Is 13.56 MHz RFID technology equally or more effective than 125 KHz for livestock identification and tracking?

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INTRODUCTION

The decision of the US Department of Agriculture (USDA) to use radio frequency identification tags to track the more than 200 million livestock in the wake of Mad Cow Disease scare of December 2003 is timely and wise. This "U.S. Animal Identification Plan (USAIP)" is most likely modeled after similar system such as the "National Livestock Identification Scheme" of Australia, Canadian Cattle Identification Program, etc.

Historically, animal tracking using RFID technology has used a 125 KHz battery powered collar band (active tag). With ISO 11784 and 11785, it has been extended to a passive tag for identifying agricultural livestock and equipment. ISO 11784 defines the code structure while ISO 11785 defines the technical communication protocols. This standard has been adopted by the National Food Animal Identification Task Force- coordinated by the National Institute for Animal Agriculture (NIAA) as a blueprint for the national animal identification system.

The "United States Animal Identification Plan (USIPA)" and the working groups under the sponsorship of the USDA will plan for infrastructure needs, preferred identification devices, and an integration plan. "The USAIP is focused on utilizing state-of-the-art national and international standards with the best available and practical technologies. It is dynamic and flexible, and will incorporate new and proven technologies as they become available."

We believe the flexible and appropriate approach taken by USAIP can benefit from the fast development of RFID technology in the supply chain market place. Based on the goals and the implementation phases expected of this plan, we believe that 13.56 MHz based on EPC or ISO 15693 may provide a lower cost and more effective system than the lower frequency 125 KHz band.

The following is the basis of our presentation:

- The cost of the tags is at least 2-10 times lower.
- The infrastructure available today allows automatic capturing of data with stationary portals at 13.56 MHz rather than the handheld devices and relatively simple antennae used for 125 KHz tags.
- Proven anti-collision can readily handle the "crowd" release from the barn.
- The cost of ownership is at least 2-3 times lower by using 13.56 MHz rather than 125 KHz RFID tags and systems.

THE OBJECTIVES OF ANIMAL TAGGING OF USAIP

In the plan of USAIP, the animal and livestock to be tagged include the species of bison, beef and dairy cattle, swine, sheep, goats, camelids (alpacas and Ilamas), cervides (deer and elk), poultry (eight species including game birds), and aquaculture (eleven species). (Please refer to www.USAIP.info for more details.) Besides the breadth of the species included in this program, the scope of the plan also includes intended usage such as seedstock, pets and other personal possessions besides the more traditional commercial meat production.

The basic goals thus far include:

- Tag each individual or group of smaller livestock with a unique "Animal Identification Number" (AIN).
- The response time for information retrieval on the location of sick animals must be within 48 hours of the confirmation of a disease outbreak (we will herein refer to this as "48 hours").
- Monitor processing plants involved in the production of meat products (we will herein refer to this as the "end product").

To achieve the above basic goals, the data captured by the system must include at least daily activity of the animals whereabouts (through the entering and exiting of barns or holding areas) because of the 48-hr response time requirement. Besides being stored in the farmer's system, some of the data must also be available in a central database, most likely managed by the USDA, through uploading via the Internet or a WAN. In order to track animals of all sizes, the tags should preferably be less than a dollar each. After all, it would be difficult to tag a chicken for the cost of a dollar. More realistic costs are around $0.10 - $0.25 each.

The following are some of the facts relating to the RFID technology that we believe are true and not subject to much dispute:

- Because livestock contain more than 50% water, the only ISO or widely available and applicable RFID technology is limited to 125 KHz and 13.56 MHz. The UHF band at 915 MHz and the Microwave band at 2.45 GHz are not applicable because of the energy absorption by the animal's bodies.
- 125 KHz being 100 times lower in frequency also means it is much slower in reading speed and also much slower in data transfer. This may impact its ability to handle "anti-collision" where many animals with tags are presenting themselves at the same time.
- When properly packaged, tags working at both the 125 KHz and 13.56 MHz have the same reliability and have been proven safe to use with animals and humans.
- Because of the frequency difference, 125 KHz tags typically require as many as 100-200 loops of wiring to achieve the resonance for proper operation and thus tends to be slightly more bulky than 13.56 MHz. The 13.56 MHz tags typically require 3-10 loops for the same dimension of 1"x1", 2"x3" or 3"x4" tags that are commonly used when tagging animals.
- There is a substantially longer (2-5 times) read distance for the 13.56 MHz tag than 125 KHz tag with the same size of physical form-factors.

