LGCell™ Wireless Networking System

Version 4.0

Installation, Operation, and Reference Manual

PN 8100-40
620004-0 Rev. B

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:

- Section 1.1 Purpose and Scope 1-2
- Section 1.2 Conventions in this Manual 1-3
- Section 1.3 Acronyms in this Manual 1-4
- Section 1.4 Standards Conformance 1-6
- Section 1.5 Related Publications 1-6

1.1 Purpose and Scope

This document describes the LGCell™ Distributed Antenna System and its installation. The following sections are included:

- Section 2 LGCell 4.0 System Description
- Section 3 LGCell Main Hub
- Section 4 LGCell Expansion Hub
- Section 5 LGCell Remote Access Unit
- Section 6 Managing and Planning an LGCell Project
- Section 7 Designing an LGCell Solution
- Section 8 Installation Requirements and Safety Precautions
- Section 9 Installing the LGCell
- Section 10 Maintenance, Troubleshooting, and Technical Assistance
- Appendix A Cables and Connectors
- Appendix B TIA/EIA 568-A Cabling Standard
- Appendix C Compliance Information
- Appendix D Frequently Asked Questions

1.2 Conventions in this Manual

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

Convention	Description
bold	Used for emphasis
BOLD CAPS	Used to indicate labels on equipment

Measurements are listed first in metric units, followed by U.S. Customary System of units in parentheses. For example:

0° to 45°C (32° to 113°F)

The following symbols are used to highlight certain information as described:

NOTE: This format is used to emphasize text with special significance or importance, and to provide supplemental information.

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

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

Procedure

This format is used to highlight a procedure.

1.3 Acronyms in this Manual

Acronym	Definition
BDA	bidirectional amplifier/repeater
BTS	base transceiver station
Cat-5	Category 5 (twisted pair cable)
CDMA	Code Division Multiple Access
C/I	carrier to interface
CISP	Certified Installation Service Provider
dB	decibel
dBm	decibels relative to 1 milliwatt
DCS	Digital Communications System
DL	downlink
EGSM	Extended Global Standard for Mobile Communications
GHz	gigahertz
GSM	Groupe Speciale Mobile (now translated in English as Global Standard for Mobile Communications)
Hz	hertz
iDEN	Integrated Digital Enhanced Network (Motorola variant of TDMA wireless)
IF	intermediate frequency
LAN	local area network
LED	light emitting diode
mA	milliamps
MBS	microcellular base station
MHz	megahertz
MMF	multimode fiber
MTBF	mean time between failures
NF	noise figure
nm	nanometer
PBX	private branch exchange
PCS	Personal Communications System
PLL	phase-locked loop
PLS	path loss slope
RAU	Remote Access Unit
RF	radio frequency
RSSI	received signal strength indicator

Acronym	Definition
SMA	sub-miniature A connector (coaxial cable connector type)
SNR	signal-to-noise ratio
ST	straight tip (fiber optic cable connector type)
STP	shielded twisted pair
TDMA	Time Division Multiple Access
TP	twisted pair
UL	uplink; Underwriters Laboratories
UMTS	Universal Mobile Telecommunications System
UPS	uninterruptable power supply
UTP	unshielded twisted pair
WOS	wireless office service

1.4 Standards Conformance

- Complies with industry standards for IS-19B/AMPS, J-STD-8, IS-136/TDMA, IS-95B/CDMA.
- Utilizes the TIA/EIA 568-A Ethernet cabling standards for ease of installation (see Appendix B).
- Distributes signals over a building’s existing industry-standard cable infrastructure of multimode fiber (MMF) and unshielded twisted pair/shielded twisted pair (UTP/STP) cable.
- See Appendix C for compliance information.

1.5 Related Publications

- MetroReach Focus Configuration, Installation, and Reference Manual; LGC Wireless part number 8500-10
- ARM2000 Installation, Operation, and Reference Manual; LGC Wireless part number 8305-10
- LGC Wireless Complementary Products Catalog; LGC Wireless part number 8600-10
- Neutral Host System Planning Guide; LGC Wireless part number 9000-10

SECTION 2

LGCell 4.0 System Description

This section contains the following:

- Section 2.1 System Overview 2-2
- Section 2.2 System Operation 2-5
- Section 2.3 System Bandwidths 2-10
- Section 2.4 System Specifications 2-13

2.1 System Overview

The LGCell acts as an extension of the outdoor, macrocellular network to provide RF signal coverage and capacity to places where the signals are not always available or adequate, such as inside a building, tunnel, subway, or other hard-to-reach locations.

LGCell features:

- Supports all cellular protocols.
- Provides uniform radio coverage.
- Distributes cellular signals through standard multimode fiber (MMF) and standard UTP/STP cables, which are found in most office buildings.
- Uses a double-star topology, which allows for easy, cost-effective growth of coverage and capacity.

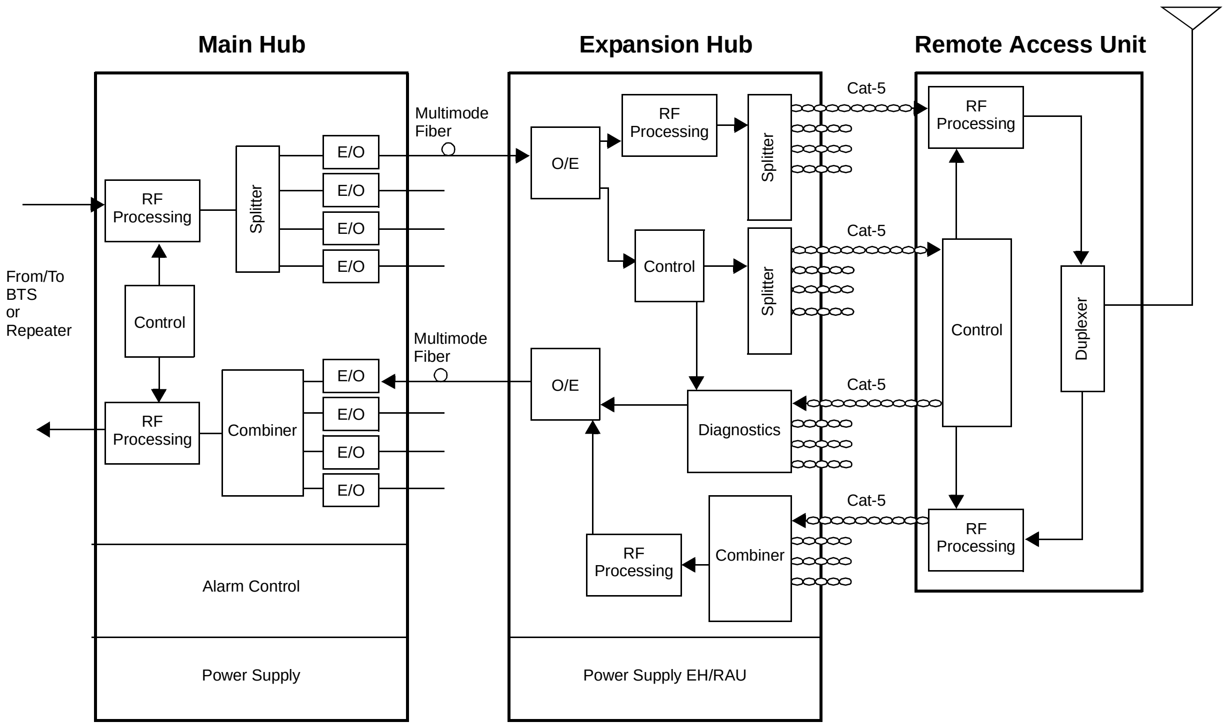
The LGCell system consists of three components, as shown (from top to bottom) in the following figure:

- Remote Access Unit
- Expansion Hub
- Main Hub

Figure 2-1 LGCell Components

The following figure shows a block diagram of a single band LGCell system. Note that uplink and downlink RF and control signals for an RAU travel through one Cat-5 cable.

Figure 2-2 **LGCell System Block Diagram (Single Band)**



LGCell components are available in the following frequencies and protocols:

- **Single-Band Frequencies and Protocols**
  - 800 MHz AMPS
  - 800 MHz TDMA
  - 800 MHz CDMA
  - 800 MHz iDEN
  - 900 MHz GSM
  - 900 MHz EGSM
  - 1800 MHz DCS (5 band options)
  - 1800 MHz Korean CDMA
  - 1900 MHz TDMA (4 band options)
  - 1900 MHz CDMA (4 band options)
  - 1900 MHz GSM (4 band options)
- **Dual-Band Frequencies and Protocols**

  A dual band system consists of two single band systems.
  - 800 MHz & 1900 MHz CDMA/TDMA
  - 800 MHz CDMA/TDMA & 1900 MHz GSM
  - 900 MHz GSM & 1800 MHz DCS
  - 900 MHz EGSM & 1800 MHz DCS
  - 1800 MHz DCS & 1800 MHz DCS

2.2 System Operation

Downlink (Base Station/Repeater to Wireless Handsets)

- The LGCell system's **Main Hub** is usually installed in a 19 in. (483 mm) equipment rack in a wiring closet or equipment room inside the facility where coverage will be provided. Coaxial cable is used to connect the Main Hub to a local base station or to a repeater that is attached to a roof-top antenna. The Main Hub receives the incoming RF signals and splits them to feed four internal fiber optic transceivers that convert the RF signals to optical signals. The Main Hub transmits the optical signals over multimode fiber to up to four Expansion Hubs, which are usually installed in other telecom closets throughout the facility.

WARNING: Exceeding the maximum input power could cause failure of the Main Hub (refer to Section 7.1 on page 7-3 for maximum power ratings). Attenuators may be required to limit the maximum composite power into the Main Hub.

- The **Expansion Hub** converts the optical signals back to electrical signals, which are then transmitted to up to four Remote Access Units (RAUs) over Cat-5 UTP/STP cabling.
- The **Remote Access Unit** receives the electrical signals from the Expansion Hub and transports the signals over a short coaxial cable to an attached passive antenna, which then transmits the RF signals to wireless handsets.

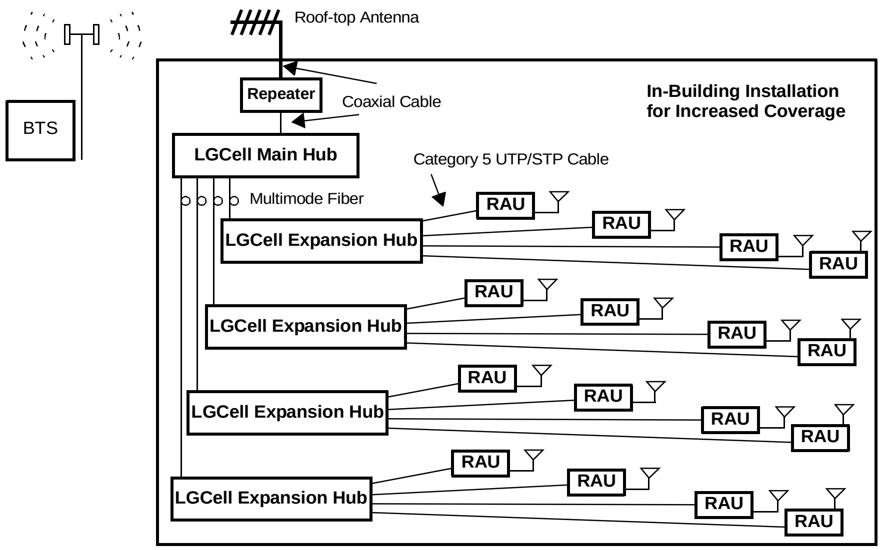
Uplink (Wireless Handsets to Base Station)

- The passive antenna relays the RF signals from wireless handsets to the **Remote Access Unit**, which then transmits the signals to the Expansion Hub over Cat-5 UTP/STP cabling.
- The **Expansion Hub** converts the electrical signals to optical signals and transmits the signals to the Main Hub over MMF.
- The **Main Hub** converts the optical signals to the proper frequency band RF signals and sends them to a local base station or to a repeater that is connected to a roof-top antenna.

2.2.1 Using LGCell to Increase Coverage and Capacity

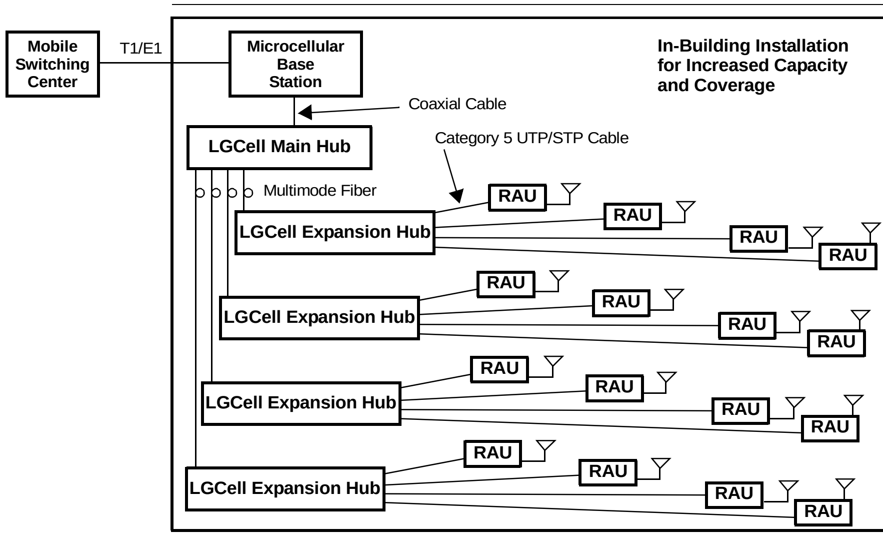
You can extend the outdoor, macrocellular network indoors by connecting the LGCell system to a repeater that is attached to a roof-top antenna. The following figure illustrates how the LGCell can be used to enhance in-building coverage.

Figure 2-3 **Increasing Coverage with LGCell**



You can increase the number of users who are able to communicate through their wireless handheld devices by connecting an LGCell system to a local, centralized base station. In this configuration, the base station provides voice channel capacity and the LGCell provides coverage.

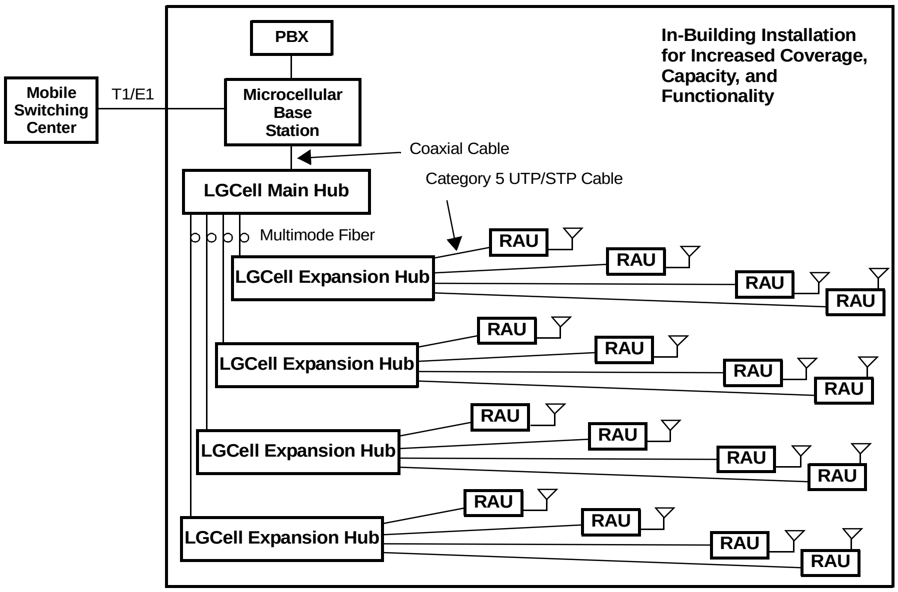
Figure 2-4 **Increasing Capacity and Coverage with LGCell**



2.2.2 Using LGCell to Increase Coverage, Capacity, and Functionality

Interfacing the LGCell with a base station/PBX network gives wireless phone users PBX functionality through their wireless phones, anytime, anywhere. The following figure shows an example installation for wireless office service (WOS).

Figure 2-5 Increasing Coverage, Capacity, and Functionality with LGCell



With the LGCell/base station/PBX* solution, employees can use a wireless phone in place of a wireline desk phone to access the PBX while inside the building and use the same phone for wireless communications while outside the building. Employees can access PBX features such as four-digit dialing, call delivery, call forwarding, call-waiting, conferencing, and voice mail from their wireless phone.

In this configuration, the base station private wireless network transmits RF signals indoors, and the macrocellular network takes over outdoors.

*Check with your PBX manufacturer/vendor for compatibility, connection, and operation.

2.2.3 Using LGCell to Simultaneously Support Multiple Bands/Protocols

An LGCell neutral host configuration can simultaneously support more than one frequency band and/or protocol. The term "neutral host" refers to the fact: that the system supports multiple wireless Operators, and that the equipment typically is owned by a third-party company.

