Course: Leaky Feeder System

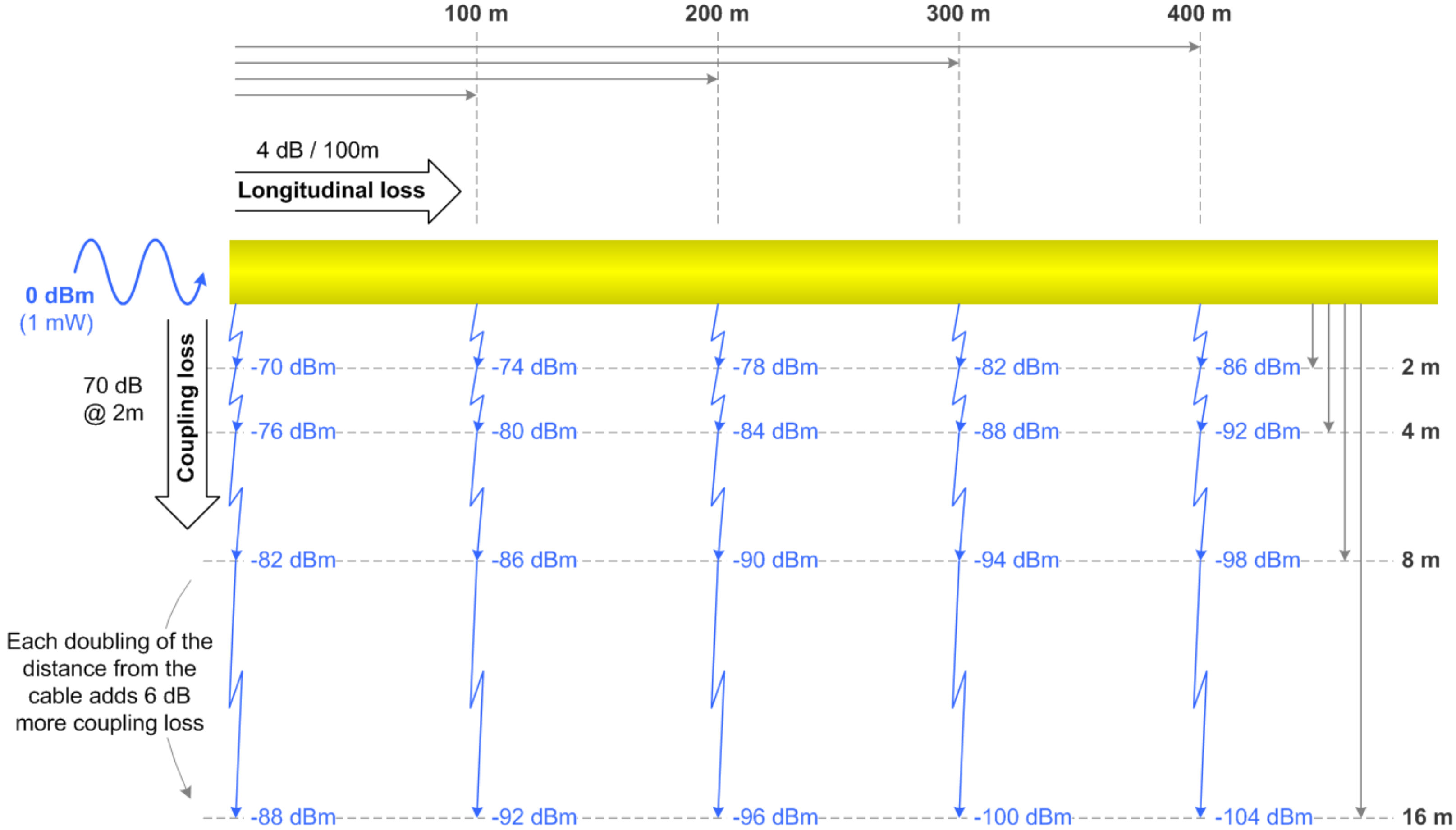
Module 2.2:

Gain Control

RFI
TECHNOLOGY SOLUTIONS

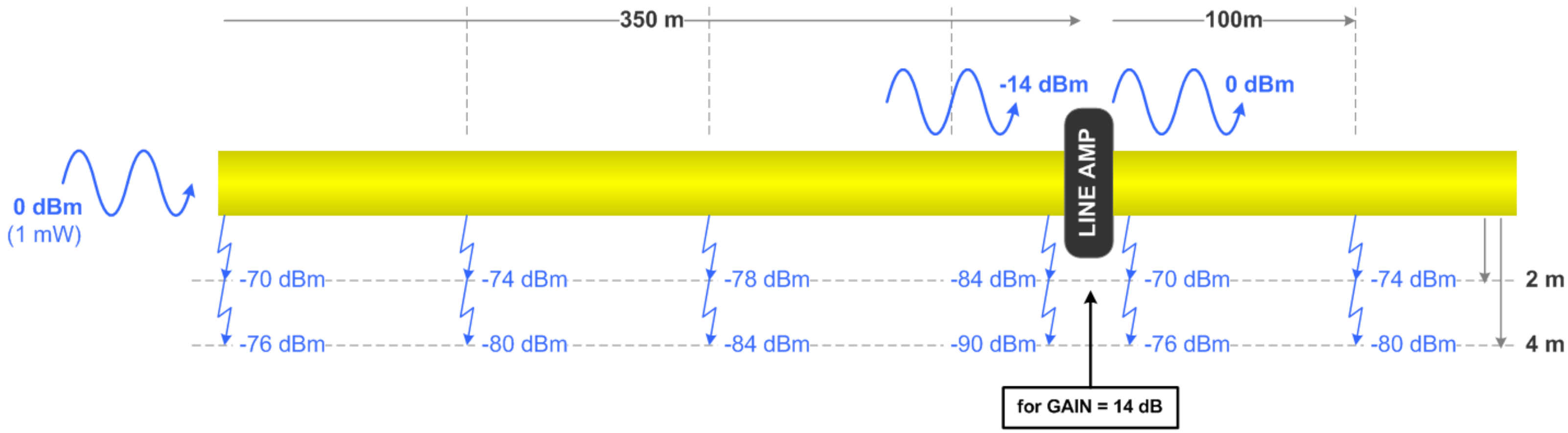
Why is gain needed?

