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USE OF UHF RFID FOR CONTINUOUS MONITORING OF CATTLE HEALTH AND INVENTORY[1,2]

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OVERALL PROJECT OBJECTIVES AND ACTIVITY AREAS

PROJECT OBJECTIVE:

The project objective was to demonstrate ultra high frequency radio frequency identification (**UHF RFID**; 902-928 MHz, ISO 18000-6C, EPC Gen 2 compliance) in a basic system which would monitor cattle attendance at water sources. The specific aim of this project was to develop an on-farm UHF RFID-based system that could be used to monitor cattle health, cattle inventory, and water source status. Because water is an essential nutrient, and access is often a point source, gathering data on attendance at water sources would allow for near real-time monitoring of cattle inventories, cattle health, and water source viability.

ACTIVITY AREAS:

The reading systems were developed for two cattle feeding facilities (MSU Beef Cattle Teaching & Research Center [Feedlot], Lansing, MI and MCA/MSU Bull Evaluation Station, Crystal, MI), and a pasture setting (MSU Beef Cow/Calf Teaching & Research Center [Cow/calf], Lansing, MI). Initially, project participants met with Dr. Robert Clarke, Associate Professor/Director, Auto-ID Research & Testing Center to discuss RFID options and approaches for assembling stationary UHF reading units. The use of animals for this project was approved by the MSU Institutional Animal Care and Use Committee (approval #11/14-208-00).

A portion of the grant funding was leveraged to hire Ms. Sarah Woodruff as part of the MSU College of Veterinary Medicine (**CVM**) Food System Fellowship program. In this way we were able to leverage project funding with that of the MSU CVM program to promote education and training of this future veterinarian. Ms. Woodruff completed much of the planning and development of the beef feedlot application discussed below.

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[1] This material was made possible, in part, by a Cooperative Agreement from the United States Department of Agriculture's Animal and Plant Health Inspection Service (APHIS). It may not necessarily express APHIS' views.
[2] Reference to commercial products or trade names does not imply endorsement by Michigan State University or the Michigan Department of Agriculture and Rural Development, nor does it imply approval to the exclusion of other products.

Beef Feedlot Application

A UHF RFID station was constructed using an Alien 9650 Gen 2 RFID reader. The alien 9650 Gen 2 RFID reader has an integrated antenna and can read relatively long distances with a modest cost. The cost of installing AC power in remote locations is often expensive. The ALR-9650 has capability of receiving power over Ethernet (**POE**), therefore avoiding costly AC power installation in semi-remote locations. The combination of POE and elimination of external antenna reduces the complexity of installation of a RFID read point. The components needed and cost of the Beef Feedlot RFID read point are presented in Table 1. The read point was mounted directly above an automatic waterer in an outdoor feedlot site (Figure 1). The reading area was approximately 5 meters in diameter at the water height, surrounding the watering area (Figure 2).

Mr. Aaron Reinholz, Assoc. Director for Electronics Technology, North Dakota State University Center for Nanoscale Science & Engineering was consulted on current UHF readers and software for our application. Mr. Reinholz granted permission to use two unsupported software programs for the project (Cattle Feed App v1.0.0.0 and Cattle Tag Reader Interface v0.2). These software allow recording of tag reads and can alert the user when a lack of reads is encountered for a user-defined period of time.

Bull Evaluation Station Application

We collaborated with AniTrace (division of Hana Micron America; Milpitas, CA) to install two AniMonitor systems at the MCA/MSU Bull Evaluation Program Station (Crystal, MI). Each reader was mounted on the inside of the station hoop barn, a single antenna mounted outside directed down at each of two automatic waterers (Figure 3.) Waterers in this facility can be accessed from within the barn, but to do so, cattle must extend their head outside.

Internet access was provided by an Ubiquiti M5-400 bridge at the station residence base internet source, and an Ubiquiti NS2 receiver and ASUS RT-N10P wireless N router at the bull evaluation station hoop barn, approximately 235 meters away. Internet access was stable and at the rated 1M bandwidth.

