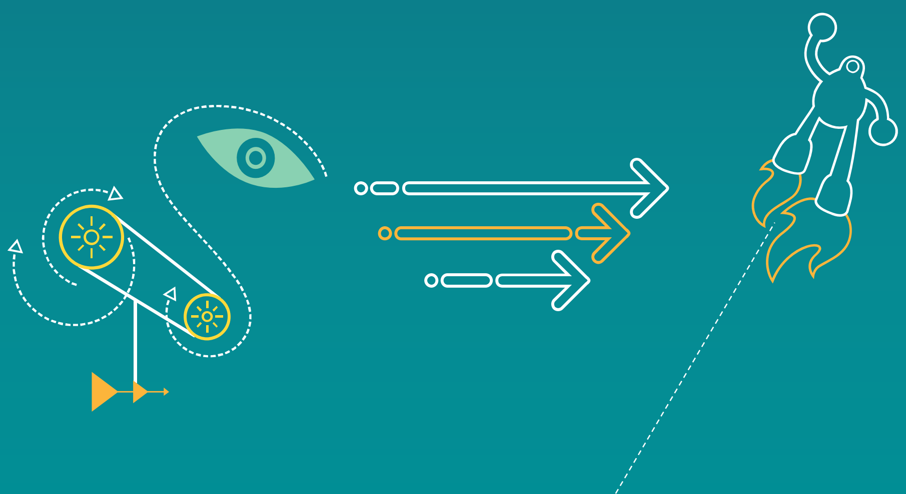
GSM Technology Troubleshooting Guidelines

Qualcomm Technologies, Inc.

80-P1130-24 Rev. A



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Revision History

Revision	Date	Description
A	August 2015	Initial release

Contents

Section 1

Overview

Overview

Purpose

- Provide an overview of the GSM radio technical specifications
- Provide guidance for troubleshooting RF failures of GSM designs
  - Test setup, instructions, and practical lab techniques
  - Examples based on previous customer requests for assistance via the Qualcomm Technologies, Inc. (QTI) knowledge base (KB) system

Scope

- GSM RF-specific and RF-related issues

Organization

- GSM radio technical specifications
  - Finding and downloading the specifications
  - Introduction to the specifications
  - Key RF parameters (and which are addressed in this document)
- Summary of the specifications' frequency bands and channel arrangements
- Transmitter and receiver characteristics
  - Key requirements of the standard
  - Test instructions
  - Troubleshooting guidelines
  - Pertinent KB information

Reference Documents

DCN	Document title
80-VP447-13	*RTR86xx, QTR86xx, QSC61x5, QSC6x95, MDM6x00, MDM8220, and MDM9x00 Select RF NV Items Application Note*
80-VP447-29	*RF Calibration Training Topics – Select Chipsets*
80-VP447-8	*GSM Linear PA Temperature Compensation Calculation Workbook*
80-VP148-12	*Concurrency Codec TX-GSM Layout Recommendations for QTR8x00 and QSC6xx5 Devices – Application Note*
80-N1622-19	*MSM8960/MDM9615/MSM8x30 RF NV Item Changes and Enhancements Application Note*
80-NH377-170	*Application Note: Comprehensive List of MDM9x35M/MDM9x30/MDM8x30/MSM8994 Family RF NV Items*
80-NR220-25	*MPSS.BO.X RF Factory GSM Calibration Design Guide*
80-V9774-16	*Application Note: GSM Linear PA Calibration and Data Processing for NV Generation*
80-N5420-171	*Comprehensive MSM8974/MDM9x25/MSM8x26/MSM8916/MSM8939 Family RF NV Items*

Section 2

GSM Standard

Finding the GSM Standard

1. Go to www.3gpp.org.
2. Click **Specifications**.
3. Under **Specifications**, select **Specification Numbering**.
4. Under **Subject of specification series**, in the **Radio aspects** row, select **45 series**.

For FDD/TDD versions:

1. Under **spec number**, select **45.005**.
2. Under **SDO publications**, click the appropriate version.
3. Click the link provided to download the specification.

GSM Transmitter Standards

3GPP TS 145 005 V12.5.0 (2015-04)

- 4 Transmitter characteristics
  - 4.1 Output power
    - 4.1.1 Mobile station
  - 4.2 Output RF spectrum
    - 4.2.1 Spectrum due to the modulation and wideband noise
    - 4.2.2 Spectrum due to switching transients
  - 4.3 Spurious emissions
  - 4.4 Radio frequency tolerance
  - 4.5 Output level dynamic operation
  - 4.6 Modulation accuracy
    - 4.6.1 GMSK modulation
    - 4.6.2 QPSK, AQPSK, 8-PSK, 16-QAM, and 32-QAM modulations
  - 4.7 Intermodulation attenuation

Annexes that may be of interest:

- Annex A (informative): Spectrum characteristics (spectrum due to the modulation)
- Annex B (normative): Transmitted power level vs. time
- Annex C (normative): Propagation conditions
- Annex D (normative): Environmental conditions

Note: All clauses include requirements for GMSK modulation (GSM) and 8-PSK modulation (EDGE).

Section 3

Frequency Bands

Frequency Bands

- GSM 850 band:
  - 824–849 MHz: mobile transmit, base receive
  - 869–894 MHz: base transmit, mobile receive
- Extended GSM 900 band, EGSM (includes standard GSM 900 band):
  - 880–915 MHz: mobile transmit, base receive
  - 925–960 MHz: base transmit, mobile receive
- DCS 1800 band:
  - 1710–1785 MHz: mobile transmit, base receive
  - 1805–1880 MHz: base transmit, mobile receive
- PCS 1900 band:
  - 1850–1910 MHz: mobile transmit, base receive
  - 1930–1990 MHz base transmit, mobile receive

Section 3.1

Mobile Output Power and Power vs. Time Profile

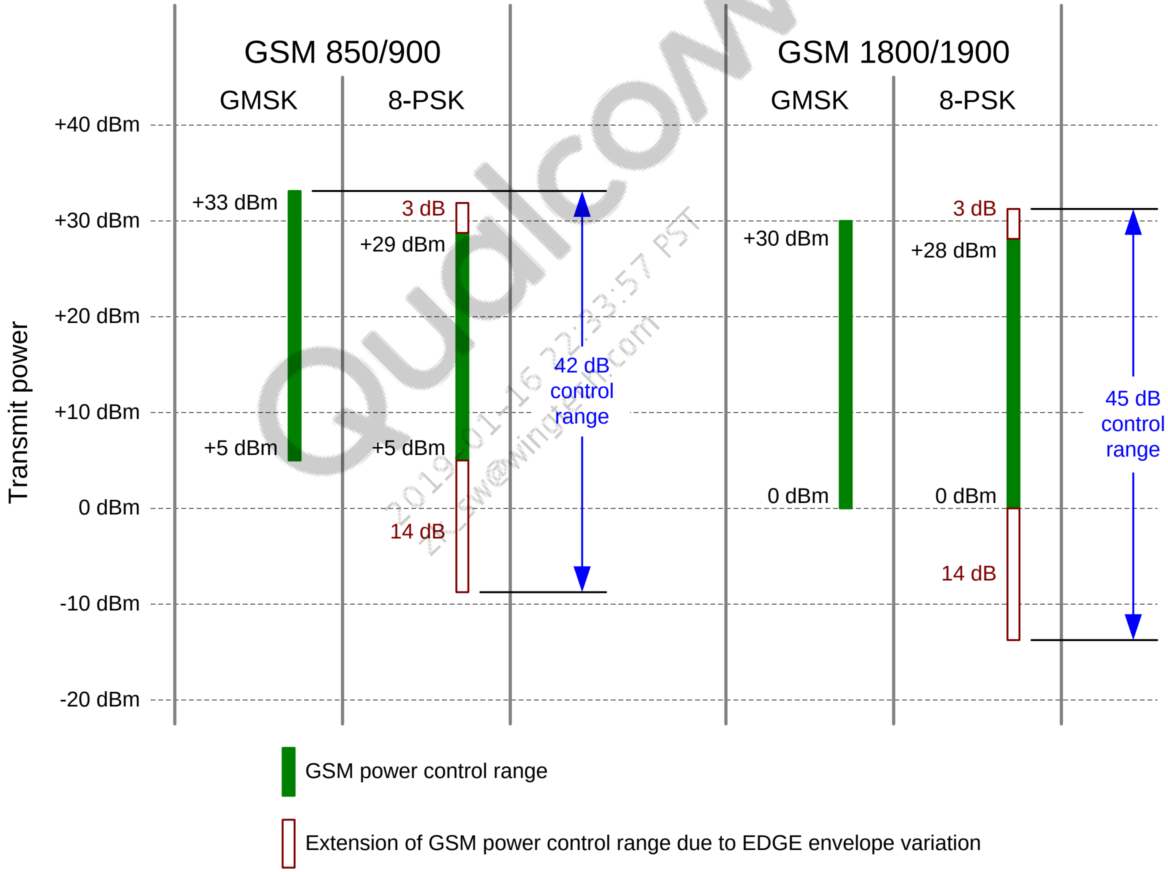
Mobile Station Output Power Specifications

For GSMK modulation					
	Maximum output power			**Tolerance vs. conditions**	
Power class	**GSM 850 & GSM 900**	**GSM 1800**	**GSM 1900**	**Normal**	**Extreme**
1	–	1 W (+30 dBm) [1]	1 W (+30 dBm) [1]	±2	±2.5
2	8 W (+39 dBm)	0.25 W (+24 dBm) [1]	0.25 W (+24 dBm) [1]	±2	±2.5
3	5 W (+37 dBm)	4 W (+36 dBm)	2 W (+33 dBm)	±2	±2.5
4	2 W (+33 dBm) [1]	–	–	±2	±2.5
5	0.8 W (+29 dBm) [1]	–	–	±2	±2.5

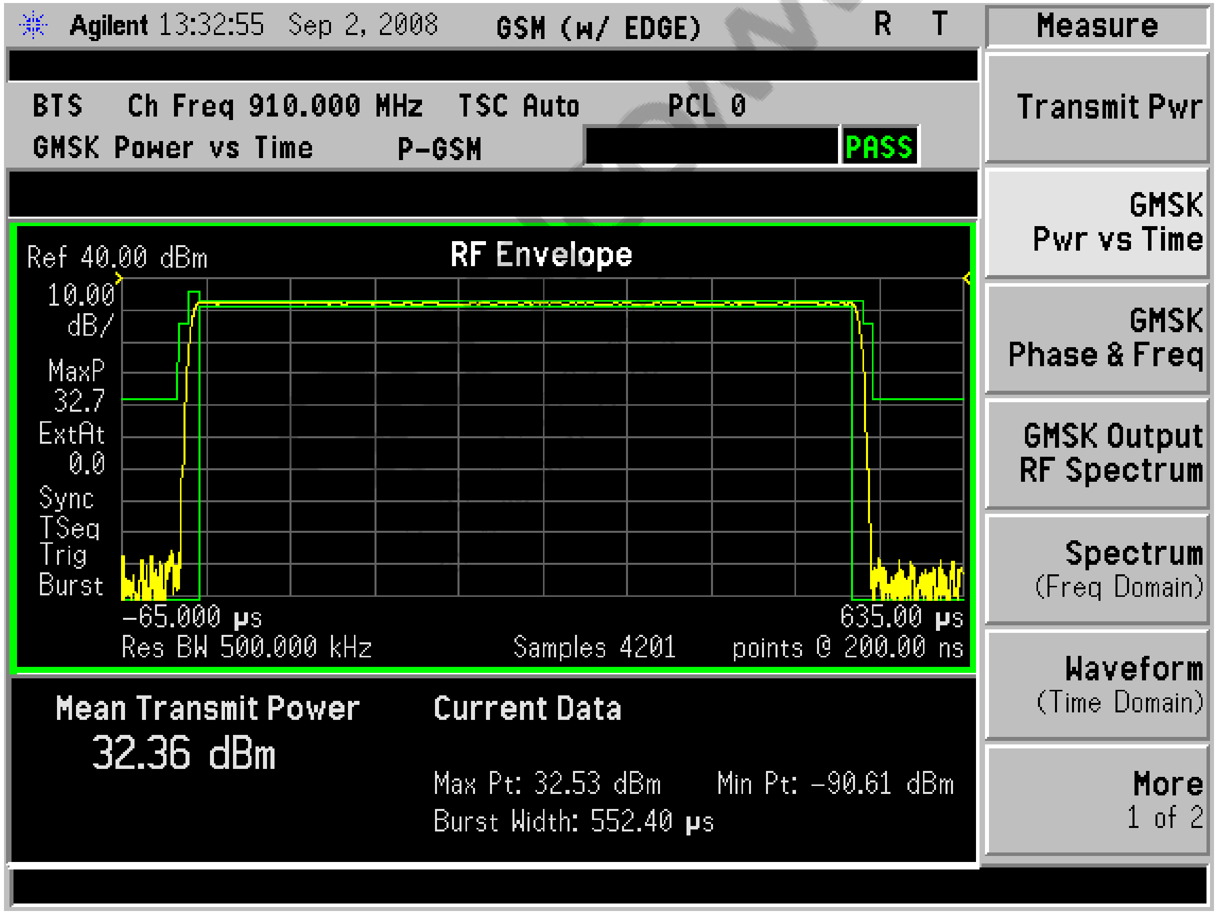
For 8-PSK modulation						
	Maximum output power	**Tolerance vs. conditions**		**Maximum output power**	**Tolerance vs. conditions**	
Power class	**GSM 850 & GSM 900**	**Normal**	**Extreme**	**GSM 1800 & GSM 1900**	**Normal**	**Extreme**
E1	+33 dBm	±2	±2.5	+30 dBm	±2	±2.5
E2	+27 dBm [1]	±3	±4	+26 dBm [1]	-4/+3	-4.5/+4
E3	+23 dBm [1]	±3	±4	+22 dBm [1]	±3	±4

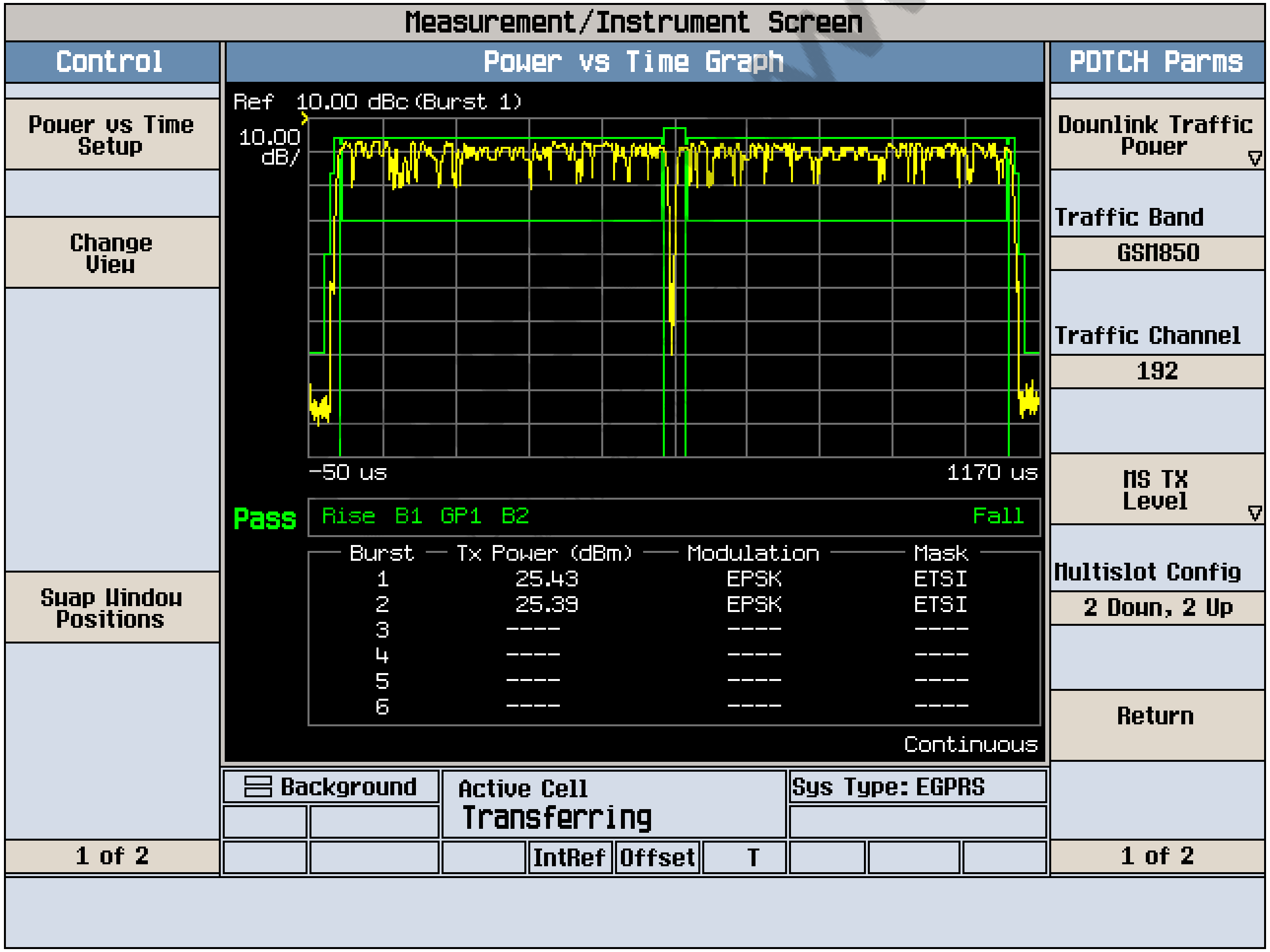
1. These are supported by QTI chipsets.