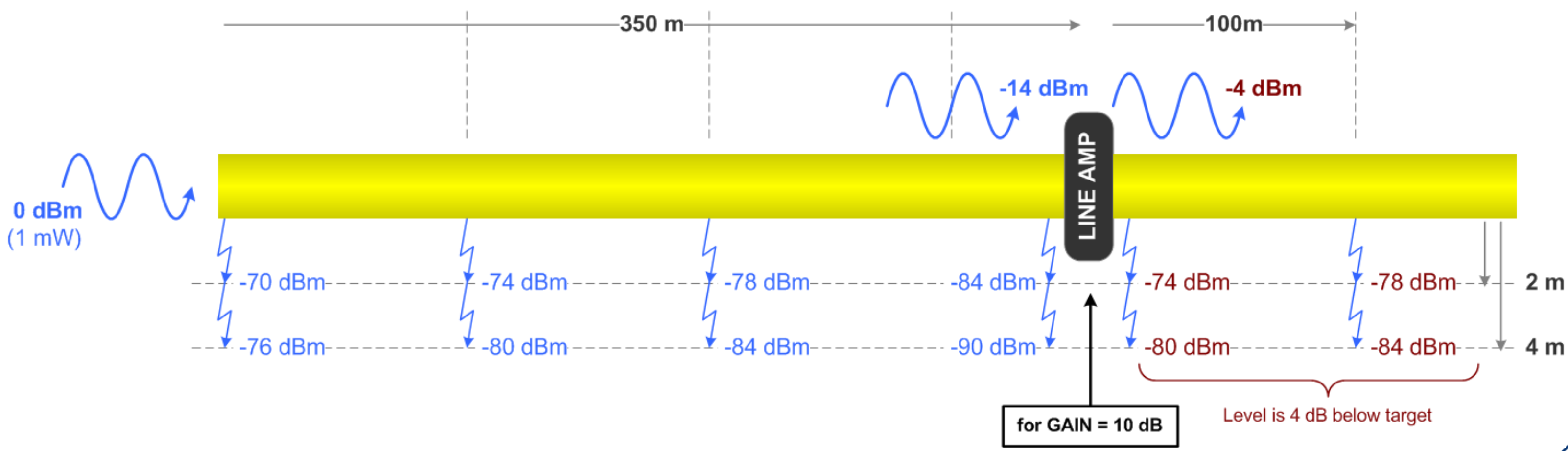
If the signal is not boosted after 350m it becomes too weak for a radio terminal to distinguish from background noise



