LGC WIRELESS®

InterReach Unison Accel

Installation, Operation, and Reference Manual

PN 9000-10
620021-0 Rev. A

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SECTION 1

General Information

This section contains the following subsections:

1.1 Purpose and Scope

This document describes the InterReach Unison Accel system.

- Section 2 InterReach Unison Accel System Description

  An overview of the Unison Accel hardware and OA&M capabilities is provided in this section. This section also contains system specifications and RF end-to-end performance tables.

- Section 3 Accel Hub

  The Main Hub is illustrated and described in this section. Connector and LED descriptions, communication cable (serial and null modem) pin outs, and unit specifications are included.

- Section 4 Unison Remote Access Unit

  The Remote Access Unit is illustrated and described in this section. Connector and LED descriptions, and unit specifications are included.

- Section 5 Designing a Unison Accel Solution

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

- Section 6 Installing Unison Accel

  Installation procedures, requirements, safety precautions, and checklists are provided in this section. The installation procedures include guidelines for troubleshooting using the LEDs as you install the units.

- Section 7 Replacing Unison Accel Components in an Operational System

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

- Section 8 Maintenance, Troubleshooting, and Technical Assistance

  Contact information and troubleshooting tables are provided in this section.

- Appendix A Cables and Connectors

  Connector and cable descriptions and requirements are provided in this section. Additionally, cable pin outs and diagrams are given.

- Appendix B InterReach Unison Accel Property Sheet

  This section contains a form that you can use during installation to record serial numbers, gain settings, system band, RAU attenuation, and unit installation location. This information is required for the final As-Built documentation.

- Appendix C Compliance

  Safety and Radio/EMC approvals are listed in this section.

- Appendix D Release Notes

  A hardware/firmware/software compatibility table is provided in this section.

- Appendix E Glossary

  The Glossary provides definitions of commonly-used RF and wireless networking terms.

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	Labels on equipment
SMALL CAPS	AdminManager window buttons

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
AGC	automatic gain control
ALC	automatic level control
AMPS	Advanced Mobile Phone Service
BTS	base transceiver station
Cat-5/6	Category 5 or Category 6 (twisted pair cable)
CDMA	code division multiple access
CDPD	cellular digital packet data
DAS	distributed antenna system
dB	decibel
dBm	decibels relative to 1 milliwatt
DC	direct current
DCS	Digital Communications System
DL	downlink
EDGE	Enhanced Data Rates for Global Evolution
EGSM	Extended Global Standard for Mobile Communications
GHz	gigahertz
GPRS	General Packet Radio Service
GSM	Groupe Speciale Mobile (now translated in English as Global Standard for Mobile Communications)
Hz	hertz
IF	intermediate frequency
iDEN	Integrated Digital Enhanced Network (Motorola variant of TDMA wireless)
LAN	local area network
LO	local oscillator
mA	milliamps
MBS	microcellular base station
MH	Main Hub
MHz	megahertz
MTBF	mean time between failures
NF	noise figure
nm	nanometer
OA&M	operation, administration, and maintenance
PCS	Personal Communication Services

Acronym	Definition
PLL	phase-locked loop
PLS	path loss slope
RAU	Remote Access Unit
RF	radio frequency
RSSI	received signal strength indicator
SMA	sub-miniature A connector (coaxial cable connector type)
ScTP	screened twisted pair
TDMA	time division multiple access
UL	uplink; Underwriters Laboratories
uW	microwatts
UMTS	Universal Mobile Telecommunications System
UPS	uninterruptable power supply
W	watt
WCDMA	wideband code division multiple access

1.4 Standards Conformance

- Utilizes the TIA/EIA 568-A Ethernet cabling standards for ease of installation.
- See Appendix C for compliance information.

1.5 Related Publications

- *AdminManager User Manual*, LGC Wireless part number 8810-10

SECTION 2

InterReach Unison Accel System Description

InterReach Unison Accel is a wireless networking system that is designed to handle both wireless voice and data communications over licensed frequencies. It provide high-quality, ubiquitous, seamless access to the wireless network in smaller buildings, including:

- Office buildings
- Hospitals

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

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

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

Key System Features

- **Superior RF performance**, particularly in the areas of IP3 and noise figure.
- **High downlink composite power** and **low uplink noise figure** enables support of a large number of channels and larger coverage footprint per antenna.
- **Software configurable** Hub. Thus, the frequency band can be configured in the field.
- **Standard Cat-5 or Cat-6** (Cat-5/6) **screened twisted pair** (ScTP) **cabling**. The Cat-5/6 ScTP cable run can be up to 100 meters recommended maximum (150 meters with RF performance degradation).
- **Flexible RF configuration capabilities**, including:
  - System gain:
    - Ability to manually set gain in 1 dB steps, from 0 to 15 dB, on both downlink and uplink.
  - RAU:
    - RAU uplink and downlink gain can be independently attenuated 10 dB.
    - Uplink level control protects the system from input overload and can be optimized for either a single operator or multiple operators/protocols.
    - VSWR check on RAU reports if there is a disconnected antenna (all RAUs except UMTS).
- **Firmware Updates** are downloaded (either locally or remotely) to operating systems when any modifications are made to the product, including the addition of new software capabilities/services.
- **Extensive OA&M capabilities**, including fault isolation to the field replaceable unit, automatic reporting of all fault and warning conditions, and user-friendly graphical-user interface OA&M software package.

2.1 System Hardware Description

The InterReach Unison Accel system consists of two modular components:

- 19" rack-mountable **Hub** *(connects to up to 8 Remote Access Units)*
  - Converts RF signals to electrical on the downlink; electrical to RF on the uplink
  - Microprocessor controlled (for alarms, monitoring, and control)
  - Software configurable band
  - Simplex interface to RF source
  - Periodically polls all downstream RAUs for system status, and automatically reports any fault or warning conditions
  - Supplies DC power to RAU
- **Remote Access Unit** (RAU)
  - Converts electrical signals to RF on the downlink; RF to electrical on the uplink
  - Microprocessor controlled (for alarms, monitoring, and control)
  - Protocol/band specific units

The minimum configuration of a Unison Accel system is one Hub and one RAU (1-1). The maximum configuration of a system is one Hub and 8 RAUs (1-8). Multiple systems can be combined to provide larger configurations.

Figure 2-1 Unison Accel System Hardware

2.2 System OA&M Capabilities Overview

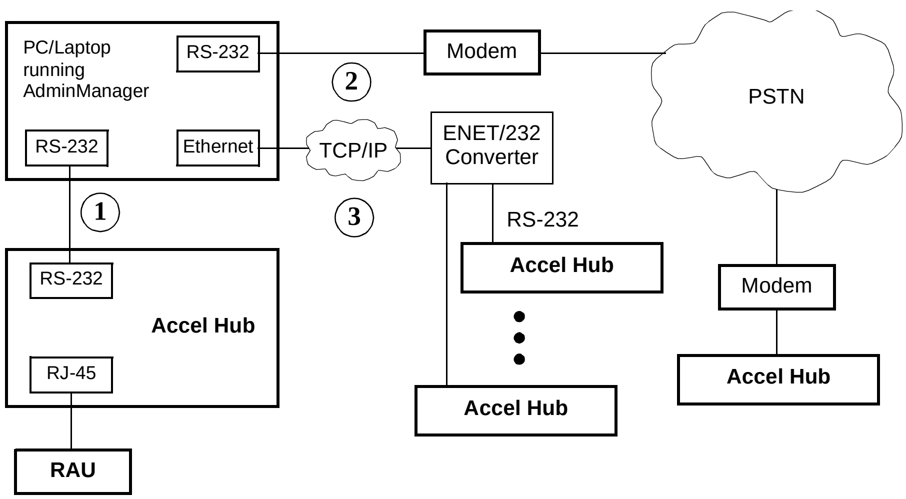
InterReach Unison Accel is microprocessor controlled and contains firmware which enables much of the operations, administration, and maintenance (OA&M) functionality.

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

- Normally closed (NC) alarm contact closures can be tied to standard NC alarm monitoring systems or directly to a base station for alarm monitoring.
- The Hub's front panel serial port connects directly to a PC (for local access) or to a modem (for remote access).

