Understanding RFID and AutoID Technologies

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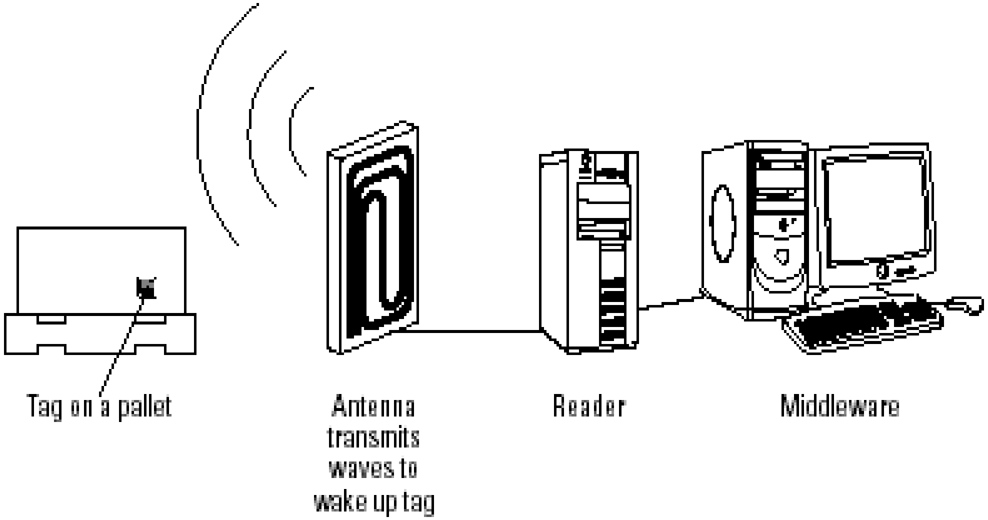
Agenda

- Basic RFID System Architecture
- How tag's working
- How antennas working
- The components of an RFID tag
- The inner workings of a reader
- Different kinds of antennas
- Various tag protocols

Basic RFID System Architecture

- Essential to understand the basics of how data travels in waves and then through a network in an RFID system.
- Necessary to analyze this system's basic components.



Patrick J. Sweeney,"RFID For Dummies" April 2005

Four Fundamental Components (1)

- **A Tag (transponder):**
  - Programmed with information that uniquely identifies itself, thus the concept of "automatic identification"
- **A Reader (transceiver):**
  - Handle radio communication through the antennas and pass tag information to the outside world

Four Fundamental Components (2)

- **An Antenna:**
  - Attached to the reader to communicate with transponders
- **A middleware (reader interface layer):**
  - Compresses thousands of tag signals into a single identification

How it works

- Step 1:
  - The tag is activated when it passes through a radio frequency field, which has been generated by an antenna and reader.

- Step 2:
  - The tag sends out a programmed response.

How it works

- Step 3:
  - The antenna that generated the field originally and is attached to the reader detects that response.

- Step 4:
  - The reader sends the data to the middleware.

How it works

- Step 5:
  - The middleware sends the information which contains the tags to whatever systems need that information.

How tag is working(1)

- The tag has a small computer chip that is programmed with information that uniquely identifies the tag.
- This information is sent when the tag is activated.

How tag is working (2)

- We must take under consideration that a passive RFID transponder does not contain its own power source.

- Rather, it absorbs energy propagated from a reader antenna’s radio frequency (RF) field to supply all the power it needs to wake up its chip

How tag is working (3)

- Then communicate with a reader by sending back (backscattering) the information contained in its memory to a receiving antenna.
- As tags move into an antenna's radio field, they are excited, and each one transmits its identification data.

How Antenna is working (1)

- Both tags and readers have their own antennas because they are both radio devices.
- A tag antenna, is only a few centimetres (or less) long.
- Attaches to the integrated circuit, to absorb a signal and then transmit out a slightly modified signal.
- About the size of a computer flat screen and are specially tuned to transmit and receive RF signals.

