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Developing a Radio Frequency Identification (RFID) as a Decision Support System in Horticulture Industry

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Radio Frequency Identification (RFID) as a decision support system in horticulture industry

Abstract

The use of Radio Frequency Identification (RFID) Technology in various industries has gain popularity in the past few years. RFID is being used by many industries including packaging, supply chain management, manufacturing, shipping and transportation, medical and healthcare and animal identification. The horticulture industry has had limited applications of RFID. Current application of RFID in horticulture industry is focused on tracking inventory along the supply chain beginning at the greenhouse level where mobility becomes an issue. Greenhouse personnel wants to know what plants they have and where it is. One problem and concern in RFID applications is the range of tag readability and the how the environment affect the tag recognition. To identify the conditions of the item it is very important to do detail research on readability of tag in different positions. The reading range of RFID tags can be affected by linear distance, height and angle positions. This paper investigates the effect of the readability of RFID tags at certain attenuation and at certain positions with different linear distances, heights and angles. The data is analyzed to obtain graphical representation of the coverage and a relationship has been developed using factorial design to understand the influences of positions and other critical factors and their interaction effects. The experimental set up can be used to investigate not only the location of an item but also how the environment affects the detectability, which in the long run will assist in developing a decision support system. This paper investigates the effect of the readability of RFID tags at certain attenuation and at certain positions with different linear distances, heights and angles. The data is analyzed to obtain graphical representation of the coverage and a relationship has been developed using factorial design to understand the influences of positions and other critical factors and their interaction effects. Due to the varied application of RFID, the authors have incorporated the experimental set up in undergraduate, Senior Project capstone course with team members drawn from both Mechanical and Mechatronics Engineering technology.

Introduction

Radio frequency identification (RFID) is a broad term that is used to describe a system that transmits the identity (in the form of a unique serial number) of an object wirelessly, using radio waves and categorized as an automatic identification technology. RFID is designed to enable readers to capture to capture data on tags and transmit it to a computer system- without needing a person to be involved. The different components of an RFID system are: an antenna, an RFID reader, a transponder (RFID tag). RFID technology implemented in a business environment can be used to track and record real-time in-transit visibility. The advantages of this technology over any other identification technology is that RFID can send and receive information remotely without human intervention, ability to read multiple tags, does not require line of sight, capable of maintaining higher amounts of digital data, and higher supply chain security [1]

It is generally accepted by researchers and educators in horticultural science that horticultural corps include; tree, bush and perennial vine fruits, perennial bush and tree nuts, vegetables, aromatic and medicinal foliage, seeds and roots, cut flowers, potted ornamental plants, and bedding plants, shrubs, turf and ornamental grasses propagated and produced in nurseries for use in landscaping or for establishing fruit orchards or other crop production units. According to most recent census conducted by U.S. Department of Agriculture's, National Agricultural Statistics Service (NASS), U.S. horticulture operations sold a total of $ 13.8 billion in floriculture, nursery and specialty crops in 2014, up 18% since 2009. Therefore, horticulture cropping systems are intensive in terms of investment, labor requirements and other inputs.

RFID technology appears to be one of the most promising emerging technologies to facilitate data collection and be able to provide growers with support for a wide range of production and management issues. To incorporate in decision support system there are several hurdles that need to be overcome. Studies have been conducted to investigate the effect of factors such as RFID tag detection in 3D space [2], effect of temperature on RFID [3] and readability of RFID penetration through three solid products varying particle sizes [4]. However, the effect of variation of height, distance and angle on tag has not been investigated fully yet. The research deals with exploring the effect of various compositions based on heights, angles and linear distances o tag readability. Based on the outcomes of current research RFID could do much more (i.e. condition level – moisture level, history of fertilizer interval etc) than just item level monitoring (individual pots and plants). This is essential during warranty replacement and insurance of high end or economically valuable plants.

Equipment

RFID technology is considered to be beneficial because it does not require line of sight. It is possible to read, write and update digital information by using this technology. A typical RFID system consists of an antenna, a transponder (tag) and a microprocessor chip with memory.
The effectiveness of a tracking system depends on RFID tagging readability. Tag readability depends on many variables, such as type of tag and antenna, distance from tag to antenna, tag orientation and tag placement. Also interferences with the surroundings due to other wireless devices might have some effects on tag readability.

There are two types of tags, active and passive tags. Active tags require a continuous source of power. They are either connected to a power infrastructure or they use energy from an integrated battery. On the other hand, passive tags do not require batteries or maintenance [5]. They are small and have indefinite lifetime. This research uses passive tags for RFID tagging. We have used a passive tag manufactured by Alien Technology® for this research. The whole experiment has used a Gen 2 tag. Passive RFID requires stronger signals from the reader, and the signal strength returned from the tag is constrained to very low levels [6]. Active RFID allows very low-level signals to be received by the tag (because the reader does not power the tag), and the tag can generate high-level signals back to the reader. These tags have a useful life of twenty years or more and also not expensive to manufacture [6].

(a) ALN –Tag (b) Alien ALR-9650 RFID reader

Figure 1: RFID Component

The RFID reader used to perform the experiment is also manufactured by Alien Technology®. Reader configuration is Model: ALR-9650.

