RADIO FREQUENCY IDENTIFICATION CLASSROOM MANAGEMENT SYSTEM

by

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Executive Summary

Professors who manage large classes are unrealistically expected to grade each student fairly and accurately. Even with all of the technological advancements that have occurred in the past thirty years, very little progress has been made in classroom management, and as a result, professors are not equipped with enough tools to successfully manage large class sizes. Because radio frequency identification (RFID) technology is making its way into student issued identification cards, there is an opportunity to use it as a tool to aid professors in the classroom. The focus of this paper is to discover an effective system that can be implemented as a classroom management instrument. Through multi criteria analysis, two different infrastructures are examined and compared to determine the best alternative: a broad passive ultra high frequency (UHF) system, and a localized passive high frequency (HF) system. It is shown that a passive HF system will lead to a reduction in time spent taking attendance, an increase in student performance, an increase in the fairness and accuracy of recording classroom participation, and an enhanced professor-student relationship.

Keywords

Radio Frequency Identification (RFID), Location Tracking, Classroom Management

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1. Introduction

Larger class sizes at universities make it difficult for professors to efficiently take attendance, record student participation, or learn students' names. In shorter classes, professors cannot afford to waste precious time with the roll call process of reading off a name, then scanning the classroom for a response. Additionally, professors in these situations struggle with keeping track of which students are actively participating in discussion. This happens simply because it is too difficult to associate every student with a name, and takes too long to make a note of an individual's participation credit on such a long roster.

Many universities are beginning to update their standard issue student identification cards to be equipped with RFID tags. This decision opens up a window to implement RFID systems in classrooms as a management tool to solve many of the problems professors face. By locating student's identification cards within a classroom and referencing the university's database, an RFID system can provide a visual display to the professor of where each student is positioned. Illustrating these positions in the classroom with student photographs and names supplies the professor with a tool to better individualize students for grading accountability, and learn students' names to establish relationships. The purpose of the paper is to not only determine the most effective system to locate students in a classroom, but construct a prototype user interface that an instructor can efficiently utilize as a classroom tool. Information delivered by this system can be used to take attendance, learn students' names faster, and even manipulated to greatly increase the ease of recording student participation.

1.1 Scope

The scope of the report is limited to an exploratory experiment comparing different location techniques of RFID systems to later improve and develop upon. Because classrooms can be so different from one another, and large RFID systems can be very expensive, the system will be initially designed for a 12' x 16' four walled room. Once a proof of concept is determined, the chosen system can be designed to meet larger, more complex spaces.

2. Background and Literary Review

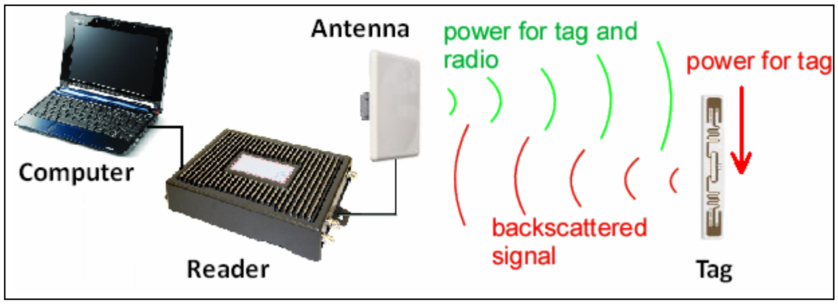
The last decade has shown an enormous increase in RFID applications and techniques. Fueled by large retail corporations requiring suppliers to use RFID systems in their supply chains (Weinstein 27- 33), the technology is continuously uncovering new purposes and functions. No longer is RFID just an improvement to bar codes; it is being used to track livestock, indicate when food has gone bad, and make quick purchases with cell phones.

2.1 RFID Technology Overview

The fundamental function of a radio frequency identification system is to use wireless communication to identify an object. RFID technology's primary advantage is that it does not require a line of site to detect an object, and can therefore simultaneously identify multiple objects within an area. A typical RFID system consists of a reader, antenna, tag, and computer or server. The basic components of a tag are a printed metal inlay, which serves as a small antenna, and a microchip, which contains the unique information of that tag. The communication process begins when the reader, acting as an interrogator, transmits a signal at a specific frequency through its antenna. If a tag is within the range of this antenna, it broadcasts a signal containing a unique identification number back to the reader, alerting it the tag is in the vicinity. Generally, a tag is attached to an object of interest, and a computer database is used to link the tag identification number to the specific object be tracked or located.

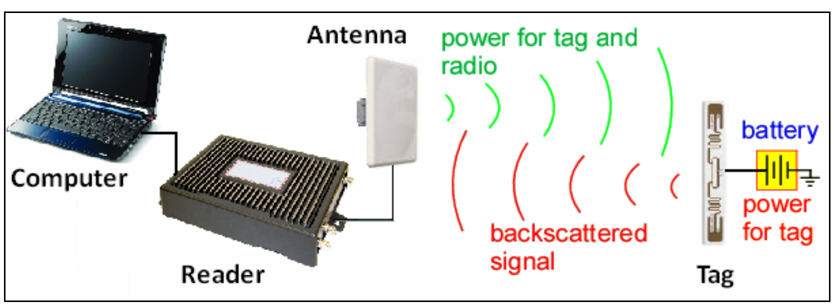
There are three main types of RFID systems: passive, semi-passive, and active which are illustrated in Figure 1, Figure 2, and Figure 3, respectively. In a passive system, the transmitted signal from the reader powers the tag's integrated circuit (IC) reaches a tag, the tag reflects the

signal in the form of backscatter. This reflected signal is modulated by the tag to transmit its unique identifier.



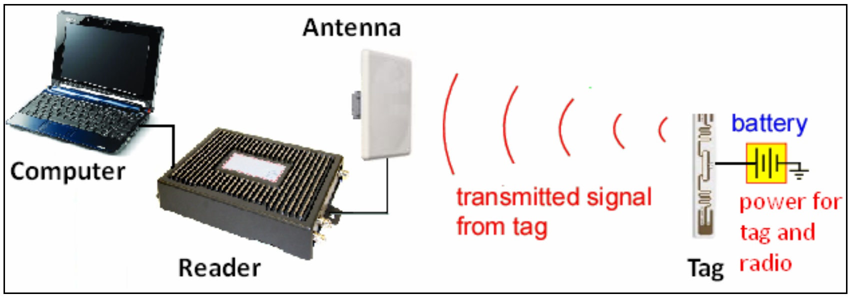
Source: Dobkin, Daniel M. *The RF in RFID: Passive UHF RFID in Practice*. Newnes, 2007.
Figure 1: Passive RFID System

Similarly, a semi-passive system reflects the signal from the antenna, but the backscatter signal it sends back is much more powerful because the tag is attached to a small battery. This battery provides the power to transmit the signal back to the reader, increasing its range.



