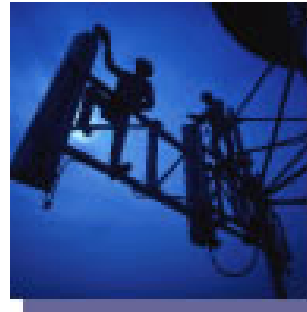
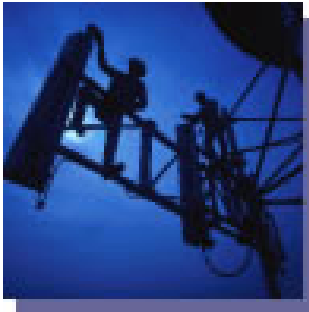




## **Series 4000 Router Installation Guide**

Rev 4.06, 2005 March 04

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# **Series 4000 Router Installation Guide**

AirTegrity Wireless, Inc.

Rev 4.06, 2005 March 04

## **AirTegrity Headquarters**

AirTegrity Wireless, Inc.  
276 Kingsbury Grade, Suite 206  
Stateline, Nevada, 89449-5188  
USA

## **AirTegrity Mailing Address**

AirTegrity Wireless, Inc.  
P.O Box 5188  
Stateline, Nevada, 89449-5188  
USA

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## Warning and Disclaimer

This book is designed to provide information about the Series 4000 Router Product(s). Every effort has been made to make this book as complete and as accurate as possible, but no warranty or fitness is implied.

The information is provided on an “as is” basis. The author, AirTegrity Wireless, Inc., shall have neither liability nor responsibility to any person or entity with respect to any loss or damage arising from the information contained in this book or from the use of equipment or software that might accompany it.

The opinions expressed in this book are not necessarily those of AirTegrity Wireless, Inc.

## Regulatory Information

### Federal Communication Commission Information

|               |                                                                                                              |
|---------------|--------------------------------------------------------------------------------------------------------------|
| Model:        | 4000 series with 2024-15                                                                                     |
| FCC ID:       | SJW-4000-2024-15                                                                                             |
| Manufacturer: | AirTegrity Wireless, Inc.<br>276 Kingsbury Grade, Suite 206<br>P.O. Box 5188<br>Stateline NV 89449-5188, USA |

### FCC Statement

This device complies with Part 15 rules. Operation is subject to the following two conditions:

1. This device may not cause harmful interference, and
2. This device must accept any interference received, including interference that may cause undesired operation.

This equipment has been tested and found to comply with the limits of a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a residential environment. This equipment generates, uses, and radiates radio frequency energy, and if not installed and used in accordance with the instructions, may cause harmful interference. However, there is no guarantee that interference will not occur. If this equipment does cause interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to correct the interference by one of the following measures:

- Reorient or relocate the receiving antenna.
- Increase separation between the equipment and receiver.
- Connect the equipment to an outlet on a circuit different from which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician.

**CAUTION:** Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

---

## Declaration of Conformity for the R&TTE Directive 1999/5/EC

**English:** This equipment is in compliance with the essential requirements and other relevant provisions of Directive 1999/5/EC.

**Deutsch:** Dieses Gerät entspricht den grundlegenden Anforderungen und den weiteren entsprechenden Vorgaben der Richtlinie 1999/5/EU.

**Français:** Cet appareil est conforme aux exigences essentielles et aux autres dispositions pertinentes de la Directive 1999/5/EC.



We, AirTegrity Wireless Inc., of 276 Kingsbury Grade, Suite 206, Stateline Nevada, 89449-5188, USA, declare under our sole responsibility that the model 4000 series installed with the 2024-06 radio card to which this declaration relates is in conformity with the following standards and/or other normative documents:

EN 300 328-1  
EN 300 328-2  
EN 301 489-1  
EN 301 489-3  
EN 301 489-17  
EN 60950

We, AirTegrity Wireless Inc., hereby declare that this product is in compliance with the essential requirements and other relevant provisions of Directive 1999/5/EC.

This product can be used in the following countries:

UK, Germany, and France.

## Antennas Tested

The following antennas were tested with the 4000 installed with a 2024-15 radio:

| Antenna Type      | Manufacturer           | Model Number | Antenna Gain |
|-------------------|------------------------|--------------|--------------|
| Directional Panel | Til-Tek                | TA-2408      | 17 dBi       |
| Omni              | HyperLink Technologies | HG2415U-PRO  | 15 dBi       |
| Yagi              | Poynting Group         | YAGI-A0005   | 13 dBi       |

## Trademark Acknowledgments

All terms mentioned in this book that are known trademarks or service marks have been appropriately capitalized. AirTegrity Wireless, Inc. cannot attest to the accuracy of this information. Use of a term in this book should not be regarded as affecting the validity of any trademark or service mark.

## Readers' Feedback

At AirTegrity Wireless, Inc., our goal is to create in-depth technical documentation of the highest quality and value. Each book is crafted with care and precision, involving many hours of research and the collaboration of many members from the development teams.

Readers' feedback is actively sought to help us improve on future revisions and publications. If there are any items that you feel are in error or areas that could be altered to better suit your needs, you can contact us through e-mail at [techpubs@airtegrity.com](mailto:techpubs@airtegrity.com). Please be sure to include the title and revision of the document.