Alien® ALR-9650 combines reader and circular polarized antenna into a single, simple-to-use, inexpensive and low-profile solution. A second antenna port enables 2-antenna applications. (ALR,2016). The ALR-9650 communicates via the popular Alien Reader Protocol, with key RFID platform support including Microsoft® BizTalk RFID, OatSystems, Oracle®, Xterprise and others. NET, Java and Ruby libraries enables easy development of custom interfaces to control the reader if desired. The user friendly Alien RFID Gateway software enables the user to begin solution development immediately. With its integrated antenna, Power-Over Ethernet (POE) and out-of-the-box software compatibility, the ALR-9650 Gen 2 RFID Reader is a simple, low profile solution that enables new users to start reading tags and developing solutions immediately [7]. An RFID tag reader uses antennas (figure- 1(b) to communicate with the RFID chip.

The reader settings for the read range can be increased or decreased accordingly as per the requirement. Power is sent to antennas through cable and the control of power can be done on RFID readers. All RFID readers will have settings to transmit power. If the transmitting power (in dB) is higher in number then the read range is increased or if the transmitting power is less in number then the read range is smaller. It is essential to understand and note what should be the reader power setting, because the power is measured in dB (decibels) where the power is cut in half or increased twice for every 3 dB is increased or decreased.

Methodology

The objective of this study is to analyze the success rate of reads of RFID tag detection in different positions. The success of read rates depicts the extent to which all the tags are successfully being detected to produce the desired result. Although RFID technology is gaining popularity, there always lie some limitations. There are different factors on which the read rate varies. For this paper, the experiments are conducted by varying the factors – linear distance of tags (1 foot and 10 feet), Angle position of tags (90^0 and 30^0) and height of tag (2 feet and -2 feet). The other variables like temperature, airflow, humidity which have effect on tag readability were controlled in this contrived lab experiment by keeping them constant.

In RFID system tags represent the basic building block of the RFID system. A tag is also known as transponder. When a tag is energized, it transmits the data stored in it via radio waves. The reader receives these waves and then communicates the necessary data to the host computer. Therefore it can read data stored in to the tag. In figure –3, this process has been described by using a block diagram.

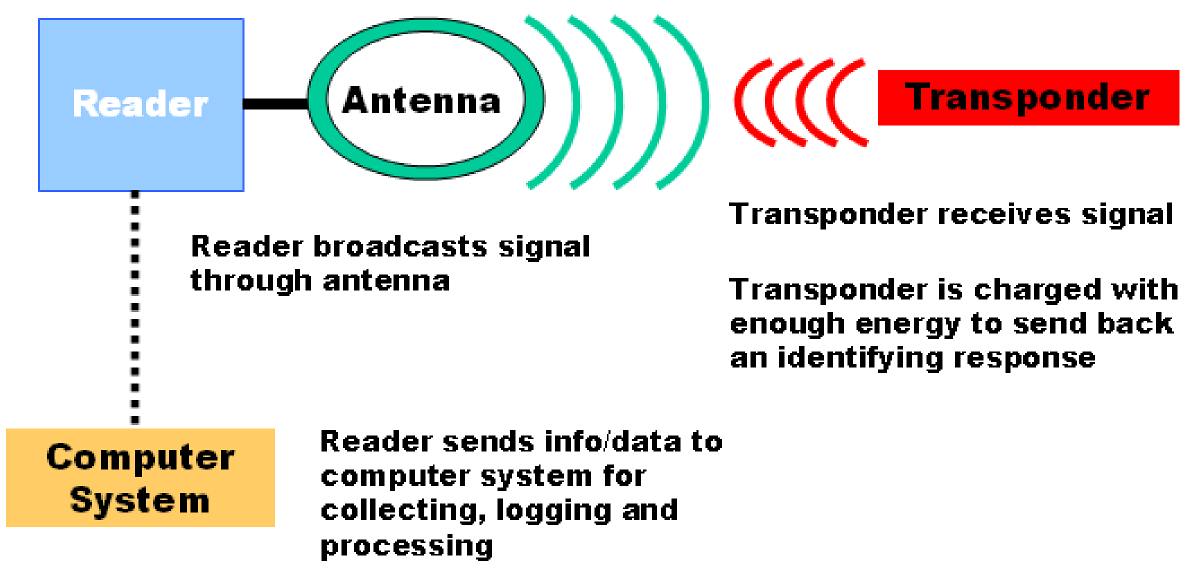

Figure 2: RFID technology process

To do the analysis, this study is divided into three research phases.

Phase one:

- Determine the factors that have effects on the readability of tag .
    - Height of the tags with reference to the antenna
    - Distance variability of tag in linear direction
    - Distance variability of the tag direction from various angles.

In the beginning of phase one, the variables are explored which have effect on the readability of item level tagging in horticulture industries. These factors are very important to consider for the analysis of the readability of RFID tags [8]. The best possible way of developing the method is to set up a system in which the variables will be controlled. This represent that the setting for research will be contrived. There are two possible ways of tag placement orientation.

- Tags placed in horizontal position.
- Tags attached in vertical position.

For this research study, the tags are considered to be only in vertical position. The antenna will read the tag face to face.