Source: Dobkin, Daniel M. *The RF in RFID: Passive UHF RFID in Practice*. Newnes, 2007.
Figure 2: Semi-Passive RFID System

An active system is battery powered, but unlike the other two systems, it transmits its signal continuously, and does not need to be activated by the signal from the reader. Thus, the reader only needs to “listen” for the active tags signal (Want 25- 33).



Source: Dobkin, Daniel M. *The RF in RFID: Passive UHF RFID in Practice*. Newnes, 2007.
Figure 3: Active RFID System

Within passive RFID systems, there are three frequency bands available: Low Frequency (LF), High Frequency (HF), and Ultra High Frequency (UHF).

Table 1 shows that when compared to semi-passive and active systems, these three passive systems have much shorter read ranges, ranging from 1 cm to 10 m, because their backscattered signal is not battery powered (Weinstein 27- 33). While this is a disadvantage of passive systems, the pivotal distinction in the comparison of passive and active systems for the purpose of a classroom management system is the price of individual tags. An active tag is generally a magnitude of one hundred times more expensive than a passive tag, usually costing around $15, compared to a passive tag for $.15.

Table 1: RFID System Characteristics

RFID System	Frequency	Read Range	Price/Tag
Passive LF	125/134 KHz	1 - 3 cm	$.10 - $.25
Passive HF	13.56 MHz	1 - 10 cm	
Passive UHF	902 - 928 MHz	10 m	
Semi-Passive	Varies	100 m	$2 - $20
Active	Varies	100 m +	$20 - $100

2.2 Passive UHF Limitations

Although a passive UHF system has many advantages, there are factors to be considered when designing and implementing such a system. Primarily, there are two interfering factors specific to the 902 – 928 MHz frequency band: signal absorption from water, and signal reflection from metal (Dobkin).

Radiated fields can be absorbed by many different materials in buildings and the environment, but the absorption rate of these waves into water increases with higher frequencies, and consequently has a much larger impact on the UHF band than HF or LF. This results in a decrease of readability of tags which are in the vicinity of water, illustrated by the Georgia Tech study shown below in

Table 2. Because humans are made up of approximately 70% water, their presence in an RFID system must be addressed in the design.

Table 2: Results of read distance relative to presence of water

Georgia Tech Research Institute Test Results

Test	Placement of Tag	Max. Read Distance
1	Without presence of water	19.4 m
2	Next to a glass of water	7.1 m
3	Behind a glass of water	6.9 m
4	In a glass of water	.29 m

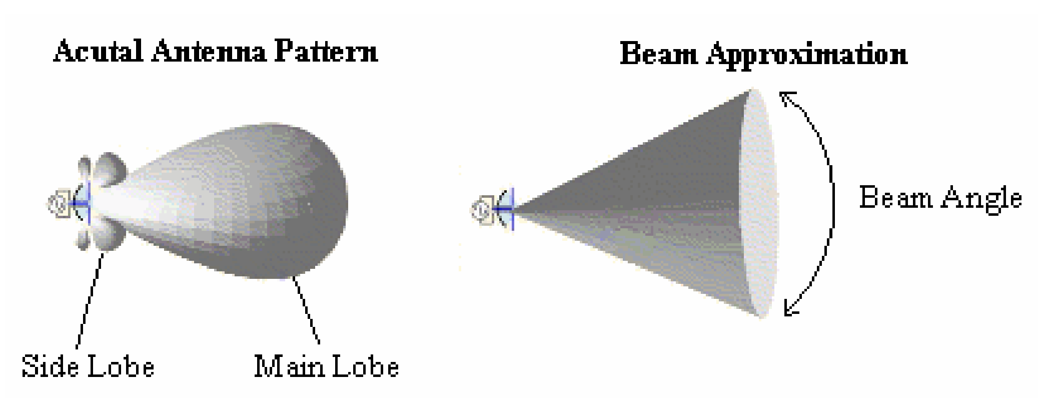
Source: Banks & Thompson for AVISIAN Publications

The density of most metals is so great that they will interfere with an electric field by reflecting it off of the metal surface. The presence of metal objects in the field of an antenna will lead to obstruction of the signal, and therefore must be considered in the design phase of an

RFID system. Additionally, typical tags cannot be placed directly on metal surfaces because the specific geometry of the tag's metal antenna will be interfered with.

2.3 Signal Geometry

It is important to understand the geometry of an antenna field when designing a system. Figure 4 illustrates the difference between the actual and approximated shape of the wave propagation. This approximated shape is assumed in the methodology and design throughout this report.



Source: Adaptation of Dobkin, Daniel M. *The RF in RFID: Passive UHF RFID in Practice*. Newnes, 2007.

Figure 4: Beam approximation of a directional antenna

2.4 Localization Methods

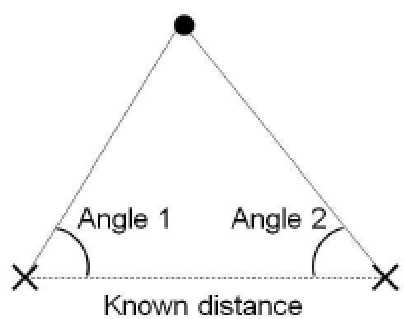
Due to the many interfering factors found in indoor environments, such as absorption and reflection, it is very difficult to precisely measure a signal. Thus, many localization methods

have been presented in literature. However, most of these methods fall into the two categories of distance estimation, and proximity (Bouet 2).

2.4.1 Distance Estimation

Distance estimation locates a tag by using various properties of triangles. The two prevailing methods are triangulation and trilateration.

The triangulation method, shown in Figure 5, uses the Angle of Arrival (AOA) of at least two reference points. The intersection of these two angles defines the location of the tag. While a two dimension method is illustrated, multiple reference points can locate a tag in three dimensional space.



Source: Bouet, Matthew. RFID Tags: Positioning Principles and Localization Techniques. Laboratoire d'Informatique de Paris 6 Universit´e Pierre et Marie Curie, 2009.

Figure 5: Triangulation method

Trilateration is a locating technique used to find the two dimensional or three dimensional location of an object in space. Using the same basic principles as GPS, it determines the distance, but not direction, an object is from a reference point. In two dimensional space, this creates a circular line around the reference point which represents all the possible locations of the object. By using three or more reference points, the possible locations of the object are narrowed

down to the intersection of all three of the reference circles, which effectively pinpoint its location. This basic principle is shown in Figure 6.

