Test Considerations for Harmonic Measurements of Passive Devices

October 2025

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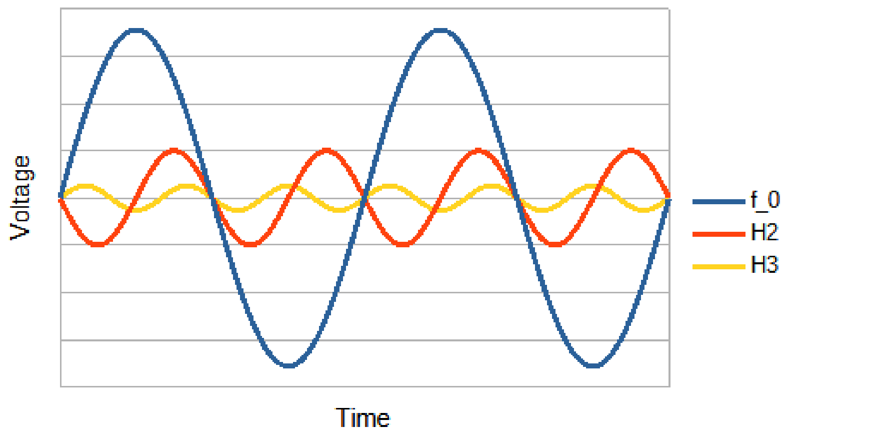
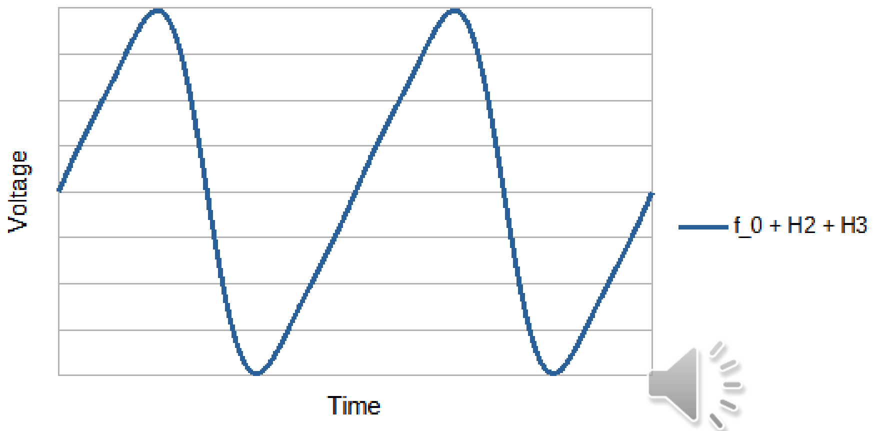
Agenda

- What is Harmonic Distortion?
- Why test Harmonics Distortion?
- Harmonic Test Challenges
- Test Hardware Comparisons
- Q&A

What is Harmonic Distortion?

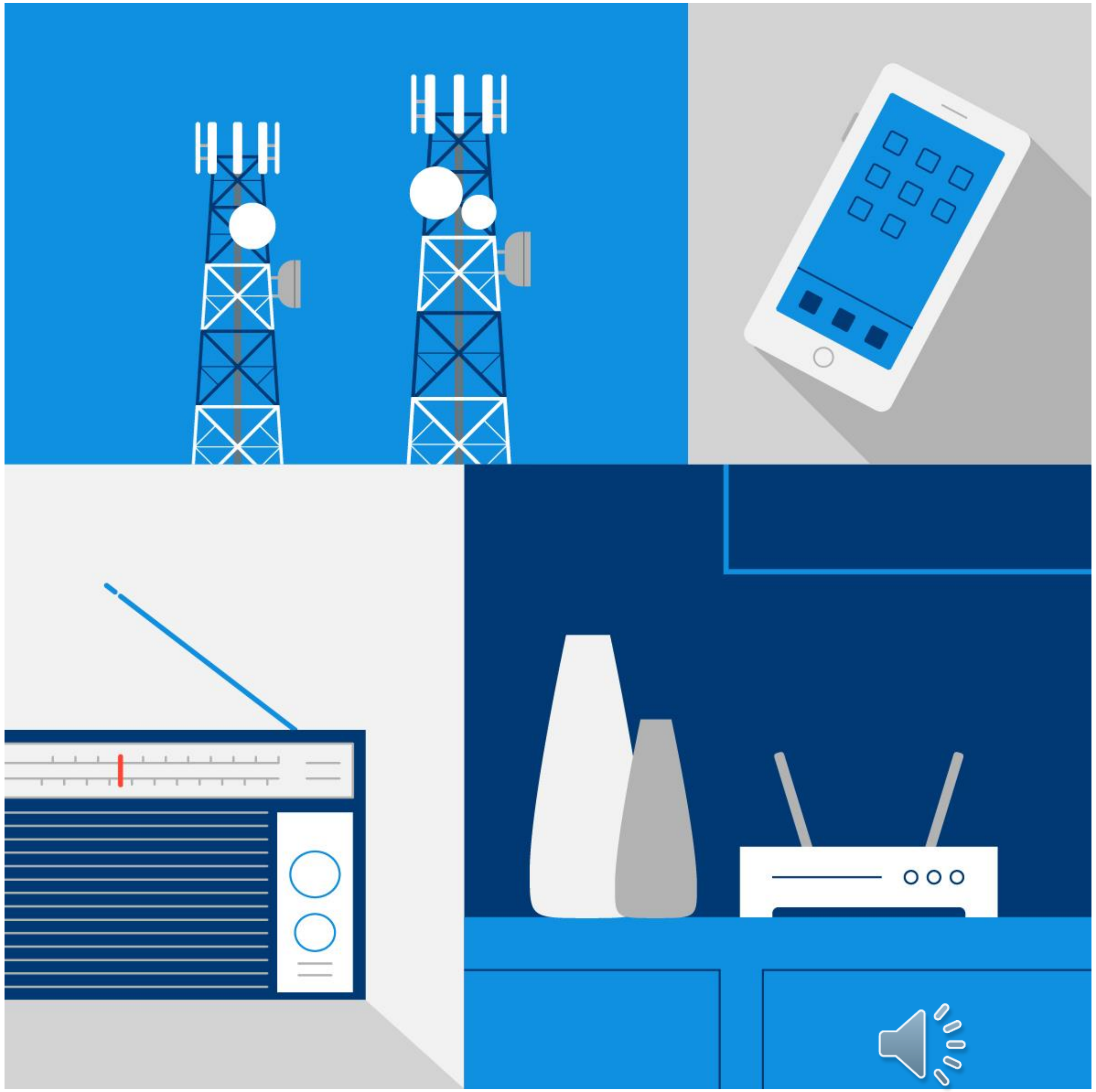
- Harmonic distortion is the generation of integer multiples of the principal frequency (f_0).
- Harmonics are created by non-linearities.
- In passive networks, common sources are intermetallic effects, oxidation, and damaged connectors.
- Different sources can affect odd or even harmonics more strongly.