How Antenna is working (2)

- Antennas are how readers communicate with the outside world
- Reader antennas send radio signals into the air to activate a tag
- Listen for an echo (or backscatter) from the tag
- Read the data transmitted by a tag
- (in some cases) Write data onto a tag.
- Antennas act as conduits between the transceiver and the tag and can function continuously or on demand.

How Antenna is working (3)

- Active antenna systems are used when tagged items are present on a regular basis or when multiple tags are passing through the antenna's detection field.

- Antenna's detection field can be activated only when needed by a sensor of some kind

- Antennas come in a variety of shapes and sizes

How Reader is working

- An antenna is connected to a transceiver.
- One to four antennas are attached to a single reader, and those antennas send out the reader's signals
- The reader tells the antennas how to generate the proper RF field, which can cover an area as small as 1 inch to as large as 100 feet or more
  - Depending on the power output and the frequency.

How Reader is working

- When an RFID transponder (or tag) moves into the antenna's radio field, it becomes active and sends back to the antenna whatever information has been programmed into its memory.

- A reader receives the tag's signal through its array of antennas, decodes the signal, and sends the information to the host computer system.

How Reader is working

- A reader can also transmit special signals to a tag — telling a tag to come alive, synchronizing a tag with the reader, or interrogating all or part of the tag's contents.

Middleware (1)

- The basic elements of an RFID system gain value as part of a production or logistics system.
- The use of more than one RFID system in an industrial process becomes a local network.
- The connection of local networks constitutes a global network.

Middleware (2)

- Local network is a node of hardware (a reader, antennas, and tags) that interacts within itself to exchange information over RF waves.
- A bunch of nodes connected together creates a global network that connects to an application that creates useful information out of the data.
- In order to move data from a single node to the local network and/or to the global network, you need the data-collection component, which ties readers, antennas, and tags together.
- This component is called by many names like middleware, reader interface layer and Savant.

Middleware (3)

- All the previous mentioned names describing the very simple glue that sticks together each node in an RFID system.
- Middleware connects the data coming into a reader to the client's host software systems.
- The middleware provides a stable and coherent interface between the RFID hardware operations and the flow of data elements, such as EPC (electronic product code) numbers
- This interface is provided into inventory, sales, purchasing, marketing, and similar database systems distributed throughout an enterprise.

Middleware's Elements (1)

RFID middleware allows users to:

- Configure
- Monitor
- Deploy
- Issue commands directly to readers
  - Through a common interface.

Middleware's Elements (2)

- RFID middleware:
  - Captures EPC or other data from readers
  - Can then intelligently filter and route it to the appropriate destinations.

Middleware’s Elements (3)

- RFID middleware solutions provide messaging, routing, and connectivity features required to integrate RFID data into:
  - Existing supply-chain management (SCM),
  - Enterprise Resource Planning Systems (ERP),
  - Warehouse Management Systems (WMS),
  - Customer relationship management (CRM) systems.

Middleware's Elements (4)

- Middleware can provide collaborative solutions like business-to-business (B2B) integration between trading partners.
- The basic elements provide the data source or the local node to generate data.
- A series of these are linked into a local network that can connect to either a larger network or even a global network by employing middleware.
- An RFID network is a peer-to-peer architecture capable of aggregating highly actionable data to a central location.

Scenario

- Supposing that a single-tiny tag, is multiplied millions of times over within a global supply chain
- Then creates a peer-to-peer network that shares data in real time across a limitless number of boundaries.
- The image of the single millimeter-sized chip quickly expands to comprise a warehouse; a company; an industry; and a world of rapidly changing, automatically updated, real-time information.
- From that tiny chip blossoms the power to know where every object is at all times in a global network.