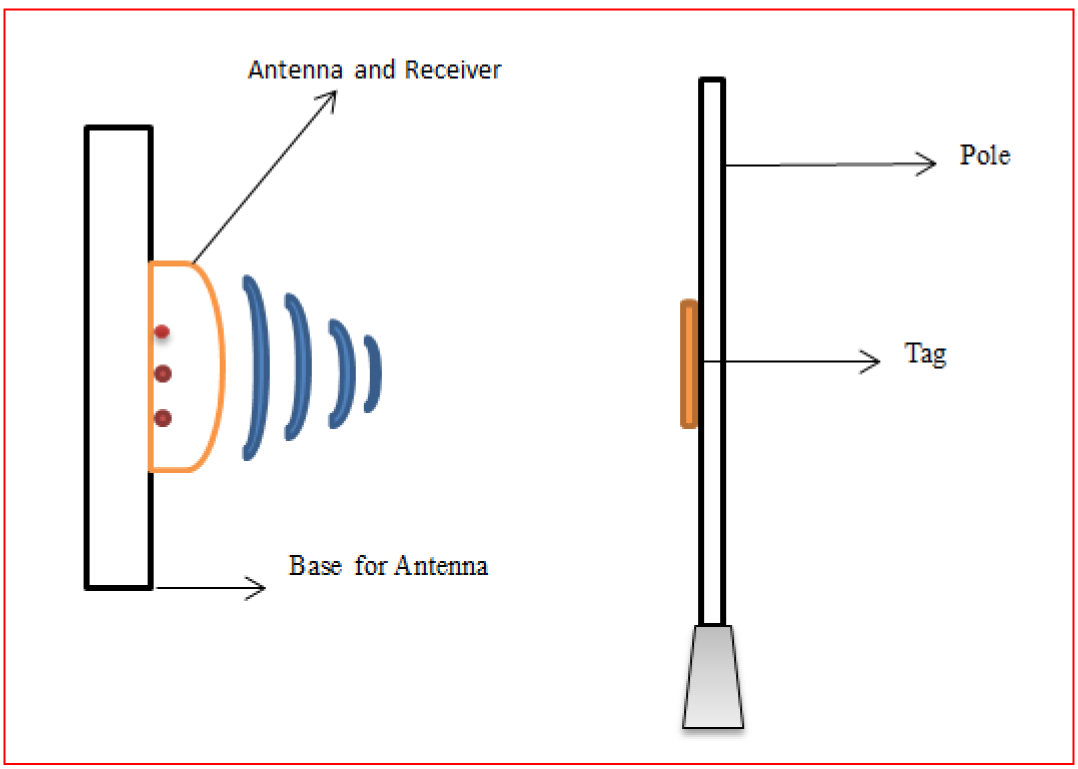

Figure 3: Experiment setup of RFID tag detection.

Phase two:

Sample Size Calculation

As sample size increases, so does the power of test. This should naturally make sense as a larger sample, means that has collected more information, which makes it easier to correctly reject the null hypothesis when it should. To run the experiment completely, 8 observations would have to be taken, one observation corresponding to each of the 5 treatments (Appendix B) For this research at 95% confidence interval (α=0.05) the sample size will be 40 runs [9]. The trials are noted for the designated item under all three conditions (Appendix-B). For deciding if this study needs more samples, a Normality Test can be performed [10]. Normality means that the distribution of the test is normally distributed with 0 mean, with 1 standard deviation and a symmetric bell shaped curve [10]. As the normal distribution is very important for statistical inference point of view so it is desired to examine the assumption to test whether the data is from a normal distribution [10]

Phase three

Since the goal is to identify the potential effects of tags that caused for variation of positions and to develop a desirable position of maximum readability for the identification and tracking of shipping carts for inventory control in horticulture industry, the study will focus on three positional factors. The propose of the study is to test the main effect and interaction effect of the following factors:

A: Linear Distance

B: Angle

C: Height

To analyze and evaluate different positions, a full factorial experimental design is planned with the three factors. Two levels are selected for each factor, thus resulting in 2^3 distinct combinations for each replicate. The analysis will illustrate that; DOE can improve tracking and shipping performance and improve item level of monitoring of valuable plants.

(1) Data collection
Appropriate statistical test for data analysis, for this study Design of Experiments (DOE) will be used.

Data Collection and Data Analysis

The data is collected in laboratory environment with minimal interference from external factors such as metal objects and interference from other antennas. For this experiment, the antenna and the receiver were connected above each other on a wooden pole. Antenna height was fixed at 3.5 feet from the ground. This set up has been shown in figure -3. When a tag is placed facing the antenna, its reading is taken for 20 seconds. All RFID readings are taken for to meet FCC regulation [11]. In an RFID reader the attenuation is one of the specifications that have to be adjusted by the user. The more the attenuation increases, the power of the Radio Frequency decreases. For this experiment, the attenuation of the RFID antenna is set to 40 dB. This attenuation was chosen because it was not expected that more RF power would penetrate through the walls to reach the other rooms of the building [12].

For the experiment the tag is placed at some certain point facing the antenna. Then it was read through the antenna via Alien Technology software. Figure-4 shows the screen shot of the software while it is reading tags.

Figure 4: Screen shot of Alien Technology software while reading a tag

A specific construction for space division has been used in this research. The antenna position is assumed fixed at position 0 (3.5 feet from ground). The tag was moved to specific allotted points at on the space of construction. Figure 5 shows the space construction for the experiment. The tag is moved across and also in the forward direction.

The tag was moved respectively 1 foot, 3 feet, 6 feet and 10 feet in forward direction and across. The research has taken angle positions for the tag. The angles are correspondingly 0, 30, 60, 90, 120, 150 and 180 degrees. For showing this in to a mathematical format, the graph has taken the center position as 90 degree. Towards right (TDR) all the positions were taken account based on 0, 30, 60 degree angles and 1 foot, 3 feet, 6 feet and 10 feet in forward direction. Similarly towards left all positions were placed based on 180,150,120 degree angles and 1 foot, 3 feet, 6 feet and 10 feet in forward direction. Figure 5 shows the tag positions.