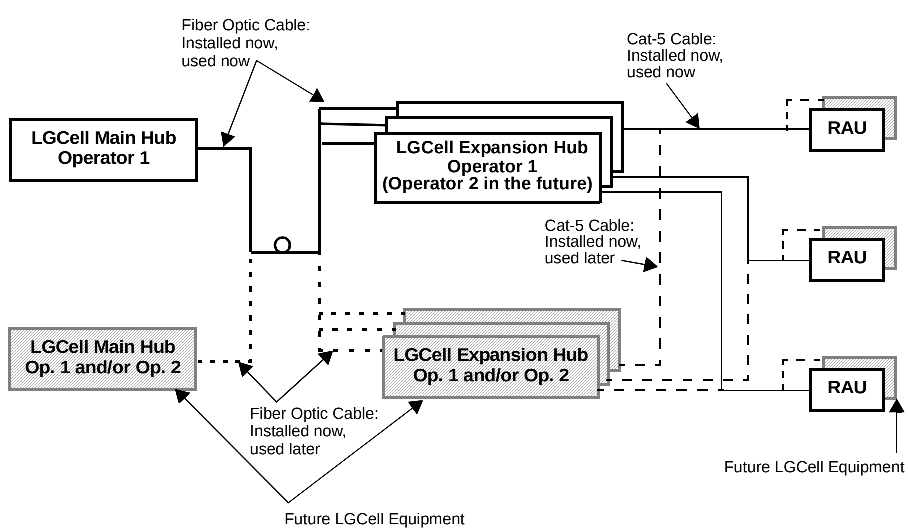
Neutral host systems are deployed in situations such as the following:

- Public microcellular applications such as airport terminals, subways/train stations, and similar public buildings usually require that the in-building RF distribution system infrastructure be capable of supporting any current frequency band and protocol, and that it be future-proof.
- It is common for the same service provider to be licensed to operate in multiple bands in the same geographical area. For example, some Asian and European service providers have licenses in both 900 MHz and 1800 MHz bands. Some North American service providers operate in both 800 MHz and 1900 MHz bands.

  Some service providers overlay networks (i.e., 900 and 1800 MHz) to alleviate capacity constraints.
- A building owner will often allow service providers to provide wireless service in their building only if they cooperate and share the infrastructure equipment and distribution system. Delays in service implementation and loss of revenue occur when the competing service providers do not agree on how to share the equipment and installation costs.

Additional distribution cabling infrastructure, beyond initial requirements, often is installed to accommodate adding Operators or services or to enhance capacity by sectorizing the distribution equipment at a later time.

Figure 2-6 Example Neutral Host Application



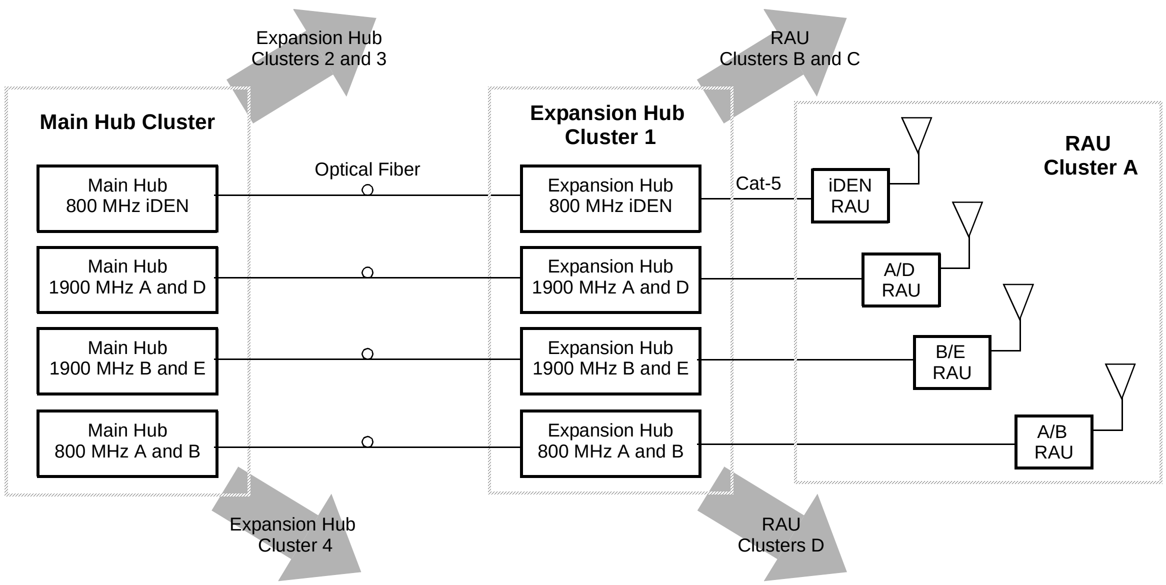
Neutral host systems are deployed as shared or dedicated systems.

- **Shared System**: Multiple wireless Operators use the same set of LGCell hardware to distribute RF signals.
- **Dedicated System**: Each Operator uses an independent LGCell system.

In order to simplify coverage planning and minimize installation costs, the equipment is “clustered” and installed in groups. The number of Hubs and RAUs required for a system is determined by their ability to be shared.

The configuration shown in Figure 2-7 supports up to 7 Operator bands.

Figure 2-7 **LGCell Neutral Host Configuration**



Refer to the *Neutral Host Planning Guide* (PN 9000-10) for more information about this type of configuration.

2.3 System Bandwidths

2.3.1 Fixed Bandwidth Systems

The 800 MHz and 900 MHz LGCell systems have fixed bandwidths of operation, as shown in the following table.

Table 2-1 **Bandwidths: 800 and 900 MHz**

LGCell System	System Bandwidth (MHz)	Uplink Freq. Range (MHz)	Downlink Freq. Range (MHz)
800 MHz: AMPS, TDMA, CDMA	25	824–849	869–894
800 MHz iDEN	18	806–824	851–869
900 MHz GSM	25	890–915	935–960
900 MHz EGSM	35	880–915	925–960

2.3.2 Variable Bandwidth Systems

The 1800 MHz DCS (GSM) and 1900 MHz CDMA, TDMA, and GSM systems have a bandpass filter that can be positioned within the uplink and downlink bands. This position is specified when the equipment is ordered and it is set during manufacturing.

1800 MHz DCS (GSM) System Bandwidth

The 1800 MHz DCS (GSM) 30 MHz bandpass filter is positioned within the 75 MHz band during manufacturing.

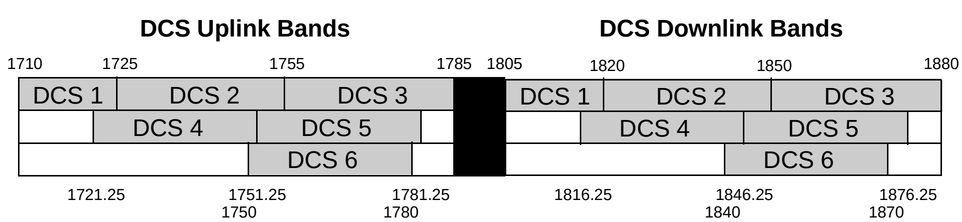
Table 2-2 Bandwidths: 1800 MHz DCS (GSM)

LGCell System	System Bandwidth (MHz)	Uplink Freq. Range (MHz)	Downlink Freq. Range (MHz)
1800 DCS (GSM)	30	1710–1785	1805–1880

You can choose where to place the 30 MHz band of operation, as shown in the following table.

Table 2-3 Band Frequency of the DCS 1800 MHz LGCell

Band	Uplink (MHz)	Downlink (MHz)
DCS 1	1710 to 1725	1805 to 1820
DCS 2	1725 to 1755	1820 to 1850
DCS 3	1755 to 1785	1850 to 1880
DCS 4	1721.25 to 1751.25	1816.25 to 1846.25
DCS 5	1751.25 to 1781.25	1846.25 to 1876.25



1900 MHz CDMA, TDMA, GSM System Bandwidth

The 1900 MHz CDMA, TDMA, and GSM 20 MHz bandpass filter is positioned within the 60 MHz band during manufacturing.

Table 2-4 **Bandwidths: 1900 MHz CDMA, TDMA, GSM**

DAS System	System Bandwidth (MHz)	Uplink Freq. Range (MHz)	Downlink Freq. Range (MHz)
1900 MHz: CDMA, TDMA, GSM	20	1850–1910	1930–1990

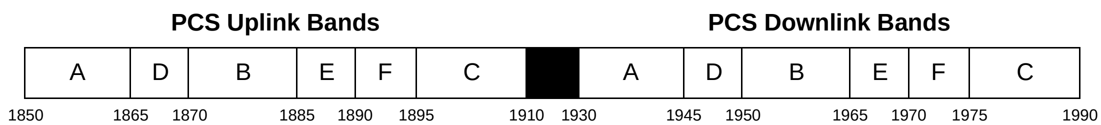
Table 2-5 **PCS Spectrum in the United States**

Band	Bandwidth (MHz)	Uplink (MHz)	Downlink (MHz)
A	15	1850 to 1865	1930 to 1945
D	5	1865 to 1870	1945 to 1950
B	15	1870 to 1885	1950 to 1965
E	5	1885 to 1890	1965 to 1970
F	5	1890 to 1895	1970 to 1975
C	15	1895 to 1910	1975 to 1990

LGCell equipment can be ordered in the following configurations:

- Bands A and D
- Bands D and B
- Bands B and E
- Bands E and F

LGCell equipment does not support band C.



2.4 System Specifications

General system specifications are provided in this section. Specifications for each component are provided in their respective sections:

- Section 3.4, “LGCell Main Hub Specifications,” on page 3-9
- Section 4.4, “LGCell Expansion Hub Specifications,” on page 4-7
- Section 5.3, “LGCell Remote Access Unit Specifications,” on page 5-5

2.4.1 Environmental Specifications

Parameter	Rating
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%

2.4.2 Physical Specifications

Parameter	Main Hub	Expansion Hub	Remote Access Unit
RF Connectors	3, N-type female	4, RJ-45	1, RJ-45 port 1, SMA female
Remote Alarm Connector (contact closure)	1, 9-pin D-sub, female 1, 25-pin D-sub (not used), male	—	—
MMF Connectors	4 Pair, ST female	1 Pair, ST female	—
LED Alarm and Status Indicators	Sync, Power, Port Link Status, Port Sync	Sync, Power, Port Link Status, Port Sync	Power, Sync
AC Power (Universal)			
Typical	117V AC, 0.22 amp @ 60 Hz 230V AC, 0.11 amp @ 50 Hz	117V AC, 0.47 amp @ 60 Hz 230V AC, 0.24 amp @ 50 Hz	—
Maximum	117V AC, 0.30 amp @ 60 Hz 230V AC, 0.15 amp @ 50 Hz	117V AC, 0.64 amp @ 60 Hz 230V AC, 0.32 amp @ 50 Hz	—
Power Consumption Typical Maximum	25 W 35 W	32 W / 55 W with 4 RAUs 45 W / 75 W with 4 RAUs	5.7 W 7.5 W
Enclosure Dimensions (height × width × depth) Excluding angle-brackets for 19" rack mounting of hubs.	44.5 mm × 438 mm × 229 mm (1.75 in. × 17.25 in. × 9 in.) 1U	44.5 mm × 438 mm × 229 mm (1.75 in. × 17.25 in. × 9 in.) 1U	36 mm × 110 mm × 140 mm (1.4 in. × 4.3 in. × 5.5 in.)
Weight	< 3 kg (< 6.5 lb)	< 3 kg (< 6.5 lb)	< 0.4 kg (<1 lb)
MTBF (hours)	298,000	461,000	965,000

2.4.3 Alarm LEDs

The Main Hub has **LINK STATUS** and **SYNC** LEDs for each fiber port. The Expansion Hub has **LINK STATUS** and **SYNC** LEDs for each Cat-5 (RAU) port.

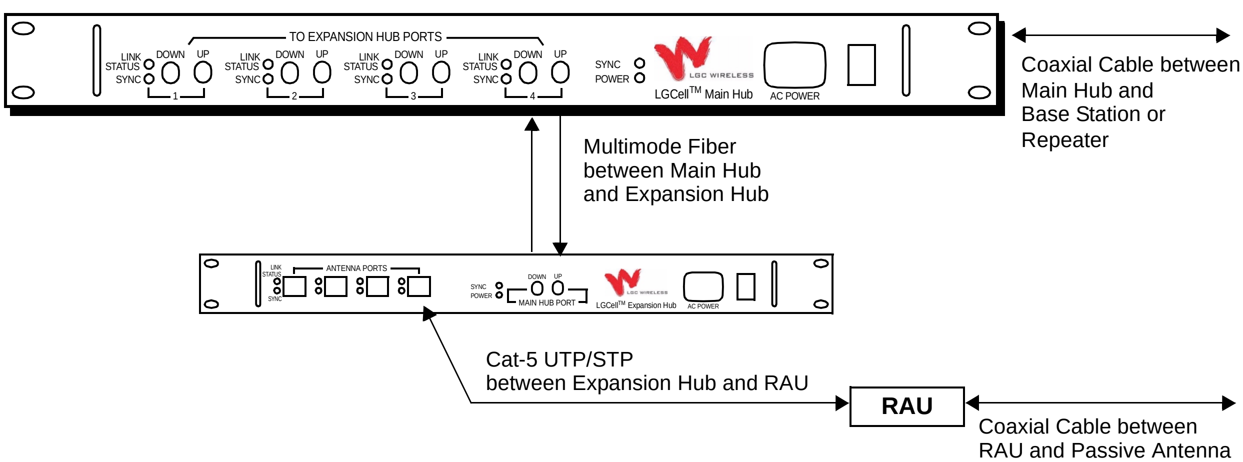
Unit	Alarm Name	LED Color	Condition
Main Hub	Power	Green	AC power is ON
	Sync (above power)	Green	Main Hub’s phase lock loop (PLL) is locked
		Off	Main Hub’s PLL is not locked
	Port Link Status	Green	The Main Hub is receiving a signal from the Expansion Hub without an alarm signal
		Red	The Main Hub is receiving an alarm signal from the Expansion Hub
	Port Sync	Green	The Expansion Hub and its connected RAUs do not have an alarm
		Red	The Expansion Hub or one of its connected RAUs has an alarm
Expansion Hub	Power	Green	AC power is ON
	Sync (above power)	Green	The Expansion Hub is receiving the pilot signal
		Off	The Expansion Hub is not receiving the pilot signal
	Port Link Status/Port Sync	Green/Green	The RAU is connected and functioning properly
		Green/Red	The Connected RAU is malfunctioning
		Red/Green	The RAU has been disconnected or the cable is cut
		Red/Red	No RAU is connected
RAU	Power	Green	DC power to RAU
	Sync	Red	PLL is not locked or clock power is low

SECTION 3

LGCell Main Hub

The Main Hub is the LGCell's central distribution point. On the dowlink, it receives RF signals from a base station or a repeater and converts them to optical signals, which it distributes to Expansion Hubs. On the uplink, the Main Hub receives optical signals from the Expansion Hubs and converts them back to RF signals to be relayed to a base station or a repeater.

Figure 3-1 The Main Hub in an LGCell 1-1-1 Configuration*



*1-1-1 configuration = 1 Main Hub, 1 Expansion Hub, and 1 Remote Access Unit

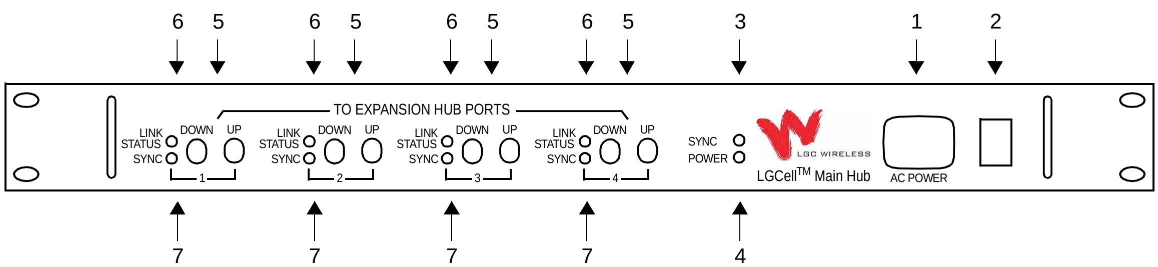
LGCell Main Hub Features

- Mounts in a standard 19 in. (483 mm) equipment rack
- Connects to a base station or repeater using coaxial cable
- Supports up to four Expansion Hubs using standard 62.5µm/125µm multimode fiber (MMF) cable
- Displays system status with front panel LEDs
- Provides contact closures and error latches for major errors through a D-sub 9-pin connector on the rear panel

3.1 LGCell Main Hub Front Panel

The front panel of a Main Hub is shown in the following figure.