Pre-numbered, UHF RFID ear tags (RaFid 5; Hana Micron) were applied in the left ear and an Allflex Super Maxi visual tag in the right ear of 71 bulls as they were delivered to the MCA/MSU Bull Evaluation Station on October 9 and 10, 2015. All bulls remained at the barn until they were weighed off test on February 12, 2016. One bull lost a UHF tag during this time by tearing its ear.

Remote Pasture Application

An AniMonitor system, similar to those installed at the bull evaluation, were installed in a pasture setting at the MSU Beef Cow/Calf Teaching and Research Center, E. Lansing, MI. This AniMonitor system had DC-power supplied by solar charged batteries. The components of the system are provided in Table 2. The read point components are pictured in Figure 4 and the entire solar powered AniMonitor system is shown in Figure 5. For this remote system, wireless internet access to the site (approximately 250 meters from the nearest building with Internet

access) was developed by creating an Ayrmesh network (Ayrmesh Hub2n, Ayrstone Productivity, North Oaks, MN).

Forty-one, non-lactating, Angus cows were tagged on Sept. 16, 2015 with two UHF panel tags (RaFid 5 Tag; Hana Micron America, Milpitas, CA; and All American UHF 4 Star; Y-Tex Corp., Cody, WY). Each cow received one tag from each manufacturer, which were randomly assigned to either the left or the right ear. AniTrace engineers modified software settings so that the Y-Tex tags could be read. Data on waterer visitation was recorded by the AniMonitor system.

UHF Field Demonstration

A cattle ultra high radio frequency ID demonstration was held on September 23, 2015 at the MSU Beef Cow/Calf Teaching and Research Center, E. Lansing, MI. The demonstration consisted of presentations on UHF (Buskirk), trial objectives (Grooms), and the AniMonitor system and AniTrace software (Choi). Presentations were followed by participants reading UHF tags with fixed and handheld UHF readers, reading low frequency (**LF**) tags with a handheld reader, attempting simultaneous reads, and comparison of read distances. Participants then viewed the remote pasture AniMonitor system.

PROJECT OUTCOMES:

The project objective was to utilize UHF RFID in a basic system which would monitor cattle attendance at water sources. We were successful in meeting the specific aim and achieving the initial objectives to develop an on-farm UHF RFID-based system that could be used to monitor cattle health, cattle inventory, and water source status. Our work indicates that water source status and inventory can be monitored with these systems. It will require additional study and more animals to determine the utility of water visitation to specifically monitor cattle health.

Read distance using the stationary reader/antenna systems was more than adequate for the applications in this project. Mounting a single antenna at approximately 2.5 to 3 meters from the ground (out of cattle's reach) and directed over an automatic waterer, resulted in a read area of roughly 4 to 6 meters in diameter at the water surface. A minimum 6 second duration of presence was required to be registered in the AniMonitor system, which appeared to be appropriate for recording of a typical drinking bout.

Tag retention was similar to other visual panel ear tags we have used. Only one tag was lost during the project, and that was torn from the animal's ear (therefore, not a tag failure). The areas used in our project were relatively free of protrusions that would snag on the tags. Long-term, we would expect lower retention of panel UHF tags compared to LF button tags, but duration of testing was very short in this demonstration.

Problems/Limitations/Challenges

Read Point Software: The two software applications from NDSU which were used, were adequate for demonstrating the waterer visitation concept. However, these software applications are rudimentary, and do not provide logging capabilities or other features that would be desired for this application. Internet connection to the reader was problematic at times, and it was not definitively determined if this was a networking or software issue. The

AniTrace software is more advanced in its capabilities, particularly in its ability to generate reports by day or over time. However, this software is also being developed and needs more work to be producer friendly and useful. For example, historic water visitation can be viewed for each animal compared to the average of the pen, however, each animal must be queried independently. Also, all of the data resides with AniTrace, therefore the data is not readily available for additional analyses.

