

Operating Manual

HP900

OEM 900 MHz Spread Spectrum Wireless Module

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Angel Aerial Systems

www.angelaerialsystems.com

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HP900 Regulatory Requirements

PLEASE READ THIS SECTION CAREFULLY



WARNING:

To satisfy FCC RF exposure requirements for mobile transmitting devices, a separation distance of 35 cm or more should be maintained between the antenna of this device and persons during device operation. To ensure compliance, operations at closer than this distance is not recommended. The antenna used for this transmitter must not be co-located in conjunction with any other antenna or transmitter.



WARNING:

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.



WARNING:

Changes or modifications not expressly approved by Angel Aerial Systems Inc. could void the user's authority to operate the equipment. This device has been tested with the antennas listed in Appendix A. When integrated in OEM products, fixed antennas require installation preventing end-users from replacing them with non-approved antennas. Antennas not listed in the tables must be tested to comply with FCC Section 15.203 (unique antenna connectors) and Section 15.247 (emissions).



WARNING:

MAXIMUM EIRP

FCC Regulations allow up to 36 dBm equivalent isotropically radiated power (EIRP). Therefore, the sum of the transmitted power (in dBm), the cabling loss and the antenna gain cannot exceed 36 dBm.



WARNING:

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

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



WARNING:

EQUIPMENT LABELING

The FCC numbers depend on the model of the radio module. Do NOT use the Marketing Name of the product but the Model to distinguish the Certifications Numbers. This device has been modularly approved. The manufacturer, product name, and FCC identifier of this product must appear on the outside label of the end-user equipment.

SAMPLE LABEL REQUIREMENT for Model: HP900:

Contains:
FCC ID: NS9HP900
This device complies with Part 15 of the FCC 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.

Co-Location with Cellular Modems

FCC: The maximum calculated MPE ratio for the EUT with 3 dBi dipole antenna is 0.216 (evaluated at 35 cm), this configuration can be co-located with other antennas provided the sum of the MPE ratios for all the other simultaneous transmitting antennas incorporated in a host device is $\leq 1.0 - 0.216 \leq 0.784$. The following co-location were evaluated for mobile configurations:

- 1) EUT with 3 dBi dipole antenna co-located with LTE Data Module LM940
(FCC ID RI7LM940, IC: 5131A-LM940)
- 2) EUT with 3 dBi dipole antenna co- located with LTE Data Module L850
(FCC ID ZMOL850GL, IC 21374-L850GL)
- 3) EUT with 3 dBi dipole antenna co- located with LTE Data Module SARA-R410M
(FCC ID XPY2AGQN4NNN, IC 8595A-2AGQN4NNN)
- 4) EUT with 3 dBi dipole antenna co- located with LTE Data Module LE910-NA-V2
(FCC ID RI7LE910NAV2, IC 5131A-LE910NAV2)

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2. General

2.0 Product Overview

The HP900 is a high-performance embedded wireless data transceiver. Operating in the 902 - 928 MHz ISM band, this frequency-hopping spread-spectrum module is capable of providing reliable wireless data transfer between almost any type of equipment which uses an asynchronous serial interface. The small-size and superior RF performance of this module make it ideal for many applications.

While a pair of HP900 modules can link two terminal devices (“point-to-point” operation); multiple modules can be used together to create a network of various topologies, including “point-to-multipoint” and “repeater” operation. Multiple independent networks can operate concurrently, so it is possible for unrelated communications to take place in the same or a nearby area without sacrificing privacy or reliability.

1.1 Features

Key features of the HP900 include:

- transmission within a public, license-exempt band of the radio spectrum¹ – this means that it can be used without access fees (such as those incurred by cellular airtime).
- a serial I/O data port with handshaking and hardware flow control, allowing the HP900 to interface directly to any equipment with an asynchronous serial interface.
- ease of installation and use – the HP900 module uses a subset of standard AT style commands, very similar to those used by traditional telephone line modems.
- all units in a system are physically identical, and can be configured as a master, repeater or slave using the AT command set. No hardware modifications are required
- 128 sets of user-selectable pseudo-random hopping patterns, intelligently designed to offer the possibility of separately operating multiple networks while providing security, reliability and high tolerance to interference.
- encryption key with 65536 user-selectable values to maximize security and privacy of communications.
- 32-bit of CRC error detection and auto re-transmit to provide accuracy and reliability of data.

