InterReach Fusion™

Installation, Operation, and Reference Manual

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Rev A

Your comments are welcome – they help us improve our products and documentation. Please address your comments to LGC Wireless, Inc. corporate headquarters in San Jose, California:

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SECTION 1

General Information

This section contains the following subsections:

- Section 1.1 Firmware Release 1-1
- Section 1.2 Purpose and Scope 1-1
- Section 1.3 Conventions in this Manual 1-2
- Section 1.4 Standards Conformance 1-3
- Section 1.5 Related Publications 1-3

1.1 Firmware Release

For the latest Software and Firmware Release and associated documentation, access the LGC Wireless Customer Portal at lgcwireless.com.

1.2 Purpose and Scope

This document describes the InterReach Fusion system.

- **Section 2 InterReach Fusion System Description**

  This section provides an overview of the Fusion hardware and OA&M capabilities. This section also contains system specifications and RF end-to-end performance tables.

- **Section 3 Fusion Main Hub**

  This section illustrates and describes the Fusion Main Hub. This section includes connector and LED descriptions, and unit specifications.

- **Section 4 Fusion Expansion Hub**

  This section illustrates and describes the Expansion Hub, as well as connector and LED descriptions, and unit specification.

- **Section 5 Remote Access Unit**

  This section illustrates and describes the Remote Access Unit. This section also includes connector and LED descriptions, and unit specifications.

- **Section 6 Designing a Fusion Solution**

  This section provides tools to aid you in designing your Fusion system, including tables of the maximum output power per carrier at the RAU and formulas and tables for calculating path loss, coverage distance, and link budget.

- **Section 7 Installing Fusion**

  This section provides installation procedures, requirements, safety precautions, and checklists. The installation procedures include guidelines for troubleshooting using the LEDs as you install the units.

- **Section 8 Replacing Fusion Components**

  This section provides installation procedures and considerations when you are replacing an Fusion component in an operating system.

- **Section 9 Maintenance, Troubleshooting, and Technical Assistance**

  This section provides contact information and troubleshooting tables.

- **Appendix A Cables and Connectors**

  This appendix provides connector and cable descriptions and requirements. It also includes cable strapping, connector crimping tools, and diagrams.

- **Appendix B Compliance**

  This section lists safety and radio/EMC approvals.

- **Appendix C Faults, Warnings, Status Tables**

  This section lists all system alarm messages.

1.3 Conventions in this Manual

The following table lists the type style conventions used in this manual.

Convention	Description
bold	Used for emphasis
BOLD CAPS	Labels on equipment
SMALL CAPS	Software menu and window selections

This manual lists measurements first in metric units, and then in U.S. Customary System of units in parentheses. For example:

0° to 45°C (32° to 113°F)

This manual uses the following symbols to highlight certain information as described.

NOTE: This format emphasizes text with special significance or importance, and provides supplemental information.

CAUTION: This format indicates when a given action or omitted action can cause or contribute to a hazardous condition. Damage to the equipment can occur.

WARNING: This format indicates when a given action or omitted action can result in catastrophic damage to the equipment or cause injury to the user.

Procedure

This format highlights a procedure.

1.4 Standards Conformance

- Fusion uses the TIA-570-B cabling standards for ease of installation.
- Refer to Appendix B for compliance information.

1.5 Related Publications

- *AdminBrowser User Manual,* LGC Wireless part number D-620607-0-20 Rev. A
- *MetroReach Focus Configuration, Installation, and Reference Manual*; LGC Wireless part number 8500-10
- *InterReach Unison Installation, Operation, and Reference Manual*; LGC Wireless part number 8700-50

SECTION 2

InterReach Fusion System Description

This section contains the following subsections:

- Section 2.1 System Overview 2-1
- Section 2.2 System Hardware Description 2-3
- Section 2.3 System OA&M Capabilities Overview 2-4
- Section 2.4 System Connectivity 2-7
- Section 2.5 System Operation 2-8
- Section 2.6 System Specifications 2-9

2.1 System Overview

InterReach Fusion is an intelligent fiber optics/CATV, multi-band (frequencies) wireless networking system designed to handle both wireless voice and data communications over licensed frequencies. It provides high-quality, ubiquitous, seamless access to the wireless network in smaller buildings.

Fusion provides RF characteristics designed for large public and private facilities such as campus environments, airports, shopping malls, subways, convention centers, sports venues, and so on. Fusion uses microprocessors to enable key capabilities such as software-selectable band settings, automatic gain control, ability to incrementally adjust downlink/uplink gain, end-to-end alarming of all components and the associated cable infrastructure, and a host of additional capabilities.

The Fusion system supports major wireless standards and air interface protocols in use around the world, including:

- Frequencies: 800 MHz, 850 MHz, 900 MHz, 1800 MHz, 1900 MHz, 2100 MHz
- Voice Protocols: AMPS, TDMA, CDMA, GSM/EGSM,WCDMA, iDEN
- Data Protocols: CDPD, EDGE, GPRS, WCDMA, CDMA2000, 1xRTT, EV-DO, and Paging

The Fusion system supports three configurable bands:

- Band 1 in 35 MHz and can be configured for 850 MHz, or 900 MHz.
- Band 2 in 75 MHz and can be configured for 1800 MHz, 1900 MHz, or 2100 MHz

  Both bands support all protocols.

  Fusion remote access units contain combinations of Band 1, Band 2, and Band 3 frequencies to support various world areas, that is 800 MHz/900 MHz/1900MHz for North America or 900 MHz/2100 MHz and 900 MHz/1800 MHz for Europe and Asia. Refer to Figure 2-6 on page 2-8 for a specific list of these RAU frequency combinations.
- Band 3 (only used for the North American FSN-809019-1 RAU) whose Band 3 is a 6 MHz sub-band of the 35 MHz Band with Band 1 being an 18 MHz sub-band of the 35 MHz Band.

Key System Features

- **Multi-Band**, supports two or more full band frequencies for spectrum growth.
- **Superior RF performance**, particularly in the areas of IP3 and noise figure.
- **High downlink composite power** and **low uplink noise figure** enables support of a large number of channels and larger coverage footprint per antenna.
- **Software configurable** Main and Expansion Hubs allow the frequency bands to be configured in the field.
- **Either single-mode or multi-mode fiber** can be used, supporting flexible cabling alternatives (in addition to standard CATV 75 Ohm cabling). You can select the cabling type to met the resident cabling infrastructure of the facility and unique building topologies.
- **Extended system “reach.”** Using single-mode fiber, fiber runs can be a long as 6 kilometers (creating a total system “wingspan” of 12 kilometers). Alternatively, with multi-mode fiber, fiber runs can be as long as 500 meters.
- **Standard 75 Ohm CATV cable,** can be run up to 150 meters for RG-59 cable (170 meters for RG-6; 275 meters for RG-11 using CommScope 2065V, 2279V, and 2293K cables).
- **Flexible RF configuration capabilities**, including:
  - System gain:
    - Ability to manually set gain in 1 dB steps, from 0 to 15 dB, on both downlink and uplink.
  - RAU:
    - RAU uplink and downlink gain can be independently attenuated 10 dB in 1 dB steps.
    - Uplink level control protects the system from input overload and can be optimized for either a single operator or multiple operators/protocols.

- VSWR check on RAU reports if there is a disconnected antenna.

- **Firmware Updates** are downloaded (either locally or remotely) to the system when any modifications are made to the product, including the addition of new software capabilities and services.
- **OA&M capabilities**, including fault isolation to the field replaceable unit, reporting of all fault and warning conditions, and user-friendly web browser user interface OA&M software package.

2.2 System Hardware Description

The InterReach Fusion system consists of three modular components:

- 19" rack-mountable **Main Hub** *(connects to up to 4 Expansion Hubs)*
  - Converts RF signals to optical IF on the downlink; optical IF-to-RF on the uplink
  - Microprocessor controlled (for alarms, monitoring, and control)
  - Auto-configurable bands
  - Simplex interface to RF source
  - Periodically polls all downstream RAUs for system status, and automatically reports any fault or warning conditions
- 19” rack mountable **Expansion Hub** *(connects to up to 8 Remote Access Units)*
  - Optical signal conversion to electrical on the downlink; electrical to optical on the uplink
  - Microprocessor controlled (for alarms, monitoring, and control)
  - Software configurable band (based on commands from the Main Hub)
  - Supplies DC power to RAUs over CATV cable.
- **Remote Access Unit** (RAU)
  - Converts IF signals to RF on the downlink; RF-to-IF on the uplink
  - Microprocessor controlled (for alarms, monitoring, and control)
  - Multi-band protocol independent, frequency specific units

The minimum configuration of a Fusion system is one Main Hub, one Expansion Hub, and one RAU (1-1). The maximum configuration of a system is one Main Hub, four Expansion Hubs, and 32 RAUs (1-4-32). Multiple systems can be combined to provide larger configurations.

Figure 2-1 Fusion System Hardware

2.3 System OA&M Capabilities Overview

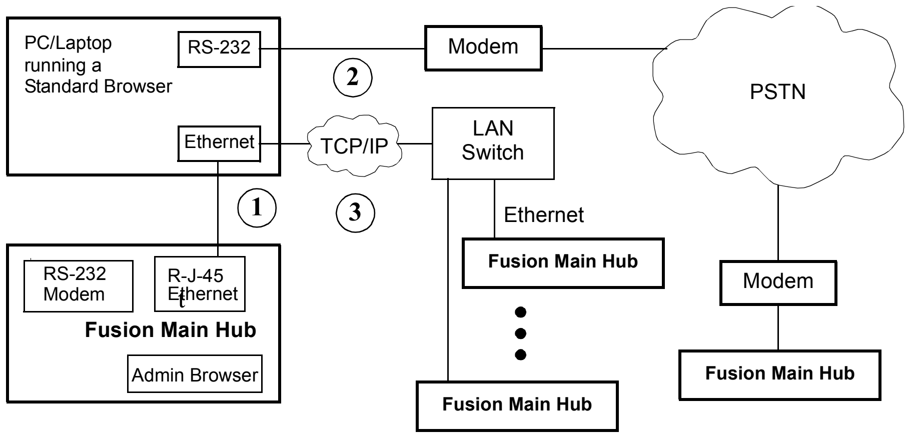
InterReach Fusion is microprocessor controlled and contains firmware to enable much of the operations, administration, and maintenance (OA&M) functionality.

Complete alarming, down to the field replaceable unit (that is, Fusion Main Hub, Expansion Hub, and Remote Access Unit) and the cabling infrastructure, is available. All events occurring in a system, defined as a Fusion Main Hub and all of its associated Expansion Hubs and Remote Access Units, are automatically reported to the Main Hub. The Main Hub monitors system status and communicates that status using the following methods:

- Normally closed (NC) alarm contact closures can be tied to standard NC alarm monitoring systems or directly to a base station for basic alarm monitoring.
- Connection Methods:
  - The Main Hub's front panel RJ-45 port connects directly to a PC (for local Ethernet access).
  - The Main Hub's front panel RS-232 serial port connects directly to a modem (for remote access).
  - Remote access is also available with an optional 100BASE-T LAN switch connections to the RJ-45 port.

Figure 2-2 **Three Methods for OA&M Communications**

Use AdminBrowser to configure or monitor a local or a remote Fusion system.



AdminBrowser OA&M software runs on the Fusion Main Hub microprocessor and communicates to its downstream Expansion Hubs and associated RAUs. Using AdminBrowser, you can perform the following from any standard web browser (Internet Explorer) running on your PC/laptop system:

- Configure a newly installed system
- Change system parameters
- Perform an end-to-end system test
- Query system status

Refer to the *AdminBrowser User Manual* (D-620607-0-20 Rev A) for information about installing and using AdminBrowser software.

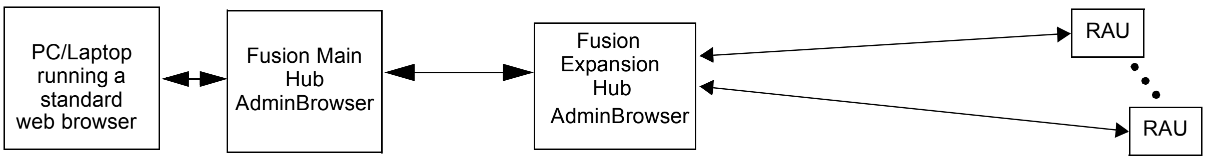
2.3.1 System Monitoring and Reporting

Each Fusion Main Hub in the system constantly monitors itself, its Expansion Hubs, and their downstream RAUs for internal fault and warning conditions. The results of this monitoring are stored in memory and compared against new results.

When a Main or Expansion Hub detects a change in status, it reports a fault or warning alarm. Faults are also indicated locally by red status LEDs. Both faults and warnings are reported to AdminBrowser software and displayed on a PC/laptop connected to the Main Hub's RJ-45 port. Passive antennas connected to the RAUs are not monitored automatically. Perform a System Test to retrieve status information about antennas.

Using AdminBrowser, you can install a new system or new components, change system parameters, and query system status. Figure 2-3 illustrates how the system reports its status to AdminBrowser.

Figure 2-3 **System Monitoring and Reporting**



Use a standard browser to communicate with remotely or locally installed Fusion systems running AdminBrowser.

If a fault or warning condition is reported, the AdminBrowser graphical user interface indicates the problem on your standard PC browser.

The Main Hub queries status of each Expansion Hub and each RAU and compares it to previously stored status.

If a fault is detected, LEDs on the front panel turn red.

The Expansion Hub queries the status of each RAU and compares it to the previously stored status.

If a fault is detected, LEDs on the front panel turn red.

Each RAU passes its status to the Hub.

If a fault is detected, the **ALARM** LED is red. If no fault is detected, the LED is green.

2.3.2 Using Alarm Contacts

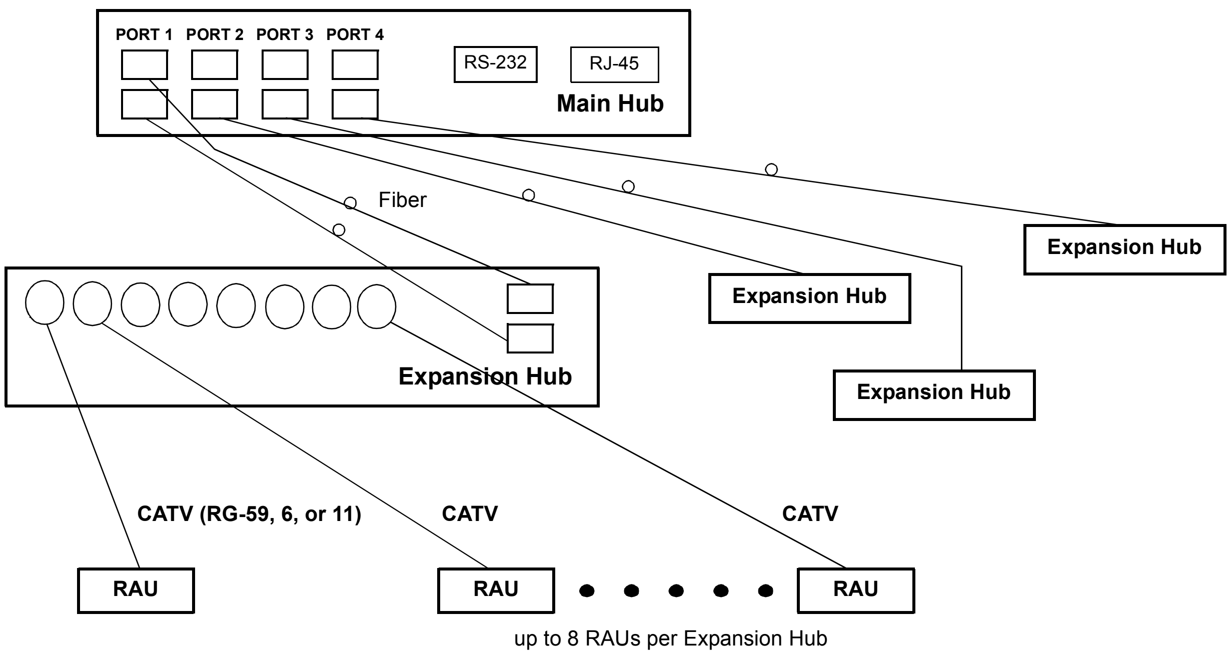
You can connect the DB-9 female connector on the rear panel of the Fusion Main Hub to a local base station or to a daisy-chained series of Fusion and/or MetroReach Focus systems.

When you connect MetroReach Focus or a BTS to the Fusion, the Fusion Main Hub outputs the alarms (alarm source) and MetroReach Focus or the BTS receives the alarms (alarm sense). This is described in Section 7.7.1 on page 7-50.

2.4 System Connectivity

The double star architecture of the Fusion system, illustrated in Figure 2-4, provides excellent system scalability and reliability. The system requires only one pair of fibers for eight antenna points. This makes any system expansion, such as adding an extra antenna for additional coverage, potentially as easy as pulling an extra CATV cable.

