1 MPR Series MultiProtocol RFID Reader User's Manual

Version 0.95 11/4/04

1.1 Cover sheet

1.2 TOC

1.3 Introduction

1.3.1 Contents of this Document

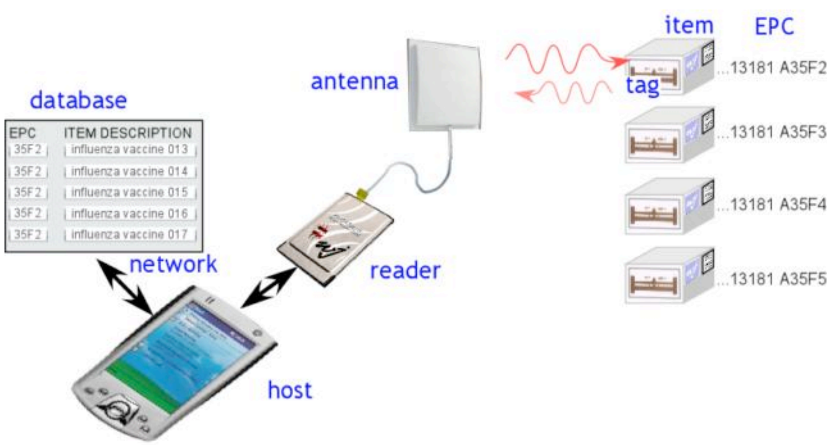
This manual describes installation and operation of the WJ Communications MPR5000, MPR6000, and MPR7000 PC-card-compatible UHF RFID readers. A description of the installation and use of the demonstration Graphical User Interface is also provided. The Application Programmer's Interface to the MPR-series devices is described.

1.3.2 Audience

This manual assumes that the reader is generally familiar with Windows personal computers and, if applicable, Windows CE or PocketPC handheld devices. An introduction to RFID technology is provided for readers who are new to the field.

1.3.3 RFID System Quickstart

Radio Frequency Identification (RFID) uses electromagnetic waves to exchange information between a ***tag***, containing (at least) a number uniquely identifying that physical tag and by implication the object to which it is attached, and a ***reader***. RFID tags are analogous to bar codes, but can contain more information and are more versatile.



The WJ Communications MPR-series readers are ***UHF*** readers, operating at a frequency of roughly 902-928 MHz. These readers are compatible with ***EPCglobal Class 0*** and ***EPCglobal Class 1*** RFID tags, as well as class 0+ tags. They are ***not*** compatible with ***HF*** (13.56 MHz) tags generally used in Smart Cards, or ***LF*** (125/134 KHz) tags generally used in animal identification. MPR-series readers are configured as PC-card (PCMCIA)-slot-compatible modules, and require a host such as a laptop computer or handheld computer. With an appropriate host and if necessary an external antenna, an MPR-series reader can be used to acquire the unique identification number (***UID***) of one or more compatible tags in its reading range. When multiple tags are present in the field, collision resolution algorithms are applied to allow effectively simultaneous reading of all the readable tags.

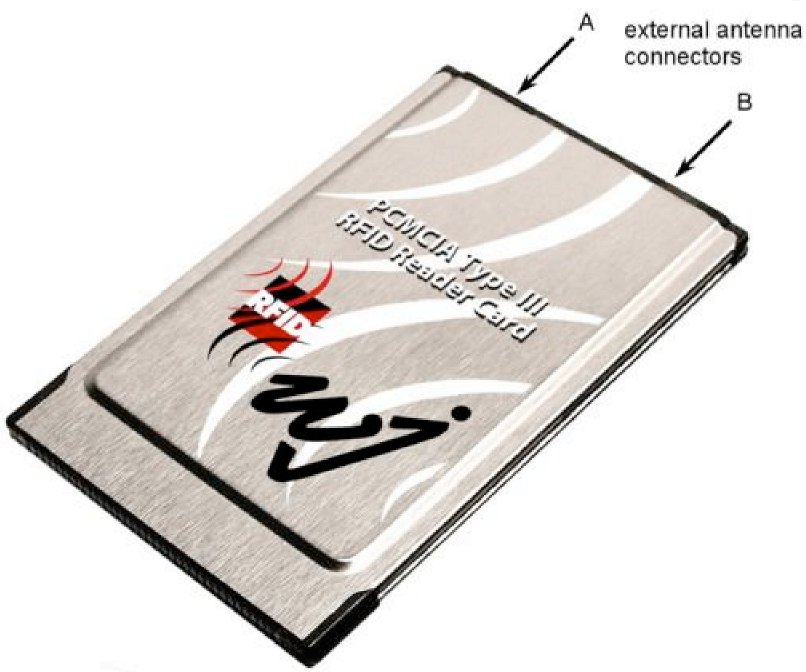
A more detailed discussion of RFID technology can be found in section 1.5.

1.3.4 Product Description

1.3.4.1 MPR 5000 card with integral antenna

The MPR5000 includes an antenna attached to the reader module, and is ready to be used as received. The antenna is not removable or replaceable.

1.3.4.2 MPR6000/7000 card with external antenna ports



The MPR6000 and 7000 incorporate two MMCX-type adaptors for connecting up to two external antennas. The ports are interchangeable, and only one antenna may be used at any given time if desired.

1.3.4.2.1 Approved Antennas

The MPR6000 is approved for operation with either of two external antennas: a nearly-isotropic low-gain monopole antenna for general short-range use, and a higher-gain directional antenna (6 dBi) when a specified coverage region is desired. The MPR7000 is approved for use with a 9 dBi directional antenna.

Use of other than the approved antennas with this unit may result in harmful interference with other users, and cause the unit to fail to meet regulatory requirements. Professional installation is required for the MPR6000 and MPR7000 models.

1.3.4.2.1.1 Low gain, isotropic

For general-purpose use where convenience is the main consideration, substantially isotropic operation is desired, and read range is unimportant, the MPR6000 may be connected to a Maxrad Z1789 The Z1789 is shipped with an MMCX connector and may be attached directly to the card antenna ports, or a small-diameter extension cable, such as an RG-405 cable, may be used. Small-diameter cables that are mechanically appropriate for connection to an MMCX adaptor are generally relatively lossy and should not be used for lengths exceeding 2 meters (6 feet).

1.3.4.2.1.2 High gain, directional

For applications where read range and control of the read zone are important, the MPR6000 may be connected to a Maxrad model MP9026CPRXFPT. This antenna is a right-hand-circularly polarized panel antenna, with a gain of 8.5 dBiC, front-to-back ratio of approximately 17 dB, and a 3 dB beamwidth of approximately 80°.

The MPR7000 may be connected to a Maxrad model MP9026CPRXFPTNF with the 12 ft length of Belden 8259 cable supplied with the product.

The antenna is available with an N-female connector (-NF), or a male SMA connector (-MSMA). In either case, an adaptor may be required to connect the antenna to the MPR antenna port. Note that caution should be exercised in attaching any long, relatively heavy cables to the MPR MMCX adaptors, as these adaptors are not intended to tolerate large mechanical stresses. WJ Communications recommends that the MPR output port be connected through a short length of small-diameter cabling, such as RG-405, with stress relief to protect the card adaptor in the event of displacement of the cabling, and then an adaptor should be used to mate this intermediate cable to the antenna cabling.

1.3.4.3 CD with this manual, drivers, and demo software

1.4 Installation and Operation with demonstration Graphical User Interface

1.4.1 Introduction

This chapter describes how to install the the WJ MPR series Multi-Protocol RFID PC Card Demo Software for Microsoft Windows, Windows CE, and PocketPC operating systems.

These instructions are written for Microsoft XP operating system. For other MS Windows operating systems the details of some instructions may be slightly different, but by following the onscreen instructions the installation will proceed similarly. Windows 95 and Windows NT operating systems are not currently supported.

The PC and Pocket PC demos were written using the .NET Framework and Compact Framework respectively. Thus, the MS .NET Common Runtime must be installed for these programs (and their installers) to run properly. The installer will warn the user if the appropriate framework is missing. Appendix A describes how to get the latest Framework from a Microsoft website.

1.4.2 Windows XP/Me Laptops

1.4.2.1 Card and driver installation

1) Insert WJ MPR Demo CD into CD-ROM drive.

2) Insert RFID PC-Card into a PCMCIA Type II slot.

3) A message should appear that new Hardware was found: "WJCI Multi-protocol reader".
SCREEN DUMP

4) Windows launches the "Found New Hardware Wizard".

5) If asked whether Windows should connect to Windows Update to search for software, select "No, not this time".

6) Click Next.

7) In Windows XP, select "Install from a list or specific location (Advanced)" when asked what you want the wizard to do.

In Windows 2000, select "Display a list of the known drivers".

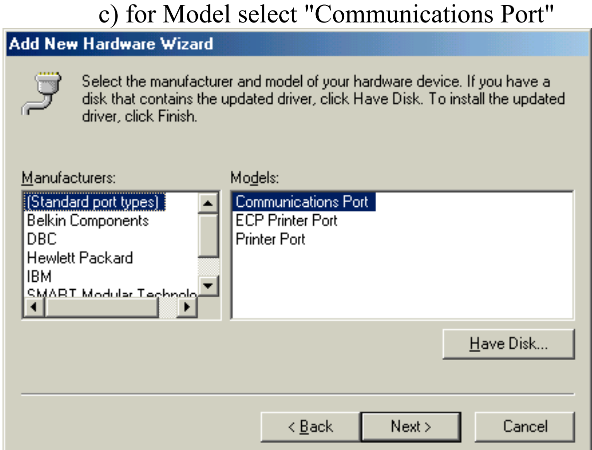
8) Click Next to continue.

9) Select "Don't search..." when asked choose search and installation options.

10) Click Next to continue.

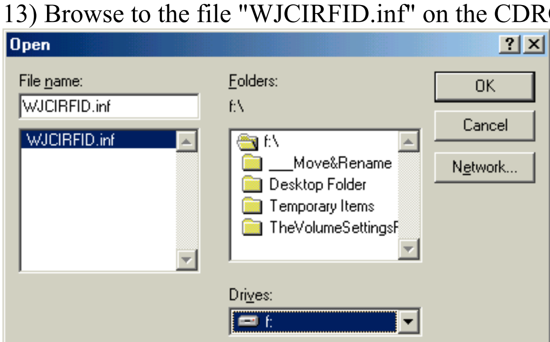
11) On the "Select the device driver you want to install for this hardware." screen,

a) deselect "Show compatible hardware" (if selected)
b) for Manufacturer select "(Standard port types)"
c) for Model select "Communications Port"



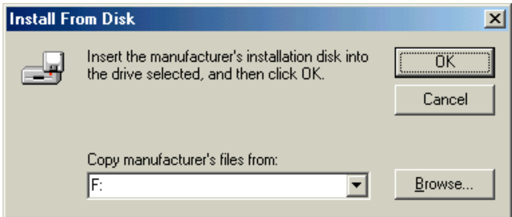
12) Click "Have Disk..."

13) Browse to the file "WJCIRFID.inf" on the CDROM (often D:)



14) Click Open or OK.

15) "Copy manufacturer's files from:" should be D:\ (the location of WJCIRFID.inf)



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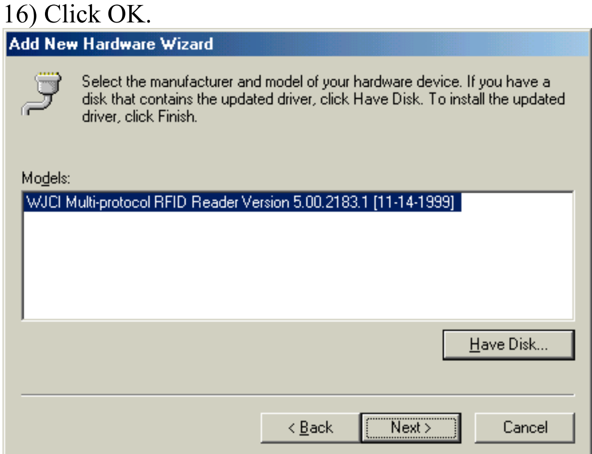
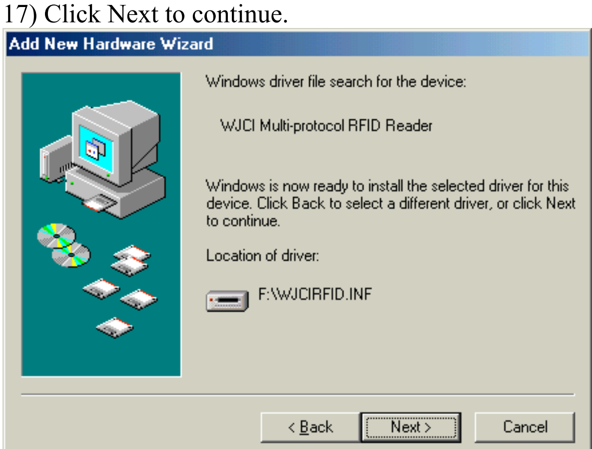
16) Click OK.



17) Click Next to continue.



18) Windows may warn that the software has not passed Windows Logo testing. This is fine, as you are actually just linking to Windows' own drivers. Just click "Continue Anyway".

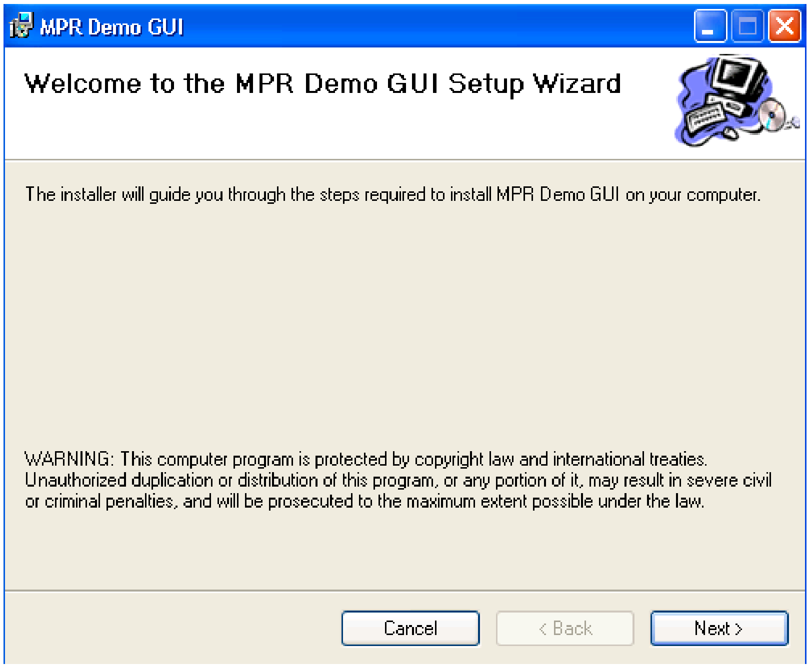
19) The wizard will now install the driver.

20) Click Finish.

1.4.2.2 Installing the demo program

1) Browse to the MPR install CD.

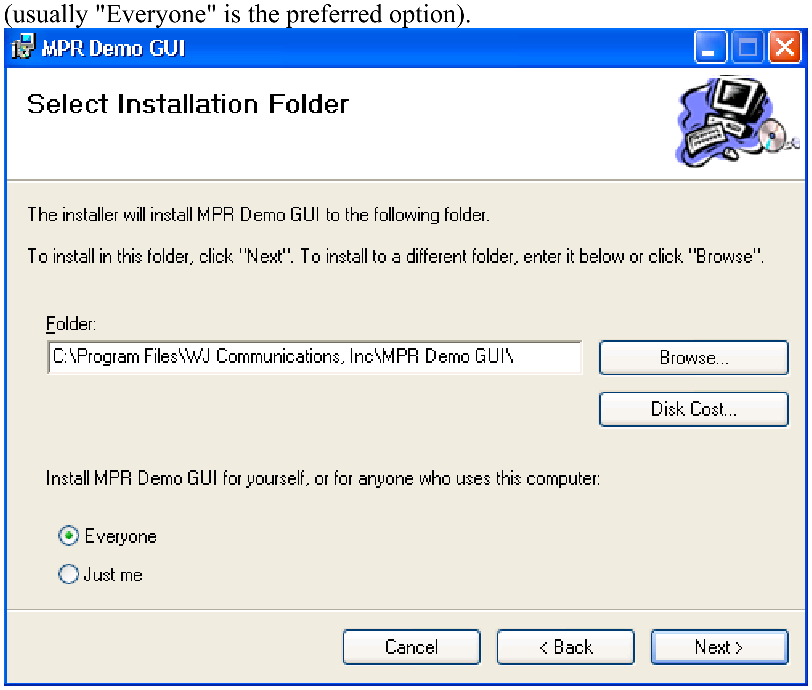
2) From the CD root directory, launch "MPRControlInstaller.msi". This will guide you through the install process.



"Windows Installer Loader" will inform you if you do not have the correct version of the .NETFramework. Do NOT allow it to obtain it from the web for you. Please see Appendix A for instructions in acquiring the Framework. If you get this message, please click NO, and Cancel out of the installation. Then proceed to Appendix A. After installing the Framework, return to step 1 of this section.

