CompTIA RFID+ Certification

Instructor's Edition

CompTIA RFID+ Certification

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Contents

Introduction

After reading this introduction, you will know how to:

A Use ILT Series training manuals in general.

B Use prerequisites, a target student description, course objectives, and a skills inventory to properly set students' expectations for the course.

C Set up a classroom to teach this course.

D Get support for setting up and teaching this course.

Topic A: About the manual

ILT Series philosophy

Our goal is to make you, the instructor, as successful as possible. To that end, our training manuals facilitate students' learning by providing structured interaction with the software itself. While we provide text to help you explain difficult concepts, the hands-on activities are the focus of our courses. Leading the students through these activities will teach the skills and concepts effectively.

We believe strongly in the instructor-led class. For many students, having a thinking, feeling instructor in front of them will always be the most comfortable way to learn. Because the students' focus should be on you, our manuals are designed and written to facilitate your interaction with the students, and not to call attention to manuals themselves.

We believe in the basic approach of setting expectations, then teaching, and providing summary and review afterwards. For this reason, lessons begin with objectives and end with summaries. We also provide overall course objectives and a course summary to provide both an introduction to and closure on the entire course.

Our goal is your success. We encourage your feedback in helping us to continually improve our manuals to meet your needs.

Manual components

The manuals contain these major components:

- Table of contents
- Introduction
- Units
- Appendix
- Course summary
- Glossary
- Index

Each element is described below.

Table of contents

The table of contents acts as a learning roadmap for you and the students.

Introduction

The introduction contains information about our training philosophy and our manual components, features, and conventions. It contains target student, prerequisite, objective, and setup information for the specific course. Finally, the introduction contains support information.

Units

Units are the largest structural component of the actual course content. A unit begins with a title page that lists objectives for each major subdivision, or topic, within the unit. Within each topic, conceptual and explanatory information alternates with hands-on activities. Units conclude with a summary comprising one paragraph for each topic, and an independent practice activity that gives students an opportunity to practice the skills they've learned.

The conceptual information takes the form of text paragraphs, exhibits, lists, and tables. The activities are structured in two columns, one telling students what to do, the other providing explanations, descriptions, and graphics. Throughout a unit, instructor notes are found in the left margin.

Appendix

The appendix lists all CompTIA RFID+ exam objectives along with references to corresponding coverage in this manual.

Course summary

This section provides a text summary of the entire course. It is useful for providing closure at the end of the course. The course summary also indicates the next course in this series, if there is one, and lists additional resources students might find useful as they continue to learn about the software.

Glossary

The glossary provides definitions for all of the key terms used in this course.

Index

The index at the end of this manual makes it easy for you and your students to find information about a particular software component, feature, or concept.

Manual conventions

We've tried to keep the number of elements and the types of formatting to a minimum in the manuals. We think this aids in clarity and makes the manuals more classically elegant looking. But there are some conventions and icons you should know about.

Instructor note/icon	Item	Description
	Italic text	In conceptual text, indicates a new term or feature.
	Bold text	In unit summaries, indicates a key term or concept. In an independent practice activity, indicates an explicit item that you select, choose, or type.
	`Code font`	Indicates code or syntax.

	`Longer strings of ►`
	`code will look ►`
	`like this.`
		In the hands-on activities, any code that's too long to fit on a single line is divided into segments by one or more continuation characters (►). This code should be entered as a continuous string of text.

Instructor notes.		In the left margin, provide tips, hints, and warnings for the instructor.
	Select **bold item**	In the left column of hands-on activities, bold sans-serif text indicates an explicit item that you select, choose, or type.
	Keycaps like ↵ ENTER	Indicate a key on the keyboard you must press.
Warning icon.		Warnings prepare instructors for potential classroom management problems.
Tip icon.		Tips give extra information the instructor can share with students.
Setup icon.		Setup notes provide a realistic business context for instructors to share with students, or indicate additional setup steps required for the current activity.
Projector icon.		Projector notes indicate that there is a PowerPoint slide for the adjacent content.

Hands-on activities

The hands-on activities are the most important parts of our manuals. They are divided into two primary columns. The "Here's how" column gives short directions to the students. The "Here's why" column provides explanations, graphics, and clarifications. To the left, instructor notes provide tips, warnings, setups, and other information for the instructor only. Here's a sample:

Do it!

A-1: Creating a commission formula

Take the time to make sure your students understand this worksheet. We'll be here a while.

Here's how	Here's why
1 Open Sales	This is an oversimplified sales compensation worksheet. It shows sales totals, commissions, and incentives for five sales reps.
2 Observe the contents of cell F4	 The commission rate formulas use the name "C_Rate" instead of a value for the commission rate.

For these activities, we have provided a collection of data files designed to help students learn each skill in a real-world business context. As students work through the activities, they will modify and update these files. Of course, students might make a mistake and therefore want to re-key the activity starting from scratch. To make it easy to start over, students will rename each data file at the end of the first activity in which the file is modified. Our convention for renaming files is to add the word "My" to the beginning of the file name. In the above activity, for example, students are using a file called "Sales" for the first time. At the end of this activity, they would save the file as "My sales," thus leaving the "Sales" file unchanged. If students make mistakes, they can start over using the original "Sales" file.

In some activities, however, it might not be practical to rename the data file. Such exceptions are indicated with an instructor note. If students want to retry one of these activities, you will need to provide a fresh copy of the original data file.

PowerPoint presentations

Each unit in this course has an accompanying PowerPoint presentation. These slide shows are designed to support your classroom instruction while providing students with a visual focus. Each presentation begins with a list of unit objectives and ends with a unit summary slide. We strongly recommend that you run these presentations from the instructor's station as you teach this course. A copy of PowerPoint Viewer is included, so it is not necessary to have PowerPoint installed on your computer.

The ILT Series PowerPoint add-in

The CD also contains a PowerPoint add-in that enables you to do two things:

- Create slide notes for the class
- Display a control panel for the Flash movies embedded in the presentations

To load the PowerPoint add-in:

1 Copy the Course_ILT.ppa file to a convenient location on your hard drive.
2 Start PowerPoint.
3 Choose Tools, Macro, Security to open the Security dialog box. On the Security Level tab, select Medium (if necessary), and then click OK.
4 Choose Tools, Add-Ins to open the Add-Ins dialog box. Then, click Add New.
5 Browse to and select the Course_ILT.ppa file, and then click OK. A message box will appear, warning you that macros can contain viruses.
6 Click Enable Macros. The Course_ILT add-in should now appear in the Available Add-Ins list (in the Add-Ins dialog box). The "x" in front of Course_ILT indicates that the add-in is loaded.
7 Click Close to close the Add-Ins dialog box.

After you complete this procedure, a new toolbar will be available at the top of the PowerPoint window. This toolbar contains a single button labeled "Create SlideNotes." Click this button to generate slide-notes files in both text (.txt) and Excel (.xls) format. By default, these files will be saved to the folder that contains the presentation. If the PowerPoint file is on a CD-ROM or in some other location to which the slide-notes files cannot be saved, you will be prompted to save the presentation to your hard drive and try again.

When you run a presentation and come to a slide that contains a Flash movie, you will see a small control panel in the lower-left corner of the screen. You can use this panel to start, stop, and rewind the movie, or to play it again.

Topic B: Setting student expectations

Properly setting students' expectations is essential to your success. This topic will help you do that by providing:

- Prerequisites for this course
- A description of the target student
- A list of the objectives for the course
- A skills assessment for the course

Course prerequisites

Students taking this course should be familiar with personal computers and the use of a keyboard and a mouse. Furthermore, this course assumes that students have completed the following courses or have equivalent experience:

- *CompTIA A+ Certification: OS Technologies, 2003 Objectives*

Target student

This course will prepare the student to be a CompTIA RFID+ Certified Professional (CRCP). Before taking this course, students should have a foundational RFID knowledge, typically 6-24 months of experience in the RFID industry, and have performed the following tasks as part of his or her job:

- Installation, configuration, and maintenance of RFID hardware and device software
- Site surveys/site analysis
- Tag selection, placement, and testing

CompTIA certification

This course will prepare students to pass the CompTIA RFID+ exam. CompTIA is a non-profit information technology (IT) trade association. CompTIA's certifications are designed by subject matter experts from across the IT industry. Each CompTIA certification is vendor-neutral, covers multiple technologies, and requires demonstration of skills and knowledge widely sought after by the IT industry.

In order to become CompTIA certified, the student must:

1. Select a certification exam provider. For more information, students can visit www.comptia.org/certification/general_information/exam_locations.aspx.
2. Register for and schedule a time to take the CompTIA certification exam at a convenient location.
3. Read and sign the Candidate Agreement, which will be presented at the time of the exam. The text of the Candidate Agreement can be found at www.comptia.org/certification/general_information/candidate_agreement.aspx.
4. Take and pass the CompTIA certification exam(s).

For additional information about CompTIA's certifications, such as their industry acceptance, benefits, or program news, you should encourage students to visit www.comptia.org/certification.

To contact CompTIA with any questions or comments, please call (630) 678-8300 or e-mail questions@comptia.org.

Course objectives

You should share these overall course objectives with your students at the beginning of the day. This will give the students an idea about what to expect, and it will help you identify students who might be misplaced. Students are considered misplaced when they lack the prerequisite knowledge or when they already know most of the subject matter to be covered.

Note: In addition to the general objectives listed below, specific CompTIA RFID+ exam objectives are listed at the beginning of each topic. For a complete mapping of exam objectives to course content, see Appendix A.

After completing this course, students will know how to:

- Explain the uses and benefits of RFID, and identify the components of an RFID system.
- Compare radio frequency with wavelength, discuss the factors affecting RF signals, and also discuss the communication methods; discuss antenna characteristics and identify reflective and absorptive materials; calculate ERP.
- Identify the types and functionalities of interrogators, and explain interrogator communication; discuss issues related to dense environment and anti-collision protocols; configure interrogation zones and interrogation commands, and optimize interrogation zones.
- Discuss power, frequency, and safety regulations and their impact on RFID systems; discuss air interface protocols and the impact of standards on business and IT infrastructure.
- Classify tags; discuss the types of antennas and their configuration, integrated circuit, and substrate configuration; discuss labels, inserts, and packing items.
- Explain the interaction between tags and interrogators; discuss the factors affecting tag performance and the effects of packaging materials on a tag; explain tag orientation and placement, the movement of tags, and the issues caused by tag stacking.
- Discuss the effects of signal interference on the RFID system; explain site obstructions that affect RFID system performance; discuss radiation patterns; Review the RF network architecture, site structures, and mechanical equipment.
- Determine the relation between virtual components and hardware components of RFID systems; discuss the hardware components of an RFID system and protection.
- Explain hardware installation and safety considerations in the RFID system; explain the installation of an RFID system in various enterprise applications.
- Explain monitoring and troubleshooting an RFID system by analyzing read rates, tuning and repositioning the antennas, and diagnosing failed reads and system hardware failure; identify symptoms for tag failure, explain tag management techniques, and identify the causes of IC failure; describe middleware and network connectivity requirements.
- Discuss RFID printers, printer properties, and ancillary devices; discuss real-time location system and warehouse management system.