Figure 3-2 Front Panel of a Main Hub



1. AC power cord connector
2. Power On/Off switch
3. One LED for unit sync status (labeled **SYNC**)
4. One LED for unit power status (labeled **POWER**)
5. Four MMF ports (labeled **1**, **2**, **3**, **4**)
   - One standard female ST optical connector for MMF downlink (labeled **DOWN**)
   - One standard female ST optical connector for MMF uplink (labeled **UP**)
6. One LED per port for port link status (labeled **LINK STATUS**)
7. One LED per port for port sync status (labeled **SYNC**)

3.1.1 MMF Downlink/Uplink Ports

The Main Hub's MMF downlink/uplink ports transmit/receive optical signals to/from Expansion Hub(s) using industry-standard 62.5μm/125μm MMF cable. There are four MMF ports (labeled **1**, **2**, **3**, and **4**) on the Main Hub's front panel. Each MMF port has two female ST optical connectors: one for downlink (output) and one for uplink (input).

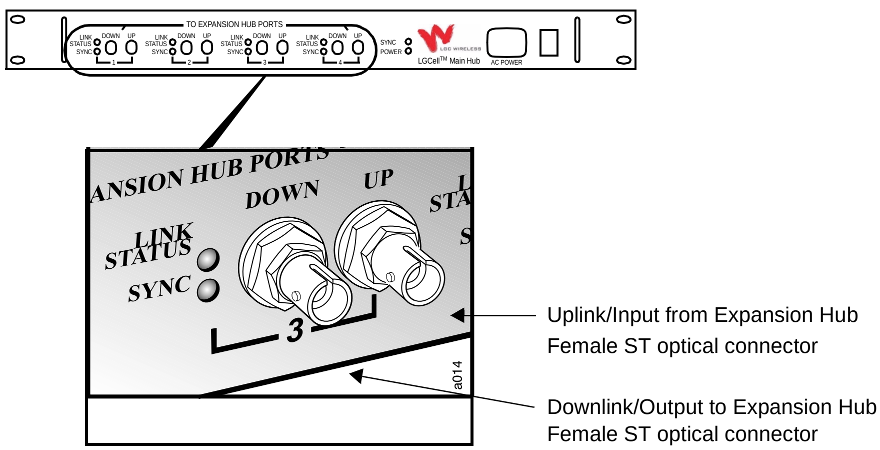
- **MMF Downlink Connector**

  This female ST connector (labeled **DOWN**) is used to transmit the downlink optical signals to an attached Expansion Hub.

- **MMF Uplink Connector**

  This female ST connector (labeled **UP**) is used to receive the uplink optical signals from an attached Expansion Hub.

Figure 3-3 MMF Downlink/Uplink Ports on the Main Hub



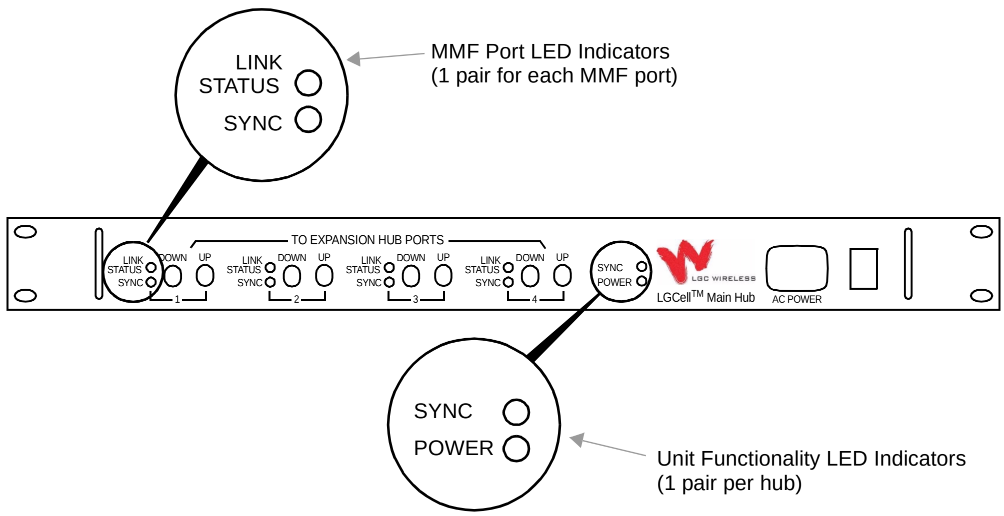
Port Disconnect Memory

The Main Hub detects when active fiber is connected to its MMF ports. An alarm is issued and latched if an active fiber cable from an MMF port on the Main Hub or an attached Expansion Hub is disconnected. The port disconnect memory and major alarm are cleared if you reconnect the fiber into the same functioning port. The error latch remains active until power is cycled. If you do not want to use that port, you should cycle the Main Hub's power to clear the port disconnect memory and the error latch.

3.1.2 Main Hub LED Indicators

The front panel of the Main Hub has LEDs that provide diagnostic information and operational status of the unit.

Figure 3-4 Main Hub Front Panel LEDs



The Main Hub's MMF port LEDs can be used to help troubleshoot downstream problems; however, the LEDs do not indicate which downstream component has the problem.

The Main Hub's LED indicators are described in the following table.

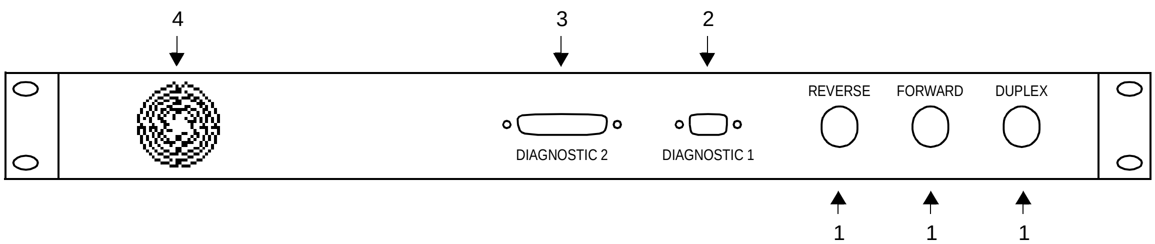
Table 3-1 Main Hub LED Indicators

MMF Port Indicators	Color	Indicates
LINK STATUS	Green	Good connection to the Expansion Hub that is connected to the port.
	Red	Connection problem with the Expansion Hub that is connected to the port.
SYNC	Green	Expansion Hub connected to the port is operating properly.
	Red	An alarm with the Expansion Hub that is connected to the port.
Unit Functionality Indicators	**Color**	**Indicates**
SYNC	Green	Main Hub is correctly producing the synchronization signal.
	Off	Main Hub is not correctly producing the synchronization signal.
POWER	Green	Main Hub has power.

3.2 LGCell Main Hub Rear Panel

The rear panel of a Main Hub is shown in the following figure.

Figure 3-5 Rear Panel of a Main Hub



1. Three N-type, female connectors with dust caps:
   - One simplex uplink, unidirectional (labeled **REVERSE**)
   - One simplex downlink, unidirectional (labeled **FORWARD**)
   - One duplexed, bidirectional (labeled **DUPLEX**)
2. One 9-pin D-sub connector (labeled **DIAGNOSTIC 1**)
3. One 25-pin D-sub connector, factory use only (labeled **DIAGNOSTIC 2**)
4. Air exhaust vent

3.2.1 Main Hub Rear Panel Connectors

N-Type Female Connectors

There are three N-type female connectors on the rear panel of the Main Hub: one duplex and two simplex. Generally, the simplex connectors are used together and the duplex connector is used by itself.

- **Simplex Connectors**

  The simplex connectors provide unidirectional connection of a Main Hub to a local base station or to a repeater that is connected to a roof-top antenna.

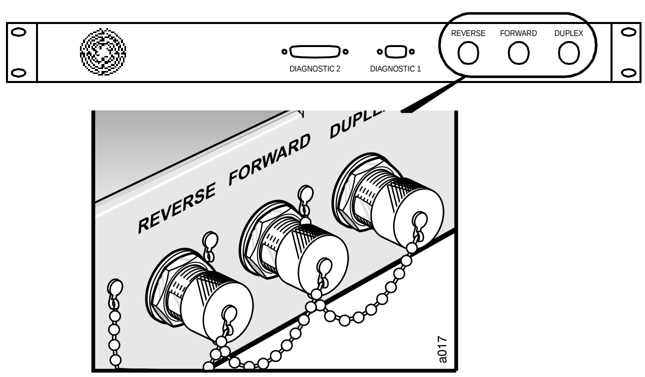
  – The **REVERSE** connector transmits uplink RF signals to a base station or a repeater.

  – The **FORWARD** connector receives downlink RF signals from a base station or a repeater.

- **Duplex Connector**

  The **DUPLEX** connector provides bidirectional (both uplink and downlink) connection between the Main Hub and a base station or a repeater. This connector has a fixed gain of 0, 30, or 40 dB, depending on the system (see Table 7-25 on page 7-28).

Figure 3-6 N-type Female Connectors on the Main Hub



NOTE: Always keep the dust cap on unused N-type connectors.

WARNING: Exceeding the maximum input power could cause failure of the Main Hub (refer to Section 7.1 on page 7-3 for maximum power ratings). Attenuators may be required to limit the maximum composite power into the Main Hub.

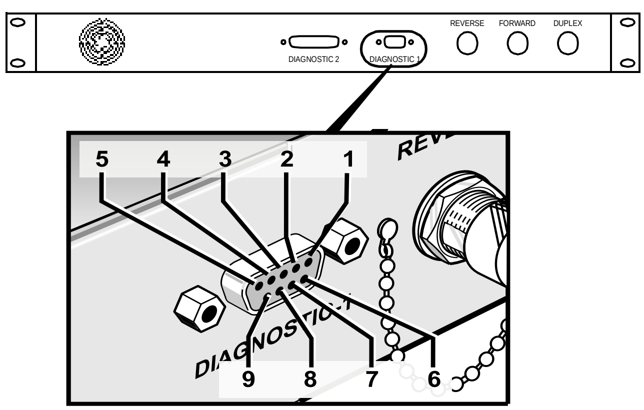
9-pin D-sub Connector

The 9-pin D-sub connector (labeled **DIAGNOSTIC 1**) provides contact closures and error latches for monitoring major errors.

The following table lists the function of each pin on the 9-pin D-sub connector. Pin locations are labeled on Figure 3-7.

Pin	Function
1	+10 V (fused)
2	Not connected
3	Not connected
4	Error Latch (positive connection)
5	Error Latch (negative connection)
6	DC Ground (common)
7	Major Error (positive connection)
8	Error Reset
9	Major Error (negative connection)

Figure 3-7 **9-pin D-sub Connector on the Main Hub**



Use the error pin connections to determine the error status: send a current of no more than 40 mA @ 40V DC maximum (4 mA @ 12V DC typical) through the positive connection. The current will return through the negative connection. An error is indicated if current ceases to flow through the error connection.

25-pin D-sub Connector

Reserved for factory use only.

3.3 LGCell Main Hub Alarm

The two error connections, Major Error and Error Latch, are relay connections. They are either open or short circuit as shown in the following table.

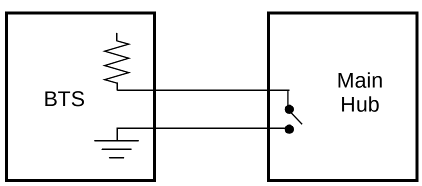
Operation	Major Error	Error Latch
Proper Operation	Short Circuit	Short Circuit
Error	Open Circuit	Open Circuit
Error Latch indicates that there has been a major error which was cleared.	Short Circuit	Open Circuit

- **Major Error**

  The Main Hub senses, then latches, major errors, which can be monitored via the alarm port's contact closures. Red or unlit (off) LEDs on the front panel indicate when an alarm is detected. (Refer to Section 10.2 on page 10-2 for help troubleshooting using LEDs.)

  The major error contact can be brought back to the BTS for alarm monitoring if the BTS provides +40V DC or less.

Figure 3-8 **Monitoring Main Hub Alarms from the BTS**



- **Error Latch**

  The error latch provides historical information for troubleshooting when you use an external alarm monitor. The recommended method of clearing an error latch is to connect pin 8 (error reset) to pin 1 (+10V) for at least one second. You can power cycle the unit to clear the error latch, but if you are not monitoring alarms externally, there is no need to do this. Normal operation of the system will not be affected by an uncleared error latch.

3.4 LGCell Main Hub Specifications

Note that for dual band systems, the specifications are per band.

Table 3-2 Main Hub Specifications

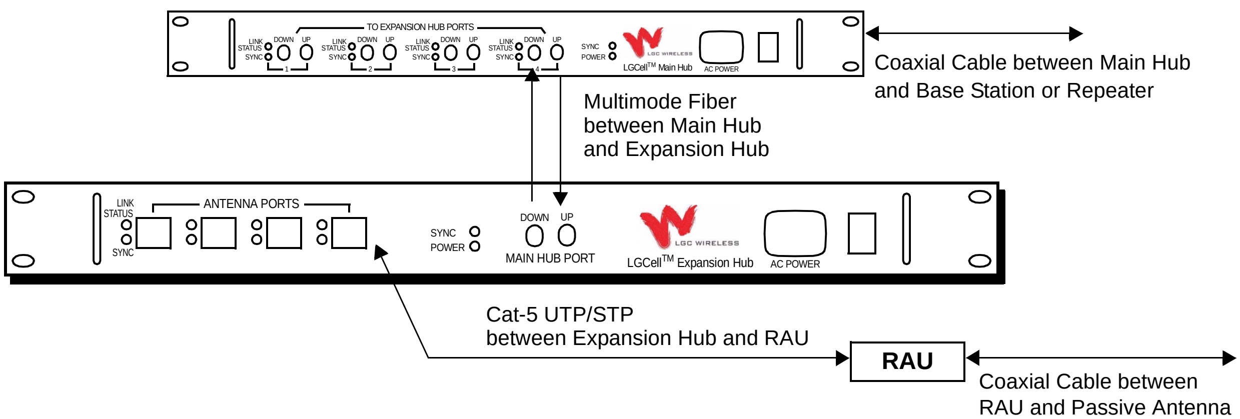
Specification	Description
Dimensions (H × W × D)	44.5 mm × 438 mm × 229 mm (1.75 in. × 17.25 in. × 9 in.); 1U
Weight	< 3 kg (< 6.5 lb)
Operating Temperature	0° to 45°C (32° to 113°F)
Operating Humidity, non-condensing	5% to 95%
Clearance	Front: minimum 50 mm (2 in.) Rear: minimum 76 mm (3 in.)
RF Connectors	3, N-type female
Remote Alarm Connector, contact closure	1, 9-pin D-sub female 1, 25-pin D-sub female (not used)
Multimode Fiber Connectors	4 pair, ST female
LED Alarm and Status Indicators	MMF Port: Link Status, Sync (4 pair) Unit Functionality: Sync, Power (1 pair)
AC Power (Universal)	
Typical	117V AC, 0.22 amp @ 60 Hz 230V AC, 0.11 amp @ 50 Hz
Maximum	117V AC, 0.30 amp @ 60 Hz 230V AC, 0.15 amp @ 50 Hz
Power Consumption	
Typical	25 W
Maximum	35 W
Frequencies	• 800 MHz AMPS/TDMA/CDMA/iDEN • 900 MHz GSM • 900 MHz EGSM • 1800 MHz DCS • 1900 MHz TDMA/CDMA/GSM • 800 MHz & 1900 MHz CDMA/TDMA • 800 MHz CDMA/TDMA & 1900 MHz GSM • 900 MHz GSM & 1800 MHz DCS • 900 MHz EGSM & 1800 MHz DCS • 1800 MHz DCS & 1800 MHz DCS
MTBF (hours)	298,000

SECTION 4

LGCell Expansion Hub

The Expansion Hub is LGCell’s intermediate distribution point. It converts optical signals that it receives from the Main Hub to intermediate frequency (IF) electrical signals that it transmits over Cat-5 cable to the RAUs.

Figure 4-1 The Expansion Hub in an LGCell 1-1-1 Configuration*



*1-1-1 configuration = 1 Main Hub, 1 Expansion Hub, and 1 Remote Access Unit

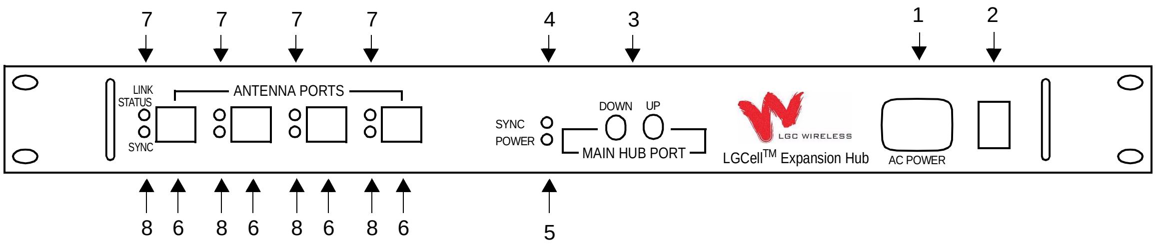
LGCell Expansion Hub Features

- Mounts in a standard 19 in. (483 mm) equipment rack
- Connects to Main Hub using 62.5µm/125µm multimode fiber (MMF) cable
- Supports up to four RAUs per band using Cat-5 UTP/STP cable with RJ-45 connectors
- Provides DC power to RAUs through the UTP/STP cable
- Has easily accessible front panel connectors
- Displays its status and the status of attached RAUs with front panel LEDs
- Communicates with Main Hub for system alarm status

4.1 LGCell Expansion Hub Front Panel

The front panel of an Expansion Hub is shown in the following figure.