Why Test Harmonic Distortion?

- Harmonic distortion lowers receive sensitivity of wireless systems.
- Test and measurement (T&M) systems generate harmonics that can mask device-under-test (DUT) performance.
- Harmonic performance of each component in T&M system should be verified.

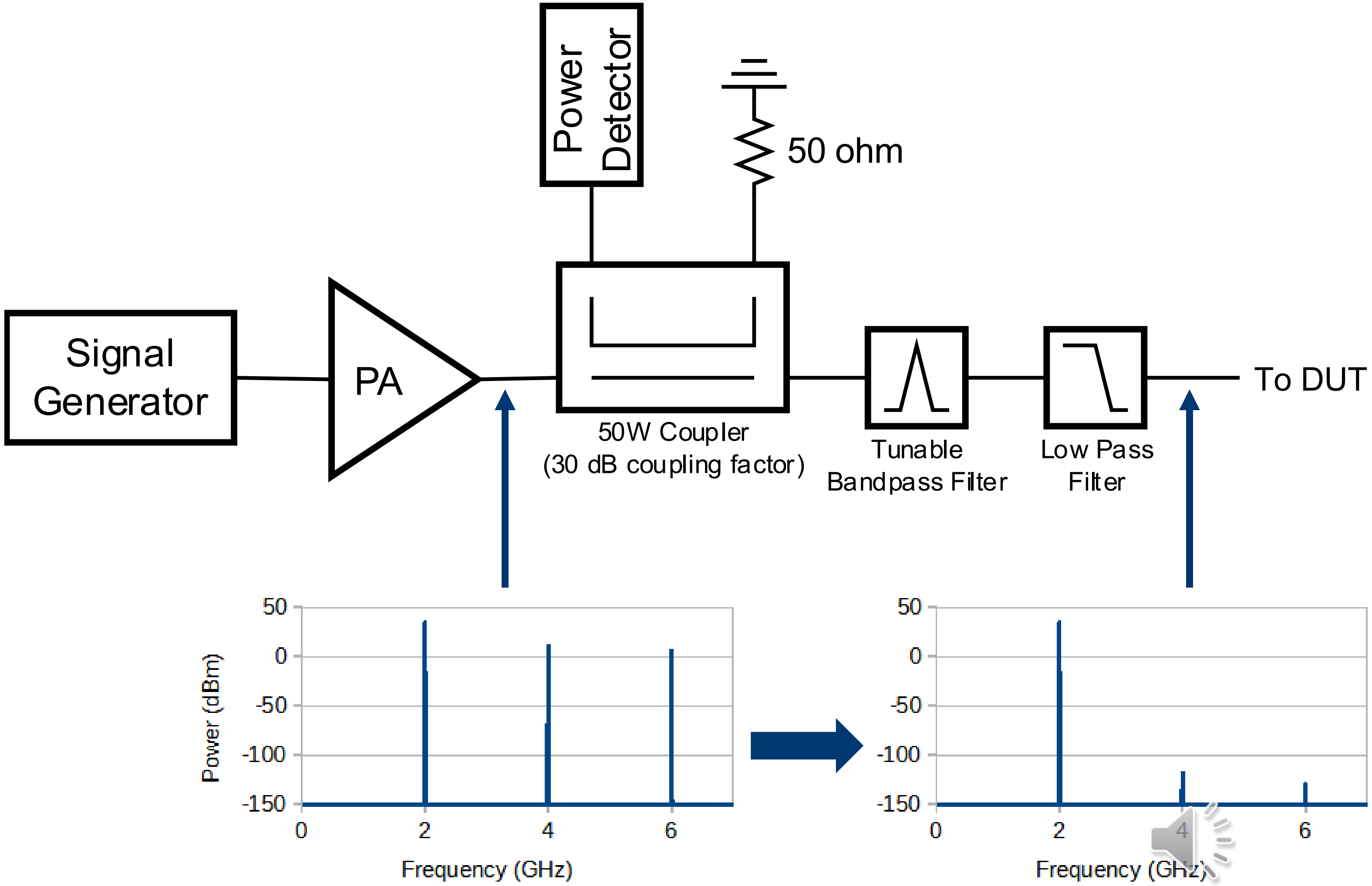


Harmonic Test Challenges

- Test systems for low harmonic distortion require:
  - High-power input signals with low harmonic distortion
  - Filters with very high rejection
  - Reliable interconnects that don’t generate distortion
  - High-performance switches for parallel testing
- Total harmonic distortion of T&M systems need margin to DUT performance to account for measurement accuracy.