A line amplifier boosts the signal

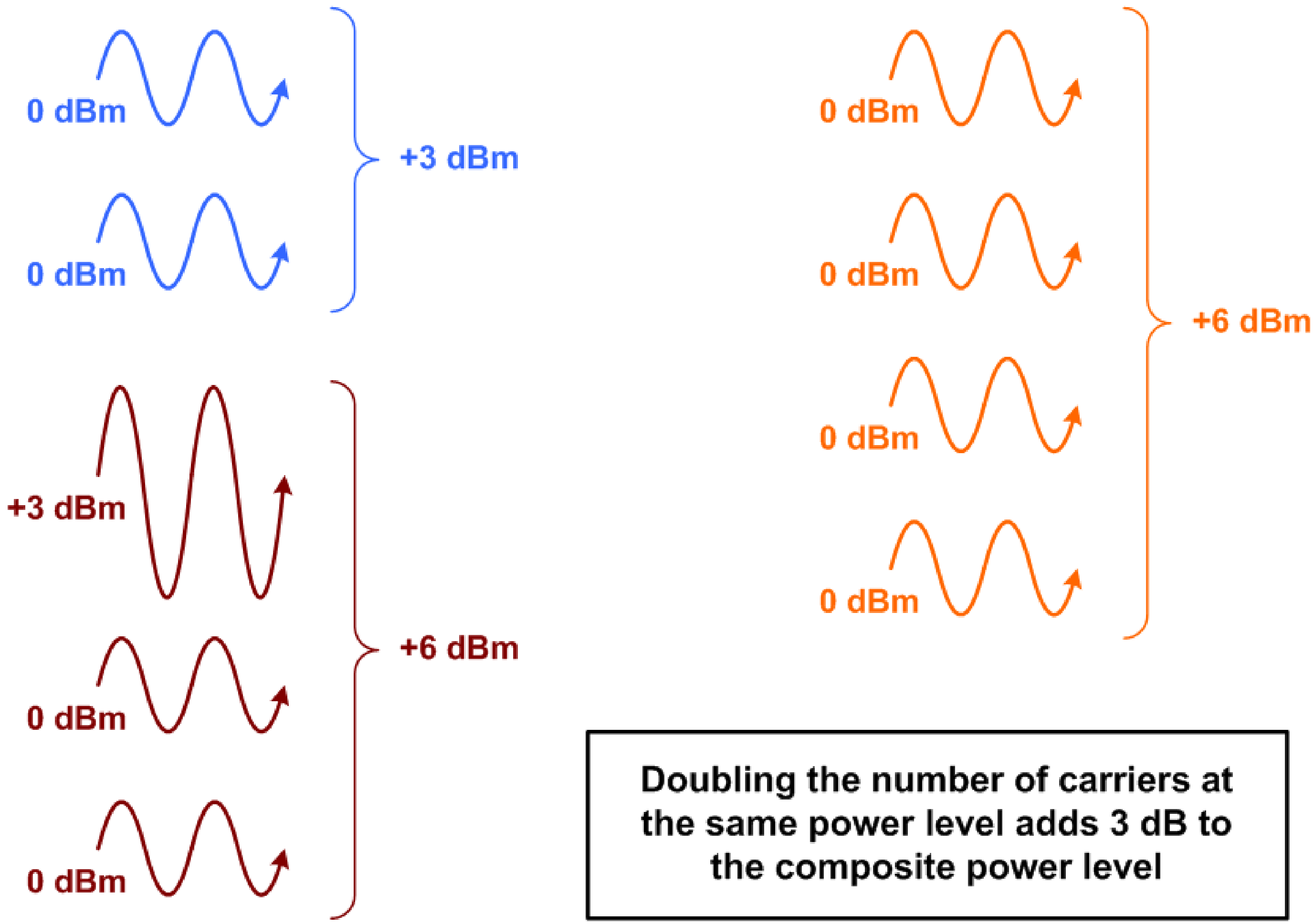
The correct gain setting will boost the signal to its original level. However, the right value depends on the losses in the preceding cable run.





Composite power recap

When multiple carriers are simultaneously active, the composite power is more than the value of the individual carriers.



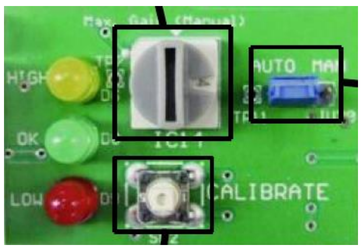
Doubling the number of carriers at the same power level adds 3 dB to the composite power level

Common gain control techniques

Most underground line amplifiers on the market will use **MANUAL** or **COMPOSITE AGC**

MANUAL GAIN CONTROL

- Rotate a dial to attenuate down from maximum gain



ISSUES:

- Technicians can get the level wrong.
- If the upstream losses change (a splitter is added), the dial needs to be manually adjusted.

COMPOSITE AGC

- Continually assess composite RF power across the passband
- Continually adjust the gain to match a 'target' composite power level (0 dBm or +4 dBm)

ISSUES:

- When there are multiple simultaneous carriers, gain fluctuates as carriers are keyed up and down.