Skills inventory

Use the following form to gauge students' skill levels entering the class (students have copies in the introductions of their student manuals). For each skill listed, have students rate their familiarity from 1 to 5, with five being the most familiar. Emphasize that this is not a test. Rather, it is intended to provide students with an idea of where they're starting from at the beginning of class. If a student is wholly unfamiliar with all the skills, he or she might not be ready for the class. A student who seems to understand all of the skills, on the other hand, might need to move on to the next course in the series.

Skill	1	2	3	4	5
Explaining the automatic identification techniques					
Explaining the uses and benefits of RFID					
Identifying RFID components					
Understanding RF propagation					
Calculating wavelength					
Comparing radio frequency with wavelength					
Discussing the factors affecting an RF signal					
Discussing the communication methods					
Explaining the performance characteristics of an antenna					
Explaining reflective and absorptive materials					
Calculating ERP					
Discussing types and uses of interrogators					
Understanding interrogator communication					
Installing an RFID reader					
Testing tag readability					
Discussing issues related to dense environments					
Discussing anti-collision protocols					
Affecting read rates					
Using the Alien command line interface					
Optimizing interrogation zones					
Discussing frequency and power regulations					
Discussing safety regulations					

Skill	1	2	3	4	5
Discussing the impact of regulations					
Understanding organizational standards					
Discussing air interface protocols					
Discussing the impact of standards					
Classifying tags					
Discussing antenna types and configuration					
Discussing IC and substrate					
Discussing labels, inserts, and packaging items					
Discussing link margin					
Discussing the relation between frequency and read range					
Testing read range					
Discussing operating frequency					
Discussing IC performance					
Discussing packaging material					
Testing read performance					
Discussing tag orientation					
Discussing substrate					
Discussing media selection of tags					
Discussing adhesive selection for tags					
Testing tag placement and orientation					
Discussing movement of tags					
Testing read rates with tag movement					
Discussing tag stacking					
Testing reads with tag stacking					
Discussing the effects of signal interference on the RFID system					
Analyzing physical environmental conditions					
Explaining site obstructions that affect the performance of RFID systems					

Skill	1	2	3	4	5
Discussing the radiation pattern					
Reviewing the RF network architecture					
Reviewing site structures and mechanical equipment					
Determining the relation between virtual and hardware components of RFID systems					
Determining frequency of operation					
Selecting tags types					
Selecting readers					
Selecting antennas					
Selecting transmission cables					
Selecting reader network hardware					
Selecting mounting equipment for RFID systems					
Discussing protection for RFID systems					
Discussing reader and antenna installation					
Discussing grounding considerations					
Discussing power sourcing and cable installation considerations					
Discussing testing installed equipment					
Discussing hardware safety considerations					
Installing RFID systems					
Discussing monitoring the RFID system					
Discussing tuning and repositioning techniques					
Diagnosing failed reads					
Diagnosing system hardware failure					
Identifying reasons for tag failure					
Evaluating tag management techniques					
Analyzing IC functionalities					
Analyzing middleware					
Analyzing network connectivity					

Skill	**1**	**2**	**3**	**4**	**5**
Explaining the uses of RFID printing					
Installing RFID printers					
Configuring RFID printers by using printer properties					
Discussing RFID ancillary devices					
Discussing RTLS					
Discussing WMS					

Topic C: Classroom setup

All our courses assume that each student has a personal computer to use during the class. Our hands-on approach to learning requires they do. This topic gives information on how to set up the classroom to teach this course. It includes minimum requirements for the students' personal computers, setup information for the first time you teach the class, and setup information for each time that you teach after the first time you set up the classroom.

Hardware requirements

Instructor hardware

The instructor will need a PC meeting the following specifications:

- A Pentium class processor running at a minimum of 500 MHz
- A minimum of 128 MB RAM
- A minimum of 45 MB free hard-disk space
- One free serial port
- CD-ROM
- Monitor requirement (SVGA at 1024×768, generally)
- A keyboard and a mouse
- Optionally, a working Internet connection

In addition, you will need a way to display the PowerPoint overheads that accompany this course.

Student hardware

Optimally, each student will have:

- An Alien ALR9780 Developer's Kit with circular polarized antenna and tags, or similar RFID reader, tag, and software kit
- An Alien linear polarized antenna
- A personal computer

Students can share one or more such RFID workstations.

Each RFID workstation PC should have:

- A Pentium class processor running at a minimum of 500 MHz
- A minimum of 128 MB RAM
- A minimum of 45 MB free hard-disk space
- One free serial port
- CD-ROM
- Monitor requirement (SVGA at 1024×768, generally)
- A keyboard and a mouse

In addition, you will need the following sample items for use in the activities:

- A canned food with a high water content (soda, juice, fruit, or vegetables)
- A bottle of soda pop
- A container of antiperspirant
- A pack of chewing gum (preferably with foil-wrapped sticks of gum)
- A ream of paper
- Boxes of dry food
- Books
- Articles of clothing
- A lightweight durable object such as a box of pencils
- 8' length of string
- A plastic ruler or similar object
- Tape

Software requirements

For each PC, you will need the following software:

- Windows 98 or higher operating system, Windows 2000 or XP preferred

First-time setup instructions

The first time you teach this course, you will need to perform the following steps to set up each classroom computer:

1. Following the instructions that accompany the software, install Windows onto each classroom computer.
2. Optionally, install, configure, and test the Internet connection.

Setup instructions for every class

Every time you teach this course, you will need to reset any defaults that have been changed in the previous classes to set up each student computer. You must uninstall the Alien RFID Gateway software from each classroom PC. Carefully remove any RFID tags that have been affixed to the sample products used in the classroom. Replace damaged tags.

Downloading the PowerPoint presentations

If you don't have the CD that came with this manual, you can download the PowerPoint presentations from our Web site. Here's what you do:

1. Connect to www.courseilt.com/instructor_tools.html.
2. Click the link for CompTIA to display a page of course listings, and then click the link for CompTIA RFID+ Certification.
3. Click the link for downloading the Presentation files, and follow the instructions that appear on your screen.

Topic D: Support

Your success is our primary concern. If you need help setting up this class or teaching a particular unit, topic, or activity, please don't hesitate to get in touch with us.

Contacting us

Please contact us through our Web site, www.axzopress.com. You will need to provide the name of the course, and be as specific as possible about the kind of help you need.

Instructor's tools

Our Web site provides several instructor's tools for each course, including course outlines and answers to frequently asked questions. To download these files, go to www.axzopress.com. Then, under Downloads, click Instructor-Led Training and browse our subject categories.

Unit 1

Introduction to RFID

Unit time: 40 minutes

Complete this unit, and you'll know how to:

A Explain the uses and benefits of RFID, and identify the components of an RFID system.

Topic A: RFID basics

Explanation

The modern business environment demands that companies save time and money at every opportunity. This requires that most tasks should be automated whenever possible. Often, this automation requires tracking inventory and objects. To achieve this tracking, you have to make use of the automatic identification techniques such as barcodes or radio frequency identification (RFID).

Automatic identification techniques

Automatic identification uses technology to track and manage items with minimal human intervention. There are two primary automatic identification techniques:

- Barcodes
- RFID

Barcodes

A *barcode* is a strip of bars and gaps that represent numbers, as shown in Exhibit 1-1. Barcodes typically encode a serial or *stock-keeping unit* (*SKU*) number and identify a class, or type, of product rather than identifying a single unit.

Various standards govern the size, shape, and pattern of barcodes. There are some limitations in using the barcodes, such as low data storage capacity and the need to be in close proximity to read the code. To overcome these limitations, you can use RFID.

Exhibit 1-1: Sample barcode

RFID

Radio frequency identification (*RFID*) is a system that involves electronic *tags* containing identification numbers or other data encoded onto an integrated circuit (IC). A device called a *reader* sends an electromagnetic signal to the tag. Upon receiving the reader's signal, the tag transmits its code to the reader. By monitoring tag IDs, the RFID system can track the presence and location of an object as it moves through the organization.

RFID is a combination of radio broadcast and digital coding technology. In digital coding technology, the digital data is encoded on a microchip.

RFID is applicable to most any sectors of industry in which data is to be collected. RFID uses radio waves to capture the digital data encoded in the microchip without any direct contact with the microchip. Therefore, RFID is used in contact-less data transfers such as smart cards.

RFID technology has been available for more than 50 years. Yet only recently has the cost of the components made the concept feasible for businesses to use. Additionally, software has evolved so that RFID can be integrated with existing warehouse and supply-chain management systems.

Uses of RFID

Different areas where you can use RFID include:

- Security and authentication—RFID is used to identify badges, key chains, and other items that provide access control for a secure area, such as a server room, thereby allowing only authenticated entry. This application of RFID is known as Electronic Article Surveillance (EAS). EAS helps you increase the security of a system.
- Track and trace—Tracking the location of a particular object helps you monitor its movements. You can use RFID to track parts, pallets of products, people, cargo, postal items, animals, and other items in a supply chain.
  Supply chain integration is an application of tracking and tracing. Using this offers strategic advantages for businesses because an RFID system can track inventory in the supply chain efficiently. An RFID system does this by storing supply chain information such as source, destination, and route.
- Industrial automation—In an industry, many types of equipment are subjected to hundreds of steps. For example, RFID is used in computer numeric controlled (CNC) milling machines to choose tools. Various tools are placed in a holding area. The machines use RFID to identify and select the tool required for the next task. If an operator needs to add or remove tools, the machine will automatically know which tools are available. Each step, from selection of the tool to the final product, follows a specific sequence. Thus, RFID helps you to reduce the time and errors that might occur.
- Environment sensing and monitoring—You can integrate RFID technology with devices that sense and monitor various environmental conditions. RFID helps in monitoring perishable items on a shelf to ensure that spoilage does not occur. You can also combine the object tracking ability of RFID technology with sensors that capture video images and determine the location of the object.

In addition to using RFID in applications such as retail and distribution, you can also use RFID in baggage handling and laboratory procedures. RFID technology is also used with automated garage door openers and tollbooths.

Benefits of RFID

RFID was introduced to overcome the limitations of barcodes. RFID technology is considered the next generation of barcode technology.

