

GRF5521

HIGH LINEARITY POWER AMPLIFIER 2.11 to 2.17 GHz

FEATURES

- Excellent OP1dB, OIP3, ACLR, and IM3 Performance
- Native Linearity Provides up to +23 dBm P_{OUT} with > 45 dBc ACLR – Without the Need for Digital Predistortion Correction
- +22.5 dBm Linear Output Power Maintained at 85 °C
- Flexible Biasing Provides Latitude for Linearity Optimization
- 115 mA Native Mode Quiescent Current Consumption
- 5 V Supply Voltage
- 50 Ω Single-ended Input and Output Impedances
- Digital Shutdown
- Rugged Design is Extremely Resilient to Mismatched Loads
- -40 to 85 °C Operating Temperature Range
- Compact 3 x 3 mm QFN-16 Package

Reference: 5 V / 2.14 GHz / 115 mA I_{CCQ}

- Gain: 31 dB
- OIP3: 45 dBm @ +23 dBm P_{OUT}/tone
- OP1dB: 33 dBm
- Noise Figure: 3.1 dB

APPLICATIONS

- Cellular Boosters/Repeaters
- Automotive Compensators
- Picocells/Femtocells
- Cellular DAS
- Customer Premise Equipment
- Wireless Infrastructure

DESCRIPTION

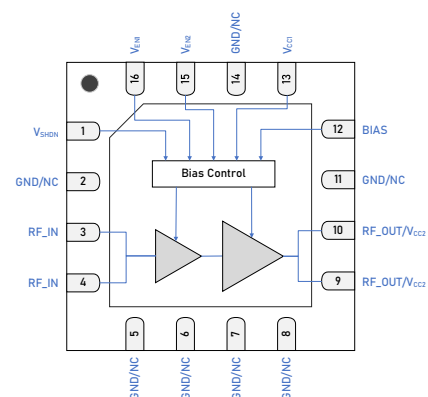
The GRF5521 is a high gain, two-stage InGaP HBT power amplifier designed to deliver excellent P1dB, ACLR, and IM3 performance over 2110 to 2170 MHz band. Its exceptional native linearity makes it an ideal choice for transmitter applications that typically do not employ digital pre-distortion correction schemes.

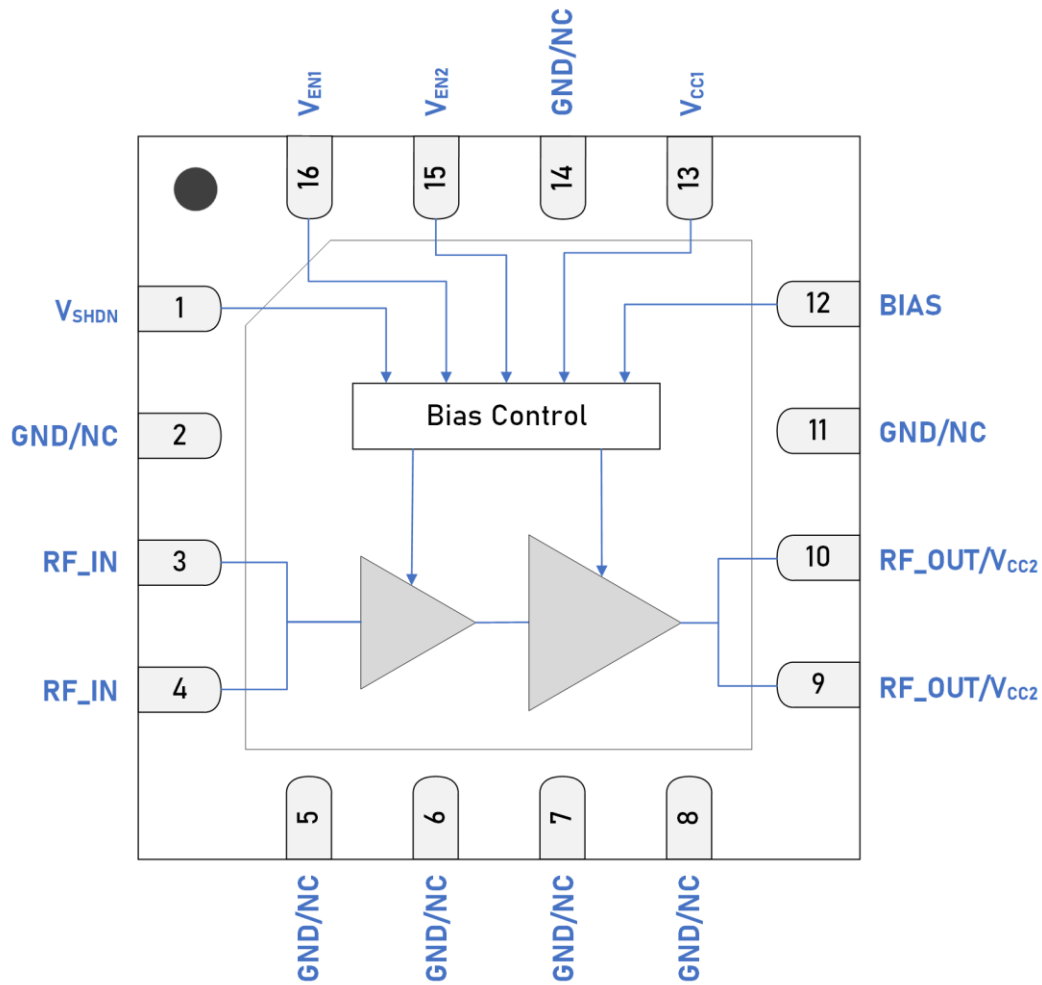
This device is part of a complete family of externally matched linear amplifiers that cover the following frequency ranges:

| | |
|--------------------------|--------------------------|
| GRF5506: 0.66 - 0.72 GHz | GRF5518: 1.8 - 1.91 GHz |
| GRF5507: 0.7 - 0.8 GHz | GRF5519: 1.92 - 2.0 GHz |
| GRF5508: 0.8 - 0.9 GHz | GRF5521: 2.11 - 2.17 GHz |
| GRF5510: 0.88 - 0.96 GHz | GRF5526: 2.5 - 2.7 GHz |
| GRF5517: 1.7 - 1.8 GHz | GRF5536: 3.3 - 4.2 GHz |

Please consult with the GRF applications engineering team for custom tuning/evaluation board data.

BLOCK DIAGRAM





3 x 3mm QFN-16 Pin Out (Top View)



Pin Assignments

| Pin | Name | Description | Note |
|-----------------------|-------------------------|------------------------|---|
| 1 | V _{SHDN} | Digital Shutdown Pin | V _{SHDN} ≥ 1.7 V (Logic HIGH) disables device. V _{SHDN} ≤ 0.9 V (Logic LOW) enables device. |
| 2, 5, 6, 7, 8, 11, 14 | GND/NC | Ground or No Connect | No internal connection to die. These pins can be left unconnected, or be connected to ground (recommended). Use a via as close to the pin as possible if grounded. |
| 3, 4 | RF_IN | RF Input | Internally matched 50 Ω. An external DC blocking cap must be used. Pins 3 & 4 tied together on system board. |
| 9, 10 | RF_OUT/V _{CC2} | PA Output/Bias Voltage | Pins 9 & 10 tied together on system board. V _{CC2} must be applied to this pin via an RF choke. |
| 12 | Bias | Bias Circuit Supply | Connect to V _{CC2} through external resistor. |
| 13 | V _{CC1} | Bias Voltage | Connect to V _{CC1} through an external resistor. |
| 15 | V _{EN2} | Enable2 Voltage Input | V _{EN2} and series resistor set I _{CCQ} for the output stage. V _{EN2} ≤ 0.2 V disables stage 2. |
| 16 | V _{EN1} | Enable1 Voltage Input | V _{EN1} and series resistor set I _{CCQ} for the input stage. V _{EN1} ≤ 0.2 V disables stage 1. Connecting an external decoupling capacitor to the ground is required for optimal NF performance. |
| PKG BASE | GND | Ground | Provides DC and RF ground for the amplifier, as well as a thermal heat sink. Recommend multiple 8 mil vias beneath the package for optimal RF and thermal performance. Refer the to evaluation board top layer graphic on schematic page. |

Absolute Ratings

| Parameter | | Symbol | Min. | Max. | Unit |
|--|---|-----------------------|------|------|-------------|
| Supply Voltage | | V_{CC} | | 5.5 | V |
| RF Input Power | 50 Ω , $V_{CC} = 5$ V, CW Tone, 100% DC, $T_{PKG\ HEAT\ SINK} = 25^{\circ}C$ | $P_{IN\ MAX-1:1}$ | | 23 | dBm |
| | Load VSWR $\leq 8:1$, all phase angles, $V_{CC} = 5$ V, CW Tone, 100% DC, $T_{PKG\ HEAT\ SINK} = -40$ to $85^{\circ}C$ | $P_{IN\ MAX-8:1}$ | | 20 | |
| Operating Temperature (Package Heat Sink) | | $T_{PKG\ HEAT\ SINK}$ | -40 | 85 | $^{\circ}C$ |
| Maximum Junction Temperature (MTTF > 10^6 Hours) | | $T_{J\ MAX}$ | | 170 | $^{\circ}C$ |
| Maximum Dissipated Power (Stage 1) | | $P_{DISS\ MAX}$ | | 500 | mW |
| Maximum Dissipated Power (Stage 2) | | $P_{DISS\ MAX}$ | | 1400 | mW |
| Shutdown Voltage | | V_{SHDN} | | 4 | V |

Electrostatic Discharge

| | | | | |
|----------------------|-----|------|--|---|
| Charged Device Model | CDM | 1000 | | V |
| Human Body Model | HBM | 1000 | | V |

Storage

| | | | | |
|----------------------------|-----------|-----|-----|-------------|
| Storage Temperature | T_{STG} | -65 | 150 | $^{\circ}C$ |
| Moisture Sensitivity Level | MSL | | 1 | |



Caution! ESD Sensitive Device

Exceeding Absolute Maximum Rating conditions may cause permanent damage to the device.

Note: For additional information, please refer to [Manufacturing Note MN-001 — Package and Manufacturing Information](#).



All Guerrilla RF products are provided in RoHS compliant lead (Pb)-free packaging requiring no exemptions. Additional information for this topic can be found at this link - [Environmental and Restricted Substance Statement Library](#).



Recommended Operating Conditions

| Parameter | Symbol | Specification | | | Unit | Condition |
|--|-----------------------|---------------|------|------|----------|--|
| | | Min. | Typ. | Max. | | |
| Supply Voltage | V_{CC} | 3 | 5 | 5.5 | V | |
| Operating Temperature (Package Heat Sink) | $T_{PKG\ HEAT\ SINK}$ | -40 | | 85 | °C | |
| RF Frequency Range | F_{RF} | 2.11 | | 2.17 | GHz | Typical Application Schematic Using the 2.11 to 2.17 GHz Tuning Set (note 2). |
| RF_IN Port Impedance | Z_{RFIN} | | 50 | | Ω | Single Ended with 2-element Match. |
| RF_OUT Port Impedance | Z_{RFOUT} | | 50 | | Ω | Single Ended with 3-element Match. |

Note 2: Operation outside this range is possible, but with degraded performance of some parameters.