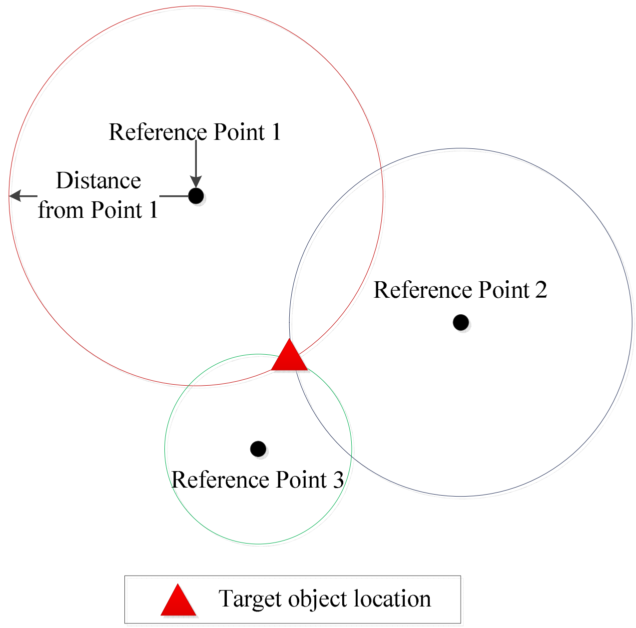


Figure 6: Trilateration in two dimensional space

Distance estimation methods provide relatively accurate localization, but require a considerable amount of information in regards to the metrics required (Sanpechuda et al. 769). Many systems and algorithms that are able to locate tags have been recently developed, including SpotOn, which uses Received Signal Strength (RSS) (Hightower et al.). Bouet introduces many systems using different metrics, including: Time of Arrival (TOA), Time Difference of Arrival (TDA), or as shown by Hekimian-Williams, using Received Signal Phase (RSP). These systems utilize a very high granularity, and are therefore highly accurate. However, in most commercial systems, these metrics are not available, and would require customized algorithms and systems to implement.

2.4.2 Proximity

Proximity systems rely on dense antennae coverage to locate tags. If a tag is read by an antenna, it can be assumed that it is within that antennas field. If it is also read by an adjacent antenna, it can be assumed that the tag is located in the overlap of the two antennae fields (Zhou et al.). In addition, signal strength can be used to more accurately determine the location of the tag. Systems using the proximity method have been used to cover large areas where a high level of accuracy is not necessary, such as a construction site (Song 367-376).

Although the proximity method is limited in accuracy by the size of each antenna's field, and the density of antennae, it is extremely simple to implement with most commercial systems, and does not require the advanced metrics that distance estimation relies on. Consequently, this localization method is much more applicable to a classroom setting.

2.5 Antenna Optimization

Covering an area accurately with the minimal number of antennas is important when they cost approximately $100 each. In addition, knowing where to position antennas and the location of the resultant radiated signals is extremely important to the design and installation of RFID systems. Thus, there are algorithms and programs which calculate these parameters. Bryce Taylor, a Cal Poly student, developed such a program for his thesis. As Taylor states, that program, RFIDMIN, "can be used in conjunction with LP software or an algorithm to determine the minimum number and location of RFID antennas, such that any given 2D and 3D space is covered by at least one antenna" (Freed and Taylor).

2.6 Related Work

Many systems have been developed and tested that are able to register attendance of events or specific rooms using simple RFID configurations. Below is a brief overview of two systems which could be applied to an educational setting.

2.6.1 WaspTime RFID Solution

This much more labor-intensive system uses a high frequency (HF) reader which requires individuals to swipe their RFID cards or badges within three inches of the device to record the time and owner of the badge. This system is designed as an employee time keeping system and is not designed for schools specifically (*Wasp Barcode*).

2.6.2 InCom InClass RFID System

This system records attendance by using an overhead antenna at every classroom's doorway to automatically detect when students wearing RFID badges enter or exit the room. Because it uses a passive UHF RFID system, students are not required to slow down and swipe their badge or change their normal habits of entering a room. It is the only school attendance system available which requires no contact to operate (*InCom Corporation*).

2.6.3 Current Deficiencies

Although each of these systems is able to take attendance and detect if a tag is within a certain room, neither has the ability to locate a tag to a specific position inside the room. In addition, there are no systems available that provide an interface for professors to record students' participation, or learn students' names.

2.7 Privacy Concerns

As RFID technology becomes more prevalent in everyday life, there are growing concerns about its security and tracking ability. An excellent example is when a small RFID company named InCom tested their attendance taking system in a local California school district. The system required students to where a lanyard holding an identification card with their photo, name, and embedded RFID tag. The company was surprised when after one week of implementing the system parents became outraged that their child was being tracked at school (O'Connor , "RFID Takes Attendance—and Heat"). Even though the technology only took attendance inside specific rooms, many parents felt their child's civil liberties were being violated. InCom quickly pulled the plug on the operation, but not after exposing a critical issue concerning RFID implementation.

While there are definitely lines that never should be crossed concerning a person's privacy, the environment that a classroom management tool operates in differs drastically from other location applications. Northern Arizona University (NAU) is currently defending RFID attendance taking systems it plans to implement by stating that "teachers are already asked to collect attendance manually—and to incorporate attendance data into students' grades—and that using the RFID cards to automate the system would simply enable those who teach large classes to save time" (O'Connor, "Northern Arizona University to use existing RFID student cards for attendance tracking").

A student does not have a choice to be recorded for attendance with or without RFID, so it is not justified to discriminate against the technology. If an RFID system simply makes a current accepted process more efficient, and does not intrude upon the privacy or liberties of an individual, it should be allowed to flourish. However, in an effort to reduce privacy concerns,

the system developed in this report will provide students with an alternative option to being automatically scanned.

2.8 Pedagogic Approaches

While there is a multitude of different views concerning education, and specifically what the relationship between student and teacher should be, one thing is true: personal relationships with students ensure that students feel respected as individuals (Cole 227).

This respect helps to build student confidence and autonomy, two characteristics students struggle with most during their educational experiences (Mensch et al. S199-S207). While personal relationships do not hinge on knowing one another's name, it can be a large hindrance in the growth and establishment of a good rapport. Learning a person's name is most often a barrier of entry into a relationship. Additionally, knowing an individual student allows professors to recognize learning deficiencies, curtail the education to improve them, and consequently enhance the effectiveness of instruction. For professors, learning names can be extremely difficult with so many students to cover, and they are given very little to assist them in the process.

2.9 Student Absenteeism

The effects of attendance on class performance has been widely researched and studied. Arulampalam et al. demonstrated that although the complete effect of student absenteeism varies with ability, higher rates of absenteeism have a direct correlation to poorer class performance. Moore reinforces the claim by also finding an increase in student performance in a freshman level biology course in which the importance of attendance was emphasized, compared to one

where it was not (17-25). Devadoss et al. published a study which provided strong empirical evidence of the positive influence of attendance on performance (499-507). In addition, he discovered a factor that lead to an increase in students' attendance. He states:

Whether or not the instructor "required" class attendance strongly influences students' behavior. All else being equal, an attendance requirement resulted in a 12.7% higher attendance rate. This supports the notion that "encouraging" students to come to classes - either through penalizing them by reducing scores or by requiring written make-up of missed class materials - seems to increase class attendance. (504)

Among Devadoss's recommendations to increase attendance and performance is for professors to allocate a certain percentage of the total grade for attendance (506).

Both of the claims of attendance's effects on performance and the motivational factors which lead to increased attendance are further substantiated by White as he remarks that in his agricultural policy class, requiring and rewarding attendance improved class attendance, and that student absenteeism resulted in lower grades (13-15). Therefore, it can be concluded that requiring attendance leads to an increase in student performance.