TECHNOLOGICAL ADVANTAGES OF 13.56 MHz vs. 125 KHz RFID

There are several advantages of using a 13.56 MHz RFID tracking system to a 125 KHz one. The first is the simple fact that the higher frequency of 13.56 MHz (close to 100 times the frequency of 125 KHz) is faster in providing faster data capturing with improved bandwidth. This is important in dealing with "anti-collision" situations. Typically, ISO 15693 protocol can easily provide the capability of handling more than 50 tags at the same time. That is, when the cattle are rushing in or out of the barn, all of the animals can be read at the same time. This may not be the case for the slower processing of 125 KHz.

Is there an antenna array that can read the animals automatically without human intervention?

AVANTE has developed antenna array technology working with 2"x3" or 3"x4" RFID tags. The system will automatically read and document (with time-stamps) the entry and exit of the animals. AVANTE has used this system for tradeshow attendance auditing applications. In this patented application (US 6,665,193), the entry of an attendee bearing an RFID identification badge can be documented automatically without any human intervention. The badge can be placed on any part of the person and in any orientation. This SMART-PORTAL™ (www.leads-trakker.com) can be 3 ft. wide or 6 ft. wide with adjustable height (US 6,657,543).

The same or modified SMART-PORTAL™ can be placed at the entrance and exit of the barn for automatic documentation of the animals' activities. It is important that most of the documentation of activities be done automatically because there is a high probability of non-compliance when scanning is done manually. Of course, non-compliance could also carry heavy fines in some cases and all of these factors may cause added costs to everyone involved.

The same tag made for 13.56 MHz using an etched copper antenna and soldering interconnections can be thin (typically 10 mils thick) and robust with an overlay of polyester or another durable plastic (Please refer to www.avantetech.com). In the case of tags made with wound wires for 125 KHz, they are typically much thicker than 50 mils. These antenna inlays must be attached to the chips using special tools and means instead of the industry standard pick-and-place equipment. This is why 125 KHz tends to be more expensive at $2 - $4 apiece while 13.56 MHz is already pricing at less than $1.0 even for modest quantities.

More importantly, even for the smallest tags (e.g. 1/2" x 1/2"), at 13.56 MHz they can be read at a distance of more 6-12 inches while the same size tags at 125 KHz must be read at more or less contact range (1 cm). For farmers, the ease of gathering data will encourage compliance and reduce the likelihood of penalty fines for non-compliance.

Looking to the future, there is a new standard in the supply chain management called electronic product code (EPC) that includes the use of 13.56 MHz for tagging item levels of products. The deployment of EPC is scheduled for 2005 and will make infrastructure such as tags, readers, and antenna arrays more available and at lower cost.

The following Table 1 is a summary of the three goals and the technology and usage implications for each of them. The identification requirements of the plan include where the animal was born, the parents of the animal (pedigree), relocation history to and from farms, and chain of custody of the animal in its entire life. This information must be documented in a suitable database where the information can be easily retrieved from anywhere at anytime. Ideally, if the animal is used for other products, it should be traceable at all times to complete the supply chain cycle.

Table 1: The goals and the implications of the means to achieve them.

REQUIREMENT	TECHNOLOGY IMPLICATIONS	USAGE IMPLICATIONS
UNIQUE ANIMAL IDENTIFICATION	• Only 13.56 MHz (ISO15963) or 125KHz (ISO 11785) is applicable. 915MHz and 2.45GHz are not effective because of the energy absorption by the animal's body. • Tag ID cannot be changed or reused. • Tag must be robust and withstand rain, snow, and UV light from sun. • Tag size must be adjustable, larger for cows and smaller for sheep/goats, and easily attached to the ear of a cow or other part of the animal. • For low cost application, farmers should be able to easily attach tags themselves. • As low a cost as possible.	• ISO, EPC or other standardized system for maximum compatibility. • For the value of cow, a $2.5 tag may be acceptable. • For the value of poultry, a cost closer to $0.25 may be more appropriate. • Tag must be able to withstand years of attachment and operation on animals.
48 HOUR RESPONSE TIME	• Detailed tracking of each and every animal at least once a day. • Reasonable database information management for large and small farms. • Uploading from farmer's database to the USDA database via the Internet may be periodic rather than real-time.	• Daily entrance and exit records. • Automatic stationary scanning rather than handheld readers. • May require at least two levels from premise exterior to some inside partitions or areas.
END PRODUCT TRACKING	• Documentation of date and time of moving out of the premises to transportation carrier identification to receiving time stamp at receiving processing plant. • Preferably the ability to tag the meat products in individual packages. • Scanner compatibility and ability to synchronize data collected from the different locations (albeit moving). • Handshake data must be clear between the farmer to the processor and to retailer.	• Cost of the tag for each package must be <$0.25. • Tag size must be small enough to fit the packaging. • Antenna array must capture data automatically in different processing phases. • Data must be directly encoded in animal tags to ensure ease in retrieval of parts.