---

# AirTegrity Limited Warranty

## Limited Warranty

**Hardware.** AirTegrity Wireless, Inc. (“AirTegrity”), warrants that commencing from the date of delivery to Customer (but in case of resale by an AirTegrity reseller, commencing not more than ninety (90) days after original shipment by AirTegrity), and continuing for a period of the longer of (a) ninety (90) days or (b) the period set forth in the Warranty Card accompanying the Product (if any), the Hardware will be free from defects in material and workmanship under normal use.

The date of shipment of a Product by AirTegrity is set forth on the packaging material in which the Product is shipped. This limited warranty extends only to the original user of the Product. Customer's sole and exclusive remedy and the entire liability of AirTegrity and its suppliers under this limited warranty will be, at AirTegrity or its service center's option, shipment of a replacement within the period and according to the replacement process described in the Warranty Card, or a refund of the purchase price if the Hardware is returned to the party supplying it to Customer, if different than AirTegrity, freight and insurance prepaid. AirTegrity replacement parts used in Hardware repair may be new or equivalent to new. AirTegrity obligations hereunder are conditioned upon the return of affected articles in accordance with AirTegrity or its service center's then-current Return Material Authorization (RMA) procedures.

**Software.** AirTegrity warrants that commencing from the date of delivery to Customer (but in case of resale by an AirTegrity reseller, commencing not more than ninety (90) days after original shipment by AirTegrity), and continuing for a period of the longer of (a) ninety (90) days or (b) the period set forth in the Warranty Card accompanying the Product (if any): (a) the media on which the Software is furnished will be free of defects in materials and workmanship under normal use; and (b) the Software substantially conforms to its published specifications.

Except for the foregoing, the Software is provided AS IS. This limited warranty extends only to the Customer who is the original licensee. Customer's sole and exclusive remedy and the entire liability of AirTegrity and its suppliers under this limited warranty will be, at AirTegrity or its service center's option, repair, replacement, or refund of the Software if reported (or, upon request, returned) to the party supplying the Software to Customer, if different than AirTegrity. In no event does AirTegrity warrant that the Software is error free or that Customer will be able to operate the Software without problems or interruptions. In addition, due to the continual development of new techniques for intruding upon and attacking networks, AirTegrity does not warrant that the Software or any equipment, system or network on which the Software is used will be free of vulnerability to intrusion or attack.

**Restrictions.** This warranty does not apply if the Product (a) has been altered, except by AirTegrity, (b) has not been installed, operated, repaired, or maintained in accordance with instructions supplied by AirTegrity, (c) has been subjected to abnormal physical or electrical stress, misuse, negligence, or accident, (d) is sold or, in the case of Software, licensed, for beta, evaluation, testing, or demonstration purposes for which AirTegrity does not receive a payment of purchase price or license fee, or (e) has been damaged by lightning, flood, or other Acts of God.

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---

# About the Manual

## Configuration Warning

Please read the following before attempting the installation of your Series 4000 Routers:

- The antenna design, alignment and placement are all critical to the successful operation of wireless networks. In the majority of cases, the network manager needs the assistance of antenna specialists to perform these tasks.
- When installing access point Routers, the antennas are often attached to antenna towers or other high places, which are not safely accessible to those without proper training.



**Warning** It is not be safe for an unqualified person to climb an antenna tower.

## Documentation Conventions

This manual uses the following naming conventions:

- Router - When capitalized, *Router* refers to a *Series 4000 Router* built by AirTegrity Wireless, Inc.

For example: “The Router supports both RIP and OSPF.”

- AOS - *AOS* refers to the *AirTegrity Operating System*.

For example: “The AirTegrity Router comes equipped with *AOS*, its own embedded operating system, stored in the unit’s non-volatile flash memory.”

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# 1. Installation

The following sections provide section-by-section, step-by-step instructions on how to get your Series 4000 Router up and running. Do not skip any sections or steps.

The first section begins with instructions after you have received the equipment and are ready to begin installation:

1. [Location of Ports and Connectors](#)
2. [Required Computer Equipment and Software](#)
3. [Install the RS232 Cabling](#)
4. [Install the USB Cabling](#)
5. [Connect the Network Administration Computer to the Router](#)
6. [Installation Caution - READ THIS SECTION](#)