Figure 2-2 Three Methods for OA&M Communications

Use AdminManager to configure or monitor a local Accel system. Remotely, AdminManager can only check system status, it cannot receive modem calls.



AdminManager OA&M software runs on a PC/laptop and communicates with one Accel Hub, and its downstream RAUs, at a time.

- Connected directly to the Hub's front panel RS-232 connector, you can access the Installation Wizard which lets you configure a newly installed system, or you can access the Configuration & Maintenance panel which lets you query system status, configure a newly added or swapped unit, or change system parameters.
- Connected remotely using a modem, AdminManager initiates communications with the Hub. You can access a read-only Configuration & Maintenance panel which lets you query system status to help you determine if an on-site visit is required.

Refer to the *AdminManager User Manual* (PN 8810-10) for information about installing and using the AdminManager software.

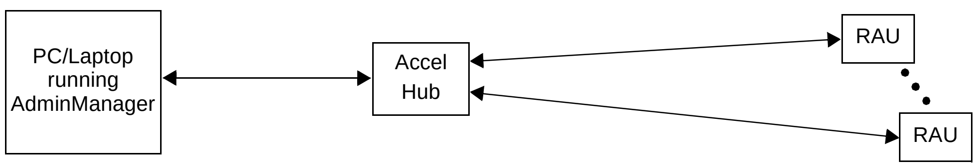
2.2.1 System Monitoring and Reporting

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

When a Hub detects a change in status, a fault or warning is reported. Faults are indicated locally by red status LEDs, and both faults and warnings are reported to the Hub and displayed on a PC/laptop, via the Hub's serial port, that is running the AdminManager software. Passive antennas that are connected to the RAUs are not monitored automatically. Perform the System Test in order to retrieve status information about antennas.

Using AdminManager, you can install a new system or new components, change system parameters, and query system status. The following figure illustrates how the system reports its status to AdminManager.

Table 2-1 System Monitoring and Reporting



Use AdminManager to communicate with one or more remotely or locally installed systems.

If a fault or warning condition is reported, the AdminManager graphical user interface indicates the problem. AdminManager can also send an e-mail and/or page notification to designated recipients.

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

- If a fault is detected, LEDs on the front panel turn red.
- If a fault or warning condition is detected in any unit, the Hub initiates a call to AdminManager.

Each RAU passes its status to the Hub.

- If a fault is detected, the **ALARM** LED is red. If no fault is detected, the LED is green.
- If a fault or warning condition is detected, the information is passed to the Hub.

2.2.2 Using Alarm Contact Closures

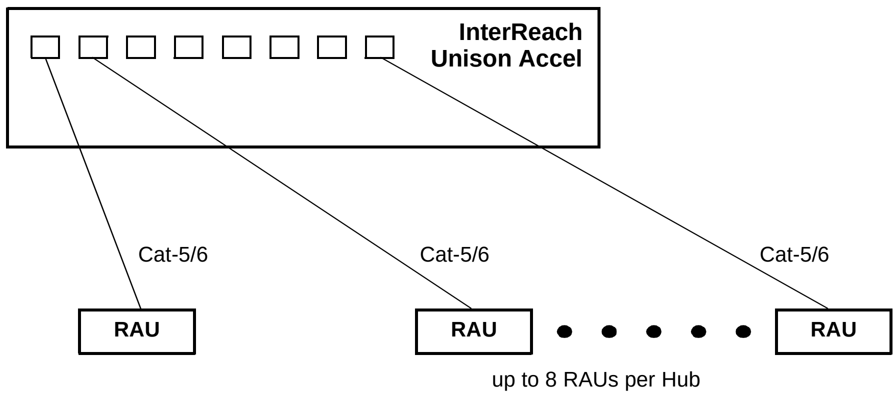
The DB-9 female connector on the rear panel of the Accel Hub can be connected to a local base station or to a daisy-chained series of Unison, LGCell, and/or MetroReach Focus systems.

- When you connect MetroReach Focus or a BTS to Accel, the Accel Hub is the output of the alarms (alarm source) and MetroReach Focus or the BTS is the input (alarm sense). This is described in Section 6.6.1 on page 6-30.
- When you connect LGCell to Accel, the Accel Hub is the input of the alarms (alarm sense) and LGCell is the output (alarm source). This is described in Section 6.6.2 on page 6-33.

2.3 System Connectivity

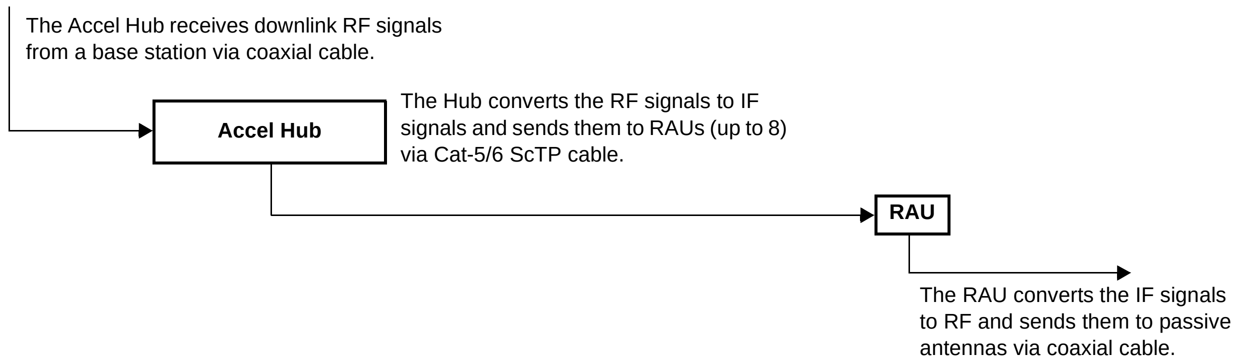
The system uses standard Cat-5/6 ScTP. This makes any system expansion, such as adding an extra antenna for additional coverage, as easy as pulling a twisted pair cable.

Figure 2-3 Unison Accel's Architecture

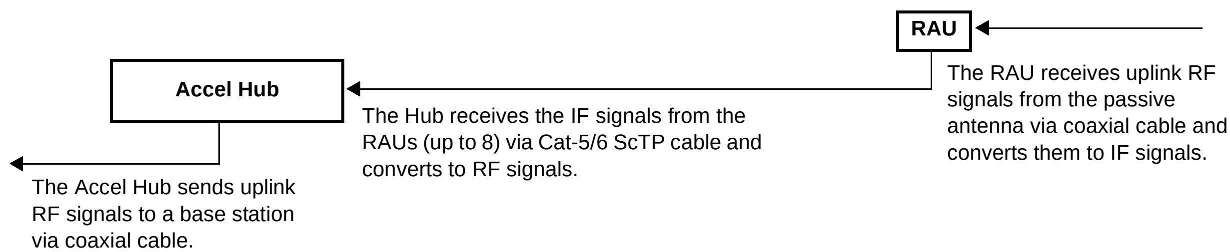


2.4 System Operation

- **Downlink (Base Station to Wireless Devices)**



- **Uplink (Wireless Devices to Base Station)**



2.5 System Specifications

2.5.1 Physical Specifications

Parameter	Unison Accel Hub	Remote Access Unit
RF Connectors	8 shielded RJ-45, female (Cat-5/6)	1 shielded RJ-45, female (Cat-5/6) 1 SMA, male (coaxial)
External Alarm Connector (contact closure)	1 9-pin D-sub, female	—
Serial Interface Connector	1 RS-232 9-pin D-sub, male	—
LED Alarm and Status Indicators	Unit Status (1 pair): • Power • Status RAU/Link Status (1 pair per RJ-45 port): • Link • RAU	Unit Status (1 pair): • Link • Alarm
AC Power (Volts)	Rating: 115/230V, 5.5/3A, 50–60 Hz Operating Range: 90–132V/170–250V auto-ranging, 4.6–2.3A/3.6–1.6A, 47–63 Hz	—
DC Power (Volts)	—	36V (from the Hub)
Power Consumption (W)	4 RAUs: 150 typ/178 max 4 RAUs & 4 Extenders: 167 typ/202 max 8 RAUs: 200 typ/242 max 8 RAUs & 8 Extenders: 234 typ/290 max	16 max (from the Hub)
Enclosure Dimensions* (height × width × depth)	133.5 mm × 438 mm × 305 mm (5.25 in. × 17.25 in. × 12 in.)	44 mm × 305 mm × 158 mm (1.7 in. × 12 in. × 6.2 in.)
Weight	< 8 kg (< 17.5 lb)	< 1 kg (< 2 lb)

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

Note: Unison Accel Hub typical power consumption assumes that the Cat-5/6 cable length is no more than 100 meters without a Cat-5 Extender and no more than 170 meters with a Cat-5 Extender.