Nominal Operating Parameters – General

The following conditions apply unless noted otherwise: Typical Application Schematic using the band 1 2.11 to 2.17 GHz tuning set. M5 = 6650 Ω, M9 = 4750 Ω. V_{SHDN} = LOW, V_{CC} = 4.75 to 5.25 V, I_{CCQ} = 115 mA. 50 Ω system impedance. P_{OUT} = +23 dBm, F_{TEST} = 2.14 GHz. T_{PKG HEAT SINK} = 25 °C. Evaluation board losses are included within the specifications.

| Parameter | Symbol | Specification | | | Unit | Condition |
|--------------------------------|----------------------------|---------------|------|-----------------|------|---|
| | | Min. | Typ. | Max. | | |
| Supply Quiescent Current | I _{CCQ} | | 115 | | mA | I _{CCQ1} + I _{CCQ2} . No RF Applied |
| Supply Current with RF Applied | I _{CC} | | 235 | | mA | I _{CC1} + I _{CC2} . RF Applied with P _{OUT} = 23 dBm |
| Enable Current 1 | I _{ENABLE1} | | 2.5 | | mA | V _{CC} = 5 V. T _{PKG HEAT SINK} = 25 °C |
| Enable Current 2 | I _{ENABLE2} | | 1.5 | | mA | V _{CC} = 5 V. T _{PKG HEAT SINK} = 25 °C |
| Operating Temperature Range | T _{PKG HEAT SINK} | -40 | | 85 | °C | Measured on Package Heat Sink |
| Logic Input Low | V _{IL} | 0 | | 0.9 | V | Applies to V _{SHDN} Input |
| Logic Input High | V _{IH} | 1.7 | | V _{CC} | V | Applies to V _{SHDN} Input |
| Logic Current Low | I _{IL} | | 3 | | nA | Applies to V _{SHDN} Input. V _{IL} = 0.9 V |
| Logic Current High | I _{IH} | | 60 | | µA | Applies to V _{SHDN} Input. V _{IH} = 1.8 V |
| | | | 280 | | | Applies to V _{SHDN} Input. V _{IH} = 3.3 V |
| Switching Rise Time | T _{RISE} | | 500 | | ns | Applies to V _{SHDN} Input |
| Switching Fall Time | T _{FALL} | | 2800 | | ns | Applies to V _{SHDN} Input |

Disabled Mode

| | | | | | | |
|--------------------------|---------------------------|--|-----|--|----|---|
| Supply Quiescent Current | I _{CCQ-SHDN} | | 1 | | µA | V _{CC} = 5 V. V _{SHDN} = HIGH |
| Enable Current 1 | I _{ENABLE1-SHDN} | | 3 | | mA | V _{CC} = 5 V. V _{SHDN} = HIGH |
| Enable Current 2 | I _{ENABLE2-SHDN} | | 1.3 | | mA | V _{CC} = 5 V. V _{SHDN} = HIGH |

Thermal Data

| | | | | | | |
|------------------------------------|-----------------|--|----|--|------|-------------------------------|
| Thermal Resistance (Infrared Scan) | Θ _{JC} | | 38 | | °C/W | On Standard Evaluation Board. |
|------------------------------------|-----------------|--|----|--|------|-------------------------------|



Nominal Operating Parameters – RF (Band 1, 2.11 to 2.17 GHz, 5 V Operation)

The following conditions apply unless noted otherwise: Typical Application Schematic using the band 1 2.11 to 2.17 GHz tuning set. M5 = 6650 Ω, M9 = 4750 Ω. V_{SHDN} = LOW, V_{CC} = 4.75 to 5.25 V, I_{CCQ} = 115 mA. 50 Ω system impedance. P_{OUT} = +23 dBm, F_{TEST} = 2.14 GHz. T_{PKG HEAT SINK} = 25 °C. Evaluation board losses are included within the specifications.

| Parameter | Symbol | Specification | | | Unit | Condition |
|--------------------------------|---------------------|------------------|------|------|------|---|
| | | Min. | Typ. | Max. | | |
| Small Signal Gain | S21 | 29 (Note 3) | 31 | | dB | LTE 20MHz 100RB TM1.1 Downlink Waveform with 9.8 dB PAR, F _{TEST} = 2.14 GHz, T _{PKG HEAT SINK} = 25 °C, V _{CC} = 5 V, P _{IN} = -25 dBm. |
| Standby Mode Gain | S21 _{STBY} | | -45 | | dB | Disabled Mode, LTE 20MHz 100RB TM1.1 Downlink Waveform with 9.8dB PAR, V _{SHDN} = HIGH, P _{IN} = 0 dBm. |
| Input Return Loss | S11 | | > 10 | | dB | F _{RF} = 2.11 to 2.17 GHz |
| Output Return Loss | S22 | | > 5 | | dB | F _{RF} = 2.11 to 2.17 GHz |
| Reverse Isolation | S12 | | > 40 | | dB | F _{RF} = 2.11 to 2.17 GHz |
| Evaluation Board Noise Figure | NF | | 3.1 | | dB | |
| Output 3rd Order Intercept | OIP3 | | 45 | | dBm | +23 dBm P _{OUT} per Tone at 600 kHz Spacing. |
| Output 1 dB Compression Power | OP1dB | 31.5 (Note 3) | 33 | | dBm | Sine wave input, V _{CC} = 5 V, T _{PKG HEAT SINK} = 25 °C. |
| Adjacent Channel Leakage Ratio | ACLR | | | -45 | dBc | P _{OUT} = +23 dBm, LTE 20MHz 100RB TM1.1 Downlink Waveform with 9.8dB PAR, F _{TEST} = 2.14 GHz, T _{PKG HEAT SINK} = 25 °C, V _{CC} = 5 V (note 3). |

Note 3: MIN/MAX limits are defined using *modeled estimates* that account for part-to-part variations and expected process spreads. As additional production lots are fabricated, accumulated test data will be used to refine the MIN/MAX limits.

Typical Operating Curve Conditions

The following conditions apply unless noted otherwise: Typical Application Schematic using the band 1 2.11 to 2.17 GHz tuning set. M5 = 6650 Ω, M9 = 4750 Ω. V_{SHDN} = LOW, V_{CC} = 5 V, I_{CCQ} = 115 mA. 50 Ω system impedance. F_{TEST} = 2.14 GHz. T_{PKG HEAT SINK} = 25 °C. Evaluation board losses are included within the plots.



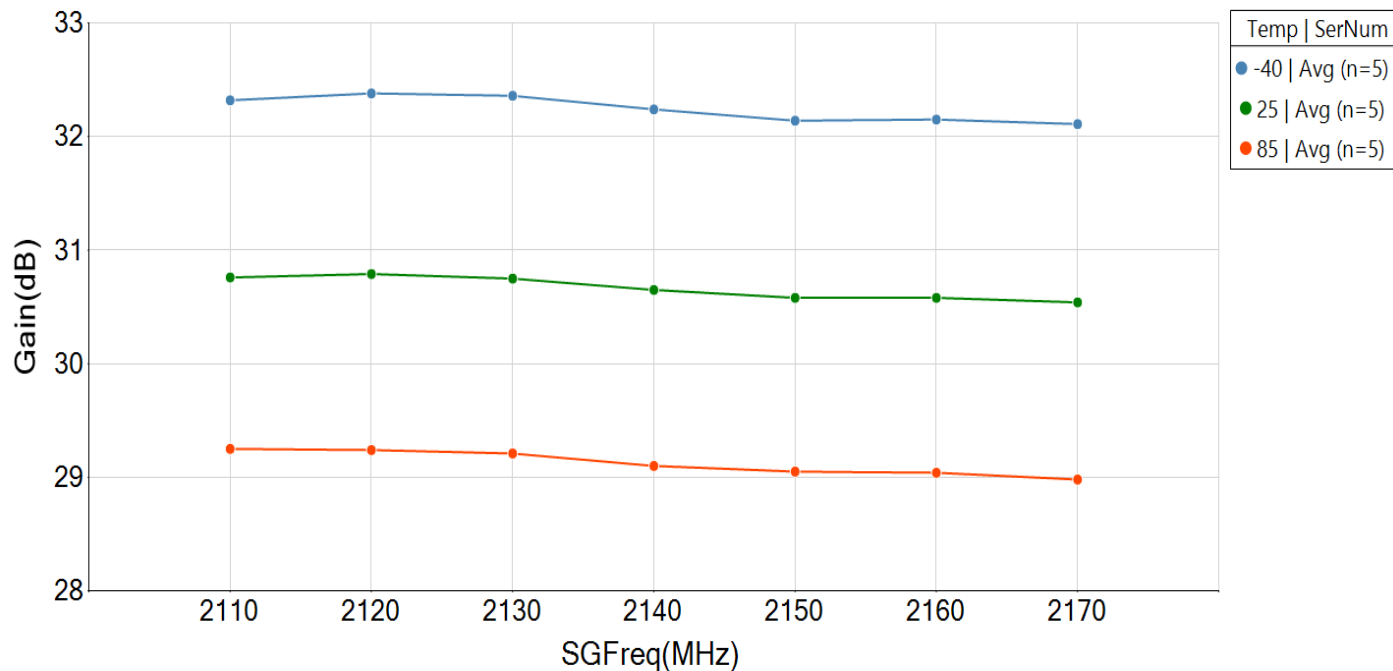
Truth Table

| Pin | Logic | Condition |
|------------|-------|-----------------------|
| V_{SHDN} | LOW | Full Operation |
| | HIGH | All Amplifiers Off |
| V_{EN1} | LOW | Stage 1 Amplifier Off |
| | HIGH | Stage 1 Amplifier On |
| V_{EN2} | LOW | Stage 2 Amplifier Off |
| | HIGH | Stage 2 Amplifier On |

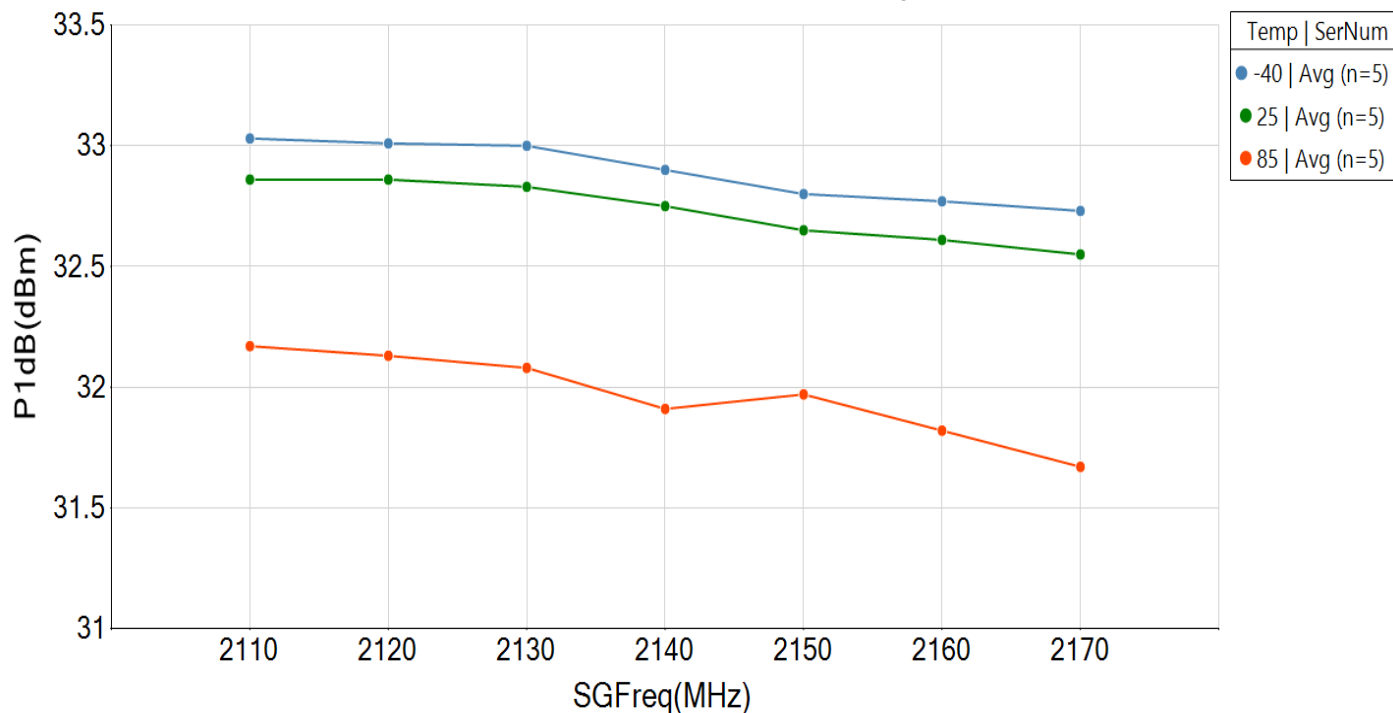


GRF5521 Typical Operating Curves: 2.11 - 2.17 GHz Tune

GRF5521 Gain vs Freq

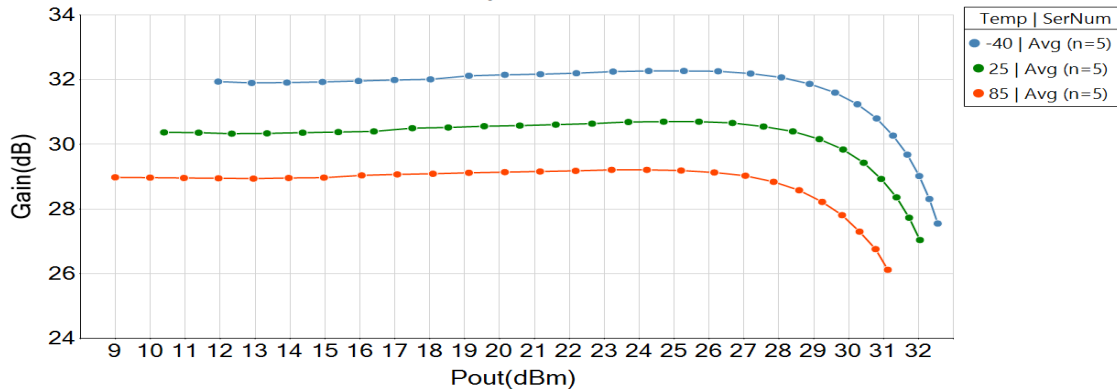


GRF5521 P1dB vs Freq

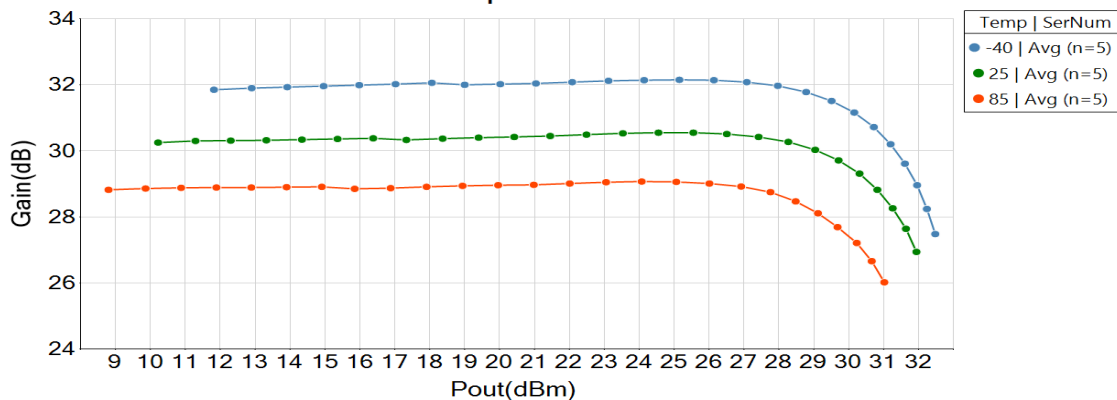


GRF5521 Typical Operating Curves: Gain vs. P_{OUT} (9.8 dB PAR)