3. Design

This chapter will describe the overall approach and steps taken to defining and solving the inherent deficiencies of modern classroom management. It begins with identifying the current problems in today's classrooms, and the associated needs of university professors. Characteristics of an optimal system are developed using this information, and are used to determine the design solution. The basic structure of this solution is presented, along with several configurations that require testing and evaluation.

3.1 Current Teaching Difficulties

California Polytechnic State University (Cal Poly) has an average class size of 35 ("Cal Poly, San Luis Obispo"), which is considered small among large public universities. Professors at Cal Poly, and many other universities, face several challenges when trying to manage large class sizes. The first difficulty, and the root cause of others, is simply identifying each student by name. Although some professors are capable of learning every student's name, many find the task too difficult when faced with large class sizes, and at minimum it takes some time before every student becomes recognizable. This challenge is compounded when teachers attempt to grade students on their in-class participation. If a professor cannot recognize every student in the class, then he or she cannot accurately record participation.

The following sections provide an in depth analysis of two classroom management challenges:

- Recording attendance
- Recording in-class participation

3.2 Cal Poly Faculty Survey

A survey of 100 Cal Poly professors was administered to assess teaching practices and difficulties related to attendance taking and participation grading, as well as to evaluate the potential need for a classroom management system.

3.2.1 Attendance

As previously discussed, lower attendance has been shown to cause poorer class performance, which agrees with intuitive logic. Although professors have different opinions on including attendance in grading schemes, many have argued that because it is a university's responsibility to provide the best education it can, students should be encouraged to attend class. Giving students credit for attending class has been previously shown to increase the attendance rate, as well as the class performance. Unfortunately, recording attendance can be extremely tedious and time consuming in large classes. The survey asked Cal Poly professors how often they currently take attendance, as well as how often they would take attendance with a hypothetical fully automated system. The results are illustrated in Figure 7, and show a projected increase in attendance recording which clearly proves that professors desire a simple and automated attendance taking system.

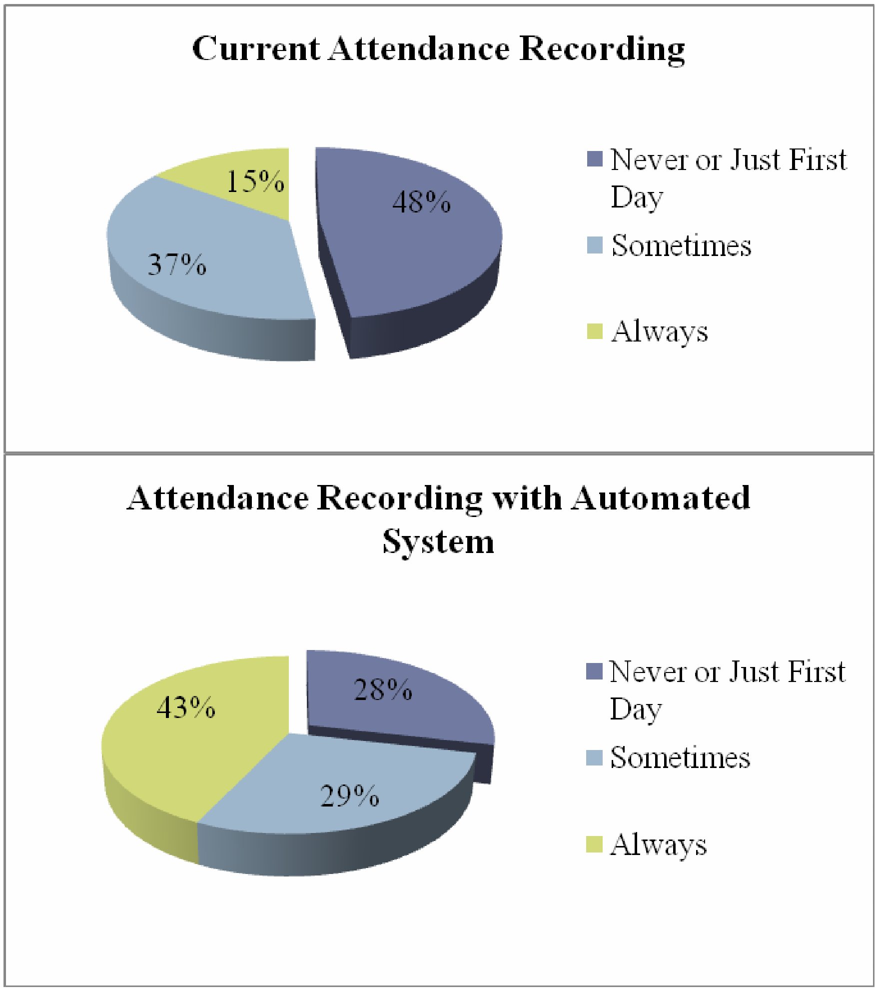


Figure 7: Survey attendance results - current system (above) v. fully automated system (below)

3.2.2 Participation

As mentioned previously, the inability to recognize a student leads to other classroom management problems, including in-class participation grading. In-class participation, in this sense, is defined as speaking up in class during discussions, or adding insightful comments, but not simply attending class. If a professor cannot recognize every student in the class, then it becomes very difficult to accurately and fairly record participation. Professors at Cal Poly were asked to describe their methods of recording participation, and the results showed that 24% made real-time notes as the student was speaking, 14% made notes after class on who they

remembered participating, and 31% based the final students' participation grades on a gist or feel for who had been participating during the 10 week grading period. To accurately grade students using each of these methods (a total of 66% of the methods professors use) requires the ability to recognize and name every student in the class; a professor cannot mark down a student for participating if the student's identity is unknown. In addition, the latter two methods require professors to have a perfect memory of which students participated as far back as an entire quarter (10 weeks). Consequently, these factors lead to a high probability of grading error, and a need for a better quantitative system to record participation.

To design a better system to record participation, the deficiencies of the current system must be known. The professors that do not record participation in all of their classes were asked to give their reasons for doing so. Because the professors were not limited to a single reason, Figure 8 shows the amount of responses for each reason, and not the percentages. The top two reasons given where that participation grading is too time consuming, and that there are too many students. Thus, an ideal system should be extremely quick, and able to handle a large amount of students.