¹ 902-928 MHz, which is license-free within North America; may need to be factory-configured differently for some countries.

- TDMA (time division multiple access) support, allowing multi-slave access in point-to-point mode.
- roaming ability, allowing repeaters and slaves to re-synchronize with a new master if the synchronization pulse from the original master is lost.

While the typical application for the HP900 is to provide a short- to mid-range wireless communications link between DTEs, it can be adapted to almost any situation where an asynchronous serial interface is used and data intercommunication is required.

2.1 Output Power Level

The Output Power Level determines at what power the HP900 transmits. The HP900's sensitive receiver can operate with very low power levels, so it is recommended that the lowest power necessary is used; using excessive power contributes to unnecessary "RF pollution".

Ideally, you should test the communications performance between units starting from a low power level and working upward until the RSSI is sufficiently high and a reliable link is established. The conditions will vary widely between applications, the output power settings can be calculated based on following information.

- Transmitter antenna gain
- Cable loss
- Equivalent Isotropically Radiated Power (EIRP) requirement by FCC Regulations

$$\text{Power Setting} = 36 - \text{Antenna Gain} - \text{Cable Loss}$$

The power setting must be no more than the above calculation value. Any higher is a violation of FCC rules. See IMPORTANT warning below.

Table 1 Output Power

Power Setting (dBm)	Approx. Output Power (mW)
0	1
20	100
21	125
22	160
23	200
24	250
25	320
26	400
27	500
28	630
29	800
30	1000

3. Installation

3.0 Overview

The HP900 complies with FCC part 15 at the modular level for operation in the license-free 902-928 MHz ISM band. This chapter provides guidelines for installing and deploying equipment which incorporates the HP900 module.

3.1 Estimating the Gain Margin

Successful communication between HP900 modules is dependent on three main factors:

- System Gain
- Path Loss
- Interference

System gain is a calculation in dB describing the performance to be expected between a transmitter-receiver pair. The number can be calculated based on knowledge of the equipment being deployed. The following four factors make up a system gain calculation:

1. Transmitter power (user selectable)
2. Transmitter gain (transmitting antenna gain minus cabling loss between the transmitting antenna and the HP900 module)
3. Receiver gain (Receiving antenna gain minus cabling loss between the receiving antenna and the module)
4. Receiver sensitivity (Specified as -108dBm on the HP900 module)

In the following illustration, the transmitting antenna has a gain of 6 dB, and the receiving antenna has a gain of 3 dB. The cable loss between the module and the antenna is 2 dB on both the transmitting and receiving side.

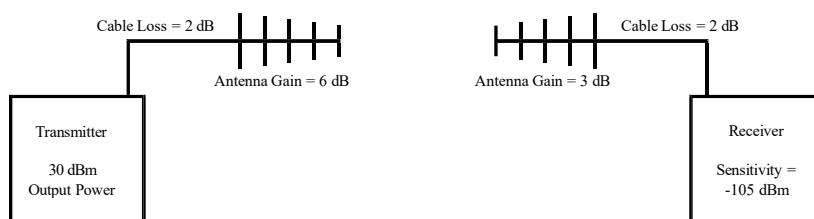


Figure 1 Gain Calculation

The power level has been set to 30dBm (1W) on the transmitter, and the receiver sensitivity for the HP900 is -108dBm.