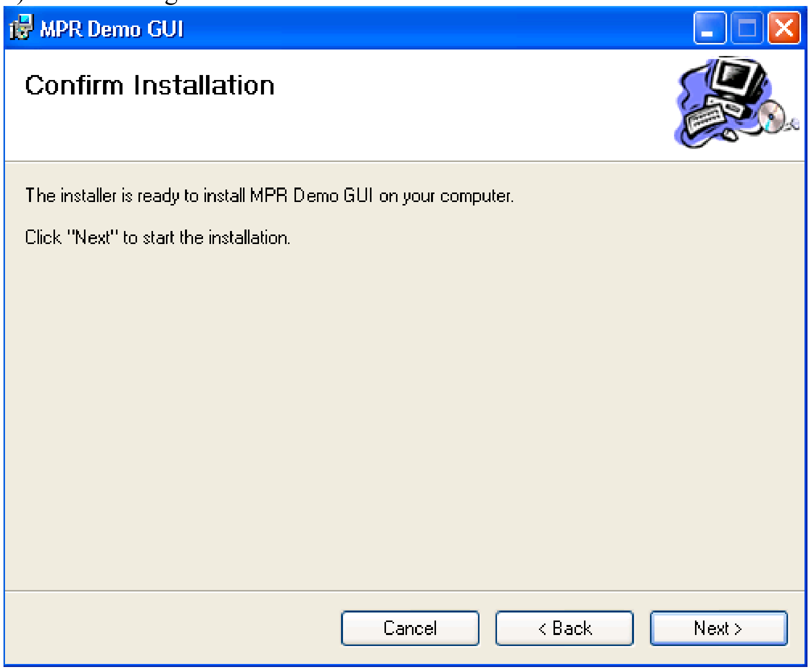
3) Click Next to start.

4) Install to the default location, and select whether to allow all users to use the demo when installed (usually "Everyone" is the preferred option).

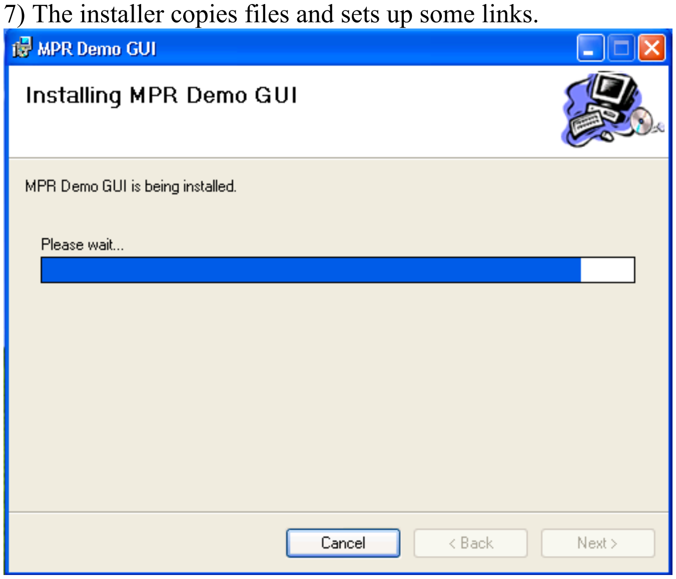


5) Click Next to continue.

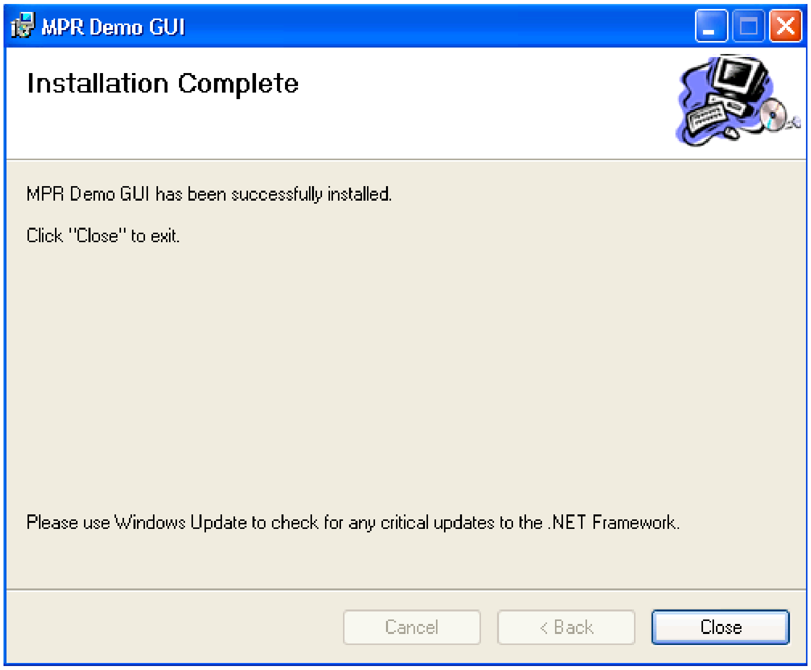
6) Click Next again to start install.



7) The installer copies files and sets up some links.



8) Click Close to exit.



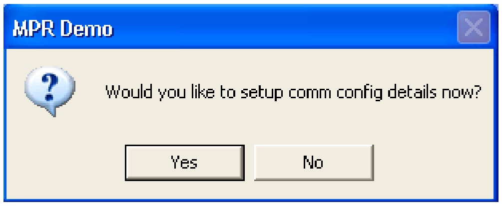
9) An "MPR Demo" link to the installed application should now be in the Start Menu and on the desktop.

1.4.2.3 Running the PC Demo

1) A shortcut to MPR Demo should be installed on the desktop, and in the START menu in the MPR Demo directory.

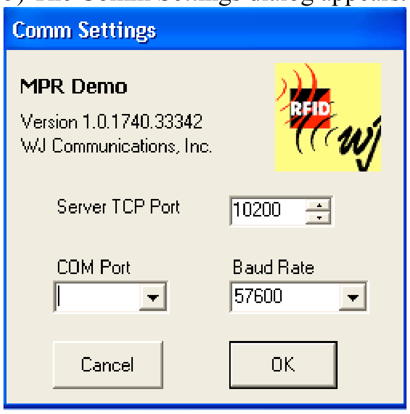
2) Launch the Demo Application.

3) It will prompt you to setup comm config details. "Would you like to setup comm config details now?"



4) Select Yes.

5) The Comm Settings dialog appears.



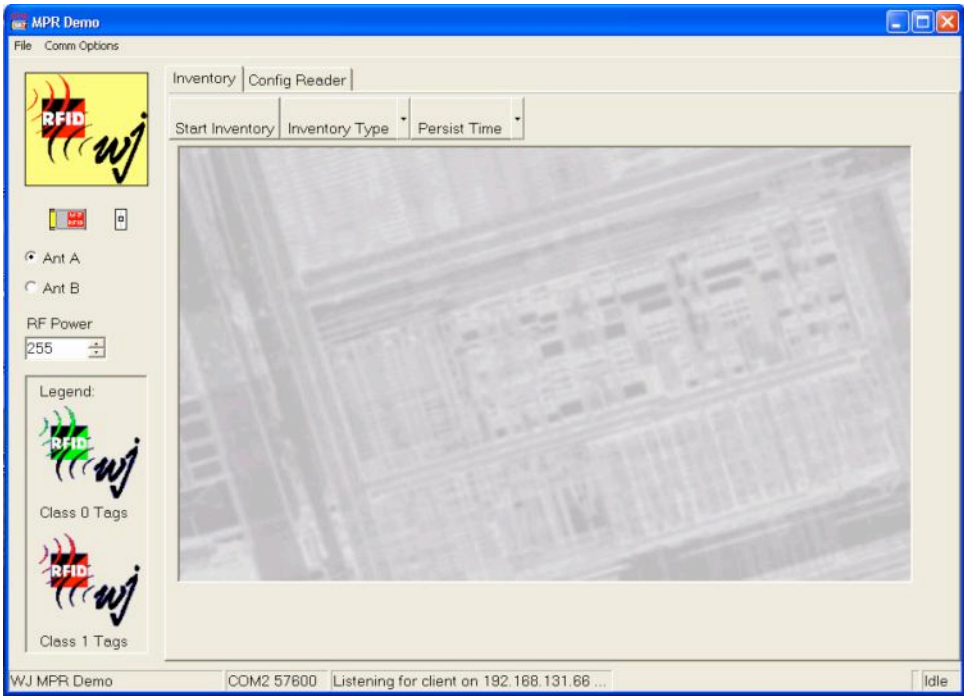
6) Server TCP Port should be left as the default, 10200.

7) COM Port should be set to whatever COM port your operating systems enumerates the MPR series reader to. See Appendix B to determine the COM port. The dropdown menu will only allow selection of the valid COM ports reported by the Windows' Registry.

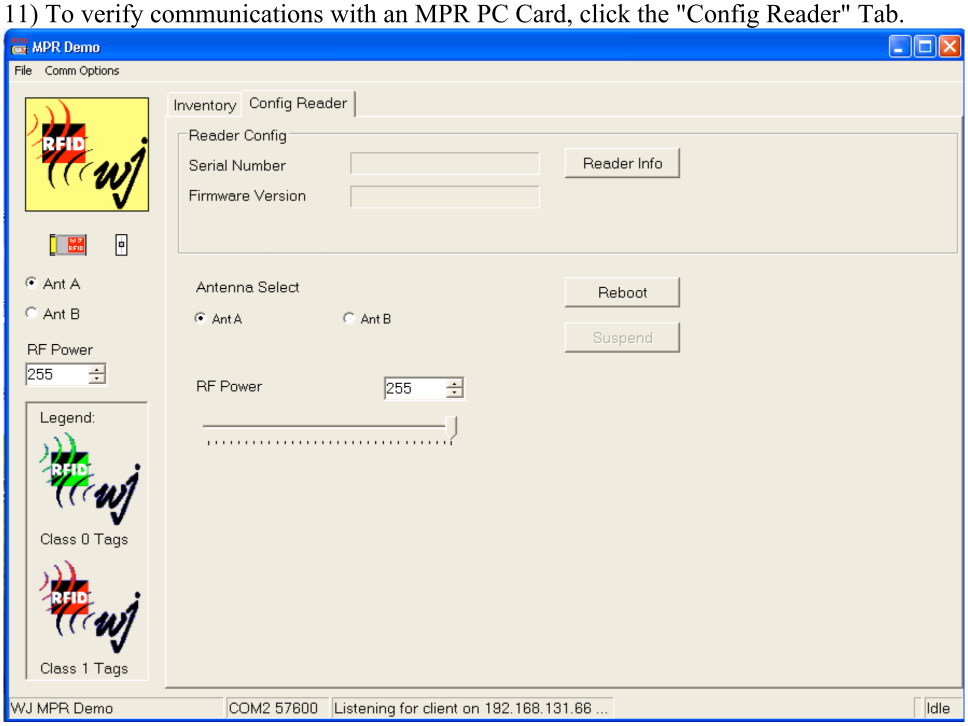
8) The Baud Rate should be left as the default, 57600.

9) Click OK.

10) The Inventory window will appear.



11) To verify communications with an MPR PC Card, click the "Config Reader" Tab.



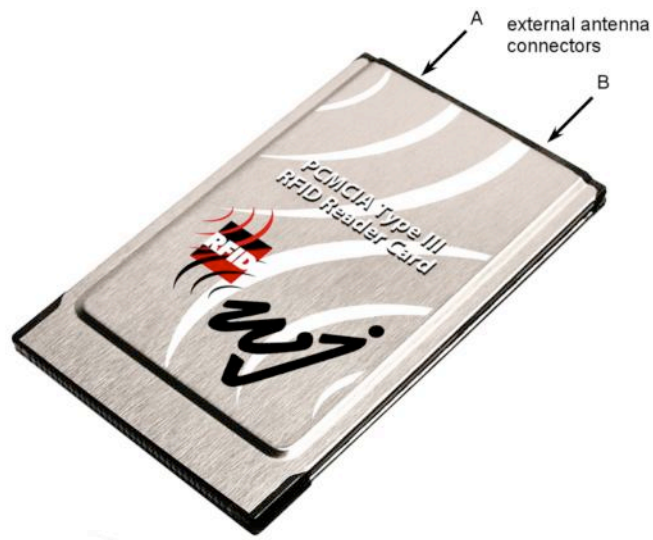
12) Clicking the "Reader Info" button will query the card for its Serial Number and Firmware Version.

13) If numbers appear, then the MPR is successfully communicating over the PC Card bus. If "unknown" appears in these boxes, verify that the reader is fully inserted into the PC Card slot. If this doesn't solve the problem, refer to TROUBLE SHOOTING for further instructions.

14) Select the "Inventory" Tab to start reading Tags.

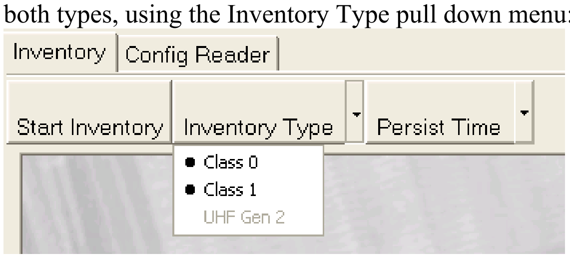
15) If using an MPR with multiple external antenna ports, attach an antenna to a port. The MMCX connector is a press-fit connector; push gently inwards until you feel it 'click' into place. Pull outwards to remove the connector. Note that the connector is mechanically delicate, and should be protected from excessive stress. If a long antenna cable is used, the portion of the cable near the card should be supported to ensure that it does not pull laterally on the connector.

16) select Ant A or Ant B radio buttons to select the antenna port used by the card (MPR6000/7000 only). The naming convention for the ports is shown below. Note that the MPR6000/7000 devices automatically detect excessive reflected power at an antenna port and attenuate the output signal to protect the amplifier; therefore no harm is done to the unit if you direct it to the wrong port, or forget to attach the antenna connector.

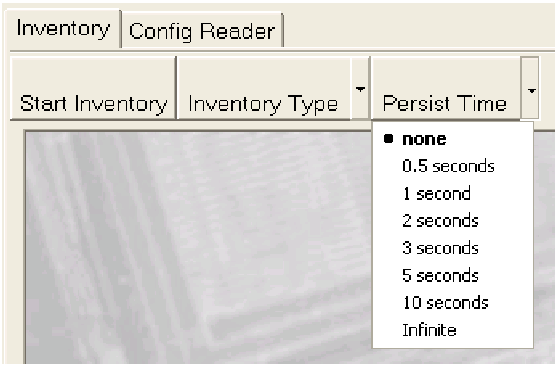


17) Click the "Get Inventory" button. Tags should appear in the box as they are read. Each new tag icon is accompanied by an alert sound. The type of icon indicates whether a class 0/0+ or class 1 tag was read; below each icon the full ID of the tag is displayed as a hexadecimal number.

18) The software can be set to inventory only class 0 tags, only class 1 tags, or to alternately search for both types, using the Inventory Type pull down menu:



19) The time that a tag icon remains displayed on the screen once it has been read can be adjusted with the Persist Time pull down menu. If 'Infinite' is selected tag icons will accumulate on screen until the inventory process is terminated or the screen is full.



1.4.3 Windows CE / Pocket PC devices

1.4.3.1 Installing the Pocket PC Demo

Note that the MPR card may be installed in the handheld device at any time during the installation process.

1) Attach Pocket PC device to PC and make ActiveSync connection.

2) Browse to the MPR install CD

3) From the CD root directory, launch "WJReader_PPCsetup.msi". This will guide you through the install process.

4) Click Next to start.

5) Install to the default location, and select whether to allow all users to use the demo when installed (usually "Everyone" is the preferred option).

6) Click Next to continue.

7) Click Next again to start install.

8) The installer copies files.

9) An Add/Remove Programs box should appear. This will allow you to download & install the demo to an attached Pocket PC device.

10) Click "Yes" to install "WJ Communications MPR Demo".

11) Check the device screen for any messages, and click OK on the PC.

12) Click Close to exit.

13) An "MPR Demo" shortcut to the installed application should now be in the Program Files directory, accessible through the PocketPC start menu.

1.4.3.2 Running the Pocket PC demo

1) A shortcut to MPR Demo should be installed in the program files directory.

2) Launch the Demo Application.

3) It will prompt you to setup comm config details. "Would you like to setup comm config details now?"

4) Select YES.

5) The Comm Settings dialog appears.

6) At first, just leave the server address and port to whatever default values appear.

7) COM Port should be set to whatever COM port your operating systems enumerates the MPR series reader to. The demo searches the Registry for an installed MPR Series reader. This is usually COM4 for Pocket PC. There is no easy way to determine the COM port to which an MPR reader enumerates itself in Pocket PC without using a registry browser.

8) The Baud Rate should be left as the default, 57600.

9) Close the Options Window by clicking on the X in the upper right corner.

10) The main demo window will appear.

11) To verify communications with an MPR PC Card, click the "Config" Tab.

12) Clicking the "Reader Info" button will query the card for its Serial Number and Firmware Version.

13) If numbers appear, then the MPR successfully communicating over the PC Card bus. If "unknown" appears in these boxes, verify that the reader is fully inserted into the PC Card slot.