RFID vs. barcodes

RFID systems provide these benefits over barcodes:

- RFID commonly provides a superior storage capacity between 128 bytes and 8 kilobytes (KB) because of integrated circuit capabilities. In contrast, a barcode typically stores no more than 100 bytes of data.
- The electromagnetic waves used with RFID systems pass through many types of materials. Therefore, reading RFID tags does not require a line of sight or contact. In contrast, barcode systems need visual contact between the scanner and the barcode to read the data.
- RFID systems can use techniques, such as authentication and encrypted data transfer methods, to provide enhanced data security. In contrast, security of data is not guaranteed in barcode systems as any scanner can read any barcode.
- RFID tags can operate in harsh, dirty, and humid environments. Barcodes cannot be read if they are dirty or heavily scratched.
- You can read several RFID tags at the same time. In contrast, a barcode scanner can read only one barcode at a time.
- RFID also provides you read/write functionality, which means that you can reprogram RFID tags. You cannot reprogram the contents of a barcode.

General RFID benefits

In addition to overcoming the limitations of barcodes, RFID has its own benefits. By using RFID in your solution, you have the following benefits:

- Serialization (unique identification)—As every object in an RFID system is provided with a unique identifying number, you can track the item and prevent counterfeiting.
- Reduced human intervention—No human intervention is involved while tracking any object. Thus, you can reduce the probability of error and reduce the labor costs. Automated toll systems are a prime example of reduced human intervention: no one is required to staff the tollbooth with RFID.
- Better time management—By using RFID, you can count many items simultaneously. This helps improve time management as more items are read in less time.
- Real-time information flow—As soon as the item is sold to the customer, the information can be updated simultaneously across the supply chain. This helps the seller to keep his stocks updated.

Do it!

A-1: Discussing RFID uses and benefits

Questions and answers

1 While RFID has many advantages over barcodes, state one benefit of barcodes over RFID?

The hardware to implement barcodes, and the barcodes themselves, are currently less expensive than RFID systems. Barcodes can be printed on product packaging, etched onto plastic or metal product components, or printed on stickers adhered to products after production. Barcodes store and collect less information, which puts fewer demands on your IT infrastructure (less data to store, manipulate, keep up-to-date, and so forth).

2 Give one example of RFID that you have used, witnessed, or benefited from.

One of the most common RFID systems that you might have encountered would be the automatic toll collection systems, such as E-ZPass. Though very simplistic, many large retailers use a theft-protection system, which is essentially an RFID system. Radio waves activate a merchandise tag that responds with its state: either you have purchased the merchandise or not.

3 Consider a use for RFID within your company. Justify why RFID would be a better solution than barcodes or other technologies. Be prepared to share your answer with the class.

Answers will vary.

4 Why is it important to track objects through an organization?

Tracking objects increases the efficiency of the supply chain. You can track specific items that might have expiration dates or unique features. In addition, there is more awareness about the location of objects.

5 What are the human tasks needed for barcoding that are NOT necessary for RFID?

Aligning the barcode with the reader (which might include handling the product to locate and access the barcode) and scanning objects individually, instead of simultaneously, are the human tasks needed for barcoding, but not necessary for RFID.

RFID components

Explanation

A basic RFID system consists of both hardware and software components. The hardware components are responsible for identifying and capturing data. The software components of an RFID system are responsible for managing the data transmitted between the tag and the reader and between the reader and the host system.

Hardware components

There are three hardware components of an RFID system: tag, reader, and host system. Exhibit 1-2 shows all the hardware components and how they work in an RFID system.

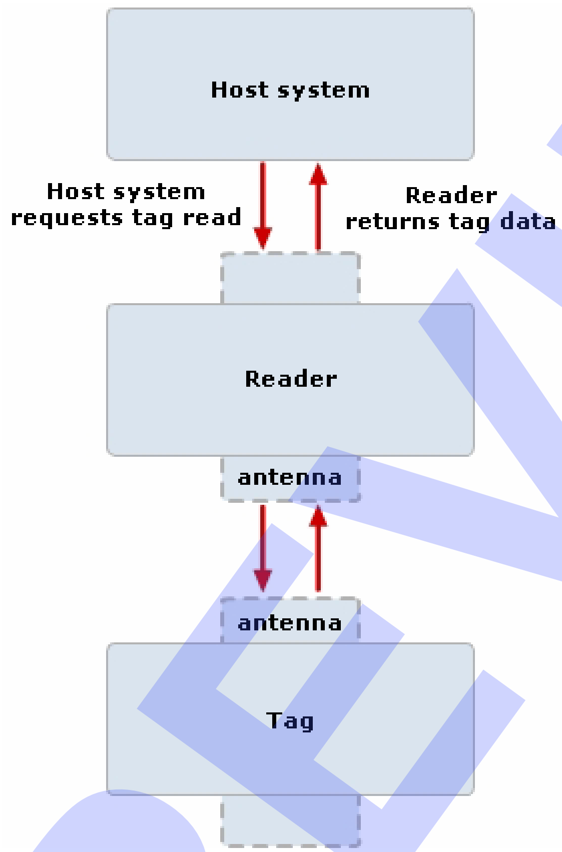

Exhibit 1-2: RFID hardware components

RFID hardware components include:

If you have examples, show them to students as you discuss each item.

- **RFID tag** — A device that is attached to or embedded in an item that you need to track. An RFID tag, also called a *transponder*, has memory where the data is stored. RFID tags are typically small, measuring a few inches or less on their longest dimension. The components of an RFID tag are:
  - **Integrated circuit (IC)** — A microchip that commonly stores between 64 to 128 bits of data. The data stored in the IC can be read several times by the reader.
  - **Tag antenna** — A component that detects the signal from the reader's antenna. The performance of the tag antenna depends on the distance between the reader antenna and the RFID tag. As the distance between the reader antenna and the RFID tag increases, performance decreases.

- **RFID reader** — A device that activates the tag and retrieves the information stored in its IC. An RFID reader sends and receives signals with the help of the reader antenna. An RFID reader, also known as an *interrogator*, is practically a bridge between the RFID host system and the reader antenna. An RFID reader consists of the following components:
  - A radio frequency module containing a transmitter and a receiver.
  - A signal processing and microcontroller unit.
  - A coupling element, such as an antenna. The reader antenna can be built into the reader itself. However, most commonly it is a separate component that you attach to the reader. Some readers support multiple antennas and most support antennas with varying transmission characteristics.
  - An interface to a host computer, such as RS-232, RS-485, or Ethernet.
- **RFID host system** — A system that manages the flow of data between the RFID readers and tags. A simple RFID host system consists of a computer connected to a reader by a serial cable. An RFID host system can also have a more complex structure where different readers are located across different locations and data flows to the host computer through LANs or the Internet.

When an item embedded with an RFID tag moves past the RFID reader, it sends its unique identification information to the reader, which passes it to the central database of the host system. The RFID software can use this data to track the item.

Software components

The software components of an RFID system vary greatly depending on the system requirements. The software programs are executed in the tag, the reader, and the host system. The software components of an RFID system are:

- **RFID system software** — A collection of functions that facilitates interaction between a tag and a reader. The communication between the tag and the reader occurs at a radio signal–processing level. It requires hardware, low-level software (firmware), and high-level system software to manage the data that flows between the tag and the reader. The RFID system software manages the following functions required at the tag and reader level:
  - Read/write
  - Anti-collision
  - Error detection/correction
  - Encryption, authorization, and authentication
- **RFID middleware** — A set of software components that acts as a bridge between the RFID hardware components and the host application software. It performs two primary functions:
  - Monitors and reports the reader status in case of malfunction and breakdown.
  - Manages the RFID hardware–components infrastructure and data flow.
- **Host application** — Software that receives processed and normalized data—sent from the tag—through the reader and the RFID middleware software. The host application is typically a previously existing software program in an enterprise, such as an inventory control or warehouse management system. Depending on the sophistication of the RFID middleware and the capabilities of the host application, the host application software receives the data.

Do it!

A-2: Identifying RFID components

Questions and answers

1 Which RFID hardware and software components might exist within your IT or supply chain infrastructure?

You might have used the RFID host application through supply-chain management (SCM), enterprise resource planning (ERP), warehouse management system (WMS), or customer relationship management (CRM) systems.

2 Match the RFID component on the left with its definition on the right:

a Tag	1. Device that activates the tag and retrieves its information.
b Middleware	2. Software components that bridge RFID hardware and host applications.
c Host application	3. Device with an IC and antenna that is attached to the item you need to track.
d Reader	4. Software that facilitates tag and reader interactions.
e Host system	5. Software that processes tracking data.
f RFID system software	6. Computer that manages the flow of data between readers and tags.

Answers: a = 3, b = 2, c = 5, d = 1, e = 6, f = 4

3 Which of these is NOT a function of RFID middleware?

A Manages a network of RFID readers to gather and assimilate EPC data and distribute it to host application software such as a warehouse management system.

B Monitors and reports the reader network status in case of malfunction.

C Coordinates events such as activities or wait states.

D Creates reports regarding the physical quantity on hand and transit status of items in multiple warehouses.

Unit summary: Introduction to RFID

Topic A

In this topic, you learned that common automatic identification techniques include **barcodes** and **radio frequency identification** (**RFID**). RFID offers distinct advantages over barcodes, including greater data capacity, no need for contact or line of sight, ability to read multiple tags simultaneously, and more. RFID systems are composed of hardware—including **tags**, **readers**, **antennas**, and a **host system**—and software—including RFID **system software**, **middleware**, and a **host application**.

Review questions

1 For which of the following scenarios would RFID be well-suited but for which barcodes would be unsuitable? (Choose all that apply.)

A Single item point of sale transaction at a supermarket.

B Reading a pallet full of item cases without human intervention.

C Changing the expiration date of a food item as it is frozen.

D Tracking luggage as it is directed through an airport terminal.

2 If RFID technology has been around for over 50 years, then what is causing its rapidly increasing adoption now?

Lower costs permit use in high-volume applications such as tracking retail goods. Therefore, growing infrastructure permits use of RFID in more applications.

3 What are the main inputs and outputs of an RFID system?

Inputs: tags containing a unique identification number and hardware to process the information. Outputs: serial numbers, product codes and location information sent to and processed by the host application.

4 Name at least three suitable applications for RFID technology.

Inventory tracking, security monitoring, track and trace, environmental monitoring, manufacturing automation, and so forth.

5 What are some important business advantages of using RFID over barcodes?

Less labor intensive to track items, better visibility that permits for more accurate inventory, better security, and more information about the object that can be collected, processed, and stored.

Unit 2

RF physics

Unit time: 60 minutes

Complete this unit, and you'll know how to:

A Compare radio frequency with wavelength, discuss the factors affecting RF signals, and also discuss the communication methods.

B Discuss antenna characteristics and identify reflective and absorptive materials.

C Calculate ERP.

Topic A: RF propagation

This topic covers the following CompTIA RFID+ exam objectives.