Figure 2-4 Fusion's Double Star Architecture



2.5 System Operation

Figure 2-5 Downlink (Base Station to Wireless Devices)

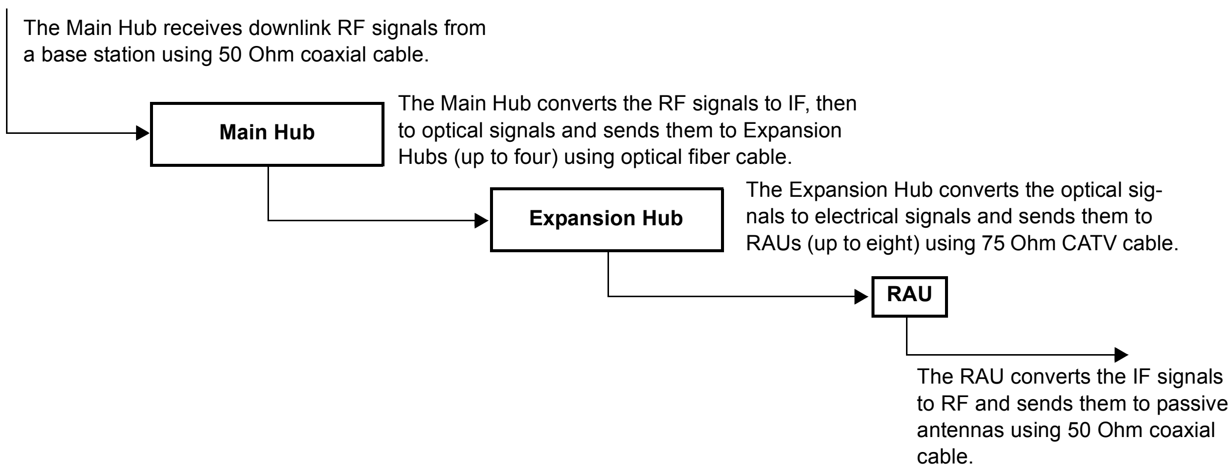
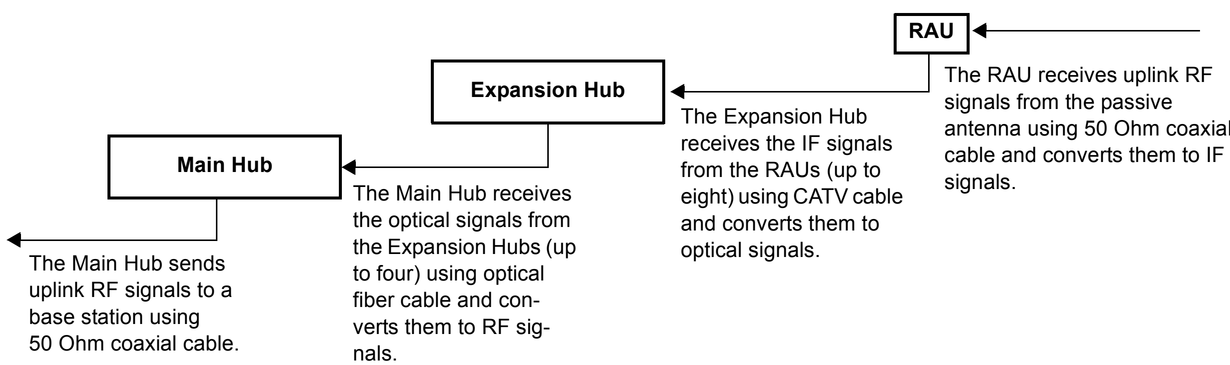


Figure 2-6 Uplink (Wireless Devices to Base Station)



2.6 System Specifications

Table 2-1 Physical Specifications

Parameter	Main Hub	Expansion Hub	Remote Access Unit
IF/RF Connectors	6-type “N”, female (50 Ohm), 1 Downlink/Uplink pair per band	8-type “F”, female (CATV 75 Ohm)	One F, female (CATV -75 Ohm) One N, female (coaxial - 50 Ohm)
External Alarm Connector (contact source)	One, 9-pin D-sub, female	One, 9-pin D-sub, female	—
ADMIN/LAN Interface Connectors	One RJ-45, female One 9-pin D-sub, male for optional modem	One RJ-45, female One 9-pin D-sub, male	—
Fiber Connectors*	4 pair, SC/APC	One pair, SC/APC	—
LED Alarm and Status Indicators	Unit Status (One pair): • Power • Main Hub Status Downstream Unit Status (One per fiber port): • Expansion Hub/RAU	Unit Status (One pair): • Power • Expansion Hub Status Fiber Link Status (One pair): • DL Status • UL Status Port Status: • One per F connector port • Link/RAU	Unit Status (One pair): • Link • Alarm
Power (Volts)	Rating: 100–240V AC, 1A, 50–60 Hz Operating Range: 90–132V AC/170-250V AC auto-ranging	Rating: 100–240V AC, 6A, 50–60 Hz Operating Range: 90–132V AC/170-250V AC auto-ranging	—
Power Consumption (W)	30	4 RAUs: 305 typical 8 RAUs: 530 typical	—
Enclosure Dimensions† (height × width × depth)	89 mm × 438 mm × 381 mm (3.5 in. × 17.25 in. × 15 in.) (2U)	89 mm × 438 mm × 381 mm (3.5 in. × 17.25 in. × 15 in.) (2U)	54 mm x 286 mm x 281 mm (2.13 in. × 11.25 in. × 11.13 in.)
Weight	< 5.5 kg (< 12 lbs.)	< 6.6 kg (< 14.5 lbs.)	< 2.1 kg (< 4.6 lbs.)

*It is critical to system performance that only SC/APC fiber connectors are used throughout the fiber network, including fiber distribution panels.

†Excluding angle-brackets for 19" rack mounting of hub.

Note: The Fusion Main Hub’s typical power consumption assumes that the CATV RG-59 cable length is no more than 150 meters, the RG-6 cable length is no more than 170 meters, and RG-11 cable length is no more than 275 meters using CommScope 2065V, 2279V, and 2293K cables.

Table 2-2 **Wavelength and Laser Power Specifications**

Wavelength	Measured Output Power	
	Main Hub	Expansion Hub
1310 nm $\pm$20 nm	890 uW	3.8 mW

Table 2-3 **Environmental Specifications**

Parameter	Main Hub and Expansion Hub	RAU
Operating Temperature	0° to +45°C (+32° to +113°F)	–25° to +45°C (–13° to +113°F)
Non-operating Temperature	–20° to +85°C (–4° to +185°F)	–25° to +85°C (–13° to +185°F)
Operating Humidity; non-condensing	5% to 95%	5% to 95%

Table 2-4 **Frequency Bands Covered by Fusion RAUs**

Fusion RAU	Part Number	Fusion Band	RF Passband		MAIN HUB/ RAU Band	RAU Band-width
			Downlink (MHz)	Uplink (MHz)		
850/1900	FSN-8519-1	850	869–894	824–849	1	25 MHz
		1900	1930–1990	1850–1910	2	60 MHz
900//1800	FSN-9018-1	900	925–960	880–915	1	35 MHz
		1800	1805–1880	1710–1785	2	75 MHz
900/2100	FSN-9021-1	900	925–960	830–715	1	35 MHz
		2100	2110–2170	1920–1980	2	60 MHz
800/900/ 1900	FSN-809019-1	800 SMR	851-869	806-824	1 (sub band 1A)	18 MHz
		900 SMR	935-941	896-902	3 (sub band 1B)	6 MHz
		1900 (A-G)	1930-1995	1850-1915	2	65 MHz

2.6.1 RF End-to-End Performance

The following tables list the RF end-to-end performance of each protocol.

NOTE: The system gain is adjustable in 1 dB steps from 0 to 15 dB, and the gain of each RAU can be attenuated up to 10 dB in 1dB steps.

850/1900 RAU

Table 2-5 850 MHz RF End-to-End Performance

Parameter	Typical	
	Downlink	Uplink
Average gain with 75 m RG-59 at 25°C (77°F) (dB)	15	15
Ripple with 150 m RG-59 (dB)	2.5	3
Output IP3 (dBm)	38	
Input IP3 (dBm)		–5
Output 1 dB Compression Point (dBm)	26	
Noise Figure 1 MH, 1 EH, 8 RAUs (dB)		16
Noise Figure 1 MH, 4 EH, 32 RAUs (dB)		22

Table 2-6 1900 MHz RF End-to-End Performance

Parameter	Typical	
	Downlink	Uplink
Average gain with 75 m RG-59 at 25°C (77°F) (dB)	15	15
Ripple with 150 m RG-59 (dB)	3.5	4
Output IP3 (dBm)	38	
Input IP3 (dBm)		-5
Output 1 dB Compression Point (dBm)	26	
Noise Figure 1 MH, 1 EH, 8 RAUs (dB)		16
Noise Figure 1 MH, 4 EH, 32 RAUs (dB)		22

900/1800 RAU

Table 2-7 900 MHz RF End-to-End Performance

Parameter	Typical Downlink	Typical Uplink
Average Downlink gain with 75 m RG-59 at 25°C (77°F) (dB)	15	15
Ripple with 75 m RG-59 (dB)	3	4
Output IP3 (dBm)	38	
Input IP3 (dBm)		–5
Output 1 dB Compression Point (dBm)	26	
Noise Figure 1 MH, 1 EH, 8 RAUs (dB)		16
Noise Figure 1 MH, 4 EH, 32 RAUs (dB)		22

Table 2-8 1800 MHz RF End-to-End Performance

Parameter	Typical Downlink	Typical Uplink
Average gain with 75 m RG-59 at 25°C (77°F) (dB)	15	15
Downlink ripple with 75 m Cat-5/5E/6 (dB)	2	
Uplink ripple with 75 m RG-59 (dB)		2
Uplink gain roll off with 75 m RG-59 (dB)*		2
Output IP3 (dBm)	38	
Input IP3 (dBm)		–5
Output 1 dB Compression Point (dBm)	26	
Noise Figure 1 MH, 1 EH, 8 RAUs (dB)		16
Noise Figure 1 MH, 4 EH, 32 RAUs (dB)		22

*Outside the center 60 MHz

900/2100 RAU

Table 2-9 900 MHz RF End-to-End Performance

Parameter	Typical	
	Downlink	Uplink
Average Downlink gain with 75 m RG-59 at 25°C (77°F) (dB)	15	15
Ripple with 75 m RG-59 (dB)	3	4
Output IP3 (dBm)	38	
Input IP3 (dBm)		–5
Output 1 dB Compression Point (dBm)	26	
Noise Figure 1 MH, 1 EH, 8 RAUs (dB)		16
Noise Figure 1 MH, 4 EH, 32 RAUs (dB)		22

Table 2-10 2100 MHz RF End-to-End Performance

Parameter	Typical	
	Downlink	Uplink
Average gain w/ 75 meters RG-59 @ 25°C (dB)	15	15
Ripple with 75 m RG-59 (dB)	2.5	4
Spurious Output Levels (dBm)	<–30	
UMTS TDD Band Spurious Output Level 1900–1920 MHz, 2010–2025 MHz (dBm/MHz)	<–52	
Output IP3 (dBm)	37	
Input IP3 (dBm)		–5
Output 1 dB Compression Point (dBm)	26	
Noise Figure 1 MH, 1 EH, 8 RAUs (dB)		16
Noise Figure 1 MH, 4 EH, 32 RAUs (dB)		22

800/900/1900 RAU

Table 2-11 800 MHz (SMR) RF End-to-End Performance

Parameter	Typical	
	Downlink	Uplink
Average Downlink gain with 150 m CATV at 25°C (77°F) (dB)	15	15
Ripple with 150 m CATV (dB)	2.5	3
Output IP3 (dBm)	38	
Input IP3 (dBm)		–5
Output 1 dB Compression Point (dBm)	25	
Noise Figure 1 MH-1 EH-8 RAUs (dB)		17
Noise Figure 1 MH-4 EH-32 RAUs (dB)		23

Table 2-12 900 MHz (SMR) RF End-to-End Performance

	Typical	
Parameter	**Downlink**	**Uplink**
Average Downlink gain with 150 m CATV at 25°C (77°F) (dB)	15	15
Ripple with 150 m CATV (dB)	2.5	3
Output IP3 (dBm)	35	
Input IP3 (dBm)		–5
Output 1 dB Compression Point (dBm)	23	
Noise Figure 1 MH-1 EH-8 RAUs (dB)		17
Noise Figure 1 MH-4 EH-32 RAUs (dB)		23

Table 2-13 1900 MHz RF End-to-End Performance

	Typical	
Parameter	**Downlink**	**Uplink**
Average Downlink gain with 150 m CATV at 25°C (77°F) (dB)	15	15
Ripple with 150 m CATV (dB)	3.5	4
Output IP3 (dBm)	38	
Input IP3 (dBm)		–5
Output 1 dB Compression Point (dBm)	26	
Noise Figure 1 MH-1 EH-8 RAUs (dB)		17
Noise Figure 1 MH-4 EH-32 RAUs (dB)		23

SECTION 3

Fusion Main Hub

This section contains the following subsections:

- Section 3.1 Fusion Main Hub Overview 3-1
- Section 3.2 Fusion Main Hub Front Panel 3-4
- Section 3.3 Fusion Main Hub Rear Panel 3-8
- Section 3.4 Main Hub Specifications 3-10
- Section 3.5 Faults, Warnings, and Status Messages 3-11

3.1 Fusion Main Hub Overview

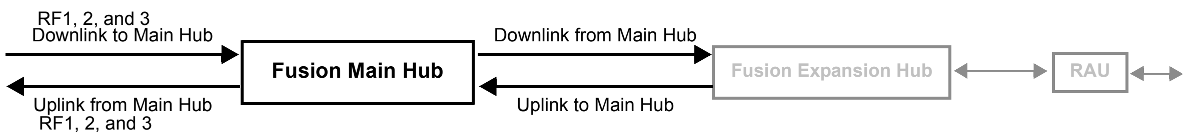
The Fusion Main Hub (shown in Figure 3-1) distributes up to three individual (Band 1, 2, or 3) downlink RF signals from a base station, repeater, or MetroReach Focus system to up to four Expansion Hubs, which in turn distribute the signals to up to 32 Remote Access Units. The Main Hub also combines uplink signals from the associated Expansion Hubs.

Fusion is a multi-band system. One RF source (Band 1 or RF1) goes to the 35 MHz band and the other RF source (Band 2 or RF2) goes to the 75 MHz band. Band 3 (or RF3) goes to a 6 MHz sub-band of the 35 MHz band and is functional only with the 800/900/1900 RAU. The system installs in a 19" equipment rack and is usually co-located with the RF source in a telecommunications closet.

Figure 3-1 **Main Hub in a Fusion System**

Downlink Path: The Main Hub receives up to 3 individual (Band1, 2, or 3) downlink RF signals from a base station, repeater, or MetroReach Focus system using 50 Ohm coaxial cable. It converts the signals to IF then to optical and sends them to up to four Expansion Hubs using fiber optic cable.

The Main Hub also sends OA&M communication to the Expansion Hubs using the fiber optic cable. The Expansion Hubs, in turn, communicate the OA&M information to the RAUs using CATV cable.

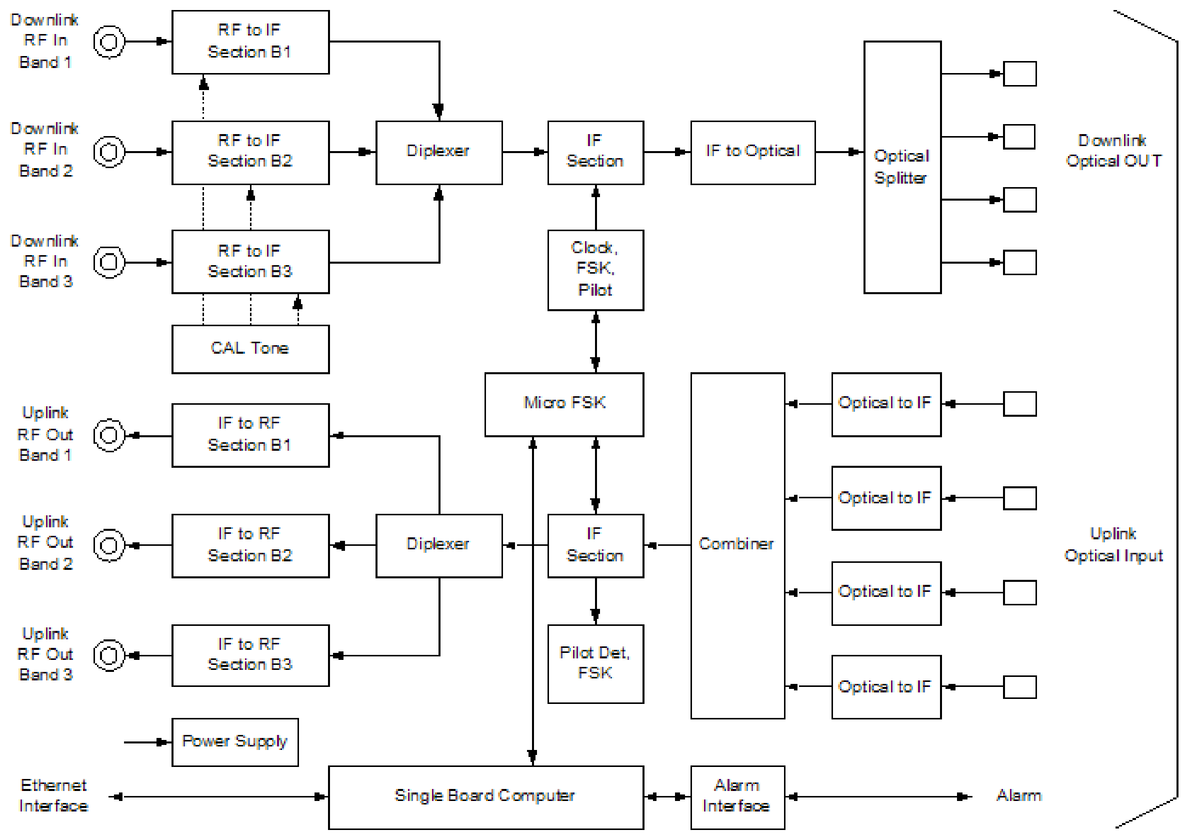


Uplink Path: The Main Hub receives uplink optical signals from up to four Expansion Hubs using fiber optic cables. It converts the signals to IF then to RF and sends them to the respective Band1, 2, or 3 base station, repeater, or MetroReach Focus system using 50 Ohm coaxial cable.