14) Select the "Read" Tab to start reading Tags.

15) Click the "Run Inventory" button...

16) Tags should appear in the box as they are read!

1.4.4 Appendix A: getting the .NET framework

1) Open web browser to http://windowsupdate.microsoft.com/

2) Select Custom Install.

3) Find a link for "Microsoft .NET Framework 1.1".
Select .NET and unselect all other updates.

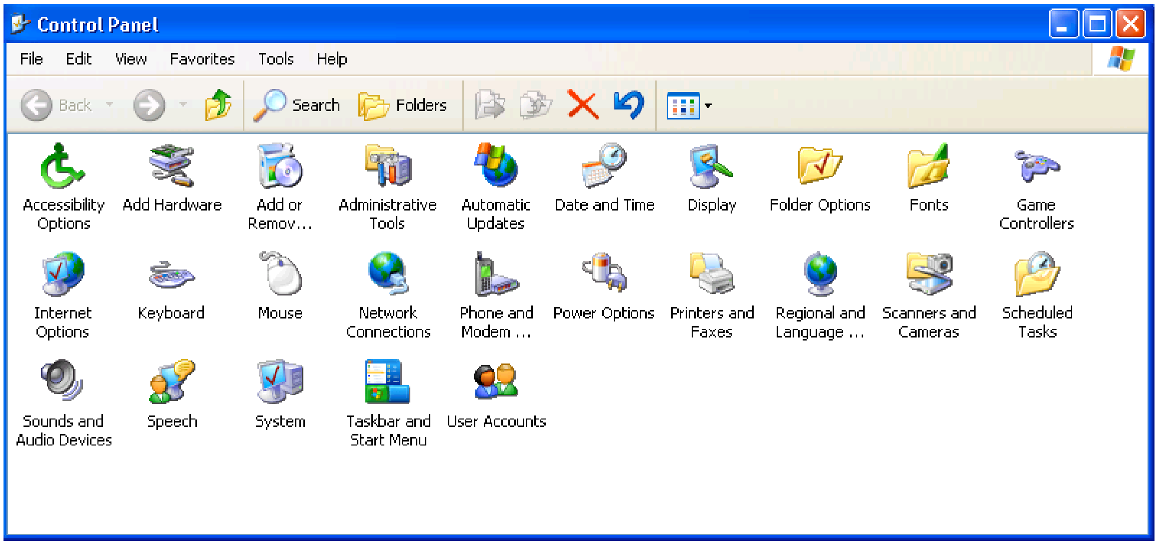
4) Click it, and MS will download & install the Framework.

5) A reboot may be needed before installing the Demos.

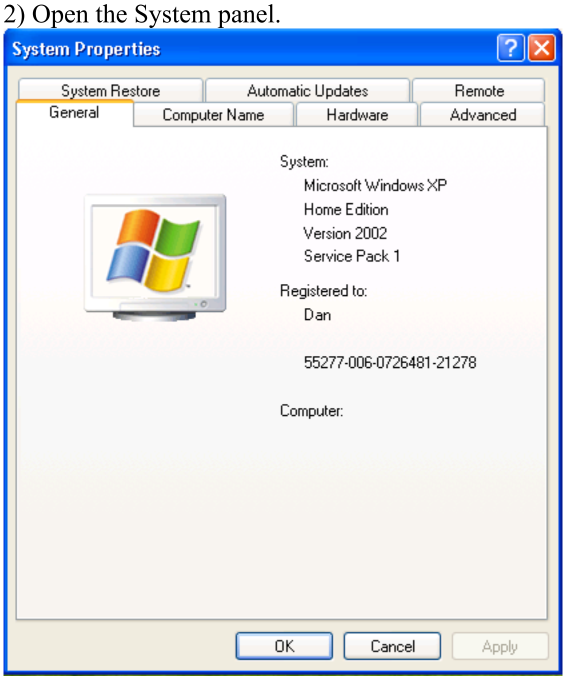
Click the Download button and then click Run to download & install the latest Framework Service Pack.

1.4.5 Appendix B: Determining the Comm port

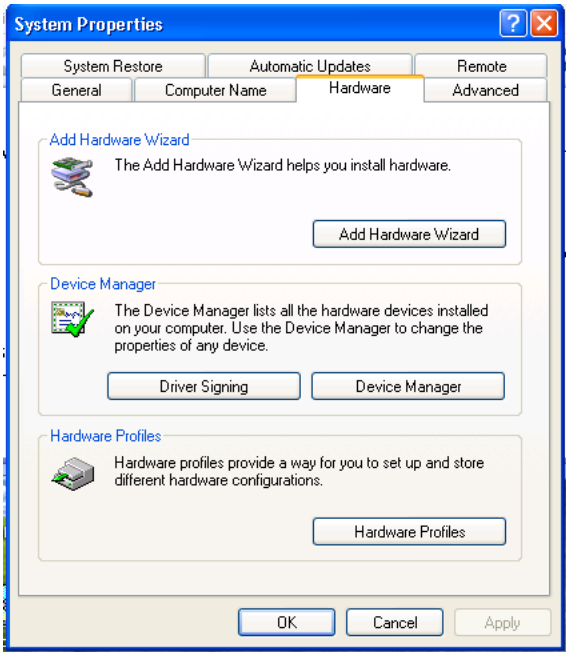
1) Open the Control Panel from the Start Menu.



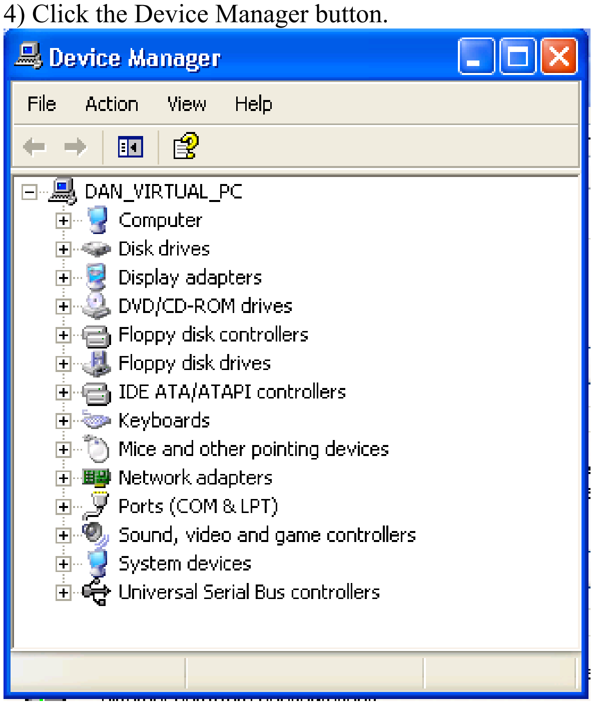
2) Open the System panel.



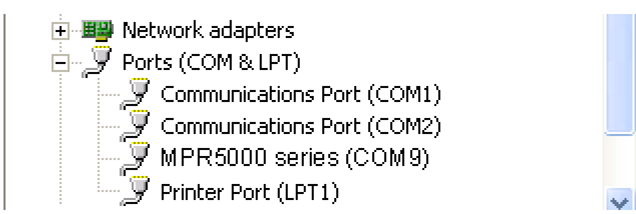
3) Select the Hardware Tab.



4) Click the Device Manager button.



5) Expand the device tree to "Ports (COM & LPT)"



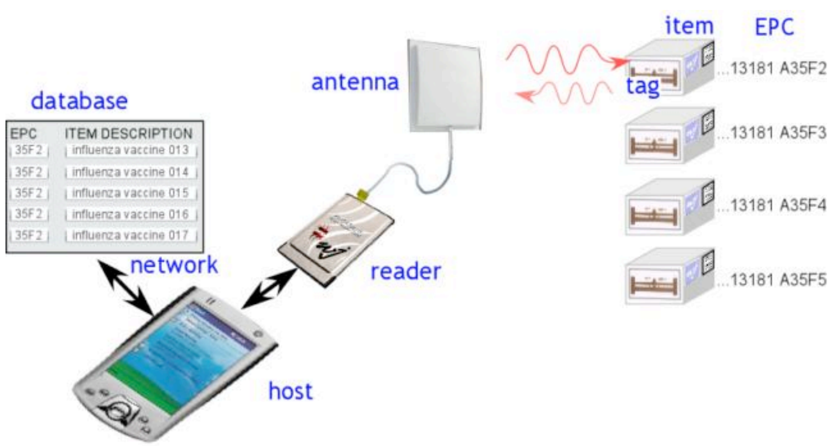
6) If an MPR is properly seated in the PC Card port, and the driver is installed, one of the resident COM Ports will say something like "MPR5000 Series (COM9)". In this example, the card is enumerating itself as COM9.

1.5 RFID overview

1.5.1 RFID operating principles

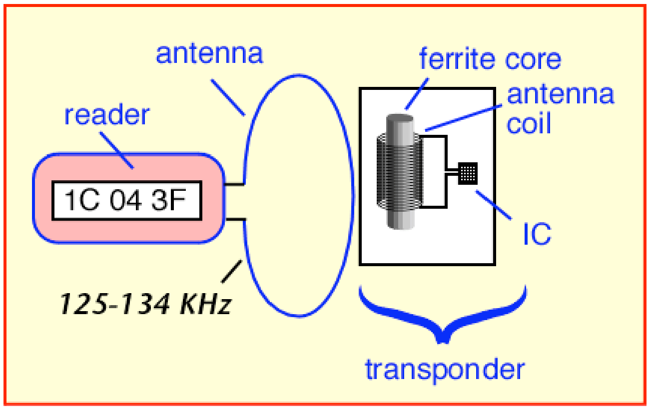
Radio-frequency identification (RFID) is an auto-identification technology, similar in concept to other common auto-identification technologies such as bar code scanners, magnetic strip readers, or magnetic ink readers. Like other auto-ID techniques. RFID associates an identifying number with a physical object. In RFID, the unique identifying number (***UID*** or, as will be explained below, ***EPC***) is incorporated in a special system, an ***RFID transponder*** (often simply known as a ***tag***). An ***RFID Interrogator*** (usually known as a ***reader***) is used to obtain the UID from the tag using electromagnetic waves. The tag is usually attached to a physical object that is to be identified, such as a carton, a pallet, or a container filled with a product.

In order to reduce the cost of the tag, most tags do not incorporate a battery or other source of power, but instead operate using DC power derived from the radio frequency signal they receive from the reader. In addition, low-cost tags do not incorporate a radio transmitter, but instead use varying reflection of the received signal from the reader to communicate back to it. Such tags are known as ***passive*** tags. Since passive tags are the most common type, the description below will assume their use. Variants are also available: ***semi-active*** tags incorporate a battery to power the integrated circuit, but still use reflected waves (***backscattering***) to communicate with the reader. ***Active*** tags incorporate both a battery and a radio transmitter, and are much more costly than passive tags, but also more versatile.

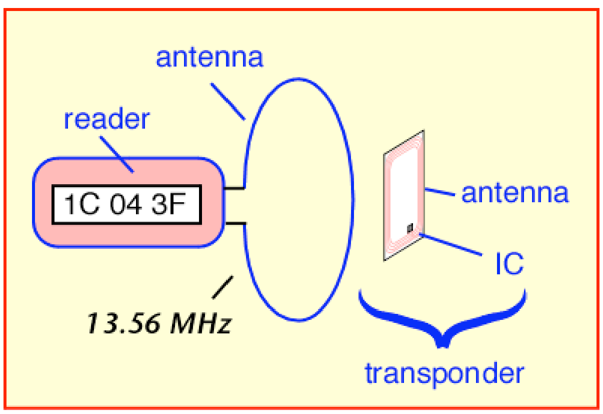


RFID systems can operate at different radio frequencies. The frequency chosen has important effects on the way tags and readers interact and on what applications are appropriate.

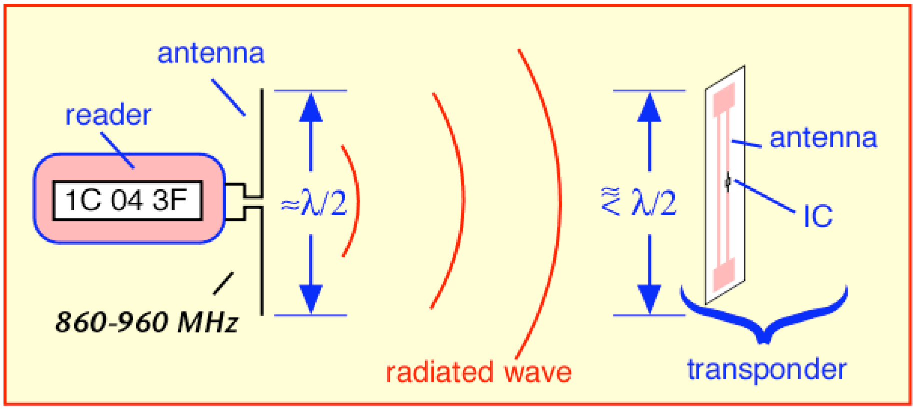
Low-frequency (***LF***) tags and readers typically operate at 125 or 134 KHz. This is a very low frequency, with a wavelength of about 2.4 kilometers (1.5 miles). Low-frequency radiation is very effective at penetrating water and living tissues, so that LF tags can be used to identify livestock. However, because the tags and readers are very much smaller than a wavelength, they cannot radiate effectively, so LF readers and tags depend on ***inductive coupling*** to operate. In effect, the reader and tag form the primary and secondary windings of a transformer. The tag must be in close proximity to the reader antenna to be read; read ranges are comparable to the size of the reader antenna, typically a few 10's of cm (5-10 inches) for a small reader antenna. Because the induced voltage per coil winding is also very small at these frequencies, the tags are composed of many turns of wire, often wound around a ferrite core to increase coupling. Since there is no radiated power, there is usually very little issue with regulatory compliance in using LF tags and readers.



High-frequency (***HF***) tags and readers operate at 13.56 MHz. This frequency is available for industrial use in most jurisdictions worldwide. The wavelength is about 20 meters (60 feet), still larger than most reader or tag antennas, so inductive coupling is used as in LF tags and readers. However, the higher frequency provides a larger induced voltage, so the reader usually uses a single-turn coil, and transponders typically incorporate 3-5 turns of wire. HF transponders can be readily constructed on a flat plastic substrate the size of a credit card, forming ***Smart Cards*** widely used as identification badges and credit cards with enhanced functionality. Typical read range varies from a few cm to a meter or so (a few inches to 3 feet), again dependent on reader antenna size.



When long read range is required, ***ultra-high-frequency*** (***UHF***) tags and readers are appropriate. The MPR-series cards are UHF RFID readers. UHF systems typically operate at frequencies between 860 and 960 MHz, depending on the regulatory jurisdiction. In the United States, unlicensed operation is allowed in the Industrial, Scientific, and Medical (ISM) band at 902-928 MHz. The wavelength at these frequencies is about 33 cm (13 inches), so the reader and tags are roughly comparable in size to the wavelength. The reader antenna creates a radiated electromagnetic wave, which can propagate long distances. UHF tags and readers can thus exploit ***radiative coupling*** to achieve read ranges not available for LF or HF devices. Read range for passive UHF tags can be as much as 10 meters (30 feet) with an appropriate directional antenna; longer ranges are achievable using semi-passive tags.



RFID readers and tags operating in the microwave ISM band at 2.4-2.45 GHz are also widely used. The 2.4-2.45 GHz band is available for unlicensed operation in most jurisdictions worldwide. At this frequency the wavelength is about 12 cm (5 inches). Very small tags can be used in the 2.45 GHz band, but because of the consequent small antennas, the amount of power collected by a tag is reduced in comparison to UHF tags. Passive 2.4 GHz tags have typical read ranges of around 1 to 3 meters (3 to 10 feet).

1.5.2 RFID vs. bar code

RFID tags and readers perform functions similar to those of bar codes and bar code scanners. How do they differ? When should one use bar codes and when should RFID tags be employed? There are four key distinctions to keep in mind:

- **COST**: bar codes can be printed on the surface of many existing packages at very low cost. Separate bar-coded tags with adhesive backing are also inexpensive. Bar code scanners of various types are widely available at modest cost, as is software to integrate bar code scanning into standard business processes and enterprise planning. RFID (particularly at UHF and microwave frequencies) is a relatively less widespread technology, and RFID tags are manufactured objects containing an integrated circuit and antenna structure. RFID tags today cost significantly more than bar codes, the exact value depending on type and quantity, though the cost of RFID tags is falling rapidly as economies of scale are applied. Low-cost readers such as the MPR5000 are just becoming available, but most readers are still expensive proprietary devices. When cost is the only or a dominant issue, bar codes should be used.

- **INFORMATION**: Bar codes usually contain very limited information. Bar codes printed on mass-produced packaging inevitably identify only the type of product and not the unique individual package in hand. Bar codes containing unique identifying information such as serial numbers can be used, but must be individually printed, raising cost, and separate codes are usually needed to identify model number and the particular instance of the model. RFID tags generally allow a 64-bit or 96-bit UID, the latter being more than adequate to identify manufacturer, model or part number, and the specific physical instance of the model to which the tag is attached. More advanced tags can contain additional user memory, which can be written to in the field, allowing for versatile storage of information conveniently attached to an object when necessary. When information storage capacity is a concern, RFID tags may be superior to bar codes.