#	Objective
4.1.1.2.1	Tag antenna to region/frequency
4.1.2	Identify inductively coupled tags vs. backscatter
5.2.1	Antenna type
8.1	Identify RF propagation/communication techniques

Understanding RF propagation

Explanation

RFID is designed on the physics of radio frequency (RF) propagation. *RF propagation* is defined as the wireless transmission of radio waves from one place to another. Radio waves are electromagnetic waves propagated by an *antenna*. To implement a functional RFID system to meet your enterprise needs, it is important to understand RF propagation.

When you supply an RF signal to an antenna, it generates an electromagnetic field. This field propagates, or travels, through the air to a receiving antenna where it is converted back into an RF signal.

By using RF propagation, you can transmit information between a reader and a tag. Typically, the data information is added to a base signal through a technique called modulation. *Modulation* is the process of altering the characteristics of the base signal in a known way to encode data into the signal. For example, with amplitude modulation, data is encoded by varying the amplitude, or height, of the radio wave. Demodulation is the process of extracting the data from the transmitted signal.

Most of the RFID systems use pulse-width modulation (PWM). In such a case, the reader uses the spacing between the pulses and not the amplitude to encode data. It is the RFID reader that modulates and demodulates the signal to encode or decode data on the signal.

Radio frequency vs. wavelength

The *frequency* of an RF signal is inversely proportional to its *wavelength* as shown in Exhibit 2-1.

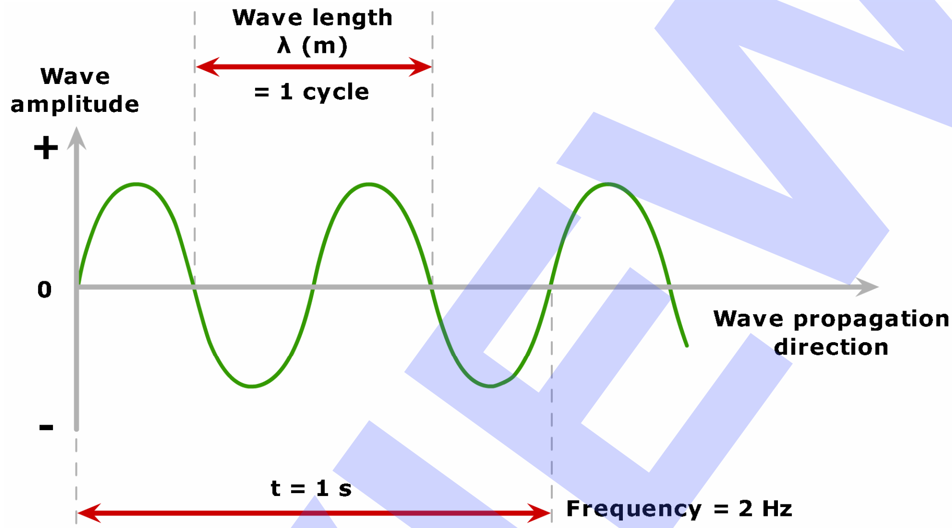

Exhibit 2-1: Radio frequency vs. wavelength

You can calculate the wavelength and frequency by using this formula:

$$f = \frac{c}{\lambda}$$

where,

- f is the frequency
- c is the speed of light (approximately 300,000,000 meters per second)
- λ is the wavelength

Students can view a frequency allocation chart at www.ntia.doc.gov/osmhome/allochrt.pdf.

Radio frequency (f) is any frequency within the electromagnetic spectrum that is associated with radio wave propagation. The US National Telecommunication and Information Administration recognizes radio frequencies to cover the range of 3 kHz to 300 GHz.

Wavelength (λ) is defined as the distance that the wave travels in one cycle. It is the distance between the repeating units of a wave pattern.

Students can visit http://en.wikipedia.org/wiki/Hertz for information on converting hertz into other units.

As the formula indicates, the wavelength of a radio signal decreases as its frequency increases. The wavelength of the radio signal determines the length of the antenna used in the RFID device. The length or height of different types of antennas are often fractions (usually one-quarter or one-half) of the wavelength of the signal to be transmitted or received.

RF field

The RF field is divided into several ranges or bands. The following table depicts the eight bands in the RF field, showing frequency and bandwidth ranges. The SHF and EHF bands are often referred to as the microwave field.

Designation	Abbreviation	Frequencies	Free–space wavelengths
Very Low Frequency	VLF	9 kHz–30 kHz	33 km – 10 km
Low Frequency	LF	30 kHz–300 kHz	10 km – 1 km
Medium Frequency	MF	300 kHz–3MHz	1 km – 100 m
High Frequency	HF	3 MHz–30 MHz	100 m – 10 m
Very High Frequency	VHF	30 MHz–300 MHz	10 m – 1 m
Ultra High Frequency	UHF	300 MHz–3 GHz	1 m – 100 mm
Super High Frequency	SHF	3 GHz–30 GHz	100 mm – 10 mm
Extremely High Frequency	EHF	30 GHz–300 GHz	10 mm – 1 mm

Do it!

A-1: Calculating wavelength

Exercises	Hints
1 Use the formula, f = c/ λ to calculate the wavelength of a signal with a frequency of 60 Hz	To calculate the wavelength λ, you can invert the formula, so λ = c/ f. ***λ = 5,000,000 m or 5,000 km***
2 Use the formula, f = c/ λ to calculate the wavelength of a signal with a frequency of 915 MHz	915 MHz = 915000000 Hz ***λ = approximately 1/3 m***

Tell students to use the same formula they have used in Question 1.

Do it!

A-2: Comparing radio frequency with wavelength

Questions and answers

1 Which of the statements about RF waves is false?

A Wavelength is calculated as the linear peak-to-peak distance of one oscillation of the wave.

B Wavelength will decrease as the amplitude increases.

C Wavelength will decrease as the frequency increases.

D RF waves are electromagnetic waves propagated by an antenna.

2 Explain how the wavelength changes if the frequency is held constant.

The speed of the RF propagating wavefront can change as it travels through a different medium. From the equation, if the value for the speed changes and the frequency is held constant, the wavelength changes.

3 Name some objects that are the size of a radio frequency wave at 915 MHz.

A wavelength at 915 MHz is about 1/3 meter. This is roughly the thickness of a human body, a case of products in a retail store, or even a wall. Many objects are around 1/3 meter.

Factors affecting RF signal in a non-perfect free space

Explanation

The geometric spread of the wavefront can affect the propagation of an RF signal. The factors that can affect the propagation of an RF signal are:

- *Free space loss* — When radio wave energy spreads over large areas that are farther from the source, it experiences a loss in signal strength as it travels. This loss is known as free space loss. Free space loss is due to spreading of the wavefront.
- *Attenuation* — The phenomenon of reduction in signal strength during transmission is called attenuation. Attenuation can occur within a transmission line or when the RF field propagates. It can also occur in wire carrying electricity, air carrying RF waves or sound, and optical fiber. Materials that absorb RF energy, such as packaged products, can also cause attenuation.
- *Scattering* — RF waves propagating through different media either encounter discontinuities in the media or interact with the material at a molecular level. The radio wave is then absorbed and re-radiated, causing energy to be scattered into the medium as shown in Exhibit 2-2. This results in a loss of the RF signal. This is called multipath, fading, Rayleigh fading, or signal dispersion.
- *Reflection* — Radio waves get reflected when they impinge upon objects that are much larger than the wave, such as floors, ceilings, and support beams.
- *Refraction* — Radio waves bend as they pass into a medium of different density or one that has a different index of refraction. For example, when the wave passes from air to water, the wave refracts as shown in Exhibit 2-3.
- *Diffraction* — When an RF signal strikes an object with sharp edges, a part of the wave bends around the edges. For example, if you speak into one end of a cardboard tube, the sound waves emerging from the other end spread out in all directions, rather than moving in a straight line. The sharpness of the edges controls the degree of diffraction. Consider waves hitting a large metal cabinet in a warehouse: the portion hitting the middle of the cabinet might be absorbed or reflected while the portion of the wave hitting the edges is diffracted around the obstruction. The area behind the cabinet receives a mix of waves.

Students can visit www.ifh.ee.ethz.ch/~fvtd/fvtd_edu.html to view an animated image of diffraction caused by a sharp edge. (Scroll down to Diffraction section.)

- *Absorption* — When an RF signal strikes an object, some of it gets absorbed into the material. Materials containing water, such as liquid products, paper and wood, and food, are especially good at absorbing RF energy.
- *Superposition* — Radio waves traveling through the same medium can occupy the same space, but remain independent of one another. The radio waves combine their electric fields at the point of their intersection. After intersecting, each wave resumes in its original direction of propagation with its original waveform. This principle of superposition is shown in Exhibit 2-4. These are the important factors relating to the principle of superposition:
  - *Phase* is defined as the measure of the alignment of two RF waves that are the same. A radio wave reflected back to its source would add to the source phase.
  - Depending on which point of the 'phase' the wave is reflected, it can increase or decrease the strength of the wave. This wave is then known as a *standing wave* when its strength increases and a *canceling wave* when its strength decreases.

