Paper ID #18531

Investigating the Effect of Temperature in RFID Technology

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Abstract

Radio Frequency Identification (RFID) technology has been adopted and widely used in many applications including agriculture, forest industry, hospitals, highway transportation, and manufacturing industry. Due to its advantages such as tracking and real-time monitoring. RFID technology uses the tag to store limited data that can be read by RFID reader through the antenna. Passive RFID technology is commonly used in industry because of no power source requirement on the tag. Instead, the tag uses the electromagnetic energy transmitted from the reader, which creates significant interference between readers, to transmit stored data. Many literatures focus on the electromagnetic interference (EMI) between antennas to investigate the effect and find the solution. However, noise is another important factor in wireless communication, which may impact on the reading rate in RFID, because RFID uses the small range wireless communication to read the transmitted data from the tag. In this paper, we consider two factors, distance and temperature, to investigate how they affect the RFID read rate. The data collected at various temperature will be compared to the results from normal temperature and the effects of temperature in RFID will be discussed.

1. Introduction

Recently, Radio Frequency Identification (RFID) has received a great attention and widely adopted and popularly used in many applications such as agriculture, forest industry, hospital, toll way, manufacturing industry, etc. The advantages of RFID usage in those applications are mainly tracking and real-time monitoring [1-3]. The traditional method used in industry was barcode, which has several disadvantages such as line of sight reading, limited data storage, and non-programmability [4]. Instead, RFID uses a tag that communicates with reader using near distance wireless communication. In addition, it can store the data that can be read by RFID reader through its antenna. There are three components in RFID system; one is antenna, another is reader, and the other is a tag or transponder. Two types of tags are available, active and passive. The active tag requires battery powered while the passive tag requires no power source. Because of no power source requirement, passive RFID is commonly used in industry.

In passive tag RFID, the tag uses the electromagnetic energy transmitted from the reader instead, which creates significant interference between readers. Therefore, many literatures focused their study on electromagnetic interference (EMI) [5,6]. However, noise is another important factor in wireless communication, which may impact on the reading rate in RFID, because RFID uses the small range wireless communication to read the transmitted data from the tag. Several researchers focused on investigating its effective range of the readings in different set of testing conditions including conveying belt in the manufacturing process [7,8]. They use the two distance factors to measure and compare the RFID reading in different tag locations.

The RFID application is broadly extended and it is also considered to be used in harsh environmental condition, for example, high temperature, which is one of the significant noise factors in wireless communications [9]. Therefore, the RFID reading may be affected by the temperature. However, the impact of the temperature in RFID reading has not been investigated at the best of my knowledge. In this paper, we select the temperature as one of the varying components including antenna setup and reading distance to measure impact of the temperature in RFID readings using experimental study. Our results can provide the guideline of the RFID reading setup such as antenna position and reading distance in different temperature for the best reading rate.

The rest of the paper is organized as follows. In section 2, we present the experiment setup and define varying factors with measuring metric. We illustrate and discuss the results in section 3. Then, we present the conclusions in section 4.

2. Experimental Study

We use the experiment to study the performance of relay node. In this section, we will explain the experimental setup and measuring metric. Then, we illustrate the results.

2.1 Experimental Setup

To simulate the designated temperature environment, we use small transparent box and heating gun with temperature controller. The heating gun injects the heat flow inside of the box and the controller maintains the designated temperature as shown in Figure 1. Due to the size limitation, we place the tag inside of the box and all other reading equipment (i.e., RFID reader and antennas) are located outside.

