cause higher conversion loss that can limit sensitivity.*

# Diplexer Characteristics

The frequency plan constraints are related to the hardware elements in the architecture where the diplexer ensures the frequencies will flow unimpeded and with adequate signal separation to optimize performance for millimeter wave spectrum analysis.  For this reason, engineers should consider the diplexer characteristics as significant hardware constraints in the overall setup.

For example, OML's DPL-518 is a diplexer supporting LO frequencies from 5 GHz to 18 GHz with 1-2 dB insertion loss.  In addition, the IF supports DC to 2 GHz.  Refer to Figure 3 for typical S-parameters of the DPL-518.  This component offers attractive performance so engineers can consider frequency plans with LO inputs of up to 20 GHz for reducing harmonic multipliers in external mixing scenarios.

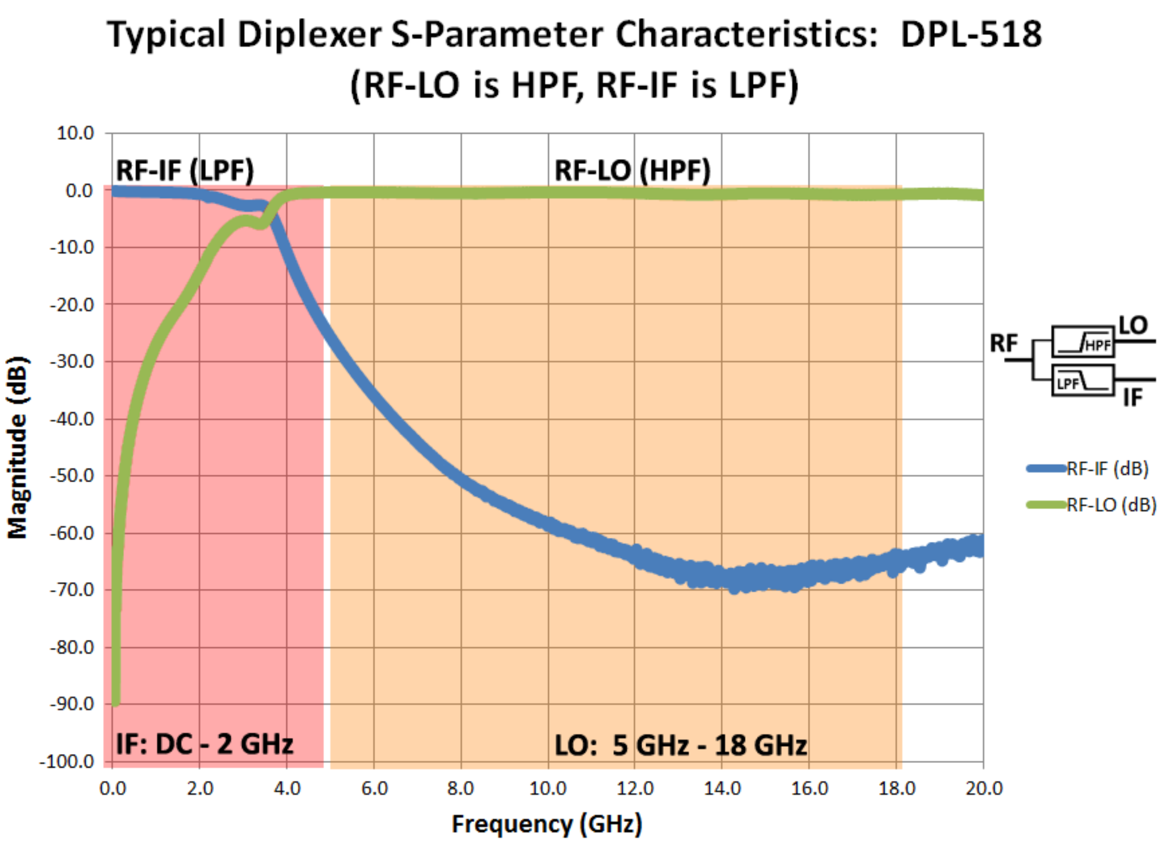



*Figure 3 – Typical S-parameters of OML's DPL-518 diplexer showing LO range of 5—18 GHz and IF range of DC—2 GHz.*

# Frequency Planning

After considering hardware constraints, an engineer can generate a frequency plan:

1. Select an IF and the desired multiplier.
2. Afterwards, calculate the LO settings using the equation:  LO=(RF+IF)/n.

A frequency plan example is shown in Figure 4.  In this example, settings are given to replicate the Keysight PSA and PXA spectrum analyzers.  In addition, the settings are shown for a user-defined case of n = 4.