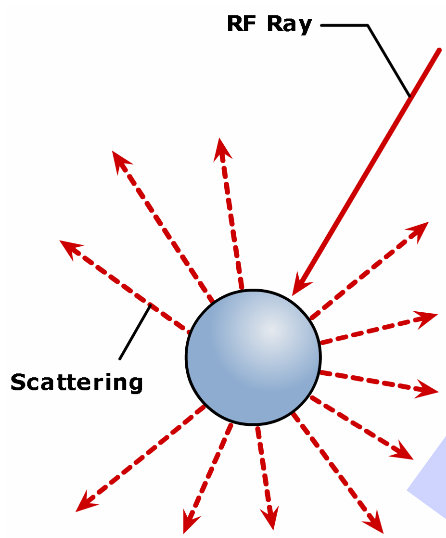

Exhibit 2-2: Scattering of RF wave

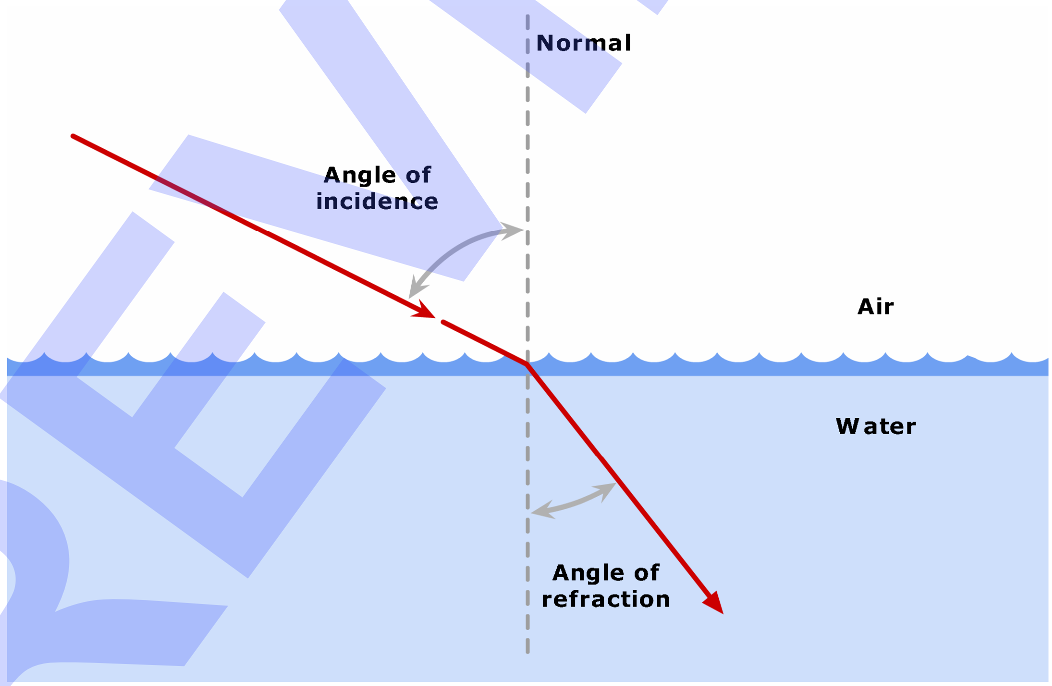

Exhibit 2-3: A wave refracts, or bends, as it passes into a different medium

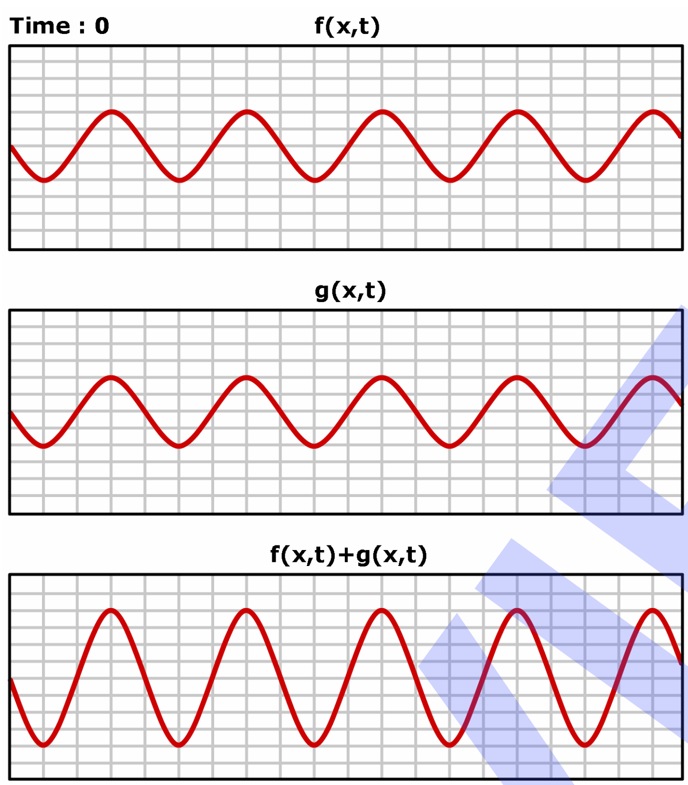

Exhibit 2-4: Two waves combine through superposition to create a larger wave

Do it!

A-3: Discussing the factors affecting an RF signal

Questions and answers

1 Which property of a wave causes it to bend when it travels from air through water?

A Reflection

B Diffraction

C Absorption

D Refraction

2 How does a forklift truck affect RF waves?

The forklift truck is mostly metal, so the RF waves reflect and diffract off the sides and edges of the truck.

3 How does an RF wave get affected when it encounters a bottle of water?

Some of the energy will be reflected, some will be absorbed, and some will be transmitted through the medium. The RF wave being transmitted will get refracted if varying indexes of refraction exist. The waves will also reflect within the bottle, causing multipath effects.

Factors affecting RF signals in a medium

Explanation

The way in which RF signals propagate through a medium is important for both transmission and reception. This is because while propagating in a medium, the RF signal undergoes frequency changes. This change affects RF signal transmission.

The two factors affecting RF signals in a medium are:

- Distortion
- Noise

Distortion

Distortion refers to the change in any attribute of a signal caused by the medium through which the signal flows (a connector or cable). The changed attribute can be amplitude, pulse width, or frequency. Distortion occurs when the level of RF signal is higher than the sensitivity of the receiver making it unable to decipher the signal.

Noise

Noise is an unwanted electrical signal that is present in a circuit or signal. Noise either alters the signal or adds a “background” signal. For example, hissing or humming “signals” present in an audio signal are a form of noise.

To calculate the effect of noise on a signal, we can use the *signal-to-noise ratio* (SNR). SNR is the ratio of signal strength to background noise. The ratio is usually measured in decibels (dB). You can calculate the SNR by using the formula:

$$SNR = 20 \times \log\left(\frac{V_s}{V_n}\right)$$

where,

- V_s is the incoming signal strength in microvolts
- V_n is the noise level in microvolts

Ideally, V_s is greater than V_n, so SNR is positive. In situations where SNR is negative, reliable communication is not possible unless the signal level is increased or noise is decreased.

Do it!

A-4: Discussing the factors affecting RF signals

Questions and answers

1 The signal-to-noise ratio is measured in ___________.

A watts

B decibels

C parsecs

D dynes

2 Why is it important to reduce noise in RF signals?

Reliable communications is not possible if noise is greater than the signal. Reducing noise will improve the chances of the signal to be "heard" by the system.

3 Can the signal gain be too high? If so, what is it called?

Yes, it is possible. This is called distortion, which is caused by the signal having too much power. This can diminish the chances of the signal being deciphered.

Communication methods

Explanation

Communication between the reader and the tag occurs through a process called *coupling*. Coupling occurs when the tag creates a closed loop by absorbing and reemitting the RF signal. The different principles of coupling that current RFID systems work upon are:

- *Inductive coupling*—The alternating electromagnetic field generated by the RF signal creates a current in the coupling element of the tag (usually a coiled antenna and a capacitor). The current induced in the coupling element can charge the on-tag capacitor to provide the operating voltage and power for the tag. Inductive coupling works only in the near-field of the RF signal. Most inductive tags use a 'loop' style or 'coil' antenna, as shown in Exhibit 2-5. By increasing the number of loops, you can increase the inductive efficiency of the tag.
- *Electromagnetic backscatter coupling*—When the reader sends out an electromagnetic wave at a specific frequency, the wave hits the RFID tag. The tag scatters back the wave modulated on the same frequency with the chip's information encoded in the backscatter wave. RFID systems with ranges significantly above one meter are known as *long-range systems*. All long-range systems operate by using electromagnetic waves in the ultra-high frequency (UHF) and microwave range. A majority of such systems are backscatter systems due to their physical operating principle.
- *Close coupling*—RFID systems with small ranges, roughly one centimeter, are known as close coupling systems. In close coupling systems, the tag is either inserted in the reader or positioned upon a surface. These systems are coupled using both electric and magnetic fields. They can theoretically be operated at any desired frequency between DC and 30 MHz because the operation of the tag does not rely upon the radiation of fields. Close coupling systems are less susceptible to interference. You use close coupling systems in applications that are subject to strict security requirements but do not need a large range. Examples of close coupling systems are electronic door locking systems or contact-less smart card systems with payment functions.

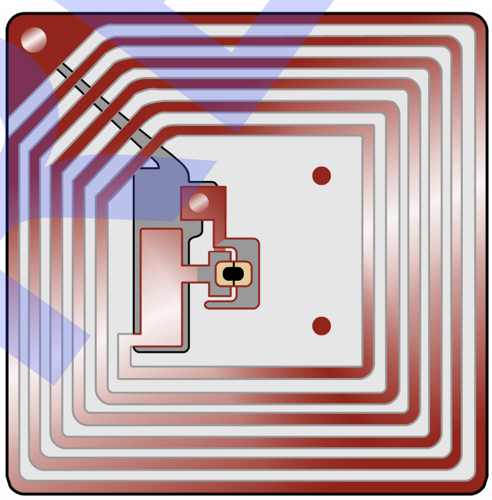

Exhibit 2-5: Loop style or coil antenna

Do it!

A-5: Discussing communication methods

Questions and answers

1 Which electronic principle does near-field inductive coupling use to its advantage?

A Backscatter

B Alternating electromagnetic fields

C Direct current

D Resonance

2 Indicate the type of coupling, inductive or backscatter, most likely to be used in these scenarios:

– Quick pay credit card	***Inductive or close coupling***
– Tracking of wooden crates	***Backscatter***
– Entry card for a secure building	***Inductive***
– Identifying pets with embedded ID chips	***Inductive***

3 How does a reader using electromagnetic backscatter coupling receive data from a tag?

A A low frequency magnetic field is oscillated after the tag is powered.

B The carrier signal of the receiver is modulated with the data from the tag.

C A high-pitch sound wave is emitted from the tag and deciphered through a microphone on the reader.

D The tips of the antenna vibrate the air around it to send encoded messages back to the reader antenna.

Topic B: Antenna field performance

This topic covers the following CompTIA RFID+ exam objectives.

#	Objective
4.2.4.5	Liquids
4.2.4.6	Metal
4.2.4.7	Polarization
5.2.1	Antenna type
8.2	Describe antenna field performance/characteristics as it relates to reflective and absorptive materials (may use scenarios)

The importance of understanding antennas

Explanation

All radio devices use antennas for communication and transmission. In an RFID system, both tags and readers use their antennas to communicate with each other. To ensure a successful communication between readers and tags, it is important to understand the characteristics of an antenna.

Absorptive and reflective materials affect the field of the antenna. Therefore, it is crucial that for a successful and low-cost deployment you carefully select and place the reader and tag antennas. This criterion of selection and placement, when combined with the method of installation and use, often determines whether an RFID system functions efficiently.

Antenna characteristics

Consider these characteristics when you select an antenna:

- Polarization
- Impedance
- Voltage standing wave ratio (VSWR)
- Resonance frequency
- Directivity
- Gain
- Beamwidth

Polarization

An antenna emits electromagnetic waves into its surroundings. The direction of oscillation of these electromagnetic waves determines *polarization* of the antenna. The readability of a tag greatly depends on the polarization of the antenna and the angle of the tag with the reader.

Based on polarization, these are the main types of antenna in UHF:

- Linear polarized
- Circular polarized or elliptically polarized

Impedance

Impedance is the measure of resistance to an electrical current when a voltage is moved across it. This resistance is the combined effect of capacitance, inductance, and resistance on a signal measured in ohms (Ω). It represents the ratio of voltage to the flow of current allowed. According to Ohm's law, voltage is the product of current and resistance at a given frequency. Each tag antenna has a capacitive element (a plate to store magnetic energy) and an inductive element (a coil to store electric energy), which make up the impedance of the antenna.