RFID at a glance

- RFID has to do with physics.
  - Laws and mathematical equations that describe the behavior of this technology have been around for decades

Electrical and magnetic Fields

- The region close to the source of the electrical current, where the magnetic or electrostatic forces can be detected, is called the *induction field.*

- Outside the induction field is the *radiation field.*

Electrical and magnetic Fields

- **In LF and HF systems,** the induction field has sufficient power to drive an electromagnetic field in the tag so that the chip is activated.

- **In UHF systems,** the radiation field powers up the tag. This detection distance is known as the *far field.*

Creating resonance between the antennas and the field

- ***Coupling*** is the matching of the tag and the reader so that they can communicate effectively together at the same frequency.

- A key feature of antenna design is the idea of a ***resonance frequency***.
  - ***Resonance*** means that two things are moving in unison or in lock step.

Creating resonance between the antennas and the field

- When a tag antenna is immersed in the field of a reader antenna the tag absorbs the radio frequency energy at the wavelength that makes it move at the same rate as the reader antenna.

- The UHF antenna design is proportional to about the wavelength of the signal.

The components of an RFID tag

- Two main parts:
  - The tag antenna
  - The integrated circuit

- The **optimal** tag design is the one that enables you to get accurate read

Components of a passive tag

- An integrated circuit or chip:
  - An antenna (or coupling element)
  - The substrate (or material that holds it all together)

The integrated circuit (chip)

- Stores data and executes specific commands.
- Most of the passive tags today carry 96 bits of memory, although some can carry as little as 2 bits or as much as 1,000 bits.
- A tag has read-only or read-write properties.

Antenna (1)

- Absorbs RF waves and then broadcast a signal back out
- It powers up the tag by collecting the energy from the RF field and exciting the onboard chip into action

Antenna (2)

- Coupling is the process where the tag antenna "couples" with the electromagnetic fields that the RFID reader emits.
- Power is transferred from air to antenna.

Antenna (3)

- **Low-frequency** (LF) and **high-frequency** (HF) antennas tend to be coils because these frequencies are predominantly magnetic in nature.

- **Ultrahigh-frequency** (UHF) designs look like radio or old-style television antennas because UHF frequencies are more purely electric in nature.

Substrate

- Mylar or plastic film , both the antenna and chip are attached to it.

Antennas work

- The fundamental problem of RFID is transmitting adequate power to RFID tags.
- The electrical current coming out of an RFID reader has to hit the conducting plane (the antenna) ***orthogonally*** that is, at right angles.

Antennas design matters

- Antennas that have many <u>different angles</u> are designed to couple with an RF wave at any opportunity.

- The <u>long, straight tags</u>, are designed to perform very well on flat, directionally sensitive applications or with a circularly polarized antenna.

Coupling characteristics of an antenna

- ***Capacitive* element** (a plate to store magnetic energy)

- ***Inductive* element** (the coil to store electric energy)

- Both make the ***impedance*** (how easily current can flow through a system, measured in ohms) of the antenna.

Tuned tags

- An antenna can be tuned to a particular frequency specifically to work best

- The length of the antenna determines the tuning

Orientation sensitivity of the antenna

- Some tag designs effectively incorporate multiple antennas
- Each is polarized in a different direction but in the same plane.
- Dual dipole tag is the tag that combines two antennas mounted at right angles to each other on the tag.

Integrated circuit – chip(1)

- **The amount of memory on the chip:**

  \- memory storage levels are kept to a bare minimum (96 bits on average).

- **The efficiency of the power circuitry:**

  \- The chip receives energy from the tag antenna in the form of an oscillating current at the frequency of the reader transmission.

Integrated circuit – chip(2)

- **The impedance match of the chip and the antenna:**
  - If impedance mismatch exists between the chip and the tag antenna, power is reflected away from the chip.