- **AUTOMATION**: Bar codes require an optical line of sight between the reading device and the code, and may also require that the code or reader be properly oriented. In many cases this means that individual objects or tags must be handled by a human being in order to be reliable read. UHF RFID tags can be read from a relatively long distance, and the path between the reader and the tag can be visually obstructed (though certain obstructions will also affect radio frequency devices, as will be discussed in more detail below). Bar codes are normally read one at a time, particularly on randomly-oriented or stacked objects, whereas tens to hundreds of RFID tags can be simultaneously present in the field of the reader and read 'simultaneously' from the viewpoint of the user. RFID techniques permit automated information handling to a much greater extent than bar codes.

- **ROBUSTNESS**: Bar codes cannot be read if the printed code becomes dirty, defaced, or excessively bent or curled. RFID tags are robust to dirt, paint, ink, and to some extent mechanical damage, and can be read (albeit with reduced range) when misoriented or mechanically distorted. RFID tags are tougher than bar codes.

1.5.3 RFID system components

An RFID system is composed of (at least) a ***reader***, one or more ***antennas***, and one or more compatible tags. In many applications it may be necessary or helpful to create human-readable labels incorporating RFID tags; in this case an RFID ***tag printer*** is also very useful. While standalone RFID systems are appropriate in some circumstances, more commonly the RFID reader is just a sensor that needs to interact with a larger information system in order to be useful. ***Middleware*** is used to enable the interaction between the reader and the network, and to filter and aggregate the large amounts of data the reader collects into a more useful compendium provided to the network.

1.5.3.1 Reader

A UHF RFID reader is a radio transmitter and receiver. Most readers are capable of interrogating passive tags, and are equipped with certain features uniquely suited to use for communicating with passive RFID tags. A reader reading passive tags simultaneously communicates with the tag population and provides power to operate the integrated circuits contained in the tags. During transmission, the reader transmits an ***amplitude-modulated*** signal that is received by tags within range. The transmit power is generally limited by regulatory requirements; for example, in the United States, no more than 1 watt average RF power may be transmitted. Modulation rate varies depending on the standard employed, but is typically a few tens of kilobits per second for UHF tags. Special coding of the transmitted data is employed to maximize the power available to the tags.

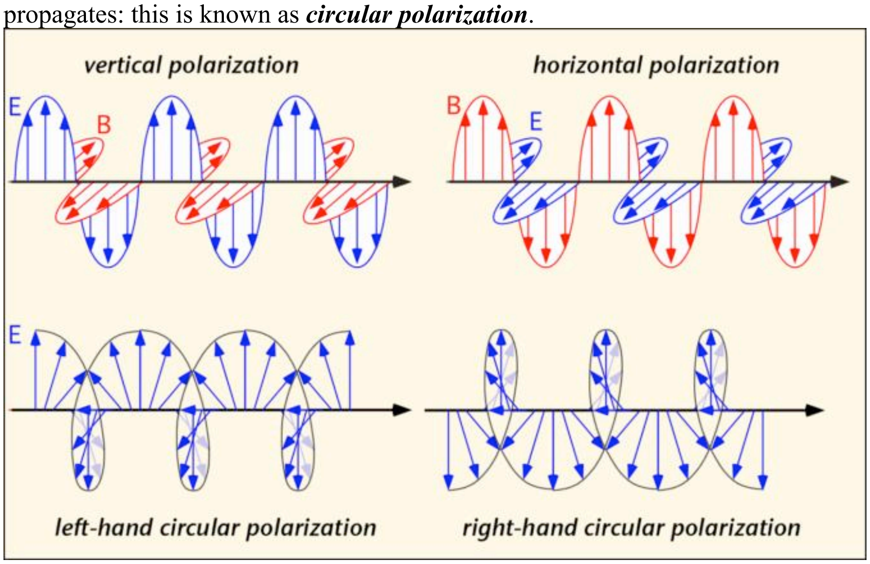
Once the tags have been powered up and received their instructions from the reader, they take turns responding with their UID. Because of the unique requirements of the backscatter radio system used by passive and semi-passive tags, the reader must continue to transmit a non-modulated (***continuous-wave*** or ***CW***) signal while it listens for tag responses. The tags employ the CW signal to continue to provide power to the tag electronics, and modulate the impedance of their own antennas in order to vary the signal reflected back to the reader. The reader must extract the very small tag reflections from all the other reflected signals it encounters. The MPR-series cards use one antenna for both transmit and receive functions. [MPR6000 and MPR7000 readers have two external antenna connectors. However, only one antenna is in use at any given time, for both transmit and receive. The reader can switch from one antenna to the other in order to cover differing physical regions, such as the high and low portions of a doorway, or to avoid missing tags because of local losses of signal strength – ***fading*** – that are sensitive to the exact position of the antenna and other objects.] Even with a well-matched antenna, the reflection from the antenna back to the reader is much larger than any other reflected signal, and represents the main obstacle to receiving the tag reflection. Degraded antenna match will lead to an increased antenna reflection, making it harder for the reader to extract the tag signal and thus reducing read range. The antenna match is sensitive to the immediate antenna environment (objects within a few cm of the antenna). For best results, antennas should always be mounted in accordance with manufacturer's recommendations, and free of obstructions for at least 50 cm (20 inches) in the read direction.

In the United States, readers are required by law to ***hop*** randomly from one frequency channel to another when operating within the ISM band, residing for no longer than 0.4 seconds at any one frequency. In addition, regulations forbid coordination of hopping patterns between collocated transmitters. When configured for US operation, the MPR series uses 50 channels separated from one another by 500 KHz, and operates in each channel for 50 to 400 milliseconds. During hops from one channel to another, the RF output is turned off.

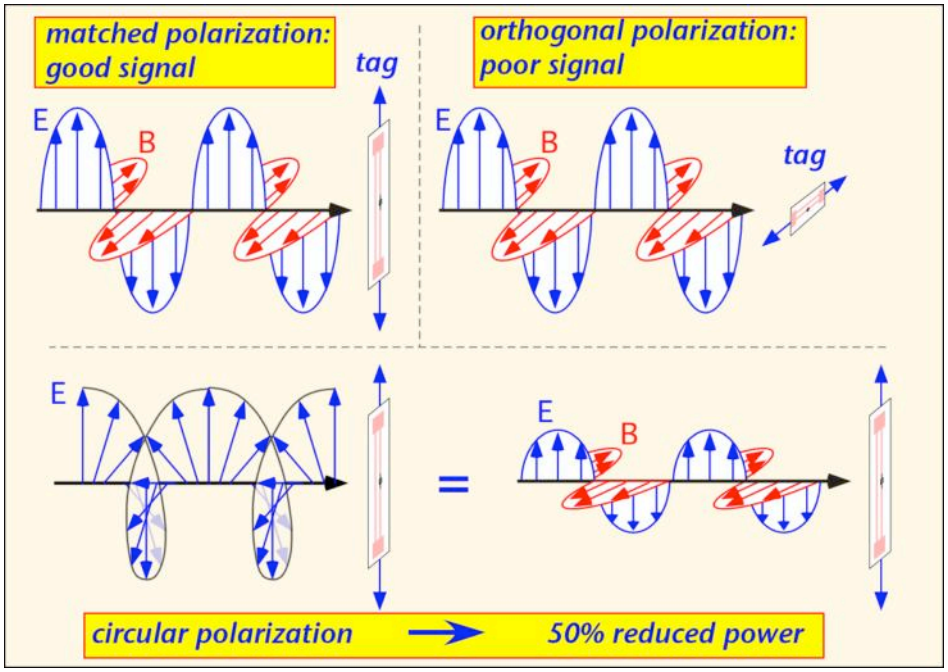
1.5.3.2 Antennas

Antennas are the intermediaries between the voltages sent and received by the reader, and the electromagnetic waves used to provide power to and communicate with the tags. Three critical characteristics of antennas used in RFID systems are their ***maximum directive gain***, ***polarization***, and ***match.***

Electromagnetic radiation consists of a traveling electric and magnetic field. The electric field has a direction at any point in space, normally perpendicular to the direction of propagation of the wave; this direction is the ***polarization*** of the wave. For linearly polarized radiation, the direction of the electric field is constant as the wave propagates in space. Configurations can also be constructed in which the direction of the electric field rotates in the plane perpendicular to the direction of propagation as the wave propagates: this is known as ***circular polarization***.

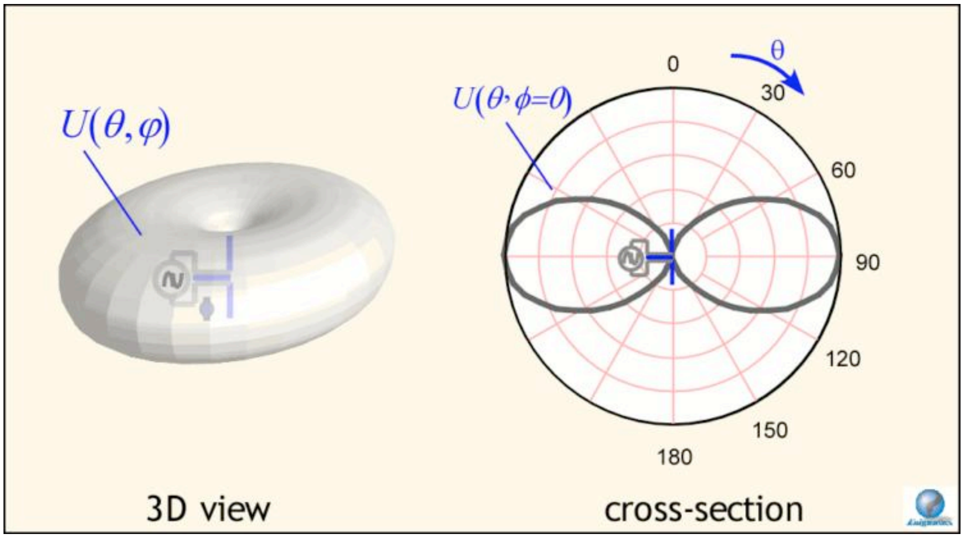


The best power transfer between antennas is obtained when their polarizations match. Thus the best read range is obtained from e.g. a vertically polarized reader antenna transmitting to a vertically polarized tag antenna. This is an excellent scheme to employ when the orientation of the tag during reading can be controlled. However, if the orientation of the tag can vary, the tag could accidentally be perpendicular to the polarization of the reader antenna – a horizontal tag with a vertically polarized signal in shown in the diagram below – in which case very little power is received, and the tag will not be read. When the tag orientation is unknown or uncontrollable, a circularly polarized reader antenna should be used. Vertical tags, horizontal tags, and tags rotated to intermediate angles can then be read with equal facility. However, this versatility is not without cost. A circularly polarized signal can be regarded as the combination of a horizontal and vertical signal, each containing half of the transmitted power. A linearly polarized tag antenna only receives its own polarization, and thus half the transmitted power, being of the wrong polarization, is wasted. The read range of a circularly polarized antenna with a linearly polarized tag is reduced from what could be obtained with a linearly polarized reader antenna, if the tag orientation is known.

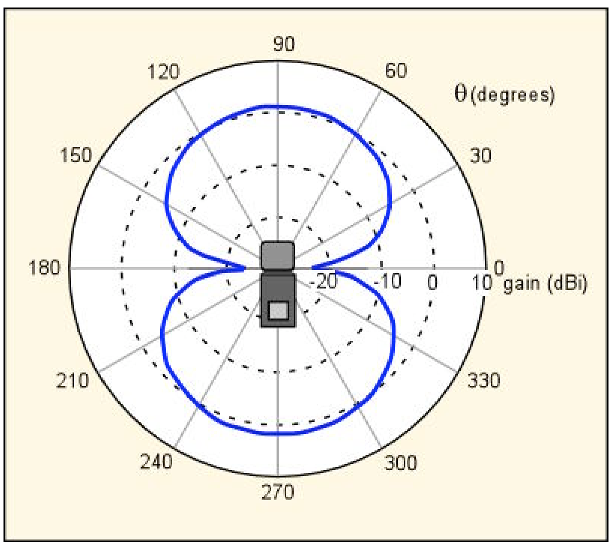


In discussing antennas, it is often convenient to speak of an ***isotropic*** antenna that radiates power equally in all directions, but no such antenna actually exists. Real antennas always transmit more effectively in some directions than others. The ratio of the power density in the direction of highest power to the average power radiated in all directions is the ***maximum directive gain***, often simply referred to as the ***gain*** of the antenna. It is important to note that antennas are passive devices and don't actually add any power to the signal provided by the reader: gain in this context refers to the increased power received by a device in the best direction relative to the average of all directions. Gain varies tremendously for different antenna designs. A very common antenna, the ***dipole*** antenna, is fairly close to an isotropic radiator: the dipole sends no radiation along its axis, but transmits equally in all directions perpendicular to the axis and nearly as well to directions at more than a few degrees away from the axis. The gain of a dipole antenna – the ratio of the power density along the direction of maximum radiated power to the average of all directions – is only about 1.7:1 or 2.3 dB[1]. Note that gain is often reported as 'dBi', the 'i' denoting the use of an ideal isotropic antenna as the reference. A dipole antenna is a good choice when all tags in any direction along a plane are to be read. Radiation from a dipole is polarized along the axis of the dipole; thus, a tag whose antenna is also a dipole should be oriented in the same direction as the reader antenna in order to be read effectively.

[1] dB = deciBel is a method of logarithmically describing the ratio of two power levels; P_{21} (dB) = 10 $\log_{10}$ (P_2/P_1). Thus 10 dB represents a factor of 10 in power.



The MPR5000 integral antenna behaves like a dipole oriented parallel to the short edge of the card. Thus, radiation is mainly forward (looking along the long axis of the card), up, and down, but with very little power radiated to the left or right of the card. The radiation pattern can be regarded as a torus (doughnut) with axis along the short side of the card.

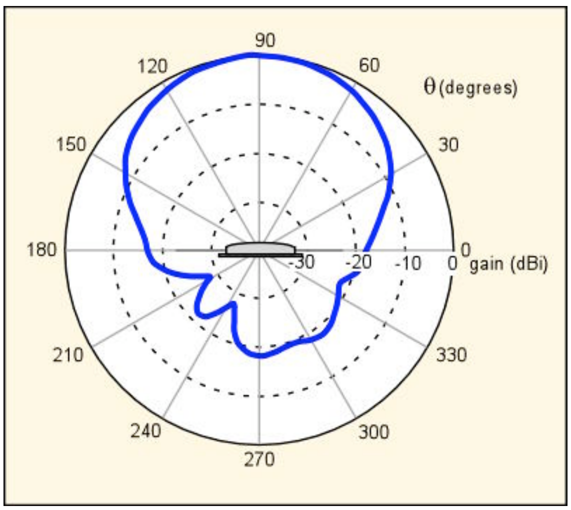


The recommended isotropic antenna for the MPR6000/7000, the MAXRAD [model number for PN1789] is a ***monopole*** antenna, essentially a half of a dipole antenna placed above a conductive ground plane. The ground plane acts to create a reflected image of the monopole; the monopole and its image together form a dipole antenna. Thus for directions above the ground plane, the radiation of the monopole resembles that of a dipole, but for sufficiently large ground planes there is very little radiation below the ground plane. The ground plane should be at least 2-3 wavelengths across (about 60 cm or 25 inches on a side at 900 MHz) to ensure minimal bottom-side radiation. Monopole antennas are compact and easy to use, and appropriate when one wishes to find tags located in any direction around the monopole axis.

PATTERN IF AVAILABLE

Relatively isotropic antennas are easy to use, but if tags are expected to be found mainly in one direction with respect to the antenna, radiation in the other directions is wasted. In such circumstances, an antenna with higher gain – a ***directional*** antenna – will provide better read range. A common type of directional antenna is the ***patch*** antenna (also known as a ***microstrip*** or ***panel*** antenna). Patch antennas are manufactured using techniques similar to those used to make printed circuits, and are inexpensive and robust. They use a metal ***ground plane*** above which are printed resonant metal blocks; as a consequence they are generally flat and radiate primarily in the direction opposite the ground plane. Most commercial patch antennas are packaged inside a plastic radome to provide mechanical protection and a more pleasing appearance.

The recommended directional antenna for the MPR6000/7000, the Maxrad MP9026CPR, is a patch antenna, with about 8.5 dBiC of gain in the direction perpendicular to the rounded face of the radome. (The notation 'dBiC' indicates that the gain is that which would be measured using a circularly polarized receiving antenna; a linearly polarized received would find 3 dB less power in the direction of maximum gain.) Patch antennas can be linearly or circularly polarized. The MP9026CPR is circularly polarized. As discussed above, circular polarization is a good choice when the tag orientation is not known. The patch antenna, being of higher gain, will provide a significant improvement in read range over the monopole antenna. Shown below is the radiation pattern of this antenna along the azimuth (horizontal plane for a typical vertically-mounted antenna).