During the course of the project, AniTrace updated their data collection software, which was pushed out to the AniMonitor systems. The software update caused the internal memory of the POS units to be exceeded. This rendered the POS unusable, which ceased data uploads from all of the units until firmware of the POS units could be locally updated. This appears to be a limitation of the POS units used by AniMonitor, because reinitializing the units takes a fair amount of time and remote IT communication.

Unfortunately, because of a number of update and server issues with the software during our testing period, our data log files were not available for this report.

Wireless Network: Two systems were initially compared for extending wireless network connectivity to remote farm locations in barns and pastures at the MSU Beef Center. One system used Ubiquiti Network products (PicoStation M2HP Access Point and Ubiquiti NanoStation locoM2 airMax; Ubiquiti Networks, Inc., San Jose, CA), and the other system used Arystone products (AyrMesh Hub2N and AryMesh Receiver; Ayrstone Productivity LLC, North Oaks, MN). Although the systems consisted of similar hardware, the Arystone system was much easier to install, had better documentation, and was found to produce an extended WiFi coverage area. Both the feedlot and pasture applications were eventually connected to the Internet via the Arystone system (Arymesh area network).

We experienced challenges in maintaining adequate wireless Internet signal at the pasture location. The pasture RFID reader location is approximately 250 meters from the barn where the nearest AyrMesh Remote Hub2n is mounted. This resulted in marginal WiFi signal strength (approximately -75 dBm). However, this challenge was exacerbated by the lack of stability of Internet signal at our base station in the barn. Internet at the MSU Beef Cow/Calf Teaching and Research Center is provide wirelessly from a remote station in the MSU Corporate Research Park, approximately 1.5 miles away. The Internet provider was changed during the course of our project, and reportedly had difficulties in providing reliable service. Lack of a reliable Internet signal was problematic for both our system, which requires a local area network, and for the AniMonitor system which relies on the Internet to upload data to the AniTrace servers.

UHF RFID Reader Interference: In two of our applications, antennas were directed down over gates which split pens or pastures. Electric fencing wire, in our intimal application, appeared to create a sizeable dead spot in the read zone. Rerouting the insulated electric wire, up and, over the backside of the antenna easily resolved the issue. In a second application, an insulated electric wire running through the read zone only created a very small dead spot (which was not directly over the watering site) and did not require modification.

Solar Power for Remote System: One solar panel was broken in initial delivery to the Center and was replaced prior to installation. During the course of the project, the original solar charge controller at the remote pasture application failed. At the request of AniTrace technicians, the controller was replaced with four individual solar charge controllers, one for each panel. These controllers have functioned properly throughout the winter (approximately 4 months). There were no other known issues with the solar powering of the AniMonitor system.

Feedback

Field day participants were generally positive about the technology and demonstrated application. The UHF RFID technology was welcomed, particularly as it was noted to provide solutions to some common limitations found with LF RFID. The ability for increased read distance and simultaneous reads (at least in some circumstances) were seen as positive aspects for UHF technology, particularly for applications in the cattle marketing chain. Currently, all livestock markets in Michigan are equipped with LF hardware and none are equipped with UHF hardware. Negative concerns related to necessary future infrastructure changes and costs, where LF technology already exists and is being routinely used. Also concerns were raised with transitions to UHF, while providing backward compatibility and support for LF technology.

CONCLUSION:

The project objective was successful in utilizing UHF RFID in a basic system which could be used to monitor cattle health, cattle inventory, and water source status. The UHF RFID technology is appropriate for this application. The UHF panel tags appear to be read easily by the hardware that we demonstrated and retention appeared to be adequate in non-obstructive environments. The majority of challenges with the technology demonstrated revolved around providing uninterrupted wireless signal to semi-remote locations and the RFID reader software interface. One of the significant challenges in adapting this technology to the cattle industry will be developing software that is robust, and requires very little user intervention.