Voltage Standing Wave Ratio (VSWR)

VSWR is the ratio of the maximum RF voltage to the minimum RF voltage in a standing wave pattern. A standing wave, also called a *stationary wave*, is a combination of two waves moving in opposite directions, each having the same amplitude and frequency. This standing wave phenomenon is the result of interference, that is, when waves are superimposed, their energies are either added or cancelled out.

You always express the value of VSWR as a ratio with 1 as the denominator (2:1, 3:1, 10:1). It is a scalar measurement because a standing wave reflects waves in opposite directions. A short circuit and an open circuit have the same VSWR value (infinity:1). A perfect impedance match corresponds to a VSWR of 1:1, which is practically impossible. A VSWR of 1.5:1 has 4 percent of the power reflected back, whereas a VSWR of 2:1 has 11 percent of the power reflected back. Therefore, a desirable VSWR would be 1.5:1.

Resonance

A key feature of an antenna design is *resonance* frequency. The resonant frequency is related to the electrical length of the antenna. The electrical length is expressed as a multiple of the wavelength of an electrical signal propagating within the medium. Typically, an antenna is tuned for a specific frequency and is effective for a range of frequencies usually centered on that resonant frequency. The resonant frequencies are multiples of the base frequency, which is also known as fundamental frequency.

Tag antennas need to match the frequency of the incoming field to set up a resonance between the antenna and the field. As resonance is based on the multiple of wavelengths, you will notice that tags have a size that is generally proportional to the size of the reader's antenna.

The shape of the antenna is also matched to the frequency it is intended to interact with. Thus LF and HF tags are shaped like coils that resonate more effectively in the near-field than the far-field. Most LF and HF tags would need to be very large to resonate on their frequencies. Therefore, they work on the principle of inductive coupling where the alternating field inducts a current in the coils of the tag.

UHF tags have a flatter shape that works better in the far-field than the near-field. These tags operate on a resonant frequency that has a wavelength of the same size of the tag. For instance, 915 MHz is ~1/3 m. Therefore, for a ½ wavelength the size of the tag would be 1/6m. The wavelength of the resonant frequency needs to match the length of the antenna.

Directivity

The ability of an antenna to focus in a particular direction while transmitting or receiving energy is called *directivity*. The directivity of an antenna is defined as the ratio of the maximum value of the power radiated per unit solid angle to the average power radiated per unit solid angle. In an RFID system, this antenna property guides the point-to-point communication between the reader and the tag, as opposed to broadcast communication.

Antenna gain

Antenna gain is defined as the ratio of the power needed for an antenna to produce the same field strength in a specific direction. Antenna gain is expressed in decibels. The higher the gain, the more powerful is the energy output. Antennas with higher gains can read tags from a long distance. Antenna gain is directly related to antenna beamwidth. Antennas with higher gain imply narrow beamwidths and vice versa.

- *Isotropic radiator*—One of the theoretical antennas used to determine the gain of an antenna. The term isotropic refers to the power radiated uniformly in all directions as shown in Exhibit 2-6. If the power is focused, the power-level ratio compared to the theoretical gain is equal to the antenna gain in decibels (dB).

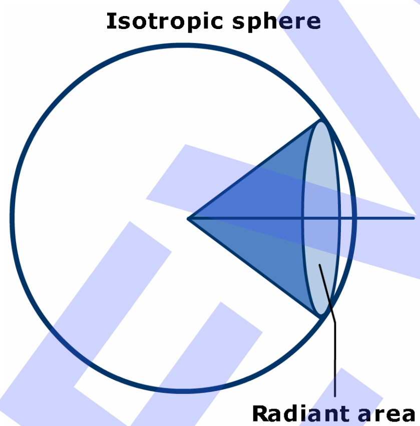

Exhibit 2-6: Isotropic radiator

Beamwidth

Beamwidth is the angle between two half-power (3 dB) points of the main lobe in the antenna pattern. This angle is defined as a *beamwidth* when referenced to the peak effective radiated power of the main lobe. For example, in Exhibit 2-7, the circular lines are levels of gain. The peak power level is the outer-most circle where the main lobe reaches. If you subtract inwards 3 dB, and measure the width (as shown in Exhibit 2-7 with two arrows), you have the beamwidth in degrees.

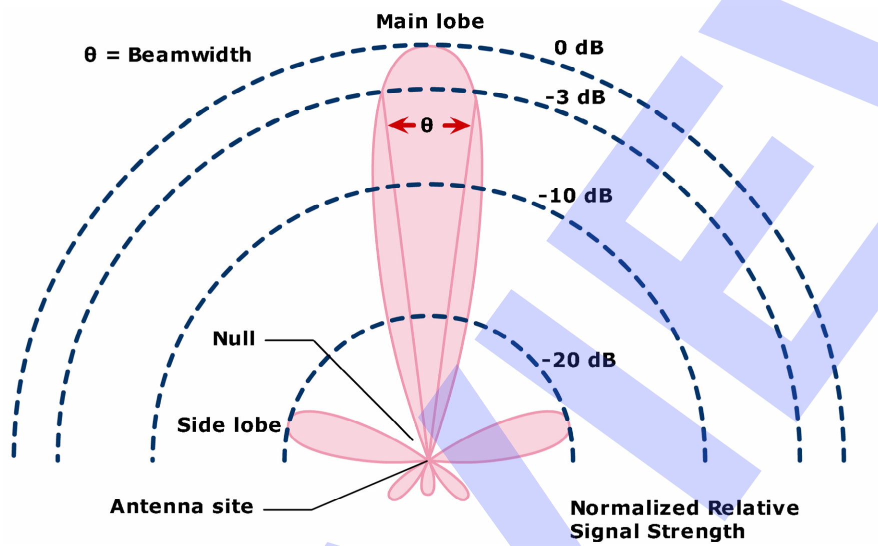

Exhibit 2-7: Beamwidth

Do it!

B-6: Discussing performance characteristics

Questions and answers

1 What is an isotropic antenna and why is it important for calculating antenna gain?

An isotropic antenna is an antenna that radiates evenly in all directions. It is a theoretical antenna used as a standard to compare the gains of other antennas.

2 Why do most LF and HF tags work on the principle of inductive coupling?

Most LF and HF tags need to be very large to resonate on their frequencies. Therefore, they work on the principle of inductive coupling where the alternating field inducts a current in the coils of the tag.

Provide students with one or more RFID antennas.

3 Examine the reader antennas supplied by your instructor. Can you tell by their shape or other physical characteristics whether it is a circularly or linearly polarized antenna?

Generally, with production RFID units, you cannot determine an antenna's polarization by its physical characteristics. However, manufacturers typically indicate the polarization on a label or by other means.

Provide students with one or more types of RFID tags.

4 Identify the antenna on the sample tag or tags provided by your instructor.

Reflective and absorptive materials

Explanation

RFID, like any other form of radio communication, is susceptible to interference. Absorptive and reflective materials—such as metal, liquid, fruits and vegetables—interfere with the RF signal. Because RF waves travel through materials, they can be absorbed, reflected and transmitted, depending on the properties of the material and the type of radiation. This change in the RF waves results in reduction or attenuation of the strength of the wave.

Different materials affect an RF signal and therefore a tag in these ways:

- **Absorption** — Some materials, such as liquid, copy paper, and frozen items, absorb the energy of the direct wave propagating out of the reader's antenna. This results in less power being available for receiving a signal back from the tag.
- **Reflection/refraction** — Ideally, the tag receives a direct wave from the interrogating antenna, but sometimes, the material around the tag can reflect or refract that direct wave. Because of this, wave properties—such as amplitude, direction, speed, and frequency—might change. The tag then receives the reflected or refracted wave, which might be different from the original direct wave.
- **Dielectric effects** — The *dielectric constant* is a measure of the charge-retention capacity of a medium. The dielectric constant of a material affects the movement of electromagnetic signals through the material. So when a dielectric material is close to the tag, the electric-field concentration can be multiplied and can result in a detuning effect on the tag's antenna.

Metal and liquid environments affect radio waves. Radio waves bounce off metals and are absorbed by water at any frequency. For example, the human body is a very good shield against RFID signals because the body has a high dielectric constant and high saline content. Interference from metal also disrupts the RFID signal. Areas of operation with metal, and liquid, such as in an RFID enabled supply chain management, become a challenge.

Objects can exhibit a wide range of characteristics in relation to RF, which are dependent on their material composition. An object can be RF transparent, RF reflecting, or RF absorbent. Most objects exhibit a combination of the three. Some examples on how different materials can affect the performance of RFID are:

- **Liquids** affect RFID performance because of their absorptive power. Even objects with high moisture content, such as paper, wood pallets, fresh fruits, and vegetables, can absorb RF energy, as water has a high dielectric constant. Therefore, it is important to evaluate whether your items have the potential to hold or attract moisture when considering the effects of liquids on RFID.
- **Metals** pose a challenge because they efficiently reflect RFID signals. They can also absorb RFID signals when the gaps in metal are greater than the wavelength of the signal. In some situations, the presence of metal can actually improve the performance of an RFID tag. There are special RFID tags designed to be placed directly on flat metal surfaces. These tags employ a relatively thin layer of dielectric insulation between the tag and the metal surface. This effectively turns the metal surface into a part of the antenna. The performance of the tag is improved by using the metal to reflect the RF signal back to the interrogator. This is the benefit of the special RFID tag; otherwise, the RF signal would radiate into the item. Irregular metals either absorb or reflect the signal in random directions. Foil bags and anti-static bags can act as a metal. You need to consider metallic content or coating on some materials before tagging them with an RFID. For example, rice has a high iron content that affects RFID performance. In addition, many automotive windshields now contain metallic compounds to improve the reception of integrated radio antennas.

Do it!

B-7: Discussing reflective and absorptive materials

Questions and answers

1 Why do reflective materials create problems for propagating RF waves?

The reflected RF energy can subtract from the original wave, which can be a problem for RF systems.

2 Why do metals act as good reflectors of electromagnetic energy?

Generally, metals are good conductors of electricity. Conductors are materials that permit electrical energy to be easily reemitted.

3 Speculate on what happens to the RF energy that a material absorbs?

It is mostly turned into heat, but can also be turned into light, sound, and other forms of radiated energy.

4 What can you do to reduce the chance of a material absorbing the RF energy from an RFID tag?

Increase the distance that separates the medium and the tag.

Provide sample items that would pose a challenge to RFID: a can or bottle of soda pop, a container of antiperspirant (high aluminum content), a pack of chewing gum (typically foil wrapped), a ream of paper (high water content in the paper), and so forth.

5 Your instructor will provide you with sample product items that might get tagged with an RFID tag. Speculate on the challenges they might pose to a successful RFID implementation.

Answers will vary depending on the items provided. For example, a soda can presents at least two challenges: it is made of metal, which will reflect RF energy, and it is filled with liquid, which will absorb or attenuate RF signals.