System gain would be calculated to be:

$$30 - 2 + 6 + 3 - 2 + 108 = 143 \text{ dB.}$$

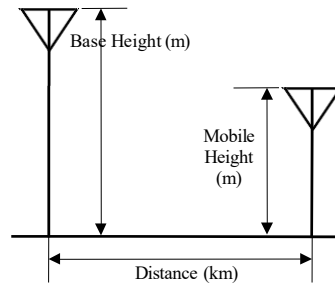


Figure 2 System Deploying

When deploying your system, care must be taken to ensure the **path loss** (reduction of signal strength from transmitter to receiver in dB) between equipment does not exceed the system gain (140 dB in the above example). It is recommended to design for a **gain margin** of at least 20 dB to ensure reliable communication. Gain margin is the difference between system gain and path loss. Referring to the same example, suppose the path loss is 100 dB, the gain margin would be 40 dB, which is more than adequate for reliable communication.

Path loss is a very complicated calculation which mainly depends on the terrain profile, and the height of the antennas off the ground.

The following table provides path loss numbers for varying antenna heights and antenna separation: These numbers are real averages taken from rural environments. They do not apply to urban, non-line-of-sight environments.

Table 2 Path Loss

Distance (km)	Base Height (m)	Mobile Height (m)	Path Loss (dB)
5	15	2.5	116.5
5	30	2.5	110.9
8	15	2.5	124.1
8	15	5	117.7
8	15	10	105
16	15	2.5	135.3
16	15	5	128.9
16	15	10	116.2
16	30	10	109.6
16	30	5	122.4
16	30	2.5	128.8

Once the equipment is deployed, you can verify the signal strength by entering into Command Mode and reading Register S123. This register provides the average signal strength in dBm. The minimum strength for communication is roughly -108dBm. For consistent reliable communication, you should try to deploy the equipment such that signal strength exceeds -95dBm.

3.2 Antennas and Cabling

This section describes the recommended procedure for PCB design for the Antenna Connector and installing cabling and antennas for use with the HP900 module.

3.2.1 PCB Requirements for Antenna Interface

The HP900 provides an RF interface for connecting an external antenna through a PCB pad (#45 **RF_Antenna**) for RF signal transmission and reception. A PCB must be designed that incorporates a 50 Ω trace to a RP-SMA connector for the HP900 to interface to an external antenna. A high quality 50 Ω RF connector, such as a RP-SMA connector, provides proper PCB-to RF-cable transition.

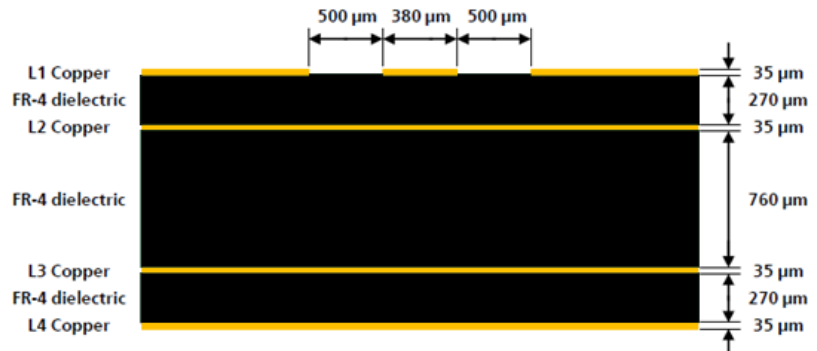
Proper transition between **RF_Antenna** pad and the application board PCB must be provided by following the design guidelines for the layout of the application PCB close to the **RF_Antenna** pad:

- On a multilayer board, the layer stack below the RF connection should be free of digital lines
- Increase GND clearance around the **RF_Antenna** pad, on the top layer of the PCB, to at least 250 μm up to adjacent pads metal definition and up to 400 μm on the area below the module, to reduce parasitic capacitance to ground.
- Add GND clearance on the buried metal layer below the **RF_Antenna** pad if the top-layer to buried layer dielectric thickness is below 200 μm , to reduce parasitic capacitance to ground.