2.5.2 Environmental Specifications

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

2.5.3 Operating Frequencies

Freq. Band	Unison Band	Description	RF Passband (MHz)	
			Downlink	Uplink
PCS	PCS6	Bands A,D,B (35 MHz)	1930–1965	1850–1885
PCS	PCS7	Bands D,B,E,F (30 MHz)	1945–1975	1865–1895
PCS	PCS8	Bands E,F,C (25 MHz)	1965–1990	1885–1910
DCS	DCS1	DCS1 Band	1805–1842.5	1710–1747.5
DCS	DCS2	DCS2 Band	1842.5–1880	1747.5–1785
DCS	DCS4	DCS4 Band	1815–1850	1720–1755
Cellular	CELL	–	869–894	824–849
iDEN	iDEN	–	851–869	806–824
GSM/EGSM	GSM/EGSM	–	925–960	880–915
UMTS	UMTS1	–	2110–2145	1920–1955
UMTS	UMTS2	–	2125–2160	1935–1970
UMTS	UMTS3	–	2135–2170	1945–1980

2.5.4 RF End-to-End Performance

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

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

Cellular 800 MHz

Table 2-2 Cellular RF End-to-End Performance

Parameter	Typical Downlink	Typical Uplink
Average gain with 75 m Cat-5 at 25°C (77°F) (dB)	15	15
Ripple with 75 m Cat-5 (dB)	3	3.5
Output IP3 (dBm)	40	
Input IP3 (dBm)		–7
Output 1 dB Compression Point (dBm)	27	
Noise Figure 1 Hub-8 RAUs (dB)		15

iDEN 800 MHz

Table 2-3 iDEN RF End-to-End Performance

Parameter	Typical Downlink	Typical Uplink
Average gain with 75 m Cat-5/6 at 25°C (77°F) (dB)	15	15
Ripple with 75 m Cat-5/6 (dB)	2	3
Output IP3 (dBm)	38	
Input IP3 (dBm)		–7
Output 1 dB Compression Point (dBm)	26	
Noise Figure 1 Hub-8 RAUs (dB)		17

GSM/EGSM 900 MHz

Table 2-4 GSM/EGSM RF End-to-End Performance

Parameter	Typical Downlink	Typical Uplink
Average Downlink gain with 75 m Cat-5/6 at 25°C (77°F) (dB)	15	15
Ripple with 75 m Cat-5/6 (dB)	3	4
Output IP3 (dBm)	38	
Input IP3 (dBm)		–7
Output 1 dB Compression Point (dBm)	26	
Noise Figure 1 Hub-8 RAUs (dB)		16

DCS 1800 MHz

Table 2-5 DCS RF End-to-End Performance

Parameter	Typical Downlink	Typical Uplink
Average gain with 75 m Cat-5/6 at 25°C (77°F) (dB)	15	15
Downlink ripple with 75 m Cat-5/6 (dB)	2	
Uplink ripple for center 35 MHz of DCS1 and DCS2, Full band for DCS4 with 75 m Cat-5/6 (dB)		2
Uplink gain roll off for Full band of DCS1 and DCS2 with 75 m Cat-5/6 (dB)		2
Output IP3 (dBm)	38	
Input IP3 (dBm)		–12
Output 1 dB Compression Point (dBm)	26	
Noise Figure 1 Hub-8 RAUs (dB)		17

PCS 1900 MHz

Table 2-6 PCS RF End-to-End Performance

Parameter	Typical Downlink	Typical Uplink
Average gain with 75 m Cat-5 at 25°C (77°F) (dB)	15	15
Ripple with 75 m Cat-5 (dB)	2.5	3
Output IP3 (dBm)	38	
Input IP3 (dBm)		–12
Output 1 dB Compression Point (dBm)	26	
Noise Figure 1 Hub-8 RAUs (dB)		16

UMTS 2.1 GHz

Table 2-7 UMTS RF End-to-End Performance

Parameter	Typical Downlink	Typical Uplink
Average Gain w/75 meters Cat-5/6 @ 25°C (dB)	15	15
Ripple w/75 meters Cat-5/6 (dB)	2.5	4
Noise Figure: 1 Accel Hub and 8 RAUs (dB)		16
Spurious Output Levels (dBm)	<–30	
UMTS TDD Band Spurious Output Level 1900–1920 MHz, 2010–2025 MHz (dBm/MHz)	<–52	
Waveform Quality (at maximum power) (ρ)	> 0.97	> 0.97
Output IP3 (dBm)	37	
Input IP3 (dBm)		–12
Output P1dB (dBm)	26	

SECTION 3 Accel Hub

The Accel Hub distributes downlink RF signals from a base station, repeater, or MetroReach Focus system to up to eight Remote Access Units. The Hub also combines uplink signals from the RAUs.

Figure 3-1 **Accel Hub in a Unison System**

Downlink Path: The Accel Hub receives downlink RF signals from a base station, repeater, or MetroReach Focus system via coaxial cable. It converts the signals to IF and sends them to up to eight RAUs via Cat-5/6 cable.

The Hub also sends OA&M communication to the RAUs via the Cat-5/6 cable.

Uplink Path: The Accel Hub receives uplink IF signals from up to eight RAUs via Cat-5/6 cable. It converts the signals to RF and sends them to a base station, repeater, or MetroReach Focus system via coaxial cable.

The Hub also receives status information from the RAUs via the Cat-5/6 cable.

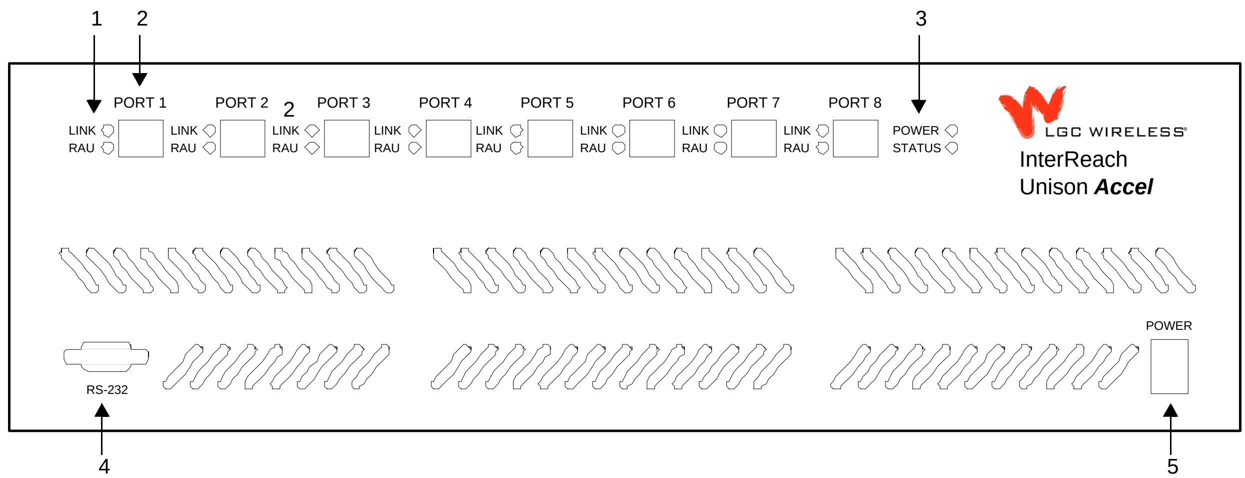
Figure 3-2 gives a detailed view of the major RF and functional blocks of the Accel Hub.