Figure 4-2 Front Panel of an Expansion Hub



1. AC power cord connector
2. Power On/Off switch
3. MMF Port (labeled **MAIN HUB**)
   - One standard female ST optical connector for MMF downlink (labeled **DOWN**)
   - One standard female ST optical connector for MMF uplink (labeled **UP**)
4. One LED for unit sync status (labeled **SYNC**)
5. One LED for unit power status (labeled **POWER**)
6. Four standard Cat-5 UTP/STP cable RJ-45 female connectors (labeled **ANTENNA PORTS 1**, **2**, **3**, and **4**)
7. One LED per RJ-45 connector for link status (labeled **LINK STATUS**)
8. One LED per RJ-45 connector for sync status (labeled **SYNC**)

4.1.1 MMF Downlink/Uplink Port

The Expansion Hub's MMF downlink/uplink port transmits and receives optical signals to/from the Main Hub using industry-standard 62.5μm/125μm MMF cable. There is one MMF port (labeled **MAIN HUB**) on the Expansion Hub's front panel. The MMF port has two female ST optical connectors: one for downlink (input) and one for uplink (output).

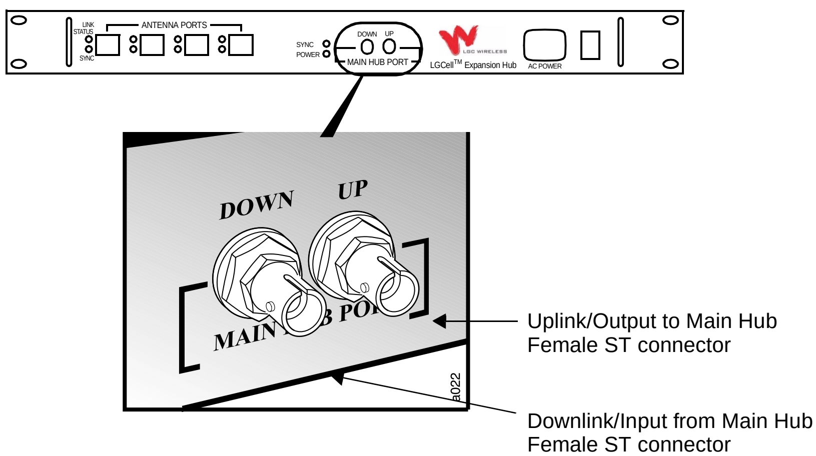
- **MMF Downlink Connector**

  This female ST optical connector (labeled **DOWN**) is used to receive downlink optical signals from the Main Hub.

- **MMF Uplink Connector**

  This female ST optical connector (labeled **UP**) is used to transmit uplink optical signals to the Main Hub.

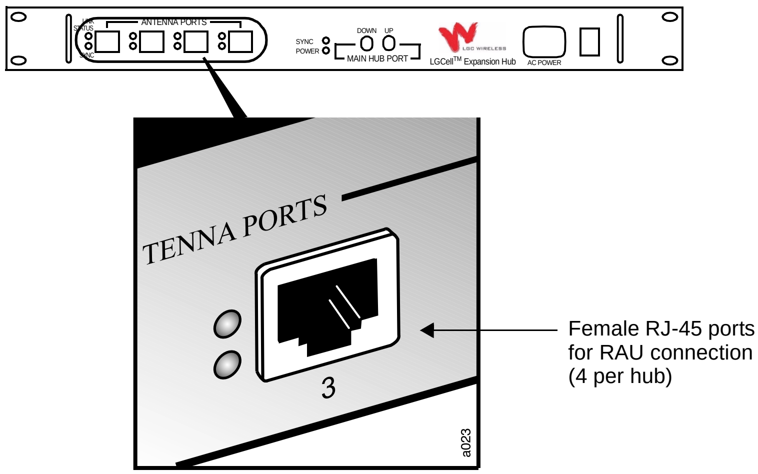
Figure 4-3 MMF Downlink/Uplink Port on the Expansion Hub



4.1.2 RJ-45 Ports

The Expansion Hub's RJ-45 ports are for the Cat-5 UTP/STP cables that are used to transmit and receive electrical signals to/from up to four RAUs. There are four ports on the Expansion Hub's front panel.

Figure 4-4 RJ-45 Ports on the Expansion Hub



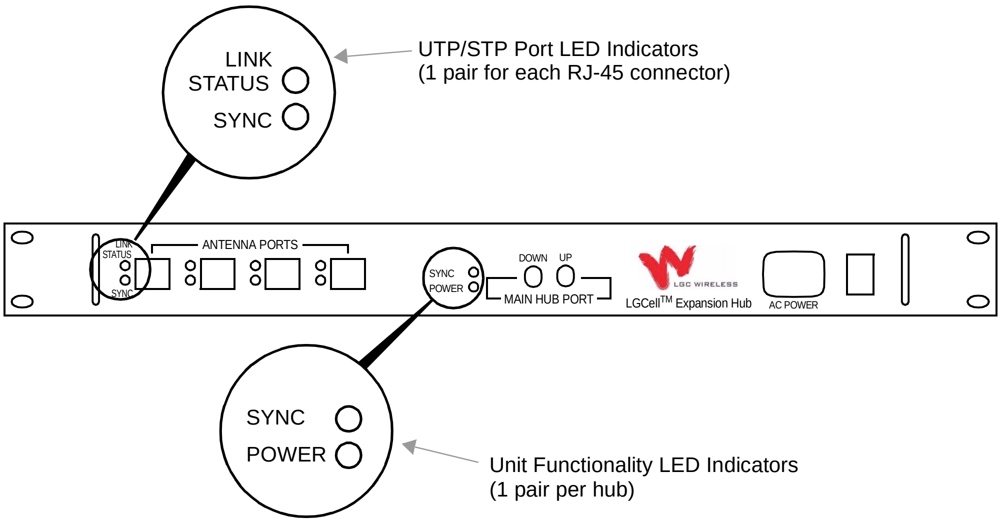
Port Disconnect Memory

The Expansion Hub detects when active UTP/STP cable and RAUs are connected to its RJ-45 ports. An alarm is issued and latched if you disconnect an active UTP/STP cable or an attached RAU. The port disconnect memory and alarm are cleared if you reconnect the cable into the same functioning port. The error latch remains active until power is cycled. If you do not want to use that port, you should cycle the Expansion Hub's power to clear the port disconnect memory and the error latch.

4.1.3 Expansion Hub LED Indicators

The front panel of the Expansion Hub has LEDs that provide diagnostic information and operational status of the unit and attached RAUs.

Figure 4-5 **Expansion Hub Front Panel LEDs**



The Expansion Hub's LED indicators are described in the following table.

Table 4-1 **Expansion Hub LED Indicators**

UTP/STP Port Indicators/Color		
LINK STATUS	**SYNC**	**Indicates**
Green	Green	RAU is connected and functioning properly.
Green	Red	RAU is connected but malfunctioning.
Red	Green	RAU has been disconnected or the cable is cut.
Red	Red	No RAU is connected.
Unit Functionality Indicators	**Color**	**Indicates**
SYNC	Green	Expansion Hub is receiving the synchronization signal from the Main Hub.
	Off	A fault with the MMF downlink or the unit is faulty.
POWER	Green	Expansion Hub has power.

4.2 LGCell Expansion Hub Rear Panel

The Expansion Hub’s rear panel has one air exhaust vent and no connectors.

4.3 LGCell Expansion Hub Alarm

The Expansion Hub communicates its status and the status of connected RAUs to the Main Hub over the MMF cable. The Main Hub’s MMF port LEDs can be used to help troubleshoot downstream problems; however, the LEDs do not indicate which downstream unit has the alarm.

4.4 LGCell Expansion Hub Specifications

Note that for dual band systems, the specifications are per band.

Table 4-2 **Expansion Hub Specifications**

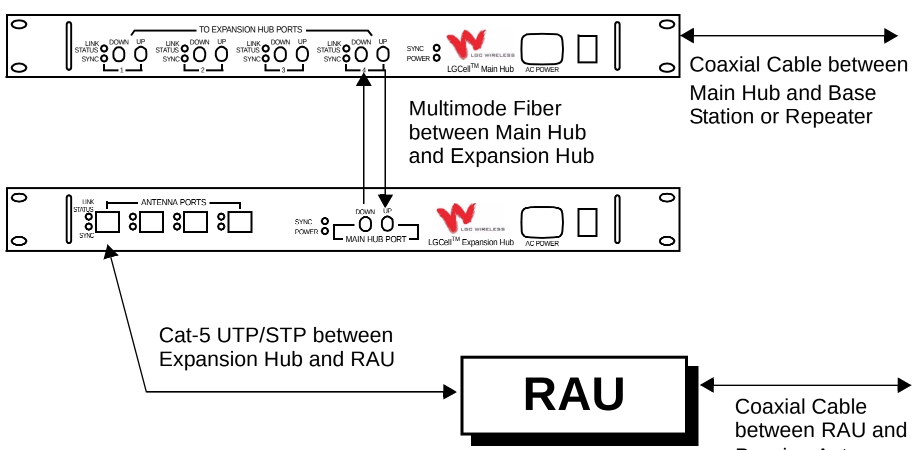
Specification	Description
Dimensions (H × W × D)	44.5 mm × 438 mm × 229 mm (1.75 in. × 17.25 in. × 9 in.); 1U
Weight	< 3 kg (< 6.5 lb)
Operating Temperature	0° to 45°C (32° to 113°F)
Operating Humidity, non-condensing	5% to 95%
Clearance	Front: minimum 50 mm (2 in.) Rear: minimum 76 mm (3 in.)
RF Connectors	4 ports, RJ-45
Multimode Fiber Connectors	1 pair, ST female
LED Alarm and Status Indicators	UTP/STP Port: Link Status, Sync (4 pair) Unit Functionality: Sync, Power (1 pair)
AC Power (Universal) Typical Maximum	 117V AC, 0.47 amp @ 60 Hz 230V AC, 0.24 amp @ 50 Hz 117V AC, 0.64 amp @ 60 Hz 230V AC, 0.32 amp @ 50 Hz
Power Consumption Typical Maximum	 32 W / 55 W with 4 RAUs 45 W / 75 W with 4 RAUs
Frequencies	• 800 MHz AMPS/TDMA/CDMA/iDEN • 900 MHz GSM • 900 MHz EGSM • 1800 MHz DCS • 1900 MHz TDMA/CDMA/GSM • 800 MHz & 1900 MHz CDMA/TDMA • 800 MHz CDMA/TDMA & 1900 MHz GSM • 900 MHz GSM & 1800 MHz DCS • 900 MHz EGSM & 1800 MHz DCS • 1800 MHz DCS & 1800 MHz DCS
MTBF (hours)	461,000

SECTION 5 LGCell Remote Access Unit

The Remote Access Unit (RAU) is an active transceiver that connects to an Expansion Hub using industry-standard Cat-5 UTP/STP cable. The cable also delivers electrical power to the RAU.

An RAU passes electrical signals between an Expansion Hub and an attached passive antenna.

Figure 5-1 The Remote Access Unit in an LGCell 1-1-1 Configuration*



*1-1-1 configuration = 1 Main Hub, 1 Expansion Hub, and 1 Remote Access Unit

LGCell Remote Access Unit Features

- Transmits intermediate frequency (IF) signals to and from Expansion Hub using Cat-5 UTP/STP cable with RJ-45 connectors
- Converts IF to RF (downlink) and RF to IF (uplink)
- Uses a female SMA connector for connecting to standard passive antennas
- Displays its operational status with LEDs
- Plenum-rated unit
- Mounts above a false ceiling or in a plenum-rated location

5.1 LGCell Remote Access Unit Connectors

RJ-45 Port

There is one RJ-45 port on a single band RAU and two RJ-45 ports on the 900/1800 MHz and the 1800/1800 MHz dual band RAUs.

Figure 5-2 RJ-45 Port on a Single Band RAU

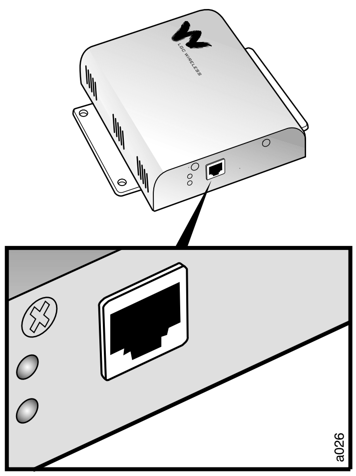
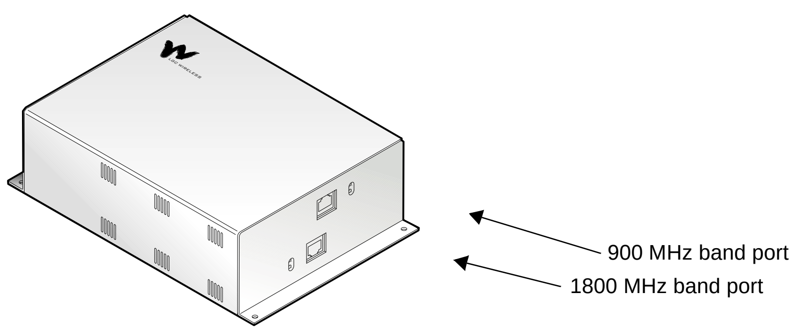


Figure 5-3 RJ-45 Ports on a Dual Band RAU



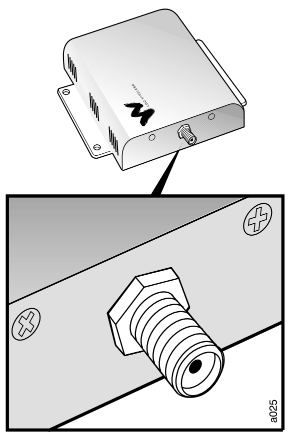
On a 900/1800 dual band RAU, the top RJ-45 port is for the 900 MHz band and the bottom port is for the 1800 MHz band. The signals are combined and passed to a single SMA connector.

On an 1800/1800 dual band RAU, the ports are interchangeable. It does not matter which Cat-5 cable coming from the 1800/1800 dual band Expansion Hub you plug into the top or the bottom. However, you may want to plug the top 1800 MHz Expansion Hub's Cat-5 cable into the top port and the bottom Expansion Hub's cable into the port for easier troubleshooting later.

SMA Connector

There is one female SMA connector on a single band RAU and on the 900/1800 dual band RAU; and two female SMA connectors on the 1800/1800 dual band RAU. The connector is a duplexed RF input/output port that connects to standard passive antennas.

Figure 5-4 **SMA Connector on the Single Band RAU**

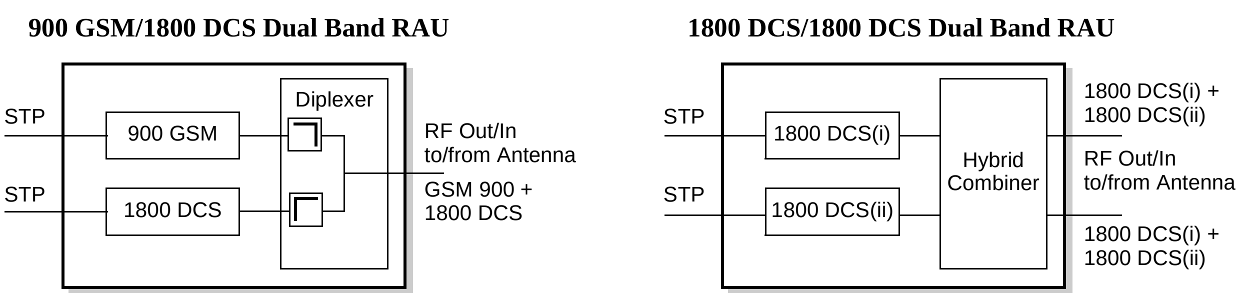


The 900/1800 dual band RAU has a single female SMA connector. The RAU uses a diplexer to combine the 900 MHz and 1800 MHz signals from the 900/1800 dual band Expansion Hub for output to a single passive antenna. Conversely, the uplink signals are separated into 900 MHz and 1800 MHz signals and sent to the 900/1800 dual band Expansion Hub.