Power Control Requirements – GMSK vs. 8-PSK



GMSK Power vs. Time





Note: The ramp profile is determined at the baseband I and Q level with a linear power amplifier (PA) instead of with the Vramp signal, as is the case with a polar PA. Therefore, the ramp is already defined before the signal reaches the PA and adjustments should not be required.

Mobile Output Power Debugging Steps

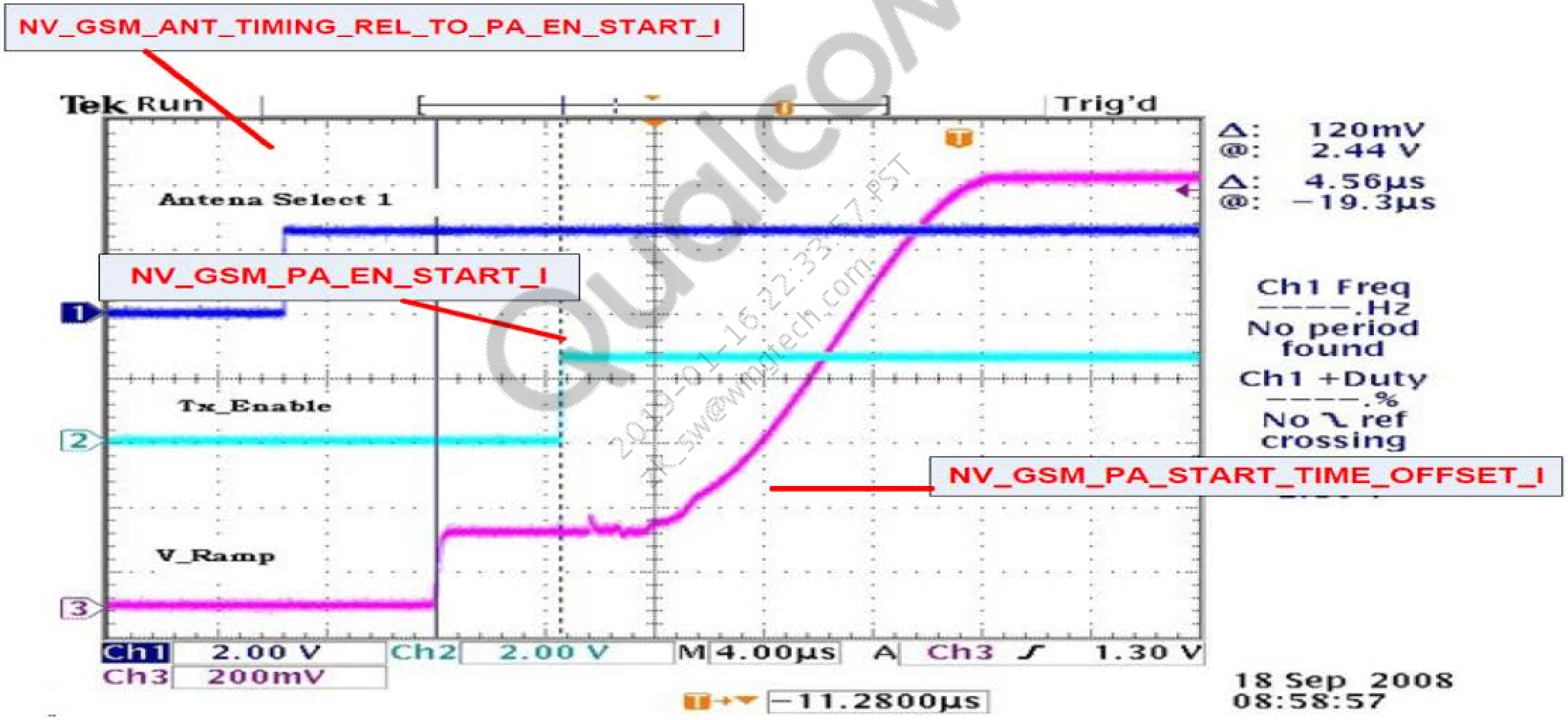
Manual measurement can be done using:

- Spectrum analyzer in fast transfer mode (FTM) (0 Hz span)
- Call boxes in call mode

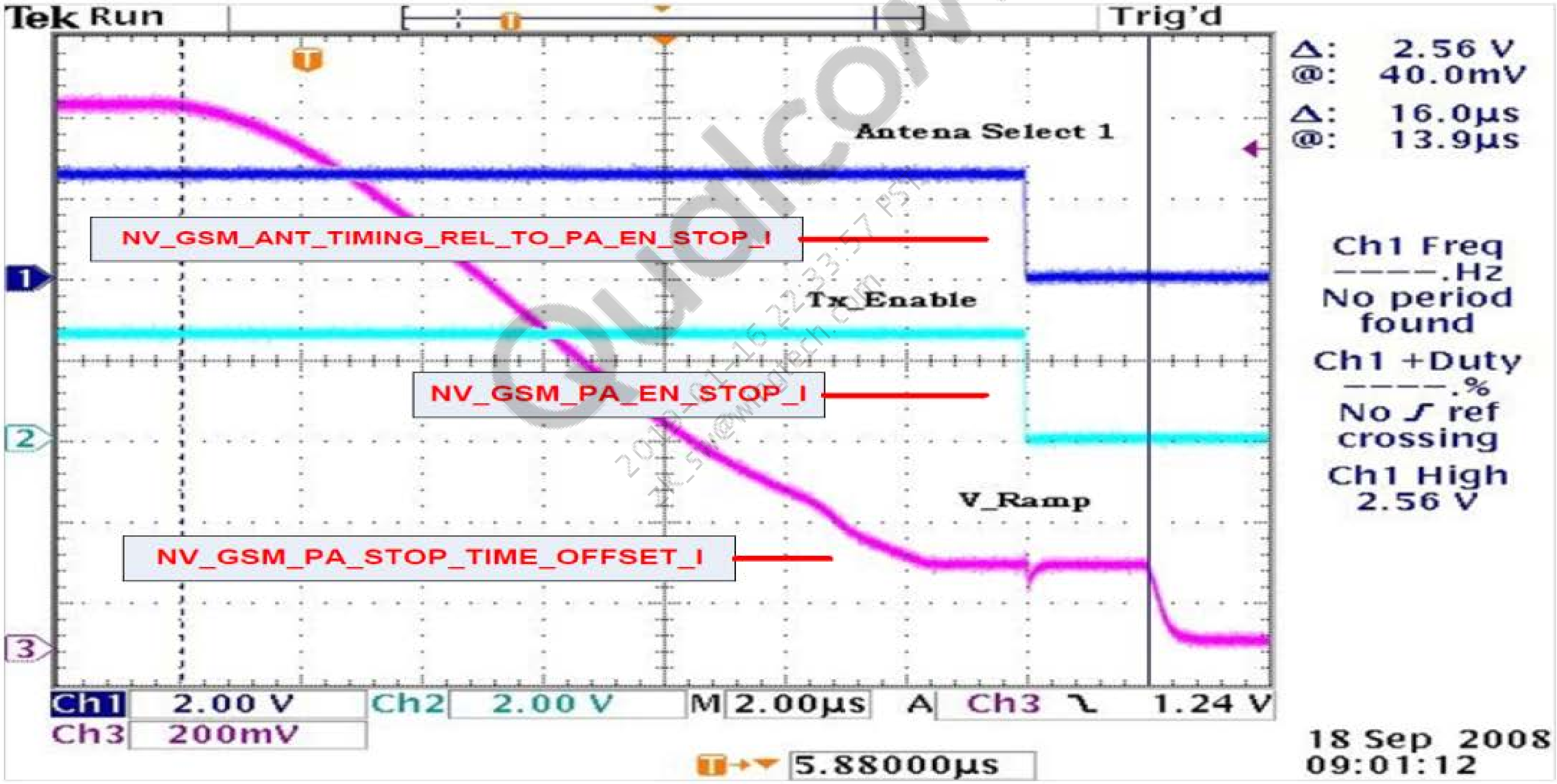
Debugging steps:

1. Ensure the user equipment (UE) has appropriate output power according to the device specification
2. Ensure that the input power to the GSM PA is appropriate according to PA specifications
3. Ensure that the antenna switch is turned on for GSM transmit and in the correct position
4. Verify post-PA losses and PA matching

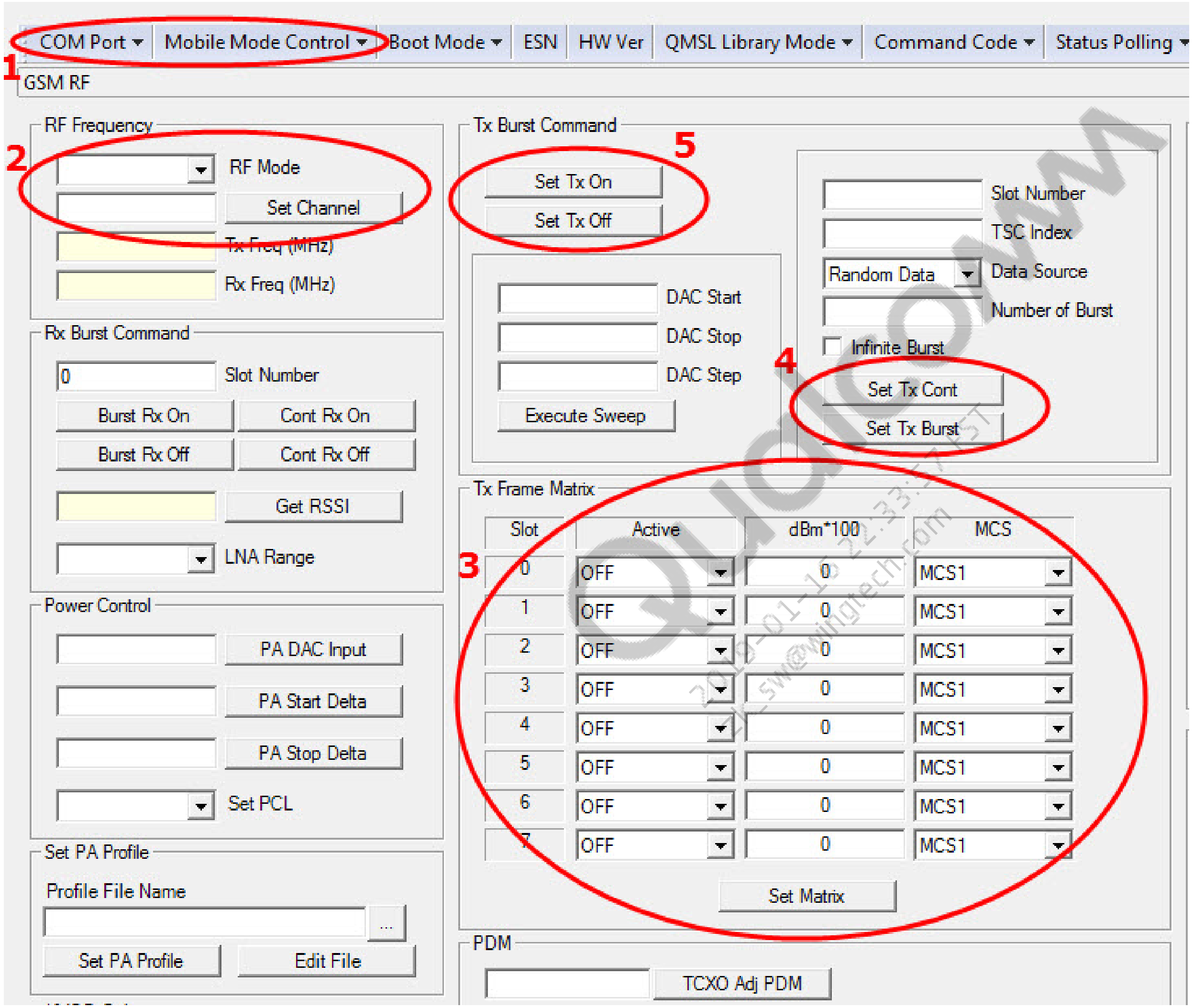
Non-volatile (NV) Items Used to Adjust Control Signals During Burst Ramp-up



NV Items Used to Adjust Control Signals During Burst Ramp-down



Steps for Manually Enabling the Transmitter in FTM Mode (Calibrated Device)

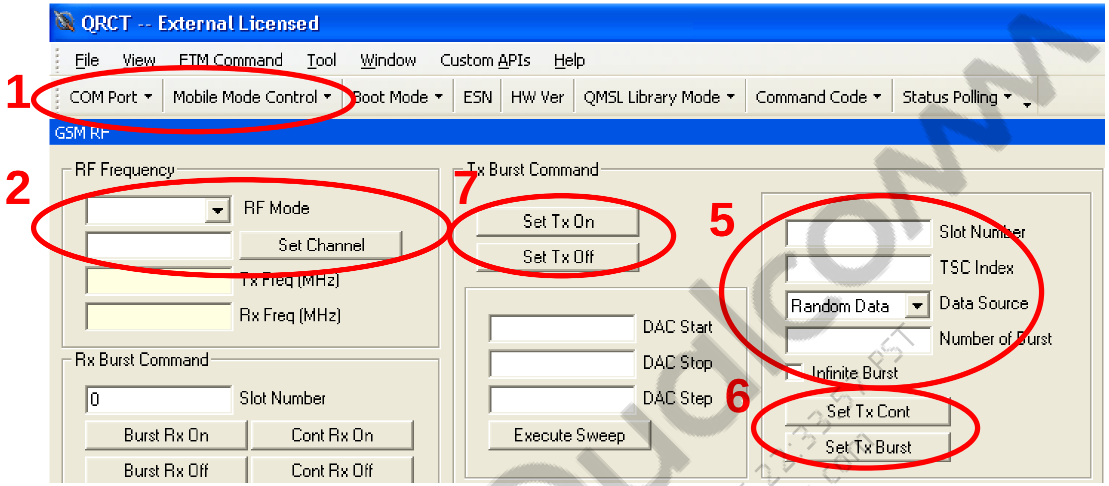


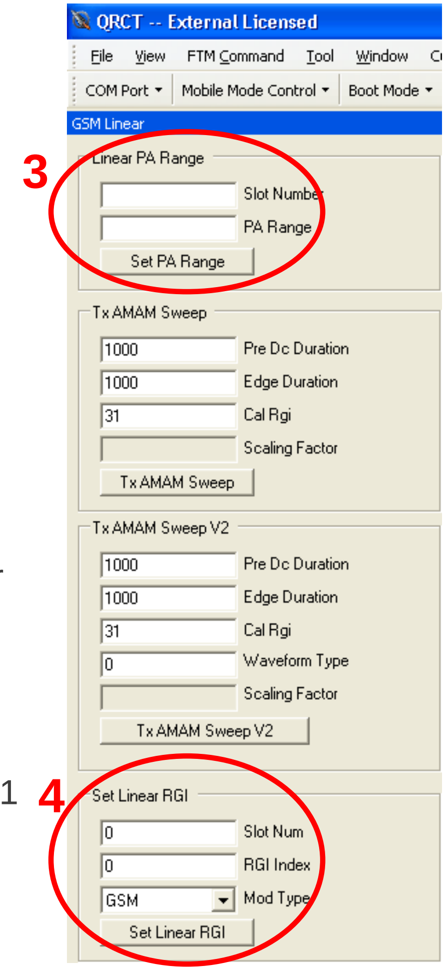
1. Select **COM Port** and set the **Mobile Mode Control** to **FTM** (or set **Boot Mode** to **FTM**).
2. Select the **RF mode** (GSM band) and click **Set Channel**.
3. Set up the **Tx Frame Matrix** by turning on the intended slots, specifying the power in **dBm*100**, and setting the modulation coding scheme (MCS5 and above is 8-PSK).
4. Click **Set Tx Cont** or **Set Tx Burst**.
5. Click **Set Tx On**.

Notes:

1. This procedure requires the device to already be RF-calibrated as the Tx frame matrix relies on the calibration data.
2. If the device is reset, all of the commands need to be sent again.
3. Leaving the transmitter on *Tx Cont* at maximum power for extended periods may damage the PA.

