Tune Up Procedure :

HE910-NAG V2 & HE910-NA

Rev. 0.1

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• Purpose of tuning up

: Units have slightly differing RF characteristics so some characteristics can vary from one unit to the next.

- Unit must estimate the Rx power properly to maximize signal-to-noise ratios and to provide a basis for Tx power output

- Unit must transmit at correct Tx power level over its large dynamic range.

- Baseband device and system software combination must know the RF and analog characteristics of the particular unit.

- Compensating for differing RF/analog characteristics may cause the unit to fail minimum performance specifications.

• How is it used ?

• RF calibration is the process of measuring data to be used in the system for the purpose of compensation of non-linear characteristics and frequency variations, and to provide absolute power reference to ensure performance of the Tx and Rx paths of an unit.

• Output from the calibration process is stored in non-volatile memory (NVm) items in system software.

• System software uses calibration values during normal operation to ensure system performance is met.

• Range of operating RF power

- Agilent 8960 / CMU200
- Max power output and range
  - WCDMA II

Band	Modulation	Data rate or sub-test	Average burst Conducted power (dBm)
WCDMA II	RMC 12.2K	-	23.5 ± 0.5
HSDPA II	QPSK	1	22.5 ± 0.5
		2	22.5 ± 0.5
		3	22.0 ± 0.5
		4	22.0 ± 0.5
HSUPA II	QPSK	1	22.0 ± 0.5
		2	20.0 ± 0.5
		3	21.0 ± 0.5
		4	20.0 ± 0.5
		5	22.0 ± 0.5

• Range of operating RF power

- Agilent 8960 / CMU200
- Max power output and range
  - WCDMA V

Band	Modulation	Data rate or sub-test	Average burst Conducted power (dBm)
WCDMA V	RMC 12.2K	-	23.5 ± 0.5
HSDPA V	QPSK	1	22.5 ± 0.5
		2	22.5 ± 0.5
		3	22.0 ± 0.5
		4	22.0 ± 0.5
HSUPA V	QPSK	1	22.0 ± 0.5
		2	20.0 ± 0.5
		3	21.0 ± 0.5
		4	20.0 ± 0.5
		5	22.0 ± 0.5

* # Range of operating RF power
  * Agilent 8960 / CMU200
  * Max power output and range
    * GSM850

Band	Modulation	Test mode	Average burst Conducted power (dBm)
GSM850	GMSK	1TX	32.5 ± 0.5
GPRS850	GMSK	1TX	32.5 ± 0.5
		2TX	32.5 ± 0.5
(GSM+GPRS) 850 DTM	GMSK	2TX	32.5 ± 0.5
EGPRS850	8PSK	1TX	26.5 ± 0.5
		2TX	26.5 ± 0.5
(GSM+EGPRS) 850 DTM	GMSK+8PSK	2TX	26.5 ± 0.5