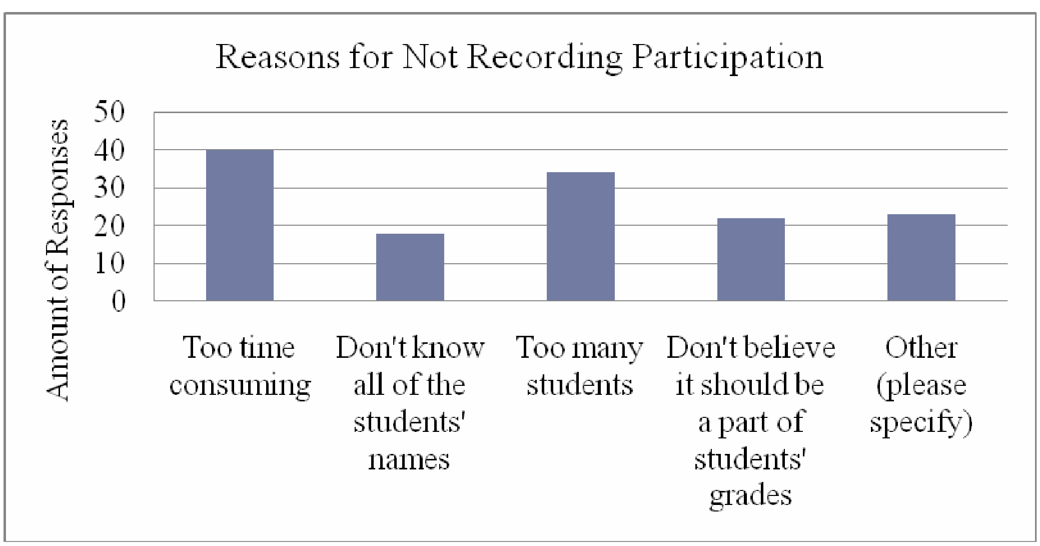


Figure 8: Survey participation results - reasons for not recording participation

To assess professors' desire for a better participation recording method, the survey included a question asking in how many classes is participation recorded in some form, and a second question asking in how many classes would participation be recorded with an easier method. This easier method is defined as an "easy way to identify a student and record his or her participation in a few seconds even in large classes." The results, illustrated in Figure 9, show a 45% reduction (from 40% - 22%) in professors not grading participation in any class with the easier system. This provides the evidence of the need for a better recording method.

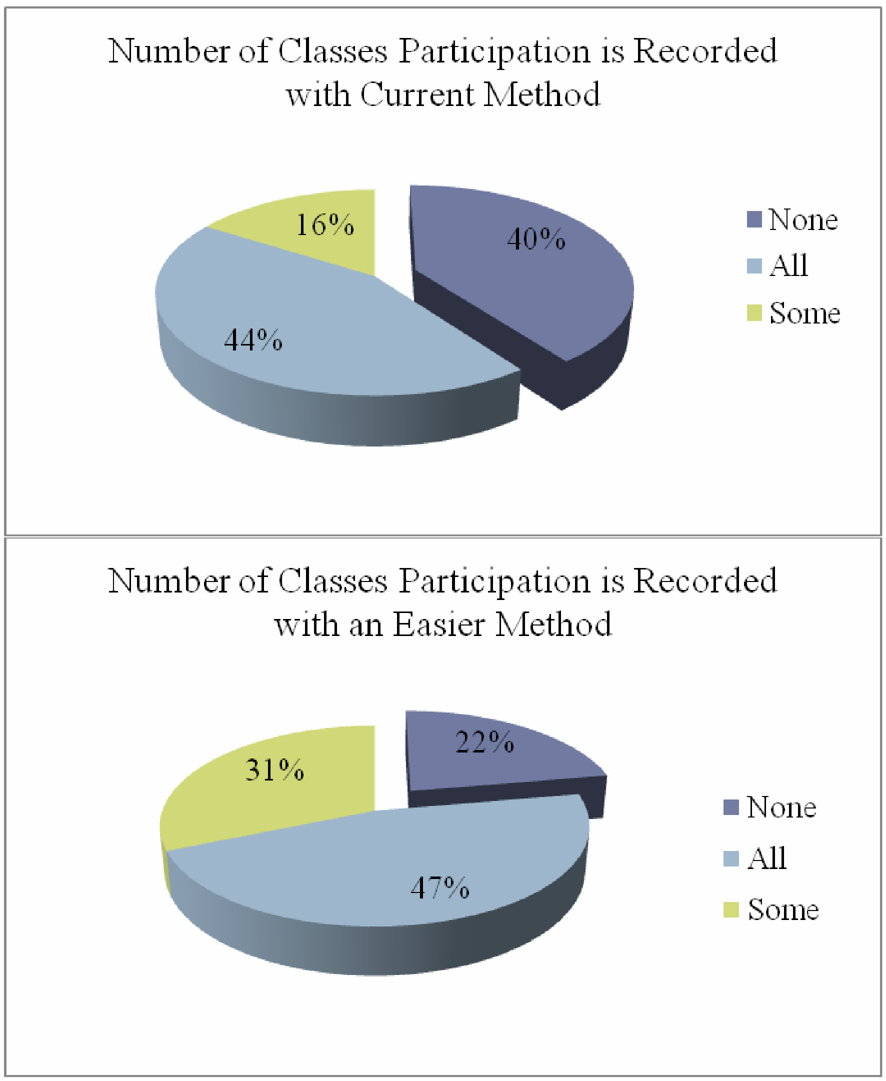


Figure 9: Survey participation results – current system (above) v. easier system (below)

3.3 System Requirements

The analysis of the survey results established a need for a system which improves attendance and participation recording. Furthermore, a system which provides a professor with a way to learn students' names can only help with participation and attendance recording. Specifically, an ideal system will have the following characteristics:

- Automatically record attendance
- Quickly assist a professor in recording participation in real time
- Save information in a accessible manner
- Provide learning aid for recognizing and identifying students

A system which accomplishes these goals will increase both classroom performance, and fair and accurate participation grading, and decrease the time wasted in class. It also has the potential to create a more personalized student-teacher relationship.

3.3.1 Formulation of RFID System

The next generation of Cal Poly's student identification (ID) cards will contain an RFID tag. While the tag will be passive HF, having a read distance of only a few centimeters, it is assumed by the university's new interest in RFID that any type of passive tag can be placed inside the ID card. This provides a unique opportunity to utilize RFID technology as a classroom management tool.

As previously discussed, existing RFID classroom systems can locate students to a particular classroom, and take attendance in doing so, but they offer no solutions to aid professors in learning students' names or recording in-class participation. By locating students *within* a classroom, an RFID system has the potential to solve both of these deficiencies. This

can be achieved by presenting the information of students' locations to the professor in an understandable and intuitive manner, and providing a system to assist in both participation recording, and student recognition.

3.3.2 User Interface

To meet these design requirements, an interactive user interface on a mobile device is necessary. Almost half of all surveyed professors preferred a tablet device over a laptop or smart phone. Therefore, in the design of the system, the professor will be equipped with a portable tablet computer, for a mobile, lightweight tool to track participation and build a relationship with students. The user interface, roughly illustrated in Figure 10, will allow professors to visually see each student in the room by locating every student's picture and name in a model of the classroom. The classroom is broken up into a grid of nine boxes, which help distinguish the relative locations of every student. Using the touchscreen device, the instructor can quickly select a student and add a participation point while the student is talking in class. Along with participation, the database of the program records attendance for grading purposes.