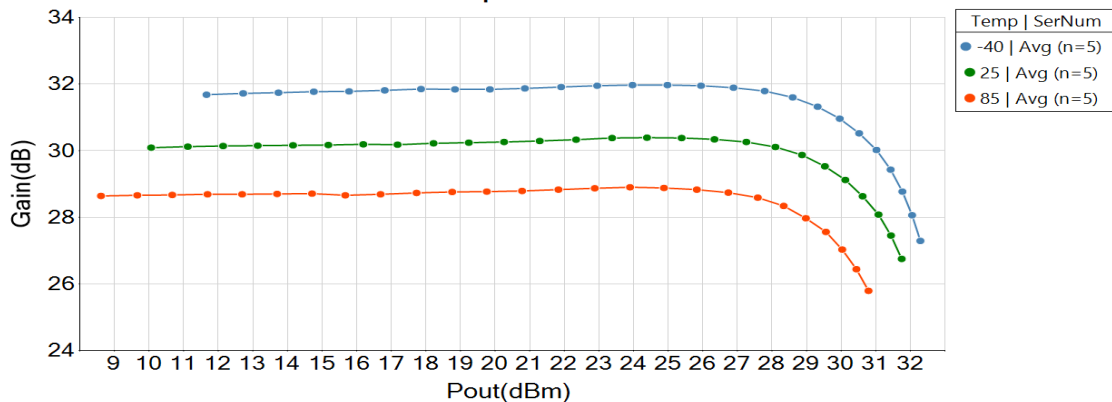
GRF5521 Gain vs Pout at Modulation = LTE_20MHz_100RB and Freq = 2110 MHz



GRF5521 Gain vs Pout at Modulation = LTE_20MHz_100RB and Freq = 2140 MHz



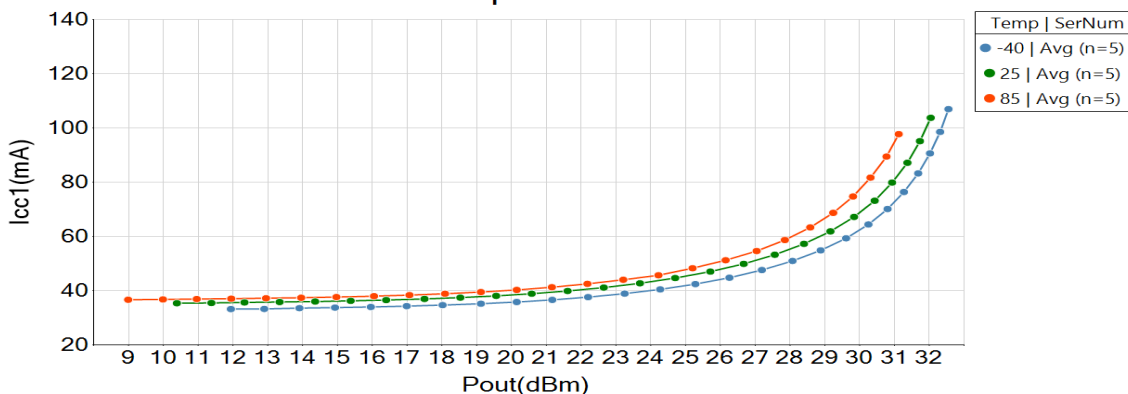
GRF5521 Gain vs Pout at Modulation = LTE_20MHz_100RB and Freq = 2170 MHz



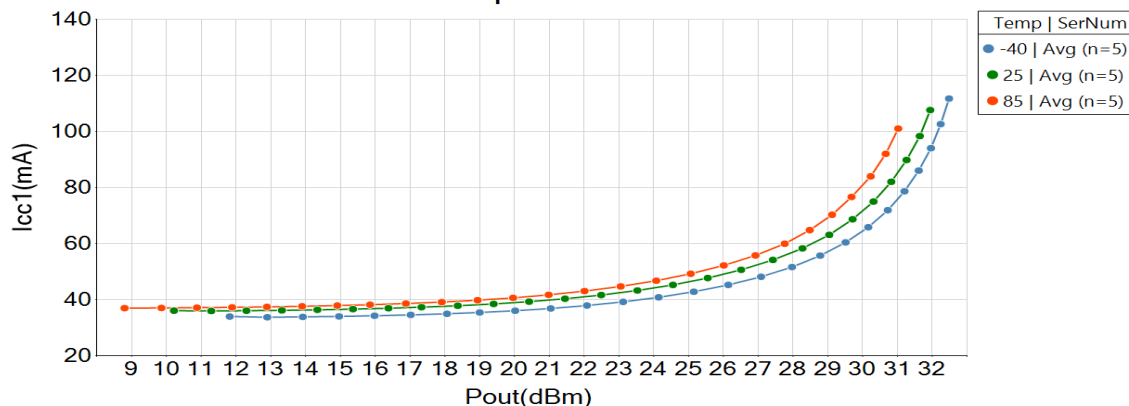


GRF5521 Typical Operating Curves: I_{cc1} vs. P_{OUT} (9.8 dB PAR)

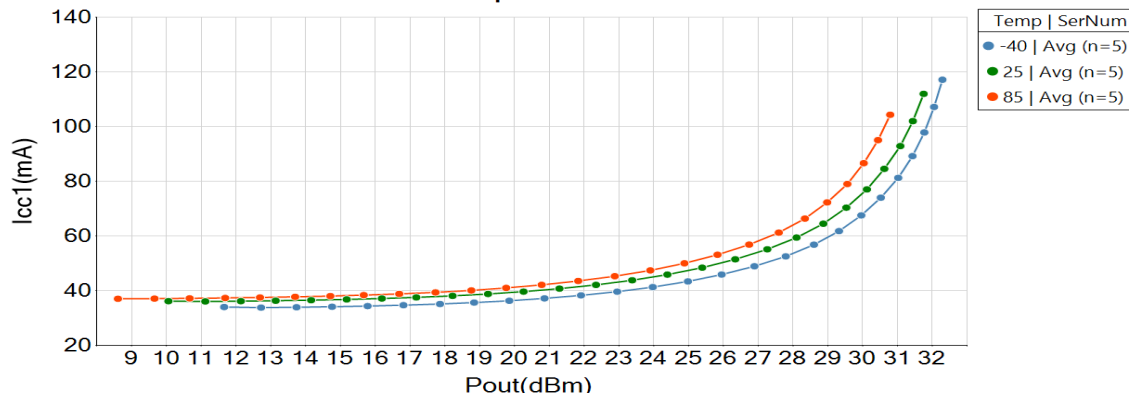
GRF5521 I_{cc1} vs P_{out} at Modulation = LTE_20MHz_100RB and Freq = 2110 MHz



GRF5521 I_{cc1} vs P_{out} at Modulation = LTE_20MHz_100RB and Freq = 2140 MHz

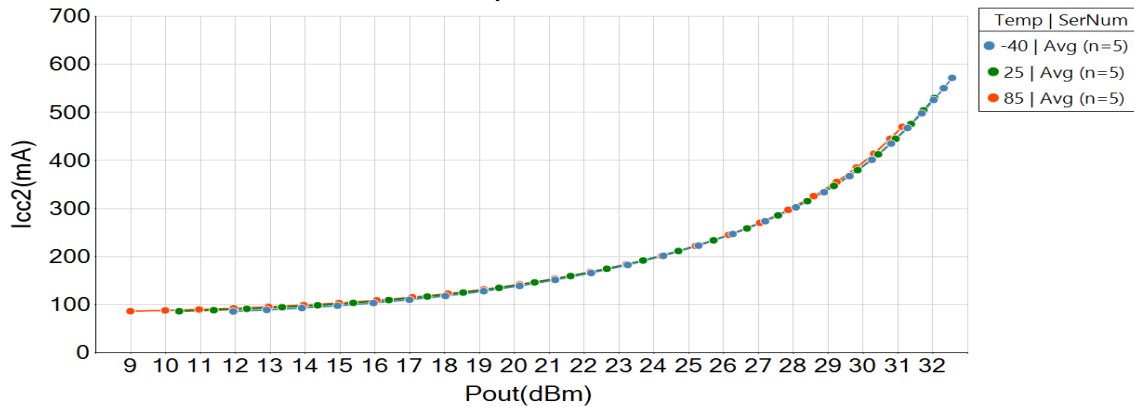


GRF5521 I_{cc1} vs P_{out} at Modulation = LTE_20MHz_100RB and Freq = 2170 MHz

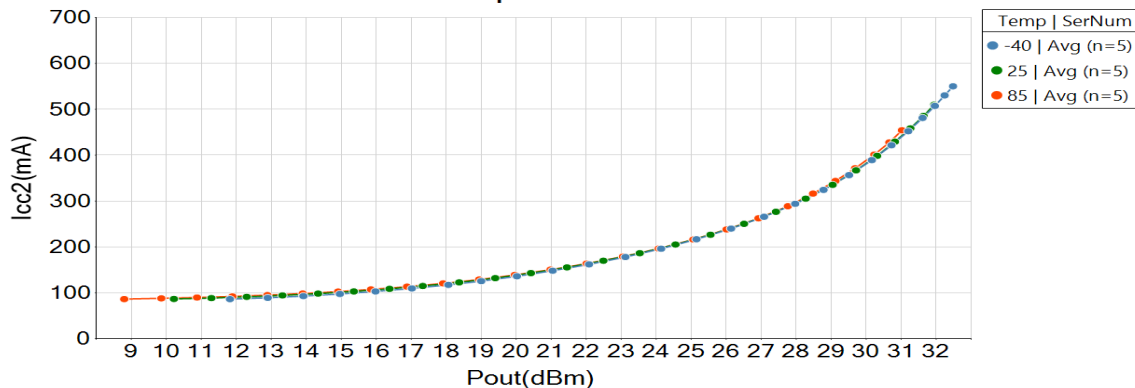


GRF5521 Typical Operating Curves: I_{cc2} vs. P_{OUT} (9.8 dB PAR)

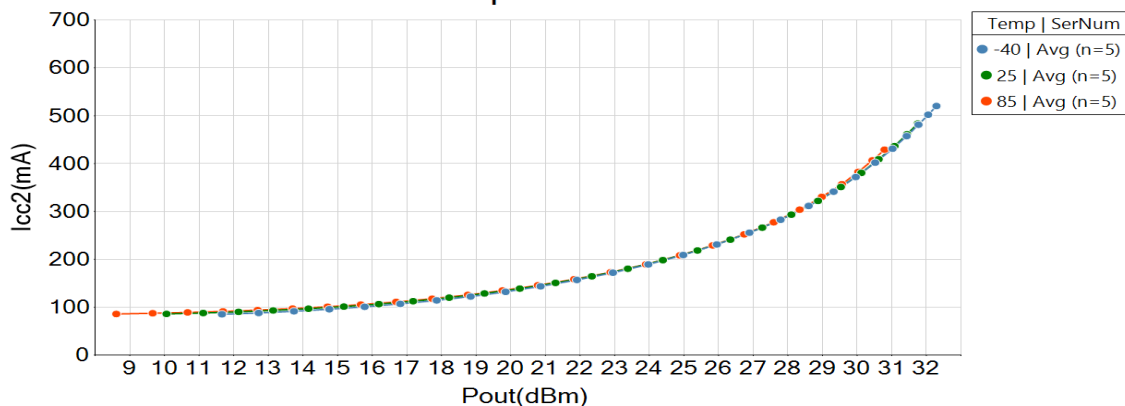
GRF5521 I_{cc2} vs P_{out} at Modulation = LTE_20MHz_100RB and Freq = 2110 MHz