In principle, antenna gain could be increased to increase read range. However, in most jurisdictions, the maximum gain employed in unlicensed operation is limited by regulation. For example, in the United States, the FCC limits the ***effective isotropic radiated power*** (EIRP, the product of the actual power and the antenna gain) to 4 watts. For the MPR6000, which is rated at _ watt output, the highest antenna gain legally allowed is a factor of 8 (9 dB) relative to an isotropic antenna. The MPR7000, which is rated at 1 Watt output, cannot use an antenna with more than 6 dBi of gain.

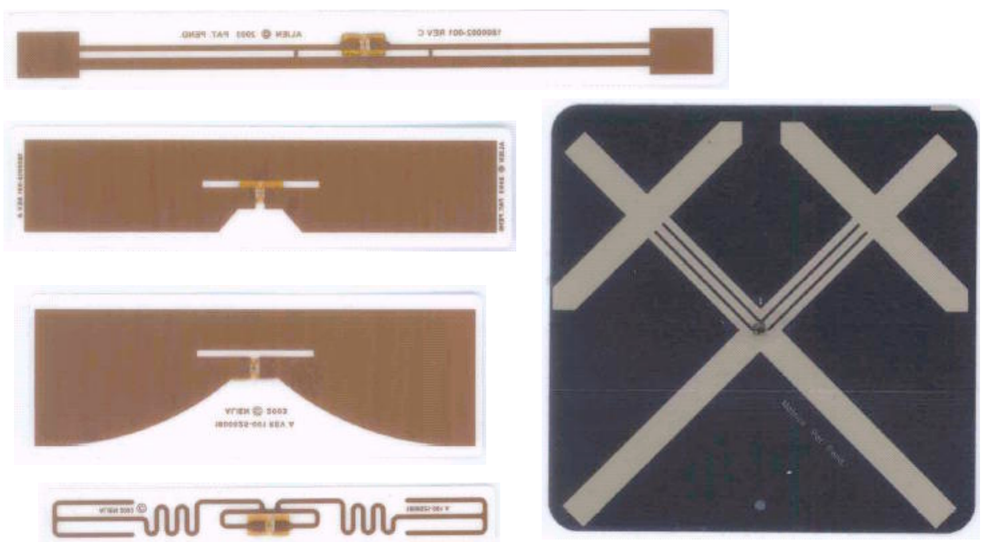
Note that the recommended antennas have been specifically approved for use with the MPR6000/7000 in the United States by the FCC. FCC regulations (title 47 part 15) require that antennas be approved for use with specific radio communications devices, unless they are installed by a professional installer, and that in all cases the combination of antenna and radio device must operate within regulatory constraints.

External antennas are generally connected to the reader using flexible coaxial cables and connectors. It is important to select these cables and connectors appropriately for the application. The MPR6000 and MPR7000 use MMCX connectors, which are very small and convenient for the limited form factor of a PC-card slot. However, MMCX connectors must be protected from mechanical stress. This can be done by using fine-diameter cabling, such as RG-405, to make the connections to the card. However, such cable has relatively high losses, and should not be used for runs longer than about 2 meters (6 feet). When the antenna must be mounted a long distance from the cable, an adaptor should be used at the end of a short run of small-diameter cable to connect to a larger cable, such as RG-213 or RG214, using an adaptor to the relevant connector, which may be an SMA or N-type connector.

The electrical impedance presented by an antenna is a complex function of the frequency, the antenna shape, and the near-antenna environment. Antennas are carefully designed so that the electrical impedance of the antenna is well-matched to the impedance of the device to which they are connected. For example, the MPR6000/7000 will generally employ a cable with 50 ohm characteristic impedance to connect the reader to the antenna. In order for the power from the reader to be effectively transferred to the antenna, the antenna must have an electrical impedance close to 50 ohms, with little capacitance or inductance, at the frequency of operation. As noted previously, conductive objects or some other materials such as aqueous liquids placed close to an antenna will change its impedance and thus degrade its match to the cable. For best read range, keep such obstructions away from the antenna in directions of maximum directive gain.

1.5.3.3 Tags

A UHF RFID tag typically consists of a specialized integrated circuit (IC) attached to an antenna structure fabricated on an inexpensive flexible plastic substrate. The antenna and substrate designs vary considerably to meet the needs of specific applications. Tags may be configured to respond primarily to one linear polarization, to have some response to both orthogonal directions, or to provide multiple antennas with capability for switching the IC to the best direction at any given moment.



The natural size for an antenna structure for a given wavelength λ of electromagnetic radiation is about half of the wavelength: $\lambda/2$. Since the wavelength is about 33 cm at 915 MHz, the natural size for a simple antenna is about 16 cm (6.5 inches). Half-wave antennas radiate and receive effectively, and tend to have convenient nearly-resistive impedances: they are ***resonant***. However, for many applications such an antenna is excessively large. Many tags are designed with antennas that are smaller than $\lambda/2$. While such antennas may be configured to provide good impedance matching, some compromise in radiation efficiency is inevitable: in general, smaller antennas will not perform as well as half-wavelength antennas. Tag antennas may be bent or curved to conserve space and allow some response to multiple linear polarizations; however, in this case only the regions of the antenna that are along the polarization direction contribute to the received signal, so again the received power is reduced. Note that most tag antennas are incorporated onto a flat plastic substrate and are thus themselves in a plane; like a dipole, the tag antenna does not transmit and cannot receive signals whose direction of propagation lies in this plane. A tag cannot be seen by the reader when it is viewed on edge.

Tag antennas are also sensitive to their local environment, a fact that is of particular import since tags are meant to be attached to objects. Many common materials, such as paper and most plastics, have little effect on microwave propagation; tags can be attached readily to cardboard or plastic boxes or containers without affecting their operation. However, large metal objects have important effects both on the local electric fields and the impedance of nearby antennas. Tag antennas cannot be attached directly to metal plates or boxes without suffering degraded performance. Tag antennas spaced 5 mm to 1 cm (0.2 to 0.4 inch) from a metal surface can perform acceptably, particularly if designed for near-metal service. Aqueous fluids (water and water-containing materials such as milk, juices, most cleaning fluids, etc.) also have a strong effect on local field intensity and may affect tag antenna impedance as well, depending somewhat on the tag design. Again the best operation of a tag will be obtained if it is kept at least 1-2 cm from bodies of aqueous fluid.

The received signal from a tag antenna is connected to an integrated circuit. Tag IC's are very small (to keep the cost of manufacturing low), and are typically embedded in a plastic coating for mechanical protection. The IC contains a rectifying circuit to convert the received 900 MHz signal to a DC voltage used to power the remainder of the IC. Variations in the received power are converted to variations in a DC voltage, providing the IC with a method of sensing information transmitted by the reader. The IC can also modify the impedance it presents to the antenna, by using a transistor as a switching element, thus causing a variation in the signal reflected back to the reader and enabling the tag to communicate back to the reader without needing its own radio transmitter.

The necessity of powering the tag is the primary limitation on the read range. Tags require a few 10's of microwatts of RF power to operate, limiting the range to about 3-6 meters with an isotropic antenna, or about 10-15 meters with a directional antenna. When linearly-polarized reader antennas are used, read range may be degraded by misorientation of the tag. Most indoor environments have very complex propagation characteristics, with the transmitted signal reflecting off numerous obstacles such as walls, floors, other tagged objects, people, vehicles, desks, tables, etc. As a consequence, the signal strength can vary by a factor of 10 or more between two neighboring locations separated by about a half-wavelength (16 cm or 5 inches): this phenomenon is known as ***fading***, and is encountered in most wireless communications systems. A tag with the misfortune to find itself in a fade may fail to power up, while a tag farther from the reader but happily located in a region of maximum signal strength responds readily. Thus there is no reliable simple correlation between tag location the likelihood of reading a tag. The exact signal strength configuration is sensitive to the positions of all reflecting / diffracting objects in proximity to the read region (including people and their tools and toys) to an accuracy of much less than a wavelength, and thus in practice is impossible to predict or control.

The best approach to deal with fading is the use of ***diversity***: intentional variations in the propagation environment to ensure that each tag finds itself in a region of decent signal strength at some point. Diversity can be achieved by alternately employing two antennas in slightly different positions (displaced by at least a half a wavelength); the MPR6000 or MPR7000 can be operated in this fashion by alternately addressing antennas A and B. Alternatively, the location of the tags relative to the reader antenna(s) can be varied; this beneficial effect occurs naturally when the tags to be read are moving on a conveyorized belt, or are rotated as a pallet of boxes is wrapped with plastic in preparation for transport.

1.5.3.4 System integration

An RFID reader can collect large amounts of data, often much more than would have been obtained by a human being employing a bar code reader. To convert this data into knowledge may require considerable filtering. For example, if a fork lift driver moves a pallet out of a door, then returns to the facility to correct an error in some paperwork, and finally drives out through the door to the truck again, the reader may take three inventories of the same pallet, but it is rarely desirable to treat the resulting information as suggesting that the same items were shipped three times. On the other hand, if the pallet is returned by a hand truck, and the operator's colleague stands in front of the reader antenna during the transfer, the reader may fail to record some or all of the tags. A successful RFID implementation requires the integration of appropriate procedures for human workers to follow in placing and using tags and objects carrying them, careful installation of reader hardware, and the right ***middleware*** to convert the raw data from the reader into information useful for operating the business.

Procedures are intimately connected with the planned usage for the RFID tags. Are the tags attached to individual items, boxes, or a pallet or other large container? Are the items to be inventoried on a shelf, counted as they move along a conveyorized transport belt, or tracked through a door? Can the orientation of objects to be read be controlled or must the reader account for randomly-oriented tags, and does this include tags placed end-on to the reader? What is the desired read range? Do the objects to be labeled contain metals or aqueous fluids, and if so can the tags be placed sufficiently far from these disturbing influences to be read? Is the necessary read reliability 90%, 99%, or 99.9%? Given the answers to such questions, the implementer can then develop procedures to ensure that the desired reliability is achieved.

As might be inferred from the discussion in section 1.5.3.2, selection and placement of reader antennas is a critical consideration for a successful installation. The MPR6000/7000 can be connected to two external antennas; these antennas should be configured to reliably cover the region over which tags are to be read. For example, at a doorway, one directional antenna may be placed < 1 meter (3 feet) from the ground and the other around 2 meters (6 feet) high, thus providing good coverage of the whole door area. When many readers are used in close proximity, consideration should be given to minimizing interference between readers; for example, configurations in which one reader antenna looks directly at a neighboring reader's antenna should be avoided. It may be useful to provide reflective or absorbtive shielding between reader installations.

The lower levels of middleware, dealing directly with the reader population, must incorporate very specific knowledge about the use procedures and environment in which the tags are being read, and are likely to be highly customized for each application. This software must provide filtering and aggregation capabilities to ensure that the data that is forwarded to the enterprise information systems is correctly categorized and representative of what is happening to the physical inventory of objects being tracked. Once this has been accomplished, the integration of a properly filtered and aggregated dataset with a standard enterprise resource planning package such as those available from vendors like Oracle or SAP is a reasonably well-established function, with the necessary customization provided by a large number of third-party vendors.

1.5.4 RFID standards

Bar codes for commercial products are standardized worldwide under the auspices of the Uniform Code Council and EAN International. In September of 2003, these organizations joined with the AutoID Labs headquartered at the Massachusetts Institute of Technology to form EPC Global Inc., chartered with the standardization of a generalization of the bar code system, the ***Electronic Product Code*** (EPC), as well as the creation of software and hardware standards to support the use of RFID systems in implementing identification of objects by means of EPC's. This work is intended to complement existing and ongoing activities at the ***International Standards Organization*** (ISO), where many standards for the operation of LF and HF RFID systems have already been defined.

1.5.4.1 EPC Global

EPC Global is creating a set of standards intended to provide a robust infrastructure for the proliferation of RFID technology:

- EPC Tag data: the standards define various formats for the unique identifier (EPC) for each tag, to be consistent with existing EAN/UCC standards: serialized version of the EAN.UCC Global Trade Item Number (GTIN®), the EAN.UCC Serial Shipping Container Code (SSCC®), the EAN.UCC Global Location Number (GLN®), the EAN.UCC Global Returnable Asset Identifier (GRAI®), the EAN.UCC Global Individual Asset Identifier (GIAI®), and a General Identifier (GID).

- UHF Tags: partial specifications for first-generation 'class 0' (factory-write-only) and 'class 1' (field-write allowed) tags are public. A second-generation standard for class 1 tags is in progress at the time of this writing.
- Physical Markup Language: In order to provide a standardized framework for exchange of EPC data between organizations, EPC Global is defining a ***physical markup language*** (PML) based on the popular extended markup language (XML) widely employed in web communications. In addition, standards for ***object name servers*** (ONS), analogous to the domain name servers employed to facilitate communications over the Internet, are being defined. Finally, specifications for ***savants*** that will provide modular, standardized RFID middleware functions are also being defined.

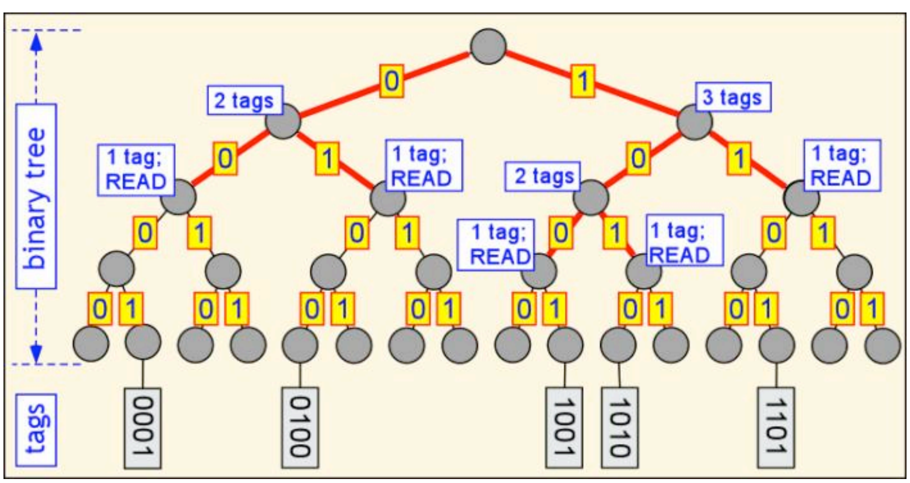
Tags compliant with the class 0 and class 1 EPC standards, manufactured by such vendors as Alien Technology, Matrics (now a division of Symbol Technologies), and Impinj, are already in common commercial use. The MPR5000 and 6000 will read both class 0 and class 1 and can write to class 0+ and class 1 tags. Firmware upgrades will allow the MPR series to read and write second-generation class 1 tags once they become available.

1.5.4.1.1 EPC Class 0 Summary

In this section we provide a very brief introduction to the operation of class 0 tags. Further information may be obtained from the document "Draft protocol specification for a 900 MHz Class 0 Radio Frequency Identification Tag", dated 2/23/03, available from the EPC Global Inc. web site.

Class 0 tags are factory-programmed and thereafter read-only. Each tag contains a nominal 64 bit EPC and a 16 bit ***cyclic redundancy check*** (CRC) in non-volatile memory. (Tags with 96-bit EPC's are also allowed, and are provided for in the MPR-series firmware.) The CRC is independently re-calculated by the reader when the EPC is read, and checked against that provided by the tag to check for errors in the read.

When more than one tag is in the field of the reader, the reader employs a binary-tree traversal to resolve possible collisions and individually address each tag (***singulation***). The traversal starts at the beginning of an ID string and chooses one of the two possible branches (first bit = 0 or first bit = 1). All tags whose first bit agrees with the reader's choice remain in the traversal, while those with the opposite bit become temporarily inactive waiting for the next traversal. When only one tag responds at any stage of the traversal, that tag can be read. Proceeding in this fashion over the whole ID string (if necessary), the reader must inevitably find all tags in the field if their ID's are unique and all the tags are able to follow the traversal.

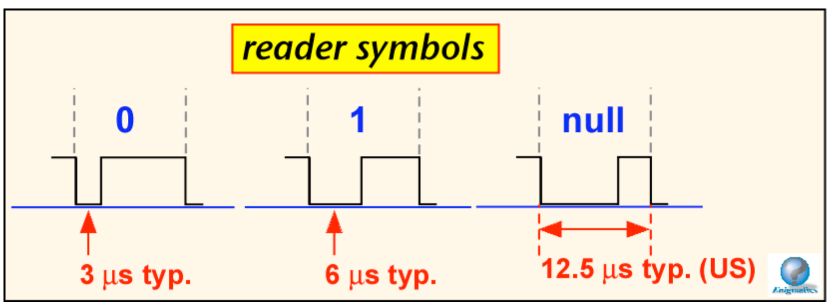


In general, there are much less than 2^{64} tags in the field in most practical cases. Thus it is often unnecessary and wastefully slow to use the 64-bit EPC to aid in singulation. The protocol requires each tag to provide two other ID's in addition to the 64-bit EPC. These ID's, known as ID0 and ID1, are both pseudo-random 16-bit numbers. ID0 is generated by each tag upon request by the reader. ID1 is programmed into each tag at the time of manufacture. In this nomenclature, the EPC is known as ID2.