The 1800/1800 dual band RAU has two female SMA connectors. The RAU combines the signals from each of the 1800 MHz bands on the 1800/1800 dual band Expansion Hub and passes the signals to both SMA connectors. On the uplink, all signals are sent to both 1800 MHz bands on the 1800/1800 dual band Expansion Hub. When attaching one passive antenna, terminate the unused connector with an SMA-type 50 ohm terminator (LGC Wireless part number 4100).

Diagrams of the dual band RAUs are shown in the following figure.

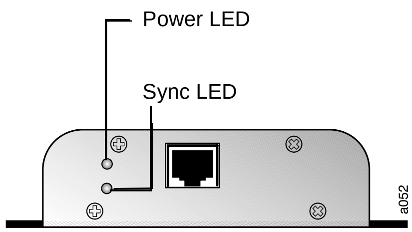
Figure 5-5 **Block Diagram of the Dual Band RAUs**



5.1.1 Remote Access Unit LED Indicators

The RAU has LEDs that provide diagnostic information and operational status of the unit.

Figure 5-6 **RAU LEDs**



The RAU's LED indicators are described in the following table.

Table 5-1 **RAU LED Indicators**

LED	Color	Indicates
POWER	Green	RAU is receiving power from the connected Expansion Hub.
SYNC	Red	PLL is not locked or clock power is low.
	Off	No fault.

When the RAU **SYNC** LED turns red, it indicates that the RF power in the RAU is shut down. When the fault is corrected, the **SYNC** LED turns off.

5.2 LGCell Remote Access Unit Alarm

The RAU communicates its status to the Expansion Hub over the Cat-5 cable. The Expansion Hub, in turn, communicates the status to the Main Hub. The Main Hub's MMF port LEDs can be used to help troubleshoot downstream problems; however, the LEDs do not indicate which downstream unit has the alarm.

5.3 LGCell Remote Access Unit Specifications

Note that for dual band systems, the specifications are per band.

Table 5-2 Remote Access Unit Specifications

Specification	Description
Dimensions (H × W × D)	
Single Band	36 mm × 110 mm × 140 mm (1.4 in. × 4.3 in. × 5.5 in.)
Dual Band	68 mm × 157 mm × 203 mm (2.7 in. × 6.2 in. × 8 in.)
Weight	
Single Band	< 0.4 kg (< 0.9 lb)
Dual Band	< 0.8 kg (< 1.8 lb)
Operating Temperature	0° to 45°C (32° to 113°F)
Operating Humidity, non-condensing	5% to 95%
RF Connectors	1 port, RJ-45 1, female SMA
LED Alarm and Status Indicators	Power, Sync
Power Consumption Typical Maximum	 5.7 W 7.5 W
Frequencies:	
Single Band	• 800 MHz AMPS/TDMA/CDMA/iDEN • 900 MHz GSM • 900 MHz EGSM • 1800 MHz DCS • 1900 MHz TDMA/CDMA/GSM
Dual Band	• 900 MHz GSM & 1800 MHz DCS • 900 MHz EGSM & 1800 MHz DCS • 1800 MHz DCS & 1800 MHz DCS
MTBF (hours)	965,000

5.4 Choosing Passive Antennas

Typically, omni-directional and directional passive antennas are used. Typical antenna gain is approximately 3 dBi for omni-directional antennas and 7 dBi for directional antennas. Antenna manufacturer specifications should be considered when selecting antennas.

Antenna selection considerations include:

- Antenna gain
- Antenna type (omni or directional, etc.)
- Performance
- Appearance (important to the building owner)
- Mounting type (ceiling mount, wall mount)

Refer to the LGC Wireless Complementary Products Catalog or contact your LGC account manager for a complete list of passive antennas that are available from LGC Wireless.

SECTION 6

Managing and Planning an LGCell Project

This section provides information to assist in managing and planning an LGCell system installation.

- Section 6.1 Managing an LGCell Project 6-2
- Section 6.2 Planning an LGCell Installation 6-5
- Section 6.3 Installation Checklist 6-8
- Section 6.4 System Optimization and Commissioning 6-9

6.1 Managing an LGCell Project

Proper project management is instrumental in providing timely and accurate deployment of the LGCell system. It is beneficial to have one person manage and coordinate all aspects of the project: planning, designing, and installing the equipment. The project manager is the person responsible for assigning tasks and ensuring scheduled work is performed on time. The project manager also acts as the coordinator between all the people involved in the project.

The following table shows an estimated timeline for project management.

Table 6-1 Project Management Estimated Timeline

Description	Details	Time Interval
Detailed site walk-through/RF survey	Prepare installation information, including RF plan, floor plan, equipment order form, and final design documents.	1 to 2 weeks
Order LGCell equipment	Get all parts and accessories required.	8 weeks*
Select cabling contractor	Complete installation statement of work and provide floor plan with equipment locations, cabling runs, and other materials and connections. Get cabling quotation after walk-through.	2 weeks
Install cable	Monitor installation.	1 to 5 days
Install LGCell	Review installation checklist and prepare all materials. *Refer to Section 6.3 on page 6-8.*	1 to 3 days
Test installation and RF coverage	Be sure there are no uncovered areas. *Refer to Section 6.4 on page 6-9.*	1 hour per RAU
Generate as-built document	Prepare site plan diagram and coverage performance.	1 to 5 days

*Standard delivery after receipt of order.

6.1.1 Project Management Responsibilities

Project management functions are performed throughout the duration of the project, from Site Survey through Commissioning, and include the following:

Lead Project Team

- Identify all project participants and document contact information
- Initiate project kick-off meeting
- Provide coordination of all participants
- Provide regular status reports to all participants including the end-user

Define Scope of Project

- Obtain system approval from all participants
- Define site coverage requirements
- Identify critical path items
- Identify all special requirements or potential “roadblocks”
- Plan installation time requirements

Conduct RF Site Survey

- Review/confirm the preliminary signal readings and results of the RF Site Survey, whether conducted by LGC Wireless or others
- Identify RF project changes and/or restrictions

Prepare Site for Installation

- Conduct site walk-through with all appropriate participants
- Coordinate required permits
- Determine material receiving/storage/disbursement location
- Engage and contract with the cabling sub-contractor
- Schedule material delivery
- Coordinate and manage the installation, termination, and testing of required cables (MMF, UTP/STP, coaxial)
- Coordinate with the base station vendor for the integration of the LGCell system
- Coordinate with the service provider for frequency allocation
- Coordinate the installation of any required AC power, power systems, or power equipment

Manage Installation of System

- Establish and distribute Installation Schedule
- Confirm cable installation if provided by third-party company
- Confirm antenna locations and selection
- Obtain approval of the Installation Plan from primary participants and the end-user
- Conduct pre-installation inspection
- Coordinate installation of the LGCell equipment
- Coordinate installation of antennas

Manage System Commissioning

- Coordinate system test
- Coordinate RF signal and coverage tests
- Coordinate complete RF system test with required participants

Manage System Acceptance

- Coordinate final inspection with required participants
- Prepare System Acceptance Document
- Issue System Acceptance Document
- Prepare As-Built Documents

6.2 Planning an LGCell Installation

Preliminary Planning

- **Complete a preliminary system design for current requirements**

  Compile all of the pertinent information to determine a preliminary system design.

- **Determine design requirements**

  Consult with the end user, the service provider, and the equipment vendors to determine system requirements.

- **Analyze floor plans**

  Review the building floor plans to determine approximate antenna locations and possible locations of equipment rooms. Also, where possible on the floor plans, check for various types of construction materials and installation restrictions.

Preliminary System Design

- **Compute equipment requirements for current traffic rates**

  Base this on the voice channels required and equipment parameters of the base station specified for the system (requires input from service provider RF Engineer).

- **Compute equipment requirements for expansion to future traffic rates**

  Base this on customer requirements and equipment parameters of the base station specified for the system.

- **Make recommendations for a system design for future traffic requirements**

  Provide a possible migration plan to achieve future capacity and coverage requirements, perhaps including provisions for additional equipment and/or sectorization of the existing cells.

Site Survey

- **Conduct on-site RF site evaluation**

  Conduct in-building signal level tests after the preliminary design is completed. Using a test transmitter, introduce an RF signal at the approximate antenna locations and record the signal levels on a copy of the floor plan.

  Conduct a physical review of the building to determine types of construction materials in the floors and walls, and amount of “clutter” in the building. (Clutter is anything that can block or reduce the RF signal coverage.) These will help determine the expected coverage area; the in-building signal loss due to walls, furniture, equipment, people, etc.; and the proposed equipment locations and cabling requirements.

  Identify AC power requirements and extra equipment (cabinets, cable trays, cable racks, etc.)

Frequency Planning

- **Coordinate frequency planning with local carriers**

  Discuss with the local carrier the channel requirements for the system.

Final System Design

- **Complete final design**

  Generate a final design based on preliminary design, results of RF tests, discussions with all appropriate parties involved in the project, and the site evaluation.

- **Create final equipment list**

  Generate a final equipment requirement list based on the final system design.

- **Design review**

  Discuss the final system design with all appropriate parties involved in the project.

- **RF Survey Report**

  Generate an RF Survey Report documenting all design information that you gathered.

- **Traffic analysis of current requirements**

  Determine capabilities in terms of current and future capacity, coverage, and quality of service.

6.2.1 Site Survey Questionnaire

LGC WIRELESS

Site Survey Questionnaire

2540 Junction Avenue | San Jose, CA 95134 | TEL 408-952-2400 | FAX 408-952-2410

Project Information		**End-User Information**	
Project Name:		End-User:	
Purchaser Address:		Site Address:	
Company Name:		Contact:	
Contact:		Phone:	
Phone:		E-mail:	
E-mail:		**BTS Information**	
Type of System Enhancement		Manufacturer:	
☐ Coverage ☐ Capacity (BTS) ☐ Wireless Office		Model No:	
Building Information		No. of Carriers:	
Are floor plans available (including map scale)?	☐ Yes ☐ No	No. of Subscribers:	
Is outdoor coverage required?	☐ Yes ☐ No	BHCR?	☐ Yes ☐ No
		Erlangs/Sub:	

Select the Downlink Power, Frequency, Protocol, and Band to Operate Under							
Downlink Power at Mobile (dBm): *Select One*	☐ –65	☐ –70	☐ –75	☐ –80	☐ –85 (default)	☐ –90	☐ –95
Frequencies (MHz): *Select all that apply*	☐ 800	☐ 900 GSM	☐ 900 EGSM	☐ 1800	☐ 1900		
Protocol:	☐ GSM	☐ TDMA	☐ CDMA	☐ SMR/iDEN	☐ AMPS		

Additional Questions	**Select One**		
Are exposed antennas tolerated inside?	☐ Yes	☐ No	☐ Unsure
Are exposed antennas tolerated outside?	☐ Yes	☐ No	☐ Unsure
Are locations above ceiling/closets available for mounting equipment?	☐ Yes	☐ No	☐ Unsure
Have available mounting locations been identified? (please identify on floor plans)	☐ Yes	☐ No	☐ Unsure
Are 19" equipment racks available?	☐ Yes	☐ No	☐ Unsure
Is AC power available at the Main and Expansion Hubs?	☐ Yes	☐ No	☐ Unsure
Are multimode fiber optic cables available?	☐ Yes	☐ No	☐ Unsure
If on a campus, are single-mode fiber optic cables available?	☐ Yes	☐ No	☐ Unsure
Are Cat-5 UTP/STP runs available?	☐ Yes	☐ No	☐ Unsure
If cabling is not available, will customer mandate a subcontractor? If yes, provide details in “Comments” section below.	☐ Yes	☐ No	☐ Unsure
Is a bi-directional amplifier (repeater) needed?	☐ Yes	☐ No	☐ Unsure

Comments: (special installation requirements, subcontractors, coverage areas, contacts, etc.)

6.3 Installation Checklist

Following is an installation checklist.

Table 6-2 Installation Checklist

✓	Item	Comments
	Floor Plans	Detailed floor plans of the project site, suitable for the installation of LGCell equipment and cable. Equipment locations clearly marked on the plans
	RF Site Survey	RF signal readings and antenna orientation details from the RF Site Survey, unless provided by LGC Wireless
	Equipment Enclosures/Structures	Any enclosures or structures required for the LGCell equipment, i.e., roof-top structure, unless provided by LGC Wireless
	Equipment Racks	Procurement and installation of equipment racks, unless provided by LGC Wireless
	Microcellular Base Station	Base station installed prior to LGCell equipment installation
	Roof-top Antenna/Repeater	Roof-top antenna and repeater installed prior to LGCell equipment installation
	Cat-5 cabling	TIA/EIA 568-A approved; RJ-45 connectors; Absolute Minimum: 10 meters (33 ft), Recommended Minimum: 20 meters (66 ft), Maximum: 50 meters (165 ft); Expansion Hubs to RAUs; installed, inspected, tested Shielded Cat-5 cable (STP) should be used for neutral host systems
	MMF	62.5µm/125µm; ST male connectors; up to 1 km (3300 ft); Main Hub to Expansion Hubs; maximum 3 dB optical loss, including connectors, splices, etc.; installed, inspected, tested
	Coaxial cabling	Coax approved; N-type male connectors; repeater or base station to Main Hub; installed, inspected, tested
	Coaxial cabling	Coax approved; N-type male connector; RAU to passive antenna; installed, inspected, tested
	Power	110/220V AC power available at hub locations
	Equipment on-hand and ready for installation:	
	LGCell Main Hub(s)	
	LGCell Expansion Hub(s)	4 per Main Hub
	Remote Access Unit(s)	4 per Expansion Hub
	Passive Antenna(s)	Omni or directional; based on RF design
	UPS/Battery	If required by customer
	Power combiner/divider	Required if cascading multiple Main Hubs. N-male to N-male coaxial cables used to connect power combiner/repeater to Main Hub and base station or repeater.

6.4 System Optimization and Commissioning

After the RF Site Survey is completed and the system is installed, perform the following tasks.

Check Installation

- Check installation of the Main Hubs, Expansion Hubs, Remote Access Units, splitters/combiners, antennas, etc.
- Confirm all cable connections
- Confirm working condition of LGCell equipment
- Confirm that equipment quantities and equipment locations are documented
- Confirm that all equipment and cables are identified and marked with ID number

Check Cabling

- Review test results of Cat-5 cable (UTP/STP) (conduct cable test if testing has not already been completed; the results are needed for the As-Built Document)
- Review test results of coaxial cables; at base station to Main Hub and RAU to antenna
- Confirm and document actual link budget in coaxial cables

Check Optical Loss and Power Levels

- Confirm and document downlink power level out of base station
- Confirm and document downlink power level into Main Hub
- Confirm and document uplink power level out of Main Hub
- Check and document optical loss from Main Hub to Expansion Hub

Verify Coverage

- Conduct floor-by-floor system walk-through, confirming RSSI in all locations of the coverage area. Document RF signal level readings from all locations onto floor plan drawings.
- Confirm outside signal levels where required
- Measure RF signal out of equipment, if required

Check Signal Quality

- Check for neighbor channels/frequencies
- Confirm adjacent channel/frequency signal strength
- Check all call quality requirements of the carrier

Prepare As-Built Document

Prepare the final As-Built Document to include the following:

- Title Page
  - Site Address
  - Contact List
- Table of Contents
  - Introduction
    – Description of system installation including equipment used, unusual applications or obstacles, etc.
  - Equipment Locations
    – Descriptions or diagrams of equipment locations within the facility
  - Wiring Configuration and Specifications
    – Descriptions and tables of MMF and Cat-5 measurements; including Expansion Hub ID numbers, RF signal level readings throughout coverage area, number of RAUs attached, results of the Cat-5 compliance tests, unusual or marginal applications, etc.
  - Base Station Settings
    – Number of channels and sectors, transceiver setting, etc.
    – RF power into Main Hub
    – Amount of attenuation used
  - Coverage Performance
    – Description of test method and outcome
  - Summary
    – Include outstanding issues, future plans, and future considerations
  - As-Built Floor Plans

SECTION 7

Designing an LGCell Solution

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

1. **Determine the wireless service provider's requirements.**

   This information is usually supplied by the service provider:

   - Frequency (i.e., 850 MHz)
   - Band (i.e., "A" band in the Cellular spectrum)
   - Protocol (i.e., TDMA, CDMA, GSM, iDEN)
   - Peak capacity requirement (this, and whether or not the building will be split into sectors, determines the number of carriers that the LGCell will have to transmit)
   - Design goal (RSSI, relative signal strength at the wireless handset, i.e., –85 dBm)

     The design goal is always a stronger signal than the cell phone needs. It includes inherent factors which will affect performance (see Section 7.4.1 on page 7-32).
   - RF source (base station or BDA), type of equipment if possible

2. **Determine the power per carrier and input power from the base station or BDA into the Main Hub: Section 7.1, "Maximum Output Power per Carrier at RAU," on page 7-3.**

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

3. **Determine the in-building environment: Section 7.2, "Estimating RF Coverage," on page 7-18.**

   - Determine which areas of the building require coverage (entire building, public areas, parking levels, etc.)