GRF5521 I_{cc2} vs P_{out} at Modulation = LTE_20MHz_100RB and Freq = 2140 MHz



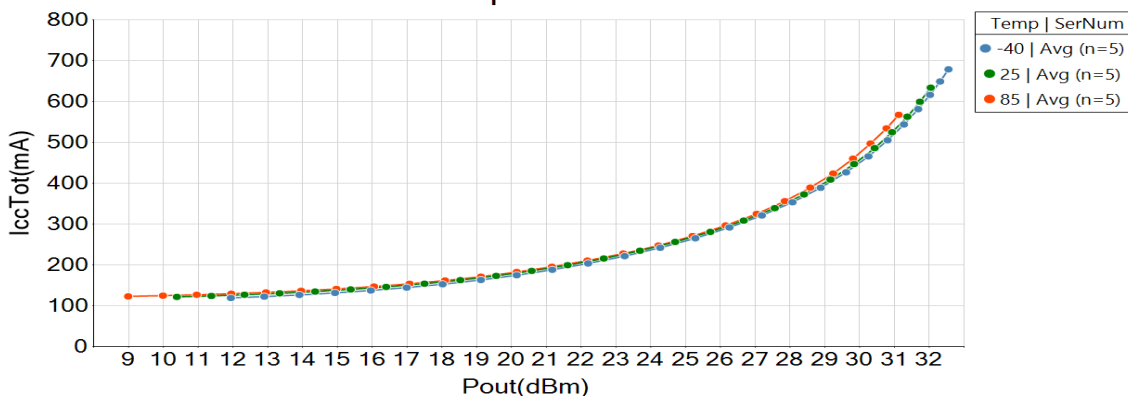
GRF5521 I_{cc2} vs P_{out} at Modulation = LTE_20MHz_100RB and Freq = 2170 MHz



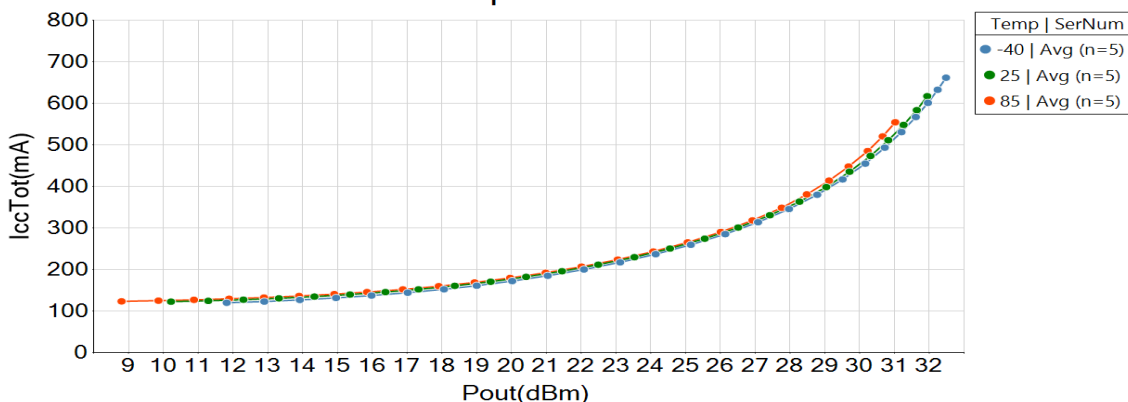


GRF5521 Typical Operating Curves: $I_{ccTotal}$ vs. P_{OUT} (9.8 dB PAR)

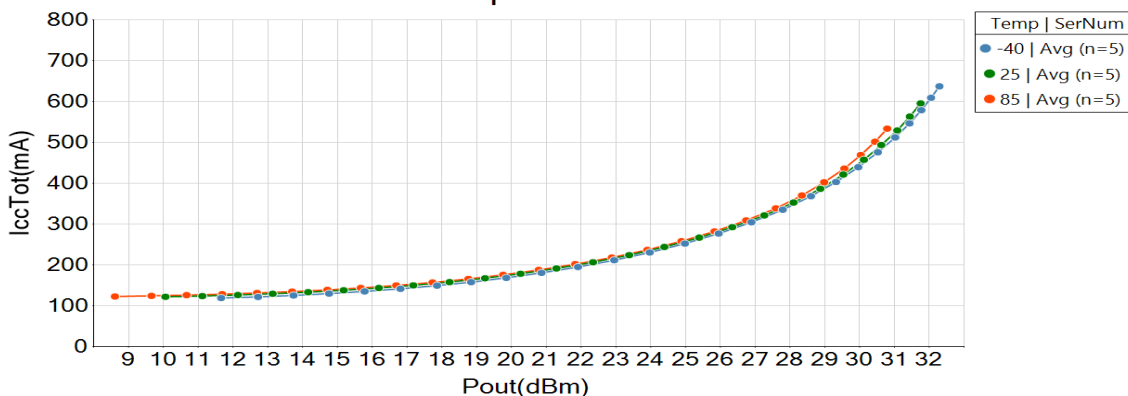
GRF5521 I_{ccTot} vs P_{out} at Modulation = LTE_20MHz_100RB and Freq = 2110 MHz



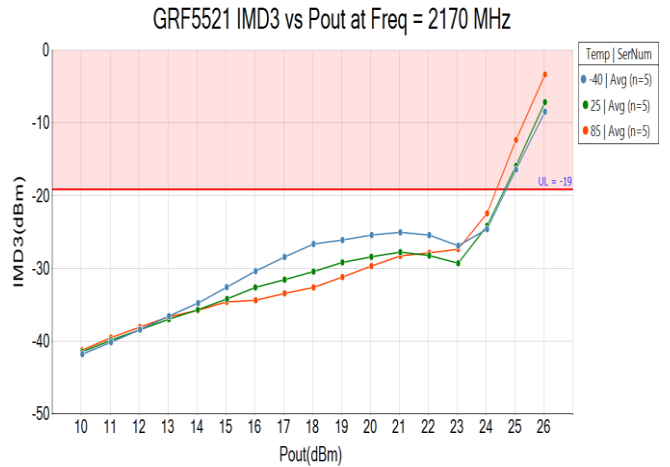
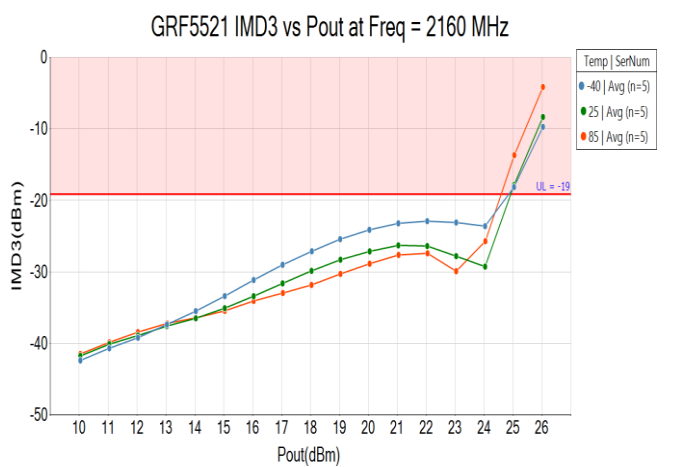
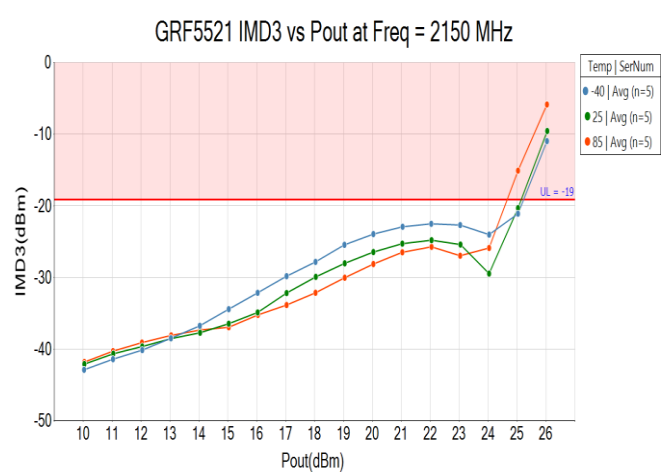
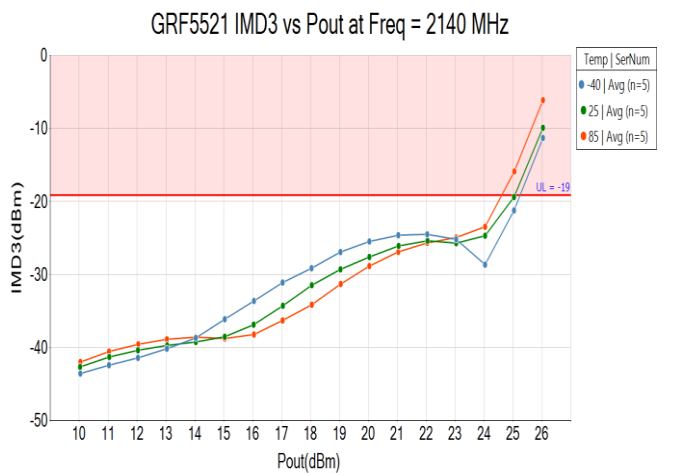
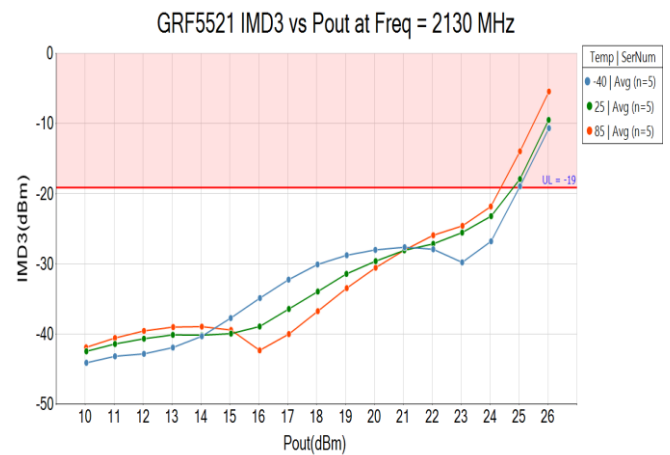
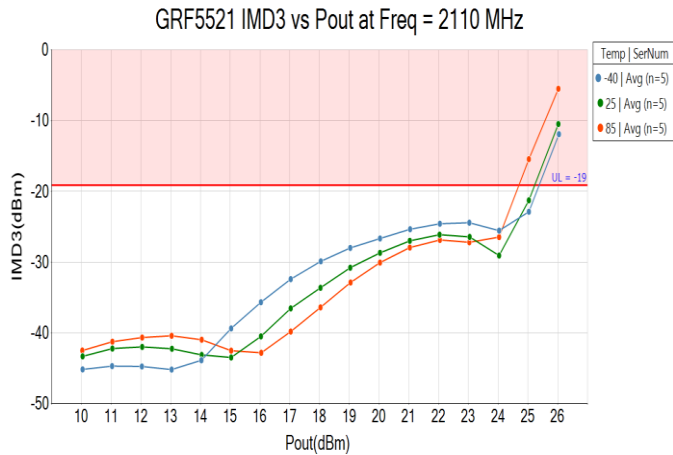
GRF5521 I_{ccTot} vs P_{out} at Modulation = LTE_20MHz_100RB and Freq = 2140 MHz