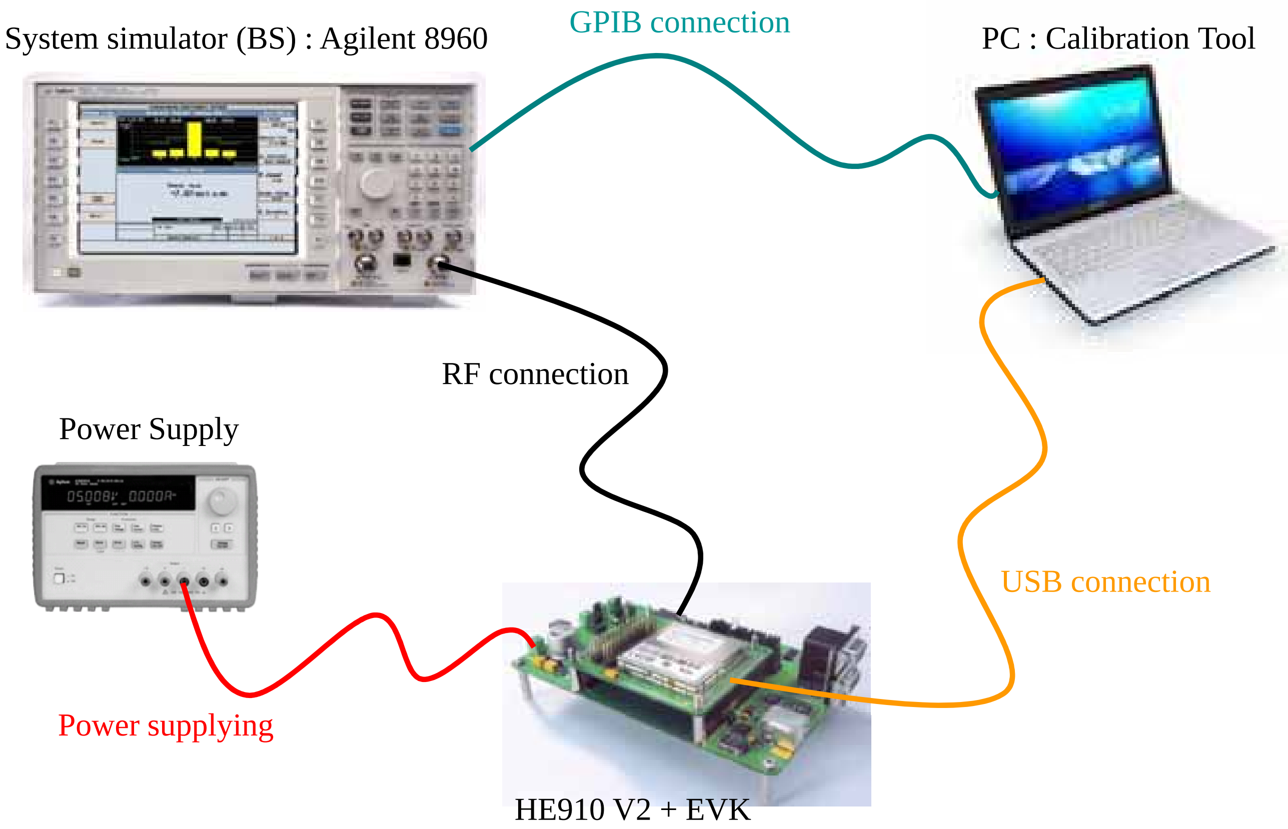
• Range of operating RF power

- Agilent 8960 / CMU200
- Max power output and range
  - PCS1900

Band	Modulation	Test mode	Average burst Conducted power (dBm)
PCS1900	GMSK	1TX	29.5 ± 0.5
GPRS1900	GMSK	1TX	29.5 ± 0.5
		2TX	29.5 ± 0.5
(GSM+GPRS) 1900 DTM	GMSK	2TX	29.5 ± 0.5
EGPRS1900	8PSK	1TX	25.5 ± 0.5
		2TX	25.5 ± 0.5
(GSM+EGPRS) 1900 DTM	GMSK+8PSK	2TX	25.5 ± 0.5