Steps for Manually Enabling the Transmitter in FTM Mode (Un-calibrated Device)



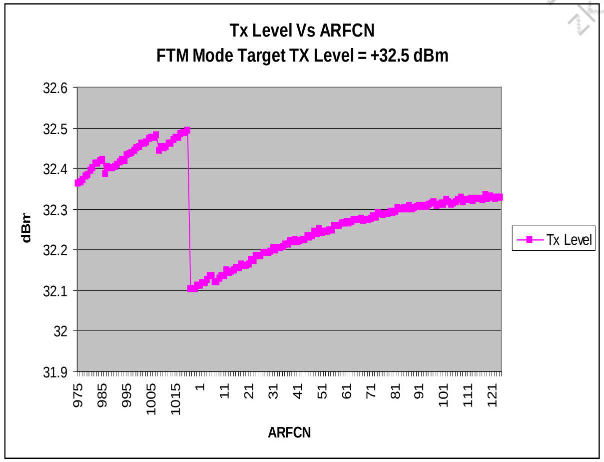


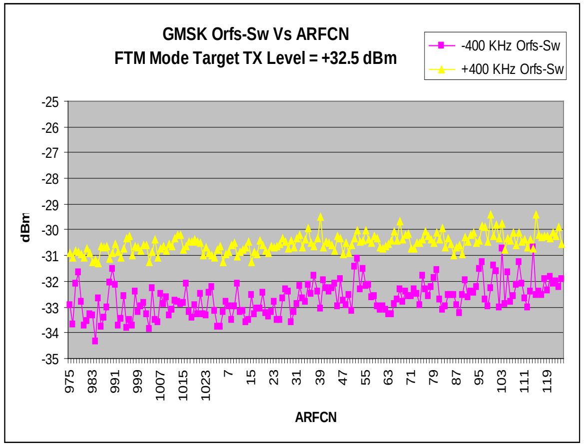
1. Using QRCT, select the **COM Port** and set the **Mobile Mode Control** to **FTM** (or set **Boot Mode** to **FTM**).
2. Select the **RF Mode** (GSM band) and channel, and click **Set Channel**.
3. Specify the **Slot Number** and **PA Range** (PA range 0 is highest).
4. Specify the **Slot Num**, **RGI Index**, and **Mod Type** (the RGI range is 0–31, with 31 being the maximum power from the RF chip).
5. Set up the Tx burst by specifying the **Slot Number**, **Data Source**, **TSC Index,** and select **Infinite Burst** or specify the **Number of Burst**. The TSC index (0–7) selection should be same setting as the call box in non-signaling mode.
6. Click **Set Tx Cont** or **Set Tx Burst**.
7. Click **Set Tx On**.

Tx Power Accuracy (1 of 2)

The following is an explanation of some common contributors to Tx power errors:

- Interpolation between RGIs on a calibration channel (affects PCL-to-PCL accuracy)
- Interpolation between RGIs channel-to-channel (affects accuracy within a PCL across channels)
  - Linear PA Tx level accuracy may not be as tight when compared to polar PA implementations. With a polar PA design, the Tx level accuracy can easily be within ±0.20 dB. With a linear PA system, there can an error up to ±0.5 dB. This is not a problem however, because it is still well below the GSM specification in nominal conditions of ±2 dB.
  - During a GSM call or low-power EDGE call, the RGI that is closest to the intended power is chosen. Between RGIs, the digital baseband scaling is used to adjust the power. The digital baseband algorithm assumes a linear progression between RGI settings and this can introduce a slight amount of error.
  - As the frequency varies, the RGI value may change to account for output power variations across frequency. This can result in a small error in power.
  - The same phenomenon is also seen when changing Tx power from one PCL to another.





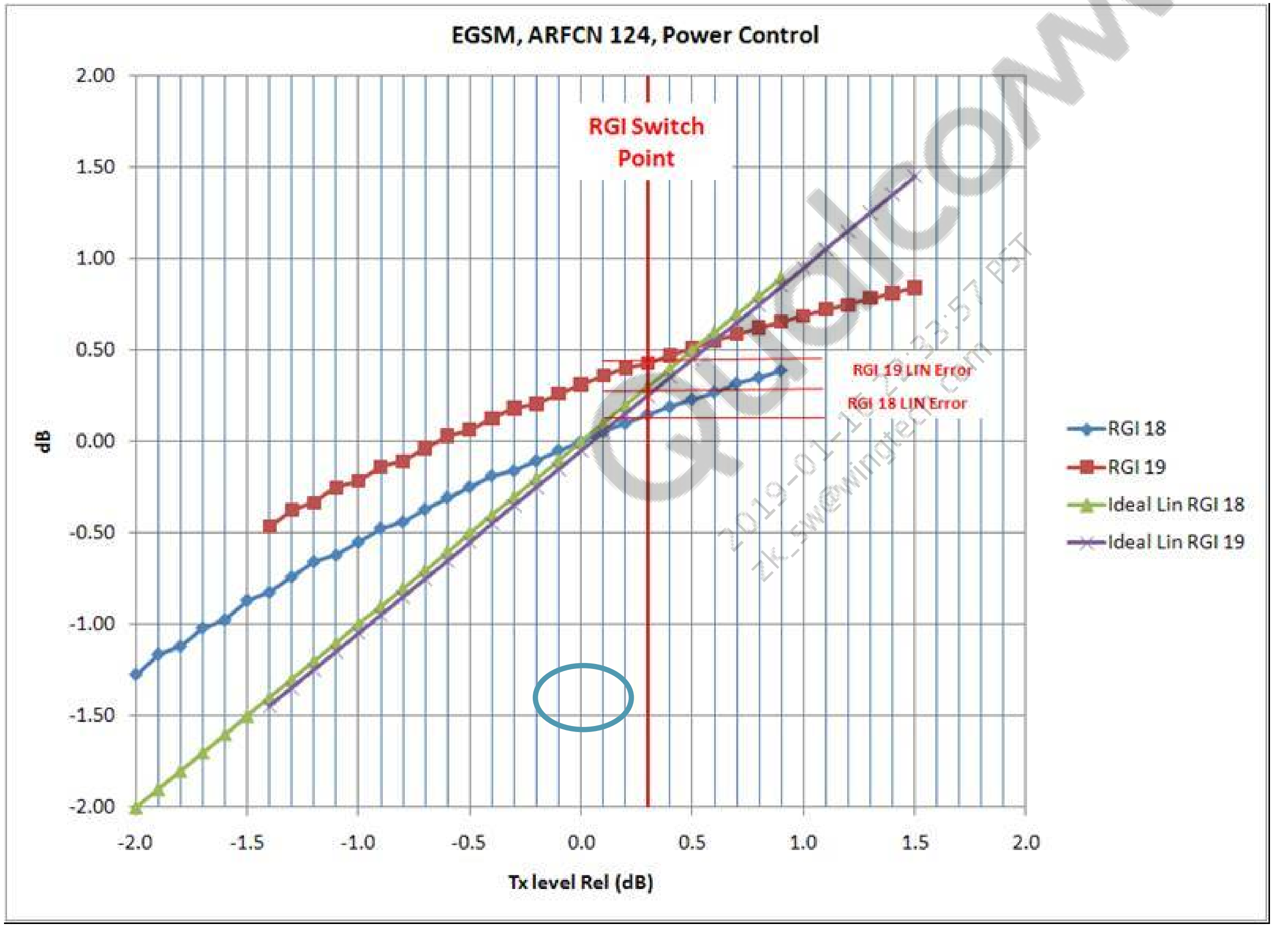
The output RF spectrum (ORFS) should not be impacted.

Tx Power Accuracy (2 of 2)

Additional errors can result from distribution amplifier (DA) compression at higher RGIs. This can be mitigated by flattening the RGI table to prevent operation at higher RGIs.

- Normally, NV_GSM_850_RGI_G0_F[1:3]_I is filled with RGI elements 0–31, however some PAs and hardware configurations that go all the way up to 31 can drive the PA too hard during calibration and damage the PA. To limit the RGI sweep below 31 (once the upper limit is determined, maximum Tx power is allowed with some margin and without damaging the PA), the value 0xFF can be populated in the unused elements of this NV item. If calibration is performed with QSPR, this change can be made in the properties dialog box of the test tree. Note: NV_GSM_850_RGI_G0_F[1:3]_I is obsolete for current chipsets. Its functionality is now included in the Tx calibration NV RFNV_GSM_Cx_GSM<band>_TX_CAL_DATA_I. Refer to the appropriate NV document for specific chipsets.
- If power level accuracy is worse than ±0.5 dB, it could be because of DA calibration accuracy degradation. This can result if the XO or TCXO frequency has a large error of a few kHz. This can be easily ruled out by testing the frequency error in FTM and checking the frequency accuracy with a spectrum analyzer. To ensure that the XO frequency is accurate, it is important to calibrate the XO before calibrating GSM. Since GSM calibration is done with a very narrowband signal, even a small amount of frequency offset can affect the calibration significantly. This is not applicable to designs using TCXO.

Tx Power Error Source Graphic Illustration



The non-ideal linearity of each RGI causes the power jump when switching between RGIs.

While this should not cause failures in the maximum Tx power or relative PCL accuracy specifications, it can be a problem in maximum GMSK power if it becomes necessary to back off maximum Tx power to prevent radiated emissions failures.

To improve this issue, the RGI slope can be calibrated out for the top two PCLs – this requires change request (CR) 263466.

Compensation to RGIs 14 and above may be required depending on PA gain.

This CR fix does not require recalibration of the phone, but uses data characterized over several phones. Refer to the *RF Calibration Training Topics – Select Chipsets* (80-VP447-29) for more details.

Deriving the Compensation

- Perform DA calibration with NV item 5477 (NV_GSM_LINEAR_TX_GAIN_PARAM_I) = 165.
- Perform DA calibration with NV item 5477 (NV_GSM_LINEAR_TX_GAIN_PARAM_I) = 147 (this value can be fine-tuned for each RGI).
  - It is mandatory to performing the above steps using the same test station to eliminate any calibration error contributions.

- Derive the digital baseband (BB) gain slope correction coefficients using the following formula:

  digBB_SlopeComp (fi, RGI) = 1024 * (1/POUTo(fi, RGI) – POUT1(fi, RGI)))

  fi = calibration channel index

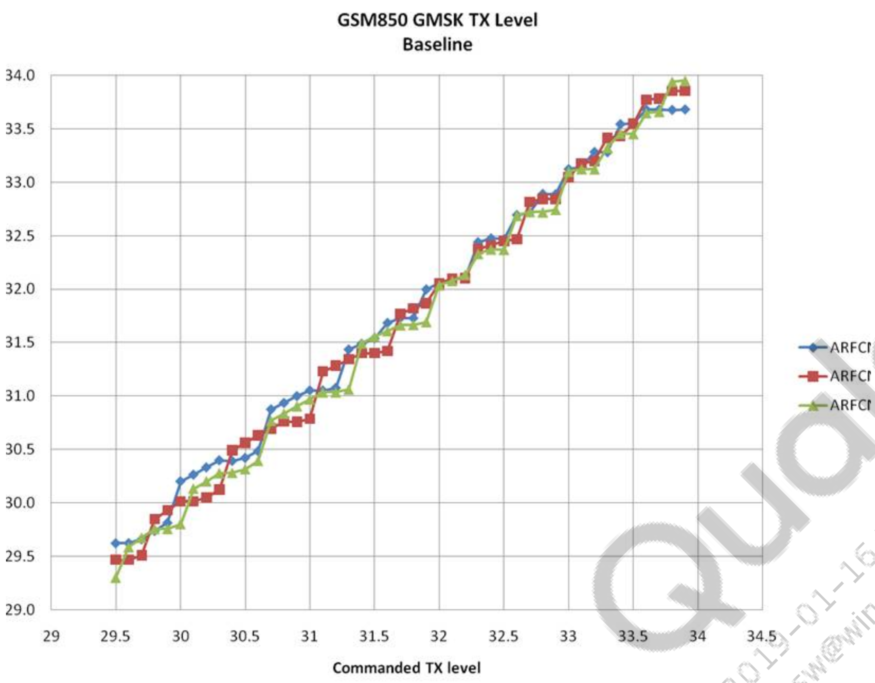
  RGI = RTR gain index

  POUTo(fi, RGI) = GMSK, PA_RANGE0, Tx output power with default digital gain NV = 165

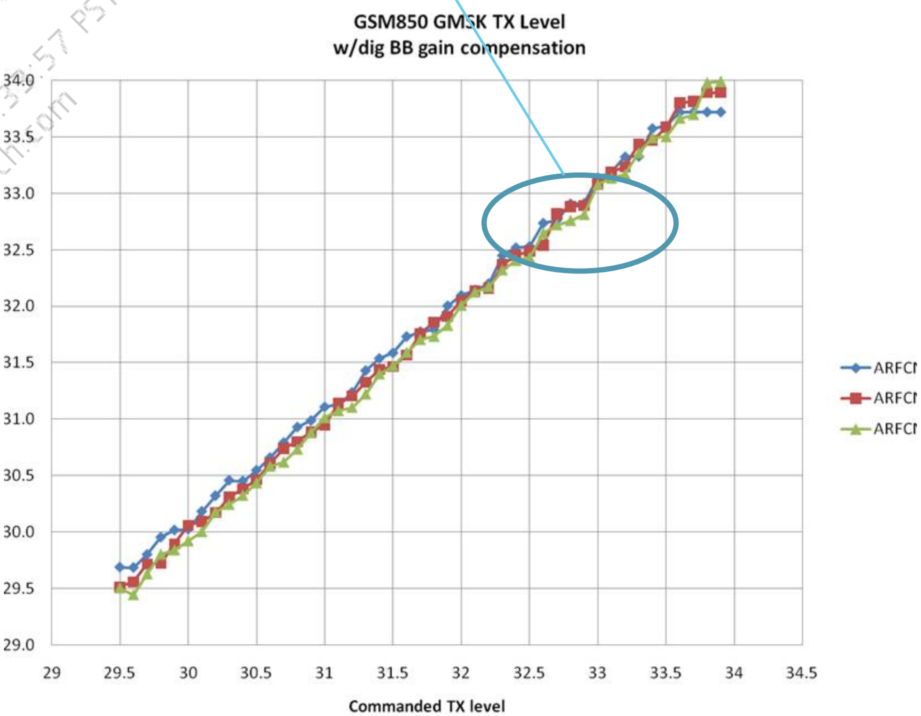
  POUT1(fi, RGI) = GMSK, PA_RANGE0, Tx output power with 1 dB less digital gain NV = 147
  - This procedure is explained further in the *RF Calibration Training Topics – Select Chipsets* (80-VP447-29).

Note: Only run the GSM Tx calibration node to get these values; do not write the NV values to the phones (the test tree is only to get the values). The NV items and procedure mentioned above are specific to MDM9x15 and prior chipsets. Use the appropriate NV item document for specific chipsets. The principle of deriving compensation remains the same. For example, refer to the *Application Note: Comprehensive List of MDM9x35M/MDM9x30/MDM8x30/MSM8994 Family RF NV Items* (80-NH377-170) for MDM9x30/MDM9x35 NV items.

Comparison Before and After the Compensation



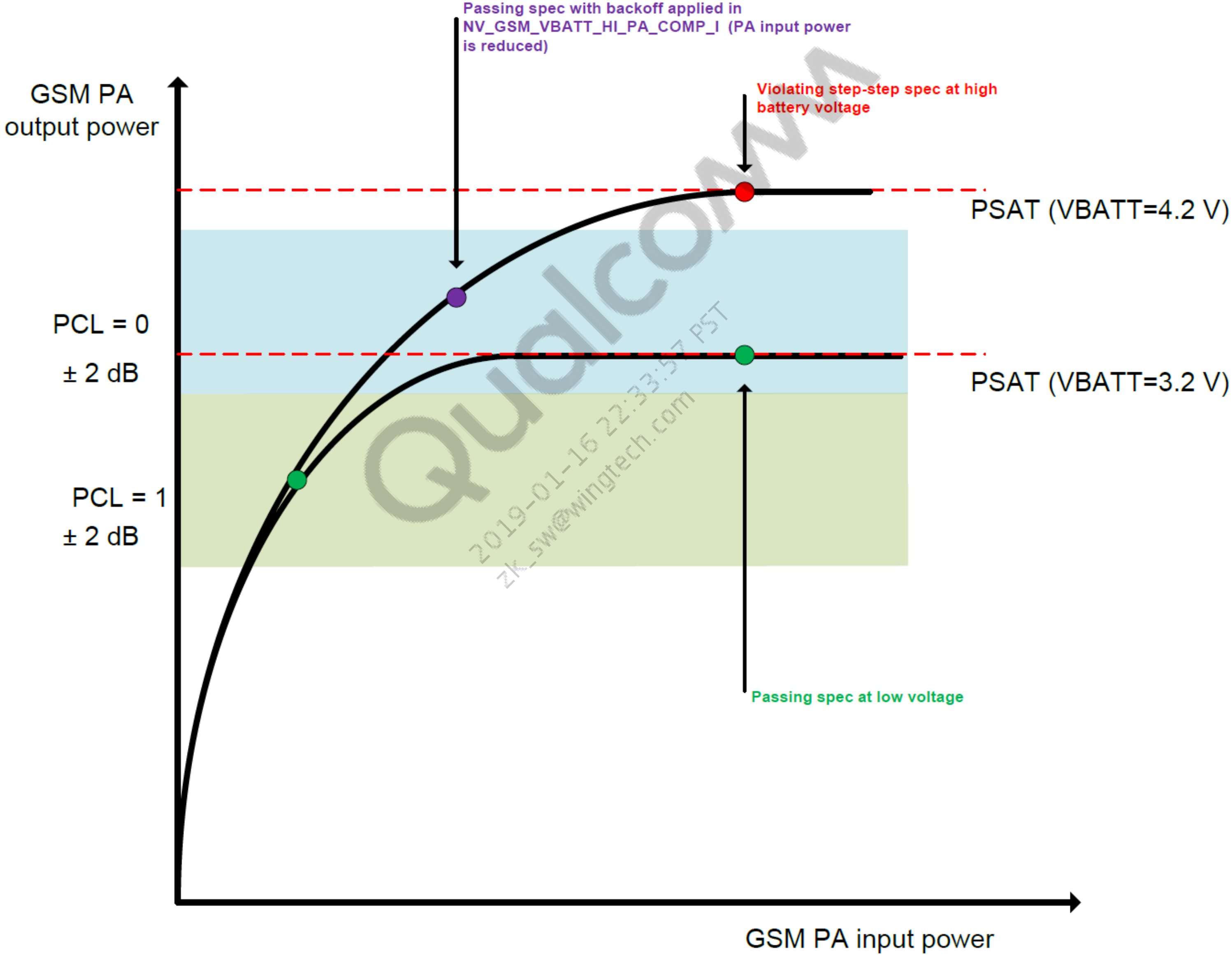
The slope may need to be fine-tuned here to get better power accuracy.