6 Given the challenges you identified for each item, how might you overcome those issues in a production RFID environment?

Answers will vary. For example, for a case of soda cans, you might employ a special tag type that capitalizes on the reflectivity of the metal cans to improve RFID read rates.

Topic C: Radiated power output

This topic covers the following CompTIA RFID+ exam objectives.

#	Objective
1.2.5	Bi-static/monostatic antennas
8.3	Given a scenario, calculate radiated power output from antenna based on antenna gains, cable type, cable length, interrogator transmit power (include formulas in scenario)

Effective radiated power (ERP)

Explanation

The measure of power radiating from the reader antenna is called *effective radiated power* (*ERP*). It is necessary to calculate the ERP so that you can match the field intensity produced by the tag's antenna with that of the reader's antenna. To calculate ERP, you need to know:

- How much energy is the reader producing?
- How much energy is being lost in the transmission lines?
- How much energy is the antenna emitting?
- How much gain does the reader antenna provide?

Interrogator transmit power

2 slides

Interrogator transmit power is the actual amount of power of the RF energy that an interrogator produces at its output. You can calculate the power by using dBm, which is a measure for the power level in decibels in units of milliwatts (mW). Some interrogators can control the interrogator transmit power, although the RF power is regulated to 1 watt for UHF in the United States and many other countries.

To convert dBm to milliwatts, you can use the equation:

```
dBm=10×log (power in milliwatts)
```

For example, a reader transmitting energy at 1000 mW (1 watt) would be 30 dBm.

To convert milliwatts back to dBm, you can use the equation:

```
milliwatts = 10^(dBm/10)
```

Transmission lines

A *transmission line* is the material medium for transmitting energy, such as electromagnetic waves or acoustic waves. A transmission line connects a transmitter and an antenna to deliver all the signals to the antenna. An ideal transmission line does not radiate energy and does not suffer losses.

Most RFID systems use transmission lines of 50 Ω impedance. The cable type largely depends on the application. The most commonly used cable is the coaxial cable.

Coaxial cables

Coaxial cables with simple inner conductors have impedances from 10Ω through 100Ω. A coaxial cable, as shown in Exhibit 2-8, is a two-conductor cable, where the inner conductor (copper wire) is surrounded by a braided wire jacket (copper mesh), and has a plastic insulating material separating the two. You often use such cabling to conduct weak (low-amplitude) voltage signals, because of its excellent ability to shield such signals from external interference. Because the electromagnetic field carrying the signal exists (ideally) only in the space between the inner and outer conductors, it cannot interfere with or suffer interference from external electromagnetic fields.

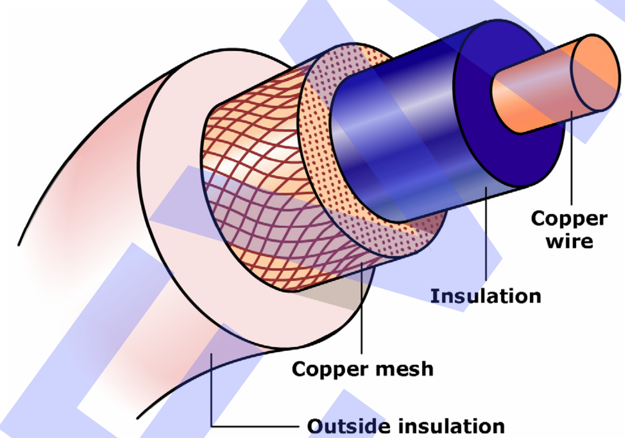

Exhibit 2-8: Coaxial cable

Whenever you choose a coaxial transmission line, you must consider the frequency of operation and insertion loss. Insertion loss is usually specified in dB/foot and is a linear relationship. Therefore, if the specified insertion loss was 8 dB/100 feet, a 20-foot coaxial line would have an insertion loss of about 1.6 dB. Insertion loss also increases in proportion to the square root of the frequency. Therefore, if the frequency is doubled, insertion loss increases by 40% and will double if the frequency is increased fourfold.

Impedance of a transmission line

The characteristic impedance (Z0) of a transmission line is the resistance it will exhibit if it were of infinite length. This is entirely different from the leakage resistance of the dielectric that separates the two conductors, and the metallic resistance of the wires. Characteristic impedance is purely a function of the capacitance and inductance distributed along the line's length, and would exist even if the dielectric were perfect (infinite parallel resistance) and the wires superconducting (zero-series resistance).

When an electromagnetic wave travels through free space, the wave's current and voltage distribution settle into a particular ratio. For free space, the current and voltage distribution of an electromagnetic wave settles in the ratio of E/I to 120 π or 377 Ω.

Cable loss

Cable loss is the amount of signal lost in the cable during the transmission and is expressed in decibels (dB). The characteristics of a coaxial cable depend on its shape. You cannot bend the cable sharply or squash it. Each area of damage introduces reflections in the signal and reduces the efficiency of the cable. A common cable type for RFID transmission lines is a 50-Ω coaxial cable, such as an RG-58. Typically, RG-58 cables have a minimum-bending radius of about 3cm.

To estimate cable loss, you can refer to this table:

Coax cable signal loss (attenuation) in dB per 100ft

Loss	RG-174	RG-58	RG-8X	RG-213	RF-9914	RF-9913
1 MHz	1.9 dB	0.4 dB	0.5 dB	0.2 dB	0.3 dB	0.2 dB
10 MHz	3.3 dB	1.4 dB	1.0 dB	0.6 dB	0.5 dB	0.4 dB
50 MHz	6.6 dB	3.3 dB	2.5 dB	1.6 dB	1.1 dB	0.9 dB
100 MHz	8.9 dB	4.9 dB	3.6 dB	2.2 dB	1.5 dB	1.4 dB
200 MHz	11.9 dB	7.3 dB	5.4 dB	3.3 dB	2.0 dB	1.8 dB
400 MHz	17.3 dB	11.2 dB	7.9 dB	4.8 dB	2.9 dB	2.6 dB
700 MHz	26.0 dB	16.9 dB	11.0 dB	6.6 dB	3.8 dB	3.6 dB
900 MHz	27.9 dB	20.1 dB	12.6 dB	7.7 dB	4.9 dB	4.2 dB
1 GHz	32.0 dB	21.5 dB	13.5 dB	8.3 dB	5.3 dB	4.5 dB
Impedance	50Ω	50Ω	50Ω	50Ω	50Ω	50Ω

Usually, when you purchase a cable, the catalog or the online store provides a cable-loss table for that cable.

Return loss

Return loss is a measure of VSWR (Voltage Standing Wave Ratio; the ratio of the maximum RF voltage to the minimum RF voltage), expressed in decibels (dB). The return loss is caused because of an impedance mismatch between two or more circuits. In an ideal situation, the impedances are identical and the VSWR is 1:1, written simply as 1.

A high value of return-loss denotes better quality of the system or device under test. For example, a cable with a return loss of 21 dB is better than a similar cable with a return loss of 14 dB.

The following table provides an estimate of return loss and VSWR where,

- *RL* is the return loss
- *VSWR* is the Voltage Standing Wave Ratio
- Γ is the reflection coefficient (the ratio of the reflected wave to the incident wave at the point of reflection)

RL (dB)	VSWR	Γ	RL (dB)	VSWR	Γ
46.0	1.01	0.00498	26.0	1.11	0.0521
40.0	1.02	0.00990	25.0	1.12	0.0566
37.0	1.03	0.0148	24.0	1.13	0.0610
34.0	1.04	0.0196	23.5	1.14	0.0654
32.0	1.05	0.0244	23.0	1.15	0.0698
30.4	1.06	0.0291	22.0	1.17	0.0783
29.0	1.07	0.0338	21.5	1.18	0.0826
28.0	1.08	0.0385	20.7	1.20	0.0909
27.0	1.09	0.0431	20.0	1.22	0.100
26.4	1.10	0.0476	19.0	1.25	0.112
17.7	1.30	0.130	8.0	2.32	0.398
17.0	1.33	0.141	7.0	2.61	0.445
16.0	1.38	0.158	6.02	3.01	0.500
15.0	1.43	0.178	5.0	3.56	0.562
14.0	1.50	0.200	4.0	4.42	0.631
13.0	1.58	0.224	3.01	5.85	0.707
12.0	1.67	0.250	2.0	8.72	0.794
11.0	1.78	0.282	1.0	17.39	0.891
10.0	1.92	0.316	0.5	34.75	0.944
9.0	2.10	0.355	0.0	Infinity	1.00

Antenna gain

2 slides

The gain of an antenna is equal to 10*log(Power out/Power in) and is measured in decibels. If the result is negative, it indicates loss; if it is positive, it indicates gain.

The gain of an antenna represents an increase in the directivity of the signal. For example, an input of 30 mW power and an output of 60 mW power equates to 3 dB of gain. A convenient fact to remember is that 3 dB of gain indicates that the power is increased to twice its strength.

The gain of an antenna is directly related to *antenna aperture*. The antenna aperture is the portion of a plane surface near the antenna, perpendicular to the direction of maximum RF wave propagation through which most of the RF waves pass. The antenna aperture is tuned to the frequency of the reader antenna. Based on the wavelength, the aperture can increase or decrease.

Anything that enters the antenna aperture will affect the operation of the antenna. The effects are pattern distortion, skewing of antenna balance, change of feed impedance, and shifting of the resonant frequency.

Effective radiated power

2 slides

The output of an RFID reader antenna is called effective radiated power. It is used for RF power accounting. It also includes the losses in the transmission lines, and the gain of the antenna. The formula to calculate ERP is:

```
ERP = RF power (dBm) - cable loss (dB) + antenna gain (dBi)
```

Link margin

The performance of an RFID system depends on the quality of the equipment being used. *Link margin* is a way of quantifying equipment performance that can be determined by these four factors:

- Transmit power
- Transmit antenna gain
- Receive antenna gain
- Minimum received signal strength or level

The link margin is:

$$L_{margin} = TX_{power} + TX_{ant.gain} + RX_{ant.gain} - RSL$$

Scenario

Display slide number 33, because it will help the students to perform the activity.

A cargo company wants to install the RFID system effectively. Every day, five trucks leave the base station to deliver cargo. The trucks stop at several other stations, until they deliver all the cargo. At every station, the cargo is checked in and checked out. As an RFID professional, you need to check whether the reader can activate the tag.