**Note:**  OML's MxxHWD single-diode design supports either even or odd multiplier selections.

| Keysight PSA External Mixer Settings | | | |
|---|---|---|---|
| **RF (GHz)** | **IF** | **n** | **LO (GHz)** |
| 50.0 | 1.5 | 14 | 3.57 |
| 62.5 | 1.5 | 14 | 4.46 |
| 75.0 | 1.5 | 14 | 5.36 |
| **Keysight PXA External Mixer Settings** | | | |
| **RF (GHz)** | **IF** | **n** | **LO (GHz)** |
| 50.0 | 1.5 | 10 | 5.00 |
| 62.5 | 1.5 | 10 | 6.25 |
| 75.0 | 1.5 | 10 | 7.50 |
| **User-Defined External Mixer Settings** | | | |
| **RF (GHz)** | **IF** | **n** | **LO (GHz)** |
| 50.0 | 1.5 | 4 | 12.50 |
| 62.5 | 1.5 | 4 | 15.63 |
| 75.0 | 1.5 | 4 | 18.75 |

*Figure 4 – Frequency plan calculations based on Keysight PSA and PXA spectrum analyzers.  In addition, a user-defined case using multiplier of x4 is shown.*

# Measurement Results

Using the frequency plan as a reference, conduct the measurement using the following procedure:

1. Translate the desired RF frequency into the corresponding LO frequency.
2. On the signal generator, input the desired LO frequency.
3. On the spectrum analyzer, input the desired IF frequency.
4. The results will appear on the spectrum analyzer display.
5. As needed, compensate the amplitude readout by the conversion loss of the harmonic mixer.

The procedure is tedious, but adding a computer to the setup can automate the collection of measurement data. An example illustrating a comparison between the Keysight PSA (multiplier of x14), Keysight PXA (multiplier of x10) and a User-Defined case (multiplier of x4) is shown in Figure 5. Note the significant improvements in conversion loss by using a lower multiplier. This improvement is especially useful for modulation measurements where instantaneous bandwidth depends on passband flatness characteristics.

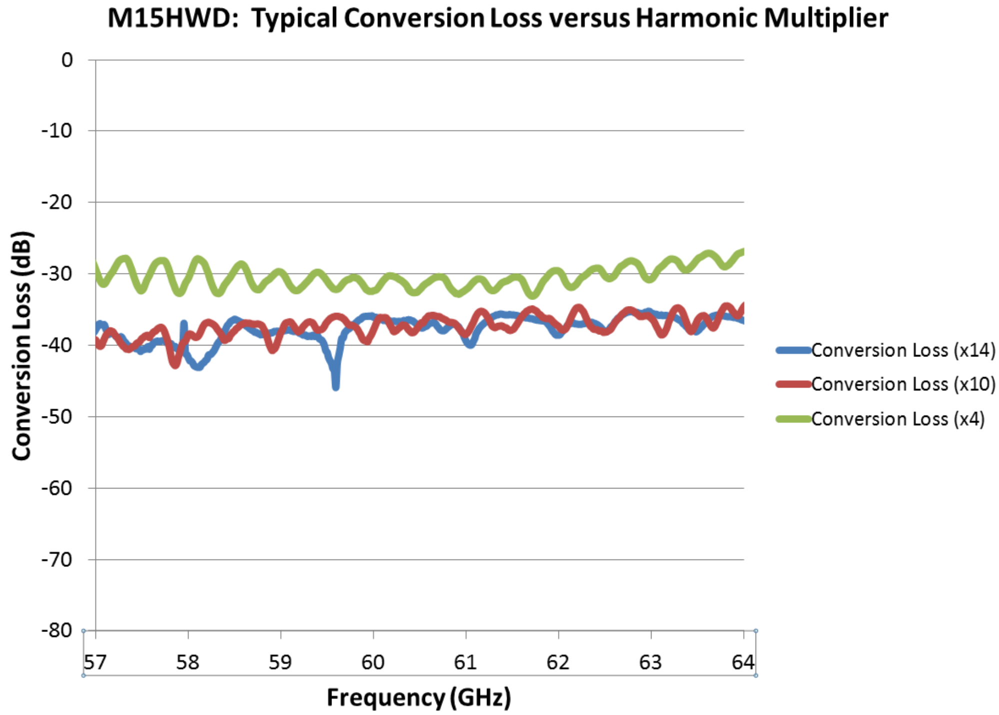



*Figure 5 – Conversion loss comparison between multipliers of x14 (Keysight PSA), x10 (Keysight PXA) and x4 (user-defined). This data illustrates for WR-15 how conversion loss can improve by reducing harmonic multipliers in external mixer frequency plans.*

# Conclusion

A generic external mixer technique for millimeter wave spectrum analysis can offer considerable flexibility to optimize conversion loss performance for a variety of criteria. The architecture utilizes common microwave instrumentation to achieve results that may prove to be a useful alternative to other commercially available solutions.