GSM Output Power Variations with Supply Voltages

- Description
  - The output power drops approximately 1 dB when varying supply voltage from 4.2–3.6 V.
- Recommended debug steps
  - The PA is already operating in a compression for a +32.5 dBm Tx level, thus increasing the VBATT level increases the Tx level for same DA output power.
  - In order to minimize the Tx level variation, customers should ensure that the PA match is optimum and the saturated power (PSAT) is > +33.5 dBm (PSAT of 0.5 dB above intended maximum power is required to meet GMSK switching ORFS).
  - This can be measured by forcing the DA to maximum power by commanding +35 dBm in FTM mode using the QRCT user interface (see the QRCT screenshots on the GMSK Power vs. Time and 8-PSK Power vs. Time slides).
  - The higher the PSAT, the less variation there is on the Tx level with a higher VBATT.
  - Keep in mind that the Tx level specification is +33.0 dBm ± 2.0 dBm for PCL5 at ambient temperatures.
  - If enough of a margin in PSAT cannot be achieved, it may be necessary to back off the Tx power at high voltages (the power at low voltage cannot be increased if saturation is reached).

GSM Output Power Variations with Supply Voltages – Back Off at High Voltages Example



GSM Output Power Variations with Temperature

- The primary NV item for GSM compensation is RFNV_GSM_Cx_GSM<band>_TEMP_COMP_I :
  - Scaling data: This element specifies the percentage of ΔHOT_NV and ΔCOLD_NV to be applied at each of the 16 thermistor ADC bins. The range (in units of percentage) of each element is from -100% to 100%. Refer to the *Application Note: Comprehensive List of MDM9x35M/MDM9x30/MDM8x30/MSM8994 Family RF NV Items* (80-NH379-170) for details.
- This NV also has elements for GSM/EDGE temperature compensation.
  - hot_temp_comp_pcl_pwr_offset_gmsk
  - cold_temp_comp_pcl_pwr_offset_gmsk
  - hot_temp_comp_pcl_pwr_offset_8psk
  - cold_temp_comp_pcl_pwr_offset_8psk
  - They store the magnitude (absolute value) of the power delta for each PCL at hot and cold temperatures (maximum and minimum temperatures of interest) relative to the room temperature for GSM/EDGE. Each element corresponds to a particular PCL. Units: absolute value (i.e., unsigned), |dB × 100|.

Note: This NV can be overridden by the enhanced temperature compensation feature. Refer to the *Application Note: Comprehensive List of MDM9x35M/MDM9x30/MDM8x30/MSM8994 Family RF NV Items* (80-NH377-170) for more details.

Section 4

ORFS

ORFS Modulation Debugging Steps

The ORFS at 400 kHz offset is usually the most difficult to meet.

- First compare the output spectrum for different power levels.
  - If the failure is at maximum power and improves as power is reduced, the issue is likely layout-dependent (including matching). The GSM PA and the radio-frequency transceiver (RTR) need to be in separate shields.
  - If the issue is not power level-dependent, then go to the next step.
- Check the local oscillator (LO) phase noise at 400 kHz offset, it should be better than -118 dBc/Hz, see slide 34 for detailed derivation.

8-PSK problems are usually pre-distortion calibration problems.

- Ensure that the calibration is done with the latest version of QDART and the latest test tree.
- Ensure that the timing delay values have been characterized.

For ORFS modulation at SMPS switching frequency:

- First, attempt to isolate where the noise gets into the GSM transmit path. Put a launch at the RF chip output and directly measure the output spectrum at the RF chip output without the PA. If the switching noise is still there, then it points to the noise being coupled into the transmit path through the RF chip. Verify that the proper star routing has been used.
- If the switching noise is improving, it points to the noise being coupled into the transmit path through the PA and control signals.

Timing Delay Calibration

- The existence of two separate waveform paths through the device can lead to different signal delays on the phase path and envelope path and can affect the waveform quality.
- For phase and envelope paths to remain in sync, delays between the two paths need to be calibrated and compensated.
- The best-case delay is determined by finding the delay value that results in the lowest ORFS due to modulation measurements at +400 kHz and -400 kHz. The ORFS due to the modulation value tied to each delay is the worst +400 kHz and -400 kHz offset.
- NV items that store the delay:
  - RFNV_GSM_Cx_GSM<band>_POLAR_PATH_DELAY_I

Note: A timing delay calibration is required for both polar and linear PA designs even though the phase and amplitude paths are combined inside the device for linear PA designs. However, this delay is more repeatable between devices for linear PA implementations. **To determine if the delay can be a static value, QTI recommends verifying that an adequate margin in ORFS due to modulation is available across the range of possible delay values for several units.** The timing delay is only one factor that influences ORFS modulation performance.

400 kHz Phase Noise Requirements Meeting ORFS at 400 kHz

Variables

- The GSM ORFS modulation measurement bandwidth = 30 kHz.
- The GSM power bandwidth = 200 kHz
- The target ORFS modulation is 65 dBc (5 dB of margin) for GMSK at ±400 kHz offset.
- The target ORFS modulation is 59 dBc (5 dB of margin) for 8PSK at ±400 kHz offset.

Calculation

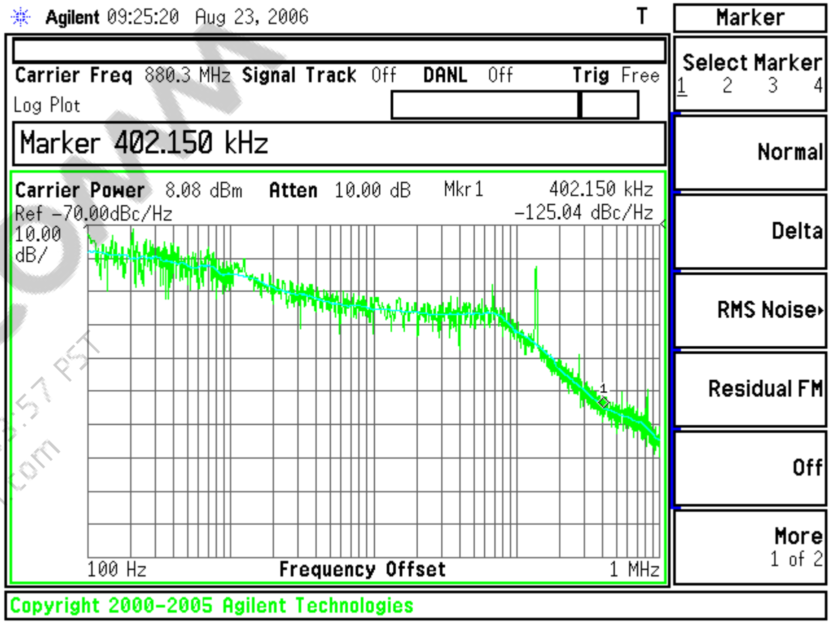
- Maximum phase noise at 400 kHz = 65 + 10 log (200/30) + 10 log (30000) = 118 dBc/Hz.

Phase Noise Verification

1. Open FTM-GUI.
2. Set the **Tx level** to +20 dBm to avoid the PA overheating.
3. Select **Channel**.
4. Set **Tx** to continuous mode.
5. Use a 67 kHz CW tone modulation.

See the Steps for Manually Enabling the Transmitter in FTM Mode (Calibrated Device) slide. CW tone can be set by changing random data to tone in the Tx burst command window.

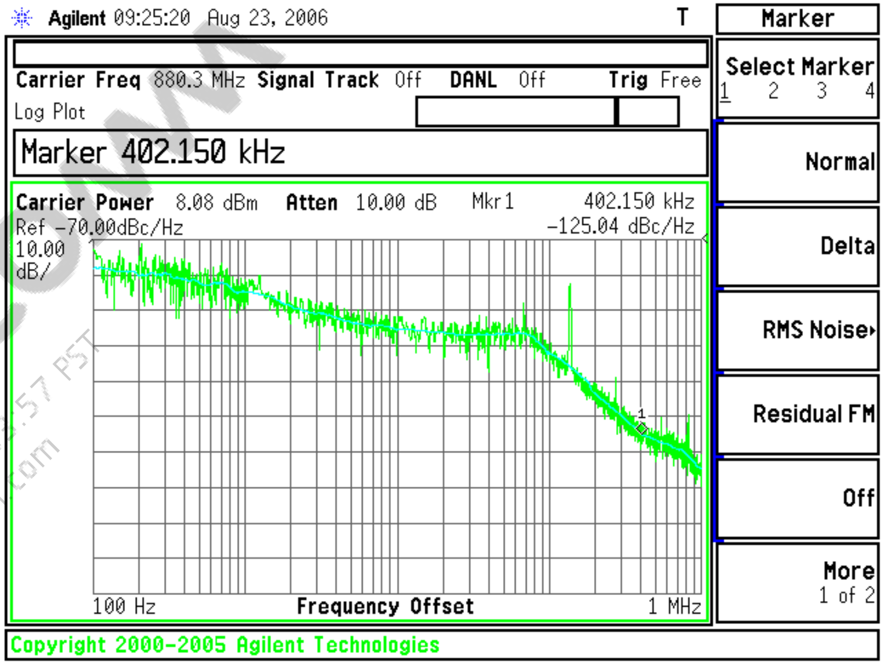
Typical phase noise example:



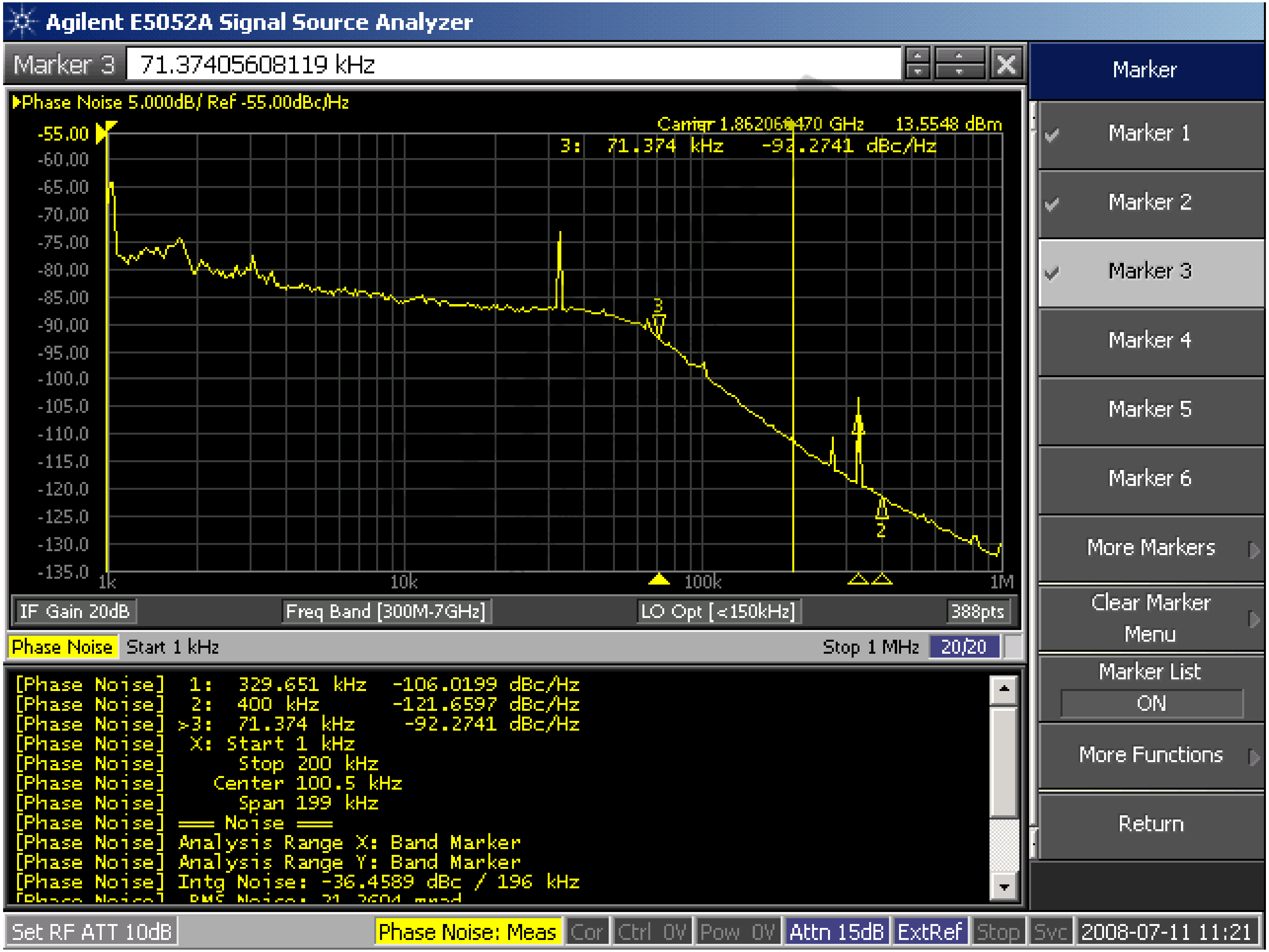
Phase Noise Contribution to GMSK ORFS Modulation at 400 kHz

- Phase noise at 400 kHz and integrated in a 30 kHz bandwidth can be significant for ORFS modulation.
- The phase noise is integrated in 30 kHz because this is the standard bandwidth for the ORFS modulation measurements as defined by the European Telecommunications Standards Institute (ETSI).

Typical phase noise at ±400 kHz:



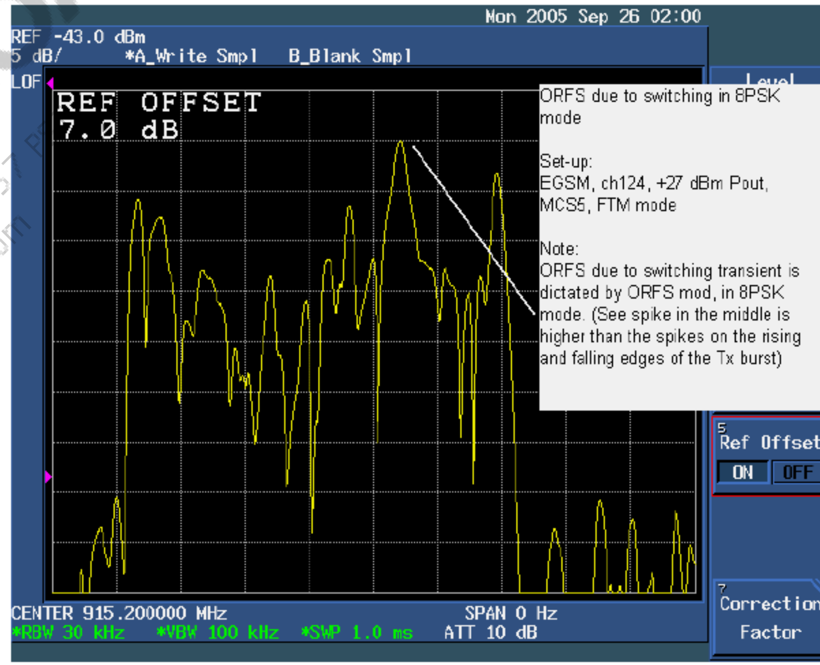
Integrated Phase Noise Measurement



GSM ORFS Switching Debugging

- GMSK failures are usually due to either low PA power or improper ramping profiles.
  - Ensure that phone can deliver +32.5 dBm (maximum power) over temperature (targeted maximum power of +0.5 dB).
  - The ramp profile should be per the QTI static Qualcomm® combined NV (QCN) file.
  - If needed, optimize PA matching to deliver maximum power.
- For 8-PSK modulation, since it is a non-constant envelope, both the ramping part and the modulation part influence the ORFS due to switching performance. This makes the 8-PSK ORFS switching specification even harder to meet than the GSMK switching performance, although it is at a lower maximum output power level.
  - Verify that calibration has been performed with the latest version of QDART (including the swapped predistortion waveform).
  - If the spectrum is asymmetric over temperature (± offsets unequal) tuning **RFNV_GSM_Cx_GSM<band>_AMAM_TEMP_COMP_I** may help.
    - Refer to the *Application Note: Using a Linear PA for GSM Applications* (80-VF846-14) for details.
    - This is typically seen over temperature.
  - ORFS switching can also be affected by power supply noise, see the Modulation Accuracy and Frequency Error Specifications slide for further details.

ORFS Switching for 8-PSK and GMSK Comparison



For GMSK, if peaking is in the middle, it points to a real problem; see the Modulation Accuracy and Frequency Error Specifications slide for further details.