GRF5521 I_{ccTot} vs P_{out} at Modulation = LTE_20MHz_100RB and Freq = 2170 MHz

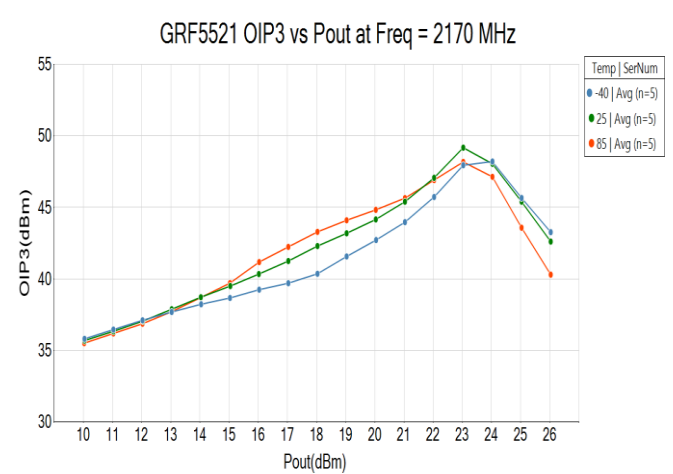
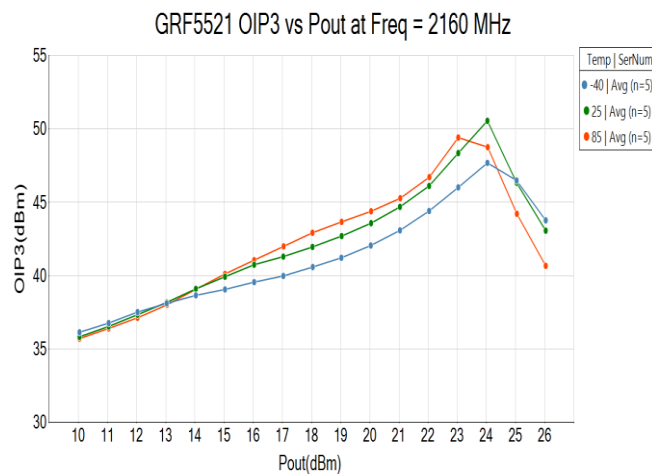
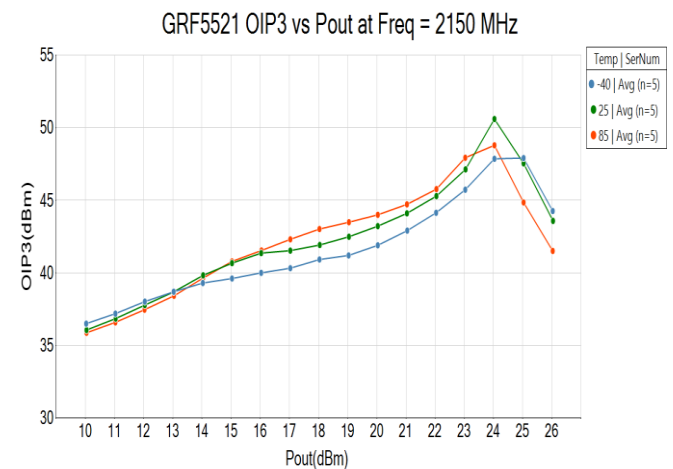
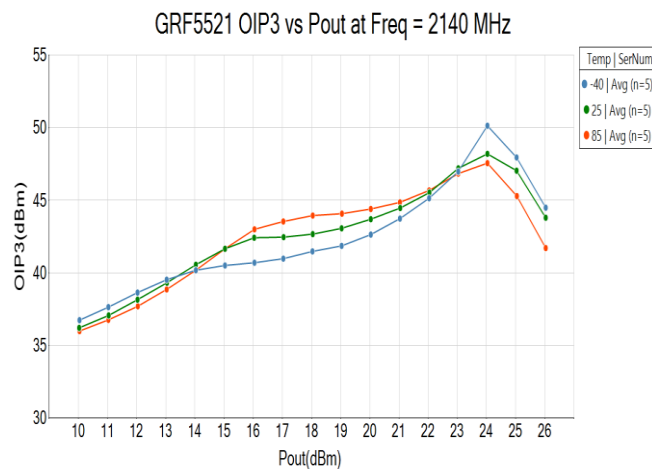
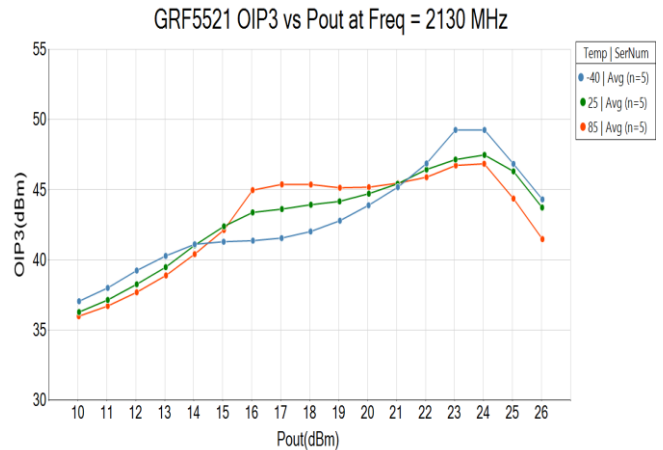
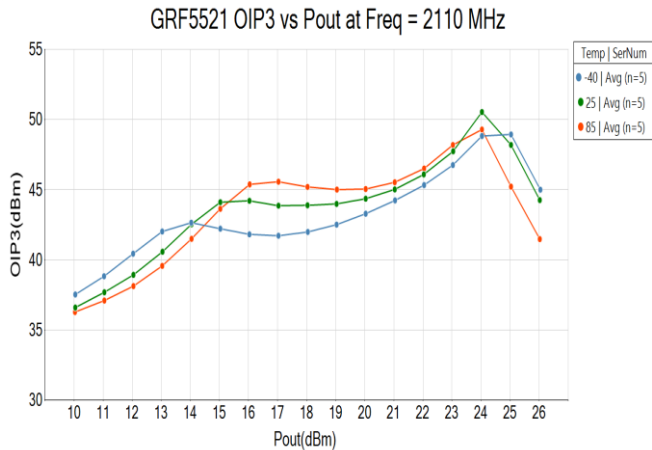


GRF5521 Typical Operating Curves: IMD3 vs. P_{OUT} (Per Tone with 600kHz Tone Spacing)



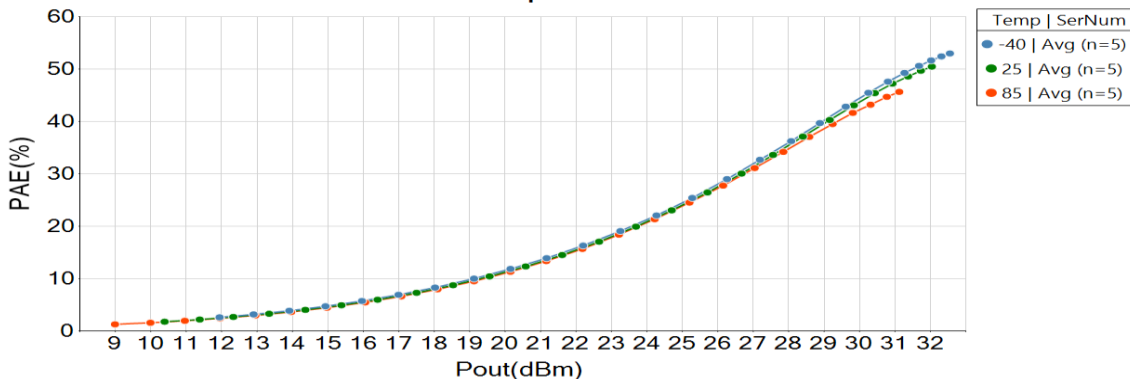


GRF5521 Typical Operating Curves: OIP3 vs. P_{OUT} (Per Tone with 600kHz Tone Spacing)

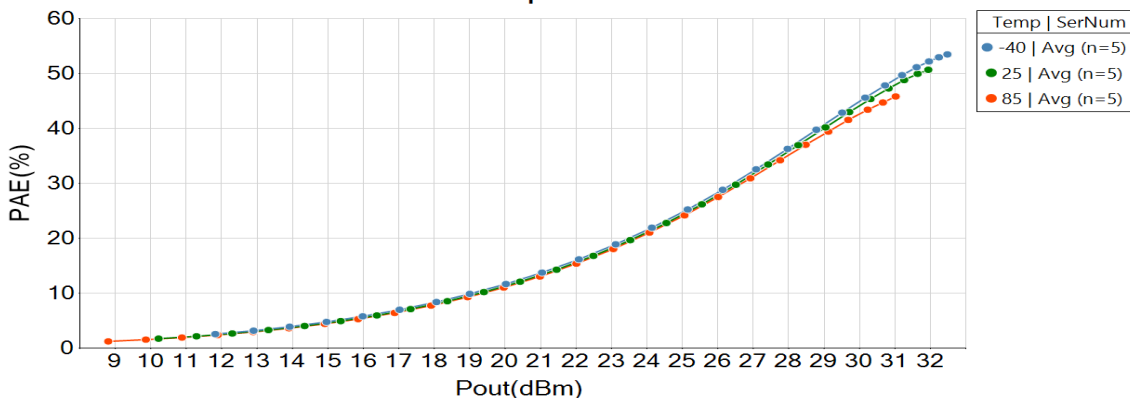


GRF5521 Typical Operating Curves: PAE vs. P_{OUT} (9.8 dB PAR)

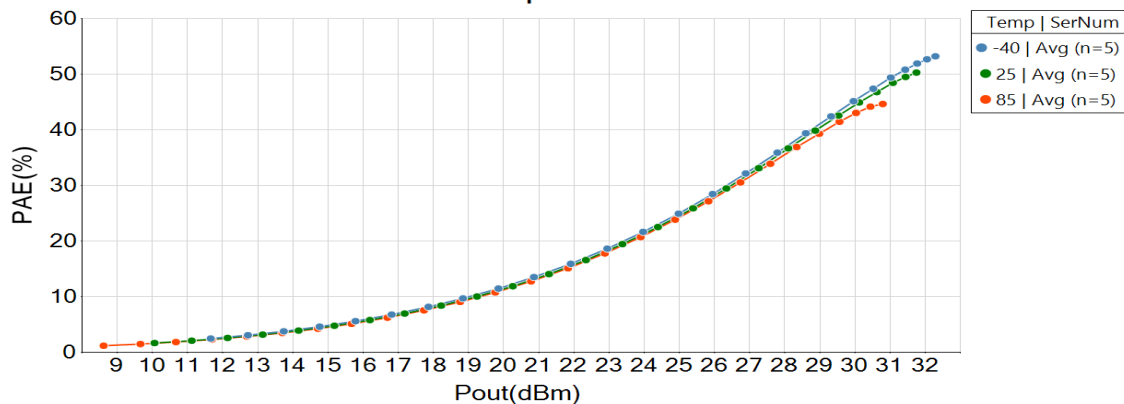
GRF5521 PAE(%) vs Pout at Modulation = LTE_20MHz_100RB and Freq = 2110 MHz



GRF5521 PAE(%) vs Pout at Modulation = LTE_20MHz_100RB and Freq = 2140 MHz



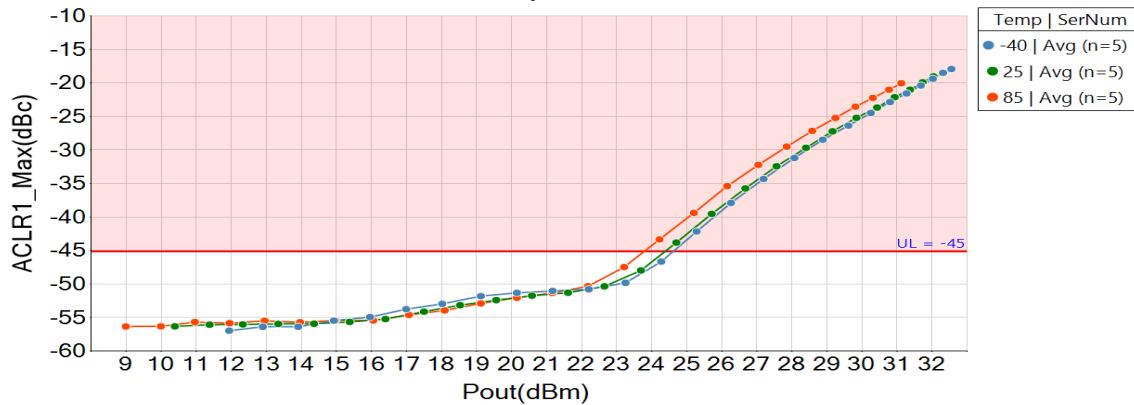
GRF5521 PAE(%) vs Pout at Modulation = LTE_20MHz_100RB and Freq = 2170 MHz



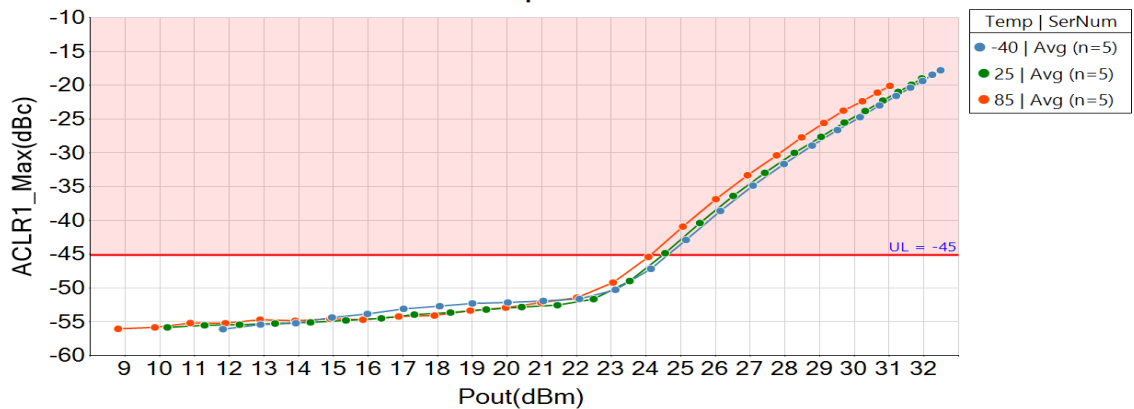


GRF5521 Typical Operating Curves: ACLR1 vs. P_{OUT} (9.8 dB PAR)