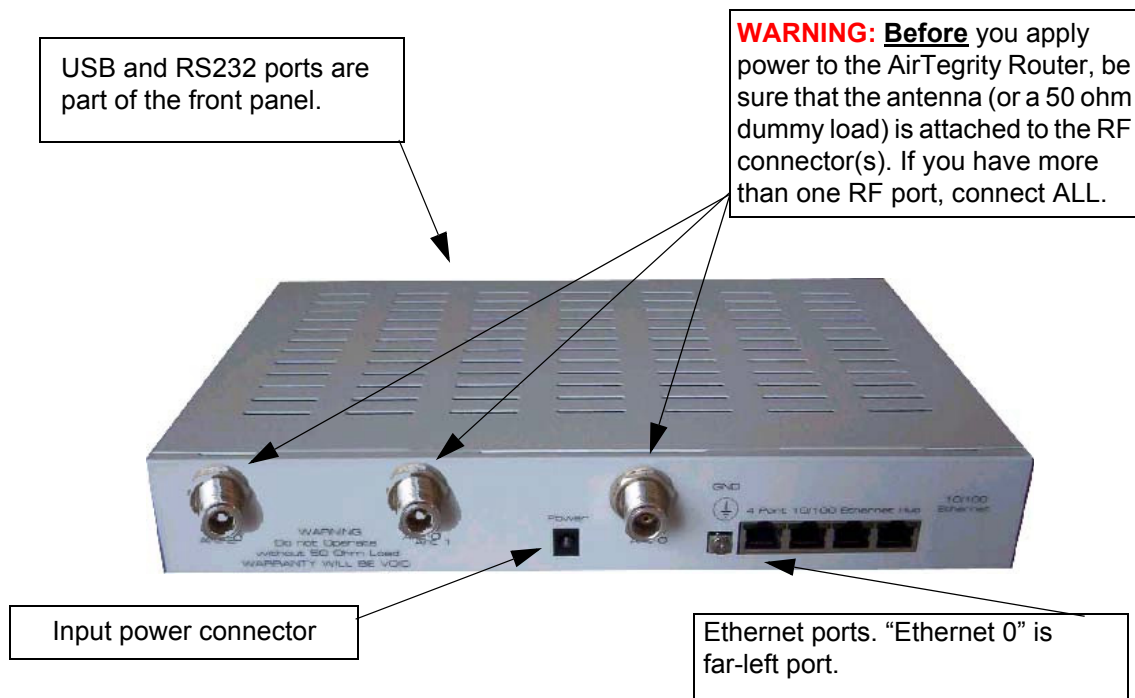
**Note** AirTegrity routers are available in a variety of models. Some models might not support all the features and hardware options described in this manual. This document covers the installation of the Series 4000 Router products.

---

## Location of Ports and Connectors

Before you apply electrical power to your Series 4000 Router, the following figure shows the locations of its various ports and connectors:

Figure 1-1 Back Panel of the Series 4000 Router



## Required Computer Equipment and Software

You need the following computer equipment and software:

- **Personal Computer (PC)** with one or more Ethernet ports:
  - **Ethernet Port and Ethernet Cable** (10BaseT 10/100 MHz Ethernet).

The Ethernet cables should be Category (CAT) 5 with 8-pin modular connectors on both ends. See ["Ethernet Cable Specifications" on page 1-3](#).



**Note** Your existing network router/switch must have an Ethernet hub or switch with two unused Ethernet ports connecting to the current LAN.

- **USB Port and USB cable**
- **RS232 (Serial) Port** (The serial port on the Series 4000 Router is a 9-pin subminiature D connector.)

You also need an RS232 straight-through cable that connects to your PC's RS232 port and the Router's RS232 port.

- **PC software:**

- **Terminal Emulation Program** (for example, Hyperterminal or Vicomsoft) is recommended to allow you to access the AOS CLI commands and other CLI administrative interfaces of the Series 4000 Router.

The WebUI provides all the functionality of AOS CLI with the exception of the unit's BIOS options. The BIOS options are available only to AirTegrity service agencies from the unit's USB or RS232 serial interface.

- **Web Browser** (for example, Internet Explorer and Mozilla). You must have a web browser if you do not have or cannot run a terminal emulation program.

Although we believe the Router will run on any reasonably standard browser, we cannot guarantee trouble-free operation with any browser other than Internet Explorer.

## Install the Ethernet Cabling

In this section the installation and selection of Ethernet cables for connection to the Series 4000 Router's Ethernet port is described. The Ethernet port also serves as the Router's 48V power port in a Power Over Ethernet (POE) configuration.

### Tools and Materials

You need the following tools and materials: (1) A medium flat-blade screwdriver, (2) Extra RJ-45 8-pin connectors, (3) Sufficient CAT5 cable for your installation. (4) An RJ-45 crimping tool for attaching the connectors to the cable.

For cable specifications, see [“Ethernet Cable Specifications” on page 1-3](#).

### Ethernet Cable Specifications

You must use only CAT5 (Category 5) cable for the Ethernet. The cable should meet either the T568A or T568B specification.

*Table 1-1 Cat 5 Cable Wire Colors*

|       | 1     | 2  | 3     | 4  | 5     | 6  | 7     | 8  |
|-------|-------|----|-------|----|-------|----|-------|----|
| T568A | Wh/Gr | Gr | Wh/Or | Bl | Wh/Bl | Or | Wh/Br | Br |
| T568B | Wh/Or | Or | Wh/Gr | Bl | Wh/Bl | Gr | Wh/Br | Br |

## Connect the Network Administration Computer to the Router

In this section we describe how to connect your computer to the AirTegrity Series 4000 Router. Once you have your PC talking to the Router, you will be ready to begin configuration of the Router for your network applications.

### Connecting your Browser to the Series 4000 Router

As described in the previous section, you need the following:

- PC with an Ethernet port

- Web browser
- Ethernet cables with the proper connectors
- Two free Ethernet ports that connect to your LAN - one for the Router and one for your PC.

Complete the following steps:

1. Connect your PC to your Ethernet LAN.
2. Connect the Series 4000 Router to your Ethernet LAN.
3. Does a DHCP server supply IP addresses to units on the Ethernet LAN? Does your PC get its IP address from a DHCP server (or DHCP relay) on this Ethernet LAN? If the answer is yes continue with [step 4](#). If the answer is no, continue with [step 10](#).
4. Verify that the DHCP server is connected to the Ethernet LAN and operating normally.
5. Power on the AirTegrity Router and the PC.
6. Wait about 1 minute for the Router to run through its boot up sequence and acquire an address from the DHCP server.
7. Access the DHCP server's logs or DHCP Table of leases to see the address assigned to the Series 4000 Router.
8. Start the browser on you PC and enter the URL with the IP address assigned to the Router. For example, if the previous step showed that the Router was given the address 192.168.1.101, then enter "http://192.168.1.101" in the location/address window of the browser.