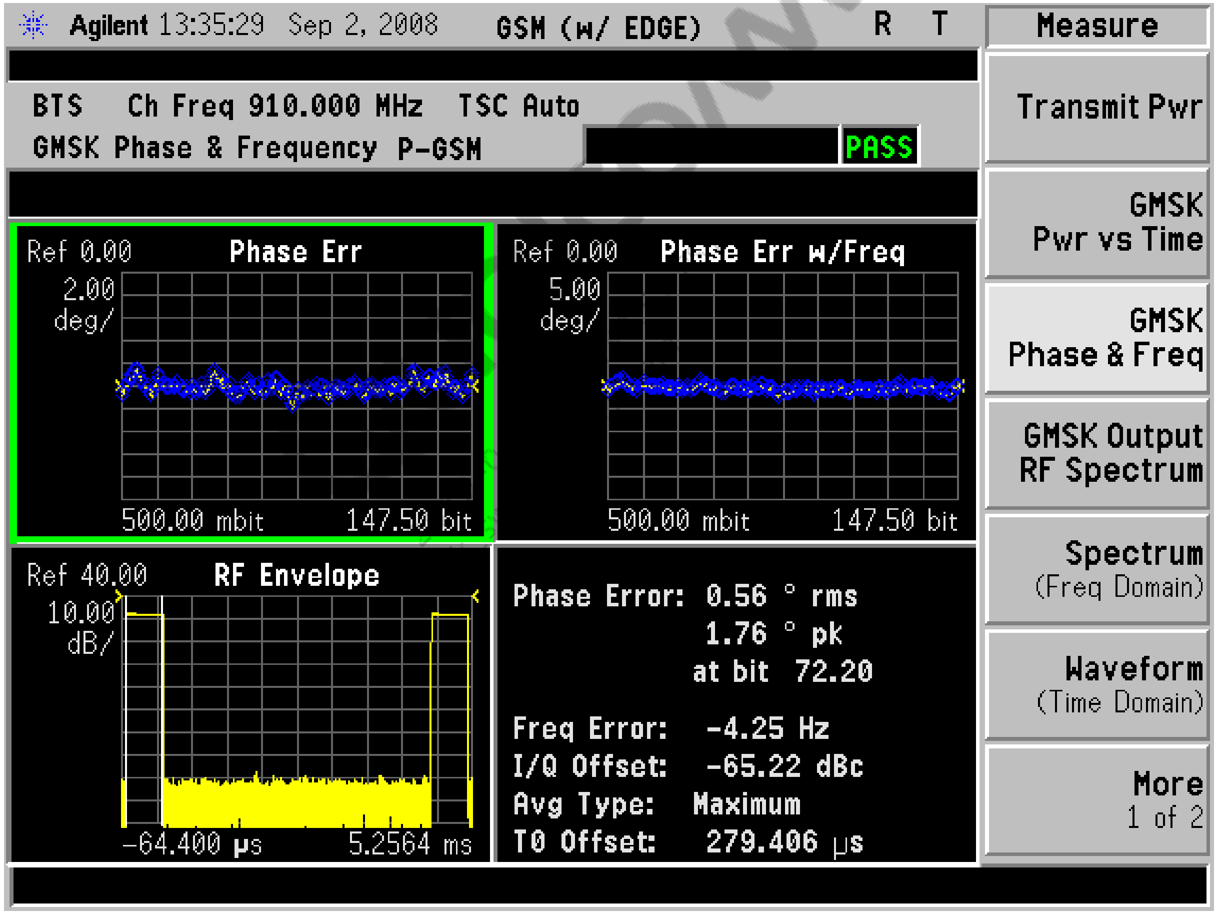
Section 5

Phase and Frequency Error

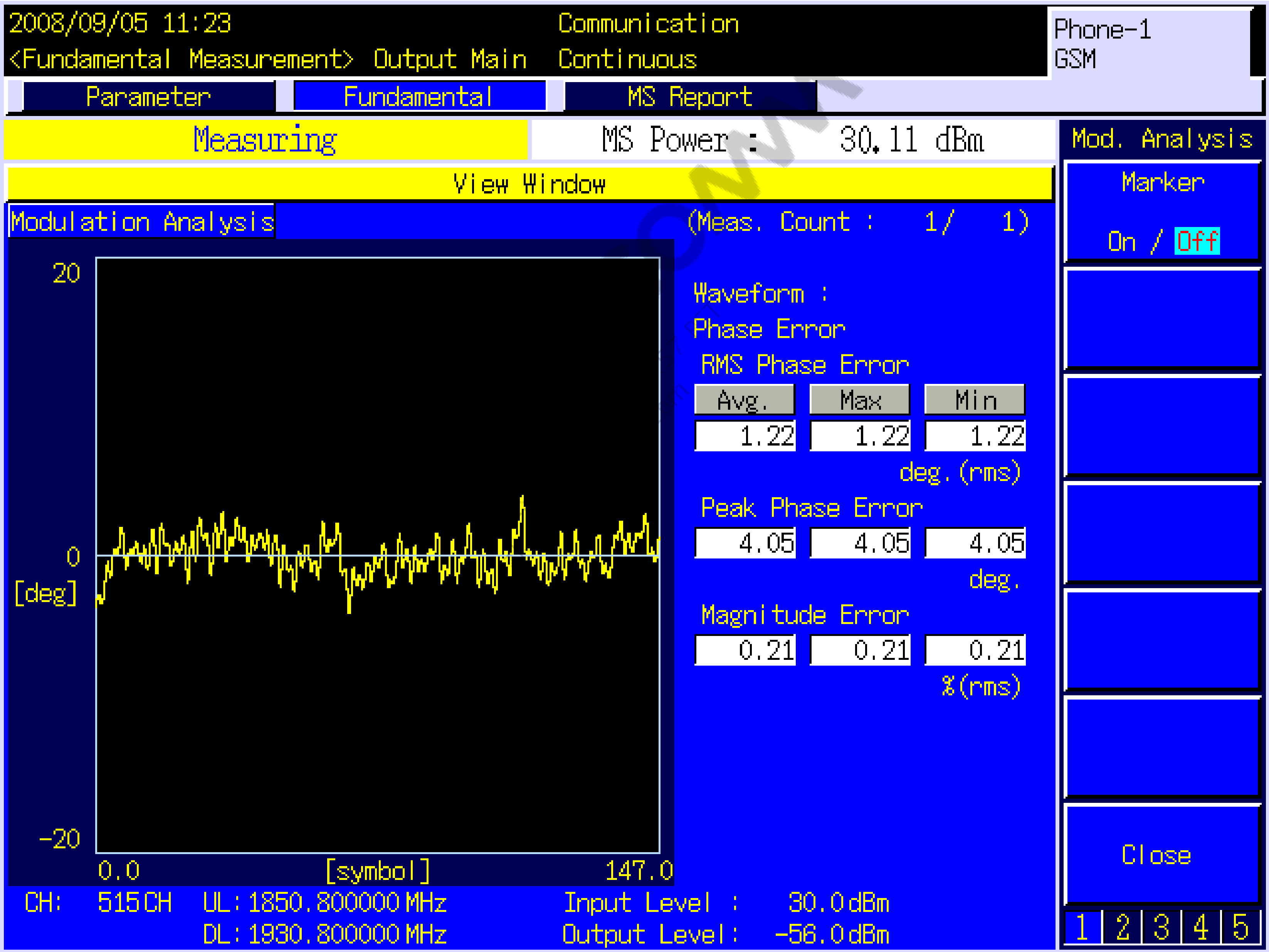
Modulation Accuracy and Frequency Error Specifications

- GMSK – the root-mean square (RMS) phase error shall not exceed five degrees and the peak phase error shall not exceed 20 degrees.
- 8-PSK modulation
  - RMS error vector magnitude (EVM) < 9% nominal and < 10% for extreme conditions
  - Origin offset suppression > 30 dB for all conditions
  - Peak EVM < 30%
  - 95th percentile EVM < 15%
- Frequency error
  - Mobile transmit frequency is specified within ±0.1 ppm of the base station frequency (around 90 Hz for low bands and around 190 Hz for high bands).
- ETSI specifies that phase and frequency errors are to be measured during the duration of a single burst.
- Most equipment can report minimum/average/maximum statistics over multiple bursts. Always use the maximum result to judge the frequency error.
- It is good practice to test more than one burst in order to catch random frequency error failures.

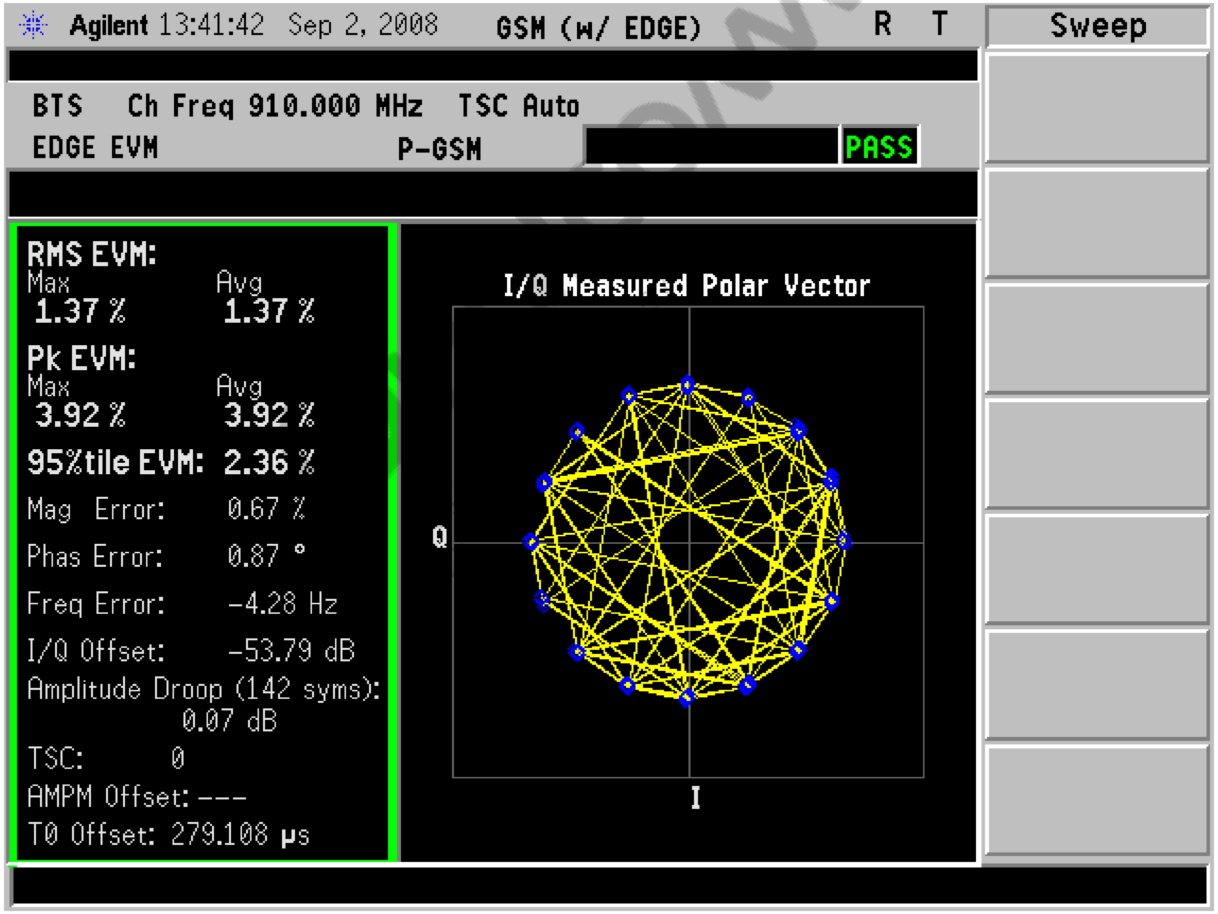
GSM RMS Phase Error and Frequency Error



GSM RMS Phase Error



EDGE EVM on a Vector Signal Analyzer (VSA)



GSM Peak-phase Error and 8-PSK Peak-EVM Debugging

- If there are any other circuits that are sharing the supply with the RF chipset's supplies, use star routing as much as possible.
- Any supply disturbances caused by on/off activities (PA being turned on or off, codec or Bluetooth) could directly convert to peak-phase and EVM issues.

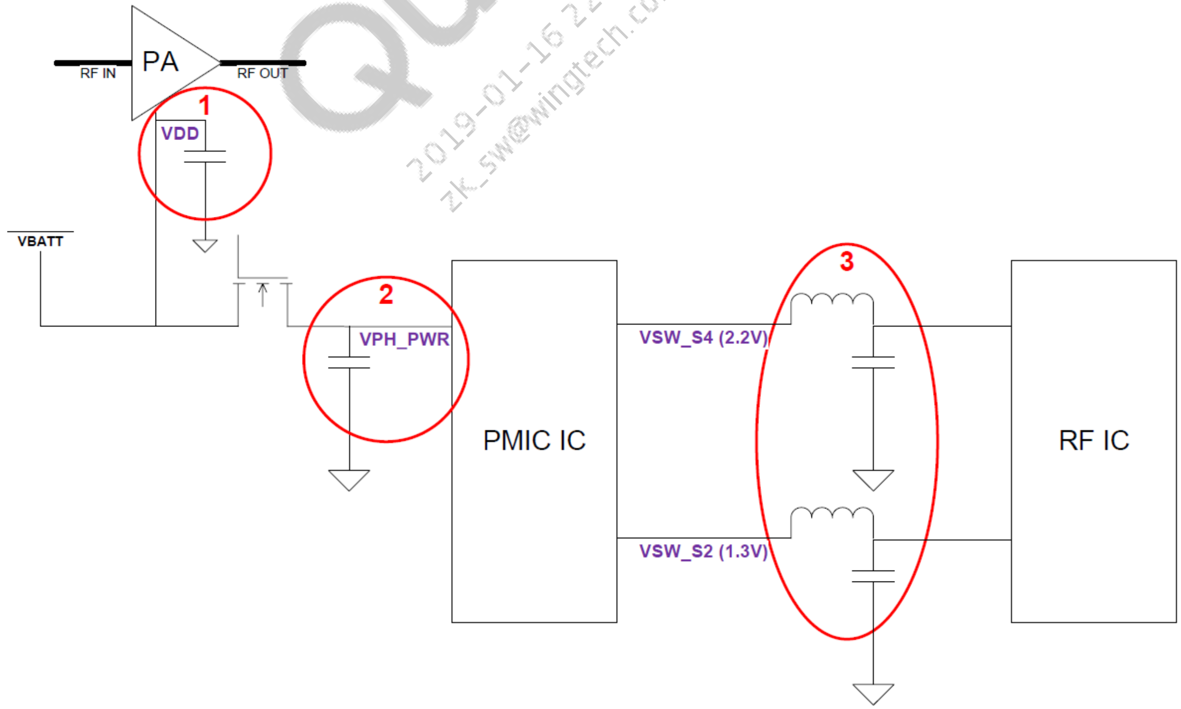
To minimize the supply disturbances:

- A large capacitor at VPH_PWR is required.
- Power supplies should have adequate decoupling capacitance (refer to reference schematics).
- Star route supply lines as much as possible (see slides 49–51 for details)
- There is a CR fix that makes the TX_PLL supply much less sensitive to the 1.3 V supply disturbances for GSM high bands. The CR fix does not affect low bands.
  - CR 269053 for MDM9xxx
  - CR 266848 for MSM7x30 and MDM6xxx/QSC6xxx
- Suppress PA supply transients at the VBATT input of the power management IC (PMIC) for improved EDGE peak EVM. Refer to the document *PMIC Modifications to Improve RF Performance QSC6xx5, MSM7x30, MSM8x60, MDM6x00, MDM9x00 Chipsets* (80-VK401-21) for more details.