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

Dave: Please provide (see RAU for example)

3.1 Accel Hub Front Panel

Figure 3-3 **Accel Hub Front Panel**



1. Eight standard Cat-5/6 ScTP cable RJ-45 connectors (labeled **PORT 1**, **2**, **3**, **4**, **5**, **6**, **7**, **8**)
2. Eight sets of RJ-45 port LEDs (one set per port)
   - One LED per port for link status (labeled **LINK**)
   - One LED per port for downstream unit status (labeled **RAU**)
3. One set of unit status LEDs
   - One LED for unit power status (labeled **POWER**)
   - One LED for unit status (labeled **MAIN HUB STATUS**)
4. One 9-pin D-sub male connector for system communication and diagnostics using a PC/laptop or modem (labeled **RS-232**)
5. Power switch.

3.1.1 RJ-45 Connectors

The eight RJ-45 connectors on the Hub are for the Cat-5/6 ScTP cables that are used to transmit and receive signals to and from RAUs. Use shielded RJ-45 connectors on the Cat-5/6 cable.

NOTE: For system performance, it is important that you use only Cat-5/6 ScTP (screened twisted pair) cable with shielded RJ-45 connectors.

The Cat-5/6 cable also delivers DC electrical power to the RAUs. The Hub's DC voltage output is 36V DC nominal. A current limiting circuit is used to protect the Hub if any port draws excessive power.

3.1.2 Communications RS-232 Serial Connector

Remote Monitoring

Use a standard serial cable to connect a modem to the 9-pin D-sub male serial connector for remote monitoring or configuring. The cable typically has a DB-9 female and a DB-25 male connector. See Appendix A.3 on page A-3 for the cable pinout.

Local Monitoring

Use a null modem cable to connect a laptop or PC to the 9-pin D-sub male serial connector for local monitoring or configuring. The cable typically has a DB-9 female connector on both ends. See Appendix A.4 on page A-4 for the cable pinout.

3.1.3 Hub LED Indicators

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

Upon power up, the Hub goes through a five-second test to check the LED lamps. During this time, the LEDs blink through the states shown in Table 3-1, letting you visually verify that the LED lamps and the firmware are functioning properly.

The Hub will automatically send the program band command to all connected RAUs. A mismatched band will cause an error message to be displayed in AdminManager and the RAU will have a fault condition.

NOTE: Refer to Section 8 for troubleshooting using the LEDs.

Status LEDs

The Hub status LEDs can be in one of the states shown in Table 3-1. These LEDs can be:

- steady green
- steady red
- blinking green/red (alternating green/red)

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

Table 3-1 Accel Hub Status LED States

	LED State	Indicates
POWER STATUS	Green Green	• Hub is connected to power • Hub is not reporting a fault; but the system test may need to be performed or a warning could exist (use AdminManager to determine)
POWER STATUS	Green Red	• Hub is connected to power • Hub is reporting a fault or lockout condition
POWER STATUS	Green Alternating Green/Red	• Hub is connected to power • Hub input signal level too high

Port LEDs

The Hub has one pair of port LEDs for each of the eight RJ-45 ports. The port LEDs can be in one of the states shown in Table 3-2. These LEDs can be:

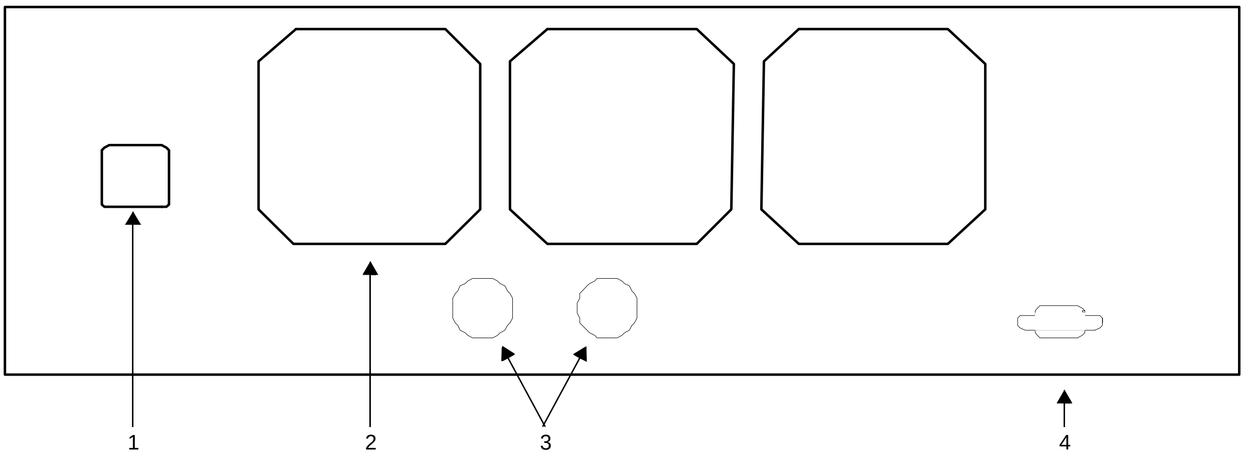
- ○ off
- ● steady green
- ● steady red

Table 3-2 Accel Hub Port LED States

	LED State	Indicates
LINK ○ RAU ○	Off Off	• RAU is not connected
LINK ● RAU ●	Green Green	• RAU is connected • No faults from RAU
LINK ● RAU ○	Red Off	• Loss of communications to RAU
LINK ● RAU ●	Green Red	• RAU is connected • RAU is reporting a fault or lockout condition

3.2 Accel Hub Rear Panel

Figure 3-4 **Accel Hub Rear Panel**



1. AC power cord connector
2. Three air exhaust vents
3. Two N-type, female connectors:
   - Downlink (labeled **DOWNLINK**)
   - Uplink (labeled **UPLINK**)
4. One 9-pin D-sub female connector for contact closure monitoring (labeled **DIAGNOSTIC 1**)

Are the back panel items labeled?

3.2.1 Accel Hub Rear Panel Connectors

3.2.1.1 9-pin D-sub Connector

The 9-pin D-sub connector (labeled **DIAGNOSTIC 1**) provides contact closure for major and minor error system alarm monitoring.

The following table lists the function of each pin on the 9-pin D-sub connector.

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

This interface can either generate contact alarms or sense a single external alarm contact.

3.2.1.2 N-type Female Connectors

There are two N-type female connectors on the rear panel of the Hub:

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

3.3 Faults and Warnings

The Accel Hub monitors and reports changes in system performance to:

- Ensure that its amplifiers and IF/RF path are functioning properly.
- Ensure that Remote Access Units are connected and functioning properly.

The Accel Hub periodically queries attached Remote Access Units for their status. Both faults and warnings are reported to a connected PC/laptop that is running the AdminManager software. Only faults are indicated by LEDs.

For more information, see:

- page 8-3 for Hub faults.
- page 8-7 for Hub warnings.
- page 8-8 for Hub status messages.
- page 8-11 for troubleshooting Hub LEDs.

3.4 Accel Hub Specifications

Table 3-3 Accel Hub Specifications

Specification	Description
Enclosure Dimensions (H × W × D):	133.5 mm × 438 mm × 305 mm (5.25 in. × 17.25 in. × 12 in.)
Weight	< 8 kg (< 17.5 lb)
Operating Temperature	0° to +45°C (+32° to +113°F)
Non-operating Temperature	–20° to +85°C (–4° to +185°F)
Operating Humidity, non-condensing	5% to 95%
External Alarm Connector (contact closure)	1 9-pin D-sub, female Maximum: 40 mA @ 40V DC Typical: 4 mA @ 12V DC
Serial Interface Connector	1 RS-232 9-pin D-sub, male
RF Connectors	8 shielded RJ-45, female (Cat-5/6)
LED Fault and Status Indicators	Unit Status (1 pair): • Power • Main Hub Status Downstream Unit/Link Status (1 pair per Cat-5/6 port): • Link • RAU
AC Power	Rating: 115/230V, 5.5/3A, 50–60 Hz Operating Range: 90–132V/170–250V auto-ranging, 4.6–2.3A/3.6–1.6A, 47–63 Hz
Power Consumption (W)	4 RAUs: 150 typ/178 max 4 RAUs & 4 Extenders: 167 typ/202 max 8 RAUs: 200 typ/242 max 8 RAUs & 8 Extenders: 234 typ/290 max
MTBF	78,998 hours

SECTION 4

Unison Remote Access Unit

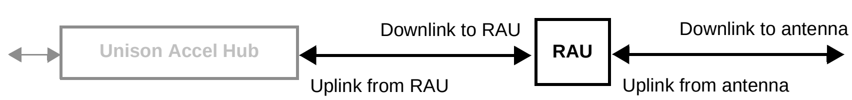
The Remote Access Unit (RAU) is an active transceiver that connects to an Accel Hub using industry-standard Cat-5/6 screened twisted pair (ScTP) cable, which delivers RF signals, configuration information, and electrical power to the RAU.