- Obtain floor plans to determine floor space of building and the wall layout of the proposed areas to be covered. Floor plans will also be useful when you are selecting antenna locations.
- If possible, determine the building's construction materials (sheetrock, metal, concrete, etc.)
- Determine type of environment
  - Open layout (e.g., a convention center)
  - Dense, close walls (e.g., a hospital)
  - Mixed use (e.g., an office building with hard wall offices and cubicles)

4. **Develop an RF link budget: Section 7.4, "Link Budget Analysis," on page 7-31.**

   Knowing the power per carrier, you can calculate an RF link budget which is used to predict how much propagation loss can be allowed in the system, while still providing satisfactory performance throughout the area being covered. The link budget is a methodical way to derive a "design goal". If the design goal is provided in advance, the link budget is simply: *allowable RF loss = max. power per carrier – design goal.*

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: Section 7.2, "Estimating RF Coverage," on page 7-18.**

   The path loss slope (PLS), which gives a value to the RF propagation characteristics within the building, is used to convert the RF link budget into an estimate of the coverage distance per antenna. This will help establish the LGCell equipment quantities you will 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: Section 7.5, "Connecting a Main Hub to a Base Station," on page 7-44.**

   Once you know the quantities of LGCell equipment you will use, you can determine the accessories (combiners/dividers, surge suppressors, repeaters, attenuators, circulators, etc.) that are required to connect the system to the base station.

The individual elements that must be considered in designing an LGCell solution are discussed in the following sections.

7.1 Maximum Output Power per Carrier at RAU

The following tables show the recommended maximum power per carrier out of the RAU SMA connector for different frequencies, formats, and numbers of carriers. These limits are dictated by RF signal quality and regulatory emissions issues. The maximum input power to the Main Hub is determined by subtracting the system gain from the maximum output power of the RAU. For most systems the gain is 0 dB. Exceptions are the duplex port for the Cellular LGCell (30 dB gain) and the duplex port of the PCS LGCell (40 dB gain).

Therefore, when you connect a Main Hub to a base station or repeater, the RF power per carrier usually needs to be attenuated in order to avoid exceeding the LGCell's maximum composite output power.

Refer to Section 7.6, "Designing for a Neutral Host System," on page 7-48 when combining frequencies or protocols on a single Main Hub.

WARNING: Exceeding the maximum input power could cause permanent damage to the Main Hub.

Table 7-1 800 MHz (AMPS) Power per Carrier

No. of Carriers	Recommended Maximum Output PPC at RAU (dBm)
1	20.0
2	14.0
3	10.5
4	7.5
5	6.0
6	4.5
7	3.5
8	2.5
9	2.0
10	1.0
11	1.0
12	0.5
13	0.0
14	–0.5
15	–0.5
16	–1.0
20	–2.0
30	–4.0

WARNING: For 800 MHz AMPS, do not exceed the maximum composite input power of 126mW (+21 dBm) to the Main Hub's simplex ports, or 126µW (–9 dBm) to its duplex port at any time.

Table 7-2 800 MHz (TDMA) Power per Carrier

No. of Carriers	Recommended Maximum Output PPC at RAU (dBm)
1	17.0
2	12.0
3	9.0
4	7.0
5	5.5
6	4.5
7	3.5
8	2.5
9	2.0
10	1.5
11	1.0
12	0.5
13	0.5
14	0.0
15	–0.5
16	–0.5
20	–1.5
30	–3.5

WARNING: For 800 MHz TDMA, do not exceed the maximum composite input power of 126mW (+21 dBm) to the Main Hub's simplex ports, or 126µW (–9 dBm) to its duplex port at any time.

Table 7-3 **800 MHz (CDMA) Power per Carrier**

No. of Carriers	Recommended Maximum Output PPC at RAU (dBm)
1	10.0
2	7.5
3	6.0
4	5.0
5	4.0
6	3.5
7	2.5
8	2.0

WARNING: For 800 MHz CDMA, do not exceed the maximum composite input power of 126mW (+21 dBm) to the Main Hub's simplex ports, or 126µW (–9 dBm) to its duplex port at any time.

Table 7-4 **800 MHz (iDEN/SMR) Power per Carrier**

No. of Carriers	Recommended Maximum Output PPC at RAU (dBm)
1	10.0
2	7.0
3	4.5
4	3.0
5	2.0
6	1.0
7	0.0
8	–0.5
9	–1.0
10	–1.5
11	–2.0
12	–2.5
13	–3.0
14	–3.0
15	–3.5
16	–4.0
20	–5.0
30	–6.5

WARNING: For 800 MHz iDEN/SMR, do not exceed the maximum composite input power of 126mW (+21 dBm) to the Main Hub's duplex and/or simplex ports at any time.

Table 7-5 900 MHz (GSM or EGSM) Power per Carrier

No. of Carriers	Maximum Output PPC at RAU (dBm)
1	8.0
2	4.0
3	2.0
4	1.0
5	0.0
6	–1.0
7	–1.5
8	–2.0
9	–2.5
10	–2.5
11	–3.0
12	–3.5
13	–3.5
14	–4.0
15	–4.0
16	–4.5

WARNING: For 900 MHz GSM or EGSM, do not exceed the maximum composite input power of 126mW (+21 dBm) to the Main Hub's duplex and/or simplex ports at any time.

Table 7-6 1800 MHz (GSM) Power per Carrier

No. of Carriers	Maximum Output PPC at RAU (dBm)
1	8.0
2	5.5
3	3.5
4	2.0
5	1.0
6	0.5
7	0.0
8	–0.5
9	–1.0
10	–1.5
11	–1.5
12	–2.0
13	–2.5
14	–2.5
15	–3.0
16	–3.0

WARNING: For 1800 MHz GSM, do not exceed the maximum composite input power of 126mW (+21 dBm) to the Main Hub's duplex and/or simplex ports at any time.

Table 7-7 1800 MHz (CDMA Korea) Power per Carrier

No. of Carriers	Recommended Maximum Output PPC at RAU (dBm)
1	8.0
2	5.5
3	4.0
4	3.0
5	2.0
6	1.5
7	0.5
8	0.0

WARNING: For 1800 MHz CDMA (Korea), do not exceed the maximum composite input power of 126mW (+21 dBm) to the Main Hub's duplex and/or simplex ports at any time.

Table 7-8 **1900 MHz (TDMA) Power per Carrier**

No. of Carriers	Recommended Maximum Output PPC at RAU (dBm)
1	17.0
2	12.0
3	9.0
4	7.0
5	5.5
6	4.5
7	3.5
8	2.5
9	2.0
10	1.5
11	1.0
12	0.5
13	0.5
14	0.0
15	–0.5
16	–0.5
20	–1.5
30	–3.5

WARNING: For 1900 MHz TDMA, do not exceed the maximum composite input power of 126mW (+21 dBm) to the Main Hub's simplex ports, or 12.6µW (–19 dBm) to its duplex port at any time.

Table 7-9 **1900 MHz (GSM) Power per Carrier**

No. of Carriers	Maximum Output PPC at RAU (dBm)
1	20.0
2	8.0
3	6.0
4	5.0
5	4.0
6	3.0
7	2.5
8	2.0
9	1.5
10	1.5
11	1.0
12	0.5
13	0.5
14	0.0
15	0.0
16	–0.5

WARNING: For 1900 MHz GSM, do not exceed the maximum composite input power of 126mW (+21 dBm) to the Main Hub's simplex ports, or 12.6µW (–19 dBm) to its duplex port at any time.

Table 7-10 1900 MHz (CDMA) Power per Carrier

No. of Carriers	Recommended Maximum Output PPC at RAU (dBm)
1	10.0
2	7.5
3	6.0
4	5.0
5	4.0
6	3.5
7	2.5
8	2.0

WARNING: For 1900 MHz CDMA, do not exceed the maximum composite input power of 126mW (+21 dBm) to the Main Hub's simplex ports, or 12.6µW (–19 dBm) to its duplex port at any time.

Table 7-11 900 MHz (GSM or EGSM) and 1800 MHz (GSM) Low Band Power per Carrier

No. of Carriers	Maximum Output PPC at RAU (dBm)
1	8.0
2	3.5
3	1.5
4	0.5
5	–0.5
6	–1.5
7	–2.0
8	–2.5
9	–3.0
10	–3.0
11	–3.5
12	–4.0
13	–4.0
14	–4.5
15	–4.5
16	–5.0

WARNING: For 900 MHz GSM or EGSM and 1800 MHz GSM, do not exceed the maximum composite input power of 126mW (+21 dBm) to the Main Hub's duplex and/or simplex ports at any time.

Table 7-12 900 MHz (GSM or EGSM) and 1800 MHz (GSM) High Band Power per Carrier

No. of Carriers	Maximum Output PPC at RAU (dBm)
1	8.0
2	4.5
3	2.5
4	1.0
5	0.0
6	–0.5
7	–1.0
8	–1.5
9	–2.0
10	–2.5
11	–2.5
12	–3.0
13	–3.5
14	–3.5
15	–4.0
16	–4.0

WARNING: For 900 MHz GSM or EGSM and 1800 MHz GSM, do not exceed the maximum composite input power of 126mW (+21 dBm) to the Main Hub's duplex and/or simplex ports at any time.

Table 7-13 1800/1800 MHz (GSM) Power per Carrier

No. of Carriers	Maximum Output PPC at RAU (dBm)
1	8.0
2	2.5
3	0.5
4	–0.5
5	–1.5
6	–2.5
7	–3.0
8	–3.5
9	–3.5
10	–4.0
11	–4.5
12	–5.0
13	–5.5
14	–5.5
15	–6.0
16	–6.5

WARNING: For 1800 MHz GSM, do not exceed the maximum composite input power of 126mW (+21 dBm) to the Main Hub's duplex and/or simplex ports at any time.

Allowing for Future Capacity Growth

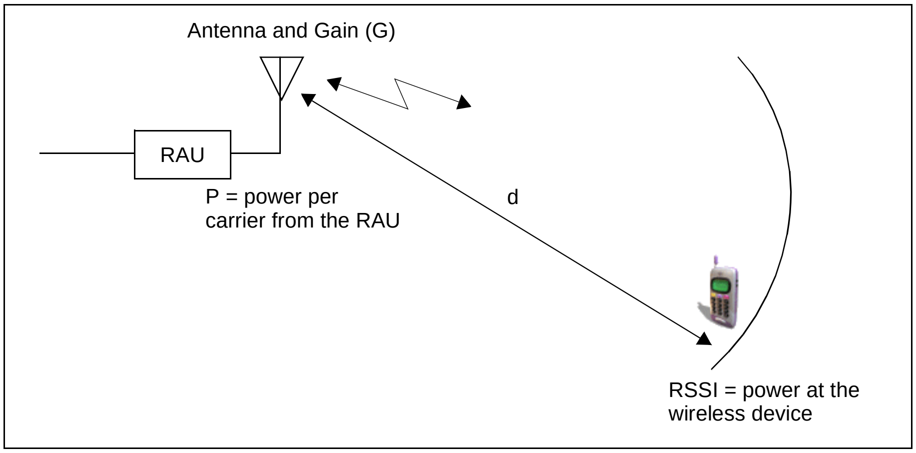
Sometimes an LGCell deployment initially is used to enhance coverage. Later that same system may also need to provide increased capacity. Thus, the initial deployment might only transmit two carriers but need to transmit four carriers later. There are two options for dealing with this scenario:

1. Design the initial coverage with a maximum power per carrier for four carriers.
2. Design the initial coverage for two carriers but leave Expansion Hub ports unused. These ports can be used later if coverage holes are discovered once the power per carrier is lowered to accommodate the two additional carriers.

7.2 Estimating RF Coverage

The maximum power per carrier (based on the number and type of RF carriers that are being transmitted) and the minimum acceptable received power at the wireless device (i.e., RSSI, the design goal) establish the RF link budget, and consequently the path loss between the antenna and the wireless device.

Figure 7-1 Determining Path Loss between the Antenna and the Wireless Device



$$(P + G) - RSSI = PL \quad (1)$$

The path loss (PL) is the loss in decibels (dB) between the antenna and the wireless device. The distance, d, from the antenna corresponding to this path loss can be calculated using the path loss equation in Section 7.2.1 or in Section 7.2.3.

The losses due to the coaxial cable that connects the RAU to the antenna are not included in this equation because, typically, the cable is short and the losses are modest. However, if further precision is desired, you can use the coaxial cable losses listed in the following table.

Table 7-14 Coaxial Cable Losses

Length of Cable	Loss at 800 MHz (dB)	Loss at 1900 MHz (dB)
0.9 m (3 ft)	0.4	0.6
1.8 m (6 ft)	0.9	1.4
3.0 m (10 ft)	1.5	2.4

7.2.1 Path Loss Equation

Indoor path loss obeys the distance power law* in equation (2):

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

where:

- PL is the path loss at a distance, d, from the antenna (the distance between the antenna that is connected to the RAU and the point where the RF signal decreases to the minimum acceptable level at the wireless device).
- d_0 is taken as 1 meter of free-space.
- f is the operating frequency in hertz.
- c is the speed of light in a vacuum (3.0×10^8 m/sec).
- n is the path loss exponent and depends on the building “clutter”.
- X_s is a normal random variable that depends on partition losses inside the building, and therefore, depends on the frequency of operation.

As a reference, the following table gives estimates of signal loss for some RF barriers.*

Table 7-15 Average Signal Loss of Common Building Materials

Partition Type	Loss (dB) @ <2 GHz	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

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

7.2.2 Path Loss Slope

Table 7-16 shows estimated path loss slope (PLS) for various environments that have different “clutter” (i.e., objects that attenuate the RF signals, such as walls, partitions, stairwells, equipment racks, etc.)

Table 7-16 Estimated Path Loss Slope for Different In-Building Environments

Facility	PLS for 800/900 MHz	PLS for 1800/1900 MHz
Manufacturing	35	32
Hospital	39.4	38.1
Airport	35	32
Retail	36.1	33.1
Warehouse	35	32
Parking Garage	33.7	30.1
Office: 80% cubicle/20% hard wall	36.1	33.1
Office: 50% cubicle/50% hard wall	37.6	34.8
Office: 20% cubicle/80% hard wall	39.4	38.1

7.2.3 Coverage Distance

Equations (1) and (2), on pages 7-18 and 7-19, respectively, can be used to estimate the distance from the antenna to where the RF signal decreases to the minimum acceptable level at the wireless device.

Equation (2) can be simplified to:

$$PL = 20\log(4\pi f/c) + PLS\log D \quad (3)$$

where PLS is chosen to account for partition losses. Because different frequencies penetrate partitions with different losses, the value of PLS will vary depending on the frequency.

For simplicity, Equation (3) can be used to estimate the coverage distance of an antenna that is connected to an RAU, for a given path loss, frequency, and type of in-building environment.

Table 7-17 gives the value of the first term of Equation (3) (i.e., (20log(4πf/c)) for various frequency bands.