- **The ability of the chip to alter the impedance of its antenna:**
  - Tags send a signal back to the antenna (***backscatter***).
  - That backscatter can also ***modulate*** (change the signal)
  - The chip can alter the ***impedance*** of the tag antenna

Integrated circuit – chip(3)

- **How tags must respond in collision-free channels:**
  - EPC tags support one of two **algorithms used to prevent data collision** in the receiver when multiple tags pass through the RFID reader's field simultaneously,

1) Tree walking

2) ALOHA slot

Tag examples(1)

- **Alien “I2” tag:**

- length: approaches half a wavelength
- (approximately six inches) at 915 MHz
- mounted parallel to an antenna’s field.
- Dimensions: 6.0 x 0.65 inches

Tag examples(2)

- **Alien “Squiggle” tag:**
  - length: “squiggles” in two dimensions to gain virtual antenna length,
  - orientation and length of the antenna element optimized
  - Dimensions: 3.8 x 0.6 inches

Tag examples (3)

- **Avery Dennison Strip tag:**
  - nearly all metal,
  - more conductive surface
  - absorb more energy
  - Dimensions: 3.75 x 0.45 inches

Tag examples (4)

- Rafsec Folded Dipole CCT tag:
  – folded dipole
  - strongest radiation occurs at the center of the antenna substrate,
  - good longdistance read range.
  - Dimensions: 4.0 x 0.5 inches

Life cycle of a read(1)

1. The energy to transmit the radio wave comes from an external power source like a battery or a wall outlet.

2. DSP chip and a regular processor modulate the frequency and the amplitude of the wave that the reader generates.

3. That flow of electricity goes to an antenna via a coax cable.

Life cycle of a read(2)

4. The antenna sends out an RF wave carrying data by using a process called *modulation.*

5. Reader antenna receives the signal back from a tag,

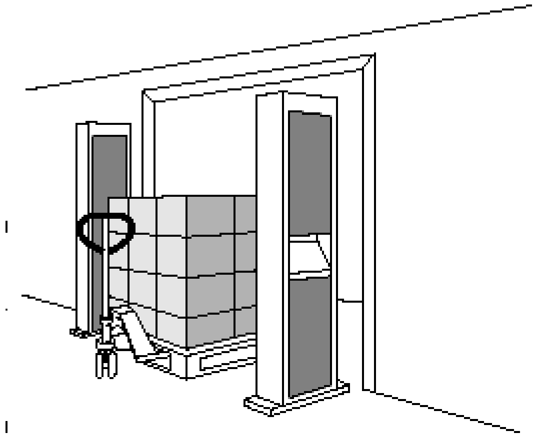
6. The electronics decode it to create useful information.

Setting Up RFID Interrogation Zones

- The interrogation zones are set up in fairly common areas that are generally *choke points:* that is, areas where all items have to flow through.

Reading at a dock door

- An *interrogation zone* (where tags are read) can be easily set around a dock door



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Needs for a dock door setup

- A high-powered UHF system
- Ample power to the antennas in the interrogation zone
- A reader set to constantly *poll,* or look for, tags

Setting up a dock door portal

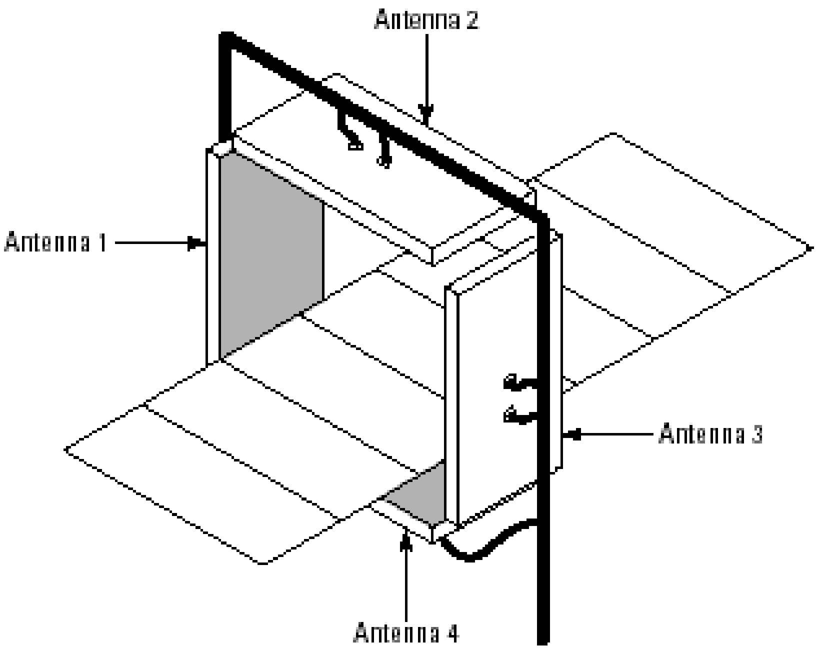
- **Decide on the area to be covered and the number of antennas to use.**