COST OF OWNERSHIP

The breadth of the requirements for tagging all livestock in the United States will cost the government and consumers at least $250 million per year beyond the initial cost using the price and performance model based on the 125 KHz RFID tags and system. With 13.56 MHz tags the cost of the larger tags may be reduced 2 to 3 times and the cost of smaller tags may be reduced up to 10 times. Startup costs and cost of ownership may be both reduced by a factor of 2 to 3.

The cost for starting up the program includes at least the following:

- Tagging all livestock, estimated to be at least 100 million cattle and similar numbers for swine and other groups. The purchasing cost for tags can be easily estimated. Because of the prohibitive cost for the lower value poultry, they will most likely be tagged as a group rather than individually.
- Tagging a group of animals is harder to manage than tagging a box of products. The animals must be moved, treated, slaughtered, and shipped as a group for the finished or repackaged processing. This can be a logistical challenge. Using 13.56 MHz with the current cost of $0.25 or less, it is possible to tag each of the poultry and other lower value animals with their own tag and unique identifier. Using the EPC or ISO 15693 standard, they can be encoded individually within a group with the same ease. Even with a 1"x1" tag, the individual poultry can still be monitored and scanned automatically with a suitable antenna array without human intervention or manual scanning.
- Some of the data can be stored in the RFID tag placed on each individual animal for ease of management by the local farmers. More importantly, it reduces the bandwidth memory required for the local database management. For example, when the animals are in the field and near the computer system the history of any antibiotic injection or other treatment can be directly stored within the tag as well as in the database for ease of management.

The cost of ownership for the operational phase includes at least the following:

- Tagging on the animal may be slightly easier with a flexible yet robust plastic laminate. The tags can easily be attached to the ears of cattle or the neck of the poultry. Lighter weight and flexibility may be more comfortable for the animal and less likely to be scratched-off.
- The ability to scan automatically by simply having the animal pass through the non-intrusive SMART-PORTAL™ ensures compliance to the plan. It is much easier to ignore or bypass the requirements for proper documentation when it is difficult to scan the tags and handle the cattle to place them in a position for scanning.
- The more established built-in anti-collision mechanism for ISO 15693 based on a 13.56 MHz RFID system will greatly reduce the amount of time and effort when "crowds" of cattle and other animals pass through a SMART-PORTAL™. AVANTE has proven that the tagged items can pass through a portal lined with suitable all-direction and all-position automatic scanning antenna arrays at up to 8 ft. per second and still be captured 100% accurately.

The lower cost associated with the ease of operation after the initial start-up phase cannot be over-stated in a herd environment. The more automatic the process of capturing the necessary

data is, the less errors will be made and the less bypassing of the requirements will occur. The effectiveness of any monitoring system like the animal identification one depends on how user-friendly the system is when actually in use.

Table 2: Cost of ownership in using 125 KHz and 13.56 MHz tags.