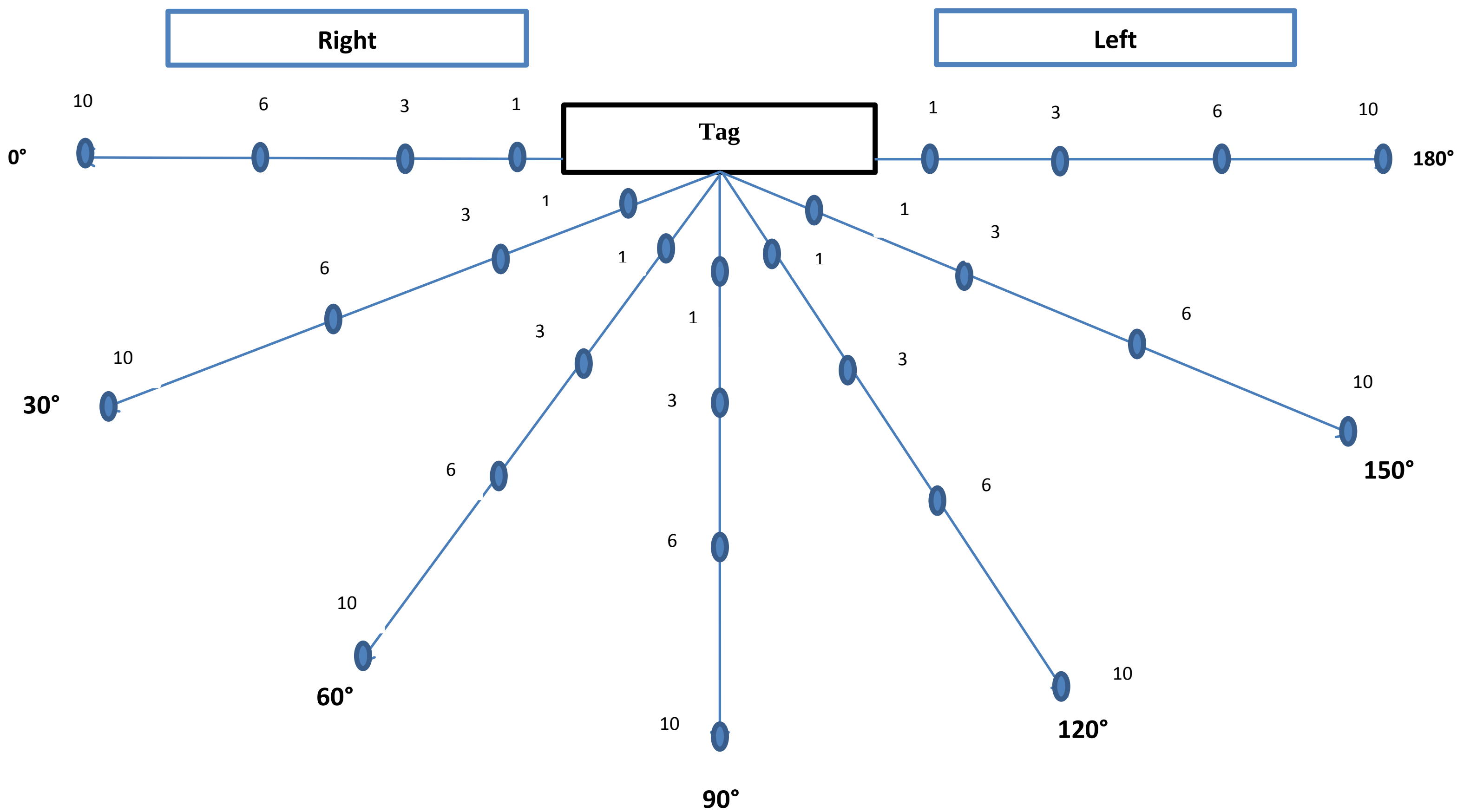

Figure 5: Tag positions in different angles and distances

The data is collected at 5 different height positions of tag. The tag was placed simultaneously at 0 position (3.5 feet), 1 foot up from 0 position, 2 feet up from 0 position, 1 foot down and 2 feet down from 0 position. The data are given below at 5 different height positions.

Table 1 to table 5 has shown five data set which are collected by moving tag in five height positions. At each height position the tag was moved to 28 positions, Toward Left (TDL) and Toward Right (TDR). From figure 6 to figure 10 data has been plotted in 3D image. In these figures the data is presented in 3 dimensions which are X axis for horizontal distance and Y axis for angular position and Z axis for RFID reads.