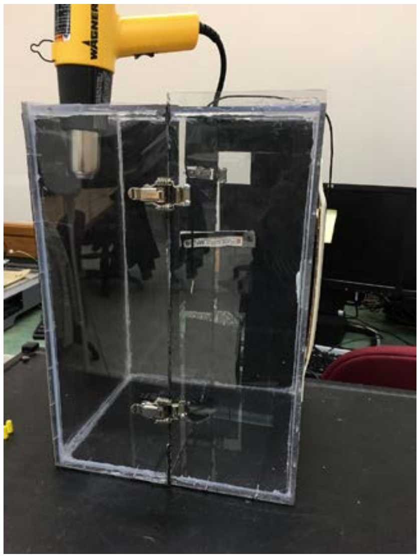

Figure 1. Transparent environment box with heating gun

For the experiment, we use the passive tag with RFID reader and antennas. Alien Technology RFID reader, EPC Class 1, Model: ALR-9800 is use for the reader. Two antennas, Alien Technology RP circular Antenna with 6.0 dbi Gain and 915MHz of operating frequency, are used; one is for the signal transmitter and the other is for the receiver.

2.2 Antenna settings and measuring metric

The selected metric to measure the performance of the RFID system is the reading rate, which indicates how fast it can detect or read the tag at the reader. We use three factors to measure the reading rate in RFID. The first factor is the distance between two antennas. The second is the distance from the tag to the antenna and the last one is the temperature. Let the distance between two antennas be D_{AA}, distance from the tag to the antenna be D_T, and the temperature be T. The tag is in the environment box (temperature controlling box), which is in the center-line of two antennas as shown in Figure 2.

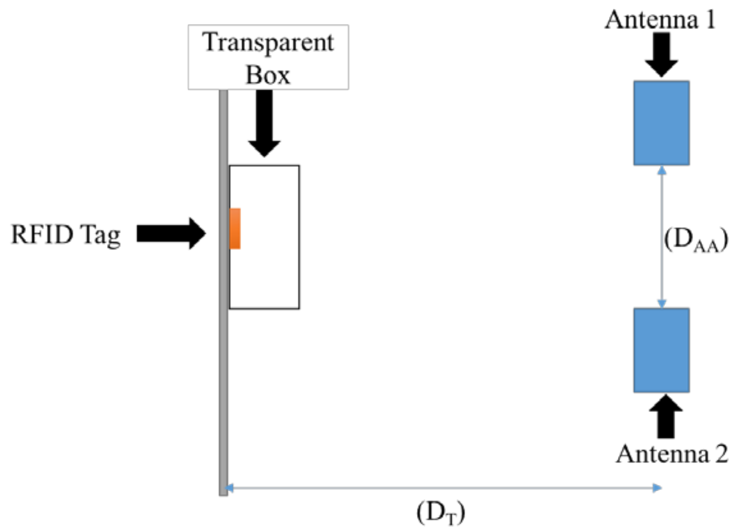

Figure 2. Experimental setup of two antennas

The tag is placed in the transparent temperature controlling box. Then, two antennas, transmitter and receiver, are in both side, left and right, of the box with the same distance and let the distance from the center-line to each antenna be D_{CA} (i.e., $D_{CA} = D_{AA} / 2$). We select seven (7) reading distances ($D_T = \{0, 1, 2, 3, 4, 5, 6\}$ in ft) and three (3) distances from the center-line of the antennas ($D_{CA} = \{1, 2, 3\}$ in ft) with three different temperatures ($T = \{68, 100, 130\}$ in Fahrenheit). We first fix the temperature and then measure the reading rate at combination of D_T and D_{CA} setups, which induce 7x3 = 21 total antenna setups for each temperature. At each setup, we measure the number of readings or detections for 20 seconds and repeat it 10 times.

3. Results and Discussions

In this section, we present our experiment results of reading rate in various temperatures for several sets of distances. Then, we discuss the results and findings.

3.1 Results

Here, we present the reading rates for various temperatures and distances between antennas (D_{AA}) and tag (D_T). Figure 3 illustrates the reading rate in three different temperatures (i.e., 68, 100, 130°F) for various distances to the tag (D_T) with 1-ft of distance from center to antennas (D_{CA}). Our results show that all three temperatures tend to have similar behavior; no reading near to the tag such as 0, 1, and 2 for 68°F and 100°F and 0 and 1 for 130°F. The reading rate reaches maximum in 3-ft of D_T for 68°F and 100°F (i.e., 167 and 138, respectively) while 2-ft at 130°F (168). As the antennas move even further away from the tag, it shows that the reading rates for all three temperatures decrease. The narrower distance between antennas, higher temperature (130°F) shows higher reading rate overall.