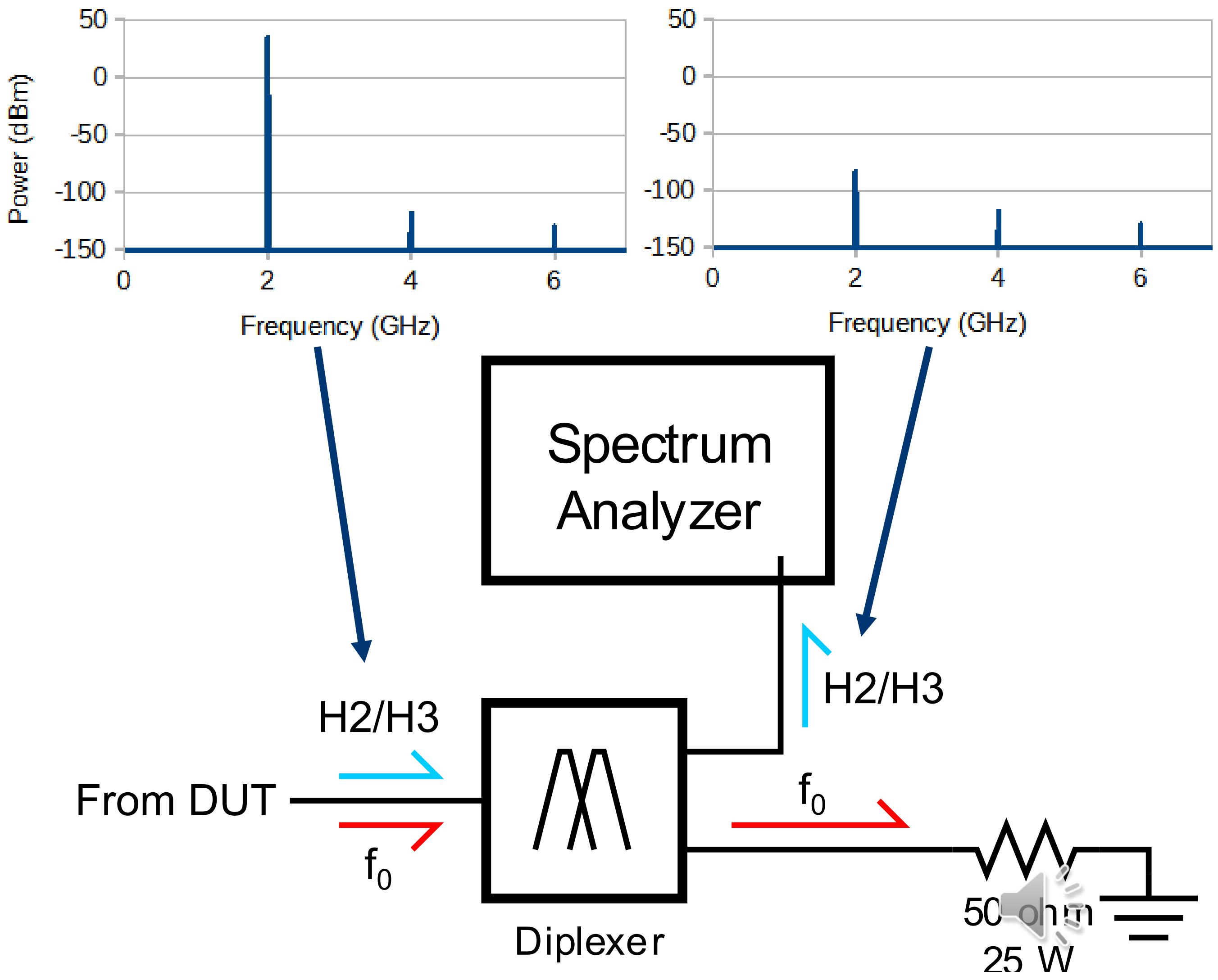
Test Hardware – Input Filtering

- PA harmonic distortion can drown out DUT harmonics and must be filtered out.
- Total rejection must leave room for DUT harmonic distortion.