Table 7-17 Frequency Bands and the Value of the first Term in Equation (3)

	Band (MHz)		Mid-Band Frequency (MHz)	20log(4πf/c)
	Uplink	Downlink		
800 Cellular	824–849	869–894	859	31.1
800 iDEN	806–824	851–869	837.5	30.9
900 GSM	890–915	935–960	925	31.8
900 E-GSM	880–915	925–960	920	31.7
1800 DCS	1710–1785	1805–1880	1795	37.5
1800 CDMA (Korea)	1750–1780	1840–1870	1810	37.6
1900 PCS	1850–1910	1930–1990	1920	38.1

For reference, Tables 7-18 through 7-24 show the distance covered by an antenna for various in-building environments. The following assumptions were made:

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

Table 7-18 Approximate Radiated Distance from Antenna for 800 MHz Cellular Applications

	Distance from Antenna	
Facility	**Meters**	**Feet**
Manufacturing	42	138
Hospital	28	91
Airport	42	138
Retail	38	123
Warehouse	42	138
Parking Garage	49	160
Office: 80% cubicle/20% hard wall	38	123
Office: 50% cubicle/50% hard wall	33	107
Office: 20% cubicle/80% hard wall	28	91

Table 7-19 Approximate Radiated Distance from Antenna for 800 MHz iDEN Applications

	Distance from Antenna	
Facility	**Meters**	**Feet**
Manufacturing	43	140
Hospital	28	92
Airport	43	140
Retail	38	125
Warehouse	43	140
Parking Garage	49	162
Office: 80% cubicle/20% hard wall	38	125
Office: 50% cubicle/50% hard wall	33	108
Office: 20% cubicle/80% hard wall	28	92

Table 7-20 Approximate Radiated Distance from Antenna for 900 MHz GSM Applications

Facility	Distance from Antenna	
	Meters	Feet
Manufacturing	40	133
Hospital	27	88
Airport	40	133
Retail	36	118
Warehouse	40	133
Parking Garage	47	153
Office: 80% cubicle/20% hard wall	36	118
Office: 50% cubicle/50% hard wall	31	103
Office: 20% cubicle/80% hard wall	27	88

Table 7-21 Approximate Radiated Distance from Antenna for 900 MHz EGSM Applications

Facility	Distance from Antenna	
	Meters	Feet
Manufacturing	41	133
Hospital	27	88
Airport	41	133
Retail	36	119
Warehouse	41	133
Parking Garage	47	153
Office: 80% cubicle/20% hard wall	36	119
Office: 50% cubicle/50% hard wall	31	103
Office: 20% cubicle/80% hard wall	27	88

Table 7-22 Approximate Radiated Distance from Antenna for 1800 MHz DCS Applications

Facility	Distance from Antenna	
	Meters	Feet
Manufacturing	38	124
Hospital	21	69
Airport	38	124
Retail	33	110
Warehouse	38	124
Parking Garage	48	156
Office: 80% cubicle/20% hard wall	33	110
Office: 50% cubicle/50% hard wall	28	93
Office: 20% cubicle/80% hard wall	21	69

Table 7-23 Approximate Radiated Distance from Antenna for 1800 MHz CDMA (Korea) Applications

Facility	Distance from Antenna	
	Meters	Feet
Manufacturing	38	123
Hospital	21	69
Airport	38	123
Retail	33	109
Warehouse	38	123
Parking Garage	47	155
Office: 80% cubicle/20% hard wall	33	109
Office: 50% cubicle/50% hard wall	28	92
Office: 20% cubicle/80% hard wall	21	69

Table 7-24 Approximate Radiated Distance from Antenna for 1900 MHz PCS Applications

Facility	Distance from Antenna	
	Meters	Feet
Manufacturing	36	119
Hospital	20	67
Airport	36	119
Retail	32	105
Warehouse	36	119
Parking Garage	45	149
Office: 80% cubicle/20% hard wall	32	105
Office: 50% cubicle/50% hard wall	27	89
Office: 20% cubicle/80% hard wall	20	67

7.2.4 Example Design Estimate

1. **Design goals**:
   - Cellular (859 MHz = average of the lowest uplink and the highest downlink frequency in 800 MHz Cellular band)
   - TDMA provider
   - 6 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 7.1, “Maximum Output Power per Carrier at RAU,” on page 7-3 provide maximum power per carrier information. The 800 MHz TDMA table (on page 7-5) indicates that the LGCell can support 6 carriers with a typical power per carrier of 4.5 dBm.

   4.5 dBm per carrier would be the typical RF signal into the Main Hub’s **FORWARD** (downlink) port. If the duplex port is used, you must take into account the gain of the port (Table 7-25 on page 7-28) and adjust the input power accordingly. For example, the duplex port on the 800 MHz LGCell provides 30 dB gain. Therefore, the input power must be no greater than –25.5 dBm per carrier (4.5 dBm – 30 dBm). Similarly, the PCS LGCell has a duplex port gain of 40 dB. All other systems have 0 dB gain through all ports.
3. **Building information**:
   - 8 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 92.5 dB (4.5 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, see Section 7.4 on page 7-31.
5. **Path Loss Slope**: For a rough estimate, Table 7-16, “Estimated Path Loss Slope for Different In-Building Environments” on page 7-20, 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 92.3 dB, the distance of coverage from each RAU will be 42 meters (138 ft). This corresponds to a coverage area of 5,641

sq. meters (60,719 sq. ft.) per RAU (see Section 7.2.1 for details on path loss estimation). For this case we assumed a circular radiation pattern, though the actual area covered will depend upon the pattern of the antenna and the obstructions in the facility.

If the area to be covered is essentially an unobstructed hallway with some coverage for the offices on either side of the hallway, a more aggressive design using a lower PLS should be used.

6. **Equipment Required**: Since you know the building size, you can now estimate the LGCell equipment quantities that will be needed. Before any RF levels are tested in the building, you can estimate that 2 antennas per level will be needed.
   a. 2 antennas per floor × 8 floors = 16 RAUs
   b. 16 RAUs ÷ 4 (max 4 RAUs per Expansion Hub) = 4 Expansion Hubs
   c. 4 Expansion Hubs ÷ 4 (max 4 Expansion Hubs per Main Hub) = 1 Main Hub

   Check that the MMF and Cat-5 cable distances are as recommended. If the distances differ, use the tables in Section 7.3, "System Gain," on page 7-28 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 LGCell equipment quantities required for the building. The site survey measures the RF losses within the building to determine the actual PLS, which will be used in the final path loss formula to determine the actual requirements of the LGCell.

7.3 System Gain

The following table shows a summary of the system gain when 1 km (3300 ft) of 62.5μm/125μm multimode fiber is used. The optical loss of 1 km (3300 ft) of MMF cable ranges from about 0.6 to 1.0 dB optical, depending on the type of cable (i.e., riser zip-cord, loose tube, slotted core, etc.).

Table 7-25 System Gain when using Duplex/Simplex Ports

LGCell Frequency and Format	System Gain (dB)	
	Duplex Port	Simplex Ports
800 MHz AMPS, TDMA	30	0
800 MHz CDMA	30	0
800 MHz iDEN	0	0
900 MHz GSM, EGSM	0	0
1800 MHz GSM	0	0
1900 MHz TDMA	40	0
1900 MHz CDMA	40	0
1900 MHz GSM	40	0

NOTE: The maximum input power to the Main Hub is equal to the maximum output power of the RAU minus the system gain. For example, for a Cellular system with 6 TDMA carriers, the maximum output power is 4.5 dBm per carrier. If the duplex port is used, the maximum input power to the Main Hub should be no greater than –25.5 dBm per carrier.

7.3.1 System Gain (Loss) Relative to MMF Cable Length

If the length of MMF cable is less than 1 km (3300 ft), the system gain will increase. If the cable length is between 1 km (3300 ft) and 2 km (6600 ft), the system gain will decrease as the cable length increases. Use the following formula for determining the nominal gain (or loss) of the LGCell. The length of the MMF cable is denoted by *L*:

$$\text{gain (dB)} = 3*(1 - \frac{L}{1000})$$

MMF Cable Length	System Gain (dB)
1 m / 3.3 ft	+3
500 m / 1650 ft	+1.5
1000 m / 3300 ft	0
1500 m / 4950 ft	–1.5
2000 m / 6600 ft	–3

MMF cable length greater than 2 km (6600 ft) is not recommended.

The optical power budget between the Main Hub and Expansion Hub, both downlink and uplink, is 3 dB optical. If fiber distribution panels are used, confirm that the total optical loss of fiber cable, from the Main Hub through distribution panels and patch cords to the Expansion Hub, does not exceed 3 dB optical.

7.3.2 System Gain (Loss) Relative to UTP/STP Cable Length

The recommended minimum length of UTP/STP cable is 20 meters (66 ft) and the recommended maximum length is 50 meters (165 ft). If the UTP/STP cable is less than 20 meters (66 ft), system performance may not meet specifications; the absolute minimum cable length is 10 meters (33 ft). If the UTP/STP cable is longer than 50 meters (165 ft), the gain of the system will decrease, as shown in Table 7-26.

Only *shielded* Cat-5 cable (STP) should be used when running parallel Cat-5 cables for an LGCell system.

Table 7-26 System Gain (Loss) Relative to UTP/STP Cable Length

UTP/STP Cable Length	Typical change in system gain (dB)	
	Downlink	Uplink
800 MHz TDMA/AMPS and CDMA; 900 MHz GSM and EGSM; and iDEN		
60 m / 198 ft	–0.7	–0.3
70 m / 231 ft	–2.9	–2.1
80 m / 264 ft	–5.1	–3.9
90 m / 297 ft	–7.3	–5.7
100 m / 330 ft	–9.5	–7.5
1800 MHz GSM (DCS)		
60 m / 198 ft	–1.2	–0.3
70 m / 231 ft	–3.9	–2.1
80 m / 264 ft	–6.6	–3.9
90 m / 297 ft	–9.3	–5.7
100 m / 330 ft	–12	–7.5
1900 MHz TDMA, CDMA, and GSM		
60 m / 198 ft	–1.0	–0.3
70 m / 231 ft	–3.5	–2.1
80 m / 264 ft	–6.0	–3.9
90 m / 297 ft	–8.5	–5.7
100 m / 330 ft	–11	–7.5

7.4 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 discussed in Section 7.1. 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 +21 dBm (126mW) minus system gain. Composite power levels above this limit will cause damage to the Main Hub.

Table 7-27 LGCell Maximum Input Power

LGCell System	Maximum Input Power	
Simplex Ports (all LGCells)	+21 dBm	126mW
Duplex Ports (Cellular)	–9 dBm	126µW
Duplex Ports (iDEN, GSM, EGSM, DCS, CDMA-Korea)	+21 dBm	126mW
Duplex Ports (1900 MHz PCS)	–19 dBm	12.6µW

WARNING: Exceeding the maximum input power could cause permanent damage to the Main Hub.

7.4.1 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 an LGCell 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 7.2.1.

Table 7-28 provides link budget considerations for narrowband systems.

Table 7-28 Link Budget Considerations for Narrowband Systems

Consideration	Description
BTS Transmit Power	The power per carrier transmitted from the base station output
Attenuation between BTS and LGCell	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 7.1. 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 LGCell noise figure minus the attenuation is at least 10 dB higher than the BTS noise figure, the system noise figure will be approximately that of the LGCell alone. See Section 7.5 for ways to independently set the uplink and downlink attenuations between the base station and the LGCell.
LGCell Gain	This is the system gain (see Table 7-25 on page 7-28)
Antenna Gain	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.
BTS Noise Figure	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).
LGCell Noise Figure	This is the LGCell’s uplink noise figure, which varies depending on the number of Expansion Hubs and RAUs, and the frequency band. The LGCell uplink noise figure is specified for a 1-1-4 configuration. Thus, the noise figure for an LGCell (or multiple LGCells whose uplink ports are power combined) will be *NF(1-1-4) + 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.

Table 7-28 **Link Budget Considerations for Narrowband Systems (continued)**

<table>
<tr><th>Consideration</th><th>Description</th></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>CDMA</td><td>1.25 MHz</td><td>–113 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 this margin will not appear because it will be averaged out over power level samples taken over many locations.</td></tr>
<tr><td>Log-normal Fade Margin</td><td>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, this shadowing will not appear because it will be averaged out over power level samples taken over many locations.</td></tr>
<tr><td>Body Loss</td><td>This accounts for RF attenuation caused by the user’s head and body.</td></tr>
<tr><td>Minimum Received Signal Level</td><td>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.</td></tr>
</table>

7.4.2 Narrowband Link Budget Analysis for a Microcell Application

Narrowband Link Budget Analysis: Downlink

Line	Downlink	
	Transmitter	
a.	BTS transmit power per carrier (dBm)	33
b.	Attenuation between BTS and LGCell (dB)	–30
c.	Power into LGCell (dBm)	3
d.	LGCell gain (dB)	0
e.	Antenna gain (dBi)	3
f.	Radiated power per carrier (dBm)	6
	Airlink	
g.	Multipath fade margin (dB)	6
h.	Log-normal fade margin with 8 dB std. deviation, edge reliability 90% (dB)	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)	12
n.	Minimum received signal (dBm)	–110
p.	**Maximum path loss** (dB)	97

- 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

Narrowband Link Budget Analysis: Uplink

Line	Uplink	
	Receiver	
a.	BTS noise figure (dB)	4
b.	Attenuation between BTS and LGCell (dB)	–10
c.	LGCell gain (dB)	0
d.	LGCell noise figure (dB)	27
e.	System noise figure (dB)	27.2
f.	Thermal noise (dBm/30 kHz)	–129
g.	Required C/I ratio (dB)	12
h.	Antenna gain (dBi)	3
i.	Receive sensitivity (dBm)	–92.8
	Airlink	
j.	Multipath fade margin (dB)	6
k.	Log-normal fade margin with 8 dB std. deviation, edge reliability 90% (dB)	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)	101.8

- 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

7.4.3 Elements of a Link Budget for CDMA Standards

A CDMA link budget is slightly more complicated because the spread spectrum nature of CDMA must be considered. 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. An example is given in the following table.

Table 7-29 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 LGCell 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-hand-off 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

$P_{TX} + P_{RX} = -73$ 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 7-30 on page 7-37). 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 7-30 provides link budget considerations for CDMA systems.

Table 7-30 Additional Link Budget Considerations for CDMA Systems

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 will be delayed by approximately one chip.
Power per carrier, downlink	This depends on how many channels are active. For example, the signal will be 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 LGCell is being driven. The total power for a fully-loaded CDMA signal is given by (approximately): total power = voice channel power + 13 dB + $10 log_{10}$ (50%) = voice channel power + 10 dB
Information Rate	This is simply $10 log_{10}$(9.6 Kbps) = 40 dB for rate set 1 $10 log_{10}$(14.4 Kbps) = 42 dB for rate set 2

Table 7-30 Additional Link Budget Considerations for CDMA Systems

Consideration	Description
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.
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 will be 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 $= NF + E_b/N_o - 113\ (dBm/1.25\ MHz) - P_G$
Noise Rise	On the uplink, the noise floor is determined not only by the LGCell, 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: $noise\ rise = 10log_{10}(1 / (1 - loading))$ 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 an LGCell. 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.

7.4.4 Spread Spectrum Link Budget Analysis for a Microcell Application

Spread Spectrum Link Budget Analysis: Downlink

Line	Downlink	
	Transmitter	
a.	BTS transmit power per carrier (dBm)	30.0
b.	Voice activity factor	50%
c.	Maximum composite power (dBm)	40.0
d.	Attenuation between BTS and LGCell (dB)	–30
e.	Power per carrier into LGCell (dBm)	3.0
f.	Composite power into LGCell (dBm)	10.0
g.	LGCell gain (dB)	0.0
h.	Antenna gain (dBi)	3.0
i.	Radiated power per carrier (dBm)	3.0
j.	Total radiated power (dBm)	13.0
	Airlink	
k.	Handoff gain (dB)	7.0
l.	Multipath fade margin (dB)	6.0
m.	Log-normal fade margin with 8 dB std. deviation, edge reliability 90% (dB)	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/(No+lo)	7.0
v.	Receive Sensitivity (dBm)	–118.4
w.	Minimum received signal (dBm)	–99.4
x.	**Maximum path loss** (dB)	102.4
y.	Difference between open- and closed-loop transmitter power (dB)	–2.0

- b and c: see notes in Table 7-30 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 = p + v
- x = j – w
- y = j (downlink) + m (uplink) + P

  where

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

Spread Spectrum Link Budget Analysis: Uplink

Line	Uplink	
	Receiver	
a.	BTS noise figure (dB)	3.0
b.	Attenuation between BTS and LGCell (dB)	–30.0
c.	LGCell gain (dB)	0.0
d.	LGCell noise figure (dB)	23.0
e.	System noise figure (dB)	33.4
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/(No+lo)	5.0
k.	Handoff gain (dB)	0.0
l.	Antenna gain (dBi)	3.0
m.	Minimum received signal (dBm)	–91.0
	Airlink	
n.	Multipath fade margin (dB)	6.0
o.	Log-normal fade margin with 8 dB std. deviation, edge reliability 90% (dB)	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.	Effective transmitted power (dBm)	9.0
u.	**Maximum path loss** (dB)	100.0

- 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.)

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

7.4.5 Considerations for Re-Radiation (over-the-air) Systems

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

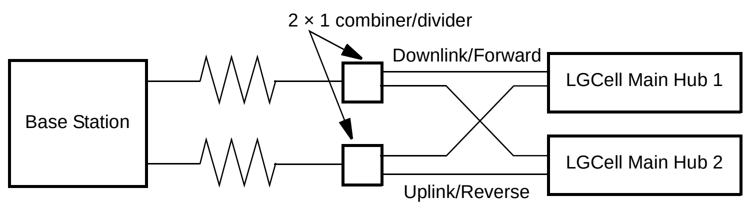
- Sizing the gain and output power requirements for a bi-directional amplifier (repeater).
- Ensuring that noise radiated on the uplink from the in-building system does not cause the outdoor base station to become desensitized to wireless handsets in the outdoor network.
- Filtering out signals that 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.

7.5 Connecting a Main Hub to a Base Station

The first consideration when connecting LGCell Main Hubs to a base station is to ensure there is an equal amount of loss through cables, combiners, etc. from the base station to the Main Hubs. For this example, assume that the base station will have simplex connections, one uplink and one downlink. Each of these connections will need to be divided to equilibrate power for each Main Hub. For example, two Main Hubs will require a 2×1 combiner/divider; four Main Hubs will require a 4×1 combiner/divider; and so on.

Figure 7-2 Connecting LGCell Main Hubs to a Simplex Base Station



When connecting an LGCell to a base station, also consider the following:

1. The downlink power from the base station must be attenuated enough so that the power radiated by the RAU does not exceed the maximum power per carrier listed in Section 7.1, “Maximum Output Power per Carrier at RAU,” on page 7-3.
2. The uplink attenuation should be small enough that the sensitivity of the overall system is limited by the LGCell, not by the attenuator. However, some base stations are adversely affected by received signals that are above –50 dBm, for example. It is therefore helpful to attenuate the uplink in order to retain the maximum number of received signals.