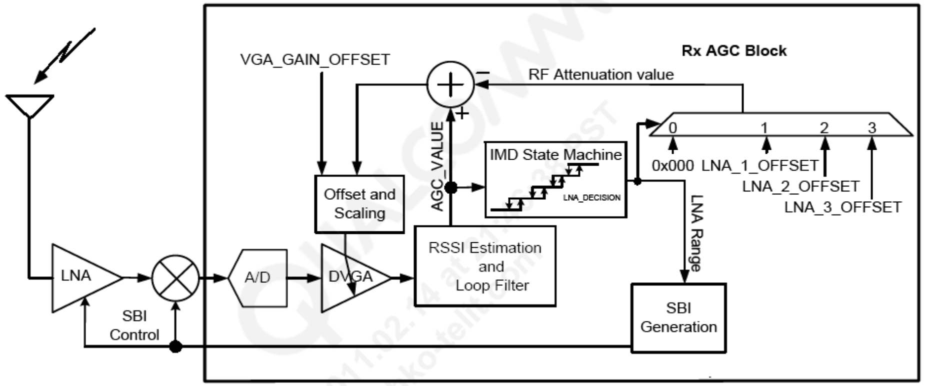
• Burst average power Tune Up Procedure

• Configuration



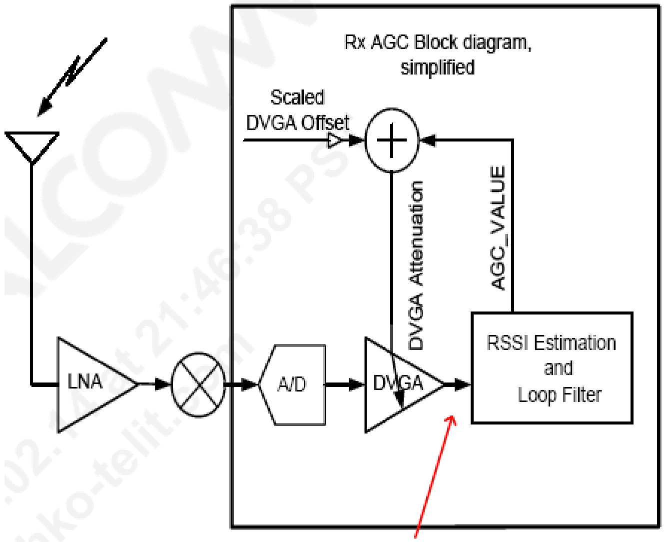
• Burst average power Tune Up Procedure

• WCDMA RX Adjustment



If RF signal power falls, DVGA gain rises (and vice versa)

– Receiver calibration primarily consists of measuring the digital variable gain amplifier (DVGA) offset (also called VGA gain offset) and multiple LNA offsets, all at each chosen frequency index.



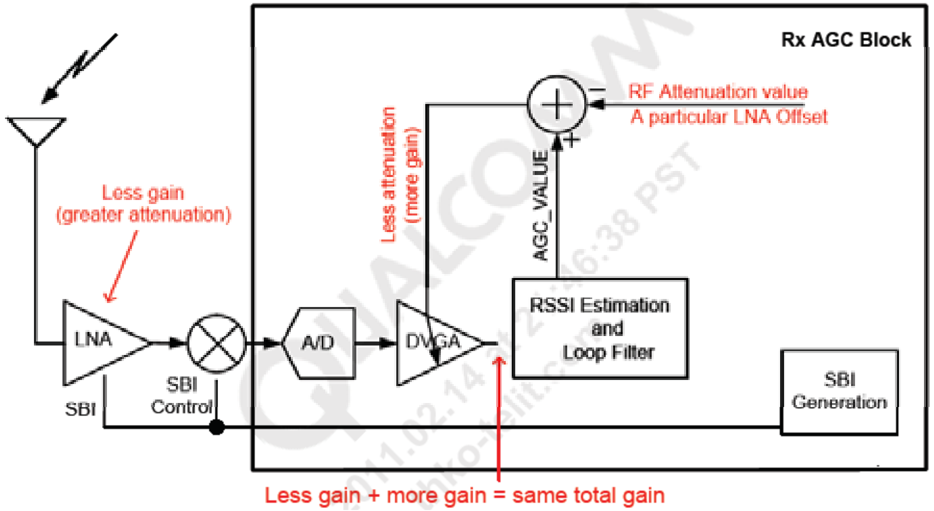
Leaving a constant power level at the output of the DVGA

– The DVGA offset always remains a constant value for a given frequency channel (scaling is only done to match the resolution of AGC_VALUE before combining the two).

– The sole purpose of the DVGA offset is to adjust the overall DVGA gain by a constant amount, so that the receive signal strength indication (RSSI), represented by AGC_VALUE, matches the true Rx power at the antenna connector (particularly when the LNA is in its highest gain state). The DVGA offset serves no other purpose.