Debugging Steps for a GMSK Phase Error and EDGE EVM (1 of 2)

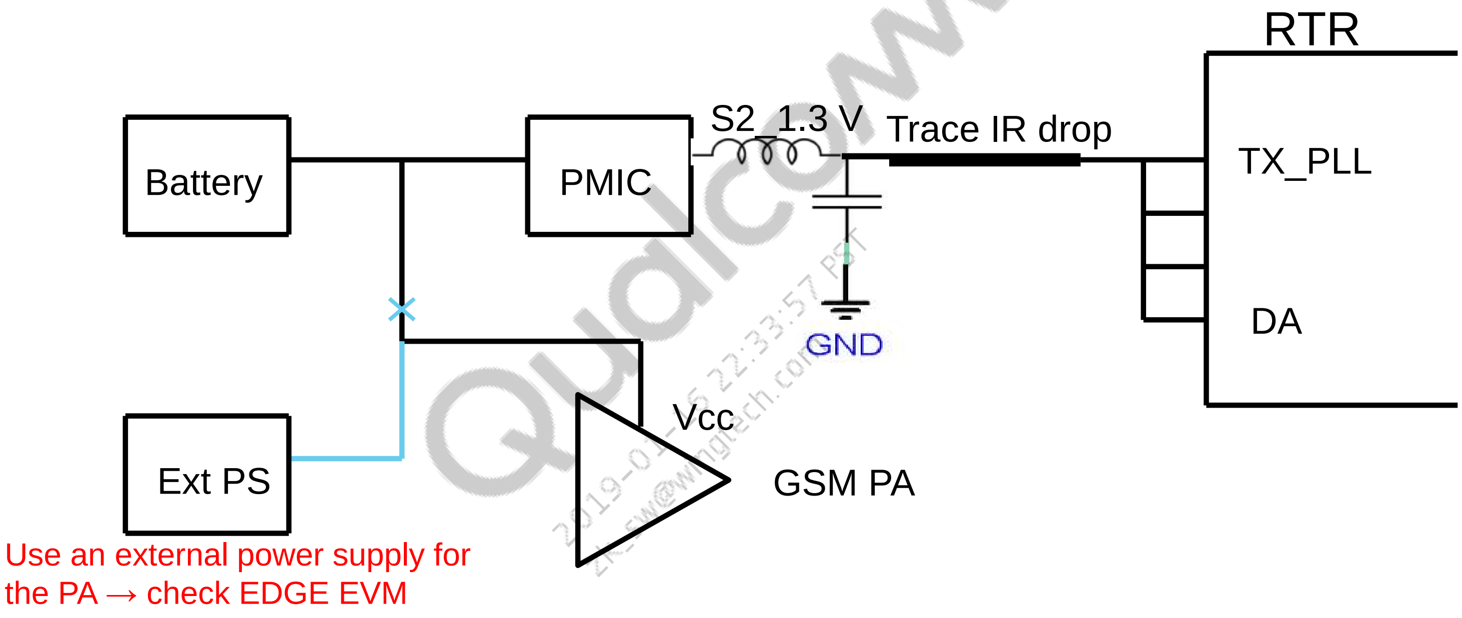
Note: The following steps go over debugging steps for MSM8960 and older chipset families. Although future generations of transceivers have changed in design, the debug methodology remains very similar.

- During the start of a GSM burst, there is a very large switching transient that can disturb the 1.3 V and 2.2 V power supplies to the RFIC. The first step in debugging a GMSK phase error and EDGE EVM is to determine if the disturbance is at the start of the burst.
- If the disturbance is at the start of the burst, it is most likely caused by a high current draw of either the PA or the DA on the supply lines.
- To minimize the pulling effects of the PA, adequate power supply decoupling is recommended in the three locations shown in this diagram. Following the QTI reference schematic is recommended.



Debugging Steps for a GMSK Phase Error and EDGE EVM (2 of 2)

To determine if the power supply disturbance is caused by the PA, QTI recommends disconnecting the PA from the supply on the device and connecting it to an external power supply. The ground should be connected to the PA ground and the supply should be clean.



If the peak EVM and phase error at the start of the burst improve, then the power supply decoupling on the VBATT, VPH_PWR, or VSW_S2 or S4 supplies could be improved. It is also important to minimize the IR drop of high current traces.

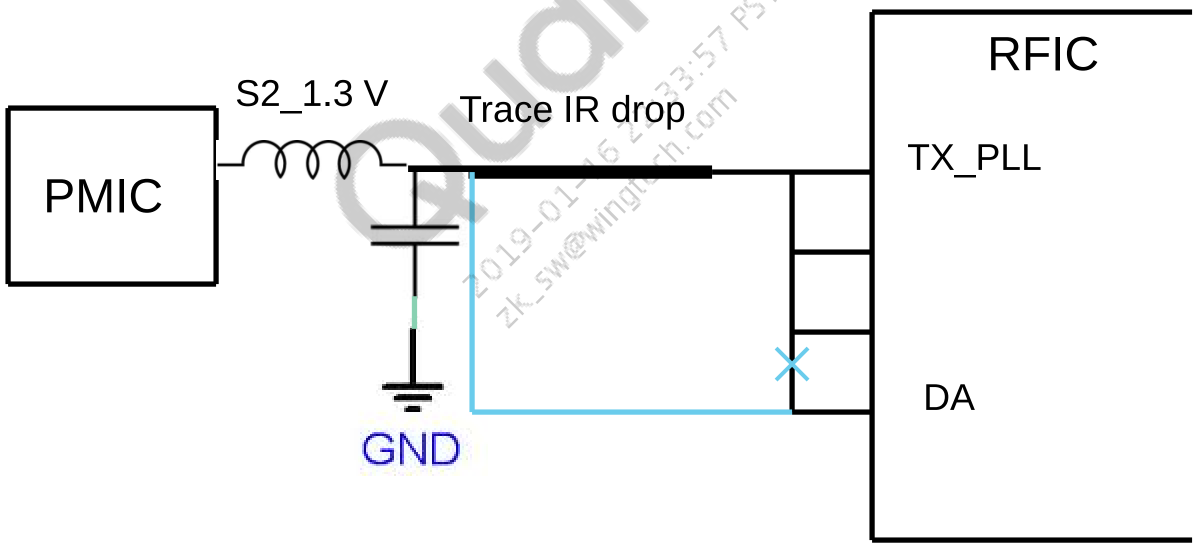
For a comprehensive debugging guide for improving these supplies, view the reference documents listed at the beginning of this document.

If using an external power supply for the PA does not improve the EVM or ORFS performance, further testing of the RF power supplies on the RFIC may be required. See the next few slides for details.

Block Diagram Detailing Separation of Tx PLL and DA Supply Pins

If there is a large IR drop in the 1.3 V trace between the PMIC and the RFIC (i.e., if the PMIC is a long distance from the RFIC), then the extra current draw from the DA supply pin on the RFIC during the start of a GSM burst may pull the Tx PLL supply pin, causing a disturbance in peak phase error or EVM.

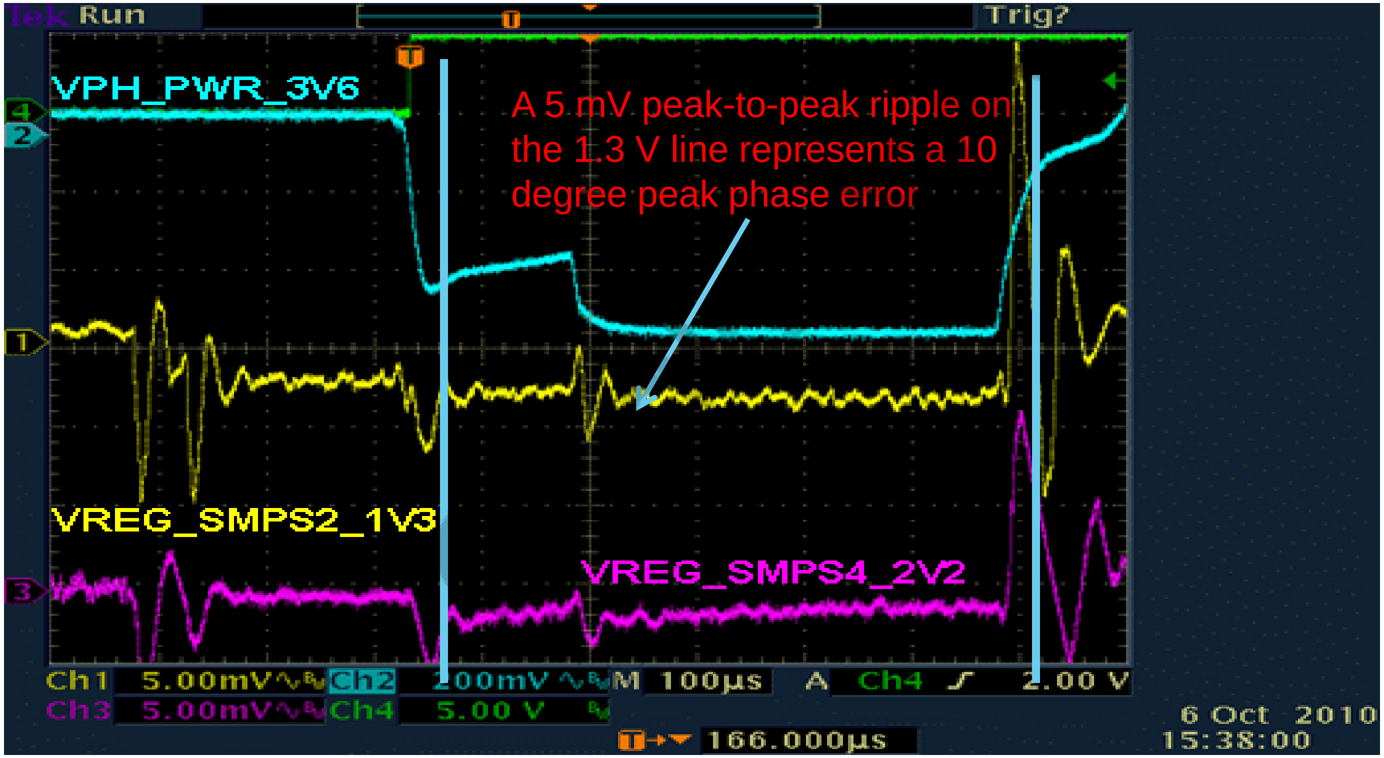
To test this, QTI recommends breaking the connection between the DA supply pin and the Tx PLL supply pin and connecting the DA supply pin closer to the PMIC.



Break the 1.3 V to DA and use star routing from the PMIC buck → check GMSK phase error.

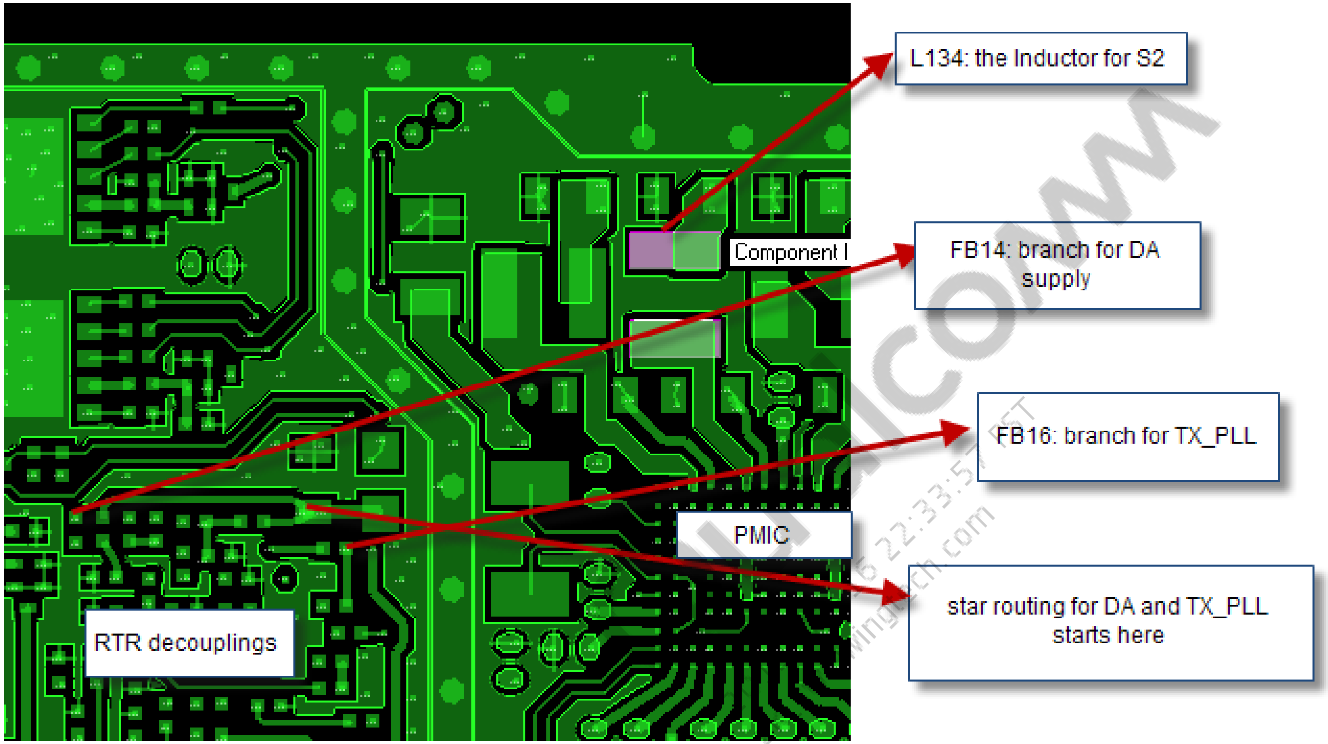
Note: Verify if more decoupling is needed at the DA, if separated.

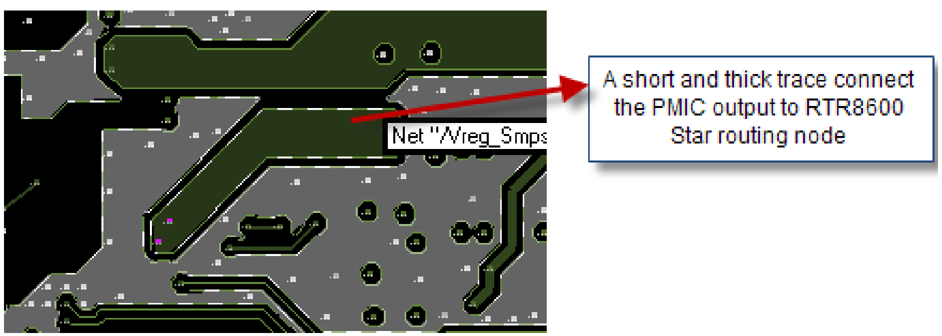
Example FFA Measurement



This diagram shows that any disturbance in the 1.3 V power supply during the GSM burst can cause peak phase error or peak EVM degradation (the red bars indicate the start and end of the burst). A 5 mV peak-to-peak ripple can induce about 10 degrees of peak phase error; 10 mV can induce about 20 degrees.

RTR8600 FFA Layout Example





Inject External 1.3 V and 2.2 V Supply to RFIC Supply Pins

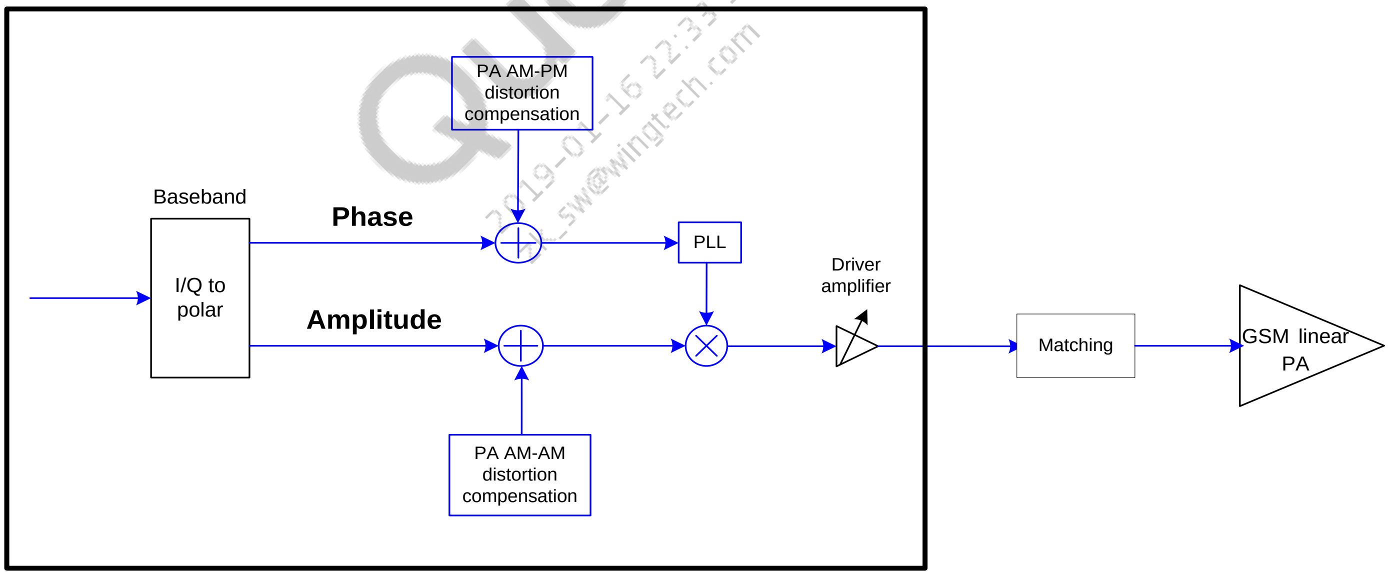
In addition to separating supply pins, it may also be useful to connect external power supplies to the 1.3 V and 2.2 V power supply rails on the RFIC device (refer to the applicable reference schematic for pin and component details).

- Guidelines for connecting external power supplies:
  - Check the supply on an oscilloscope to confirm that it will not present more than 5 mV peak-to-peak of ripple to the circuit.
  - Solder a pigtail connection to the power supply pin, assuring the ground of the pigtail is connected as close as possible to the center conductor.
  - Using an RF cable, connect the pigtail to an external power supply.
  - This type of connection is also recommended for simply monitoring the power supplies to determine if more than 5 mV of ripple is present during the burst.

Importance of KV Calibration

Before any modulation accuracy measurements are made, it is important that KV calibration has been performed.