Table 1. Components and cost of UHF fixed reader and wireless internet access for outdoor beef feedlot application*

Item	Cost
UHF RFID read point	
Alien ALR-9650 Gen 2 RFID reader (integrated antenna)	$775.61
I.T.E. Power Supply PW130 POE	$21.95
L-com weatherproof enclosure (14” x 10” x 4”; (120 VAC)	$51.50
Remote WiFi	
AyrMesh Hub2n & Receiver	$593.36
Cat6 Ethernet cable (5 ft.; 5)	$12.99
Cat5e Ethernet patch cable (200 ft.)	$49.97
Cat6 Ethernet cable (1 ft.; 5)	$9.99
120 lb. tensile strength cable ties, 15 in. (50)	$12.88
Self-adhesive cable tie mounts (100)	$11.24
Mounting hardware	$40.00
Total	$1,579.49

*Requires network connected computer with Windows OS.

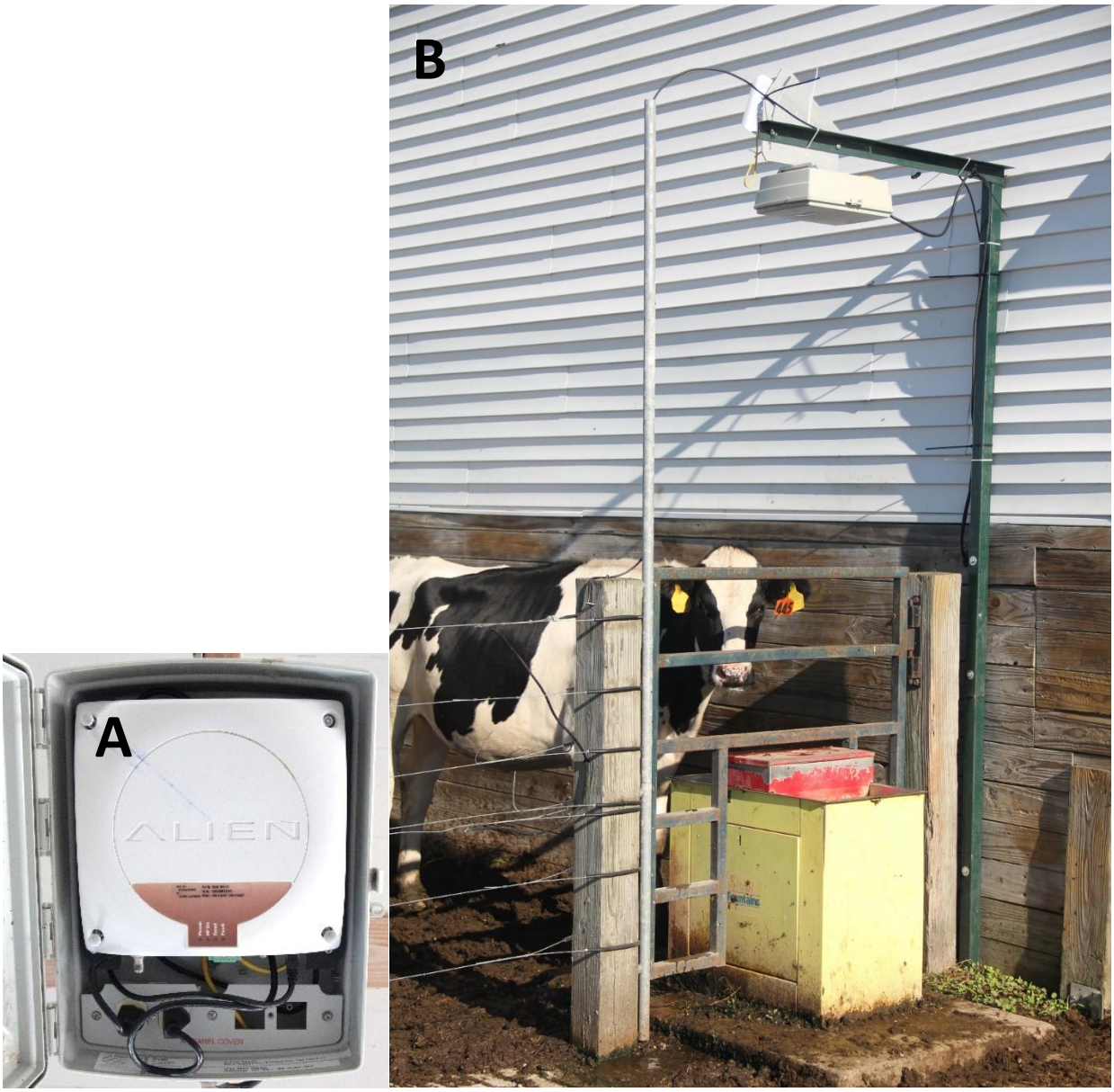

Figure 1. A weather-resistant enclosed ALR-9650 Gen 2 RFID reader (Alien Technology San Jose, CA; panel A) located directly above an automatic waterer in an outdoor beef feedlot application (panel B). Remote Internet connectivity was provided by an Arymesh network (Ayrstone Productivity, LLC, North Oaks, MN).