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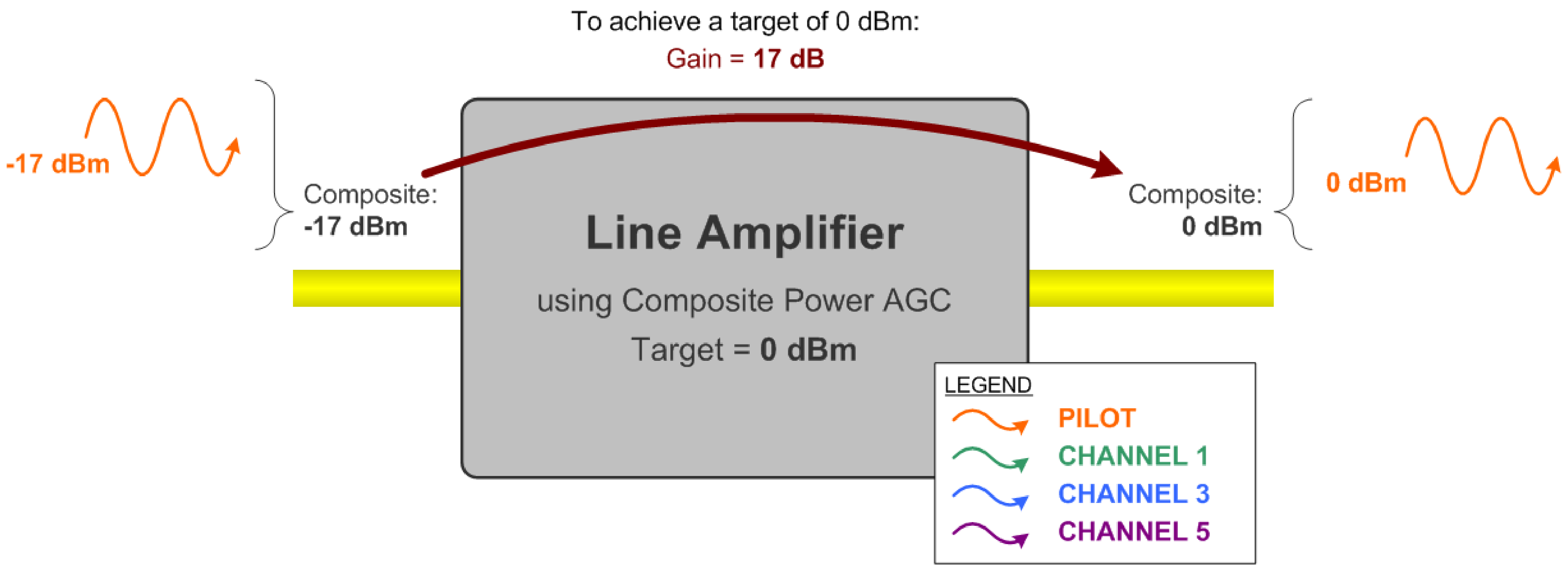
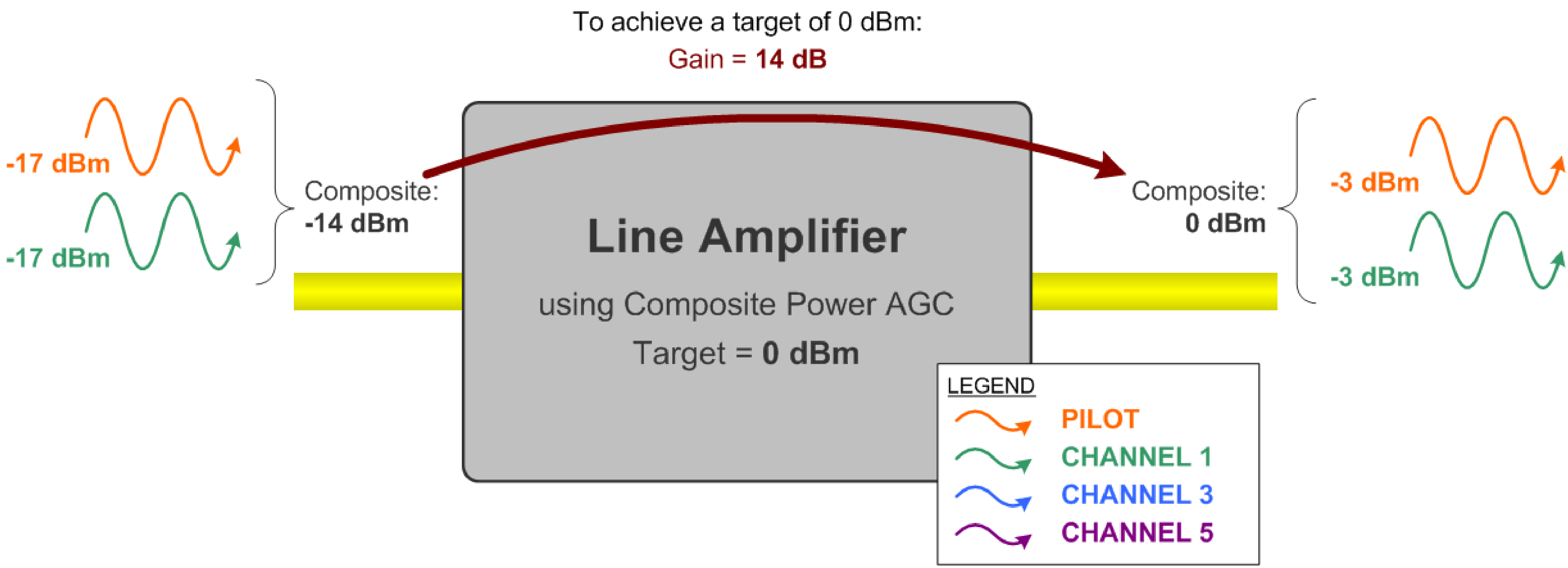
Composite AGC example – no voice carriers active

When no voice carriers are active, the amplifier sends the pilot out at the AGC target level.