Next, we present the results of the reading rate in three different temperatures for various distances to the tag (D_T) with 2-ft of distance from center to antennas (D_{CA}) in Figure 4. The results show that the reading rate reaches highest at 1 and 2-ft of DT (i.e., 167, 180, and 165 at 68, 100, and 130°F, respectively). At 100°F, the reading rate varies the most and reaches the maximum (i.e., 180) and minimum (i.e., 0) among three temperatures. According to Figure 4, in this antenna setup, 1 or 2-ft away from the tag provides the best reading rate for room temperature (68°F), 1 to 3-ft for 100°F, and 1 to 4-ft for 130°F. Overall, higher temperature (130°F) shows better reading rate than other two temperatures.

Figure 5 illustrates the reading rate in three different temperatures for various distances to the tag (D_T) with 3-ft of distance from center to antennas (D_{CA}). In all three temperatures, the reading rate reaches highest at 2-ft away from the tag (i.e, 172, 170, 165 for 68, 100, and 130°F, respectively). AS the antennas move away from the tag (i.e, D_T = 3 to 6ft), the reading rate decreases at 68 and 100°F while it increases after 4ft at 130°F. For this antenna setup, 2-ft away from the tag presents the best reading rate for all temperatures.

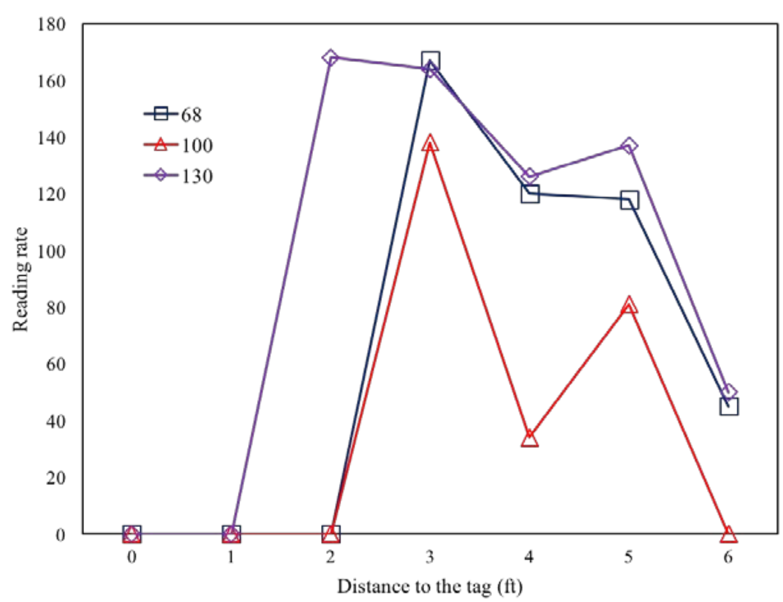

Figure 3. Reading rate at 1-ft of distance from center to antenna (D_{CA} = 1ft) for various temperatures (T = 68, 100, 130°F)