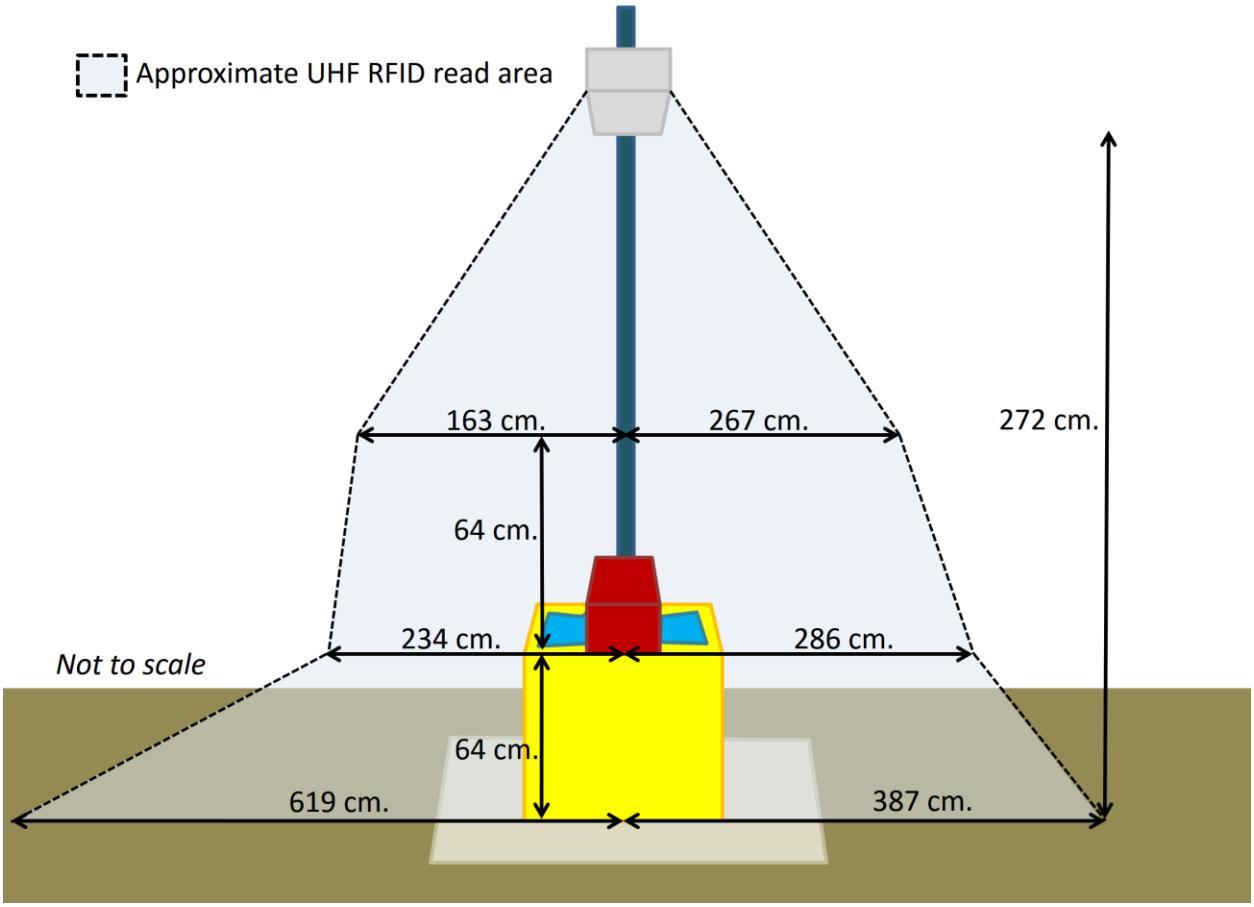

Figure 2. Approximate UHF RFID reading area of beef feedlot application at automatic waterer site. Read distance was approximately 5 meters in diameter at the water height.