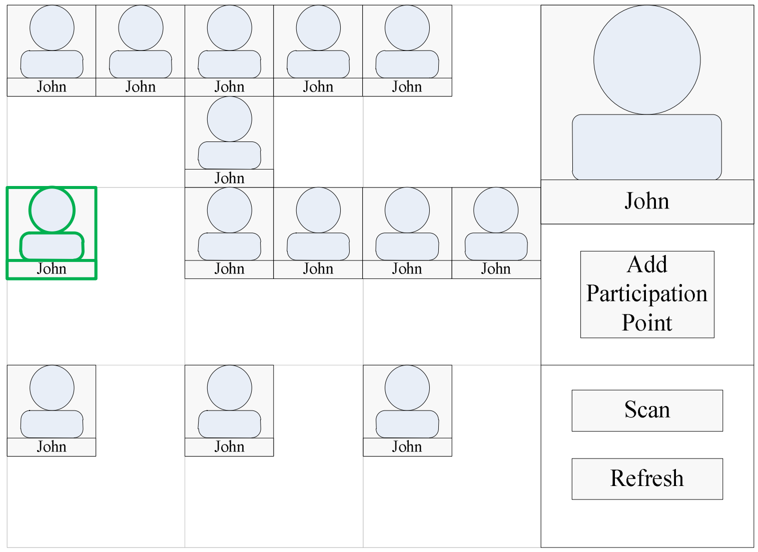


Figure 10: User Interface Display Model

The backbone of this system is its ability to locate students relatively accurately within a classroom. Developing a localization method for the classroom environment is the focus of the following sections.

3.3.3 Localization

Before developing the localization system, the type of RFID system to be used, and the type of localization method must both be evaluated.

When considering inserting tags into twenty or thirty thousand student identification cards, passive tags become a much more cost effective option. This fact, coupled with read ranges of up to 10 meters, make the UHF passive RFID system the ideal choice for a classroom management system. However, when compared to HF systems, the cost per UHF reader is an order of magnitude greater than the cost of an HF reader, with prices generally ranging from $800 - $1600. Even though a UHF reader can connect to four antennas, each with read ranges of up to 10 meters, multiple localized HF readers are a cost effective option to consider.

The distance estimation method of localization is very accurate, but requires many custom algorithms and metrics that are not readily available in commercial systems. The simplicity of the proximity approach makes it appealing, as well as its versatility to indoor environments. While accuracy is important, locating a student in a large classroom with the help of a visual display does not require the level of accuracy that the distance estimation method provides. The goal of the system is to provide the teacher with a general vicinity of a student. In addition, the proximity method's accuracy is dependent on the density and number of antennae, making it a very customizable option. For these reasons, the optimal localization method is the proximity approach.

3.4 System Designs

The following sections present and compare two system configurations: a passive UHF four-antenna system, and a localized passive HF system.

3.4.1 Ceiling Corner Four-Antenna System

Because RFID systems generally get much more expensive as their complexity increases, the first design involves only one reader and four antennas and will test if a highly simplistic design is effective enough to be a viable classroom management tool. The basic structure of this configuration places each antenna at the highest corners of a room where the walls meet the ceiling, and positions them so they are all facing directly to the middle of the room. The proximity localization method is the basis behind this design. Figure 11 illustrates the system configuration, and shows four antennas, represented as different colored squares in the corners of the room. The colored half circles represent the range of each antenna. These four antenna

fields and their overlap create nine separate zones. In reality, because antenna ranges are not perfect spheres, this depiction is not as exact as shown, but it does show the basic idea behind the design. By creating these nine different zones, a tag's location can be determined to be within a small area. For instance, if a tag is read by both Antenna 1 and Antenna 2, then the tag should be located within zone 2. Zone 9 is unique because it actually contains five different overlap zones, but due to their small size, they are combined to form one central zone. As a result, if a tag is read by any three antennas, or all four, the tag should be located in the middle of the room where zone 9 is.

In theory, this method should locate tags accurately, but there are many factors that can interfere with the transmissions of an antenna. As discussed previously, the absorption of radio waves by the water in human bodies and wave reflection off of metal objects are two main interferences to consider. Experimentation of the localization method is therefore required to test the viability of the system.

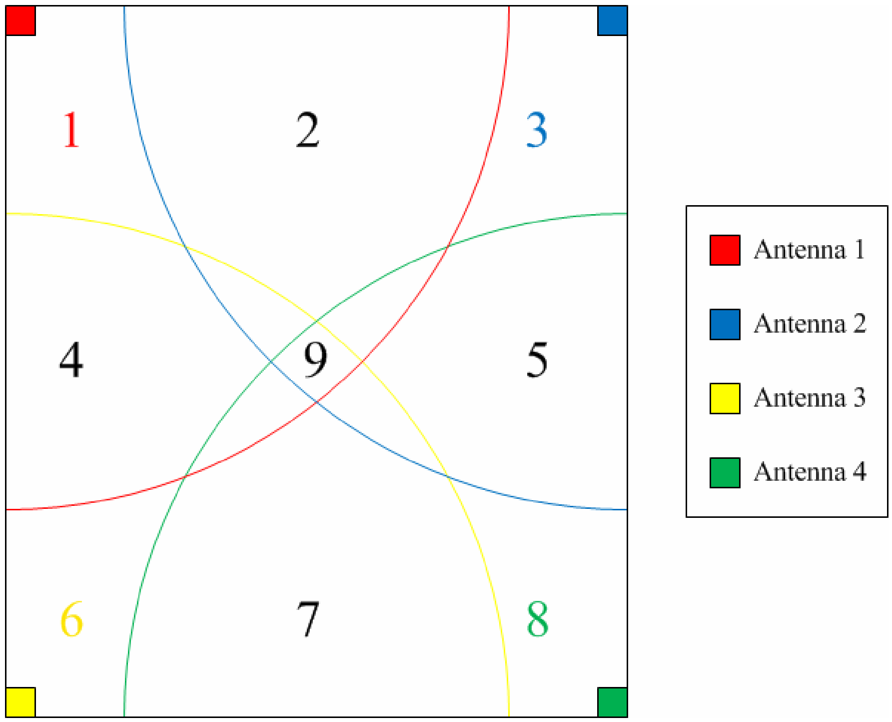


Figure 11: Proximity Ceiling Corner Four-Antenna System

3.4.2 Local HF Reader System

This design uses several small passive HF RFID readers located at every large table or cluster of desks in a classroom. HF readers are much smaller than UHF readers, about the size of a computer mouse, and would not take up significant room. These HF readers require students to pass their identification card within a three inch proximity of the reader at the beginning of each class. The largest benefit of this system is that it guarantees the location accuracy of every tag in the classroom. A severe drawback to the system is that it requires a great deal of infrastructure and money to implement because of the work required wiring so many readers. Due to this, the system will not be a viable option for most classrooms, although it will be ideal in many new business classrooms that have complex, preexisting electrical infrastructure at every table.