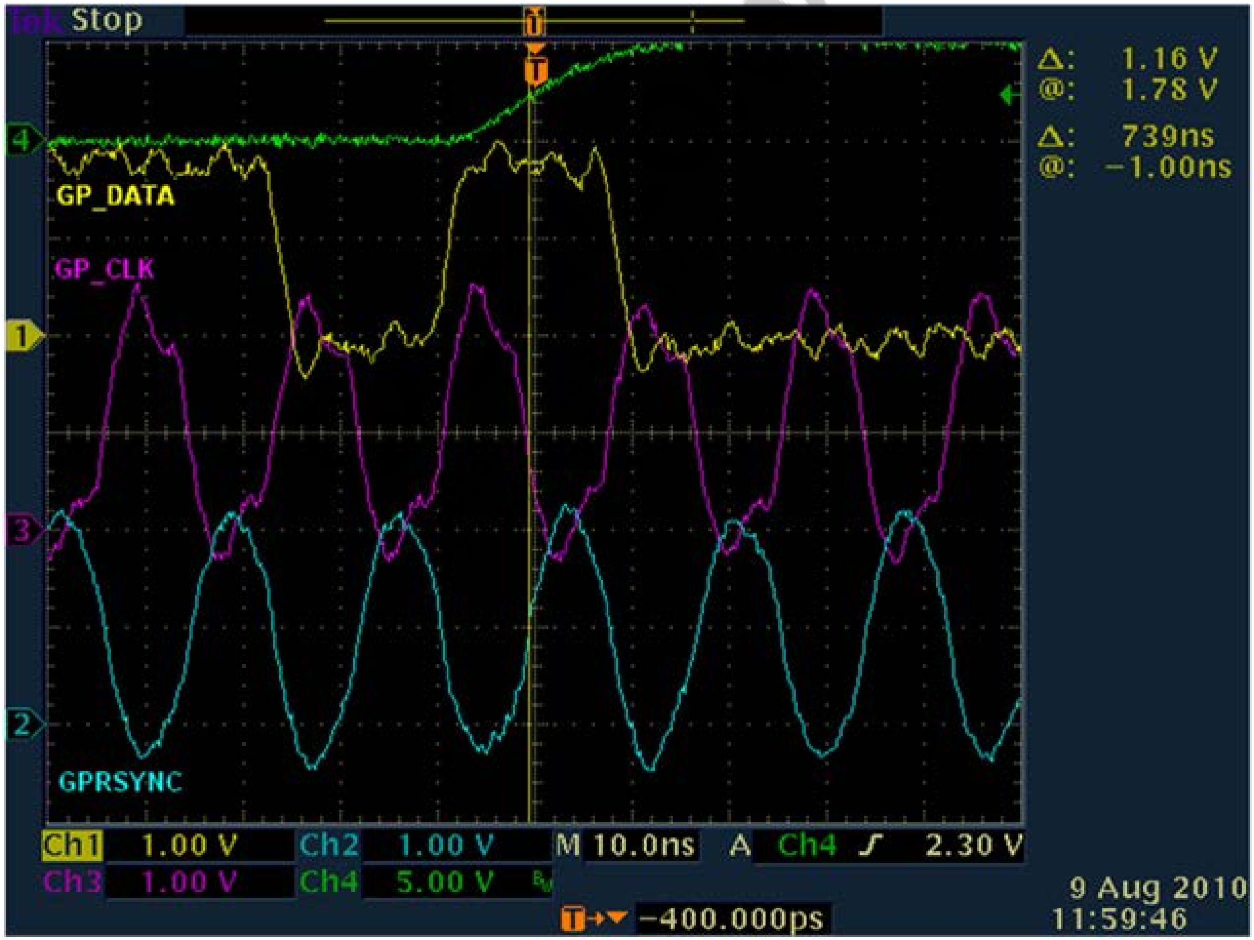
- KV calibration is required because the phase component of the signal modulates the LO.
- KV calibration is handled internal to the device and involves tuning the PLL to a high and low channel and determining the code required vs. the LO frequency.
- Failure to perform KV calibration results in an excessive phase error.



Note: KV calibration is not required/supported on several newer RF chipsets. If in doubt, follow the example of the RF configuration's QSPR test tree.

Baseband Signal Quality – FFA Example

This plot is an example capture of the baseband signals for GSM and can be used as a reference for debugging possible signal integrity problems from the baseband side.



Section 6

Rx Band Noise

What is GSM Rx Band Noise?

Rx band noise

- The ETSI standard's spurious emission specification asks for the following:
  - Less than -79 dBm/100 kHz in the band 935–960 for GSM 900 and in the band 869–894 for GSM 850 on mid channels.
  - For high bands, the specification is relaxed to -71 dBm/100 kHz in the band 1805–1880 for DCS and in the band 1930–1990 for PCS.
  - Exceptions up to five with a level up to -36 dBm are permitted. This is the Rx band noise specification.
- The measurement of Rx band noise should use video averaging per the standard. This can help to gain 2 dB of margin vs. using RMS averaging.
- Spurs that could cause Rx band noise failures:
  - Fractional spurs
  - TCXO harmonics
  - Other noise sources that can get into the GSM transmit path
  - GP_Syn, GP_Clk (57.6 MHz)
  - N-pler (57.6 MHz)

Rx Band Noise Specifications

For idle channels:

Frequency band	Maximum (dBm)	Measured bandwidth (kHz)
9 kHz to 1 GHz [1, 2]	-57	100
1850–1910 MHz [1]	-53	100
1–12.75 GHz [1, 2]	-47	100
Exceptions		
880–915 MHz [2]	-59	100
1710–1785 MHz [2]	-53	100
1900–1980 MHz [2]	-76	100
2010–2025 MHz [2]	-76	100
2110–2170 MHz [2]	-76	100

1. Applies to GSM 850 and GSM 1900
2. Applies to GSM 900 and GSM 1800

Rx band noise (center F multiples of 200 kHz):

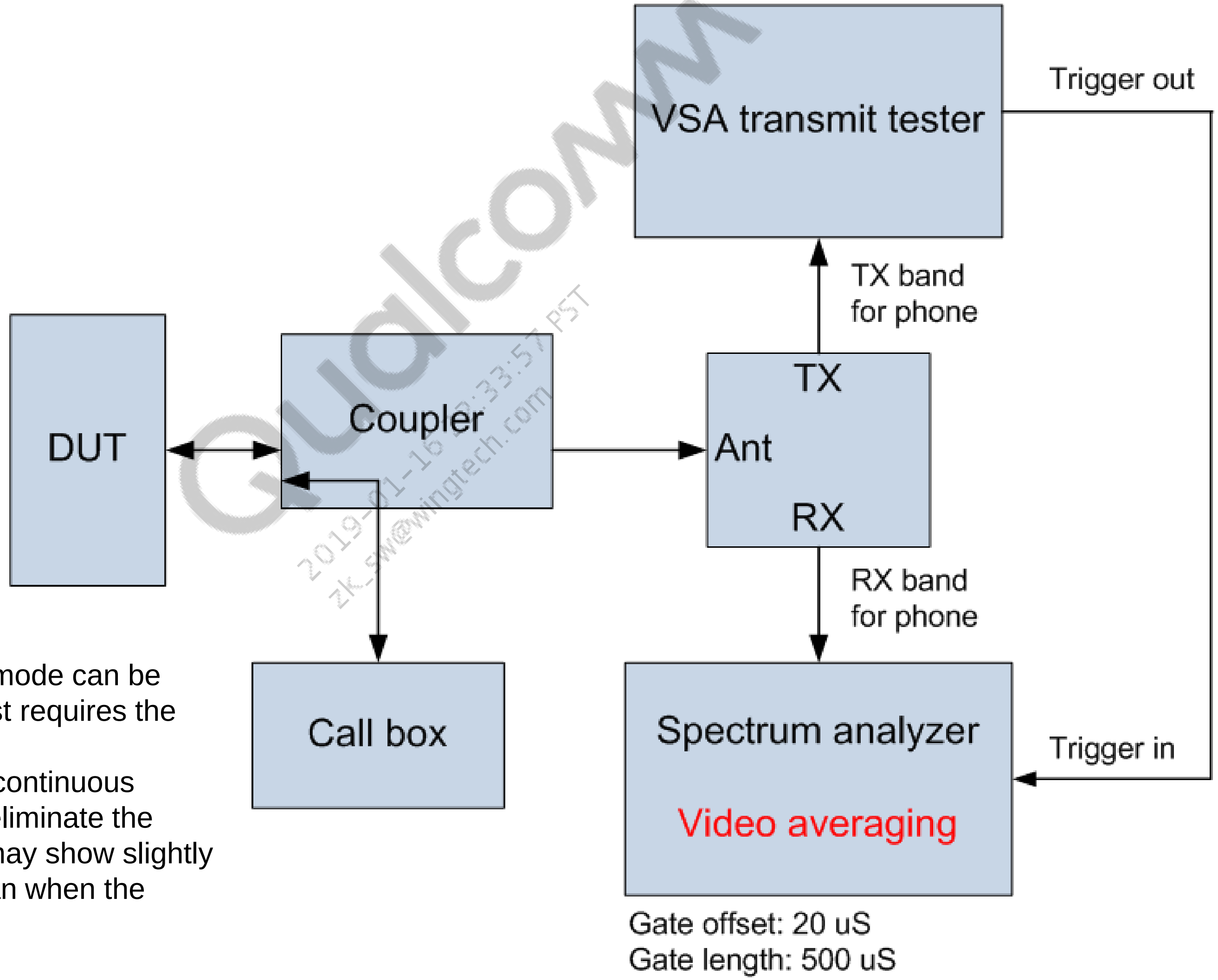
Frequency band	Maximum (dBm)	Measured bandwidth (kHz)
925–935 MHz [1]	-67	100
935–960 MHz [1]	-79	100
1805–1880 MHz [1]	-71	100
1900–1980 MHz [1]	-66	100
2010–2025 MHz [1]	-66	100
2110–2170 MHz [1]	-66	100
747–757 MHz [2]	-79	100
757–762 MHz [2]	-73	100
869–894 MHz [2]	-79	100
1930–1990 MHz [2]	-71	100

1. Applies to GSM 900 and GSM 1800
2. Applies to GSM 850 and GSM 1900

Note: Some Rx band noise exceptions are allowed. Up to five measurements can be as high as -36 dBm for each test in the following bands:

- For GSM 900 and GSM 1800: 925–960 MHz, 1805–1880 MHz, 1900–1980 MHz, 2010–2025 MHz, and 2110–2170 MHz
- For GSM 850 and GSM 1900: 747–762 MHz, 869–894 MHz, and 1930–1990 MHz

Rx Band Noise Test Setup in Call Mode



Notes:
1. For a quick test, FTM mode can be used but the official test requires the device to be in a call.
2. In an FTM mode test, continuous mode can be used to eliminate the need for a VSA but it may show slightly better performance than when the device is bursting.

Possible Spurs in the Rx Band

- N-pler spurs – the strongest spur in the GSM Rx band noise measurement
  - Tx frequency + N × 57.6 MHz
- GP_Clk (57.6 MHz, more sinusoidal) and GP_Sync (more square wave like, more spectral contents)
  - Layout should avoid the Tx path, power supply, and XO buffer
- Modulated
  - 2 × Tx - 15 × 57.6 MHz for EGSM band, mixed in the PA; low-pass filtering at the DA output is recommended
- PMIC switching noise (battery voltage variation testing could help to identify)
  - Tx + N × 1.6 MHz
- XO harmonics
  - Tx + N × 19.2 MHz
- Other noise sources on customer-specific designs
  - Example: the application processor PMIC switching noise

Base Station Duplexer Specifications for Rx Band Noise Measurements

DCS

- Passbands:
  - **Receive 1710–1785 MHz**
  - **Transmit 1805–1880 MHz**
- Passband-to-passband isolation:
  - 85 dB minimum

PCS

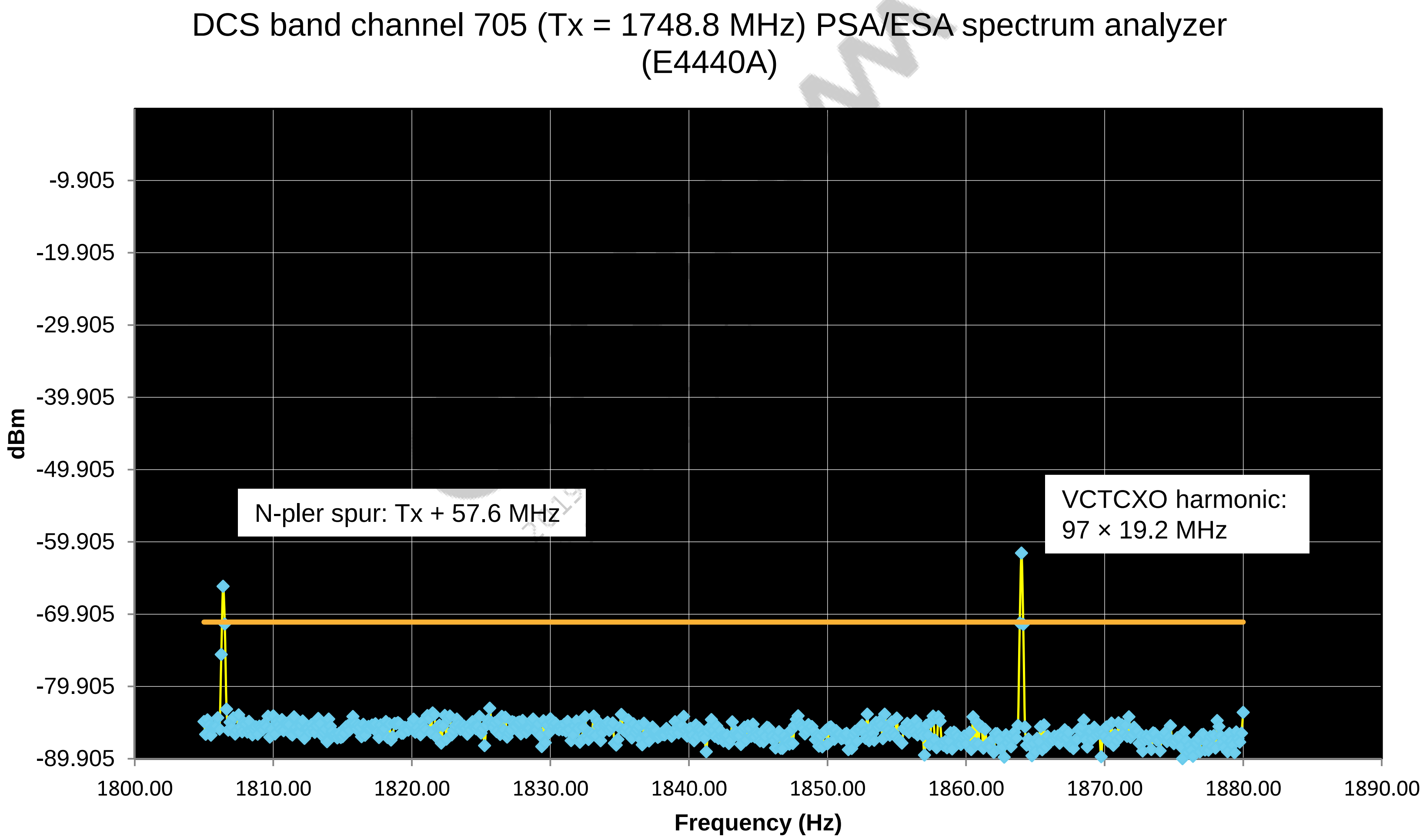
- Passbands:
  - **Receive 1850–1910 MHz**
  - **Transmit 1930–1990 MHz**
- Passband-to-passband isolation:
  - 95 dB minimum

GSM

- Passbands:
  - **Receive 824–849 MHz**
  - **Transmit 869–894 MHz**
- Passband-to-passband isolation:
  - 85 dB minimum

EGSM

- Passbands:
  - **Receive 880–915 MHz**
  - **Transmit 925–960 MHz**
- Passband-to-passband isolation:
  - 75 dB minimum


DCS band channel 705 (Tx = 1748.8 MHz) PSA/ESA spectrum analyzer (E4440A)
-9.905
-19.905
-29.905
-39.905
-49.905
-59.905
-69.905
-79.905
-89.905
dBm
N-pler spur: Tx + 57.6 MHz
VCTCXO harmonic: 97 × 19.2 MHz
1800.00
1810.00
1820.00
1830.00
1840.00
1850.00
1860.00
1870.00
1880.00
1890.00
Frequency (Hz)

Section 7

Knowledge Base

Section 7.1

Tx Power

Tx Power in GSM DA Calibration Lower than QRCT Output with the Same RGI

Applicable chipsets: All

- When using a different PA , there is a slight power degradation in the DA calibration phase.
- Adjusting the following parameters in the calibration tree can resolve the issue:
  - DA calibration → DA: step duration: 273: increase this.
  - One symbol length = 3.692 ms; step duration = 273 × 3.692 ms controls how long the RGI is held at the same value by the unit under test (UUT). A segment length of 1 corresponds to 3.692 ms, which is one time interval.

  - DA calibration → DA: measurement start delay: 300: increase this.
  - A measurement start delay of 300 ms means that the measurement will start 300 ms after the phone starts transmitting.

  - DA calibration → DA: measurement offset: 300
  - A measurement offset of 300 µs delays the DA measurement length from taking effect once the trigger occurs. The default is 112 µs.

  - DA calibration → DA: measurement length: 600
  - A measurement length of 600 µs controls how long each segment is measured. The default is 250 µs. Do not go lower since some equipment may not support this.
  - The requirement is: (measurement length + measurement offset) < (step duration × (1008/273)).