The Main Hub also receives status information from the Expansion Hubs and all RAUs using the fiber optic cable.

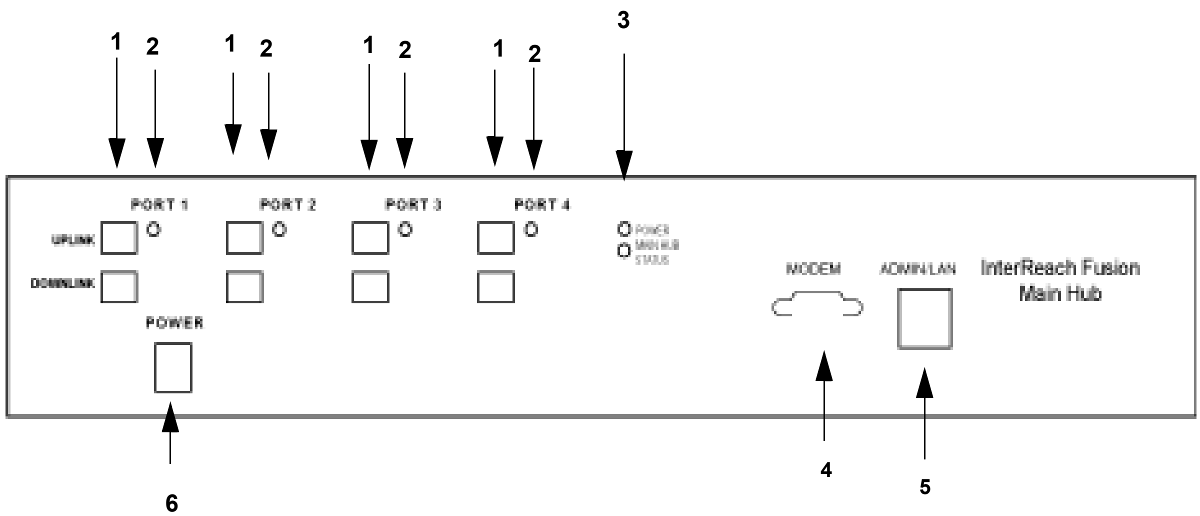
Figure 3-2 shows a detailed view of the major RF and optical functional blocks of the Main Hub.

Figure 3-2 **Main Hub Block Diagram**



3.2 Fusion Main Hub Front Panel

Figure 3-3 **Fusion Main Hub Front Panel**



1. Four fiber optic ports (labeled **PORT 1**, **PORT 2**, **PORT 3**, **PORT 4**)
   - One standard female SC/APC connector per port for MMF/SMF input (labeled **UPLINK**)
   - One standard female SC/APC connector per port for MMF/SMF output (labeled **DOWNLINK**)
2. Four sets of fiber port LEDs (one set per port)
   - One LED per port for port link status and downstream unit status
3. One set of unit status LEDs
   - One LED for unit power status (labeled **POWER**)
   - One LED for unit status (labeled **MAIN HUB STATUS**)
4. One 9-pin D-sub male connector for system remote dial-up communication and diagnostics using a modem (labeled **MODEM**)
5. One RJ-45 female connector for system communication and diagnostics using a PC/laptop with direct connect or using a LAN switch (labeled **ADMIN/LAN**)
6. Power switch

3.2.1 Optical Fiber Uplink/Downlink Ports

The optical fiber uplink/downlink ports transmit and receive optical signals between the Main Hub and up to four Expansion Hubs using industry-standard SMF or MMF cable. There are four fiber ports on the front panel of the Main Hub; one port per Expansion Hub. Each fiber port has two female SC/APC connectors:

- **Optical Fiber Uplink Connector**

  This connector (labeled **UPLINK**) is used to receive the uplink optical signals from an Expansion Hub.

- **Optical Fiber Downlink Connector**

  This connector (labeled **DOWNLINK**) is used to transmit the downlink optical signals to an Expansion Hub.

CAUTION: To avoid damaging the Main Hub's fiber connector ports, use only SC/APC fiber cable connectors when using either single-mode or multi-mode fiber. Additionally, it is critical to system performance that only SC/APC fiber connectors are used throughout the fiber network, including fiber distribution panels.

3.2.2 Communications RS-232 Serial Connector

Remote Monitoring

Use a standard serial cable to connect a modem to the 9-pin D-sub male serial connector for remote monitoring or configuring. The cable typically has a DB-9 female and a DB-25 male connector. Refer to Appendix A.6 on page A-11 for the cable pinout diagram.

Remote monitoring is also available by connecting the RJ-45 (ADMIN/LAN) port to a LAN switch for remote Ethernet LAN access or direct dial-up router access.

Local Monitoring

Use a crossover Ethernet cable (PN-4069-ADB) to connect a laptop or PC to the RJ-45 female connector for local monitoring or configuring using the AdminBrowser resident software. The cable typically has a RJ-45 male connector on both ends. Refer to Appendix A.5 on page A-10 for the cable pinout.

3.2.3 Main Hub LED Indicators

The unit's front panel LEDs indicate faults and commanded or fault lockouts. The LEDs do not indicate warnings or whether the system test has been performed. Use the LEDs to provide basic information only, or as a backup when you are not using AdminBrowser.

Upon power up, the Main Hub goes through a 20-second test to check the LED lamps. During this time, the LEDs blink through the states shown in Table 3-1, letting you visually verify that the LED lamps and the firmware are functioning properly. Upon completion of initialization, the LEDs stay in one of the first two states shown in Table 3-1.

The Main Hub automatically sends the program bands command to all connected RAUs. A mismatched band causes a fault message to be displayed in AdminBrowser and places the RAU in a disabled condition.

NOTE: Refer to Section 9.3.2 for troubleshooting using the LEDs.

NOTE: AdminBrowser should be used for troubleshooting the system. Only use LEDs for backup or confirmation. However, if there are communication problems within the system, the LEDs may provide additional information that is not available using AdminBrowser.

Unit Status LEDs

The Main Hub has one pair of status LEDs, labeled **POWER** and **STATUS**, which can be in one of the states shown in Table 3-1. These LEDs can be:

- ● steady green
- ● steady red
- ○ off - no color (valid only during 90 second power cycle)
- ● flashing red (60 ppm)

There is no off state when the unit's power is on.

Table 3-1 Fusion Hub Status LED States

	LED State	Indicates
POWER STATUS	Green Green	• The Main Hub is connected to power and all power supplies are operating. • The Main Hub is not reporting a fault; however, the system test may need to be performed or a warning condition may exist. Use AdminBrowser to determine this.
POWER STATUS	Green Red	• The Main Hub is connected to power and all power supplies are operating. Use AdminBrowser to power status. • The Main Hub is reporting a fault or lockout condition.
POWER STATUS	Green Red (60-ppm)	• The Main Hub is connected to power and all power supplies are operating. • The Main Hub DL input signal level is too high.
POWER STATUS	Red Red	• One or more power supplies are out-of-specification.

Fiber Port LEDs

The Main Hub has one fiber port LED for each of the four fiber ports. The LED can be in one of the states shown in Table 3-2. This LED can be:

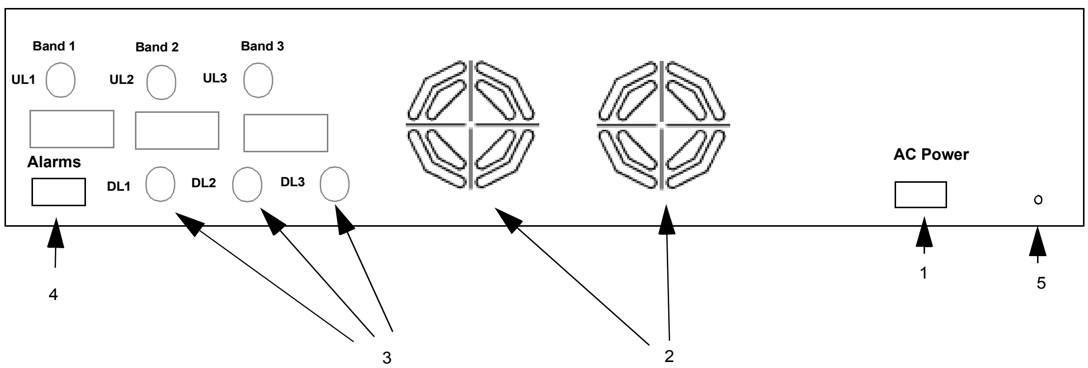
- off
- steady green
- steady red
- flashing red (60 ppm)

Table 3-2 Fusion Hub Port LED States

	LED State	Indicates
PORT	Off	• The Expansion Hub is not connected.
PORT	Green	• The Expansion Hub is connected. • There are no faults from the Expansion Hub or any connected RAU.
PORT	Red (60 PPM)	• There was a loss of communications with the Expansion Hub.
PORT	Red (Steady)	• The Expansion Hub is disconnected. • The Expansion Hub or any connected RAU reported a fault or lockout condition.

3.3 Fusion Main Hub Rear Panel

Figure 3-4 **Fusion Main Hub Rear Panel**



1. AC power cord connector
2. Two air exhaust vents
3. Three N-type, female connectors for each band (Band 1, Band 2, and Band 3):
   - Uplink (labeled **UL1**, **UL2**, and **UL3**)
   - Downlink (labeled **DL1**, **DL2**, and **DL3**)
4. One 9-pin D-sub female connector for contact alarm monitoring (labeled **ALARMS**)
5. Ground lug for connecting unit to frame ground (labeled **GROUND**)

3.3.1 Fusion Main Hub Rear Panel Connectors

3.3.1.1 9-pin D-sub Connector

The 9-pin D-sub connector (labeled **ALARMS**) provides a contact alarm for fault and warning system alarm monitoring.

Table lists the function of each pin on the 9-pin D-sub connector.

Table 3-3 9-pin D-sub Pin Connector Functions

Pin	Function
1	Alarm Sense Input (DC Ground)
2	Alarm Sense Input 3
3	Alarm Sense Input 2
4	Warning Source Contact (positive connection)
5	Warning Source Contact (negative connection)
6	DC Ground (common)
7	Fault Source Contact (positive connection)
8	Alarm Sense Input 1
9	Fault Source Contact (negative connection)

This interface can both generate two source contact alarms (Fault and Warning) and sense 3 single external alarm contacts (Alarm Sense Input 1 through 3).

3.3.1.2 N-type Female Connectors

There are two 50 Ohm N-type connector pairs for each of the 3 bands on the rear panel of the Hub:

- The **DOWNLINK** connector receives downlink RF signals from a repeater, local base station, or MetroReach Focus system.
- The **UPLINK** connector transmits uplink RF signals to a repeater, local base station, or MetroReach Focus system.

CAUTION: The **UPLINK** and **DOWNLINK** ports cannot handle a DC power feed from the local base station. If DC power is present, a DC block must be used or the Fusion hub may be damaged.

3.4 Main Hub Specifications

Table 3-4 Main Hub Specifications

Specification	Description
Enclosure Dimensions (H × W × D)[a]:	89 mm x 438 mm x 381 mm (3.5 in. x 17.25 in. x 15 in.) 2U
Weight	<5.5 kg (<12 lb)
Operating Temperature	0° to +45°C (+32° to +113°F)
Non-operating Temperature	–20° to +85°C (–4° to +185°F)
Operating Humidity, non-condensing	5% to 95%
External Alarm Connector (contact closure)	1 9-pin D-sub, female Maximum: 40 mA @ 40V DC Typical: 4 mA @ 12V DC
ADMIN/LAN Interface Connector	1 RJ-45, female 1 9-pin D-sub, male for optional modem
Fiber Connectors	4 Pair, SC/APC[b]
RF Connectors	6 N, female (50 Ohm), 1 Downlink/Uplink pair per band
LED Fault and Status Indicators	Unit Status (1 pair): • Power • Main Hub Status Downstream Unit/Link Status (1 per fiber port): • Link/E-Hub/RAU
AC Power	Rating 115/230V AC, 2/1A, 50-60 Hz Operating Range: 90-132V AC/170-250V AC auto-ranging
Power Consumption (W)	30
MTBF	117,972 hours

a. Excluding angle brackets for the 19” rack mounting of the Hub.

b. It is critical to system performance that only SC/APC fiber connectors are used throughout the fiber network, including fiber distribution panels.

3.5 Faults, Warnings, and Status Messages

3.5.1 Description

The Fusion Main Hub monitors and reports changes or events in system performance to:

- Ensure that fiber receivers, amplifiers and IF/RF paths are functioning properly.
- Ensure that Expansion Hubs and Remote Access Units are connected and functioning properly.

An event is classified as fault, warning, or status message.

- Faults are service impacting.
- Warnings indicate a possible service impact.
- Status and informational messages are generally not service impacting.

The Fusion Main Hub periodically queries attached Expansion Hub and Remote Access Units for their status. Both faults and warnings are reported to a connected PC/laptop running a standard browser communicating with the AdminBrowser software. Only faults are indicated by the faceplate LEDs.

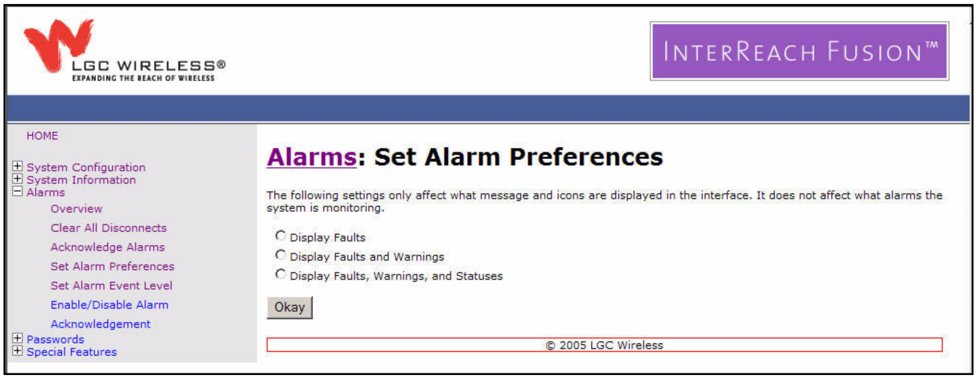
For more information regarding the events, refer to:

- Appendix C for Main Hub faults.
- Appendix C for Main Hub warnings.
- Appendix C for Main Hub status messages.
- Section 9 for troubleshooting Main Hub LEDs.

3.5.2 View Preference

AdminBrowser 1.0 or higher enables you to select (using the screen shown in Figure 3-5) the type of events to be displayed.

Figure 3-5 Preferences Check Boxes



To modify the setting, using AdminBrowser, select Alarms → Set Alarm Preference and select the desired choice. After you click OK, AdminBrowser refreshes and updates the tree view according to the new setting.

NOTE: The setting is strictly visual and only in AdminBrowser. There is no affect on the hardware itself. By default, the event filtering is set to “Enable viewing of Faults only”.

The only exception to when the event filtering is ignored is during the Install/Configure command. All events are displayed regardless of the event filtering setting. This ensures a smooth installation.

SECTION 4

Fusion Expansion Hub

This section contains the following subsections:

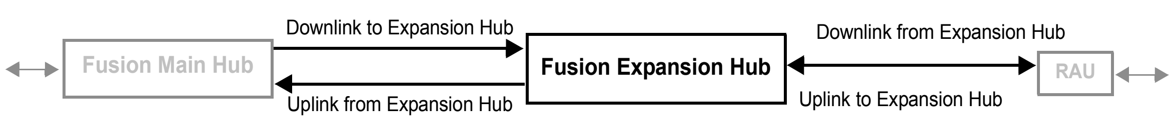
- Section 4.1 Expansion Hub Overview 4-1
- Section 4.2 Expansion Hub Front Panel 4-3
- Section 4.3 Expansion Hub Rear Panel 4-7
- Section 4.4 Faults, Warnings, and Status Messages 4-8
- Section 4.5 Expansion Hub Specifications 4-9

4.1 Expansion Hub Overview

The Expansion Hub acts an interface between the Main Hub and the Remote Access Unit(s) by converting optical signals to electrical signals and vice versa, as shown in Figure 4-1. It also supplies control signals and DC power to operate the Remote Access Unit(s) as well as passing status information from the RAUs to the Main Hub.