APPLICABLE RFID TECHNOLOGY	13.56 MHz (ISO 15963 & EPC)	125 KHz (ISO 11785)
1. Tag that is ISO standard based	• ISO 11784 • ISO 15693 • EPC (Emerging)	• ISO 11784 • ISO 11785 • EPC (Not applicable)
2. Proper tag size (e.g. to fit the ear of a cow, may be smaller for poultry)	• Typically 5-10 loops on an etched antenna. • Read distance for 3"x4" tag is approximately 3-4 ft. • Read distance for 1"x1" tag is approximately 2 ft.	• Typically 100-200 loops with wires that are mechanically wound. • Read distance for 3"x4" tag is approximately 1-2 ft. • Read distance for 1"x1" tag is approximately 1/2 ft.
3. Handling and Tagging	• Tag can be as thin as 10 mils (0.010"). • More rugged and robust plastics such as polyester can be used. • Can easily be tagged on a convenient part of the animal without interfering with the animal's activities.	• As least 50 mils in thickness. • Must be encased in thick plastics or glass. • Not so easily tagged on smaller or younger animals without interfering with their activities.
4. Data Capturing and Rate of Communication	• Proven automatic scanning with suitable antenna arrays for access as wide as 3-6 ft. • Faster capturing speed because of the higher bandwidth and frequency. • Established anti-collision in handling more than 50 animals at the same time.	• No antenna arrays for automatic scanning during access developed. • May not have adequate anti-collision handling capability for "crowds". • Slow data capturing rate.
5. Cost of Tags	• Less than $1 even for the largest size tags. • Less than $0.25 for the smaller 1"x1" tags.	• More than $2 for the larger tags. • Similar price of $2 for smaller tags (more winding and harder to make).
6. Cost of Ownership (Operational Expenses)	• Automatic data capturing for daily moving in and out of barn using SMART-PORTALS. • Automatic data capturing means less error. • Cost or penalty of non-compliance will be low.	• Manual scanning and data capturing for daily moving in and out of barns will be difficult and time consuming. • Manual data capturing tends to cause error. • Cost or penalty of non-compliance may be high.

CAN MORE BENEFITS BE OBTAINED BY INTEGRATING OTHER TECHNOLOGY?

We believe that the goals as set forth in the initial USAIP are relatively modest and highly achievable. We also believe that there may be other possible benefits that can easily be achieved without additional costs when the right choice of technologies are integrated into the system. In fact, with the right choice of more suitable technologies the cost can be much lower than originally anticipated.

Figure 1 below is an illustration on how easy the process of tracking people without manual intervention is using SMART-PORTAL™. The SMART-PORTAL™ is designed to automatically capture the tag data when the tag is in any orientation or position by simply placing antenna to the left and right side of the chute. The same kind of portals can be constructed at the entrances/exits of a barn, a grazing field, a treatment area, a slaughter area, the chute, etc. to help automatically and accurately capture the ID of animals being processed. It can easily capture the ID of cows with time-stamps while they move down a chute to and from a corral even when the animals are lined up head to tail in the chute. If the parents of newborns are tagged, the pedigree of the food supply chain of livestock can also easily be documented without any additional cost.

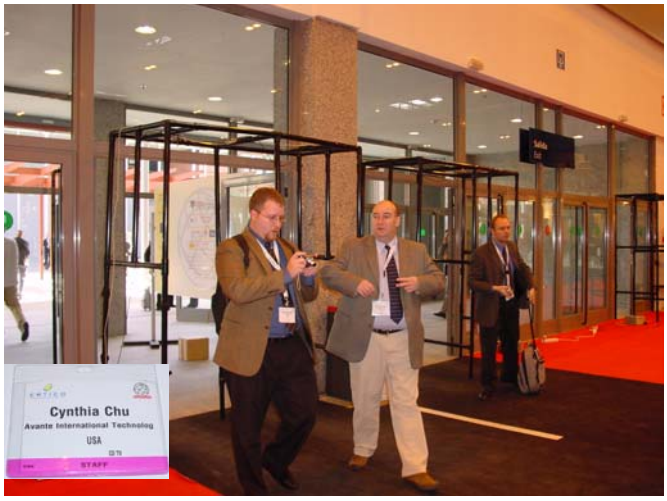


Figure 1

Figure 2 below is a picture representing RFID tags at 125 KHz and 13.56 MHz for the same card size form-factor. More than 100 loops are needed to produce the tag for 125 KHz in contrast to the 5-7 loops for the tag operating at 13.56 MHz. The interconnection technology between the chip for RFID uses the soldering of the chip-jumper to facilitate the automatic pick-and-place, and reflow soldering in the case of 13.56 MHz using the patented process of AVANTE. In the case of a 125 KHz tag, the chip is first packaged into a component before soldering to the wound wire that must be encapsulated in a plastic film for a secure mechanical structure. The cost differentials and potential in cost reduction is dramatic.