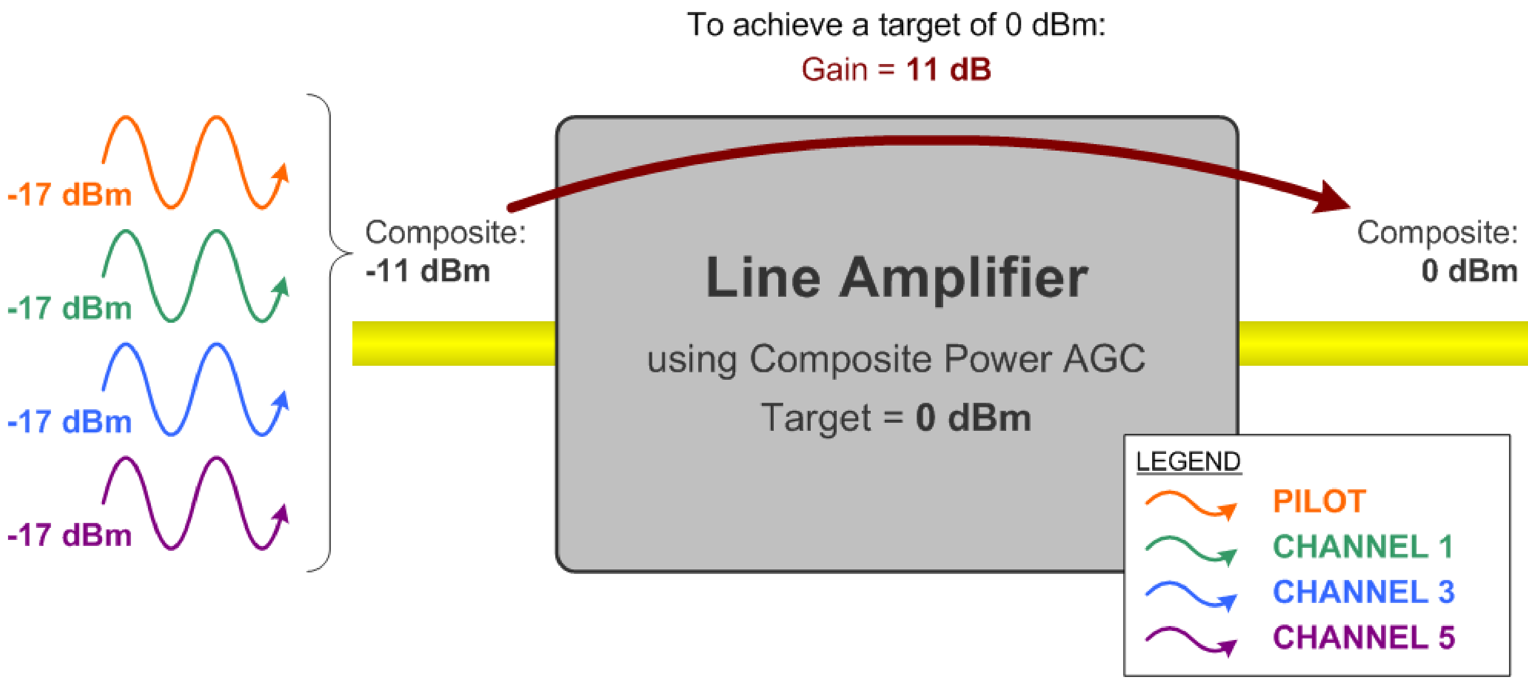
Composite AGC example – 1 voice carrier active

When 1 voice carrier is active, the amplifier gain decreases, sending the pilot and voice carrier out at 3 dB below the AGC target level .



Composite AGC example – 3 voice carriers active

When 3 voice carriers are active, the amplifier gain decreases further, sending the pilot and voice carrier out at 6 dB below the AGC target level .



The traditional composite AGC approach has issues in systems with multiple voice radio carriers:

- Amplifier gain changes dynamically with the number of active voice radio carriers.
- The 'per carrier' range from the leaky feeder cable decreases as more voice radio carriers become active.

A better way

All three gain control modes employed by RFI LineAmps avoid rapid changes to the gain levels.

RFI Design Principles:

- **Primary purpose:** of a LineAmp is to compensate for RF losses in the cabling and passive devices.
- **Once losses are learnt:** the gain should not change with the number of active voice radio carriers.
- **Only change the gain:** when there has been a genuine change in the cabling losses or passive devices.

Gain control mode	Theory of operation
MANUAL	The required gain level is determined by a technician and set statically.
AUTO	A pulsed signal with a known power level is regularly sent down the system with each LineAmp measuring the signal's remaining energy after the upstream cabling and passive device losses.
PILOT	Each LineAmp measures its incoming composite RF power level to learn the long-term average number of active carriers in the system. The difference between this value and the target outgoing composite power determines the gain.

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MANUAL gain control mode

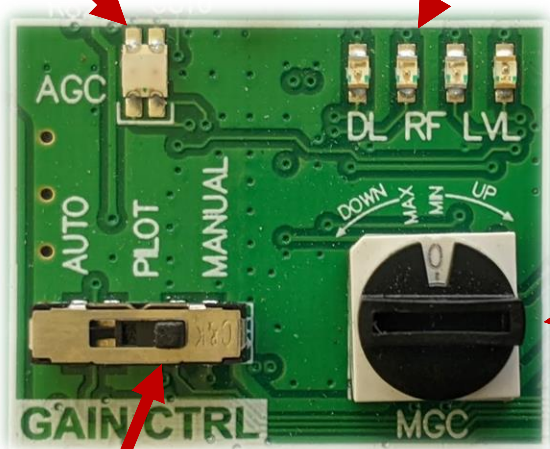
Manual gain control mode is used in very small systems or when bench testing.

AGC INDICATOR:

- Always OFF when operating in MANUAL gain control mode.

DOWNLINK RF LEVEL INDICATORS:

- Useful when adjusting the downlink gain level *(more details to follow)*.



MANUAL GAIN LEVEL:

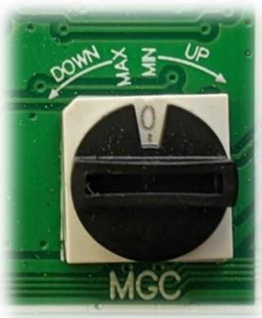
- The vertical position (as shown) equals 10 dB gain.
- Each clockwise step adds 1 dB, up to a maximum of 25 dB.

MODE:

- Select the MANUAL position

MANUAL gain control mode – examples

The rotary control has 16 positions, enabling 10 to 25 dB of gain to be selected, in 1 dB steps.



10 dB

19 dB

25dB

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AUTO gain control mode

Auto gain control mode is recommended. However, there cannot be any 'Composite AGC' devices between the head-end and the RFI LineAmps.