Figure 4-1 Expansion Hub in a Fusion System

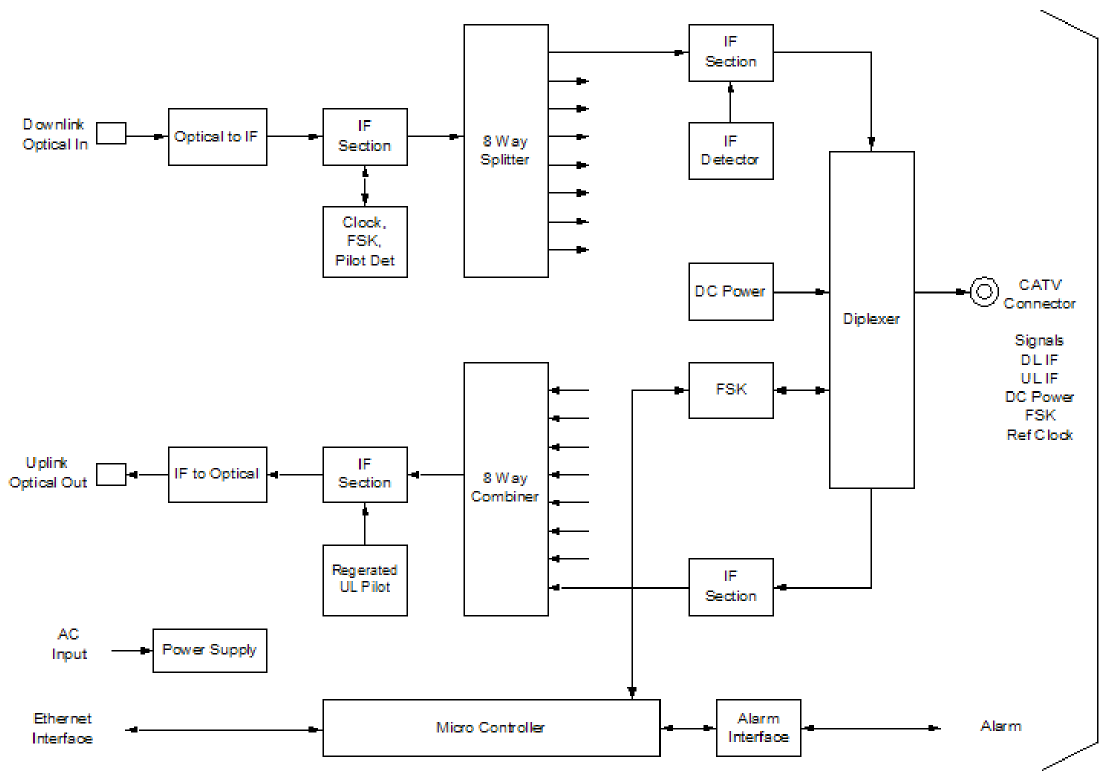
Downlink Path: The Expansion Hub receives downlink (Band1, 2, and 3) optical signals from the Main Hub using fiber optic cable. It converts the signals to electrical and sends them to up to eight Remote Access Units (RAUs) using CATV cables. The Expansion Hub also receives configuration information from the Main Hub using the fiber optic cable and relays it to the RAUs using CATV cable.



Uplink Path: The Expansion Hub receives uplink (Band1, 2, and 3) IF signals from up to eight RAUs using CATV cables. It converts the signals to optical and sends them to a Main Hub using fiber optic cable.

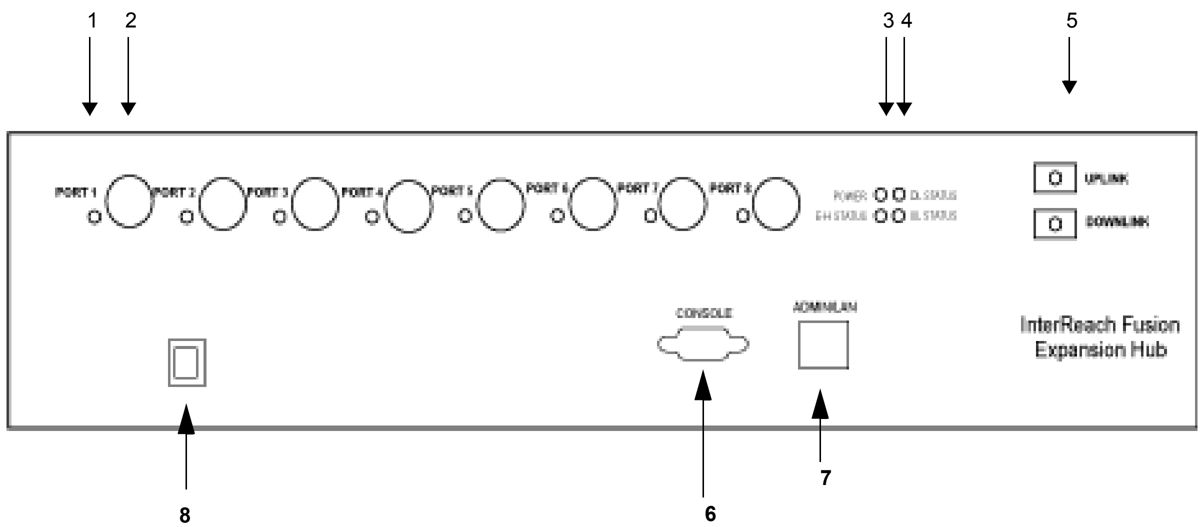
The Expansion Hub also receives RAU status information using CATV cable and sends it and its own status information to the Main Hub using the fiber optic cable.

Figure 4-2 Expansion Hub Block Diagram



4.2 Expansion Hub Front Panel

Figure 4-3 Expansion Hub Front Panel



1. One port LED per type F connector port for link status and downstream RAU status (8 pair total).
2. Eight CATV cable, type F connectors (labeled **PORT 1**, **2**, **3**, **4**, **5**, **6**, **7**, **8**)
3. One pair of unit status LEDs
   - One LED for unit power status (labeled **POWER**)
   - One LED for unit status (labeled **E-HUB STATUS**)
4. One set of fiber connection status LEDs
   - One LED for fiber downlink status (labeled **DL STATUS**)
   - One LED for fiber uplink status (labeled **UL STATUS**)
5. One fiber optic port which has two connectors
   - One standard female SC/APC connector for MMF/SMF output (labeled **UPLINK**)
   - One standard female SC/APC connector for MMF/SMF input (labeled **DOWNLINK**)
6. One 9-pin D-sub male connector for LGC factory testing (labeled **CONSOLE**)
7. One RJ-45 female connector for system communication and diagnostics using a PC/laptop with direct connect or using a LAN switch (labeled **ADMIN/LAN**)
8. Power Switch

4.2.1 75 Ohm Type F Connectors

The eight type F connectors on the Expansion Hub are for the CATV cables used to transmit and receive signals to and from RAUs. Use only 75 ohm type F connectors on the CATV cable.

The CATV cable also delivers DC electrical power to the RAUs. The Expansion Hub's DC voltage output is 54V DC nominal. A current limiting circuit protects the Hub if any port draws excessive power.

NOTE: For system performance, it is important to use only low loss solid copper center conductor CATV cable with quality type F connectors that use captive centerpin connectors. Refer to Appendix A for approved cables and connectors.

4.2.2 Manufacturing RS-232 Serial Connector

Console Port

This console port is only used by LGC Wireless manufacturing test purposes. **DO NOT CONNECT ANYTHING TO IT.**

Local Monitoring

Use a crossover Ethernet cable (PN-4069-ADB) to directly connect a laptop or PC to the RJ-45 female connector for local monitoring or configuring the Expansion Hub and associated RAUs using the AdminBrowser-EH resident software. The cable typically has a RJ-45 male connector on both ends. Refer to Appendix A.4 on page A-8 for the cable pinout and the AdminBrowser manual.

4.2.3 Optical Fiber Uplink/Downlink Connectors

The optical fiber uplink/downlink port transmits and receives optical signals between the Expansion Hub and the Main Hub using industry-standard SMF or MMF cable. The fiber port has two female SC/APC connectors:

- **Optical Fiber Uplink Connector**

  This connector (labeled **UPLINK**) is used to transmit (output) uplink optical signals to the Main Hub.

- **Optical Fiber Downlink Connector**

  This connector (labeled **DOWNLINK**) is used to receive (input) downlink optical signals from the Main Hub.

CAUTION: To avoid damaging the Expansion Hub's fiber connector ports, use only SC/APC fiber cable connectors. Additionally, use only

SC/APC fiber connectors throughout the fiber network, including fiber distribution panels. This is critical for ensuring system performance.

4.2.4 LED Indicators

The unit's front panel LEDs indicate fault conditions and commanded or fault lockouts. The LEDs do not indicate warnings or whether the system test has been performed. Only use the LEDs to provide basic information or as a backup when you are not using AdminBrowser.

Upon power up, the Expansion Hub goes through a five-second test to check the LED lamps. During this time, the LEDs blink through the states shown in Table 4-2, letting you visually verify that the LED lamps and the firmware are functioning properly.

NOTE: Refer to Section 9 for troubleshooting using the LEDs.

Unit Status and DL/UL Status LEDs

The Expansion Hub unit status and DL/UL status LEDs can be in one of the states shown in Table 4-1. These LEDs can be:

- ● steady green
- ● steady red
- ○ off

Table 4-1 Expansion Hub Unit Status and DL/UL Status LED States

	LED State	Indicates
POWER ● ● DL STATUS EH STATUS ● ● UL STATUS	Green / Green Green / Green	• The Expansion Hub is connected to power and all power supplies are operating. • The Expansion Hub is not reporting a fault or lockout condition; but the system test may need to be performed or a warning condition could exist (use AdminManager to determine this). • Optical power received is above minimum (the Main Hub is connected) although the cable optical loss may be greater than recommended maximum. • Optical power transmitted (uplink laser) is normal and communications with the Main Hub are normal.
POWER ● ● DL STATUS EH STATUS ● ● UL STATUS	Green / Green Red / Green	• Optical power received is above minimum (the Main Hub is connected) although the cable optical loss may be greater than recommended maximum. • Optical power transmitted (uplink laser) is normal and communications with the Main Hub are normal. • The Expansion Hub is reporting a fault or commanded lockout.

Table 4-1 Expansion Hub Unit Status and DL/UL Status LED States (continued)

	LED State	Indicates
POWER / **DL STATUS** **EH STATUS** / **UL STATUS**	Green / Red Red / Green	• A fault condition was detected, optical power received is below minimum. (the Main Hub is not connected, is not powered, or the Main Hub's downlink laser has failed, or the downlink fiber is disconnected or damaged.)
POWER / **DL STATUS** **EH STATUS** / **UL STATUS**	Green / Green Red / Red	• The Expansion Hub is reporting a fault condition. • Optical power received is above minimum (Main Hub is connected) although the cable optical loss may be greater than recommended maximum. • Optical power transmitted is below minimum (Expansion Hub uplink laser has failed; unable to communicate with Main Hub). **UL STATUS** LED state must be checked within the first 90 seconds after power on. If initially green, then red after 90 seconds, it means that there is no communication with the Main Hub. If red on power up, replace the Expansion Hub.
POWER / **DL STATUS** **EH STATUS** / **UL STATUS**	Green / Red Red / Red	• Optical power received is below minimum (the Main Hub is not connected, is not powered, or the Main Hub's downlink laser has failed, or the downlink fiber is disconnected or damaged.) • Optical power transmitted is below minimum (the Expansion Hub uplink laser has failed; is unable to communicate with the Main Hub). **UL STATUS** LED state must be checked within the first 90 seconds after power on. If initially green, then red after 90 seconds, it means that there is no communication with the Main Hub. If red on power up, the uplink laser has failed, replace the Expansion Hub.
POWER / **DL STATUS** **EH STATUS** / **UL STATUS**	Green /Off Green / Off	• Expansion Hub is in factory test mode, return it to the factory.
POWER / **DL STATUS** **EH STATUS** / **UL STATUS**	Red/ Don't Care Red/ Don't Care	• One or more power supplies are out of specification. The hub needs to be replaced.
POWER / **DL STATUS** **EH STATUS** / **UL STATUS**	Green/ Red Off/ Off	• Expansion Hub failure. The Hub must be replaced.

RJ-45 Port LEDs

The Expansion Hub has a port LED, labeled **PORT**, for each of the eight 75 Ohm, Type F ports. The port LEDs can be in one of the states shown in Table 4-2. These LEDs can be:

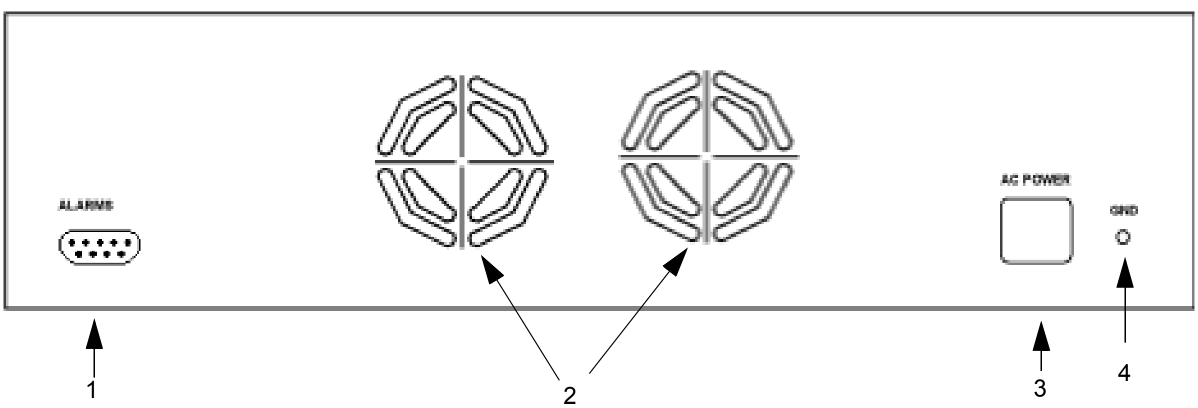
- off
- steady green
- steady red
- flashing red (60 pulses per minute [PPM])

Table 4-2 Fusion Expansion Hub Port LED States

	LED State	Indicates
PORT ○	Off	• The RAU is not connected.
PORT ●	Green	• The RAU is connected. • No faults from the RAU.
PORT ●	Red (60 PPM)	• The RAU was disconnected. • The RAU is not communicating. • The RAU port power is tripped.
PORT ●	Red (Steady)	• The RAU is disconnected. • The RAU is reporting a fault or lockout condition.

4.3 Expansion Hub Rear Panel

Figure 4-4 Expansion Hub Rear Panel



1. AC power cord connector
2. Two air exhaust vents
3. One 9-pin D-sub female connector for contact alarm monitoring (labeled **ALARMS**)
4. Ground lug for connecting unit to frame ground (labeled **GROUND**)

Table 4-3 9-pin D-sub Pin Connector Functions

Pin	Function
1	Alarm Sense Input (DC Ground)
2	Alarm Sense Input 3
3	Alarm Sense Input 2
4	N/C
5	N/C
6	DC Ground (common)
7	N/C
8	Alarm Sense Input 1
9	N/C

This interface can monitor three single external alarm contacts (Alarm Sense Input 1 This interface monitors the output contact closures from a Universal Power Supply (UPS). Verify the output contact closure state (normally closed or normally open) of the UPS, and set the appropriate contact definition using AdminBrowser.

- Faults are service impacting.
- Warnings indicate a possible service impact.
- Status messages are generally not service impacting.through 3).

4.4 Faults, Warnings, and Status Messages

Both fault and warning conditions of the Expansion Hub and attached RAUs are reported to the Main Hub. Only faults are indicated by LEDs.

For more information, refer to Appendix C, “Faults, Warnings, Status Tables,” on page C-1.

NOTE: You can select what type of events AdminBrowser displays. Refer to Section 3.5.2 View Preference 3-12.

4.5 Expansion Hub Specifications

Table 4-4 **Expansion Hub Specifications**

Specification	Description
Enclosure Dimensions (H × W × D)	89 mm x 438 mm x 381 mm (3.5 in. x 17.25 in. x 15 in.) 2U
Weight	< 6.6 kg (< 14.5 lb.)
Operating Temperature	0° to +45°C (+32° to +113°F)
Non-operating Temperature	–20° to +85°C (–4° to +185°F)
Operating Humidity, non-condensing	5% to 95%
CATV Connectors[a]	8 F, female (CATV - 75 Ohm)
Fiber Connectors[b]	1 Pair, SC/APC
LED Alarm and Status Indicators	Unit Status (1 pair): • Power • E-Hub Status Fiber Link Status (1 pair): • DL Status • UL Status Port Status (1 pair per CATV port): • Link/RAU
External Alarm Connector (contact sense monitor)	1 9-pin D-sub, female
AC Power (Volts) (47–63 Hz)	Rating: 115/230V AC, 6/3A, 50-60 Hz Operating Range: 90-132V AC/170-250V AC auto-ranging
Power Consumption (W)	4 RAUs: 305 typical 8 RAUs: 530 typical
MTBF	54,477 hours

a. It is important that you use only recommended CATV 75 Ohm cable with quality F connectors.

b. It is critical to system performance that only SC/APC fiber connectors are used throughout the fiber network, including fiber distribution panels.

SECTION 5 Remote Access Unit

This section contains the following subsections:

- Section 5.1 RAU Overview 5-1
- Section 5.2 Remote Access Unit Connectors 5-5
- Section 5.3 RAU LED Indicators 5-6
- Section 5.4 Faults and Warnings 5-7
- Section 5.5 Remote Access Unit Specifications 5-7

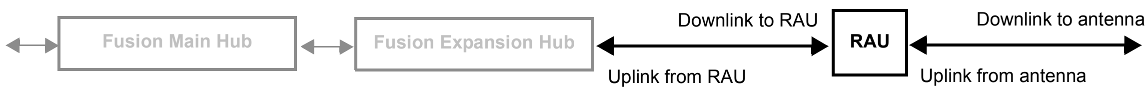
5.1 RAU Overview

The Remote Access Unit (RAU) is an active transceiver that connects to an Expansion Hub using industry-standard CATV cable, which delivers RF signals, configuration information, and electrical power to the RAU.