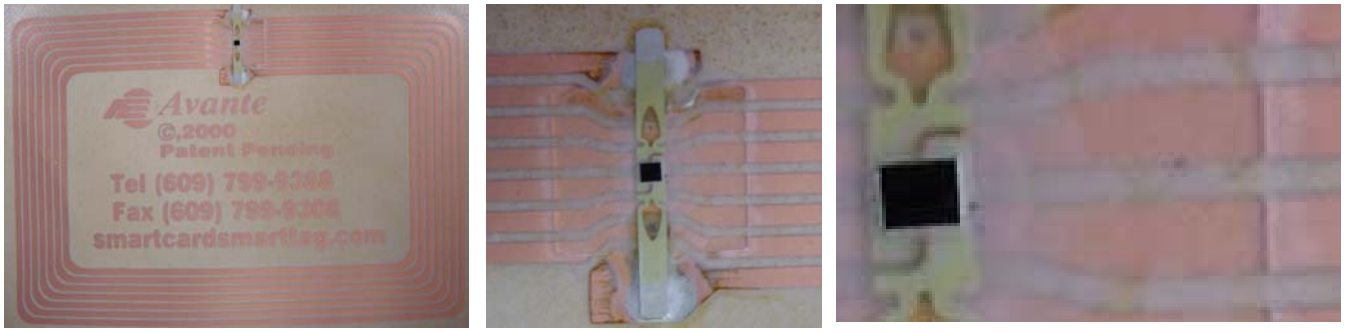
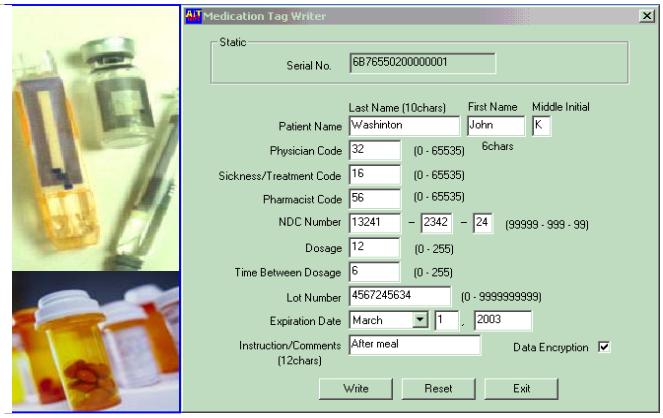


Figure 2: Soldering attachment of "chip-jumper" to etched copper for 13.56 MHz inlays made by AVANTE. The "chip-jumper" serves as a "cross-over" as well as an easily surface mounting pick-and-place device. The connection between the "chip-jumper" is soldered onto the inlay on a substrate with etched copper. Etched copper has the advantage of consistent conductivity and precision in dimension. The proprietary substrate has high temperature performance similar to that of a polyimide but at a cost similar to PET polyester. This card size tag enables reading at approximately 3 feet and has been used extensively for AVANTE tradeshow leads capturing and retrieval applications that also included walk-through portals.

Figure 3 below depicts an example of another application of 13.56 MHz technology. AVANTE has successfully utilized 13.56 MHz technology for medication tagging, scanning, and information capture with tag as small as 1/2"x1/2".

Figure 3: Prescribed mediations including smallest vials and syringes have been successfully tagged with 13.56 MHz RFID tags identifying the NDC number, lot/date, dosage, special instructions, the intended patient's name, the physician and the pharmacist, etc. The smaller counter scanner has been designed and tested for this kind of application.



The following are some of the potential benefits that can be obtained without any additional costs:

- A relatively inexpensive laptop computer can easily be loaded with a suitable database to capture and store the data for even the smallest of farms. The system can be set-up to link to the USDA database and periodically and automatically upload the required data via a phone. With such infrastructure, instead of the 48-hour response time allowed to trace back to animals of concern it can be done within an hour or less.
- Software can be designed to help farmers manage their animals. For example, prompts can be made available to help remind farmers of the activities and actions needed to ensure the success of their herds. While the farmers follow the prompts for actions, the data can be automatically captured as part of the health record that includes the history of each animal.

- While data of processing and yield are generated is collected, information may emerge to help to improve the yield from the animals.

CONCLUSION:

The decision of the USDA to adopt a quick and effective means of tracking the livestock of United States is wise and important for the integrity of our farming industry. The use of RFID technology to help track the animals need not be a cost center for the industry. Instead we should capitalize on the infrastructure to help farmers manage their activities.

The key for compliance lies in the ability to automatically capture the required data without the hassle of manual intervention. We believe that 13.56 MHz RFID technology may provide an easier solution by using antenna arrays in non-intrusive manner for automatic data capturing.

Bring USAIP data structure to be compatible to the emerging EPC standard for tagging general supply chain items helps to lower the cost of the tags and the costs of ownership. More importantly, the data can be easily transferred to the standard format of barcodes on packaged goods at the item level for products made from the animals. The third phase objectives of the USAIP program in managing the processing and products can simply be the default results of data that is available when the animals are being processed.