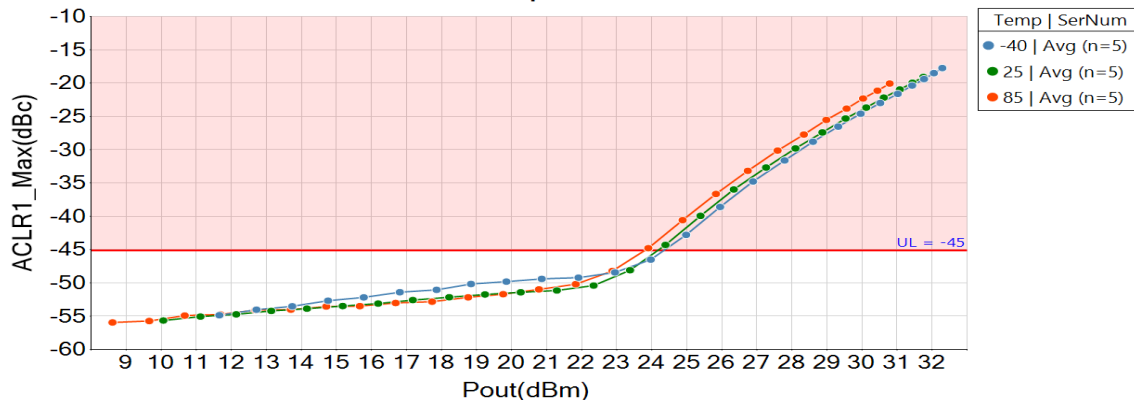
GRF5521 ACLR1 vs Pout at Modulation = LTE_20MHz_100RB and Freq = 2110 MHz



GRF5521 ACLR1 vs Pout at Modulation = LTE_20MHz_100RB and Freq = 2140 MHz

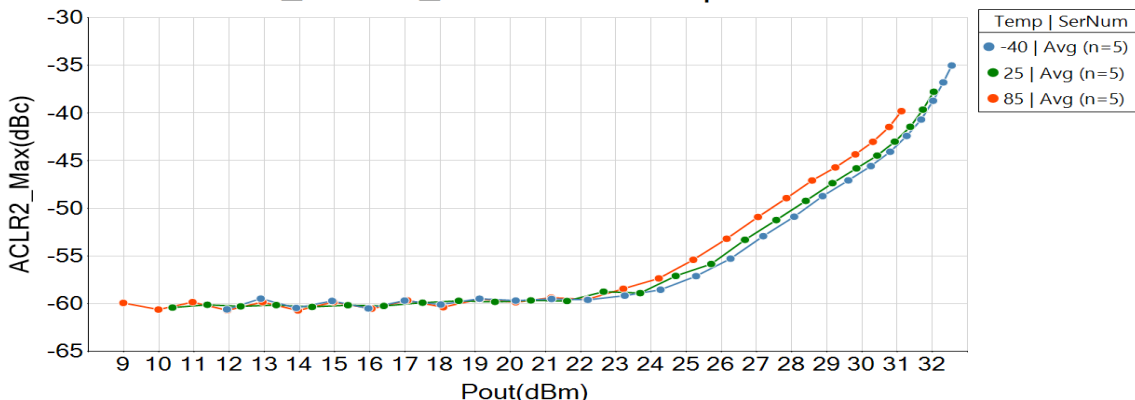


GRF5521 ACLR1 vs Pout at Modulation = LTE_20MHz_100RB and Freq = 2170 MHz

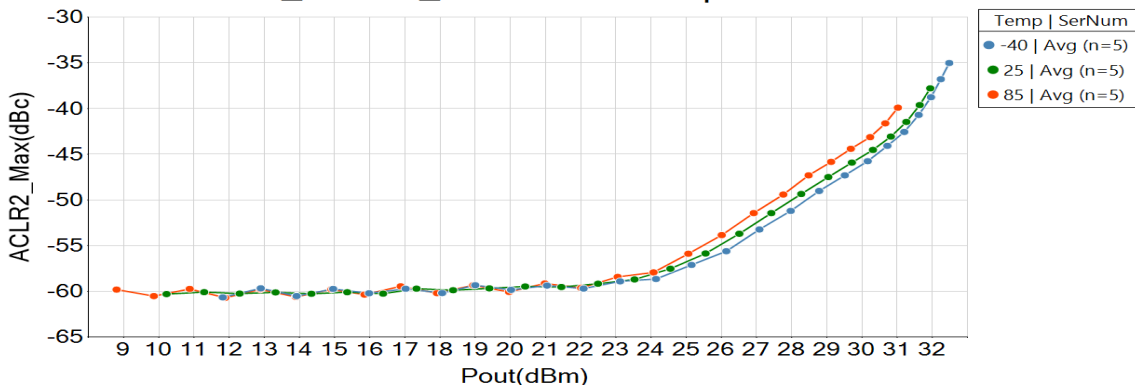


GRF5521 Typical Operating Curves: ACLR2_Max vs. P_{OUT} (9.8 dB PAR)

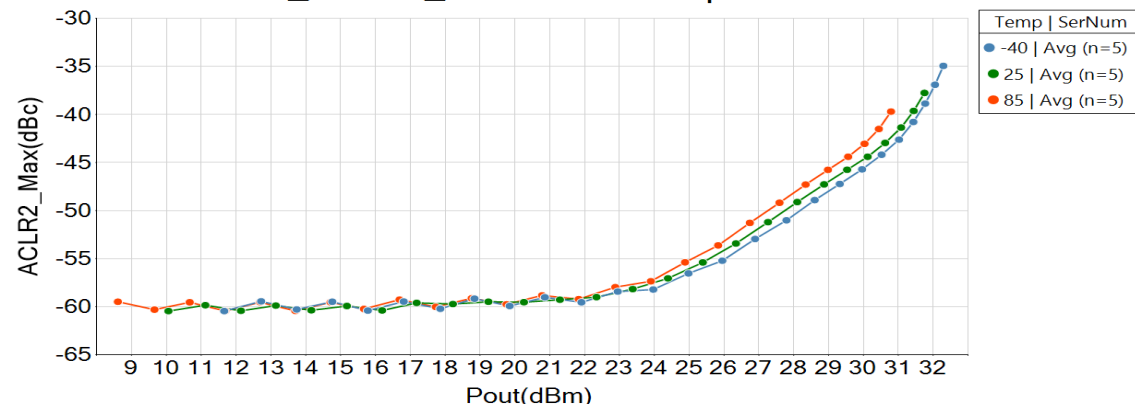
GRF5521 ACLR2_Max(dBc) vs Pout at Modulation = LTE_20MHz_100RB and Freq = 2110 MHz



GRF5521 ACLR2_Max(dBc) vs Pout at Modulation = LTE_20MHz_100RB and Freq = 2140 MHz

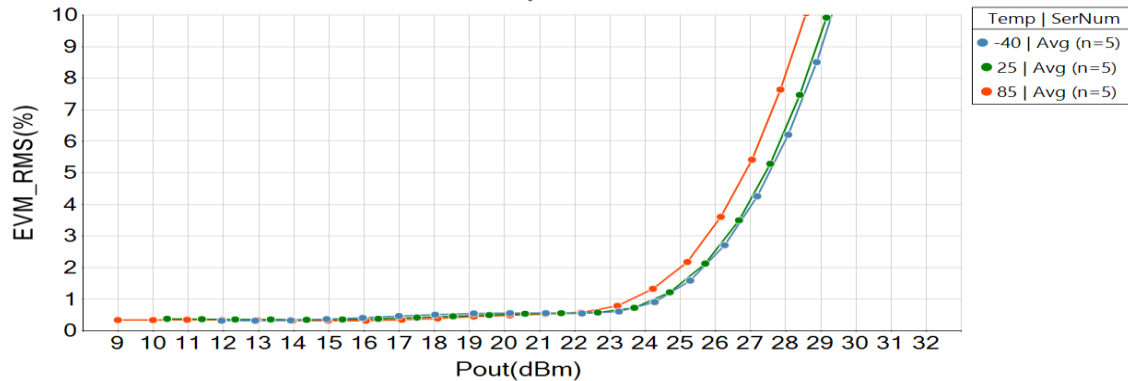


GRF5521 ACLR2_Max(dBc) vs Pout at Modulation = LTE_20MHz_100RB and Freq = 2170 MHz

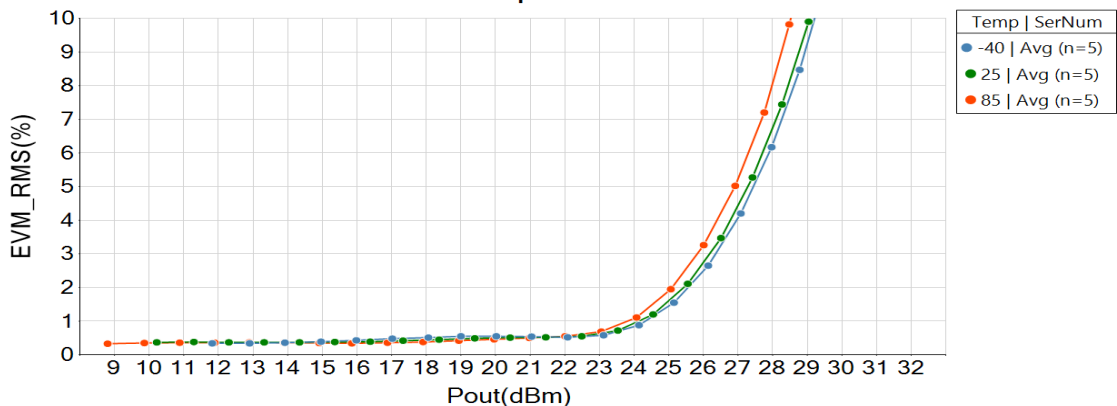


GRF5521 Typical Operating Curves: *EVM_RMS* vs. *P_{OUT}* (9.8 dB PAR)

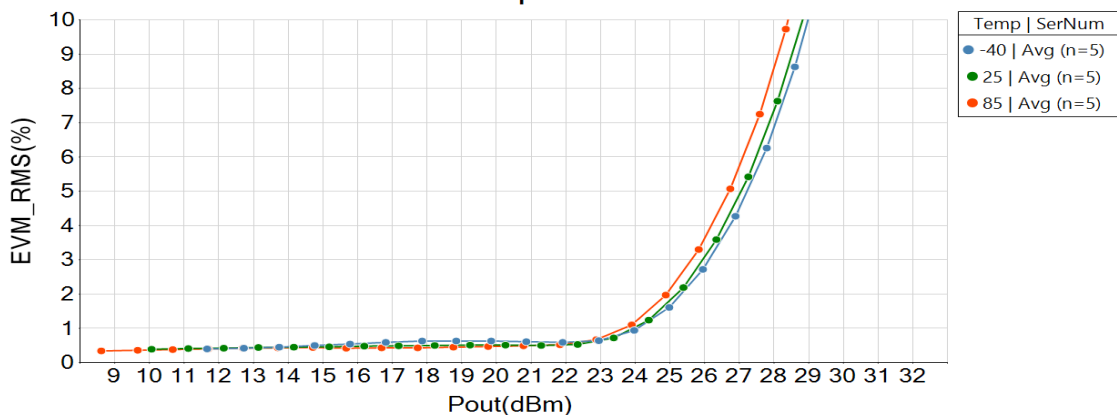
GRF5521 *EVM_RMS* vs Pout at Modulation = LTE_20MHz_100RB and Freq = 2110 MHz