• Burst average power Tune Up Procedure

• WCDMA RX Adjustment *cont'd*



- The LNA offsets compensate for gain steps.
- The LNA offsets represent the gain difference between the LNA's gain at a particular gain state and the LNA's highest gain state.
- The DVGA's gain is adjusted to compensate for the LNA's change in gain. For example, when the LNA's gain is reduced by *xdB, the DVGA's gain is increased by x' dB, where x' is derived from the particular LNA offset. Compensation works fine, as long as x' matches x.*

• Burst average power Tune Up Procedure

• WCDMA TX Adjustment

- The transmitter AGC must adjust the Tx power level, based on the RSSI, access probe parameters, closed loop power control bits , and channel configuration attributes.
- Tx power level changes must happen quickly and sometimes only on certain time-boundaries. Control must be done in hardware
- At one frequency index, called the reference frequency, a set of PDM and power level tables must be measured for each PA range state.
- The table set represents a list of up to 64 Tx power levels and their associated PDM values. They are called NV_WCDMA_<band>_TX_PDM_LIN_0_ENH_I and NV_WCDMA_<band>_TX_LIN_MASTER_0_ENH_I for PA range 0.
- For PA range 1 and 2, the table set represents a list of up to 32 Tx power levels and their associated PDM values. They are called NV_WCDMA_<band>_TX_PDM_LIN_z_I and NV_WCDMA_<band>_TX_LIN_MASTER_z_I.
- The valid Txpower range is [-70, 32.4 dBm] for all bands.
- It is important to provide overlap between different gain states across PA switch pointsand at the top of the highest table to account for variation across frequency and temperature. The amount of margin required depends on the design, however, 4 dB is a good place to start.

NV_WCDMA_<band>_TX_PDM_LIN_0_ENH_I

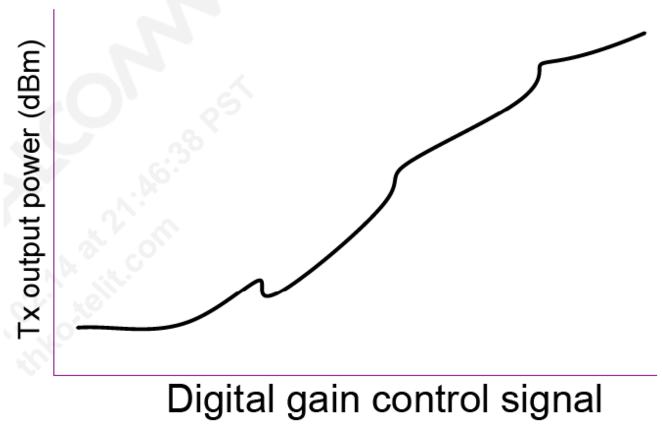
0	37
1	38
2	39
3	40
4	41
5	42
6	43
:	:
59	96
60	97
61	98
62	99
63	100

NV_WCDMA_<band>_TX_LIN_MASTER_0_ENH_I

0	253
1	264
2	272
3	285
4	297
5	300
6	314
:	:
59	824
60	825
61	827
62	828
63	829

• Burst average power Tune Up Procedure

• WCDMA TX Adjustment *cont'd*



• **PA Bias Characterization**

– Unfortunately, the relationship between the Tx output power and the Tx AGC Adj PDM control signal is nonlinear, contains discontinuities, and may even be nonmonotonic. Tx gain curve characteristics vary from one phone to the next.

– These discontinuities are eliminated using the new RF drivers and associated new RF calibration scheme for the devices.

• **Linearity over Frequency**

– Tx linearization is performed by creating sets of two calibration tables. The two tables establish a relationship between TX_AGC_ADJ PDM control values and their corresponding output powers. A separate set of tables is used for each PA gain state.

– The control hardware uses the values in these tables in conjunction with baseband signal power adjustments to control the overall Tx power level.