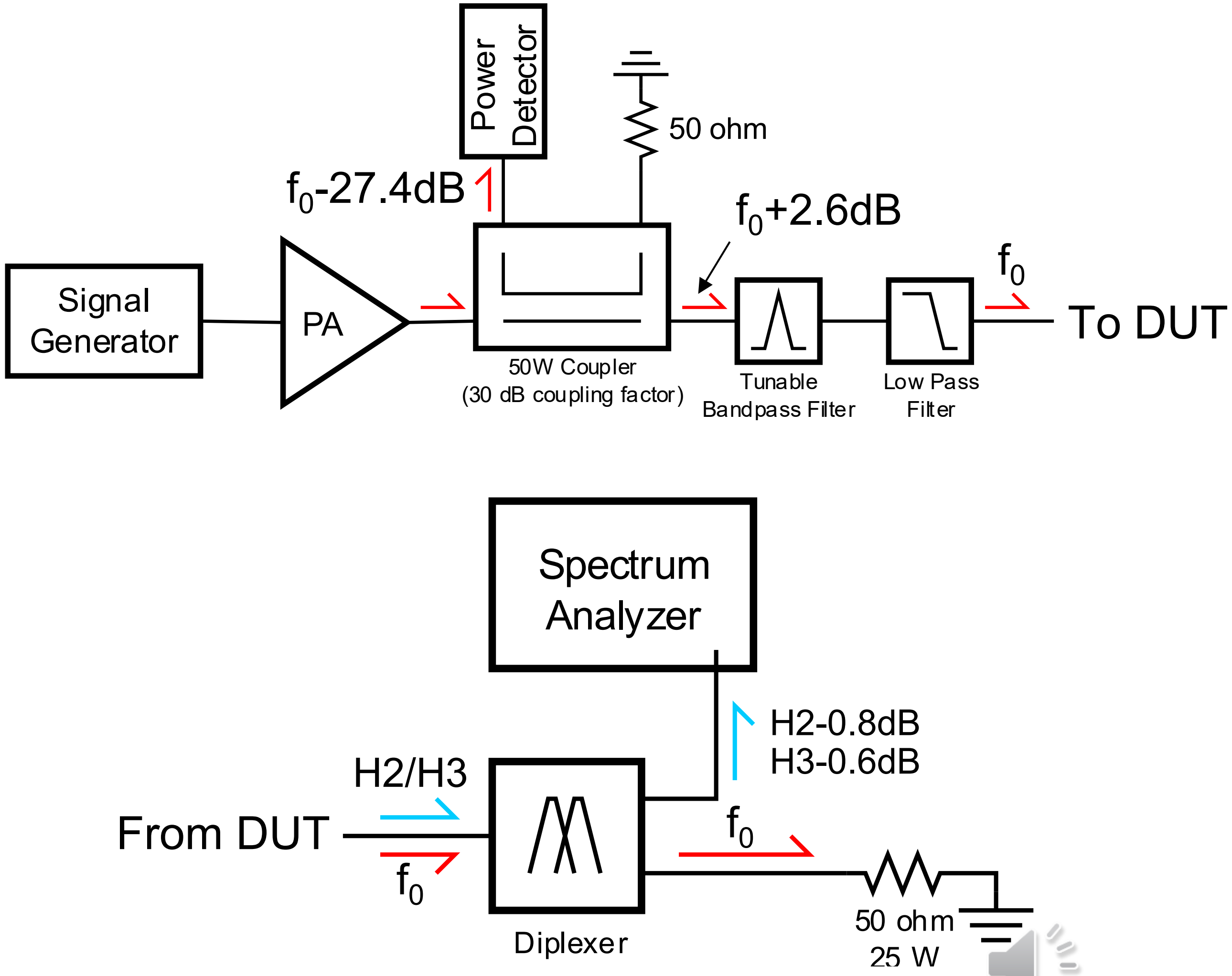
Test Hardware – Output Filtering

- Use a harmonic diplexer to separate high-power f_0 tone from harmonics.
- Reducing f_0 power at SpecAn improves sensitivity.
- Avoid reflective filters which can reflect RF power back to the DUT.



Test Hardware – Calibration

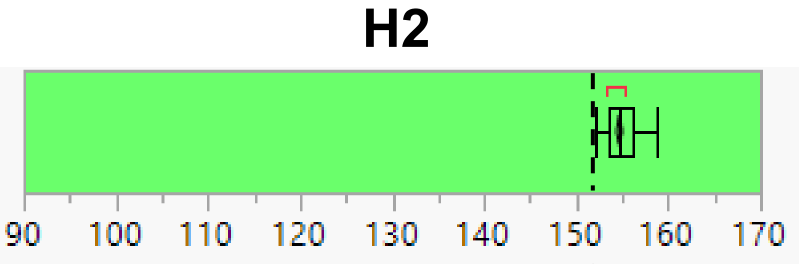
- Measure insertion loss of fixtures, cables, and diplexer at harmonic frequencies to calibrate for real harmonic power.
- High-loss filters or couplers will reduce sensitivity.

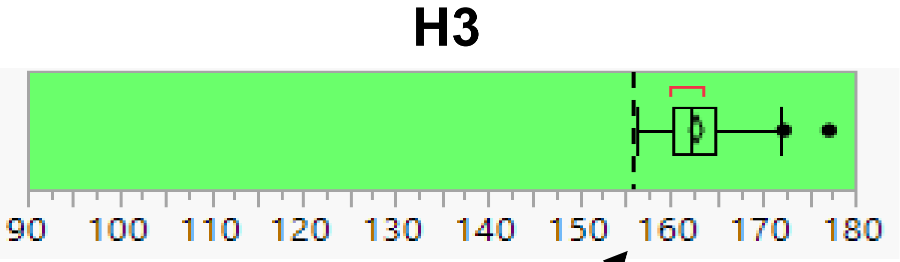


Test Hardware – Measurement Accuracy

- To evaluate test setup performance, make repeated measurements to determine worst-case noise floor.

SMA F-F Adapter
Sample Size: 100 Measurements

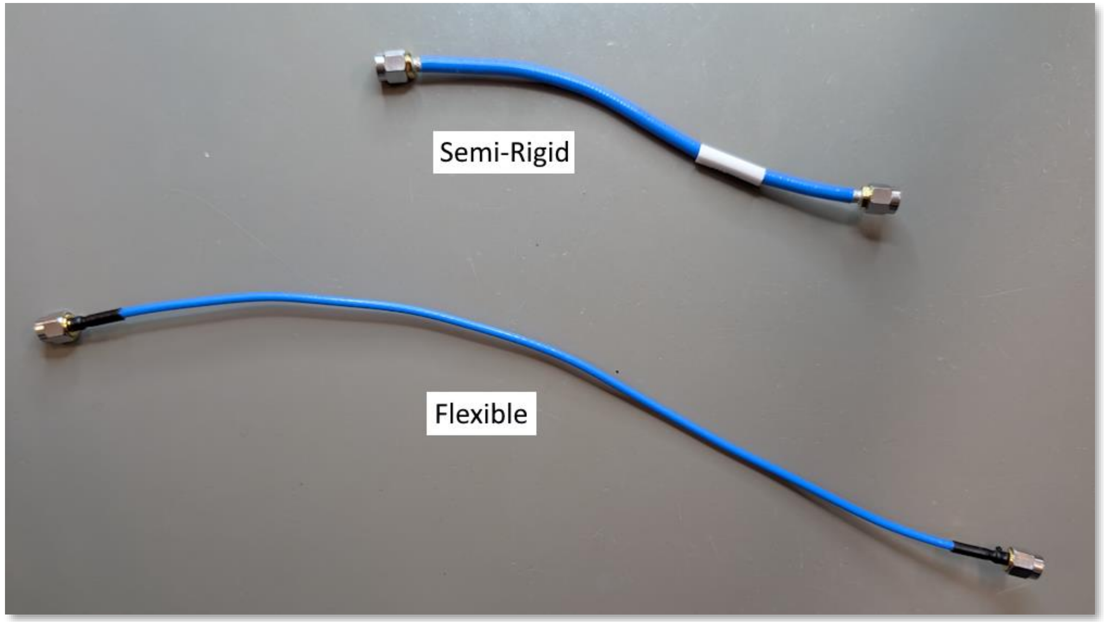




Measurement Setup Noise Floor

Test Hardware – Cabling

- Our measurements show semi-rigid cables reduce total harmonic distortion of the test system compared to flexible cables.
- Harmonic performance of each cable, especially those between the input and output filters, should be validated.
- Damaged insulation can increase harmonic distortion.

