## 6.5 Downlink Setup Procedure

### 6.5.1 Downlink Gain Allocation

A wide operating range is required for downlink gain in the RAU. A large amount of range is required for accommodating the specified range of cable losses. Significant margin is also allocated at each end of the gain range to accommodate errors in the ATE setup and cable model. Additionally, the user can adjust the gain in the system on a per-RAU basis. The figure below illustrates the gain allocations in the RAU, and maps the allocations to the absolute operating gain range. This range must be met for all RAU conditions, including over temperature.

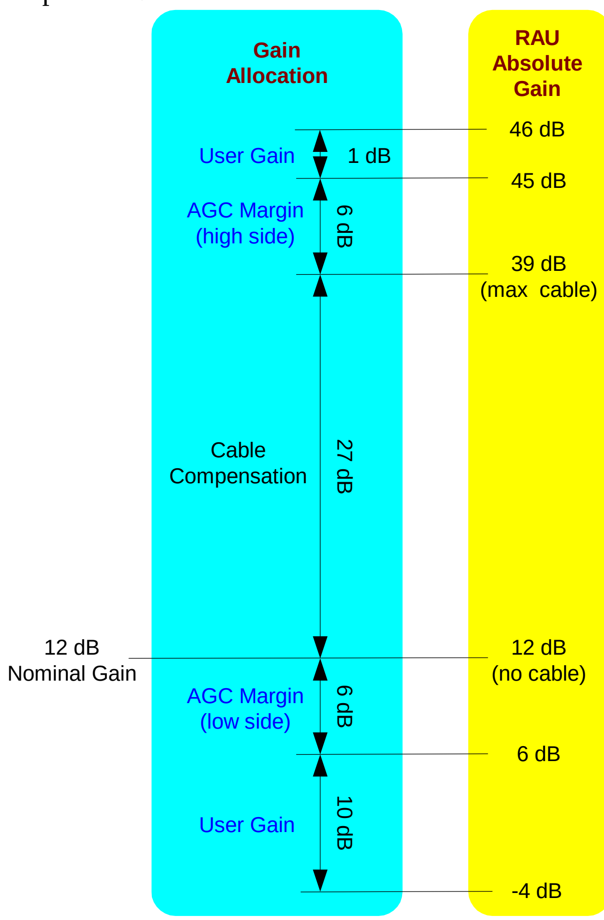


**Table 1: Downlink Gain Setup Parameters**

| Parameter | Units | Minimum | Typical | Maximum |
|---|---|---|---|---|
| DL ref signal, into coax cable (system test tone) | dBm | -17.5 | -17 | -16.5 |
| Gain of band 1 (for system gain of 0dB, includes coax cable loss) | dB | 11.5 | 12 | 12.5 |
| Gain of band 2 referenced to band 1 | dB | -0.5 | 0 | +0.5 |
| Band 1 DL system test output level | dBm | -5.5 | -5 | -4.5 |
| Band 2 DL system test output level | dBm | -5.5 | -5 | -4.5 |
| | | | | |
| Maximum frequency step size for swept measurements | MHz | | | TBD |

Note: The downlink pilot level is specified in the Dualband Hub spec.

### 6.5.2 Downlink AGC setup

#### *6.5.2.1 Overview*

Downlink gain in the DBR is set based on the received downlink pilot level. Since the pilot and IF signal are not at the same frequency, they experience different amounts of loss across the cable. A pilot table is used to relate the pilot loss for a particular cable length to the corresponding IF signal loss. ATE is responsible for generating the pilot table. After it is computed, the pilot table is stored in non-volatile memory on the DBR where it can be recalled at runtime.

The AGC attenuator compensates for the loss due to various cable lengths for the high-band (ie, band 2) path. The band-specific IF attenuators compensate primarily for unit-to-unit gain variations, as well as for part of the low-band (ie, band 1) cable loss. The variable slope circuits in the IF sections are used to accommodate (1) slope incurred by the coaxial cable loss, and (2) unit-to-unit slope variations introduced by filters in the RF and IF paths.

As described in section 4.2.1, the downlink path of the DBR is comprised of two main sections for gain control: the AGC portion and the IF/RF portion. The AGC section is common to both frequency bands whereas the IF/RF portions are unique to each band.