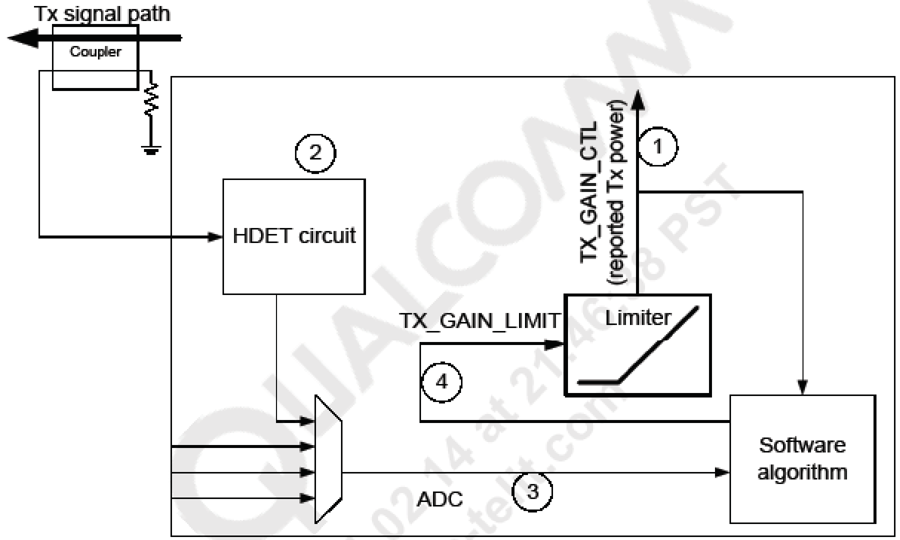
– In normal online mode operation, power levels in between table elements are automatically produced by scaling the baseband signal. This is performed automatically by the mDSP in a process called beta scaling.

– Unfortunately, due to temperature gradients and items that cannot be compensated, TX_GAIN_CTL is not accurate enough for maximum Tx output power limiting. A power detector (HDET) feedback loop is needed.

• Burst average power Tune Up Procedure

• WCDMA TX Adjustment *cont'd*

• **HDET Feedback**



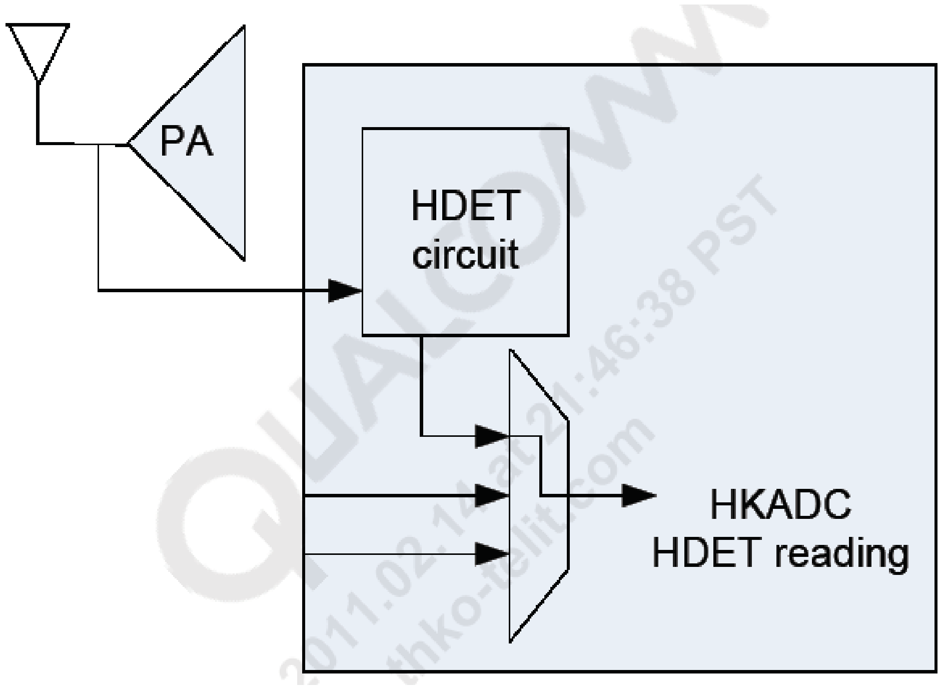
– The NV_BCy_TX_LIM_VS_TEMP_I specifies the desired maximum Tx power and is the initial value for the TX_GAIN_LIMIT register (after reformatting and compensating for the frequency channel).