If, in an area covered by an LGCell, a mobile phone indicates good signal strength but consistently has difficulty completing calls, it is possible that the attenuation between the LGCell and 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.

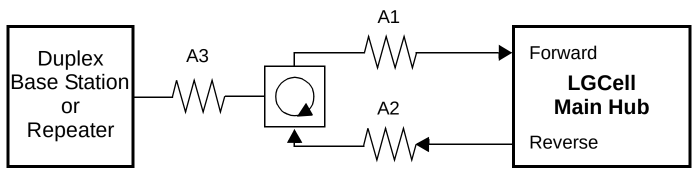
The simplex ports of the Main Hub are usually used for base station connections. However, there is an exception. In cases where several base stations are combined to drive the LGCell(s), the loss from the combiners may be high enough to adversely affect the uplink sensitivity. Since the Cellular and PCS LGCells have gain on the duplex port, this port can be used as the reverse port to overcome the attenuation.

NOTE: When using the duplex port on Cellular or PCS Main Hubs, reduce the power out of the base station to accommodate for the gain of the duplex port. For example, if the power out of the base station is 30 dBm per carrier, and the target RAU output is 0 dBm per carrier, you must attenuate the base station signal by 60 dB before going into the Main Hub because the system gain through the duplex port of the 800 MHz Cellular LGCell is 30 dB. (Refer to Table 7-25 on page 7-28.)

7.5.1 Attenuation

Figure 7-3 shows a typical setup wherein a duplex base station is connected to an LGCell. For a simplex base station, eliminate the circulator and connect the simplex ports of the base station to the simplex ports of the Main Hub. Add attenuators to regulate the power appropriately.

Figure 7-3 LGCell to Duplex Base Station or Repeater Connections



- A typical circulator has an IP3 of +70dBm. If you drive the circulator too hard it will produce intermods that are bigger than the intermods produced by the LGCell. Depending on the LGCell model, the IP3 at the Forward port input of the LGCell can be as high as +30 dBm. The IP3 of the circulator at that same point (i.e., following attenuator A1) is +70dBm – A1. Thus, to keep the system IP3 from being adversely affected by the circulator, attenuator A1 should be no more than 35 dB.
- A filter diplexer can be used in place of the circulator. The IP3 of the diplexer can be assumed to be greater than +100 dBm. If a diplexer is used, A3 can be omitted.
- A1+A3 should be chosen so that the output power per carrier at the RAU's output is correct for the number of carriers being transmitted. Suppose the base station transmits 36 dBm per carrier and it is desired that the RAU output be 6 dBm per carrier and the forward port gain is 0 dB. Then A1+A3=30 dB.
- A2+A3 should, ideally, be at least 10 dB less than the noise figure plus the gain of the LGCell. For example, if the reverse port has a 0 dB gain (it does for all current LGCell models) and if there are eight RAUs, the noise figure (depending on the LGCell model) is approximately 25 dB. So A2+A3 should be about 10 to 15 dB. If A2+A3 is too large, the uplink coverage distance can be severely reduced.
- Given these three equations:
  A1 ≤ 35 dB
  A1+A3 = 30 dB (in this example)
  A2+A3 = 10 dB (in this example)
  we could choose A2=20 dB, A2=0 dB, A3=10 dB for this example.

7.5.2 Uplink Attenuation

The attenuation between the LGCell's **REVERSE** port and the base station does two things:

1. It attenuates the noise coming out of the LGCell.
2. It attenuates the desired signals coming out of the LGCell.

Setting the attenuation on the uplink is a trade-off between keeping the noise and maximum signal levels transmitted from the LGCell to the base station receiver low while not reducing the SNR (signal-to-noise ratio) of the path from the LGCell RAU inputs to the base station inputs. This SNR can not be better than the SNR of the LGCell by itself, although it can be significantly worse.

For example, suppose we have a GSM LGCell system consisting of one Main Hub, four Expansion Hubs, and 16 RAUs (1-4-16) with uplink NF=28 dB. (See Table 7-30 on page 7-37.) If we use 30 dB of attenuation between the LGCell's reverse port and the base station (which has its own noise figure of about 4 dB), the overall noise figure will be 35 dB. (Refer to the formula on page 7-35.) Thus, by using this amount of attenuation, the SNR is reduced by 7 dB. That causes a 7 dB reduction in the uplink coverage distance. Now, if the attenuation instead is 0 dB, the cascaded noise figure is NF=28.01 dB, which implies that the uplink sensitivity is limited by the LGCell, a desirable condition. But now the maximum signal from the LGCell into the base station is as high as –40 dBm. This can cause problems for some base stations. We can reduce the maximum received signal levels by using some attenuation. For instance, if the attenuation is 10 dB, the maximum received signal is –50 dBm and the noise level is reduced by 10 dB but the cascaded noise figure is still only 28.16 dB (for a SNR reduction of only 0.15 dB). Even with a 20 dB attenuator, the cascaded noise figure is 29.45 dB. This is an SNR reduction of 1.44 dB. So, in this situation it would be good to use at least 10 dB of uplink attenuation but not more than 20 dB.

Rule of Thumb

A good rule of thumb is to set the uplink attenuation, A2+A3 in Figure 7-3 on page 7-45, as follows:

A2+A3 < LGCell uplink NF + uplink gain (0 dB for reverse port) – BTS NF – 10dB

and round A2 *down* to the nearest convenient attenuation value.

7.5.2.1 Uplink Attenuation Exception: CDMA

In CDMA systems, the power transmitted by the mobile is determined by the characteristics of both the uplink and downlink paths. The power transmitted by the mobile should be similar in open-loop control (as determined by the downlink path) as during closed-loop control (as determined by the uplink and downlink paths). In addition, the mobile's transmit power when it communicates with a base station through the LGCell should be similar to the power transmitted when it communicates with a base station in the outdoor network (during soft hand-off). Because of these considerations, you should not allow the downlink and uplink gains to vary widely.

Open-loop power control:

P_{TX} = –76 dBm (for PCS) – P_{RX}

where P_{TX} is the power transmitted and P_{RX} is the power received by the mobile. If PL is the path loss (in dB) between the RAU and the mobile, and P_{DN} is the downlink power radiated by the RAU, then

P_{TX} = –76 dBm (for PCS) – P_{DN} + PL

Closed-loop power control:

P_{TX} = noise floor + uplink NF – process gain + Eb/No + PL

= –113 dBm/1.25 Mhz + NF – 19 dB + 7 dB + PL

where Eb/No = 7 dB is a rough estimate, and NF is the cascaded noise figure of the LGCell uplink, the uplink attenuation, and the base station noise figure. Equating P_{TX} for the open-loop and closed-loop we see that

NF = 49 – P_{DN}

where P_{DN} is determined by the downlink attenuation. Since P_{DN} for the LGCell is about 10 dBm, we see that the cascaded noise figure is about 39 dB, which is considerably higher than that of the LGCell itself. This implies that we should use a fairly large attenuation on the uplink. This case suggests using as much attenuation on the downlink as on the uplink. The drawback of doing this is that the uplink coverage sensitivity is reduced. A link budget analysis will clarify these issues. Typically, the uplink attenuation between the LGCell and the base station will be the same as, or maybe 10dB less than, the downlink attenuation.

7.6 Designing for a Neutral Host System

Designing the LGCell for a neutral host system uses the same design rules previously discussed. Since a neutral host system typically uses *multiple systems in parallel,* we find it best to design for the worst case system so that there will not be holes in the covered area and the economies of a single installation can be achieved. For example, as indicated Section 7.1, the 1900 MHz RF signals do not propagate throughout a building as well as the 800 MHz systems, therefore, we design to the 1900 MHz path loss formula.

7.6.1 Capacity of the LGCell Neutral Host System

As indicated in Section 2.3, “System Bandwidths,” on page 2-10, each Main Hub can support more than one sub-band of the Cellular or PCS bands. The exception to this is the iDEN Main Hub, because the SMR band is not split into sub-bands.

The 800 MHz Main Hub can support both the A band and the B band simultaneously. Also, the 1800 MHz and 1900 MHz Main Hubs can support two bands each (as the frequencies currently are allocated).

For example, a neutral host system that consists of one iDEN, one 800 MHz, and two 1900 MHz systems can support up to seven separate service providers:

- 1 on iDEN
- 2 on 800 MHz, A band and B band
- 2 in each 1900 MHz

7.6.2 Example LGCell Neutral Host System

The following example configuration assumes:

- 0 dBm per carrier output
- Each System supports two bands, and therefore, two Operators (Exception: iDEN supports one Operator)

Example Configuration:

- 800 MHz iDEN: System 1
  l - iDEN system: 8 Channels, 23 voice calls
- 800 MHz Cellular: System 2
  l - TDMA Band: 8 Channels, 23 voice calls
  l - CDMA Band: 2 Channels, 30–40 voice calls
- 1900 MHz PCS: Systems 3 & 4 (2 band combinations/system)
  l - TDMA Band: 8 Channels, 23 voice calls
  l - CDMA Band: 2 Channels, 30–40 voice calls
  l - GSM Band: 4 Channels, 31 voice calls

Number of subscribers* that could be served in this example:

- 800 MHz Cellular: System 1
  l - iDEN Operator: 23 voice calls, 315 subscribers
- 800 MHz Cellular: System 2
  l - TDMA Operator: 23 voice calls, 315 subscribers
  l - CDMA Operator: 30–40 voice calls, 438–620 subscribers
- 1900 MHz PCS: Systems 3 & 4 (2 band combinations/system)
  l - TDMA Operator: 23 voice calls, 315 subscribers
  l - CDMA Operator: 30–40 voice calls, 438–620 subscribers
  l - GSM Operator: 31 voice calls, 456 subscribers

This configuration supports growth for up to 7 Operators.

* Based on Standard Erlang B 2% GOS requirement. Each user has a 0.05 wireless Erlang which is higher than the standard 0.035 wireless Erlang.

SECTION 8

Installation Requirements and Safety Precautions

This section contains the following subsections:

- Section 8.1 Installation Requirements 8-2
  - Section 8.1.1 Cable and Connector Requirements 8-2
  - Section 8.1.2 Neutral Host System Requirements 8-2
  - Section 8.1.3 Distance Requirements 8-3
- Section 8.2 Safety Precautions 8-4
  - Section 8.2.1 Underwriters Laboratory Installation Guidelines 8-4
  - Section 8.2.2 General Safety Precautions 8-5
  - Section 8.2.3 Fiber Port Safety Precautions 8-6

8.1 Installation Requirements

8.1.1 Cable and Connector Requirements

The LGCell equipment operates over standard TIA/EIA 568-A specification, Category 5 (Cat-5) unshielded twisted pair (UTP) or shielded twisted pair (STP) and standard 62.5µm/125µm multimode fiber cable (MMF), at a wavelength of 1310 nanometers (nm).

These cables are widely used industry standards for Local Area Networks (LANs). The regulations and guidelines for LGCell cable installation are identical to those specified by the TIA/EIA 568-A standard for LANs (see Appendix B).

European standards require that only STP cable be used. Also, to ensure specified performance, STP cable is required in all multi-system installations that use parallel Cat-5 cables in common ducting.

LGC Wireless recommends plenum-rated Cat-5 UTP/STP and MMF cable and connectors for conformity to building codes and standards.

8.1.2 Neutral Host System Requirements

As in any LGCell system, a neutral host system requires one pair of MMF strands between each Main Hub and each Expansion Hub, and one Cat-5 cable between each Expansion Hub and each RAU. To help achieve the cost savings possible in a neutral host system, it is advantageous to install additional cables for future growth.

To alleviate the possibility of interference between LGCell systems, **STP cable is required** for neutral host systems.

8.1.3 Distance Requirements

The following table shows the distances between LGCell components and related equipment.

Table 8-1 LGCell Distance Requirements

Equipment Combination	Cable Type	Distance	Additional Information
Repeater to Main Hub	Coaxial; N male connectors	3–6 m (10–20 ft) typical	Limited by loss and noise. Refer to your link budget calculation.
Base Station to Main Hub	Coaxial; N male connectors	3–6 m (10–20 ft) typical	Limited by loss and noise. Refer to your link budget calculation.
Main Hub to Expansion Hub	62.5µm/125µm Multimode Fiber; ST male optical connectors	1 km (3300 ft)	Up to 2 km (6600 ft) allowed. (See “System Gain (Loss) Relative to MMF Cable Length” on page 7-29.) 3 dB optical loss, port-to-port
Expansion Hub to RAU	Cat-5 STP/UTP; RJ-45 male connectors	10 m (33 ft) absolute minimum 20 m (66 ft) recommended min. 50 m (165 ft) recommended max.	Up to 100 m (330 ft) allowed. (See “System Gain (Loss) Relative to UTP/STP Cable Length” on page 7-30.)
RAU to passive antenna	Coaxial; SMA male connectors	1–3.5 m (3–12 ft) typical	Limited by loss and noise. Refer to your link budget calculation.

8.2 Safety Precautions

8.2.1 Underwriters Laboratory Installation Guidelines

Use the following guidelines when installing the LGCell:

1. Do not exceed the maximum ambient air temperature of 45°C during operation. Provide sufficient airflow and cooling within the rack to prevent heat build-up from exceeding this limit.
2. Be careful when servicing these products. If you are removing the system from the rack, turn it off and remove the power cord first. There are no user-serviceable parts inside the hubs or RAUs.
3. Do not compromise the amount of airflow required for safe operation of the equipment when installing it in a rack. Both the Main Hub and the Expansion Hub draw in air on the left side and exhaust heated air at the rear. The hubs pass approximately 6 cu. ft. of air per minute through themselves. The Main Hub dissipates a maximum of 25 watts of heat from its internal circuitry and the Expansion Hub dissipates a maximum of 55 watts (with 4 RAUs attached).
4. The AC input current consumption of the hubs is rated as follows:
   - Main Hub
     - Typical:

       117V AC, 0.22 amp @ 60 Hz
       230V AC, 0.11 amp @ 50 Hz
     - Maximum:

       117V AC, 0.30 amp @ 60 Hz
       230V AC, 0.15 amp @ 50 Hz
   - Expansion Hub
     - Typical:

       117V AC, 0.50 amp @ 60 Hz
       230V AC, 0.25 amp @ 50 Hz
     - Maximum:

       117V AC, 0.70 amp @ 60 Hz
       230V AC, 0.35 amp @ 50 Hz

   The internal power supply has internal fuses that are not user replaceable. Consider the worst-case power consumption shown on the product labels when provisioning the rack's AC power source and distribution.

8.2.2 General Safety Precautions

The following precautions apply to LGCell products.

- LGCell has no user-serviceable parts. Faulty or failed units are fully replaceable through LGC Wireless. Please contact us at:

  1-800-530-9960 (U.S. only)
  +1-408-952-2400 (International)
  +44(0) 1223 597812 (Europe)

- Never input an RF signal to the Main Hub's duplex or simplex ports that is higher than those defined in Section 7.1 on page 7-3 because the Main Hub could be damaged.
- Although modeled after an Ethernet/LAN architecture and connectivity, LGCell units are not intended to connect to Ethernet data hubs, routers, cards, or other similar data equipment.
- When you connect the multimode fiber (MMF) optical cable, take the same precaution as if installing Ethernet network equipment. All optical fiber ST connectors should be cleaned according to the connector manufacturer's instructions.
- When you connect a radiating antenna to an RAU, **DO NOT** over-tighten the SMA connector. Firmly hand-tightening the connector is adequate.

WARNING: To reduce the risk of fire or electric shock, do not expose this equipment to rain or moisture.

8.2.3 Fiber Port Safety Precautions

The following are suggested safety precautions for working with LGCell fiber ports. For information about LGCell compliance with safety standards, see Appendix C.

WARNING: Observe the following warning about viewing fiber ends in ports. Do not stare with unprotected eyes at the connector ends of the fibers or the ports of the hubs. Invisible infrared radiation is present at the front panel of the Main Hub and the Expansion Hub. Do not remove the fiber port dust caps unless the port is going to be used. Do not stare directly into a fiber port.

- **Test fiber cables:** When you test fiber optical cables, connect the optical power source last and disconnect it first.
- **Fiber ends:** Cover any unconnected fiber ends with an approved cap. Do not use tape.
- **Broken fiber cables:** Do not stare with unprotected eyes at any broken ends of the fibers. Report any broken fiber cables and have them replaced.
- **Cleaning:** Use only approved methods for cleaning optical fiber connectors.
- **Modifications:** Do not make any unauthorized modifications to this fiber optical system or associated equipment.
- **Live work:** Live work is permitted on the LGCell as it is a Class 1 hazard.
- **Signs:** No warning signs are required.
- **Test equipment:** Use Class 1 test equipment.