TDR ⟵ ⟶ TDL ⟵ ⟶

Tag vertical position: 0 (42 inches from ground is considered as 0 position)							
Angular Position → Horizontal Distance ↓	0°	30°	60°	90°	120°	150°	180°
1 foot	11.2	151.2	205	205.8	213.2	210	210.2
3 feet	51.4	0	159.8	206.4	204.6	195.2	38.8
6 feet	0	0	86	168.8	147.4	125.8	34.6
10 feet	0	0	0	50.6	59.2	77.6	0

Table 1: RFID reads for tag position – 42 inches above ground

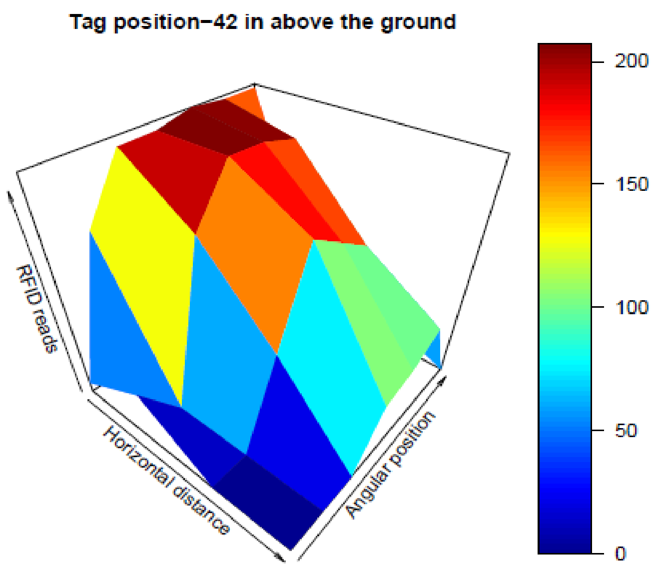

Figure 6: 3D image of tag position – 42 inches above from ground

TDR ⟵ ⟶ TDL ⟵ ⟶

Tag vertical position: 1foot up from 0 (42 inches from ground is considered as 0 position)							
Angular Position → Horizontal Distance ↓	0°	30°	60°	90°	120°	150°	180°
1 foot	157	186.2	192	13.4	208.6	211	186.8
3 feet	57.6	126.8	152	205.2	210.8	210	72.6
6 feet	74.2	83.4	117.8	208.4	122.8	156.6	78.8
10 feet	0	0	98.2	186.2	153.4	80.6	0

Table 2: RFID reads for tag position – 54 inches above ground

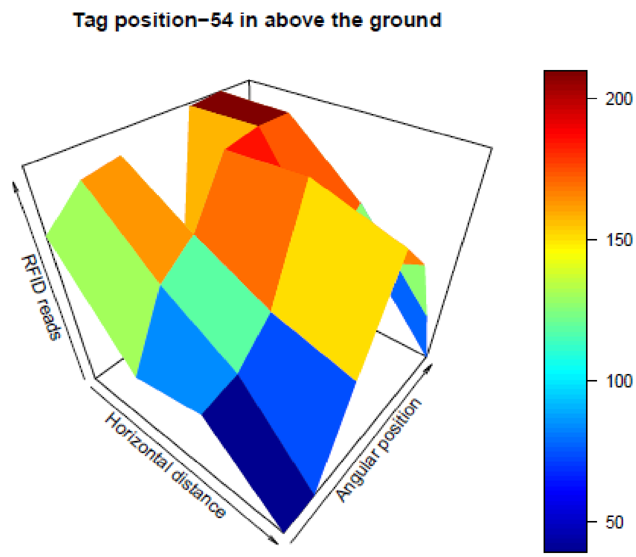

Figure 7: 3D image of tag position – 54 inches above from ground

TDR ← → TDL ← →

Tag vertical position: 2 feet up from 0 (42 inches from ground is considered as 0 position)							
Angular Position → Horizontal Distance ↓	0°	30°	60°	90°	120°	150°	180°
1 foot	126.4	57.4	0	87.6	72	198	47.6
3 feet	77.6	159.4	66.6	45.2	175.4	183.4	0
6 feet	79	90.4	128.6	104.2	133	123.2	100.2
10 feet	0	0	129.2	121	52	88.6	9.2

Table 3: RFID reads for tag position – 66 inches above ground

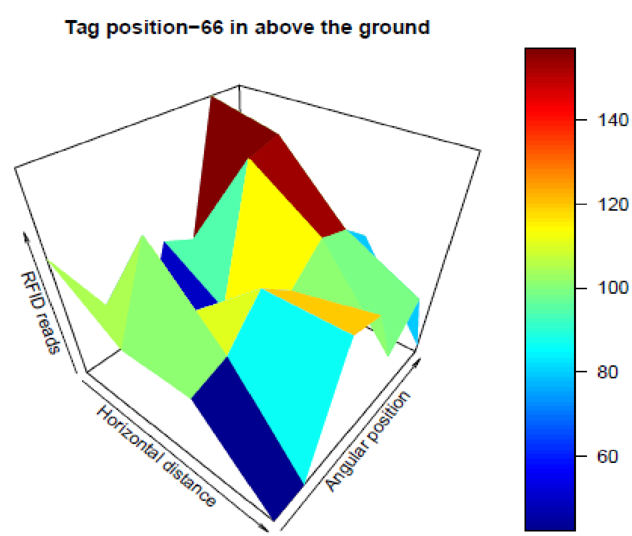

Figure 8: 3D image of tag position – 66 inches above from ground

← TDR → ← TDR →

Tag vertical position: 1 foot down from 0 (42 inches from ground is considered as 0 position)							
Angular Position → Horizontal Distance ↓	0°	30°	60°	90°	120°	150°	180°
1 foot	183.6	207.2	208.4	206.8	211.2	210.4	95.2
3 feet	0	77.4	178.4	207.2	208.4	209.6	0
6 feet	0	53.4	97.8	152	65.8	159.4	0
10 feet	0	0	0	74.8	0	51	0

