Improve Measurement Integrity
for RF and Microwave Wideband Signals

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Product Marketing / Keysight Technologies

KEYSIGHT TECHNOLOGIES

New Applications Are Driving New Requirements

DRIVEN BY DEMAND FOR DATA

Enabling Next-Generation Broadband Access

TEST AND MEASUREMENT MUST KEEP PACE

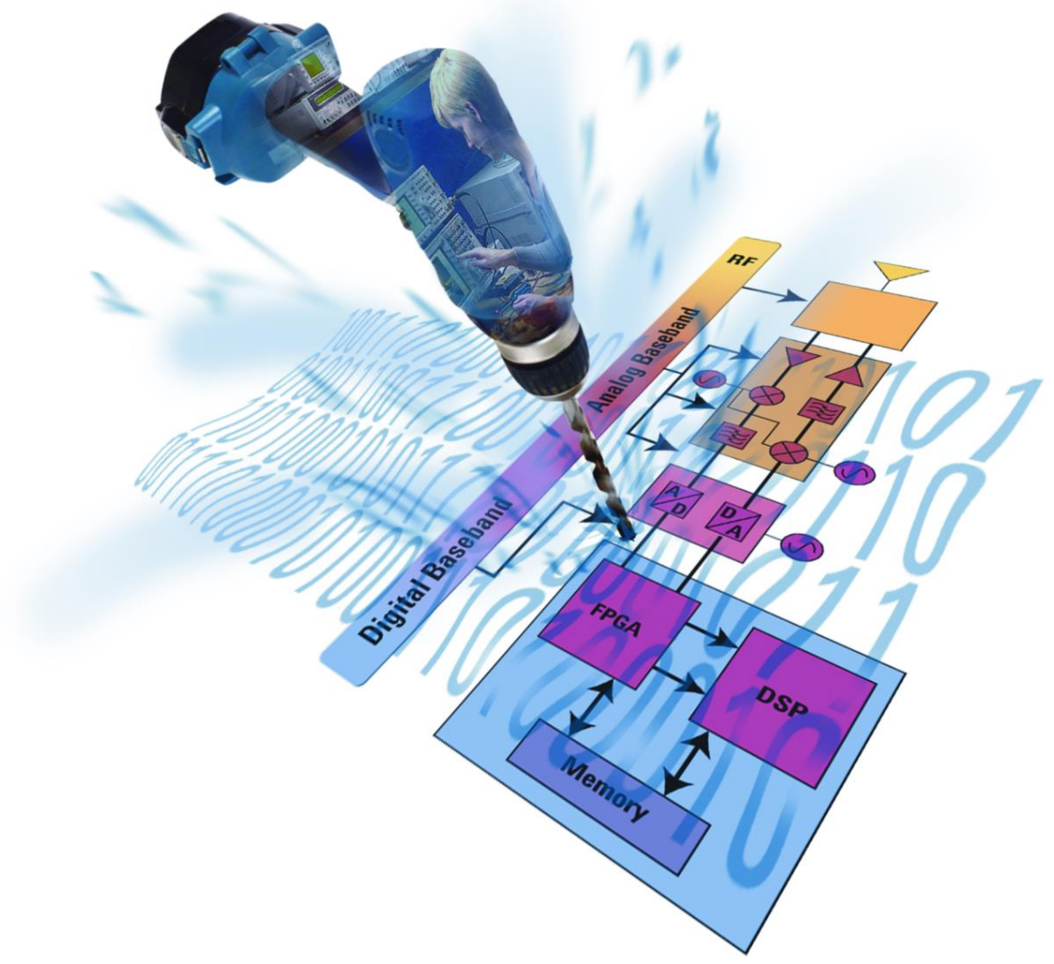
	5G NR	HTS*	Wi-Fi
			
Frequency range	FR1: < 7.125 GHz FR2: 24 – 52 GHz	K: 18 – 26.5 GHz Ka: 26.5 – 40 GHz	11ax: < 7.125 GHz 11ad: 60 GHz ISM
Signal bandwidth	FR1: 100 MHz FR2: 400 MHz	0.5 – 2 GHz	11ax: 160 MHz 11ad: 2 GHz

*HTS: High-throughput satellites

Design and Measurement Challenges

WIDER BANDWIDTHS AT HIGHER FREQUENCIES

- Excessive path loss
- Higher phase noise
- Inferior frequency responses
- I/Q modulator impairments

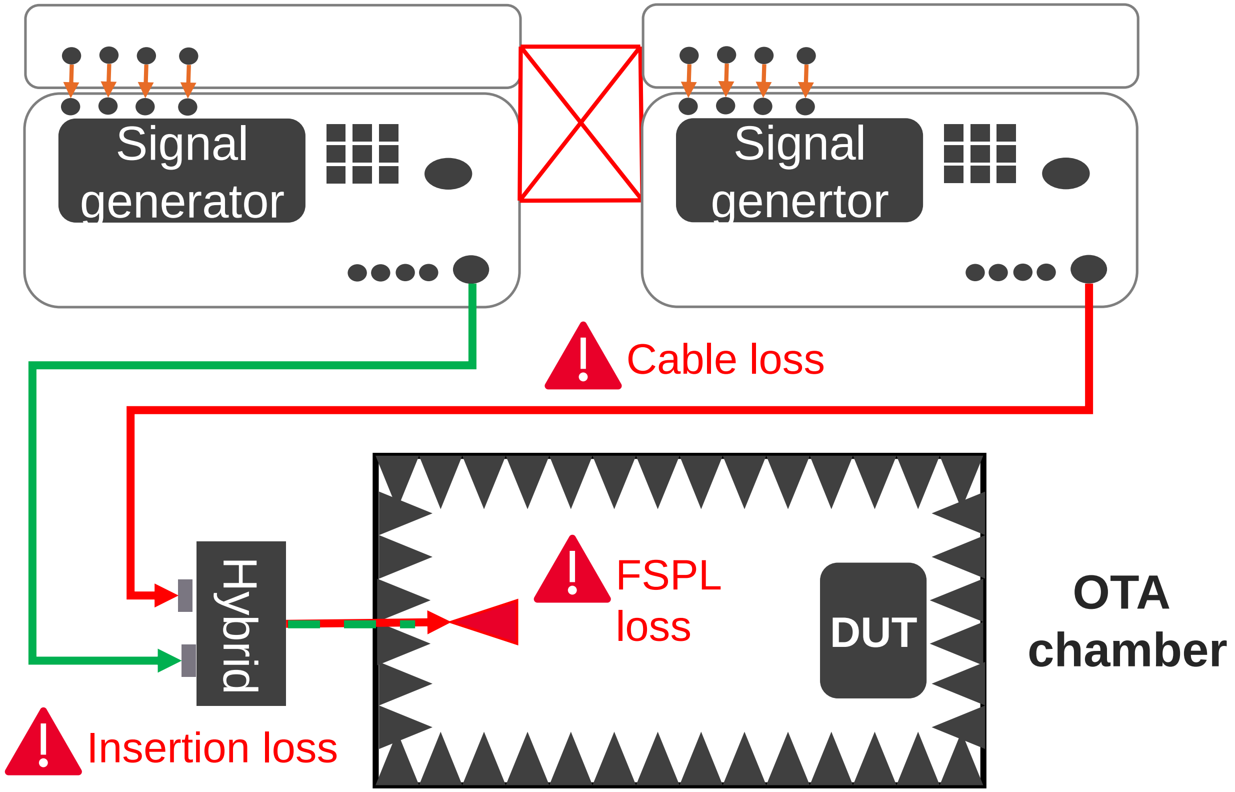


Result of Frequency Increases

PATH LOSS INCREASES

- insertion loss of cables and accessories
- free space path loss (FSPL) in dB

$$FSPL\ (dB) = 20 * \log_{10}(d) + 20 * \log_{10}(f) + 20 * \log_{10}\frac{4\pi}{c}$$

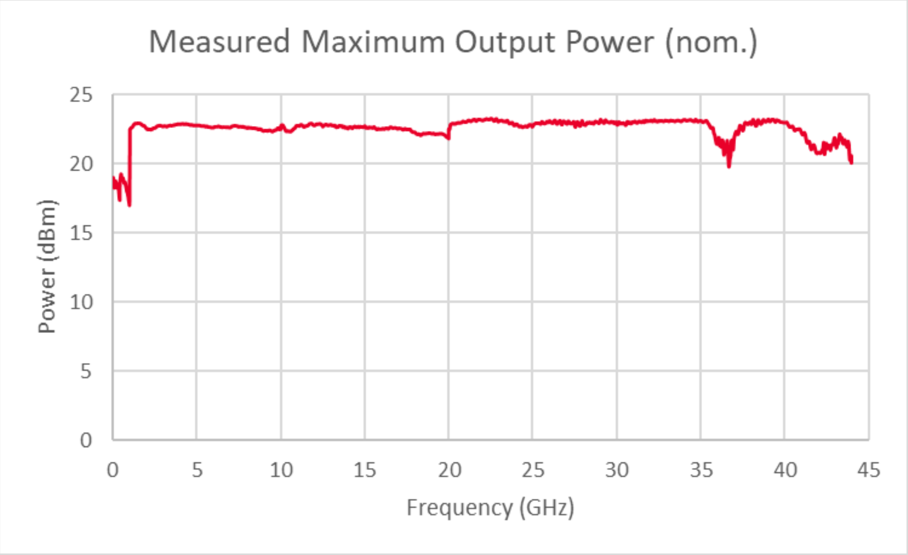


d: distance between the antennas in units of km
f: carrier frequency in units of GHz
c: speed of light

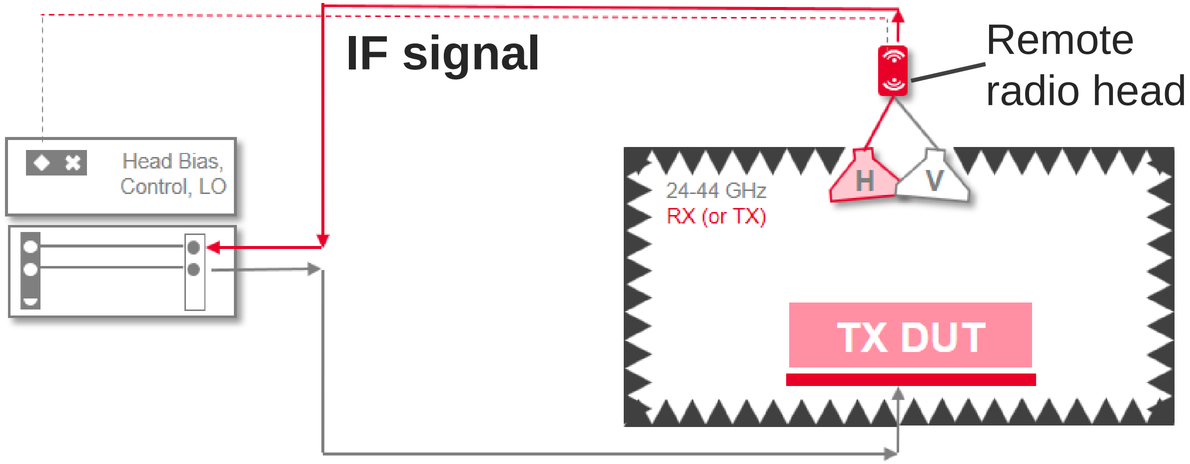
How to Overcome Insertion and Propagation Losses