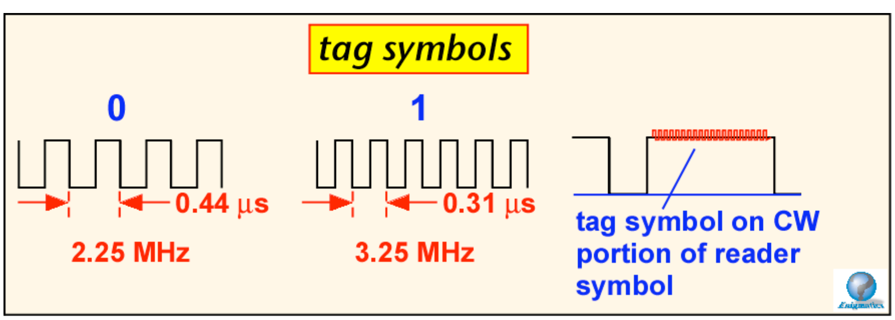
During traversal, each tag still in the traversal backscatters the next bit of its active ID to the reader, and listens for the reader to confirm that bit before remaining in the traversal. This procedure provides some simple error checking. However, if the EPC (ID2) is being used for singulation, it has the consequence that the reader sends some or all the bits of each tag's EPC. Since it is much easier to intercept high-powered reader transmissions than the low-power tag reflections, if security of tag EPC's is a concern, ID2 should not be used for singulation. Note that once a tag is singulated, the EPC can be read without echo by the reader.

The protocol also allows for ***filtering***, in which the inventory process is performed only on tags whose ID2 contains a fixed bit string provided by the reader. Filtering can be used to inventory only tags assigned to a particular manufacturer or a particular product type.

Amplitude-modulation is used to transmit information from the reader to the tag. In order to maximize the power simultaneously provided to the tag, special coding is employed to ensure that the reader power is high most of the time. The particular scheme employed here is known as ***pulse-interval modulation***. In each symbol, a short low-power pulse (1/4 of the bit time) denotes a binary 0, and a longer low-power pulse (half of the total bit time) denotes a binary 1. Thus the average transmitted power for a string with an equal number of 1's and 0's is 5/8 of the CW power. A long low-power pulse (3/4 of the bit time) denotes a special 'NULL' character, which appears infrequently and thus has little effect on the average power delivered to the tag. In the United States, a data rate of 80 kilobits per second (Kbps) is used. In Europe, a lower 16 Kbps rate is employed in order to operate within a narrower allowed channel.



Communication from the tag to the reader employs a sub-carrier modulation, in which the tag inverts states at a rate much faster than the data rate. In the particular scheme used in this protocol, the tag sends a 2.25 MHz backscattered signal for a binary 0, and 3.25 MHz for a binary 1. Tag backscatter is performed on the 'high' portion of each reader bit. Sub-carrier signaling has two benefits: the reader need only detect transitions of the tag state without regard to the direction of the transition (up or down), and if two or more tags simultaneously backscatter binary 1 and binary 0, the presence of both symbols can be detected by the reader, allowing it to gather some information about the tag population even when collisions are present.



Each time power is turned on, the reader proceeds through a set of steps to initialize the tag IC timing. First, the reader transmits a RESET consisting of 800 μs of CW power. A tag's "ID'd" flag (telling it that it was already read by the reader) may survive a RESET, but in other respects the tag returns to its default state. After the RESET, 8 pulses are used to calibrate the tag internal oscillator to the 2.2 MHz sub-carrier frequency. Finally, a set of pulses of varying length is transmitted to set the thresholds for distinguishing between 0, 1, and null, and to signal the tag when to begin its transmission.

In the United States, communications devices operating in unlicensed bands must either use direct-sequence or frequency-hopping spreading techniques. The MPR series products use pseudo-random hopping from one frequency to another. The Class 0 protocol does not require the reader to power down during hops, but the MPR5000 does in order to minimize spurious radiation. Therefore, a RESET / calibration sequence is necessary after each hop. The time between hops is available for the user to adjust, although regulations require that the transmitter remain on any given frequency for no longer than 400 ms at a time. In Europe, revised regulations allowing 10 channels have been promulgated and it is anticipated that with the passing of time frequency-hopping operation will become the normal means of operation in most European jurisdictions. European regulations will require that the reader ***listen before talking***: that is, the reader must check each putative channel for other active transmitters before beginning its own transmission. Note that the MPR5000/6000/7000 operate at 902-928 MHz and are not approved for use in Region 1 (European) jurisdictions.

Tags have 10 possible states, roughly corresponding to [startup / calibrate], [global commands], [binary tree traversal], and [singulated commands]. Each command is 8 bits long, with an additional parity bit provided for error checking. The tag echoes each bit it receives in order to provide a simple error check and acknowledgement function. Mandatory commands are:

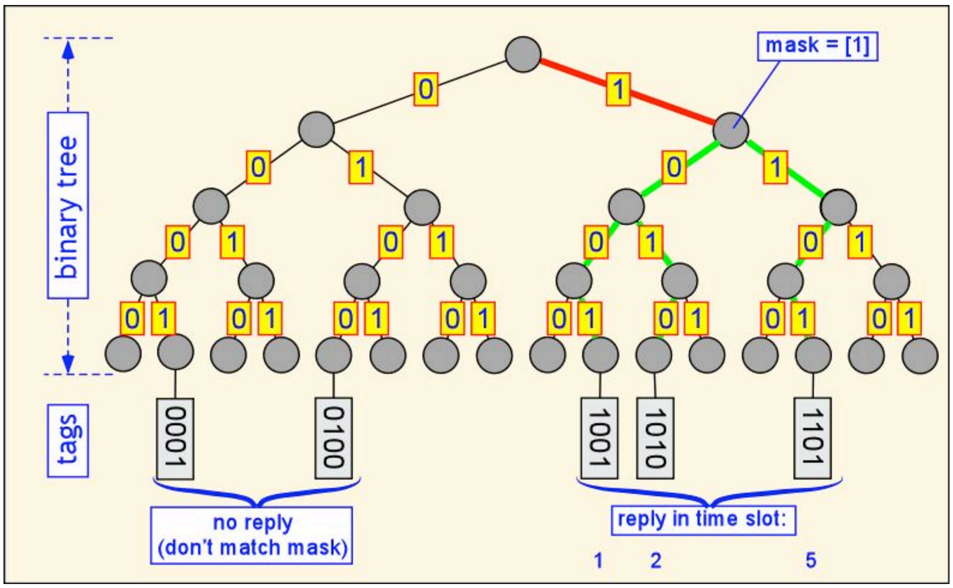
- ResetIDFlag: resets the identified flag to NOT READ; that is, it forces tags to forget whether they have been previously inventoried.
- SetNegotiationPage: this curious terminology is used to describe the choice of ID (ID0, 1, or 2) used for singulation during binary tree traversal.
- SegRegionofOperation: sets the backscatter parameters according to whether the device is operating under FCC or European regulations.
- ForceDormant: tags receiving this command immediately enter the Dormant state. The Dormant state is the default tag turn-on state, exited when a RESET is received.
- ForceMute: tags receiving this command immediately enter the Mute state. In the Mute state, the tags receive data but do not respond until a NULL is received. Tags that have been bypassed during traversal reside in the Mute state until the next traversal begins.
- Read: Read ID1 or ID2 (ID0, being randomly generated at the time of request, has no enduring interest and need not be read from the tag).
- Kill: Permanently disables the tag if a valid argument (passcode) is provided.

1.5.4.1.2 EPC Class 1 Summary

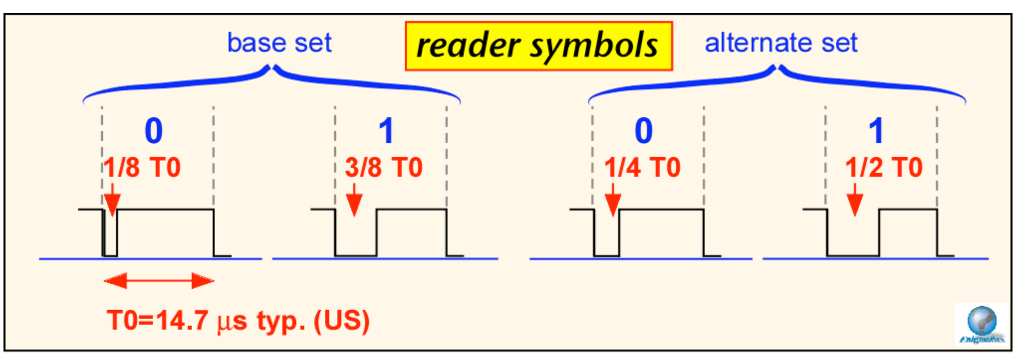
In this section we provide a very brief introduction to the operation of class 1 tags. Further information may be obtained from the document "Candidate Specification 860 MHz – 2500 MHz – Class 1 RFID Air Interface", revision 1.02, available from the EPC Global Inc. web site.

Class 1 tags are nominally factory-programmed but the write operation employs the radio interface and could be performed at manufacture or in the field. It is expected that once the tag is written to, the memory is locked and further write operations are disallowed. Each tag contains a nominal 64 bit or 96-bit EPC and a 16 bit ***cyclic redundancy check*** (CRC) in non-volatile memory. The CRC is independently re-calculated by the reader when the EPC is read, and checked against that provided by the tag to check for errors in the read. Unlike class 0 tags, where the rag responds immediately to each bit sent by the reader, class 1 tags use a more conventional packet-oriented protocol, with the reader transmitting a packet containing commands and data, followed by a response by the tag.

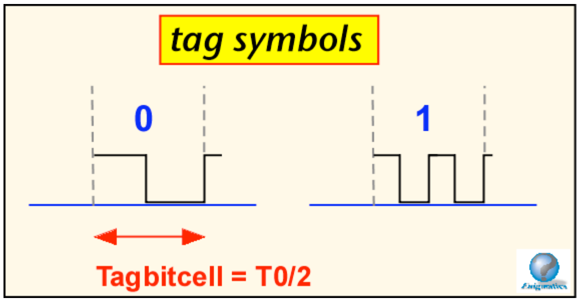
When more than one tag is in the field of the reader, the reader employs a binary-tree traversal to resolve possible collisions and individually address each tag (***singulation***). To begin the traversal, the reader sends a filter string consisting of a pointer location and a bit stream. The pointer location indicates where the bit stream starts in the EPC. Each tag tests the relevant portion of its EPC; those whose bits match the transmitted bit stream then send the next 8 bits of their EPC back to the reader. Filtering is thus incorporated in passing into the protocol. There are eight time slots for response, with the one chosen dependent upon 3 of the reply bits. This time slot mechanism provides some collision resolution and a simple error-checking mechanism. A simplified version of such a traversal is shown in the diagram below. If the reader hears only 1 tag in a given bin, the reader can immediately request that tag's full ID. Note that with this mechanism, the reader may but need not transmit all or much of the tag's EPC. Where security is an issue, large sections of the EPC should not be used as filters.



Amplitude-modulation is used to transmit information from the reader to the tag. In order to maximize the power simultaneously provided to the tag, special coding is employed to ensure that the reader power is high most of the time. Class 1 tags use a ***pulse-interval modulation*** scheme quite similar to that employed by class 0 tags. There are two options provided: a base set using a low pulse of 1/8 of a bit time for a binary 0 and 3/8 for a binary 1, and an alternate set using times of _ and _ of a bit time respectively (just like the class 0 symbols). There is no NULL symbol. Thus the average transmitted power for a string with an equal number of base-set 1's and 0's is _ of the CW power. In the United States, a data rate of about 62 kilobits per second (Kbps) is typically used. In Europe, a lower 15 Kbps rate is employed in order to operate within a narrower allowed channel.



The return link uses a simple form of subcarrier modulation, ***F2F***. Each bit time begins with a transition in the tag state. To transmit a binary 0, the tag adds one transition in the middle of the bit. To transmit a binary 1, 3 additional transitions are employed. (Thus, a string of binary 0's has a fundamental frequency of (1/Tbit), whereas the fundamental frequency of a string of binary 1's is (2/Tbit), hence the name of this coding scheme.) Each tag bit occupies _ of the time used for a reader bit, so that the nominal data rates are about 140 Kbps in the US and 30 Kbps in Europe.



Instead of employing a single long RESET and synchronization for a sequence of exchanges, as is done in class 0, class 1 provides packet-by-packet tag synchronization. Each packets starts with a 64 µs CW period to power up any tags in listening range, followed by data. During binary tree traversal, the reader then sends a binary 1 to mark the edge of a response time slot or 'bin', so the tags have no need to maintain an accurate clock to time the edges of the 8 possible response bins. A tag that response begins its packet with a fixed 8-bit preamble, followed by the next few bits of its EPC, or in the case of a full scroll the remainder of the EPC.

Tags have six possible states: Power Up, Awake, Asleep, Reply, Program , and Dead. Responses to commands depend solely on the current state and not on how the tag arrived there. The basic commands are:

- ScrollID: a tag whose EPC bits match the filter bits responds with its complete EPC
- Quiet: a tag whose EPC bits match the filter bits goes to sleep
- Kill: Permanently disable the tag if a valid argument (passcode) is provided.
- PingID: a tag whose EPC bits match the filter responds with the next 8 bits of its EPC
- Talk: a tag whose EPC bits match the filter bits wakes up
- ScrollallID: all tags hearing this command respond with their full EPC
- Pincscroll: Optional command allowing quick scroll of full ID from any tag that is the sole responder in a given bin.

1.5.4.2 ISO

The international standards organization has defined a number of standards covering RFID hardware and operation. Currently, ISO is defining a series of tag and reader standards under ISO 18000, covering operation at LF, HF, UHF, and microwave bands. ISO 18000-3 describes 13.56 MHz tags and readers, generally assuming a thin, flexible form factor appropriate to smart cards or labels. ISO 18000-4 describes operation at 2.45 GHz, including both passive and active versions. ISO 18000-6 describes two variant forms (A and B) of UHF tags. Finally, ISO 18000-7 describes active tags operating at 433 MHz, providing long range and high data rates but at much higher expense than passive tags.

ISO 15963 specifies unique tag identification numbers, and 15961 and 15962 specify data protocols and encoding. ISO 18046 and 18047 specify test methods for tags and readers.

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1.6 MPR Host-Reader Interface

1.6.1 Scope

The scope of this section is to specify the MPR-series RFID reader's PCMCIA host interface protocol.

1.6.2 Physical interface

The physical interface is a standard 68-pin PC-card bus. See the document "The PC Card Standard", published by the Personal Computer Memory Card International Association (PCMCIA) and the Japan Electronics and Information Technologies Industry Association (JEITA) for further information.

1.6.3 Host Virtual Serial Interface

In normal operating mode, the host communicates with the reader over the UART-on-PC Card bus. When inserted in the PC Card slot, the host recognizes the Reader as a MPR5000, and associates it with an available COM port. The host can then communicate with the reader as if it was attached via a traditional RS232 serial port.

For normal command communication with the MPR5000, the standard serial COM port is configured as in table 0.

Baud Rate	Parity	Stop Bits	Handshaking	Data Bits
57600	None	1	None	8

Table 0: COM port configuration for standard communications.

1.6.4 Host Interface Protocol

The following sections will define this protocol by breaking down the different fields and layers of the protocol. The data packet from the host to the reader is known as the request and the reply from the reader to the host as the response. The host initiates all communication sequences, which consist of request-response pairs. After sending a request, the host waits for a response before continuing. The data section for the request packet is limited to 64 bytes maximum while a total buffer space of 256 bytes should be reserved for the response packet.

NOTE: All multi-byte packet fields are communicated 'big-endian,' which is the same as MS-byte first.

1.6.5 Messaging Protocol

1.6.5.1 Protocol Description

- Host – Reader communications follows a Request-Response protocol.
- The Host sends request packets, and the Reader sends Responses. The Reader never sends unsolicited traffic.
- Every properly received request is acknowledged with at least one response packet.
- A response may consist of more than one packet.
- Bytes received before a proper SOF (Start of Frame) byte and packets with CRC errors are ignored.
- There is no explicit message termination.
- The Length byte must be used to determine the location of CRC, and therefore, the end of packet.
- Maximum data section length is 64 bytes for host Request Packets.
- Maximum data section length is 256 bytes for reader Response Packets.