1. The mobile station intends to output at a power level defined by TX_GAIN_CTL.
2. The HDET circuit measures the output power.
3. The HDET value is transferred to software.
4. The HDET value is indexed into a calibration table that maps the HDET value to the corresponding Tx power level (a frequency-compensated version of EXP_HDET_VS_AGC). The HDET's estimated power level is compared to TX_GAIN_CTL to determine an error value. TX_GAIN_LIMIT is adjusted by that error value.

• Burst average power Tune Up Procedure

• WCDMA TX Adjustment *cont'd*

- Also at the reference frequency, the expected HDET value versus AGC must be measured.
- This table consists of 16 HDET values, associated with 16 equally spaced Tx power levels. It is called NV_BCy_EXP_HDET_VS_AGC_V2_I for CDMA mode and NV_WCDMA_EXP_HDET_VS_AGC_V2_I for WCDMA mode. The size is 12 bits stored in two bytes.
- The HDET values measured are interpolated and extrapolated to fit into the pre-defined HDET_VS_AGC table (refer to [1]for table information). Note that the table goes above 30 dBm. This is the software limit, any actual measured readings are not anticipated to be that high.



- # Burst average power Tune Up Procedure
  - ## GSM RX Adjustment
    - The GSM receive chain is calibrated across frequency at each LNA gain state. The calibration is performed for eight different channels spaced across the band.
    - An FTM command is provided that will return the GSM Receive RSSI level fora given LNA gain range and receive signal level (in dBm). See the following slide for details on the FTM command.

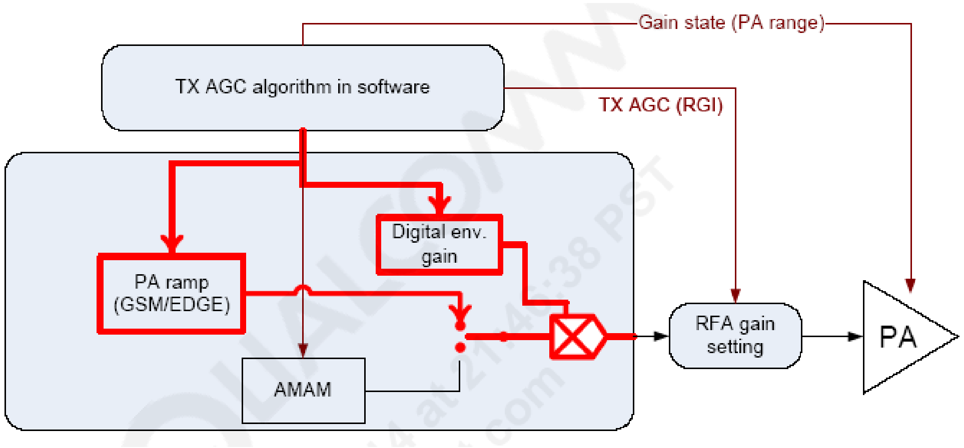
    - The following formula is used to populate the applicable NV items:

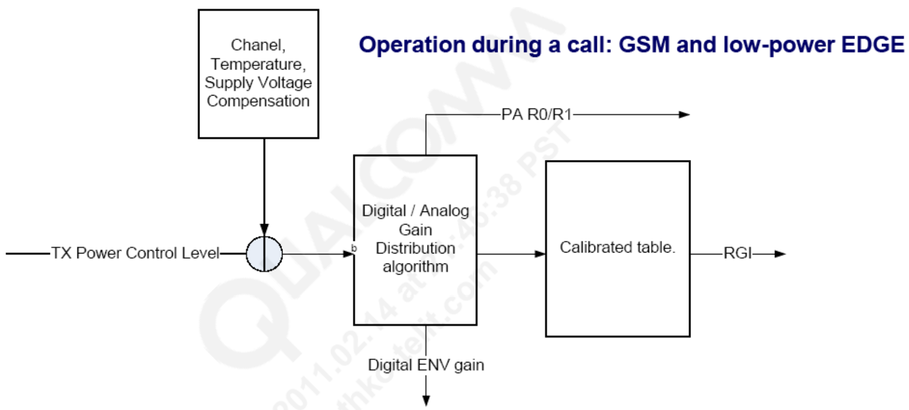
    - NV_GSM_RX_GAIN_RANGE_x_FREQ_COMP[i] = 16*(10*log(RSSI[i])-(Receive level at RF connector))
      (Where 'i' represents the channel)

• Burst average power Tune Up Procedure

• GSM TX Adjustment

– The gain control for GSM / low-power EDGE™ is done using the RF Again setting (RGI) and the digital envelope gain.
– The AMAM table is bypassed, and the PA ramp is used to control the ramp shape.
– Calibration measures the output power versus the RGI for each gain range.
– The Tx AGC algorithm then attempts to find the RGI setting, gain state, and the digital envelope gain that together can achieve the required power.
– The digital envelope gain is only used for fine gain adjustments and not to truly control gain in GSM/low-power EDGE.
– The Tx AGC algorithm takes as input the power in dBm that needs to be transmitted.
– The switchpoints in NV are then used to determine which PA gain range needs to be set.
– The calibration table is then searched to find the RGI that yields the closest match to the required power.
– The difference between the calibrated value and the required power is then made up using the digital ENV gain.





• Burst average power Tune Up Procedure

• GSM TX Adjustment *cont'd*

– For high-power EDGE operation, the PA is fixed to the highest gain state, and the RGI index is fixed at a constant value.
– The AMAM table produced during RF calibration is used to apply predistortion to counteract the nonlinearity of the PA when it is operating in its saturation region (only occurs during high-power EDGE operation).

– The Tx AGC algorithm takes as input the power in dBm that needs to be transmitted.
– The PA is set to the highest gain range and the RGI index is fixed.
– The AMAM calibration table is searched to find the DAC value that corresponds to the desired Tx output power.
– The AMPM calibration table is then searched to find the phase predistortion value that corresponds to the desired DAC value from found in step 3.

– Calibration of the linear PA is performed in two steps:
1.Tx AGC calibration (or DA calibration) over the linear portion of the dynamic range
2.AMAM/AMPM (or predistortion) calibration over the nonlinear dynamic range (only required for high power EDGE)
– Tx AGC calibration
– Tx AGC calibration involves sweeping through the RGIs –RF gain indices and measuring output power.
– This is accomplished by turning on the transmitter in CW mode, and sweeping through the RGI settings in a stair step fashion. The diagram below shows a detailed view of the sweep.
– This sweep is repeated for three frequencies per band for each PA gain range*, and the results are interpolated for the current transmit channel.

• Burst average power Tune Up Procedure

• GSM TX Adjustment *cont'd*

– The data from the sweep is then analyzed to generate the calibration tables. This calibration is run for three frequencies per band and stored in the NV. During Tx operations, these curves are then interpolated to get the final calibration table to use for the given frequency.

– The final step that must be performed during Tx AGC calibration in preparation for the AMAM/AMPM calibration is as follows:

1. The smallest RGI index that will allow the required maximum 8PSK Tx power for the predistortion (27 dBm for low bands and 26 dBm for high bands) for AMAM/AMPM calibration needs to be determined for each calibration channel.
2. Then the *highest of those three RGI values is chosen.*
3. This RGI index is then populated in the NV item: NV_GSM_TX_AGC_SETTING_FOR_PRED_I.
4. The RGI value is then fixed at this setting during the AMAM/AMPM calibration.