Shifting the Rising and Falling Edge of the GSM Tx Power Burst

Applicable chipsets: MDM9x15 and prior

Customers should move the ramp profile entries to adjust PA RAMP if needed. By moving the entries in the ramp profile (see the ramp profile example below), the number of leading zeros are changed. This achieves same result as changing the PA_START/STOP_TIME_OFFSET setting in older targets.

For example:

<NvItem id="3353" name=" NV_GSM_POLAR_RAMP_PROFILE_I " mapping="direct" encoding="dec">0,0,0,0,0,0,276,286,344,496,758,1124,1581,2123,2737,3411,4128,4872,5626,6367,7077,7737,8331,8842,9252,9556,9740,9800,9800,9800,9800,9800,9740,9556,9252,8842,8331,7737,7077,6367,5626,4872,4128,3411,2737,2123,1581,1124,758,496,344,286,276,0,0,0,0,0,0,0</NvItem>

How to Adjust the GSM Tx Power Limit in Online Mode

Applicable chipsets: MDM9x15 and prior

- In the original AMSS GSM design, the Tx power of all PCLs can only be adjusted by tuning the value of NV items. For example, in EGSM900, customers can adjust the value of *NV_GSM_POWER_LEVELS_I* to adjust the Tx power level of each PCL. By using this method, the user is only able to preset the Tx power level of each PCL in GSM before the phone is powered on in online mode and cannot adjust them after the phone is powered up.
- Some customers need to adjust the Tx power of some PCLs, especially some high-power PCLs dynamically in online mode, to pass some critical RF performance tests. Users can adjust the *rfnv_gsm_900_nv_tbl.power_levels* variable to achieve this feature. This table stores the intended power level of each PCL for EGSM. By adjusting the value of its elements, a user may dynamically adjust the Tx power of each PCL. The same can be done for other GSM bands

How to Enable the GSM Tx Power Indicator Feature

Applicable chipsets: All

Follow the below procedure:

1. Browse the file *rfc_msm_signal_info_ag.c*, and identify which signal will be as the GSM power indicator (GTR_THRESH). The file can be found in *(..\modem_proc\modem\rfa\rfc\target\<MSM/MDM Target>\src\)*
2. Add the GTR_THRESH signals in the RF card file *rfc_<HWconfig>_cmn_ag.c/.h*. Configure the RF card files and set the signal default to RFC_CONFIG_ONLY. The files can be found under *(..\modem_proc\modem\rfa\rfc\rf_card\rfc_wtr1605_na717\common\)* in the *inc* and *src* folder.
3. Add the GTR_THRESH signal to specify the timing in the GSM file *rfc_<HWconfig>_gsm_config_ag.c*. The file can be found in *(..\modem_proc\modem\rfa\rfc\rf_card\<HWconfig>\gsm\src\)*
   A. For example:

      rf_card_wtr1605_na717_tx0_gsm_g1800_sig_cfg { { (int)RFC_WTR1605_NA717_TX_GTR_THRESH_DEFAULT, RFC_CONFIG_ONLY}, {325,354} },
4. In NV23872 to NV23875 (based on the band one wants to implement on), specify 1) *Enable* parameter - 1 (enable) and 2) *Rise_thresh* parameter - Tx power level rise threshold in dBm × 100.

GSM Power vs. Time Failure at a Low Tx Power Level

Applicable chipsets: MSM8974 and prior, MSM8x26, and MSM8x10/MSM8x12

Description: The device fails power vs. time (PvT) at a low Tx power level. The failure happens during ramping up approximately 50 µs before Tx data.

Solution: The root cause is leakage of the voltage-controlled oscillator (VCO) during the warm-up period. For the GSM Tx slot, the Tx VCO needs to be turned on first, and the wait for the warm-up time. After the VCO warm up time, the GSM PA turns on and then ANT_SEL goes to its dedicated status. Some antenna switch modules have a connection to one of the RF paths' ANT_SEL logic OFF. This cannot provide enough isolation during the time between the Rx and Tx slot in case all zero is used for *NV_RF_ANTSEL_GSM_DEFAULT_I*. The VCO signal can leak before ANT_SEL goes to GSM Tx status. The workaround is to find an optimal *NV_RF_ANTSEL_GSM_DEFAULT_I* value that minimizes Tx VCO leakage. Another problem is caused by improper layout when the VCO signal is directly coupled to ASM output for which there is no improvement seen by changing the *NV_RF_ANTSEL_GSM_DEFAULT_I* value.

NV Items and Source Code Changes for Pre-distortion and PVT Failures

Applicable chipsets: MSM8x30 and MDM9x15 and prior

If customers are facing a problem with pre-distortion calibration and PVT failures, here is the method to solve it by tweaking the NV item and making certain changes in the source code. Start the following procedure with default source code.

1. *NV_<BAND>_PA_EN_START_I* = -200 (to be decided after testing): This value has to be found by adjusting/fine-tuning to a certain value where pre-distortion passes every time. Run several times to confirm the value chosen for this NV item is good for calibration.
2. To choose the value for *NV_<BAND>_PA_EN_START_I*, there are two options:
   A. Option 1: Check the symbol's difference in the oscilloscope for the pre-distortion wave. Calculate the value for the NV item by converting the symbol to units required for the NV item. 1 unit = 1 µs = 1/4 symbol in the pre-distorted signal.
   B. Option 2: Arbitrarily choose a value and perform pre-distortion calibration using QSPR XTT. Find an optimal value for which the pre-distortion calibration passes comfortably. 1 unit = 1 µs = 1/4 symbol in the pre-distorted signal.
3. For example, a customer decided to go with a certain value, *X*, for the NV item *NV_<BAND>_PA_EN_START_I* by following either of the options listed above. Customers have to check the PVT graph. Typically it fails with the same amount of time/symbols included in the NV item. Since the customer decided *X* value, the power ramp in PVT graph happens *X* units earlier. To rectify this, adjust the start delta value of TX_ON0, PA_ON, and ANT_PATH_SEL signals in the source code. Reduce the same value of *X* units in the source code for the TX_ON0, PA_ON, RF_PATH_SEL_00, and RF_PATH_SEL_01~03 (the antenna select signals customers have configured) start delta value.

GMSK Power Discontinuity

Applicable chipsets: WTR3925 and WTR4905

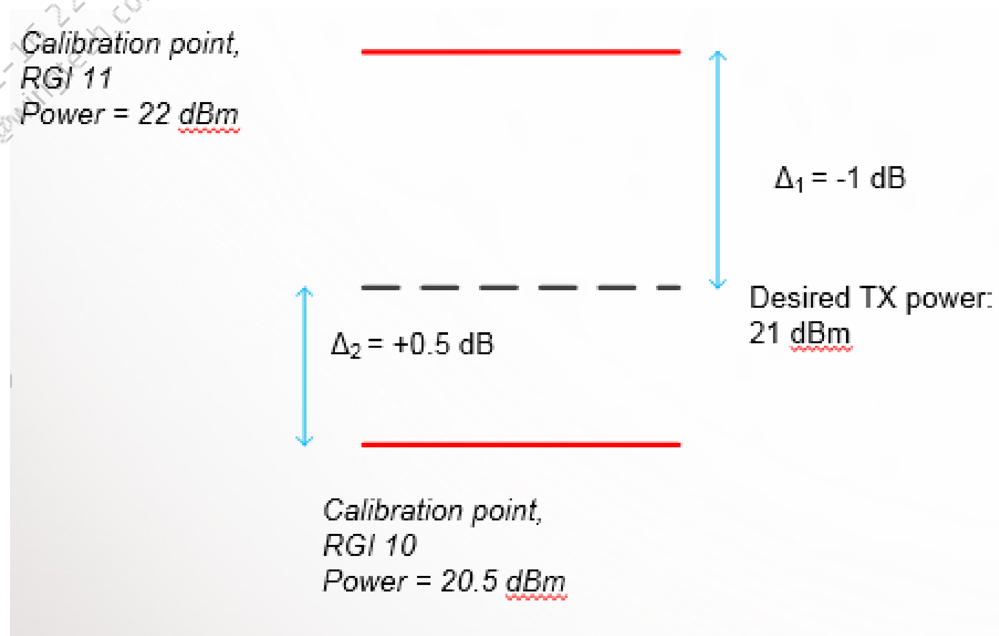
- Issue: Some customers reported GSM Tx power discontinuity, where the WTR output power does not scale linearly with digital scaling. EDGE does not see the same issue.

- Solution: The discontinuity is because of internal saturation in the WTR signal path at high signal levels from the digital-to-analog converter (DAC) output. Changing the baseband signal level using *RFNV_GSM_C0_GSM<BAND>_LINEAR_TX_GAIN_PARAM_I* works, but it is not recommended. The software workaround uses unidirectional digital scaling as opposed to bi-directional scaling to fix this issue.

In the example here, GSM Tx digital scaling is shown, assuming that calibration gives two points for RGI 10 and RGI 11 with power levels of 20.5 dBm and 22 dBm (both calibrated with the sane ENV_GAIN setting).

To achieve 21 dBm, this can be done by choosing RGI 10 (power level of 20.5 dBm and digitally scaling upward by 0.5 dB (Δ2).If more than 1 dB of digital boost is required, then go to the next highest power level and scale down. This is bi-directional digital scaling.

The solution QTI uses is to always scale downward (i.e., apply only Δ1). In this figure, pick the 22 dBm point and scale downward by 1 dB.



Section 7.2

EVM

Failing/Marginal EDGE (8-PSK) EVM Performance Improvement

Applicable chipsets: RTR86xx, QTR86xx, QSC61x5, and QSC6x95

Besides the front-end matching, the power supply could also be the culprit of a bad EVM performance. To debug, use an external power supply to power the GSM PA. If the EVM improves, that suggests an RC filter between the battery and PMIC could help the EVM performance. If the PMIC charger is used, use R = 1 Ω, C = 47 µF. If the PMIC charger is not used, use R = 10 Ω, C = 4.7 µF. This reduces the voltage fluctuation into the PMIC VBATT pin, hence better EVM performance in the 8-PSK modulation scheme. Refer to the document *PMIC Modifications To Improve RF Performance QSC6xx5, MSM7x30, MSM8x60, MDM6x00, MDM9x00 Chipsets* (80-VK401-21) for more information.

Section 7.3

Phase/Frequency Error

GSM Peak Phase Error Improvement

Applicable chipsets: RTR86xx, QTR86xx, QSC61x5, and QSC6x95

- Monitor the peak phase error on the call box transient measurement and see if the peak error happens at the beginning of the burst. If yes, it suggests that the DA is pulling the voltage on the RF VDD line (1.3 V) that is shared by the Tx PLL pin.
- To improve this performance, hardware/layout modification is required:
  1. Separate the VDD line to the DA from the main line to the rest of the pins (including Tx PLL) powered by the RF_1.3V line.
  2. Instead of star routing close to the RF transmitter/receiver (RTR), break the line into two branches at the PMIC buck. This way the DA pulling effect can be reduced, hence, a better GSM peak phase error can be achieved.
- Refer to the *GSM Troubleshooting Guide Applicable Chipsets: RTR860x, QTR8x00, MDM6x00, QSC6x95* (80-VP447-9).

GSM Peak Phase Error Failure Due to RF Unrelated Events (Key Press or Display Turn On/Off)

Applicable chipsets: RTR86xx, QTR86xx, QSC61x5, and QSC6x95

- GSM peak phase errors can occur if the GSM Tx pins (especially Tx oscillator, Tx PLL, and Tx LO) observe large voltage transients.
- One of the sources of these transients is the IR drop on the baseband peripherals, which leads to a voltage drop on V_PHPWR (Input supply to the PMIC). Thus, baseband-related voltage transients can cause GSM peak phase errors.

Peak EVM and Peak Phase Errors Get Worse by Changing TX_PLL Voltage

Applicable chipset: RTR8600

- The peak EVM and peak phase errors get worse by changing the TX_PLL voltage from VDD_2p2_TXCO to VDD_1P3_PLL_TX as per the *Application Note: GSM Tx Synthesizer Reference Clock Options for RTR860080-N5264-1* (80-N5264-1).
- When TX_PLL is supplied voltage through the 2.2 V, it uses an internal 2.2 V LDO, which provides more power supply noise rejection but, adds more noise resulting in poor Rx-band noise performance. Changing to 1.3 V improves the Rx-band noise but makes the TX_PLL circuit more sensitive to power supply glitches. Hence, there is a degradation in the peak EVM and peak phase errors in GSM.
- QTI recommends checking the peak EVM, peak phase error, and Rx-band noise after any change.

GSM Frequency Error Testing

Applicable chipsets: All

ETSI specifies that phase and frequency errors should be measured during the duration of a single burst. Most equipment can report minimum/average/maximum statistics over multiple bursts. Customers should always use the maximum result to judge frequency errors. It is a good practice to test more than one burst to catch random frequency error failures.

Section 7.4

ORFS

How to Debug the ORFS Modulation Degradation Caused by the SMPS Switching Noise

Applicable chipsets: RTR86xx, QTR86xx, QSC61x5, and QSC6x95

1. Try to isolate where the noise gets into the GSM transmit path. Put a launch at the transceiver output and directly measure the output spectrum without the PA. If the problem still exists, then it points to the noise coupling to the transmit path through the transceiver. In this case, increasing the capacitor on the 2.1 V supply line could help to reduce the switching noise. Attention should be paid to the TX_I/Q and DAC_IREF lines; they should be treated as sensitive analog signals and should be routed carefully with enough ground isolation from any digital lines or switching supply lines.
2. If the switching noise gets better, it points to the noise coupling into the transmit path through the PA and Vramp. The Vramp and the PA_DAC_REF from PMIC to MSM™ lines should be routed carefully, away from digital and switching noise sources with enough ground isolation.

Section 7.5

Sensitivity

BLER Degradation on EGPRS 8-PSK Sensitivity EGSM Band CH124

Applicable chipsets: All

This is a known issue and has been identified by QTI. There is a fix in software, which is in CR 190925.

Correlation Between RF Sensitivity and Current Consumption in GSM

Applicable chipsets: All

- In the QTI implementation, the LNA is typically switchable and other sections of the receiver chain contain adjustable gain elements. There are discrete receive level points where the gain elements are switched. Switching the LNA ON or OFF has an effect on current draw. Even in GSM dedicated mode, this is a small amount because the receiver is only on 1/8 of the time (about 2.5 mA). Thus, the net effect is negligible.
- Does poor RF sensitivity translate into high current consumption? The cases which QTI tests for standby time would not show an issue with RF sensitivity and idle current simply because the DL power is ample for the receiver. In the field, the result varies depending on the RF conditions. A phone with better tolerance of interference may perform better than a phone having slightly better sensitivity, but less tolerance of interference. If a phone encounters more out of service due to lack of sensitivity or lack of tolerance for interference, it may spend more time performing tasks that require current (like more time searching for a network).

GSM Desense Every 9.6 MHz Harmonics

Applicable chipsets: QSC61x5 and QSC6x95

1. Typically, if there is GSM sensitivity desense at 9.6 MHz harmonics frequencies, the TRK_LO_ADJ circuitry needs to be checked.
2. Check if the first RC components are located close to the MSM/QSC chipset, and also check if the layout of the TRK_LO_ADJ line is clean and well-isolated.
3. Conduct another experiment to use external TCXO to see if it can improve the performance.

GSM Rx Sensitivity at High Rx Levels

Applicable chipsets: WTR3925, WTR4905, and WTR2955

Issue: Some customers see GSM sensitivity failures (>2.439% BER) at relatively high Rx levels. The GSM demodulator is sensitive to DC drift and flicker noise on the Rx I and Q path (varying from layout to layout).

Solution: QTI added a low-IF (LIF) down-conversion feature for GSM, where GSM signals are down-converted at a 135 KHz offset from the Rx frequency. However, this is enabled only below a hard-coded Rx level threshold.

The LIF Rx level threshold may need tuning for each customer layout. The default threshold (-105 dBm) is based on the modem test platform (MTP); other layouts may need a different threshold. The recommended threshold limit is -103 dBm – increasing further above this level could cause GCF jammer test failures (3GPP TC 14.7.1. blocking and spurious response – speech channels). Customers must ensure that these tests pass and that there are no side effects of threshold modification.

Section 7.6

Rx Band Noise

Rx Band Noise Due to GPDATA Length

Applicable chipsets: WTR3925

Issue: The MSM8994 MTP needs a high drive strength for GPDATA due to a longer GPDATA trace length. Currently, 8 mA of drive strength is hard-coded in software and might be too high for some customer boards having shorter traces. The potential issue with a high drive strength on customer boards is GSM LB Rx band noise degradation.

Solutions:

- Limit GPDATA trace capacitance to 5 pF maximum (in addition to a 22 pF shunt capacitor).
- MSM899x GPDATA drive strength can be configured from 2–16 mA with 2 mA steps. Reconfigure the GPDATA drive strength to 2 mA if the GPDATA trace capacitance can meet the 5 pF requirement. If the 5 pF requirement cannot be met, GPDATA drive strength might need to be increased accordingly.
- Check GPDATA signal integrity after the change.
- The 8-PSK phase path delay might be impacted and need re-characterization.

Questions?

You may also submit questions to: https://createpoint.qti.qualcomm.com/