SIGNAL GENERATION

- use a signal generator with high output power

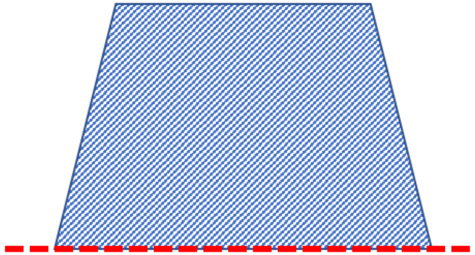
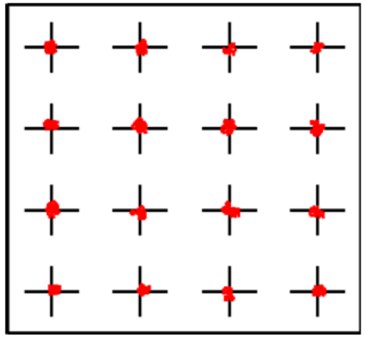
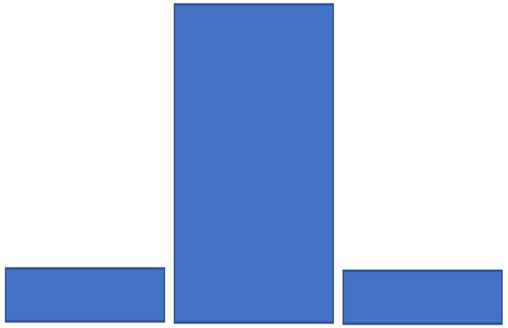
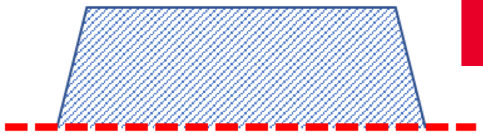
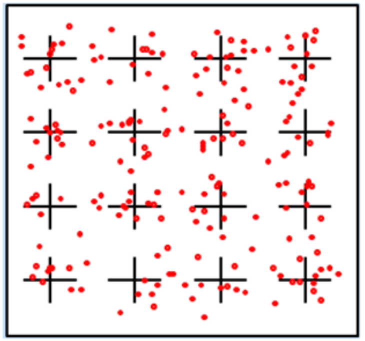
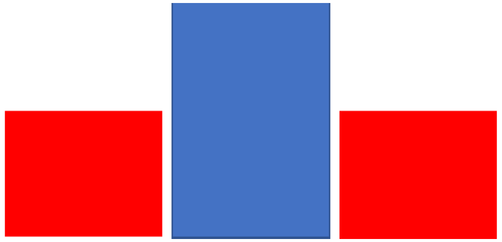


- use a remote radio head to reduce path loss



Higher Frequencies and Wider Bandwidths

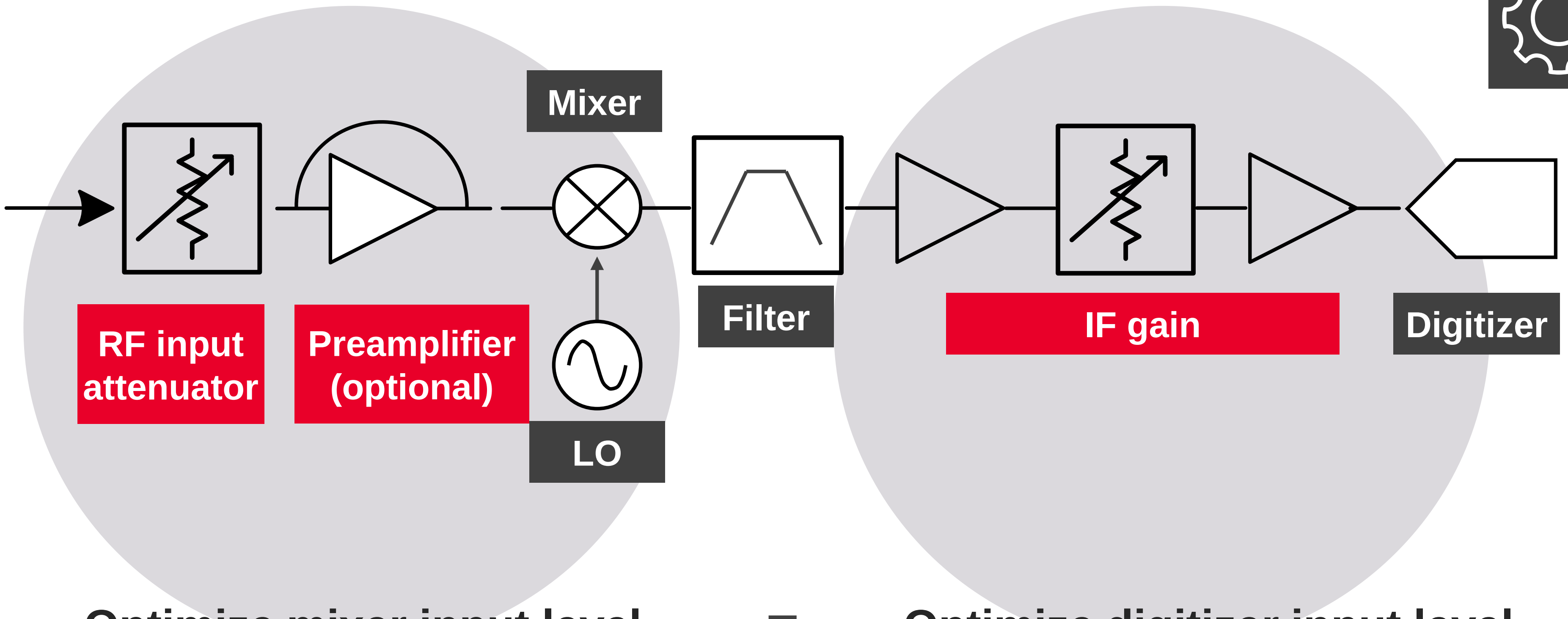
RESULT: A LOWER SNR FOR SIGNAL ANALYSIS

SNR	Constellation	ACPR
High SNR 		
Low SNR 		

SNR: signal-to-noise ratio
ACPR: adjacent channel power ratio

Achieve the Best EVM Measurement Results

OPTIMIZE SIGNAL CONDITIONING



OPTIMIZE

Signal analyzers offer a one-button solution to accelerate setting the signal conditioning for EVM measurements.

You need to adjust the attenuation manually to achieve the best measurement results.

Optimize mixer input level

- adjust input attenuation
- enable a built-in preamplifier

+

Optimize digitizer input level

- adjust IF gain

Design and Measurement Challenges

WIDER BANDWIDTHS AT HIGHER FREQUENCIES

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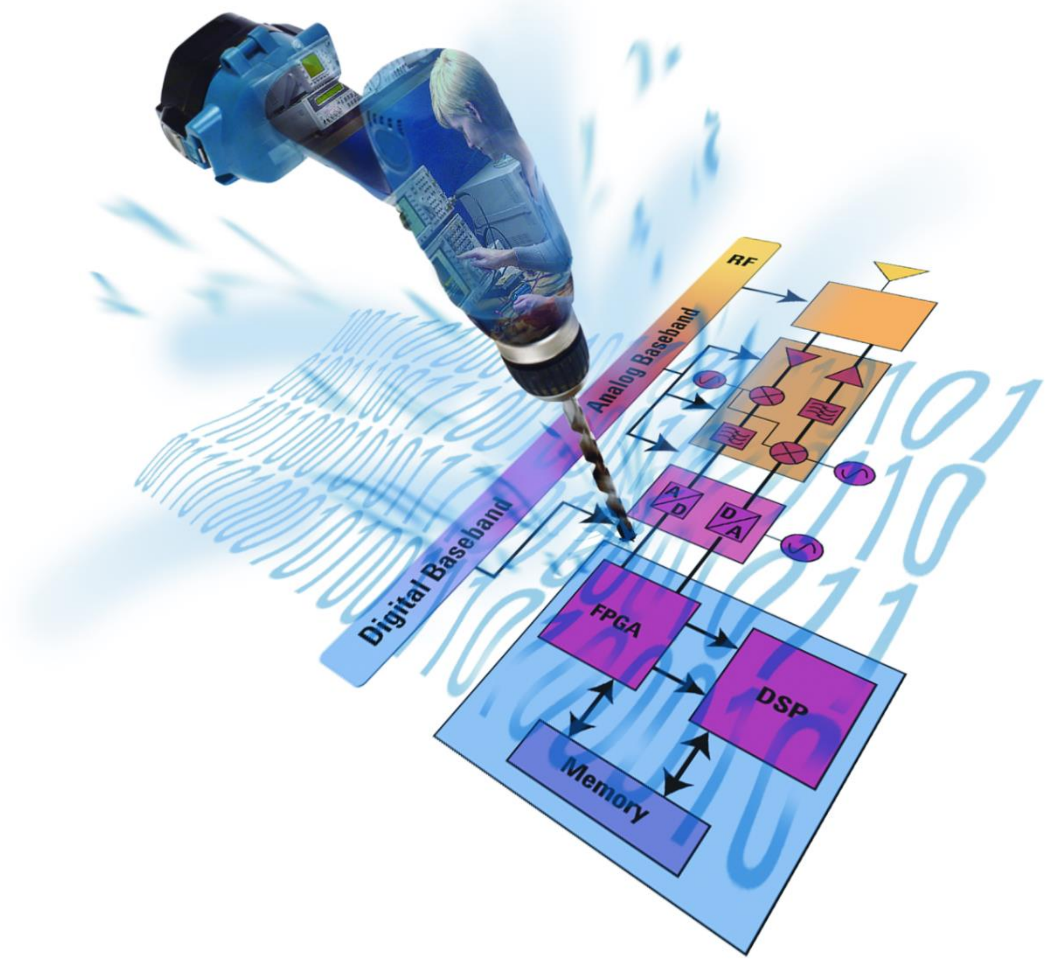
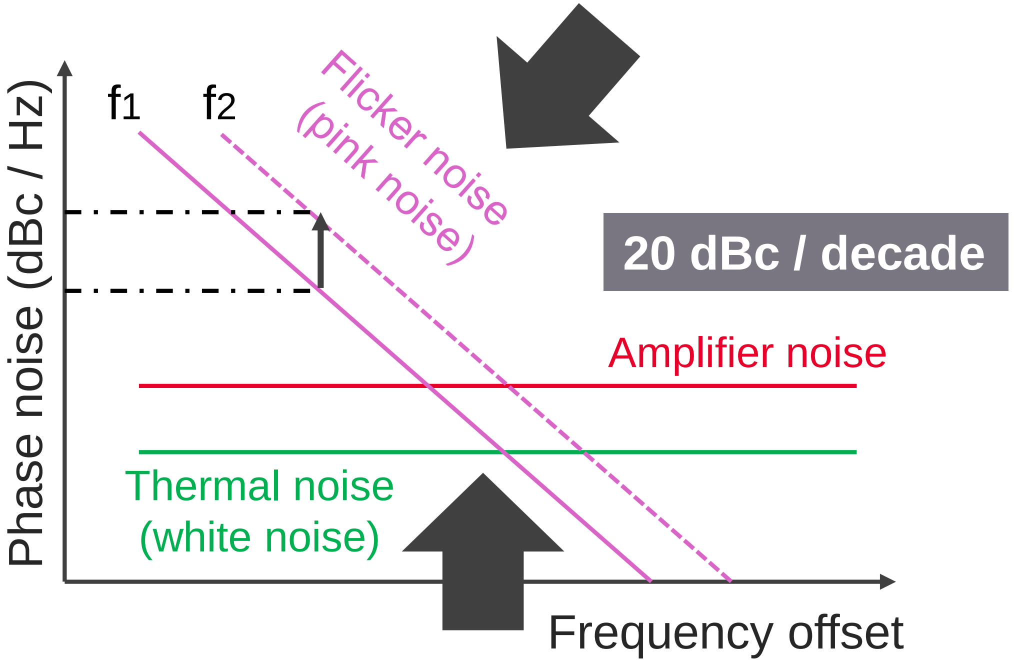
- I/Q modulator impairments