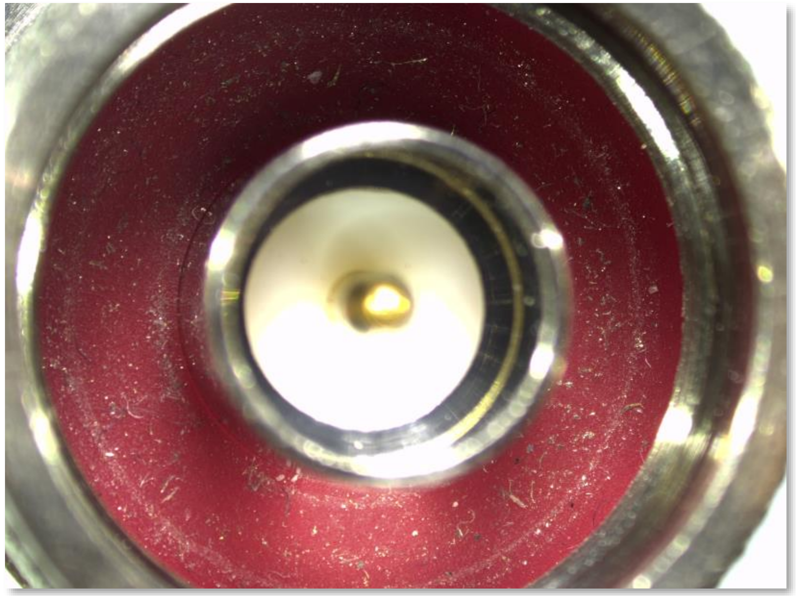


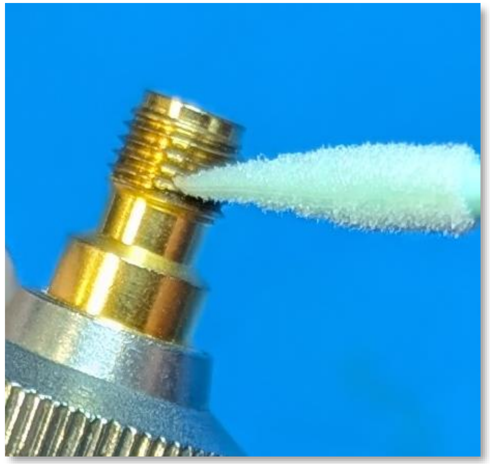
Cable Type	H2	H3
Semi-Rigid	-154 dBc	-172 dBc
Flexible	-137 dBc	-160 dBc

>12 dB Improvement

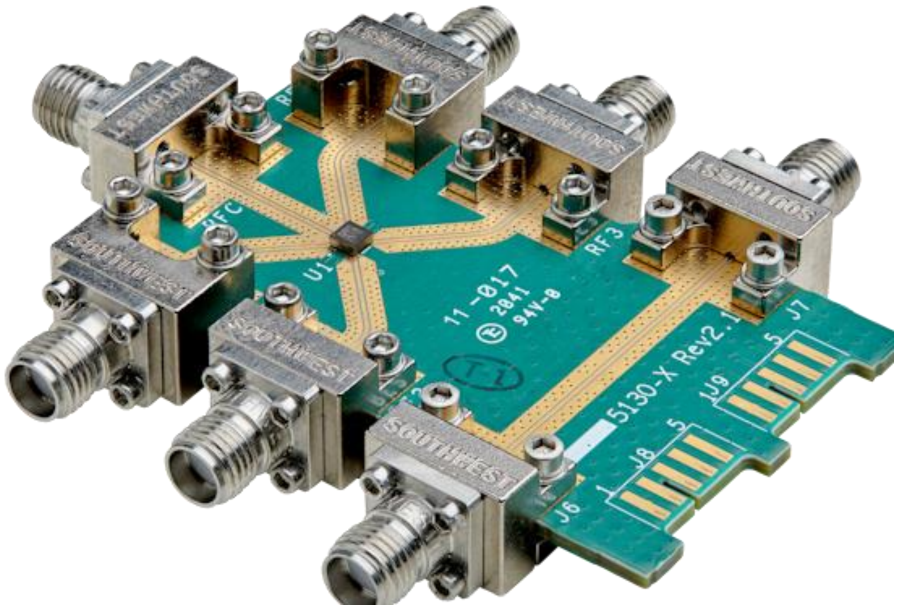
Test Hardware – Interconnects

- Coaxial connectors can build up metal shavings from repeated mating/unmating.
- Metal debris inside connectors can increase harmonic distortion.
- Use fine-tip swabs to clean dirty connectors before installing in sensitive RF test systems.