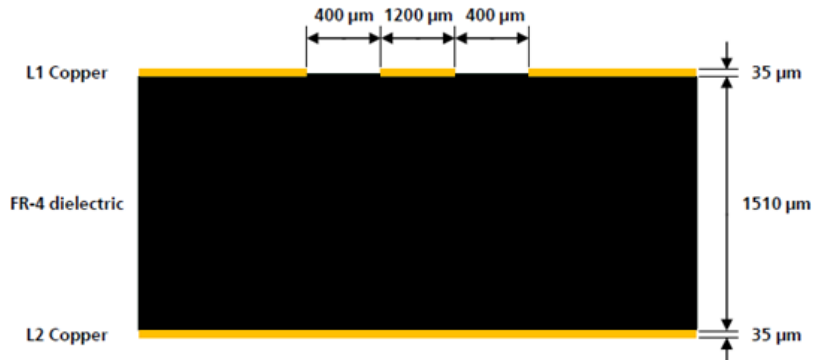
3.2.2 PCB Requirements for RF Transmission line design

Any RF transmission line, such as the ones from the **RF_Antenna** pad up to the related antenna connector or up to the related internal antenna pad, must be designed so that the characteristic impedance is as close as possible to 50 Ω .

The following figures provide two examples of proper 50 Ω coplanar waveguide designs. The first example is of a RF transmission line implemented in a 4-layer PCB, and the second is an example of a RF transmission line implemented in a 2-layer PCB.



Example of 50 Ω coplanar waveguide transmission line for 4-layer PCB



Example of 50 Ω coplanar waveguide transmission line for 2-layer PCB

To achieve a 50 Ω characteristic impedance, the width of the transmission line must be chosen depending on:

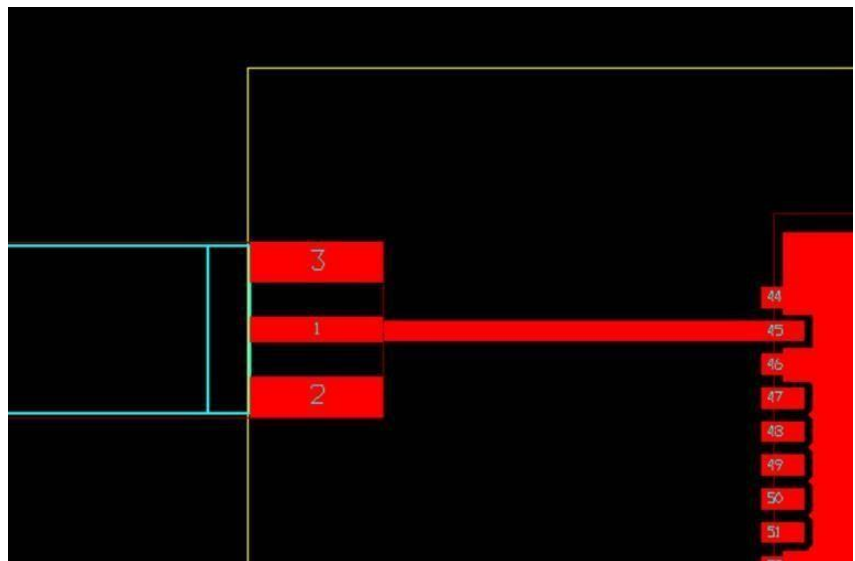
- the thickness of the transmission line itself (e.g. 35 μm)
- the thickness of the dielectric material between the top layer and the next inner layer implementing the ground plane (e.g. 270 μm (4-Layer), 1510 μm (2-Layer))
- the dielectric constant of the dielectric material (e.g. dielectric constant of the FR-4 dielectric material)
- the gap from the transmission line to the adjacent ground plane on the same layer of the transmission line (e.g. 500 μm in 4 Layer, 400 μm in 2 Layer boards).