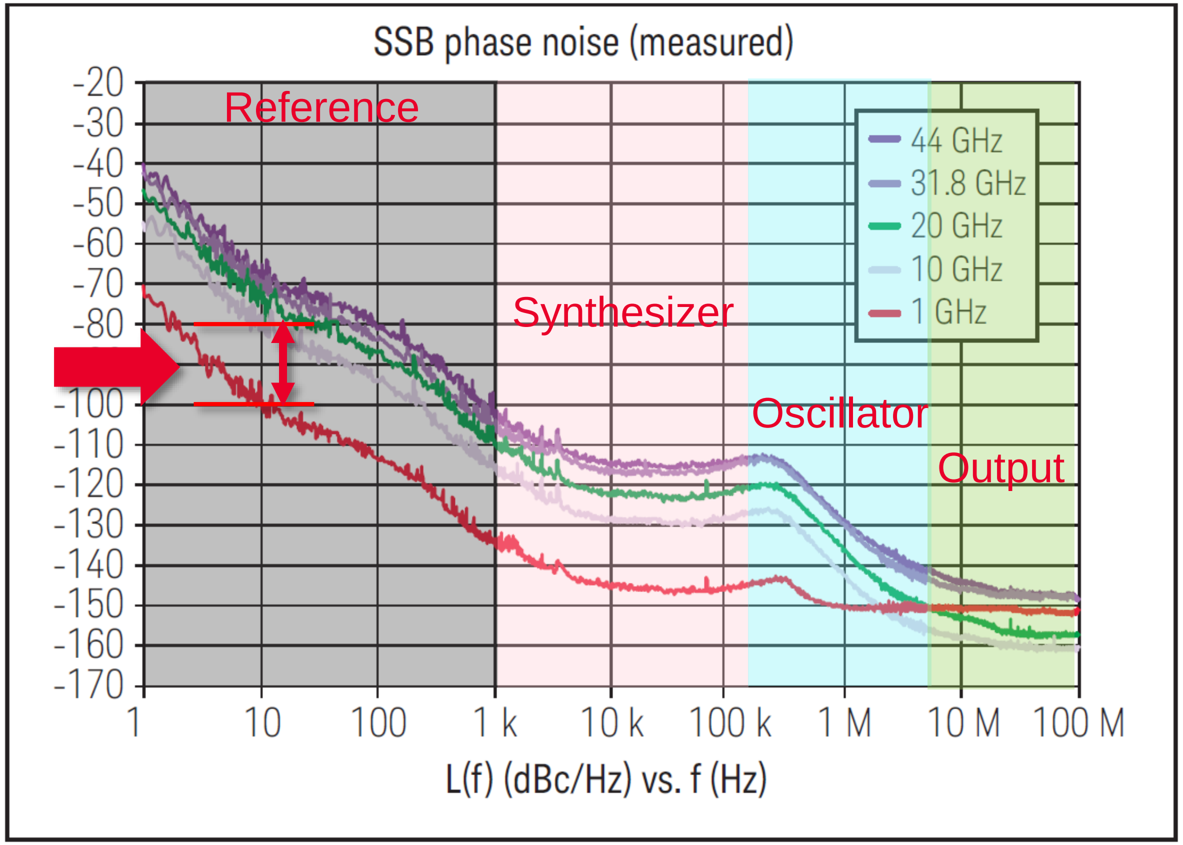


Result of Frequency Increases

PHASE NOISE INCREASES

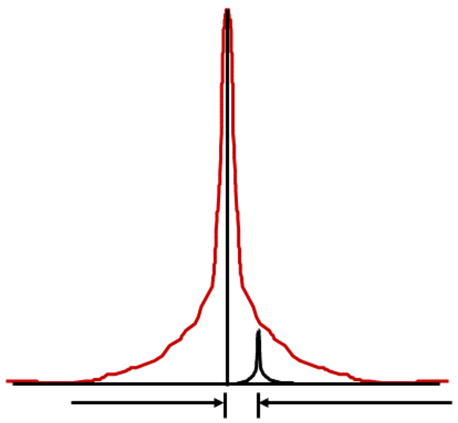
- Main contributors to phase noise
  - thermal noise
  - flicker noise (1/f)