AGC INDICATOR:

- Consult the list of indicator codes that apply to AUTO mode *(more details to follow)*.

DOWNLINK RF LEVEL INDICATORS:

- Useful when verifying the correct RF levels after the gain level has stabilised *(more details to follow)*.

MANUAL GAIN LEVEL:

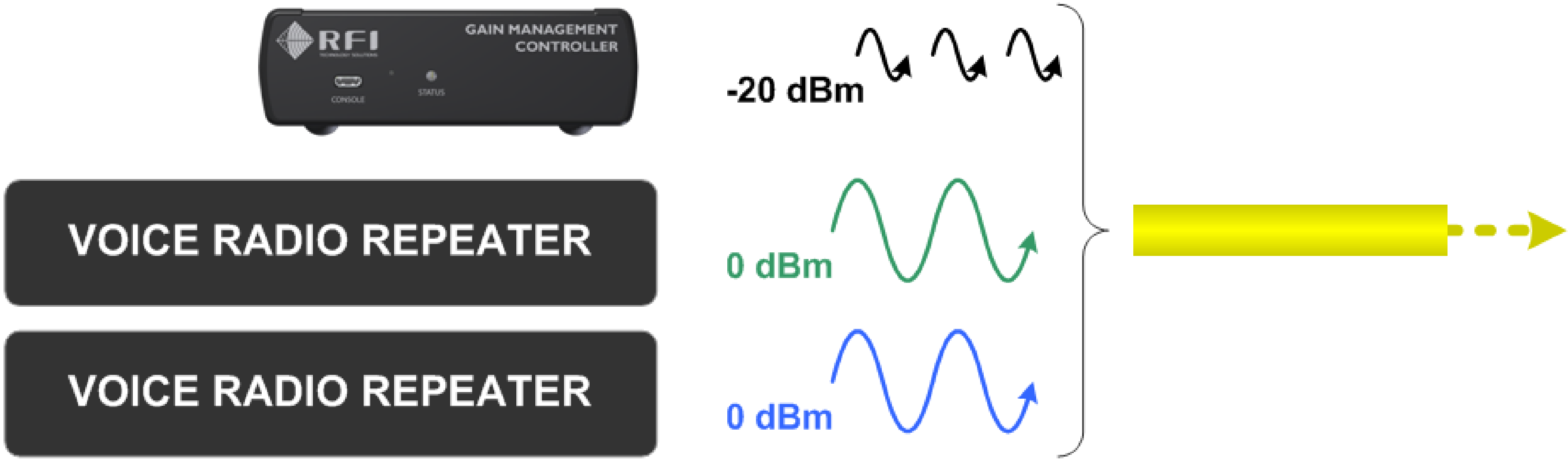
- Ignored in this mode.

MODE:

- Select the AUTO position

AUTO gain control mode – theory of operation (Headend)

A pulsed signal (a beacon) is regularly sent from the headend at a level 20 dB below each of the voice radio carriers, with information about its target level encoded inside each transmission.



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AUTO gain control mode – theory of operation (LineAmp)

Each LineAmp receives the beacon, measuring the energy of just that signal, and it also decodes the target level of the beacon.

2. Decode
The target beacon level, which is contained inside. *(usually –20 dBm)*

3. Compare
The difference between the target level and the measured RF power, which equals the cable losses.

1. Measure
The RF power of the received beacon, <u>not</u> the composite RF power.

4. Set
The gain to ensure the beacon exits at the target level.

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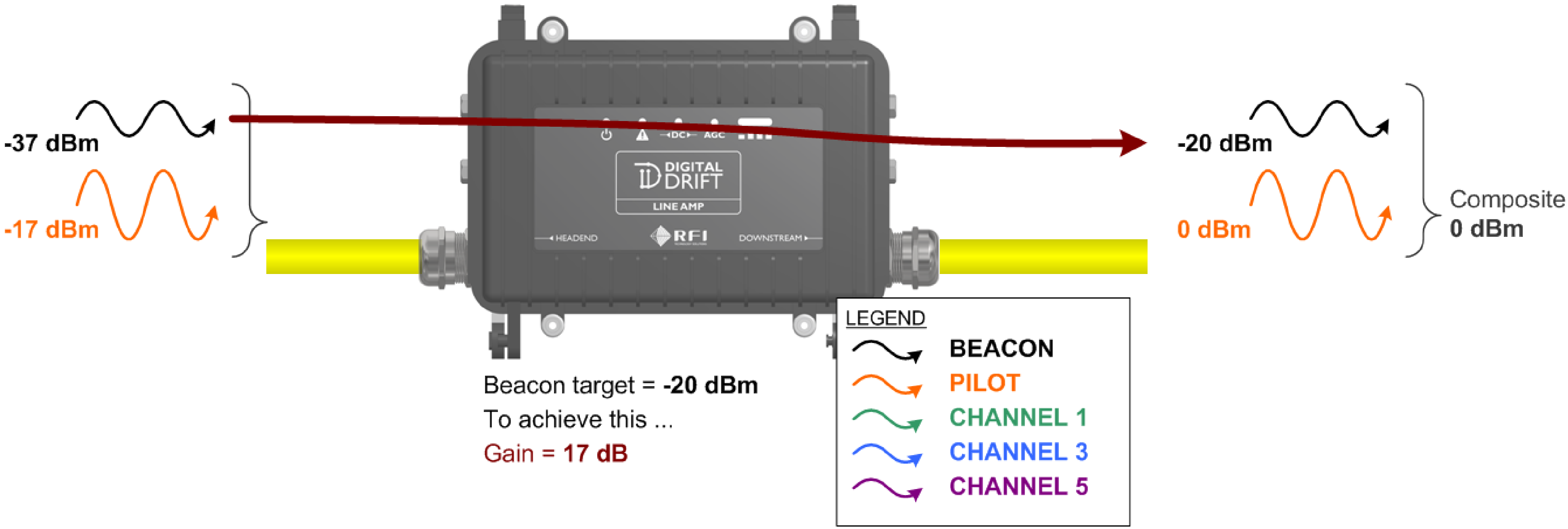
AUTO gain control example – no voice carriers active