Test Hardware – Fixtures

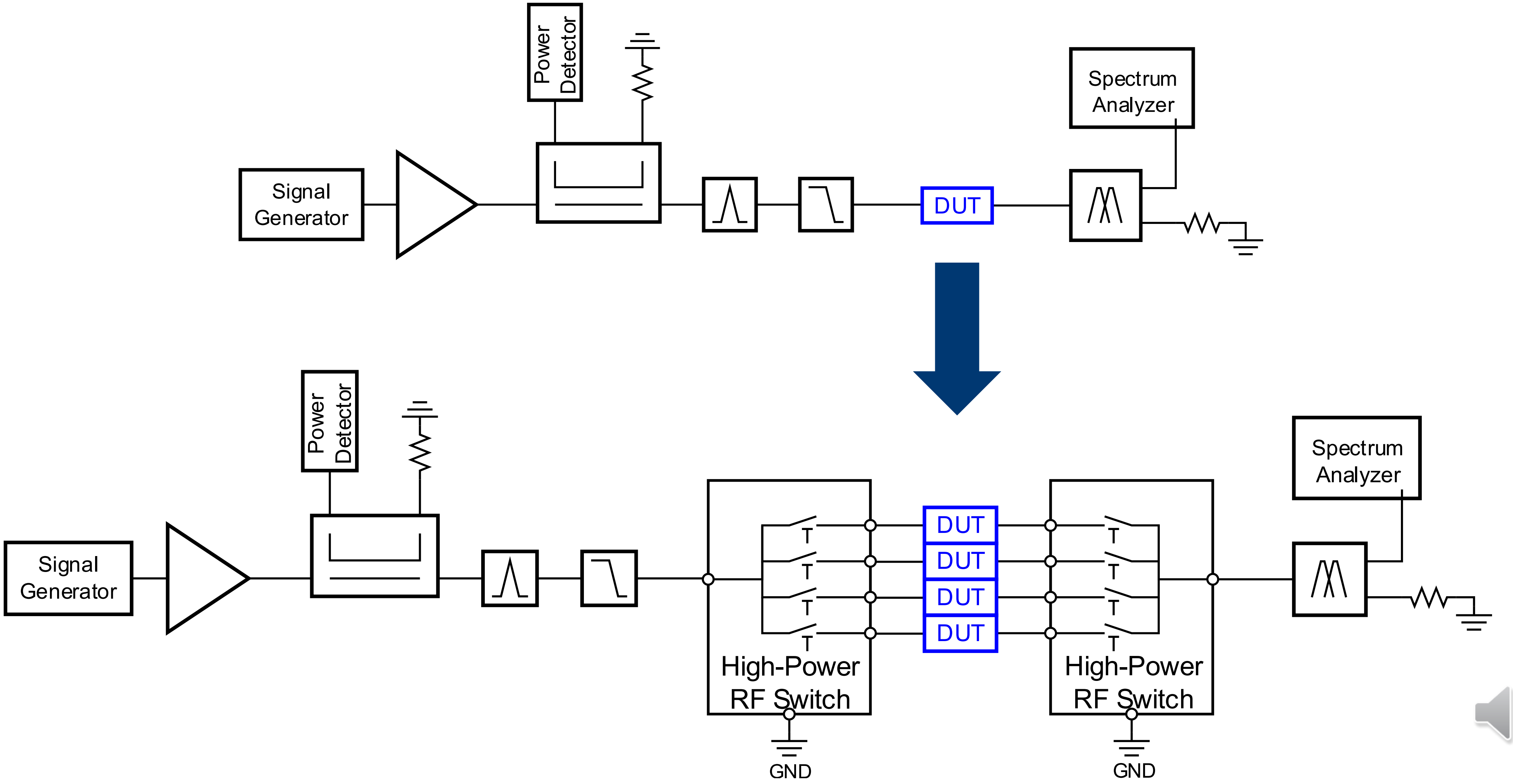


- Nickel plating on test fixtures will increase total harmonic distortion.
- Connector material and mounting type do not show significant difference.

PCB Plating	H2	H3
EPAG	-152 dBc	-151 dBc
ENIG	-114 dBc	-111 dBc

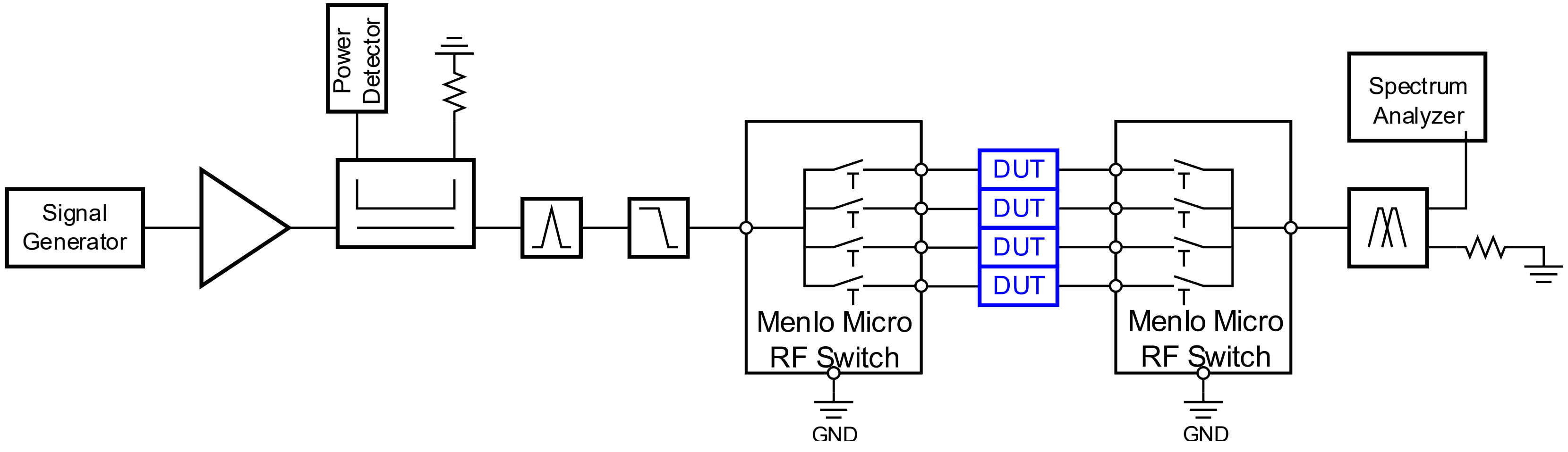
>30 dB Improvement

Test Hardware – Using Switches for Parallel Test



Test Hardware – Switches

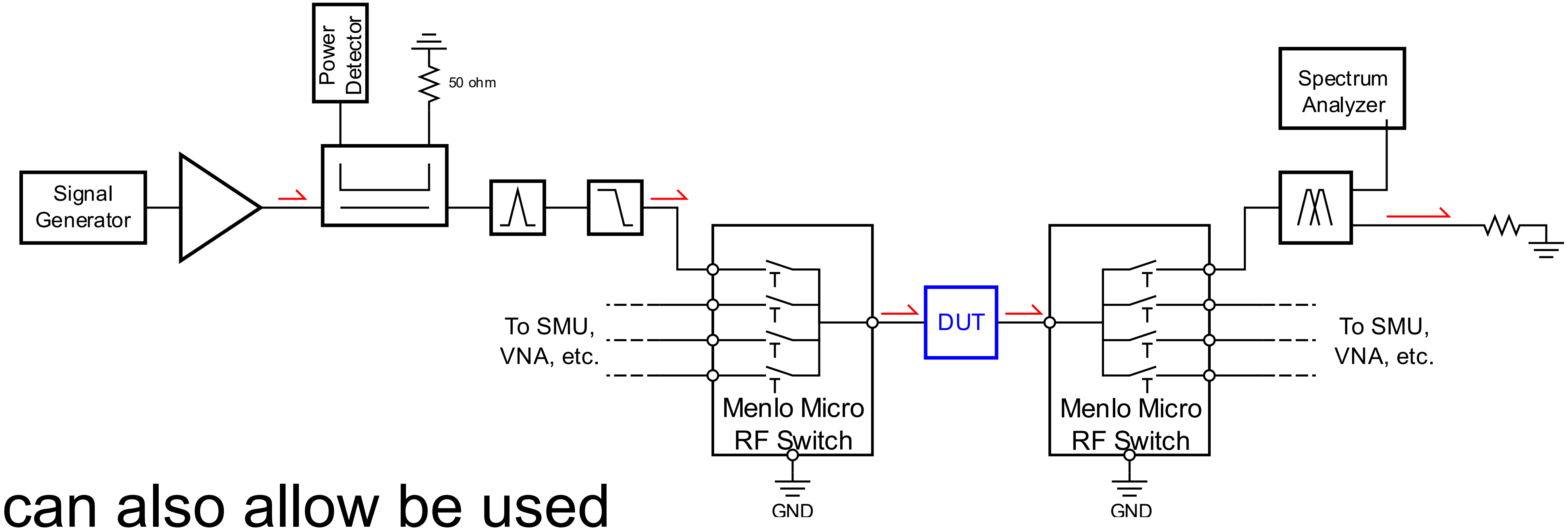
- Adding RF switches increases testing throughput by testing multiple DUTs sequentially.
- Avoid semiconductor switches, as they increase harmonic distortion and have varying performance over temperature and input power.
- Use coaxial or Menlo Micro MEMS switches for lowest impact to harmonic distortion.