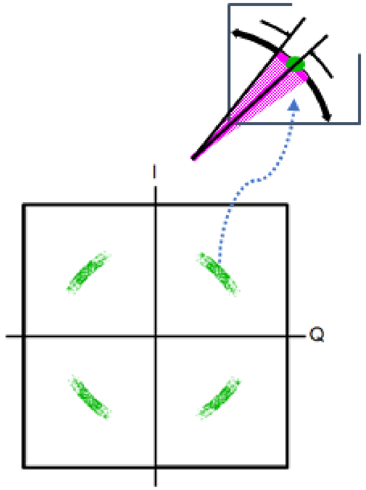


Importance of Phase Noise

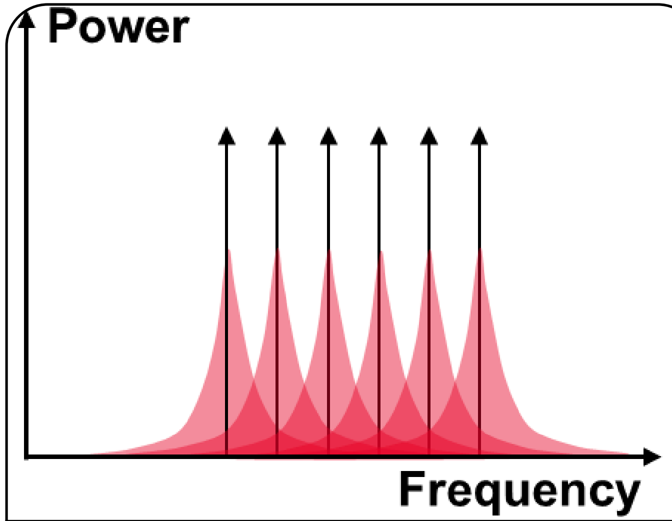
TEST NEEDS

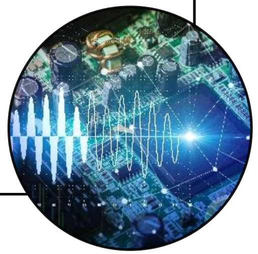


Radar applications



Digital modulation



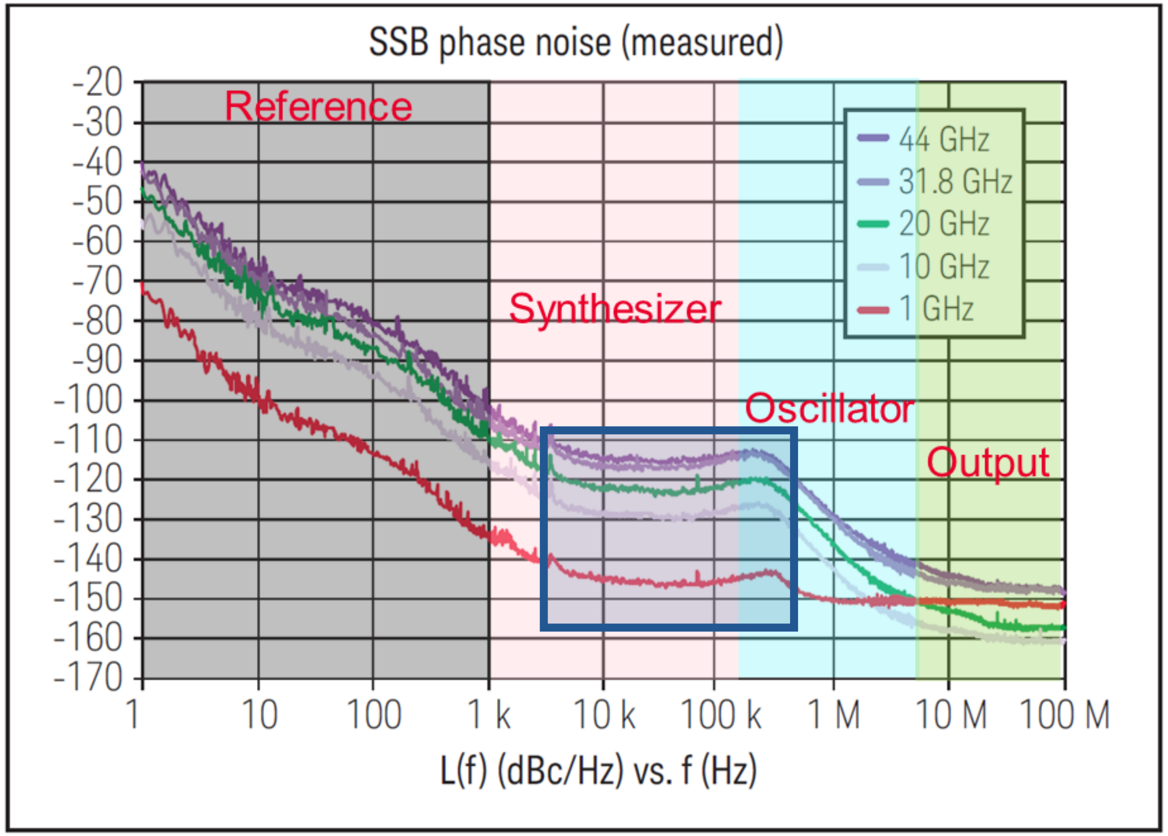


OFDM modulation

Importance of Phase Noise – OFDM

INTERSYMBOL INTERFERENCE

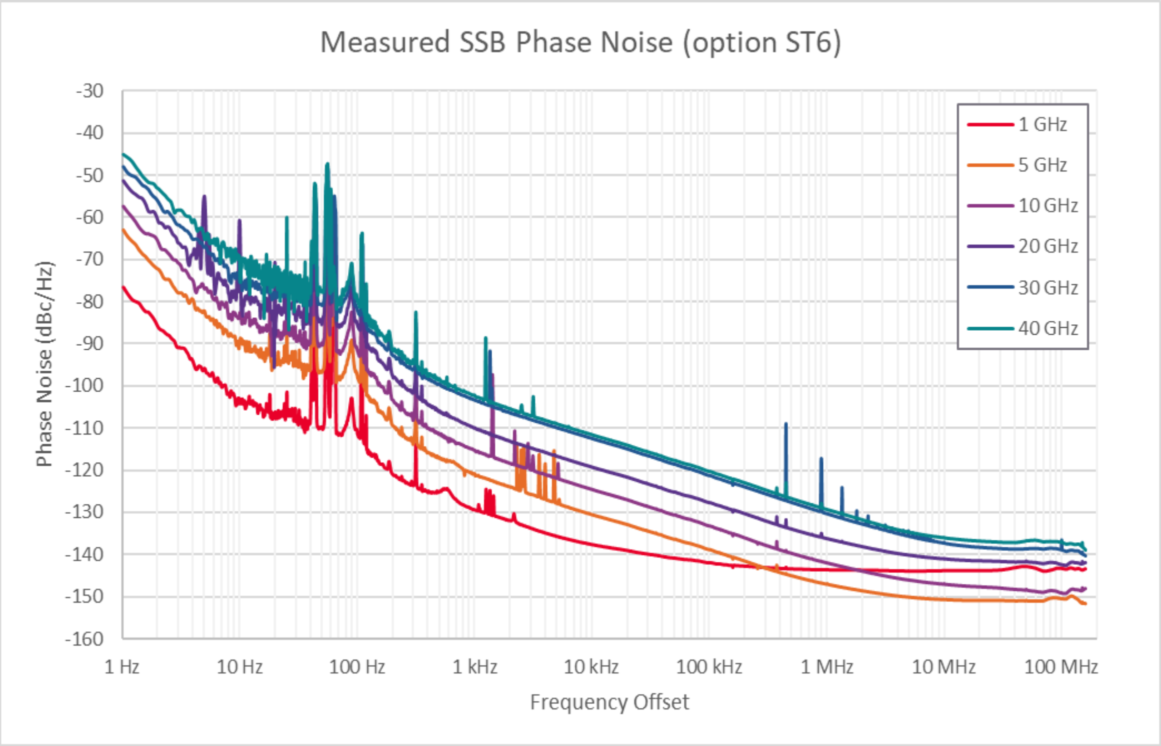
	Sub-carrier spacing
IEEE 802.11ac	312.5 kHz
IEEE 802.11ax	78.125 kHz
LTE / LTE-A	7.5, 15 kHz
5G New Radio	15, 30, 60, 120, 240, 480 kHz



Choose and Optimize Phase Noise Performance

SIGNAL GENERATION

- choose a signal generator with ultra-low phase noise

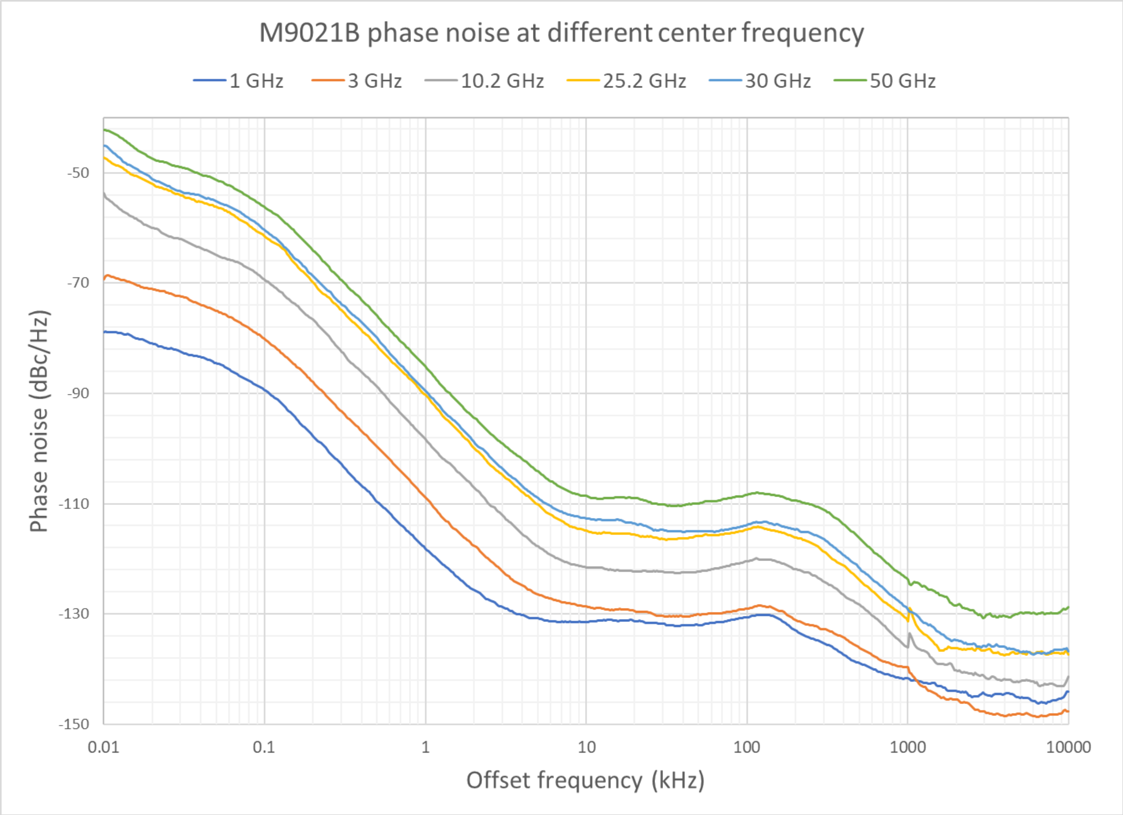


- optimize phase noise at different offsets
  - apply external references (reference section)
  - use built-in adjustments
    - adjust reference oscillator bandwidth (reference section)
    - adjust the PLL bandwidth (synthesizer section)

Choose and Optimize Phase Noise Performance

SIGNAL ANALYSIS

- Choose a signal analyzer with ultra-low phase noise.



- Optimize phase noise at different offsets for your test applications:
  - apply external references (reference section)
  - use built-in adjustments
    - close-in
    - wide offset
    - fast tuning

Phase Noise Optimization

SIGNAL ANALYSIS

OPTIMIZE

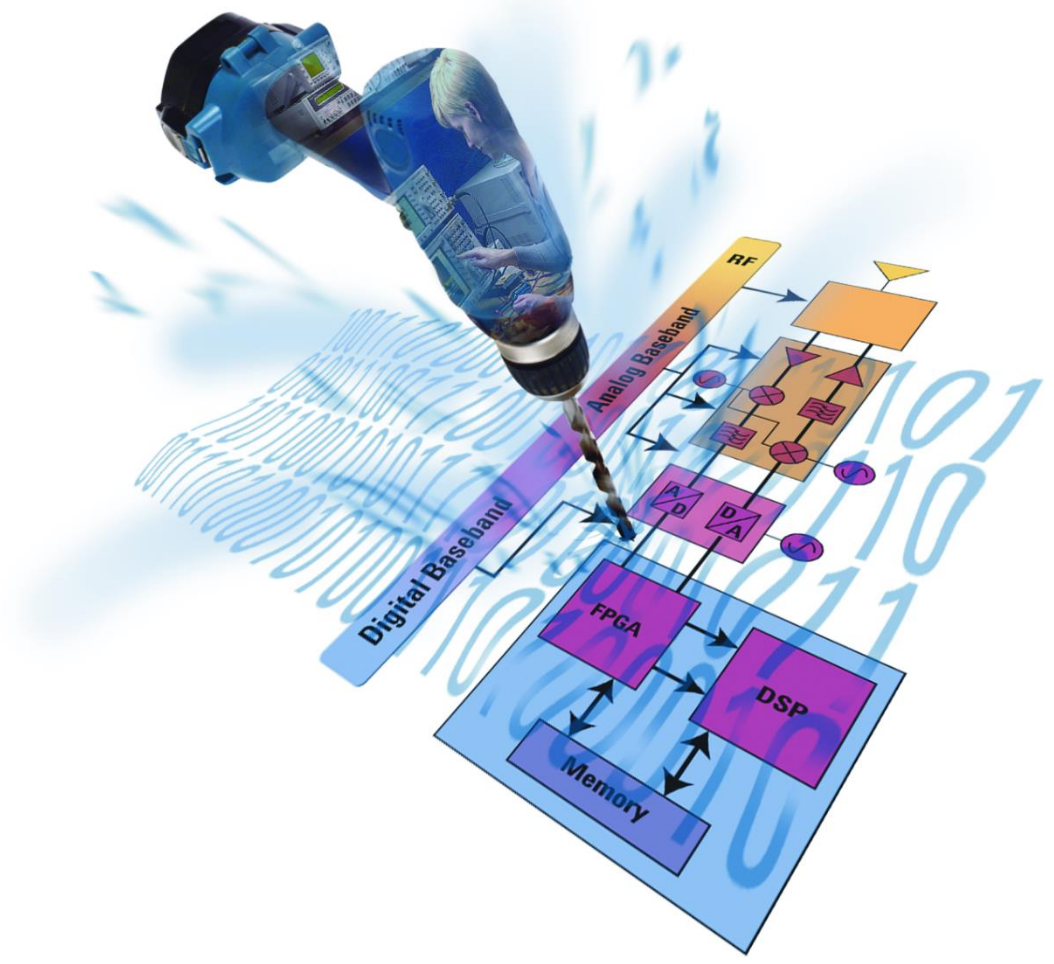
Phase noise optimization provides various phase noise behaviors for different operating conditions.

Actual behavior varies, depending on the Keysight model number and option.

Design and Measurement Challenges

WIDE BANDWIDTHS AT HIGHER FREQUENCIES

- Excessive path loss
- Higher phase noise
- Inferior frequency responses
- I/Q modulator impairments