Table 4: RFID reads for tag position – 30 inches above ground

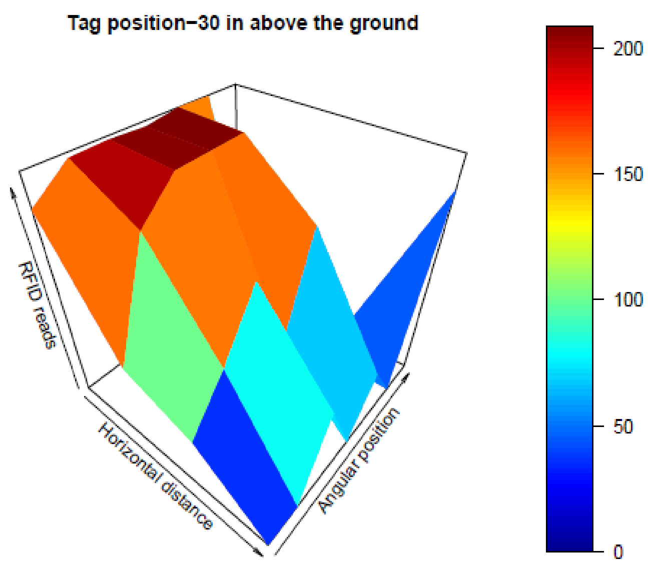

Figure 9: 3D image of tag position – 30 inches above from ground

← TDR → ← TDR →

Tag vertical position: 2 feet down from 0 (42 inches from ground is considered as 0 position)							
Angular Position → Horizontal Distance ↓	0°	30°	60°	90°	120°	150°	180°
1 foot	110.8	121.6	134.6	105.8	92.8	0	43.8
3 feet	118.6	216.4	208.4	196.2	206.4	73.2	5.8
6 feet	12	0	124.8	80.2	77.4	0	0
10 feet	0	65.8	46.4	0	29.8	0	0

Table 5: RFID reads for tag position – 18 inches above ground

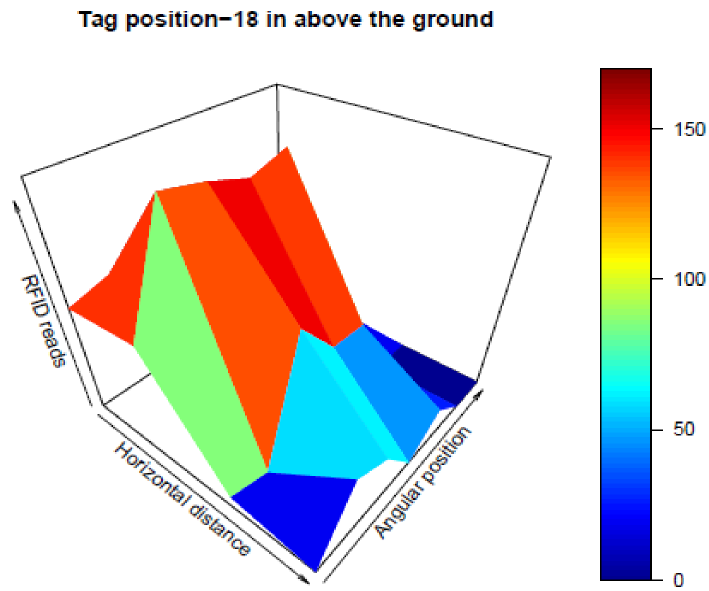

Figure 10: 3D image of tag position – 30 inches above from ground

DOE methodology is used to analyze data using 2^3 factorial designs (2-levels, 3-factors). DOE is a dominant tool that allows for several input variables or factors to be manipulated determining their effect on a desired response (input) [10]. By changing multiple inputs, DOE can recognize important interactions that may be lost when experimenting with one factor at a time [10]. Appendix A shows the factors (linear distance, angle and height) and their respective levels. Design matrix for the experiment is given in Appendix B which gives the order in which the experiments is performed [10]. For 3 factors A, B and C are investigated in an experiment, factor A has 2 levels, factor B has 2 levels and factor C has 2 levels. The total combinations or treatments for the experiment would be 2*2*2 = 8 (2^3 Factorial Design) [10]. To run the experiment completely, 8 observations would have to be taken, one observation corresponding to each of the five treatments for both the total process time and the total lead time separately (Appendix B). While conducting an experiment, observations are recorded in a random order so that the effect of nuisance factors may get cancelled out. Each experiment will be performed three times as the matter of economic and time; the study does not want any change in the environmental condition.

Run	Combination	A (Distance)	B (Angle)	C(Height)	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average
1	-1	- 1 foot	- 30°	- -2	78	54	55	48	63	59.6
2	a	+ 10 feet	- 30°	- -2	3	2	8	10	5	5.6
3	b	- 1 foot	+ 90°	- -2	183	180	185	183	190	184.2
4	ab	+ 10 feet	+ 90°	- -2	0	0	0	0	0	0
5	c	- 1 foot	- 30°	+ + 2	0	0	0	0	0	0
6	ac	+ 10 feet	- 30°	+ + 2	10	12	9	14	16	12.2
7	bc	- 1 foot	+ 90°	+ + 2	81	80	78	76	73	77.6
8	abc	+ 10 feet	+ 90°	+ + 2	140	139	143	140	143	141

Table 6: The three factor and two level fractional factorial data

Main Effects:

Once the data is ready after running the experiments for all the five treatments the summary of mean and standard deviation for the response data has calculated. Those resultant values are used to find the main effects figure 11. Often the impact of levels is described as effect. A main effect is the difference between the factor average and the grand mean. Effect size determines which factors have the most significant impact on the results [13].The values are then plotted as Main Effect Plot which is a quick and efficient way to visualize effect size. Factors with sharper slopes have larger effects and thus larger impacts on the results [13].