1.6.6 Packet Formats

1.6.6.1 Request Packet Format

Table 1 Request Packet Format

SOF	Node Address	Length	Command	Data 0	…	Data N	CRC MSB	CRC LSB

Table 2 Request Packet Format Details

Field Name	Size (bytes)	Value	Purpose
SOF	1	0x01	Start of Frame (Packet) delimiter
Node Address	1	0x00	Ignored
Length	1	Packet length excluding SOF	
Command	1	(See command details)	The command to be processed
Data	0-64	(See command details)	Specifies the parameters and data for a command
CRC	2	Bitwise inversion of 16bit CCITT-CRC of packet excluding SOF, MSB first (see Section 1.6.6.3)	Allows validation of correct reception of the request packet

1.6.6.2 Response Packet Format

Table 3 Response Packet Format

SOF	Node Address	Length	Status	Data 0	…	Data N	CRC MSB	CRC LSB

Table 4 Response Packet Format Details

Field Name	Size (bytes)	Value	Purpose
SOF	1	0x01	Start of Frame (Packet) delimiter
Node Address	1	0x00	Ignored
Length	1	Packet length excluding SOF	
Status	1	(See **Error! Reference source not found.**)	The status of the last requested command
Data	0-256	(See command details)	The results for the command that was just processed
CRC	2	Bitwise inversion of 16bit CCITT-CRC of packet excluding SOF, MSB first (see Section 1.6.6.3)	Allows validation of correct reception of the response packet

1.6.6.3 CRC Calculation

A 16bit CCITT CRC is used for error detection and placed at the end of the frame. The calculation uses all bytes of the frame excluding the leading SOF. The CCITT CRC polynomial is $x^{16} + x^{12} + x^5 + 1$, and the preload value is 0xFFFF. The CRC is appended to the frame after the command data, MSB first. The following code snippet and test vectors can be used as a guide to implement the CRC. The bitwise inversion (CRC XOR 0xFF) of the CRC is included in a transmitted frame. On receipt, the CRC is computed on the bytes between SOF and CRC. For valid frames, this will agree with the transmitted CRC value.

Some Test Vectors:

"ABCDEFG" returns 0xB82F

"WJCI RFID" returns 0x9ACF

An array of 256 capital 'N' characters returns 0xE45C

```
/*
This calculation uses a table lookup to generate CCITT CRC values.
The CCITT polynomial is: x^16 + x^12 + x^5 + 1
Forward direction table - i.e. msbit first
*/


static unsigned int crctab[256] = {
0x0000, 0x1021, 0x2042, 0x3063, 0x4084, 0x50A5, 0x60C6, 0x70E7, 0x8108,
0x9129, 0xA14A, 0xB16B, 0xC18C, 0xD1AD, 0xE1CE, 0xF1EF, 0x1231, 0x0210,
0x3273, 0x2252, 0x52B5, 0x4294, 0x72F7, 0x62D6, 0x9339, 0x8318, 0xB37B,
0xA35A, 0xD3BD, 0xC39C, 0xF3FF, 0xE3DE, 0x2462, 0x3443, 0x0420, 0x1401,
0x64E6, 0x74C7, 0x44A4, 0x5485, 0xA56A, 0xB54B, 0x8528, 0x9509, 0xE5EE,
0xF5CF, 0xC5AC, 0xD58D, 0x3653, 0x2672, 0x1611, 0x0630, 0x76D7, 0x66F6,
0x5695, 0x46B4, 0xB75B, 0xA77A, 0x9719, 0x8738, 0xF7DF, 0xE7FE, 0xD79D,
0xC7BC, 0x48C4, 0x58E5, 0x6886, 0x78A7, 0x0840, 0x1861, 0x2802, 0x3823,
0xC9CC, 0xD9ED, 0xE98E, 0xF9AF, 0x8948, 0x9969, 0xA90A, 0xB92B, 0x5AF5,
0x4AD4, 0x7AB7, 0x6A96, 0x1A71, 0x0A50, 0x3A33, 0x2A12, 0xDBFD, 0xCBDC,
0xFBBF, 0xEB9E, 0x9B79, 0x8B58, 0xBB3B, 0xAB1A, 0x6CA6, 0x7C87, 0x4CE4,
0x5CC5, 0x2C22, 0x3C03, 0x0C60, 0x1C41, 0xEDAE, 0xFD8F, 0xCDEC, 0xDDCD,
0xAD2A, 0xBD0B, 0x8D68, 0x9D49, 0x7E97, 0x6EB6, 0x5ED5, 0x4EF4, 0x3E13,
0x2E32, 0x1E51, 0x0E70, 0xFF9F, 0xEFBE, 0xDFDD, 0xCFFC, 0xBF1B, 0xAF3A,
0x9F59, 0x8F78, 0x9188, 0x81A9, 0xB1CA, 0xA1EB, 0xD10C, 0xC12D, 0xF14E,
0xE16F, 0x1080, 0x00A1, 0x30C2, 0x20E3, 0x5004, 0x4025, 0x7046, 0x6067,
0x83B9, 0x9398, 0xA3FB, 0xB3DA, 0xC33D, 0xD31C, 0xE37F, 0xF35E, 0x02B1,
0x1290, 0x22F3, 0x32D2, 0x4235, 0x5214, 0x6277, 0x7256, 0xB5EA, 0xA5CB,
0x95A8, 0x8589, 0xF56E, 0xE54F, 0xD52C, 0xC50D, 0x34E2, 0x24C3, 0x14A0,
0x0481, 0x7466, 0x6447, 0x5424, 0x4405, 0xA7DB, 0xB7FA, 0x8799, 0x97B8,
0xE75F, 0xF77E, 0xC71D, 0xD73C, 0x26D3, 0x36F2, 0x0691, 0x16B0, 0x6657,
0x7676, 0x4615, 0x5634, 0xD94C, 0xC96D, 0xF90E, 0xE92F, 0x99C8, 0x89E9,
0xB98A, 0xA9AB, 0x5844, 0x4865, 0x7806, 0x6827, 0x18C0, 0x08E1, 0x3882,
0x28A3, 0xCB7D, 0xDB5C, 0xEB3F, 0xFB1E, 0x8BF9, 0x9BD8, 0xABBB, 0xBB9A,
0x4A75, 0x5A54, 0x6A37, 0x7A16, 0x0AF1, 0x1AD0, 0x2AB3, 0x3A92, 0xFD2E,
0xED0F, 0xDD6C, 0xCD4D, 0xBDAA, 0xAD8B, 0x9DE8, 0x8DC9, 0x7C26, 0x6C07,
0x5C64, 0x4C45, 0x3CA2, 0x2C83, 0x1CE0, 0x0CC1, 0xEF1F, 0xFF3E, 0xCF5D,
0xDF7C, 0xAF9B, 0xBFBA, 0x8FD9, 0x9FF8, 0x6E17, 0x7E36, 0x4E55, 0x5E74,
0x2E93, 0x3EB2, 0x0ED1, 0x1EF0
```

```
};

unsigned short CalculateBlockCRC16(byte count, char *buffer)
{
	unsigned short crc = 0xFFFF;
	char *pBuf;
	pBuf = (char *)buffer;

	while (count--)
		crc = (unsigned short)((crc << 8) ^ crctab[(crc >> 8) ^
*pBuf++]);
	return (unsigned short)(~crc);
}
```

1.6.7 Command Set

1.6.7.1 Reader Commands

1.6.7.1.1 Reader Information Get (01_h)

Reads basic information from the reader.

<u>Returned Information:</u>
Serial Number
Firmware Version
Hardware Version *(not implemented yet)*
Bootloader Version *(not implemented yet)*

Request Packet

Opcode	0x01
Command Data	N/A

Response Packet

Status	0x00	Complete
Serial Number	8 bytes	MSB First
Software Version	2 bytes	MSB First

1.6.7.1.2 Reader Sleep (--) – not implemented yet

Puts the reader in its lowest power "sleep" state.

1.6.7.1.3 Reader Reboot (--) – not implemented yet

Reboots the reader firmware.

1.6.7.1.4 Manufacturing Information Write (--) – not implemented yet

This is a protected command used during calibration & configuration stage to store manufacturing information in onboard Nonvolatile storage. See 1.6.13for manufacturing information details.

1.6.7.2 Tag Commands

1.6.7.2.1 Class0 Inventory (11_h)

Returns a list of all Class0 tags found in the field of the reader.

Request Packet

Opcode	0x11

Command Data

Antenna	1 byte	0x00: Ant A 0x01: Ant B
RF Power Level	1 byte	0x01 (min) – 0xFF (max)
Singulation (Negotiation Page) Field	1 byte	0x00 (ID0) 0x01 (ID1) 0x02 (ID2)
Filter Bit Count	1 byte	0-64 or 0-96
Filter Bits	0-12 bytes	Tag ID filter bits are left justified in bytes, MSByte sent first

Note: If the RF power level is 0, a Zero Power Error (0xF3) is returned.
Note: Filter bits must be left justified within the field. The least significant bits of the LSB might not be filled.
Note: Singulation Fields ID0 & ID1 are not implemented yet.

The response is composed of one or more packets. The non-final packets will have a Status Byte of 0x01 (In Progress) and will contain TagIDs. The final packet will contain an inventory summary, and a Status Byte of 0x00.

Non-final Response Packet

Status	0x01 (In Progress)
Number of TagIDs in Packet	1 byte
TagID	8 or 12 bytes
…	…
TagID	8 or 12 bytes

TagID is returned MSByte first. The first byte of the TagID encodes the EPCglobal tag type. This must be used to determine the tag length. EPC-64 tags return 8 bytes, EPC-96 return 12 bytes. The two highest order bits for EPC-96 are 0b00, all other values indicate an EPC-64 tag.

The final response packet contains an inventory summary.

Final Response Packet

Status	0x00 (Complete)
Total Tags reported	2 bytes
Under-run error count	2 bytes
Tag CRC error count	2 bytes

Example

Using Antenna B, an RF Power of 0xC0, and singulating with ID1, read all tags that match 38 (0x26) Filter bits having a value of 0xC80507A000.

Entire Request Packet:

SOF	Node	Len	Command	Ant	Power	Sing	Filt Bits	Filter	CRC
01	00	0E	11	01	C0	01	26	C8 05 07 A0 00	xx xx

Response for two matching ePC tags:

Response Packet (first packet)

SOF	Node	Len	Status	Num TagIDs	Tag EPC	Tag EPC	CRC
01	00	16	01	02	C8 05 07 A0 00 81 09 30	C8 05 07 A0 00 81 09 2E	xx xx

Response Packet (final packet)

SOF	Node	Len	Status	Total Tags Reported	Under-run errors	CRC errors	CRC
01	00	0B	00	00 02	00 0D	00 00	xx xx

1.6.7.2.2 Class0 Kill Tag (12_h)

Attempts to kill one Class0 Tag.

Request Packet

Opcode	0x12

Command Data

Antenna	1 byte	0x00: Ant A 0x01: Ant B
RF Power Level	1 byte	0x01 (min) – 0xFF (max)
Singulation (Negotiation Page) Field	1 byte	0x00 (ID0) 0x01 (ID1) 0x02 (ID2)
Kill Passcode	3 bytes	As required to kill the tag
Tag ID bits	8 or 12 bytes	Tag ID bits, MSB first

Note: Singulation Fields ID0 & ID1 are not implemented yet.

Response Packet

Status	0x00	Complete
Count	0x01	Tag found and processed

1.6.7.2.3 Class0 Plus Commands (18_h)

The Class0 Plus (Impinj/ZUMA) capabilities are accessed via this single command. Specific functions are specified by a subcommand.

1.6.7.2.3.1 Class0 Plus Write Row Subcommand (00_h)

Writes a row (3 bytes) of data to a specified row address of a Class0 Plus (Impinj/ZUMA) Tag. If a filter is supplied, tags are first singulated then processed. If no filter is supplied, the global mode is used for processing.

Request Packet

Opcode	0x18

Command Data

Antenna	1 byte	0x00: Ant A 0x01: Ant B
RF Power Level	1 byte	0x01 (min) – 0xFF (max)
Singulation (Negotiation Page) Field	1 byte	0x00 (ID0) 0x01 (ID1) 0x02 (ID2)
Subcommand	1 byte	0x00
Row Number	1 byte	0-15
Row Data	3 bytes	18 bits are right justified in bytes, MSByte is sent first
Filter Bit Count	1 byte	0-64 or 0-96
Filter Bits	0-12 bytes	Tag ID filter bits are left justified in bytes, MSByte is sent first

Note: Singulation Fields ID0 & ID1 are not implemented yet.

Response Packet

Status	0x00 (Complete)
Total Tags reported	2 bytes
Under-run error count	2 bytes
Tag CRC error count	2 bytes

1.6.7.2.3.2 Class0 Plus Read Row Subcommand (01_h)

Reads a row of data from a Class0 Plus (Impinj/ZUMA) tag. This subcommand only operates on singulated tags.

Request Packet

Opcode	0x18

Command Data

Antenna	1 byte	0x00: Ant A 0x01: Ant B
RF Power Level	1 byte	0x01 (min) – 0xFF (max)
Singulation (Negotiation Page) Field	1 byte	0x00 (ID0) 0x01 (ID1) 0x02 (ID2)
Subcommand	1 byte	0x01
Row Number	1 byte	0-15
Filter Bit Count	1 byte	0-64 or 0-96
Filter Bits	0-12 bytes	Tag ID filter bits are left justified in bytes, MSByte is sent first

Note: Singulation Fields ID0 & ID1 are not implemented yet.

The response is composed of one or more packets. The non-final packets will have a Status Byte of 0x01 (In Progress) and will contain a TagID and a row of data for each singulated Tag. The final packet will contain an inventory summary and a Status Byte of 0x00 (Complete).

Non-final Response Packet

Status	0x01 (In Progress)
Number of TagIDs in Packet	1 byte
TagID	8 or 12 bytes
Tag Data	3 bytes
…	…
TagID	8 or 12 bytes
Tag Data	3 bytes

The final response packet contains an inventory summary.

Final Response Packet

Status	0x00 (Complete)
Total Tags reported	2 bytes
Under-run error count	2 bytes
Tag CRC error count	2 bytes

Example

Using Antenna B, an RF Power of 0xC0, and singulating with ID1, read all tags that match 38 (0x26) Filter bits having a value of 0xC80507A000 and return data from row 13 (0x0d).

Entire Request Packet:

SOF	Node	Len	Cmd	Ant	Power	Sing	Subcmd	Row #	# Filt Bits	Filter	CRC
01	00	10	18	01	C0	01	01	0D	26	C8 05 07 A0 00	xx xx

Response for two matching ePC tags:

Response Packet (first packet)

SOF	Node	Len	Stat	#Tags	Tag EPC	Tag data
01	00	1C	01	02	C8 05 07 A0 00 81 09 30	00 45 67

Tag EPC	Tag data	CRC
C8 05 07 A0 00 81 09 2E	00 12 34	xx xx

Response Packet (final packet)

SOF	Node	Len	Status	Total Tags Reported	Under-run errors	CRC errors	CRC
01	00	0B	00	00 02	00 0D	00 00	xx xx

1.6.7.2.3.3 Class0 Plus INIT Subcommand (02_h)

Performs a Class 0 Plus (Impinj/ZUMA) INIT command. If a filter is supplied, tags are first singulated then processed. If no filter is supplied, the global mode is used for processing.

Request Packet

Opcode	0x18

Command Data

Antenna	1 byte	0x00: Ant A 0x01: Ant B
RF Power Level	1 byte	0x01 (min) – 0xFF (max)
Singulation (Negotiation Page) Field	1 byte	0x00 (ID0) 0x01 (ID1) 0x02 (ID2)
Subcommand	1 byte	0x02
Lock Flag	1 byte	0x00 (Do Not Lock) 0x01 (Lock)
Filter Bit Count	1 byte	0-64 or 0-96
Filter Bits	0-12 bytes	Tag ID filter bits are left justified in bytes, MSByte is sent first

Note: Any tag that processes this command MUST then complete a power cycle.
Note: Singulation Fields ID0 & ID1 are not implemented yet.

Response Packet

Status	0x00 (Complete)
Total Tags reported	2 bytes
Under-run error count	2 bytes
Tag CRC error count	2 bytes

1.6.7.2.3.4 Class0 Plus Write ACK Subcommand (03_h)

Performs a Class 0 Plus (Impinj/ZUMA) Write ACK command. This subcommand only operates on singulated tags.

Request Packet

Opcode	0x18

Command Data

Antenna	1 byte	0x00: Ant A 0x01: Ant B
RF Power Level	1 byte	0x01 (min) – 0xFF (max)
Singulation (Negotiation Page) Field	1 byte	0x00 (ID0) 0x01 (ID1) 0x02 (ID2)
Subcommand	1 byte	0x03
Row Number	1 byte	0-15
Row Data	3 bytes	18 bits are right justified in bytes, MSByte is sent first
Filter Bit Count	1 byte	0-64 or 0-96
Filter Bits	0-12 bytes	Tag ID filter bits are left justified in bytes, MSByte is sent first

Note: If writing to row 0 or at the completion of writing the Tag EPC and CRC, the tag MUST then complete a power cycle.
Note: Singulation Fields ID1 & ID2 are not implemented yet.

Response Packet

Status	0x00 (Complete)
Total Tags reported	2 bytes
Under-run error count	2 bytes
Tag CRC error count	2 bytes

1.6.7.2.4 Class1 Inventory (21_h)

Returns a list of all Class1 tags found in the field of the reader.

Request Packet

Opcode	0x21

Command Data

Antenna	1 byte	0x00: Ant A 0x01: Ant B
RF Power Level	1 byte	0x01 (min) – 0xFF (max)
Filter Bit Count	1 byte	0-64 or 0-96
Filter Bits	0-12 bytes	Tag ID filter bits are left justified in bytes, MSByte sent first

Note: If RF Power Level is zero, a Zero Power Error is returned.

Response:

The response is composed of one or more packets. The nonfinal packets will have a Status Byte of 0x01 (In Progress) and will contain TagIDs. The final packet will contain an inventory summary, and a Status Byte of 0x00.