In Addition to the 50 Ω impedance, the following guidelines are recommended for transmission lines design:

- Minimize the transmission line length: the insertion loss should be minimized as much as possible
- Add GND clearance on buried metal layers below any pad of component present on the RF transmission lines, if top-layer to buried layer dielectric thickness is below 200 μm , to reduce parasitic capacitance to ground

- The transmission lines width and spacing to GND must be uniform and routed as smoothly as possible: avoid abrupt changes of width and spacing to GND
- Add GND stitching vias around transmission lines
- Ensure solid metal connection of the adjacent metal layer on the PCB stack-up to main ground layer, providing enough vias on the adjacent metal layer
- Route RF transmission lines far from any noise source and from any sensitive circuits
- Avoid stubs on the transmission lines
- Avoid signal routing in parallel to transmission lines or crossing the transmission lines on buried metal layer
- Do not route microstrip lines below discrete component or other mechanics placed on top layer

An example of proper RF circuit design is shown below. In this case, the **RF_Antenna** pin is directly connected to SMA connectors by means of a 50Ω transmission line, with the recommended design layout.



3.2.3 Internal Cabling

The most common method for installing the module is to run a cable from the RPSMA antenna connector on the application PCB to a reverse TNC bulkhead connector on the chassis of the equipment as shown in

Figure 3. This cable can be purchased from Angel Aerial Systems.

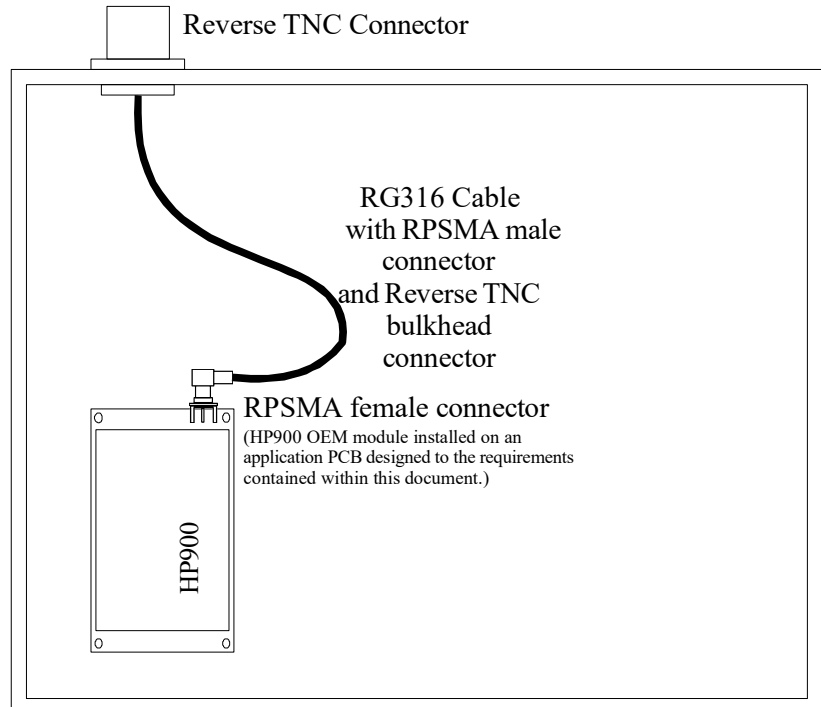


Figure 3 Suggested Internal Cabling

Cable losses are negligible for the short piece used within the chassis. Additional losses up to 0.5 dB may be present in the RPSMA and Reverse TNC connections.

**WARNING:**

To satisfy FCC RF exposure requirements for mobile transmitting devices, a separation distance of 35 cm or more should be maintained between the antenna of this device and persons during device operation. To ensure compliance, operations at closer than this distance is not recommended. The antenna used for this transmitter must not be co-located in conjunction with any other antenna or transmitter.

**WARNING:**

Direct human contact with the antenna is potentially unhealthy when the HP900 is generating RF energy. Always ensure that the HP900 equipment is powered down during installation.

**WARNING:**

Never work on an antenna system when there is lightning in the area.

3.2.4 Installing External Cables, Antennas and Lightning Arrestors

Never work on an antenna system when there is lightning in the area.

Direct human contact with the antenna is potentially unhealthy when the HP900 is generating RF energy. Always ensure that the HP900 equipment is powered down during installation. At all times a distance of 35 cm must be maintained between the antenna and any person when the device is in operation.