#### *6.5.2.2 General Concepts*

This section outlines a general overview of the downlink gain setup procedure. Details are reserved for the section that follows. Downlink gain is set for the DBR using the two general steps outlined below.

**I. Characterize slope circuit responses.**
The responses of the two slope circuits are determined by creating tables that equate the slope circuit setting (ie, voltage) to the measured slope. Each slope table is created for a small number

of points using pre-set voltages. After the table has been created, an arbitrary slope can be set by interpolating the circuit voltage from the measured slope data points.

Slope measurements are made through each signal path of the unit. A signal is injected at the downlink input and is swept across the downlink band. The output signal is recorded by measuring the response at the output of the antenna port. The slope of the sweep is then computed and stored in the table for the corresponding voltage (see Figure 3a).

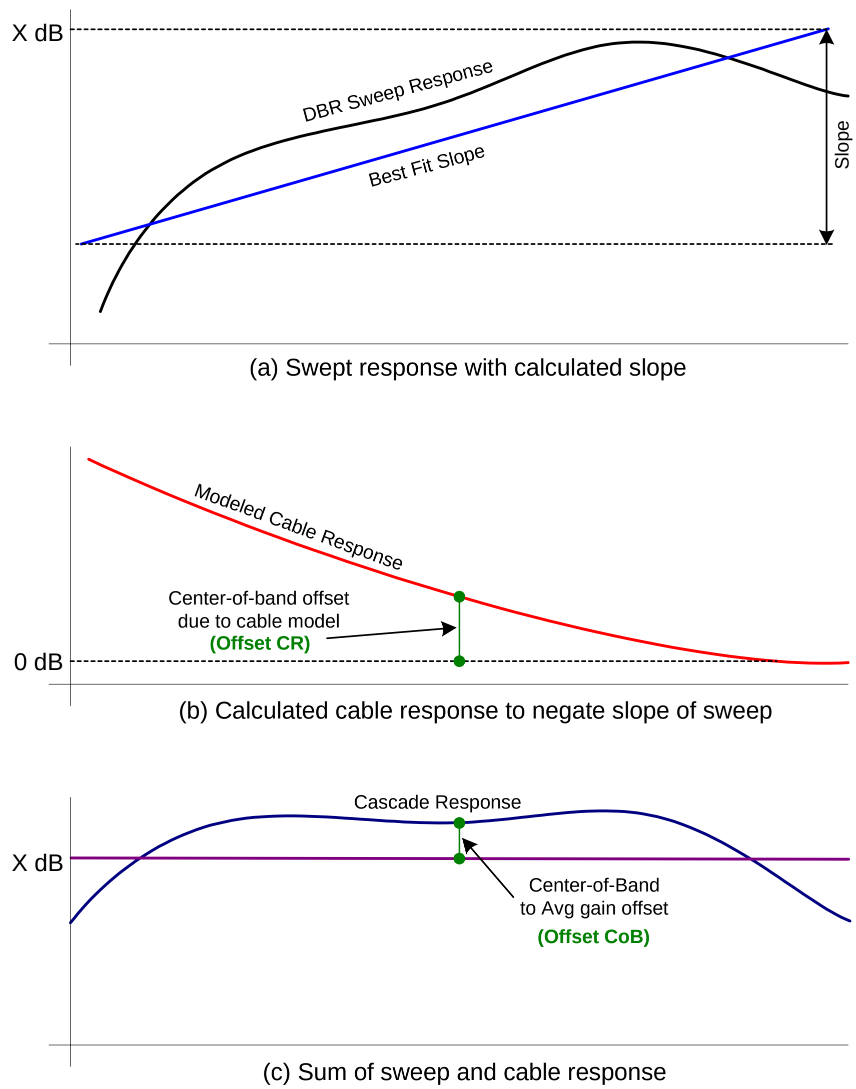
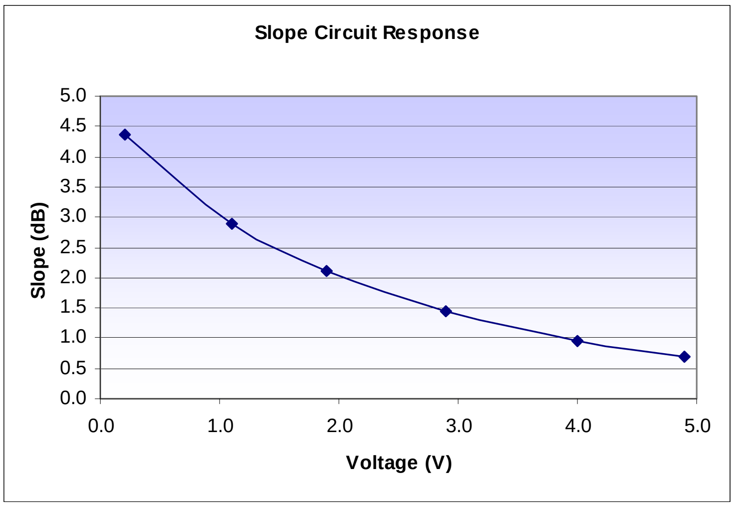