Note the banner that runs across the top of the screen. It displays the following from left to right: *model number* (such as 4032 or 3001), *serial number* (typically 12 or more digits), the *number of currently connected users* and the *version number* of the AOS image currently running in your Router.

9. Continue with [step 14](#).
10. Power on the AirTegrity Router and the PC.
11. Wait about 3 minutes for the Router to run through its boot up sequence and determine that no DHCP server is available. Upon completion of bootup, the address of the Ethernet 0 port of the Router should be 192.168.0.2 -- assuming it is still configured with its factory defaults and that you have no DHCP server.
12. Configure your PC to have the static address 192.168.0.3.

In Windows, go the *Settings - Control Panel* and from there open the network management window. In Windows 2000, the network management window is called the *Network and Dial-up Connections* window.

After you have opened the network management dialog window in your PC, select the *Local Area Connection* device. This is the interfaces to your LAN.

Double-click to open *Local Area Connection* and click the *Properties* button.

A list of devices should appear. Select the *TCP/IP* device and click the *Properties* button.

Choose the *Use the following IP address:* option and enter 192.168.0.3. Click OK and close the dialog boxes to save your modifications to the LAN interface.

13. Start the browser on you PC and enter the URL of the Router: "http://192.168.0.2."

14. After entering the URL with the IP address of the Router, you should now be seeing the login screen of the Router's WebUI.

Note the banner that runs across the top of the screen. It displays the following from left to right: *model number* (such as 4032 or 3001), *serial number* (typically 12 or more digits), the *number of currently connected users* and the *version number* of the AOS image currently running in your Router.

15. If your browser and PC were configured with static IP addresses in [step 10](#) through [step 13](#), reconfigure those static IP addresses to be compatible with other equipment on the Ethernet LAN.

16. This concludes the procedure that connects the administrator's computer to the Router.

Continue with the [“Pole Mounting Instructions” on page -HIDDEN](#) for mounting on antenna towers and poles.

Continue with the *AOS CLI and WebUI Reference Guide* and the *AirTegrity Wireless Router Application Guide* (included in the User Documentation CD) for configuration instructions.

## Connecting to the Series 4000 Router through the RS232 Serial Console

Use a DB9 => DB9 straight-through cable and a terminal emulation program to connect to the Router's serial console port.

If you use HyperTerminal with Windows, go to: Start, Programs, Accessories, Communications, HyperTerminal. Select the COM port you will be using along with the following parameters:

Bits per Second: 115200

Data bits: 8

Parity: None

Stop bits: 1

Flow Control: None

## Installation Caution - READ THIS SECTION

This section contains important information about the installation and configuration of your Series 4000 Router router.

AirTegrity products *require* professional installation for the following reasons:

- The products are components of a solution and do not work stand-alone; they must be installed from a systems point of view, which an unqualified or inexperienced person would not be familiar with or aware of.
- Operation of these products as components of the overall system requires operating parameters be set on the products relative to the overall network, which an unqualified or inexperienced person will not have knowledge necessary to perform.

See the *AOS CLI and WebUI Reference Guide* for instructions on configuring the Router's parameters.

- As a wireless product requiring antenna installation, the antenna alignment is critical to operation of the unit. An unqualified or inexperienced person would not be able to perform antenna alignment. For example, they would need to know the exact location of the Base Station when installing a CPE device and they would experience in estimating the effect of obstructions, distance and weather.
- When installing an AirTegrity Base Station Router, the antennas are often be attached to antenna towers, which an inexperienced person could not and should not attempt to climb.



---

**Warning** It is not safe for an unqualified or inexperienced person to climb an antenna tower.

---

- Do not attempt to install antennas or Routers on towers or other dangerous locations. Consult with professionals licensed to perform the installation whenever there is any doubt about the safety of the installation locations and/or antenna configurations.



---

**Caution** Do not power up the Series 4000 Router unless you have an antenna or 50 ohm dummy load connected to the RF output. Failure to properly load the RF output will damage the router's RF circuitry.

---

---

# Hardware Features

# 2

The Series 4000 Router product is multi-protocol router supporting both wireless and wired interfaces. The Router is available in a variety of models and optional plug-in modules. Some models and plug-in configurations might not support all the features and hardware options described in this manual.

## Series 4000 Router

The Series 4000 Router has operational and status LEDs on the front panel. The functions of these LEDs vary depending on the mode that the Series 4000 Router is operating in. The front panel also supports the serial and USB interface and displays the activity LEDs for the Ethernet and RF interfaces. The RF interface ports and ethernet 0 ports are found on the back panel.

The serial console port is a DB9 connector configured as a DCE device. Use a straight through (not null-modem) cable to connect it to a terminal or PC.

*Figure 2-1 Series 4000 Router Front Panel*



The rear panel supports connections to power, ground, ethernet, and RF antenna.

*Figure 2-2 Series 4000 Router Rear Panel*



The power connector, mounted in the center of the back panel, supports international voltage and frequency input. Input Power Specification: 12VDC, 2.0A

The four port ethernet hub/switch supports 10/100 Mb Base-T LAN connections.