Surge Arrestors

The most effective protection against lightning is to install two lightning (surge) arrestors, one at the antenna, the other one at the interface with the equipment. The surge arrestor grounding system should be fully interconnected with the transmission tower and power grounding systems to form a single, fully integrated ground circuit. Typically, both ports on surge arrestors are N-female.

External Filter

Although the HP900 is capable of filtering out RF noise in most environments, there are circumstances that require external filtering. Paging towers and cellular base stations in close proximity to the HP900 antenna can desensitize the receiver. Angel Aerial Systems' external cavity filter eliminates this problem. The filter has two N-female ports and should be connected in line at the interface to the RF equipment.

Weatherproofing

RPSMA and RPTNC connectors are not weatherproof. All connectors should be taped with rubber splicing tape (weatherproofing tape), and then coated with a sealant.

Cabling

The following coax cables are recommended:

Table 3 Cable Loss

Cable	Loss (dB/100ft)
LMR 195	10.7
LMR 400	3.9
LMR 600	2.5

Factors to take into consideration when choosing a cable are:

- price;
- bend radius limitations (the lower performance cables generally can bend more sharply)
- performance requirements; and,
- distance between the equipment and the antenna.

**WARNING:**

MAXIMUM EIRP
FCC and IC Regulations allow up to 36dBm effective isotropically radiated power (EIRP). Therefore, the sum of the transmitted power (in dBm), the cabling loss and the antenna gain cannot exceed 36 dBm with respect to the isotropic radiator.

**WARNING:**

The HP900 can only be used with any antennas listed in Appendix A.

**WARNING:**

Be careful with dBi vs dBd gains on antenna specifications. Antenna manufactures may not clearly indicate the gain on the antenna if it is dBd or dBi. Note 1dBd = 2.15dBi.

When installing the cable, always begin fastening at the top near the antenna connector/surge arrestor. The cable must be supported at the top with a hose clamp or wrap lock, and at 5 ft intervals down the length of the tower. Over-tightening the fasteners will dent the cable and reduce performance. If properly grounded surge arrestors are not installed at both the top and the bottom of the cable, then the cable should be grounded to the tower at these locations using a cable grounding kit. If the tower is non-conductive, then a separate conductor, physically separate from the cable, should be run down the tower.

Antenna

Before choosing an antenna, you should have some knowledge of the path loss and the topology of the equipment. If the equipment is in a fixed location and is to communicate with only one other unit also in a fixed location, then a Yagi antenna is suitable. Choose a Yagi with enough gain to ensure adequate gain margin. When deploying the Yagi, point the antenna towards the intended target, ensuring the antenna elements are perpendicular to the ground for vertical polarization.

In applications where there are multiple units that you must communicate with or units, which are in motion, you may select an Omni-directional antenna with appropriate gain.

See appendix A for a list of approved antennas that can be used with the HP900 radio modem. If you require another type of antenna please contact Angel Aerial Systems Inc. The HP900 CANNOT be used with any antenna that does not appear in Appendix A.

Angel Aerial Systems Inc. can provide you with approved antennas to ensure FCC compliance.

FCC Regulations allow up to 36dBm effective isotropically radiated power (EIRP). Therefore, the sum of the transmitted power (in dBm), the cabling loss and the antenna gain cannot exceed 36dBm with respect to the isotropic radiator.

EIRP is calculated as follows:

$$\text{EIRP} = \text{Tx Power(dBm)} - \text{Cable/Connector Loss(dB)} + \text{Ant Gain(dBi)}$$

Antenna Gains must be in dBi when calculating the 36dBm EIRP limit.

$$1\text{dBd} = 2.15\text{dBi}$$

Use the guidelines in the previous section for calculating cable and connector losses. If cabling and connector losses are 2 dB, then the maximum allowable gain of the antenna will be 8 dB.

Examples of Antenna and Power settings to maintain 36dBm EIRP

Antenna	Power Level	Minimum Cable / Loss	EIPR
8.15 dBi Omni	30dBm	25 feet LMR195 / 2.675dB	35.475dBm
12.5 dBi Patch	23dBm	10 feet LMR195 / 1.07dB	34.43dBm
14.15 dBi Yagi	21dBm	10 feet LMR400 / 0.39dB	34.76dBm

Examples:

FCC Regulations allow up to 36dBm effective isotropically radiated power (EIRP). Therefore, the sum of the transmitted power (in dBm), the cabling loss and the antenna gain cannot exceed 36dBm with respect to the isotropic radiator.