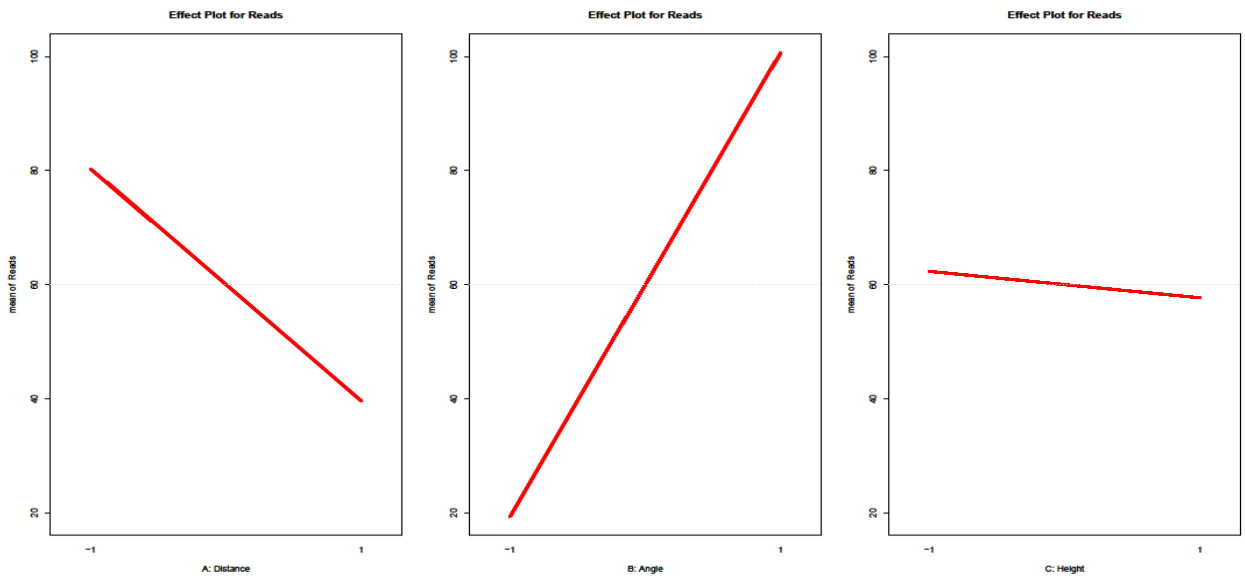

Figure 11: Main effects of factors

T-statistic is calculated for calculating the Decision Limits (DL) at alpha risk of 0.05 percent [14]. With known degrees of freedom (df), using t-table, the t-statistic is calculated. DL for significance of effect (here it is 95% confidence interval) in this experiment can be calculated to compute and determine the effects are significantly different, and not due to random variation [14]. DL is calculated by, DL=± (t statistic)*(StdDevEff). If the effects exceed the DL, they are judged to be significant. To depict the relative importance of the effects absolute values are plotted as a Pareto chart figure 12.

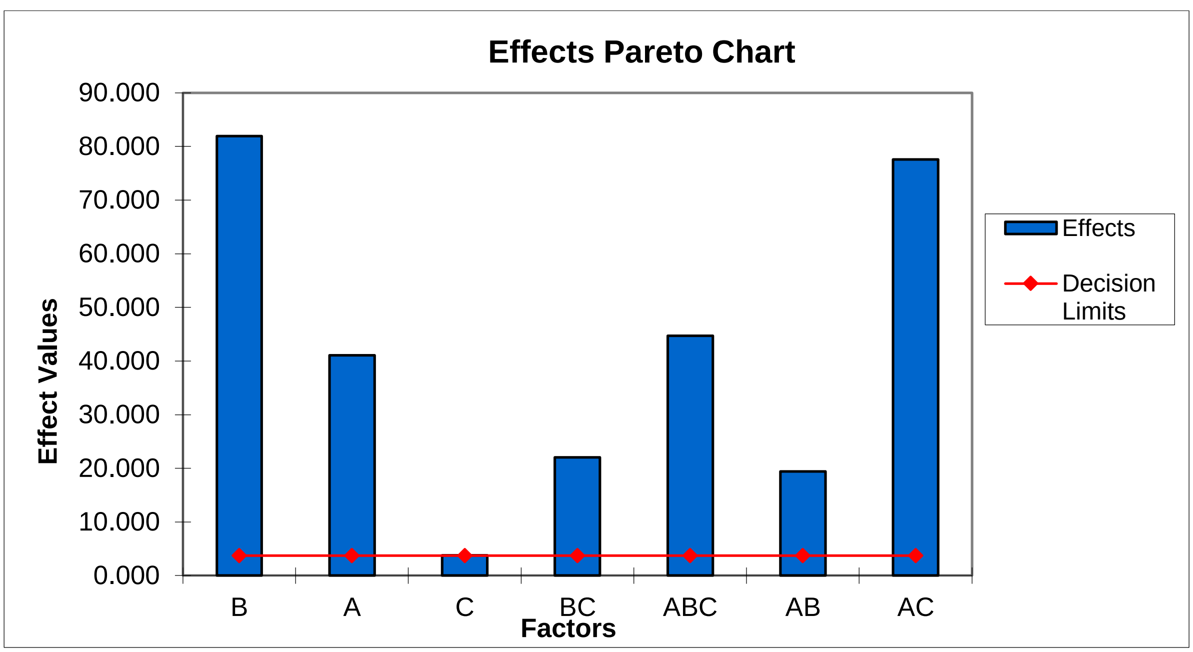

Figure 12: Pareto Chart for decision limits

Interaction Effects:

In addition to the main effects, it is also important to check for interaction effects, especially three-factor interaction effects [15]. A factorial design is an experimental design in which each level of each factor is paired up or crossed with each level of every other factor [15]. In other words, each combination of the levels of the factors is included in the design. This type of design is often depicted in a table [10]. Factorial designs allow us to determine if there are interactions between the independent variables or factors considered. An interaction implies that differences in one of the factors depend on differences in another factor. The DOE interaction effects plot is an effective tool for this [10]. An interaction occurs when a particular combination of three factors behave unexpectedly. Therefore, an interaction is defined as one-half of the difference between the effect of A at the high level of B and the effect A at the low level of B. If an interaction proved to be significant, the interaction chart is very important [15]. Figure 12 shows the interactions of factor A, B & C which represents respectively linear distance, angle and height.

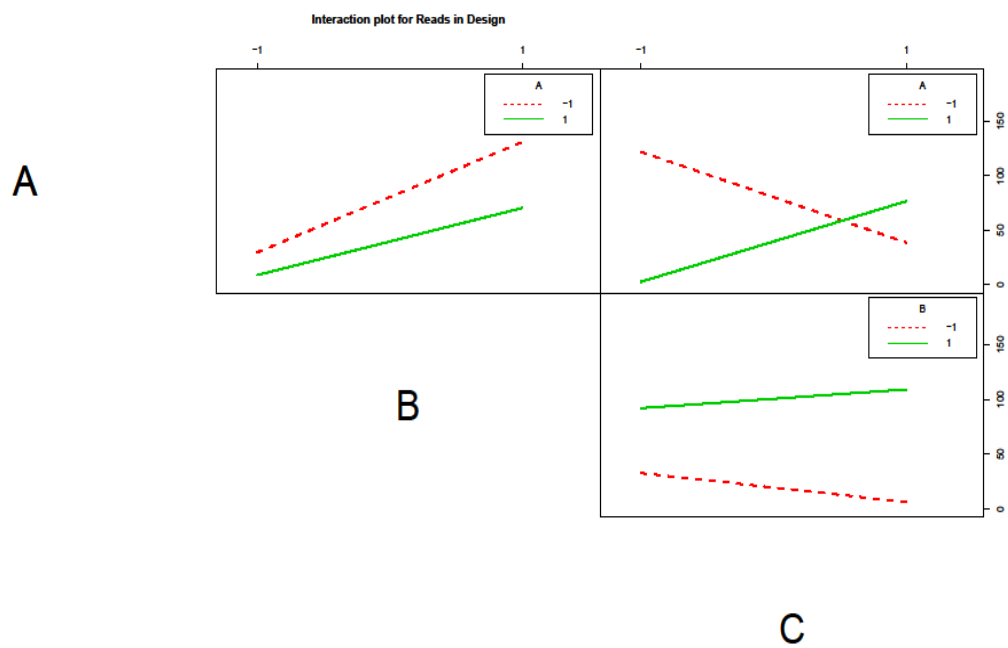

Figure 12: Interaction effects of factors

Conclusion

It has been observed that the readability of RFID tag varies with the changes of factors. 3D plots have visualized the frequent variations of reads of tag due to combinations of different linear distances, heights and angles. It has been also observed from DOE analysis that, factors A and B do not have any interaction but factor A & C and a factor B & C has significant interactions. Pareto charts has given the decision limit based on height's read (factor C) that is 3.705. It can be expected that this study on the readability of RFID tags at certain attenuation and at certain positions with different linear distances, heights and angles serve as a reference and help to do advance future research in horticulture industry for condition level of items.

Some suggestions that can be offered to help those who teach or want to incorporate RFID in courses. From our experience gained we would suggest to incorporate RFID in courses like, Production & Operations Management, Supply Chain Management and Quality related areas. Due to the many potential areas of RFID applications of RFID, it is difficult to suggest or advise to incorporate RFID in specific courses. However, at this institution we are attempting to introduce this technology in Senior Project course this semester. The project team involves a multidisciplinary group of students in Mechanical and Mechatronics engineering technology. The equipment identified in this paper can be purchased under $20,000 with some fabrication needed to develop accessories such as portable stands. This can support a class size of 25 students in groups of 3 or 4 performing experiments in a rotation basis. Typical topics to expose students would be to create RFID foot-prints in 2D and 3-D space, incorporating the envelope of detectability to place items that are uncommon such as horticultural products. This could also be used to introduce variation within the same item such as the moisture level, density of material inside the package such as soil material and temperature.

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Appendix A

Factor	Name of Factor	Low	High
A	Linear Distance	1 foot	10 feet
B	Angle	30°	90°
C	Height	-2 feet	+2 foot

Appendix B

Trial no./run	A	B	C	1	2	3	4	5
1 (5) -1	-1	-1	-1					
2 (5) a	+1	-1	-1					
3 (5) b	-1	+1	-1					
4 (5) ab	+1	+1	-1					
5 (5) c	-1	-1	+1					
6 (5) ac	+1	-1	+1					
7 (5) bc	-1	+1	+1					
8 (5) abc	+1	+1	+1					