An RAU passes RF signals between an Accel Hub and an attached passive antenna where the signals are transmitted to wireless devices.

Figure 4-1 Remote Access Unit in a Unison Accel System

Downlink Path: The RAU receives downlink IF signals from an Accel Hub via Cat-5/6 cable. It converts the signals to RF and sends them to a passive RF antenna via coaxial cable.

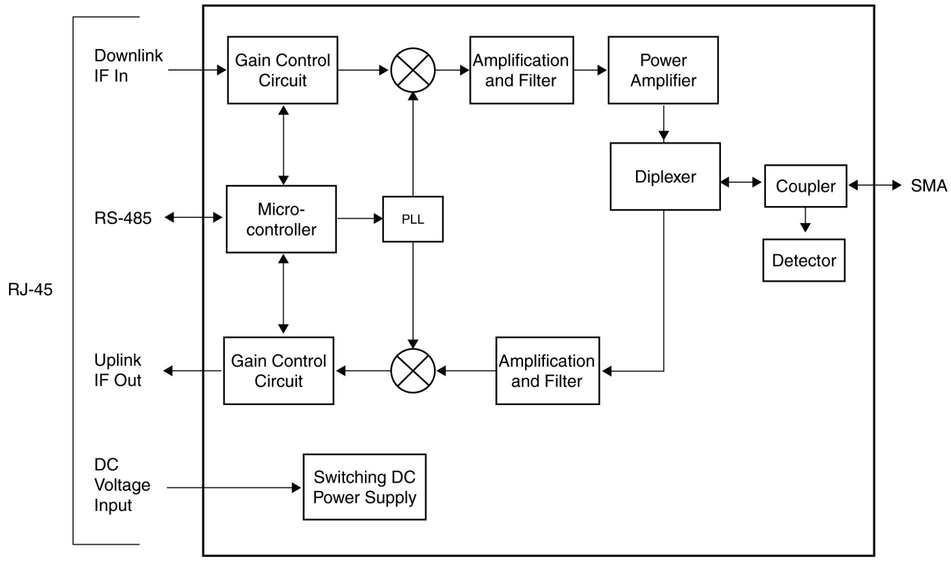
Also, the RAU receives configuration information from the Accel Hub via the Cat-5/6 cable.



Uplink Path: The RAU receives uplink RF signals from a passive RF antenna via coaxial cable. It converts the signals to IF and sends them to an Accel Hub via Cat-5/6 cable.

Also, the RAU sends its status information to the Accel Hub via the Cat-5/6 cable.

Figure 4-2 Remote Access Unit Block Diagram



The Unison RAUs are manufactured to a specific band or set of bands (i.e., there is one PCS RAU which can be used for A/D, B/E, E/F, B/D, or F/C). Table 4-1 lists the six Unison RAUs, the Unison Band, and the frequency band(s) they cover.

Table 4-1 Frequency Bands covered by Unison RAUs

Unison RAU	Unison Band	RF Passband	
		Downlink (MHz)	Uplink (MHz)
Cellular	Cellular	869–894	824–849
DCS	DCS1	1805–1842.5	1710–1747.5
	DCS2	1842.5–1880	1747.5–1785
	DCS3	1840–1875	1745–1780
	DCS4	1815–1850	1720–1755
GSM	GSM	925–960	880–915
	EGSM	935–960	890–915
iDEN	iDEN	851–869	806–824
PCS	Bands A,D,B	1930–1965	1850–1885
	Bands D,B,E,F	1945–1975	1865–1895
	Bands E,F,C	1965–1990	1885–1910
UMTS	UMTS 1	2110–2145	1945–1975
	UMTS 2	2125–2160	1965–1990
	UMTS 3	2135–2170	1945–1980

4.1 Remote Access Unit Connectors

4.1.1 SMA Connector

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

4.1.2 RJ-45 Connector

The RAU has one RJ-45 connector that connects it to an Accel Hub using Cat-5/6 ScTP cable. Use shielded RJ-45 connectors on the Cat-5/6 cable.

NOTE: For system performance, it is important that you use only Cat-5/6 ScTP cable with shielded RJ-45 connectors.

4.2 RAU LED Indicators

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

NOTE: Refer to Section 8 for troubleshooting using the LEDs.

Status LEDs

The RAU status LEDs can be in one of the states shown in Table 4-2. These LEDs can be:

- ○ off
- ● steady green
- ● steady red

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

Table 4-2 Remote Access Unit LED States

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

4.3 Faults and Warnings

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

For more information, see:

- page 8-6 for RAU faults.
- page 8-7 for RAU warnings.
- page 8-9 for RAU status messages.

4.4 Remote Access Unit Specifications

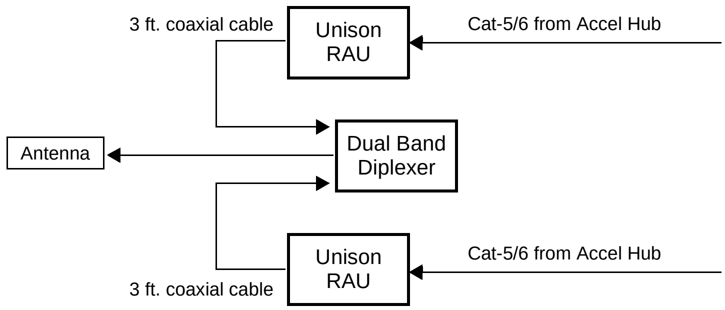
Table 4-3 Remote Access Unit Specifications

Specification	Description
Dimensions (H × W × D)	44 mm × 305 mm × 158 mm (1.7 in. × 12 in. × 6.2 in.)
Weight	< 1 kg (< 2 lb)
Operating Temperature	–25° to +45°C (–13° to +113°F)
Non-operating Temperature	–25° to +85°C (–13° to +185°F)
Operating Humidity, non-condensing	5% to 95%
RF Connectors	1 shielded RJ-45, female (Cat-5/6)[a] 1 SMA, male (coaxial)
LED Alarm and Status Indicators	Unit Status (1 pair): • Link • Alarm
Maximum Heat Dissipation (W)	16 max (from the Hub)
MTBF	282,207 hours

a. For system performance, it is important that you use only Cat-5/6 ScTP cable with shielded RJ-45 connectors.

4.5 RAUs in a Dual Band System

A Dual-Band Diplexer can be used to combine the output from two RAUs, one that is below 1 GHz and one that is above 1 GHz, for output to a single passive antenna..



Refer to the Dual Band Diplexer specifications (PN 8000-54) for technical information.

SECTION 5

Designing a Unison Accel Solution

Designing a Unison Accel 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 determined 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 system will have to transmit)
   - Design goal (RSSI, received 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 5.4.1 on page 5-30).
   - 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 5.1, "Maximum Output Power per Carrier at RAU," on page 5-3.**

   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 Unison's RF performance. Typically, the power per carrier decreases as the number of carriers increases.

3. **Determine the in-building environment: Section 5.2, "Estimating RF Coverage," on page 5-17.**

   - 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 5.4, "Link Budget Analysis," on page 5-29.**

   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 = maximum 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 5.2, "Estimating RF Coverage," on page 5-17.**

   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 Unison 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 5.5, "Connecting a Main Hub to a Base Station," on page 5-42.**

   Once you know the quantities of Unison 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 a Unison solution are discussed in the following sections.

5.1 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. System gain is software selectable from 0 dB to 15 dB in 1 dB steps. Additionally, both the uplink and downlink of each RAU gain can be reduced by 10 dB.

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 Unison's maximum output power recommendations.

Refer to Section 5.6, "Designing for a Neutral Host System," on page 5-46 when combining frequencies or protocols on a single Main Hub.