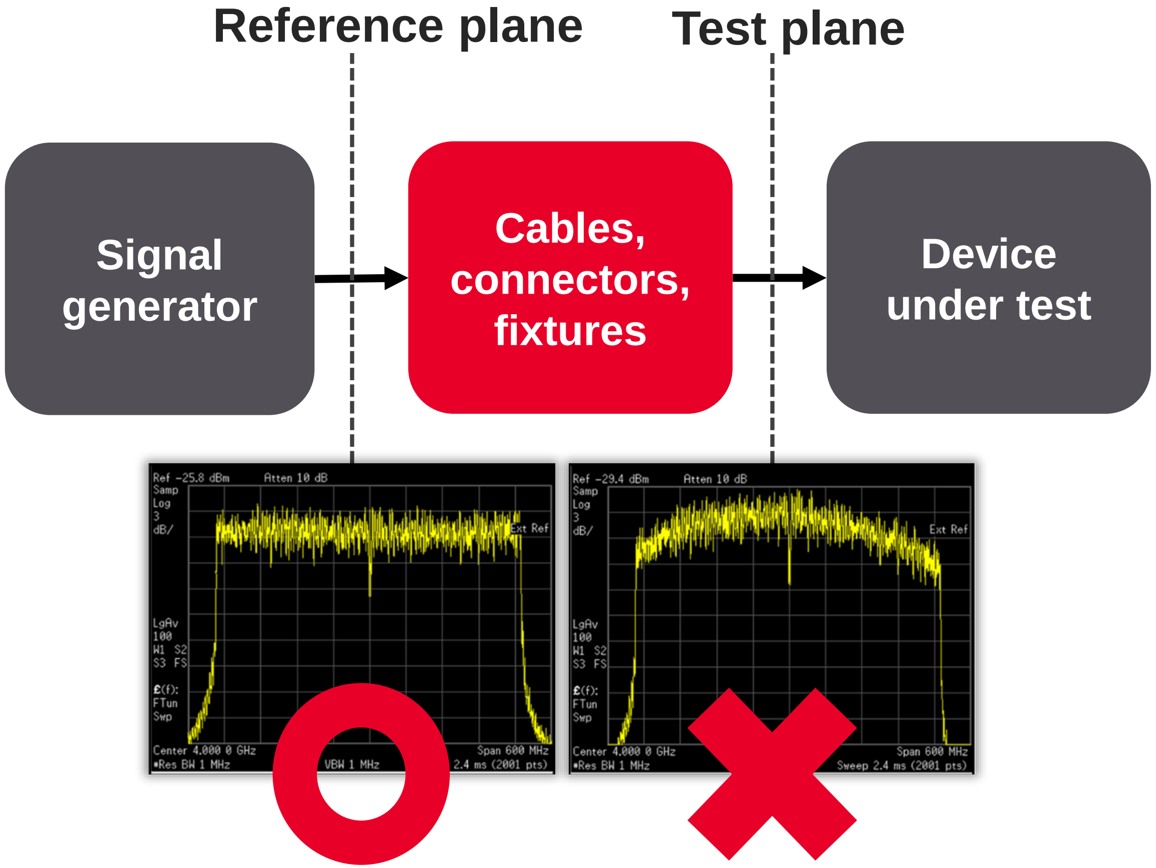


Solutions for Wide Bandwidth Signal Generation

Specification	M8190A and E8267D	S9100A	M9384B or M9383B
Frequency	Up to 44 GHz	< 6 GHz; 24.25 to 43.5 GHz	Up to 44 GHz
Max. RF bandwidth	4 GHz	1.2 GHz	2 GHz
Output power (CW)	+19 dBm (at 40 GHz)	+10 dBm (at 40 GHz)	+18 dBm (at 40 GHz)
Modulation quality	Excellent	Good	Excellent
System calibration	Required	Required	Calibrated
Number of channel	1	Up to 8	Up to 2
Application	Versatile capabilities for advanced research	Lowers cost of test and high-throughput for high-volume test	Optimal performance and test features for R&D and DVT

Frequency Responses – Outside the Signal Generator

SIGNAL WITH WIDER BANDWIDTHS AND HIGHER FREQUENCIES



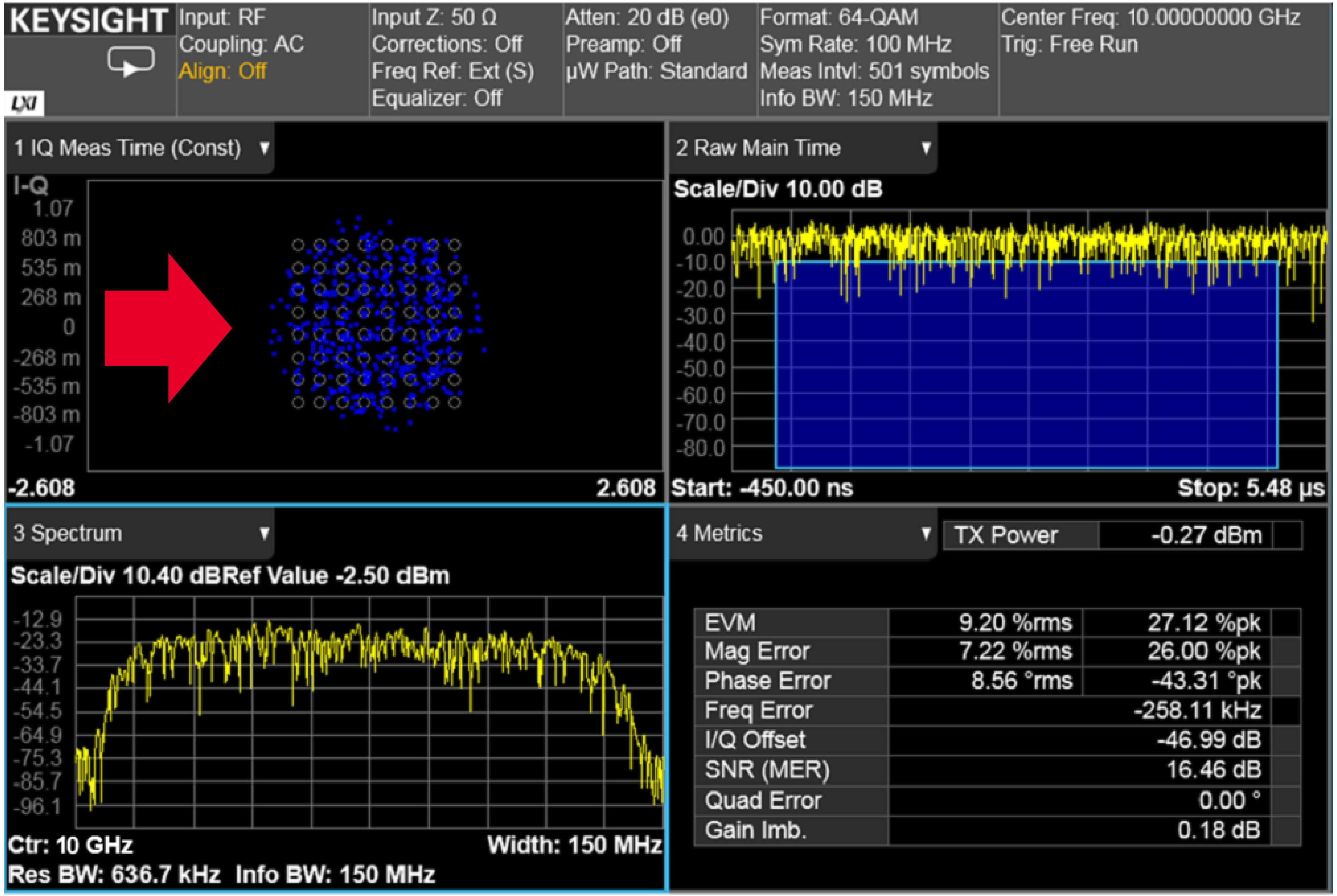
use a power sensor

use a signal analyzer

use a vector network analyzer

Why Frequency Response is Important

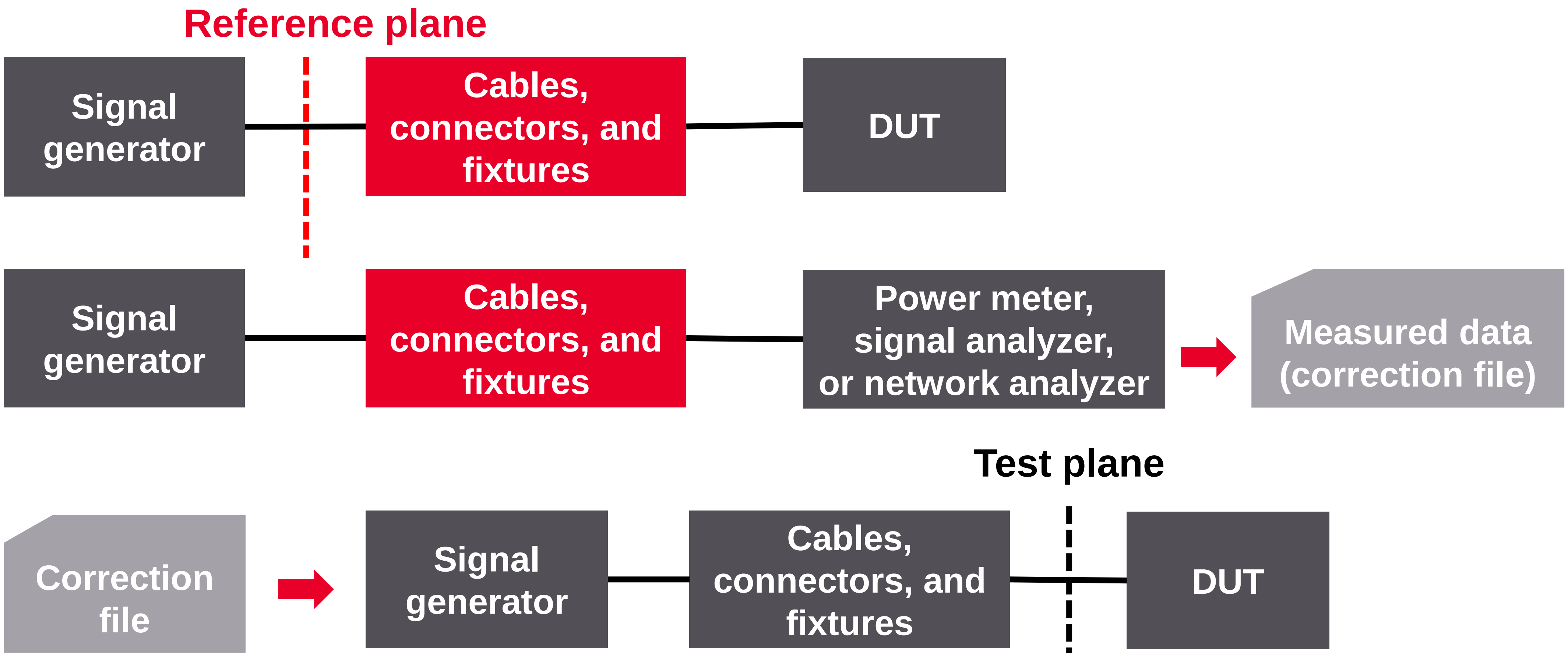
AMPLITUDE AND PHASE RESPONSES



Signal analyzer setup
Modulation: 64-QAM
Symbol rate: 100 MHz
Baseband filter: RRC