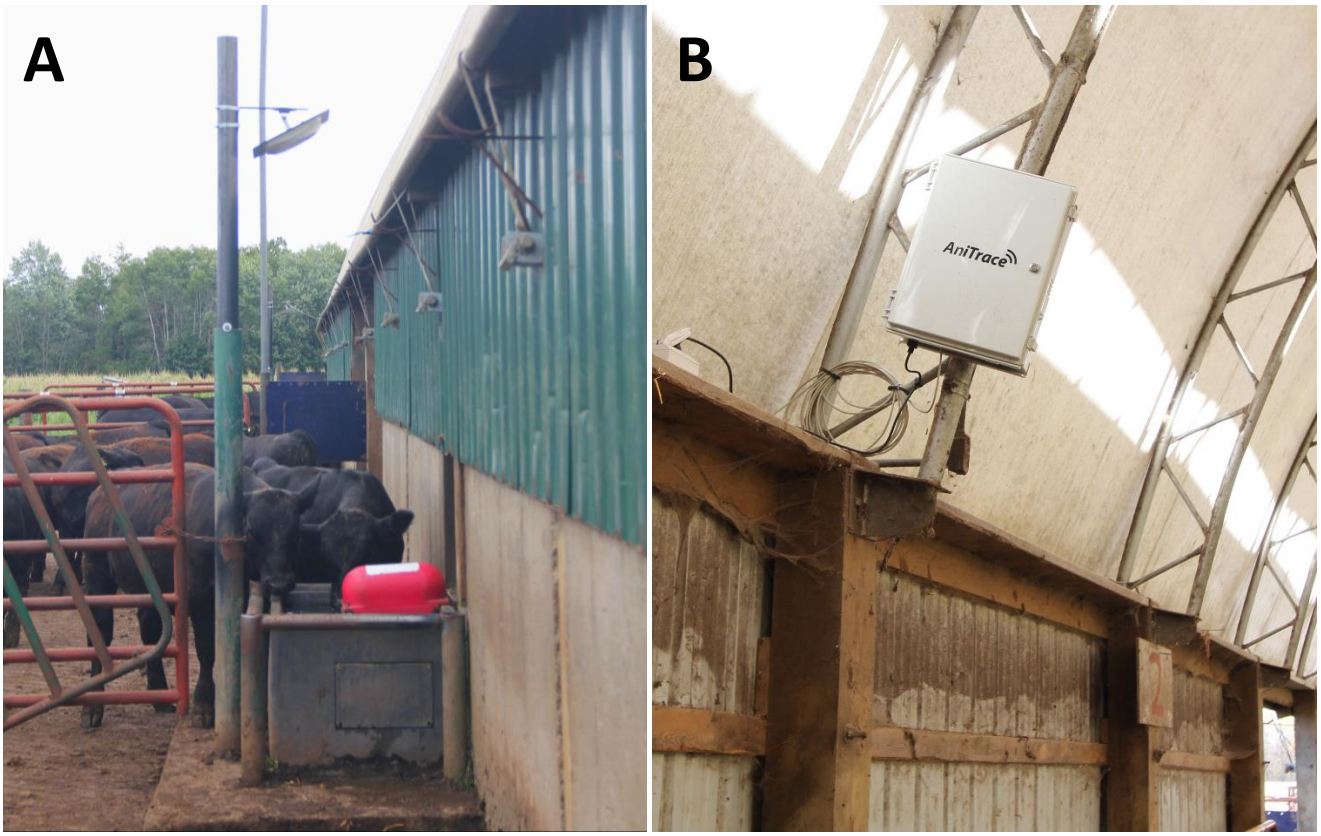

Figure 3. AniTrace system installed at MCA/MSU Bull Evaluation Program Station, Crystal, MI. Antennas were mounted directly above outdoor automatic waterers (panel A). Reader boxes were mounted inside adjacent hoop barn (panel B). Remote Internet connectivity was extended from the station residence wirelessly by an Ubiquiti bridge, Ubiquiti receiver, and ASUS wireless router.

Table 2. Components of the UHF fixed reader and wireless Internet access for bull evaluation station and remote pasture applications (AniTrace, AniMonitor Systems)
UHF RFID (AniMonitor) read point*
UHF RFID fixed type reader (NL-RF1000; Nesslab, Yongsan-dong, South Korea)
UHF RFID antenna (IDRO Co. Ltd., Gyeonggi-do, South Korea)
Microcomputer timer switch (ZYT16G 12V, Shanghai Zhuoyi Electronic, Shanghai, China)
Point of sale terminal (S80, PAX Global Technology, Shenzhen, China)
Weatherproof outdoor electrical enclosure
Cooling fan
Solar powered unit (pasture application)**
4, 100 watt solar panels (4, SP100 mono-crystalline solar modules, Ramdsond, Detroit, MI)
3 batteries (2, 31-GEL (12v, 97.6 Ah), 1, 22NF-GEL (12v, 51 Ah), Battery Giant, Madison Heights, MI)
Step down DC-DC converter (TH15W24055, TOBSUN, Guangdong, China)
(Original) Solar charge controller (P30L LCD 30A, WindyNation, Ventura, CA)