When no voice carriers are active, the amplifier sends the pilot out at 0 dBm.



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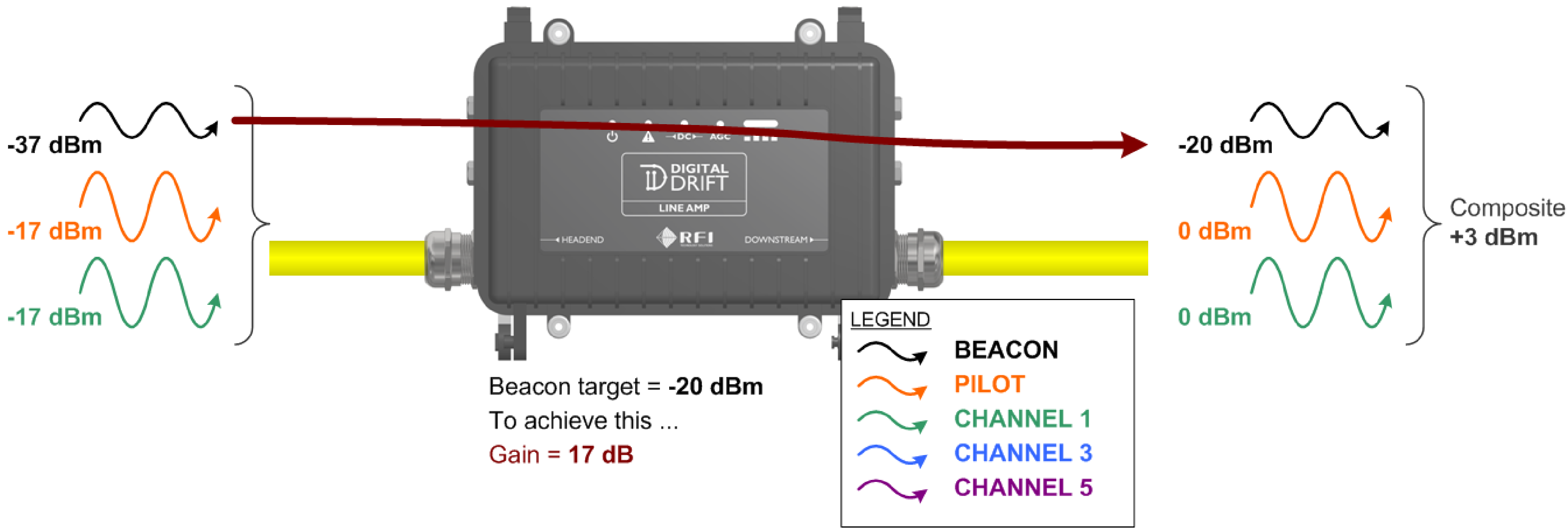
AUTO gain control example – 1 voice carrier active

When 1 voice carrier is active, the amplifier gain remains steady, sending both the pilot and voice carrier out at 0 dBm, which increases the composite output power to +3 dBm.



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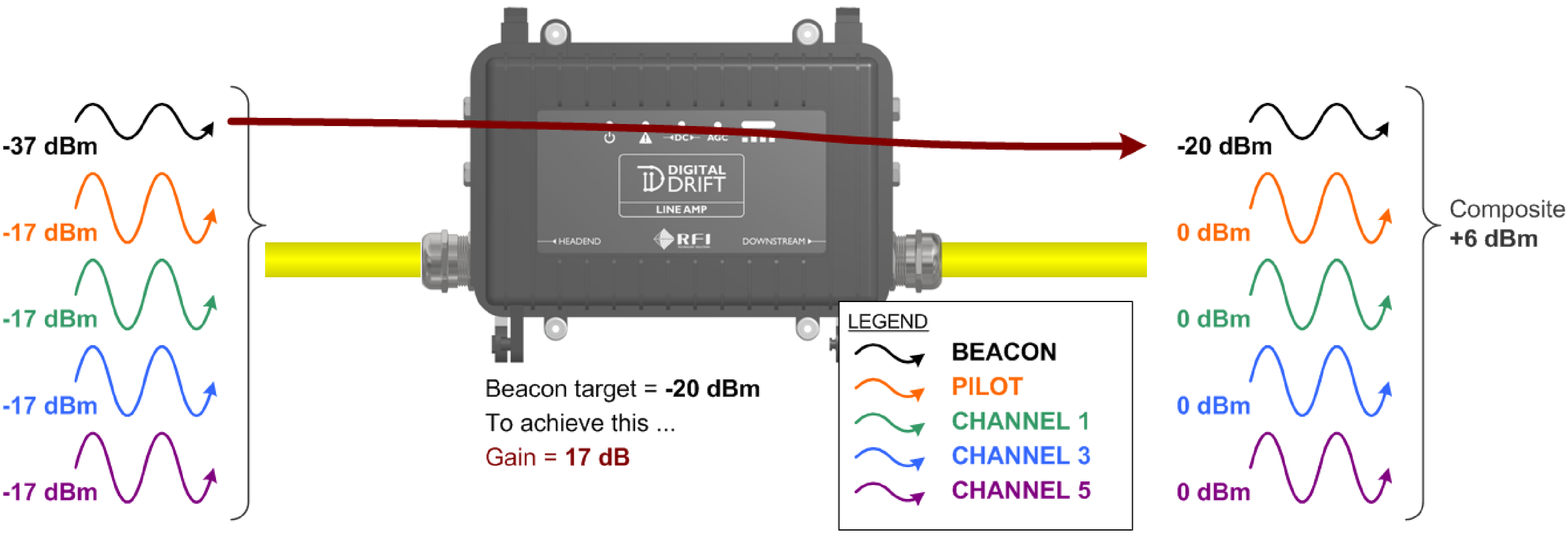
AUTO gain control example – 3 voice carriers active