Remove Frequency Responses for Signal Generation

USING THE DE-EMBEDDING METHOD

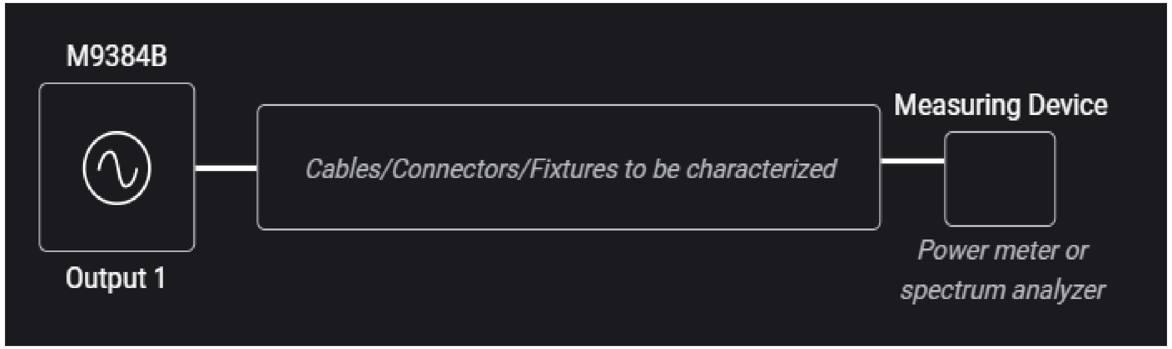


Corrections / De-embedding

SIGNAL GENERATION

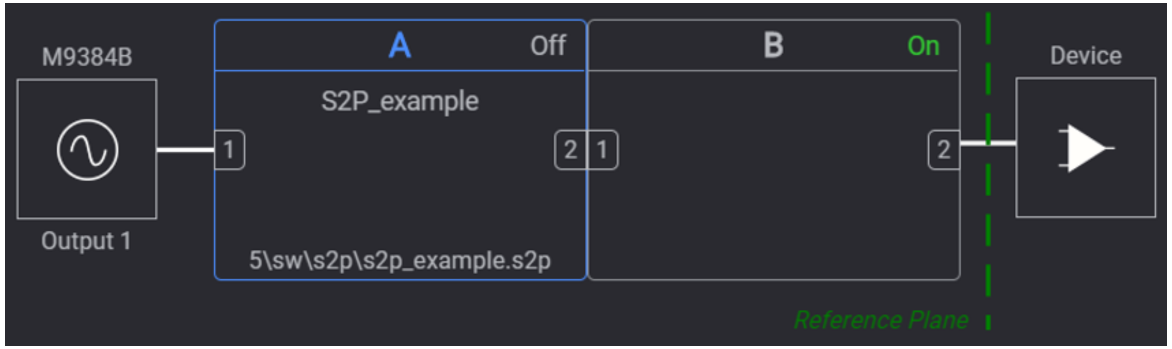
Add from measurements

- Measure corrections with block wizard:
  1. connect test equipment
  2. configure power meter / signal analyzer
     - start / stop frequencies, number of steps, amplitude
  3. measure corrections



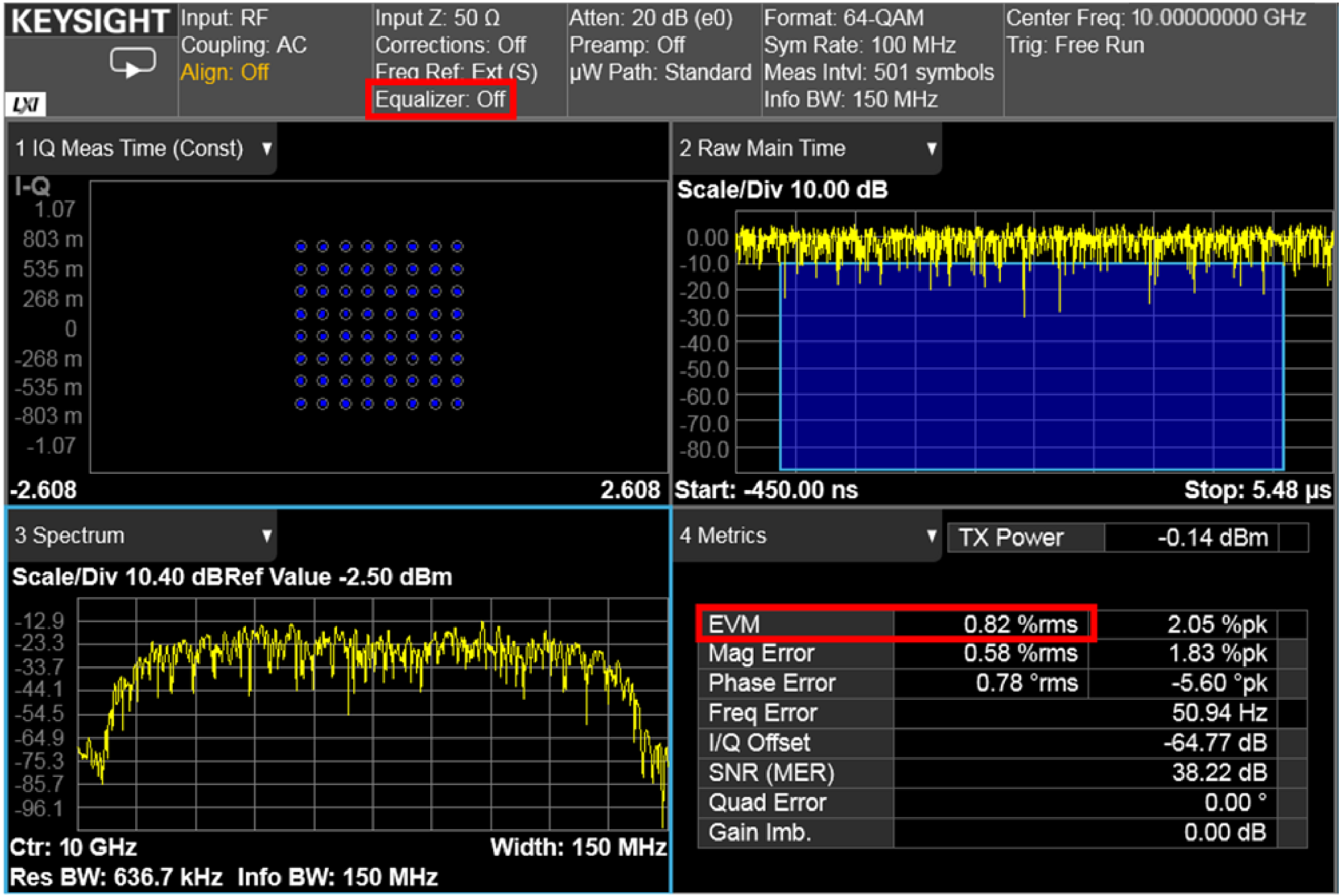
Add from files

- Import and cascade the correction files:
  - download measured correction data (.ulflat)
  - receive file in CSV format
  - download .s2p file



Apply Correction Filter to the Baseband Waveform

REMOVE EXTERNAL FREQUENCY RESPONSES

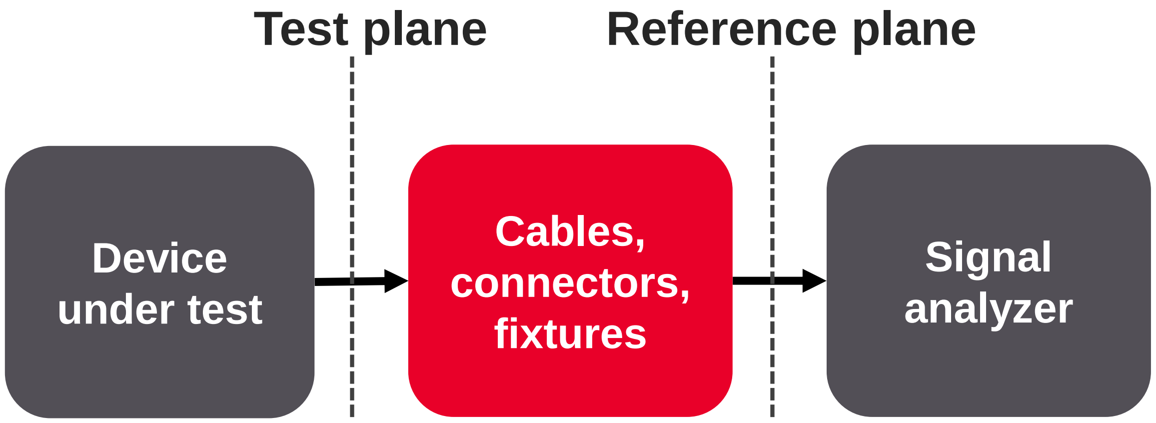


OPTIMIZE

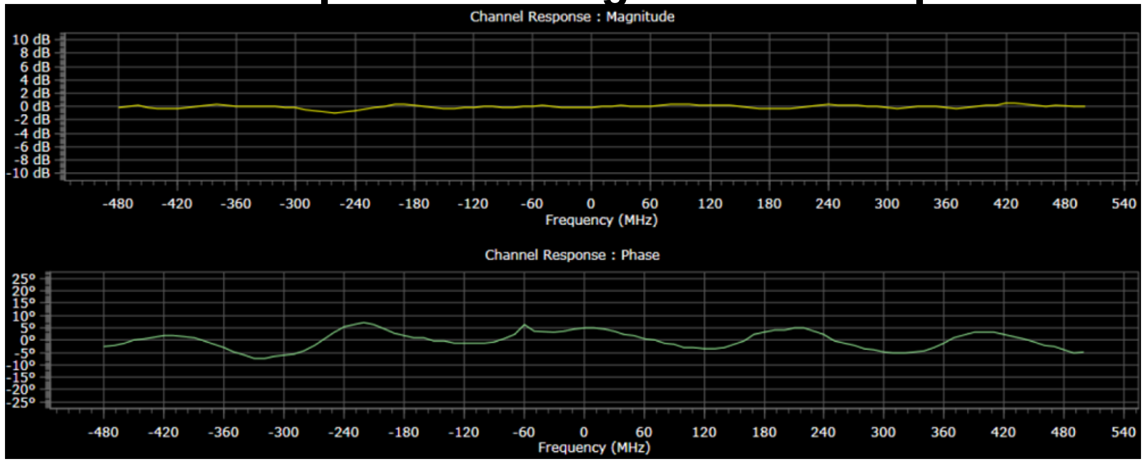
Frequency responses occur at different frequencies and output levels, and include amplitude and phase responses.

Remove Frequency Responses

SIGNAL ANALYSIS



Channel response of magnitudes and phases



Use a signal generator and power sensor for power corrections.

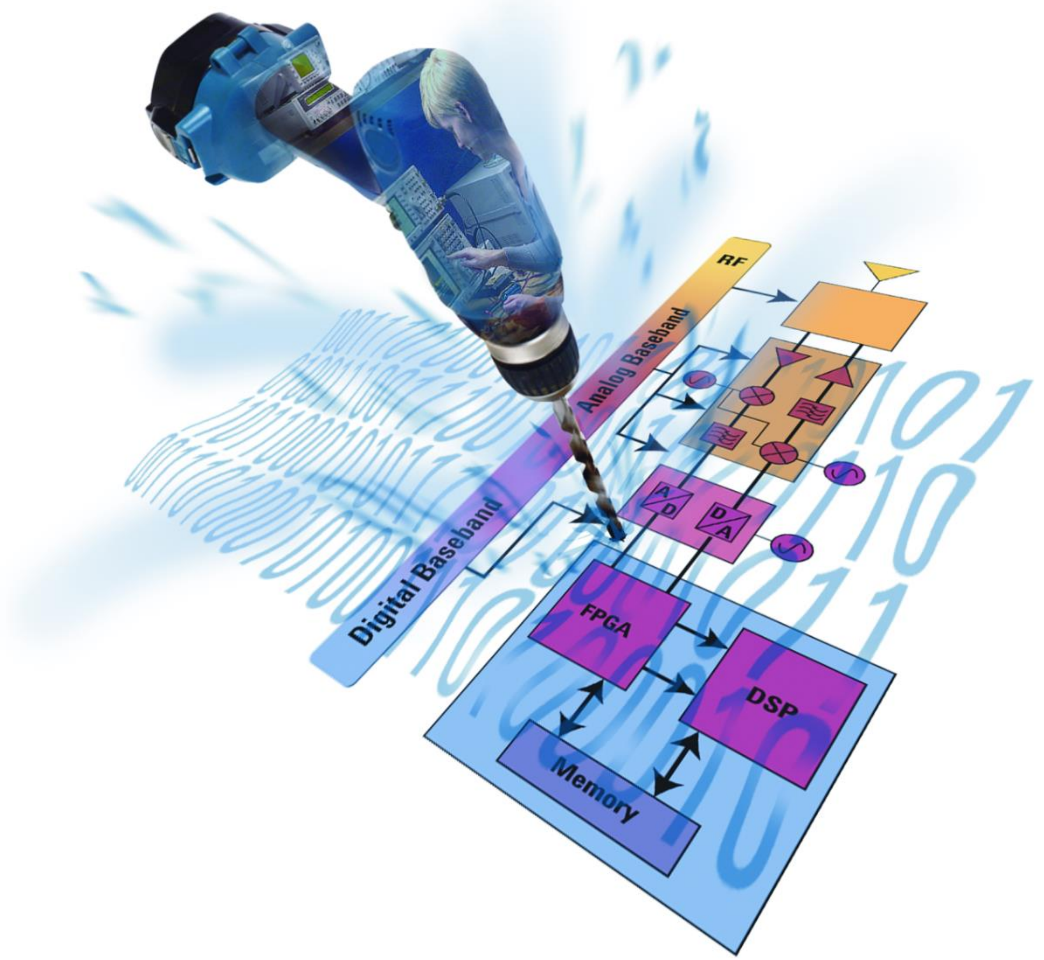
Use a vector network analyzer for complex corrections.