Example 1)

What is the maximum power the HP900 can be set to comply with FCC and IC given the following equipment given a Rubber Ducky Ant Gain 2dBi and no cable or connectors in the system?

Max EIRP 36dBm

Max TX power = EIRP – Ant Gain(dBi) + Cable/Connector loss (dB)

Ant Gain dBi = 2dBi

Max TX power = 36dBm – 2dBi + 0dB = 34dBm

We can set the modem to the maximum power setting of 30dBm.

Example 2)

What is the maximum power the HP900 can be set to comply with FCC and IC given the following equipment given a Yagi Ant Gain 11dBd and cable and connector loss of 4.5 dB?

Max EIRP 36dBm

Max TX power = EIRP – Ant Gain(dBi) + Cable/Connector loss (dB)

Ant Gain dBi = Ant Gain dBd + 2.15 dB

Yagi Gain (dBi) = 11 + 2.15 = 13.15dBi

Max TX power = 36dBm – 13.15dB + 4.5dB = 27.35dBm

We must round down

Hence Max TX power = 27dBm

Example 3)

What is the maximum power the HP900 can be set to comply with FCC and IC given the following equipment given a Omni Ant Gain 6dBd and cable and connector loss of 2.5 dB?

Max EIRP 36dBm

Max TX power = EIRP – Ant Gain(dBi) + Cable/Connector loss (dB)

Ant Gain dBi = Ant Gain dBd + 2.15 dB

Omni Gain (dBi) = 6 + 2.15 = 8.15dBi

Max TX power = 36dBm – 8.15dB + 2.5dB = 30.35dBm

Hence Max TX power = 30dBm

A. Approved Antennas

Antenna types not included in this list that have a gain greater than the maximum gain indicated for any type listed are strictly prohibited for use with this device.

Group	Part Number	Description
Rubber Ducky		
	MHS031000	3dBi, 900MHz Rubber Ducky Antenna RPTNC Swivel
	MHS031070	3dBi, 900MHz Rubber Ducky Antenna Reverse SMA Swivel
	MHS031080	3dBi, 900MHz Rubber Ducky Antenna Reverse SMA Straight
Puck Antennas		
	MHS035460	4dBi, Puck Antenna 700-960 MHz/1575-2700 MHz Mag Mount
	MHS035480	4dBi, Puck Antenna Main and Div 700-960 MHz/1575-2700 MHz Mag Mount
	MHS035470	4dBi, Puck Antenna Main and Div 700-960 MHz/1575-2700 MHz Permanent Mount
Yagi Antennas		
	MHS031311	6dBd, 900MHz Yagi Directional Antenna Antenex, RPTNC Pigtail
	MHS031431	6.5dBd, 900MHz Yagi Directional Antenna Bluewave, RPTNC Pigtail
	MHS031501	9dBd, 900MHz Yagi Directional Antenna Antenex, RPTNC Pigtail
	MHS031441	10dBd, 900 MHz Yagi Directional Antenna Bluewave, RPTNC Pigtail
	MHS031451	11dBd, 900 MHz Yagi Directional Antenna Bluewave, RPTNC Pigtail
Patch Antennas		
	MHS031440	8dBi 900 MHz Patch Antenna, RPTNC Pigtail
Omni Directional		
	MHS031251	3dBd, 900MHz Omni Directional Antenna Antenex, RPTNC Pigtail
	MHS031461	3dBd, 900 MHz Omni Directional Antenna Bluewave, RPTNC Pigtail
	MHS031321	6dBd, 900MHz Omni Directional Antenna Antenex, RPTNC Pigtail
	MHS031471	6dBd, 900 MHz Omni Directional Antenna Bluewave, RPTNC Pigtail



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