4. Methodology

Experimentation and testing are necessary to evaluate the accuracy and characteristics of the Ceiling Corner Four-Antenna system. For the Local HF Reader system, it is assumed that it will produce near 100% read accuracy, and therefore does not require additional testing. This can be justified by including a visual control into the design, such as a small light, to show the student whether his or her card has been read. This chapter discusses the testing of the passive UHF system, for which accuracies and read range are unknown.

4.1 Ceiling Corner Four-Antenna System

The goal of the experimentation is to establish a probability distribution for the read rate (or accuracy) of the system. By knowing the probability distribution, the system can be further customized to more accurately interpret the data of a given scan.

4.1.1 Experimental Design

The four antennas are mounted in each corner of a 12' x 16' room and positioned to face directly to the center of the room. The room is divided into a grid of thirty-two rectangular sections (Figure 12), each measuring 2' x 3'. The section dimensions are chosen as such, because they reproduce the average space that one student occupies inside a classroom. After careful measurements, tape is laid down on the floor of the room along the lines of the grid to provide a visual method of determining the location of each section. To suspend the RFID tags, string is strung across the room at 38" above the ground. If the grid of the room (Figure 12, left) is regarded as four columns and eight rows, there are eight pieces of string running across the

entire length of the eight rows. Eight, simple PVC structures, seen in Figure 13, are built to support the string, and are placed down the middle of the room, between the second and third columns (Figure 12, right). The string is threaded through two drilled holes in the PVC, at 38" above the ground. Above the middle of each of these sections, an RFID tag is taped to a two inch piece of plastic straw and attached to the string. The strings and tags are measured and adjusted so that they are suspended exactly three feet above the floor.

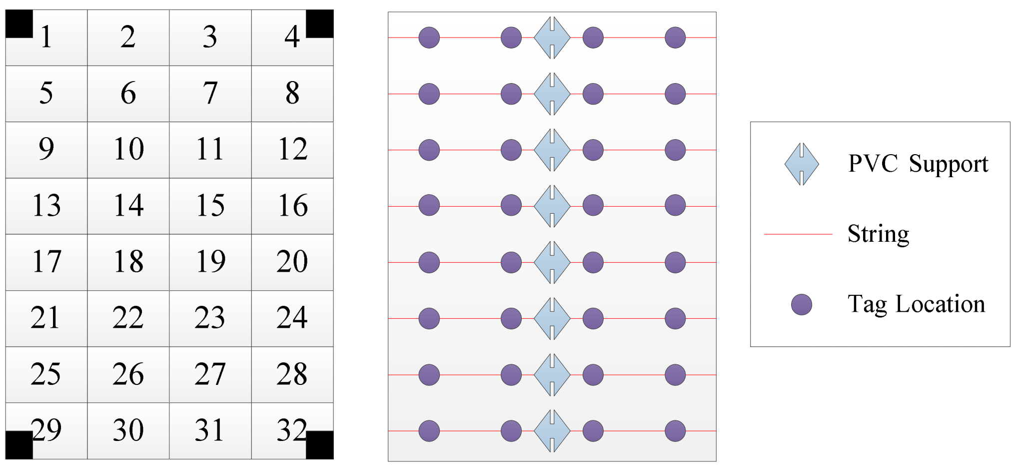


Figure 12: 12' x 16' experiment room grid (left); PVC, string, and RFID tag positions (right)

4.1.2 Experimental Procedure

For the purposes of reducing the experimentation time, each column, consisting of eight suspended tags, is tested individually. The RFID reader is turned on to detect tags for 10 seconds, and then is turned off. Data is recorded that shows which tags are read by which antennas. The tags are left in the same positions, and the process is repeated two more times. After the third replication, the current column is exhausted, and the tags are moved to a different column. After the four different columns have been tested, a sequence is finished. The column order of the eight tags is randomly recalculated, and another sequence begins. In all, the

experiment lasts three sequences, resulting in thirty-six different replications, and almost 1000 data points.

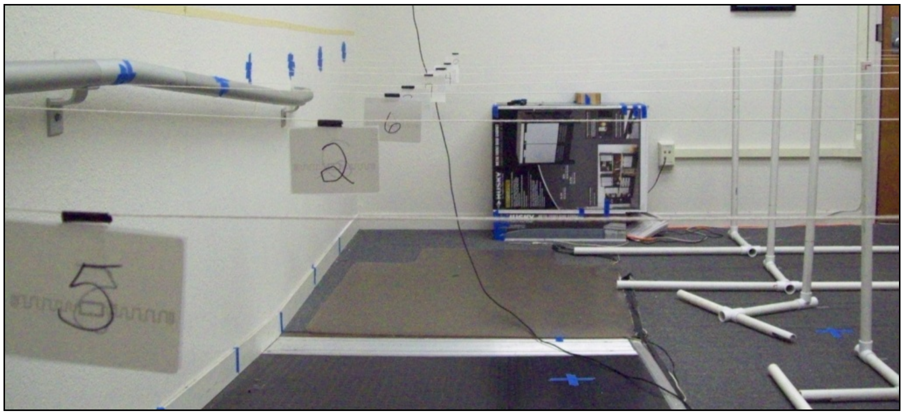


Figure 13: Setup of Control Room with Suspended Tags

5. Results

The accuracy of a localization method is important because attendance and participation can be impacted. At this stage, to be considered a viable system, read rates above 90% are required, and those above 95% are desirable. This chapter presents and analyzes the results of the experimentation of Chapter 4.

5.1 Ceiling Corner Four-Antenna System

Because the room is symmetrical about both the horizontal and vertical medians, the data is effectively repeated four times, and therefore has been consolidated into the single repetitive piece. This piece, which is a 2’ x 3’ rectangle shown in Figure 14, gives the read accuracy of each section relative to the four different positions of the antennas. Relative to every section are four antennas that are located diagonally across, vertically adjacent, horizontally adjacent, and nearest to it. These relative antenna positions are shown as the colored boxes outside of the grid. This symmetry allows all the data for each of the antenna relationships to be separated and analyzed. This attempts to reduce confounding factors such as interference in specific places in the room, or variation in antenna performance.

Unfortunately, the results are not good. Figure 14 clearly demonstrates the sporadic and poor read rates of this system. The only clear tendencies that can be inferred about the system are that sections along the longer walls are read with the lowest accuracy, while sections in the middle of the room are read with the highest. The difference in these read accuracies is not clear enough to provide an adequate location system.