An RAU passes converted 1F to RF (Downlink) and converted RF to 1F (Uplink) signals between an Expansion Hub and an attached passive antenna where the signals are transmitted to wireless devices as shown in Figure 5-1.

Figure 5-1 **Remote Access Unit in a Fusion System**

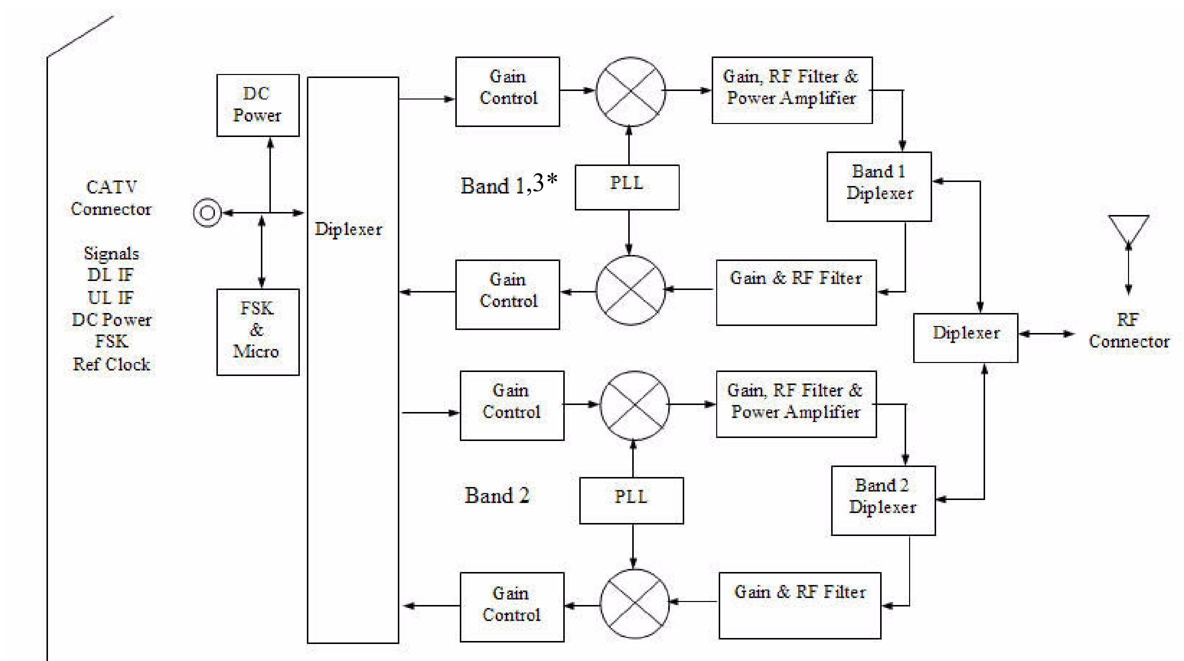
Downlink Path: The RAU receives downlink IF signals from a Fusion Hub using 75 Ohm CATV cable. It converts the signals to RF and sends them to a passive RF antenna using 50 Ohm coaxial cable. Also, the RAU receives configuration information from the Fusion Hub using the 75 Ohm CATV cable.



Uplink Path: The RAU receives uplink RF signals from a passive RF antenna using 50 Ohm coaxial cable. It converts the signals to IF and sends them to a Fusion Hub using 75 Ohm CATV cable. Also, the RAU sends its status information to the Fusion Hub using CATV cable.

The RAU receives 54VDC power from the Fusion Hub port through the 75 Ohm CATV cable center pin.

Figure 5-2 **Remote Access Unit Block Diagram (Multiband)**



* for FSN-809019-1 RAU when Band 3 is active.

The Fusion RAUs are manufactured to a specific set of bands: one 35 MHz Band 1 (split into two sub-bands 1A and 1B for FSN-809019-1 RAU), and one 75 MHz-Band 2. Table 5-1 lists the Fusion RAUs, the Fusion Band, and the frequency bands they cover.

Table 5-1 Frequency Bands Covered by Fusion RAUs

Fusion RAU	Part Number	Fusion Band	RF Passband Downlink (MHz)	RF Passband Uplink (MHz)	MAIN HUB/ RAU Band	RAU Bandwidth
850/1900	FSN-8519-1	850	869–894	824–849	1	25 MHz
		1900	1930–1990	1850–1910	2	60 MHz
900//1800	FSN-9018-1	900	925–960	880–915	1	35 MHz
		1800	1805–1880	1710–1785	2	75 MHz
900/2100	FSN-9021-1	900	925–960	830–715	1	35 MHz
		2100	2110–2170	1920–1980	2	60 MHz
800/900/ 1900	FSN-809019 -1	800 SMR	851-869	806-824	1 (sub band 1A)	18 MHz
		900 SMR	935-941	896-902	3 (sub band 1B)	6 MHz
		1900 (A-G)	1930-1995	1850-1915	2	65 MHz

Table 5-2 **System Gain (Loss) Relative to CATV Cable Length (All RAUs except 800/900/1900)**

Cable Type	Comm-Scope Part Number	Plenum Rated	Solid Copper Conductor	Copper Clad Conductor	Zero-loss RF Maximum Length (meters)	Distance RF is 10dB Below Input RF (meters)
RG-59						
	2065V	Yes	X		150	210
	2022V	Yes		X	120	120*
	5572R	No		X	110	110*
	5565	No	X		150	210
RG-6						
	2279V	Yes	X		170	230
	2275V	Yes		X	170	175*
	5726	No		X	170	170*
	5765	No	X		170	230
RG-11						
	2293K	Yes	X		275	375
	2285K	Yes		X	275	370*
	5913	No		X	275	370*

* Exceeding the distance of copper-clad cable will result in the attached RAU becoming non-functional. If the distance of a cable run is at its maximum and is of concern, LGC recommends the use of solid copper cable to ensure successful operation.

Table 5-3 **System Gain (Loss) Relative to CATV Cable Length for RAUs**

Cable Type	Comm-Scope Part Number	Plenum Rated	Solid Copper Conductor	Copper Clad Conductor	Zero-loss RF Maximum Length (meters)	Distance Where RF is 10dB Below Input RF (meters)
RG-59						
	2065V	Yes	X		150	210
	2022V	Yes		X	80	80*
	5572R	No		X	70	70*
	5565	No	X		150	210
RG-6						
	2279V	Yes	X		170	230
	2275V	Yes		X	115	115*
	5726	No		X	110	110*
	5765	No	X		170	230
RG-11						
	2293K	Yes	X		275	375
	2285K	Yes		X	240	240*
	5913	No		X	240	240*

* Exceeding the distance of copper-clad cable will result in the attached RAU becoming non-functional. If the distance of a cable run is at its maximum and is of concern, LGC recommends the use of solid copper cable to ensure successful operation.

5.2 Remote Access Unit Connectors

5.2.1 50 Ohm Type-N Connector

The RAU has one female type-N connector. The connector is a duplexed RF input/output port that connects to a standard 50Ω passive antenna using coaxial cable.

5.2.2 75 Ohm Type-F Connector

The RAU has one type-F female connector that connects it to a Fusion Hub using CATV 75 Ohm cable. Use RG-59, 6, or 11 solid copper center conductor cables.

NOTE: For system performance, it is important that you use only low loss, solid copper center conductor CATV cable with quality F connectors that use captive centerpin conductors. Refer to Appendix A for specific information.

5.3 RAU LED Indicators

Upon power up, the RAU goes through a two-second test to check the LED lamps. During this time, the LEDs blink green/green red/red, letting you visually verify that the LED lamps and the firmware are functioning properly.

NOTE: Refer to Section 9 for troubleshooting using the LEDs.

Status LEDs

The RAU status LEDs can be in one of the states shown in Table 5-4. These LEDs can be:

- ○ off
- ● steady green
- ● steady red

There is no off state when the unit's power is on.

Table 5-4 Remote Access Unit LED States

	LED State	Indicates
LINK ○ **ALARM** ○	Off Off	• The RAU is not receiving DC power.
LINK ● (green) **ALARM** ● (green)	Green Green	• The RAU is powered and is not indicating a fault condition. Communication with the Fusion Hub is normal; however, the system test may need to be performed or a warning condition may exist (use AdminBrowser to determine this).
LINK ● (green) **ALARM** ● (red)	Green Red	• The RAU is indicating a fault or lockout condition, but communication with the Fusion Hub is normal.
LINK ● (red) **ALARM** ● (red)	Red Red	• The RAU is reporting a fault or lockout condition and is not able to communicate with the Fusion Hub

5.4 Faults and Warnings

Both fault and warning conditions are reported to the Fusion Hub where they are stored. Only faults are indicated by the faceplate LEDs.

For more information, refer to Appendix C.

5.5 Remote Access Unit Specifications

Table 5-5 Remote Access Unit Specifications

Specification	Description
Dimensions (H × W × D)	133.5 mm × 438 mm × 381 mm (5.25 in. × 17.25 in. × 15 in.)
Weight	< 2.1 kg (< 4.6 lb.)
Operating Temperature	–25° to +45°C (–13° to +113°F)
Non-operating Temperature	–25° to +85°C (–13° to +185°F)
Operating Humidity, non-condensing	5% to 95%
RF Connectors	One Type-F, female (CATV - 75 ohms) One Type-N, female (coaxial 50 ohms)
LED Alarm and Status Indicators	Unit Status (1 pair): • Link • Alarm
Maximum Heat Dissipation (W)	50 typical, 64 max (from the Hub)
MTBF	211,600 hours (All Dual Band RAUs) 144,409 hours (800/900/1900 Tri-Band RAUs)

NOTE: For system performance, it is important that you use only low loss, solid copper center conductor CATV cable with quality F connectors that use captive centerpin conductors. Refer to Appendix A for more information.

SECTION 6

Designing a Fusion Solution

This section contains the following subsections:

- Section 6.1 Overview 6-1
- Section 6.2 Downlink RSSI Design Goal 6-3
- Section 6.3 Maximum Output Power per Carrier 6-4
- Section 6.4 System Gain 6-11
- Section 6.5 Estimating RF Coverage 6-14
- Section 6.6 Link Budget Analysis 6-25
- Section 6.7 Optical Power Budget 6-37
- Section 6.8 Connecting a Main Hub to a Base Station 6-38

6.1 Overview

Designing a Fusion solution is a matter of determining coverage and capacity needs. This requires the following steps:

1. **Determine the wireless service provider's requirements: Refer to Section 6.2, "Downlink RSSI Design Goal," on page 6-3.**

   The following information is typically provided by the service provider:

   - Frequency (for example, 1900 MHz)
   - Band (for example, "A-F" band in the PCS spectrum)
   - Protocol (for example, CDMA, GSM, 1xRTT, GPRS, and so on)
   - Number of sectors and peak capacity per sector (translates to the number of RF carriers that the system will have to transmit)
   - Downlink RSSI design goal (RSSI, received signal strength at the wireless handset, for example, –85 dBm)

The design goal is always a stronger signal than the mobile phone needs. It includes inherent factors which affect performance.

- RF source (base station or bidirectional amplifier or repeater), type of equipment if possible.

2. **Determine the downlink power per carrier from the RF source through the DAS: Refer to Section 6.3, "Maximum Output Power per Carrier," on page 6-4.**

   The maximum power per carrier is a function of modulation type, the number of RF carriers, signal quality issues, regulatory emissions requirements, and Fusion's RF performance. Power per carrier decreases as the number of carriers increases.

3. **Develop an RF link budget: Refer to Section 6.5, "Estimating RF Coverage," on page 6-14.**

   Knowing both the power per carrier and RSSI design goal, you can develop an RF downlink link budget which estimates the allowable path loss from an RAU's antenna to the wireless handset.

   allowable path loss = power per carrier + antenna gain – design goal

   Satisfactory performance can be expected as long as path loss is below this level.

4. **Determine the in-building environment: Refer to Section 6.5, "Estimating RF Coverage," on page 6-14.**

   - Determine which areas of the building require coverage (entire building, public areas, parking levels, and so on.)
   - Obtain floor plans to determine floor space of building and the wall layout of the proposed areas to be covered. Floor plans are also useful when you are selecting antenna locations.
   - If possible, determine the building's construction materials (sheetrock, metal, concrete, and so on.)
   - Determine the type of environment:
     – Open layout (for example, a convention center)
     – Dense, close walls (for example, a hospital)
     – Mixed use (for example, an office building with hard wall offices and cubicles)

5. **Determine the appropriate estimated path loss slope that corresponds to the type of building and its layout, and estimate the coverage distance for each RAU: Refer to Section 6.5, "Estimating RF Coverage," on page 6-14.**

   Use the path loss slope (PLS), which gives a value to the RF propagation characteristics within the building, to convert the RF link budget into an estimate of the coverage distance per antenna. This helps establish the quantities of Fusion equipment you need. The actual path loss slope that corresponds to the specific RF environment inside the building can also be determined empirically by performing an RF site-survey of the building. This involves transmitting a calibrated tone for a fixed antenna and making measurements with a mobile antenna throughout the area surrounding the transmitter.

6. **Determine the items required to connect to the base station: Refer to Section 6.8, "Connecting a Main Hub to a Base Station," on page 6-38.**

   Once you know the quantities of Fusion equipment to be used, you can determine the accessories (combiners/dividers, surge suppressors, repeaters, attenuators, circulators, and so on.) required to connect the system to the base station.

The individual elements that must be considered in designing a Fusion solution are explained in the following sections.

NOTE: Access the LGC Wireless Customer Portal at LGCWireless.com for on-line dimensioning and design tools.

6.2 Downlink RSSI Design Goal

Wireless service providers typically provide a minimum downlink signal level and an associated confidence factor when specifying coverage requirements. These two figures of merit are a function of wireless handset sensitivity and margins for fading and body loss. Wireless handset sensitivity is the weakest signal that the handset can process reliably and is a combination of the thermal noise in the channel, noise figure of the handset receiver front end and minimum required SNR. Fade margins for multipath fading (fast or small-scale) and log-normal shadow fading (slow or large-scale) are determined by the desired confidence factor, and other factors. Downlink RSSI design goal calculations for the GSM protocol are shown below for a 95% area coverage confidence factor.

Noise Power 10 Log (KT)+10 Log (200 KHz); $K=1.38X10^{-23}$, T=300 degrees Kelvin		–121	dBm
Wireless Handset Noise Figure		8	dB
Required SNR		9	dB
Multipath Fade Margin 95% Reliability for Rician K=6 dB		6	dB
Log-normal Fade Margin 95% Area/87% Edge Reliability for 35 dB PLS and 9 dB Sigma		10	dB
Body Attenuation	+	3	dB
Downlink RSSI Design Goal ($P_{DesignGoal}$) Signal level received by wireless handset at edge of coverage area		–85	dBm

Downlink design goals on the order of –85 dBm are typical for protocols, such as GSM and iDEN. Wireless service providers may choose a higher level to ensure that in-building signal dominates any macro signal that may be leaking into the building.

6.3 Maximum Output Power per Carrier

The following tables show the recommended maximum power per carrier out of the RAU 50 Ohm Type-N connector for different frequencies, protocols, and numbers of carriers. These maximum levels are dictated by RF signal quality and regulatory emissions issues. In general, as the number of RF carrier increases, the maximum power per carrier decreases. If these levels are exceeded, signal quality will be degraded and/or regulator requirements will be violated. The maximum input power to the Hub is determined by subtracting the system gain from the maximum output power of the RAU. System gain is software selectable from 0 dB to 15 dB in 1 dB steps. Additionally, both the uplink and downlink gain of each RAU can be reduced by 10 dB in 1 dB steps.

When connecting a Hub to a base station or repeater, attenuation on the downlink is typically required to avoid exceeding Fusion's maximum output power recommendations.

WARNING: Exceeding the maximum input power may cause permanent damage to the Hub. Do not exceed the maximum composite input power of 1W (+30 dBm) to the Hub at any time.

NOTE: These specifications are for downlink power at the RAU output (excluding antenna).

6.3.1 850 MHz Cellular

Cellular Power per Carrier

No. of Carriers	Power per Carrier (dBm)					
	AMPS	TDMA	GSM	EDGE	CDMA	WCDMA
1	**16.5**	**16.5**	**16.5**	**16.5**	**16**	**15**
2	16.5	16.5	13.5	13.5	13	11
3	16.5	15.0	11.5	11.5	11	8
4	13.5	13	10.0	10.0	10.0	6.5
5	12.0	11.5	9.0	9.0	9.0	5.0
6	10.5	10.5	8.5	8.5	8.0	
7	9.5	9.5	8.0	8.0	7.5	
8	8.5	8.5	7.5	7.5	7.0	
9	8.0	8.0	7.0	7.0		
10	7.0	7.5	6.5	6.5		
11	7.0	7.0	6.5	6.5		
12	6.5	6.5	6.0	6.0		
13	6.0	6.5	6.5	5.5		
14	5.5	6.0	5.5	5.5		
15	5.5	5.5	5.0	5.0		
16	5.0	5.5	5.0	5.0		
20	4.0	4.5	4.5	4.0		
30	2.0	2.5	3.0	2.0		

Note: Operation at or above these output power levels may prevent Fusion from meeting RF performance specifications or FCC Part 15 and EN55022 emissions requirements.

