Lesson Title: RFID Modulation, Encoding, and Data Rates

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Rationale
Why is this lesson important? Why does the student need this lesson? How does this lesson fit in the larger module?

Modulation, encoding, and data rates are basic concepts needed to understand how to transfer information across any media such as a vacuum, air, water, soil, etc. The student needs this lesson to understand the media layer of RFID to comprehend the performance limitations of RFID. Modulation, encoding, and the data rates are dependent upon the characteristics of the media layer.

Objective(s)
What will the student know, be able to do, and value at the end of this lesson? This is smaller amounts of information than the module objectives.

The student will be able to describe ASK, FSK, and PSK. He will be able to encode and decode a bit stream using a given encoding scheme. In addition, he will be able to describe the advantages and disadvantages of FM0 and Miller encoding.

Exploration
Explicit concepts related to the Module goal are explored. It is at this point that the student will be provided basic information about the topic and the chance to explore some basic concepts about the topic. This is where the instructor imparts information.

- Define modulation: Modulation is the process of modifying the characteristics of a signal, called a carrier wave, to convey information. The characteristics of a signal to modify include amplitude, frequency, and phase.
- Introduction to analog modulation techniques (Ziemer and Tranter, 1985, ch. 3)
  - Amplitude modulation
- Digital modulation
  - Amplitude-shift keying (ASK)
  - On/Off keying (OOK)
  - Frequency-shift keying (FSK)
  - Phase shift-keying (PSK)
- Define encoding: Encoding is the process of converting a message into symbols.
- Define symbol rate: The symbol rate is the rate the symbols change per unit of time (baud). Note that only in certain cases is the symbol rate equal to the data rate because each symbol may represent more than one bit.
- Define data rate: The data rate is the rate in bits per second (bps) that information is transferred.
- BPS vs. Baud
- Gen-2 RFID reader
  - Pulse interval encoding (PIE)
  - ASK modulation
- Gen-2 RFID tag
  - Encoding
- FM0
- Miller
  - Modulation
    - ASK
    - PSK

- Examine Gen-2 signals between a reader and tag using screenshots and off-line spectrum analyzer software.

**Reflection**

Several questions are posed to the student to answer and then often discuss as a class. This is an attempt to determine whether the student "gets" the basic concepts delivered above. If they do get it, move on to engagement. If they do not get it, go back to exploration above. It could be as simple as asking a few probing questions or as complex as asking the student to write a paper.

- What is the difference between modulation and encoding?
- Can you guess what other types of analog modulation techniques exist?
- Can you name the three major types of digital modulation and explain how they work?
- Given a particular four-level ASK system, what is the ratio of the data rate to the symbol rate?
- What kind of encoding does the reader use in Gen2?
- Name the two types of encoding for a tag in Gen2?
- Which tag encoding provides a higher data rate in Gen2? What are the disadvantages of this encoding?

**Engagement**

Concepts learned in the Exploration are further developed by conducting experiments, designing and building solutions, and solving problems. This is an attempt to cause the student to apply the new knowledge. By applying the new knowledge, the student is much more likely to retain this information. This engagement could be accomplished through a debate, an experiment, a problem solving activity, or anything else that would cause the student to demonstrate understanding and competence.

- Load the file tag7_ad222.iqt using the off-line spectrum analyzer software. This file is a capture of the communication between a reader and tag using a spectrum analyzer.
  - Launch the RSAVu which will bring up the Main window
  - Click on the blue bar in the main window to bring up front panel.
  - Click [Front panel:utility]Load.
  - Click [Main window]Load Data
  - Click [Main window]Folder…
  - Click [Main window]Folder…
  - Browse and select the folder which contains the iqt file
  - Click [Main window]Select folder and [Main window]Done
  - Select the file "*****.iqt" from the files displayed
  - Click on [Main window]Load File Now.
- View the communication in the time domain
  - Click [Front panel:Mode]Time
  - Click [Main window]Transient
  - Click [Main window]Power versus Time
There are three grids displayed in the main window as shown in figure 1. The upper left grid displays the whole capture. The lower grid displays the portion of the capture that is analyzed. The area within the green vertical lines of the upper left grid is shown in the lower grid.

- **Analyze the communication in the time domain.**
  - Click [Front panel:Settings] Acquisition/Analysis
  - A numeric pad for input will be displayed when you click [Front panel] More.
  - Adjust [Main window] Analysis Offset and [Main window] Analysis Length for selecting and analyzing a part from the complete capture. The part that is analyzed is viewed in the lower grid.
  - In the left upper grid the first green line is a representation of theAnalysis offset and the second green line is a representation of the Analysis length.
  - Enter **** ms in [Main window] Analysis Offset and 80 ms in [Main window] Analysis Length. The lower grid now shows a communication cycle between the reader and tag.
  - Change [Main window] Analysis Length to **** ms. The lower grid now shows a communication of the reader.
  - Change [Main window] Analysis Length to **** ms and [Main window] Analysis Length to **** ms. The lower grid now shows a communication of the tag.

- **Enable a marker in the analysis grid to find the value of time and power at a position.**
  - Click once on the lower grid to select it.
  - Click [Front panel: Markers] Marker Setup
  - Click [Main window: Markers] Single
  - Click [Main window] Reference Cursor Off
  - The value displayed on the top left corner of the lower grid shows the position of the marker in the grid
  - Click [Front panel: Markers] Peak. Now the marker is at the maximum position of the analyzed signal.

- **What is the difference in decibels between the reader and tag signal?**
  - What is the maximum power in the tag communication?
  - What is the maximum power in the reader communication?

- **Look at the frequency spectrum.**
  - Click [Front panel: Settings] Acquisition/Analysis
  - The top right grid can be used to view how the frequency and power vary over time. The purple line in the top left grid is a representation of the view in the top right grid
  - Enter different values between *** ms and *** ms for [Main window] Spectrum offset to view how the spectrum (top right grid) changes at various points of the capture

- **Enable a marker in the spectrum grid to find the value of frequency and power at a position.**
  - Click once on the top right grid to select it.
  - Click [Front panel: Markers] Marker Setup
  - Click [Main window: Markers] Single
  - Click [Main window] Reference Cursor Off
  - The value displayed on the top left corner of the grid shows the position of the marker in the grid
Click [Front panel:Markers] Peak. Now the marker is at the maximum position of the spectrum (carrier frequency).

- Look at frequency hopping
  - Find the carrier frequency at various points of the capture. Is the carrier frequency the same at all positions?

**Expansion**

Provide opportunities for students to expand the concepts to more general or global situations including connection to the Module goal. Expand back to the big ideas of the module and prepare for the next lesson.

- Why do passive RFID readers use an encoding scheme like PIE?
- What are the advantages and disadvantages of using FM0 versus Miller encoding on the tag?

**Lesson Assessment**

Assess student understanding of the lesson content. This does not have to be a full-blown examination. It could be a graded homework assignment, a quiz, a performance examination, a graded problem solving activity, or something similar.

- Homework assignment

**Equipment**

- PC running Windows

**Software**

- Tektronix RSAVU offline analysis software RSA series
  - Available: http://www.tek.com

**References**

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