The RF antenna connector is an N-type male connector. Connect this to your antenna using a suitable RF quality cable. A minimum of LMR-400 cable should be used.

---

# A. Understanding Radio Frequency Transmission Power Values

The goal of this appendix is to familiarize the reader with basic technology concepts and terms involved in wireless communications specific to AirTegrity products.

The topics to be covered include

- Additive and subtractive effect by system components on the overall system.
- The Decibel (dB)
- Transmitted RF power measured in milliwatts (mW)
- Receiver sensitivity measured in -dB
- Cable loss measured in -dB
- Antenna Gain measured in dBs
- *Effective Isotropic Radiated Power (EIRP)* the measure of radiated power from an antenna.
- In addition, the reader will be introduced to the AirTegrity *Path Loss Calculator*, which is an estimation tool developed to assist with the design and deployment of outdoor wireless networks.

## Required Knowledge

Readers of this document should have an understanding of the electromagnetic radiation and its mathematical basis including the application of logarithms.

## Hardware and Software Versions

The concepts discussed in this paper are applicable to all hardware or software revision levels of AirTegrity products.

## The Decibel dB

In a system employing *radio frequency (RF)* transmission, a large number of component circuits contribute to the overall gain or loss and the calculation of the power ratio may become extremely laborious. To simplify this calculation, individual power ratios are expressed in a logarithmic unit, enabling addition to be employed in place of multiplication.

The logarithmic unit employed is the *decibel* (abbreviated to dB). The dB is a measure of the power of a signal as a function of its ratio to another standardized value.

(Mathematically, the number of dB is calculated as  $\text{dB} = 10 \cdot \log_{10}(P_1/P_2)$  where  $P_1$  and  $P_2$  are power levels.)

For example: Power (in dB) =  $10 * \log_{10} (\text{Signal/Reference})$

Where:

- Signal is the power of the signal from the RF transmitter
- (for example 50 mW)
- Reference is the reference power
- (for example 1 mw)

In the example:

Power (in dB) =  $10 * \log_{10} (50/1) = 10 * \log_{10} (50) = 10 * 1.7 = 17 \text{ dBm}$

Because the measurement decibel (dB) is a ratio comparing two power levels, you can use math equations to manipulate the dB level for designing and building networks.

Using the previous example:

Power (in dB) =  $10 * \log_{10} (5 * 10) = (10 * \log_{10} (5)) + (10 * \log_{10}(10)) = 7 + 10 = 17 \text{ dBm}$

Often the power level of device is measured in dB. Further, the symbol dB is often combined with other symbols to represent what values are being compared and sometimes numeric values to indicate power.

For example:

- dBm where the decibel value is being compared to 1 milliwatt (mW)
- dBW where the decibel value is being compared to 1 watt (w).

The following table shows a number of commonly used general rules:

**Table A-1 Change in dB versus Change in Power**

| An increase of:  | A decrease of:   | Produces:                           |
|------------------|------------------|-------------------------------------|
| 3dB of Tx power  |                  | Doubles transmit power              |
|                  | 3dB of Tx power  | Halves transmit power               |
| 10dB of Tx power |                  | 10 times the transmit power         |
|                  | 10dB of Tx power | Divides transmit power by 10        |
| 30dB of Tx power |                  | 1000 times the transmit power       |
|                  | 30dB of Tx power | Decreases transmit power 1000 times |

The following table shows how decibels are related to milliwatts:

**Table A-2 Approximate dBm to mW conversion values**

| Approximate dBm Antenna gain | Approximate mW transmit power at the RF interface as presented to the coaxial cable or antenna if directly attached |
|------------------------------|---------------------------------------------------------------------------------------------------------------------|
| 0dBm                         | 1mW                                                                                                                 |
| 1dBm                         | 1.25mW                                                                                                              |
| 2dBm                         | 1.56mW                                                                                                              |

**Table A-2 Approximate dBm to mW conversion values**

| <b>Approximate dBm Antenna gain</b> | <b>Approximate mW transmit power at the RF interface as presented to the coaxial cable or antenna if directly attached</b> |
|-------------------------------------|----------------------------------------------------------------------------------------------------------------------------|
| 3dBm                                | 2.0mW                                                                                                                      |
| 4dBm                                | 2.5mW                                                                                                                      |
| 5dBm                                | 3.12mW                                                                                                                     |
| 6dBm                                | 4.0mW                                                                                                                      |
| 7dBm                                | 5.0mW                                                                                                                      |
| 8dBm                                | 6.25mW                                                                                                                     |
| 9dBm                                | 8.0mW                                                                                                                      |
| 10dBm                               | 10.0mW                                                                                                                     |
| 11dBm                               | 12.5mW                                                                                                                     |
| 12dBm                               | 16.0mW                                                                                                                     |
| 13dBm                               | 20.0mW                                                                                                                     |
| 14dBm                               | 25.0mW                                                                                                                     |
| 15dBm                               | 32.0mW                                                                                                                     |
| 16dBm                               | 40.0mW                                                                                                                     |
| 17dBm                               | 50.0mW                                                                                                                     |
| 18dBm                               | 64.0mW                                                                                                                     |
| 19dBm                               | 80.0mW                                                                                                                     |
| 20dBm                               | 100.0mW                                                                                                                    |
| 21dBm                               | 128.0mW                                                                                                                    |
| 22dBm                               | 160.0mW                                                                                                                    |
| 23dBm                               | 200.0mW                                                                                                                    |
| 24dBm                               | 256.0mW                                                                                                                    |
| 25dBm                               | 320.0mW                                                                                                                    |
| 26dBm                               | 400.0mW                                                                                                                    |
| 27dBm                               | 512.0mW                                                                                                                    |
| 28dBm                               | 640.0mW                                                                                                                    |
| 29dBm                               | 800.0mW                                                                                                                    |
| 30dBm                               | 1000.0mW or 1 Watt                                                                                                         |

The table above clearly shows the logarithmic effect of the increase of dBm against the respective mW power.