**Figure 3: Slope Table Generation.**

A second parameter is also stored in the table for each slope offset. This parameter is the gain offset. It relates the center-of-band gain to the average gain (across the band) for each slope offset. This value allows the DBR gain for each pilot table entry to be determined by measuring at only a single frequency, rather than sweeping the entire band. Before this parameter is measured, the sweep response is "leveled" to zero slope by adding the modeled cable response that corresponds to the calculated slope. The center-of-band to average gain is measured on the resulting sweep. Refer to Figure 3 for a pictorial representation of the process.

Separate slope tables must be created for long and short cable mode and for each band (for a total of four tables). An example AGC slope circuit response is shown in the plot and table below.




| Voltage (V) | Slope (dB) | Gain Offset (dB) |
|---|---|---|
| 0.2 | 4.4 | 0.0 |
| 1.1 | 2.9 | -0.3 |
| 1.9 | 2.1 | -0.4 |
| 2.9 | 1.5 | -0.3 |
| 4.0 | 1.0 | 0.0 |
| 4.9 | 0.7 | 0.1 |

**Figure 4: Slope Circuit Response Table.**

## II. Create pilot table.

With the slope settings determined, the pilot table can be created. The first entry in the pilot table corresponds to the maximum amount of cable loss the system is designed to handle, plus some margin. Since system operation at such a high gain is outside the specified range, a high level of gain accuracy is not required. For this reason, the values for the first table entry may be calculated rather than measured. The first pilot table entry corresponds to minimum attenuation on the AGC attenuator and lower than typical attenuation on the IF & RF attenuators.

The second entry in the pilot table (and all subsequent entries) must be measured for accuracy. The first step to computation is to set the slope circuits for each band to correspond to maximum cable length, and the AGC attenuator to minimum attenuation. Next, the IF attenuators for bands 1 and 2 are adjusted until the desired "maximum measured gain" through the unit is obtained. At this point, the average gain of the two bands is measured and a synthetic pilot with the appropriate level is injected into the downlink path. The pilot detector is read and stored in the pilot table along with the corresponding attenuator and slope settings.

Additional entries are created in the pilot table for successively lower amounts of cable loss until the entire gain range has been covered. Special heed is paid to provide proper overlap between the two table halves due to the long and short cable modes.

Although the gain for each entry in the pilot table is measured, the pilot signal level is a calculated value. The level of the pilot is computed based on a model of the expected cable response. The cable model relates the IF signal loss to the pilot loss for all lengths of cable.

#### *6.5.2.3 Detailed Description*

| **Parameter** | **Definition** |
|---|---|
| Slope table | Used to characterize response of the slope circuits. One for each of long cable & short cable paths for each band (four tables total). |
| Center-of-band gain offset | Difference between center-of-band gain and average gain. |