6.3.2 800 MHz or 900 MHz SMR

Table 6-1 Power per Carrier

No. of Carriers	Power per Carrier (dBm) - 800MHz/900 MHz					POCSAG/ REFLEX
	iDEN	Analog FM	CQPSK	C4FM	DataTac/ Mobitex	
1	**16.6/14.5**	**24.0/23.0**	**21.0/19.0**	**24.0/23.0**	**24.0/23.0**	**23.0**
2	13.0/11.0	19.0/17.0	16.0/14.0	18.5/16.5	18.5/16.5	16.5
3	10.5/8.5	15.5/13.5	13.5/11.5	15.0/13.0	15.0/13.0	13.0
4	9.0/7.0	12.5/10.0	11.5/9.5	12/510.5	12.5/10.5	10.5
5	8.0/6.0	11.0/9.0	10.0/8.0	10.5/8.5		
6	7.0/5.0	9.5/7.5	8.5/6.5	9.0/7.0		
7	6.0/4.0	8.5/6.5	8.0/6.0	8.0/6.0		
8	5.5/3.5	7.5/5.5	7.0/5.0	7.5/5.5		
9	5.0/3.0	7.0/8.0	6.5/4.5	6.5/4.5		
10	4.5/2.5	6.0/4.0	6.0/4.0	6.0/4.0		
11	4.0/2.0					
12	3.5/1.5					
13	3.0/1.0					
14	3.0/1.0					
15	2.5/0.5					
16	2.0/0					

Note: Operation at or above these output power levels may prevent Fusion from meeting RF performance specifications or FCC Part 15 and EN55022 emissions requirements.

6.3.3 900 MHz EGSM and EDGE

Table 6-2 GSM/EGSM and EDGE Power per Carrier

No. of Carriers	Power per Carrier (dBm)	
	GSM	EDGE
1	**16.0**	**16.0**
2	13.0	13.0
3	11.0	11.0
4	10.0	10.0
5	9.0	9.0
6	8.0	8.0
7	7.5	7.5
8	7.0	7.0
9	6.5	6.5
10	6.0	6.0
11	5.5	5.5
12	5.0	5.0
13	5.0	5.0
14	4.5	4.5
15	4.0	4.0
16	4.0	4.0
20	3	3
30	1	1

Note: Operation at or above these output power levels may prevent Fusion from meeting RF performance specifications or FCC Part 15 and EN55022 emissions requirements.

6.3.4 1800 MHz DCS

Table 6-3 DCS Power per Carrier

No. of Carriers	Power per Carrier (dBm)	
	GSM	EDGE
1	**16.5**	**16.5**
2	14.5	14.5
3	12.5	12.5
4	11.5	11.5
5	10.5	10.5
6	9.5	9.5
7	9.0	9.0
8	8.5	8.0
9	8.0	7.5
10	7.5	7.0
11	7.0	6.5
12	6.5	6.0
13	6.5	6.0
14	6.0	5.5
15	5.5	5.0
16	5.5	5.0
20	4.5	4.0
30	2.5	2.0

Note: Operation at or above these output power levels may prevent Fusion from meeting RF performance specifications or FCC Part 15 and EN55022 emissions requirements.

6.3.5 1900 MHz PCS

Table 6-4 **PCS Power per Carrier**

No. of Carriers	Power per Carrier (dBm)				
	TDMA	GSM	EDGE	CDMA	WCDMA
1	**16.5**	**16.5**	**16.5**	**16.0**	**15.0**
2	16.5	15.5	15.5	13.0	11.0
3	15.0	13.5	13.5	11.0	8.0
4	13.0	12.0	12.0	10.0	6.5
5	11.5	11.0	10.5	9.0	5.0
6	10.5	10.5	9.5	8.0	
7	9.5	10.0	9.0	7.5	
8	8.5	9.0	8.0	7.0	
9	8.0	8.5	7.5		
10	7.5	8.0	7.0		
11	7.0	7.5	6.5		
12	6.5	7.0	6.0		
13	6.5	6.5	6.0		
14	6.0	6.5	5.5		
15	5.5	6.0	5.0		
16	5.5	5.5	5.0		
20	4.5	4.5	4.0		
30	2.5	3.0	2.0		

Note: Operation at or above these output power levels may prevent Fusion from meeting RF performance specifications or FCC Part 15 and EN55022 emissions requirements.

6.3.6 2.1 GHz UMTS

Table 6-5 UMTS Power per Carrier

No. of Carriers	Power per Carrier (dBm) WCDMA
1	**15.0**
2	11.0
3	8.0
4	6.5
5	5.0
6	4.0
7	3.0

Note: measurements taken with no baseband clipping.
Note: Operation at or above these output power levels may prevent Fusion from meeting RF performance specifications or FCC Part 15 and EN55022 emissions requirements.

Designing for Capacity Growth

Fusion systems are deployed to enhance in-building coverage and/or to off-load capacity from a macro cell site. In many instances, subscriber usage increases with time and the wireless provider responds by increasing the load on the installed Fusion system. For example, the initial deployment might only require two RF carriers, but four RF carriers may be needed in the future based on capacity growth forecasts. There are two options for dealing with this scenario:

1. Design the initial coverage with a maximum power per carrier for four RF carriers. This will likely result in additional RAUs.
2. Design the initial coverage for two RF carriers, but reserve RAU ports on the Hub for future use. These ports can be used to fill potential coverage holes once the power per carrier is lowered to accommodate the two additional carriers.

6.4 System Gain

The system gain of the Fusion defaults to 0 dB or can be set up to 15 dB in 1 dB increments. In addition, uplink and downlink gains of each RAU can be independently decreased by 10 dB in one dB steps using AdminBrowser.

The recommended maximum lengths of CATV cable are as follows:

- For RG-59 cable 150 meters for CommScope PN 2065V.
- For RG-6 cable 170 meters for CommScope PN 2279V.
- For RG-11 cable 275 meters for CommScope PN 2293K.

If the maximum distance is not required, then copper-clad over steel center-conductor cable may be use to reduce cable costs.

If the CATV cable is longer than the recommended distance per cable type, the gain of the system will decrease, as shown in Table 6-6 and Table 6-7.

Table 6-6 **System Gain (Loss) Relative to CATV Cable Length (All RAUs except 800/900/1900)**

Cable Type	Comm-Scope Part Number	Plenum Rated	Solid Copper Conductor	Copper Clad Conductor	Zero-loss RF Maximum Length (meters)	Distance Where RF is 10dB Below Input RF (meters)
RG-59						
	2065V	Yes	X		150	210
	2022V	Yes		X	120	120*
	5572R	No		X	110	110*
	5565	No	X		150	210
RG-6						
	2279V	Yes	X		170	230
	2275V	Yes		X	170	175*
	5726	No		X	170	170*
	5765	No	X		170	230
RG-11						
	2293K	Yes	X		275	375
	2285K	Yes		X	275	370*
	5913	No		X	275	370*

* Exceeding the distance of copper-clad cable will result in the attached RAU becoming non-functional. If the distance of a cable run is at its maximum and is of concern, LGC recommends the use of solid copper cable to ensure successful operation.

Table 6-7 **System Gain (Loss) Relative to CATV Cable Length for 800/900/1900 RAUs**

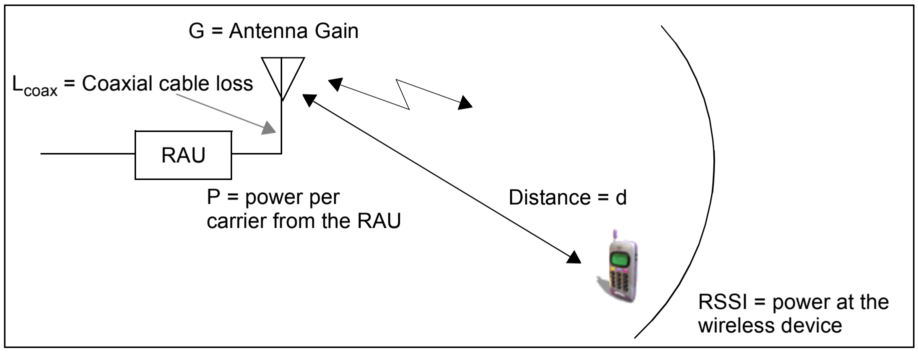
Cable Type	Comm-Scope Part Number	Plenum Rated	Solid Copper Conductor	Copper Clad Conductor	Zero-loss RF Maximum Length (meters)	Distance Where RF is 10dB Below Input RF (meters)
RG-59						
	2065V	Yes	X		150	210
	2022V	Yes		X	80	80*
	5572R	No		X	70	70*
	5565	No	X		150	210
RG-6						
	2279V	Yes	X		170	230
	2275V	Yes		X	115	115*
	5726	No		X	110	110*
	5765	No	X		170	230
RG-11						
	2293K	Yes	X		275	375
	2285K	Yes		X	240	240*
	5913	No		X	240	240*

* Exceeding the distance of copper-clad cable will result in the attached RAU becoming non-functional. If the distance of a cable run is at its maximum and is of concern, LGC recommends the use of solid copper cable to ensure successful operation.

6.5 Estimating RF Coverage

The maximum output power per carrier (based on the number and type of RF carriers being transmitted) and the minimum acceptable received power at the wireless device (that is, the RSSI design goal) essentially establish the RF downlink budget and, consequently, the maximum allowable path loss (APL) between the RAU's antenna and the wireless device. Since in-building systems, such as the Fusion, are generally downlink-limited, this approach is applicable in the majority of deployments.

Figure 6-1 Determining APL between the Antenna and the Wireless Device



$$APL = (P - L_{coax} + G) - RSSI \quad (1)$$

where:

- APL = the maximum allowable path loss in dB
- P = the power per carrier transmitted by the RAU in dBm
- L_{coax} = the coaxial cable loss between the RAU and passive antenna in dB
- G = the gain of the passive antenna in dBi

Coaxial cable is used to connect the RAU to an antenna. Table 6-8 lists coaxial cable loss for various cable lengths.

Table 6-8 Coaxial Cable Losses (^{L}coax)

Length of Cable (.195 in. diameter)	Loss at 850 MHz (dB)	Loss at 1900 MHz (dB)
0.9 m (3 ft)	0.6	0.8
1.8 m (6 ft)	1.0	1.5
3.0 m (10 ft)	1.5	2.3

You can calculate the distance, d, corresponding to the maximum allowable path loss using equations introduced in the following sections.

6.5.1 Path Loss Equation

In-building path loss obeys the distance power law[1] in equation (2):

$$PL = 20\log_{10}(4\pi d_0 f/c) + 10n\log_{10}(d/d_0) + X_s \quad (2)$$

where:

- PL is the path loss at a distance, d, from the antenna
- d = the distance expressed in meters
- d_0 = free-space path loss distance in meters
- f = the operating frequency in Hertz.
- c = the speed of light in a vacuum (3.0×10^8 m/sec).
- *n* = the path loss exponent and depends on the building "clutter" and frequency of operation
- X_s = a normal random variable that depends on partition material and geometries inside the building and is accounted for by the log-normal fade margin used in the downlink RSSI design goal calculation

As a reference, Table 6-9 provides estimates of signal loss for some RF barriers[1].

Table 6-9 Average Signal Loss of Common Building Materials

Partition Type	Loss (dB)	Frequency (MHz)
Metal wall	26	815
Aluminum siding	20	815
Foil insulation	4	815
Cubicle walls	1.4	900
Concrete block wall	13	1300
Concrete floor	10	1300
Sheetrock	1 to 2	1300
Light machinery	3	1300
General machinery	7	1300
Heavy machinery	11	1300
Equipment racks	7	1300
Assembly line	6	1300
Ceiling duct	5	1300
Metal stairs	5	1300

1. Rappaport, Theodore S. *Wireless Communications, Principles, and Practice*. Prentice Hall PTR, 1996.

6.5.2 RAU Coverage Distance

Use equations (1) and (2), on pages 6-14 and 6-15, respectively, to estimate the distance from the antenna to where the RF signal decreases to the minimum acceptable level at the wireless device.

With d_0 set to one meter and path loss slope (PLS) defined as 10*n*, Equation (2) can be simplified to:

$$PL(d) = 20\log_{10}(4\pi f/c) + PLS\cdot\log_{10}(d) \quad (3)$$

Table 6-10 gives the value of the first term of Equation (3) (that is., ($20\log_{10}(4\pi f/c)$) for various frequency bands.

Table 6-10 Frequency Bands and the Value of the First Term in Equation (3)

Frequency	Band (MHz) Uplink	Band (MHz) Downlink	Mid-Band Frequency (MHz)	$20\log_{10}(4\pi f/c)$
800 MHz SMR	806-824	851-869	838	30.9
900 MHz SMR	896-902	935-941	919	31.9
850 MHz Cellular	824–849	869–894	859	31.1
900 MHz GSM	890–915	935–960	925	31.8
900 MHz EGSM	880–915	925–960	920	31.7
1800 MHz DCS	1710–1785	1805–1880	1795	37.5
1900 MHz PCS	1850–1910	1930–1990	1920	38.1
2.1 GHz UMTS	1920–1980	2110–2170	2045	38.7

Table 6-11 shows estimated PLS for various environments that have different "clutter" (that is, objects that attenuate the RF signals, such as walls, partitions, stairwells, equipment racks, and so.).

Table 6-11 Estimated Path Loss Slope for Different In-Building Environments

Environment Type	Example	PLS for 850/900 MHz	PLS for 1800/1900 MHz
Open Environment very few RF obstructions	Parking Garage, Convention Center	33.7	30.1
Moderately Open Environment low-to-medium amount of RF obstructions	Warehouse, Airport, Manufacturing	35	32
Mildly Dense Environment medium-to-high amount of RF obstructions	Retail, Office Space with approximately 80% cubicles and 20% hard walled offices	36.1	33.1
Moderately Dense Environment medium-to-high amount of RF obstructions	Office Space with approximately 50% cubicles and 50% hard walled offices	37.6	34.8
Dense Environment large amount of RF obstructions	Hospital, Office Space with approximately 20% cubicles and 80% hard walled offices	39.4	38.1

By setting the path loss to the maximum allowable level (PL = APL), equation (3) can be used to estimate the maximum coverage distance of an antenna connected to an RAU, for a given frequency and type of in-building environment.

$$d = 10^{\wedge}((APL - 20\log_{10}(4\pi f/c))/PLS) \quad (4)$$

For reference, Tables 6-13 through 6-17 show the distance covered by an antenna for various in-building environments. The following assumptions were made:

- Path loss Equation (4)
- 6 dBm output per carrier at the RAU output
- 3 dBi antenna gain
- RSSI design goal = –85 dBm (typical for narrowband protocols, but not for spread-spectrum protocols)

Table 6-12 Approximate Radiated Distance from Antenna for 800 MHz SMR Applications

Environment Type	Distance from Antenna	
	Meters	Feet
Open Environment	75	244
Moderately Open Environment	64	208
Mildly Dense Environment	56	184
Moderately Dense Environment	48	156
Dense Environment	40	131

Table 6-13 Approximate Radiated Distance from Antenna for 850 MHz Cellular Applications

Environment Type	Distance from Antenna	
	Meters	Feet
Open Environment	73	241
Moderately Open Environment	63	205
Mildly Dense Environment	55	181
Moderately Dense Environment	47	154
Dense Environment	39	129

Table 6-14 Approximate Radiated Distance from Antenna for 900 MHz SMR Applications

Facility	Distance from Antenna	
	Meters	Feet
Open Environment	70	230
Moderately Open Environment	60	197
Mildly Dense Environment	53	174
Moderately Dense Environment	45	148
Dense Environment	38	125

Table 6-15 Approximate Radiated Distance from Antenna for 900 MHz EGSM Applications

Facility	Distance from Antenna	
	Meters	Feet
Open Environment	70	231
Moderately Open Environment	60	197
Mildly Dense Environment	53	174
Moderately Dense Environment	45	149
Dense Environment	38	125

Table 6-16 Approximate Radiated Distance from Antenna for 1800 MHz DCS Applications

Facility	Distance from Antenna	
	Meters	Feet
Open Environment	75	246
Moderately Open Environment	58	191
Mildly Dense Environment	50	166
Moderately Dense Environment	42	137
Dense Environment	30	100

Table 6-17 Approximate Radiated Distance from Antenna for 1900 MHz PCS Applications

Facility	Distance from Antenna	
	Meters	Feet
Open Environment	72	236
Moderately Open Environment	56	183
Mildly Dense Environment	49	160
Moderately Dense Environment	40	132
Dense Environment	29	96

Table 6-18 Approximate Radiated Distance from Antenna for 2.1 GHz UMTS Applications

Facility	Distance from Antenna	
	Meters	Feet
Open Environment	69	226
Moderately Open Environment	54	176
Mildly Dense Environment	47	154
Moderately Dense Environment	39	128
Dense Environment	28	93

6.5.3 Examples of Design Estimates

Example Design Estimate for an 850 MHz TDMA Application

1. **Design goals**:
   - Cellular (859 MHz = average of the lowest uplink and the highest downlink frequency in 800 MHz Cellular band)
   - TDMA provider
   - 12 TDMA carriers in the system
   - –85 dBm design goal (to 95% of the building) — the minimum received power at the wireless device
   - Base station with simplex RF connections
2. **Power Per Carrier**: The tables in Section 6.3, "Maximum Output Power per Carrier," on page 6-4 provide maximum power per carrier information. The 850 MHz TDMA table (on page 6-5) indicates that Fusion can support 10 carriers with a recommended maximum power per carrier of 7.0 dBm. The input power should be set to the desired output power minus the system gain.
3. **Building information**:
   - Eight floor building with 9,290 sq. meters (100,000 sq. ft.) per floor; total 74,322 sq. meters (800,000 sq. ft.).
   - Walls are sheetrock construction, suspended ceiling tiles.
   - Antennas used will be omni-directional, ceiling mounted.
   - Standard office environment, 50% hard wall offices and 50% cubicles.
4. **Link Budget**: In this example, a design goal of –85 dBm is used. Suppose 3 dBi omni-directional antennas are used in the design. Then, the maximum RF propagation loss should be no more than 94.5 dB (6.5 dBm + 3 dBi + 85 dBm) over 95% of the area being covered. *It is important to note that a design goal such as –85 dBm is usually derived taking into account multipath fading and log-normal shadowing characteristics. Thus, this design goal will only be met "on average" over 95% of the area being covered. At any given point, a fade may bring the signal level underneath the design goal.*

   Note that this method of calculating a link budget is only for the downlink path. For information to calculate link budgets for both the downlink and uplink paths, refer to Section 6.6 on page 6-25.
5. **Path Loss Slope**: For a rough estimate, Table 6-11, "Estimated Path Loss Slope for Different In-Building Environments" on page 6-17, shows that a building with 50% hard wall offices and 50% cubicles, at 859 MHz, has an approximate path loss slope (PLS) of 37.6. Given the RF link budget of 95.5 dB, the distance of coverage from each RAU will be 52 meters (170.6 ft). This corresponds to a coverage area of 8,494 sq. meters (91,425 sq. ft.) per RAU (refer to Section 6.5.1 for details on path loss estimation). For this case we assumed a circular radiation pattern, though the actual area covered depends upon the pattern of the antenna and the obstructions in the facility.