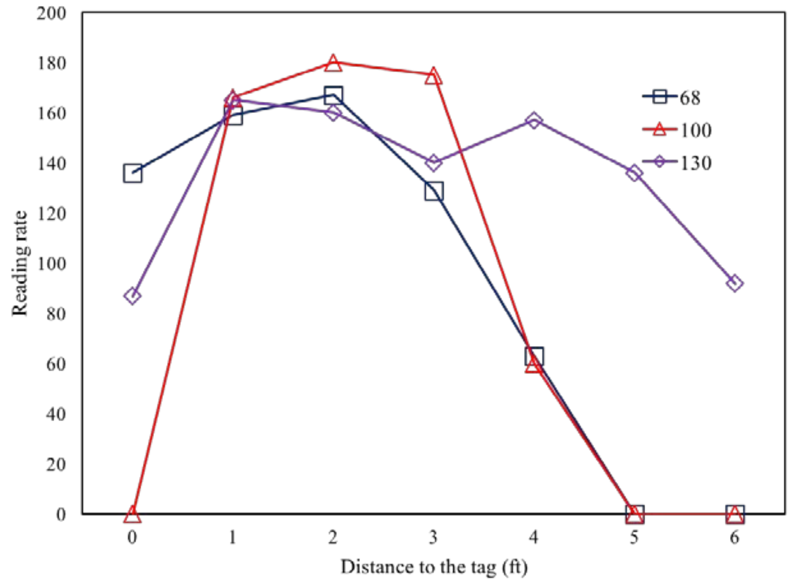

Figure 4. Reading rate at 2-ft of distance from center to antenna (D_{CA} = 2ft) for various temperatures (T = 68, 100, 130°F)

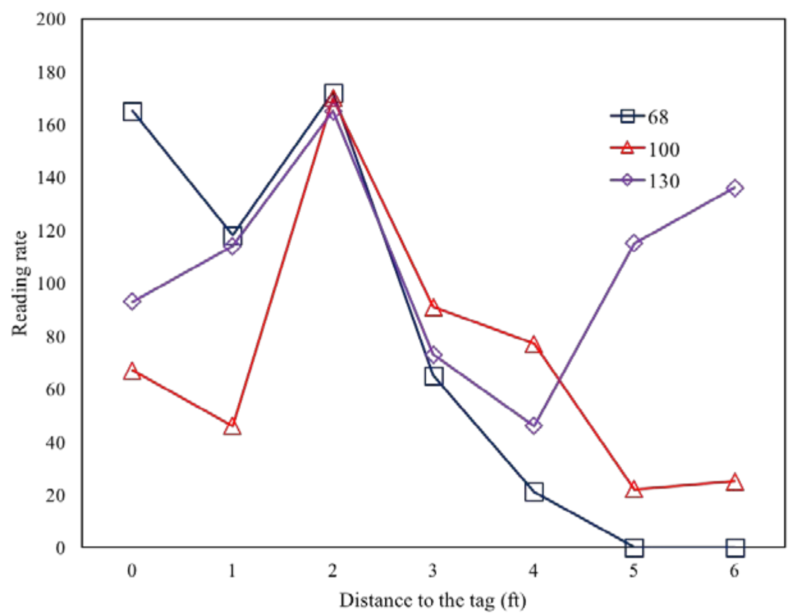

Figure 5. Reading rate at 3-ft of distance from center to antenna (D_{CA} = 3ft) for various temperatures (T = 68, 100, 130°F)

Now, we present the reading rate with different distances from the center to the antenna for each fixed temperature. Figure 6 illustrates the reading rate with three different D_{CA} (i.e., 1, 2, and 3ft) for various distances to the tag (D_T) at room temperature (i.e., 68°F). The results show the higher reading rate at near the tag (i.e., 0 to 3ft) with wider D_{CA} (i.e., 2 and 3ft). As the antennas move further away from the tag (i.e., D_T = 3 to 6ft), the reading rate decreases dramatically. With the narrower D_{CA} (i.e., 1ft), the reading rate significantly increases at the antenna is 3ft away from the tag (i.e., 0 to 167), but it keeps dropping after 4ft (i.e., 120, 118, 45 at D_T = 4, 5, 6ft respectively).

The reading rate results at 100 and 130°F are shown in Figure 7 and 8, respectively. According to Figure 7, the reading rate is stable between 1 and 3ft of D_T with 2ft of D_{CA} while it is not stable over D_{CA} with the other D_{CA}s (1 and 3ft) at 100°F. The reading rate reaches maximum 170 at D_T = 2 with D_{CA} = 2 and 138 at D_T = 3 with D_{CA} = 1ft. When the temperature increases (i.e., 130°F), the reading rate also increases across the all D_Ts as shown in Figure 8. The antenna distance at D_{CA} = 2 outperforms in reading rate, which shows 87 for the lowest reading rate and 165 for the highest.