For example:

1. If 0dB = 1mW, then 14dB = 25mW.
2. If 0dB = 1mW, then 10dB = 10mW, and 20dB = 100mW.
3. Subtract 3dB from 100 mw to drop the power by half (17dB = 50mW), then subtract 3dB again to drop the power by 50% yet again (14dB = 25mW.)



**Note** Additionally, there are other representations of dB that relate specifically to antenna systems, that include dBd (dipole), dBi (isotropic). These are discussed later.

## Estimating Cable Loss

The use of coaxial cable between the base station equipment or subscriber station equipment and the associated antenna, introduces impedance or attenuation to the transmitted signal coming from the radio module in the Series 4000 Router.

This table shows the approximate signal attenuation. The table has been developed using product information from Times Microwave Systems™ LMR product.

**Table A-3 Typical Cable Losses at 2.5 and 5.8 Ghz**

| Frequency in MHz | 2500 (2.5Ghz)       | 5800 (5.8Ghz)      |
|------------------|---------------------|--------------------|
| LMR cable number | Attenuation dB/100) | Attenuation dB/100 |
| 200              | 16.90               | 26.35              |
| 240              | 12.90               | 20.35              |
| 300              | 10.40               | 16.55              |
| 400              | 6.80                | 10.82              |
| 500              | 5.50                | 8.86               |
| 600              | 4.40                | 7.26               |
| 900              | 2.98                | 4.87               |

For AirTegrity applications, terminate the ends of the RF cable with male N-type connectors. N-type connectors introduce impedance, typically 0.6dB per connector, assuming proper installation.

## Antennas

An antenna is any structure or device used to collect or radiate electromagnetic waves. Furthermore, an antenna is a device that converts radio frequency electrical energy to radiated electromagnetic energy and vice versa. Antennas focus the electromagnetic energy and the effective gain from the focusing is expressed in dB compared to a hypothetical isotropic antenna or a reference dipole antenna.

The primary classes of antenna are based on their three-dimensional radiation patterns: *sectoral*, *omni-directional* and *directional*.

In addition, there are some 24 specific physical types antennas grouped into 6 categories. (Detailed descriptions of the physical types or categories is beyond the scope of this document.) For reference the 6 categories are:

- Basic
- Loops, Dipoles and Slots
- Opened-out coaxial, twin line and waveguide
- Reflector and Aperture
- End-fire broadband
- Flat panel, slot and grid arrays

When the gain of actual physical antennas is expressed, two standards of decibel measurements are commonly employed:

- Isotropic antennas use the measure of *decibels isotropic (dBi)*, where decibels are referenced to the gain of a theoretical isotropic radiator.

*Isotropic antennas* are hypothetical omni-directional antennas that radiate or receive equally in all directions. Isotropic antennas do not physically exist but represent convenient reference antennas for expressing directional properties of physical antennas.

Antenna designs are generally compared to the dBi system to assess their respective viability. The FCC (US regulatory authority) compares antenna submissions against the dBi system.

- Dipole antennas use the measure of *decibels dipole (dBd)*, where decibels are referenced to the gain of a theoretical dipole radiator. However; it is not uncommon to find most antennas quoted with dBi. There is a power rating differential between dBd and dBi which is approximately 2.2; that is,  $0 \text{ dBd} = 2.2 \text{ dBi}$ . An antenna that is rated as a 3 dBd would be rated as 5.2 dBi ( $3 + 2.2 = 5.2$ )

*Dipole antennas* are category of antennas whose design is a variance of the basic electric dipole. Many physical antenna designs, including many in the 6 categories listed above, are variants of the basic dipole antenna. Accordingly, these antennas are often rated using dBd. However, the dBi system is also used by many antennas manufacturers for dipole variants.

## Gain

Gain is the ratio of output current, voltage, or power to input current, voltage, or power, respectively. Gain is usually expressed in dB. If the ratio is less than unity, the gain, expressed in dB, will be negative, in which case there is a loss between input and output.

## Amplifiers

Amplifiers are an electronic component that boosts the voltage or power level of a received signal. The output signal from the amplifier that is a linear replica of the input signal, but with greater power or voltage level, and sometimes with an impedance transformation. Often, depending on the requirement it is not unusual to find third party inline amplifiers wired into the coaxial cabling system.

## Effective Isotropic Radiated Power

The radiated (transmitted) power is rated in either dBm or watts. Power coming off an antenna is measured as *Effective Isotropic Radiated Power (EIRP)*. EIRP is the value that regulatory agencies such as the FCC or European Telecommunications Standards Institute (ETSI) use to determine and measure power limits in applications such as 2.4 GHz wireless equipment. EIRP is calculated by adding the transmitter power (in dBm) to antenna gain (in dBi) and subtracting any cable losses (in dB.)