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

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

800 MHz AMPS

Table 5-1 **800 MHz (AMPS) Power per Carrier**

No. of Carriers	Power per Carrier (dBm)	
	2 km SMF	1 km MMF
1	27.0	27.0
2	21.0	21.0
3	17.5	17.5
4	14.5	14.5
5	13.0	13.0
6	11.5	11.5
7	10.5	10.5
8	9.5	9.5
9	9.0	9.0
10	8.0	8.0
11	8.0	8.0
12	7.5	7.5
13	7.0	7.0
14	6.5	6.5
15	6.5	6.5
16	6.0	6.0
20	5.0	5.0
30	3.0	3.0

800 MHz TDMA

Table 5-2 **800 MHz (TDMA) Power per Carrier**

No. of Carriers	Power per Carrier (dBm)	
	2 km SMF	1 km MMF
1	24.0	24.0
2	19.0	19.0
3	16.0	16.0
4	14.0	14.0
5	12.5	12.5
6	11.5	11.5
7	10.5	10.5
8	9.5	9.5
9	9.0	9.0
10	8.5	8.5
11	8.0	8.0
12	7.5	7.5
13	7.5	7.5
14	7.0	7.0
15	6.5	6.5
16	6.5	6.5
20	5.5	5.5
30	3.5	3.5

800 MHz CDMA

Table 5-3 **800 MHz (CDMA) Power per Carrier**

No. of Carriers	Power per Carrier (dBm)	
	2 km SMF	1 km MMF
1	17.0	17.0
2	14.0	14.0
3	12.0	12.0
4	11.0	11.0
5	10.0	10.0
6	9.0	9.0
7	8.5	8.5
8	8.0	8.0

800 MHz iDEN

Table 5-4 **800 MHz iDEN/SMR Power per Carrier**

iDEN

No. of Carriers	Power per Carrier (dBm)	
	2 km SMF	1 km MMF
1	10.0	10.0
2	10.0	10.0
3	10.0	10.0
4	10.0	10.0
5	9.0	9.0
6	8.0	8.0
7	7.0	7.0
8	6.5	6.5
9	6.0	6.0
10	5.5	5.5

Analog FM

No. of Carriers	Power per Carrier (dBm)	
	2 km SMF	1 km MMF
1	10.0	10.0
2	10.0	10.0
3	10.0	10.0
4	10.0	10.0
5	10.0	10.0
6	10.0	10.0
7	9.5	9.5
8	8.5	8.5
9	8.0	8.0
10	7.0	7.0

CQPSK/C4FM

No. of Carriers	Power per Carrier (dBm)	
	2 km SMF	1 km MMF
1	10.0	10.0
2	10.0	10.0
3	10.0	10.0
4	10.0	10.0
5	10.0	10.0
6	10.0	10.0
7	9.0	9.0
8	8.5	8.5
9	7.5	7.5
10	7.0	7.0

Motient Data TAC

No. of Carriers	Power per Carrier (dBm)	
	2 km SMF	1 km MMF
1	10.0	10.0
2	10.0	10.0
3	10.0	10.0
4	10.0	10.0

900 MHz GSM or EGSM

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

No. of Carriers	Power per Carrier (dBm)	
	2 km SMF	1 km MMF
1	16.0	16.0
2	13.0	12.0
3	11.0	10.0
4	10.0	9.0
5	9.0	8.0
6	8.0	7.0
7	7.5	6.5
8	7.0	6.0
9	6.5	5.5
10	6.0	5.5
11	5.5	5.0
12	5.0	4.5
13	5.0	4.5
14	4.5	4.0
15	4.0	4.0
16	4.0	3.5

900 MHz EDGE

Table 5-6 **900 MHz (EDGE) Power per Carrier**

No. of Carriers	Power per Carrier (dBm)	
	2 km SMF	1 km MMF
1	16.0	16.0
2	13.0	12.0
3	11.0	10.0
4	10.0	9.0
5	9.0	8.0
6	8.0	7.0
7	7.5	6.5
8	7.0	6.0
9	6.5	5.5
10	6.0	5.5
11	5.5	5.0
12	5.0	4.5
13	5.0	4.5
14	4.5	4.0
15	4.0	4.0
16	4.0	3.5

1800 MHz DCS

Table 5-7 1800 MHz (DCS) Power per Carrier

No. of Carriers	Power per Carrier (dBm)	
	2 km SMF	1 km MMF
1	17.5	17.5
2	14.5	14.0
3	12.5	12.0
4	11.5	11.0
5	10.5	10.0
6	9.5	9.0
7	9.0	8.5
8	8.5	8.0
9	8.0	7.5
10	7.5	7.5
11	7.0	7.0
12	6.5	6.5
13	6.5	6.5
14	6.0	6.0
15	5.5	5.5
16	5.5	5.5

1800 MHz EDGE

Table 5-8 1800 MHz (EDGE) Power per Carrier

No. of Carriers	Power per Carrier (dBm)	
	2 km SMF	1 km MMF
1	17.5	17.5
2	14.5	14.0
3	12.5	12.0
4	11.5	11.0
5	10.5	10.0
6	9.5	9.0
7	9.0	8.5
8	8.0	8.0
9	7.5	7.5
10	7.0	7.0
11	6.5	6.5
12	6.0	6.0
13	6.0	6.0
14	5.5	5.5
15	5.0	5.0
16	5.0	5.0

1900 MHz TDMA

Table 5-9 1900 MHz (TDMA) Power per Carrier

No. of Carriers	Power per Carrier (dBm)	
	2 km SMF	1 km MMF
1	23.0	23.0
2	18.0	18.0
3	15.0	15.0
4	13.0	13.0
5	11.5	11.5
6	10.5	10.5
7	9.5	9.5
8	8.5	8.5
9	8.0	8.0
10	7.5	7.5
11	7.0	7.0
12	6.5	6.5
13	6.5	6.5
14	6.0	6.0
15	5.5	5.5
16	5.5	5.5
20	4.5	4.5
30	2.5	2.5

1900 MHz GSM

Table 5-10 **1900 MHz (GSM) Power per Carrier**

No. of Carriers	Power per Carrier (dBm)	
	2 km SMF	1 km MMF
1	26.0	26.0
2	15.5	14.0
3	13.5	12.0
4	12.0	11.0
5	11.0	10.0
6	10.5	9.0
7	10.0	8.5
8	9.0	8.0
9	8.5	7.5
10	8.0	7.5
11	7.5	7.0
12	7.0	6.5
13	6.5	6.5
14	6.5	6.0
15	6.0	6.0
16	5.5	5.5

1900 MHz CDMA

Table 5-11 **1900 MHz (CDMA) Power per Carrier**

No. of Carriers	Power per Carrier (dBm)	
	2 km SMF	1 km MMF
1	16.0	16.0
2	13.0	13.0
3	11.0	11.0
4	10.0	10.0
5	9.0	9.0
6	8.0	8.0
7	7.5	7.5
8	7.0	7.0

1900 MHz EDGE

Table 5-12 1900 MHz (EDGE) Power per Carrier

No. of Carriers	Power per Carrier (dBm)	
	2 km SMF	1 km MMF
1	23.0	23.0
2	15.5	14.0
3	13.5	12.0
4	12.0	11.0
5	10.5	10.0
6	9.5	9.0
7	9.0	8.5
8	8.0	8.0
9	7.5	7.5
10	7.0	7.0
11	6.5	6.5
12	6.0	6.0
13	6.0	6.0
14	5.5	5.5
15	5.0	5.0
16	5.0	5.0

2.1 GHz UMTS

Table 5-13 2.1 GHz (UMTS) Power per Carrier

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

Note: measurements taken with no baseband clipping.