When 3 voice carriers are active, the amplifier gain remains steady, sending the pilot and every voice carrier out at 0 dBm, which increases the composite output power to +6 dBm.



The AUTO gain control mode improves upon the traditional composite AGC approach:

- Gain remains constant, regardless of the number of active voice radio carriers.
- The range from the leaky feeder cable remains consistent.

AUTO gain control – AGC indicator values

The AGC indicator provides feedback about the state of the AUTO gain control algorithm.

Colour	Pattern	Meaning
Green	Solid	Gain is locked.
	Slow flash (1 Hz, 75% duty)	Gain is being tuned.
Orange	Slow flash (1 Hz, 75% duty)	Searching for the beacon.
Red	Slow flash (1 Hz, 75% duty)	Beacon not found.
	Double flash	Upper gain limit reached, LineAmps are too far apart.
	Triple flash	Lower gain limit reached, LineAmps are too close.
	Quad flash	Beacon level too low.

AUTO gain control – extras

<u>TO DO:</u>

- **DL RF LVL LEDs are useful to see activity …. because composite power will increase and decrease with channel activity**
- **Target level is configurable at the GMC (default = -20)**

PILOT gain control mode

Pilot gain control mode must be used in systems where there are 'Composite AGC' devices between the head-end and the RFI LineAmps.

<u>TO DO:</u>

- **Theory = continually measure incoming average composite power with a long-time interval. This averages out the duty cycles of each voice radio carrier.**
- **Use the difference between the measured average and the target composite power to set the gain, but do not change it dynamically as the carrier count changes.**
- **Rather, hold the 'learnt' gain until a genuine 'topology change' is detected. However, this can take up to 5 minutes.**
- **When a 'topology change' is detected:**
    - **Re-start the learning algorithm to determine the new average incoming composite power**
- **The downlink RF level meter is useful to see activity …. because composite power will increase and decrease with channel activity.**
- **The target level is configurable (default = +1.5) – recommended to be set at the GMC.**

RFI TECHNOLOGY SOLUTIONS

PILOT gain control – AGC indicator values

The AGC indicator provides feedback about the state of the PILOT gain control algorithm.

Colour	Pattern	Meaning
Green	Solid	Gain is locked.
	Slow flash (1 Hz, 75% duty)	Gain is being tuned.
Orange	Slow flash (1 Hz, 75% duty)	Re-learning the incoming composite power average.
Red	Slow flash (1 Hz, 75% duty)	Incoming signal not found.
	Double flash	Upper gain limit reached, LineAmps are too far apart.
	Triple flash	Lower gain limit reached, LineAmps are too far close.

Uplink gain level

The uplink gain is equal to the downlink gain plus an 'uplink gain boost' factor to compensate for higher RF losses that occur in the cable at the uplink frequency band.

Regardless of the gain control mode (*AUTO*, *PILOT* or *MANUAL*):

- **Uplink gain =** Downlink gain + **uplink gain boost**
- Uplink gain is **capped at 25 dB**

Uplink gain boost:

- The value can be configured either:
  - Locally *(via the serial CLI)*
  - Site-wide *(via the GMC)*
- Default value = **+1.2 dB**

TECHNOLOGY SOLUTIONS

Gain limiter

Outgoing RF power is continually monitored and if +10 dBm is exceeded, the gain is reduced to avoid saturating the amplifiers.

An example:

- If gain is set to 20 dB (via MANUAL gain control):

Incoming signals	Incoming composite RF power	Outgoing composite RF power *(before limiter)*	Applied gain	Outgoing Composite RF power *(after limiter)*	
1 @ –15 dBm	-15 dBm	+5 dBm	20	+5 dBm	
2 @ –15 dBm	-12 dBm	+8 dBm	20	+8 dBm	
4 @ –15 dBm	-9 dBm	+11 dBm	19 (limited)	+10 dBm	*(flashing)*
8 @ -15 dBm	-6 dBm	+14 dBm	16 (limited)	+10 dBm	*(flashing)*

Future developments

An improved uplink gain control mechanism is possible when the entire system uses RFI LineAmps and 2-way diagnostics is implemented.