(Replacement) 4 solar charge controllers (Sunshield 12V 8A, Ramdsond, Detroit, MI)
2 mounting steel poles, schedule 40, 3.5” OD x 14 ft.
Remote WiFi connectivity
Ubiquiti M5-400 bridge, Ubiquiti NS2 receiver, ASUS RT-N10P wireless N router (bull evaluation station)
Ayrmesh Hub2n (Ayrstone Productivity, North Oaks, MN) (remote pasture application)

*AniMonitor Model #HITW4000-W00 was priced at $2,500 (does not include shipping or installation).

**AniMonitor solar panel system was priced at $3,800 (does not include shipping or installation).

Figure 4. Contents of UHF RFID read point (AniMonitor, division of Hana Micron America; Milpitas, CA), which was a solar powered unit installed at the MSU Beef Cow/Calf Teaching and Research Center. Original solar charge controller was replaced with 4 solar charge controllers (Sunshield 12V 8A, Ramdsond, Detroit, MI), shown on left. Remote wireless Internet connectivity was provided by an Arymesh area network (Ayrstone Productivity, LLC, North Oaks, MN).

Figure 5. UHF RFID read point (AniMonitor, division of Hana Micron America; Milpitas, CA) that is solar powered at the MSU Beef Cow/Calf Teaching and Research Center. Antenna is located directly above an automatic waterer which is split between two pastures.