Use Keysight U9361 receiver calibrator (RCal) for complex corrections.

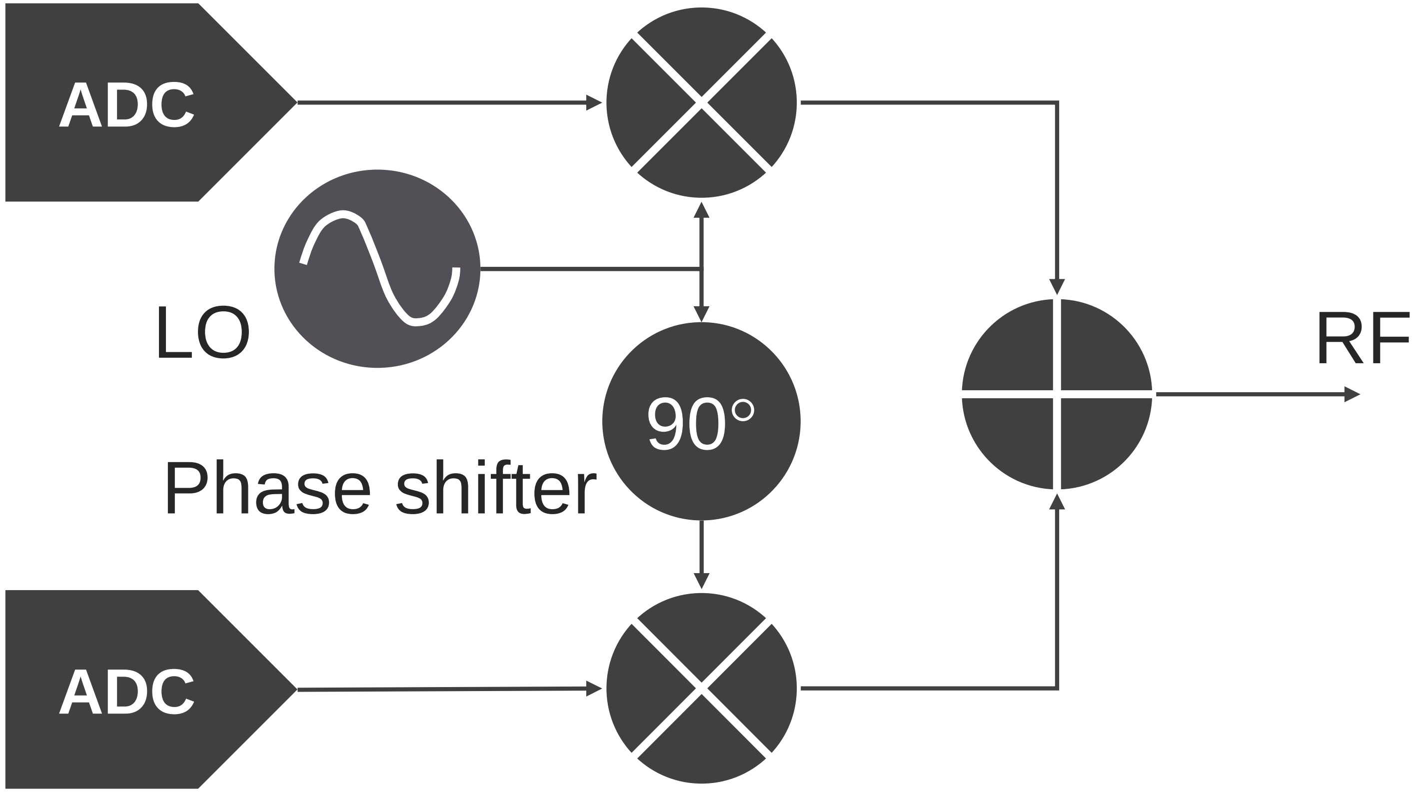
Design and Measurement Challenges

WIDER BANDWIDTHS AT HIGHER FREQUENCIES

- Excessive path loss
- Higher phase noise
- Inferior frequency responses
- I/Q modulator impairments



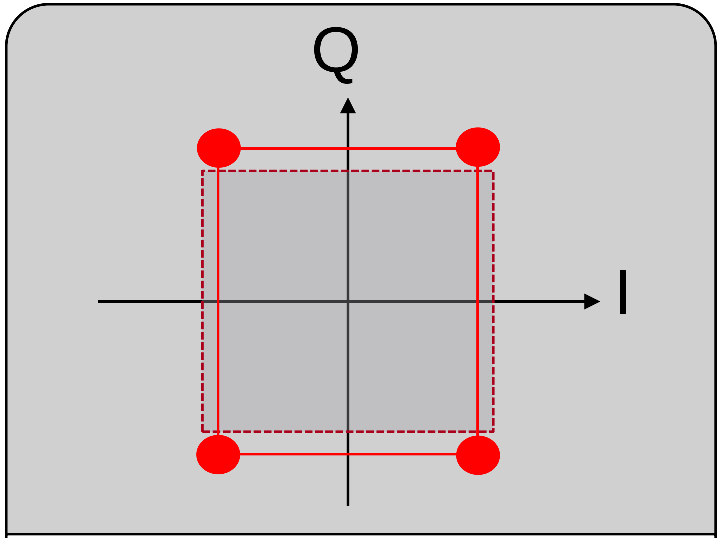
I/Q Modulator Imperfections



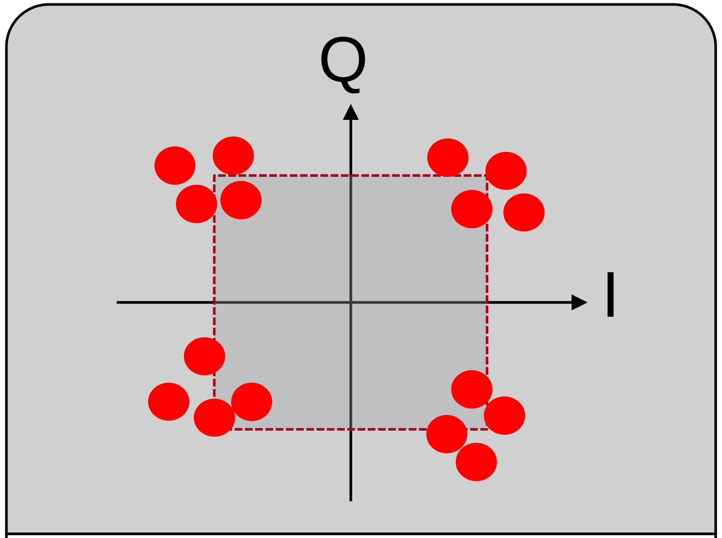
I/Q mismatch errors	I/Q origin offset
• amplitude • phase • timing	• DC offset • carrier feedthrough

I/Q Mismatch Errors

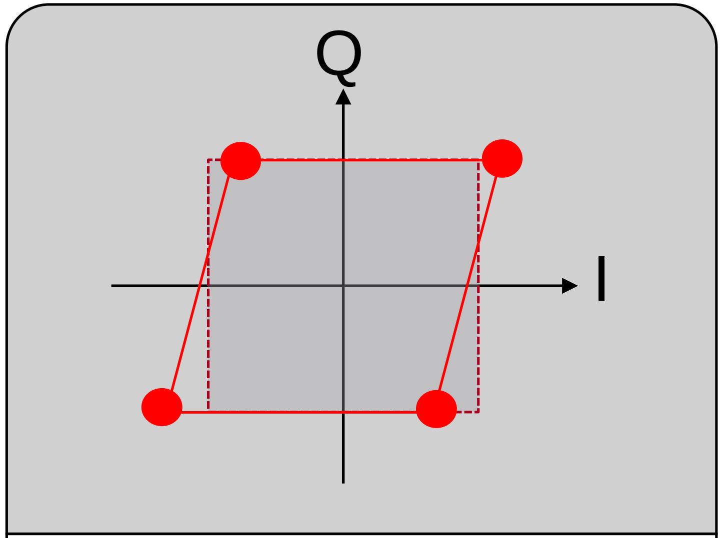
AMPLITUDE, TIMING, AND PHASE ERRORS



Amplitude mismatch (gain imbalance)

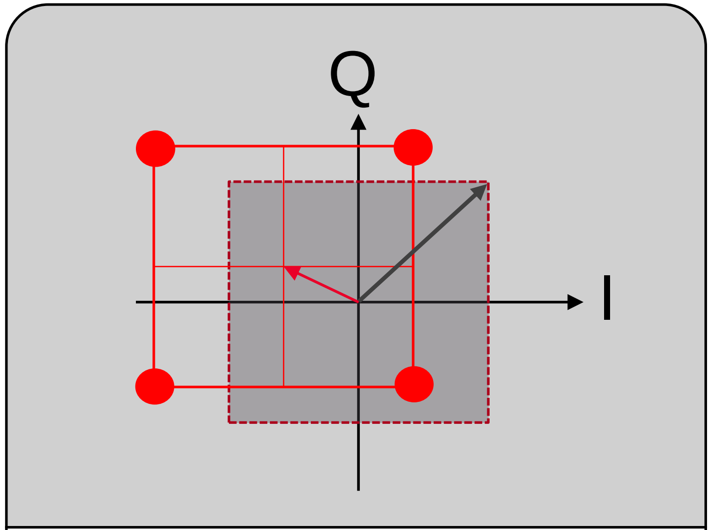


Timing mismatch (timing skew)



Phase mismatch (quadrature error)

I/Q Origin Offset

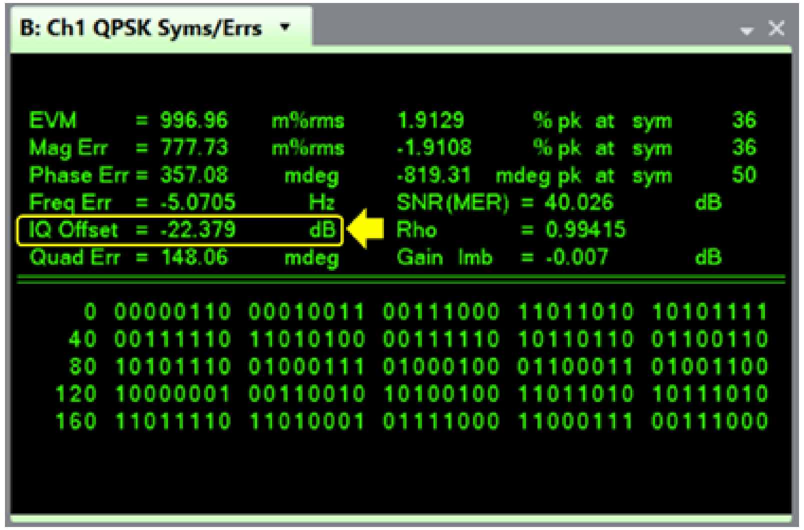


I/Q origin offset

(carrier feedthrough)

Possible design issues:

- RF carrier feedthrough
- baseband DC offset



MEASURE

When demodulating a signal with an I/Q origin offset, the constellation diagram will shift the new origin to the center and report the I/Q offset (in dB) in the error summary table.