With Menlo MM5230

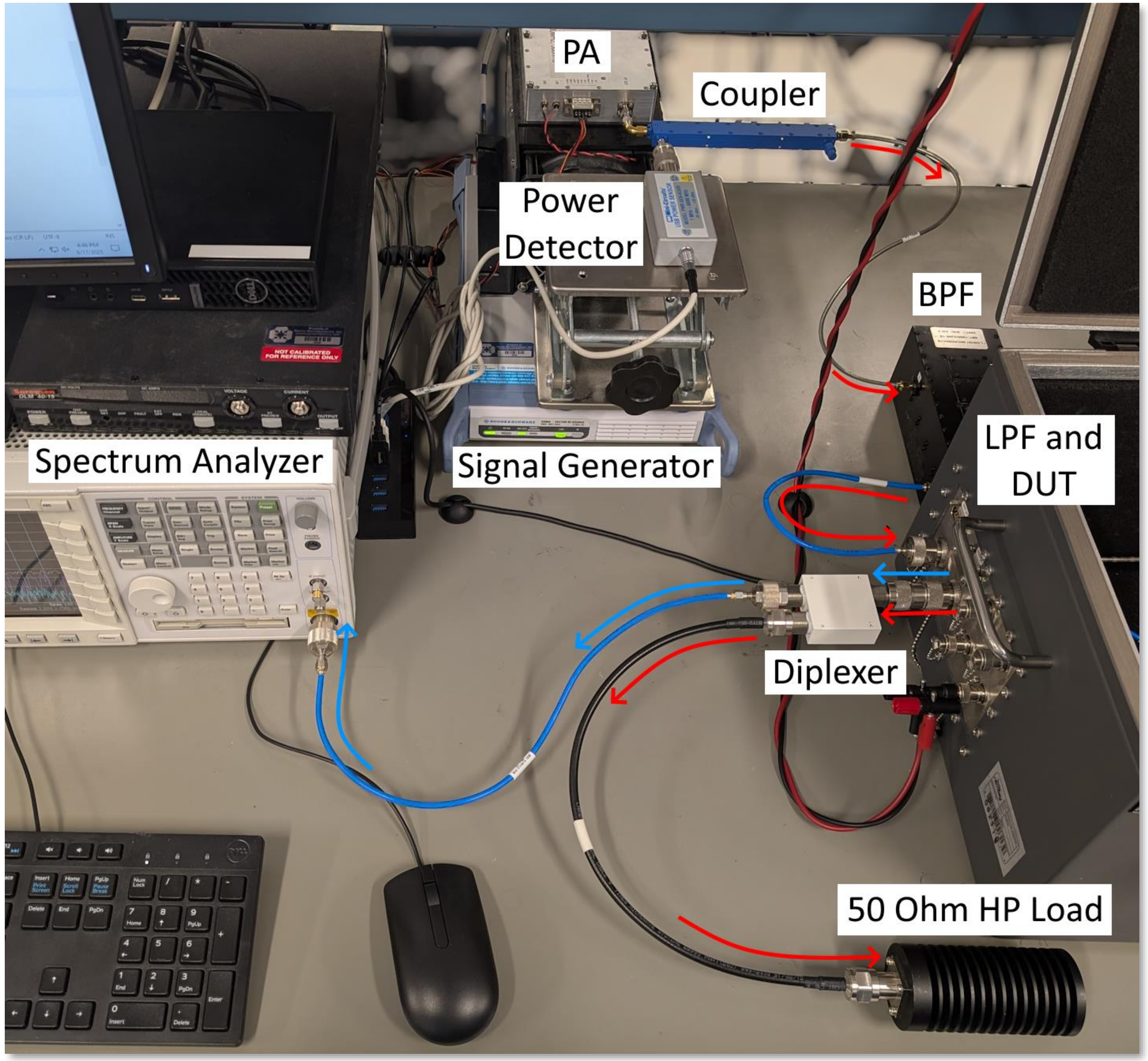
f_0 Power at DUT	Measured Noise @ H2	Measured Noise @ H3
+35 dBm	-143 dBc	-151 dBc