Paging/SMR

Table 5-14 Paging/SMR Power per Carrier: Analog FM, CQPSK, C4FM

Analog FM

No. of Carriers	Power per Carrier (dBm) 2 km SMF	Power per Carrier (dBm) 1 km MMF
1	26.0	26.0
2	19.5	19.5
3	16.5	16.5
4	13.5	13.5
5	12.0	12.0
6	10.5	10.5
7	9.5	9.5
8	8.5	8.5
9	8.0	8.0
10	7.0	7.0

CQPSK

No. of Carriers	Power per Carrier (dBm) 2 km SMF	Power per Carrier (dBm) 1 km MMF
1	22.0	22.0
2	17.0	17.0
3	14.5	14.5
4	12.5	12.5
5	11.0	11.0
6	9.5	9.5
7	9.0	9.0
8	8.0	8.0
9	7.5	7.5
10	7.0	7.0

C4FM

No. of Carriers	Power per Carrier (dBm) 2 km SMF	Power per Carrier (dBm) 1 km MMF
1	26.0	26.0
2	19.5	19.5
3	16.0	16.0
4	13.5	13.5
5	11.5	11.5
6	10.0	10.0
7	9.0	9.0
8	8.5	8.5
9	7.5	7.5
10	7.0	7.0

Table 5-15 Paging/SMR Power per Carrier: Mobitex, POCSAG/Reflex

Mobitex

No. of Carriers	Power per Carrier (dBm) 2 km SMF	Power per Carrier (dBm) 1 km MMF
1	26.0	26.0
2	19.5	19.5
3	16.0	16.0
4	13.5	13.5

POCSAG/Reflex

No. of Carriers	Power per Carrier (dBm) 2 km SMF	Power per Carrier (dBm) 1 km MMF
1	26.0	26.0
2	19.5	19.5
3	16.0	16.0
4	13.5	13.5

800 MHz Cellular/1900 MHz PCS Dual Band

Table 5-16 800 MHz Cellular/1900 MHz PCS Power per Carrier

	Recommended Maximum Output Power per Carrier at RAU (dBm)											
	800 MHz Cellular						1900 MHz PCS					
	TDMA		AMPS		CDMA		TDMA		GSM		CDMA	
No. of Carriers	2 km SMF	1 km MMF	2 km SMF	1 km MMF	2 km SMF	1 km MMF	2 km SMF	1 km MMF	2 km SMF	1 km MMF	2 km SMF	1 km MMF
1	23.0	23.0	26.0	26.0	16.0	16.0	21.5	21.5	24.5	24.5	14.5	14.5
2	18.0	18.0	20.0	20.0	13.0	13.0	16.5	16.5	14.0	12.5	11.5	11.5
3	15.0	15.0	16.5	16.5	11.0	11.0	13.5	13.5	12.0	10.5	9.5	9.5
4	13.0	13.0	13.5	13.5	10.0	10.0	11.5	11.5	10.5	9.5	8.5	8.5
5	11.5	11.5	12.0	12.0	9.0	9.0	10.0	10.0	9.5	8.5	7.5	7.5
6	10.5	10.5	10.5	10.5	8.0	8.0	9.0	9.0	9.0	7.5	6.5	6.5
7	9.5	9.5	9.5	9.5	7.5	7.5	8.0	8.0	8.5	7.0	6.0	6.0
8	8.5	8.5	8.5	8.5	7.0	7.0	7.0	7.0	7.5	6.5	5.5	5.5
9	8.0	8.0	8.0	8.0			6.5	6.5	7.0	6.0		
10	7.5	7.5	7.0	7.0			6.0	6.0	6.5	6.0		
11	7.0	7.0	7.0	7.0			5.5	5.5	6.0	5.5		
12	6.5	6.5	6.5	6.5			5.0	5.0	5.5	5.0		
13	6.5	6.5	6.0	6.0			5.0	5.0	5.0	5.0		
14	6.0	6.0	5.5	5.5			4.5	4.5	5.0	4.5		
15	5.5	5.5	5.5	5.5			4.0	4.0	4.5	4.5		
16	5.5	5.5	5.0	5.0			4.0	4.0	4.0	4.0		
20	4.5	4.5	4.0	4.0			3.0	3.0				
30	2.5	2.5	2.0	2.0			1.0	1.0				

Allowing for Future Capacity Growth

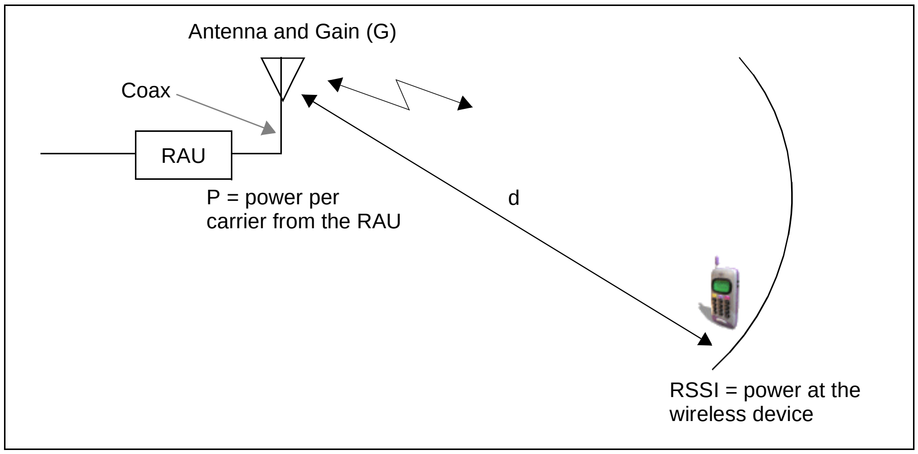
Sometimes a Unison deployment initially is used to enhance coverage. Later that same system may also need to provide increased capacity. Thus, the initial deployment might only transmit two carriers but need to transmit four carriers later. There are two options for dealing with this scenario:

1. Design the initial coverage with a maximum power per carrier for four carriers.
2. Design the initial coverage for two carriers but leave RAU ports on the Hubs 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.

5.2 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 maximum acceptable path loss between the antenna and the wireless device.

Figure 5-1 Determining Path Loss between the Antenna and the Wireless Device



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

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 equations in Section 5.2.1 and in Section 5.2.2.

Coaxial cable is used to connect the RAU to an antenna. The following table lists coaxial cable loss for various cable lengths.

Table 5-17 Coaxial Cable Losses

Length of Cable (.195 in. diameter)	Loss at 800 MHz (dB)	Loss at 1900 MHz (dB)
0.9 m (3 ft)	0.6	0.8
1.8 m (6 ft)	1.0	1.5
3.0 m (10 ft)	1.5	2.3

5.2.1 Path Loss Equation

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

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

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 is the distance expressed in meters
- d_0 is usually 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.[1]

Table 5-18 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

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

5.2.2 Coverage Distance

Equations (1) and (2), on pages 5-17 and 5-18, 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:

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

where PLS (path loss slope) is chosen to account for the building's environment. Because different frequencies penetrate partitions with different losses, the value of PLS will vary depending on the frequency.

Table 5-19 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 5-19 Estimated Path Loss Slope for Different In-Building Environments

Environment Type	Example	PLS for 800/900 MHz	PLS for 1800/1900 MHz
Open Environment with very few RF obstructions	Parking Garage, Convention Center	33.7	30.1
Moderately Open Environment with low-to-medium amount of RF obstructions	Warehouse, Airport, Manufacturing	35	32
Mildly Dense Environment with medium-to-high amount of RF obstructions	Retail, Office Space with approximately 80% cubicles and 20% hard walled offices	36.1	33.1
Moderately Dense Environment with medium-to-high amount of RF obstructions	Office Space with approximately 50% cubicles and 50% hard walled offices	37.6	34.8
Dense Environment with large amount of RF obstructions	Hospital, Office Space with approximately 20% cubicles and 80% hard walled offices	39.4	38.1

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 5-20 gives the value of the first term of Equation (3) (i.e., ($20\log(4\pi f/c)$) for various frequency bands.