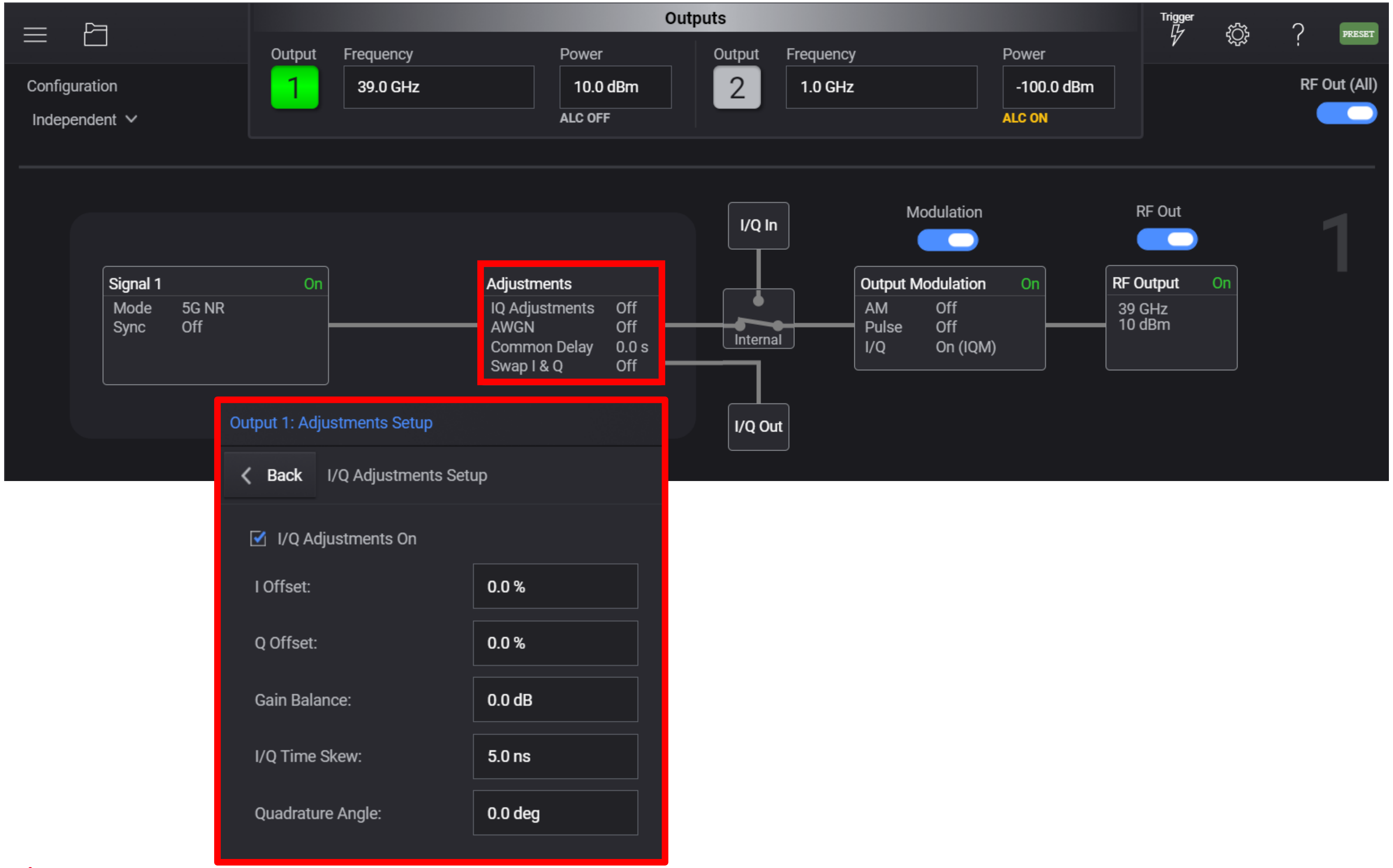
Baseband I/Q Adjustments

EFFECTS AND IMPAIRMENTS

I/Q adjustment	Effect	Impairment
Offset	Carrier feedthrough	DC offset
Quadrature angle	Error vector magnitude (EVM) error	Phase skew
	I/Q images	I/Q path delay
Timing skew	EVM error	High sample rate phase skew
		I/Q path delay
Gain imbalance	I/Q amplitude difference	I/Q gain ratio

Baseband I/Q Adjustments

INTERNAL BASEBAND GENERATOR



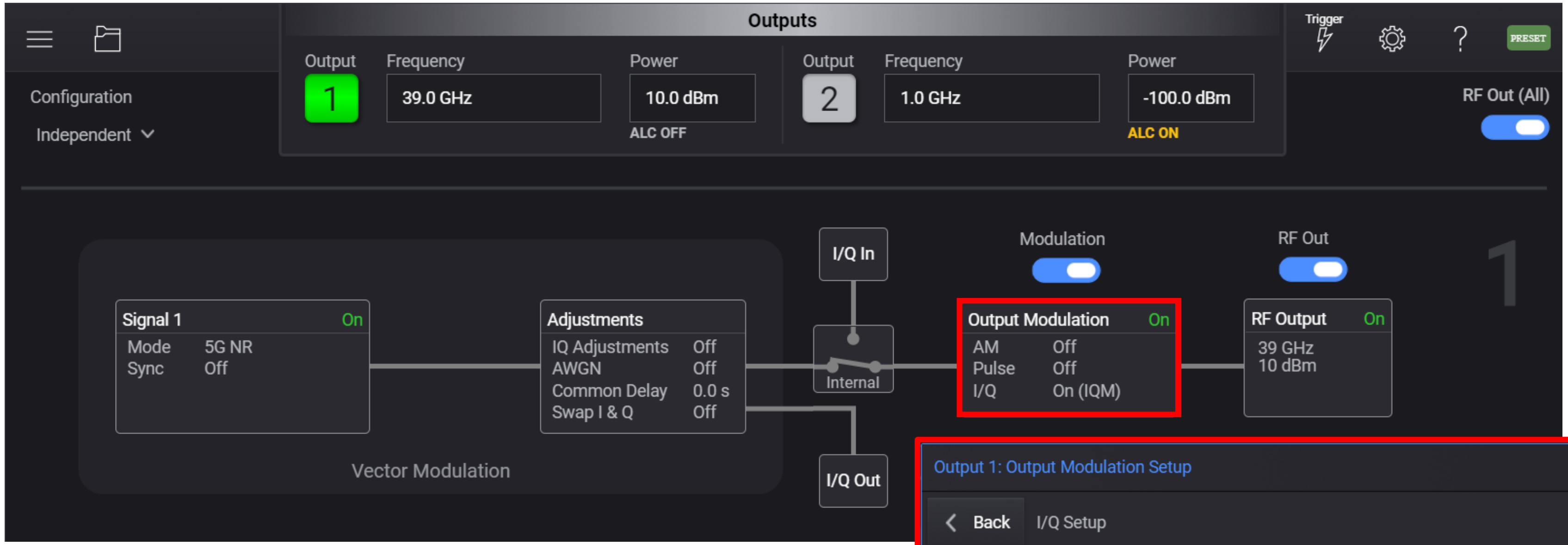
ADJUST

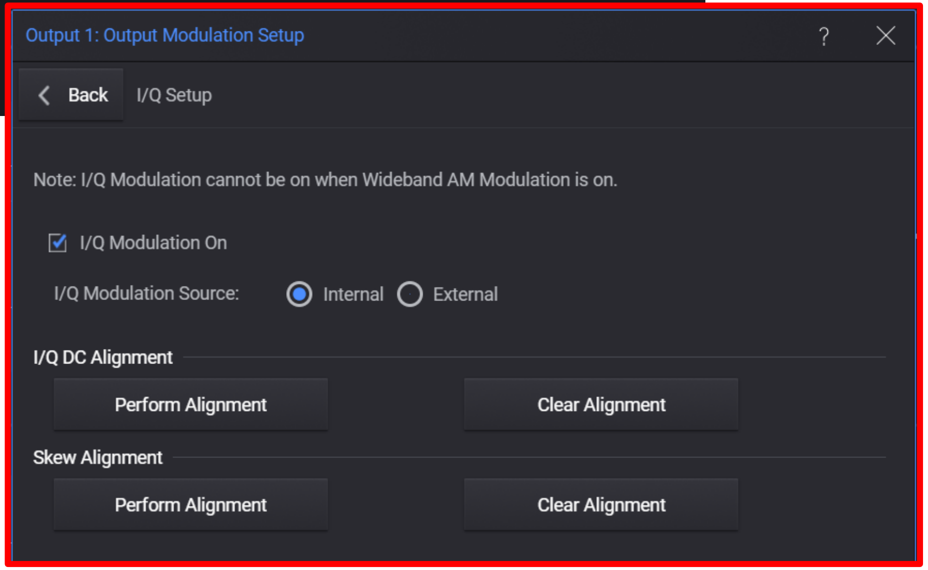
Baseband I/Q adjustments:

- compensate I/Q modulator’s errors
- simulate the real signals
- evaluate DUT’s tolerance

I/Q Calibration (Alignment)

DRIFT RELATED TO TEMPERATURE CHANGES





- Modulation source
  - external I/Q input
  - internal baseband generator
- Type of alignment
  - DC: I/Q offset, gain and quadrature error
  - skew: timing skew

CALIBRATE

Run an I/Q calibration when the ambient temperature and the latest calibration temperature have changed by more than ±5 degrees Celsius.

Improve Measurement Integrity

- Increasing demand for wider bandwidths to support next-generation wireless standards.
- Design and measurement challenges for wider bandwidths at high frequencies:
  - excessive path loss
  - higher phase noise
  - irregular frequency responses
  - significant modulator impairments

KEYSIGHT
TECHNOLOGIES

Resources

- Improve Test Integrity for RF and Microwave Signal Generation – White Paper
- 4 tips for 5G NR signal analysis – White Paper
- 4 Tips for 5G New Radio (5G NR) Signal Creation – White Paper
- 3 Best Practices for Optimizing EVM Measurements for Wideband Signal – White Paper
- Understanding Phase Noise Needs and Choices in Signal Generation – Application Note
- I/Q Modulation Considerations for PSG Vector Signal Generators – Application Note