Non-final Response Packet

Status	0x01 (In Progress)
Number of TagIDs in Packet	1 byte
TagID	8 or 12 bytes
…	…
TagID	8 or 12 bytes

TagID is returned MSByte first. The first byte of the TagID encodes the ePC tag type. This must be used to determine the tag length. EPC-64 tags return 8 bytes, EPC-96 12 bytes. The two highest order bits for EPC-96 are 0b00, all other values indicate an EPC-64 tag.

The final response packet contains an inventory summary.

Final Response Packet

Status	0x00 (Complete)
Total Tags reported	2 bytes
Under-run error count	2 bytes
Tag CRC error count	2 bytes

Example

Using Antenna A, and RF Power 0xB0, read all Class 1 tags that match 38 (0x26) Filter bits having a value of 0xC80507A000.

Entire Request Packet:

SOF	Node	Len	Command	Ant	Power	Filt Bits	Filter	CRC
01	00	0D	11	00	B0	26	C8 05 07 A0 00	xx xx

Response for two matching ePC tags:

Response Packet (first packet)

SOF	Node	Len	Status	Num Tag IDs	Tag EPC	Tag EPC	CRC
01	00	16	01	02	C8 05 07 A0 00 81 09 30	C8 05 07 A0 00 81 09 2E	xx xx

Response Packet (final packet)

SOF	Node	Len	Status	Total Tags Reported	Under-run errors	CRC errors	CRC
01	00	0B	00	00 02	00 0D	00 00	xx xx

1.6.7.2.5 Class1 Kill Tag (22_h)

Attempt to kill one Class1 Tag.

Request Packet

Opcode	0x22

Command Data

Antenna	1 byte	0x00: Ant A 0x01: Ant B
RF Power Level	1 byte	0x01 (min) – 0xFF (max)
Tag ID bits	8 or 12 bytes	Tag ID bits, MSB first
Kill Passcode	1 bytes	As required to kill the tag

Response Packet

Status	0x00	Complete

1.6.7.2.6 Class1 Tag Write (23_h)

Write to a Class1 Tag.

Request Packet

Opcode	0x23

Command Data

Antenna	1 byte	0x00: Ant A 0x01: Ant B
RF Power Level	1 byte	0x01 (min) – 0xFF (max)
Pointer	1 byte	0, 16, 32, 48, 64, 80 or 96
Data	2 bytes	16 bits sent MSByte first

Response Packet

Status	0x00	Complete

1.6.7.2.7 Class1 Verify ID (24_h)

Verify the ID was correctly programmed into a Class1 tag.

Request Packet

Opcode	0x24

Command Data

Antenna	1 byte	0x00: Ant A 0x01: Ant B
RF Power Level	1 byte	0x01 (min) – 0xFF (max)

<u>Response:</u>

The response is composed of one or more packets. The nonfinal packets will have a Status Byte of 0x01 (In Progress) and will contain Tag CRCs, Ids and Passwords. The final packet will contain a summary, and a Status Byte of 0x00 (Complete).

Non-final Response Packet

Status	0x01 (In Progress)	In Progress
Number of TagIDs in Packet	1 byte	
Tag CRC (MSByte first)	1 byte	MSByte first
Tag ID	8 or 12 bytes	
Tag Password	1 byte	
…	…	
Tag CRC (MSByte first)	1 byte	MSByte first
Tag ID	8 or 12 bytes	
Tag Password	1 byte	

The final response packet contains an inventory summary.

Final Response Packet

Status	0x00 (Complete)
Total Tags reported	2 bytes
Under-run error count	2 bytes
Tag CRC error count	2 bytes

1.6.7.2.8 Class1 Erase ID (25_h)

Erase the ID that was previously programmed into a Class1 tag.

Request Packet

Opcode	0x25

Command Data

Antenna	1 byte	0x00: Ant A 0x01: Ant B
RF Power Level	1 byte	0x01 (min) – 0xFF (max)

Response Packet

Status	0x00	Complete

1.6.8 Host Side Drivers

1.6.9 VPU

The VPU (Versatile PCMCIA UART) is a PCMCIA to serial UART bridge. It provides the hardware interface between the PCMCIA socket and the hardware in the MPR. The MPR appears as a standard COM port to the host. Commands are sent and received via serial interface APIs that are common to most programming languages.

The MPR, when used in a Windows 95/98/XP operating system will use the standard Microsoft serial drivers. An information file (MS Windows .inf file) is provided to associate the MPR5000 with the Windows 95/98/XP built-in serial drivers. During the installation process, the user will be prompted to supply this file.

During the installation of the MPR Series PC Card on Windows XP platforms, the user will be warned that the drivers are not digitally signed.

Warning
Microsoft strongly recommends you only use device drivers with the **Designed for Microsoft Windows XP** logo. Installing device drivers that have not been digitally-signed by Microsoft may disable the system, allow viruses onto your computer, or otherwise impair the correct operation of your computer either immediately or in the future.

This is not a problem. The MPR will work properly without the digital signature. This hardware uses *Microsoft's own drivers*! There is no additional risk of disabling the system, allowing viruses on your computer or to otherwise impair the correct operation of your computer.

1.6.10 Special Functions

The vast majority of signaling with the MPR is done over the virtual COM port channel provided by the PCMCIA to UART bridge. There are a couple of extra functions that the host may perform by communicating directly with the bridge module. These functions are initiated by changing the COM port settings to the values specified in **Error! Reference source not found.**, followed by sending a sequence of bytes.

Table 5 Special Function COM port settings

Baud Rate	Parity	Stop Bits	Handshaking	Data Bits
57600	None	1.5 (See Note)	None	5

Note: Some serial port APIs do not correctly interpret the 1.5 stop bit setting (LabView's VISA is one such API). If these functions don't work, try using 2 stop bits instead of 1.5.

Always return the serial settings to those specified in *Error! Reference source not found.* ***(****Error! Reference source not found.****) for normal operation of the reader.***

1.6.10.1 Hard Reset

This function performs a hard reset of the MPR5000. This could be used to cause the MPR5000 to recover from a catastrophic fault, or to return it to its initial powered on state.

Byte Sequence: 0x10, 0x00

1.6.11 Specialized PCMCIA Operating Modes

1.6.11.1 TTL Serial Port Mode

Pin 33 of the PC-card interface is the COM_ENABLE pin. When this pin is held HIGH (default condition), the MPR5000 operates under the standard PCMCIA interface rules, and serial control is provided through UART emulation over the PC-card bus. When this pin is held LOW (grounded), the card can be operated as a 'true' TTL serial device, with the pin assignments shown in the table.

1.6.11.1.1.1.1 TTL SERIAL COMMUNICATIONS MODE	
Pin	**Function**
37	TX
38	RX
39	BOOT_LOAD
40	WAKE
41	RESET

Table 6: TTL Serial Communications Mode

1.6.12 Status Codes

Table 7 Response Status Codes

Code	Meaning

0xFF	Error
0x00	Complete
0x01	In Progress

1.6.13 Error Codes

Table 8 Error Codes

Code	**Meaning**
0xF0	Invalid command parameter(s)
0xF1	Insufficient data
0xF2	Command not supported
0xF3	Zero Power
0xF4	PLL Lock Fail
0xF5	Antenna Fault (not present or shorted)
0xF6	Subcommand not supported
0xF7	Invalid subcommand parameter(s)
0xFF	Undefined Error

Note: Error Codes are present in the first data byte of a Response message when the Response Status Code = 0xFF (Error).

1.6.14 Manufacturing Information

Manufacturing information should include, at a minimum, the following string data:

- Serial Number (11 ASCII Characters)
- Date of Manufacture (6 ASCII Characters)
- Model Number (6 ASCII Characters)
- Hardware Revision (5 ASCII Characters)
- Manufacturer's Name (16 ASCII Characters)

This information is stored in onboard non-volatile storage.

1.7 Troubleshooting / technical support

1.7.1 COM Port Reset

If the MPR-series card is removed and replaced while an application (such as the demo user interface) is running, communications with the card may be lost. This typically results from a failure to re-associate with the correct COM port within the application. Restarting the application will normally reset the COM port and restore normal communications functions.

For technical support, contact WJ Communications Applications Engineering:

By email: applications.engineering@wj.com

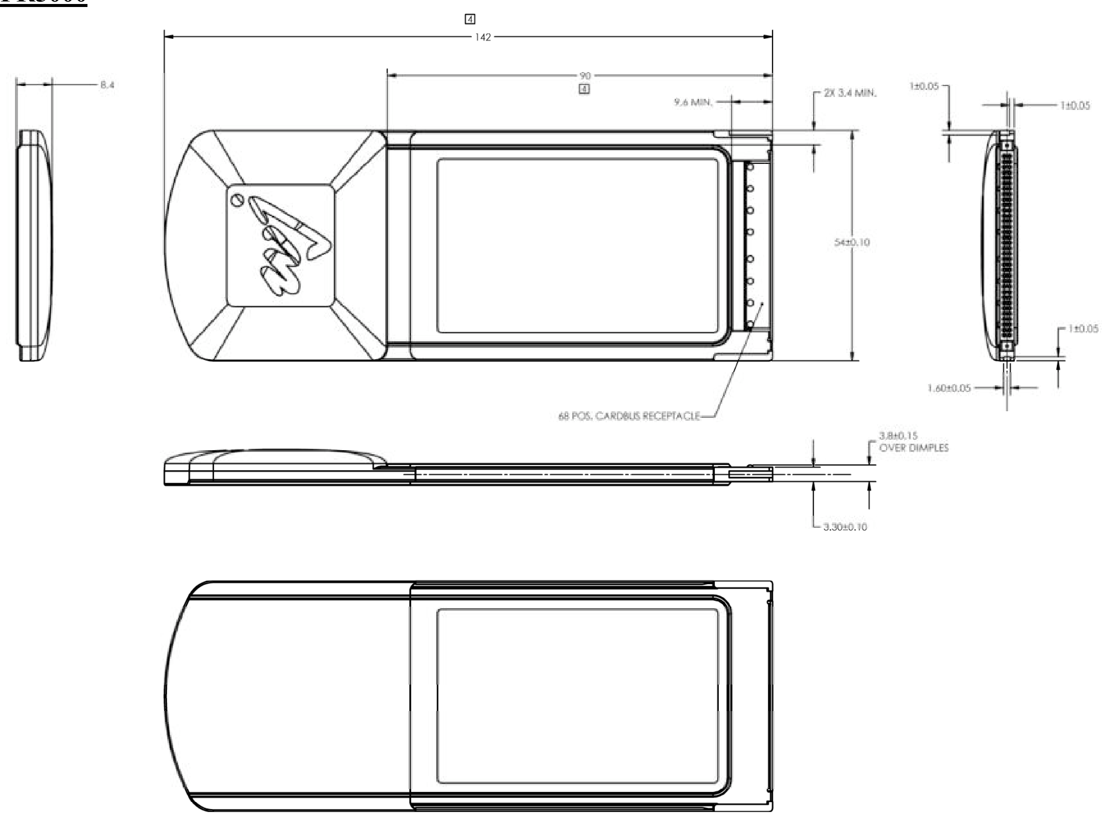
By phone: 1-800-951-4401

1.8 Technical specifications: MPR5000 / MPR6000 / MPR7000

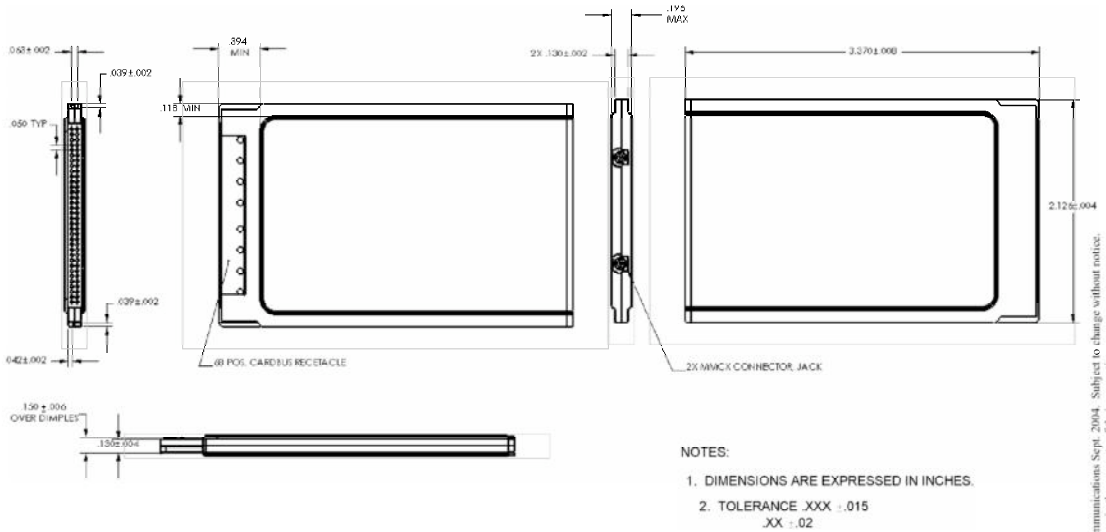
FREQUENCY OF OPERATION	902-928 MHz (US ISM band)	pseudo-random frequency hopping over 50 channels
MAXIMUM OUTPUT POWER	27 dBm (0.5 Watt)	MPR5000/6000
	30 dBm (1.0 Watt)	MPR7000
TAG PROTOCOLS	EPCglobal Class 0	firmware upgradeable for future standards
	EPCglobal Class 1	
	Class 0+ compatible	
REGULATORY COMPLIANCE	US FCC part 15	
HOST INTERFACE	Standard PC-card™ interface	equivalent to PCMCIA type II, 68-pin
DC POWER CONSUMPTION	500 mA @ 5 V	
OPERATING TEMPERATURE	0 to 40º C	
STORAGE TEMPERATURE	-20 to 70º C	
ANTENNA CONNECTION	2x(MMCX female)	MPR6000/7000 only

MECHANICAL CONFIGURATION:

MPR5000



MPR6000/7000:



1.9 Notices

1.9.1 RFID limitations

Communication between tags and readers at UHF frequencies is a complex phenomenon depending on details of the environment surrounding the tags and reader(s) as well as the equipment being used. Some environmental aspects (such as tag placement and orientation) may be controllable by the user; others (such as reflections of the RF radiation by ambient objects) are generally not. Careful installation and testing, and development and adherence to appropriate operating procedures, are indispensable for successful implementation of RFID. WJ Communications Inc. makes no representation or warrantee that any specific configuration of RFID tags and readers will provide any given performance characteristics.

1.9.2 Safety

Any use of this equipment with antennas or cabling installed outdoors or otherwise exposed to inclement weather must avoid proximity with power lines or other high-voltage conductors, and provide for proper grounding and lightning arresting devices to protect the equipment user in the event of a lightning strike. See National Electrical Code (NEC) requirements articles 725, 800, and 810 for further information.

Do not operate the MPR5000/6000/7000 in any area where critical safety equipment may be sensitive to RF interference, such as medical or life support equipment.

Do not operate the MPR5000/6000/7000 on board any aircraft in flight, or at any other time when operation of radio devices such as cellular phones is prohibited.

Personnel should not be closer than 23 cm (9 inches) from any MPR antenna for prolonged periods of time. See FCC bulletins 56 and 65 for further information on electromagnetic field exposure.

1.9.3 Limitation of liability

The information in this manual is subject to change without notice and does not represent a commitment on the part of WJ Communications Inc. WJ Communications, Inc. specifically disclaims liability for any and all direct, indirect, special, general, incidental, consequential, punitive or exemplary damages, including but not limited to loss of profits, revenue, or anticipated loss of profits or revenue, arising out of the use or inability to use any WJ Communications Inc. product, even if WJ Communications Inc. has been advised or the possibility of such damages or they are foreseeable, or for claims by any third party.

1.9.4 Patents

Portions of the products described in this manual may be covered by currently-pending US and foreign patents.

1.9.5 Copyright notice

1.9.6 Comments and feedback

WJ Communications welcomes comments,suggestions, and feedback related to this manual or to the products it describes. Please submit your remarks to:

Titus Wandinger
titus.wandinger@wj.com
1-800-WJ1-4401 (951-4401)

WJ Communications, Inc.
401 River Oaks Parkway
San Jose, CA 95134-1916
USA

1.10 Regulatory Compliance

1.10.1 FCC Statement

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.

NOTE: Changes or modifications not expressly approved by WJ Communications could void the user's authority to operate the equipment described in this manual.

The MPR6000 and MPR7000 have been approved for use only with approved external antennas described in this manual; use of any other antenna may void the user's authority to operate the equipment.

1.10.1.1 RF Radiation Exposure Statement

These devices complies with FCC radiation exposure limits set forth for an uncontrolled environment, and users must follow specific operating instructions for satisfying RF exposure compliance.

To comply with RF radiation exposure requirements in FCC's Rules, the MPR6000 and MPR7000 products must be installed so there is a separation distance of at least 23 cm (9 in) between all persons and the antenna. These devices may not be co-located with any other transmitter or transmitter antenna.

Model MPR5000 has been SAR – evaluated and is authorized for use in laptop and notebook computers.