GRF5521 *EVM_RMS* vs Pout at Modulation = LTE_20MHz_100RB and Freq = 2140 MHz

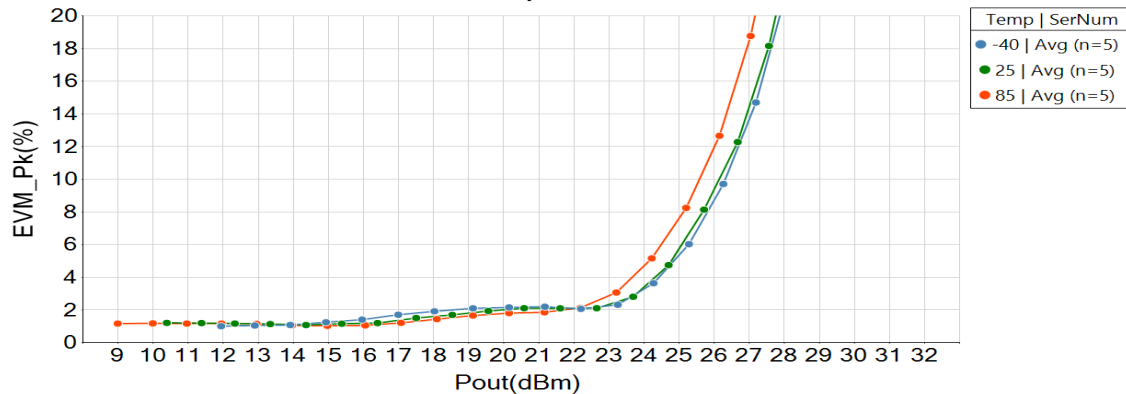


GRF5521 *EVM_RMS* vs Pout at Modulation = LTE_20MHz_100RB and Freq = 2170 MHz

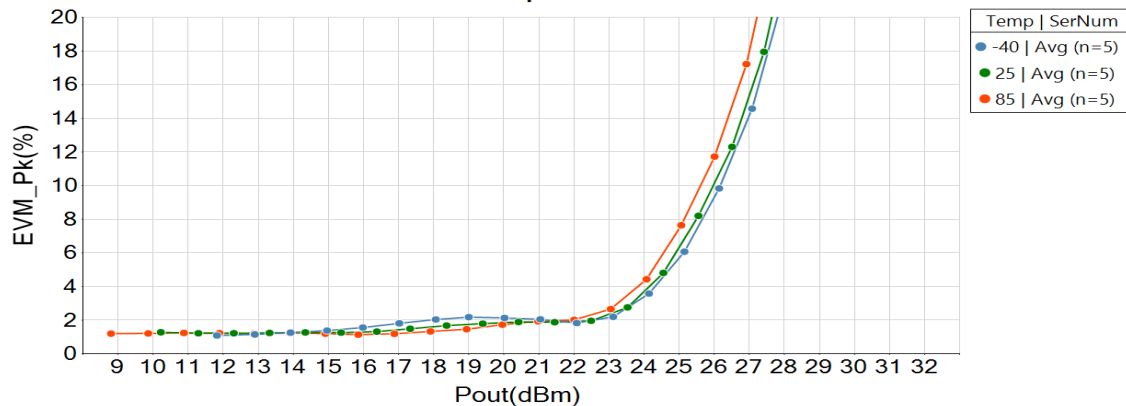


GRF5521 Typical Operating Curves: *EVM_Pk* vs. *P_{OUT}* (9.8 dB PAR)

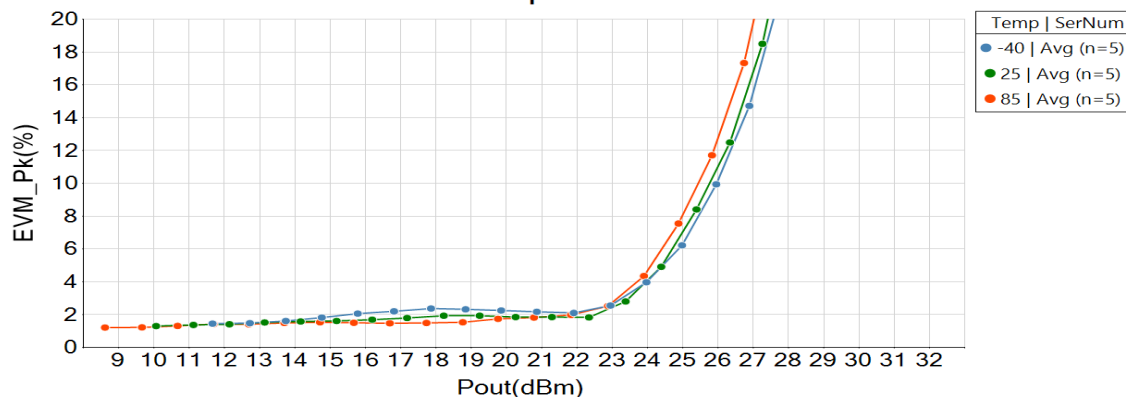
GRF5521 *EVM_Pk* vs *P_{out}* at Modulation = LTE_20MHz_100RB and Freq = 2110 MHz



GRF5521 *EVM_Pk* vs *P_{out}* at Modulation = LTE_20MHz_100RB and Freq = 2140 MHz



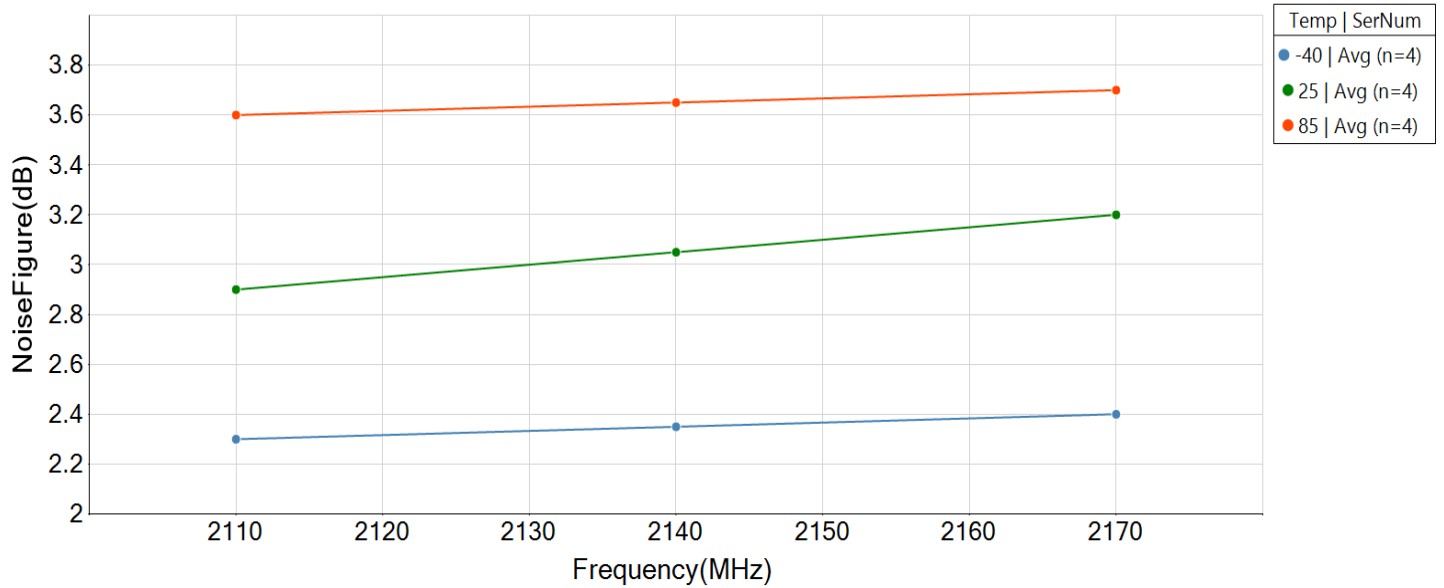
GRF5521 *EVM_Pk* vs *P_{out}* at Modulation = LTE_20MHz_100RB and Freq = 2170 MHz



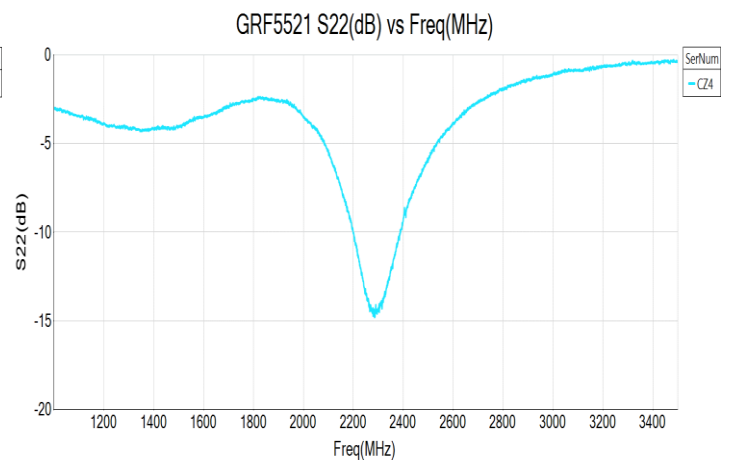
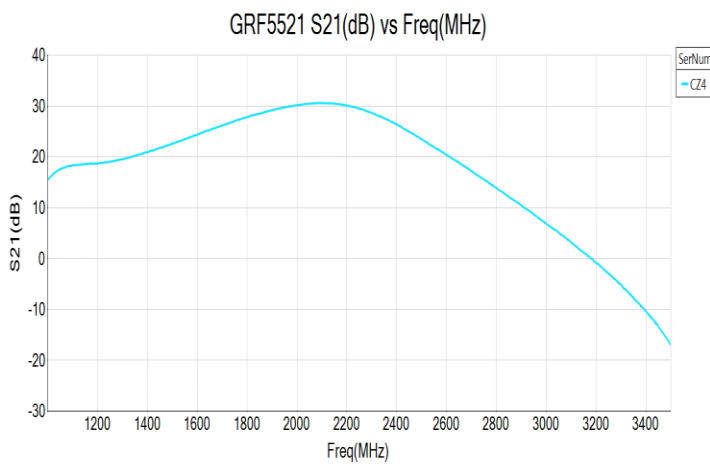
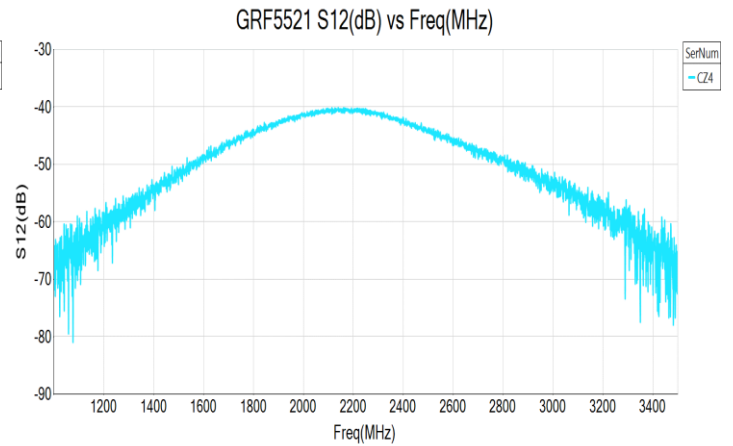
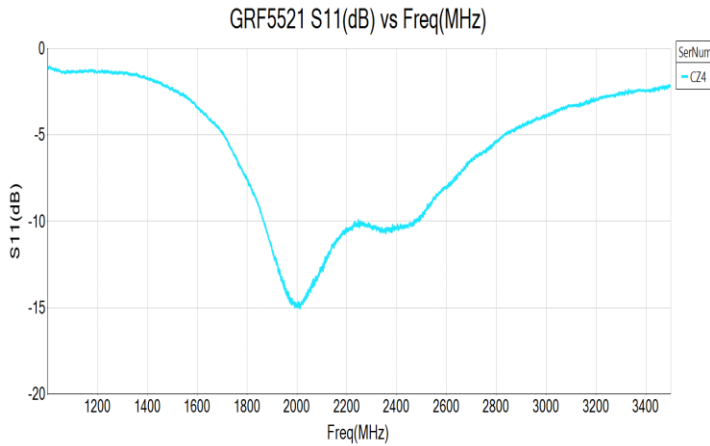