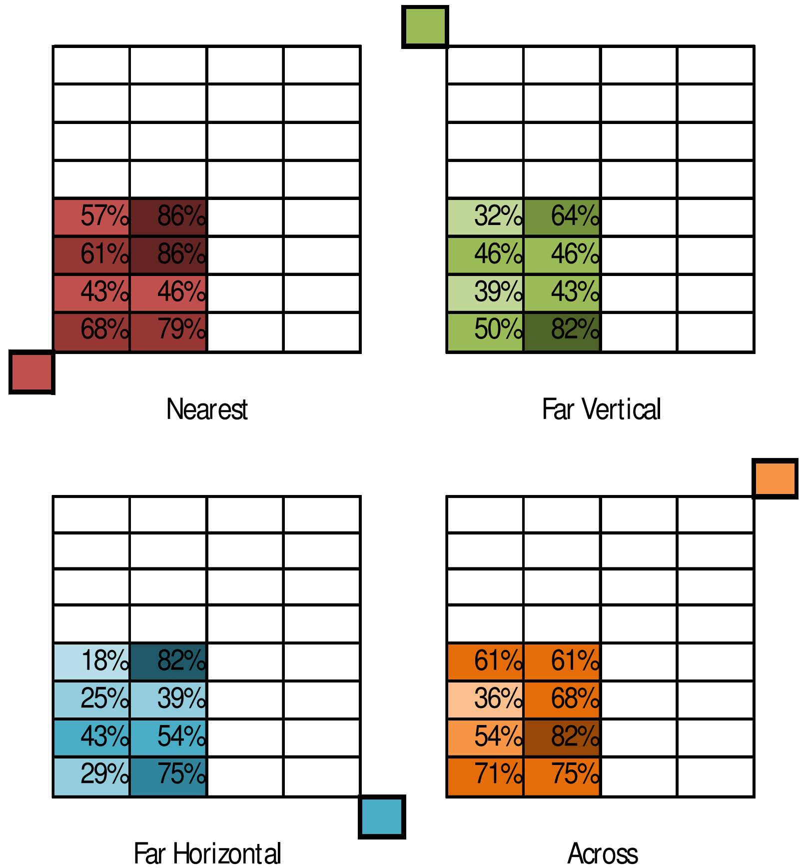


Figure 14: Perspective read rates of Ceiling Corner Four-Antenna System

5.2 Interfering Factors

Because the testing of the Ceiling Corner Four-Antenna system is performed in an actual classroom, the environment is not completely ideal. The results indicate a potential reflection off of the walls, and other objects in the classroom, and with further interference from students in the classroom, the configuration is simply not a viable option. Additionally, the vertical tag orientation tested in this experimentation attributes to the poor results. The signal from the antenna does not reach the tag in an orientation capable of maximizing the reflected signal power. Therefore, additional testing with optimized tag orientations is necessary.

5.3 Cost Analysis

At first glance, the cost analysis shows that both passive UHF and HF RFID systems are expensive, with the HF system being the cheaper of the two. Additionally, the size and characteristics of the classroom can have a dramatic effect on the price of the HF system. The high price tag is especially difficult to justify because most of the benefits a classroom management system provides are not easy to economically value. However, automatically recording attendance does eliminate the time necessary to manually do so, therefore increasing the value of the class to the students. A very simple calculation, based on the 2010 average cost of attending a public in-state four year university of $16140 (Baum 10), results in a cost per minute of lecture of $.60 per student (see Equation 1). If it is conservatively assumed that manually recording attendance takes two minutes, then the cost to take attendance is approximately $42.00 (see Equation 2). If attendance is taken every class period, then the annual cost is $2520.00 (see Equation 3). Thus, the payback periods for the UHF and HF systems are 8.66 months and 5.25 months, respectively.

Equation 1: Student cost per minute of lecture
($16140/ year) x (1 year/45 units) x (1 unit/1 hour/week) x (1/10 weeks) x (1 hour/60 min) =

$.60/minute

Equation 2: Cost of recording attendance
($.60/minute) x (2 minutes) x (35 students) = $42.00

Equation 3: Annual cost of recording attendance
($42.00/class) x (2 classes/week) x (10 weeks/term) x (3 terms/year) = $2520.00/year

Table 3: Cost per classroom of Ceiling Corner Four-Antenna System

Item	Price per Unit	Total Price
Hardware		
Motorola FX7400 RFID Reader (4 Port)	$ 1,032.00	$ 1,032.00
Poynting Antennas (4)	$ 69.99	$ 279.96
Superpad 10.2" Tablet PC	$ 199.99	$ 199.99
Passive UHF Tags (50)	$ 0.15	$ 7.50
Installation		$ 300.00
	Total Cost	$ 1,819.45

Table 4: Cost per classroom of eight Local HF Reader System

Item	Price per Unit	Total Price
Hardware		
HF RFID Reader (8)	$ 49.48	$ 395.84
Superpad 10.2" Tablet PC	$ 199.99	$ 199.99
HF Tags (50)	$ 0.15	$ 7.50
Installation		$ 500.00
	Total Cost	$ 1,103.33

Although this analysis contains many assumptions, it is meant to point out the possibly unrealized economic benefits such a system can have. Furthermore, it does not include the benefits of accurate and fair participation grading or of a more personalized learning experience. Professors who struggle learning students' names, forget who exactly participated in class discussions, and take, or want to take, class attendance every period, will benefit the most from a classroom management system. Consequently, both RFID systems are economically viable options for professors and classrooms that would utilize the system to its potential.

6. Conclusions and Further Analysis

This chapter will discuss the problems of classroom management and associated objectives of the report, along with the solution approach. A recommendation of the optimal classroom management system for particular conditions will be given, and the related benefits will be presented. Finally, further analysis will be discussed to improve current designs.

6.1 Summary

This project set out to solve the difficulties involved with managing large classes. Specifically: accurately and fairly grading in-class participation, learning students' names, and recording attendance in a timely manner. It established the need that professors have for a classroom management tool, and took advantage of new RFID trends to help develop such a device. Different RFID configurations and methods were examined, and although some of the results were not promising, an applicable system was discovered that is not only cost effective, but carries along many invaluable benefits as well.

6.2 System Recommendation

The high accuracy and low cost of the localized HF reader system makes it the optimal system for most classrooms. Although, this system requires a large amount of infrastructure to connect and power all of the readers, and may not be viable in classrooms with limited energy resources. The procedure for detecting tags in this configuration is for students to "sign in" to the system at the beginning of class by moving their ID card next to the HF reader in their vicinity. This information is relayed to the professor through the handheld, touchscreen, user

interface. This classroom management system achieves its original goals and provides professors with a tool that will:

- Increase student performance
- Aid in learning students names
- Automatically record attendance
- Provide a quantitative method to quickly and accurately record in-class participation

These improved abilities will lead to an improved student teacher relationship and personalization of the learning experience. There will be less wasted time, and an associated increase in class value. Most importantly, students will be graded fairly and accurately on their in-class participation, and will improve their performance.

6.3 Further Analysis

While the HF system is chosen as the optimal configuration, a UHF system does not require as high of infrastructure to operate, and if accurate, could be a more cost effective solution that covers larger areas. For full implementation of a UHF classroom management system, additional analysis is required. Specifically, the effects of students occupying a classroom, and the subsequent absorption of UHF signals, were never tested, as all experimentation was kept under semi-ideal conditions. Experiments testing tag orientation, tag location, read duration, and antenna attenuation and position are required to further develop a viable passive UHF. Additional configurations such as overhead antenna mounts, and side wall antenna mounts are further possibilities for experimentation. The effects of the motion

introduced by student retrieving a card and placing it on the desk are unknown, and also require further testing.

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