Table 5-20 Frequency Bands and the Value of the first Term in Equation (3)

	Band (MHz)		Mid-Band Frequency (MHz)	$20\log(4\pi f/c)$
	Uplink	Downlink		
800 MHz Cellular	824–849	869–894	859	31.1
800 MHz iDEN	806–824	851–869	837.5	30.9
900 MHz GSM	890–915	935–960	925	31.8
900 MHz EGSM	880–915	925–960	920	31.7
1800 MHz DCS	1710–1785	1805–1880	1795	37.5
1800 MHz CDMA (Korea)	1750–1780	1840–1870	1810	37.6
1900 MHz PCS	1850–1910	1930–1990	1920	38.1
2.1 GHz UMTS	1920–1980	2110–2170	2045	38.7

For reference, Tables 5-21 through 5-27 show the distance covered by an antenna for various in-building environments. The following assumptions were made:

- Path loss Equation (3)
- 6 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 5-21 Approximate Radiated Distance from Antenna for 800 MHz Cellular Applications

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

Table 5-22 Approximate Radiated Distance from Antenna for 800 MHz iDEN Applications

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

Table 5-23 Approximate Radiated Distance from Antenna for 900 MHz GSM Applications

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

Table 5-24 Approximate Radiated Distance from Antenna for 900 MHz EGSM Applications

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

Table 5-25 Approximate Radiated Distance from Antenna for 1800 MHz DCS Applications

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

Table 5-26 Approximate Radiated Distance from Antenna for 1800 MHz CDMA (Korea) Applications

Facility	Distance from Antenna	
	Meters	**Feet**
Open Environment	75	247
Moderately Open Environment	58	191
Mildly Dense Environment	51	167
Moderately Dense Environment	42	138
Dense Environment	30	100

Table 5-27 Approximate Radiated Distance from Antenna for 1900 MHz PCS Applications

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

Table 5-28 Approximate Radiated Distance from Antenna for 2.1 GHz UMTS Applications

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

5.2.3 Examples of Design Estimates

Example Design Estimate for an 800 MHz TDMA Application

1. **Design goals**:
   - Cellular (859 MHz = average of the lowest uplink and the highest downlink frequency in 800 MHz Cellular band)
   - TDMA provider
   - 12 TDMA carriers in the system
   - –85 dBm design goal (to 95% of the building) — the minimum received power at the wireless device
   - Base station with simplex RF connections
2. **Power Per Carrier**: The tables in **Section 5.1, “Maximum Output Power per Carrier at RAU,” on page 5-3** provide maximum power per carrier information. The 800 MHz TDMA table (on page 5-5) indicates that Unison can support 12 carriers with a recommended maximum power per carrier of 7.5 dBm. The input power should be set to the desired output power minus the system gain.
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 95.5 dB (7.5 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 5.4 on page 5-29.
5. **Path Loss Slope**: For a rough estimate, Table 5-19, “Estimated Path Loss Slope for Different In-Building Environments” on page 5-19, shows that a building with 50% hard wall offices and 50% cubicles, at 859 MHz, has an approximate path loss slope (PLS) of 37.6. Given the RF link budget of 95.5 dB, the distance of coverage from each RAU will be 52 meters (170.6 ft). This corresponds to a coverage area of 8,494 sq. meters (91,425 sq. ft.) per RAU (see Section 5.2.1 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.

Equipment Required: Since you know the building size, you can now estimate the Unison 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. This assumes no propagation between floors. If there is propagation, you may not need antennas on every floor.

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

Check that the Cat-5 cable distances are as recommended. If the distances differ, use the tables in Section 5.3, “System Gain,” on page 5-28 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 Hubs cannot be placed so that the RAUs are within the distance requirement, additional 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 Unison 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 Unison system.

Example Design Estimate for an 1900 MHz CDMA Application

1. **Design goals**:
   - PCS (1920 MHz = average of the lowest uplink and the highest downlink frequency in 1900 MHz PCS band)
   - CDMA provider
   - 8 CDMA carriers in the system
   - –85 dBm design goal (to 95% of the building) — the minimum received power at the wireless device
   - Base station with simplex RF connections
2. **Power Per Carrier**: The tables in **Section 5.1, "Maximum Output Power per Carrier at RAU," on page 5-3** provide maximum power per carrier information. The 1900 MHz CDMA table (on page 5-12) indicates that Unison can support 8 carriers with a recommended maximum power per carrier of 6.5 dBm. The input power should be set to the desired output power minus the system gain.
3. **Building information**:
   - 16 floor building with 9,290 sq. meters (100,000 sq. ft.) per floor; total 148,640 sq. meters (1,600,000 sq. ft.)
   - Walls are sheetrock construction; suspended ceiling tiles
   - Antennas used will be omni-directional, ceiling mounted
   - Standard office environment, 80% hard wall offices and 20% cubicles
4. **Link Budget**: In this example, a design goal of –85 dBm is used. Suppose 3 dBi omni-directional antennas are used in the design. Then, the maximum RF propagation loss should be no more than 94.5 dB (6.5 dBm + 3 dBi + 85 dBm) over 95% of the area being covered. *It is important to note that a design goal such as –85 dBm is usually derived taking into account multipath fading and log-normal shadowing characteristics. Thus, this design goal will only be met "on average" over 95% of the area being covered. At any given point, a fade may bring the signal level underneath the design goal.*

   Note that this method of calculating a link budget is only for the downlink path. For information to calculate link budgets for both the downlink and uplink paths, see Section 5.4 on page 5-29.
5. **Path Loss Slope**: For a rough estimate, Table 5-19, "Estimated Path Loss Slope for Different In-Building Environments" on page 5-19, shows that a building with 80% hard wall offices and 20% cubicles, at 1920 MHz, has an approximate path loss slope (PLS) of 38.1. Given the RF link budget of 94.5 dB, the distance of coverage from each RAU will be 30.2 meters (99 ft). This corresponds to a coverage area of 2,868 sq. meters (30,854 sq. ft.) per RAU (see Section 5.2.1 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.

6. **Equipment Required**: Since you know the building size, you can now estimate the Unison equipment quantities that will be needed. Before any RF levels are tested in the building, you can estimate that 4 antennas per level will be needed. This assumes no propagation between floors. If there is propagation, you may not need antennas on every floor.

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

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

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

   Check that the MMF and Cat-5 cable distances are as recommended. If the distances differ, use the tables in Section 5.3, “System Gain,” on page 5-28 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 Hubs cannot be placed so that the RAUs are within the distance requirement, additional 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 Unison 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 Unison system.

5.3 System Gain

The system gain can be decreased from 15 dB to 0 dB gain in 1 dB increments and the uplink and downlink gains of each RAU can be independently decreased by 10 dB in one step using AdminManager or OpsConsole.

5.3.1 System Gain (Loss) Relative to ScTP Cable Length

The recommended minimum length of ScTP cable is 10 meters (33 ft) and the recommended maximum length is 100 meters (328 ft). The system should not be operated with ScTP cable that is less than 10 meters (33 ft) in length, system performance will be greatly compromised. If the ScTP cable is longer than 100 meters (328 ft), the gain of the system will decrease, as shown in Table 5-29.

Table 5-29 System Gain (Loss) Relative to ScTP Cable Length

ScTP Cable Length	Typical change in system gain (dB)	
	Downlink	Uplink
800 MHz TDMA/AMPS and CDMA; 900 MHz GSM and EGSM; and iDEN		
110 m / 361 ft	–1.0	–0.7
120 m / 394 ft	–3.2	–2.4
130 m / 426 ft	–5.3	–4.1
140 m / 459 ft	–7.5	–5.8
150 m / 492 ft	–9.7	–7.6
1800 MHz GSM (DCS); 1900 MHz TDMA, CDMA, and GSM		
110 m / 361 ft	–1.0	–0.7
120 m / 394 ft	–4.0	–2.4
130 m / 426 ft	–6.4	–4.1
140 m / 459 ft	–8.8	–5.8
150 m / 492 ft	–11.3	–7.6
2.1 GHz UMTS		
110 m / 361 ft	–1.0	–0.7
120 m / 394 ft	–3.2	–2.4
130 m / 426 ft	–5.3	–4.1
140 m / 459 ft	–7.5	–5.8
150 m / 492 ft	–9.7	–7.6

5.4 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 5.1. 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 1W (+30 dBm). Composite power levels above this limit will cause damage to the Main Hub.

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

5.4.1 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 a Unison 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 5.2.1.

Table 5-30 provides link budget considerations for narrowband systems.

Table 5-30 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 Unison	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 5.1. 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 Unison 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 Unison alone. See Section 5.5 for ways to independently set the uplink and downlink attenuations between the base station and Unison.
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).
Unison Noise Figure	This is Unison’s uplink noise figure, which varies depending on the number of Hubs and RAUs, and the frequency band. Unison’s uplink noise figure is specified for a 1-1-4 configuration. Thus, the noise figure for a Unison system (or multiple systems whose uplink ports are power combined) will be *NF(1-1-4) + 10*log(# of Hubs)*. This represents an upper-bound because the noise figure is lower if any of the Hub’s RAU ports are **not** used.