## Path Loss

AirTegrity has developed a tool called the *Path Loss Calculator* that will help you to design and deploy your outdoor system. The Path Loss Calculator found at [Outdoor Path Calculator](#) is designed primarily for outdoor application estimates, but may be used to gain rough estimates for indoor applications.

The distance a signal can be transmitted depends on several factors. The primary hardware factors involved are

- Transmitter power
- Cable losses between transmitter and its antenna
- Antenna gain of the transmitter
- Localization of the two antennas, line-of-sight and distance apart. At frequencies below 7GHz and over distances less than 5km there are no significant environmental effects from rain, fog or snow
- Receiving antenna gain
- Cable losses between receiver and its antenna
- Receiver sensitivity

## Receiver Sensitivity

*Receiver sensitivity* is defined as the minimum signal power level (in dBm or mW) for the receiver to accurately decode a given signal. Since dBm is compared to 0mW, 0dBm is relative. The following table shows example values of receiver sensitivity.

**Table A-4 Receiver Sensitivity**

| <b>dBm</b> | <b>mW</b> |
|------------|-----------|
| 10 dBm     | 10 mW     |
| 3 dBm      | 2 mW      |
| 0 dBm      | 1 mW      |
| -3 dBm     | 0.5 mW    |
| -10 dBm    | 0.01 mW   |
| -20 dBm    | 0.001 mW  |

**Table A-4 Receiver Sensitivity**

| dBm     | mW            |
|---------|---------------|
| -30 dBm | 0.0001 mW     |
| -40 dBm | 0.00001 mW    |
| -50 dBm | 0.000001 mW   |
| -60 dBm | 0.0000001 mW  |
| -70 dBm | 0.00000001 mW |

## Outdoor and Indoor Propagation and Range

The following guidelines show the approximate effects of range and other factors on wireless propagation outdoors and indoors.

### Outdoors

Wireless propagation outdoors is mainly a factor of distance, although other factors such as weather, reflection and multi-pathing can also come into play.

Effect of Distance on Wireless Propagation Outdoors:

- For every increase of 6dB, the coverage area doubles
- For every decrease of 6dB, the coverage area is cut in half

You can make adjustments for range by choosing antennas with higher (or lower) gain or by using longer (or shorter) antenna cables.

### Indoors

Estimating indoor RF propagation is particularly difficult. Indoor applications vary greatly in design and concept from outdoor applications. In indoor applications, RF signals suffer greatly from signal attenuation, reflection and multi-pathing all being relative to the application environment.



**Note** Due to these factors, reasonably accurate path loss calculators of RF propagation for indoor environments is virtually impossible. However, there are some quick calculations that you can do to estimate performance.

Effect of Distance on Wireless Propagation Indoors (See preceding note):

- For every increase of 9dB, the coverage area doubles
- For every decrease of 9dB, the coverage area is cut in half

---

## B. Maximum Power Levels and Permitted Channels in Regulatory Domains

This appendix contains the maximum power levels and radio channels permitted by various regulatory domains. Specifications for IEEE 802.11a and IEEE 802.11b systems are presented.

Links to the table in this appendix follow:

- [Maximum Power Levels per Antenna Gain for IEEE 802.11a Table B-1](#)
- [Maximum Power Levels Per Antenna Gain for IEEE 802.11b Table B-2](#)
- [IEEE 802.11a Channels Table B-3](#)
- [IEEE 802.11b Channels Table B-3](#)

### Maximum Power

This section contains lists the maximum radio power levels at specific antenna gains for each regulatory domain.

The following table shows the maximum power levels and antenna gains allowed for each IEEE 802.11a regulatory domain. The maximum power level is specified in equivalent isotropic radiated power (EIRP). An improper combination of power level and antenna gain can result in EIRP above the amount allowed per regulatory domain.

**Table B-1 Maximum Power Levels per Antenna Gain for IEEE 802.11a**

| Regulatory Domain                                                                                                    | Maximum Power Level (mW) with 6-dBi Antenna Gain |
|----------------------------------------------------------------------------------------------------------------------|--------------------------------------------------|
| US, Canada, Central and South America (160 mW EIRP maximum on channels 36-48, 800 mW EIRP maximum on channels 52-64) | 40                                               |
| Japan (10 mW/MHz EIRP maximum)                                                                                       | 40                                               |
| Singapore (100 mW EIRP maximum)                                                                                      | 20                                               |
| Taiwan (800 mW EIRP maximum)                                                                                         | 40                                               |

The following table shows the maximum power levels and antenna gains allowed for each IEEE 802.11b regulatory domain. The maximum power level is specified in equivalent isotropic radiated power (EIRP). An improper combination of power level and antenna gain can result in EIRP above the amount allowed per regulatory domain.