| **Parameter** | **Description** | **Value** |
|---|---|---|
| MAX_ CABLE_LOSS | Maximum amount of cable loss the pilot table is designed to handle, excluding margin. This value is referenced at the highest IF frequency of the unit. The actual unit gain at this point is equal to MAX_CABLE_LOSS plus a fixed value (ie, desired unit gain when cascaded with any length of cable – see “gain” spec in section 6.3.2). | 27 dB |
| MAX_ GAIN_OFFSET | When added to MAX_AVG_GAIN, corresponds to the first entry in the pilot table | 2 dB |
| MAX_AVG_GAIN | Maximum average downlink gain that pilot table is set up for (by measurement). This value applies to the second entry in the pilot table. | 31 dB (27 + 4) |
| MAX_AVG_SLOPE | Maximum downlink slope used in pilot table. Different values for band 1 & band 2. This value tracks the gain for 0 – 27 dB of cable loss. Above 27 dB of loss, the slope value stays fixed. | Slope for 27 dB cable loss (?? & ?? dB) |
| NUM_SLOPE_PTS | Number of voltage settings on slope circuit used for characterizing slope circuit response | 10? |
| NUM_SWEEP_PTS | Number of points across band used in sweep on spectrum analyzer | 9? |
| PTstep | Step size of AGC attenuator (in dB) between successive rows in the pilot table. Step size of the actual attenuator (ie, resolution) is smaller than PTstep. | 2 dB |
| TableOverlap | Gain overlap between long cable and short cable modes in pilot table (dB). | 2 dB |

The following steps describe the detailed ATE procedure for setting up the downlink slope and gain in the DBR.

I. **Characterize slope response (Steps 1-3)**

1. Characterize the slope circuit response for band 1 long cable mode. This is done by injecting a signal at the DBR input for band 1, then measuring it at the output.
    a. Initialize
        - Set long cable mode
        - Set AGC digital attenuator to mid range.
        - Set IF & RF digital attenuators to mid range
    b. Measure slope for first voltage setting
        - Program slope circuit with first voltage setting
        - Sweep band 1 downlink path and compute slope (see Figure 3a)
        - Store voltages and slope measurements as first entry in *Band 1 slope table* (for long cable mode).
    c. Determine center-of-band gain measurement offset for first voltage setting
        - Compute the cable loss vector that corresponds to the slope of the current sweep (see Figure 3b)
        - Add the cable loss vector to the current sweep to create a new sweep with zero slope (see Figure 3c)
        - Determine the gain offset by subtracting the center-of-band offset due to the cable model from the center-of-band to average gain offset (ie, gain offset = Offset CoB – Offset CR).
        - Store the gain offset in the table
    d. Repeat steps b & c for all NUM_SLOPE_PTS pre-determined voltage settings.
2. Characterize AGC slope circuit response for band 1 short cable mode
    a. Set short cable mode
    b. Repeat steps 1 b-d to create *Band 1 slope table* for short cable mode
3. Characterize AGC slope circuit response for band 2
    a. Repeat steps 1 & 2 for band 2

II. **Create pilot table (Steps 4-11)**

4. Initialize slope setting and attenuators for max cable length for band 2
    a. Set long cable mode
    b. Set AGC attenuator to 0 dB
    c. Set band 2 unit IF attenuator to 4 dB
    d. Set band 2 unit RF attenuator to 4 dB

   e. Set band 2 slope circuit for MAX_AVG_SLOPE[1]
      - Compute slope circuit setting for MAX_AVG_SLOPE by interpolating values from *Band 2 slope table* (for long cable mode)
      - Program slope circuit
      - Store slope circuit setting in **second** entry of pilot table ($S_{B2L0}$)
5. Interpolate band 2 gain offset from slope table
6. Determine band 2 unit IF & RF attenuator settings
   a. Inject a tone at center-of-band (band 2)
   b. Alternately adjust the unit band 2 IF & RF attenuators until the average gain is as close as possible to *Max average gain* + interpolated gain offset
   c. Store IF attenuator ($A_{IFB2L0}$) & RF attenuator ($A_{RFB2L0}$) settings in pilot table (**2nd entry**) for band 2
   d. Convert measured average gain to a byte value and store in pilot table ($G_{B2L0}$)
7. Determine band 1 unit IF & RF attenuator settings
   a. Initialize band 1
      - Set band 1 unit IF attenuator to 4 dB
      - Set band 1 unit RF attenuator to 4 dB
   b. Set band 1 slope
      - Compute band 1 slope based on the measured average gain for band 2
      - Program slope circuit with computed value
      - Store band 1 slope value in first entry of pilot table as $S_{B1L0}$
   c. Interpolate band 1 gain offset from slope table
   d. Determine band 1 unit IF attenuator setting
      - Inject a tone at center-of-band (band 1)
      - Alternately adjust the unit band 1 IF & RF attenuators until the average gain is as close as possible to the measured gain for band 1 (use band 1 gain offset)[2]
      - Store IF attenuator ($A_{IFB2L0}$) and RF attenuator ($A_{RFB2L0}$) settings in pilot table for band 1 (**2nd table entry**)
      - Convert measured average gain to a byte value and store in pilot table ($G_{B1L0}$)
8. Measure pilot detector level
   a. Compute the average maximum gain by averaging the measured average gains for band 1 and band 2
   b. Using the cable loss model and the average maximum gain, compute the equivalent cable loss at the pilot frequency