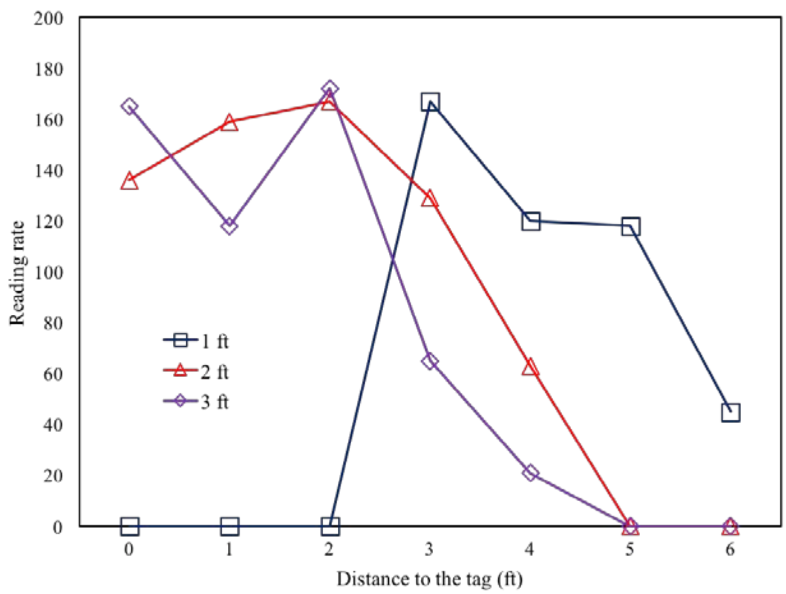

Figure 6. Reading rate for various distances from center to antenna (D_{CA} = 1, 2, and 3ft) at T = 68°F

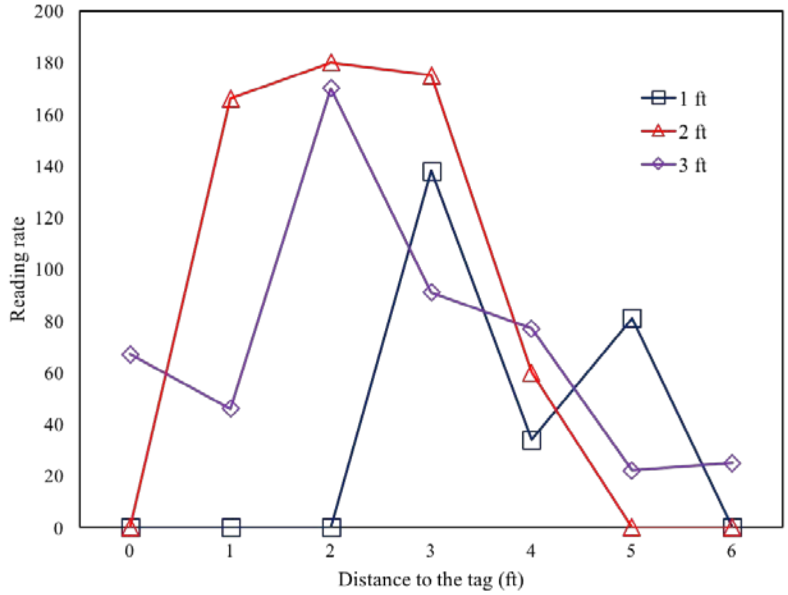

Figure 7. Reading rate for various distances from center to antenna (D_{CA} = 1, 2, and 3ft) at T = 100°F