Equipment Required: Since you know the building size, you can now estimate the Fusion equipment quantities that will be needed. Before any RF levels are tested in the building, you can estimate that two antennas per level will be needed. This assumes no propagation between floors. If there is propagation, you may not need antennas on every floor.

a. 2 antennas per floor × 8 floors = 16 RAUs
b. 16 RAUs ÷ 8 (maximum 8 RAUs per Expansion Hub) = 2 Expansion Hubs
c. 2 Expansion Hubs ÷ 4 (maximum 4 Expansion Hubs per Main Hub) = 1 Main Hub

Check that the fiber and CATV cable distances are as recommended. If the distances differ, use the tables in Section 6.4, "System Gain," on page 6-11 to determine system gains or losses. The path loss may need to be recalculated to assure adequate signal levels in the required coverage distance.

The above estimates assume that all cable length requirements are met. If Expansion Hubs cannot be placed so that the RAUs are within the distance requirement, additional Expansion Hubs may need to be placed closer to the required RAUs locations.

An RF Site Survey and Building Evaluation is required to accurately establish the Fusion equipment quantities required for the building. The site survey measures the RF losses within the building to determine the actual PLS, which are used in the final path loss formula to determine the actual requirements of the Fusion system.

Example Design Estimate for an 1900 MHz CDMA Application

1. **Design goals**:
   - PCS (1920 MHz = average of the lowest uplink and the highest downlink frequency in 1900 MHz PCS band)
   - CDMA provider
   - 8 CDMA carriers in the system
   - –85 dBm design goal (to 95% of the building) — the minimum received power at the wireless device
   - Base station with simplex RF connections
2. **Power Per Carrier**: The tables in Section 6.3, “Maximum Output Power per Carrier,” on page 6-4 provide maximum power per carrier information. The 1900 MHz CDMA table (on page 6-9) indicates that Fusion can support eight carriers with a recommended maximum power per carrier of 6.5 dBm. The input power should be set to the desired output power minus the system gain.
3. **Building information**:
   - 16 floor building with 9,290 sq. meters (100,000 sq. ft.) per floor; total 148,640 sq. meters (1,600,000 sq. ft.).
   - Walls are sheetrock construction, suspended ceiling tiles.
   - Antennas used are omni-directional, ceiling mounted.
   - Standard office environment, 80% hard wall offices and 20% cubicles.
4. **Link Budget**: In this example, a design goal of –85 dBm is used. Suppose 3 dBi omni-directional antennas are used in the design. Then, the maximum RF propagation loss should be no more than 94.5 dB (6.5 dBm + 3 dBi + 85 dBm) over 95% of the area being covered. *It is important to note that a design goal such as –85 dBm is usually derived taking into account multipath fading and log-normal shadowing characteristics. Thus, this design goal will only be met “on average” over 95% of the area being covered. At any given point, a fade may bring the signal level underneath the design goal.*

   Note that this method of calculating a link budget is only for the downlink path. For information to calculate link budgets for both the downlink and uplink paths, refer to Section 6.6 on page 6-25.
5. **Path Loss Slope**: For a rough estimate, Table 6-11, “Estimated Path Loss Slope for Different In-Building Environments” on page 6-17, shows that a building with 80% hard wall offices and 20% cubicles, at 1920 MHz, has an approximate path loss slope (PLS) of 38.1. Given the RF link budget of 94.5 dB, the distance of coverage from each RAU will be 30.2 meters (99 ft). This corresponds to a coverage area of 2,868 sq. meters (30,854 sq. ft.) per RAU (refer to Section 6.5.1 for details on path loss estimation). For this case we assumed a circular radiation pattern, though the actual area covered depends upon the pattern of the antenna and the obstructions in the facility.

6. **Equipment Required**: Since you know the building size, you can now estimate the Fusion equipment quantities needed. Before you test any RF levels in the building, you can estimate that four antennas per level will be needed. This assumes no propagation between floors. If there is propagation, you may not need antennas on every floor.

   a. 4 antennas per floor × 16 floors = 64 RAUs

   b. 64 RAUs ÷ 8 (maximum 8 RAUs per Expansion Hub) = 8 Expansion Hubs

   c. 8 Expansion Hubs ÷ 4 (maximum 4 Expansion Hubs per Main Hub) = 2 Main Hubs

   Check that the fiber and Cat-5/5E/6 cable distances are as recommended. If the distances differ, use the tables in Section 6.4, "System Gain," on page 6-11 to determine system gains or losses. The path loss may need to be recalculated to assure adequate signal levels in the required coverage distance.

The above estimates assume that all cable length requirements are met. If Expansion Hubs cannot be placed so that the RAUs are within the distance requirement, additional Expansion Hubs may need to be placed closer to the required RAUs locations.

An RF Site Survey and Building Evaluation is required to accurately establish the Fusion equipment quantities required for the building. The site survey measures the RF losses within the building to determine the actual PLS, used in the final path loss formula to determine the actual requirements of the Fusion system.

6.6 Link Budget Analysis

A link budget is a methodical way to account for the gains and losses in an RF system so that the quality of coverage can be predicted. The end result can often be stated as a "design goal" in which the coverage is determined by the maximum distance from each RAU before the signal strength falls beneath that goal.

One key feature of the link budget is the maximum power per carrier explained in Section 6.3. While the maximum power per carrier is important as far as emissions and signal quality requirements are concerned, it is critical that the maximum signal into the Main Hub never exceed 1W (+30 dBm). Composite power levels above this limit will cause damage to the Main Hub.

WARNING: Exceeding the maximum input power of 1W (+30 dBm) could cause permanent damage to the Main Hub.

NOTE: Visit the LGC Wireless customer portal at LGCWireless.com for the on-line Link Budget Tool.

6.6.1 Elements of a Link Budget for Narrowband Standards

The link budget represents a typical calculation that might be used to determine how much path loss can be afforded in a Fusion design. This link budget analyzes both the downlink and uplink paths. For most configurations, the downlink requires lower path loss and is therefore the limiting factor in the system design. It is for this reason that a predetermined "design goal" for the downlink is sufficient to predict coverage distance.

The link budget is organized in a simple manner: the transmitted power is calculated, the airlink losses due to fading and body loss are summed, and the receiver sensitivity (minimum level a signal can be received for acceptable call quality) is calculated. The maximum allowable path loss (in dB) is the difference between the transmitted power, less the airlink losses, and the receiver sensitivity. From the path loss, the maximum coverage distance can be estimated using the path loss formula presented in Section 6.5.1.

Table 6-19 provides link budget considerations for narrowband systems.

Table 6-19 Link Budget Considerations for Narrowband Systems

<table>
<tr><th>Consideration</th><th>Description</th></tr>
<tr><td>BTS Transmit Power</td><td>The power per carrier transmitted from the base station output</td></tr>
<tr><td>Attenuation between BTS and Fusion</td><td>This includes all losses: cable, attenuator, splitter/combiner, and so forth.
On the downlink, attenuation must be chosen so that the maximum power per carrier going into the Main Hub does not exceed the levels given in Section 6.3.
On the uplink, attenuation is chosen to keep the maximum uplink signal and noise level low enough to prevent base station alarms but small enough not to cause degradation in the system sensitivity.
If the Fusion noise figure minus the attenuation is at least 10 dB higher than the BTS noise figure, the system noise figure is approximately that of Fusion alone. Refer to Section 6.8 for ways to independently set the uplink and downlink attenuations between the base station and Fusion.</td></tr>
<tr><td>Antenna Gain</td><td>The radiated output power includes antenna gain. For example, if you use a 3 dBi antenna at the RAU that is transmitting 0 dBm per carrier, the effective radiated power (relative to an isotropic radiator) is 3 dBm per carrier.</td></tr>
<tr><td>BTS Noise Figure</td><td>This is the effective noise floor of the base station input (usually base station sensitivity is this effective noise floor plus a certain C/I ratio).</td></tr>
<tr><td>Fusion Noise Figure</td><td>This is Fusion's uplink noise figure, which varies depending on the number of Expansion Hubs and RAUs, and the frequency band. Fusion's uplink noise figure is specified for a 1-1-8 configuration. Thus, the noise figure for a Fusion system (or multiple systems whose uplink ports are power combined) is NF(1-1-8) + 10*log(# of Expansion Hubs). This represents an upper-bound because the noise figure is lower if any of the Expansion Hub's RAU ports are not used.</td></tr>
<tr><td>Thermal Noise</td><td>This is the noise level in the signal bandwidth (BW).
Thermal noise power = –174 dBm/Hz + 10Log(BW).
<table>
<tr><th>Protocol</th><th>Signal Bandwidth</th><th>Thermal Noise</th></tr>
<tr><td>TDMA</td><td>30 kHz</td><td>–129 dBm</td></tr>
<tr><td>GSM</td><td>200 kHz</td><td>–121 dBm</td></tr>
<tr><td>iDEN</td><td>25 kHz</td><td>–130 dBm</td></tr>
</table></td></tr>
<tr><td>Required C/I ratio</td><td>For each wireless standard, a certain C/I (carrier to interference) ratio is needed to obtain acceptable demodulation performance. For narrowband systems, (TDMA, GSM, EDGE, iDEN, AMPS) this level varies from about 9 dB to 20 dB.</td></tr>
<tr><td>Mobile Transmit Power</td><td>The maximum power the mobile can transmit (power transmitted at highest power level setting).</td></tr>
<tr><td>Multipath Fade Margin</td><td>This margin allows for a certain level of fading due to multipath interference. Inside buildings there is often one or more fairly strong signals and many weaker signals arriving from reflections and diffraction. Signals arriving from multiple paths add constructively or destructively. This margin accounts for the possibility of destructive multipath interference. In RF site surveys the effects of multipath fading are typically not accounted for because such fading is averaged out over power level samples taken over many locations.</td></tr>
</table>

Table 6-19 **Link Budget Considerations for Narrowband Systems (continued)**

Consideration	Description
Log-normal Fade Margin	This margin adds an allowance for RF shadowing due to objects obstructing the direct path between the mobile equipment and the RAU. In RF site surveys, the effects of shadowing are partially accounted for since it is characterized by relatively slow changes in power level.
Body Loss	This accounts for RF attenuation caused by the user’s head and body.
Minimum Received Signal Level	This is also referred to as the “design goal”. The link budget says that you can achieve adequate coverage if the signal level is, on average, above this level over 95% of the area covered, for example.

6.6.2 Narrowband Link Budget Analysis for a Microcell Application

Table 6-20 **Narrowband Link Budget Analysis: Downlink**

Line	Downlink	
	Transmitter	
a.	BTS transmit power per carrier (dBm)	33
b.	Attenuation between BTS and Fusion (dB)	–23
c.	Power into Fusion (dBm)	10
d.	Fusion gain (dB)	0
e.	Antenna gain (dBi)	3
f.	Radiated power per carrier (dBm)	**13**
	Airlink	
g.	Multipath fade margin (dB)	6
h.	Log-normal fade margin with 9 dB std. deviation, 95% area coverage, 87% edge coverage	10
i.	Body loss (dB)	3
j.	Airlink losses (not including facility path loss)	**19**
	Receiver	
k.	Thermal noise (dBm/30 kHz)	–129
l.	Mobile noise figure (dB)	7
m.	Required C/I ratio (dB)	17
n.	Minimum received signal (dBm)	**–105**
p.	**Maximum path loss** (dB)	**+99**

- c = a + b
- f = c + d + e
- j = g + h + i
- n = k + l + m
- k: in this example, k represents the thermal noise for a TDMA signal, which has a bandwidth of 30 kHz
- p = f – j – n

Table 6-21 **Narrowband Link Budget Analysis: Uplink**

Line	Uplink	
	Receiver	
a.	BTS noise figure (dB)	4
b.	Attenuation between BTS and Fusion (dB)	–10
c.	Fusion gain (dB)	0
d.	Fusion noise figure (dB) 1-4-32	22
e.	System noise figure (dB)	22.6
f.	Thermal noise (dBm/30 kHz)	–129
g.	Required C/I ratio (dB)	12
h.	Antenna gain (dBi)	3
i.	Receive sensitivity (dBm)	**–97.4**
	Airlink	
j.	Multipath fade margin (dB)	6
k.	Log-normal fade margin with 9 dB std. deviation, 95% area coverage, 87% edge coverage	10
l.	Body loss (dB)	3
m.	Airlink losses (not including facility path loss)	**19**
	Transmitter	
n.	Mobile transmit power (dBm)	28
p.	**Maximum path loss** (dB)	**106.4**

- e: enter the noise figure and gain of each system component (a, b, c, and d) into the standard cascaded noise figure formula

$$F_{sys} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} + \ldots$$

where

$F = 10^{(\text{Noise Figure}/10)}$

$G = 10^{(\text{Gain}/10)}$

(See Rappaport, Theodore S. *Wireless Communications, Principles, and Practice*. Prentice Hall PTR, 1996.)

- i = f + e + g – h
- m = j + k + l
- p = n – m – i

Therefore, the system is downlink limited but the downlink and uplink are almost balanced, which is a desirable condition.

6.6.3 Elements of a Link Budget for CDMA Standards

A CDMA link budget is slightly more complicated because you must consider the spread spectrum nature of CDMA. Unlike narrowband standards such as TDMA and GSM, CDMA signals are spread over a relatively wide frequency band. Upon reception, the CDMA signal is de-spread. In the de-spreading process the power in the received signal becomes concentrated into a narrow band, whereas the noise level remains unchanged. Hence, the signal-to-noise ratio of the de-spread signal is higher than that of the CDMA signal before de-spreading. This increase is called *processing gain*. For IS-95 and J-STD-008, the processing gain is 21 dB or 19 dB depending on the user data rate (9.6 Kbps for rate set 1 and 14.4 Kbps for rate set 2, respectively). Because of the processing gain, a CDMA signal (comprising one Walsh code channel within the composite CDMA signal) can be received at a lower level than that required for narrowband signals. A reasonable level is –95 dBm, which results in about –85 dBm composite as shown below.

An important issue to keep in mind is that the downlink CDMA signal is composed of many orthogonal channels: pilot, paging, sync, and traffic. The composite power level is the sum of the powers from the individual channels. Table 6-22 shows an example.

Table 6-22 Distribution of Power within a CDMA Signal

Channel	Walsh Code Number	Relative Power Level	
Pilot	0	20%	–7.0 dB
Sync	32	5%	–13.3 dB
Primary Paging	1	19%	–7.3 dB
Traffic	8–31, 33–63	9% (per traffic channel)	–10.3 dB

This table assumes that there are 15 active traffic channels operating with 50% voice activity (so that the total power adds up to 100%). Notice that the pilot and sync channels together contribute about 25% of the power. When measuring the power in a CDMA signal you must be aware that if only the pilot and sync channels are active, the power level will be about 6 to 7 dB lower than the maximum power level you can expect when all voice channels are active. The implication is that if only the pilot and sync channels are active, and the maximum power per carrier table says that you should not exceed 10 dBm for a CDMA signal, for example, then you should set the attenuation between the base station and the Main Hub so that the Main Hub receives 3 dBm (assuming 0 dB system gain).

An additional consideration for CDMA systems is that the uplink and downlink paths should be gain and noise balanced. This is required for proper operation of soft-handoff to the outdoor network as well as preventing excess interference that is caused by mobiles on the indoor system transmitting at power levels that are not coordinated with the outdoor mobiles. This balance is achieved if the power level transmitted by the mobiles under close-loop power control is similar to the power level transmitted under open-loop power control. The open-loop power control equation is

$$P_{TX} + P_{RX} = -73 \text{ dBm (for Cellular, IS-95)}$$

$P_{TX} + P_{RX} = –76$ dBm (for PCS, J-STD-008)

where P_{TX} is the mobile's transmitted power and P_{RX} is the power received by the mobile.