---

[1] Since the slope circuit may have additional range, we don't want to program it for maximum available slope. Instead, we set it for the slope that corresponds to the maximum measured cable length plus some margin.

[2] The average gains for band 1 & 2 will be different since the cable loss is different for the two IFs. The desired average gain for band 2 is the actual average gain for band 1, offset by the difference in calculated gains for the two bands.

c. Inject a pilot signal into the DBR downlink path at the computed signal level
d. Measure the pilot detector value and record in the pilot table ($P_{MaxL}$)

9. Store first entry in pilot table
   a. Modify IF & RF attenuator settings for each band in the second pilot table entry by subtracting MAX_GAIN_OFFSET/2 dB from each. Store in first table entry ($A_{IFB1L-1}$, $A_{RFB1L-1}$, $A_{IFB2L-1}$ & $A_{RFB2L-1}$)
   b. Modify detected pilot from 2nd entry by subtracting expected additional pilot loss for MAX_GAIN_OFFSET dB more IF loss. Store as first entry in pilot table ($P_{MaxL-1}$).
   c. Copy all remaining pilot table values from the second entry to the first entry.
10. Increase AGC attenuation by *PTstep* dB and compute next pilot table entry (starting with third entry)
   a. Compute slope setting for (*PTstep* + $\Delta G_{SAGC}$) dB lower gain by interpolation from *band 1, band 1 slope tables* for long cable mode.[3] Program slope circuits ($S_{B1LX}$, $S_{B2LX}$). This step must be done before measuring the lower gain since the slope circuit affects gain.
   b. Step the AGC attenuator by *PTstep* dB (calculated)
   c. Measure the downlink average gain for bands 1 & 2
      - Sweep bands 1 & 2 and determine average gain for each
      - Determine *center-of-band gain offset* for bands 1 & 2
      - If the difference in average gain between the two bands is greater than ¼ dB, adjust band 2 IF attenuator to compensate
   d. Repeat step 8 to determine pilot detector entry in table
11. Repeat step 10 until the long cable portion of the table is fully populated. The stopping point is when the gain corresponds to a cable loss of less than (MAX_CABLE_LOSS - TableOverlap)/2.
12. Set long cable/short cable overlap point
   a. Select short cable mode
   b. Set AGC attenuator to minimum attenuation
   c. Set IF slopes for short cable ($S_{B1S0}$ & $S_{B2S0}$)
   d. Adjust Band 1 IF attenuator until gain is TableOverlap dB higher than last entry in long cable mode
   e. Measure the average gain for band 1
   f. Adjust band 2 average gain until it is as close as possible to the measured gain for band 1 (offset by difference in calculated gains for the two bands – see footnote 2).

[3] Since both the AGC Attenuator and AGC slope circuits affect the gain, the step size for the slope circuit should correspond to the total gain change due to both factors. *PTstep* is the gain change due to the attenuator portion while $\Delta G_{SAGC}$ is due to the slope. $\Delta G_{SAGC}$ is a pre-set value that is empirically determined.