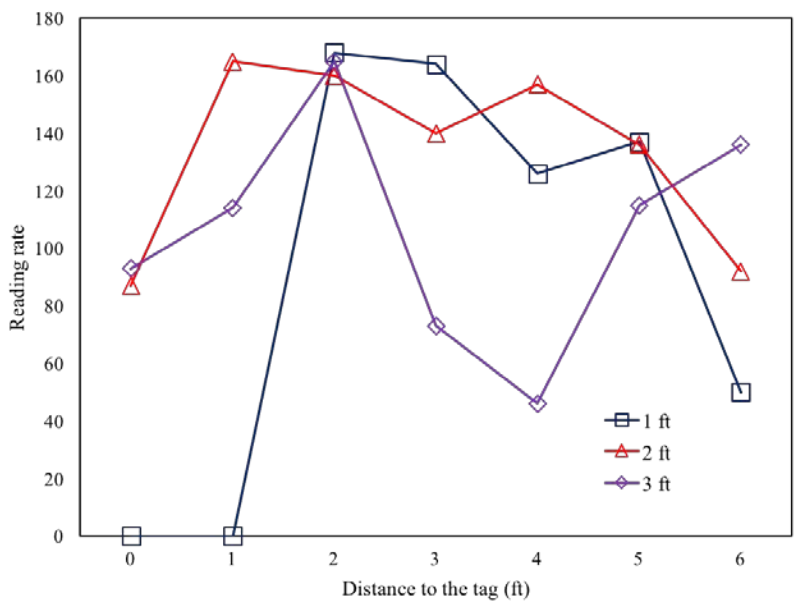

Figure 8. Reading rate for various distances from center to antenna (D_{CA} = 1, 2, and 3ft) at T = 130°F

3.2 Discussions

In this paper, we compare the reading rates in different antenna setups and distances to the tag with various temperatures. We use the environmental chamber to simulate the various temperatures. When the temperature is fixed, reading rate varies with the distance to the tag and antenna setup. Our results show that the optimal distance between antenna for three different temperatures is 4ft when D_{CA} = 2ft. It also shows that the optimal distance to the tag for the detection is 2ft for all three temperatures. At room temperature, the shorter distance between antennas increases the detection rate when the tag is located further than 5ft from the antenna. However, as the temperature increases, the reading rate is getting better with the wider antenna setup for the long-distance detection. When the environment temperature is concerned, overall reading rate is more stable and reaches highest at 100°F. At higher temperature, short range tag detection works better than long range detection for all antenna setup. In other words, as the temperature decreases, long range detection shows the better reading rate.

Our results imply that the antenna should be setup carefully for the best reading for all temperatures. If the distance between antennas is fixed at 2ft or D_{CA} = 1ft with 130°F, it is better to locate the antenna 2 or 3ft away from the tag for the best detection rate. When the antenna needs to be setup in 6ft away or D_{CA} = 3ft, the antenna should be located 2ft away from the tag to reach the best reading rate for all temperatures. In addition, the antenna setup should be carefully selected for temperature. For example, at room temperature, if the RFID antenna is required 2ft of antenna to antenna distance, the best distance between tag and the antenna is 3ft for the best detection rate. At the higher temperature, T = 130°F, if the tag is located 4ft away from the reading antenna, 4ft of antenna distance or D_{CA} = 2ft is the best for the maximum reading rate.

There are couple of limitations. First, the environmental temperature is simulated using small box and only the tag is inside of the box while the antennas are outside. This implies that only the tag is affected by the temperature, while the reflected signal from the passive tag is partially affected. In other word, the testing setup does not perfectly simulate the high temperature environment. The other limitation is that the reading rate does not mean the correct reading. The accuracy of the reading is not concerned in this paper.

4. Conclusions

Passive RFID technology is widely used in many applications due to no power source requirement on the tag and ease of its usage. The tag uses the electromagnetic energy transmitted from the reader, which creates significant interference between readers, to transmit stored data. The distance and temperature are considered in this paper to investigate their impacts on reading rate using experimental study. The reading rate is measured in three different temperature with the different distance antenna setups at various reading distance to the tag.

Our results show that the reading rate significantly changes with the temperature and antenna distances. At room temperature, the reading rate behaves similarly for all antenna setup while it varies more with higher temperature. At higher temperature, it shows the higher reading rate in the long range detection than short rage. Our findings could provide the guideline of the RFID antenna setup with fixed temperature for the maximum reading rate. In addition, detection range is also investigated in various antenna setups and temperatures.

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