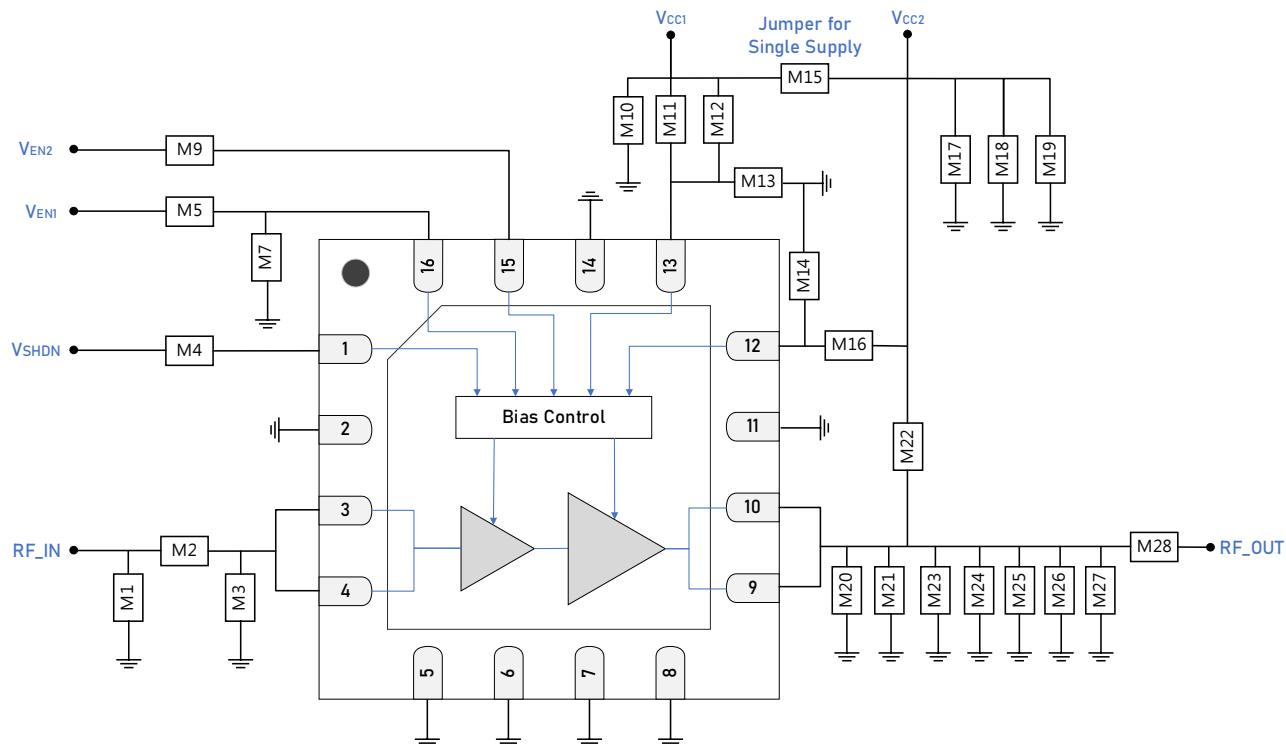
GRF5521 Typical Operating Curves: *Noise Figure (2.11 – 2.17 GHz Tune)*

GRF5521 Noise Figure vs Frequency

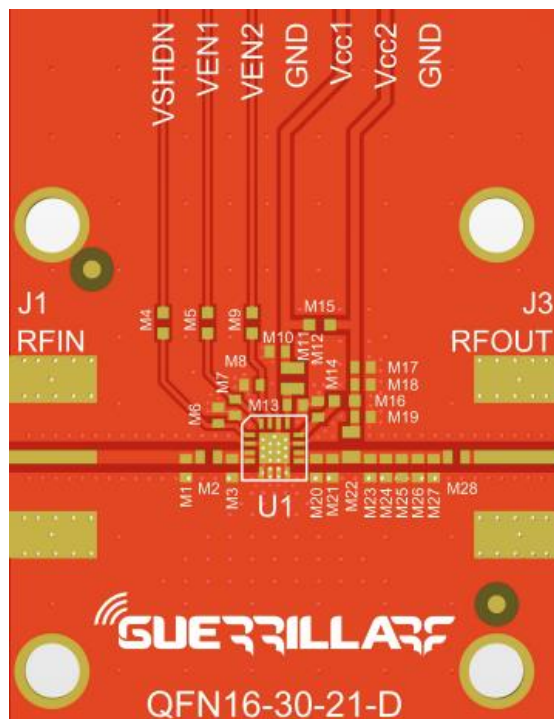


GRF5521 Typical Operating Curves: S-Parameters (2.11 – 2.17 GHz Tune)





GRF5521 Standard Test Schematic

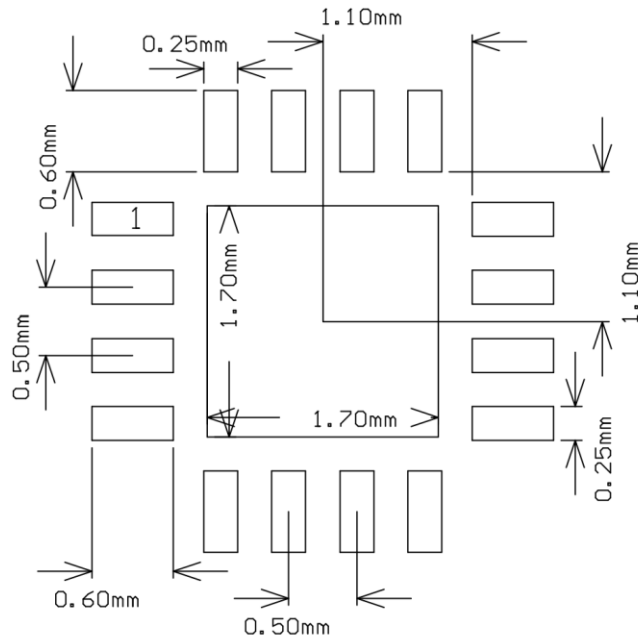


GRF5521 Evaluation Board Assembly Diagram

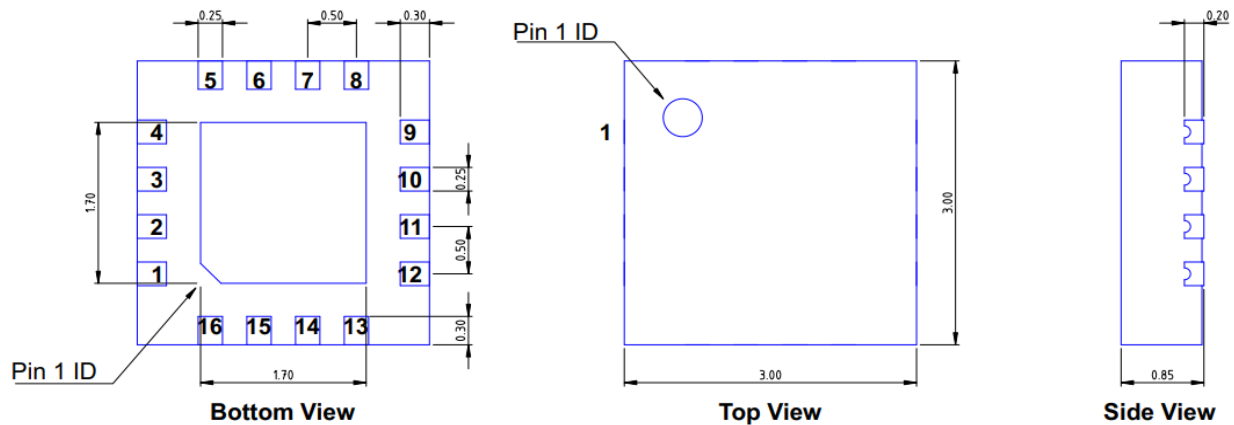
GRF5521 Evaluation Board Assembly Diagram Reference

| Component | Type | Manufacturer | Family | Value | Package Size | Substitution |
|---|-------------------|--------------|-----------------------|--------|--------------|--------------|
| M1 | Inductor | Murata | LQG | 2.7 nH | 0402 | ok |
| M2 | Capacitor | Murata | GJM | 2.2 pF | 0402 | ok |
| M4 | Resistor | Various | 5% | 0 Ω | 0402 | ok |
| M5 | Resistor | Various | 5% | 6650 Ω | 0402 | ok |
| M9 | Resistor | Various | 5% | 4750 Ω | 0402 | ok |
| M11 | Resistor | Murata | LQG | 0 Ω | 0402 | ok |
| M13 | Capacitor | Murata | GRM | 0.1 μF | 0402 | ok |
| M14, M18 | Capacitor | Murata | GRM155C80J06 ME11D | 10 μF | 0402 | ok |
| M15 | Resistor (jumper) | Various | 5% | 0 Ω | 0402 | ok |
| M16 | Resistor | Various | 5% | 0 Ω | 0402 | ok |
| M19 | Capacitor | Murata | GRM | 100 pF | 0402 | ok |
| M21 | Capacitor | Murata | GJM | 3.6 pF | 0402 | ok |
| M22 | Inductor: High Q | Murata | LQW18AN4N3B80 | 4.3 nH | 0603 | ok |
| M28 | Capacitor | Murata | GJM | 5.1pF | 0402 | ok |
| M3, M7, M10, M12, M17, M20, M23, M24, M25, M26, M27 | DNP | -- | -- | -- | -- | -- |
| Evaluation Board | QFN16-30-21-D | -- | -- | -- | -- | -- |

Note 4: Standard Evaluation Board Bias: $V_{CC} = 5\text{ V}$. $V_{ENABLE} = 5\text{ V}$.



3 x 3 mm QFN-16 Suggested PCB Footprint (Top View)



QFN16 3x3mm
 Dimensions in millimeters
 Dimensional Tolerance: ± 0.05

3 x 3 mm QFN-16 Package Dimensions

Package Marking Diagram



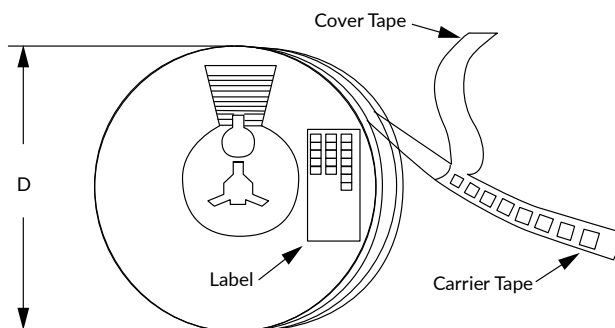
- Line 1: "YY" = YEAR. "WW" = WORK WEEK the Device was assembled.
- Line 2: "GRF" = Guerrilla RF.
- Line 3: "XXXX" = Device PART NUMBER.

Tape and Reel Information

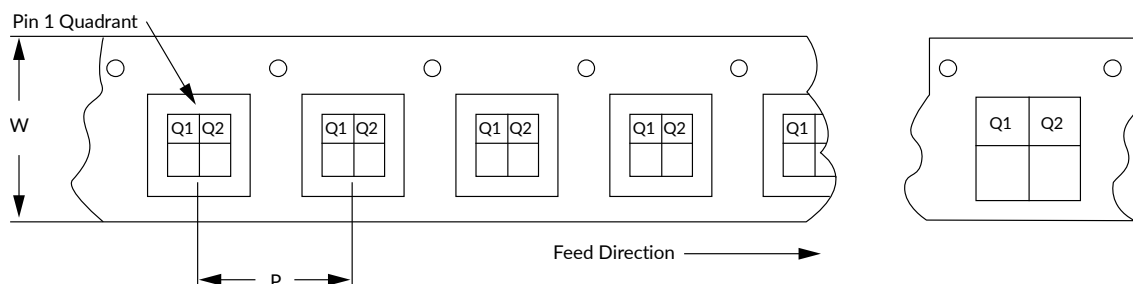
Guerrilla RF's tape and reel specification comply with Electronics Industries Association (EIA) standards for "Embossed Carrier Tape of Surface Mount Components for Automatic Handling" (reference EIA-481). See the following page for the Tape and Reel Specification and Device Package Information table, which includes units per reel.

Devices are loaded with pins down into the carrier pocket with protective cover tape and reeled onto a plastic reel. Each reel is packaged in a cardboard box. There are product labels on the reel, the protective ESD bag, and the outside surface of the box.

For the Tape and Reel Reference Table, please refer to: [Package Manufacturing Information | Guerrilla RF \(guerrilla-rf.com\)](#)



Tape and Reel Packaging with Reel Diameter Noted (D)



Carrier Tape Width (W), Pitch (P), Feed Direction and Pin 1 Quadrant Information



Revision History

| Revision Date | Description of Change |
|------------------|---|
| July 19, 2021 | Updated to new format. |
| May 11, 2022 | Changed HBM minimum specification from TBD to 1000v. |
| July 21, 2022 | Added new data plots. Updated EVB BOM and schematic. |
| October 20, 2022 | Release 0 update. Replaced all TBDs in the Absolute Ratings table. Implemented changes to the datasheet formatting. |



Data Sheet Classifications

| Data Sheet Status | Notes |
|-------------------|--|
| Advance | S-parameter and NF data based on EM simulations for the fully packaged device using foundry-supplied transistor S-parameters. Linearity estimates based on device size, bias condition and experience with related devices. |
| Preliminary | All data based on evaluation board measurements taken within the Guerrilla RF Applications Lab. Any MIN/MAX limits represented within the data sheet are based solely on <i>estimated</i> part-to-part variations and process spreads. All parametric values are subject to change pending the collection of additional data. |
| Release Ø | All data based on measurements taken with <i>production-released</i> material. TYP values are based on a combination of ATE and bench-level measurements, with MIN/MAX limits defined using <i>modelled estimates</i> that account for part-to-part variations and expected process spreads. Although unlikely, future refinements to the TYP/MIN/MAX values may be in order as multiple lots are processed through the factory. |
| Release A-Z | All data based on measurements taken with production-released material <i>derived from multiple lots which have been fabricated over an extended period of time</i> . MIN/MAX limits may be refined over previous releases as more statistically significant data is collected to account for process spreads. |

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