**Table B-2 Maximum Power Levels Per Antenna Gain for IEEE 802.11b**

| Regulatory Domain                                          | Antenna Gain (dBi) | Maximum Power Level (mW) |
|------------------------------------------------------------|--------------------|--------------------------|
| US, Canada, Central and South America<br>(4W EIRP maximum) | 0                  | 100                      |
|                                                            | 2.2                | 100                      |
|                                                            | 5.2                | 100                      |
|                                                            | 6                  | 100                      |
|                                                            | 8.5                | 100                      |
|                                                            | 12                 | 100                      |
|                                                            | 13.5               | 100                      |
| EMEA<br>(100 mW EIRP maximum)                              | 0                  | 100                      |
|                                                            | 2.2                | 50                       |
|                                                            | 5.2                | 30                       |
|                                                            | 6                  | 30                       |
|                                                            | 8.5                | 5                        |
|                                                            | 12                 | 5                        |
|                                                            | 13.5               | 5                        |
| Israel<br>(100 mW EIRP maximum)                            | 0                  | 100                      |
|                                                            | 21                 | 1                        |
|                                                            | 2.2                | 50                       |
|                                                            | 5.2                | 30                       |
|                                                            | 6                  | 30                       |
|                                                            | 8.5                | 5                        |
|                                                            | 12                 | 5                        |
|                                                            | 13.5               | 5                        |
|                                                            | 21                 | 1                        |

**Table B-2 Maximum Power Levels Per Antenna Gain for IEEE 802.11b**

| Regulatory Domain                 | Antenna Gain (dBi) | Maximum Power Level (mW) |
|-----------------------------------|--------------------|--------------------------|
| China<br>(10 mW EIRP maximum)     | 0                  | 5                        |
|                                   | 2.2                | 5                        |
|                                   | 5.2                | n/a                      |
|                                   | 6                  | n/a                      |
|                                   | 8.5                | n/a                      |
|                                   | 12                 | n/a                      |
|                                   | 13.5               | n/a                      |
|                                   | 21                 | n/a                      |
| Japan<br>(10 mW/MHz EIRP maximum) | 0                  | 50                       |
|                                   | 2.2                | 30                       |
|                                   | 5.2                | 30                       |
|                                   | 6                  | 30                       |
|                                   | 8.5                | n/a                      |
|                                   | 12                 | n/a                      |
|                                   | 13.5               | 5                        |
|                                   | 21                 | n/a                      |

## Channels

This section contains lists the permitted radio channels for each regulatory domain.

The channel identifiers, channel center frequencies, and regulatory domains of each IEEE 802.11a 20-MHz-wide channel are listed in the following table.

**Table B-3 IEEE 802.11a Channels**

| Channel ID | Frequency (MHz) | Regulatory Domains                    |       |           |        |
|------------|-----------------|---------------------------------------|-------|-----------|--------|
|            |                 | US, Canada, Central and South America | Japan | Singapore | Taiwan |
| 34         | 5170            | -                                     | X     | --        | -      |
| 36         | 5180            | X                                     | -     | X         | -      |
| 38         | 5190            | -                                     | X     | -         | -      |
| 40         | 5200            | X                                     | -     | X         | -      |

**Table B-3 IEEE 802.11a Channels**

| Channel ID | Frequency (MHz) | Regulatory Domains                    |       |           |        |
|------------|-----------------|---------------------------------------|-------|-----------|--------|
|            |                 | US, Canada, Central and South America | Japan | Singapore | Taiwan |
| 42         | 5210            | -                                     | X     | -         | -      |
| 44         | 5220            | X                                     | -     | X         | -      |
| 46         | 5230            | -                                     | X     | -         | -      |
| 48         | 5240            | X                                     | -     | X         | -      |
| 52         | 5260            | X                                     | -     | -         | X      |
| 56         | 5280            | X                                     | -     | -         | X      |
| 60         | 5300            | X                                     | -     | -         | X      |
| 64         | 5320            | X                                     | -     | -         | X      |
| 149        | 5745            | -                                     | -     | -         | -      |
| 153        | 5765            | -                                     | -     | -         | -      |
| 157        | 5785            | -                                     | -     | -         | -      |
| 161        | 5805            | -                                     | -     | -         | -      |

The channel identifiers, channel center frequencies, and regulatory domains of each IEEE 802.11b 22-MHz-wide channel are listed below.

**Table B-4 IEEE 802.11b Channels**

| Channel ID | Frequency (MHz) | Regulatory Domains                    |      |        |       |       |
|------------|-----------------|---------------------------------------|------|--------|-------|-------|
|            |                 | US, Canada, Central and South America | EMEA | Israel | China | Japan |
| 1          | 2412            | X                                     | X    | -      | X     | X     |
| 2          | 2417            | X                                     | X    | -      | X     | X     |
| 3          | 2422            | X                                     | X    | -      | X     | X     |
| 4          | 2427            | X                                     | X    | -      | X     | X     |
| 5          | 2432            | X                                     | X    | X      | X     | X     |
| 6          | 2437            | X                                     | X    | X      | X     | X     |
| 7          | 2442            | X                                     | X    | X      | X     | X     |
| 8          | 2447            | X                                     | X    | X      | X     | X     |
| 9          | 2452            | X                                     | X    | -      | X     | X     |

**Table B-4 IEEE 802.11b Channels**

| Channel ID | Frequency (MHz) | Regulatory Domains                    |      |        |       |       |
|------------|-----------------|---------------------------------------|------|--------|-------|-------|
|            |                 | US, Canada, Central and South America | EMEA | Israel | China | Japan |
| 10         | 2457            | X                                     | X    | -      | X     | X     |
| 11         | 2462            | X                                     | X    | -      | X     | X     |
| 12         | 2467            | -                                     | X    | -      | -     | X     |
| 13         | 2472            | -                                     | X    | -      | -     | X     |
| 14         | 2484            | -                                     | -    | -      | -     | X     |



**Note** In Mexico, channels 1 through 8 are for indoor use only. Channels 9 through 11 can be used indoors and outdoors. Users are responsible for ensuring that the channel set configuration complies with Mexico's regulatory standards.

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