| AGC Circuit | | | Unit Circuits | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Band 1 | | | | Band 2 | | | |
| **Gain Path** | **Atten** | **Pilot** | **Slope** | **IF Atten** | **RF Atten** | **Gain** | **Slope** | **IF Atten** | **RF Atten** | **Gain** |
| Long | 0 dB | $P_{MaxL-1}$ | $S_{B1L0}$ | $A_{IFB1L-1}$ | $A_{RFB1L-1}$ | $G_{B1L-1}$ | $S_{B2L0}$ | $A_{IFB2L-1}$ | $A_{RFB2L-1}$ | $G_{B2L-1}$ |
| Long | 0 dB | $P_{MaxL}$ | $S_{B1L0}$ | $A_{IFB1L0}$ | $A_{RFB1L0}$ | $G_{B1L0}$ | $S_{B2L0}$ | $A_{IFB2L0}$ | $A_{RFB2L0}$ | $G_{B2L0}$ |
| Long | *PTstep* | $P_{PTstep}$ | $S_{B1L1}$ | $A_{IFB1L1}$ | $A_{RFB1L1}$ | $G_{B1L1}$ | $S_{B2L1}$ | $A_{IFB2L1}$ | $A_{RFB2L1}$ | $G_{B2L1}$ |
| Long | *2PTstep* | $P_{2PTstep}$ | $S_{B1L2}$ | $A_{IFB1L2}$ | $A_{RFB1L2}$ | $G_{B1L2}$ | $S_{B2L2}$ | $A_{IFB2L2}$ | $A_{RFB2L2}$ | $G_{B2L2}$ |
| … | *3PTstep* | $P_{3PTstep}$ | $S_{B1L3}$ | $A_{IFB1L3}$ | $A_{RFB1L3}$ | $G_{B1L3}$ | $S_{B2L3}$ | $A_{IFB2L3}$ | $A_{RFB2L3}$ | $G_{B2L3}$ |
| | | | | | | | | | | |
| Short | | | $S_{B1S0}$ | $A_{IFB1S0}$ | $A_{RFB1S0}$ | $G_{B1S0}$ | $S_{B2S0}$ | $A_{IFB2S0}$ | $A_{RFB2S0}$ | $G_{B2S0}$ |
| Short | | | $S_{B1S1}$ | $A_{IFB1S1}$ | $A_{RFB1S1}$ | $G_{B1S1}$ | $S_{B2S1}$ | $A_{IFB2S1}$ | $A_{RFB2S1}$ | $G_{B2S1}$ |
| Short | | | $S_{B1S2}$ | $A_{IFB1S2}$ | $A_{RFB1S2}$ | $G_{B1S2}$ | $S_{B2S2}$ | $A_{IFB2S2}$ | $A_{RFB2S2}$ | $G_{B2S2}$ |
| … | | | | | | | | | | |

**Table 2: Pilot Table Construction.**

The gain columns in the pilot table consist of single byte values (0 to 255) that store a relative gain value with 0.1 dB resolution. All gain values for the short cable mode portion of the table (bottom half) are referenced to the gain of the last entry (minimum gain entry). As the reference point, the gain for both bands in the last pilot table entry ($G_{B1SX}$ and $G_{B2SX}$) are set to 0. The gains for all other table entries for the short cable path equal the difference between its row's corresponding gain and the gain of the last table entry (in $1/10^{th}$ dB increments).

Likewise, the gains in the last table entry for long cable mode are set to 0. All other long cable gain entries are referenced to this point. Three additional variables for each band contain additional values that are useful for obtaining the absolute gain for any table entry. All values have 0.1 dB resolution.

MinAvgPTShortGain contains the absolute gain for the minimum gain entry (ie, last pilot table entry for short cable mode). It is a single byte value. MinAvgPTLongGain contains the absolute gain for the last entry for long cable mode. This value is 2 bytes, and retains the 0.1 dB resolution. DeltaAvgPTGainShort2Long contains the gain difference between the first short cable entry and the last long cable entry (in other words, the gain delta of the overlap region between the two paths). It is a single byte value.

### 6.5.3 Downlink Pilot Setup

The pilot level is referenced to the input of the system and the level is determined in the DBH. Refer to the DBH specification for setup details. A simulated pilot is injected in the DBR to setup the level for 0 to 300 meters.

### 6.5.4 Downlink Detector Setup

## 6.6 Uplink Setup Procedure

**Table 3: Uplink Setup Parameters**

| Parameter | Units | Minimum | Typical | Maximum |
|---|---|---|---|---|
| UL ref signal (into SMA connector) | dBm | -55.5 | -55 | -54.5 |
| Gain of band 1 | dB | 29.5 | 30 | 30.5 |
| Gain of band 2 referenced to band 1 | dB | -0.5 | 0 | +0.5 |
| UL pilot level set point (relative to –55 dBm input signal) | dB | -0.5 | 0 | +0.5 |
| | | | | |
| Maximum frequency step size for swept measurements | MHz | | | TBD |