Test Hardware – Switches



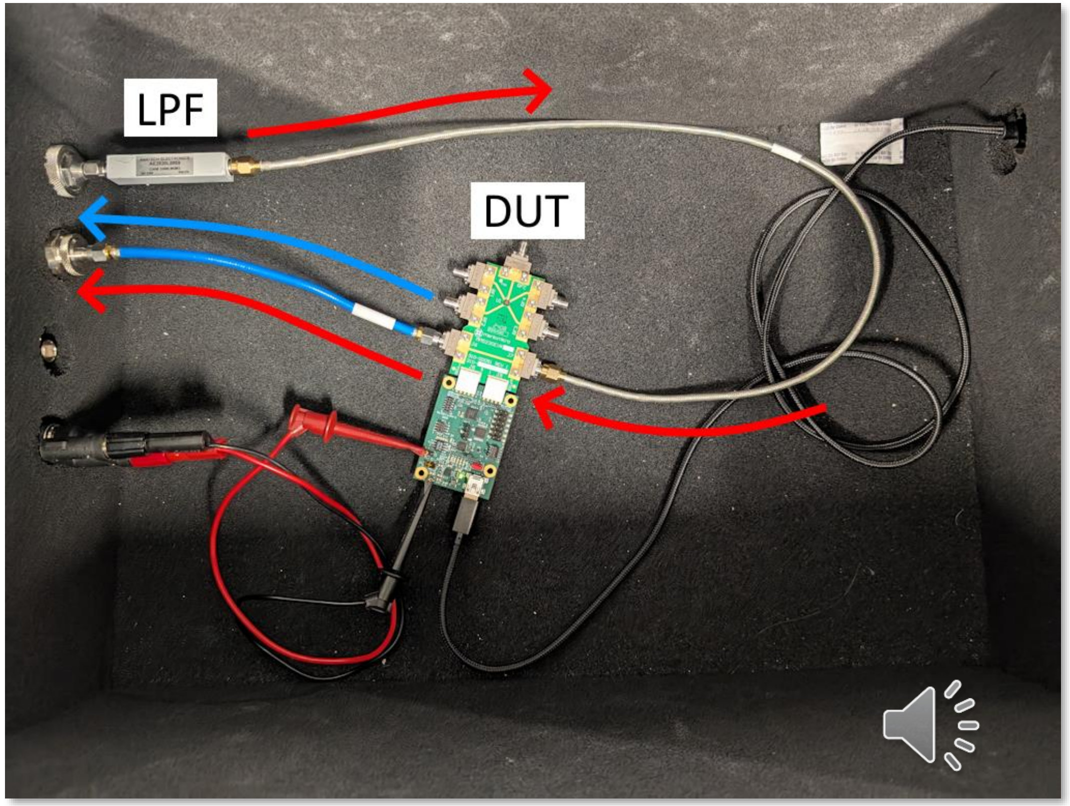
- RF Switches can also allow be used to expand test coverage.

Test Hardware – Reference Images



High Power Signal

DUT Harmonics



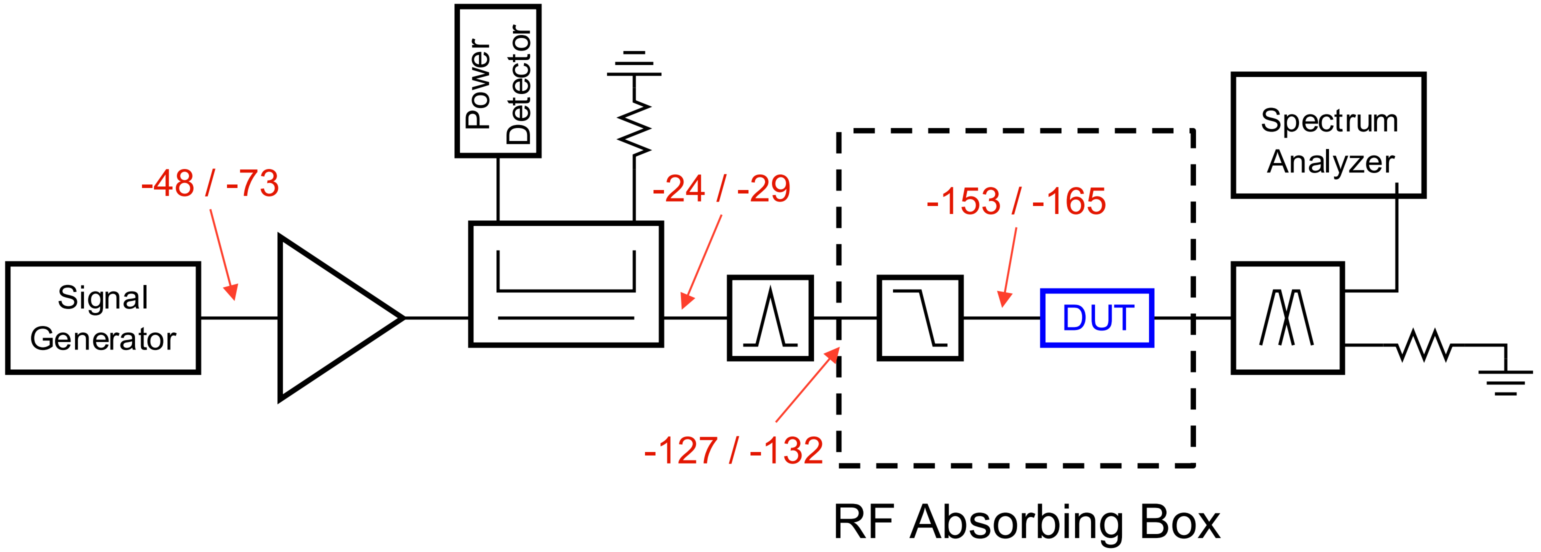
Test Hardware – Test Procedure

1. Power on SigGen, SpecAn, power supplies. RF is OFF.
2. Verify SigGen and SpecAn reference clocks (EXT REF) are connected.
3. Power on PA and cooling fans.
4. Install and power on DUT. Terminate unused ports if applicable.
5. Turn ON SigGen RF output at low power.
6. Use coupled power sensor to calibrate RF input power at DUT.
7. Set center frequency of SpecAn to 2 x f_0 and measure RF power.
8. Repeat step 7 for higher-order harmonics (3 x f_0, etc.)
9. Turn OFF SigGen RF output.

Thank you.

Harmonic Setup w/ RF Absorbing Box Hardware Details

Parameter	Value
Principle Frequency (f_0)	2 GHz
f_0 Power	+35 dBm
Input Coupling Factor*	26.5 dB
Output H2 Offset	0.8 dB
Output H3 Offset	0.6 dB
SpecAn Pre-Amp	ON (Internal)
SpecAn Internal Attenuation	0 dB
SpecAn Averaging	OFF (Single Sweep)



*Offset between RF power at detector and power at DUT input.

Spectrum Analyzer – Min Hold, Clear Write, Max Hold