- **Determine where to place the antennas.**

- **Install the antennas *canted* (angled) slightly outward (pointing into the back of the truck) to eliminate cross talk among readers at adjacent dock doors.**

Setting up RFID at a conveyor

- The conveyor setup often consists of four antennas in a quad arrangement



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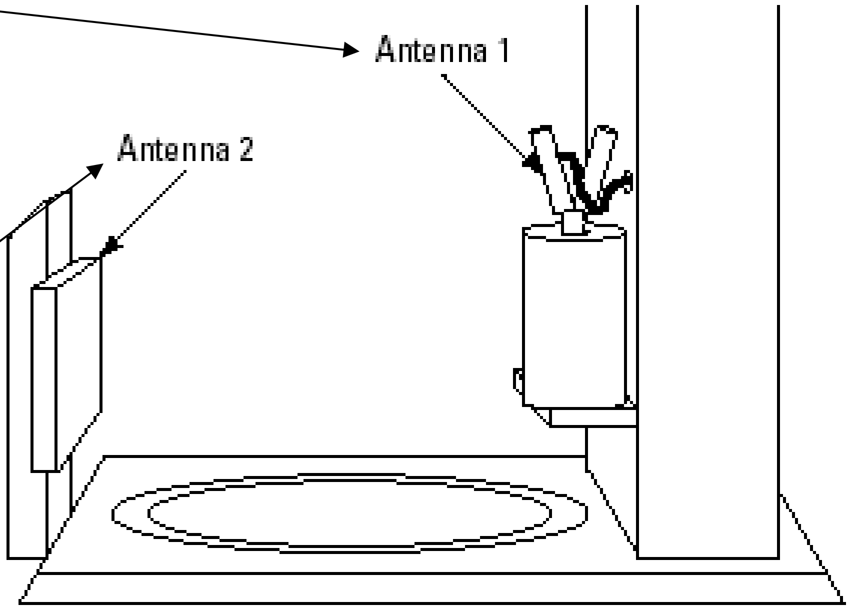
Positioning the antennas

- **Set the antennas far enough away to have strong far-field communication.**
  - about 18 inches away from the edge of the conveyor.

- **Position an antenna underneath the conveyor**
  - **to interrogate tags that may end up facing the ground**

Interrogating at a shrink-wrap station

- Affix an antenna to the arm that moves with the roll of shrink-wrap.
- Set up the other antenna just next to the stretch-wrap machine.



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Reading objects on a shelf

- Choosing the right frequency:
  - High frequency (HF), at 13.56 MHz, works best in a shelf situation where it's important to know the location of the items but not to read across multiple shelves.
- Configuring a shelf reader
  - Poll at relatively long intervals.

Applying RFID in the Real World

- Ski resorts
- Law enforcement
- Tracking imports
- Controlling access to secure areas
- Pharmaceuticals
  - Theft and counterfeiting
  - Diversion

Applying RFID in the Real World

- Additional business applications:
  - Hazardous materials and recalls
  - Warranty verification and returns
  - Manufacturing
  - Maintenance