The power level transmitted under closed-loop power control is adjusted by the base station to achieve a certain E_b/N_0 (explained in Table 6-23 on page 6-31). The difference between these power levels, Δ_P, can be estimated by comparing the power radiated from the RAU, $P_{downink}$, to the minimum received signal, P_{uplink}, at the RAU:

$\Delta_P = P_{downink} + P_{uplink} + 73$ dBm (for Cellular)

$\Delta_P = P_{downink} + P_{uplink} + 76$ dBm (for PCS)

It's a good idea to keep $–12 \text{ dB} < \Delta_P < 12 \text{ dB}$.

Table 6-23 provides link budget considerations for CDMA systems.

Table 6-23 Additional Link Budget Considerations for CDMA

Consideration	Description
Multipath Fade Margin	The multipath fade margin can be reduced (by at least 3 dB) by using different lengths of optical fiber (this is called "delay diversity"). The delay over fiber is approximately 5µS/km. If the difference in fiber lengths to Expansion Hubs with overlapping coverage areas produces at least 1 chip (0.8µS) delay of one path relative to the other, then the multipaths' signals can be resolved and processed independently by the base station's rake receiver. A CDMA signal traveling through 163 meters of MMF cable is delayed by approximately one chip.
Power per carrier, downlink	This depends on how many channels are active. For example, the signal is about 7 dB lower if only the pilot, sync, and paging channels are active compared to a fully-loaded CDMA signal. Furthermore, in the CDMA forward link, voice channels are turned off when the user is not speaking. On average this is assumed to be about 50% of the time. So, in the spreadsheet, both the power per Walsh code channel (representing how much signal a mobile will receive on the Walsh code that it is de-spreading) and the total power are used. The channel power is needed to determine the maximum path loss, and the total power is needed to determine how hard the Fusion system is being driven. The total power for a fully-loaded CDMA signal is given by (approximately): total power = voice channel power + 13 dB + $10log_{10}(50\%)$ = voice channel power + 10 dB
Information Rate	This is simply $10log_{10}$(9.6 Kbps) = 40 dB for rate set 1 $10log_{10}$(14.4 Kbps) = 42 dB for rate set 2
Process Gain	The process of de-spreading the desired signal boosts that signal relative to the noise and interference. This gain needs to be included in the link budget. In the following formulas, P_G = process gain: $P_G = 10log_{10}(1.25\ MHz / 9.6\ Kbps)$ = 21 dB rate set 1 $P_G = 10log_{10}(1.25\ MHz / 14.4\ Kbps)$ = 19 dB rate set 2 Note that the process gain can also be expressed as $10log_{10}$ (CDMA bandwidth) minus the information rate.

Table 6-23 Additional Link Budget Considerations for CDMA (continued)

Consideration	Description
Eb/No	This is the energy-per-bit divided by the received noise and interference. It's the CDMA equivalent of signal-to-noise ratio (SNR). This figure depends on the mobile's receiver and the multipath environment. For example, the multipath delays inside a building are usually too small for a rake receiver in the mobile (or base station) to resolve and coherently combine multipath components. However, if artificial delay can be introduced by, for instance, using different lengths of cable, then the required E_b/N_o is lower and the multipath fade margin in the link budget can be reduced in some cases. If the receiver noise figure is NF (dB), then the receive sensitivity (dBm) is given by: $P_{sensitivity} = NF + E_b/N_o$ + thermal noise in a 1.25 MHz band $- P_G$ $= \mathrm{NF} + E_b/N_o - 113\ (dBm/1.25\ MHz) - P_G$
Noise Rise	On the uplink, the noise floor is determined not only by the Fusion system, but also by the number of mobiles that are transmitting. This is because when the base station attempts to de-spread a particular mobile's signal, all other mobile signals appear to be noise. Because the noise floor rises as more mobiles try to communicate with a base station, the more mobiles there are, the more power they have to transmit. Hence, the noise floor rises rapidly: $noise\ rise = 10 log_{10}(1 / (1 - loading))$ where *loading* is the number of users as a percentage of the theoretical maximum number of users. Typically, a base station is set to limit the loading to 75%. This noise ratio must be included in the link budget as a worst-case condition for uplink sensitivity. If there are less users than 75% of the maximum, then the uplink coverage will be better than predicted.
Hand-off Gain	CDMA supports soft hand-off, a process by which the mobile communicates simultaneously with more than one base station or more than one sector of a base station. Soft hand-off provides improved receive sensitivity because there are two or more receivers or transmitters involved. A line for hand-off gain is included in the CDMA link budgets worksheet although the gain is set to 0 dB because the in-building system will probably be designed to limit soft-handoff.

Other CDMA Issues

- Never combine multiple sectors (more than one CDMA signal at the same frequency) into a Fusion system. The combined CDMA signals will interfere with each other.
- Try to minimize overlap between in-building coverage areas that utilize different sectors, as well as in-building coverage and outdoor coverage areas. This is important because any area in which more than one dominant pilot signal (at the same frequency) is measured by the mobile will result in soft-handoff. Soft-handoff decreases the overall network capacity by allocating multiple channel resources to a single mobile phone.

6.6.4 CDMA Link Budget Analysis for a Microcell Application

Table 6-24 CDMA Link Budget Analysis: Downlink

Line	Downlink	
	Transmitter	
a.	BTS transmit power per traffic channel (dBm)	30.0
b.	Voice activity factor	50%
c.	Composite power (dBm)	40.0
d.	Attenuation between BTS and Fusion (dB)	–24
e.	Power per channel into Fusion (dBm)	9.0
f.	Composite power into Fusion (dBm)	16.0
g.	Fusion gain (dB)	0.0
h.	Antenna gain (dBi)	3.0
i.	Radiated power per channel (dBm)	12.0
j.	Composite radiated power (dBm)	**19.0**
	Airlink	
k.	Handoff gain (dB)	0.0
l.	Multipath fade margin (dB)	6.0
m.	Log-normal fade margin with 9 dB std. deviation, 95% area coverage, 87% edge coverage	10.0
n.	Additional loss (dB)	0.0
o.	Body loss (dB)	3.0
p.	Airlink losses (not including facility path loss)	**19.0**
	Receiver	
q.	Mobile noise figure (dB)	7.0
r.	Thermal noise (dBm/Hz)	–174.0
s.	Receiver interference density (dBm/Hz)	–167.0
t.	Information ratio (dB/Hz)	41.6
u.	Required $Eb/(N_o+I_o)$	7.0
v.	Minimum received signal (dBm)	–118.4
w.	**Maximum path loss** (dB)	**+99.4**

- b and c: see notes in Table 6-23 regarding power per carrier, downlink
- e = a + d
- f = c + d
- i = e + g + h
- j = f + g + h
- p = –k + l + m + n + o
- s = q + r
- v = s + t + u
- w = j – p – v
- x = j (downlink) + m (uplink) + P

  where

  P = Ptx + Prx = –73 dB for Cellular
  –76 dB for PCS

Table 6-25 CDMA Link Budget Analysis: Uplink

Line	Uplink	
	Receiver	
a.	BTS noise figure (dB)	3.0
b.	Attenuation between BTS and Fusion (dB)	–30.0
c.	Fusion gain (dB)	0.0
d.	Fusion noise figure (dB)	22.0
e.	System noise figure (dB)	33.3
f.	Thermal noise (dBm/Hz)	–174.0
g.	Noise rise 75% loading (dB)	6.0
h.	Receiver interference density (dBm/Hz)	–134.6
i.	Information rate (dB/Hz)	41.6
j.	Required Eb/(N_o+l_o)	5.0
k.	Handoff gain (dB)	0.0
l.	Antenna gain (dBi)	3.0
m.	Minimum received signal (dBm)	**–91.1**
	Airlink	
n.	Multipath fade margin (dB)	6.0
o.	Log-normal fade margin with 9 dB std. deviation, 95% area coverage, 87% edge coverage	10.0
p.	Additional loss (dB)	0.0
q.	Body loss (dB)	3.0
r.	Airlink losses (not including facility path loss)	**19.0**
	Transmitter	
s.	Mobile transmit power (dBm)	28.0
t.	**Maximum path loss** (dB)	**100.1**

- e: enter the noise figure and gain of each system component (a, b, c, and d) into the standard cascaded noise figure formula

$$F_{sys} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} + ...$$

where

$F = 10^{(\text{Noise Figure}/10)}$

$G = 10^{(\text{Gain}/10)}$

(See Rappaport, Theodore S. *Wireless Communications, Principles, and Practice*. Prentice Hall PTR, 1996.)

- h = e + f + g
- m = h + i + j –k – l
- r = n + o + p + q
- t = s – r – m

6.6.5 Considerations for Re-Radiation (Over-the-Air) Systems

Fusion can be used to extend the coverage of the outdoor network by connecting to a roof-top donor antenna pointed toward an outdoor base station. Additional considerations for such an application of Fusion are:

- Sizing the gain and output power requirements for a bi-directional amplifier (repeater).
- Ensuring that noise radiated on the uplink from the in-building system does not cause the outdoor base station to become desensitized to wireless handsets in the outdoor network.
- Filtering out signals that lie in adjacent frequency bands. For instance, if you are providing coverage for Cellular B-band operation it may be necessary to filter out the A, A’ and A” bands which may contain strong signals from other outdoor base stations.

Further information on these issues can be found in LGC Wireless’ application notes for re-radiation applications.

6.7 Optical Power Budget

Fusion uses SC/APC connectors. The connector losses associated with mating to these connectors is accounted for in the design and *should not* be included as elements of the optical power budget. The reason is that when the optical power budget is defined, measurements are taken with these connectors in place.

The Fusion optical power budget for both multi-mode and single-mode fiber cable is 3.0 dB (optical).

The maximum loss through the fiber can not exceed 3 dB (optical). The maximum lengths of the fiber cable should not exceed 500m (1,640 ft) for multi-mode and 6 km (19,685 ft) for single-mode. Both the optical budget and the maximum cable length must be taken into consideration when designing the system.

NOTE: It is critical to system performance that only SC/APC fiber connectors are used throughout the fiber network, including fiber distribution panels.

6.8 Connecting a Main Hub to a Base Station

The Fusion system supports up to three RF sources: one for Band 1, one for Band 2, and one for Band 3. This section explains how each band can be connected to its associated base station.

Each Fusion Main Hub band has separate system gain parameters. For example, Band 1 can be set for +5 dB of downlink system gain while Band 2 can have +15 dB of downlink system gain. Thus, each band can be configured as a separate system to allow for full integration to its associated base station.

When connecting each of the Fusion Main Hub bands to its base station, the following equipment may be required: circulators, filter diplexers, directional couplers, combiner/splitters, attenuators, coax cables, and connectors. In addition, use the following considerations to achieve optimal performance:

1. The downlink power from the base stations must be attenuated enough so that the power radiated by the RAU does not exceed the maximum power per carrier listed in Section 6.3, “Maximum Output Power per Carrier,” on page 6-4.
2. The uplink attenuation should be small enough that the sensitivity of the overall system is limited by Fusion, not by the attenuator. However, some base stations trigger alarms if the noise or signal levels are too high. In this case the attenuation must be large enough to prevent this from happening.

CAUTION: The **UPLINK** and **DOWNLINK** ports cannot handle a DC power feed from a BTS. If DC power is present, a DC block must be used or the Fusion main hub may be damaged.

If, in an area covered by Fusion, a mobile phone indicates good signal strength but consistently has difficulty completing calls, it is possible that the attenuation between Fusion and the base station needs to be adjusted. In other words, it is possible that if the uplink is over-attenuated, the downlink power will provide good coverage, but the uplink coverage distance will be small.

When there is an excessive amount of loss between the Fusion Main Hub uplink and its associated band’s base station, the uplink system gain can be increased to as much as 15 dB to prevent a reduction in the overall system sensitivity.

6.8.1 Uplink Attenuation

The attenuation between the Main Hub’s uplink port and the associated band’s base station reduces both the noise level and the desired signals out of Fusion. Setting the attenuation on the uplink is a trade-off between keeping the noise and maximum signal levels transmitted from Fusion to the base station receiver low while not reducing the SNR (signal-to-noise ratio) of the path from the RAU inputs to the base station inputs. This SNR can not be better than the SNR of Fusion by itself, although it can be significantly worse.

A good rule of thumb is to set the uplink attenuation such that the noise level out of Fusion is within 10 dB of the base station's sensitivity.

6.8.2 RAU Attenuation and ALC

The RAU attenuation and ALC are set using the AdminBrowser **Edit Unit Properties** screen.

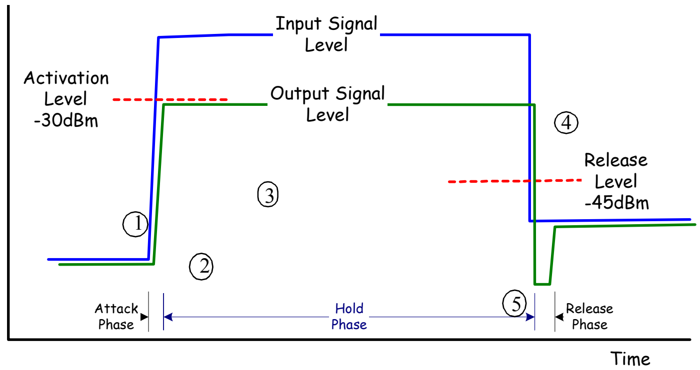
Embedded within the uplink RF front-end of each Fusion RAU band is an ALC circuit. This ALC circuit protects the Fusion system from overload and excessive intermodulation products due to high-powered mobiles or other signal sources that are within the supported frequency band and are in close proximity to the RAU.

Each individual Band (1, 2, or 3) of a Fusion RAU has an uplink ALC circuit that operates as a feedback loop. A power detector measures the level of each band's uplink RF input and if that level exceeds –30 dBm, an RF attenuator is activated. The level of attenuation is equal to the amount that the input exceeds –30 dBm. The following sequence describes the operation of the ALC circuit, as illustrated in Figure 6-2.

1. The RF signal level into either Band of the RAU rises above the activation threshold (–30 dBm), causing that ALC loop to enter into the attack phase.
2. During the attack phase, the ALC loop increases the attenuation (0 to 30 dB) until the detector reading is reduced to the activation threshold. The duration of this attack phase is called the attack time.
3. After the attack time, the ALC loop enters the hold phase and maintains a fixed attenuation so long as the high-level RF signal is *present*.
4. The RF signal level drops below the release threshold (–45 dBm) and the ALC loop enters the release phase.
5. During the release phase, the ALC loop holds the attenuation for a fixed period then quickly releases the attenuation.

An important feature of the ALC loop is that in Step 3, the attenuation is maintained at a fixed level until the signal drops by a significant amount. This prevents the ALC loop from tracking variations in the RF signal itself and distorting the waveform modulation.

Figure 6-2 **ALC Operation**



6.8.2.1 Using the RAU 10 dB Attenuation Setting

Each RAU band can, independently of the other RAUs in a system, have its uplink or downlink gain attenuated by 10dB in 1dB steps for each RAU band (1, 2, or 3). This is accomplished by selecting the appropriate UPLINK and/or DOWNLINK attenuation for each RAU band in the **Edit Unit Properties** screen of AdminBrowser for the selected RAU.

- **Downlink Attenuation:** The downlink attenuator provides a mechanism to reduce the signal strength from an RAU band. For instance, this could be for an RAU band located near a window in a tall building that is causing excessive leakage to the macro-network. In such a case it is important to attenuate the downlink only. The uplink should not be attenuated. If the uplink is attenuated, the uplink sensitivity is reduced and mobile phones in the area of that RAU band will have to transmit at a higher power. This would increase interference to the outdoor network from such mobiles.
- **Uplink Attenuation:** The uplink attenuator attenuates environmental noise picked up by an RAU band located in an area where heavy electrical machinery is operating. In such environments the electrical noise can be quite high and it is useful to reduce the amount of such noise that gets propagated through the distributed antenna system. Attenuating the uplink of an RAU band located in areas of high electrical noise helps preserve the sensitivity of the rest of the system.

The effect of activating the uplink or downlink attenuators is to reduce the coverage area of the adjusted RAU band. The coverage radius will be reduced by roughly a factor of 2. More specifically, if *d* is the coverage distance without attenuation and *d'* is the coverage radius with the attenuation, then

$$\frac{d}{d'} = 10^{10dB/PLS}$$

where PLS is path loss slope (dBm).

6.8.2.2 Using the Uplink ALC Setting

Uplink automatic level control (UL ALC) circuitry for each band within the RAU provides automatic level control on high-power signals in the uplink path. This functionality is required to prevent RF signal compression caused by a single or multiple wireless devices in very close proximity to the RAU band. Compression causes signal degradation and, ultimately, dropped calls and data errors, and should be prevented. Two settings are available to optimize UL ALC performance:

- **Multiple Operators**: Use when more than one operator and/or protocol is present in the Fusion system's band frequency or adjacent frequency bands. This setting is most commonly used.
- **Single Operator and Protocol**: Use when only one operator and protocol is on-the-air within the Fusion system's configured and adjacent frequency bands. This setting is seldom used.