Available information

The following table provides the available reader and tag information:

Transmit frequency band	915 MHz
Transmitter output power	1000 milliwatts (mW)
Reader antenna make and model	Monostatic
Reader antenna gain (in dB over a half-wave dipole)	3.85 dBd
Reader antenna gain (in dB over an isotropic antenna)	6 dBi
Type of antenna feed line	RG–58
Length of reader antenna feed line	12.5 feet
Tag antenna gain	2 dB

Table I: 50 Ω coaxial cable feed line loss factors (dB per 100 feet):

Frequency Band (MHz)	Cable type			Foam type	
	RG-58, RG-223	RG-8, RG-213	RG-9, RG-214	1/2"	7/8"
29	2.8	1.0	1.0	0.4	0.26
52	3.8	1.3	1.4	0.55	0.36
144	7.0	2.6	2.6	1.0	0.66
220	9.0	3.4	3.4	1.3	0.85
440	13.0	5.3	5.1	1.9	1.3
1240	19.0	10.3	10.3	4.2	3.2

Do it!

C-1: Calculating ERP

Use the reader and tag information and Table I in the preceding scenario to complete this activity.

You need to work through the calculations with the entire class.

Use the reader and tag information and Table I given in the preceding scenario to complete this step.

Instruct the students to use the value for system gain and system loss from the output of steps 1 and 2.

Exercises	Hints
1 Calculate system gain	System gain = transmitter output power + antenna gain Before calculating the system gain, convert mW to dBm by using the formula dBm =10×log(mW). Transmitter output power = ____ dBm ***30*** Therefore system gain = ________ ***36 dB***
2 Calculate system loss	Total system loss (dB) = Length of antenna feed line/100 × cable loss factor Cable loss factor for 915 MHz = ~16 Total system loss = ___________ ***2 dB***
3 Calculate ERP	ERP = system gain - system loss ERP = ____ dBm ***34 dBm*** To convert dBm into milliwatts, the formula is: mW = 10^(dBm/10) ERP = _____ mW ***2512 mW***
4 Calculate the free space propagation loss through the equation known as Friis: Free space propagation loss (dB) = $-10\times\log[4\times\pi\times d/\lambda]^2$, where d is the distance from the antenna and λ is the wavelength, both measured in meters.	So for a 915 MHz RFID tag (λ = ~.33 m), which is at 3 m from the antenna The free space propagation loss = ______ dB ***-41 dB***

Instruct the students to use reader and tag information in the preceding scenario and the value for ERP and free space propagation loss from the output of steps 3 and 4.

5 The power needed for the IC to work is **-10 dBm**, so calculate the power required to activate the tag using the values acquired from steps 1-4	The power available to enter the IC = ERP + Free space propagation loss + tag antenna gain The power available to enter the IC = _____ dBm ***–5 dBm. As –5 dBm > –10 dBm, the tag will be activated.***
6 What are some elements of the transmission line that contribute to the loss in energy?	***Answers might include:*** • ***Long cables*** • ***Improper impedance matching*** • ***Connectors*** • ***Cable bends*** • ***Low quality materials***
7 Does the gain of an antenna actually increase the total power output of the system?	***No, the gain is only a measure of the increased power density in the direction of radiation, compared with an isotropic antenna. The overall power is actually lost because of the inefficiency inherent in all antennas.***
8 Identify the gain on the reader antennas provided by your instructor.	***The antenna gain is typically noted on a label or other marking.***

Unit summary: RF physics

Topic A In this topic, you learned that RFID is based on the **physics** of RF propagation. You learned the relation between **frequency** and **wavelength**. You also learned about the various factors that affect RF signals in a **non-perfect free space** and a **medium**. Then, you learned about the different principles of coupling such as **inductive coupling**, **electromagnetic backscatter coupling**, and **close coupling**.

Topic B In this topic, you learned that in an RFID system, both **readers** and **tags** use **antennas** to communicate with each other. You also learned about the different **antenna characteristics** that have to be considered before selecting an antenna. Next, you learned about the **absorptive** and **reflective** materials, such as **metals** and **liquids**, which interfere with the RF signal.

Topic C In this topic, you learned how to calculate **ERP**. You also learned about **interrogator transmit power**, **transmission lines**, and **antenna gain**, which help in calculating ERP.

Independent practice activity

A pharmaceutical company wants to install an RFID system. They make drugs for which raw material is not only expensive but also difficult to get. The company wants to ensure that the product is checked at every stage of the manufacturing process. Therefore, the product should be checked-in before a process and checked-out after the process completes. As an RFID professional, you need to check whether the reader can activate the tag.

Available information

This table provides the available reader and tag information:

Transmit frequency band	915 MHz
Transmitter output power	500 milliwatts (mW)
Reader antenna make and model	Monostatic
Reader antenna gain (in dB over a half-wave dipole)	3.85 dBd
Reader antenna gain (in dB over an isotropic antenna)	6 dBi
Type of antenna feed line	RG–58
Length of reader antenna feed line	50 feet
Tag antenna gain	1 dB

50 Ω coaxial cable feed line loss factors (dB per 100 feet):

Frequency Band (MHz)	Cable type			Foam type	
	RG-58, RG-223	RG-8, RG-213	RG-9, RG-214	1/2"	7/8"
29	2.8	1.0	1.0	0.4	0.26
52	3.8	1.3	1.4	0.55	0.36
144	7.0	2.6	2.6	1.0	0.66
220	9.0	3.4	3.4	1.3	0.85
440	13.0	5.3	5.1	1.9	1.3
1240	19.0	10.3	10.3	4.2	3.2

1 Calculate system gain. (*Hint*: System gain = transmitter output power + antenna gain. Before calculating the system gain, convert mW to dBm. System gain = 33 dB.)

2 Calculate system loss. (*Hint*: Total system loss (dB) = Length of antenna feed line/100 × cable loss factor. Total system loss = 8.5 dB, taking the cable loss factor as ~17 dB.)

3 Calculate ERP. (*Hint*: ERP = system gain - system loss. ERP = 25.5 dBm.)

4 Calculate the free space propagation loss using the Friis equation for a 915 MHz RFID tag (λ = ~.33 m), which is at 3 m from the antenna. (*Hint*: Free space propagation loss (dB) = 10×log [4×π×d(m)/ λ (m)]^2, where d is the distance from the antenna. The free space propagation loss = -41 dB.)

5 The power needed for the IC to work is -10 dBm, so calculate the power required to activate the tag using the values acquired from steps 1-4. (*Hint*: The power available to enter the IC = ERP + Free space propagation loss + tag antenna gain. The power available to enter the IC = –14.5 dBm. As –14.5 dBm < –10 dBm, the tag will NOT be activated.)

Review questions

1 What is the difference between low, high, and ultra-high frequencies?

RFID tags and readers have to be tuned to the same frequency to communicate with each other. RFID systems use different frequencies, but generally the most common are low (around 125 KHz), high (13.56 MHz), and ultra-high frequency (850-900 MHz). Microwave (2.45 GHz) is also used in some applications. Radio waves behave differently at different frequencies. Therefore, you have to choose the right frequency for the right application.

2 Does RFID work near metal and water? Can it be used to track cans or liquid products?

Radio waves bounce off metal and are absorbed by water at ultra-high frequencies. This makes tracking metal products or those with high water content problematic, but good system design and engineering can overcome this shortcoming. Low- and high-frequency tags work better on products with water and metal. In fact, there are applications in which low-frequency RFID tags are actually embedded in metal auto parts to track the metal auto parts.

3 What is the difference between return loss and VSWR?

Return loss is the portion of a signal that is lost due to reflection of power. Return loss is similar to VSWR and is generally preferred in the cable industry. As it is a logarithmic measurement, it is very useful when displaying very small reflections.

VSWR is the ratio of voltage applied to voltage reflected. VSWR is similar to return loss and is generally preferred in the connector industry. As it is a linear measurement, it can be useful when displaying large reflections.

4 Why is the wavelength in a coaxial cable physically shorter than what is calculated from the formula for wavelength?

The formula to calculate the wavelength is meant for calculating a free space (air) wavelength. In fact, RF energy moves more slowly in a transmission line than it does in air because the materials used in cable slow it down. Therefore, a wavelength in cable takes up less length.

5 Explain how the wavelength changes if the frequency is held constant.

The speed of the RF propagating wavefront can change as it travels through a different medium. From the formula $f = c/\lambda$, if the value for the speed changes and the frequency is held constant, the wavelength changes.

6 What modulation techniques are used in the RFID systems? Explain how data is transferred from tag to reader and vice versa?

Most of the RFID systems use pulse-width modulation (PWM) as a digitally modulated signal. The reader interprets the spacing between the pulses. The RFID reader picks up the modulated wave and turns it into the ones and zeroes of a binary code.

7 What is attenuation and how does RF energy get attenuated?

The loss or reduction in signal strength during transmission is called attenuation. Attenuation can occur within a transmission line or when the RF field propagates through materials that absorb energy such as packaged foods.

8 Define effective radiated power and what constituents influence it?

The measure of power radiating from the reader antenna is called effective radiated power (ERP). The energy produced by the reader, the energy losses during transmission, and the energy emitted by the antenna influence the ERP.

9 Define impedance of a transmission line.

Characteristic impedance of a transmission line is the resistance it will exhibit if it were of infinite length.

10 What is return loss? Which is better, a cable with a return loss of 37 db or a cable with a return loss of 21 db?

Return loss is a measure of VSWR (Voltage Standing Wave Ratio; the ratio of the maximum RF voltage to the minimum RF voltage), expressed in decibels (dB). A high value of return loss denotes better quality and a cable with a return loss of 37 dB is better than a similar cable with a return loss of 21 dB.

11 List the phenomena that affect the propagation of an RF signal.

There are many phenomena that affect the propagation of an RF signal such as reflection, absorption, refraction, and diffraction.

12 Which of the following is the correct definition for wavelength?

A The time taken for the wave to travel in one cycle.

B The distance that the wave travels in one cycle.

C The distance between the wave patterns of waves intersecting each other.

D The measure of the alignment of two RF waves that are the same.

13 Given the frequency of an RF wave, which one of the following formulas can you use to calculate its wavelength?

A $f = \lambda/c$

B $f = d/\lambda$

C $f = c/\lambda$

D $f = \pi/\lambda$

14 Most RFID systems use transmission lines of __________ impedance.

A 50 Ω

B 75 Ω

C 100 Ω

D 10 Ω

15 Which equation will you use to convert dBm to milliwatts?

A 10×log (power in milliwatts)

B 10^(dBm/10)

C 20×log^(power in milliwatts)

D (dBm/10)^10

16 440MHz = __________ Hz.

A 44000000Hz

B 4400000Hz

C 4400000000Hz

D 440000000Hz

17 2.4GHz = __________ Hz.

A 24000000000Hz

B 240000000Hz

C 2400000000Hz

D 24000000Hz

18 You can calculate the SNR by using the formula:

A $10 \times \log(V_s/V_n)$

B $20 \times \log(V_s/V_n)$

C $10\hat{}\log(V_s/V_n)$

D $\log(V_s/V_n)\hat{}10$

19 A possible VSWR would be __________.

A 1.5:1

B 2:1

C 1:2

D 1:1

20 In __________ antennas, the power radiates uniformly in all directions.

A dipole

B helical

C monopole

D isotropic